Fisheries New Zealand

Tini a Tangaroa

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 2018 season

New Zealand Fisheries Assessment Report 2021/13

K. Large,
R.L. O’Driscoll,
A.C.G. Schimel

ISSN 1179-5352 (online)
ISBN 978-1-99-100343-0 (online)

March 2021

New Zealand Government

Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries websites at:
http://www.mpi.govt.nz/news-and-resources/publications
http://fs.fish.govt.nz go to Document library/Research reports

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Large, K.; O'Driscoll, R.L.; Schimel, A.C.G. (2021). 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 2018 season.

***New Zealand Fisheries Assessment Report 2021/13.* 56 p.**

This document updates and summarises the observational and research data for southern blue whiting (SBW) over recent decades. These data include the time series of relative abundance from acoustic surveys for each of the four main stocks (both from the wide area R.V. *Tangaroa* surveys and the local aggregation surveys), CPUE indices for Bounty Platform 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.

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 Platform. The 2016 acoustic biomass estimate from the Campbell Island Rise was the second highest on record. However, there has been very large inter-snapshot and inter-annual variability in the index from the Bounty Platform making it difficult to use for assessment and management purposes. 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 in 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 (2005–16). The trawl survey biomass estimates for the Campbell Island Rise in 2014 and 2016 are the highest on record and are consistent with the high acoustic estimate recorded in 2016. Trawl survey biomass estimates for the Pukaki Rise continue to fluctuate, peaking in 2016, but since there has been virtually no fishing on the Pukaki Rise for the past four years there is no information on recent size and age distribution of catches or year class strength to determine reasons for this increase.

Acoustic data were collected from F.V. *Tomi Maru 87* at the Bounty Platform from 18 August to 2 September 2018. Aggregated SBW were observed at 280–300 m water depth southeast of the Bounty Islands on 28–30 August but dispersed before an acoustic snapshot to estimate abundance could be carried out. It is possible that the first spawning in 2018 was earlier than in recent years, and therefore that the acoustic data collection was too late.

The catch on the Bounty Platform is still dominated by the strong 2002 year class, with recent recruitment deriving primarily from the 2007 and 2012 year classes. On the Campbell Island Rise, there was strong evidence of several recent year classes of moderate strength, with both acoustic indices and commercial-catch-at-age proportions suggesting strong recruitment in 2006 and 2009. Also, the most recent catch-at-age data from the Campbell commercial fishery suggests that the 2011 year class may be about average or above average and that the 2014 year class is moderately strong. The catch on the Pukaki Rise has previously been dominated by fish from the 2004–06 year classes, but there has been recent recruitment of the 2009 year class, which may prove to be moderately strong. However, catches and sampling for age and length on the Pukaki Rise have been low in recent years, and identification of recruitment patterns is difficult. 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.

1. INTRODUCTION

Southern blue whiting are almost entirely restricted to sub-Antarctic waters. They are dispersed throughout the Campbell Platform and Bounty Platform for much of the year, but during August and September they aggregate to spawn near the Campbell Islands, on Pukaki Rise, on Bounty Platform, 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.

Commercial fishing has concentrated on the Campbell Island Rise and, to a lesser extent, the Bounty Platform. 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 Platform fisheries.

Stock assessments for southern blue whiting on the Campbell Island Rise and the Bounty Platform have been conducted at approximately biennial intervals using age-structured stock assessment models; the latest being the 2016 assessment of the Campbell Island stock (Roberts & Dunn 2017) and the 2014 assessment of the Bounty Platform stock (Dunn & Hanchet 2017). 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 Platform was rejected by the Deepwater Working Group, with a harvest control rule developed instead that uses the most recent acoustic index of abundance as an absolute measure of abundance.

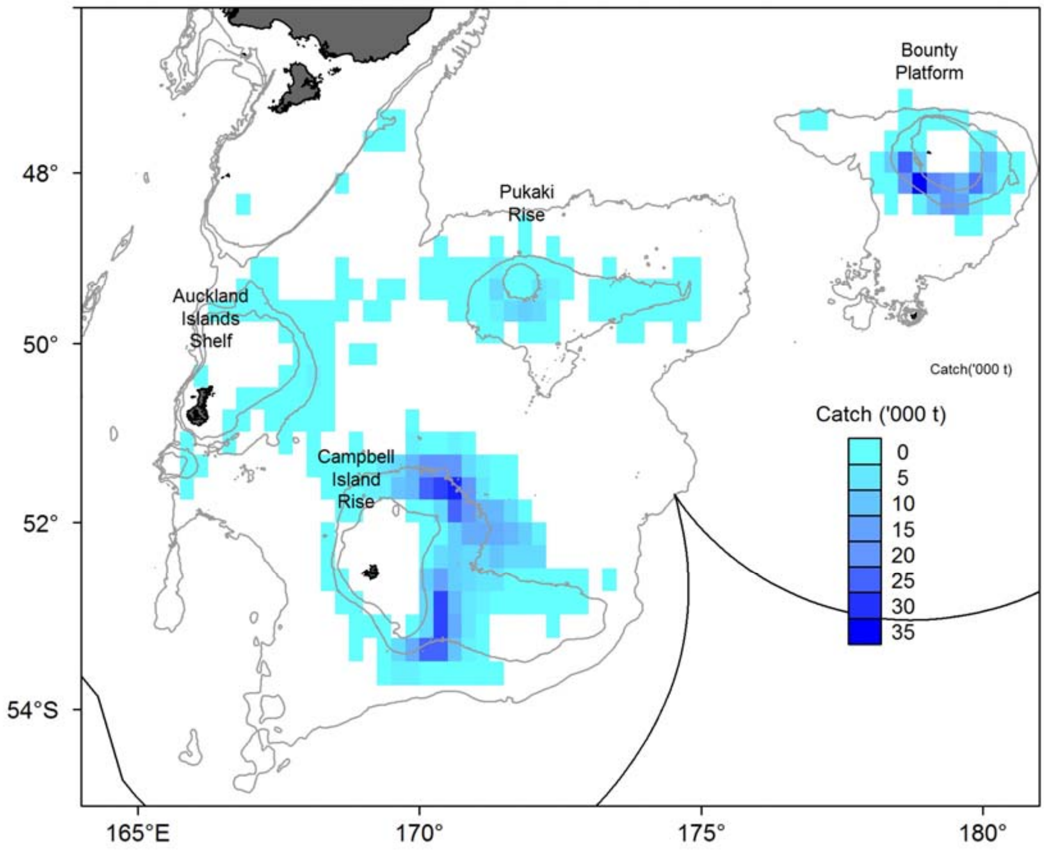

Figure 1: Relative total density of the commercial catch of southern blue whiting by location, TCEPR data 1990–2018. Depth contours are at 250, 500, and 1000 m.

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), 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, 2016b, 2016c, 2017, Doonan 2017, 2018, Roberts & Hanchet 2019). 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 of observations from the 2018 acoustic survey of the Bounty Platform. Further, the commercial catch-at-age proportions were revised and updated for the Bounty Platform and Campbell Island Rise. This report updates the summaries provided by Cole et al. (2013), Dunn & Hanchet (2015a, 2016a), Large & Hanchet (2017), and Large (2021).

The data described in this report were based on data extracts from the Fisheries New Zealand Catch-Effort database in November 2018 (REPLOG 12100), the Fisheries New Zealand Observer database in December 2018, and the Fisheries New Zealand Trawl Survey database in December 2018.

This report is the 2018/19 final reporting requirement for Fisheries New Zealand projects SBW201801 (Estimation of southern blue whiting biomass using acoustic methods (Bounty Platform)) and SBW201802 (Southern blue whiting Bounties stock assessment) and for the southern blue whiting part of Project MID201803 (Routine age determination of middle depth and deepwater species from commercial fisheries and resource surveys).

2. FISHERY SUMMARY

2.1 Commercial fisheries

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). Early reports recorded that southern blue whiting spawned in most years on the Bounty Platform (Shpak 1978) and in some years on the Campbell Platform (Shpak & Kuchina 1983), and that feeding aggregations could be caught on the Pukaki Rise, southeast of the Campbell Island Rise, and on the Auckland Islands Shelf (Shpak 1978). Some fishing probably took place on each of the grounds, but the proportion of catch from each ground was not accurately recorded before 1978. Landings were chiefly taken by the Soviet foreign licensed fleet during the 1970s and early 1980s. The entire Campbell Platform (Campbell Island Rise and Pukaki Rise) was fished year-round between 1978 and 1984, but highest catches were usually made during spawning, typically during September. In some seasons (notably 1979, 1982, and 1983) vessels also targeted spawning fish on the Bounty Platform in August and September (Table 1).

As a result of the increase in hoki quota in 1985 and 1986, the Japanese surimi fleet increased its presence in New Zealand waters and some vessels stayed on after the hoki fishery to fish for southern blue whiting. After 1985, many of the Japanese and Soviet (replaced latterly by Ukrainian) vessels which fish for hoki on the west coast of the South Island during July and August each year move in late August or early September to the southern blue whiting spawning grounds. Between 1986 and 1989, fishing was confined to the spawning grounds on the northern Campbell Island Rise. From 1990 onwards, vessels also started fishing spawning aggregations on the Bounty Platform, the Pukaki Rise, and the southern Campbell Island Rise. Fishing effort increased markedly between 1990 and 1992, culminating in a catch of over 75 000 t in 1992 (Table 1). The increased catch came mainly from the Bounty Platform. In 1993, a fishery developed for the first time on the Auckland Islands spawning grounds, but fishing has continued there at a low level since then. A strong year class on the Bounty Platform led to a rapid increase in catches there from 2008 to 2010. Relatively large catches also occurred at the Pukaki Rise in 2009, 2010, and 2012.

Total annual landings (along with proportion of the total TACC caught) have, in general, been declining in the last ten years, ranging between 39 500 t in 2009–10 to 16 300 t in 2018–19, most of which has been taken from the Campbell Island Rise grounds. The catch in 2018–19 was the lowest since the TACC was introduced in 1993, apart from a catch of 13 900 t in 1995–96. The total catch for all areas in 2018–19 is 33% of the total TACC and the total TACC has been under-caught by over 50% in the last 4 years. The under-catch has mostly been due to an oversupply in the market for southern blue whiting, resulting in reduced effort (see later sections), and also an increased TACC for the Campbell Island Rise since 2014–15.

The TACC on the Campbell Island Rise was almost completely caught between 2000–01 and 2013–14, but has been less than 60% of the TACC for the last four years, and only 38% in 2018–19. On the Bounty Platform the TACC was almost fully caught over much of the last decade. The catch in 2016–17 was about 85% of the TACC, it was overcaught by 2% in 2017–18, but only 35% of the TACC was taken in 2018–19. The total catch also approached the level of the TACC at Pukaki Rise in 2008–09 and 2009–10, but since then the TACC has been considerably under-caught. At Auckland Islands, the catch limits have generally been under-caught in most years since their introduction. 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.

Catch quotas, allocated 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 were introduced to the Quota Management System on 1 November 1999 with the following TACCs: Auckland Islands (SBW 6A) 1640 t, Bounty Platform (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 1 April to 31 March 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 EEZ (SBW 1). Less than 20 t per year has been reported from SBW 1 in most years since 2000–01, but catches have ranged up to 36 t in 2015–16, with 85 t reported in 2016–17, and declining to 18 t in each year for 2017–18 and 2018–19. The TACC for SBW 1 was increased to 100 t for the 2017–18 season.

Details of recent stock-specific changes in catch over time are given in Table 1. Since its introduction into the QMS, the TACC for the Bounty Platform was gradually reduced to 3500 t by 2003, reflecting a period of poor recruitment to the stock. The TACC remained at that level until 2008 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 Platform stock was reduced to 6860 t, but for the 2013 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 tonnes in 2014 but an additional 1810 t of catch in SBW 6B over the TACC was taken under MPI Special Permit 576 by the F.V. *Tomi Maru 87* for the purpose of "investigative research". Following a period of poor recruitment, the TACC was reduced to 2940 t for 2015 and 2016, and further to 2377 t for 2017. The catch limit was then increased for 2018 to 3145 t. The TACC for the Campbell Island Rise was gradually reduced to 20 000 t by 2006, reflecting a period of poor to average recruitment to the stock. The TACC remained at that level until 2009 when the strong 2006 year class entered the fishery, and the TACC was increased to 23 000 t in 2010 and then to 29 400 t for 2011, 2012, and 2013, and increased again to 39 200 t for the 2014–15 season where it has remained. Catch limits for Pukaki Rise and Auckland Islands have remained unchanged since 1997–98.

Table 1: Estimated catches and catch limits (TACCs) (t) of southern blue whiting by area for 1978 to 2018–19 (source: QMRs and MHRs; '–' denotes no catch limit in place).

Fishing year[1]	Bounty Platform (SBW 6B)		Campbell Island Rise (SBW 6I)		Pukaki Rise (SBW 6R)		Auckland Island (SBW 6A)		Total (All areas)	
	Catch	Limit	Catch	Limit	Catch	Limit	Catch	Limit[2]	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	2 357	8 000	8 681	21 000	772	3 000	40	–	13 882	32 000
1996–97	6 071	20 200	24 736	30 100	1 806	7 700	895	–	32 299	58 000
1997–98	10 565	15 400	29 374	35 460	1 142	5 500	0	1 640	41 082	58 000
1998–00	3 997	15 400	20 154	35 460	2 621	5 500	247	1 640	27 078	58 000
2000–01	2 262	8 000	25 196	20 000	515	5 500	32	1 640	28 010	35 148
2001–02	2 263	8 000	29 357	30 000	862	5 500	394	1 640	32 879	45 148
2002–03	7 564	8 000	33 445	30 000	508	5 500	262	1 640	41 795	45 148
2003–04	3 812	3 500	23 718	25 000	163	5 500	116	1 640	27 812	35 648
2004–05	1 477	3 500	19 799	25 000	240	5 500	95	1 640	21 620	35 648
2005–06	3 962	3 500	26 190	25 000	58	5 500	66	1 640	30 278	35 648
2006–07	4 395	3 500	19 763	20 000	1 115	5 500	84	1 640	25 363	30 648
2007–08	3 799	3 500	20 996	20 000	513	5 500	278	1 640	25 587	30 648
2008–09	9 863	9 800	20 483	20 000	1 377	5 500	143	1 640	31 887	36 948
2009–10	15 468	14 700	19 040	20 000	4 853	5 500	174	1 640	39 540	41 848
2010–11	13 913	14 700	20 224	23 000	4 433	5 500	131	1 640	38 708	44 848
2011–12	6 660	6 860	30 982	29 400	701	5 500	92	1 640	38 440	43 400
2012–13	6 827	6 860	21 321	29 400	1 702	5 500	49	1 640	29 906	43 400
2013–14[4]	4 278	4 028	29 006	29 400	71	5 500	79	1 640	33 455	43 400
2014–15[5]	7 054	6 860	24 592	39 200	34	5 500	156	1 640	31 867	53 200
2015–16	2 405	2 940	22 100	39 200	12	5 500	181	1 640	24 733	49 280
2016–17	2 569	2 940	19 875	39 200	11	5 500	46	1 640	22 588	49 280
2017–18	2 423	2 377	18 334	39 200	36	5 500	202	1 640	20 821	48 717
2018–19	1 101	3 145	15 147	39 200	36	5 500	218	1 640	16 502	49 583

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). SBW 1 had a TACC of 8 t until it was increased to 100 t for the 2017–18 season, and reported annual catches since 2000–01 have ranged from 1 t up to 86 t in 2016–17 and 18 t in each of 2017–18 and 2018–19.
4. In 2013–14, although the TACC for SBW 6B 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 SBW 6B over the TACC was taken under MPI Special Permit 576 by the F.V. *Tomi Maru 87* for the purpose of "investigative research".

2.2 Illegal catches

The level of illegal and unreported catch for southern blue whiting has been reported as "thought to be low" (Ministry for Primary Industries 2013). However, there have been several instances of area misreporting and illegal discards.

In 2002–03, the operators of one vessel were convicted for area misreporting — the vessel had caught about 204 t of southern blue whiting on the Campbell Island Rise (SBW 6I) and reported this against quota for the Pukaki Rise (SBW 6R); another 480 t caught on the Campbell Island Rise had been reported against quota for the Auckland Islands Shelf (SBW 6A). In addition, in 2004, the operators of a vessel were convicted of dumping southern blue whiting at sea — crew members estimated that between 40 and 310 t were illegally discarded during a two and a half week period of fishing on the Campbell Island Rise (Ministry for Primary Industries 2013).

In addition to these convictions, some catch was alleged to have been misreported between SBW 6R, SBW 6B, and SBW 6I. The then Ministry of Fisheries noted that in August and September 2002, there was some evidence that a vessel caught 81 t of southern blue whiting in SBW 6R and misreported it as catch from SBW 6B; and also misreported 108 t from SBW 6I as being from SBW 6R. The Ministry noted that in 2004, there was some evidence that 64.5 t of southern blue whiting was caught in SBW 6I and misreported as being caught in SBW 6B (G. Backhouse, Senior Fisheries Investigator, MPI, pers. comm.).

2.3 Other sources of fishing mortality

Scientific observers reported discards of undersize fish and accidental loss from torn or burst codends, particularly during the early years of the fishery. Discarding in the southern blue whiting fishery has been estimated by Clark et al. (2000), and Anderson (2004, 2009). Anderson (2004) quantified total annual discard estimates (including estimates of fish lost from the net at the surface) as ranging between 0.4% and 2.0% of the estimated catch for all southern blue whiting fisheries. Anderson (2009) reviewed fish and invertebrate bycatch, and discards in the southern blue whiting fishery based on observer data from 2002 to 2007. He estimated that 0.23% of the catch was discarded from observed vessels. The low levels of discarding occurred primarily because the fishery targeted spawning aggregations.

In August 2010, the fishing vessel *Oyang 70* sank while fishing for southern blue whiting on the Bounty Platform. It was fishing an area between 48° 00' S and 48° 20' S, and 179° 20' E and 180° 00' E between 15 and 17 August 2010, before sinking on 18 August 2010. The Ministry of Fisheries estimated that it had taken a catch of between 120 t and 190 t that was lost with the vessel (G. Backhouse, Senior Fisheries Investigator, MPI, pers. comm.).

2.4 The 2018 season

The location of trawls made during the 2018 season (mid-August to beginning of October) is shown in Figure 3. Most of the catch was taken by vessels flagged to New Zealand, Dominican Republic, Japan and Ukraine and most fishing was carried out on the Bounty and Campbell stocks (Table 2). In 2018, one vessel fished on the Bounty Platform arriving on 19 August and fishing until 1 September (Figure 4). They took small to moderate catches, mainly from the south of Bounty Island (Figure 2), and typically less 150 t per day. Fish were not spawning during this period (Figure 4). Spawning on the Bounty Platform has tended to occur in mid- to late-August (Figures A5-A7, Appendix 2). However, in the 2016 and 2017 fishing seasons spawning occurred in early September (Figure A7, Appendix 2). In 2018 no vessels were fishing in the area after the end of August, therefore no biological samples are available from this period to assess the possibility of later spawning (as occurred in 2016 and 2017). Conversely, spawning may have occurred earlier, before the vessel arrived on 19 August (see Section 4.1.2).

