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

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New Zealand Fisheries Assessment Report 2010/32
September 2010

Published by Ministry of Fisheries
Wellington
2010

ISSN 1175-1584 (print)
ISSN 1179-5352 (online)

Hanchet, S.M.; Dunn, A. (2010).
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 2010/32.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

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For the first time the large amount of research carried out on southern blue whiting over the past 20 years has been consolidated into one place. We have included 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 small area industry vessel surveys); CPUE indices for Bounty Platform and Campbell Island Rise; updated trawl survey indices for the Auckland Islands Shelf, Campbell Island Rise, and Pukaki Rise; and revised and updated time series of commercial catch length-at-age and catch-at-age proportions.

Following this review and documentation we make several recommendations. There has been some concern that certain parts of the fleet target larger fish and so a tree-based regression analysis of the length frequency data for the Bounty and Campbell stocks could be carried out for optimal post-stratification to address this issue. The data used for the estimation of catch-at-age on the Campbell Island Rise before 1990 should be better documented and if appropriate reanalysed. The trawl survey indices and ancillary data for the Auckland Islands Shelf, Campbell Island Rise, and Pukaki Rise up to and including the 2010 survey should be updated. A fishery characterisation including vessel characteristics and location and months of catches by year and area, including non-spawning season catches, would be useful to identify recent changes in the fishery. The last assessment of the Pukaki Rise was completed in 2002. Since then, considerable data have been collected including catch-at-age, acoustic indices, and trawl survey indices which would allow the assessment to be updated.

1. INTRODUCTION

Southern blue whiting (SBW) are almost entirely restricted in distribution to Subantarctic waters. They are dispersed throughout the Campbell Plateau 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 from 35 to 55 cm fork length (FL), although occasionally smaller size classes (25–30 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 are important fisheries, but have tended to have much lower annual catches compared with the Campbell Island Rise and Bounty Platform fisheries.

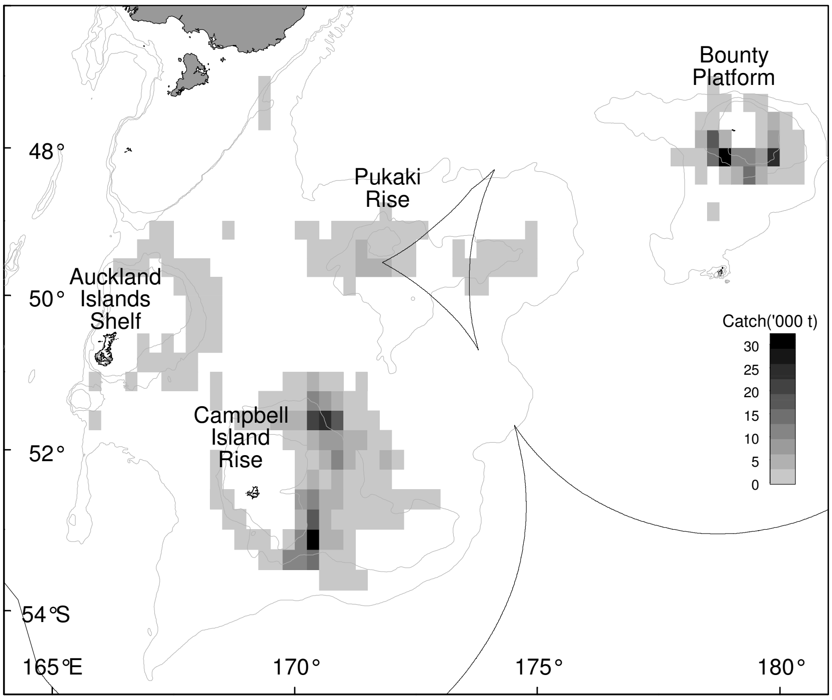

Figure 1: Relative total density of the commercial catch of southern blue whiting by location, TCEPR data 1990–2009.

Much research has been carried out on southern blue whiting over the past 20 years, including work on stock structure (Hanchet 1998, 1999), age and growth (Hanchet & Uozumi 1996), catch-at-age (e.g., Hanchet 2005, Hanchet et al. 2003), acoustic surveys (e.g., O'Driscoll et al. 2009), CPUE analyses (e.g., Hanchet & Blackwell 2003, Hanchet et al. 2005), and trawl surveys (Hanchet & Stevenson 2006). 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 (e.g., Hanchet 2005, Hanchet et al. 2006). Model inputs have included time series of acoustic survey indices, commercial catch-at-age composition data, and, in some years, CPUE indices. The objective of this report is to summarise and document the time series of input data which could potentially be used for stock assessment. Further, we revise and update the commercial catch catch-at-age proportions for the Bounty Platform, Campbell Island Rise, and Pukaki Rise.

2. FISHERY SUMMARY

2.1 Commercial fisheries

The SBW fishery was developed by Soviet vessels during the early 1970s, with early reported landings in peaking at almost 50 000 t in 1973 (Table 1). Early reports recorded that SBW spawned in most years on the Bounty Platform (Shpak 1978) and in some years on the Campbell Plateau (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, and hence the amount of catch for each ground cannot accurately be determined before 1978.

Landings were chiefly taken by the Soviet foreign licensed fleet during the 1970s and early 1980s. The entire Campbell Plateau (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 SBW. Since then, 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 SBW 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 and fishing has continued there at a low level sporadically since then. Annual landings over the past five years have averaged between 22 000 t and 37 000 t, most of which has been taken from the Campbell Island Rise grounds. However, in the most recent two years a strong year class on the Bounty Platform has led to a recent rapid increase in catches.

On the Bounty Platform and Campbell Island Rise the TACC has been almost fully caught in each of the last 5 years. However, on the other grounds, the catch limits have generally been under-caught in most years since their introduction. This reflects the low economic value of the fish and difficulties in timing and locating aggregations experienced by operators. On the Bounty Platform, the amount of fishing effort in any season depends largely on the timing of the west coast hoki fishery. If there is a delayed hoki season, then the vessels remain longer on the hoki grounds and consequently miss the peak fishing season on the Bounty Platform. On the Pukaki Rise and Auckland Islands Shelf, operators find it difficult to justify expending time to locate fishable aggregations, given the small allocation available in these areas and the relatively low value of the product.

In general, the fleet and processing has gradually changed from one being dominated by Japanese surimi and Soviet 'head and gut' vessels to a fleet dominated by vessels from Ukraine and Dominican Republic which process fish to a dressed product. Over the past 5 years about 60% of the product has been dressed and about 35% has been surimi, with the latter dropping to about 10% in 2009–10.

Table 1: Estimated catches (t) of southern blue whiting for 1971 to 2009–10, and by area for 1978 to 2009–10 (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	6 508	8 000	14 959	21 000	772	3 000	40	–	22 279	32 000
1996–97	1 761	20 200	15 685	30 100	1 806	7 700	895	–	20 147	58 000
1997–98	5 647	15 400	24 273	35 460	1 245	5 500	0	1 640	31 165	58 000
1998–00	8 741	15 400	30 386	35 460	1 049	5 500	750	1 640	40 926	58 000
2000–01	3 997	8 000	18 055	20 000	2 864	5 500	37	1 640	24 963	35 140
2001–02	2 261	8 000	29 999	30 000	230	5 500	10	1 640	32 500	45 140
2002–03	7 564	8 000	33 433	30 000	712	5 500	254	1 640	41 785	45 140
2003–04	3 812	3 500	23 718	25 000	163	5 500	116	1 640	27 812	35 640
2004–05	1 477	3 500	19 776	25 000	239	5 500	70	1 640	21 567	35 640
2005–06	3 962	3 500	26 190	25 000	58	5 500	50	1 640	30 260	35 640
2006–07	4 395	3 500	19 763	20 000	1 070	5 500	82	1 640	25 315	30 640
2007–08	3 799	3 500	20 996	20 000	470	5 500	242	1 640	25 508	30 640
2008–09	9 863	9 800	20 483	20 000	1 377	5 500	143	1 640	31 866	36 948
2009–10	15 467	15 000	19 040	20 000	4 808	5 500	157	1 640	39 477	42 140

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 has a TACC of 8 t and reported annual catches since 2000–01 of 9 t, 1 t, 16 t, 3 t, 9 t, 2 t, 7 t, 1 t, and 21 t.

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 3 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 3 years (Table 1). Before 1997–98 there was no separate catch limit for Auckland Islands, but in 1997–98, a 1640 t limit was set for the Auckland Islands fishery.

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. SBW 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 (SBW 1) was set for the rest of the EEZ. Less than 20 t per year has been reported from SBW 1 since 2000–01.

From 1 April 2008, the TACC for the Bounty Platform stock was increased to 9800 t and from 1 April 2009 further increased to 15 000 t. From 1 April 2006, the TACC for the Campbell Island Rise stock was reduced from 25 000 t to 20 000 t.

2.2 Illegal catches

The level of illegal and unreported catch for southern blue whiting has been reported as "thought to be low" (Ministry of Fisheries 2009).

In 2002–03, the operators of one vessel were convicted for area misreporting — the vessel had caught about 204 t of SBW 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 SBW at sea — crew members estimated that between 40 and 310 tonnes of SBW were dumped during a two and a half week period fishing on the Campbell Island Rise (Ministry of Fisheries 2009).

2.3 Other sources of fishing mortality

Scientific observers have reported discards of undersized fish and accidental loss from torn or burst codends, particularly during the early years of the fishery. 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. There is no quantitative estimate of this mortality from non-observed vessels. No estimates of discards have been considered in previous stock assessments.

In the most recent Initial Position Paper (SBW 6I) (Ministry of Fisheries 2010) a discard allowance of 2% was proposed along with a revised TACC for the 2010–11 fishing year.

2.4 The 2009 season

The location of trawls made during the 2009 season (mid August to mid October) is shown in Figure 2. Most of the catch was taken by vessels flagged to Ukraine, Dominican Republic, and New Zealand and most fishing was carried out on the Bounty and Campbell stocks (Table 2). The first vessels arrived on the Bounty Platform on 28 July and gradually worked their way south and east making small to moderate catches. From 10 to 23 August vessels were fishing in the south west and made high catches (over 500 t per day). Fish were spawning from 15 to 21 August. Catches were lower after spawning had finished and all vessels had left by 4 September.

