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Review and summary of the time series of input data available for the assessment of southern blue whiting (*Micromesistius australis*) stocks up to and including the 2022 season

New Zealand Fisheries Assessment Report 2023/63

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EXECUTIVE SUMMARY

Holmes, S.J.[1]; Bian, R.[2]; Doonan, I.J.[1] (2023). Review and summary of the time series of input data available for the assessment of southern blue whiting (*Micromesistius australis*) stocks up to and including the 2022 season.

***New Zealand Fisheries Assessment Report 2023/63.* 75 p.**

This document updates and summarises the observational and research data for New Zealand southern blue whiting (*Micromesistius australis*) (SBW) fisheries. These data include: (1) the time series of relative abundance from acoustic surveys for three of the four main stocks (both from the wide-area R.V. *Tangaroa* surveys and the local aggregation surveys), as well as for the single survey of the Auckland Islands Shelf that was carried out in 1995 using R.V. *Tangaroa;* (2) commercial fishery catch-per-unit-effort (CPUE) indices for Bounty Plateau and Campbell Island Rise; (3) trawl survey indices for the Auckland Islands Shelf, Campbell Island Rise, and Pukaki Rise; and (4) updated time series of length-at-age and catch-at-age from observer sampling of commercial catch.

The main source of information on SBW stock size remains the acoustic indices from wide-area surveys on the Campbell Island Rise and local aggregations surveys on the Bounty Plateau. The 2016, 2019, and 2022 acoustic biomass estimates from the Campbell Island Rise were (respectively) the third, fifth, and second highest on record (of 14 surveys since 1993). There has been large inter-annual variability in the aggregation-based acoustic index from the Bounty Plateau making it difficult to use for assessment and management purposes, and no acoustic estimates are available from the past five years (2018–22). Aggregation surveys for SBW on the Pukaki Rise have so far been largely unsuccessful with high variability between snapshots and years.

Estimates of SBW abundance from the sub-Antarctic trawl surveys on the Auckland Islands Shelf, Campbell Island Rise, and Pukaki Rise since 1991 have high inter-annual variability and moderate to high CVs. Despite this high variability, the trawl surveys may have some utility for monitoring relative abundance. The time series on the Auckland Islands Shelf suggests an almost 10-fold increase in average abundance between the early part of the series (1991–2004) and the later part (2005–22), although the estimate for 2022 was the lowest since 2008. The trawl survey biomass estimates for the Campbell Island Rise in 2016, 2020, and 2022 were relatively high, consistent with the high acoustic estimates recorded in 2016, 2019, and 2022. Trawl survey biomass estimates for the Pukaki Rise have fluctuated since peaking in 2009, but estimates from the four most recent trawl surveys in 2016, 2018, 2020, and 2022 were amongst the highest in the time series.

The catch on the Bounty Plateau in 2022 was dominated by the 2018 year class, with the 2002, 2007, and 2012 year classes also making significant contributions. On the Campbell Island Rise, there was evidence of several recent year classes of moderate strength, with both acoustic indices and commercial-catch-at-age proportions suggesting relatively strong recruitment in 2009, 2011, 2014, and 2015. Catches and sampling for age and length on the Pukaki Rise have been low in recent years, and identification of recruitment patterns is difficult. There was a relatively large catch (3631 t) taken from the Pukaki Rise in 2019 which consisted of a broad range of fork lengths of 30–50 cm, but no fish were aged. Catch in this area returned to very low levels for 2020–2022. Very few length measurements or otoliths were collected from the Auckland Islands in recent years, and the length data were not sufficient to infer recruitment patterns in that fishery.

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1. INTRODUCTION

In New Zealand, southern blue whiting (*Micromesistius australis*, SBW) are almost entirely restricted to sub-Antarctic waters. They are dispersed throughout the Campbell Plateau and Bounty Plateau for much of the year, but during August and September they aggregate to spawn near the Campbell Islands, on Pukaki Rise, on Bounty Plateau, and near Auckland Islands over depths of 250–600 m (Figure 1). During most years fish in the spawning fishery range between 35 and 50 cm fork length (FL), although occasionally smaller size classes of males (29–32 cm FL) are observed in the catch (Fisheries New Zealand 2023).

Commercial fishing has concentrated on the Campbell Island Rise and, to a lesser extent, the Bounty Plateau. The Pukaki Rise and Auckland Islands have been important fisheries in the past but have recently had much lower annual catches than the Campbell Island Rise and Bounty Plateau fisheries (Figure 1).

Stock assessments for southern blue whiting on the Campbell Island Rise have been conducted at approximately biennial intervals using age-structured stock assessment models; the latest being the 2020 assessment of the Campbell Island stock (Doonan 2020). The last stock assessment for the Bounty Plateau was in 2014 (Dunn et al. 2015). Model inputs have included time series of acoustic survey indices, commercial catch-at-age composition data, and, in earlier years, CPUE indices. The 2014 stock assessment for the Bounty Plateau was rejected by the Deepwater Working Group, because it did not provide a satisfactory fit to changes in acoustic biomass estimates. A harvest control rule was developed instead that uses the most recent acoustic index of abundance as an absolute measure of abundance (Doonan 2017, 2018).

A large amount of research has been carried out on southern blue whiting, including work on stock structure (Hanchet 1998, Hanchet 1999), age and growth (Hanchet & Uozumi 1996), catch-at-age (e.g., Hanchet et al. 2003, Hanchet 2005), acoustic surveys (e.g., Ingerson & Hanchet 1996, Hanchet et al. 2000a, 2000b, Fu et al. 2013, O'Driscoll & Hanchet 2004, O'Driscoll et al. 2012, 2014, 2016, O'Driscoll 2011a, 2011b, 2011c, 2013, 2015, 2018, O'Driscoll & Dunford 2017, O'Driscoll & Ladroit 2017, Ladroit et al. 2020), CPUE analyses (e.g., Hanchet & Blackwell 2003, Hanchet et al. 2005), trawl surveys (Hanchet & Stevenson 2006, O'Driscoll & Bagley 2009), and stock assessments (e.g., Hanchet 2002, 2005, Hanchet et al. 2006, Hanchet & Dunn 2009, Dunn & Hanchet 2011a, 2011b, 2015b, 2015c, 2016a, 2016b, 2017, Doonan 2018, Roberts & Hanchet 2019, Doonan 2020). The objective of this report is to summarise and document the time series of input data which could potentially be used for stock assessment. This includes reporting the revised and updated commercial catch-at-age proportions for the Bounty Plateau and Campbell Island Rise.

The data described in this report were based on data extracts from the Fisheries New Zealand electronic data warehouse (EDW) database in November 2022 (REPLOG 14692), the Fisheries New Zealand observer database in November 2022, and the Fisheries New Zealand trawl and age databases in December 2022.

This report fulfils the final reporting requirement for objective 1 of Fisheries New Zealand Project SBW2022-01 (Stock assessment of southern blue whiting around Campbell Island (SBW 6I)) "To update the descriptive analysis of the commercial catch and effort and observer data for SBW 6I". Although project SBW2022-01 only required an update for the SBW 6I stock (Campbell Island Rise), updates have been given for all four areas highlighted in Figure 1.

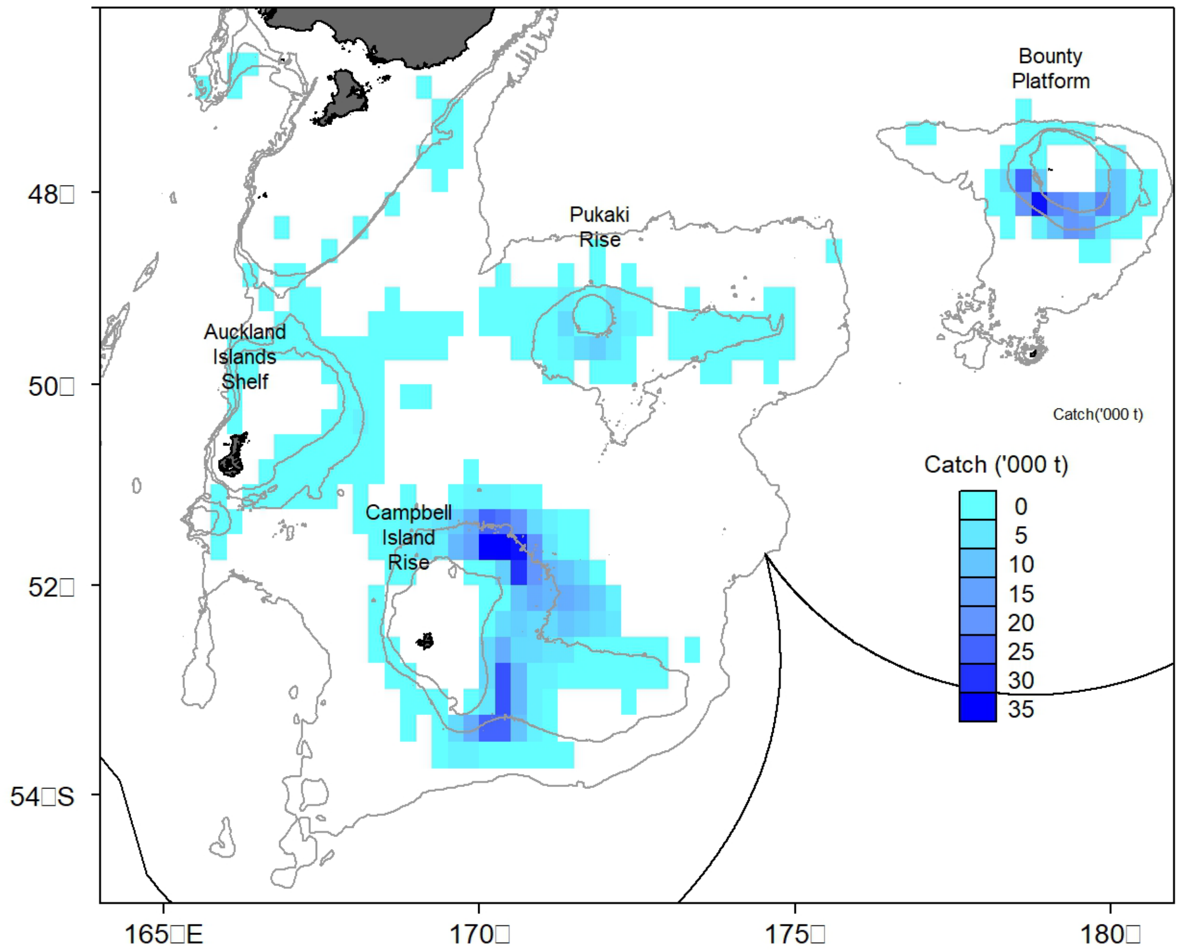

Figure 1: Relative total density of the commercial catch of southern blue whiting by location, from Trawl-Catch-Effort-Processing-Record (TCEPR) and Electronic Reporting (ERS) data over the period 1990–2022. Depth contours are at 250, 500, and 1000 m.

2. FISHERY SUMMARY

The southern blue whiting fishery was developed by Soviet vessels during the early 1970s, with early reported landings peaking at almost 50 000 t in 1973 (Table 1). Further details of the fishery prior to the introduction of catch quotas are given by Large et al. (2021).

Catch quotas, with allocations given to individual operators, were introduced for the first time in the 1992–93 fishing year. The catch limit of 32 000 t, with stock-specific sub-limits, was retained for the next three years (Table 1). The stock-specific sub-limits were revised for the 1995–96 fishing year, and the total catch limit increased to 58 000 t in 1996–97 for three years (Table 1). In 1997–98, a separate catch limit of 1640 t was set for the Auckland Islands fishery for the first time (Table 1).

The southern stocks of southern blue whiting (SBW) were introduced to the Quota Management System on 1 November 1999 with the following Total Allowable Commercial Catches (TACCs): Auckland Islands Shelf (SBW 6A) 1640 t; Bounty Plateau (SBW 6B) 15 400 t; Campbell Island Rise (SBW 6I) 35 460 t; and Pukaki Rise (SBW 6R) 5500 t (Table 1). At the same time, the fishing year was changed to start 1 April to reflect the timing of the main fishing season. Southern blue whiting has been managed using a Current Annual Yield (CAY) strategy (Annala et al. 2004), which has contributed to the fluctuating catch limits and TACCs (Table 1). A nominal TACC of 8 t was set for the rest of the New Zealand Exclusive Economic Zone (EEZ) (SBW 1). The TACC for SBW 1 was increased to 98 t for the 2017–18 season following a reported catch of 86 t in 2016–17.

The TACC for the Campbell Island Rise was gradually reduced to 20 000 t by 2006–07, following a period of poor to average recruitment to the stock. The TACC remained at that level until 2009–10 when the strong 2006 year class entered the fishery, and the TACC was increased to 23 000 t in 2010–11 and then to 29 400 t for 2011–12. The Campbell Rise TACC was increased again to 39 200 t for the 2014–15 season where it has remained.

The TACC for the Bounty Plateau was gradually reduced to 3500 t by 2003–04, following a period of poor recruitment to the stock. The TACC remained at that level until 2008–09 when the strong 2002 year class entered the fishery, and the TACC was increased to 9800 t and then 14 700 t. From 1 April 2011, the TACC for the Bounty Plateau stock was reduced 6860 t, but for the 2013–14 season the industry shelved 2832 t under a voluntary agreement resulting in a catch limit for that year of 4028 t. The TACC was 6860 t in 2014–15 but an additional 1810 t of catch in SBW 6B over the TACC was taken under Ministry for Primary Industries (MPI) Special Permit 576 by the F.V. *Tomi Maru 87* for the purpose of "investigative research". Following a period of poor recruitment, the Bounty Plateau TACC was reduced to 2830 t in 2020–21 and to 2264 t in 2022. The TACCs for Pukaki Rise and Auckland Islands Shelf have remained unchanged since 1997–98.

Total annual landings (along with proportion of the total TACC caught) declined from 39 540 t in 2009–10 to 16 535 t in 2018–19, increased in 2019–20 to 31 157 t but fell again in 2020–21 to 13 256 t, the lowest SBW catch since 1984–85 (Table 1). Total annual landings increased in 2021–22 and again in 2022–23 to 22 967 t. The total catch for all areas in 2022–23 was 47% of the total TACC.

Most of the total annual landings have been taken from the Campbell Island Rise grounds, where the TACC has been under-caught since being increased to 39 200 t in 2014–15; in 2022–23, 58% of the Campbell Island Rise TACC was caught. On the Bounty Plateau the TACC was almost fully caught from 2005–06 to 2017–18 but has been under-caught since then. In 2022–23, catches totalled only 125 t representing less than 6% of the TACC for the area. The under-catch has mostly been due to reduced effort (see later sections).

In the last ten years, the total catches from the Auckland Islands Shelf and Pukaki Rise have not approached the TACC. The relatively large catch from the Pukaki Rise in 2019–20 was only 66% of the TACC. In these two areas operators find it difficult to justify expending time to locate fishable aggregations, given the small allocation available in these areas and the relatively low value of the product.

In general, the fleet has gradually changed from one being dominated by Japanese surimi and Soviet vessels to one of New Zealand registered vessels which process fish to a dressed product. Before 2003, about 70% of the product was surimi and about 30% was dressed, but since 2005 the proportion of surimi declined to 40% in 2006 and 6–21% since 2009 (Figure 2). The proportion in 2022 was 8%.

Table 1: Estimated catches and catch limits (TACCs) (t) of southern blue whiting by area for 1971 to 2021–22 (source: QMRs and MHRs; '–' denotes no catch limit in place or no recorded catch).

Fishing year[1]	Bounty Plateau (SBW 6B)		Campbell Island Rise (SBW 6I)		Pukaki Rise (SBW 6R)		Auckland Islands (SBW 6A)		Rest of NZ (SBW 1)		Total (All areas)	
	Catch	Limit	Catch	Limit	Catch	Limit	Catch	Limit[2]	Catch	Limit	Catch[3]	Limit
1971	–	–	–	–	–	–	–	–	–	–	10 400	–
1972	–	–	–	–	–	–	–	–	–	–	25 800	–
1973	–	–	–	–	–	–	–	–	–	–	48 500	–
1974	–	–	–	–	–	–	–	–	–	–	42 200	–
1975	–	–	–	–	–	–	–	–	–	–	2 378	–
1976	–	–	–	–	–	–	–	–	–	–	17 089	–
1977	–	–	–	–	–	–	–	–	–	–	26 435	–
1978	0	–	6 403	–	79	–	15	–	–	–	6 497	–
1978–79	1 211	–	25 305	–	601	–	1 019	–	–	–	28 136	–
1979–80	16	–	12 828	–	5 602	–	187	–	–	–	18 633	–
1980–81	8	–	5 989	–	2 380	–	89	–	–	–	8 466	–
1981–82	8 325	–	7 915	–	1 250	–	105	–	–	–	17 595	–
1982–83	3 864	–	12 803	–	7 388	–	184	–	–	–	24 239	–
1983–84	348	–	10 777	–	2 150	–	99	–	–	–	13 374	–
1984–85	0	–	7 490	–	1 724	–	121	–	–	–	9 335	–
1985–86	0	–	15 252	–	552	–	15	–	–	–	15 819	–
1986–87	0	–	12 804	–	845	–	61	–	–	–	13 710	–
1987–88	18	–	17 422	–	157	–	4	–	–	–	17 601	–
1988–89	8	–	26 611	–	1 219	–	1	–	–	–	27 839	–
1989–90	4 430	–	16 542	–	1 393	–	2	–	–	–	22 367	–
1990–91	10 897	–	21 314	–	4 652	–	7	–	–	–	36 870	–
1991–92	58 928	–	14 208	–	3 046	–	73	–	–	–	76 255	–
1992–93	11 908	15 000	9 316	11 000	5 341	6 000	1 143	–	–	–	27 708	32 000
1993–94	3 877	15 000	11 668	11 000	2 306	6 000	709	–	–	–	18 560	32 000
1994–95	6 386	15 000	9 492	11 000	1 158	6 000	441	–	–	–	17 477	32 000
1995–96	6 508	8 000	14 959	21 000	772	3 000	40	–	–	–	22 279	32 000
1996–97	1 761	20 200	15 685	30 100	1 806	7 700	895	–	–	–	20 147	58 000
1997–98	5 647	15 400	24 273	35 460	1 245	5 500	0	1 640	–	–	31 165	58 000
1998–00	8 741	15 400	30 386	35 460	1 049	5 500	750	1 640	–	–	40 926	58 000
2000–01	3 997	8 000	18 049	20 000	2 864	5 500	19	1 640	9	8	24 804	35 148
2001–02	2 262	8 000	29 999	30 000	230	5 500	10	1 640	1	8	31 114	45 148
2002–03	7 564	8 000	33 445	30 000	508	5 500	262	1 640	16	8	41 795	45 148
2003–04	3 812	3 500	23 718	25 000	163	5 500	116	1 640	3	8	27 812	35 648
2004–05	1 477	3 500	19 799	25 000	240	5 500	95	1 640	9	8	21 620	35 648
2005–06	3 962	3 500	26 190	25 000	58	5 500	66	1 640	2	8	30 287	35 648
2006–07	4 395	3 500	19 763	20 000	1 115	5 500	84	1 640	7	8	25 363	30 648
2007–08	3 799	3 500	20 996	20 000	513	5 500	278	1 640	1	8	25 587	30 648
2008–09	9 863	9 800	20 483	20 000	1 377	5 500	143	1 640	21	8	31 867	36 948
2009–10	15 468	14 700	19 040	20 000	4 853	5 500	174	1 640	5	8	39 540	41 848
2010–11	13 913	14 700	20 224	23 000	4 433	5 500	131	1 640	8	8	38 708	44 848
2011–12	6 660	6 860	30 971	29 400	686	5 500	92	1 640	2	8	38 412	43 408
2012–13	6 827	6 860	21 321	29 400	1 702	5 500	49	1 640	8	8	29 906	43 408
2013–14[4]	4 278~	4 028	28 607	29 400	14	5 500	47	1 640	21	8	32 950	43 408
2014–15[5]	7 054	6 860	24 592	39 200	34	5 500	156	1 640	29	8	31 887	53 208
2015–16	2 405	2 940	22 100	39 200	12	5 500	181	1 640	35	8	24 733	49 288
2016–17	2 569	2 940	19 875	39 200	11	5 500	46	1 640	86	8	22 588	49 288
2017–18	2 423	2 377	18 334	39 200	36	5 500	202	1 640	51	98	21 046	48 815
2018–19	1 101	3 145	15 147	39 200	36	5 500	218	1 640	33	98	16 535	49 583
2019–20	788	3 145	26 517	39 200	3 631	5 500	182	1 640	39	98	31 157	49 583
2020–21	1 100	2 830	11 982	39 200	71	5 500	211	1 640	71	98	13 436	49 268
2021–22	801	2 830	19 514	39 200	33	5 500	174	1 640	22	98	20 544	49 268
2022–23	125	2 264	22 985	39 200	40	5 500	247	1 640	12	98	23 410	48 702

1. Fishing years defined as 1 April to 30 September for 1978; 1 October to 30 September for 1978–79 to 1997–98; 1 October 1998 to 31 March 2000 for 1998–2000; 1 April to 31 March for 2000–01 to current.
2. Before 1997–98, there were no separate catch limits for Auckland Islands.
3. Totals include SBW 1 (i.e., all EEZ areas outside QMA 6).
4. In 2013–14, although the TACC for SBW6B remained at 6860 t, the catch limit was limited to 4028 t as 2832 t was shelved under a voluntary agreement.
5. In 2014–15, an additional 1810 t of catch in SBW6B over the TACC was taken under MPI Special Permit 576 by the F.V. *Tomi Maru 87* for the purpose of "investigative research".

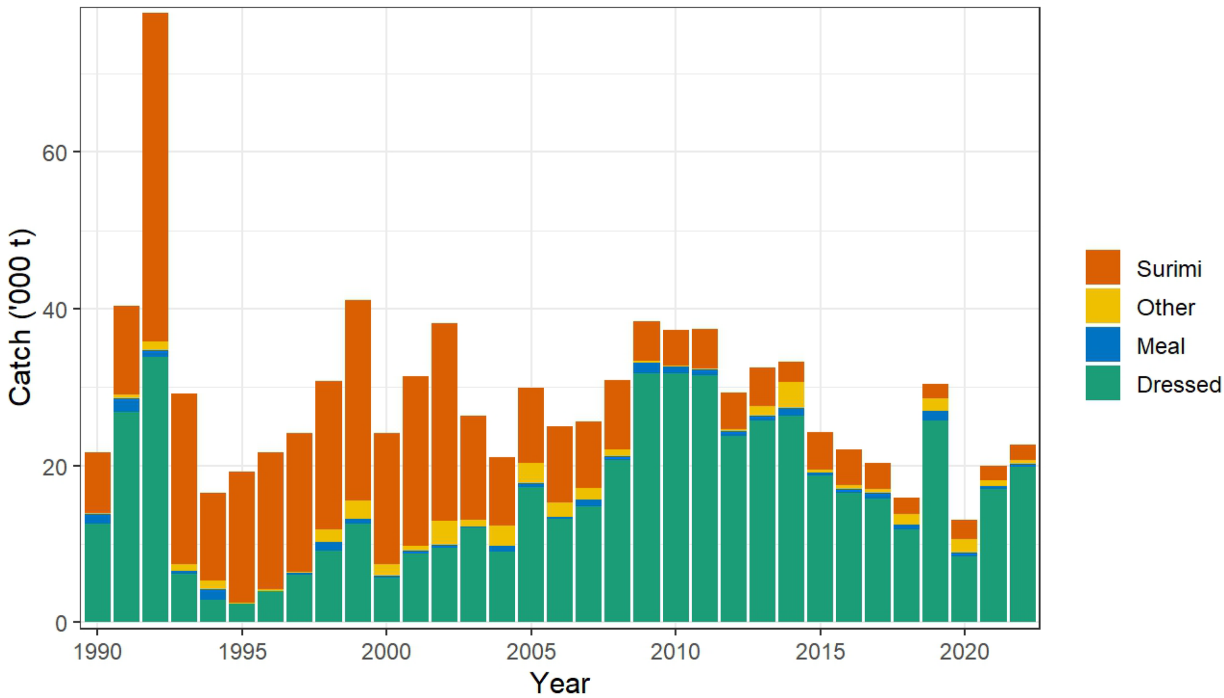

Figure 2: Estimated total processed catch for southern blue whiting by processed state, for all areas, between July and October (inclusive), 1990–2022.

2.1 The 2022 season

Most of the fishing effort carried out during the 2022 season (mid-August to beginning of October 2022) was on the Campbell stock (Table 2).

In 2022, vessels started fishing the Campbell Island Rise on 21 August and continued fishing until 23 September (Figure 3). Compared with recent years when the fleet fished mainly in the north, in 2022 the fleet fished in the north, south, and east of the Campbell Island Rise grounds (Figure 4). Daily proportions spawning at Campbell Island appeared to show several distinct peaks but the zero record from 14 September was because bad weather curtailed fishing (and prevented data collection). It was therefore most likely there were two distinct spawning periods with the first spawning peak in late August and the second in mid-September (Figure 3).

Fishing on the Bounty Plateau occurred on only two days in 2022 for a total catch of 125 t. There are insufficient data to draw conclusions about timing of spawning (Figure 3).

There were two targeted southern blue whiting tows on the Auckland Islands Shelf and five on Pukaki Rise in 2022–23 (Table 2). Southern blue whiting were taken mainly as a bycatch of fishing for other species, with total landings of 23 t from the Auckland Islands and 13 t for the Pukaki Rise (Table 1). There were no observer data in 2022–23 from these areas.

Table 2: Number of tows and vessels for vessels targeting southern blue whiting by area, 1990–2022 (source: TCEPR & ERS data). The year 2022 refers to 2022–23 fishing year (which runs from 1 April 2022 to 31 March 2023).

Year	Auckland Islands		Bounty Plateau		Campbell Island		Pukaki Rise		Other	
	Tows	Vessels	Tows	Vessels	Tows	Vessels	Tows	Vessels	Tows	Vessels
1990	3	1	263	25	1 030	35	191	32	3	8
1991	1	1	661	31	1 228	33	262	24	3	8
1992	7	2	1 858	51	1 530	47	374	40	13	27
1993	20	4	433	21	423	20	393	23	6	12
1994	43	7	178	9	480	15	81	11	4	4
1995	15	5	155	10	285	12	71	9	6	12
1996	6	3	67	5	474	11	10	4	1	1
1997	18	5	37	5	650	18	46	8	1	2
1998	14	5	117	11	959	24	34	11	3	9
1999	14	3	288	14	790	21	26	7	2	2
2000	1	1	99	6	447	16	57	8	–	–
2001	25	3	32	5	650	14	12	7	1	1
2002	6	2	94	7	862	18	15	5	–	–
2003	–	–	24	3	599	15	4	3	–	–
2004	1	1	32	3	690	16	3	3	–	–
2005	1	1	100	5	755	17	3	2	–	–
2006	–	–	94	5	521	13	19	1	–	–
2007	–	–	51	4	544	13	20	3	–	–
2008	–	1	200	8	557	14	57	4	–	–
2009	14	3	401	13	627	14	158	9	2	3
2010	–	–	394	13	550	12	170	10	–	–
2011	–	–	175	8	976	14	72	8	–	–
2012	–	–	173	8	592	11	128	9	–	–
2013	–	–	77	5	693	10	4	4	–	–
2014	3	1	190	8	589	11	3	1	–	–
2015	3	1	25	1	641	10	–	–	–	–
2016	1	1	40	2	434	8	–	–	–	–
2017	3	1	25	1	462	9	–	–	–	–
2018	–	–	34	2	424	10	–	–	–	–
2019	1	1	12	2	624	14	117	8	–	–
2020	–	–	14	2	325	9	–	–	–	–
2021	–	–	22	4	419	10	–	–	–	–
2022	2	2	3	1	503	9	5	3	1	1

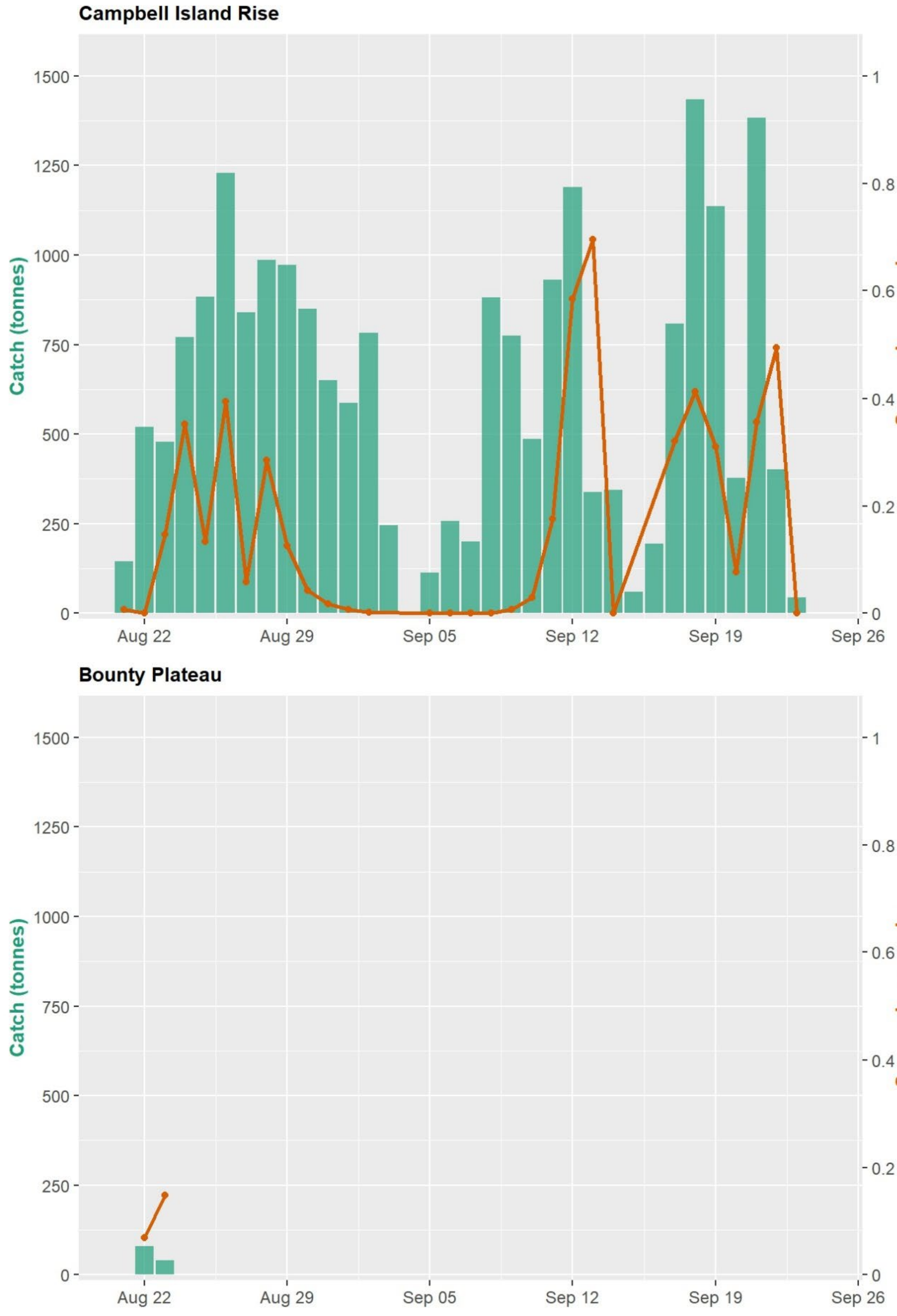

Figure 3: Daily target southern blue whiting catch (green bars) and daily proportion of females spawning (proportions at stage 4) for target southern blue whiting tows on the Campbell Island Rise and Bounty Plateau in 2022 between July and October.

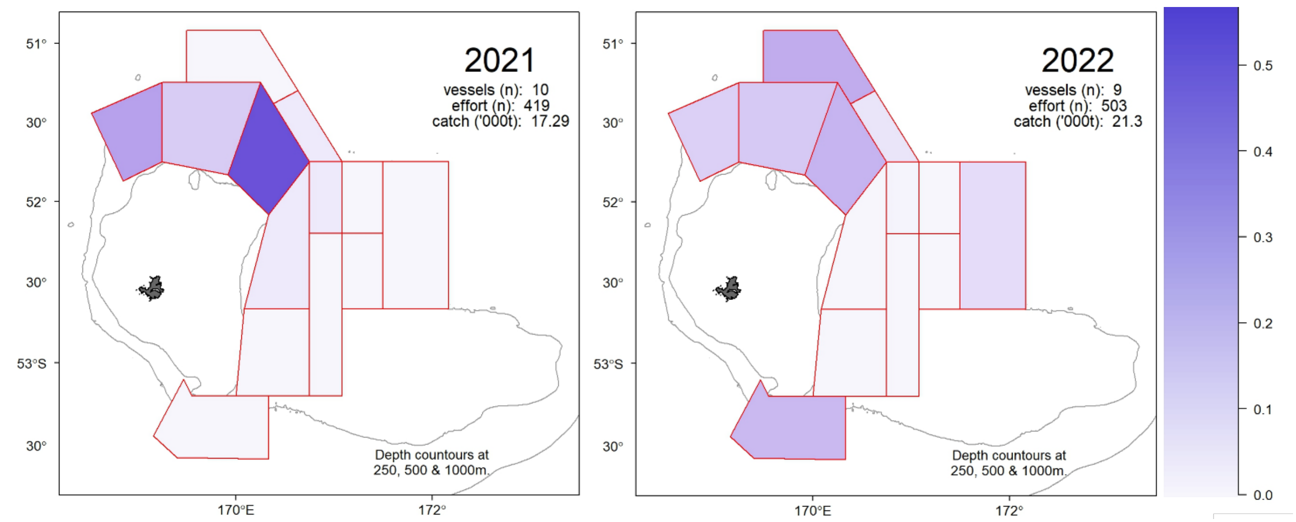

Figure 4: Proportions of catch taken from the Campbell Island Rise by acoustic survey strata from 2021 (left) and 2022 (right) fishing seasons.