In 2018, vessels started fishing the Campbell Island Rise on 24 August and continued fishing until 1 October (Figure 3). Comparable to previous years the fleet fished mainly in the east, but less in the south of the Campbell Island Rise ground, and as in recent years (prior to 2016) also fished on the northern spawning aggregations. Daily proportions spawning at Campbell Island showed two distinct spawning peaks with the first spawning peak from 10 to 16 September and the second from 19 to 23 September (Figure 4).

In 2018, there were no targeted southern blue whiting tows on the Auckland Islands Shelf or on the Pukaki Rise (Table 2). Southern blue whiting were taken mainly as a bycatch of fishing for other species, with total landings of 202 t and 36 t from the two areas, respectively (Table 1).

Table 2: Number of tows and vessels for vessels targeting southern blue whiting by area, 1990–2018 (source: TCEPR data).

Year	Auckland Islands		Bounty Platform		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	–	–	–	–

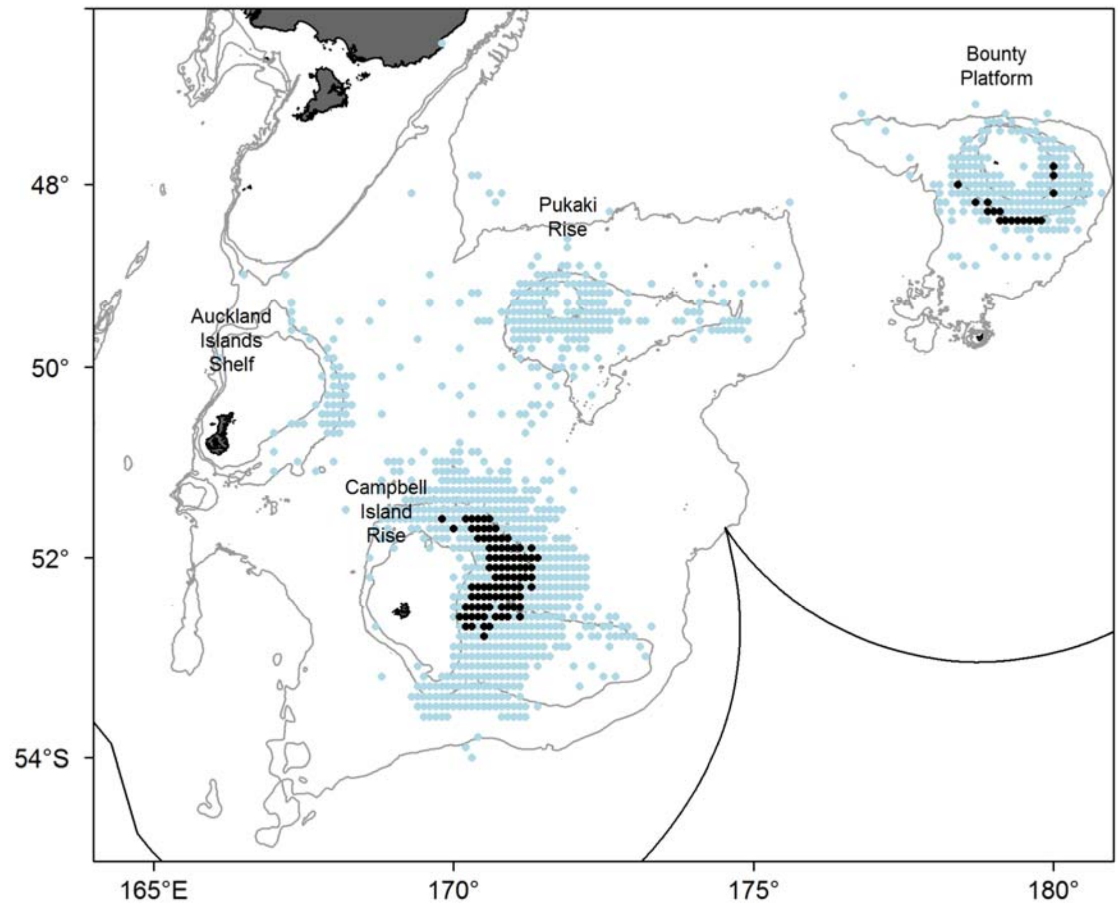

Figure 2: Commercial trawls made during the 2018 season targeting southern blue whiting (late August to early October, black points) and the location of historical target tows 1990–2017 (grey points).

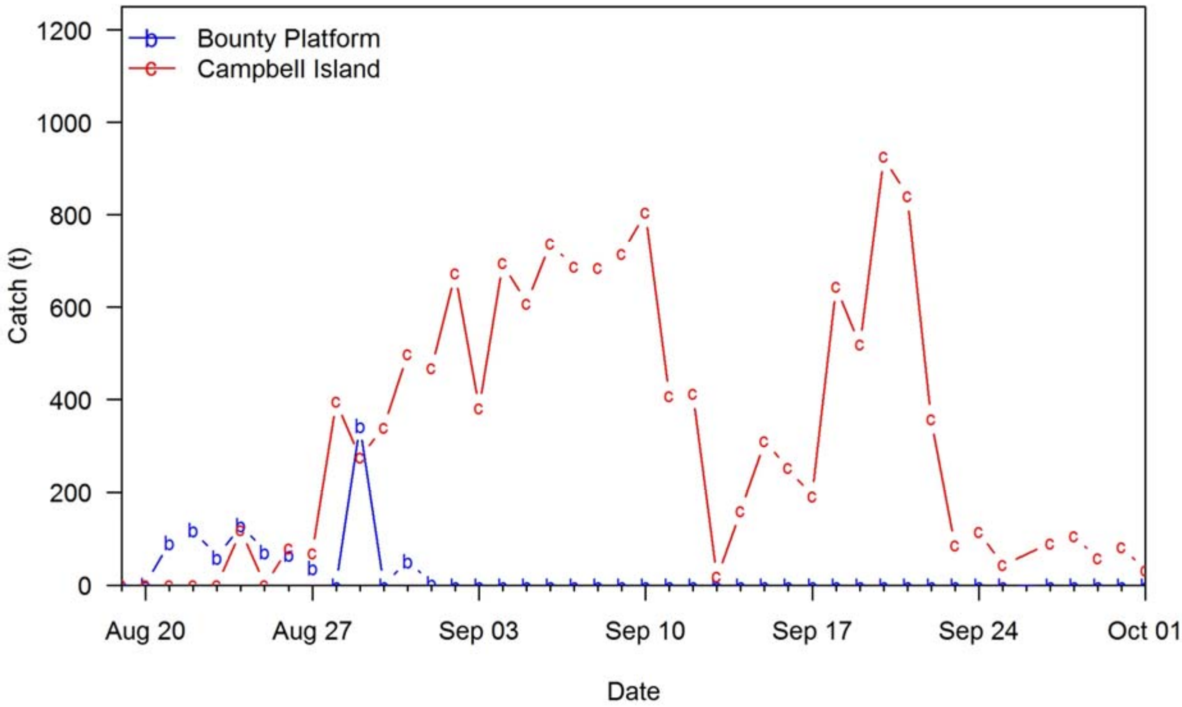

Figure 3: Daily target southern blue whiting catch on the Bounty Platform (blue), and Campbell Island Rise (red) in 2018 between July and October.

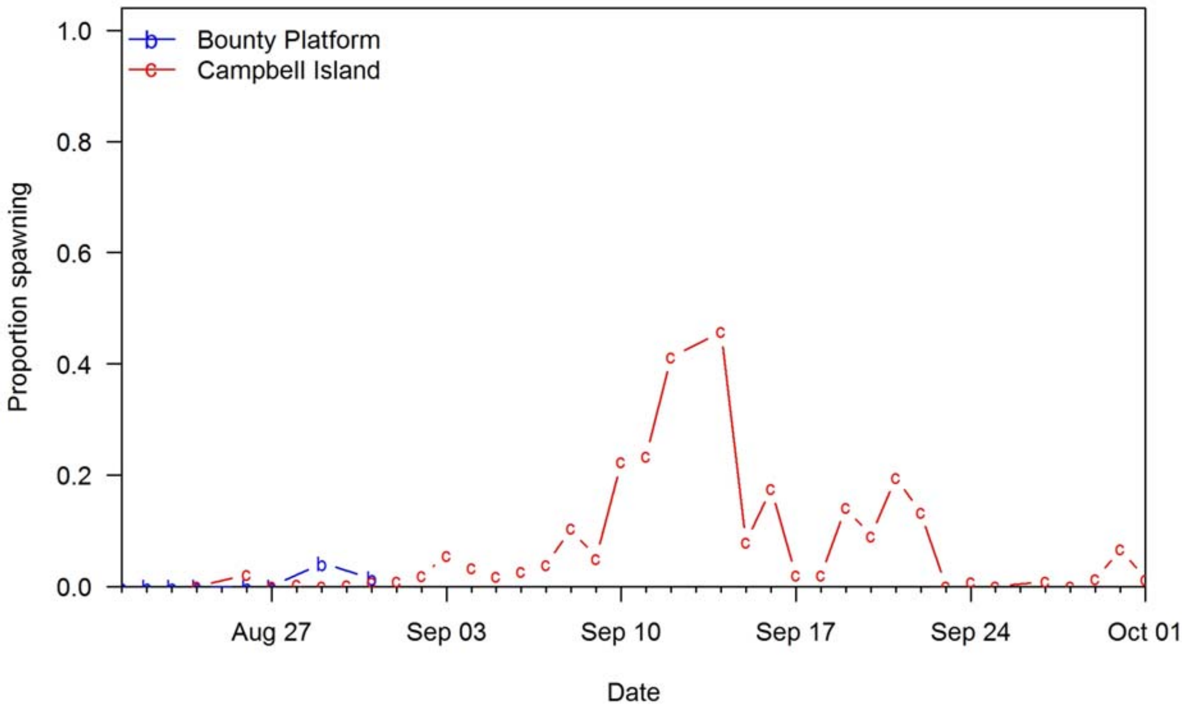

Figure 4: Daily proportion of females spawning (proportions at stage 4) for target southern blue whiting tows on the Bounty Platform (blue), and Campbell Island Rise (red) in 2018 between July and October.

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 Platform, 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 Platform, Pukaki Rise, and Campbell Island Rise could be distinguished on the basis of their morphometric measurements. This constitutes strong 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 is 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 Platform stock, the Pukaki Rise stock, the Auckland Islands stock, and the Campbell Island Rise stock. Southern blue whiting are also managed as four separate stocks.

3.2 Biological parameters

3.2.1 Age and growth

Early growth has been well documented with fish reaching a length of about 20 cm FL after one year and 30 cm FL after two years (Hanchet & Uozumi 1996). Growth slows down after five years and virtually ceases after ten years. Ages have been validated up to at least 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 biology 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 5). A similar large reduction in growth rate occurred on the Bounty Platform with the strong 2002 year class (Figure 6), with the subsequent two year classes also growing at a similar 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 a vector of length at age based on the von Bertalanffy growth parameters.

Mean length at age estimates for each area (based directly on the annual age-length key) were presented by Hanchet et al. (2003). These estimates have been updated and recalculated using 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 5 and Figure 6 for the Campbell Island Rise and the Bounty Platform, respectively.

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

Table 3: Estimates of growth parameters for the Pukaki Rise stock.

Parameter	Male	Female	Source
t0	-0.92	-0.77	Dunn & Hanchet (2016c)
K	0.273	0.260	
Linf	49.9	53.9	
CV	0.08	0.08	

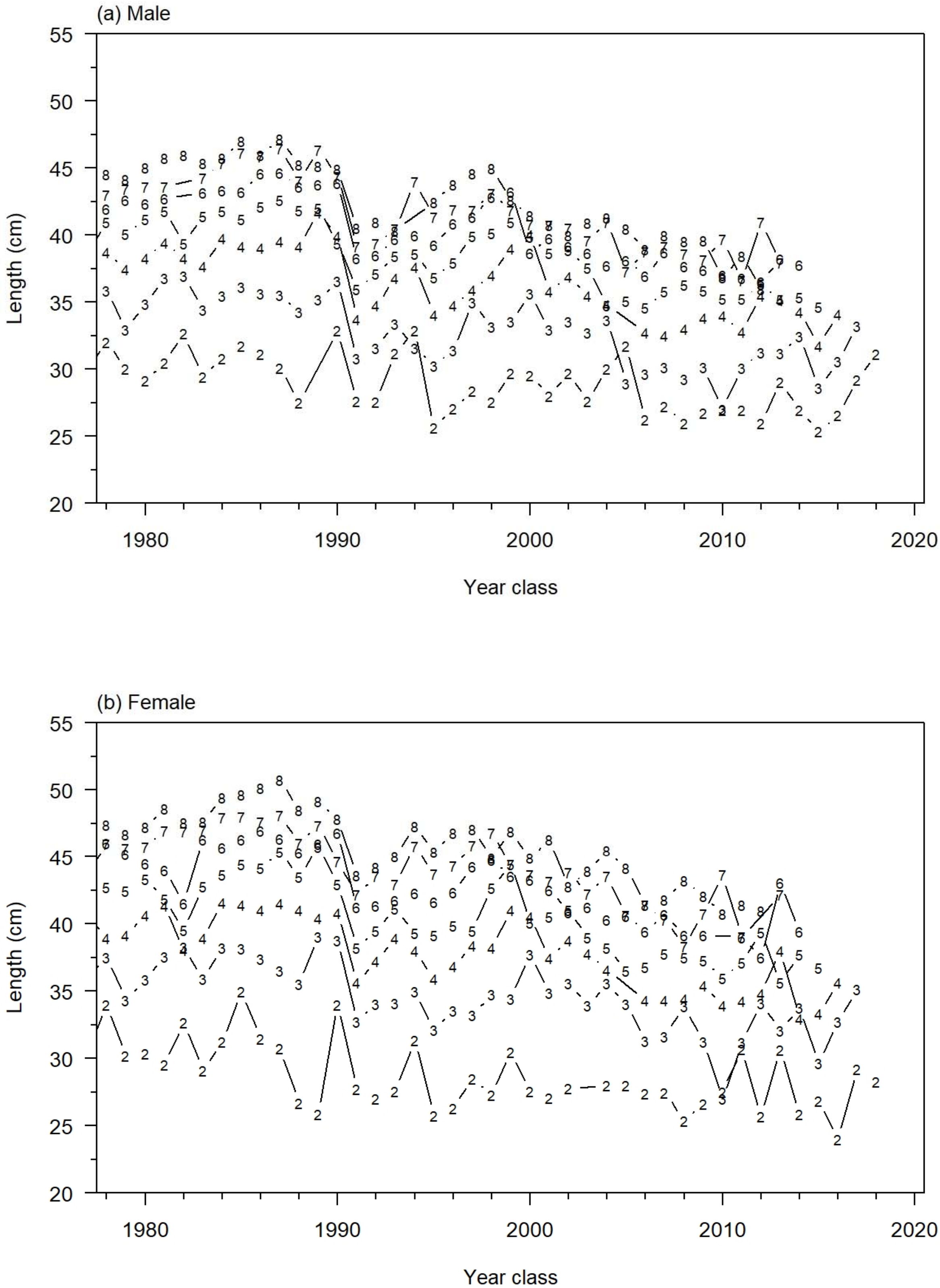

Figure 5: Observed mean length-at-age (ages 2–8) for the Campbell Island stock by sex and year class, 1978–2018.

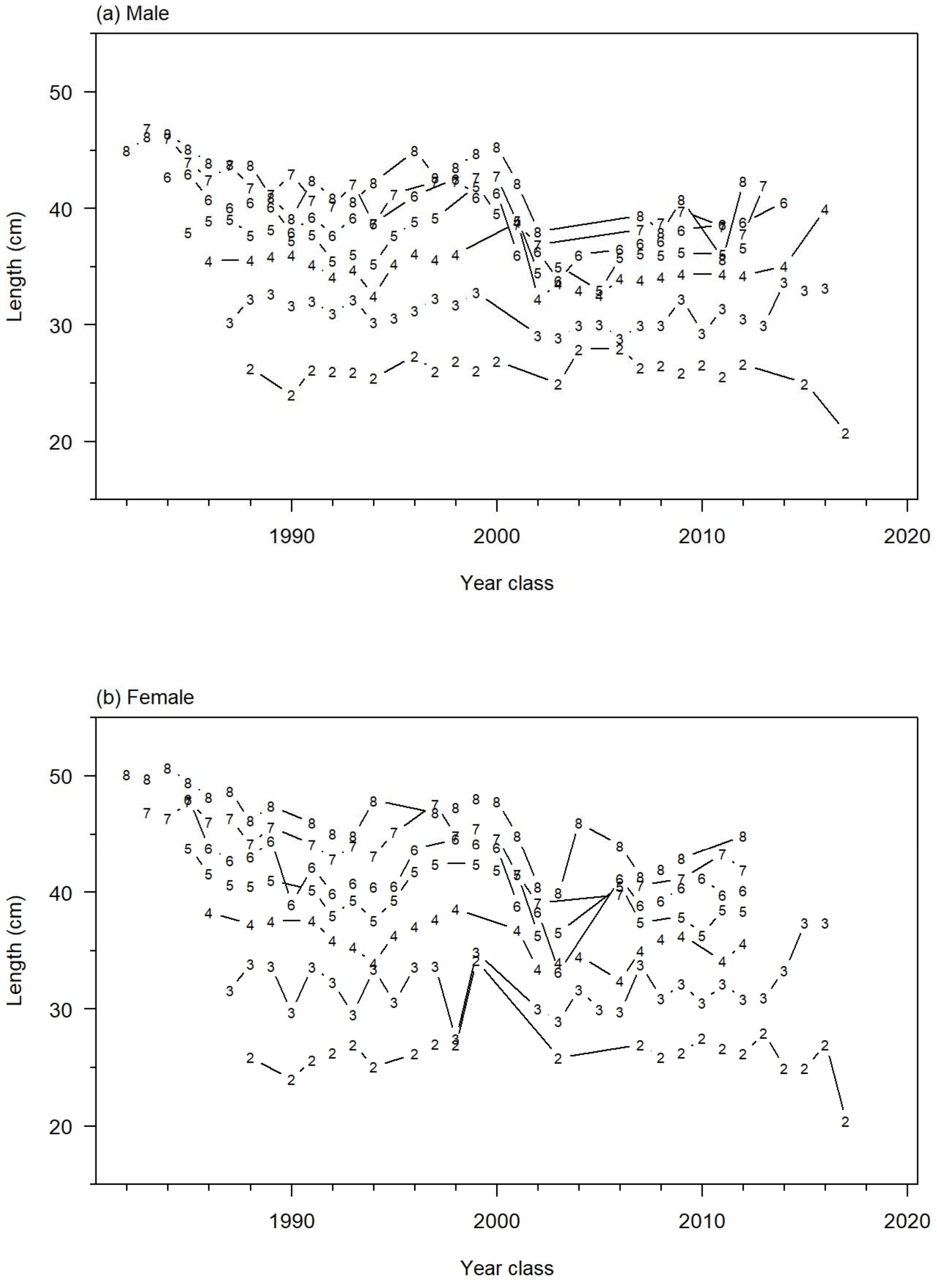

Figure 6: Observed mean length-at-age (ages 2–8) for the Bounty Platform stock by sex and year class, 1990–2018.