Vessels started fishing the Campbell Island Rise on 30 August and continued fishing until 30 September. As in recent years, the fleet fished the northern and southern spawning aggregations on the Campbell Island Rise ground this season. The southern aggregation was being fished by most of the commercial fleet from 30 August to 12 September, but no observers worked there after 6 September and so the timing of spawning is unknown. The northern aggregation was fished from 6 September with fish spawning from 10 to 14 September. The last observer left on 20 September and so the timing of the second spawning is not known.

Ten vessels fished the Pukaki Rise between 6 August and 19 September in the 2009 season. Most of the catch was taken by vessels fishing from 23 August to 8 September, when catches exceeded 150 t per day. The timing of spawning could not be determined because there were no observers present between 31 August and 14 September. Five vessels reported catches of SBW on the Auckland Islands Shelf during the 2009–10 fishing year, but no fishing was carried out during the spawning season. Daily catches were small and SBW were taken as bycatch of fishing for other species.

Table 2: Number of tows and vessels for vessels targeting SBW by area, 1990–2009 (source: TCEPR data).

Year	Auckland Islands		Bounty Platform		Campbell Island		Pukaki Rise		Other	
	Tows	Vessels	Tows	Vessels	Tows	Vessels	Tows	Vessels	Tows	Vessels
1990	9	4	230	22	949	35	153	27	7	6
1991	3	1	616	31	1185	34	249	24	17	8
1992	6	3	1766	51	1248	49	434	41	24	13
1993	19	5	347	20	363	19	326	22	11	5
1994	49	9	139	8	451	15	64	11	6	5
1995	25	6	144	11	276	12	52	8	4	3
1996	9	5	65	6	453	12	9	5	1	1
1997	44	8	34	8	622	17	45	8	18	5
1998	42	8	105	13	912	25	45	12	14	8
1999	18	6	251	16	772	22	54	12	32	6
2000	43	10	79	6	516	20	247	20	10	4
2001	101	12	27	5	722	19	302	22	22	9
2002	202	17	98	10	1076	25	282	23	13	7
2003	167	16	26	5	682	19	233	14	6	5
2004	144	10	37	5	685	16	141	17	2	2
2005	90	9	99	6	746	17	33	6	1	1
2006	46	6	94	5	510	13	55	7	10	4
2007	274	9	49	4	544	13	100	11	3	3
2008	132	9	203	10	547	14	104	9	10	6
2009	83	5	402	14	611	14	202	13	24	2

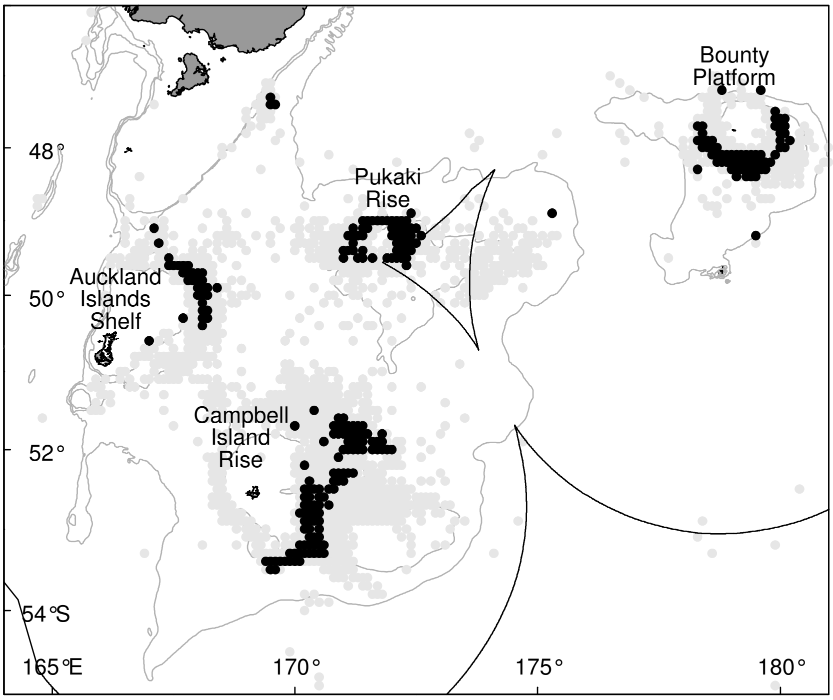

Figure 2: Commercial trawls made during the 2009 season (late August to early October, black points) targeting southern blue whiting and the location of historical tows 1990–2009 (grey points).

3. BIOLOGY

3.1 Stock structure

Stock structure of SBW 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 to which they first recruit. 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 between 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 1 year and 30 cm FL after 2 years Hanchet & Uozumi (1996). Growth slows down after 5 years and virtually ceases after 10 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 3 and Table 3). The subsequent two year classes grew at a similar slow rate. For this reason, mean length at age is input 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 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 LF distribution of fish in the plus group. The results are presented in Figure 3 and Figure 4 for the Campbell Island Rise and the Bounty Platform respectively. Note that the revised mean lengths in the plus group are typically slightly (1–2 cm) smaller than the original lengths calculated directly from the age-length key given by Hanchet et al. (2003).

3.2.2 Spawning and length and age at maturity

Southern blue whiting are highly synchronised batch spawners. Four spawning areas have been identified on Bounty Platform, Pukaki Rise, Auckland Islands Shelf, and Campbell Island Rise. The Campbell Island Rise has two separate spawning grounds to the north and south. Fish appear to recruit first to the southern ground, but thereafter spawn on the northern ground. Spawning on Bounty Platform 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 occur at night, in mid-water, over depths of 400–500 m on Campbell Island Rise but shallower elsewhere.

The age and length of 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 to equal 0.21 $^{y-1}$, and a value of 0.2 y^{-1} has been assumed in assessments. Recent Campbell Island stock assessments have estimated *M* within the model, using an informed prior with a mean of 0.2 y^{-1}.

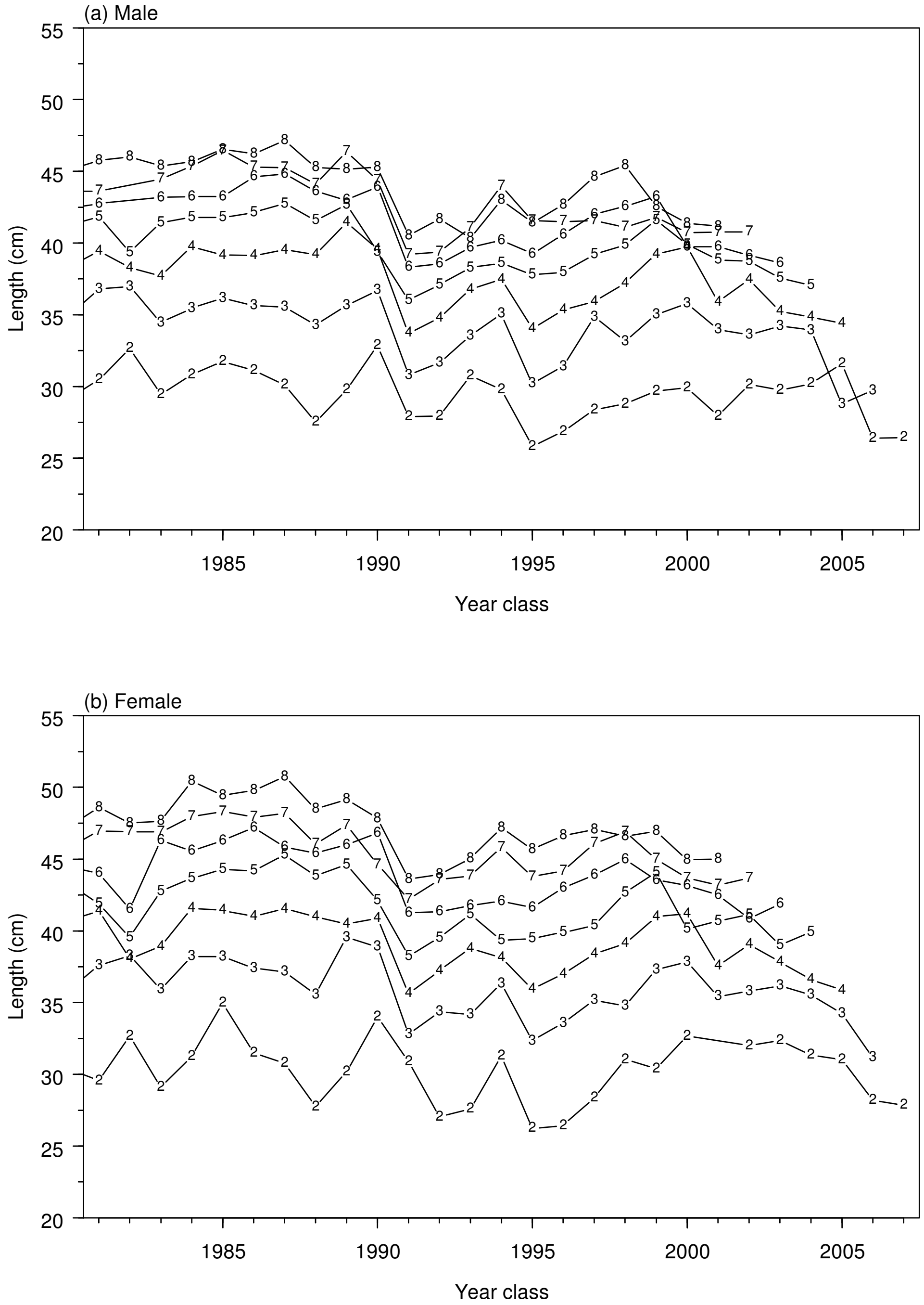

Figure 3: Estimated mean length-at-age (ages 2–8) for the Campbell Island stock by sex and year class, 1978–2009.