3. BIOLOGY

3.1 Stock structure

Stock structure of southern blue whiting was reviewed by Hanchet (1998, 1999) who examined data on distribution and abundance, reproduction, growth, and morphometrics. There appear to be four main spawning grounds: Bounty Plateau, Pukaki Rise, Auckland Islands Shelf, and Campbell Island Rise. There are also consistent differences in the size and age distributions of fish, in the recruitment strength, and in the timing of spawning, between these four areas. Multiple discriminant analysis of data collected in October 1989 and 1990 showed that fish from Bounty Plateau, Pukaki Rise, and Campbell Island Rise could be distinguished using morphometric measurements. This provides evidence that fish in these areas return to spawn on the grounds where they first recruited. There have been no genetic studies, but, given the close proximity of the areas, it seems unlikely that there would be detectable genetic differences in the fish among these four areas.

For stock assessment, it is assumed that there are four stocks of southern blue whiting with fidelity within stocks: the Bounty Plateau stock, the Pukaki Rise stock, the Auckland Islands Shelf stock, and the Campbell Island Rise stock. Southern blue whiting are also managed as four separate stocks (the stocks being the same as the assessment stocks), but with a nominal TACC set for the rest of the New Zealand EEZ.

In 2022 it was investigated whether, for stock assessment purposes, the stock on the Campbell Island Rise should be divided into sub-stocks. The investigation was motivated by catches from the 2022 acoustic survey of larger fish in the east of the survey area. Informed by raised numbers-at-length data, categories of recently recruited (males less than or equal to 31 cm; females less than or equal to 35 cm) and large (males greater than 40 cm; females greater than 45 cm) fish were defined. Tow specific length data were then averaged over 0.5 degree latitude and longitude cells to find the proportion of small, intermediate (medium), and large size fish in each cell in a given year. Proportions of medium and large fish (having excluded small fish) were also calculated. Depending on year, recently recruited fish were found to be more prevalent to the north or the south of the Campbell Island Rise. High proportions of large fish (when compared with medium size fish) were also present either to the north or the south of the Campbell Island Rise, with other years showing the ratio between medium and large fish the same in the north and south (Figure 5). The eastern area of the Campbell Island Rise (defined as east of 171° E) contained few years with catch data but the proportion of large fish in those years was not consistent.

It was concluded there was no consistent pattern of smaller sizes compared with larger sizes of fish north compared with south, or east compared with west. For the years 1989–2022, larger fish were predominant in the south in 13 years, predominant in the north in 6 years and relatively evenly split between north and south in 8 years (and there was insufficient fishing in both north and south to make a comparison in 7 years). The proportion of large fish in the eastern area was not consistent. It was therefore concluded no sub-stock or migration considerations needed to be added to the Campbell Island Rise assessment.

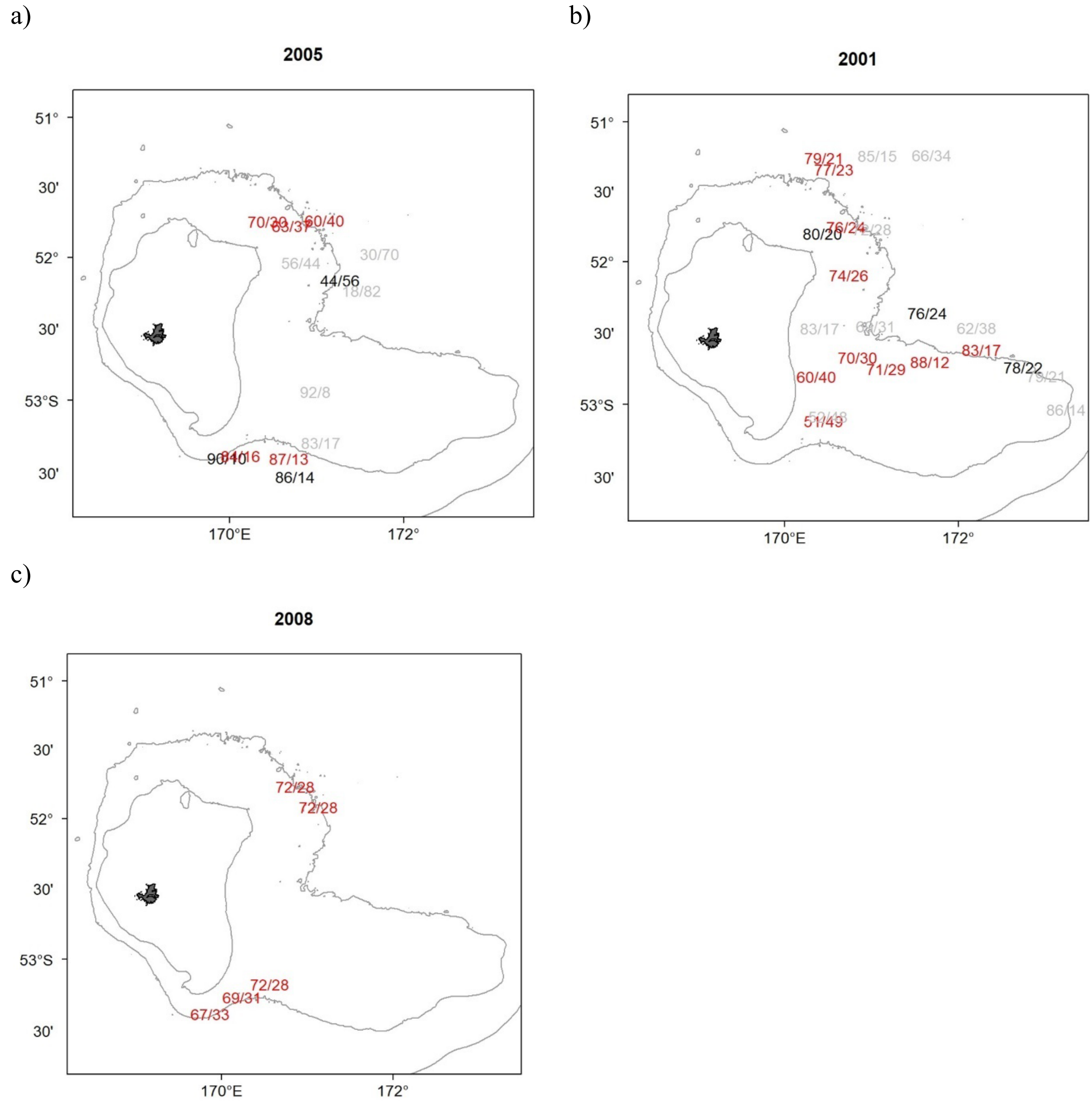

Figure 5: Proportions of medium size (males > 31 and <= 40 cm, females > 35 cm and <= 45 cm) and large fish, e.g., 60/40 = 60% medium size fish, 40% large size fish. Commercial tow data were divided into 0.5 by 0.5 degree cells and values are located at the median location of the tows of a given cell. Colours indicate number of tows forming the data, red: 10 or more tows; black: 4 to 9 tows; grey: 1 to 3 tows. Panels show examples of years in which: a) a high proportion of large fish are located in the north but not the south; b) a larger proportion of large fish are located in the south compared with the north; and c) proportions of medium and large fish are equivalent between north and south.

3.2 Biological parameters

3.2.1 Age and growth

An early growth analysis by Hanchet & Uozumi (1996) indicated female southern blue whiting attain a slightly larger average maximum size than males although growth rates for both sexes were similar. Growth slows down after five years and virtually ceases after ten years. Ages have been validated up to about 15 years by following strong year classes, but ring counts from otoliths suggest individual fish may reach 25 years (Hanchet & Uozumi 1996).

An important feature of the known population dynamics of southern blue whiting is very high recruitment variability and associated density dependent growth (Hanchet et al. 2003). For example, the very strong 1991 year class on the Campbell Island Rise grew at a much slower rate (smaller length and weight at age) than previous year classes (see Figure 6). A similar large reduction in growth rate occurred on the Bounty Plateau with the strong 2002 year class (Figure 7), with the subsequent two year classes also growing at a slower rate. For this reason, mean length-at-age is input into the assessment models as a year specific matrix of lengths-at-age rather than length-at-age based on constant von Bertalanffy growth parameters.

Mean length-at-age estimates for each area (based directly on the annual age-length key) were derived by Hanchet et al. (2003). These estimates have been updated and recalculated from fishery compositional data (described in Section 5 of this report) using NIWA catch-at-age software (Bull & Dunn 2002). In this approach, the raw age-length key data are scaled up so that the mean length-at-age for the plus group is based on the scaled length frequency distribution of fish in the plus group. The results are presented in Figure 6 and Figure 7 for the Campbell Island Rise and the Bounty Plateau, respectively. There is some evidence of a long-term decline in size at age across ages on the Campbell Island Rise. Few otoliths have been collected for aging from the Bounty Plateau in recent years.

Von Bertalanffy growth curves were estimated for males and females on the Pukaki Rise by Dunn & Hanchet (2016b) and are given in Table 3.

Table 3: Estimates of von Bertalanffy growth parameters for the Pukaki Rise stock. CV, coefficient of normally distributed variation of length at age.

Parameter	Male	Female	Source
t_0	-0.92	-0.77	Dunn & Hanchet (2016b)
K	0.273	0.260	
L_{inf}	49.9	53.9	
CV	0.08	0.08	

3.2.2 Spawning and length and age at maturity

Southern blue whiting are thought to be highly synchronised batch spawners. Spawning on Bounty Plateau usually begins in mid-August and finishes by mid-September. Spawning begins 3–4 weeks later in the other areas, finishing in late September or early October. In 2022, spawning on Campbell Island Rise occurred in the fourth week of August. Spawning appears to mainly occur at night, in mid-water, over depths of 400–500 m on Campbell Island Rise but shallower elsewhere (Hanchet 1998).

The age- and length-at-maturity, and recruitment to the fishery, vary between areas and between years. In some years a small proportion of males mature at age 2, but most do not mature until age 3 or 4, usually at a length of 33–40 cm FL. Most females also mature at age 3 or 4 years at a length of 35–42 cm FL. Ageing studies have shown that this species has very high recruitment variability (Hanchet et al. 2003).

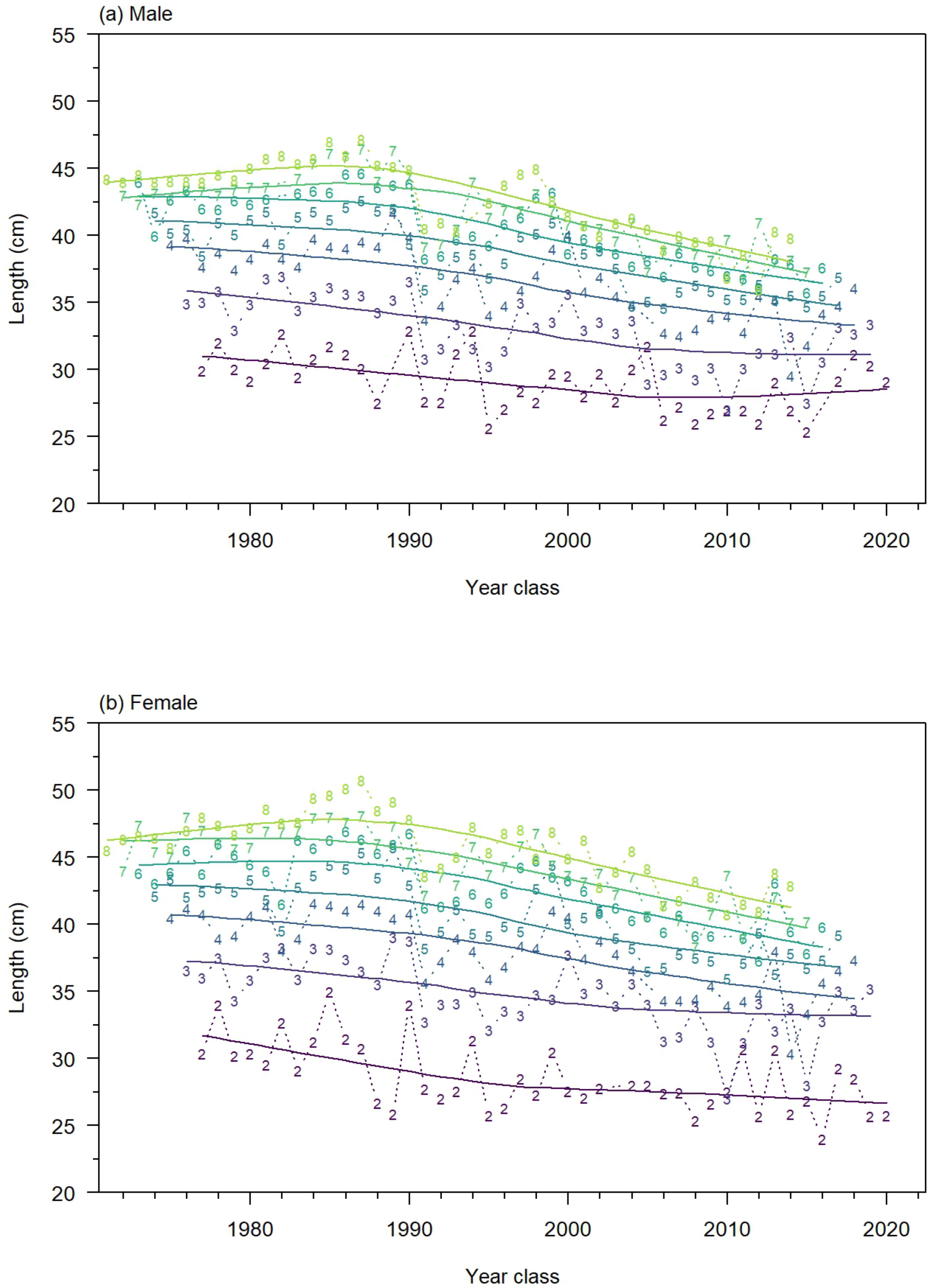

Figure 6: Observed mean length-at-age (ages 2–8) for the Campbell Island stock by sex and year class, 1979–2022. Lines are loess smooths.

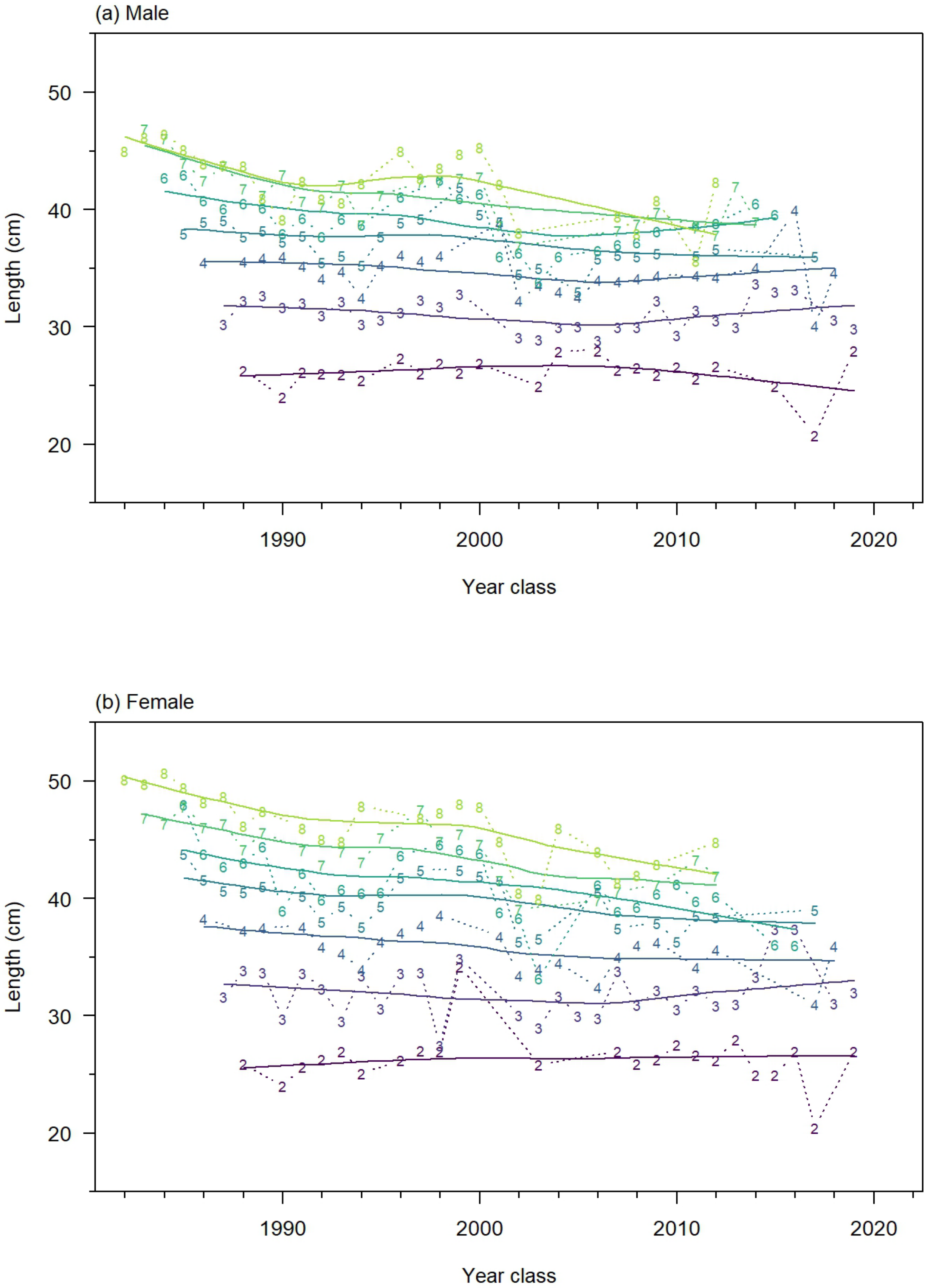

Figure 7: Observed mean length-at-age (ages 2–8) for the Bounty Plateau stock by sex and year class, 1990–2022. Lines are loess smooths.

3.2.3 Length-weight relationship

The length-weight relationship for southern blue whiting was estimated by Hanchet (1991) using data from August–September surveys conducted using the fishing vessel *Shinkai Maru* between 1979 and 1986 (Table 4). To confirm the estimate was still appropriate, length-weight relationships were fitted to catch sample data collected during all acoustic research surveys (see Section 4.1), a total of 14 surveys conducted between 1993 and 2022. Data from the acoustic surveys was restricted to the Campbell Island Rise area. The comparison between results is shown in Figure 8. The length-weight relationships are very similar, therefore the parameterisation of Hanchet (1991) is still appropriate.

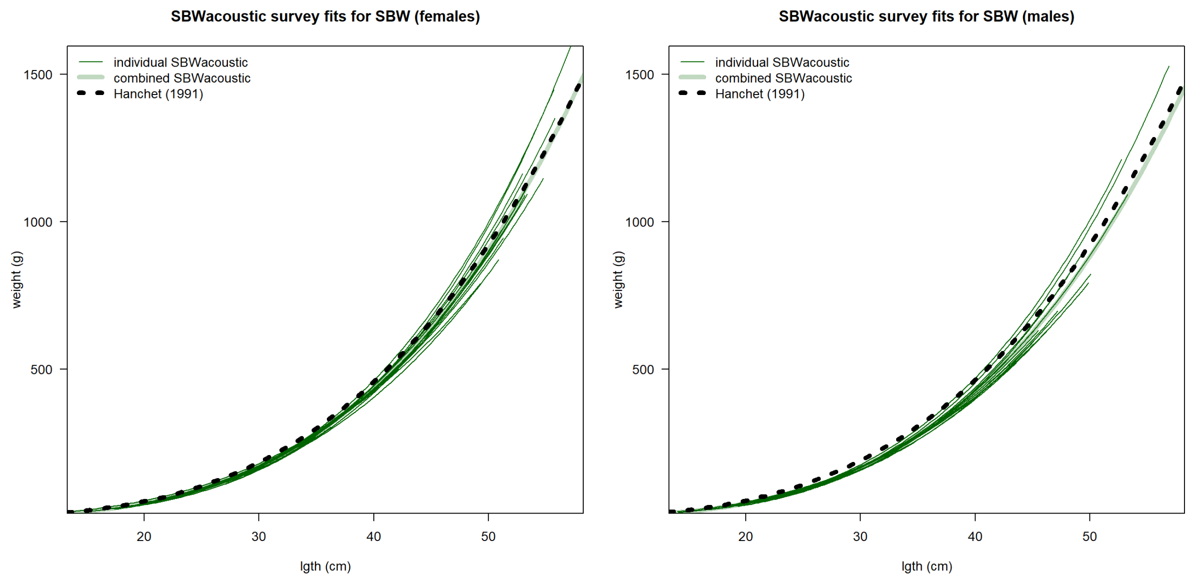

Figure 8: Length-weight relationship from Hanchet (1991) compared with relationships estimated from acoustic survey data for the Campbell Island Rise area for females (left) and males (right).

3.2.4 Natural mortality

Natural mortality rate (*M*) was estimated using the equation $\log_e(100)$/maximum age, where maximum age is the age to which 1% of the population survives in an unexploited stock. Using a maximum age of 22 years, *M* was estimated as 0.21 y^{-1}, and a value of 0.2 y^{-1} has been assumed in assessments (Table 4). Previous Campbell Island stock assessments have estimated *M* within the model. MCMC estimates of 0.20–0.31 were obtained for the Campbell Island stock when *M* was estimated in the 2013 stock assessment model (Dunn & Hanchet 2015b). In the 2015 stock assessment, *M* was estimated to be 0.34 for males and 0.32 for females, but these were considered implausible by the Deepwater Working Group (Dunn & Hanchet 2016a). Combined investigations by Roberts & Dunn (2017) were unable to identify a model structure that produced stable and unbiased estimates of *M* and recommended that, since the value of *M* strongly influences B_0, current stock status, and TACC estimates, assessments continue to use 0.2 (with sensitivities at 0.16 and 0.25) until the causes of bias are identified and corrected. The 2017 assessment (Roberts & Hanchet 2019) assumed a value for *M* of 0.2 y^{-1}, with sensitivities where the value of *M* was fixed at 0.15 and 0.25. A further sensitivity run where *M* was estimated produced a natural mortality estimate of 0.17 (0.13–0.21) for males and 0.18 (0.14–0.22) for females. The 2020 assessment (Doonan 2020) also assumed a value for *M* of 0.2 y^{-1}, with a sensitivity where the value of *M* was estimated, which gave natural mortality estimates of 0.16 (0.13–0.21) for males and 0.17 (0.14–0.21) for females.

Table 4: Biological parameters estimated for the Campbell Island Rise stock and assumed for all stocks.

Estimate	Parameter	Male	Female	Source
Natural mortality (y^{-1})	*M*	0.20	0.20	Hanchet (1992)
		0.17	0.18	Roberts & Hanchet (2019)
		0.16	0.17	Doonan (2020)
Weight = *a* (length)^b	*a*	0.00515	0.00407	Hanchet (1991)
Weight in g, fork length in cm	*b*	3.092	3.152	

4. RESEARCH SURVEYS AND OTHER ESTIMATES OF ABUNDANCE

4.1 Acoustic research surveys

A programme to estimate southern blue whiting spawning stock biomass on each fishing ground using acoustic techniques began in 1993. The Bounty Plateau, Pukaki Rise, and Campbell Island Rise were each surveyed annually between 1993 and 1995. After the first three annual surveys, these areas were surveyed less regularly. The Bounty Plateau grounds were surveyed in 1997, 1999, and most recently in 2001. The Pukaki area was surveyed in 1997 and 2000. The only on-going series of research surveys is on the Campbell Island Rise grounds, which have been surveyed in 1998, 2000, 2002, 2004, 2006, 2009, 2011, 2013, 2016, 2019, and 2022. All these surveys have been carried out from R.V. *Tangaroa* using towed transducers and have been wide-area surveys intended to survey spawning southern blue whiting and pre-recruits. The results of these surveys have been an important input into southern blue whiting stock assessments for the last decade (Dunn & Hanchet 2011a, 2011b, 2015a, 2015b, 2016a, 2017, Large & Hanchet 2017, Roberts & Hanchet 2019, Doonan 2020). Various designs for acoustic surveys of southern blue whiting were investigated using simulation studies by Dunn & Hanchet (1998) and Dunn et al. (2001), whilst Hanchet et al. (2000a) examined diel variation in southern blue whiting density estimates.

The primary objective of the R.V. *Tangaroa* wide-area surveys has been to estimate the biomass of the adult spawning stock. A secondary objective has been to provide estimates of pre-recruit fish in each of the areas and so the surveys have been extended into shallower water where the younger fish live. When adult southern blue whiting are actively spawning, the marks are easily identified because they are very dense and have characteristic features (McClatchie et al. 2000, Hanchet et al. 2000b). However, the pre-spawning and post-spawning adult marks are somewhat more diffuse and the adult fish distribution at this time often overlaps with the pre-recruits. The original analysis separated southern blue whiting marks into categories of adult, immature (mainly 2 and 3 years old) and juvenile (mainly 1 year old). In some areas and years, the marks classified as adults also contained some immature 2 and 3 year old fish, whilst juveniles were often a mix of 1 and 2 year old fish. This problem was addressed by Hanchet et al. (2000b) who carried out a re-analysis of the early R.V. *Tangaroa* acoustic survey and decomposed the estimates into age 1, 2, 3, and 4+ fish. This decomposition of acoustic marks was based on the age composition of targeted research trawls for juvenile and immature marks and on the age composition of commercial trawls for adults. Decomposed estimates of abundance were used as input for stock assessments of all three areas until 2012. However, this introduced a concern that the commercial catch-at-age data were being used twice inside the model: once to decompose the adult acoustic indices and then again as a separate input to the stock assessment model. So, for the next assessments of the Bounty Plateau and Campbell Island stocks the models were revised to use the biomass estimates of the southern blue whiting categories (adult, immature, juvenile) instead (e.g., Dunn & Hanchet 2015b, 2016a, Roberts & Hanchet 2019, Doonan 2020).

There have also been changes in the target strength to fish fork-length (TS–FL) relationship over time. The original estimate was based on the target strength used for the closely related blue whiting (*M. poutassou*) in the northern hemisphere (Monstad et al. 1992), which had itself been derived from measurements of juvenile cod (Nakken & Olsen 1977). A TS–FL relationship for southern blue whiting was first developed by Dunford & Macaulay (2006), which had a much steeper slope and gave higher adult TS than the previous relationship. More recently, O'Driscoll et al. (2013) developed a revised TS–FL relationship using an autonomous optical acoustic system. This new relationship has a shallower slope and lower intercept and is more like the value estimated for blue whiting (Pedersen et al. 2011). O'Driscoll et al. (2013) suggested that part of the reason for the discrepancy between the estimates of Dunford & Macaulay (2006) and the *in situ* estimates of O'Driscoll et al. (2013) was due to an inappropriate application of the Kirchhoff-approximation model at small swimbladder sizes.

The time series of acoustic estimates of the R.V. *Tangaroa* wide-area surveys have been revised on several occasions to reflect these changes in target strength and other changes to the acoustic analysis. Most recently, Fu et al. (2013) revised estimates of biomass of the southern blue whiting categories using the new TS–FL relationship of O'Driscoll et al. (2013). For the purposes of this report, the acoustic estimates for all areas and surveys used the most recent TS–FL relationship for southern blue whiting (O'Driscoll et al. 2013), apart from the single survey of the Auckland Islands Shelf. Where necessary, acoustic indices in earlier reports have been updated. An update for the single survey of the Auckland Islands Shelf (which used the earlier TS-FL relationship of Monstad et al. 1992) was not available.

4.1.1 Auckland Islands Shelf

A single survey of the Auckland Islands Shelf was carried out in 1995 using R.V. *Tangaroa*. This provided a spawning stock biomass estimate of 7800 t (CV = 0.34) based on the original TS–FL relationship for blue whiting (Ingerson & Hanchet 1996).

4.1.2 Bounty Plateau

Two time series of acoustic indices are available for the Bounty Plateau stock (Fu et al. 2013). The first was a wide-area time series of juvenile, immature, and adult southern blue whiting using the R.V. *Tangaroa* for the period 1993 to 2001 (Table 5). A time series of aggregation or local-area acoustic surveys using industry vessels (usually from only one vessel in each year) was initiated in 2004 and continued in most years to 2017 (Table 6). Aggregation-based acoustic surveys were also attempted in 2018, 2019, and 2020, but no acoustic snapshots were carried out due to bad weather and/or the failure to locate a stable spawning aggregation. Aggregation-based acoustic surveys were also contracted for 2021 and 2022 but did not take place.

Table 5: R.V. *Tangaroa* juvenile, immature, and mature acoustic southern blue whiting biomass estimates (t) and CVs for the Bounty Plateau using the O'Driscoll et al. (2013) target strength and reported by (Fu et al. 2013).

Year	Juvenile		Immature		Adult	
	Biomass	CV	Biomass	CV	Biomass	CV
1993	6 449	0.27	15 269	0.33	43 338	0.58
1994	38	0.27	7 263	0.29	17 991	0.25
1995	25 961	0.37	0	–	17 945	0.23
1997	56	0.62	3 265	0.54	27 594	0.37
1999	674	0.57	344	0.37	21 956	0.75
2001	2 141	0.28	668	0.12	11 784	0.35

Table 6: The local-area acoustic southern blue whiting biomass estimates (t) and CVs for the Bounty Plateau using the target strength of O'Driscoll et al. (2013) and reported by Fu et al. (2013) and the proportion of catch taken at the time of the survey (TCEPR & ERS data).

Year	Biomass	CV	Proportion[2]	Source
2004	8 572	0.69	0.73	Fu et al. (2013)
2005 [1]	–	–		Fu et al. (2013)
2006	11 949	0.12	0.78	Fu et al. (2013)
2007	79 285	0.19	0.93	Fu et al. (2013)
2008	75 899	0.34	0.68	Fu et al. (2013)
2009	16 640	0.21	0.29	Fu et al. (2013)
2010	18 074	0.36	0.35	Fu et al. (2013)
2011	20 990	0.28	0.89	Fu et al. (2013)
2012	16 333	0.07	0.84	Fu et al. (2013)
2013	28 533	0.27	0.76	O'Driscoll et al. (2015)
2014	11 832	0.31	0.75	O'Driscoll (2015)
2015	6 726	0.42	0.44	O'Driscoll & Dunford (2016)
2016	6 201	0.35	0.93	O'Driscoll & Ladroit (2017)
2017	7 719	0.24	0.70	O'Driscoll (2018)

1. In 2005, a local-area aggregation survey was carried out, but the acoustic data could not be used because of acoustic interference from the scanning sonar used by the vessel.
2. The proportion of commercial catch that occurred prior to the survey. The local-area aggregation surveys were carried out by fishing vessels in-between fishing activities, and hence the resulting estimates of biomass represented a different time period during the fishing season in each year.

The utility of the industry acoustic surveys up to and including 2013 were reviewed by O'Driscoll et al. (2016). Acoustic data collected in 2005 could not be used because of acoustic interference from the scanning sonar used by the vessel for searching for fish marks and inadequate survey design. There was also concern that the surveys in 2006 and 2009 did not sample the entire aggregation because on several transects the fish marks extended beyond the area being surveyed (O'Driscoll 2011c). Surveys from 2010 to 17 are thought to have had reasonably good coverage and to have surveyed the aggregations successfully (O'Driscoll 2011a, O'Driscoll et al. 2015, O'Driscoll 2015, O'Driscoll & Dunford 2017, O'Driscoll & Ladroit 2017, O'Driscoll 2018).

4.1.3 Campbell Island Rise

Fourteen acoustic surveys of the Campbell Island Rise spawning grounds have been completed using R.V. *Tangaroa*. Results of recent surveys were reported by O'Driscoll et al. (2012, 2014, 2018), Ladroit et al. (2020), and Escobar-Flores et al. (2023) and are summarised in Table 7. The estimate of biomass of juveniles in 2022 was the highest in the time series. The biomass of juveniles was consistent with the observation of extensive acoustic marks in the shallow areas in the northern (e.g., 2, 4, and 5) and southern strata (e.g., 7N) in both snapshots conducted. The larger than usual contribution from juvenile biomass makes the total biomass estimate in 2022 the second highest in the time series.