3.2.2 Spawning and length and age at maturity

Southern blue whiting are highly synchronised batch spawners. Spawning on Bounty Platform usually begins in mid-August and finishes by mid-September. Spawning begins 3–4 weeks later in the other areas, finishing in late September/early October. Spawning appears to mainly occur at night, in mid-water, over depths of 400–500 m on Campbell Island Rise but shallower elsewhere.

The age and length at maturity, and recruitment to the fishery, varies 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 at a length of 35–42 cm FL. Ageing studies have shown that this species has very high recruitment variability (Hanchet et al. 2003).

3.2.3 Natural mortality

Natural mortality (*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). Recent 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 which were considered implausible by the Deepwater Working Group (Dunn & Hanchet 2016a). 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 sensitivity runs 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 sensitivity runs where the value of M was fixed at 0.15 and 0.25. A further sensitivity run where *M* was estimated, produced natural mortality estimates of 0.17 (0.13–0.21) for males and 0.18 (0.14–0.22) 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*	0.2	0.2	Hanchet (1992)
Weight = a $(\text{length})^b$	*a*	0.00515	0.00407	Hanchet (1991)
Weight in g, length in cm fork length	*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 Platform, 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 Platform 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 and 2016. 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, 2015b, 2016a). Various designs for acoustic surveys of southern blue whiting were investigated using simulation studies by Dunn & Hanchet (1998) and Dunn et al. (2001), and 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 the 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 recent assessments of the Bounty Platform 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).

There have also been changes in the target strength–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 similar to the value estimated for blue whiting (Pedersen et al. (2011). O'Driscoll et al. (2013) also 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. Grimes et al. (2007) updated the decomposed estimates by: (i) incorporating the new target strength-fish length relationship of Dunford & Macaulay (2006); (ii) using the revised sound absorption coefficient of Doonan et al. (2003); (iii) including corrections and changes to strata areas; and (iv) estimating CVs of the decomposed estimates by age. Estimates of biomass of the southern blue whiting categories were recalculated in 2010 by P. Grimes (NIWA unpublished data) who revised the estimates by making the changes identified in (i)–(iii) above, and these revised estimates have been summarised in Fu et al. (2013). 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 almost all areas and surveys used the most recent TS–FL relationship for blue whiting (O'Driscoll et al. 2013). Where necessary, acoustic indices in earlier reports have been updated (Richard O'Driscoll, NIWA, pers. comm.). 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

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 Platform

Two time series of acoustic indices are available for the Bounty Platform 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 has continued in most years to 2017 (Table 6). These surveys have had mixed levels of success and the utility of the 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 since 2010 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).

Table 5: R.V. *Tangaroa* juvenile, immature, and mature acoustic biomass estimates (t) and CVs for the Bounty Platform using the O'Driscoll et al. (2013) target strength (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 biomass estimates (t) and CVs for the Bounty Platform with the O'Driscoll et al. (2013) target strength and the proportion of catch taken at the time of the survey (TCEPR 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 2017)
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.

Bounty Platform acoustic data collection in 2018

An aggregation-based acoustic survey of the Bounty Platform was again attempted in 2018. Calibration of the Simrad ES80 echosounder on F.V. *Tomi Maru 87* took place in the Hauraki Gulf on 27 June 2018 (Appendix 1). Diagnostics indicated that the calibration was of excellent quality. The calibration parameters for the 38 kHz echosounder were very similar (within 0.05 dB) to that in 2017 (see Appendix 1 Table A3).

Acoustic data were recorded continuously from F.V. *Tomi Maru 87* after departing Timaru on 17 August 2018 to arriving back in port on 13 September 2018. The vessel was on the Bounty Platform fishing grounds from 18 to 22 August and 26 August to 2 September.

No acoustic snapshots suitable for abundance estimation were carried out. Data collected while fishing and searching was affected by acoustic noise due to sonar and other instruments and is not suitable for quantitative analysis, but these data do provide a useful record of vessel activities and the presence of fish (Figure 7). Only one aggregation of SBW was observed: at about 47° 55' S and 179° 50' W, in 280–300 m water depth southeast of the Bounty Islands on 28–30 August (e,g., Figure 8), and the vessel made two large catches (177 t and 195 t). An acoustic snapshot was planned on the night of 30 August 2018, but the SBW had dispersed before this begun.

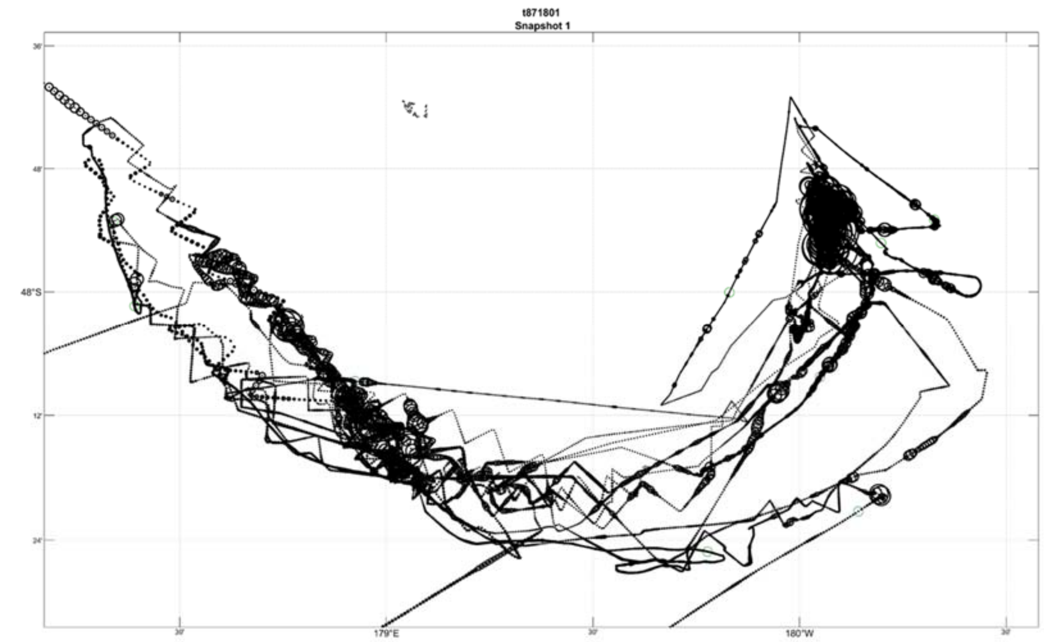

Figure 7: Vessel track of the F.V. *Tomi Maru* on the Bounty Platform in 2018. Circle area of black circles is proportional to total acoustic backscatter estimated in 100 ping (200 s) intervals. Green circles show start and end points of acoustic recordings.

Aggregation-based acoustic surveys work best when fish are actively spawning as this is when the stock is most aggregated (O'Driscoll et al. 2016). Acoustic data collection in 2018 was over a similar period to that from 2011 to 2017 (O'Driscoll 2018). Between 2008 and 2010 surveys begun earlier in August. Timing of SBW spawning has varied between years (see Appendix 2). Spawning on the Bounty Platform was very late in 2017 and 2018, occurring in early September. Biological data on fish spawning condition collected by observers in 2018 showed that spawning did not occur during the period when fishing occurred (see Figure 4). It is possible that the first spawning in 2018 occurred later, as in 2016 and 2017, and therefore that the acoustic data collection was too early. However, the location of the aggregation in 2018 indicates that spawning may have occurred earlier, before the period of acoustic data collection. The distribution of spawning SBW on the Bounty Platform changes over time (e.g., Hanchet & Grimes 2000, Hanchet et al. 2002). As spawning approaches, SBW typically move into shallower water and then migrate anti-clockwise along the depth contour (i.e., west to east). The aggregation in 2018 was detected in relatively shallow water (280–300 m) in the east, consistent with the location of spawning aggregations late in the spawning season in previous years (O'Driscoll et al. 2016).

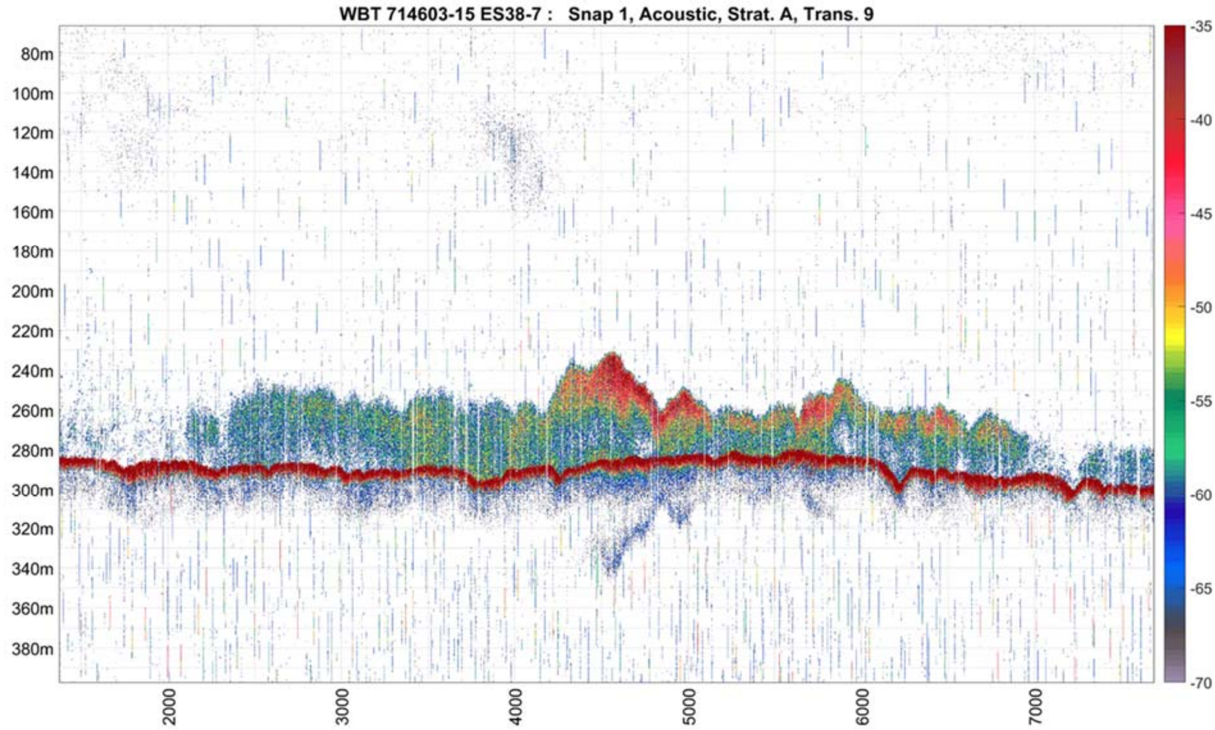

Figure 8: Example of acoustic echogram collected at the Bounty Platform at 23:20 NZST on 29 August 2018. Vertical dashed lines are interference from other acoustic instruments. Southern blue whiting aggregation is the red and green layer at 240–280 m depth above the seabed (thick red line).

4.1.3 Campbell Island Rise

As of 2018, twelve acoustic surveys of the Campbell Island Rise spawning grounds have been completed using the R.V. *Tangaroa*. Results of recent surveys were reported by O'Driscoll et al. (2012, 2014, 2018) and are summarised in Table 7.

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 biomass estimates (t) and CV for the Campbell Island Rise 1993–2017 using the target strength of O'Driscoll et al. (2013).

Year	Juvenile		Immature		Mature		Total	Source
	Biomass	CV	Biomass	CV	Biomass	CV	Biomass	
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)

Table 8: The local area acoustic biomass estimates (including zero transects) and CVs for the Campbell Island Rise using industry vessels and the target strength of O'Driscoll 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*	Northeast	4	225	4 145	0.72
	Alexandrov		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

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

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 of 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* from 23 to 26 September 2012 (Hampton & Nelson 2014). Biomass estimates from six snapshots ranged from 142 to 1940 t (Hampton & Nelson 2014).

Table 9: R.V. *Tangaroa* juvenile, immature, sub-adult, and adult acoustic 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

Table 10: The local area acoustic biomass estimates (ignoring zero transects) for the Pukaki Rise 2009, 2010 and 2012. All estimates calculated using the TS-FL relationship of O'Driscoll 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 targeting hoki, hake, and ling have been carried out using R.V. *Tangaroa* since 1991 (e.g., O'Driscoll & Bagley 2009). Although southern blue whiting are 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).

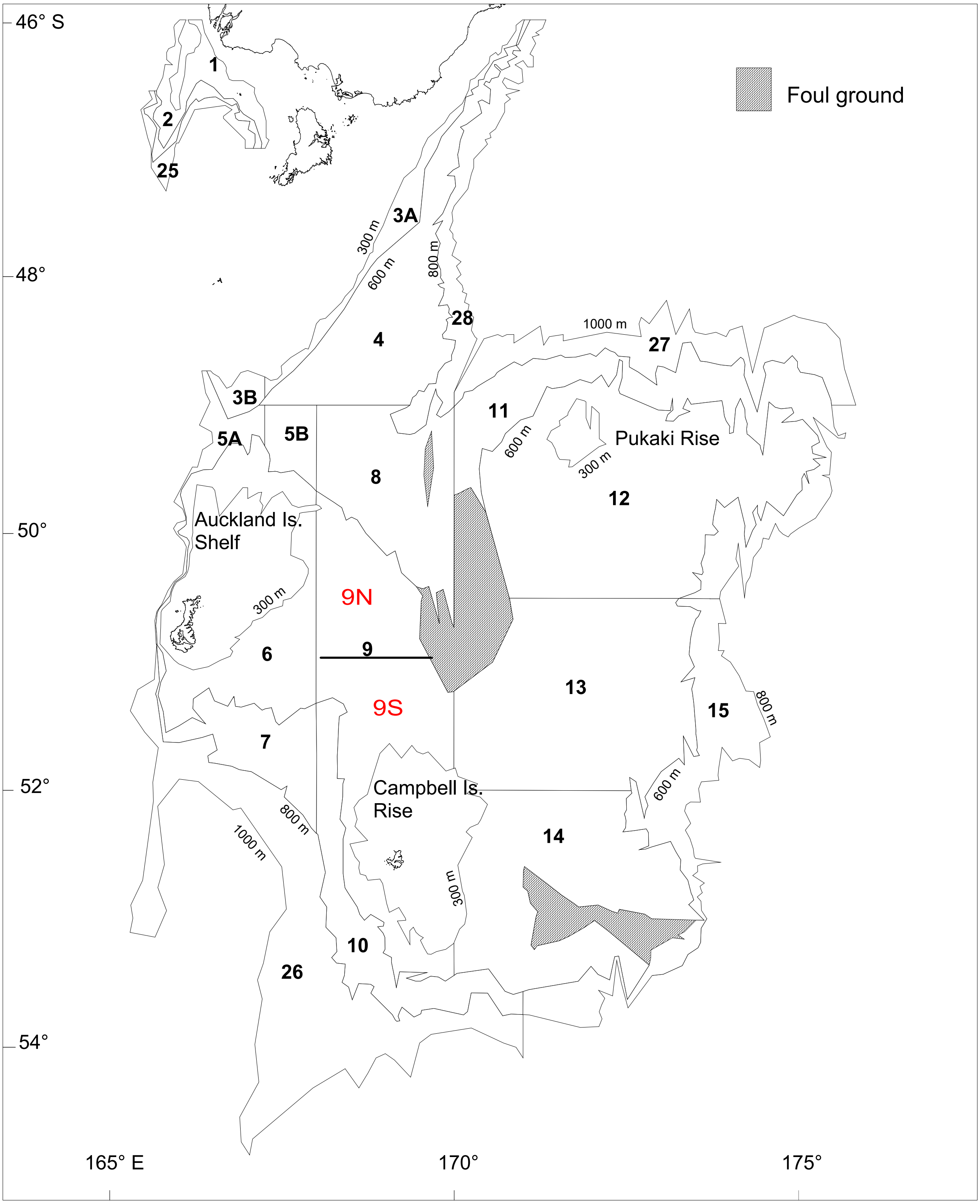

Figure 9: Survey area and stratum boundaries used for R.V. *Tangaroa* sub-Antarctic trawl surveys since 1996. Stratum 9 was split into 9N and 9S at 51º S for the analysis. Stratum 26 has not been surveyed since 2011, and strata 1, 2, 3A, and 25 were not surveyed in 2016 because of time lost due to bad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

4.2.1 Auckland Island Shelf

The CVs of the 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 is 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 (2005–18). 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 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 the Fisheries New Zealand *trawl* database).

			Summer					Autumn	
Year	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					

4.2.2 Campbell Island Rise

The CVs of the biomass estimates for the Campbell Island Rise are mostly in the range 25–55%, making them only marginally useful for monitoring abundance (Table 12). There is some consistency in biomass estimates between the summer and autumn series and also 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 underestimated biomass at low stock sizes and overestimated biomass 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 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 underestimating biomass at low stock sizes and overestimating biomass at high stock sizes. The trawl survey biomass estimates in 2012 and 2016 have been the two highest on record since 1996, which is consistent with the high recent acoustic estimates (Section 4.1.3) and the current stock status (Dunn & Hanchet 2017).

Table 12: R.V. *Tangaroa* trawl survey 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 the Fisheries New Zealand *trawl* database.)

		Summer					Autumn		
Year	Trip	Biomass (t)	CV	N	Year	Trip	Biomass (t)	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					

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 biomass estimates for the Pukaki Rise are quite variable between years but mainly in the range 20–50%, making them only marginally useful for monitoring abundance (Table 13). There is some consistency in biomass estimates between the summer and autumn series and also 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). Recent biomass estimates have fluctuated considerably and the conclusions of Hanchet & Stevenson (2006) remain valid.

A 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 biomass estimates (t), CVs, and number of stations (N) for selected strata for the Pukaki Rise (data for 1991–2005 from Hanchet & Stevenson (2006), data for 2006 onwards taken from the Fisheries New Zealand *trawl* database.

Year	Summer				Autumn				
	Trip	Biomass (t)	CV	N	Year	Trip	Biomass (t)	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					

4.3 CPUE analyses

Standardised CPUE analyses were carried out for the southern blue whiting spawning fisheries on the Campbell Island Rise from 1986 to 2002, and on the Bounty Platform from 1990 to 2002 by Hanchet & Blackwell (2003). Indices were calculated 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. The authors summarised the data and the method of calculating the indices, and then compared the CPUE indices with the results of recent stock assessments.

Unstandardised CPUE indices for each ground are listed in Table 14. CPUE on the Bounty Platform has been relatively high over the last decade, and the 2017 value was the highest on record and similar to that in 2015. However, the 2018 value is the lowest on record since 2000. On the Campbell Island Rise, the 2018 CPUE was less than that in recent years and the lowest it has been since the early 2000s.

Table 14: Unstandardised target median catch per unit effort indices (t/hour) for the Auckland Islands, Bounty Platform, Campbell Island Rise, and Pukaki Rise fisheries, July–October 1990–2018 (source: TCEPR data).

Year	Auckland Islands	Bounty Platform	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	–

4.3.1 Bounty Platform

The Bounty Platform analysis was based on a data set of 3288 non-zero 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. The authors noted that there were other 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 Platform fishery were consistent with trends in biomass from the 2002 NIWA 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 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 Platform fishery (Hanchet & Blackwell 2003).