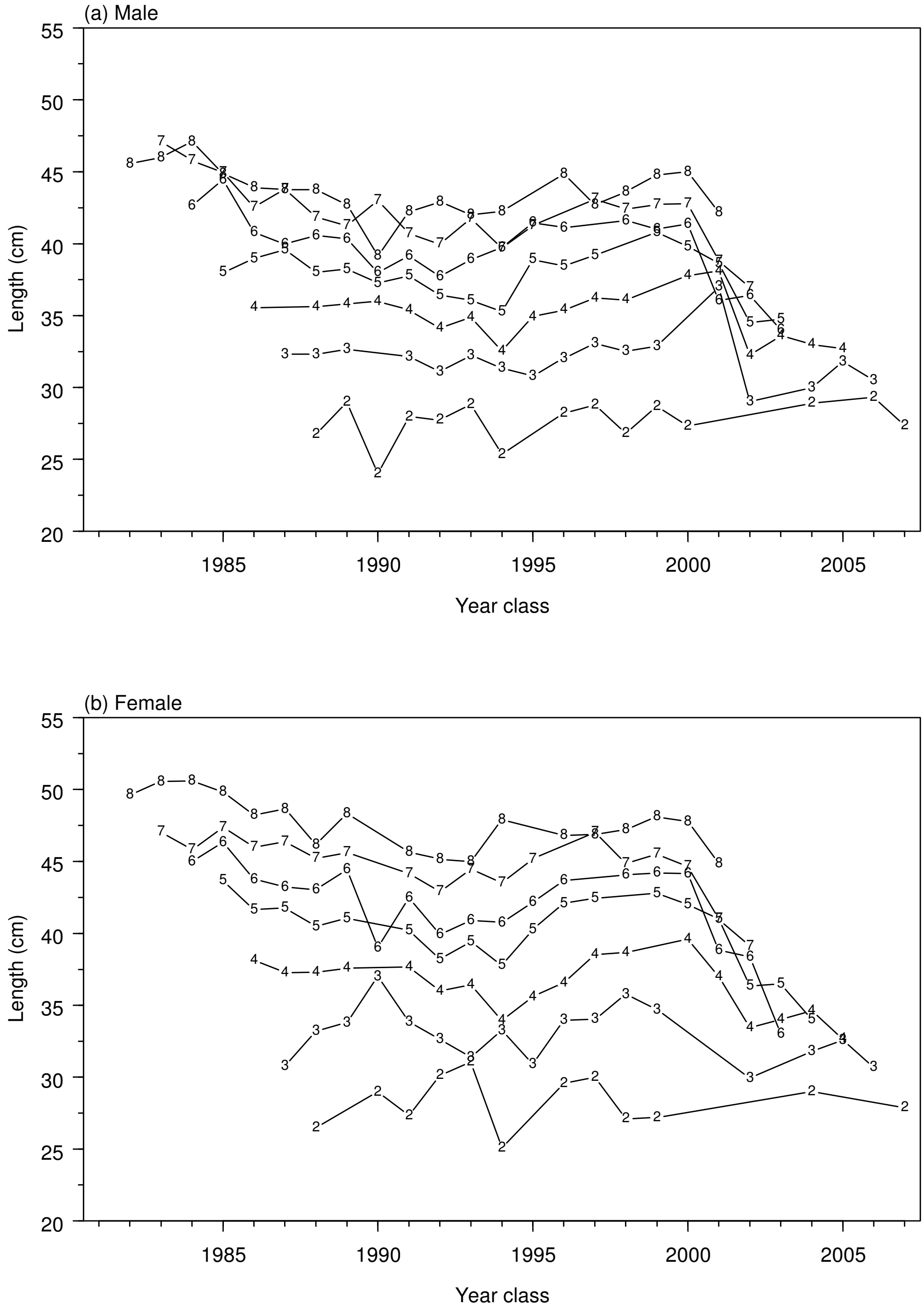

Figure 4: Estimated mean length-at-age (ages 2–8) for the Bounty Platform stock by sex and year class, 1990–2009.

Table 3: Overall mean weight and the mean weight for strong year classes (1991 and 1992) at age for SBW on the Campbell Island Rise.

Weight (g)										Age (y)
	2	3	4	5	6	7	8	9	10	11
Overall mean	170	292	420	513	599	661	716	771	794	835
Strong year class	110	220	315	400	485	550	600	680	710	780

Table 4: Estimates of biological parameters 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 (length)^b	*a*	0.00515	0.00407	
Weight in g, length in cm fork length	*b*	3.092	3.152	Hanchet (1991)

4. RESEARCH SURVEYS AND OTHER ESTIMATES OF ABUNDANCE

4.1 Acoustic research surveys

A programme to estimate SBW 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 it was decided to survey these areas 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, and 2009. All these surveys have been carried out from R.V. *Tangaroa* using towed transducers and have been wide-area surveys intended to survey spawning SBW and pre-recruits. The results of these surveys have been the main input into SBW stock assessments for the last decade (e.g., Hanchet et al. 2006). Various designs for acoustic surveys of SBW were investigated using simulation studies by Dunn & Hanchet (1998) and Dunn et al. (2001), whilst Hanchet et al. (2000a) examined diel variation in southern blue whiting density estimates.

The primary objective of the 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 SBW 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 SBW marks into categories of adult, immature (mainly 2 and 3 year olds), and juvenile (mainly 1 year olds). However, in some areas and years the marks classified as adults also contained some immature 2 and 3 year olds, whilst juveniles were often a mix of 1 and 2 year old fish. This problem was addressed by Hanchet et al. (2000b) who re-analysed the early R.V. *Tangaroa* acoustic survey and decomposed the estimates into age 1, 2, 3, and 4 year old and over fish. These decomposed estimates were further reanalysed by Grimes et al. (2007) who: (i) incorporated the new target strength-fish length relationship of Dunford & Macaulay (2006), (ii) used the new sound absorption coefficient of Doonan et al. (2003), (iii) included corrections and changes to strata areas, and (iv) estimated c.v.s of the decomposed estimates by age. More recently, estimates of biomass of the SBW categories were recalculated along similar lines (i.e. revising (i)-(iii) above) (Grimes et al. 2010).

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 (c.v. = 34%).

4.1.2 Bounty Platform

Two time series of acoustic indices are available for the Bounty Platform stock. The first was a wide-area time series of aged 2, 3, and 4+ SBW using R.V. *Tangaroa* from 1993 to 2001 (Table 5 and Table 6).

A time series of aggregation or limited area acoustic surveys using industry vessels (typically from only one vessel in each year) was initiated in 2004, and continued to 2009 (Table 7). The industry surveys had mixed levels of success. 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 et al. 2006).

Table 5: R.V. *Tangaroa* juvenile, immature, and mature acoustic biomass estimates for the Bounty Platform using the revised target strength and sound absorption coefficient, 1993–2001 (Grimes et al. 2010).

Year	Juvenile		Immature		Sub-adult		Adult	
	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.
1993	18 024	0.27	20 607	0.33			61 177	0.58
1994	305	0.80	24 039	0.27			40 769	0.25
1995	160 790	0.37	0				34 246	0.24
1997	336	0.67	12526	0.54			61316	0.37
1999	1 682	0.59	1 009	0.37			42 466	0.75
2001[1]	–	0.00	6 328	0.28	2 305	0.12	21 883	0.35

1. In 2001, and additional category of 'sub-adults' was used.

Table 6: R.V. *Tangaroa* age 1, 2, 3 and 4+ acoustic biomass estimates for the Bounty Platform using the revised target strength and sound absorption coefficient, 1993–2001 (Grimes et al. 2007).

Year	Age 1		Age 2		Age 3		Age 4+	
			Biomass	c.v.	Biomass	c.v.	Biomass	c.v.
1993	29 057	0.23	11 347	0.25	777	0.37	47 087	0.64
1994	299	0.81	9 082	0.28	36 445	0.25	20 844	0.25
1995	155 460	0.37	7 108	0.32	7 874	0.34	23 480	0.24
1997	5 054	0.39	7 274	0.36	30 668	0.41	31 929	0.32
1999	993	0.57	1 134	0.33	5618	0.62	34 194	0.73
2001	379	0.16	4 669	0.23	7 261	0.19	16 396	0.36

Table 7: Industry vessel acoustic biomass estimates for the Bounty Platform with the revised target strength and sound absorption coefficient, 2004–09.

Year	Biomass	c.v.	Source
2004	13 473	0.69	O'Driscoll 2005
2006	21 765	0.12	O'Driscoll et al. 2006
2007	159 589	0.19	O'Driscoll et al. 2007
2008	144 187	0.34	O'Driscoll & Dunford 2008
2009	36 814	0.24	O'Driscoll et al. 2009

4.1.3 Campbell Island Rise

As of 2009, nine acoustic surveys of the Campbell Island Rise spawning grounds have been completed using R.V. *Tangaroa*; results of recent surveys were reported by Hanchet et al. (2003, 2002), O'Driscoll et al (2005), O'Driscoll et al. (2007) and are summarised in Table 8 and Table 9.

The first industry survey of the Campbell Island stock was carried out from F.V. *Aoraki* in September 2003 (O'Driscoll & Hanchet 2004). This demonstrated that industry vessels with hull-mounted acoustic systems could also be used to collect acoustic data on SBW in good weather (less than 25 knots of wind). However, surveys from industry vessels on the Campbell Island grounds in subsequent years (e.g., O'Driscoll et al. 2006), have not been successful and have not provided estimates useful for assessment.

Table 8: R.V. *Tangaroa* juvenile, immature, and mature acoustic biomass estimates for the Campbell Island Rise using the revised target strength and sound absorption coefficient, 1993–2009 (Grimes et al. 2010).

Year	Juvenile		Immature		Adult	
	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.
1993	0		129 380	0.25	28 649	0.24
1994	0		26 280	0.38	180 439	0.34
1995	0		48 844	0.29	123 124	0.30
1998	2 103	0.45	26 987	0.20	171 199	0.14
2000	2 468	0.39	6 074	0.24	138 196	0.17
2002	13 228	0.39	681	0.76	116 178	0.68
2004	3 090	0.67	16 833	0.16	79 074	0.35
2006	1 458	0.38	9 968	0.24	128 754	0.32
2009	0		98 098	0.26	204 539	0.27

Table 9: R.V. *Tangaroa* age 1, 2, 3 and 4+ acoustic biomass estimates for the Campbell Island Rise using the revised target strength and sound absorption coefficient, 1993–2009 (Grimes et al. 2007).

Year	Age 1		Age 2		Age 3		Age 4+	
	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.
1993	210	1.72	107 227	0.28	13 320	0.23	16 798	0.25
1994	699	0.57	19 634	0.29	168 006	0.32	23 213	0.28
1995		0.00	17 269	0.27	27 952	0.21	124 892	0.25
1998	8 678	0.25	20 895	0.15	35 579	0.12	139 388	0.18
2000	2 443	0.38	15 606	0.16	8 785	0.16	110 931	0.17
2002	13 436	0.38	4 610	0.63	10 632	0.62	103 423	0.66
2004	3 144	0.65	24 380	0.15	36 683	0.30	39 007	0.39
2006	1 284	0.32	24 848	0.23	12 606	0.34	102 186	0.32
2009	0	–	110 252	0.22	115 944	0.26	92 598	0.27

4.1.4 Pukaki Rise

Five acoustic surveys of the Pukaki Rise spawning grounds have been completed using the *Tangaroa* (Table 10 and Table 11).