An industry survey of the Campbell stock (Table 8) was carried out from F.V. *Aoraki* in September 2003 (O'Driscoll & Hanchet 2004). However, subsequent surveys from industry vessels on the Campbell Island grounds have not provided estimates useful for stock assessment (e.g., Hampton & Nelson 2014, O'Driscoll 2011b).

Table 7: R.V. *Tangaroa* juvenile, immature, and mature acoustic southern blue whiting biomass estimates (t) and CV for the Campbell Island Rise during 1993–2022 using the target strength of O'Driscoll et al. (2013) and reported by Fu et al. (2013).

	Juvenile		Immature		Mature		Total	
Year	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	Source
1993	0	0.00	35 208	0.25	16 060	0.24	51 268	Fu et al. (2013)
1994	0	0.00	5 523	0.38	72 168	0.34	77 691	Fu et al. (2013)
1995	0	0.00	15 507	0.29	53 608	0.30	69 114	Fu et al. (2013)
1998	322	0.45	6 759	0.20	91 639	0.14	98 720	Fu et al. (2013)
2000	423	0.39	1 864	0.24	71 749	0.17	74 035	Fu et al. (2013)
2002	1 969	0.39	247	0.76	66 034	0.68	68 250	Fu et al. (2013)
2004	639	0.67	5 617	0.16	42 236	0.35	48 492	Fu et al. (2013)
2006	504	0.38	3 423	0.24	43 843	0.32	47 770	Fu et al. (2013)
2009	0	–	24 479	0.26	99 521	0.27	124 000	Fu et al. (2013)
2011	0	–	14 454	0.17	53 299	0.22	67 753	Fu et al. (2013)
2013	0	–	8 004	0.55	65 801	0.25	73 805	O'Driscoll et al. (2014)
2016	775	0.37	4 456	0.19	97 117	0.16	102 348	O'Driscoll et al. (2018)
2019	0	–	4 060	0.18	91 145	0.27	95 205	Ladroit et al. (2020)
2022	12 764	0.14	5 356	0.22	91 968	0.20	110 088	Escobar-Flores et al. (2023)

Table 8: The local-area acoustic southern blue whiting biomass estimates (including zero transects) and CVs for the Campbell Island Rise using industry vessels and using the target strength of O'Driscoll et al. (2013) and reported by Fu et al. (2013).

Year	Vessel	Area	No. transects	Area (km^2)	Biomass (t)	CV
2003	*Aoraki*	Northeast	6	303	5 442	0.13
			7	407	7 518	0.17
			5	579	10 359	0.24
			5	342	18 162	0.55
			7	332	15 529	0.84
			5	330	13 586	0.57
			7	276	25 594	0.49
		South	5	393	22 722	0.60
			6	330	9958	0.39
2006	*Professor Alexandrov*	Northeast	4	225	4 145	0.72
			8	255	6 940	0.17
2010	*Meridian 1*	Northeast	7	171	32 736	0.40
			7	168	27 891	0.67
			6	42	7 924	0.79
			7	31	5 518	0.65
	Buryachenko	Northeast	7	89	10 408	0.31
			7	67	11 918	0.58
2012	*San Waitaki*	Northeast	13	216	14 006	0.12

4.1.4 Pukaki Rise

Five acoustic surveys of the Pukaki Rise spawning grounds were completed using R.V. *Tangaroa* between 1993 and 2000 (Table 9).

Table 9: R.V. *Tangaroa* juvenile, immature, sub-adult, and adult acoustic southern blue whiting biomass estimates (t) and CVs for the Pukaki Rise using the target strength of O'Driscoll et al. (2013) and reported by Fu et al. (2013).

Year	Juvenile		Immature		Sub-adult		Adult	
	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	CV
1993	0	–	9 558	0.25			26 298	0.32
1994	0	–	125	1.00	3 591	0.48	21 506	0.44
1995	0	–	0	–			6 552	0.18
1997	0	–	1 866	0.12			16 862	0.34
2000	0	–	1 868	0.62	8 363	0.74	6 960	0.37

Large aggregations of spawning southern blue whiting were detected by vessels fishing on the Pukaki Rise in 2009 (O'Driscoll 2011c). Two vessels opportunistically collected acoustic data on these aggregations and the acoustic biomass estimates ranged from 188 t (CV 29%) to 11 321 t (CV 38%) (Table 10). The latter estimate was of a similar magnitude to the abundance of sub-adult and adult southern blue whiting estimated from previous wide-area acoustic surveys of the area (Table 9).

Acoustic surveys on Pukaki Rise in September 2010, using *F.V. Meridian 1*, are reported in Table 10. The estimated acoustic biomass from the survey by *Meridian 1* was 1085 t (CV 17%). O'Driscoll (2011b) re-iterated the problems with trying to use aggregation-based surveys on the Pukaki Rise and recommended the use of wide-area surveys instead. However, another aggregation-based acoustic survey of the Pukaki Rise was carried out by F.V. *San Waitaki* during 23–26 September 2012 (Hampton & Nelson 2014). Biomass estimates from six snapshots ranged from 142 to 1940 t (Hampton & Nelson 2014).

Table 10: The local-area acoustic southern blue whiting biomass estimates (ignoring zero transects) for the Pukaki Rise in 2009, 2010, and 2012 using the target strength of O'Driscoll et al. (2013) and reported by Fu et al. (2013).

Year	Vessel	No. transects	Area (km^2)	Biomass	CV	Source
2009	*Meridian 1*	4	50	188	0.29	O'Driscoll, unpublished results
		5	283	9 459	0.30	O'Driscoll, unpublished results
		5	71	6 272	0.41	O'Driscoll, unpublished results
	Buryachenko	6	60	2 361	0.12	O'Driscoll, unpublished results
		7	117	7 903	0.26	O'Driscoll, unpublished results
		6	19	11 321	0.38	O'Driscoll, unpublished results
2010	*Meridian 1*	10	364	1 085	0.17	O'Driscoll, unpublished results
2012	*San Waitaki*	9	–	642	0.45	Hampton & Nelson (2014)
		10	–	1 914	0.15	Hampton & Nelson (2014)
		12	–	1 940	0.38	Hampton & Nelson (2014)
		10	–	951	0.28	Hampton & Nelson (2014)
		10	–	748	0.22	Hampton & Nelson (2014)
		11	–	142	0.23	Hampton & Nelson (2014)
		Mean	–	1 056	0.14	Hampton & Nelson (2014)
		Mean (2,3,5)	–	1 602	0.14	Hampton & Nelson (2014)

4.2 Trawl research surveys

Trawl surveys of the sub-Antarctic designed to measure primarily hoki, hake, and ling have been carried out using R.V. *Tangaroa* since 1991 (e.g., O'Driscoll & Bagley 2009). Although southern blue whiting is not a target species of this survey, they are often caught in moderate numbers, particularly on the Pukaki Rise and Campbell Island Rise, and it was considered possible that the surveys could be used to monitor their abundance. Hanchet & Stevenson (2006) reanalysed biomass estimates and scaled length frequency distributions for southern blue whiting from the sub-Antarctic summer and autumn survey series for each of three sub-areas, Pukaki Rise, Campbell Island Rise, and Auckland Island Shelf. They defined the three areas as follows: Pukaki Rise (strata 11, 12); Campbell Island Rise (10, 13, 14, 15, and 9S); Auckland Island Shelf (3, 4, 5, 6, 7, 8, 9N) (Figure 9).

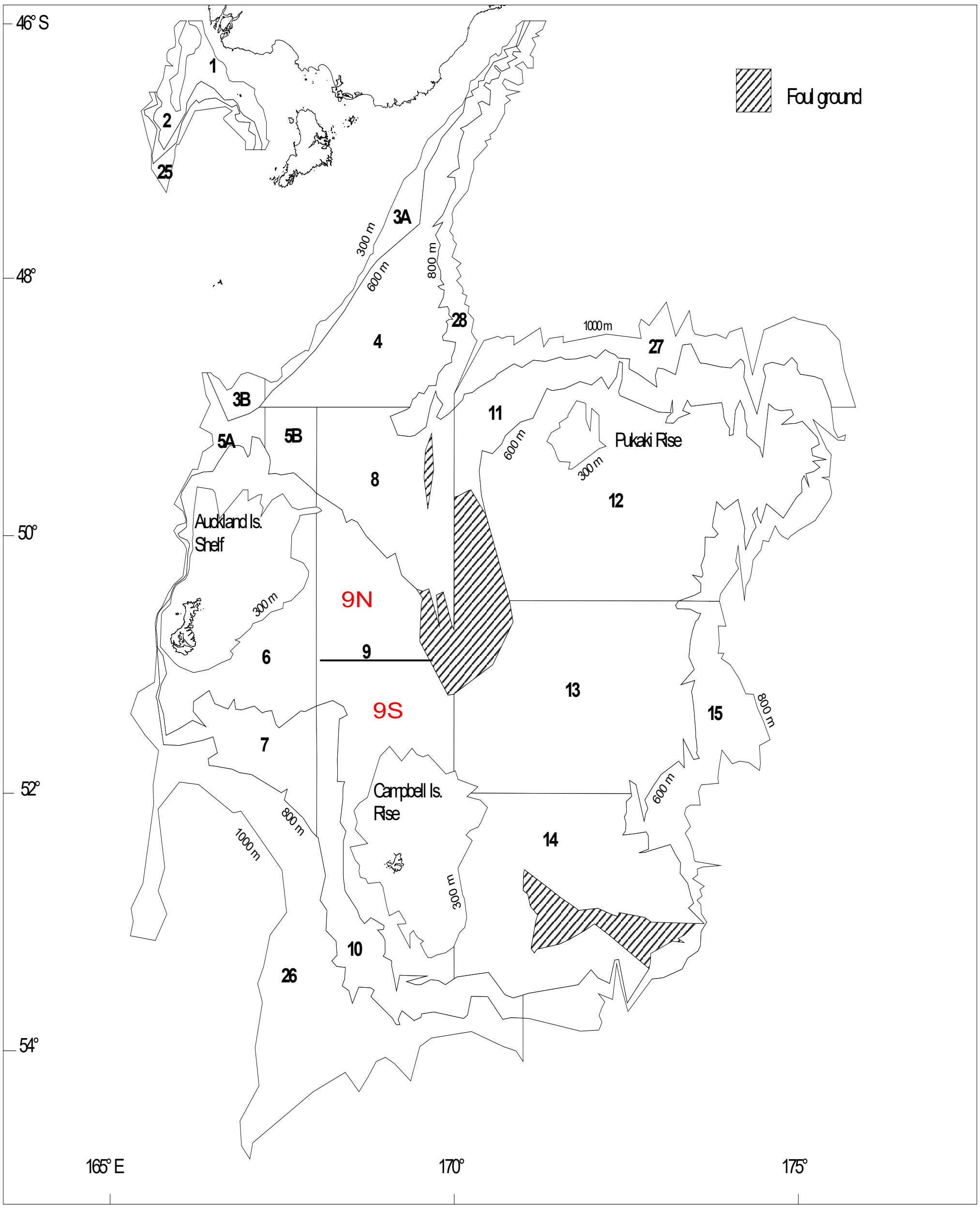

Figure 9: Survey area and stratum boundaries used for R.V. *Tangaroa* sub-Antarctic trawl surveys since 1996. Stratum 9 was split into 9N and 9S at 51° S for the analysis. Stratum 26 has not been surveyed since 2011, and strata 1, 2, 3A, and 25 were not surveyed in 2016 because of time lost due to bad weather.

4.2.1 Auckland Island Shelf

The CVs of the trawl survey biomass estimates for the Auckland Islands Shelf are typically 40–70%, making them too imprecise for monitoring abundance (Table 11). There is little consistency in biomass estimates between the summer and autumn series and between adjacent surveys. Hanchet & Stevenson (2006) concluded that because of the erratic biomass estimates and very high CVs, it was extremely unlikely that the trawl survey indices were monitoring abundance on the Auckland Islands Shelf. Despite this high variability, the trawl surveys may have some utility in monitoring relative abundance.

The time series suggests an almost 10–fold increase in average abundance between the early part of the series (1991–2004) and the later part, i.e., from 2005 (although estimates in 2008 and 2022 were below 1000 t). It is unknown whether this increase reflects a period of stronger recruitment of fish in this area or a redistribution of fish from other areas, because there has been no targeted commercial fishing.

Table 11: R.V. *Tangaroa* trawl survey southern blue whiting biomass estimates (t), CVs, and number of stations (N) for selected strata for the Auckland Islands Shelf (data for 1991–2005 from Hanchet & Stevenson (2006), data for 2006 onwards from NIWA Trawl database).

Year	Summer				Autumn				
	Trip	Biomass	CV	N	Year	Trip	Biomass	CV	N
1991	TAN9105	565	0.75	58	1992	TAN9211	125	0.98	60
1992	TAN9204	40	0.31	31	1993	TAN9310	3 458	0.60	51
1993	TAN9304	159	0.89	44	1996	TAN9605	447	0.33	40
2000	TAN0012	135	0.61	38	1998	TAN9805	746	0.69	25
2001	TAN0118	527	0.68	36					
2002	TAN0219	68	0.76	38					
2003	TAN0317	281	0.85	27					
2004	TAN0414	28	0.69	30					
2005	TAN0515	3 972	0.39	98					
2006	TAN0617	1 146	0.81	40					
2007	TAN0714	1 686	0.45	41					
2008	TAN0813	275	0.55	36					
2009	TAN0911	1 432	0.60	39					
2011	TAN1117	3 628	0.61	45					
2012	TAN1215	1 079	0.40	39					
2014	TAN1412	3 053	0.68	37					
2016	TAN1614	2 059	0.34	23					
2018	TAN1811	6 296	0.58	31					
2020	TAN2014	1 967	0.49	29					
2022	TAN2215	699	0.26	26					

4.2.2 Campbell Island Rise

The CVs of the trawl survey biomass estimates for the Campbell Island Rise are mostly in the range 25–55%, making them marginally useful for monitoring abundance (Table 12). There was some consistency in biomass estimates between the summer and autumn series and between adjacent surveys, although less so in recent years. Hanchet & Stevenson (2006) noted that although the trend in the trawl survey abundance indices on the Campbell Island Rise was generally similar to estimates of biomass from the population model, the trawl survey observed biomass was lower than expected at low stock sizes and higher than expected at high stock sizes. Hanchet & Stevenson (2006) suggested that increasing the number of trawl stations would improve the precision of the surveys, but they could not determine if this would also remove this potential bias.

Dunn & Hanchet (2011a) included observations of biomass from the sub-Antarctic trawl survey and the associated age frequencies in an assessment model for the Campbell Island Rise. They drew a similar conclusion to Hanchet & Stevenson (2006), with the fits suggesting some consistency in the pattern of biomass estimates between the summer series, but the observations lower than model-estimated biomass at low stock sizes and higher at high stock sizes. The trawl survey biomass estimates for the Campbell Island Rise in 2016, 2020, and 2022 were relatively high (Table 12), consistent with the high acoustic estimates recorded in 2016, 2019, and 2022 (Section 4.1.3) and the current stock status (Doonan et al. in review).

Table 12: R.V. *Tangaroa* trawl survey southern blue whiting biomass estimates (t), CVs, and number of stations (N) for selected strata for the Campbell Island Rise (data for 1991–2005 from Hanchet & Stevenson (2006), data for 2006 onwards from NIWA Trawl database).

	Summer					Autumn			
Year	Trip	Biomass	CV	N	Year	Trip	Biomass	CV	N
1991	TAN9105	2 328	0.53	52	1992	TAN9211	5 013	0.31	54
1992	TAN9204	5 942	0.58	39	1993	TAN9310	2 472	0.25	52
1993	TAN9304	1 714	0.29	34	1996[1]	TAN9605	31 203	0.36	19
2000	TAN0012	10 738	0.14	23	1998	TAN9805	10 321	0.37	17
2001	TAN0118	6 393	0.40	23					
2002	TAN0219	3 198	0.45	21					
2003	TAN0317	1 047	0.56	19					
2004	TAN0414	778	0.26	21					
2005	TAN0515	1 502	0.27	17					
2006	TAN0617	4 729	0.73	16					
2007	TAN0714	2 631	0.53	19					
2008	TAN0813	5 870	0.29	17					
2009	TAN0911	4 884	0.31	15					
2011	TAN1117	1 610	0.25	15					
2012	TAN1215	14 283	0.49	20					
2014	TAN1412	2 272	0.28	18					
2016	TAN1614	20 731	0.14	17					
2018	TAN1811	4 779	0.36	19					
2020	TAN2014	7 393	0.50	18					
2022	TAN2215	9 468	0.49	18					

1. Only 1 station for TAN9605 was in stratum 9S. This was supplemented with a second station taken from 9N to allow the stratum biomass and variance to be calculated. The contribution of stratum 9S to the total biomass was about 64 t, and hence the impact of this correction was negligible.

4.2.3 Pukaki Rise

The CVs of the trawl survey biomass estimates for the Pukaki Rise are quite variable between years but mainly in the range 20–50%, making them marginally useful for monitoring abundance (Table 13). There is some consistency in biomass estimates between the summer and autumn series and between adjacent surveys, although less so in recent years.

Hanchet & Stevenson (2006) concluded that given the reduction in station density over time and poor agreement of the indices with either modelled biomass or catch history, it was unlikely that the trawl survey indices were monitoring abundance on the Pukaki Rise. After reviewing the work, the Middle Depths Working Group recommended that the number of stations in the core Pukaki Rise stratum be increased slightly during the surveys and this has been undertaken in some recent surveys, where time allowed (e.g., O'Driscoll & Bagley 2009). Nevertheless, recent biomass estimates have fluctuated considerably, and the conclusions of Hanchet & Stevenson (2006) remain valid.

The most recent assessment of the Pukaki Rise stock (Dunn & Hanchet 2016b) was mainly influenced by the trawl survey index and the commercial catch proportions-at-age data. The authors recommended that some consideration should be given towards further increasing the number of stations carried out in the core Pukaki Rise strata to improve the precision of the estimates. A moderate increase to 15–20 stations per survey may provide a more precise and useful index of abundance.

Table 13: R.V. *Tangaroa* trawl survey southern blue whiting biomass estimates (t), CVs, and number of stations (N) for selected strata for the Pukaki Rise by voyage season (data for 1991–2005 from Hanchet & Stevenson (2006), data for 2006 onwards from NIWA Trawl database).

Year	Summer				Autumn				
	Trip	Biomass	CV	N	Year	Trip	Biomass	CV	N
1991	TAN9105	3 037	0.31	30	1992	TAN9211	2 368	0.31	29
1992	TAN9204	2 894	0.60	17	1993	TAN9310	3 550	0.24	20
1993	TAN9304	3 684	0.44	16	1996	TAN9605	13 698	0.65	15
2000	TAN0012	6 659	0.33	10	1998	TAN9805	11 102	0.31	10
2001	TAN0118	2 995	0.26	14					
2002	TAN0219	3 251	0.63	12					
2003	TAN0317	1 731	0.35	12					
2004	TAN0414	2 537	0.47	10					
2005	TAN0515	1 109	0.18	10					
2006	TAN0617	911	0.43	10					
2007	TAN0714	3 747	0.28	12					
2008	TAN0813	9 078	0.14	14					
2009	TAN0911	45 657	0.85	12					
2011	TAN1117	2 106	0.21	12					
2012	TAN1215	6 295	0.47	12					
2014	TAN1412	4 598	0.41	13					
2016	TAN1614	13 265	0.28	12					
2018	TAN1811	7 753	0.48	11					
2020	TAN2014	9 538	0.35	10					
2022	TAN2215	10 794	0.25	10					

4.3 CPUE analyses

Standardised CPUE indices were calculated for the Bounty and Campbell stocks using lognormal linear models of catch-per-tow, catch-per-hour, and catch-per-day for all vessels, and catch-per-tow for subsets of vessels based on processing type (surimi or dressed), and by relative experience in each fishery (Hanchet & Blackwell 2003, Hanchet et al. 2006). The data and methods were summarised, and the indices compared with the results of recent corresponding stock assessments (Hanchet et al. 2006). Standardised CPUE have not been updated since 2002 for the Bounty Plateau stock, and since 2005 for the Campbell Island stock.

Unstandardised CPUE indices for each fishing ground are listed in Table 14. CPUE on the Bounty Platform was relatively high from 2007 compared with earlier years but the values after 2017 may be a poor indication of stock health because of a reduction in fishing activity in the area (in 2022 catch was only recorded on two days). On the Campbell Island Rise, the 2022 CPUE (8.5 t/hour) was at the upper end of values recorded since 2014.

Table 14: Unstandardised target median catch per unit effort indices (t/hour) for the Auckland Islands, Bounty Plateau, Campbell Island Rise, and Pukaki Rise fisheries, July–October 1990–2022 (source: TCEPR & ERS data).

Year	Auckland Islands	Bounty Plateau	Campbell Island Rise	Pukaki Rise
1990	0.0	5.8	3.3	1.1
1991	0.0	4.2	4.5	4.9
1992	<0.1	10.0	1.0	0.9
1993	8.1	4.8	4.0	1.8
1994	0.5	0.9	5.5	3.2
1995	1.5	6.1	5.8	1.9
1996	0.5	7.5	6.7	13.3
1997	5.7	6.4	5.7	4.5
1998	4.7	6.5	6.3	2.7
1999	1.6	6.9	10.2	14.3
2000	0.0	3.0	6.6	3.7
2001	0.8	6.0	7.2	0.4
2002	0.5	7.2	6.5	0.0
2003	–	14.3	8.0	0.0
2004	1.4	5.4	7.4	1.2
2005	5.6	9.0	7.2	0.7
2006	–	7.9	9.8	5.5
2007	–	12.9	9.7	2.4
2008	–	16.6	9.4	13.6
2009	0.2	12.9	8.1	12.0
2010	–	12.6	10.2	8.8
2011	–	16.7	9.5	1.4
2012	–	12.3	10.0	2.4
2013	–	16.1	10.5	1.0
2014	<0.1	11.1	8.6	0.2
2015	1.5	17.3	7.2	–
2016	0.0	11.2	7.8	–
2017	0.1	18.0	6.7	–
2018	–	5.2	5.6	–
2019	–	6.9	8.6	7.0
2020	–	18.8	7.3	–
2021	–	7.5	7.7	–
2022	1.8	19.8	8.5	0.3

4.3.1 Bounty Plateau

The Bounty Plateau analysis was based on a data set of 3288 non-zero catch tow records from 1990 to 2002 (Hanchet & Blackwell 2003). The CPUE indices fluctuated considerably, peaking in 1992, 1996–1998, and again in 2002 (Table 15). The indices were similar between most of the CPUE models until 1997, but after 1997 they became more erratic between years and inconsistent amongst vessel subsets. Hanchet & Blackwell (2003) noted that there were problems with the model assumptions, and that the model structure may be inadequate to reliably determine the indices and their standard errors. Trends in CPUE for the Bounty Plateau fishery were consistent with trends in biomass from the 2002 stock assessment model of Hanchet (2002), apart from the first two years and last two years. The CPUE indices were rejected as indices of abundance by the (then) Middle Depths Working Group and have not been used for stock assessments.

Table 15: Relative year effects and standard errors (s.e.) for the all vessels catch-per-tow model 1990 to 2002 for the Bounty Plateau fishery (Hanchet & Blackwell 2003).

Year	Standardised CPUE	
	Index	s.e.
1990	1.00	–
1991	1.20	0.12
1992	1.69	0.15
1993	0.89	0.10
1994	0.35	0.06
1995	0.57	0.09
1996	1.06	0.20
1997	0.98	0.25
1998	1.06	0.16
1999	0.68	0.08
2000	0.75	0.12
2001	0.98	0.25
2002	1.52	0.24

4.3.2 Campbell Island Rise

The original Campbell Island Rise analysis was based on 11 853 non-zero catch records from 1986 to 2002. CPUE indices decreased slowly to a minimum in 1992, increased to a peak in 1996, followed by a slight decline to 2002 (Hanchet & Blackwell 2003). This trend was consistent among alternative measures of effort and among subsets of surimi and dressed vessels. *Vessel* was the most important variable, together with *day in season*, *end time of tow*, and *sub-area*. Model diagnostics indicate a poor fit to the data, and the models were unable to fit very high or very low catch rates.

The trends in CPUE for the Campbell Island Rise fishery were consistent with the trends in the 2003 assessment model (Hanchet & Blackwell 2003). They followed the increase from 1993 to 1996 associated with the strong 1991 year class, and then followed the decline in relative abundance as this year class was fished down. Exploratory stock assessment model runs including the CPUE indices gave very similar results to those excluding the CPUE indices. The authors concluded that the CPUE indices for the Campbell Island Rise were monitoring the stock abundance and could be used in future stock assessments. However, they also cautioned that there can be considerable variability in the CPUE indices for individual years, and several years of data may be necessary before any trends become apparent.

The standardised CPUE analysis (Table 16) was updated to 2005 by Hanchet et al. (2006). They found that there was some divergence in the CPUE indices between the various models in the years 2002 to 2005. The Working Group was unable to agree on which indices were monitoring abundance. As such, the CPUE indices were rejected as indices of abundance by the Middle Depths Working Group and have not been used for stock assessments.

Table 16: Relative year effects and standard errors (s.e.) for all vessels catch-per-hour and catch-per-tow models, and raw mean CPUE (catch-per-hour and catch-per-tow) for the Campbell Island fishery, 1986 to 2005 (source: Hanchet et al. 2006).

Year	Catch per hour model			Catch per tow model		
	Year index	s.e.	CPUE (t/hr)	Year index	s.e.	CPUE (t/tow)
1986	1.00	–	9.7	1.00	–	14.9
1987	0.79	0.06	7.7	0.91	0.06	15.4
1988	0.59	0.05	6.7	0.88	0.06	19.9
1989	0.68	0.07	8.7	1.40	0.12	27.2
1990	0.52	0.05	7.0	1.04	0.09	17.7
1991	0.44	0.05	7.2	1.31	0.13	18.3
1992	0.29	0.03	4.3	0.60	0.06	11.7
1993	0.69	0.09	9.4	1.05	0.13	24.0
1994	0.69	0.10	9.2	1.19	0.14	25.8
1995	0.93	0.14	11.3	1.26	0.17	46.2
1996	1.88	0.27	14.0	2.34	0.29	42.0
1997	1.67	0.23	10.3	2.34	0.29	32.1
1998	1.17	0.15	11.5	1.79	0.21	28.3
1999	1.91	0.26	17.3	2.57	0.30	36.0
2000	1.23	0.17	10.8	1.87	0.23	32.7
2001	1.00	0.13	11.1	1.77	0.21	36.1
2002	1.02	0.14	11.1	1.88	0.22	33.2
2003	0.82	0.11	10.3	2.11	0.25	36.6
2004	0.92	0.12	12.1	1.95	0.23	28.9
2005	0.95	0.13	13.5	2.51	0.30	33.6

5. LENGTH AND AGE COMPOSITION OF THE FISHERY

5.1 Methods

Historical time series of catch-at-age data are available from at-sea observers for each of the stocks, and these form an important input into the stock assessments. A summary of the number of length measurements and otoliths read, on which these catch-at-age estimates were based, is tabulated for each area in Tables 17–21. The raw length frequency data were examined graphically for variability in length composition by time of season and/or locality within each of the main areas and divided into appropriate strata. The length frequency data for each tow were first scaled up to the catch from the tow, and these were then scaled up to the catch for each of the strata, and then the strata were combined to form a single length frequency for that area/year combination.

Age-length keys were year and area specific. In most years, 400–500 otoliths were read for each area/year combination. Catch-at-age data for each stock were analysed using the NIWA catch-at-age software (Bull & Dunn 2002). This also gives the CVs that incorporate the variance from both the length frequency data and the age-length key using bootstrapping. Where necessary, 'proxy' ages were assumed for those length intervals with no corresponding age—typically only smaller fish lengths (less than about 30 cm) that were assigned age 1 or 2 depending on their size. Therefore, an age was available for every length interval below 50 cm for males and 52 cm for females, for which length frequency observations were available. Any larger fish were put into an 'unassigned' category, which were placed in the plus group (at age 15) for assessment modelling.

Commercial catch proportions-at-age (for all ages measured) by year and associated year class progressions are summarised for each fishery in Figures 10, 12, 15, and 17. Each fishery section includes figures of proportions-at-length and proportions-at-age for all ages measured by sex and year. Larger format figures of proportions-at-length and proportions-at-age (with age 15+ group) are included in the appendices.

5.2 Auckland Islands Shelf

The Auckland Islands has been fished only sporadically since 1990 (Table 17). Some targeting of aggregations of southern blue whiting during the spawning season occurred between 1993 and 1998, but since then most of the southern blue whiting catch has been taken as bycatch of fisheries targeting hoki, hake, ling, and squid during other months of the year (Hanchet & Dunn 2009).

Small numbers of fish were measured in some years from a small amount of effort around the Auckland Islands (Table 17), but few otoliths were collected and these have not been read. Catch-at-age data are available for 1993 to 1998, and 2002 (Figure 10 and Figure 11). The catch during 1995 to 1998 was dominated by the strong 1992 year class, and this year class persisted through to the most recent age data in 2002.

Table 17: Total number of tows and TCEPR/ERS estimated catch of southern blue whiting (including non-target), observed tows and estimated catch (including non-target), number of measured and aged males and females, Auckland Islands 1990–2022 (source: TCEPR, ERS, and Observer data, 1990–2022).

Year	Catch			Observed				Measured		Aged	
	Vessels	Tows	t	Vessels	Tows	t	%t	Male	Female	Male	Female
1990	7	93	0	0	0	0	0.0	0	0	0	0
1991	6	130	5	0	0	0	0.0	0	0	0	0
1992	11	90	73	0	0	0	0.0	0	0	0	0
1993	5	82	1 133	2	5	457	40.4	495	264	28	37
1994	12	315	1 056	1	7	324	30.6	601	563	57	79
1995	5	15	408	4	10	345	84.4	732	974	46	94
1996	3	6	54	0	0	0	0.0	0	0	0	0
1997	7	59	935	3	11	517	55.4	1 019	827	126	114
1998	11	121	520	1	6	238	45.8	649	550	80	38
1999	10	174	214	0	0	0	0.0	0	0	0	0
2000	11	273	7	0	0	0	0.0	0	0	0	0
2001	9	219	0	0	0	0	0.0	0	0	0	0
2002	15	499	45	2	3	3	6.0	100	89	20	25
2003	14	466	14	0	0	0	0.0	0	0	0	0
2004	11	314	27	1	1	4	16.7	12	28	0	0
2005	13	445	43	0	0	0	0.0	0	0	0	0
2006	12	226	35	0	0	0	0.0	0	0	0	0
2007	11	488	240	2	5	4	1.8	107	77	0	0
2008	7	186	67	1	11	16	24.4	307	220	0	0
2009	8	295	93	0	0	0	0.0	0	0	0	0
2010	9	257	39	1	3	5	13.5	175	175	0	0
2011	9	297	29	1	1	1	2.0	9	11	0	0
2012	4	268	13	0	0	0	0.0	0	0	0	0
2013	6	319	17	0	0	0	0.0	0	0	0	0
2014	5	149	9	0	0	0	0.0	0	0	0	0
2015	10	306	37	1	1	19	51.3	55	95	0	0
2016	11	562	1	0	0	0	0.0	0	0	0	0
2017	16	850	10	0	0	0	0.0	0	0	0	0
2018	15	799	8	2	4	<1	2.6	21	50	0	0
2019	23	1309	364	1	5	16	4.4	57	43	0	0
2020	15	814	93	4	13	14	15.1	89	171	0	0
2021	20	850	37	0	0	0	0.0	0	0	0	0
2022	18	704	72	0	0	0	0.0	0	0	0	0

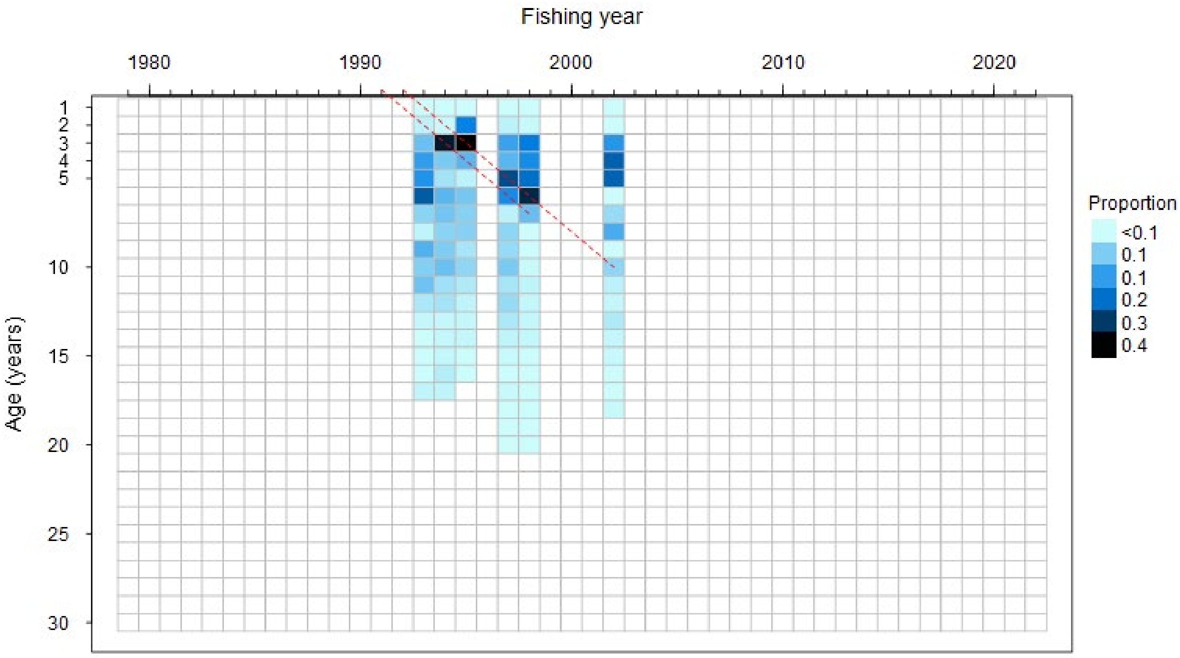

Figure 10: Commercial catch proportions-at-age for the Auckland Islands stock, 1993–2002. Year classes can be tracked on the diagonal, with earlier dominant year classes highlighted by the dashed lines.