	Standardised CPUE	
Year	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 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' 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 for the Campbell Island fishery, 1986 to 2005 (source: Hanchet et al. 2006).

	Catch per hour model			Catch per tow model		
Year	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 for each of the stocks, and these form an important input into the southern blue whiting 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 Table 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 was first scaled up to the catch from that 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 modelling.

5.2 Auckland Islands

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). Almost 90% of the catch but less than 40% of the tows have been made in the months July to October.

Small numbers of fish were measured in some years from a small amount of effort around the Auckland Islands (Figure 10, Table 17), but few otoliths were collected and these have not been read. Catch-at-age data are available only for 1993 to 1998 (Figure 11). The catch at that time was dominated by the strong 1991 year class.

Table 17: Total number of tows and TCEPR 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 1990–2018 (source: TCEPR and Observer data, 1990–2018).

			Catch				Observed		Measured		Aged
Year	Vessels	Tows	t	Vessels	Tows	t	%t	Male	Female	Male	Female
1990	7	90	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	2	0	0	0	0.0	0	0	0	0
2018	13	660	8	2	4	>1	2.6	21	50	0	0

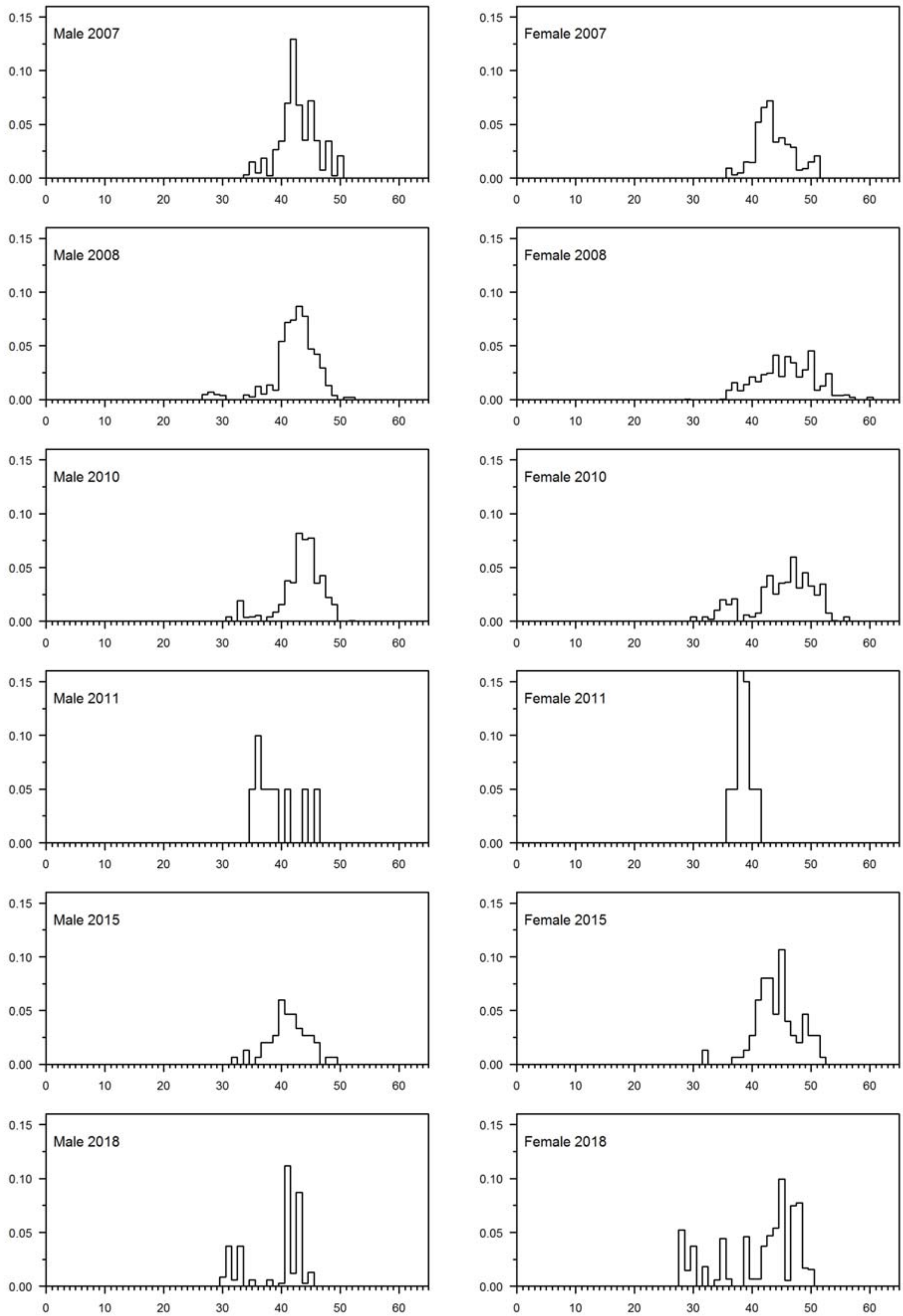

Figure 10: Commercial catch proportions-at-length for the Auckland Islands stock by sex, 2007–18.

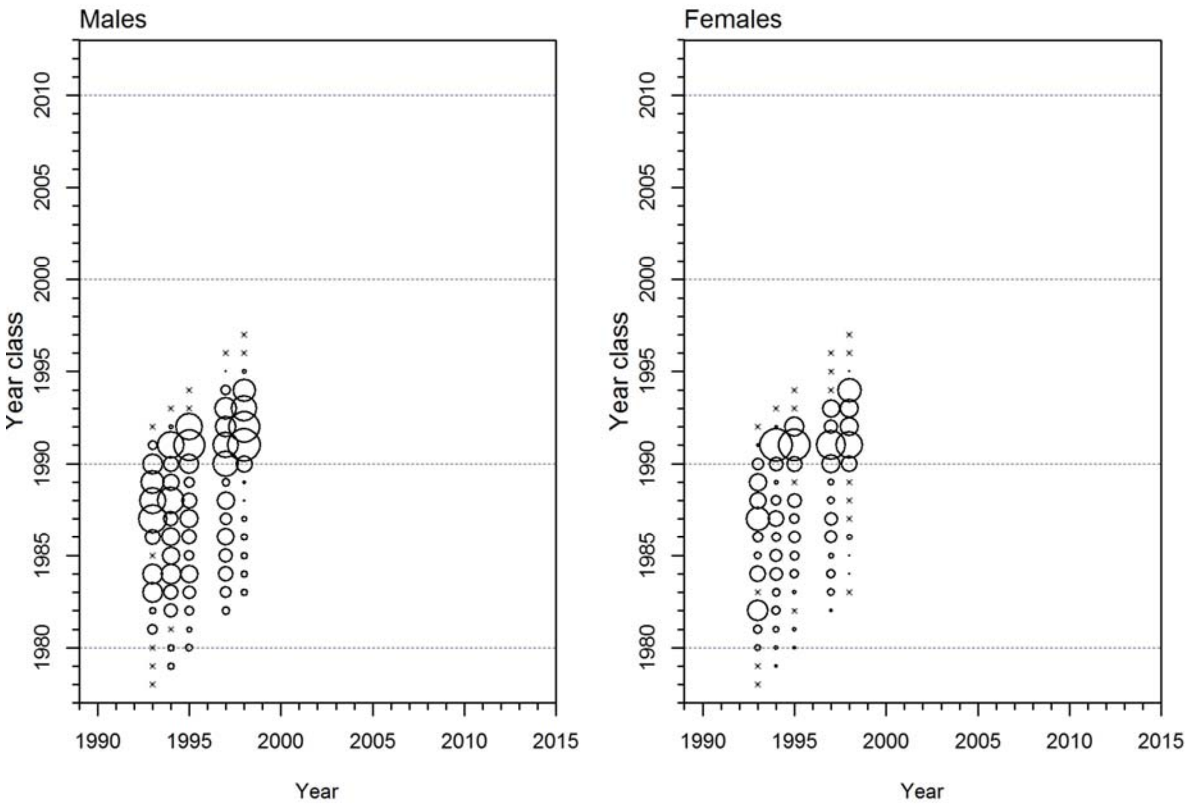

Figure 11: Commercial catch proportions-at-age for the Auckland Islands stock by sex and year class, 1990–2018. Symbol area is proportional to the proportions-at-age within the sampling event.

5.3 Bounty Platform

The Bounty Platform has been fished consistently since 1990 (Table 18), and in each year all of the catch and almost all of the tows have been made between July and October. Catch-at-age data are available for the entire period 1990 to 2018, 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 through the season and across the area and so in most years all the length frequency data were placed into a single stratum. The catch in recent years has been dominated by a single mode of fish (the 2002 year class), which can be tracked from 2005, when it first entered the fishery at about 30 cm as 3 year olds, to 2018, when it still dominated the fishery as 16 year olds (Figures 12 and 13). In the past few years, the moderate strength 2007 and 2012 year classes have appeared in the length and age frequency distributions. Previously, the catch over the 30 year period has been dominated by several other strong year classes — in particular those from 1986, 1988, 1991, 1992, and 1994 (Figure 14).

Table 18: Total number of tows and TCEPR 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 Platform, 1990–2018 (source: TCEPR and Observer data, 1990–2018).

	Catch			Observed				Measured		Aged	
Year	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	12	119	5 824	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	9	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	228
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

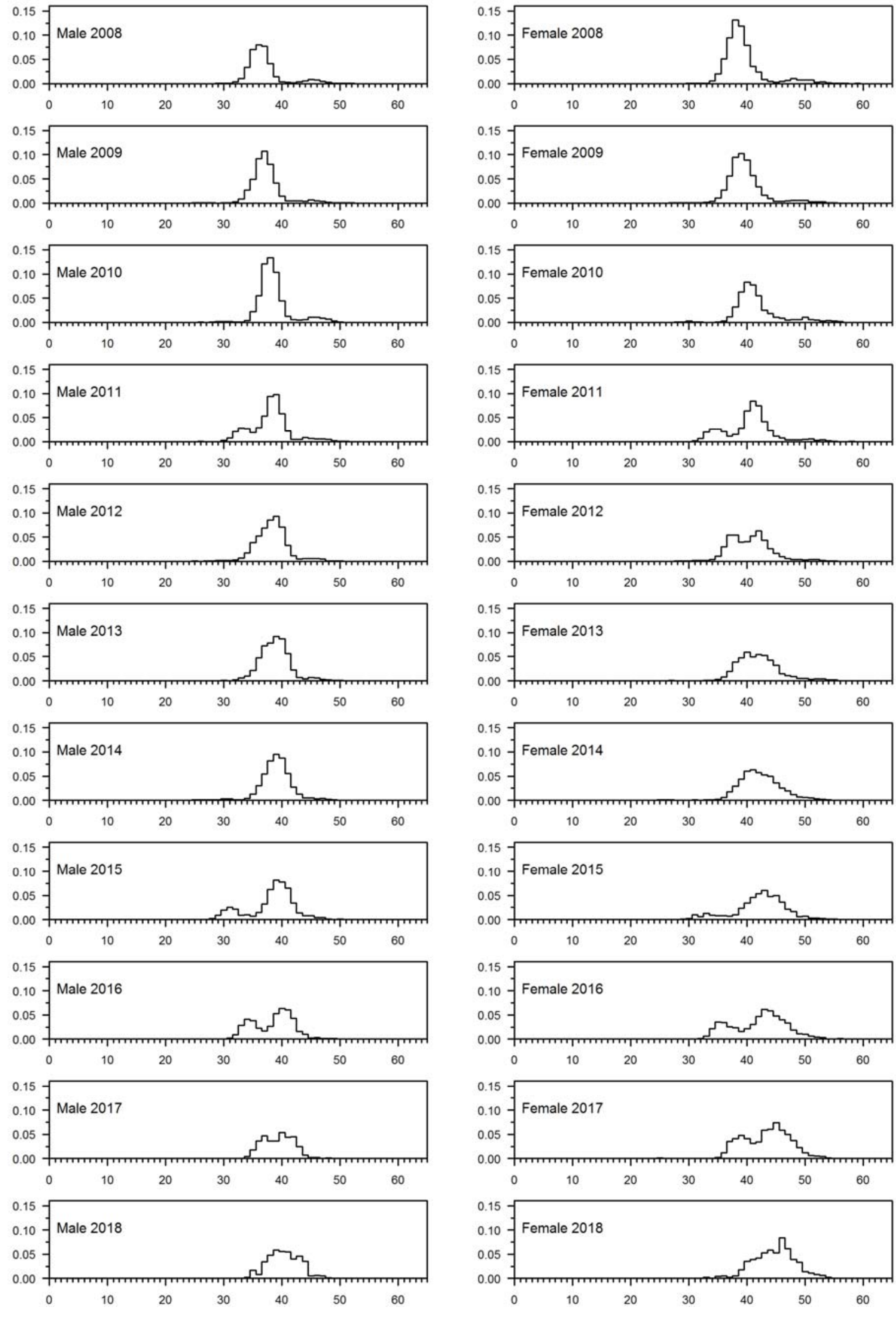

Figure 12: Commercial catch proportions-at-length for the Bounty Platform stock by sex, 2008–2018.

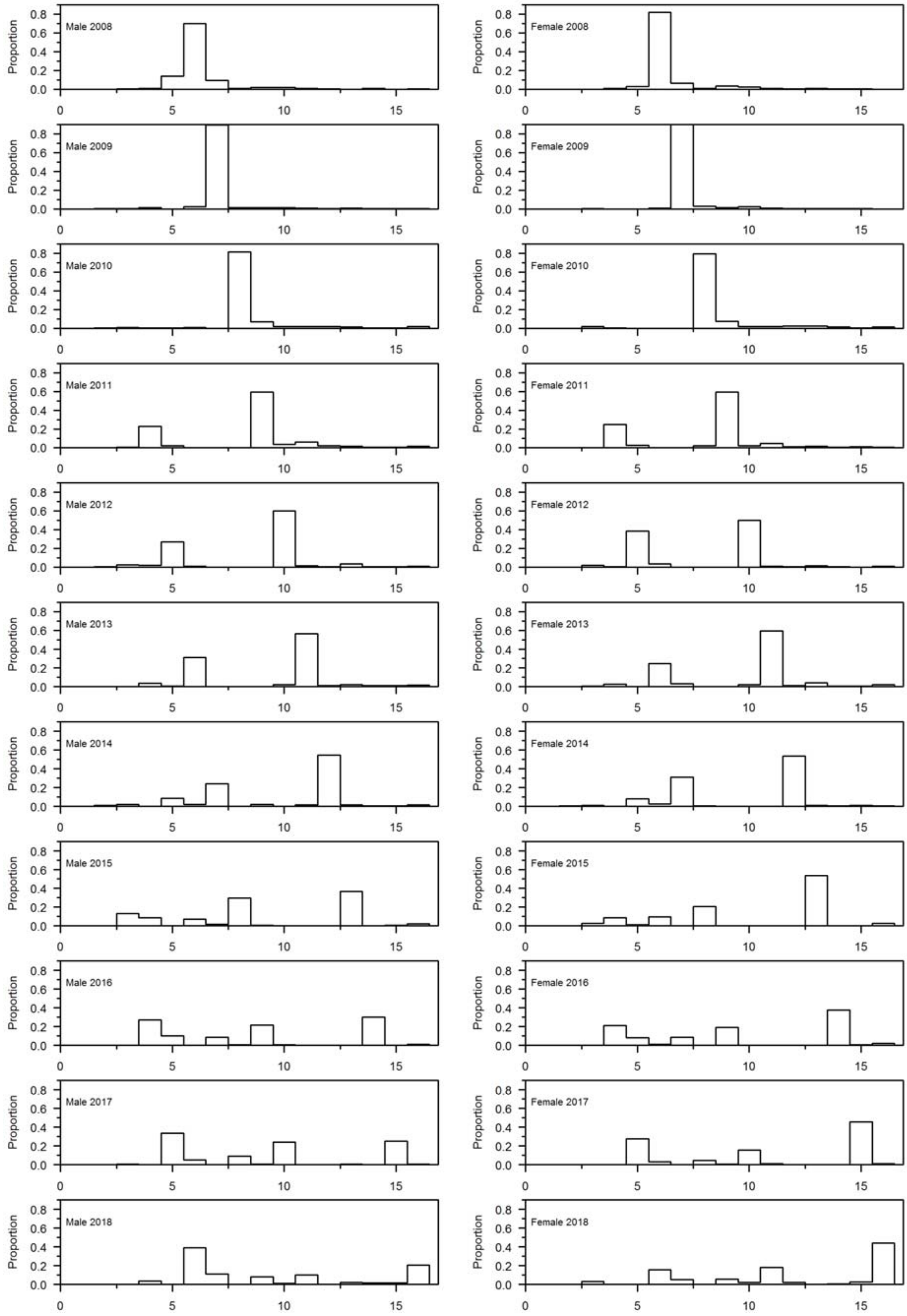

Figure 13: Commercial catch proportions-at-age for the Bounty Platform stock by sex, 2008–2018.

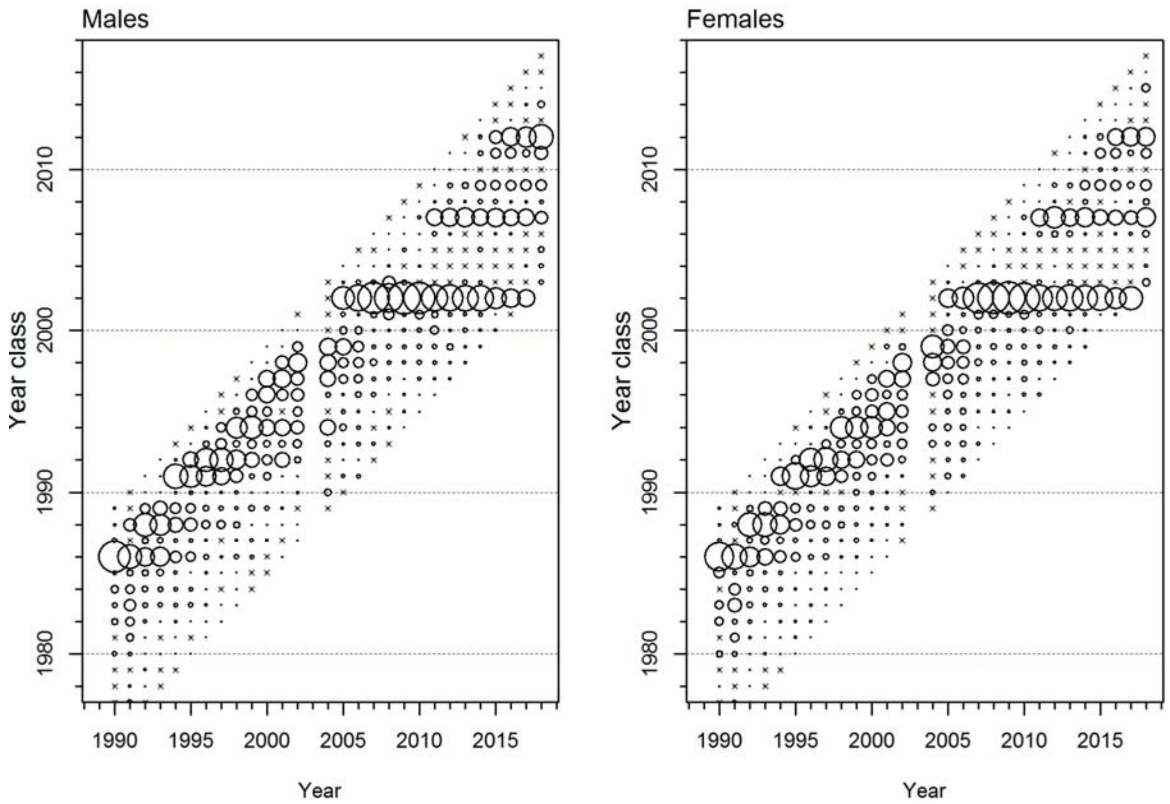

Figure 14: Commercial catch proportions-at-age for the Bounty Platform stock by sex and year class, 1990–2018. Symbol area proportional to the proportions-at-age within the sampling event.