Large aggregations of spawning SBW were detected by vessels fishing on the Pukaki Rise in 2009. Three vessels opportunistically collected acoustic data on these aggregations. The acoustic biomass estimates for the two daytime snapshots at the Pukaki Rise in 2009 were 26 000 t (c.v. 29%) and 17 000 t (c.v. 41%), which is of a similar magnitude to the abundance of 4+ SBW estimated from previous wide-area acoustic surveys of the area (Table 10).

Table 10: R.V. *Tangaroa* juvenile, immature, and mature acoustic biomass estimates for the Pukaki Rise using the revised target strength and sound absorption coefficient, 1993–2000 (Grimes et al. 2010).

Year	Juvenile		Immature		Sub-adult		Adult	
	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.
1993	0	–	31 406	0.25			42 817	0.32
1994	0	–	544	1.00	7 488	0.48	43 094	0.69
1995	0	–	0	–			10 936	0.18
1997	0	–	4 104	0.12			27 576	0.34
2000	0	–	5 760	0.62	16 695	0.74	12 341	0.37

Table 11: R.V. *Tangaroa* age 1, 2, 3 and 4+ acoustic biomass estimates for the Pukaki Rise using the revised target strength and sound absorption coefficient, 1993–2000 (Grimes et al. 2007).

Year	Age 1		Age 2		Age 3		Age 4+	
	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.	Biomass	c.v.
1993	1 055	0.18	41 966	0.16	9 206	0.31	18 822	0.30
1994	23	0.80	1 978	0.38	8 910	0.32	27 124	0.40
1995	0	–	144	0.18	884	0.18	8 382	0.18
1997	41	0.12	4 442	0.13	890	0.29	22 696	0.32
2000	102	0.63	10 183	0.42	5 584	0.57	16 277	0.50

4.2 Trawl research surveys

Trawl surveys of the subantarctic targeting hoki, hake, and ling have been carried out from R.V. *Tangaroa* since 1991 (e.g., O'Driscoll & Bagley 2009). Although SBW 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 subantarctic 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 5). As part of this compilation we updated their analysis and have updated the tables of biomass estimates for the four most recent surveys from 2006 to 2009.

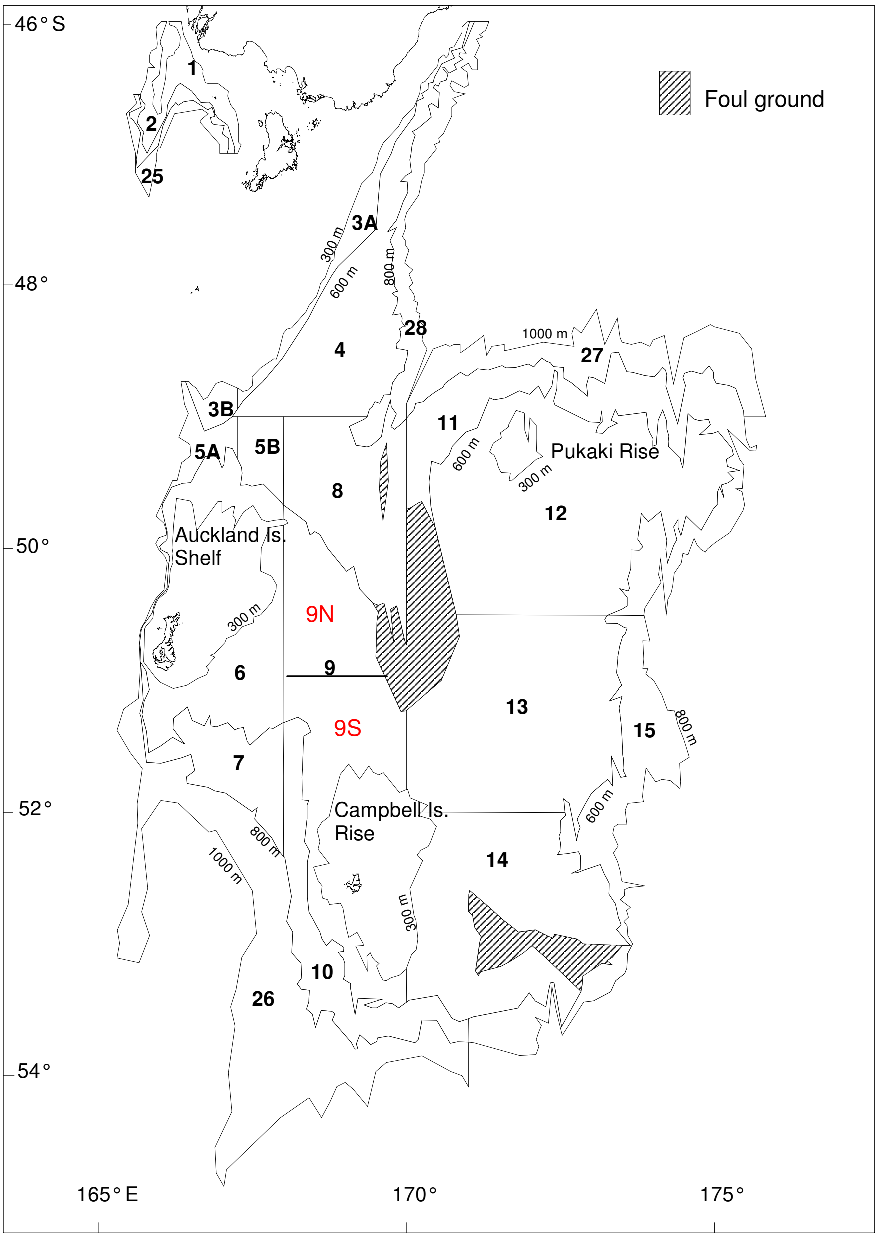

Figure 5: Survey area and stratum boundaries used for subantarctic trawl surveys since 1996. Stratum 9 was split into 9N and 9S at 51ºS for the analysis.

4.2.1 Auckland Islands Shelf

The c.v.s of the biomass estimates for the Auckland Islands Shelf were typically 60–90%, making them too imprecise for monitoring abundance (Table 12). There was also 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 c.v.s, it is extremely unlikely that the trawl survey indices are monitoring abundance on the Auckland Islands Shelf. Although the c.v.s of the biomass estimates have reduced slightly in recent years, it is still unknown whether this index is monitoring the abundance of this stock.

Table 12: R.V. *Tangaroa* trawl survey biomass estimates for the Auckland Islands Shelf (Hanchet & Stevenson (2006), this study).

	Summer				Autumn		
Year	Biomass (t)	c.v.	N	Year	Biomass (t)	c.v.	N
1991	565	0.747	58	1992	41	0.798	29
1992	125	0.976	60	1993	159	0.893	44
1993	3 458	0.599	51	1996	447	0.329	40
2000	135	0.606	43	1998	746	0.689	25
2001	527	0.683	40				
2002	68	0.758	42				
2003	281	0.852	30				
2004	28	0.694	34				
2005	1 543	0.977	40				
2006	1 136	0.812	25				
2007	1 720	0.438	26				
2008	682	0.328	23				
2009	3 227	0.497	24				

4.2.2 Campbell Island Rise

The c.v.s of the biomass estimates for the Campbell Island Rise were mainly 25–40%, making them only marginally useful for monitoring abundance (Table 13). There was some consistency in biomass estimates between the summer and autumn series and also between adjacent surveys. 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, it appeared that the trawl survey underestimates biomass at low stock sizes and overestimates biomass at high stock sizes. They noted that increasing station density would improve the precision of the surveys, but it is unknown whether it would completely remove this bias. The recent increase in biomass estimates from the surveys is consistent with the increase in acoustic indices (see Table 8).

Table 13: R.V. *Tangaroa* trawl survey biomass estimates for the Campbell Island Rise (Hanchet & Stevenson (2006), this study).

	Summer				Autumn		
Year	Biomass (t)	c.v.	N	Year	Biomass (t)	c.v.	N
1991	2 328	0.527	52	1992	5 942	0.581	39
1992	5 013	0.314	54	1993	1 714	0.287	34
1993	2 472	0.251	52	1996	31 222	0.356	20
2000	10 738	0.144	23	1998	10 321	0.366	17
2001	6 393	0.403	23				
2002	3 198	0.447	20				
2003	1 047	0.557	19				
2004	778	0.260	21				
2005	1 502	0.274	17				
2006	4 965	0.698	21				
2007	3 272	0.459	23				
2008	6 018	0.286	19				
2009	5 347	0.291	18				

4.2.3 Pukaki Rise

The c.v.s of the biomass estimates for the Pukaki were quite variable between years but mainly in the range 25–40%, making them only marginally useful for monitoring abundance (Table 14). There was some consistency in biomass estimates between the summer and autumn series and also between adjacent surveys. Hanchet & Stevenson (2006) noted that there was generally poor agreement between trawl survey indices and estimates of biomass from the population model and that this could be due problems with the modelled biomass, trawl survey indices, or both. They also noted that station densities had declined in the core Pukaki Rise stratum 12 over time. After reviewing the analysis, 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 done when time allowed in recent surveys (e.g., O'Driscoll & Bagley 2009). The biomass estimates have shown a large increase since 2006, but it is still unknown whether this index is monitoring the abundance of this stock.

Table 14: R.V. *Tangaroa* trawl survey biomass estimates for the Pukaki Rise (Hanchet & Stevenson (2006), this study).

	Summer				Autumn		
Year	Biomass (t)	c.v.	N	Year	Biomass (t)	c.v.	N
1991	3 037	0.311	30	1992	2 894	0.604	17
1992	2 368	0.315	29	1993	3 684	0.440	16
1993	3 550	0.237	20	1996	13 698	0.647	15
2000	6 659	0.329	10	1998	11 102	0.312	10
2001	2 995	0.263	14				
2002	3 251	0.628	12				
2003	1 731	0.355	12				
2004	2 537	0.469	10				
2005	1 109	0.180	10				
2006	911	0.429	10				
2007	3 745	0.285	12				
2008	9 078	0.135	14				
2009	45 657	0.848	12				

4.3 CPUE analysis

Standardised CPUE analyses were carried out for the southern blue whiting (SBW) 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 is shown for the four areas in Table 15.