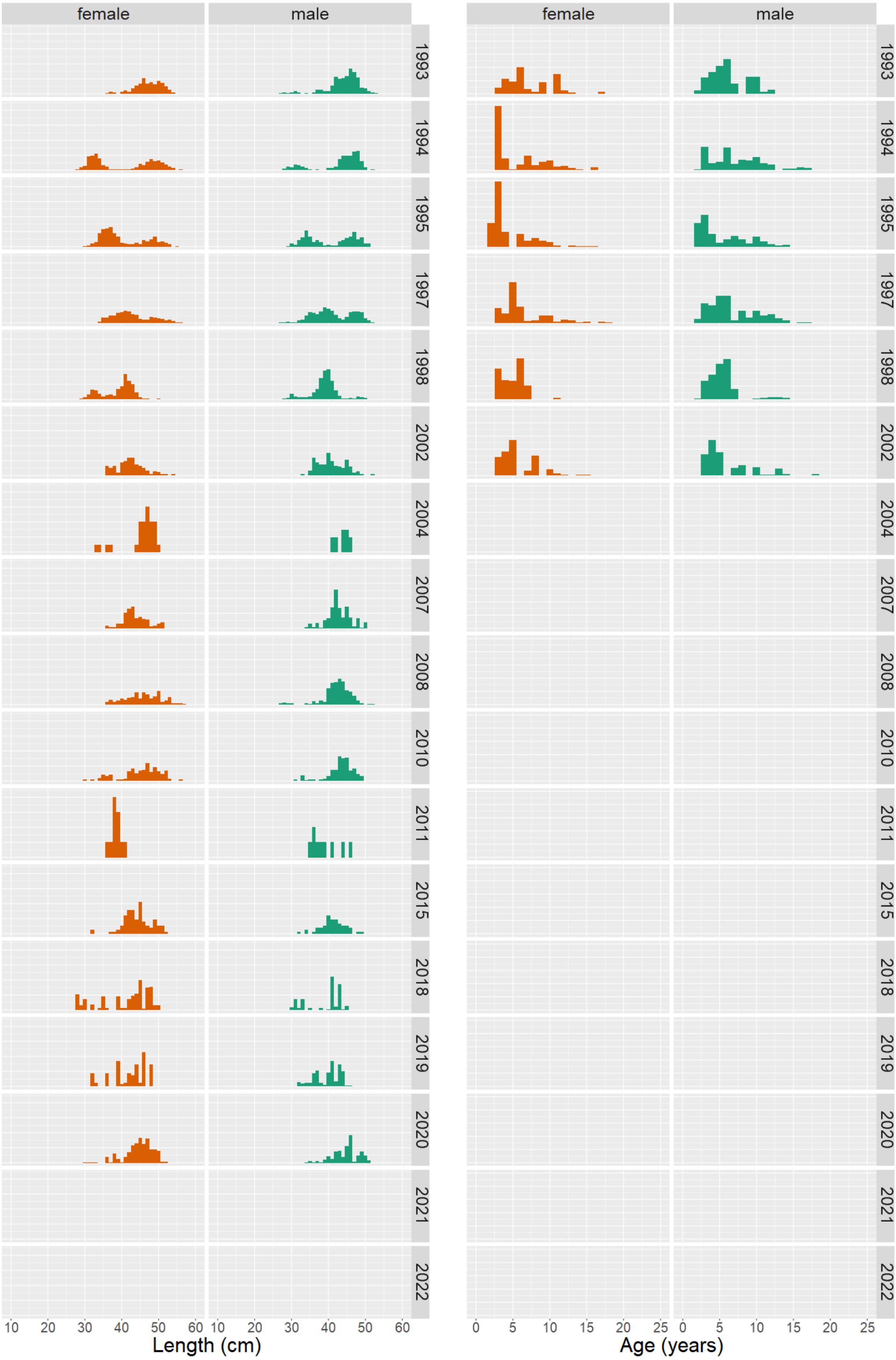

Figure 11: Commercial catch proportions at length (left) and age (right) for the Auckland Islands stock by sex, 1993–2022. Proportions sum to one across males and females in each year.

5.3 Bounty Plateau

The Bounty Plateau has been fished consistently since 1990 although the amount of fishing declined after 2017 to a very low level in 2022 (Table 18), and in each year all of the catch and almost all of the tows have occurred between July and October. Catch-at-age data are available for the entire period 1990 to 2022, although the numbers of fish measured and aged were low in some years and zero in 2003 (Table 18). Examination of the raw data showed that the length composition was relatively constant throughout the season and across the area and so in most years all the length frequency data were placed into a single stratum.

Table 18: Total number of tows and TCEPR/ERS estimated catch of southern blue whiting (including non-target), observed tows and estimated catch (including non-target), number of measured and aged males and females, Bounty Plateau, 1990–2022 (source: TCEPR, ERS, and Observer data, 1990–2022).

Year			Catch				Observed		Measured		Aged
	Vessels	Tows	t	Vessels	Tows	t	%t	Male	Female	Male	Female
1990	26	269	4 438	5	23	391	8.8	2 569	1 690	135	118
1991	31	662	11 185	3	16	458	4.1	1 613	1 140	85	56
1992	49	1 732	58 696	10	161	10 086	17.2	12 726	12 189	318	282
1993	21	433	11 788	6	72	5 037	42.7	4 901	7 065	213	319
1994	9	202	3 877	4	40	2 836	73.1	4 202	3 126	255	253
1995	10	156	6 473	5	65	5 816	89.9	5 992	4 299	215	189
1996	5	67	5 113	2	22	2 511	49.1	2 171	2 465	201	280
1997	5	37	2 043	3	8	689	33.7	692	884	151	293
1998	11	118	5 794	6	69	5 627	96.6	7 574	6 743	211	261
1999	14	289	10 573	5	73	4 765	45.1	6 145	6 217	195	383
2000	6	99	3 851	3	27	2 716	70.5	1 858	3 323	110	288
2001	5	32	1 554	2	12	1 060	68.2	836	1 133	218	283
2002	8	182	6 209	1	8	1 116	18.0	590	671	62	87
2003	3	24	3 603	0	0	0	0.0	0	0	0	0
2004	4	234	1 478	1	3	379	25.7	202	292	80	111
2005	8	284	3 769	4	40	2 818	74.8	3 212	3 256	159	261
2006	6	145	4 256	3	62	3 375	79.3	5 658	4 231	232	268
2007	5	103	3 602	3	27	3 458	96.0	2 118	2 124	110	190
2008	9	209	9 582	5	91	6 489	67.7	6 085	9 713	130	276
2009	14	426	14 958	4	104	5 269	35.2	7 637	8 526	130	292
2010	14	601	13 783	4	57	3 810	27.6	4 918	3 836	193	203
2011	9	241	6 468	4	49	3 876	59.9	4 121	4 205	140	200
2012	8	174	6 855	5	62	4 049	59.1	6 024	5 280	179	216
2013	5	77	3 860	5	30	2 638	68.3	2 356	2 224	186	3228
2014	8	190	8 069	8	138	7 662	94.1	12 378	12 850	236	210
2015	1	25	2 278	1	22	2 385	100.0	2 041	1 850	232	172
2016	2	40	2 457	2	31	2 519	100.0	2 903	3 616	152	257
2017	2	68	2 189	1	21	2 335	100.0	1 196	1 956	132	201
2018	3	39	986	2	11	609	61.7	614	922	51	166
2019	3	19	699	2	8	821	100.0	576	808	46	109
2020	2	19	1 023	2	10	1 136	100.0	616	880	61	108
2021	5	64	707	3	9	407	57.6	587	760	46	58
2022	1	3	120	1	3	118	98.3	188	386	29	56

The catch in recent years was dominated by a single mode of fish (the 2002 year class), which could be tracked from 2005, when it first entered the fishery at about 30 cm as 3 year olds, to 2020, when it still dominated the catch of females in the fishery as 18 year olds (Figures 12–14). This dominance reduced sharply in 2021 and again in 2022. In the past few years, the 2007 and 2012 year classes of moderate strength appeared in the length and age frequencies. In 2022, the dominant year class was that from

2018. Previously, the catch over the 30-year period had been dominated by several other strong year classes, in particular those from 1986, 1988, 1991, 1992, and 1994. It should be noted the decline in fishing activity in recent years caused a consequent reduction in fish sampled for length and age. The number of fish measured in 2022 was one sixth (males) to one fifth (females) compared with 2017, and the number of fish aged in 2022 was less than a quarter (males) and less than a third (females) of 2017 numbers.

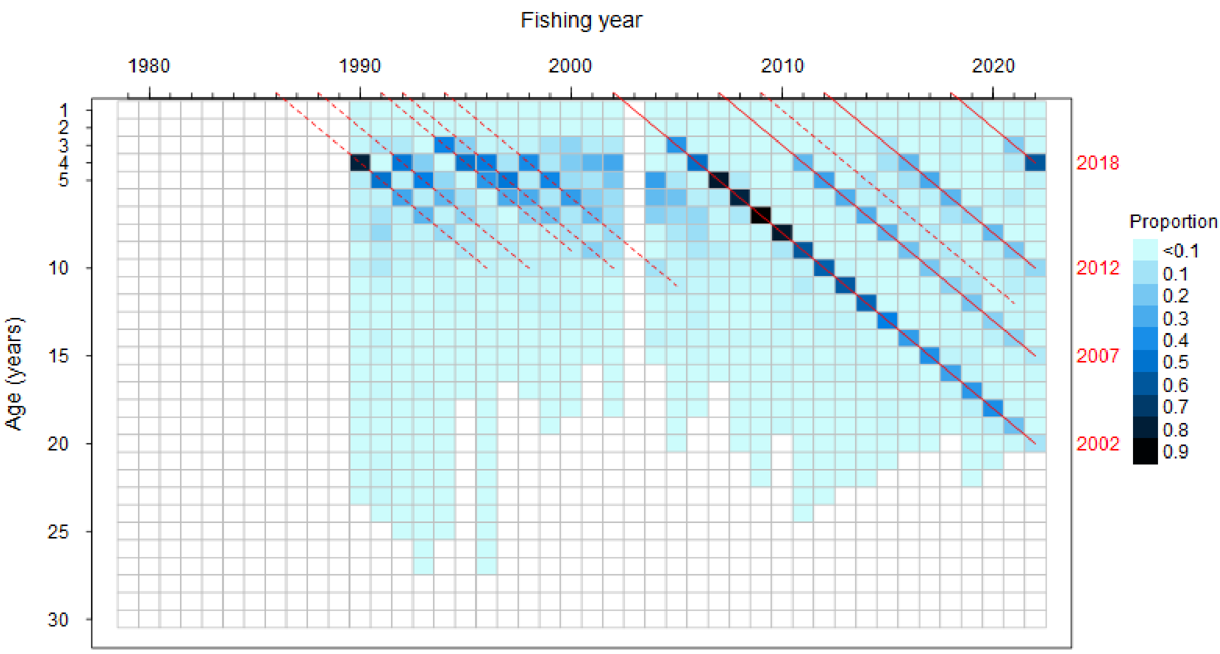

Figure 12: Commercial catch proportions-at-age for the Bounty Plateau stock, 1990–2022. Year classes can be tracked on the diagonal, with recent dominant year classes highlighted in red solid lines. Earlier dominant year classes highlighted with dashed red lines.

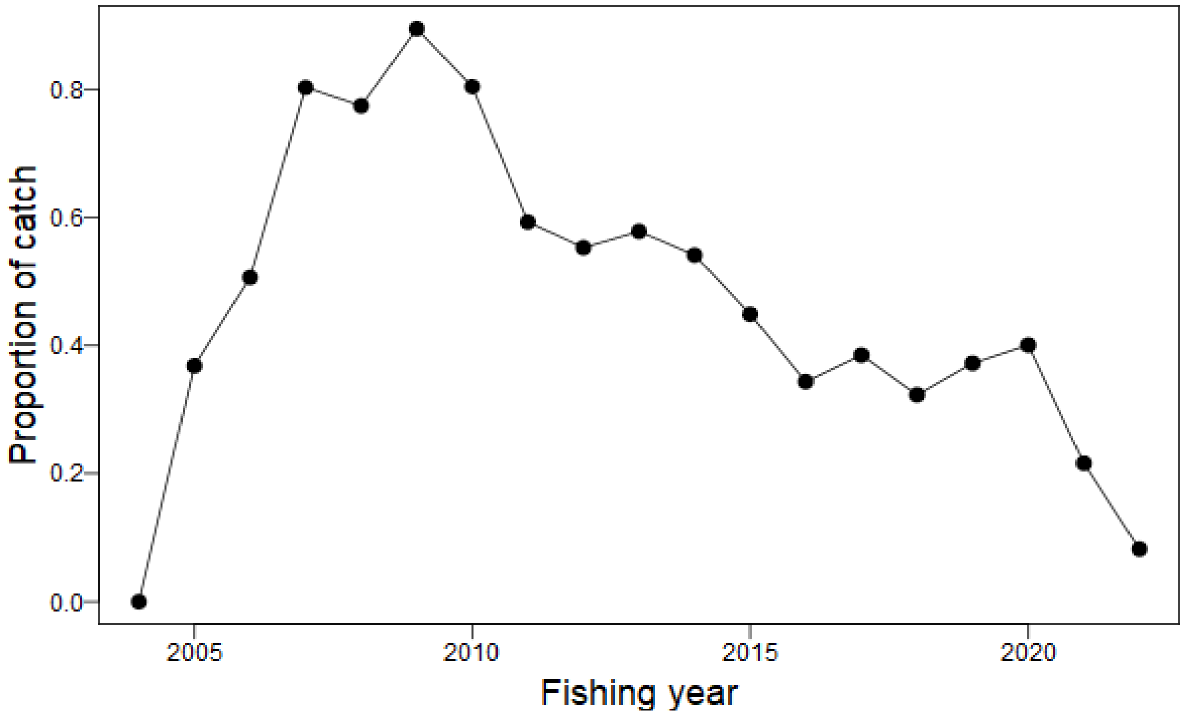

Figure 13: Contribution of the 2002 year-class to the proportion of catch (by number) at the Bounty Plateau 2004–2022.

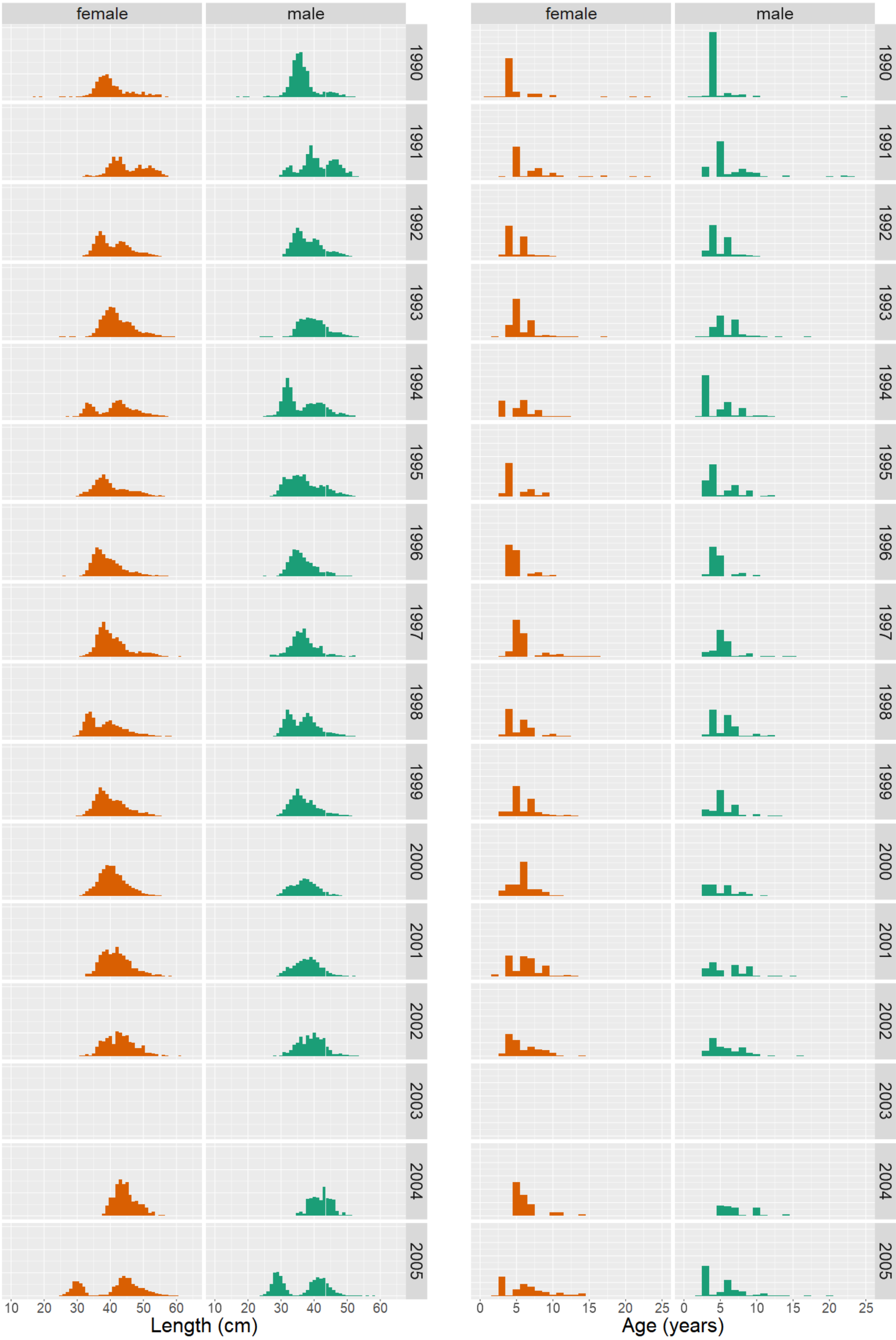

Figure 14: Commercial catch proportions at length (left) and age (right) for the Bounty Plateau stock by sex, 1990–2005. Proportions sum to one across males and females in each year. (Continued next page)

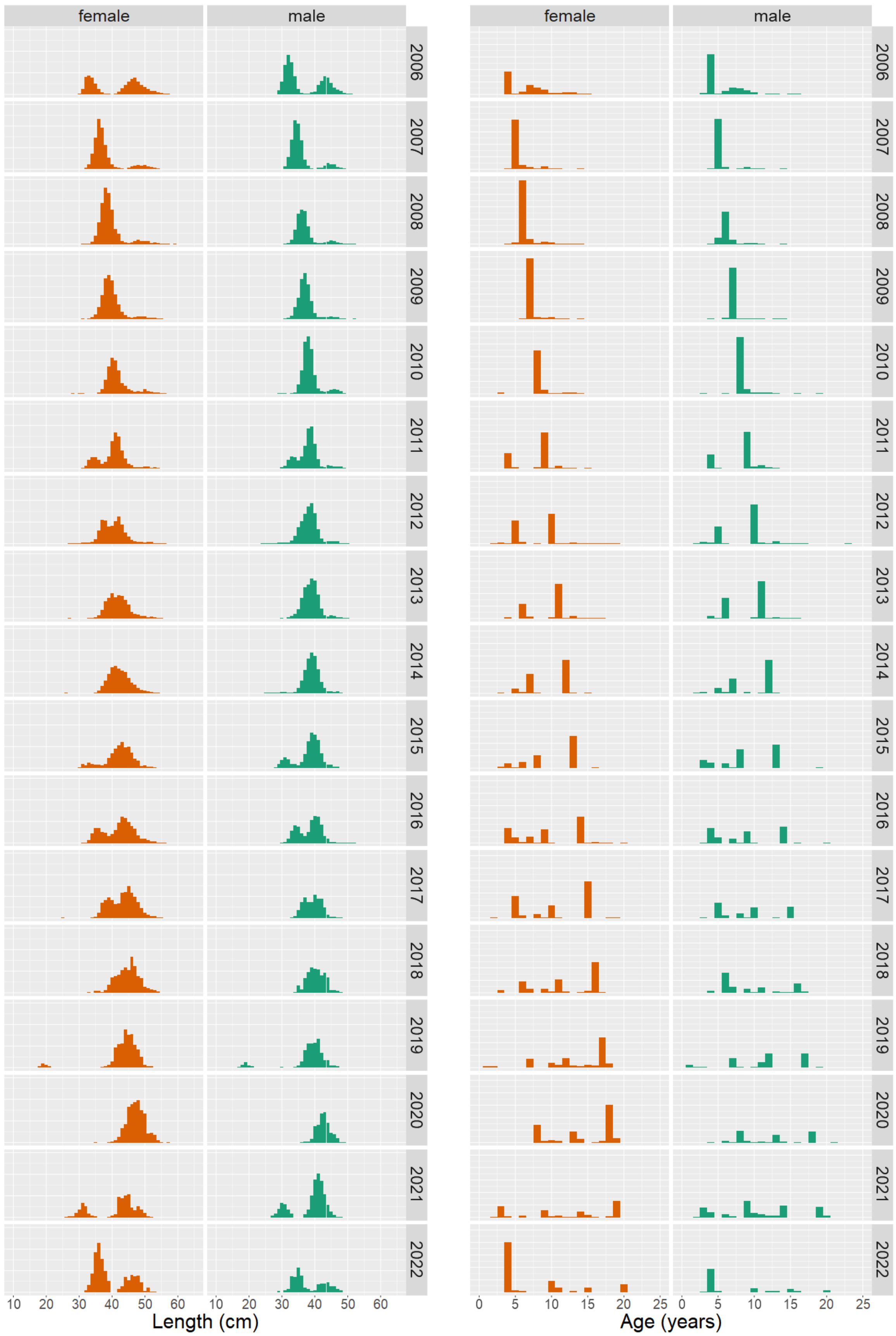

Figure 14 continued: Commercial catch proportions at length (left) and age (right) for the Bounty Plateau stock by sex, 2006–2022. Proportions sum to one across males and females in each year.

5.4 Campbell Island Rise

The Campbell Island Rise has been fished since 1979, although much of the data presented here have been restricted to that collected since 1990 (Table 19). Almost all the catch and the tows during these years were made in the months July to October.

Table 19: Total number of tows and TCEPR/ERS estimated catch of southern blue whiting (including non-target), observed tows and estimated catch (including non-target), number of measured males and females, Campbell Island Rise, 1990–2022 (source: TCEPR, ERS, and Observer data, 1990–2022).

Year	Catch			Observed				Measured		Aged	
	Vessels	Tows	t	Vessels	Tows	t	%t	Male	Female	Male	Female
1990	36	1 079	16 559	7	94	2 508	15.1	10 459	7 677	346	282
1991	35	1 242	21 934	3	52	1 107	5.0	3 852	4 864	281	413
1992	48	1 533	13 454	10	121	1 911	14.2	9 839	8 287	330	287
1993	20	423	8 812	5	55	2 722	31.1	4 456	4 623	247	321
1994	15	480	11 405	4	80	5 622	49.3	8 458	4 717	416	346
1995	12	285	9 989	5	76	7 726	77.3	5 807	7 301	212	358
1996	11	474	16 744	4	97	5 406	32.3	7 802	10 270	182	347
1997	18	650	19 145	6	185	9 476	49.5	16 756	16 254	239	255
1998	24	960	24 216	8	254	12 740	52.7	26 603	23 237	259	361
1999	21	790	27 206	9	175	11 308	41.6	15 024	15 522	227	190
2000	18	556	14 470	10	168	9 695	67.0	15 098	14 289	210	289
2001	16	919	24 410	10	321	19 144	78.4	27 994	25 500	135	270
2002	20	1 013	29 148	7	185	9 863	33.8	15 990	16 212	178	319
2003	16	636	22 695	5	124	2 922	12.9	9 259	10 979	236	383
2004	16	726	19 513	7	132	7 263	37.2	12 083	11 958	276	439
2005	17	757	25 200	6	187	9 041	35.9	14 184	18 757	147	262
2006	13	524	18 905	4	110	7 653	40.5	11 779	7 700	206	294
2007	13	549	20 437	6	119	8 345	40.8	10 291	11 504	182	234
2008	14	557	19 723	6	171	9 658	49.0	15 112	14 513	225	252
2009	14	629	18 299	3	53	3 145	17.2	4 506	3 856	123	311
2010	13	553	19 415	7	175	8 460	43.6	14 405	13 809	214	260
2011	14	976	29 204	8	246	9 739	35.2	19 884	24 570	207	254
2012	11	592	20 156	10	287	11 391	56.5	24 427	25 472	235	260
2013	11	721	25 624	9	299	13 460	52.5	23 435	23 870	191	174
2014	12	604	22 549	11	439	18 388	47.9	36 422	37 635	276	219
2015	10	641	20 088	10	305	11 167	55.6	21 239	25 899	222	290
2016	8	434	17 447	8	190	9 895	56.7	18 099	13 865	230	217
2017	10	475	16 171	9	144	6 012	37.2	10 089	12 719	231	267
2018	10	426	13 879	10	189	7 226	52.1	14 497	14 391	224	256
2019	14	626	24 273	14	265	11 590	47.7	18 983	22 209	211	276
2020	9	325	11 518	9	158	6 486	56.3	9 283	14 643	270	349
2021	10	419	17 291	8	158	7 255	42.0	10 229	14 684	260	321
2022	9	503	21 300	7	129	6 623	31.1	11 538	10 865	275	375

Previous examination of the raw data has shown that the length composition is often different between the northern and southern Campbell Island Rise (Hanchet 1998). Therefore, the analysis was carried out by dividing the area into two strata (at 52º 30’ S) for each year. The commercial catch at Campbell Island in 2022 was dominated by the 2015 year class (7 year old fish), with the next most significant contributions from 5 and 6 year old fish (Figures 15 and 16).

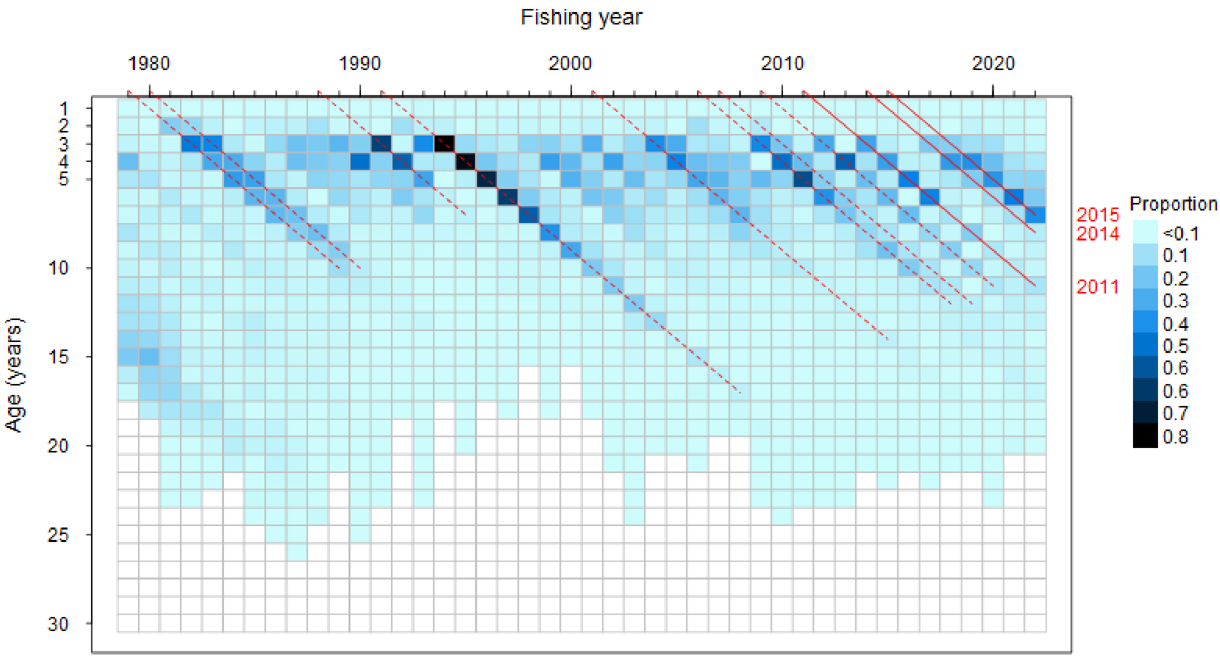

Figure 15: Commercial catch proportions-at-age for the Campbell Island Rise stock, 1979–2022. Year classes can be tracked on the diagonal, with recent dominant year classes highlighted in red solid lines. Earlier dominant year classes highlighted with dashed red lines.

The time series of numbers-at-age (and CVs) from 1979 to 1989 are given by Hanchet et al. (2003). As described in earlier reports (e.g., Hanchet 1991, Hanchet & Ingerson 1995) the data for the early years (1979–1985) came from single vessels fishing during the spawning season and are probably less reliable than the more recent data, which have all been from multiple vessels. This tends to be reflected in the mean weighted CV, which ranged from 0.2 to 0.5 in the early years but from 0.1 to 0.2 in more recent years (Hanchet et al. 2003).