5.4 Campbell Island Rise

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

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 is bi-modal, with one mode at 35–37 cm, comprising the 2011 year class (7-year-old fish), with a broad shoulder extending out to 50 cm, comprising the 2006 and 2009 year classes (9–12-year-old fish) (Figures 15 and 16). A mode of shorter fish at 25–35 cm comprises mainly 3 and 4-year-old fish and is indicative of a new year class. This 2014 year class looks to be moderately strong and the 2011 cohort no longer dominates the catch as it has done in the last 4 years. Previously, the catch since 1990 has been dominated by several other strong year classes – in particular those from 1988, 1991, and 2001 (see Figures 17 and 18).

The time series of numbers-at-age (and CVs) from 1979 to 1989 are given in 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 0.1–0.2 in more recent years (Hanchet et al. 2003).

Table 19: Total number of tows and TCEPR 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, 1990–2018 (source: TCEPR and Observer data, 1990–2018).

	Catch			Observed				Measured		Aged	
Year	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	8 757	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	24 162	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	13 878	10	189	7 226	52.1	14 497	14 391	224	256

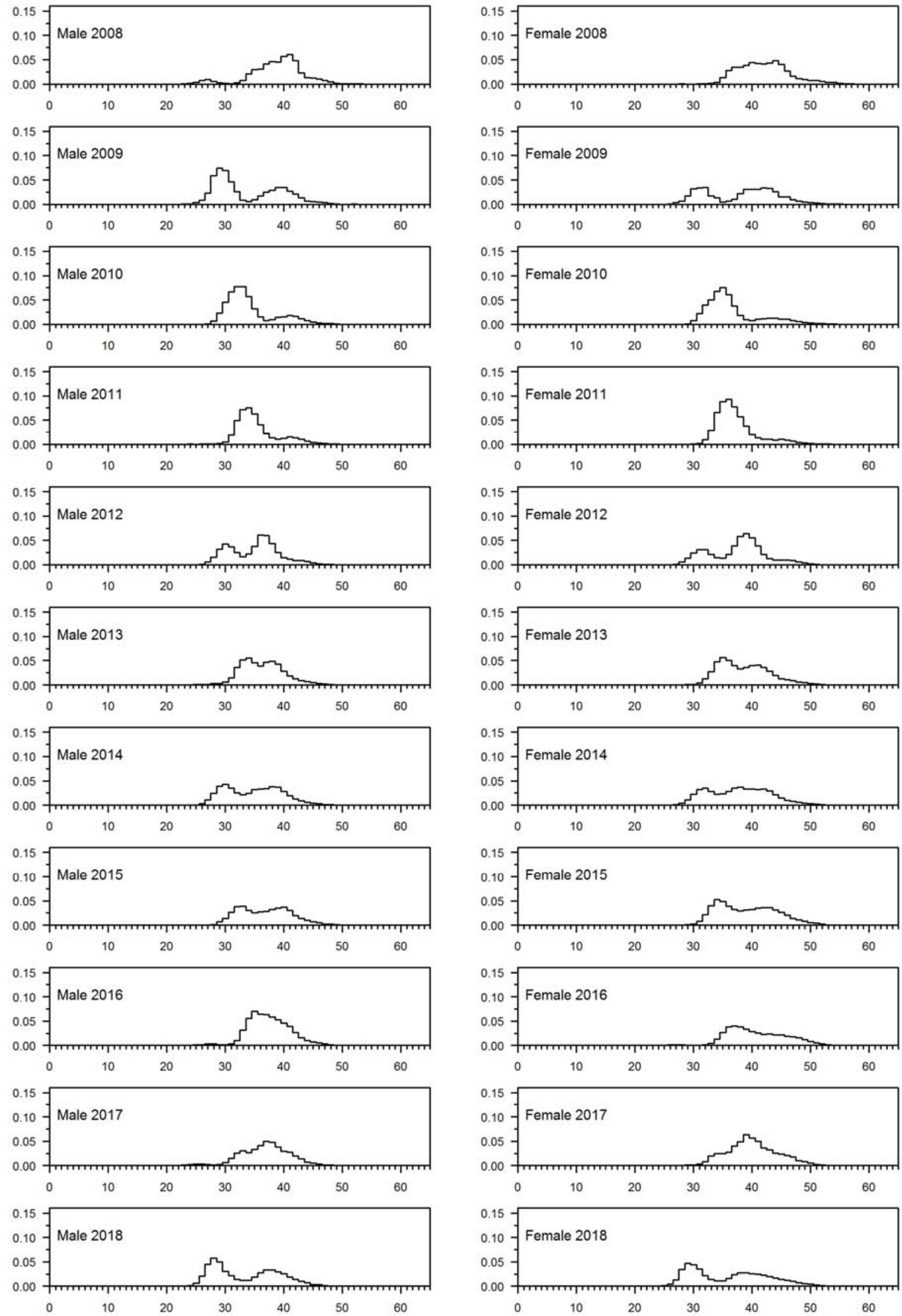

Figure 15: Commercial catch proportions at length for the Campbell Island Rise stock by sex, 2008–2018.

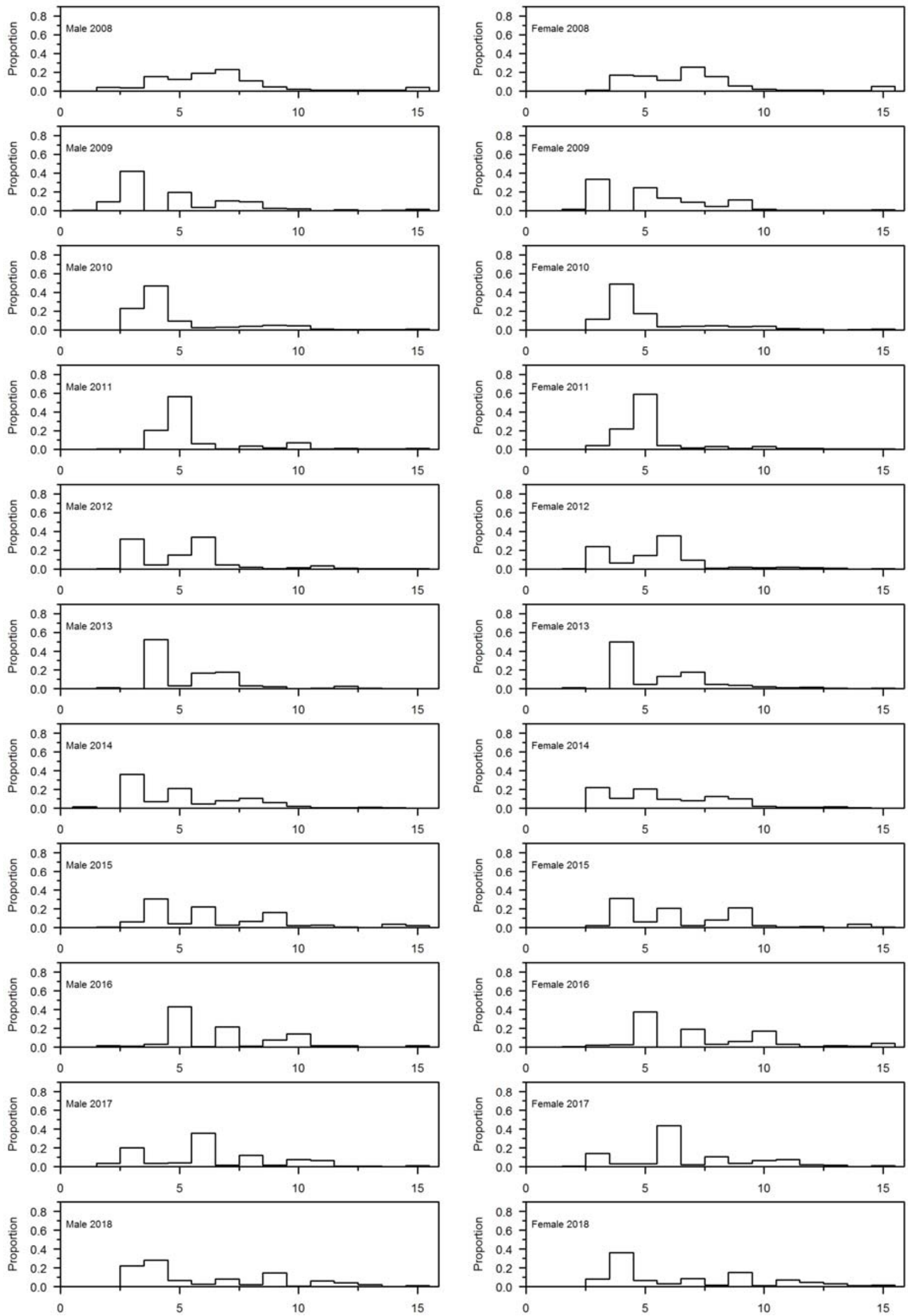

Figure 16: Commercial catch proportions at age for the Campbell Island Rise stock by sex, 2009–2018.

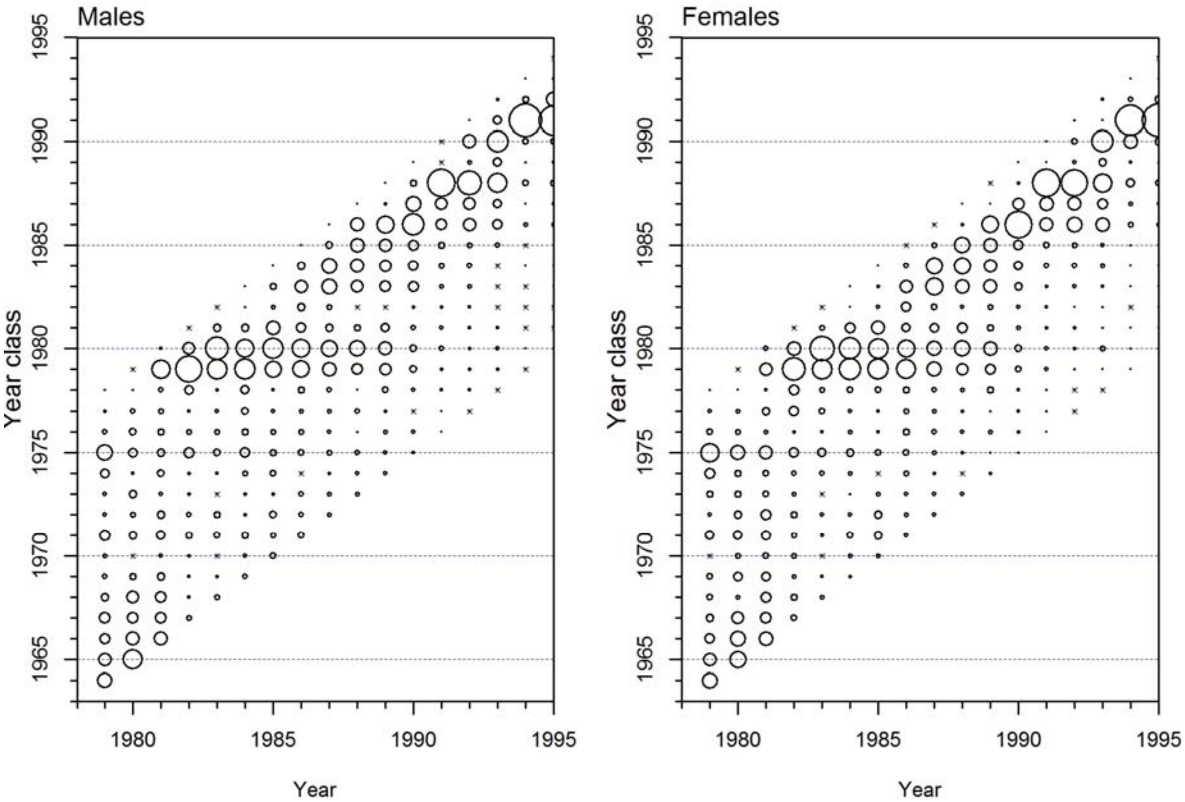

Figure 17: Commercial catch proportions-at-age for the Campbell Island Rise stock by sex and year class, 1979–1994. Symbol area proportional to the proportions-at-age within the sampling event.

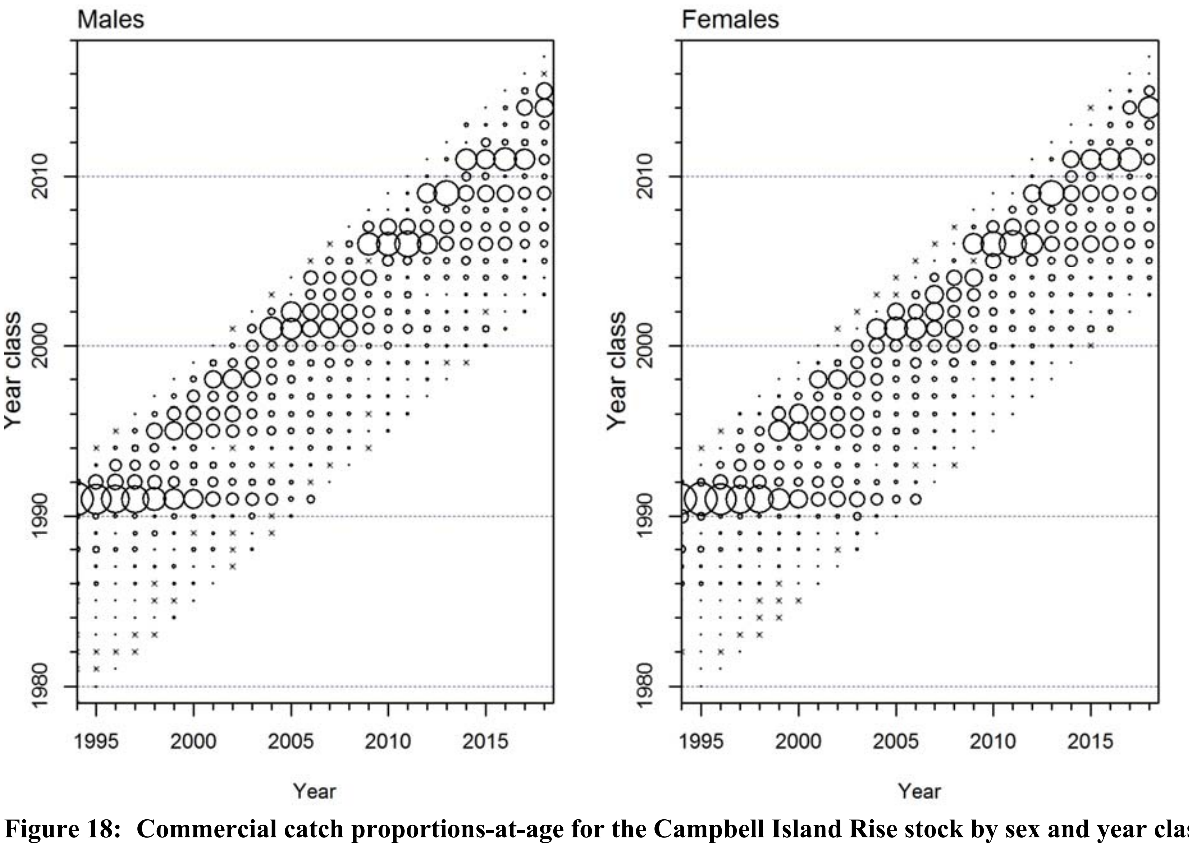

Figure 18: Commercial catch proportions-at-age for the Campbell Island Rise stock by sex and year class, 1995–2018. Symbol area proportional to the proportions-at-age within the sampling event.

5.5 Pukaki Rise

The Pukaki Rise has been fished only sporadically since 1990 with most of the catch taken between 1991 and 1993 and again in 2009 and 2010 (Table 20). Although most of the catch has been made in the months July to October, 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 through 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 there has been recent recruitment of the 2009 year class, which may prove to be moderately strong (Figure 19). Length measurements were only taken from two tows in 2014 which caught only 1 t of fish, and so it is unlikely that the catch is representative of the population. The catch since 1990 has been dominated by several other moderate year classes – in particular those from 1985, 1986, 1990, and 1991 (Figure 20).

Table 20: Total number of tows and TCEPR 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 1990–2018 (source: TCEPR and Observer data, 1990–2018).

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	118	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	10	471	625	4	6	96	15.4	482	359	0	0
2012	10	251	1 421	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	165	19	1	1	19	100	36	119	0	0

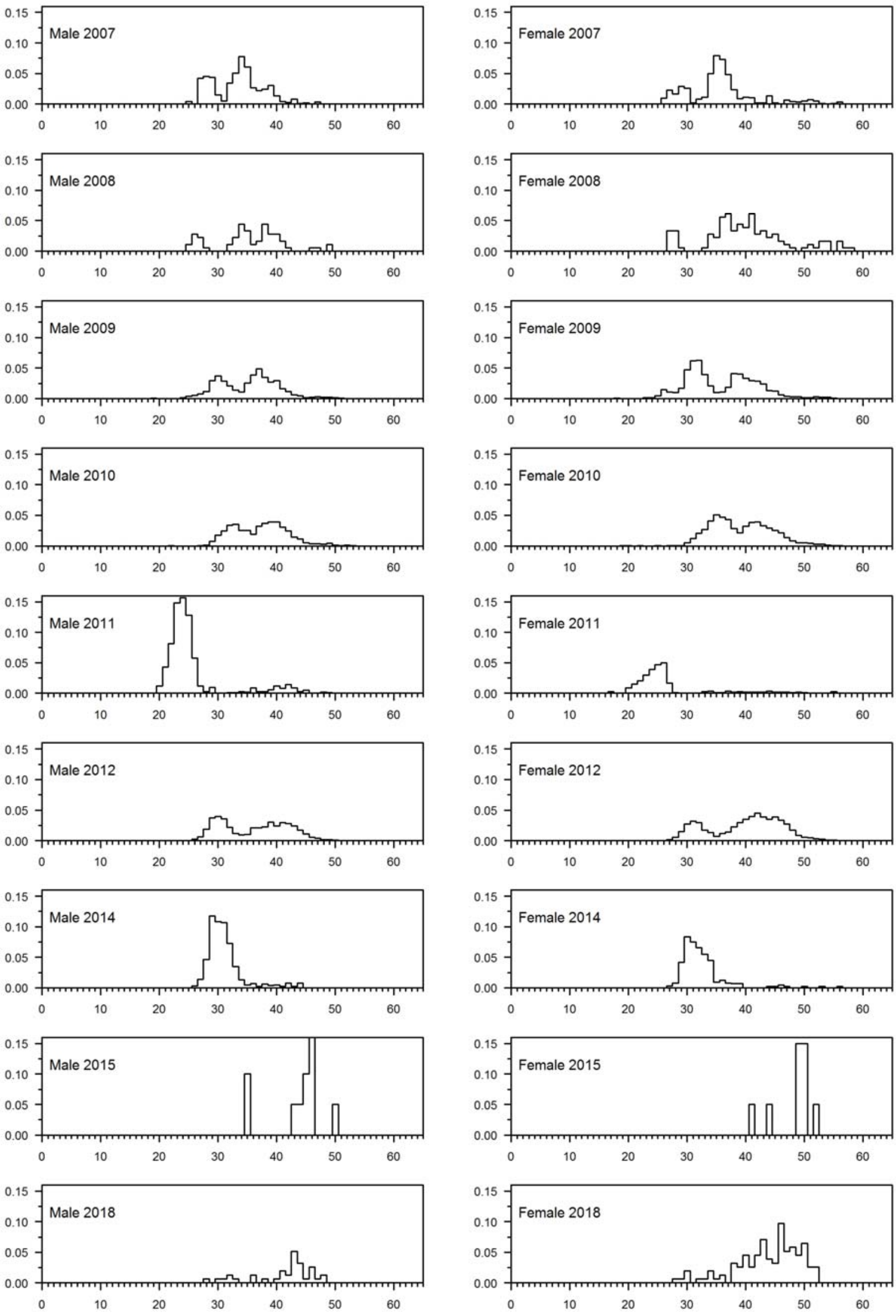

Figure 19: Commercial catch proportions at length for the Pukaki Rise stock by sex, 2007–18.