4.3.1 Bounty Platform

The Bounty Platform analysis was based on a data set of 3288 non-zero records from 1990 to 2002 (Hanchet & Blackwell 2003). The CPUE indices fluctuated considerably, peaking in 1992, 1996–1998, and again in 2002 (Table 16). 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 lower indices in the first two years may be due to lack of experience, whilst the higher indices in the last two years are suggestive of hyperstability. The authors noted that the CPUE indices needed to be more fully examined in a modelling context, and possible reasons for hyperstability examined further, before the indices could be endorsed. 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 15: Unstandardised median catch effort indices (t/hour) for the Auckland Islands, Bounty Platform, Campbell Island Rise, and Pukaki Rise fisheries, July–October 1990–2009 (source: TCEPR data).

Year	Auckland Islands	Bounty Platform	Campbell Island Rise	Pukaki Rise
1990	0.0	7.1	3.6	1.7
1991	0.3	4.9	4.7	5.0
1992	0.9	10.6	1.8	1.4
1993	8.0	7.3	5.3	2.8
1994	0.1	2.5	6.3	4.8
1995	1.6	8.5	6.5	4.1
1996	1.6	8.4	7.4	20.3
1997	6.7	10.6	5.9	4.7
1998	4.8	8.8	7.0	4.7
1999	2.3	10.0	10.8	18.4
2000	0.0	6.7	6.7	1.9
2001	0.0	15.3	7.2	0.2
2002	0.0	7.7	6.5	0.1
2003	0.0	14.3	7.8	0.2
2004	0.1	5.5	7.6	0.2
2005	0.1	9.7	7.3	0.5
2006	0.1	7.8	10.0	4.1
2007	0.1	14.0	9.8	1.0
2008	0.1	17.6	9.5	14.8
2009	0.3	13.1	8.4	11.0

Table 16: Relative year effects and standard errors for all vessels catch per tow model 1990 to 2002 for the Bounty Platform fishery (Hanchet & Blackwell 2003).

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

4.3.2 Campbell Island Rise

The original Campbell Island Rise analysis was based on 11 853 non-zero 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 was updated to 2005 by Hanchet et al. (2006), who found that there was some divergence in the CPUE indices between the various models in the years 2002 to 2005 Table 17). 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 17: Relative year effects and standard errors 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).

Year	Catch per hour model			Catch per tow model		
	Year index	s.e.	CPUE (t/hr)	Year index	s.e.	CPUE (t/tow)
1986	1.00	–	9.7	1.00	–	14.9
1987	0.79	0.06	7.7	0.91	0.06	15.4
1988	0.59	0.05	6.7	0.88	0.06	19.9
1989	0.68	0.07	8.7	1.40	0.12	27.2
1990	0.52	0.05	7	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
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	2.34	0.29	42
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
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 SBW stock assessments. We tabulate a summary of the raw data on which these catch-at-age estimates are based for each area below. The raw LF data were examined graphically for variability in length composition by time of season and/or locality within each of the main areas, and divided into appropriate strata. The length frequency data for each tow were first scaled up to the catch from 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. Where possible, 400–500 otoliths were read for each area/year combination. Before 2002, the catch-at-age was estimated by combining the scaled length frequency data with the age-length key using the old NIWA catch-at-age software. Catch-at-age data for each stock were re-analysed in 2002 using the new NIWA catch-at-age software (Bull & Dunn 2002) and the revised catch-at-age series for the Bounty Platform and Campbell Island Rise were summarised by Hanchet (2005) and Hanchet et al. (2003) respectively. This software produces c.v.s that incorporate the variance from both the length-frequency data and the age-length key using bootstrapping, and is an improvement over earlier algebraic calculations. Some of the age-length keys used for the analysis were also slightly modified during that re-analysis. 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. We therefore ensured that 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 11 for modelling.

As part of the current project, the catch-at-age analysis for all areas has been repeated using updated length data for each area over July–October and the original age-length keys. As in the original analysis, two strata were retained for the Campbell Island stock, but one stratum was used elsewhere.

5.2 Auckland Islands

The Auckland Islands have been fished only sporadically since 1990 (Table 18). Some targeting of aggregations of SBW during the spawning season occurred between 1993 and 1998, but since then most of the SBW catch has been taken as bycatch of fisheries targeting hoki, hake, ling, and squid during other months of the year (Hanchet & Dunn 2009). Almost 86% of the catch but only 37% of the tows have been made in July to October. Small numbers of fish were measured in 2007 and 2008 (Figure 6, Table 18), but few otoliths were collected and these have not been read. Catch-at-age data are available only for 1993 to 1998 (Figure 7). The catch at that time was dominated by the strong 1991 year class.

Table 18: Number of tows and TCEPR total estimated catch, observed tows and total estimated catch, number of measured and aged males and females, Auckland Islands 1990–2009 (source: TCEPR and Observer data, 1990–2009).

Season	Catch			Observed				Measured		Aged	
	Vessels	Tows	t	Vessels	Tows	t	%t	Male	Female	Male	Female
1990	2	4	0	0	0	0	0.0	0	0	0	0
1991	2	4	5	0	0	0	0.0	0	0	0	0
1992	2	6	73	0	0	0	0.0	0	0	0	0
1993	5	20	1 143	2	5	457	40.0	495	264	28	37
1994	10	62	1 056	1	7	324	30.6	601	563	57	79
1995	4	14	408	4	10	345	84.4	732	974	46	94
1996	3	4	54	0	0	0	0.0	0	0	0	0
1997	5	17	935	3	11	517	55.4	1 019	827	126	114
1998	5	13	520	1	6	238	45.8	649	550	80	38
1999	3	14	223	0	0	0	0.0	0	0	0	0
2000	3	14	7	0	0	0	0.0	0	0	0	0
2001	2	5	0	0	0	0	0.0	0	0	0	0
2002	3	7	45	2	3	3	6.0	100	89	20	25
2003	7	37	14	0	0	0	0.0	0	0	0	0
2004	3	31	27	1	1	4	16.7	12	28	0	0
2005	3	15	43	0	0	0	0.0	0	0	0	0
2006	4	25	35	0	0	0	0.0	0	0	0	0
2007	6	218	240	2	5	4	1.8	107	77	0	0
2008	4	52	67	1	11	16	24.4	307	220	0	0
2009	2	11	21	0	0	0	0.0	0	0	0	0

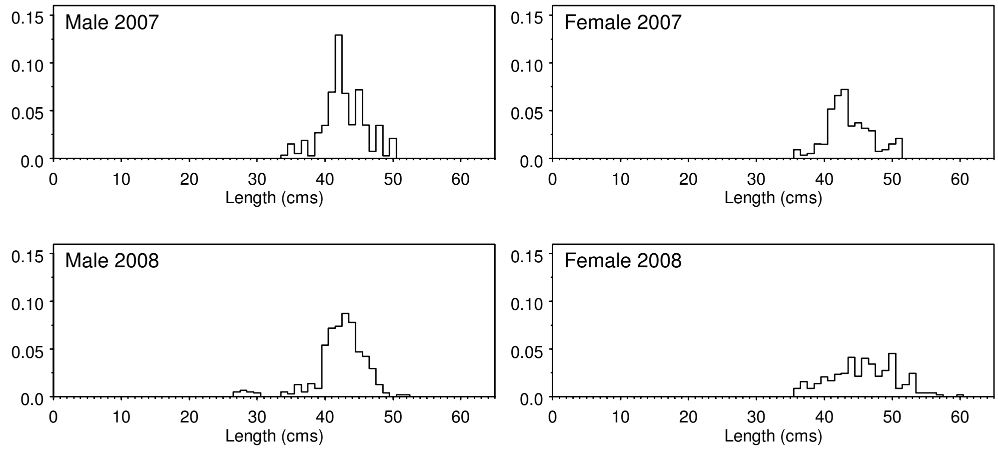

Figure 6: Commercial catch proportions at length for the Auckland Islands by sex, 2007–08.

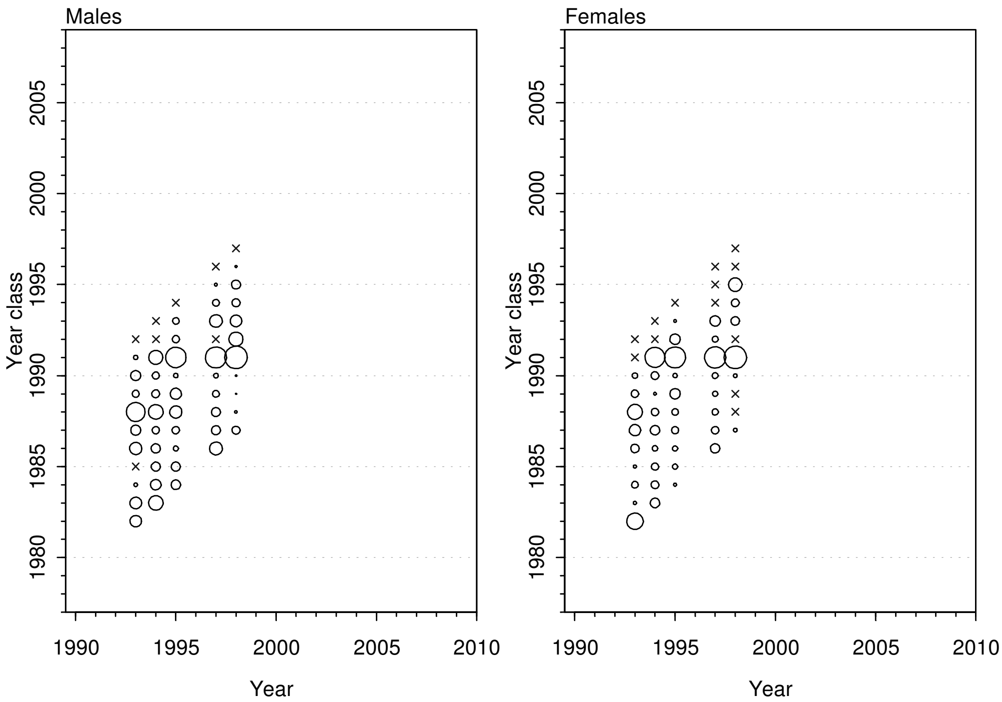

Figure 7: Commercial catch proportions at age for the Auckland Islands stock by sex and year class, 1990–2009. Symbol area proportional to the proportions-at-age within the sampling event.