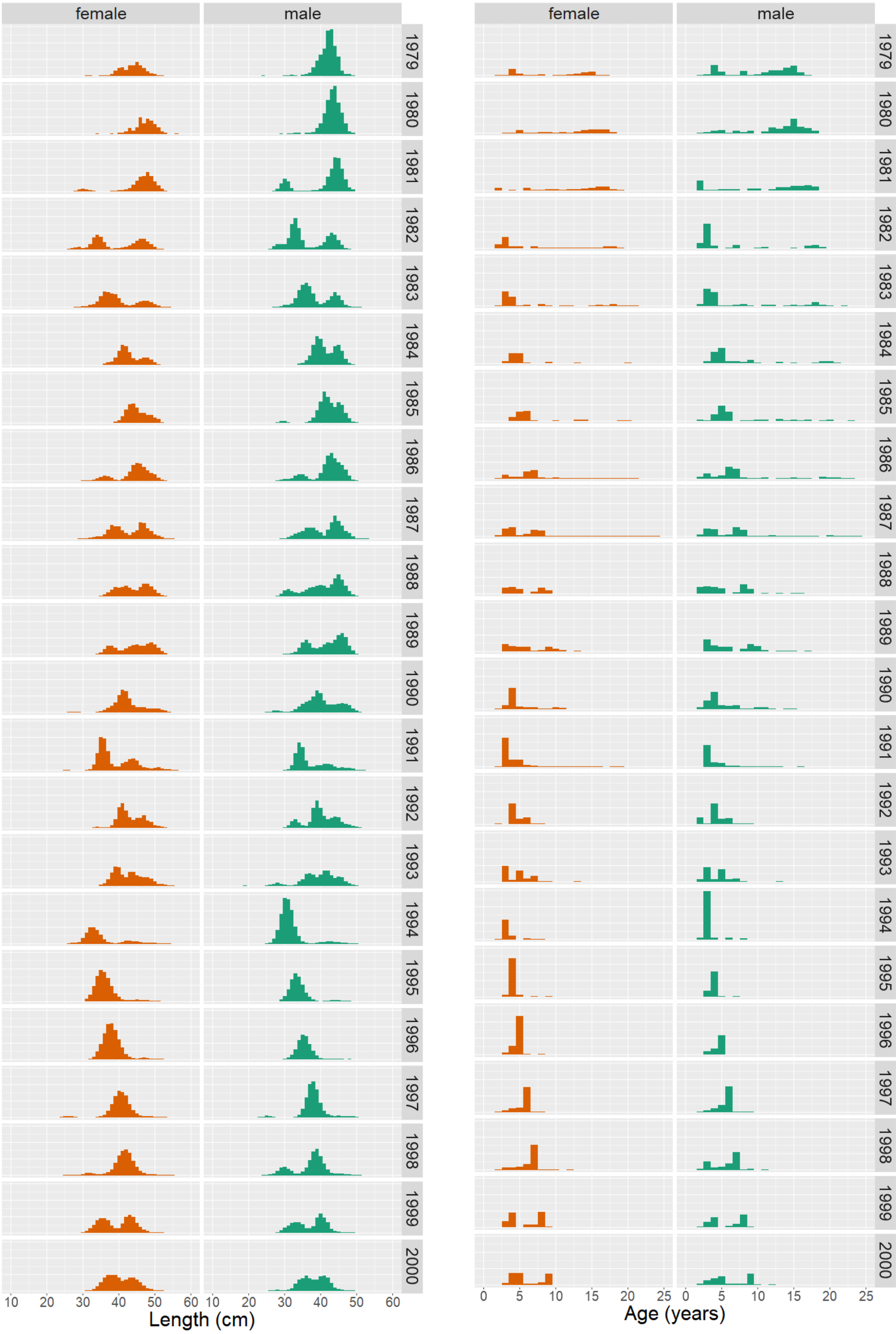

Figure 16: Commercial catch proportions at length (left) and age (right) for the Campbell Island Rise stock by sex, 1979–2000. Proportions sum to one across males and females in each year. (Continued next page)

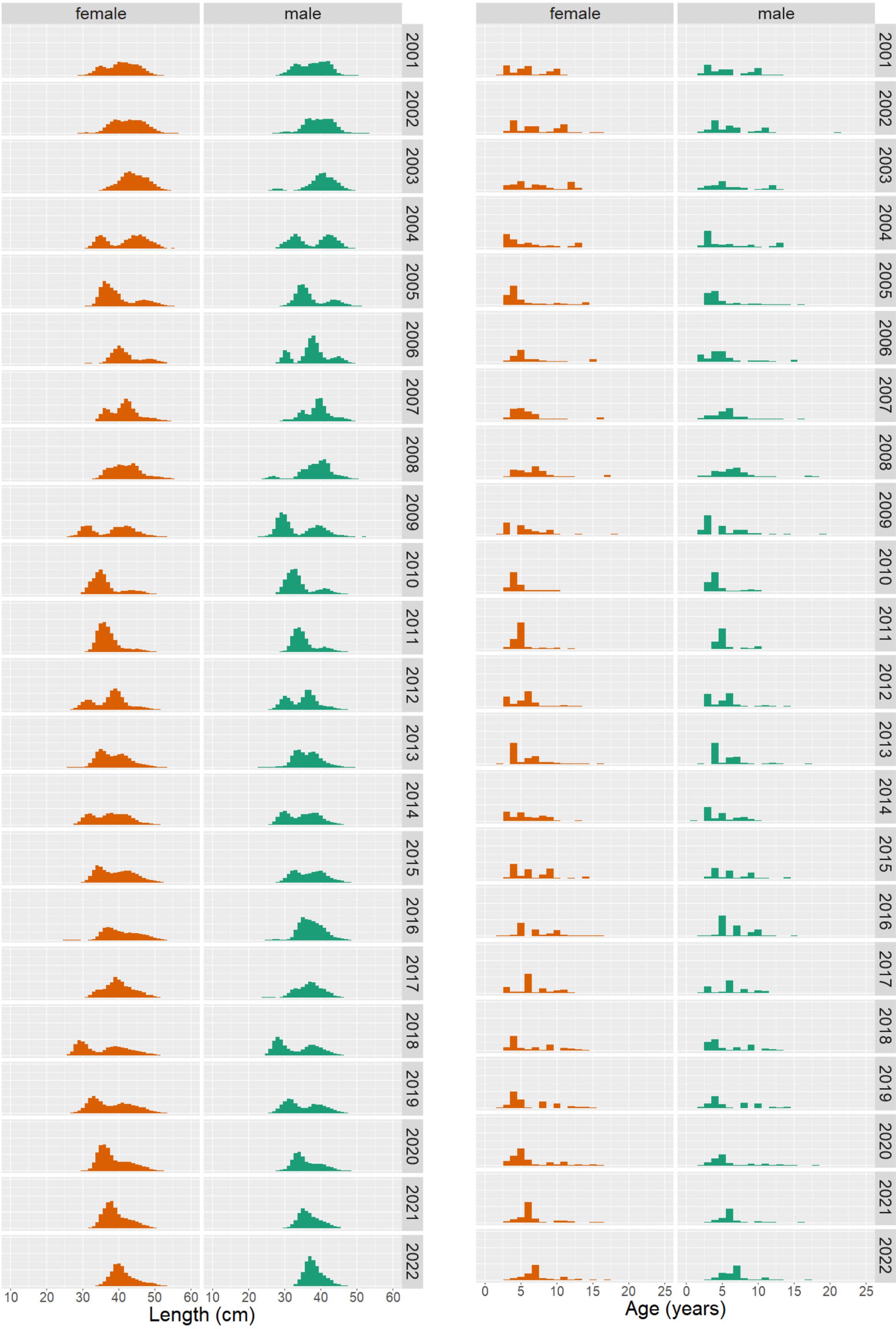

Figure 16 continued: Commercial catch proportions at length (left) and age (right) for the Campbell Island Rise stock by sex, 2001–2022. Proportions sum to one across males and females in each year.

5.5 Pukaki Rise

The Pukaki Rise has been fished sporadically since 1990 with most of the catch taken between 1991 and 1993 and again in 2009 and 2010, but there was another relatively large catch of 3410 t in 2019 (Table 20). While most of the catch has been made in the months July to October, usually less than half of the effort occurs during this period. The remaining effort has typically targeted hoki and other middle depth species (Hanchet & Dunn 2009).

Catch-at-age data are available for most years in the period 1989 to 2000 and again for 2007, 2009, 2010, and 2012 although the numbers of fish measured and aged were low in some years (Table 20). Examination of the raw data showed that the length composition was relatively constant throughout the season and across the area and so the length frequency data were analysed as a single stratum. The catch on the Pukaki Rise was dominated previously by fish comprising the 2004–06 year classes but the 2009 year class may also have been moderately strong (Figure 17 and Figure 18). Length measurements from the larger catch in 2019 consisted of a broad range of fork lengths from 30–50 cm (Figure 18), but no fish were aged (even though sufficient otoliths were available for ageing).

Table 20: Total number of tows and TCEPR/ERS estimated catch of southern blue whiting (including non-target), observed tows and estimated catch (including non-target), number of measured males and females, Pukaki Rise 1990–2022 (source: TCEPR, ERS, and Observer data, 1990–2022).

Year	Catch			Observed				Measured		Aged	
	Vessels	Tows	t	Vessels	Tows	t	%t	Male	Female	Male	Female
1990	35	464	1 295	6	20	204	15.7	2 624	1 050	182	197
1991	27	512	4 697	4	24	771	16.4	1 983	2 265	191	282
1992	44	614	2 866	5	23	227	7.9	1 611	1 391	233	243
1993	23	396	5 341	6	43	2 004	37.5	3 496	3 237	234	345
1994	14	195	1 918	4	22	1 191	62.1	1 831	1 940	222	188
1995	10	82	1 364	4	12	725	53.2	885	1 136	240	274
1996	5	11	299	1	1	112	37.5	72	113	0	0
1997	11	117	2 109	4	24	1 609	76.3	1 720	2 312	184	305
1998	15	115	1 219	7	18	1 248	102.4	1 686	1 756	174	168
1999	10	67	955	0	0	0	0.0	0	0	0	0
2000	15	131	2 402	3	15	1 475	61.4	1 236	1 703	172	229
2001	15	68	284	1	2	45	15.9	153	157	0	0
2002	13	207	111	0	0	0	0.0	0	0	0	0
2003	12	113	19	0	0	0	0.0	0	0	0	0
2004	11	178	53	0	0	0	0.0	0	0	0	0
2005	11	83	44	1	1	4	8.3	85	69	0	0
2006	8	47	1 048	0	0	0	0.0	0	0	0	0
2007	12	200	391	1	4	103	26.4	382	287	39	48
2008	8	113	1 306	1	1	4	0.3	63	117	0	0
2009	16	393	4 777	4	48	1 078	22.6	3 016	3 953	164	261
2010	14	470	4 168	4	51	1 505	36.1	3 319	4 085	170	235
2011	12	471	625	4	6	96	15.4	482	359	0	0
2012	10	254	1 422	7	76	1 120	78.7	5 048	6 986	166	221
2013	7	36	10	0	0	0	0.0	0	0	0	0
2014	4	35	1	1	2	1	100	242	183	0	0
2015	5	67	7	1	1	7	100	11	9	0	0
2016	4	61	6	0	0	0	0	0	0	0	0
2017	7	85	0	0	0	0	0	0	0	0	0
2018	7	175	19	1	1	19	100	36	119	0	0
2019	16	289	3 410	8	58	2 137	62.7	3 214	4 570	0	0
2020	7	113	26	2	3	11	42.3	50	282	0	0
2021	10	121	3	1	1	3	100	36	114	0	0
2022	8	123	9	0	0	0	0.0	0	0	0	0

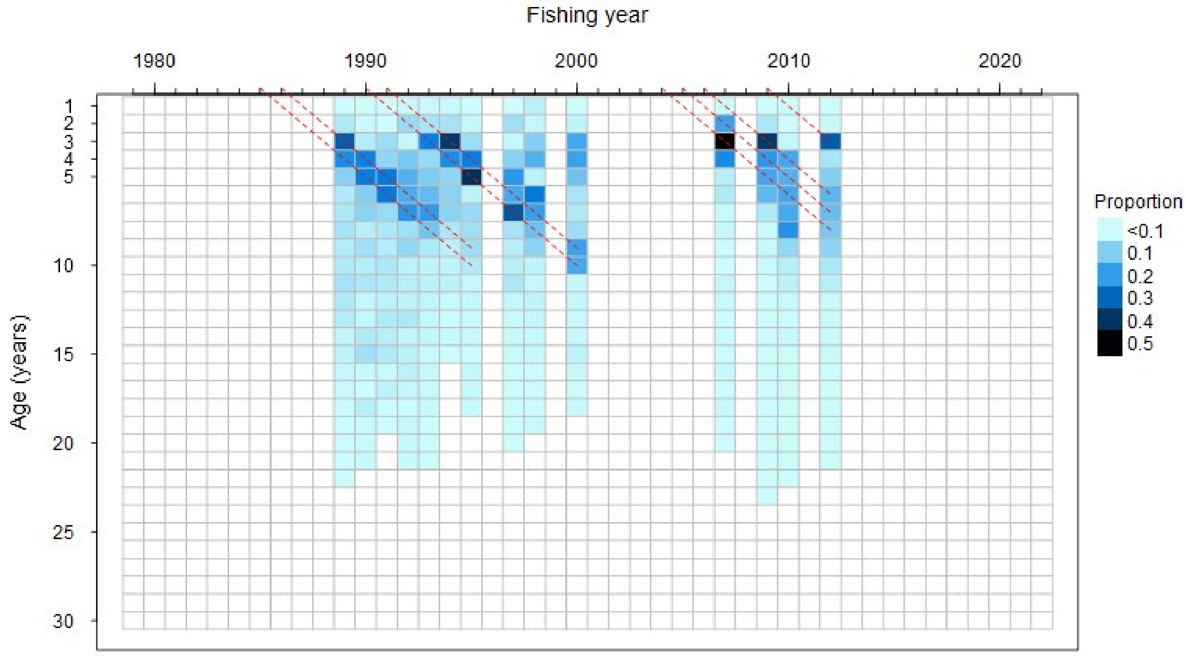

Figure 17: Commercial catch proportions-at-age for the Pukaki Rise stock, 1989–2012. Year classes can be tracked on the diagonal, with dominant year classes highlighted with dashed red lines.

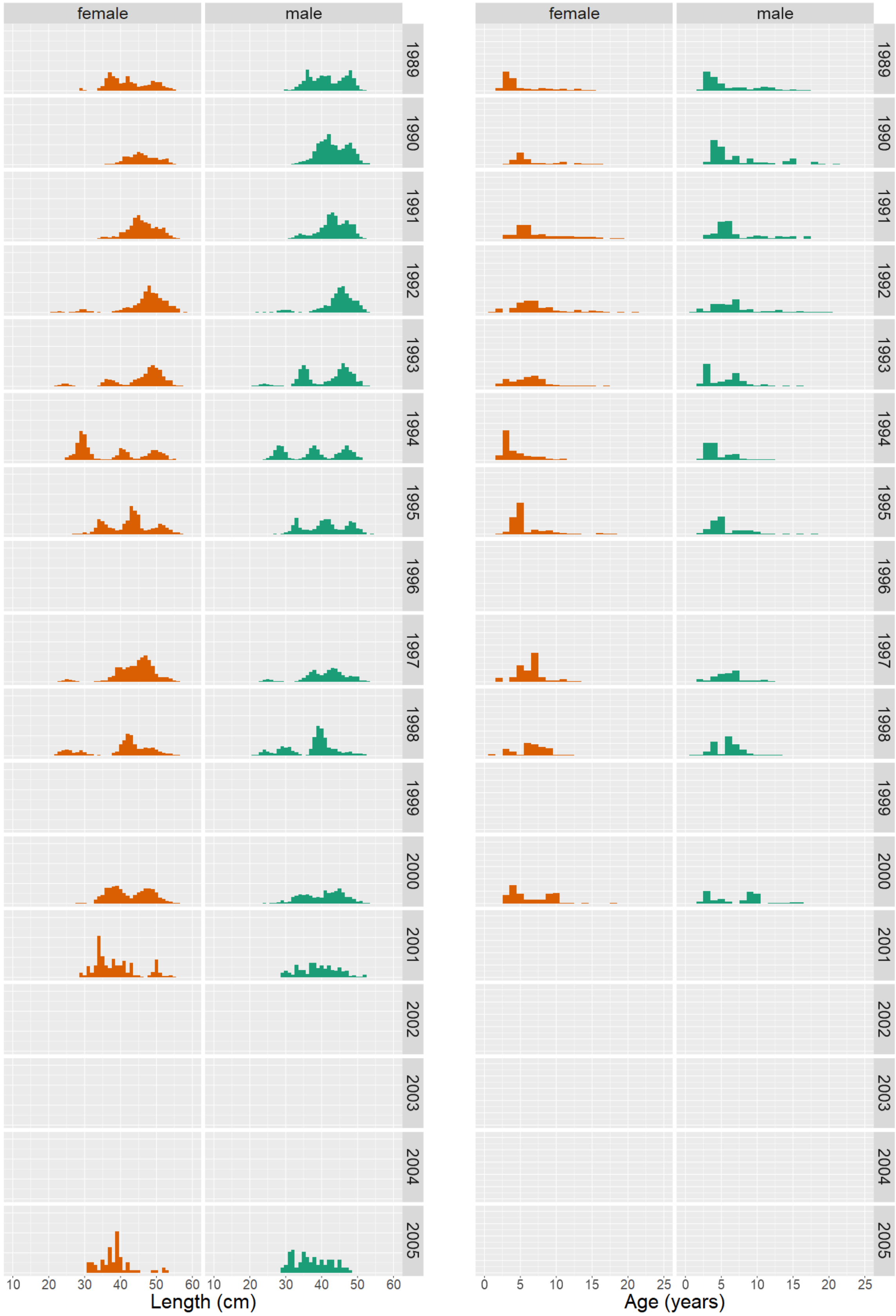

Figure 18: Commercial catch proportions at length (left) and age (right) for the Pukaki Rise stock by sex, 1989–2005. Proportions sum to one across males and females in each year. (Continued next page)

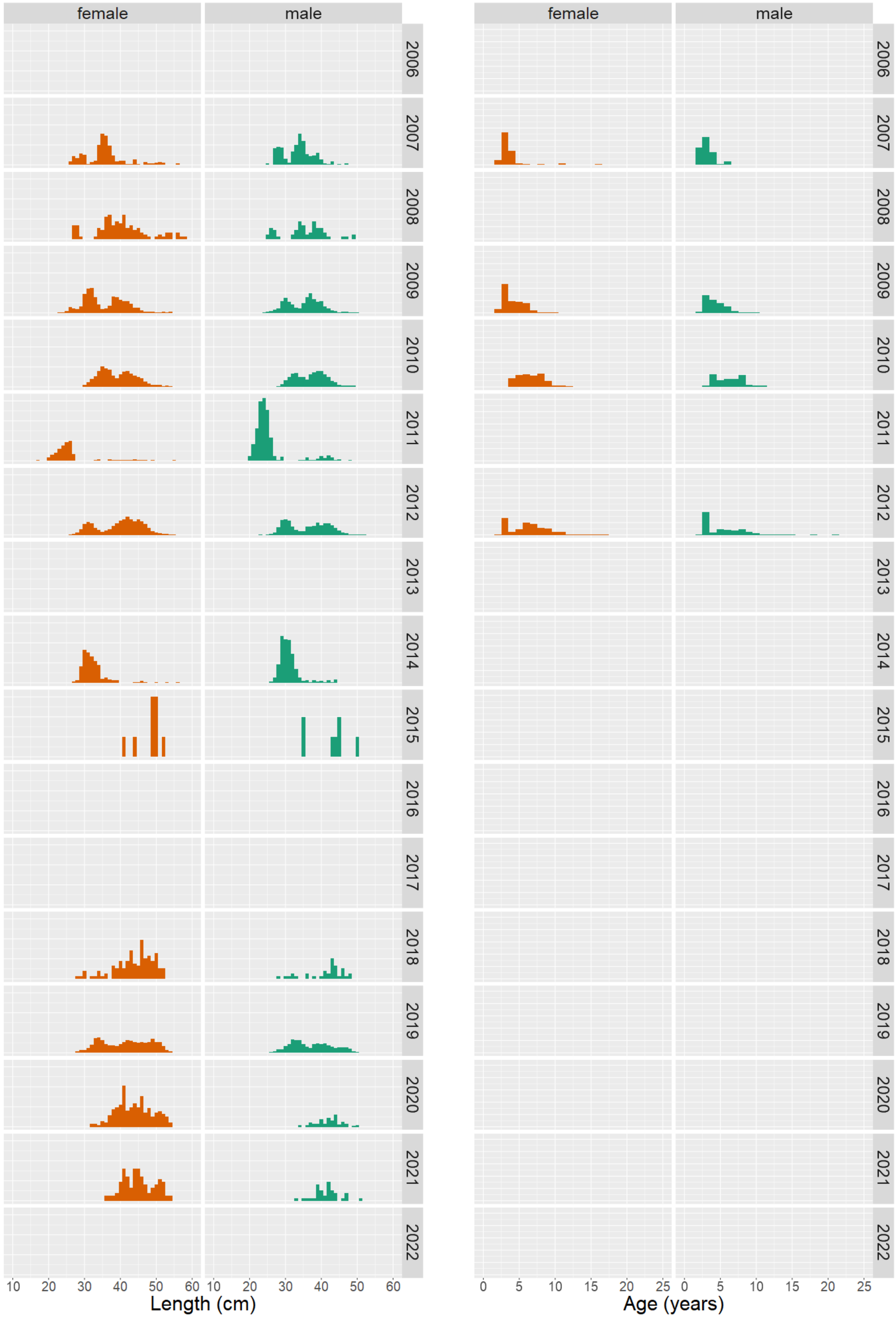

Figure 18 continued: Commercial catch proportions at length (left) and age (right) for the Pukaki Rise stock by sex, 2006–2022. Proportions sum to one across males and females in each year.

5.6 Other areas (SBW 1)

The remaining catch was taken as bycatch of fisheries for hoki and other middle depths species from the Stewart-Snares shelf and southern Chatham Rise. Bycatch of southern blue whiting was not usually in the top five or eight species by weight in a catch and, as such, was not reported on TCEPR (now ERS) forms. This is the reason for the difference between reported landings and estimated catch, e.g., 86 t reported as landed from SBW 1 in 2016–17 (Table 1) but only 4 t of estimated catch from the TCEPR records (Table 21). Historically, most of the large catches reported from this area are likely to be due to positional errors in the TCEPR database.

Table 21: Total number of tows and TCEPR/ERS estimated catch of southern blue whiting (including non-target), observed tows and estimated catch (including non-target), number of measured and aged males and females, SBW 1 1990–2022 (source: TCEPR, ERS, and Observer data, 1990–2022). Most of the large catches reported from this area are likely to be due to positional errors in the TCEPR database.

Year	TCEPR			Observer			Measured		Aged	
	Vessels	Tows	Catch	Vessels	Tows	Catch	Male	Female	Male	Female
1990	20	498	144	0	0	0	0	0	0	0
1991	27	899	70	0	0	0	0	0	0	0
1992	39	1 441	658	0	0	0	0	0	0	0
1993	21	655	711	0	0	0	0	0	0	0
1994	19	1 128	305	0	0	0	0	0	0	0
1995	14	642	693	1	1	20	139	19	4	2
1996	7	405	45	0	0	0	0	0	0	0
1997	13	823	163	0	0	0	0	0	0	0
1998	23	1 082	93	0	0	0	0	0	0	0
1999	26	1 732	14	0	0	0	0	0	0	0
2000	26	1 803	0	0	0	0	0	0	0	0
2001	29	1 660	52	0	0	0	0	0	0	0
2002	29	1 948	4	0	0	0	0	0	0	0
2003	23	1 187	8	1	1	0	54	1	0	0
2004	23	1 394	0	0	0	0	0	0	0	0
2005	22	1 388	0	0	0	0	0	0	0	0
2006	22	1 230	1	0	0	0	0	0	0	0
2007	19	1 402	0	0	0	0	0	0	0	0
2008	22	1 609	6	0	0	0	0	0	0	0
2009	22	1 243	226	0	0	0	0	0	0	0
2010	23	1 569	0	0	0	0	0	0	0	0
2011	20	1 100	0	0	0	0	0	0	0	0
2012	20	1 051	1	0	0	0	0	0	0	0
2013	19	1 096	0	0	0	0	0	0	0	0
2014	19	1 168	0	1	1	0	15	10	0	0
2015	18	1 144	2	0	0	0	0	0	0	0
2016	20	1 906	4	1	1	2	9	11	0	0
2017	26	2 305	1	2	3	<1	8	16	0	0
2018	23	2 122	2	0	0	0	0	0	0	0
2019	21	1 892	310	0	0	0	0	0	0	0
2020	20	1 610	1	0	0	0	0	0	0	0
2021	23	1 943	0	1	1	<1	10	8	0	0
2022	21	1 925	22	0	0	0	0	0	0	0

6. DISCUSSION

This document updates and summarises the observational and research data for southern blue whiting. Included here are time series of relative abundance from the wide-area R.V. *Tangaroa* acoustic surveys, as well as from local-area aggregation acoustic surveys from industry vessels, CPUE indices for Bounty Plateau and Campbell Island Rise, and trawl survey indices for the Auckland Islands Shelf, Campbell Island Rise, and Pukaki Rise, as well as updated time series of length-at-age and catch-at-age.

R.V. *Tangaroa* acoustic surveys were carried out on the three main stocks (Bounty Plateau, Campbell Island Rise, and Pukaki Rise) from 1993 until around 2000 when, because of the low catch limits on the Bounty and Pukaki stocks, the returns from the fishery were too low to be able to afford funding *Tangaroa* acoustic surveys and the time series for these two areas were discontinued. Local-area aggregation surveys from industry vessels on the Bounty Plateau since 2004 have provided the only biomass information on this stock. However, there has been very large inter-snapshot and inter-annual variability in these biomass estimates making it difficult to use them for assessment and management purposes (Dunn & Hanchet 2011a, 2015c). There have been no acoustic abundance estimates from the Bounty Plateau in the last five years (2018–22).

Local-area aggregation surveys from industry vessels on the Pukaki Rise were also carried out from 2009 to 2012 and have had similar problems of high inter-snapshot and inter-annual variability in the biomass estimates again making it difficult to use them for assessment and management purposes. Without wide-area surveys to provide a ground-truthing of the aggregation results there will be on-going uncertainty about the status of these stocks (O'Driscoll 2011b, O'Driscoll 2011c, O'Driscoll 2015, O'Driscoll et al. 2016, O'Driscoll 2018).

Local-area industry acoustic surveys on the Campbell Island Rise have also been unsuccessful to date, in part because of the much larger area which needs to be surveyed and the frequent inadequacy of hull-mounted echosounders in rougher weather conditions. Wide-area acoustic surveys using the *R.V. Tangaroa* have been the preferred option for monitoring the Campbell Island stock because of the ability to use a towed acoustic tow-body and the estimates of immature (age 2 and 3 year old) fish provided from this survey. Fourteen surveys of the Campbell Rise spawning ground have been completed since 2003, with the most recent survey in 2022. The next acoustic survey of the Campbell Island Rise is scheduled to be carried out in August-September 2025.

Estimates of abundance from the sub-Antarctic trawl surveys on the Auckland Islands Shelf, Campbell Island Rise, and Pukaki Rise were available for the period 1991 to 2022. While the surveys were not designed to monitor southern blue whiting, the biomass estimates for the latter two areas had moderate-high CVs (20–50%), showed some consistency between years, and the trends showed some correspondence with biomass trajectories from stock assessments (Hanchet & Stevenson 2006). Dunn & Hanchet (2011b) investigated fitting the sub-Antarctic summer trawl survey time series in the Campbell assessment model but found that, although there was some consistency in biomass estimates between the summer series and the model estimates, the trawl survey underestimated biomass at low stock sizes and overestimated biomass at high stock sizes. They concluded that the time series is not particularly useful for monitoring abundance. The trawl survey biomass estimates for the Campbell Island Rise in 2016, 2020, and 2022 were relatively high and are consistent with the high acoustic estimates recorded in 2016, 2019, and 2022, as well as the current stock status (Doonan et al. in review).

The most recent assessment of the Pukaki Rise stock (Dunn & Hanchet 2016b) was mainly influenced by the trawl survey index and the commercial catch proportions-at-age data. It was recommended that some consideration should be given towards further increasing the number of stations carried out in the core Pukaki Rise strata to improve the precision and usefulness of the estimates (i.e., to 15–20 stations per survey). In addition, the utility of these data would be improved by the increased collection of otoliths and subsequent ageing of these fish to determine proportions-at-age. However, no additional survey time has been added to the sub-Antarctic trawl survey to increase the number of stations sampled. A relatively high catch from the Pukaki Rise in 2019 consisted of fish from a broad range of sizes.

Otoliths were collected in 2019, but no fish were aged. Very little catch was taken from this area in 2020–2022.

The utility of the trawl survey biomass indices for the Auckland Islands stock has not been formally examined. However, the time series on the Auckland Islands Shelf suggests an almost 10-fold increase in average abundance between the early part of the series (1991–2004) and the later part (from 2005). Again, there has been no targeted commercial fishing in recent years and so it is unknown whether this increase reflects a period of stronger recruitment of fish in this area or a redistribution of fish from other areas.

CPUE indices for the Bounty Plateau and Campbell Island Rise are available for the periods 1990–2002 and 1986–2005, respectively. Although most fishing is carried out on highly aggregated spawning concentrations of southern blue whiting, there was moderate agreement between some of the CPUE indices and the biomass trajectories from modelling the stocks (Hanchet et al. 2003, Hanchet 2005). However, the Middle Depths Working Group was unable to agree on a time series to use and rejected these indices for stock assessment modelling (Ministry for Primary Industries 2012).

The time series of catch-at-age were updated for the Bounty Plateau and Campbell Rise stocks for this report. The very strong 2002 year class finally stopped being a major part of the Bounty Plateau fishery in 2021, although the cohort could still be tracked in the age distribution into 2022. More recently, relatively strong recruitment occurred for the 2007 and 2012 year classes. In 2022 a major component of the fishery comprised 4 year olds from the 2018 year class. It should be noted, however, that the amount of fishing on the Bounty Plateau reduced to a very low level in 2022 with a consequent reduction in fish sampled for length and age. There is evidence of several year classes of moderate strength at the Campbell Island Rise, with both acoustic indices and commercial catch-at-age proportions suggesting strong recruitment in 2009, 2011, 2014, and 2015. Data from the Pukaki Rise and Auckland Islands fisheries are insufficient to infer patterns of recent recruitment. Catches from areas outside the four main fisheries (SBW 1) remain low.

7. FULFILLMENT OF BROADER OUTCOMES

This project delivered against the following aspect of broader outcomes.

Building capacity and capability in the research sector

Extracting, grooming, and summarising the southern blue whiting commercial and observer data was overseen by a researcher with considerable experience of southern blue whiting but conducted by two researchers new to the stock and the established grooming techniques. In this way NIWA was able to share expertise and grow institutional knowledge of New Zealand fisheries and stock assessments.

8. ACKNOWLEDGEMENTS

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APPENDIX A (additional figures): Commercial catch proportions-at-length

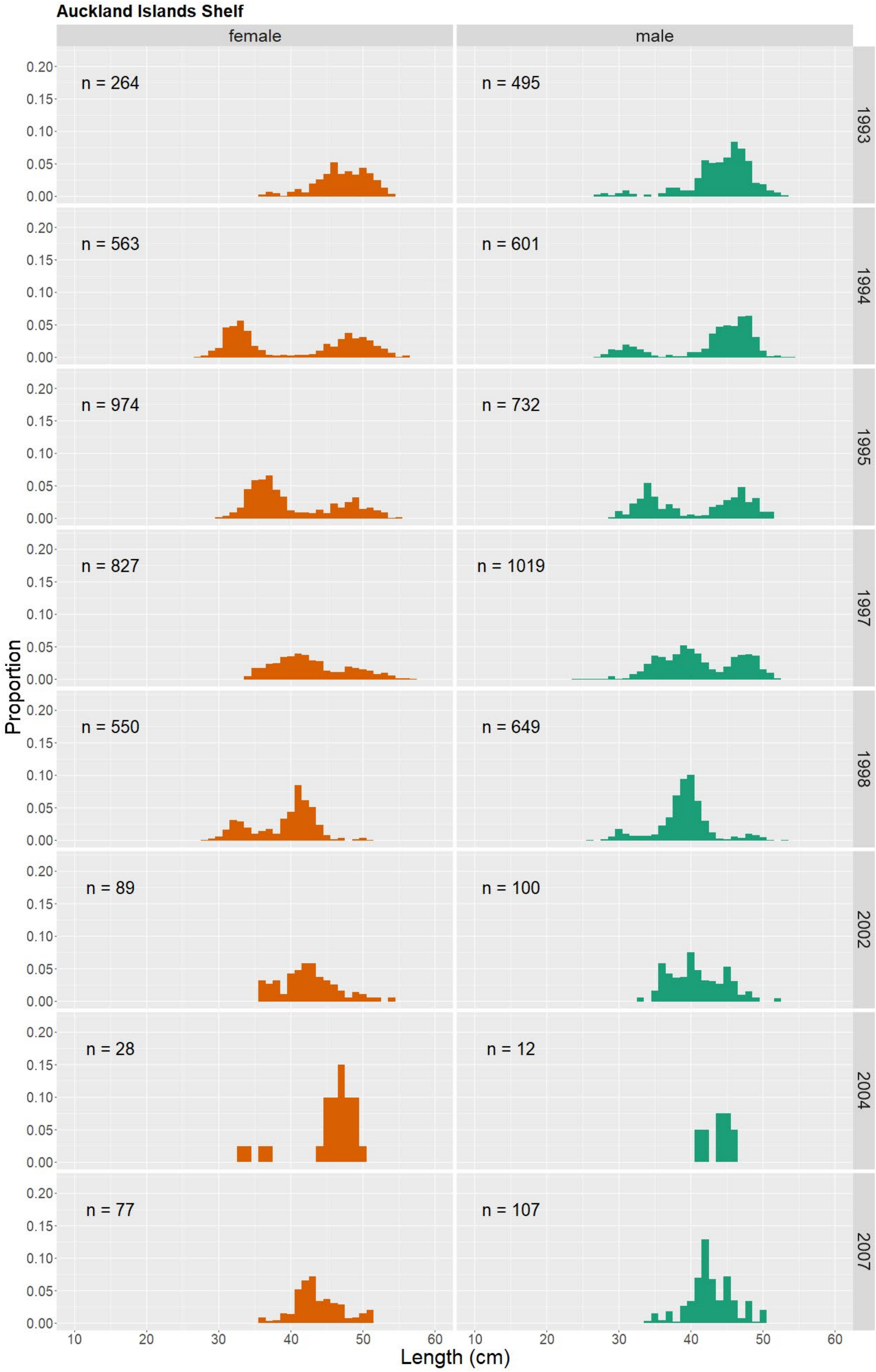

Figure A-1: Commercial catch proportions-at-length for the Auckland Islands stock by sex, 1993–2007. Proportions sum to one across males and females in each year. n = number of fish measured.