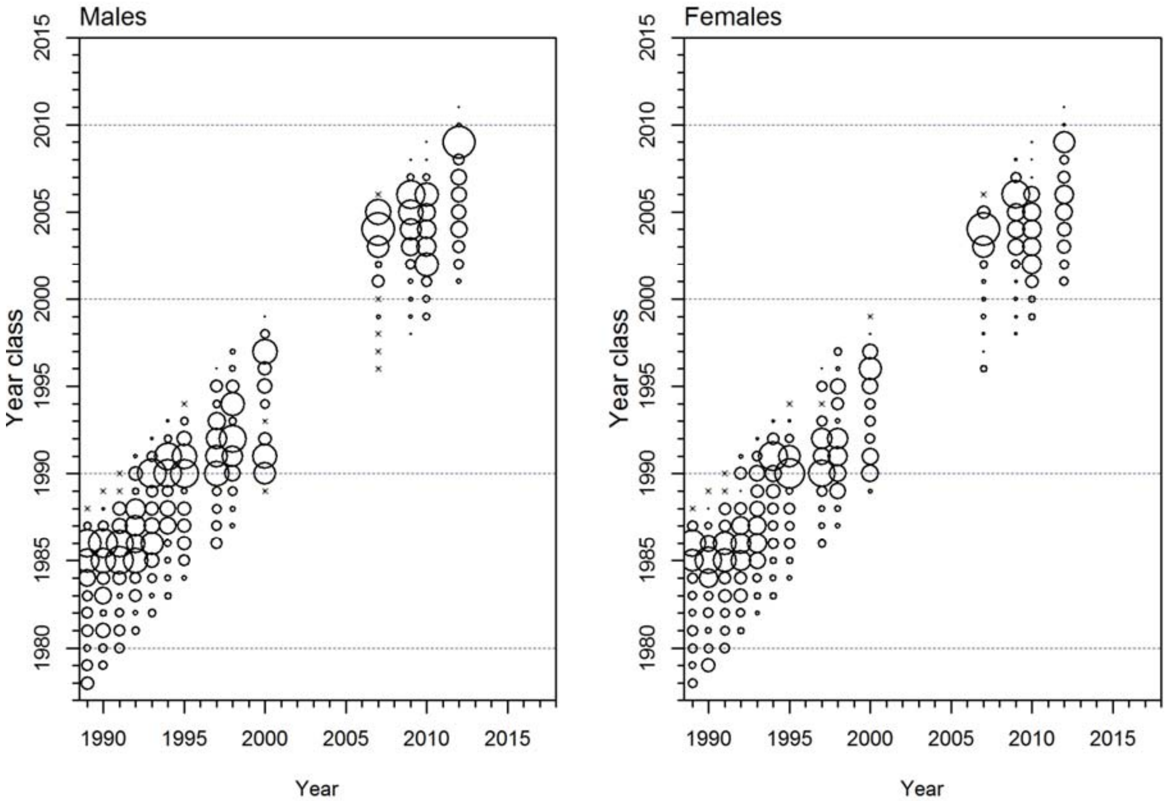

Figure 20: Commercial catch proportions at age for the Pukaki Rise stock by sex and year class, 1989–2018. Symbol area proportional to the proportions-at-age within the sampling event.

5.6 Other areas (SBW 1)

The remaining catch has been taken as bycatch of fisheries for hoki and other middle depths species from the Snares Shelf and southern Chatham Rise. Bycatch of southern blue whiting is not usually in the top five or eight species by weight in a catch and, as such, is not reported on TCEPR forms. Hence, the difference between reported landings and estimated catch, e.g., 86 t reported as landed from SBW 1 in 2016–17 (Table 1) and 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).

Table 21: Total number of tows and TCEPR 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 1990–2018 (source: TCEPR and Observer data, 1990–2018). Most of the large catches reported from this area are likely to be due to positional errors in the TCEPR database.

			TCEPR			Observer	Measured			Aged
Year	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	909	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	20	1 905	2	0	0	0	0	0	0	0

6. DISCUSSION

This document updates and summarises the observational and research data for southern blue whiting into one document. Included here are time series of relative abundance from the wide area R.V. *Tangaroa* acoustic surveys, as well as from local area aggregation industry vessel acoustic surveys, CPUE indices for Bounty Platform 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 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 additional R.V. *Tangaroa* acoustic surveys and the time series for these two areas were discontinued. Local area aggregation surveys from industry vessels on the Bounty Platform 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). On the Bounty Platform there was a seven-fold increase in biomass between 2006 and 2007 followed by a similar sized decline in biomass between 2008 and 2009. There was no acoustic abundance estimate from the Bounty Platform in 2018.

Local area aggregation surveys from industry vessels on the Pukaki Rise have also been 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 yardstick with which to compare the aggregation results there will be ongoing 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.

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 2018. 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 2012 and 2016 are the highest on record and are consistent with the high acoustic estimate recorded in 2016 and the current stock status (Roberts & Hanchet 2019).

A recent assessment of the Pukaki Rise stock (Dunn & Hanchet 2016c) 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. Trawl survey biomass estimates for the Pukaki Rise have continued to fluctuate, peaking in 2016, but since there has been virtually no fishing on the Pukaki Rise for the past four years there is no information on recent size and age distribution of catches or year class strength to determine reasons for this increase. 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 (2005–2018). 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 Platform 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 all areas except the Pukaki Rise for this report. Catch at Bounty Platform is still dominated by the 2002 year class, with the 2007 and 2012 year classes recruiting to the commercial fishery more recently. 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 2006, 2009, 2011 and 2014. The catch on the Pukaki Rise has been dominated recently by fish comprising the 2004–06 year classes but there has been recent recruitment of the 2009 year class, which may prove to be moderately strong. Very little fishing has been carried out around the Auckland Islands in recent years, and the data are insufficient to infer when or if strong recruitment has entered the fishery.

Catches from areas outside the four main fisheries (in SBW 1) remain low and, until recently, have been less than 20 t annually. Larger catches have been reported on the MHR since 2013, with 86 t (0.4% of the total for all areas) reported for 2017 and 18 t reported for 2018 and 2019. Also note that the TACC for SBW 1 was increased to 100 t for the 2017 season.

7. ACKNOWLEDGMENTS

We are grateful to the scientific observers for the collection of the length frequency data and otoliths. Thanks to Shohei Takeuchi (captain) and the crew of *Tomi Maru 87*, as well as Peter Ballantyne and Grant Curtis (Solander Fisheries) for their assistance with acoustic data collection. Alan Hart and Colin Sutton (NIWA) read and processed the southern blue whiting otoliths. Neil Bagley (NIWA) was responsible for acquiring trawl survey data from the Fisheries New Zealand database. This project was funded by the Ministry for Primary Industries under Projects SBW201801, SBW201802, and MID201803. We thank Peter Horn (NIWA) for his thoughtful discussion and advice regarding ageing analysis and for reviewing an earlier draft of this document.

8. REFERENCES

Anderson, O. (2004). Fish discards and non-target fish catch in the fisheries for southern blue whiting and oreos. *New Zealand Aquatic Environment and Biodiversity Report 2004/09*. 40 p.

Anderson, O. (2009). Fish and invertebrate bycatch and discards in southern blue whiting fisheries, 2002–2007. *New Zealand Aquatic Environment and Biodiversity Report 43*. 28 p.

Annala, J.H.; Sullivan, K.J.; Smith, N.W.M.; Griffiths, M.H.; Todd, P.R.; Mace, P.M.; Connell, A.M. (2004). Report from the Fishery Assessment Plenary, May 2004: stock assessments and yield estimates. 690 p. Ministry of Fisheries.

Bull, B.; Dunn, A. (2002). Catch-at-age: User manual v1.06.2002/09/12. NIWA Internal Report 114. 23 p. Unpublished report held by National Institute of Water and Atmospheric Research, Wellington.

Clark, M.R.; Anderson, O.F.; Gilbert, D.J. (2000). Discards in trawl fisheries for southern blue whiting, orange roughy, hoki, and oreos in New Zealand waters. *NIWA Technical Report 71*. 73 p.

Cole, R.; Dunn, A.; Hanchet, S.M. (2013). Review and summary of the time series of input data available for the assessment of southern blue whiting (*Micromesistius australis*) stocks. *New Zealand Fisheries Assessment Report 2013/69*. 41 p.

Demer, D.A.; Berger, L.; Bernasconi, M.; Bethke, E.; Boswell, K.; Chu, D.; Domokos, R., et al. (2015). Calibration of acoustic instruments. *ICES Cooperative Research Report No. 326*. 133 p.

Doonan, I.J. (2017). Evaluation of a simple harvest control rule for the Bounty southern blue whiting management area (SBW6B). *New Zealand Fisheries Assessment Report 2017/52*. 14 p.

Doonan, I.J. (2018). Objective 2: To apply the agreed harvest control rule for SBW6B, 2018. Final Research Report, unpublished document held by Fisheries New Zealand. 2 p.

Doonan, I.J.; Coombs, R.F.; McClatchie, S. (2003). The absorption of sound in seawater in relation to the estimation of deep-water fish biomass. *ICES Journal of Marine Science 60*: 1047–1055.

Dunford, A.J.; Macaulay, G.J. (2006). Progress in determining southern blue whiting (*Micromesistius australis*) target strength: results of swimbladder modelling. *ICES Journal of Marine Science 63*: 952–955.

Dunn, A.; Grimes, P.J.; Hanchet, S.M. (2001). Comparative evaluation of two-phase and adaptive cluster sampling designs for acoustic surveys of southern blue whiting (*Micromesistius australis*) on the Campbell Rise. (Unpublished Final Research Report to the Ministry of Fisheries for Project SBW1999/01, Objective 1, held by Fisheries New Zealand, Wellington.) 15 p.

Dunn, A.; Hanchet, S.M. (1998). Two-phase acoustic survey designs for southern blue whiting on the Bounty Platform and the Pukaki Rise. *NIWA Technical Report 28*. 29 p.

Dunn, A.; Hanchet, S.M. (2011a). Southern blue whiting (*Micromesistius australis*) stock assessment for the Bounty Platform. *New Zealand Fisheries Assessment Report 2011/26*. 31 p.

Dunn, A.; Hanchet, S.M. (2011b). Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise, 2009–10. *New Zealand Fisheries Assessment Report 2011/40*. 37 p.

Dunn, A.; Hanchet, S.M. (2015a). 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 2013 season. *New Zealand Fisheries Assessment Report 2015/56*. 45 p.

Dunn, A.; Hanchet, S.M. (2015b). Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for 2013 with revised target strength acoustic biomass estimates. *New Zealand Fisheries Assessment Report 2015/80*. 23 p

Dunn, A.; Hanchet, S.M. (2015c). Southern blue whiting (*Micromesistius australis*) stock assessment for the Bounty Platform up to and including the 2011 season. *New Zealand Fisheries Assessment Report 2015/55*. 30 p.

Dunn, A.; Hanchet, S.M. (2016a). 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 2015 season. *New Zealand Fisheries Assessment Report 2016/43*. 43 p.

Dunn, A.; Hanchet, S.M. (2016b). Southern blue whiting (*Micromesistius australis*) stock assessment for the Pukaki Rise up to and including the 2014 season. (Unpublished Final Research Report to the Ministry for Primary Industries for Project DEE202002SBWD, held by Fisheries New Zealand, Wellington.) 27 p.

Dunn, A.; Hanchet, S.M. (2016c). Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise up to and including the 2015 season. *New Zealand Fisheries Assessment Report 2016/43*. 43 p.

Dunn, A.; Hanchet, S.M. (2017). Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for 2016. *New Zealand Fisheries Assessment Report 2017/38*. 20 p.

Fofonoff, P.; Millard, R., Jr (1983). Algorithms for computation of fundamental properties of seawater. *UNESCO Technical Papers in Marine Science 44*. 53 p.

Fu, D.; Hanchet, S.M.; O'Driscoll, R.L. (2013). Estimates of biomass and c.v.s of southern blue whiting from previous acoustic surveys from 1993 to 2012 using a new target strength – fish length relationship. (Unpublished Final Research Report to the Ministry of Fisheries for Project DEE201002SBWB, held by Fisheries New Zealand, Wellington.) 52 p.

Grimes, P.J.; Fu, D.; Hanchet, S.M. (2007). Estimates of biomass and c.v.s of decomposed age classes of southern blue whiting from previous acoustic surveys from 1993 to 2004 using a new target strength–fish length relationship. (Unpublished Final Research Report to the Ministry of Fisheries for Project SBW2005/01, held by Fisheries New Zealand, Wellington.) 7 p.

Hampton, J.I.; Nelson, J.C. (2014). Acoustic estimates of the biomass of southern blue whiting (*Micromesistius australis*) on Pukaki Rise (SBW 6R) and Campbell Island Plateau (SBW 6I) from a commercial vessel in September 2012. *New Zealand Fisheries Assessment Report 2014/23*. 28 p.

Hanchet, S.M. (1991). Southern blue whiting (*Micromesistius australis*) fishery assessment for the 1991–92 fishing year. New Zealand Fisheries Assessment Research Document 91/7. (Unpublished report held by NIWA library, Wellington.) 32 p.

Hanchet, S.M. (1992). Southern blue whiting (*Micromesistius australis*) fishery assessment for the 1992–93 fishing year. New Zealand Fisheries Assessment Research Document 92/19. (Unpublished report held by NIWA library, Wellington.) 28 p.

Hanchet, S.M. (1998). A review of southern blue whiting (*Micromesistius australis*) stock structure. New Zealand Fisheries Assessment Research Document 98/8. (Unpublished report held by NIWA library, Wellington.) 29 p.

Hanchet, S.M. (1999). Stock structure of southern blue whiting (*Micromesistius australis*) in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research 34(2):* 599–610.

Hanchet, S.M. (2002). Southern blue whiting (*Micromesistius australis*) stock assessment for the Bounty Platform for 2002 and 2003. *New Zealand Fisheries Assessment Report 2002/53*. 23 p.

Hanchet, S.M. (2005). Southern blue whiting (*Micromesistius australis*) stock assessment for the Bounty Platform for 2004–2005. *New Zealand Fisheries Assessment Report 2005/45*. 36 p.

Hanchet, S.M.; Blackwell, R.G. (2003). Development and evaluation of catch-per-unit-effort indices for southern blue whiting (*Micromesistius australis*) on the Campbell Island Rise (1986–2002) and the Bounty Platform (1990–2002). (Unpublished Final Research Report to the Ministry of Fisheries for Project SBW2001/01 Objective 3, held by Fisheries New Zealand, Wellington.)

Hanchet, S.M.; Blackwell, R.G.; Dunn, A. (2005). Development and evaluation of catch per unit effort indices for southern blue whiting (*Micromesistius australis*) on the Campbell Island Rise, New Zealand. *ICES Journal of Marine Science 62*: 1131–1138.

Hanchet, S.M.; Blackwell, R.G.; Stevenson, M.L. (2006). Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for 2006. *New Zealand Fisheries Assessment Report 2006/41.* 45 p.

Hanchet, S.M.; Bull, B.; Bryan, C. (2000a). Diel variation in fish density estimates during acoustic surveys of southern blue whiting. *New Zealand Fisheries Assessment Report 2000/16*. 22 p.

Hanchet, S.M.; Dunn, A. (2009). Southern blue whiting (*Micromesistius australis*) stock assessment for the Bounty Platform for 2007–08. Final Research Report to Ministry of Fisheries for Project SBW2006/01 & SBW2007/01, Objective 1 & 2. (Unpublished report held by Fisheries New Zealand, Wellington.) 34 p.

Hanchet, S.M.; Dunn, A.; Stevenson, M.L. (2003). Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for 2003. *New Zealand Fisheries Assessment Report 2003/59*. 42 p.

Hanchet, S.M.; Grimes, P.J. (2000). Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, August 1999. *New Zealand Fisheries Assessment Report 2000/30*. 25 p.

Hanchet, S.M.; Grimes, P.J.; Coombs, R.F. (2002). Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, August–September 2001. *New Zealand Fisheries Assessment Report 2002/58*. 35 p.

Hanchet, S.M.; Ingerson, J.K.V. (1995). Southern blue whiting (*Micromesistius australis*) fishery assessment for the 1995–96 fishing year. New Zealand Fisheries Assessment Research Document 95/20. (Unpublished report held by NIWA library, Wellington.) 37 p.

Hanchet, S.M.; Richards, L.; Bradford, E. (2000b). Decomposition of acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) using length and age frequency data. *New Zealand Fisheries Assessment Report 2000/43*. 37 p.

Hanchet, S.M.; Stevenson, M.L. (2006). Biomass and scaled length frequency distribution of southern blue whiting by stock from the Tangaroa sub-Antarctic trawl surveys. Final Research Report to the Ministry of Fisheries. Project SBW2005/01, Objective 4. (Unpublished report held by Fisheries New Zealand, Wellington.) 22 p.

Hanchet, S.M.; Uozumi, Y. (1996). Age validation and growth of southern blue whiting, *Micromesistius australis*, in New Zealand. *New Zealand Journal of Marine and Freshwater Research 30*: 57–67.

Ingerson, J.K.V.; Hanchet, S.M. (1996). Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, Pukaki Rise, Auckland Islands Shelf, and Campbell Island Rise, August–September 1995. New Zealand Fisheries Assessment Research Document 96/18. (Unpublished report held by NIWA library, Wellington.) 29 p.

Large, K. (2021). 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 2017 season. *New Zealand Fisheries Assessment Report 2021/11*. 41 p.

Large, K.; Hanchet, S.M. (2017). 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 2016 season. *New Zealand Fisheries Assessment Report 2017/35*. 44 p.