5.3 Bounty Platform

The Bounty Platform has been fished annually since 1990 (Table 19). Almost 100% of the catch and over 97% of the tows have been made in July to October.

Catch-at-age data are available for the entire period 1990 to 2009, although the numbers of fish measured and aged were low in some years and completely lacking in 2003 (Table 19). 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 is currently 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 2009 when it completely dominated the fishery as 7 year olds (Figure 8). This year class is believed to be particularly strong (Hanchet & Dunn 2009). The catch over the 20 year period has been dominated by several other strong year classes — in particular those from 1986, 1988, 1991, 1992, and 1994 (Figure 9).

Table 19: Number of tows and TCEPR total estimated catch, observed tows and total estimated catch, number of measured and aged males and females, Bounty Platform, 1990–2009 (source: TCEPR and Observer data, 1990–2009).

Year	Catch			Observed				Measured		Aged	
	Vessels	Tows	t	Vessels	Tows	t	%t	Male	Female	Male	Female
1990	22	227	4 430	5	23	391	8.8	2 569	1 690	135	118
1991	31	616	11 229	3	16	458	4.1	1 613	1 140	85	56
1992	49	1 659	58 643	10	161	10 086	17.2	12 921	13 479	318	282
1993	19	345	11 908	6	72	5 037	42.3	4 901	7 065	213	319
1994	8	139	3 877	4	40	2 836	73.1	4 202	3 126	255	252
1995	10	135	6 730	5	65	5 816	86.4	5 992	4 299	215	189
1996	5	60	5 113	2	22	2 511	49.1	2 171	2 465	201	280
1997	7	33	2 215	3	8	689	31.1	692	884	151	293
1998	13	105	5 837	6	69	5 627	96.4	7 574	6 743	211	261
1999	14	248	10 573	5	73	4 765	45.1	6 145	6 217	195	383
2000	6	79	3 851	3	27	2 716	70.5	1 858	3 323	110	288
2001	4	25	1 554	2	12	1 060	68.2	836	1 133	218	283
2002	7	92	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	31	1 478	2	11	643	43.5	1 037	1 059	80	111
2005	6	99	3 769	4	40	2 818	74.8	3 212	3 256	159	261
2006	5	94	4 256	3	62	3 375	79.3	5 658	4 231	232	268
2007	4	49	3 602	3	27	3 458	96.0	2 118	2 124	110	190
2008	9	199	9 582	4	90	6 488	67.7	6 082	9 706	97	209
2009	13	401	15 009	4	104	5 269	35.1	7 637	8 526	130	292

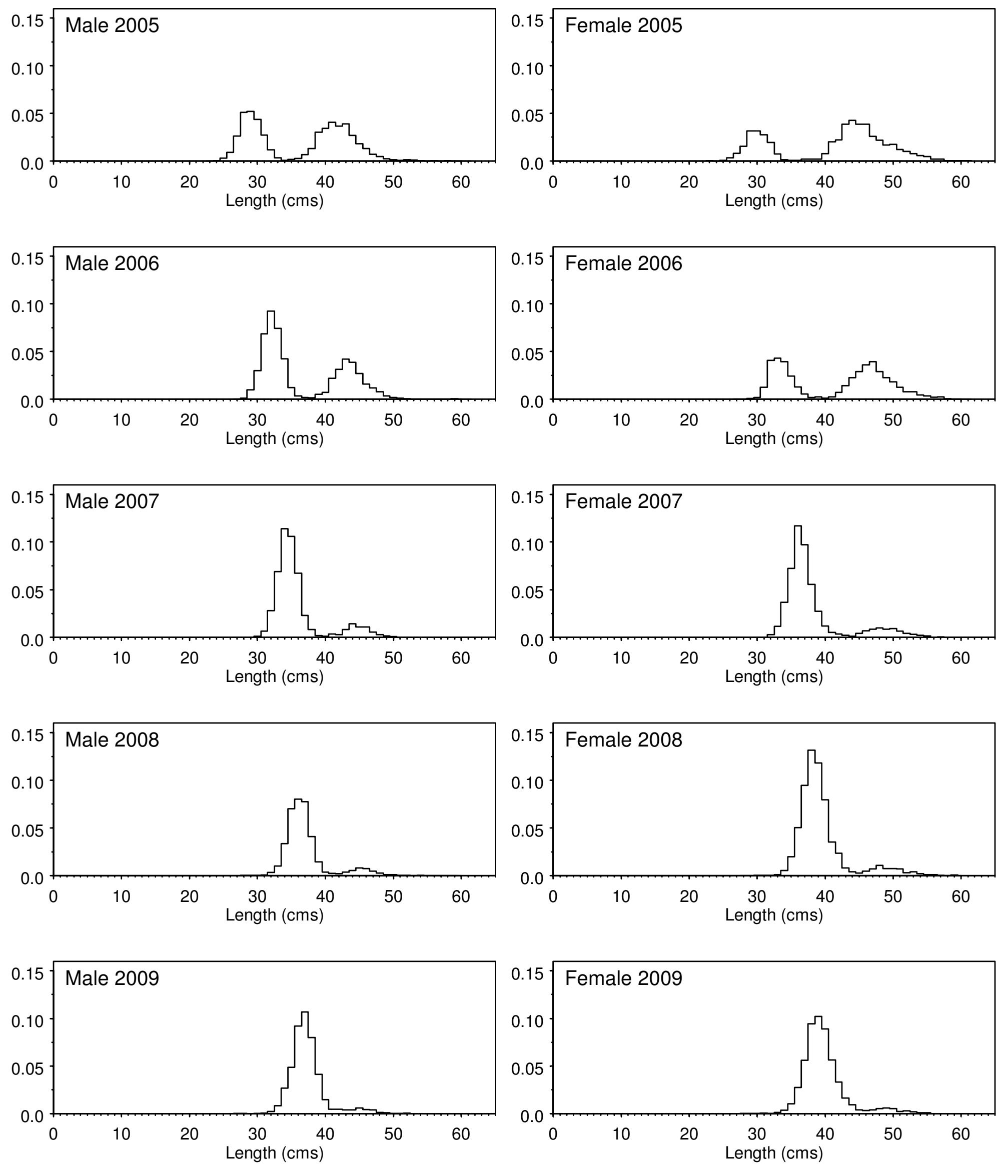

Figure 8: Commercial catch proportions at length for the Bounty Platform by sex, 2005–09.

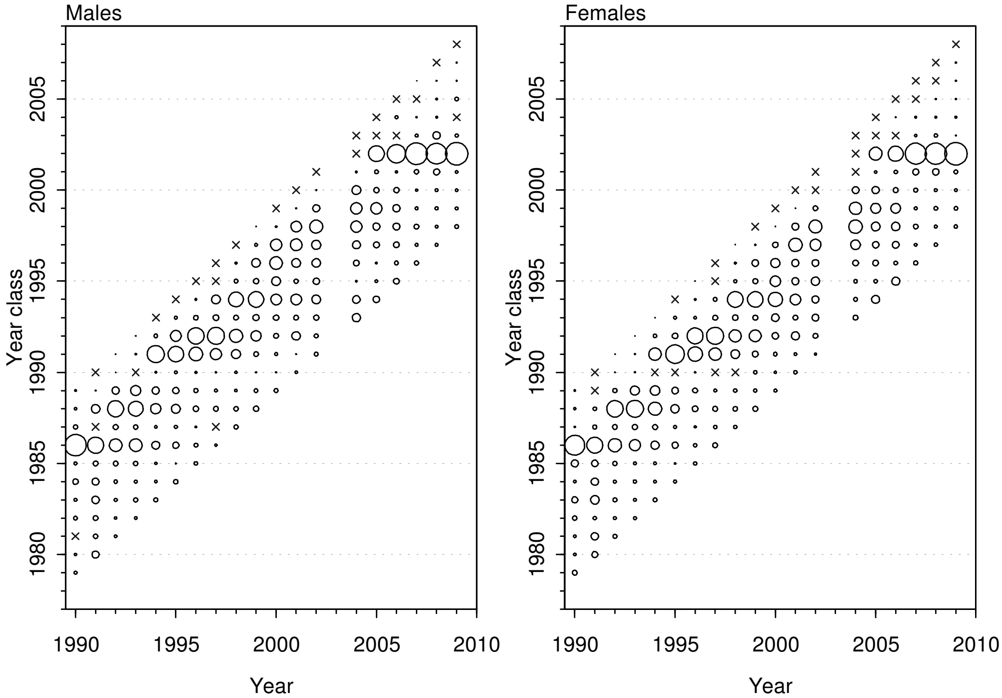

Figure 9: Commercial catch proportions at age for the Bounty Platform stock by sex and year class, 1990–2009. Symbol area proportional to the proportions-at-age within the sampling event.

5.4 Campbell Island Rise

The Campbell Island Rise has been fished consistently since 1979, although we have restricted the data presented here to 1990–2009 (Table 20). Almost 100% of the catch and over 96% of the tows during these years have been made in July to October.

Catch-at-age data are available for the entire period 1990 to 2009, although the proportion of the catch observed was low in some years (Table 20) Examination of the raw data showed that the length composition was often different between the northern and southern Campbell Island Rise. Therefore, the analysis was carried out by dividing the area into two strata (at 52º 30'S) for each year. The catch is currently dominated by two main modes: a mode of larger fish comprising the 2001 and 2002 year classes and a mode of smaller fish at about 30 cm which are 3 year olds of the 2006 year class (Figure 10). The catch over the 20 year period has been dominated by several other strong year classes – in particular those from 1988, 1991, and 2001 (Figure 11).

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

Table 20: Number of tows and TCEPR total estimated catch, observed tows, and total estimated catch, number of measured and aged males and females, Campbell Island Rise, 1990–2009 (source: TCEPR and Observer data, 1990–2009).