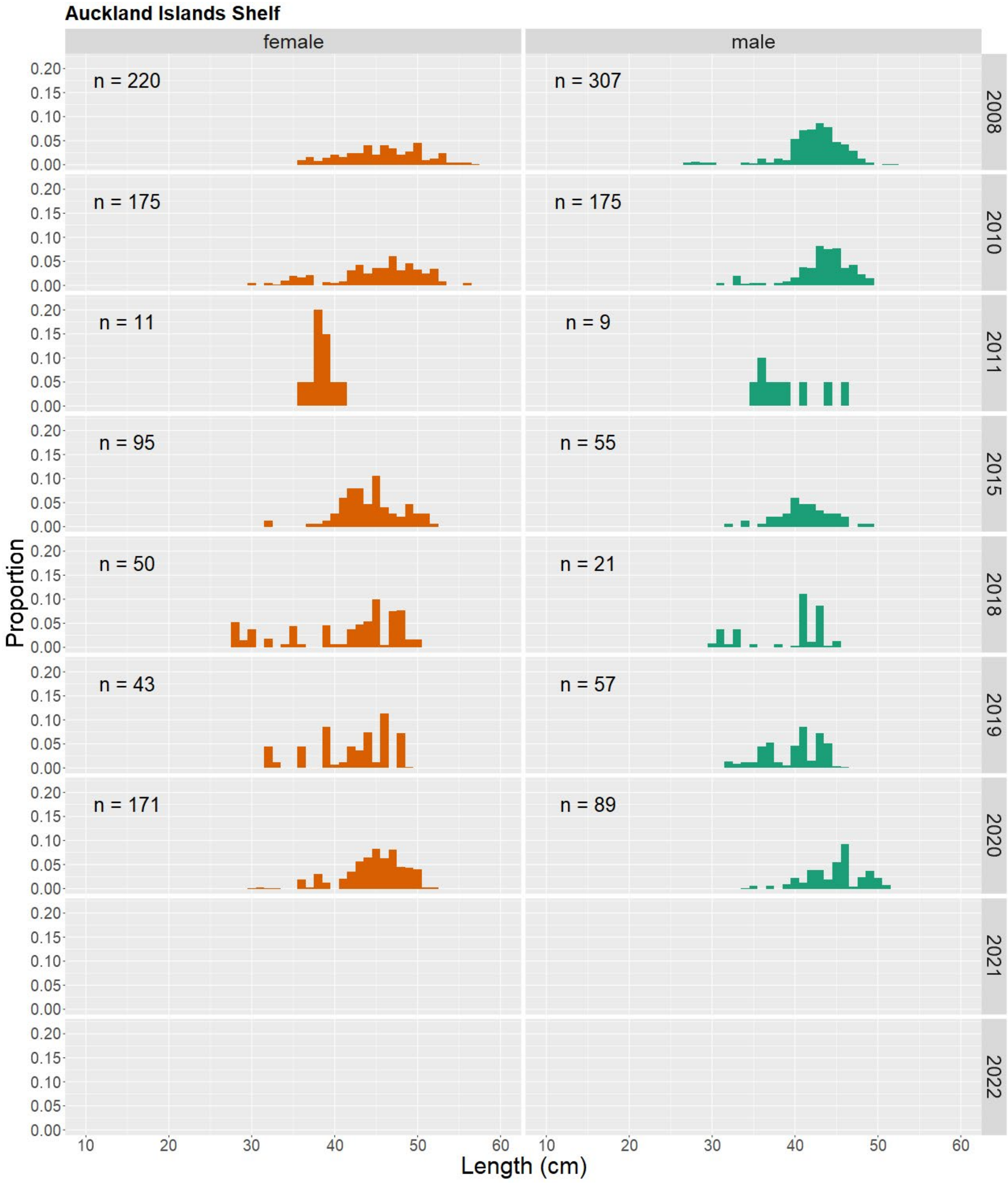

Figure A-2: Commercial catch proportions-at-length for the Auckland Islands stock by sex, 2008–2022. Only years with data are shown except years since most recent data. Proportions sum to one across males and females in each year. n = number of fish measured.

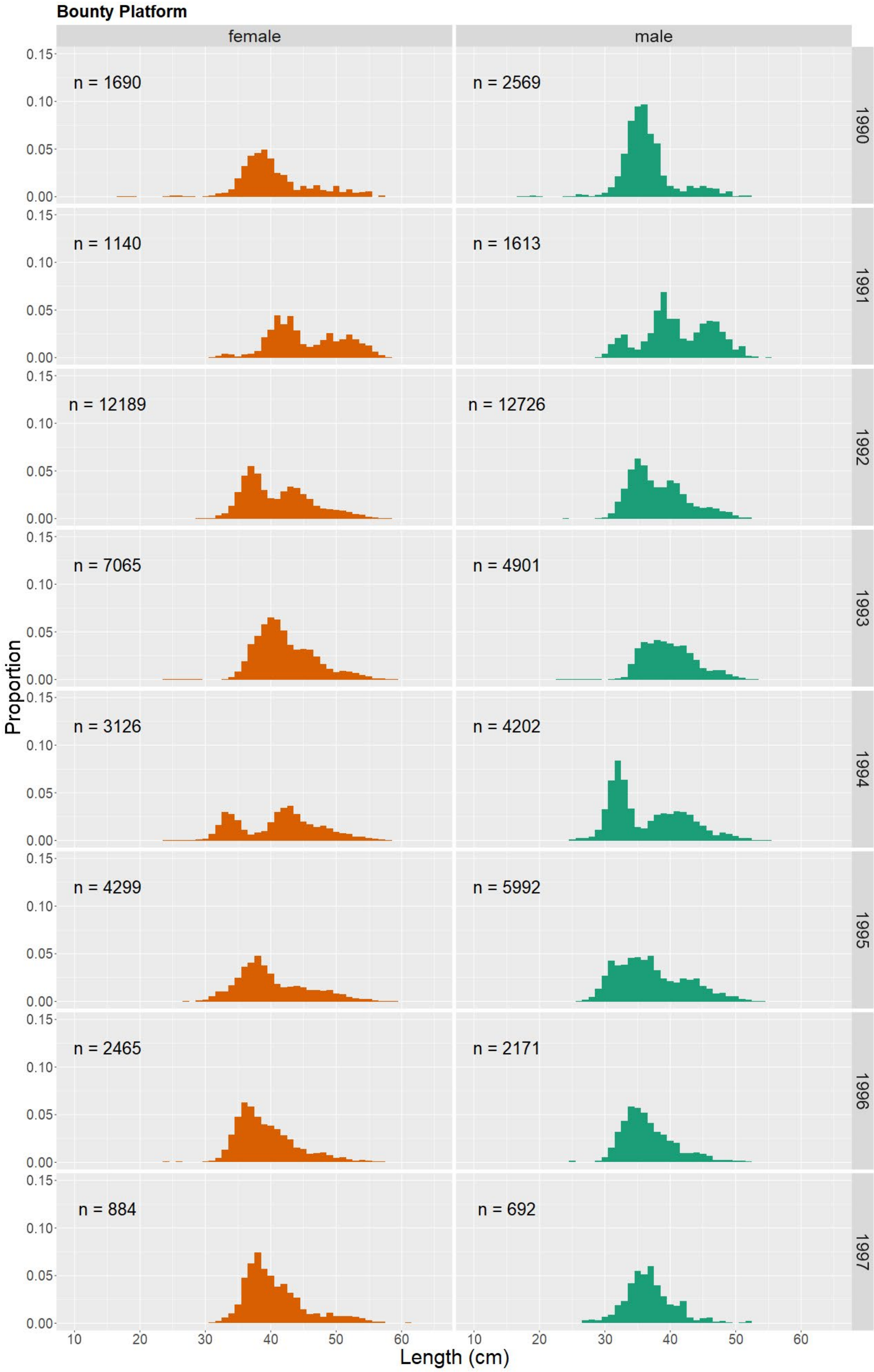

Figure A-3: Commercial catch proportions-at-length for the Bounty Plateau stock by sex, 1990–1997. Proportions sum to one across males and females in each year. n = number of fish measured.

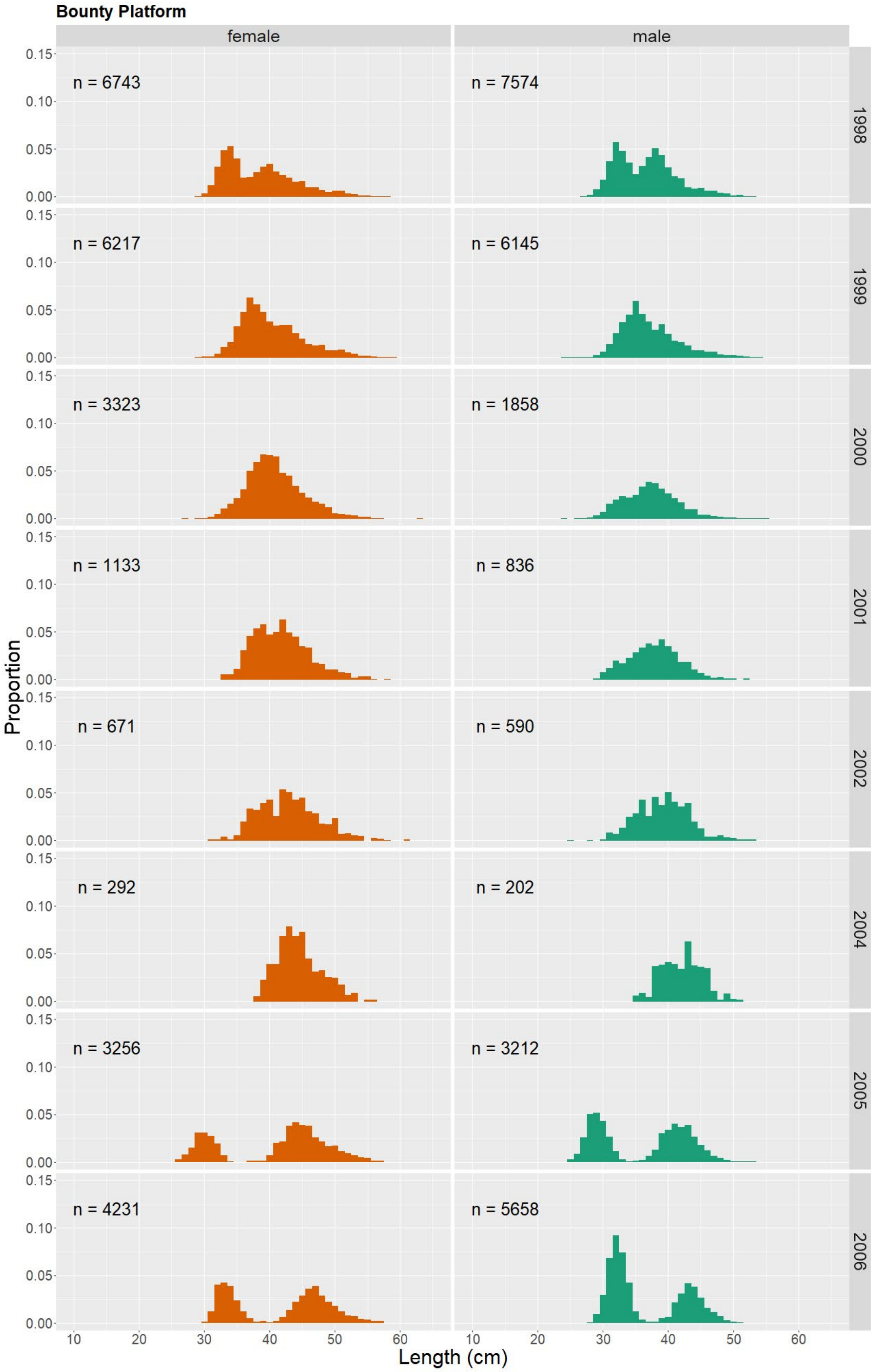

Figure A-4: Commercial catch proportions-at-length for the Bounty Plateau stock by sex, 1998–2006. Proportions sum to one across males and females in each year. n = number of fish measured.

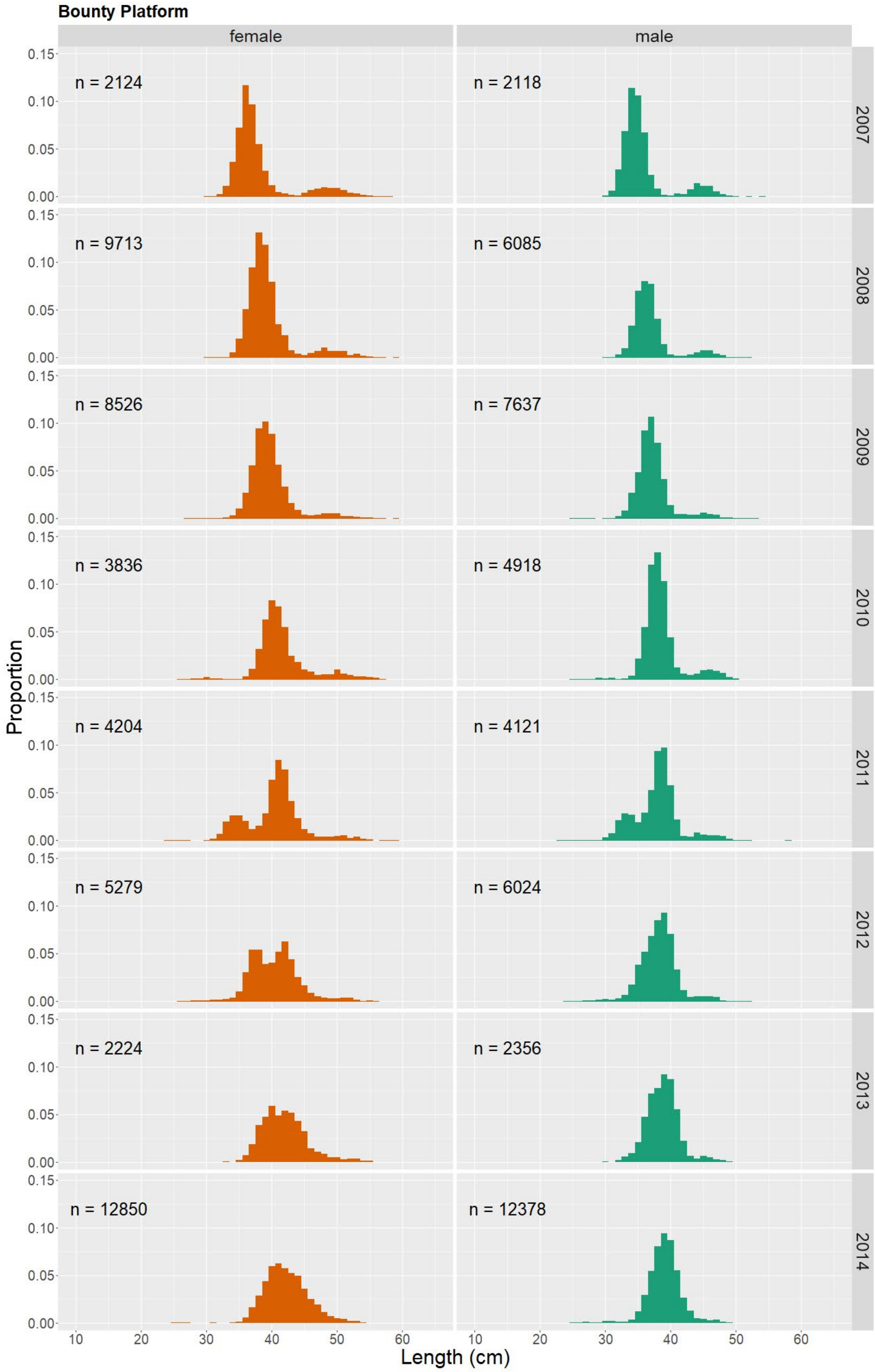

Figure A-5: Commercial catch proportions-at-length for the Bounty Plateau stock by sex, 2007–2014. Proportions sum to one across males and females in each year. n = number of fish measured.

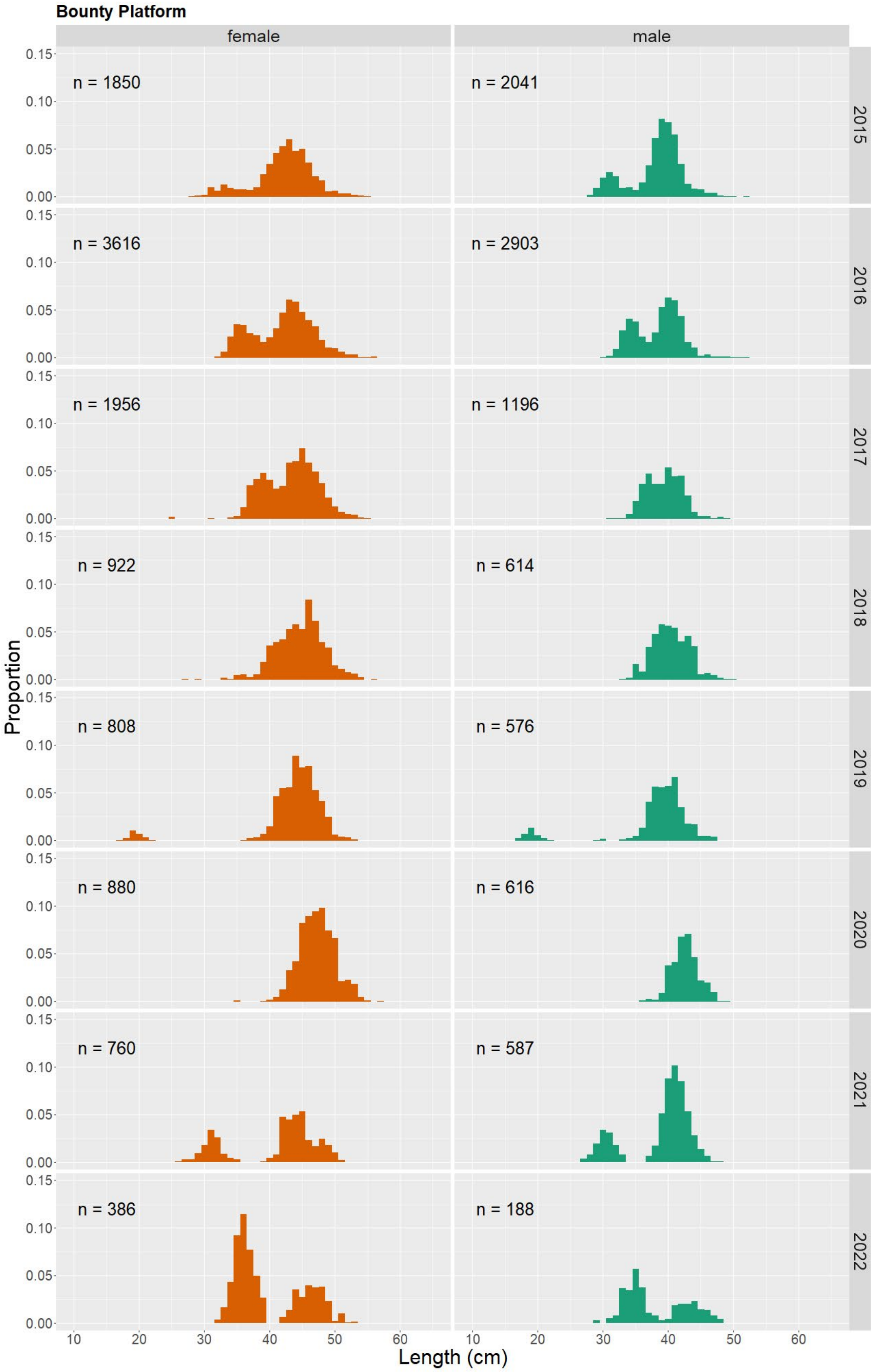

Figure A-6: Commercial catch proportions-at-length for the Bounty Plateau stock by sex, 2015–2022. Proportions sum to one across males and females in each year. n = number of fish measured.

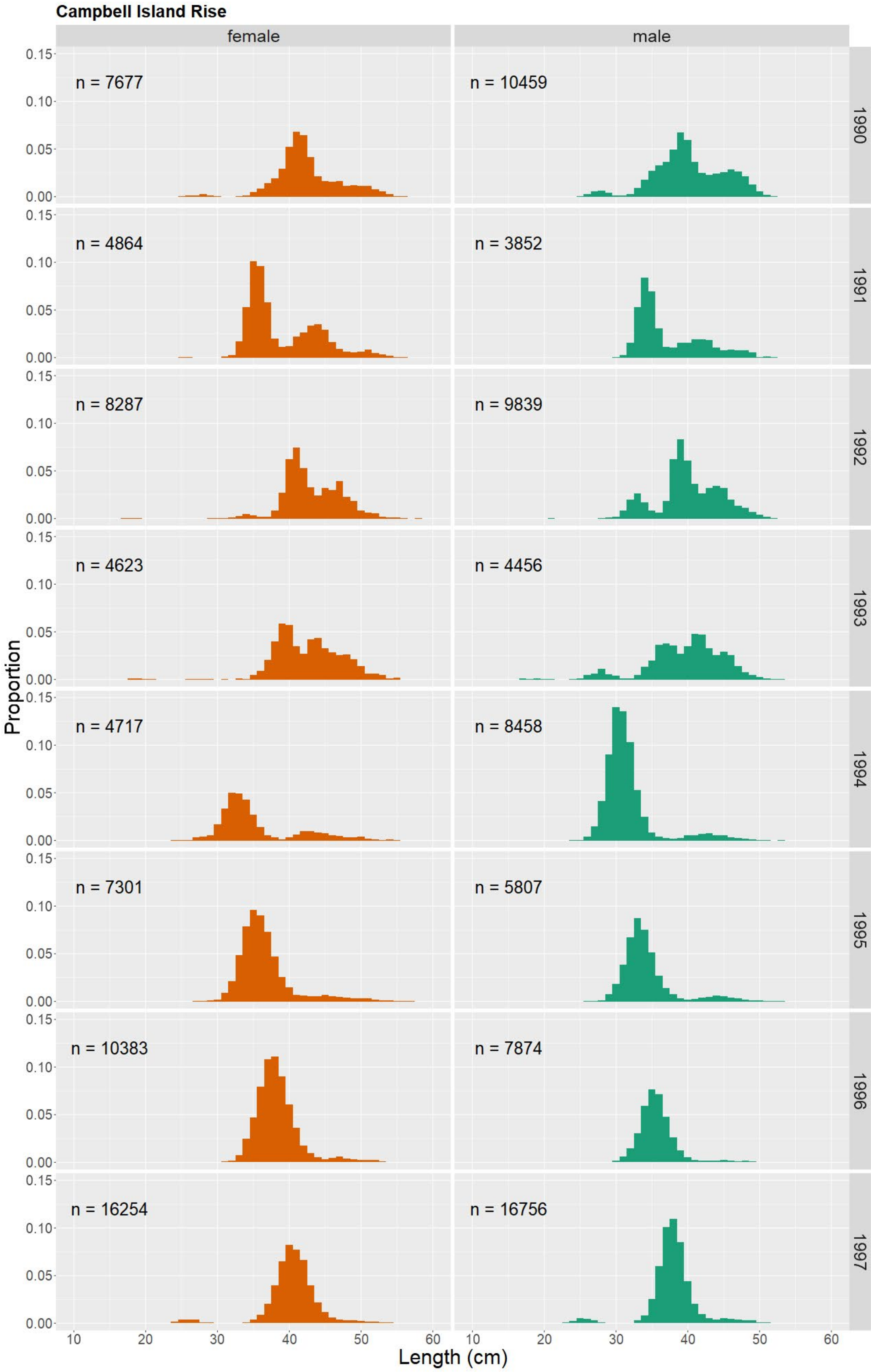

Figure A-7: Commercial catch proportions-at-length for the Campbell Island stock by sex, 1990–1997. Proportions sum to one across males and females in each year. n = number of fish measured.

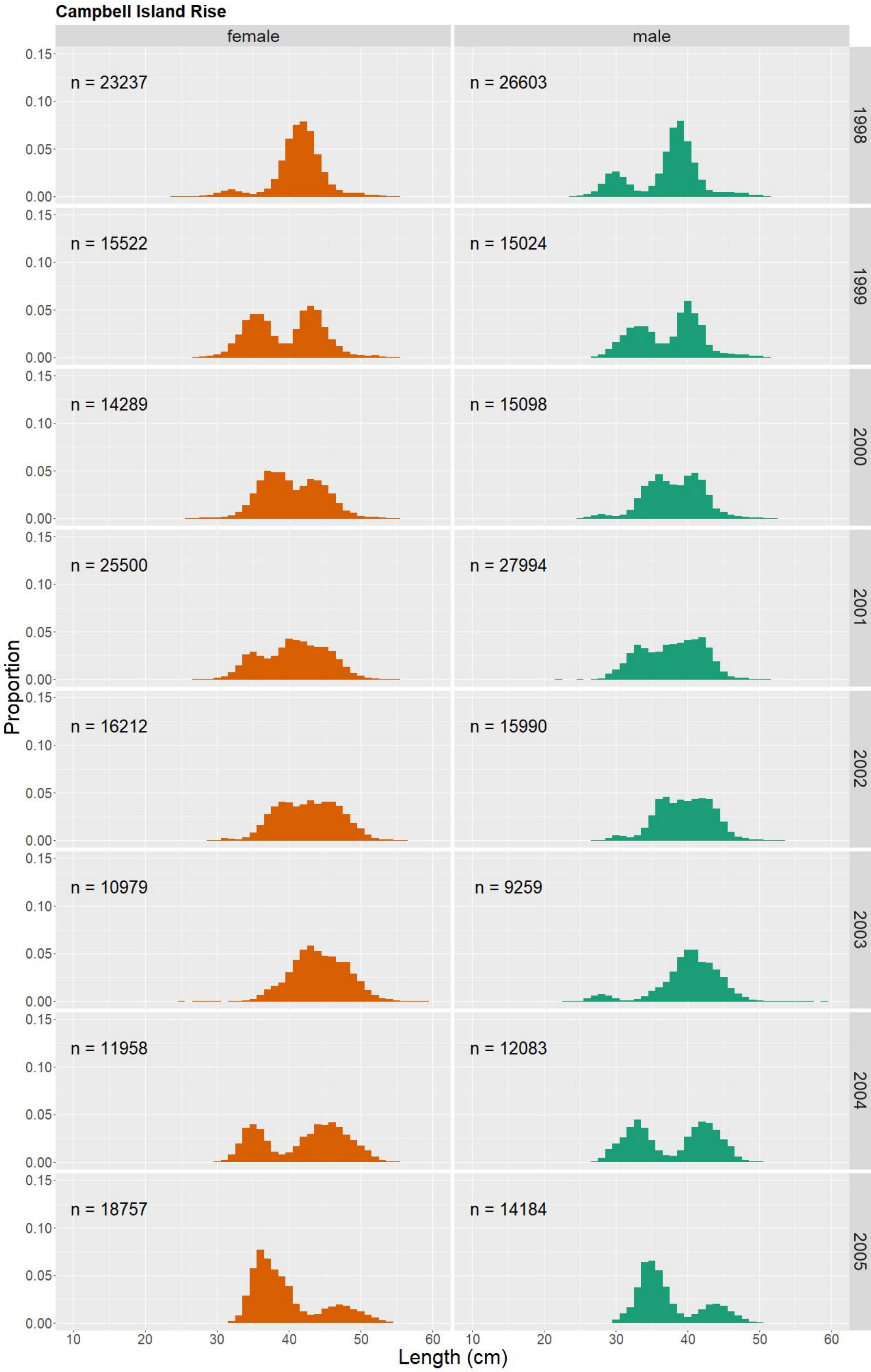

Figure A-8: Commercial catch proportions-at-length for the Campbell Island stock by sex, 1998–2005. Proportions sum to one across males and females in each year. n = number of fish measured.

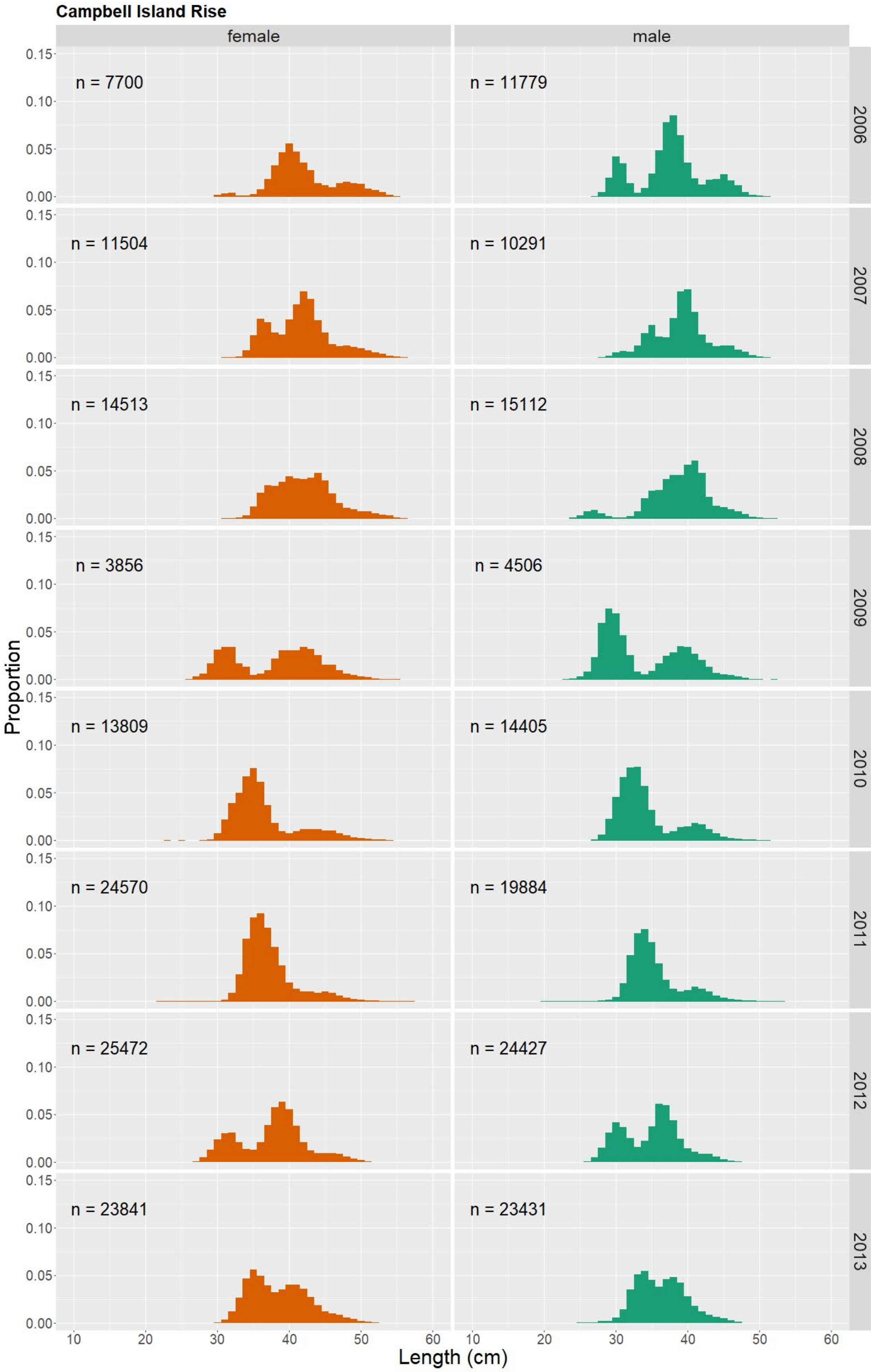

Figure A-9: Commercial catch proportions-at-length for the Campbell Island stock by sex, 2006–2013. Proportions sum to one across males and females in each year. n = number of fish measured.

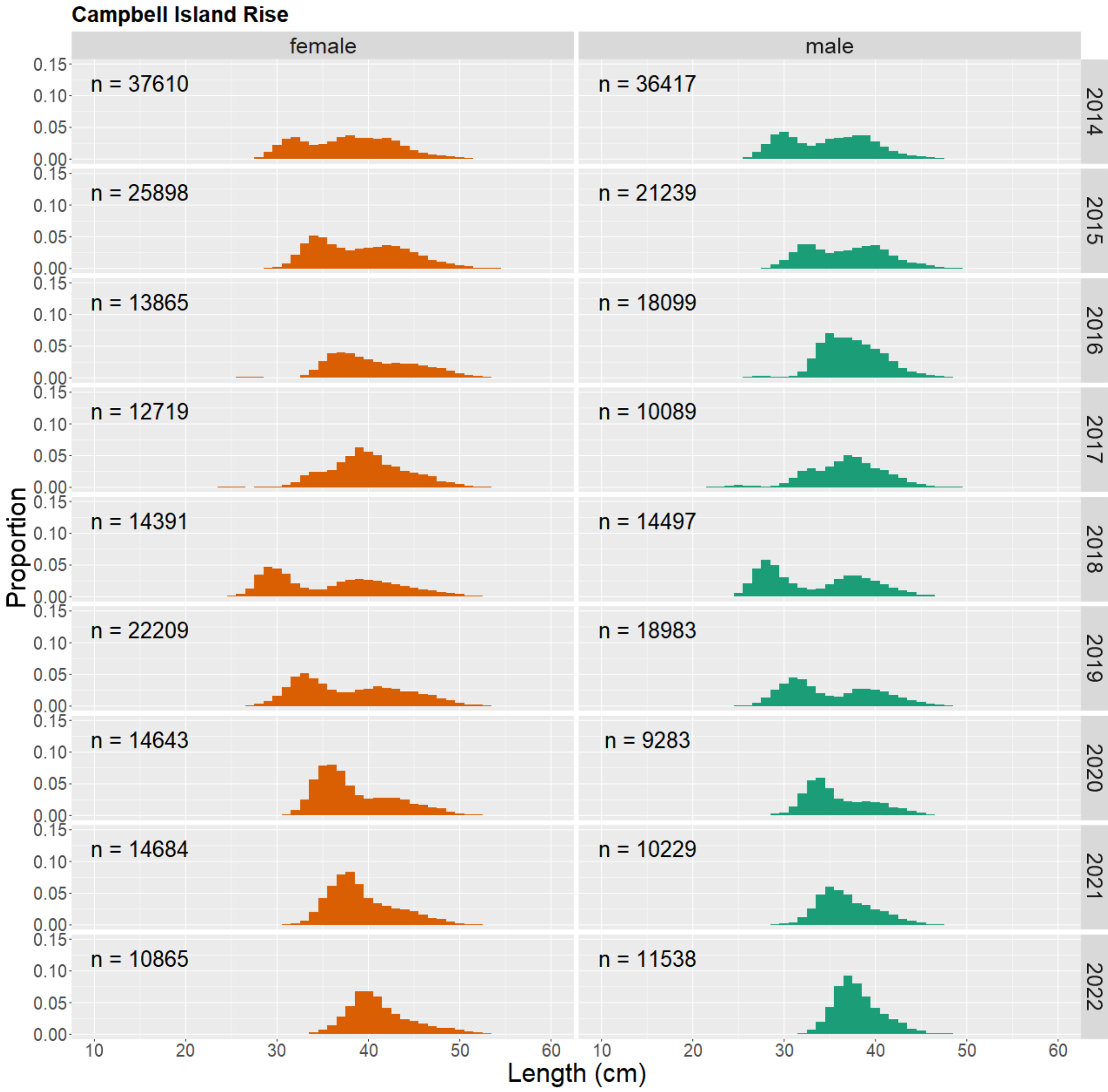

Figure A-10: Commercial catch proportions-at-length for the Campbell Island stock by sex, 2014–2022. Proportions sum to one across males and females in each year. n = number of fish measured.