McClatchie, S.; Thorne, R.; Grimes, P.J.; Hanchet, S.M. (2000). Ground truth and target identification for fisheries acoustics. *Fisheries Research 47*: 173–191.

Ministry for Primary Industries (2012). Report from the Fishery Assessment Plenary, May 2012: stock assessments and yield estimates. 1194 p. Fisheries Science Group, Ministry for Primary Industries.

Ministry for Primary Industries (2013). Report from the Fishery Assessment Plenary, May 2013: stock assessments and yield estimates. 1357 p. Fisheries Science Group, Ministry for Primary Industries.

Monstad, T.; Borkin, I.; Ermolchev, V. (1992). Report of the joint Norwegian-Russian acoustic survey on blue whiting, spring 1992. ICES CM 1992/H:6, Pelagic Fish Committee: 26 p.

Nakken, O.; Olsen, K. (1977). Target strength measurements of fish. *Rapports et Procés-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer 170*: 52–69.

O'Driscoll, R.L. (2011a). Acoustic biomass estimate of southern blue whiting on the Bounty Platform in 2010. NIWA Client Report: WLG2011-1. 27 p. National Institute of Water and Atmospheric Research.

O'Driscoll, R.L. (2011b). Acoustic biomass estimates of southern blue whiting on the Pukaki Rise and Campbell Island Rise in 2010. NIWA Client Report: WLG2011-3. 37 p. National Institute of Water and Atmospheric Research.

O'Driscoll, R.L. (2011c). Industry acoustic surveys of spawning southern blue whiting on the Bounty Platform and Pukaki Rise 2004-2009. *New Zealand Fisheries Assessment Report 2011/17*. 52 p.

O'Driscoll, R.L. (2013). Acoustic estimates of southern blue whiting on the Bounty Platform in 2012. *New Zealand Fisheries Assessment Report 2013/4*. 26 p.

O'Driscoll, R.L. (2015). Acoustic estimates of southern blue whiting on the Bounty Platform in 2014. *New Zealand Fisheries Assessment Report 2015/02.* 28 p.

O'Driscoll, R.L. (2018). Acoustic estimates of southern blue whiting on the Bounty Platform in 2017. *New Zealand Fisheries Assessment Report 2018/11*. 28 p.

O'Driscoll, R.L.; Bagley, N.W. (2009). Trawl survey of hoki, hake, and ling in the Southland and Sub-Antarctic areas, November-December 2008 (TAN0813). *New Zealand Fisheries Assessment Report 2009/56*. 67 p.

O'Driscoll, R.L.; Dunford, A.J. (2017). Acoustic estimates of southern blue whiting on the Bounty Platform in 2015. *New Zealand Fisheries Assessment Report 2017/19*. 20 p.

O'Driscoll, R.L.; Dunford, A.J.; Dunn, A. (2016). Industry acoustic surveys of spawning southern blue whiting on the Bounty Platform, New Zealand. *Fisheries Research 178*: 61–70.

O'Driscoll, R.L.; Dunford, A.J.; Fu, D. (2012). Acoustic estimates of southern blue whiting from the Campbell Island Rise, August–September 2011 (TAN1112). *New Zealand Fisheries Assessment Report 2012/18*. 56 p.

O'Driscoll, R.L.; Dunford, A.J.; Ladroit, Y. (2014). Acoustic estimates of southern blue whiting from the Campbell Island Rise, August-September 2013. *New Zealand Fisheries Assessment Report 2014/22*. 46 p.

O'Driscoll, R.L.; Hanchet, S.M. (2004). Acoustic survey of spawning southern blue whiting on the Campbell Island Rise from FV Aoraki in September 2003. *New Zealand Fisheries Assessment Report 2004/27*. 31 p.

O'Driscoll, R.L.; Ladroit, Y. (2017). Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2016. *New Zealand Fisheries Assessment Report 2017/20*. 24 p.

O'Driscoll, R.L.; Large, K.; Marriott, P. (2018). Acoustic estimates of southern blue whiting from the Campbell Island Rise, August-September 2016. *New Zealand Fisheries Assessment Report 2018/56*. 62 p.

O'Driscoll, R.L.; Oeffner, J.; Dunford, A.J. (2013). In situ target strength estimates of optically verified southern blue whiting (*Micromesistius australis*). *ICES Journal of Marine Science 70*: 431–439.

O'Driscoll, R.L.; Oeffner, J.; Dunford, A.J. (2015). Acoustic estimates of southern blue whiting on the Bounty Platform in 2013. *New Zealand Fisheries Assessment Report 2015/01*. 28 p.

Pedersen, G.; Rune Godø, O.; Ona, E.; Macaulay, G.J. (2011). A revised target strength–length estimate for blue whiting (*Micromesistius poutassou*): implications for biomass estimates. *ICES Journal of Marine Science 68*: 2222–2228.

Roberts, J.; Dunn, A. (2017). Investigation of alternative model structures for the estimation of natural mortality in the Campbell Island Rise southern blue whiting (*Micromesistius australis*) stock assessment (SBW 6I). *New Zealand Fisheries Assessment Report 2017/26*. 14 p.

Roberts, J.; Hanchet, S. (2019). Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for 2017. *New Zealand Fisheries Assessment Report 2019/44.* 21p.

Shpak, V.M. (1978). The results of biological investigations of the southern putassu *Micromesistius australis* (Norman, 1937) on the New Zealand plateau and perspectives of its fishery. (Unpublished TINRO manuscript. TINRO.)

Shpak, V.M.; Kuchina, V.V. (1983). Dynamics of abundance of southern putassu. *Biologiya Morya 2:* 35–39. (English translation held in NIWA library, Wellington.)

APPENDIX 1: Calibration Report: *Tomi Maru 87* 27 June 2018

Calibration of the Simrad ES80 echosounder on *Tomi Maru 87* took place in the Hauraki Gulf (36° 35.8' S 175° 03.3' E) on 27 June 2018. Water depth was about 39 m (below the transducer). The calibration was carried out by Richard O'Driscoll and Alexandre Schimel (NIWA) following the procedures of Demer et al. (2015).

This is the second calibration of the current ES80 echosounder and transducer configuration on this vessel. The previous calibration took place off Timaru on 9 July 2017 (O'Driscoll 2018). Both the 38 kHz and 70 kHz ES80 echosounders were operating synchronously and were calibrated together.

There were 11 calibrations of the previous ES60 and ES70 38-kHz echosounders on *Tomi Maru 87*, with annual calibrations since 2005. In May 2016 the ES38B transducer was replaced with a new Simrad ES38-7 unit, which has a different element configuration and required a new processing card to be installed in the GPT. This calibration was carried out with the new transducer and GPT, but with the old (ES70) software. However, data collection during the 2016 SBW season was carried out with newer (ES80 version 1.0.0) software, which had different transducer configuration settings, and a bug which meant that the echosounder was operating in single-beam mode (O'Driscoll & Ladroit 2017). Because the incompatibility between the ES80 and the GPT was not resolved by later versions of the ES80 software, a new 38 kHz WBT was installed in February 2017, and this is the current configuration to date.

Richard O'Driscoll and Alexandre Schimel boarded *Tomi Maru 87* at 07:30 NZST at Davenport Naval Base, where it had been in dry-dock. The vessel departed at 08:10 and steamed offshore for trials on the main engine. The ES80 was configured to survey 38 kHz and 70 kHz settings (see Table A1) and the PC time was set to the GPS before the calibration began. A 4 TB hard drive was installed to record data. No keyboard was available, and the ES80 computer only had one available USB port, so a portable keyboard was used to configure settings before installing the hard drive.

The calibration commenced at 10:50 NZST. A weighted line was passed under the keel to facilitate setting up the three lines and calibration sphere. Long (3.8 m) fibreglass calibration poles were used to help keep the calibration lines clear of the hull. The sphere and associated lines were immersed in a soap solution prior to entering the water. A lead weight was also deployed about 3 m below the sphere to steady the arrangement of lines. The sphere was detected in the main lobe about 24 m below the transducer, then centred in the 38 kHz beam for acquisition of data for on-axis parameters, and was then moved around the beam to obtain data for the beam shape calibration.

The weather was good with 5–10 knot southwest winds and no swell. The vessel was allowed to drift, and the drift speed was about 0.7 knots. The sphere was located in the beam at immediately and calibration data were collected until 12:25 in three ES80 .raw format files (t871801-D20180626-T230216, t871801-D20180626-T232811, t871801-D20180627-T001335). A Furuno echosounder was running during the first file (until 11:25), so only the second and third files were analysed to estimate calibration parameters. Raw data are stored on NIWA's *acoustic* server (X:\calibration_ex60\Tomi Maru 87\2018_SBW201801 - calibration).

Immediately after calibration and before leaving the calibration site, water temperature measurements were taken using an RBR TDR2050 temperature depth probe, serial number 011882. The measurements indicated that the water column was weakly stratified, with a surface temperature of 14.8 ºC, a temperature at the sphere depth (~30 m) of 15.8 ºC, and an average through the water column of 14.9 ºC.

After the calibration, the *Tomi Maru 87* returned to Davenport berthing at about 16:30.

The data in the ES80 files were visualized and processed using NIWA software ESP3.

Sound absorption was estimated in ESP3 using the formulae of Doonan et al. (2003) and the following parameters: temperature of 14.9 ºC, assumed salinity of 35 PSU, and average depth of 15 m. Sound speed was estimated using the formulae of Fofonoff & Millard (1983), and the same parameters as above.

The amplitude of the sphere echoes was obtained by filtering on range, and choosing the sample with the highest amplitude. Pings where the sphere echo was disturbed by fish echoes were discarded. The alongship and athwartship beam widths and offsets were calculated by fitting the sphere echo amplitudes to the Simrad theoretical beam pattern:

$$compensation = 6.0206\left(\left(\frac{2\theta_{fa}}{BW_{fa}}\right)^2 + \left(\frac{2\theta_{ps}}{BW_{ps}}\right)^2 - 0.18\left(\frac{2\theta_{fa}}{BW_{fa}}\right)^2\left(\frac{2\theta_{ps}}{BW_{ps}}\right)^2\right),$$

where θ_{ps} is the port/starboard echo angle, θ_{fa} the fore/aft echo angle, BW_{ps} the port/starboard beamwidth, BW_{fa} the fore/aft beamwidth, and *compensation* the value, in dB, to add to an uncompensated echo to yield the compensated echo value. The fitting was done using an unconstrained nonlinear optimisation (as implemented by the Matlab fminsearch function). The Sa correction was calculated using the formula:

$$S_{a,corr} = 5\log_{10}\left(\frac{\sum P_i}{4P_{\max}}\right),$$

where P_i is the sphere echo power measurement and P_{max} the maximum sphere echo power measurement. A value for $S_{a,corr}$ is calculated for all valid sphere echoes and the mean over all sphere echoes is used to determine the final $S_{a,corr}$.

No correction was necessary for the triangle wave error in ES60 and ES70 data as this is not applied in ES80 data.

Results

The mean range of the sphere, estimated sound speed and estimated acoustic absorption between the transducer (about 6 m deep) and the sphere are given in Table A2.

The estimated beam pattern and sphere coverage for the 38 kHz transducer are given in Figure A1. The symmetrical nature of the pattern and the zero centre of the beam pattern indicate that the transducer and transceiver were operating correctly. The fits between the theoretical beam pattern and the sphere echoes are shown in Figure A2 and confirm that the transducer beam pattern is correct. The RMS of the difference between the Simrad beam pattern model and that measured from the sphere echoes out to 3.5° off axis was 0.06 dB (Table A3), indicating that the 38 kHz calibration was of excellent quality (>0.4 dB is poor, 0.3–0.4 dB good, and <0.2 dB excellent). The estimated peak gain (G_0) was 26.40 dB and the Sa correction was -0.02 dB, which are very similar results (within 0.05 dB) to those from the 2017 calibration (Table A3). Results from the 38 kHz calibration will be used for analysis of results from the 2018 Bounty southern blue whiting survey.

Results from the simultaneous calibration of the 70 kHz echosounder are also given in Table A4 with the estimated beam pattern and sphere coverage in Figure A3 and the beam fit in Figure A4. This was also an excellent quality calibration (RMS deviation of 0.10 dB), which showed that the 70 kHz echosounder was operating correctly. The estimated peak gain (G_0) at 70 kHz was 27.70 dB and the Sa correction was -0.07 dB. The value of G_0 in 2018 was about 0.2 dB lower than that from the calibration in 2017 (Table A4).

Table A1: Transceiver settings and other relevant parameters for 38 kHz and 70 kHz echosounders during the ES80 calibration in June 2018.

Parameter	38 kHz	70 kHz
Echosounder	ES80	ES80
Software version	1.1.4	1.1.4
Transducer model	ES38-7	ES70-7C
Transducer serial number	130	Not recorded
ES80 WBT serial number	714603	700875
WBT software version	2.16 FPGATX firmware Rev 5 FPGARX firmware Rev 7	2.16 FPGATX firmware Rev 5 FPGARX firmware Rev 7
Sphere type/size	tungsten carbide/38.1 mm diameter	
Operating frequency (kHz)	38	70
Transducer draft setting (m)	0.0	0.0
Transmit power (W)	2000	1000
Pulse length (ms)	1.024	1.024
Slope (%)	25.699	4.185
Transducer peak gain (dB)	26.5	27.0
Sa correction (dB)	0.0	0.0
Sample interval (m)	0.040	0.048
Two-way beam angle (dB)	–20.7	–-20.7
Absorption coefficient (dB/km)	10.0	23.0
Speed of sound (m/s)	1490	1490
Angle sensitivity (dB) alongship/athwartship	28.0/28.0	23.0/23.0
3 dB beamwidth (º) alongship/athwartship	7.0/7.0	7.0/7.0
Angle offset (º) alongship/athwartship	0.0/0.0	0.0/0.0

Table A2: Auxiliary calibration parameters derived from depth and temperature measurements.

Parameter	38 kHz	70 kHz
Mean sphere range (m)	24.33	24.44
S.D. of sphere range (m)	0.74	0.75
Mean sound speed (m/s)	1506.8	1506.8
Mean temperature (°C)	14.9	14.9
Mean absorption (dB/km)	8.78	22.81
Sphere TS (dB re $1m^2$)	-42.42	-41.52

Table A3: Calculated echosounder calibration parameters for 38 kHz ES80 echosounder on *Tomi Maru 87*. Values were calculated using ESP3 software version 0.9.7.

Parameter	2018	2017
Mean TS within 0.20° of centre (dB)	-42.45	-42.68
Std dev of TS within 0.20° of centre (dB)	0.09	0.27
Max TS within 0.20° of centre (dB)	-42.14	-41.71
No. of echoes within 0.20° of centre	388	147
On axis TS from beam-fitting (dB)	-42.38	-42.63
Transducer peak gain (dB) mean TS	26.40	26.36
Sa correction (dB)	-0.02	-0.03
Beamwidth (º) along/athwartship	6.4/6.4	6.4/6.4
Beam offset (º) along/athwartship	0.04/-0.00	0.05/-0.02
RMS deviation (dB)	0.06	0.13
Number of echoes	7 975	10 079

Table A4: Calculated echosounder calibration parameters for 70 kHz ES80 echosounder on *Tomi Maru 87*. Values were calculated using ESP3 software version 0.9.7.

Parameter	2018	2017
Mean TS within 0.20° of centre (dB)	-40.11	-39.44
Std dev of TS within 0.20° of centre (dB)	0.12	0.16
Max TS within 0.20° of centre (dB)	-39.87	-39.10
No. of echoes within 0.20° of centre	148	51
On axis TS from beam-fitting (dB)	-39.98	-39.25
Transducer peak gain (dB) mean TS	27.70	27.93
Sa correction (dB)	-0.07	-0.06
Beamwidth (º) along/athwartship	6.8/6.4	6.5/6.5
Beam offset (º) along/athwartship	0.04/0.07	-0.03/0.04
RMS deviation (dB)	0.10	0.15
Number of echoes	7 443	7 253

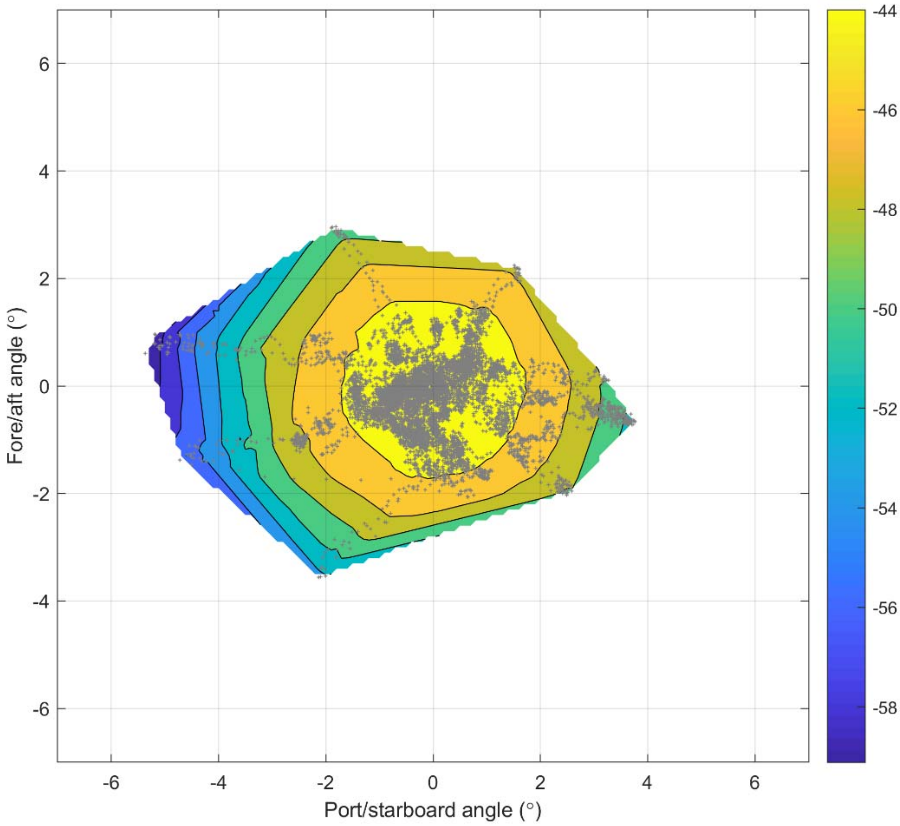

Figure A1: The estimated beam pattern from the sphere echo strength and position for the 38 kHz calibration. The dots indicate where sphere echoes were received. The colours indicate the received/computed sphere echo strength in dB re 1 m^2.