Year	Catch			Observed				Measured		Aged	
	Vessels	Tows	t	Vessels	Tows	t	%t	Male	Female	Male	Female
1990	35	950	16 569	7	94	2 508	15.1	10 459	7 677	287	223
1991	34	1 183	21 826	3	52	1 107	5.1	3 852	4 864	281	413
1992	48	1 191	13 506	10	121	1 911	14.1	12 131	10 060	330	287
1993	19	364	8 942	5	55	2 722	30.4	4 456	4 623	247	321
1994	15	451	11 649	4	80	5 622	48.3	8 458	4 717	416	346
1995	12	273	10 144	5	76	7 726	76.2	5 807	7 301	212	358
1996	11	450	16 659	4	97	5 406	32.4	7 802	10 270	182	347
1997	17	622	19 074	6	185	9 476	49.7	16 756	16 254	239	255
1998	24	908	24 350	8	254	12 740	52.3	26 603	23 237	259	361
1999	21	769	27 206	9	175	11 308	41.6	15 024	15 522	228	190
2000	18	446	14 470	10	167	9 695	67.0	14 816	14 193	210	289
2001	16	653	24 445	10	321	19 144	78.3	27 994	25 500	135	269
2002	19	861	29 148	7	185	9 863	33.8	15 990	16 212	178	319
2003	15	619	22 703	5	124	2 922	12.9	9 259	10 979	236	383
2004	16	680	19 513	8	143	7 613	39.0	13 109	13 147	251	398
2005	17	746	25 200	6	187	9 041	35.9	14 184	18 757	147	262
2006	13	510	18 905	4	110	7 653	40.5	11 779	7 700	206	294
2007	13	544	20 437	6	119	8 345	40.8	10 291	11 504	182	234
2008	14	547	19 723	6	171	9 658	49.0	15 112	14 513	225	252
2009	14	611	18 424	3	53	3 145	17.1	4 506	3 856	123	311

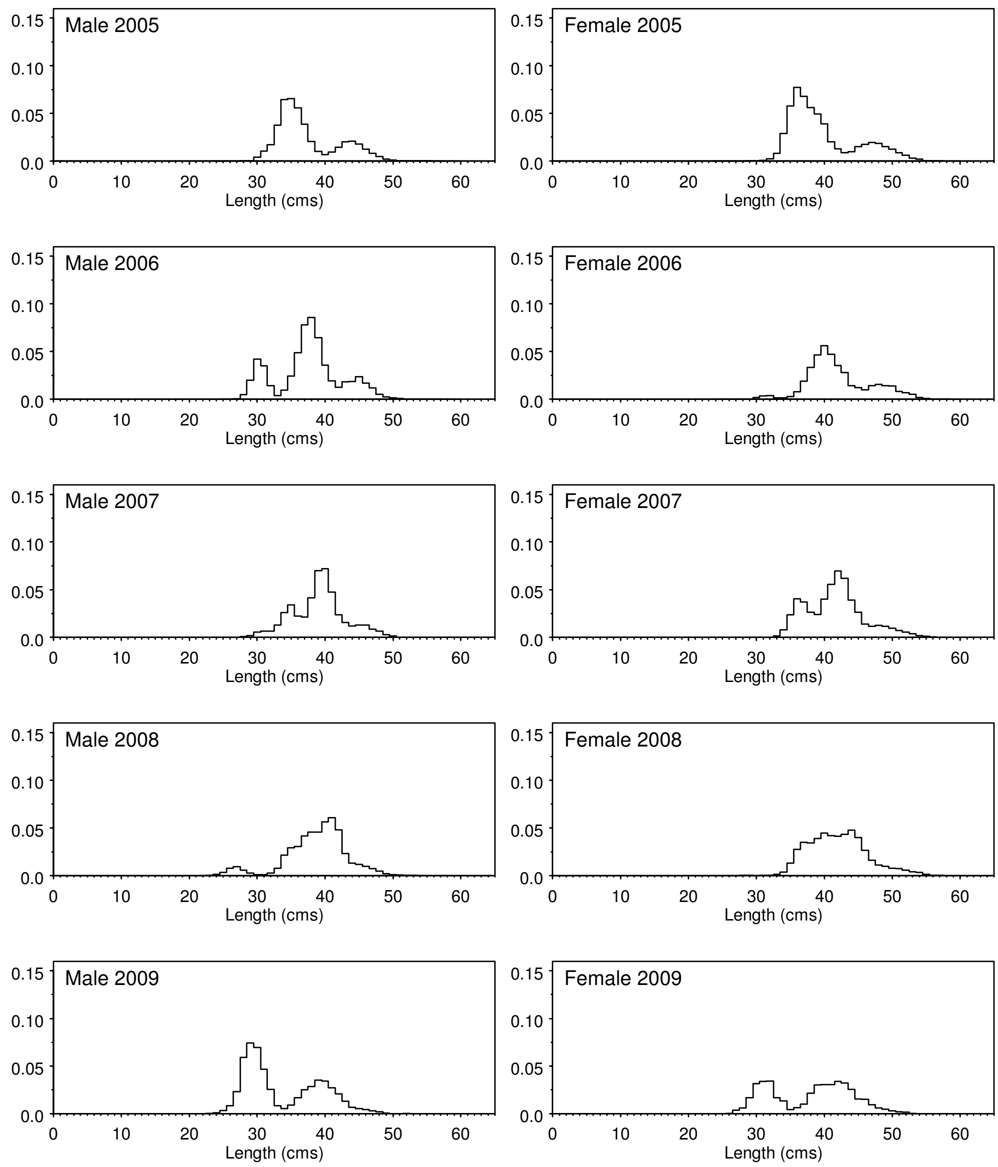

Figure 10: Commercial catch proportions at length for the Campbell Island Rise stock by sex, 2005–09.

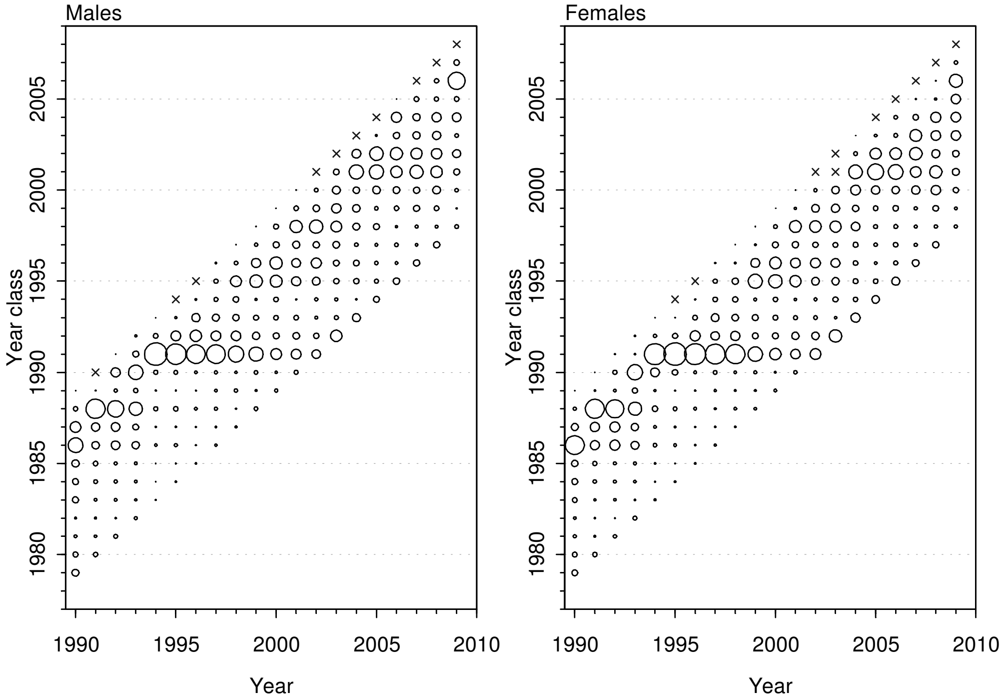

Figure 11: Commercial catch proportions at age for the Campbell Island Rise stock by sex and year class, 1990–2009. Symbol area proportional to the proportions-at-age within the sampling event.

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 (Table 21). Almost 95% of the catch but only 55% of the tows have been made in July to October. Most of the remaining tows were targeting hoki and other middle depth species (Hanchet & Dunn 2009).

Catch-at-age data are available for 1989 to 2000 and again for 2007 and 2009, although the numbers of fish measured and aged were low in some years (Table 21). 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 is currently dominated by two main modes: a mode of larger fish comprising the 2003–05 year classes and a mode of smaller fish at about 30 cm which are 3 year olds of the 2006 year class (Figure 12). The catch over the 20 year period has been dominated by several other strong year classes – in particular those from 1985, 1986, 1990, and 1991 (Figure 13).

Table 21: Number of tows and TCEPR total estimated catch, observed tows and total estimated catch, number of measured and aged males and females, Pukaki Rise 1990–2009 (source: TCEPR and Observer data, 1990–2009).

Year	Catch			Observed				Measured		Aged	
	Vessels	Tows	t	Vessels	Tows	t	%t	Male	Female	Male	Female
1990	26	150	1 285	6	20	204	15.9	2 624	1 050	181	194
1991	25	252	4 660	4	24	771	16.6	1 983	2 265	191	282
1992	39	319	2 933	5	23	227	7.8	1 914	2 000	233	243
1993	22	326	5 341	6	43	2 004	37.5	3 496	3 237	234	345
1994	11	64	1 915	4	22	1 191	62.2	1 831	1 940	222	188
1995	8	52	1 364	4	12	725	53.2	885	1 136	240	274
1996	4	8	299	1	1	112	37.5	72	113	0	0
1997	8	45	2 121	4	24	1 609	75.9	1 720	2 312	184	305
1998	11	34	1 227	7	18	1 248	101.8	1 686	1 756	174	168
1999	6	20	955	0	0	0	0.0	0	0	0	0
2000	11	80	2 402	3	15	1 475	61.4	1 236	1 703	172	229
2001	12	46	284	1	2	45	15.9	153	157	0	0
2002	6	24	111	0	0	0	0.0	0	0	0	0
2003	3	13	19	0	0	0	0.0	0	0	0	0
2004	5	24	53	0	0	0	0.0	0	0	0	0
2005	4	6	44	1	1	4	8.3	85	69	0	0
2006	4	24	1 048	0	0	0	0.0	0	0	0	0
2007	6	26	390	1	4	103	26.4	382	287	39	48
2008	4	54	1 306	1	1	4	0.3	63	117	0	0
2009	11	175	4 768	4	48	1 078	22.6	3 016	3 953	164	261