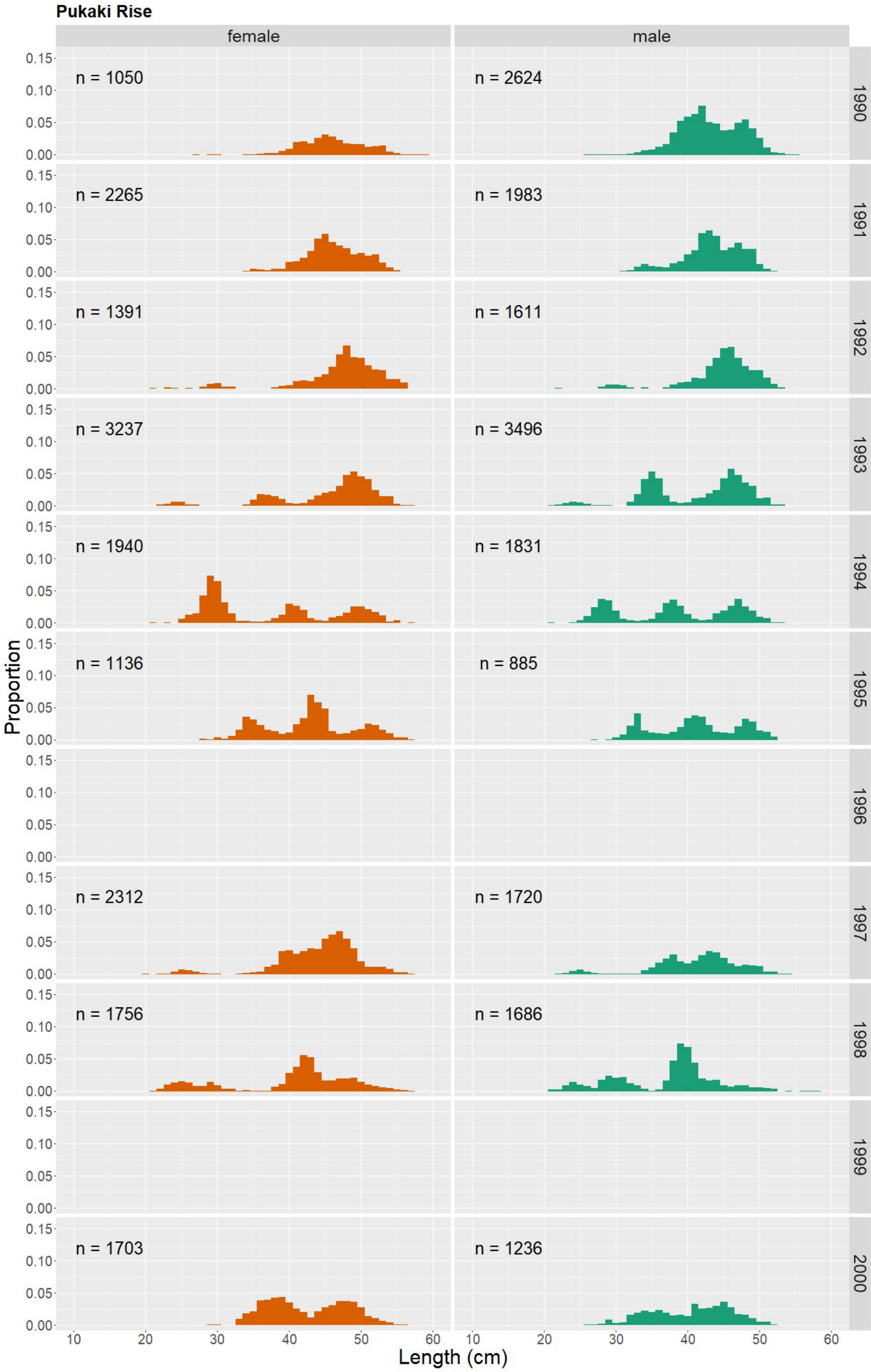

Figure A-11: Commercial catch proportions-at-length for the Pukaki Rise stock by sex, 1990–2000. Proportions sum to one across males and females in each year. n = number of fish measured.

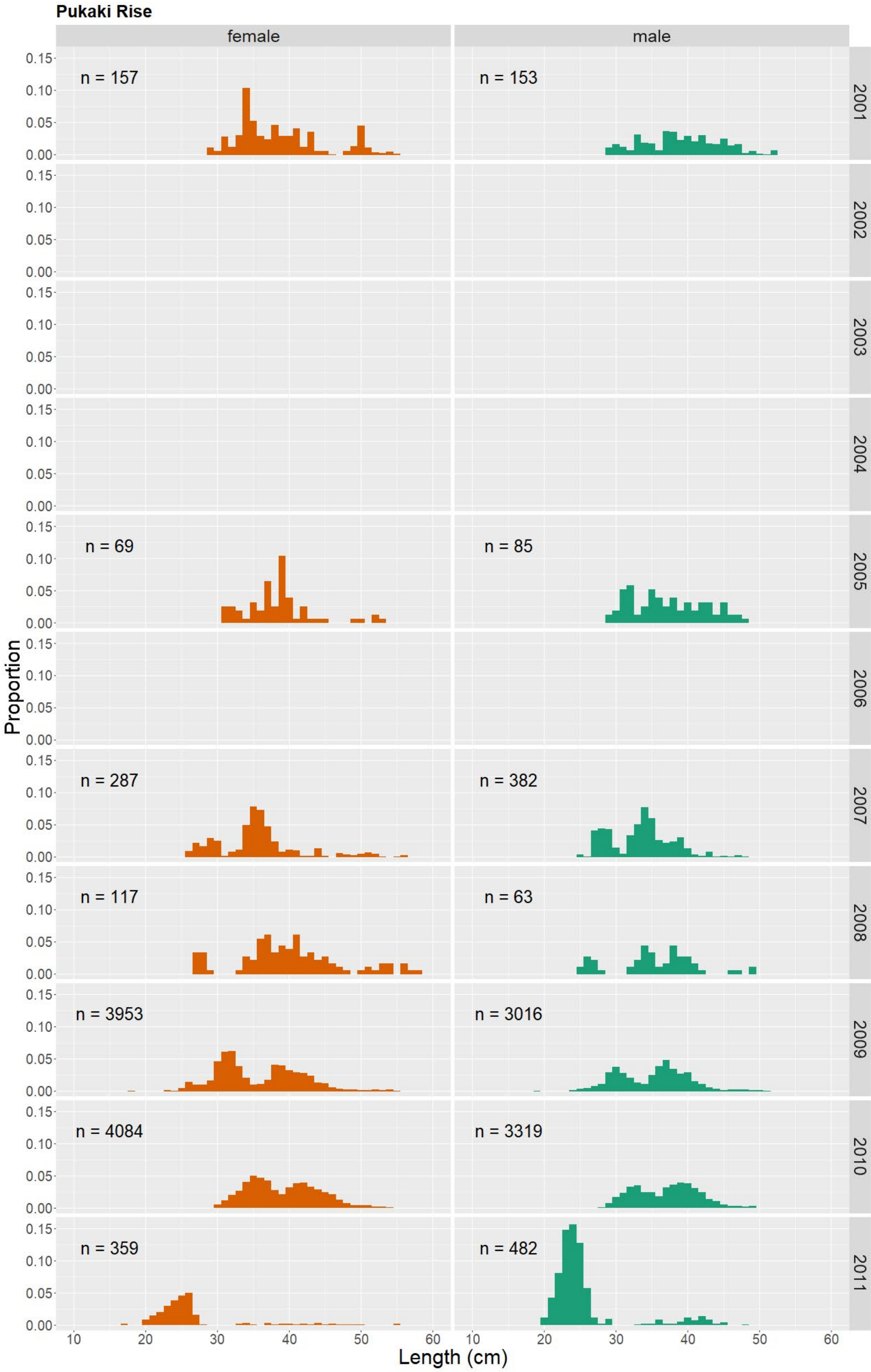

Figure A-12: Commercial catch proportions-at-length for the Pukaki Rise stock by sex, 2001–2011. Proportions sum to one across males and females in each year. n = number of fish measured.

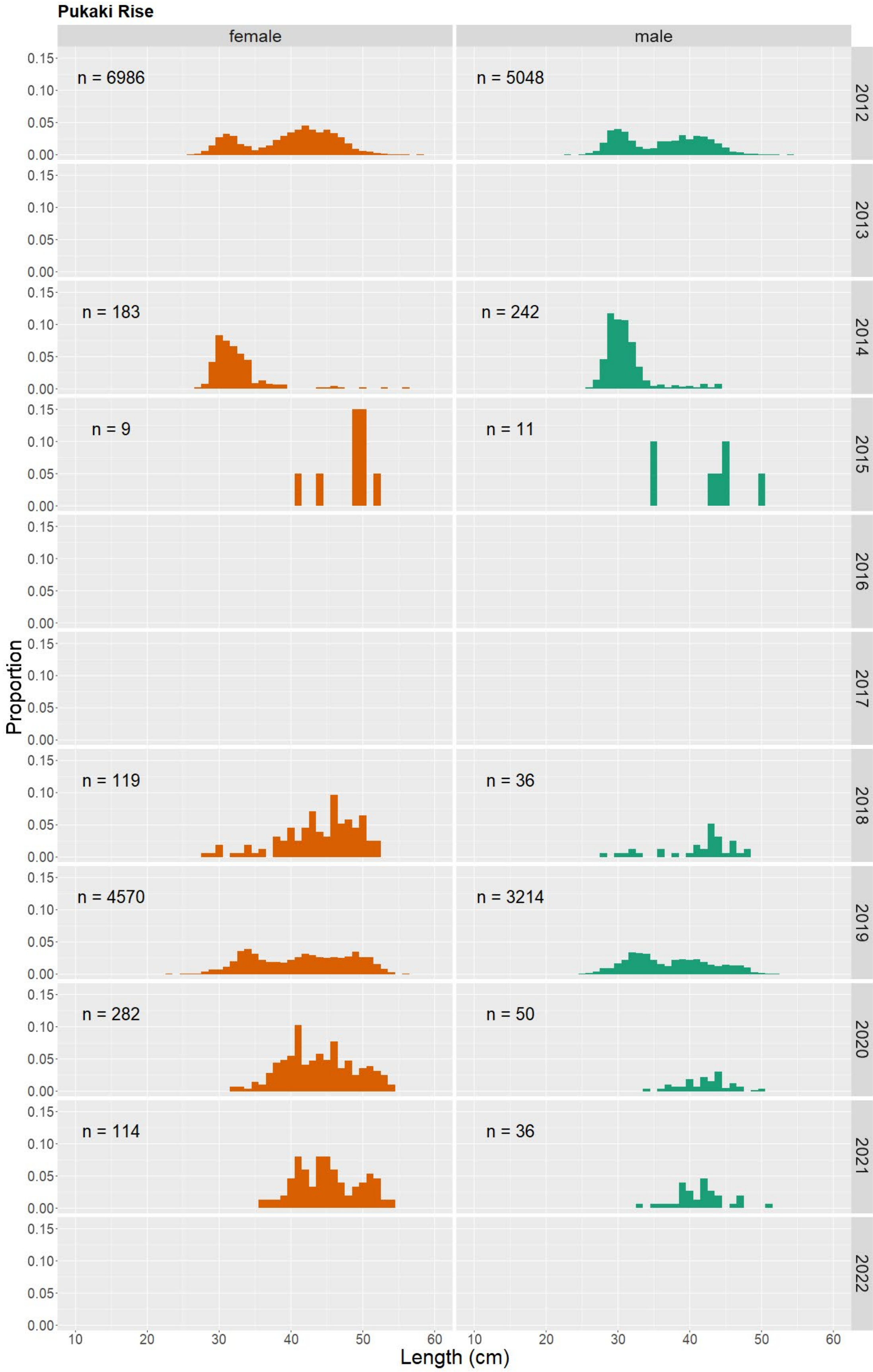

Figure A-13: Commercial catch proportions-at-length for the Pukaki Rise stock by sex, 2012–2022. Proportions sum to one across males and females in each year. n = number of fish measured.

APPENDIX B (additional figures): Commercial catch proportions-at-age with 15+ group

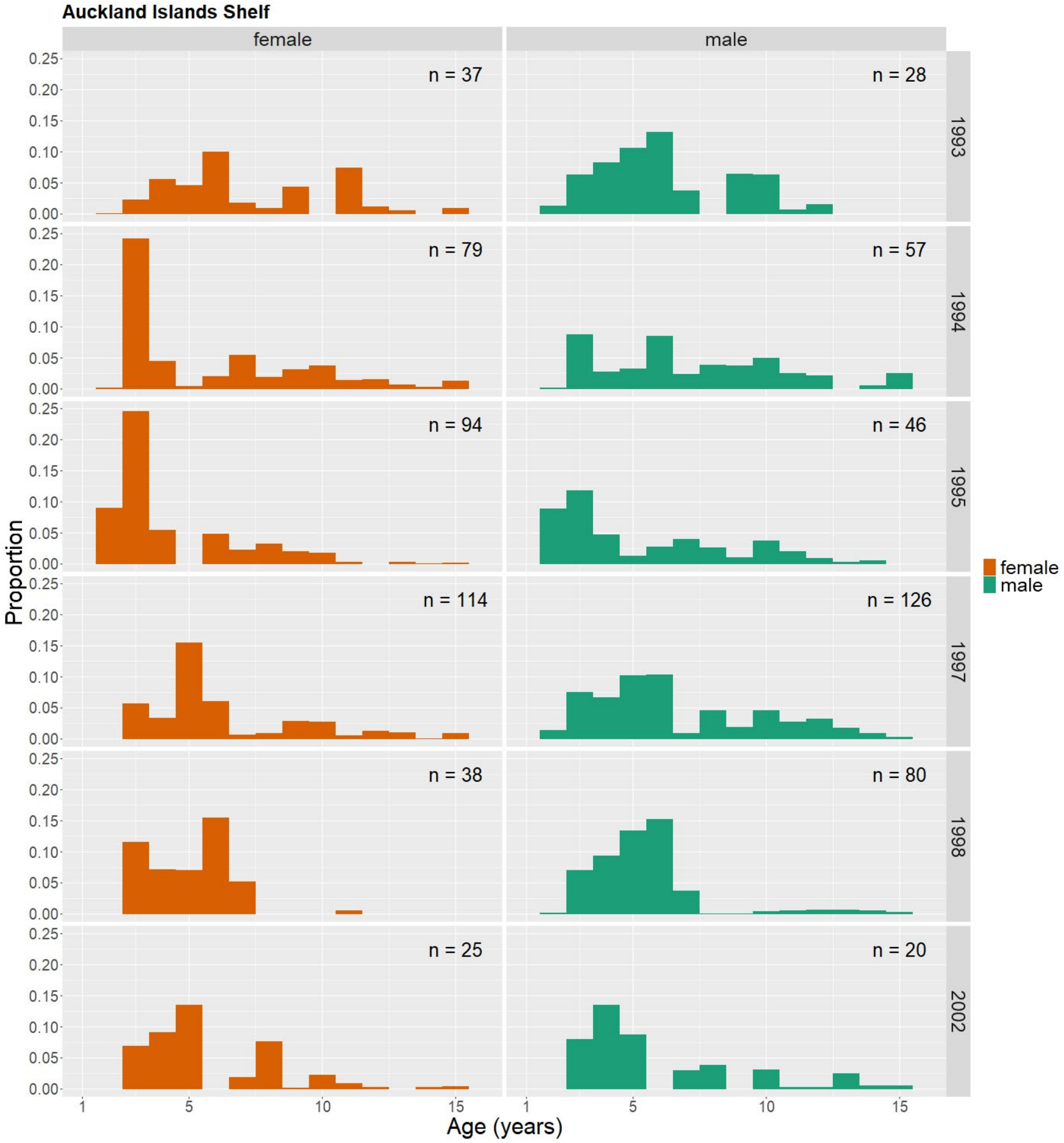

Figure B-1: Commercial catch proportions-at-age for the Auckland Islands stock by sex, 1993–2002. Plus-group at age 15. Proportions sum to one across males and females in each year. n = number of fish sampled for otoliths.

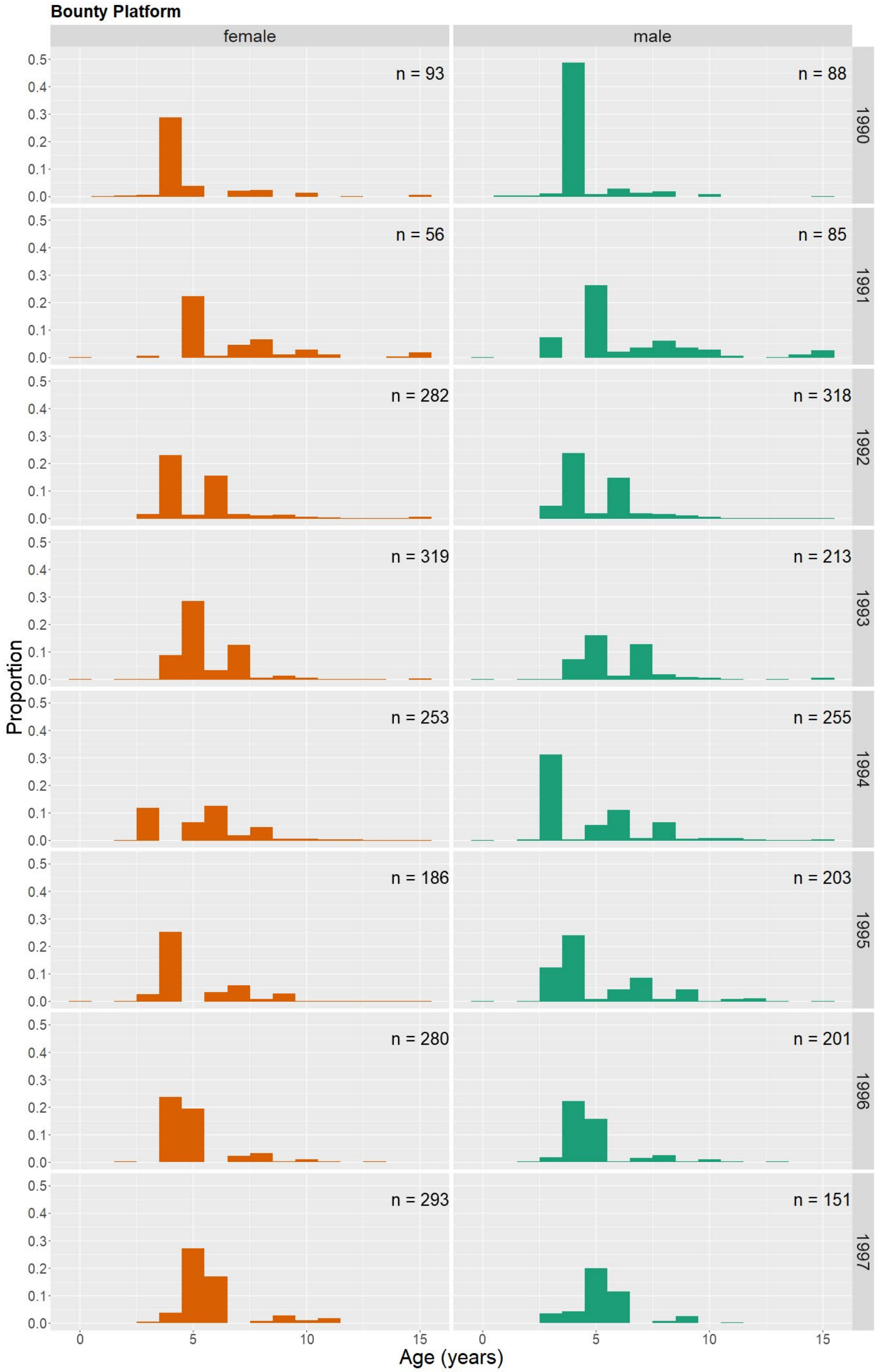

Figure B-2: Commercial catch proportions-at-age for the Bounty Plateau stock by sex, 1990–1997. Plus-group at age 15. Proportions sum to one across males and females in each year. n = number of fish sampled for otoliths.

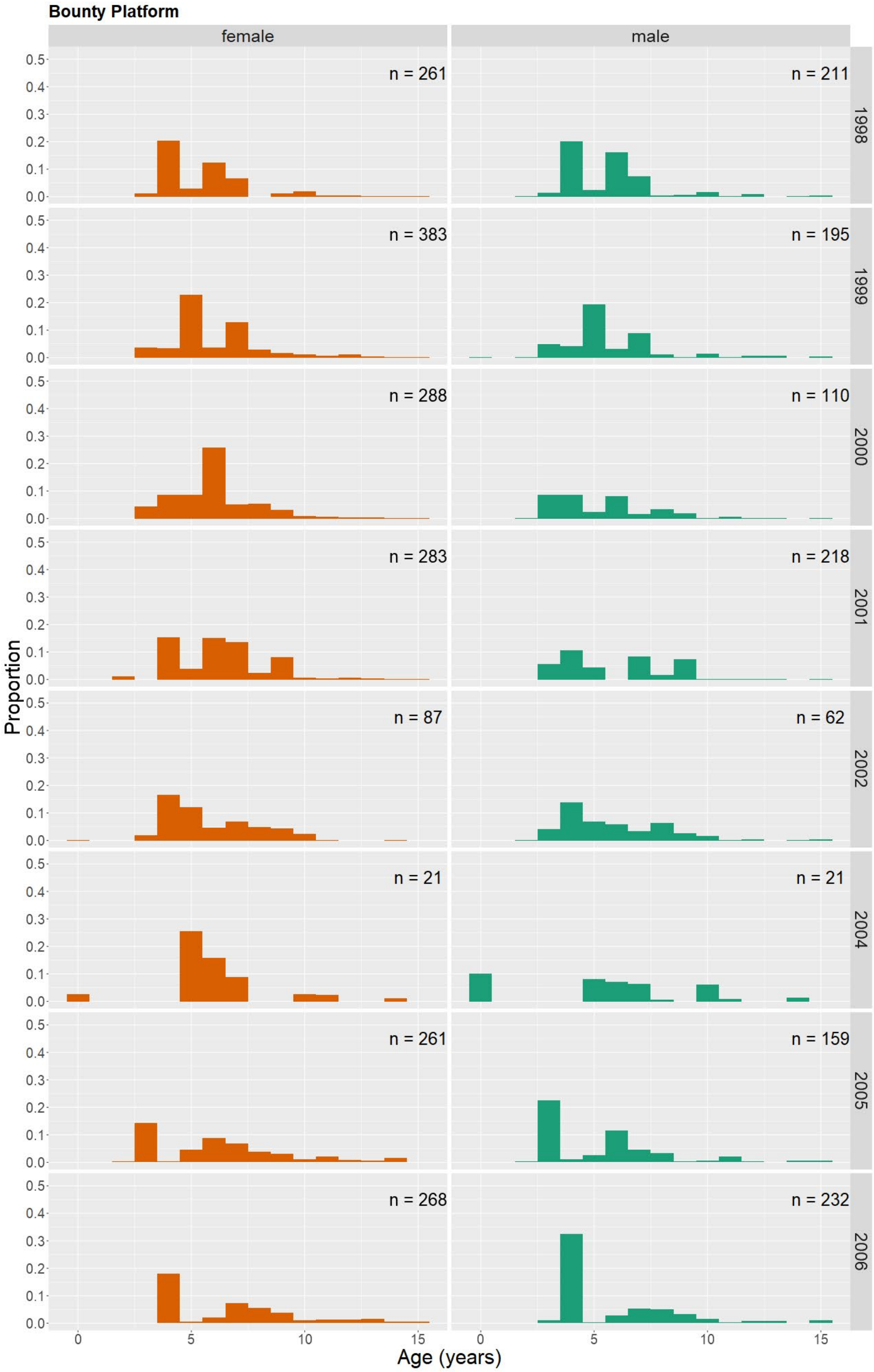

Figure B-3: Commercial catch proportions-at-age for the Bounty Plateau stock by sex, 1998–2006. Plus-group at age 15. Proportions sum to one across males and females in each year. n = number of fish sampled for otoliths.

Figure B-4: Commercial catch proportions-at-age for the Bounty Plateau stock by sex, 2007–2014. Plus-group at age 15. Proportions sum to one across males and females in each year. n = number of fish sampled for otoliths.

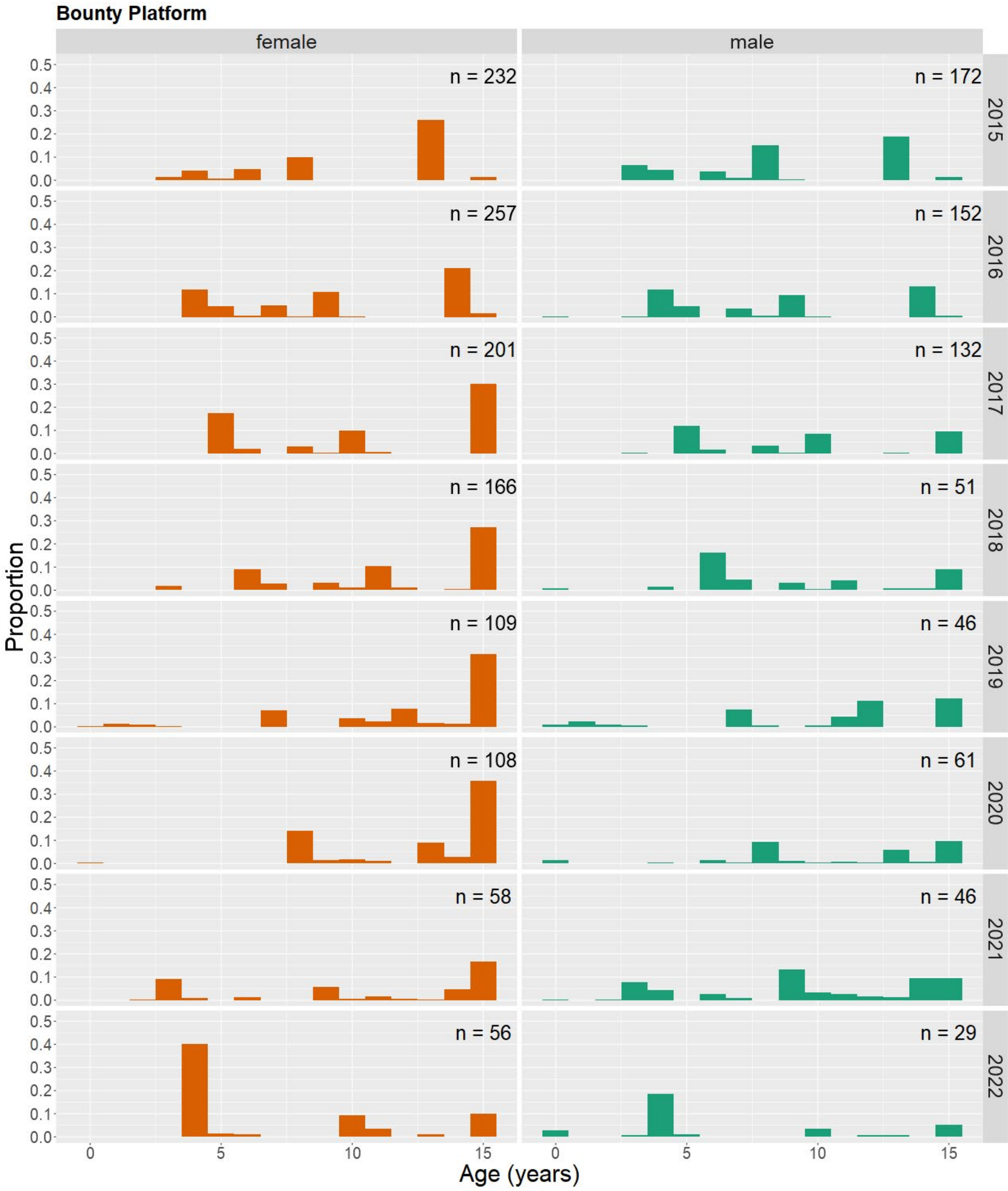

Figure B-5: Commercial catch proportions-at-age for the Bounty Plateau stock by sex, 2015–2022. Plus-group at age 15. Proportions sum to one across males and females in each year. n = number of fish sampled for otoliths.

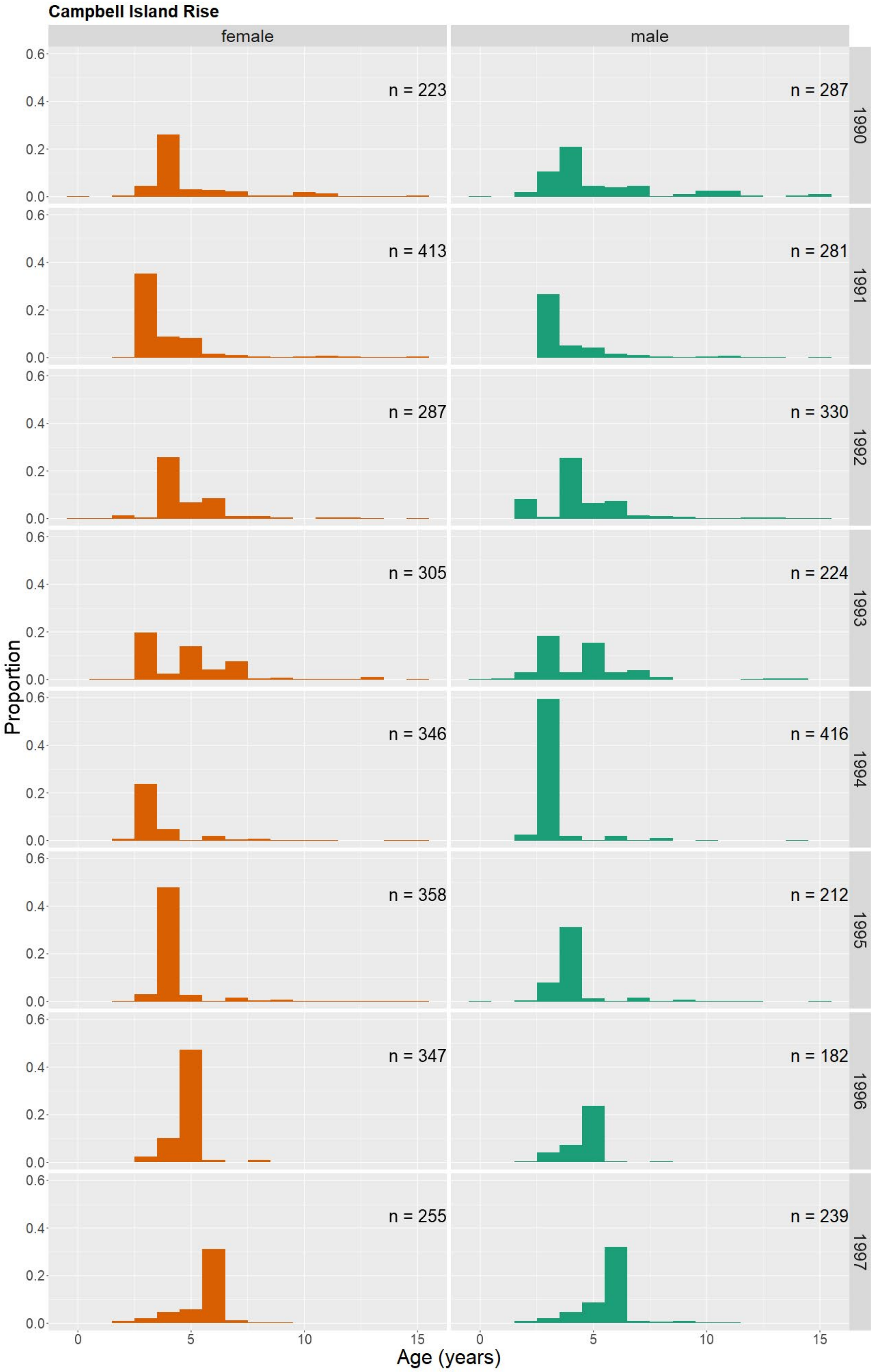

Figure B-6: Commercial catch proportions-at-age for the Campbell Island Rise stock by sex, 1990–1997. Plus-group at age 15. Proportions sum to one across males and females in each year. n = number of fish sampled for otoliths.