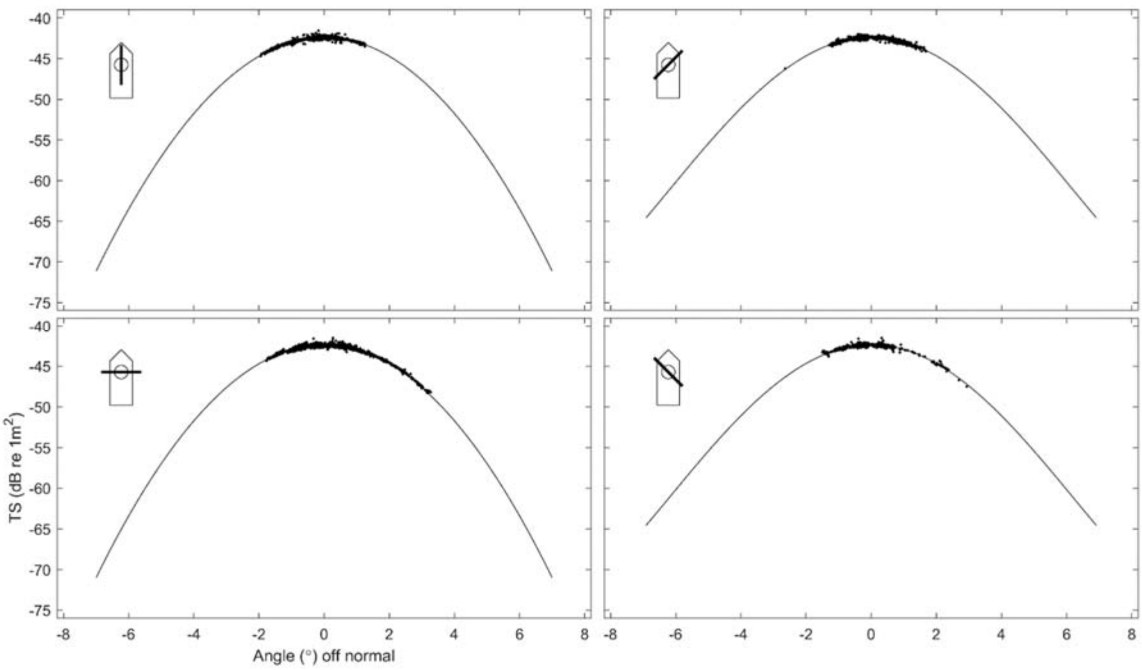

Figure A2: Beam pattern results from the 38 kHz calibration analysis. The solid line is the theoretical beam pattern fit to the sphere echoes for four slices through the beam.

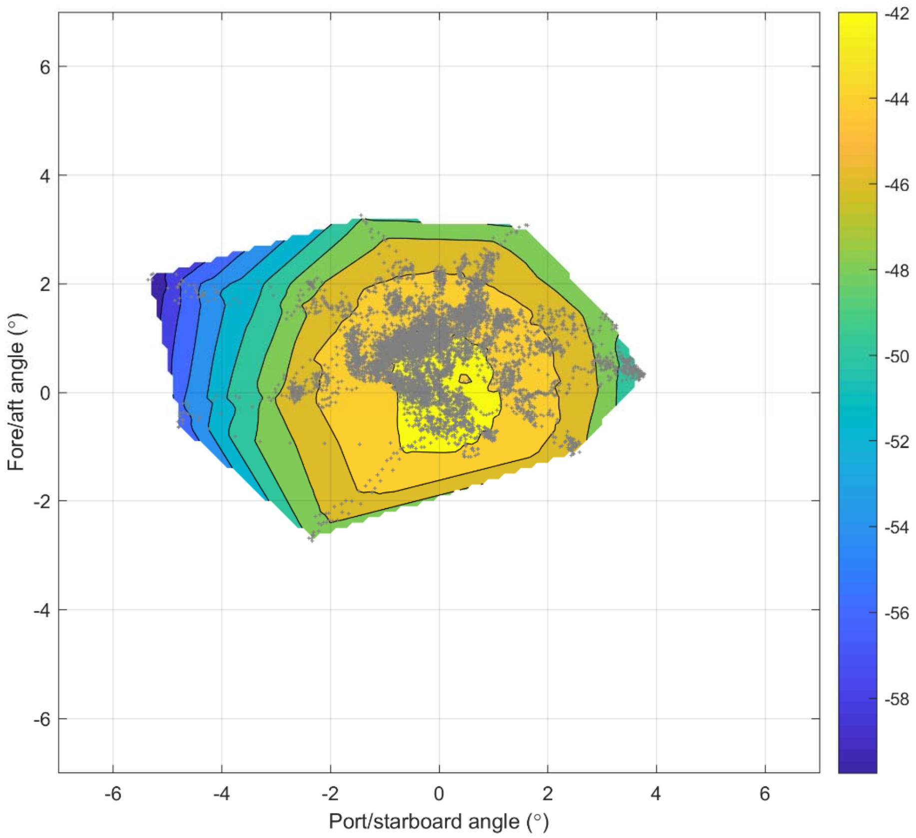

Figure A3: The estimated beam pattern from the sphere echo strength and position for the 70 kHz calibration. The dots indicate where sphere echoes were received. The colours indicate the received/computed sphere echo strength in dB re 1 m^2.

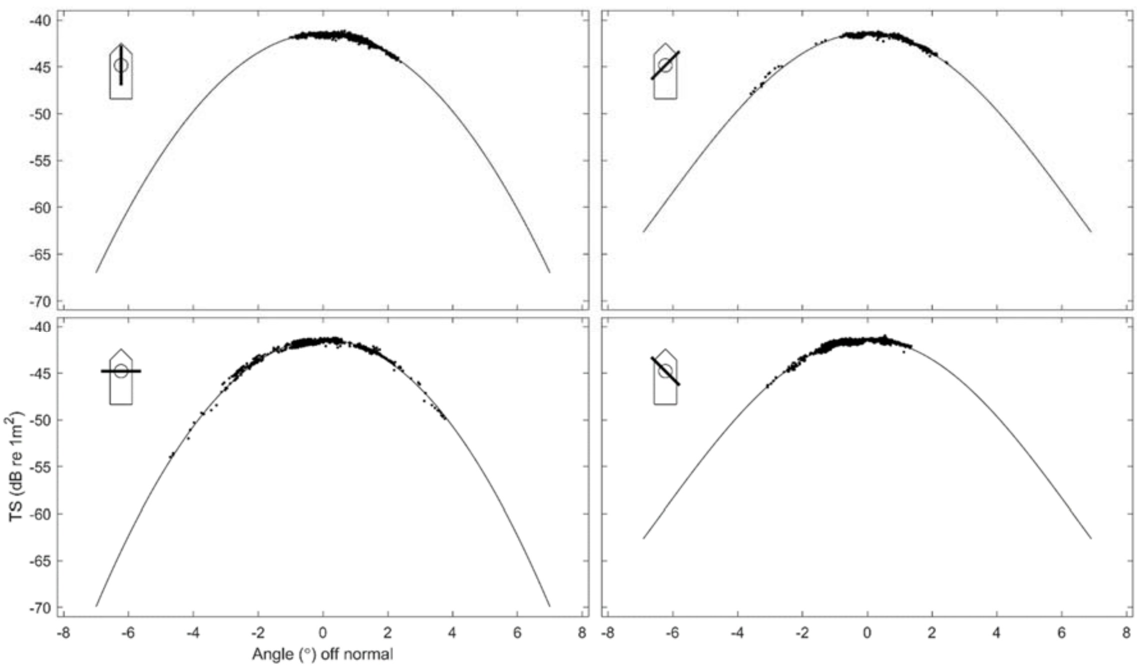

Figure A4: Beam pattern results from the 70 kHz calibration analysis. The solid line is the theoretical beam pattern fit to the sphere echoes for four slices through the beam.

APPENDIX 2: Bounty Platform: Daily proportion of females spawning, for fishing seasons 1991 to 2018

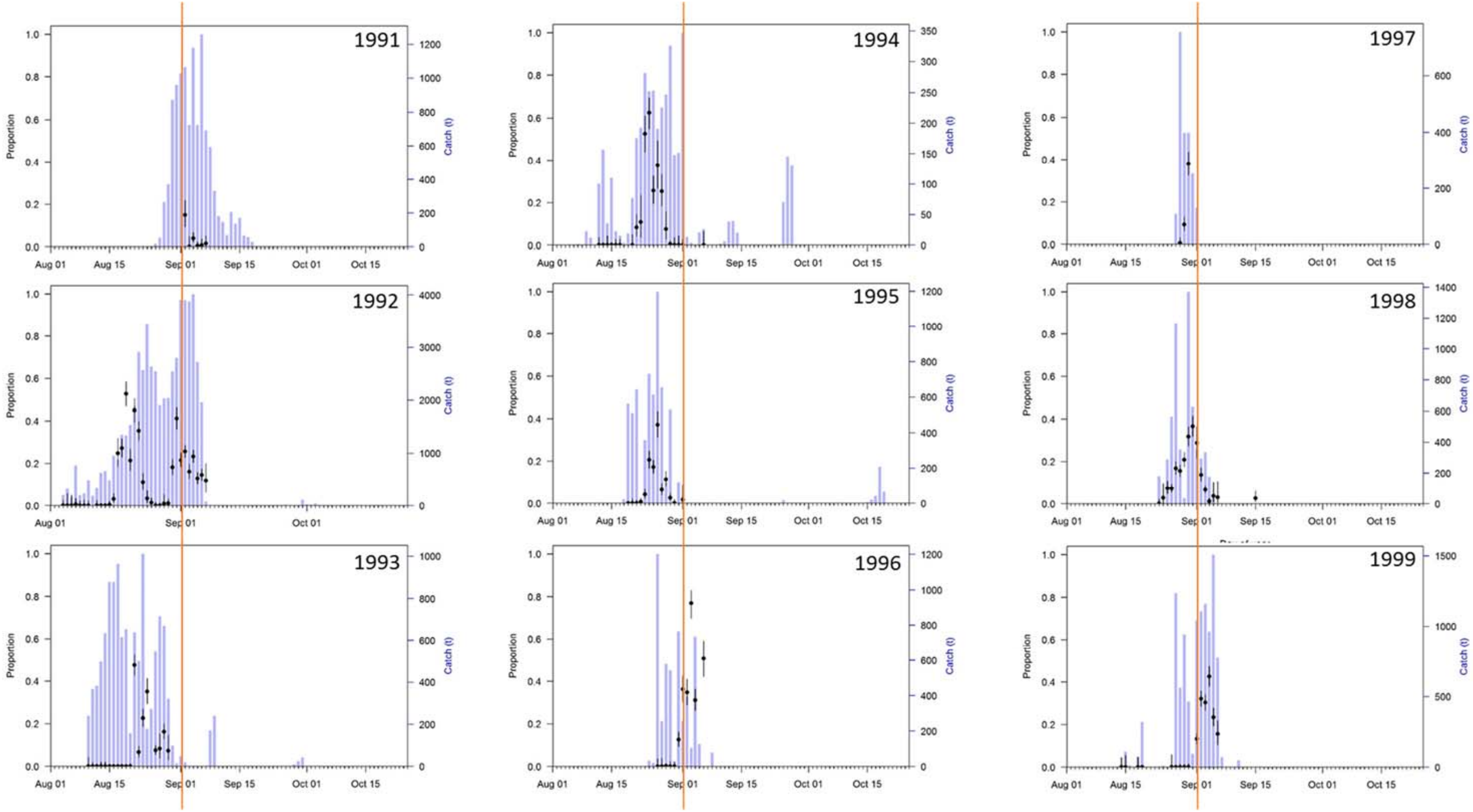

Figure A5: Daily proportion of females spawning (proportions at stage 4) (black lines) and daily catches (blue bars) for target southern blue whiting tows on the Bounty Platform between July and October for the fishing seasons from 1991 to 1999. The catch scale (right y-axis) varies and is not comparable between plots. (Vertical line arbitrarily at 1st September for reference.)

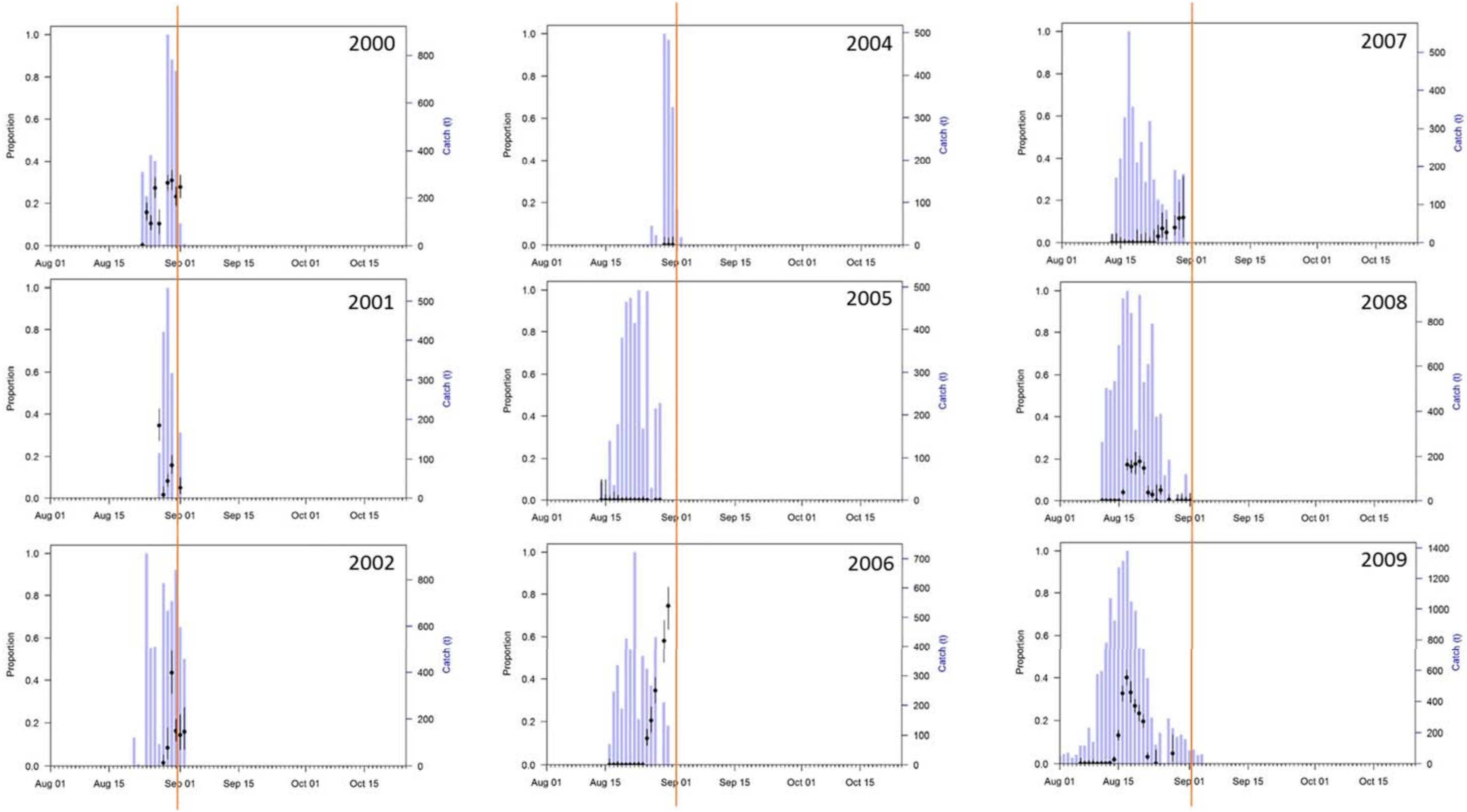

Figure A6: Daily proportion of females spawning (proportions at stage 4) (black lines) and daily catches (blue bars) for target southern blue whiting tows on the Bounty Platform between July and October for the fishing seasons from 2000 to 2009. The catch scale (right y-axis) varies and is not comparable between plots. (Vertical line arbitrarily at 1st September for reference.)

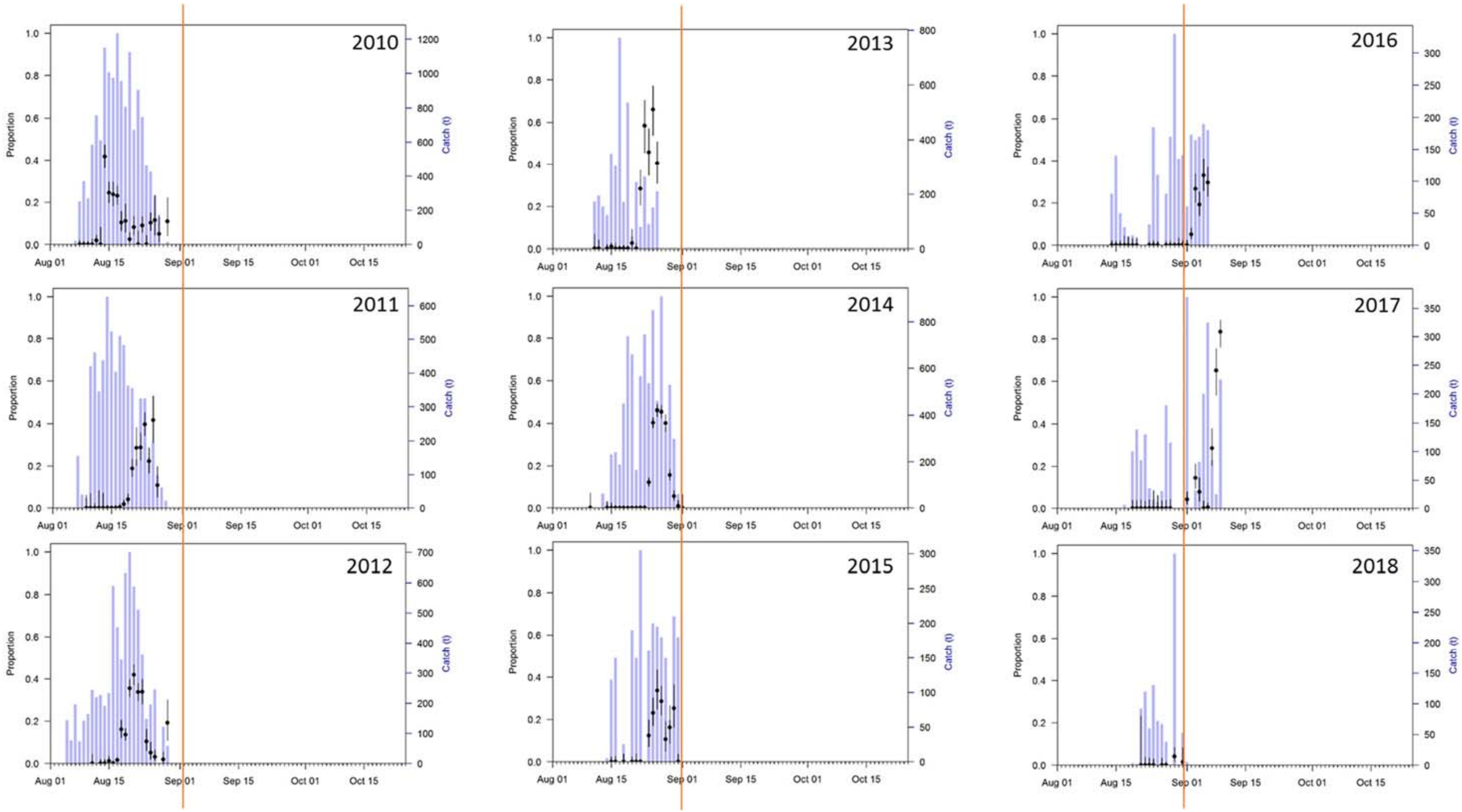

Figure A7: Daily proportion of females spawning (proportions at stage 4) (black lines) and daily catches (blue bars) for target southern blue whiting tows on the Bounty Platform between July and October for the fishing seasons from 2010 to 2018. The catch scale (right y-axis) varies and is not comparable between plots. (Vertical line arbitrarily at 1st September for reference.)