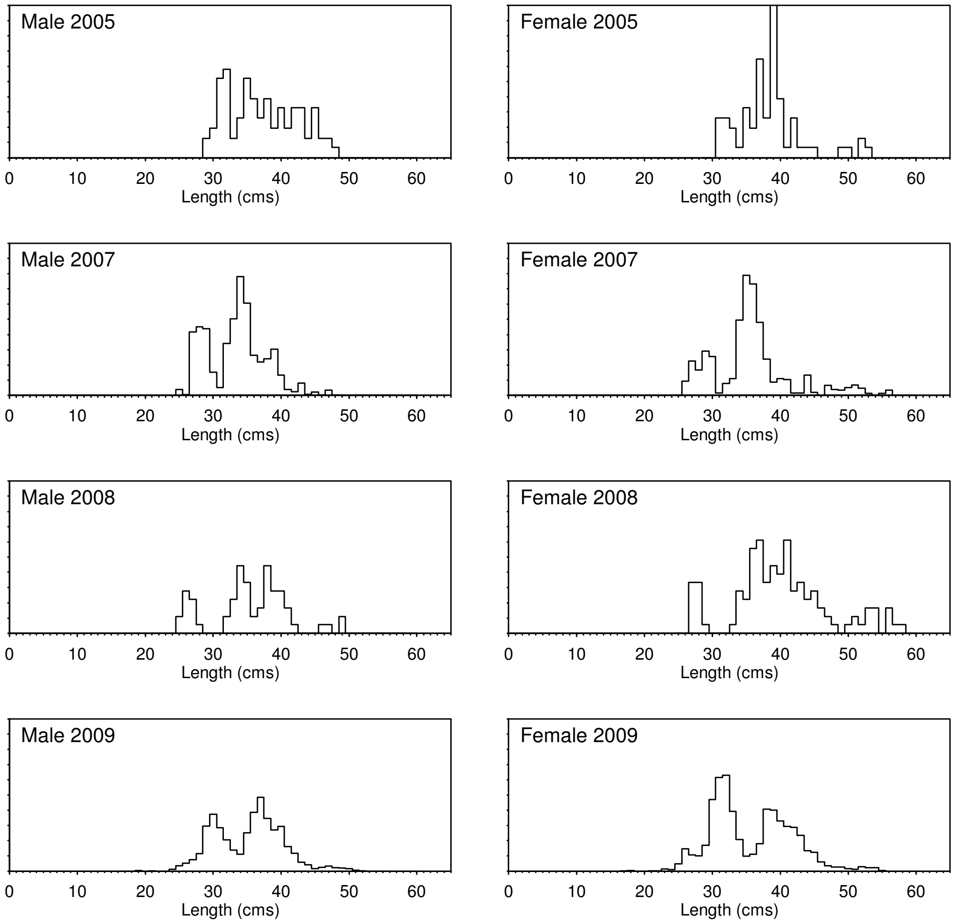

Figure 12: Commercial catch proportions at length for the Pukaki Rise stock by sex, 2005–09.

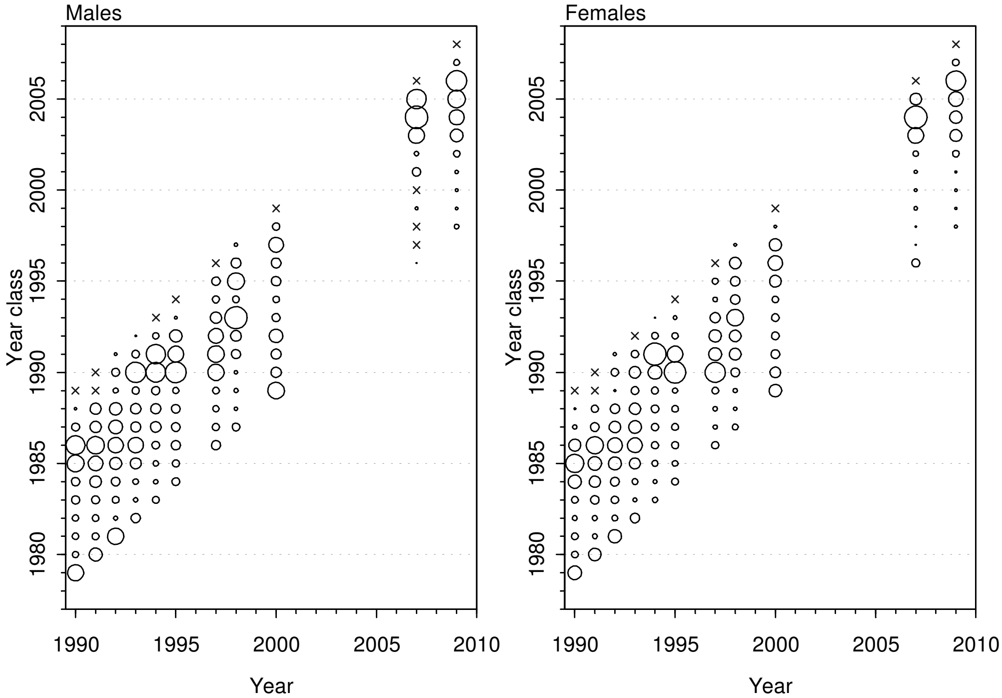

Figure 13: Commercial catch proportions at age for the Pukaki Rise stock by sex and year class, 1990–2009. Symbol area proportional to the proportions-at-age within the sampling event.

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. Some large catches reported from this area between 1990 and 1996 are almost certainly errors in the TCEPR database (Table 22). Almost 98% of the total catch but only 43% of the tows have been made in July to October. Very few of these tows have been observed, but from the few fish measured the catches seem to be dominated by males.

Table 22: Number of tows and TCEPR total estimated catch, observed tows and total estimated catch, number of measured and aged males and females, SBW1 1990–2009 (source: TCEPR and Observer data, 1990–2009).

Year			Catch			Observed		Measured		Aged	
	Vessels	Tows	t	Vessels	Tows	t	%t	Male	Female	Male	Female
1990	5	6	151	0	0	0	0.0	0	0	0	0
1991	5	9	171	0	0	0	0.0	0	0	0	0
1992	10	21	592	0	0	0	0.0	0	0	0	0
1993	4	10	396	0	0	0	0.0	0	0	0	0
1994	4	5	63	0	0	0	0.0	0	0	0	0
1995	3	4	281	1	1	20	7.2	139	19	2	4
1996	1	1	130	0	0	0	0.0	0	0	0	0
1997	3	11	50	0	0	0	0.0	0	0	0	0
1998	2	5	12	0	0	0	0.0	0	0	0	0
1999	2	7	6	0	0	0	0.0	0	0	0	0
2000	0	0	0	0	0	0	0.0	0	0	0	0
2001	3	12	17	0	0	0	0.0	0	0	0	0
2002	3	8	4	0	0	0	0.0	0	0	0	0
2003	1	1	0	1	1	0	100.0	54	1	0	0
2004	1	1	0	0	0	0	0.0	0	0	0	0
2005	0	0	0	0	0	0	0.0	0	0	0	0
2006	1	1	1	0	0	0	0.0	0	0	0	0
2007	1	2	0	0	0	0	0.0	0	0	0	0
2008	2	4	6	0	0	0	0.0	0	0	0	0
2009	2	3	1	0	0	0	0.0	0	0	0	0

6. DISCUSSION

For the first time the large amount of research carried out on southern blue whiting over the past 20 years has been consolidated into one place. We have included here 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 small area industry vessel 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 of acoustic surveys was discontinued. Industry surveys on the Bounty Platform since 2004, and more recently on the Pukaki Rise, have provided biomass estimates for these stocks, and, whilst not without problems, may allow monitoring of these stocks in the future. Industry acoustic surveys on the Campbell Island Rise have been less successful, in part because of the much larger area which needs to be surveyed and the rougher weather conditions. Wide area acoustic surveys using R.V. *Tangaroa* are still the preferred option for monitoring this stock because of the ability to use the acoustic towbody and the reliable estimates of immature (age 2 and 3 year old) fish provided by this survey.

CPUE indices for the Bounty Platform and Campbell Island Rise are available for 1990–2002 and 1986–2005. 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 of Fisheries

2009). Fishing on the other three areas has been too sporadic to warrant a standardised CPUE analysis.

Trawl survey estimates for SBW on the Auckland Islands Shelf, Campbell Island Rise, and Pukaki Rise were updated during the current study and are now available for 1991 to 2009. Although the surveys are not designed to monitor SBW, the biomass estimates for the latter two areas generally had moderate c.v.s, showed some consistency between years, and the trends showed some correspondence with biomass trajectories from stock assessments (Hanchet & Stevenson 2006). Recent increasing trends in trawl survey biomass on both the Campbell Island Rise and Pukaki Rise are consistent with the recent increase in biomass from acoustic indices and increase in catches on these grounds respectively. Additional stations have recently been included for the core Pukaki Rise stratum, and an updated analysis incorporating all data from the more recent trawl surveys is warranted.

The time series of catch-at-age and length at-at-age were updated for this report. The numbers differed only slightly for the original analysis. This was mainly due to additional observer data being loaded after the original analysis was completed and also to the extension of the months used for the analysis to encompass all data from July to October.

Following this review and documentation we make several recommendations. There has been some concern that certain parts of the fleet target larger fish, and so a tree-based regression analysis of the length frequency data for the Bounty and Campbell stocks could be carried out for optimal post-stratification to address this issue. The data used for the estimation of catch-at-age on the Campbell Island Rise before 1990 should be better documented, and if appropriate re-analysed. The trawl survey indices and ancillary data for the Auckland Islands Shelf, Campbell Island Rise, and Pukaki Rise up to and including the 2010 survey should be updated. A fishery characterisation including vessel characteristics and location and months of catches by year and area, including non-spawning season catches, would be useful to identify recent changes in the fishery. The last assessment of the Pukaki Rise was completed in 2002 (Hanchet 2002). Since then, considerable data have been collected, including catch-at-age, acoustic indices, and trawl survey indices which would allow the assessment to be updated.

7. ACKNOWLEDGMENTS

We are grateful to the scientific observers for the collection of the length frequency data and otoliths. Michael Stevenson and Colin Sutton read and processed the SBW otoliths. This project was funded by the Ministry of Fisheries under Projects SBW2008/01 and SBW2009/01.

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