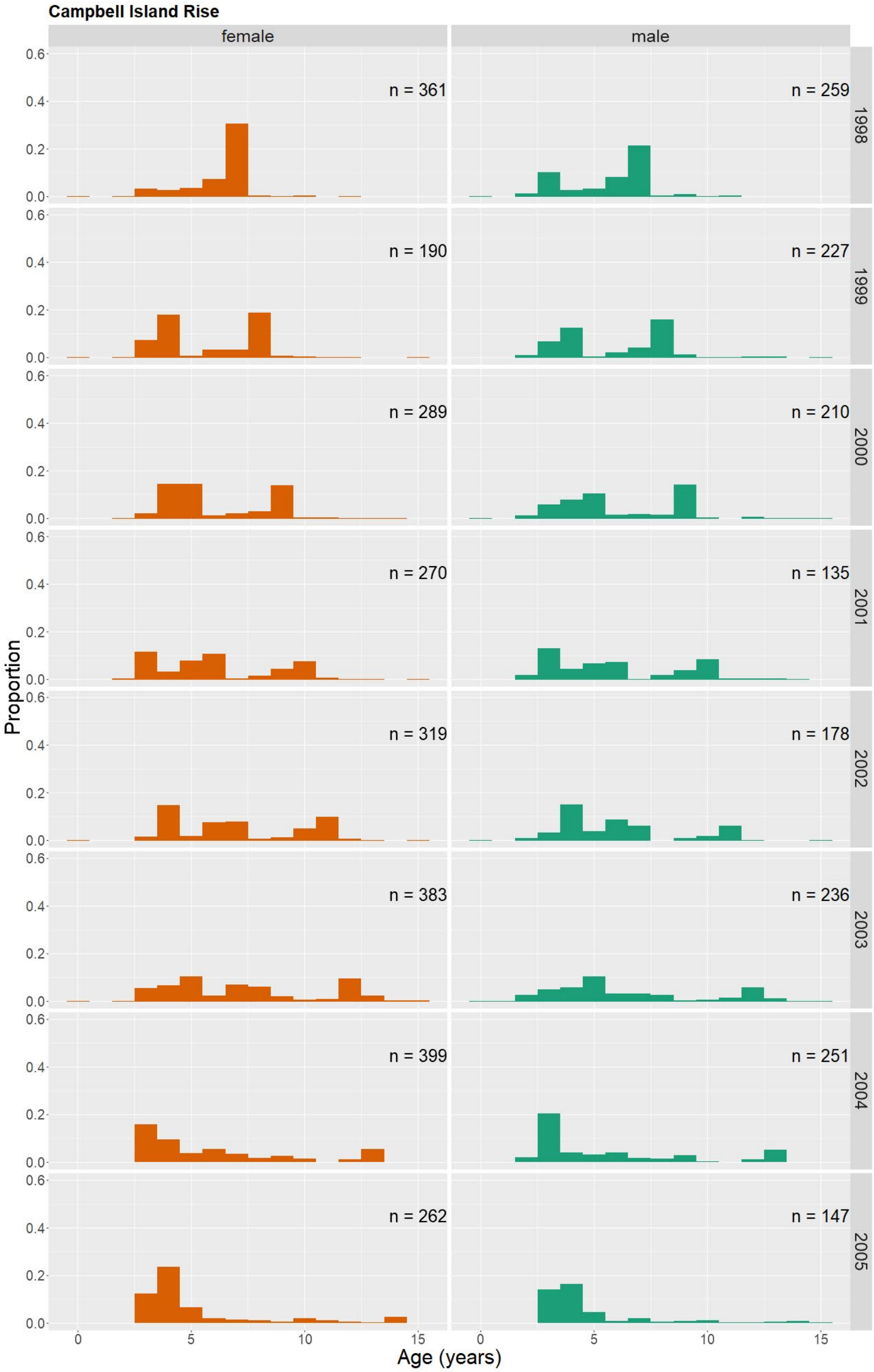

Figure B-7: Commercial catch proportions-at-age for the Campbell Island Rise stock by sex, 1998–2005. Plus-group at age 15. Proportions sum to one across males and females in each year. n = number of fish sampled for otoliths.

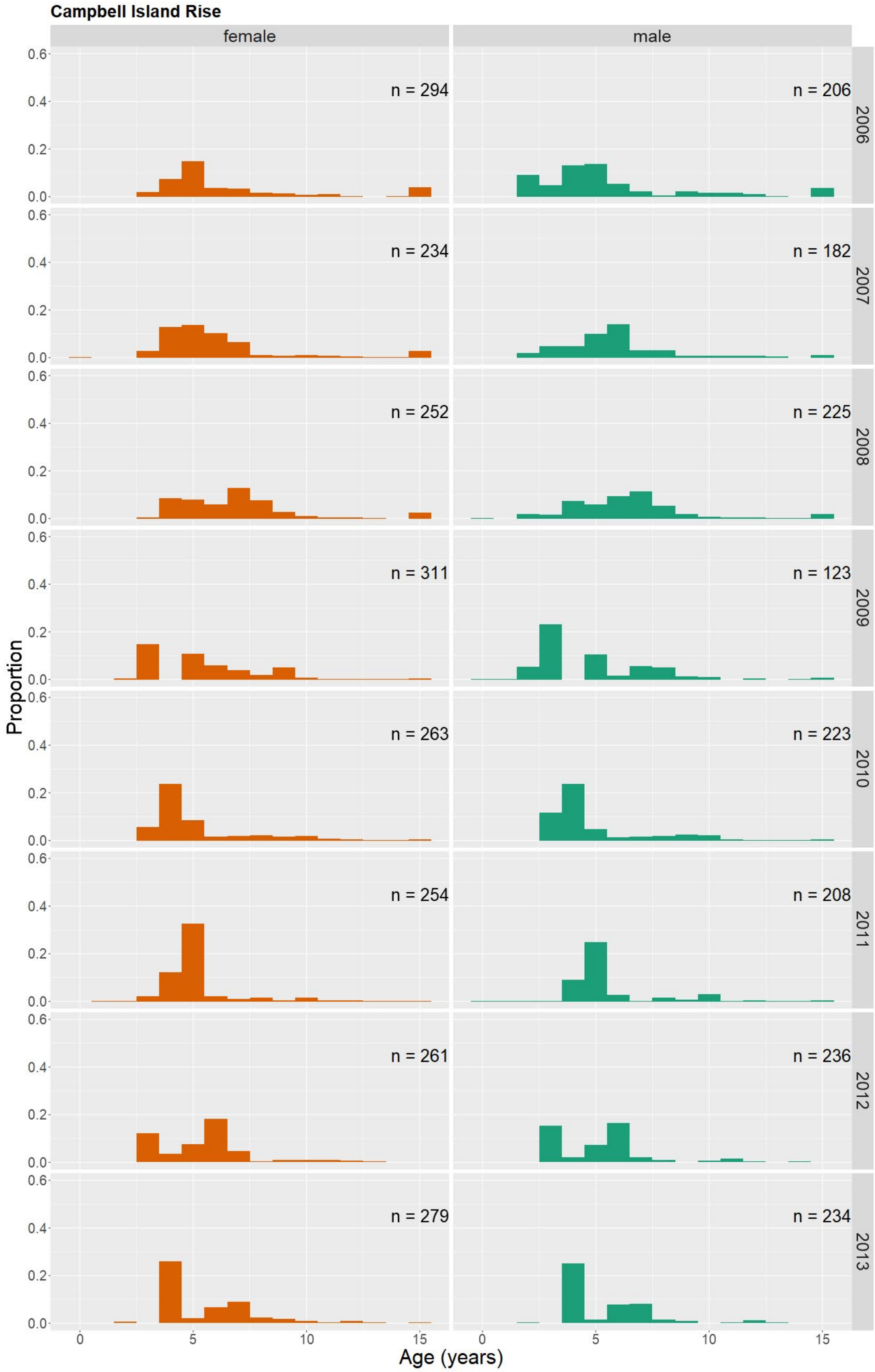

Figure B-8: Commercial catch proportions-at-age for the Campbell Island Rise stock by sex, 2006–2013. Plus-group at age 15. Proportions sum to one across males and females in each year. n = number of fish sampled for otoliths.

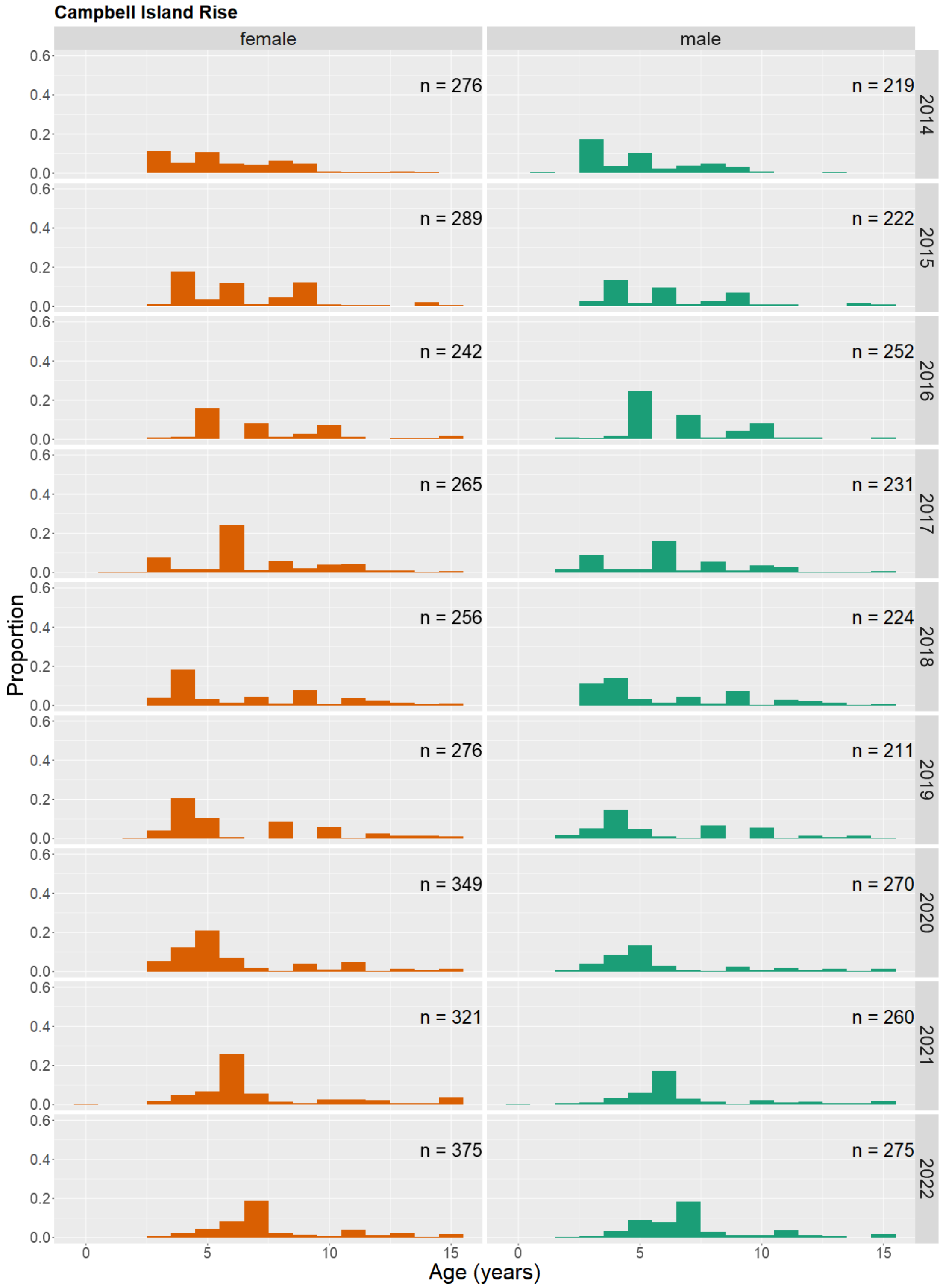

Figure B-9: Commercial catch proportions-at-age for the Campbell Island Rise stock by sex, 2014–2022. Plus-group at age 15. Proportions sum to one across males and females in each year. n = number of fish sampled for otoliths.

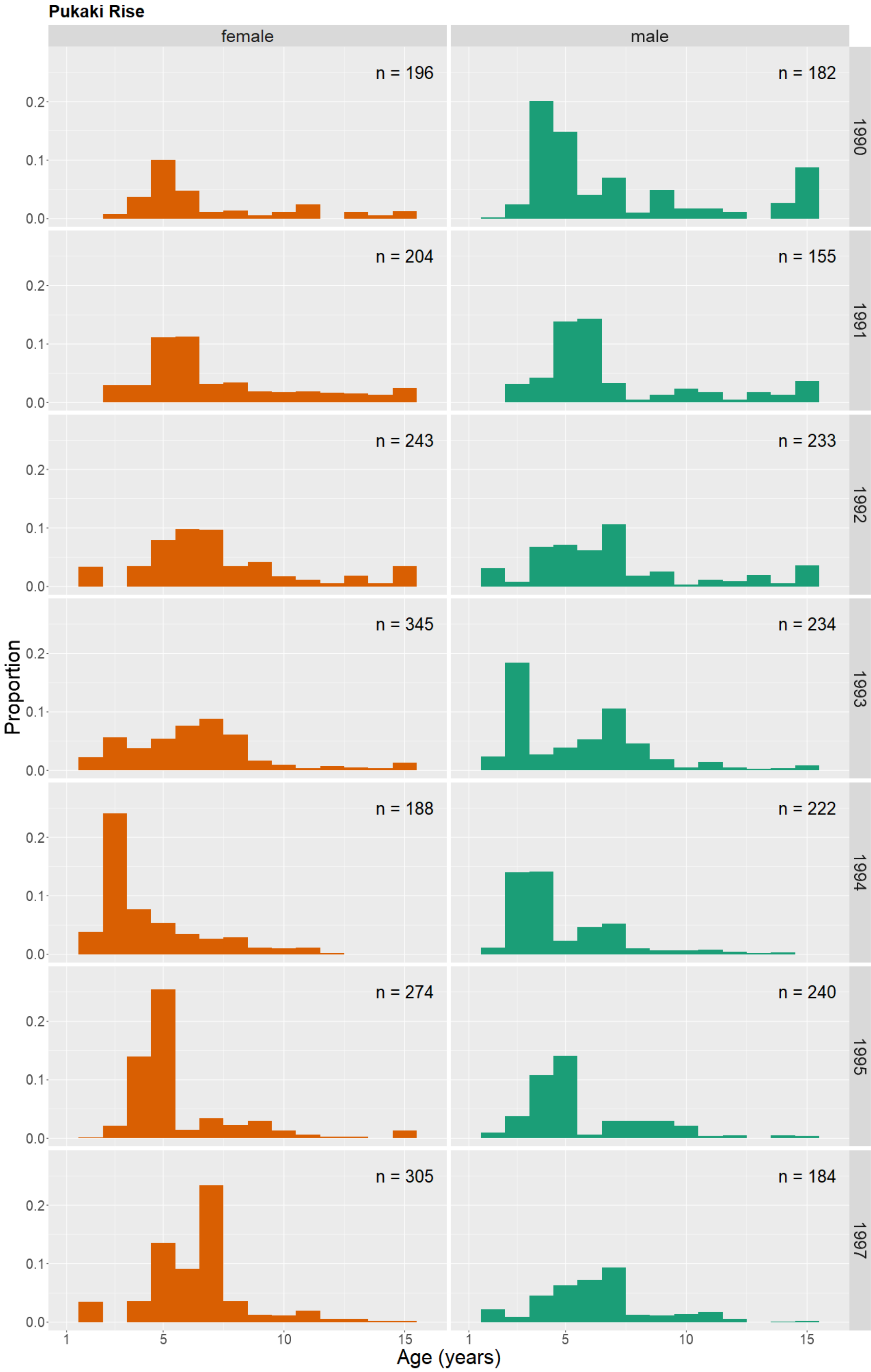

Figure B-10: Commercial catch proportions-at-age for the Pukaki Rise stock by sex, 1990–1997. Plus-group at age 15. Proportions sum to one across males and females in each year. n = number of fish sampled for otoliths. Only years with data are shown.

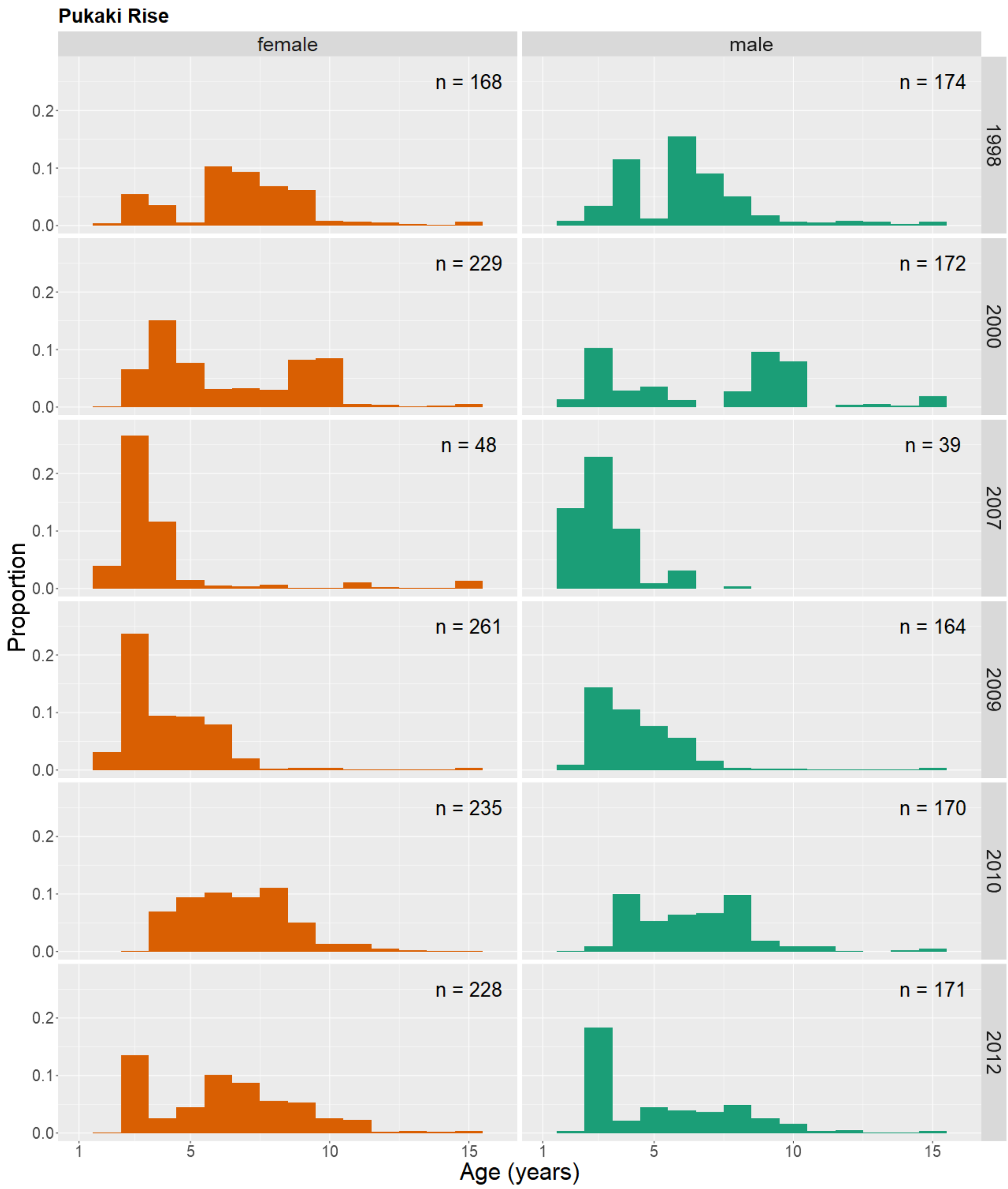

Figure B-11: Commercial catch proportions-at-age for the Pukaki Rise stock by sex, 1998–2012. Plus-group at age 15. Proportions sum to one across males and females in each year. n = number of fish sampled for otoliths. Only years with data are shown.

APPENDIX C (additional figures): Daily catch and proportions spawning

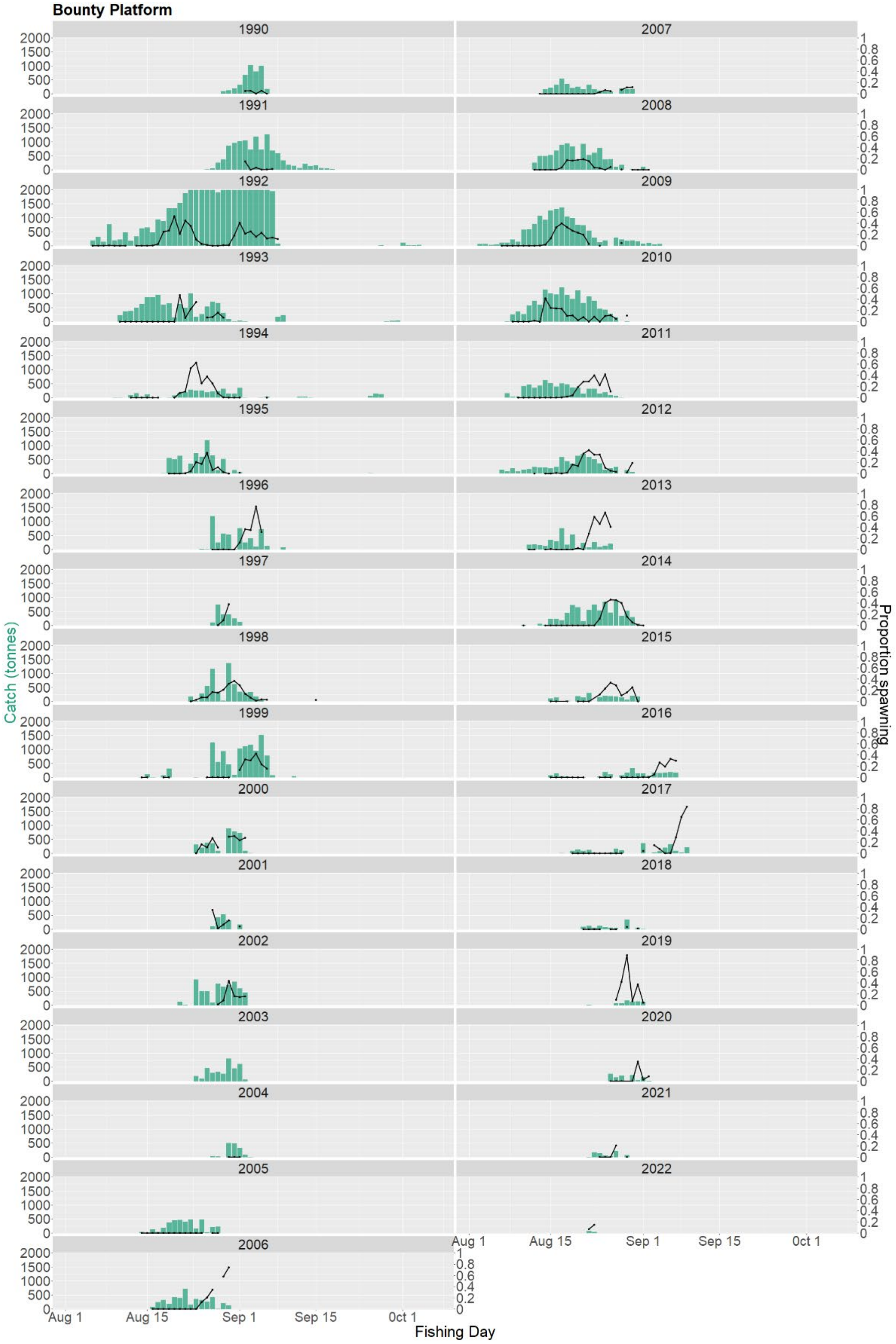

Figure C-1: Daily catch (green bars) and proportion of females spawning (proportions at stage 4) for target southern blue whiting tows on the Bounty Plateau between August and October, 1990-2022. Note, y-axis (daily catch) truncated at 2000 t for 14 days in 1992.

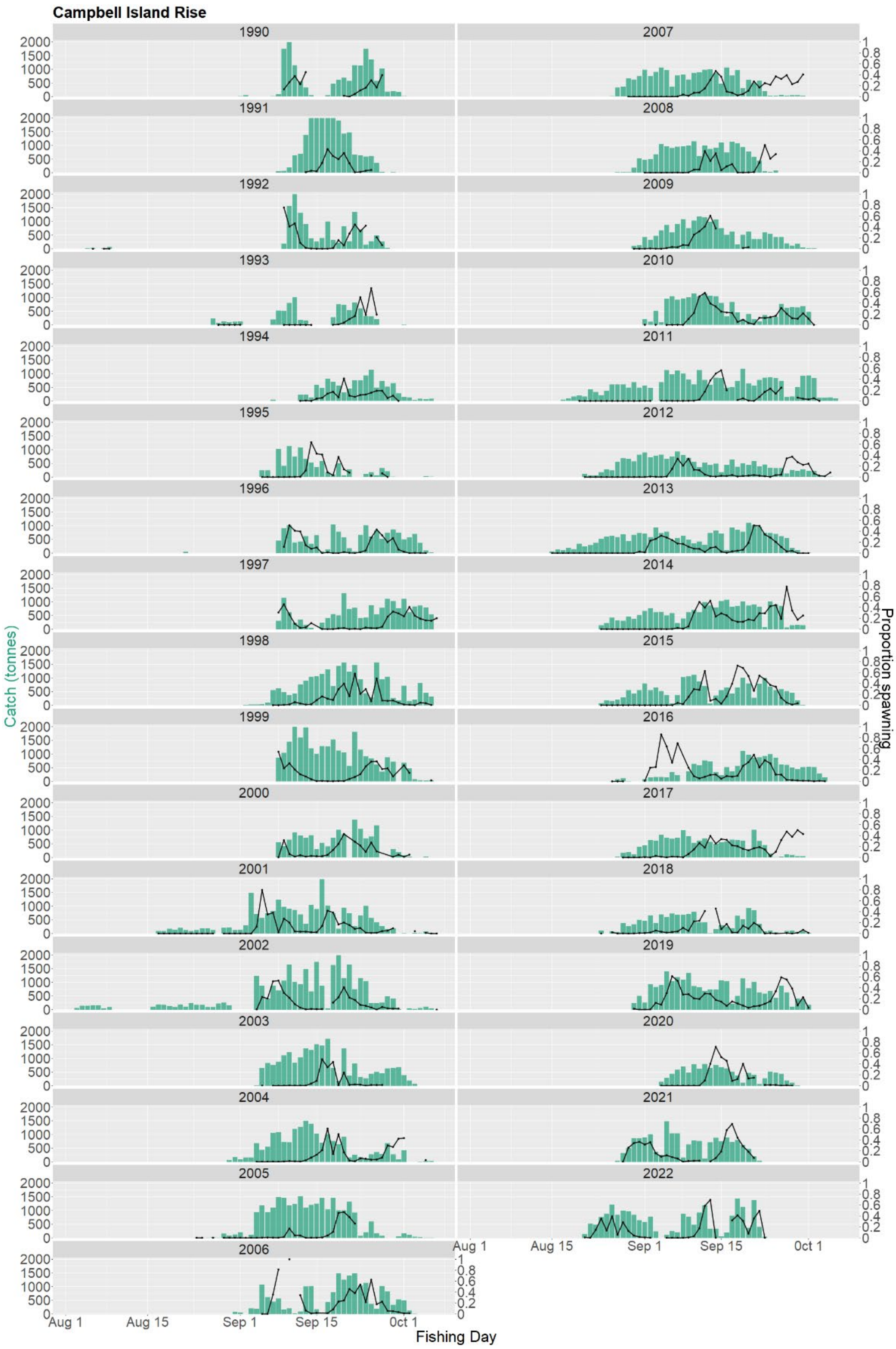

Figure C-2: Daily catch (green bars) and proportion of females spawning (proportions at stage 4) for target southern blue whiting tows on the Campbell Island Rise between August and October, 1990-2022. Note, y-axis (daily catch) truncated at 2000 t for 4 days in 1991, and 1 day each in 1990, 1992, 1999, 2001 and 2002.

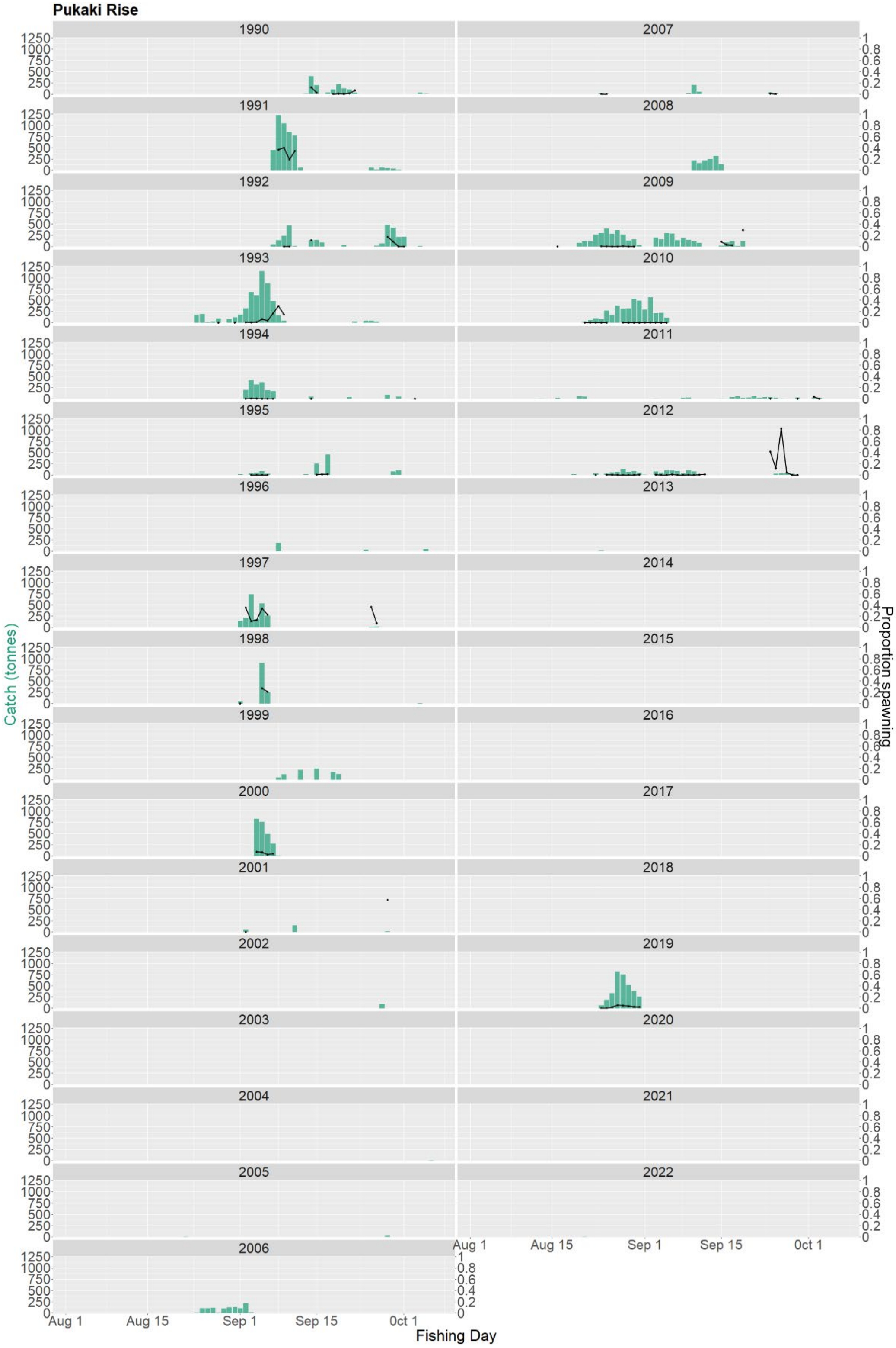

Figure C-3: Daily catch (green bars) and proportion of females spawning (proportions at stage 4) for target southern blue whiting tows on the Pukaki Rise between August and October, 1990–2022.