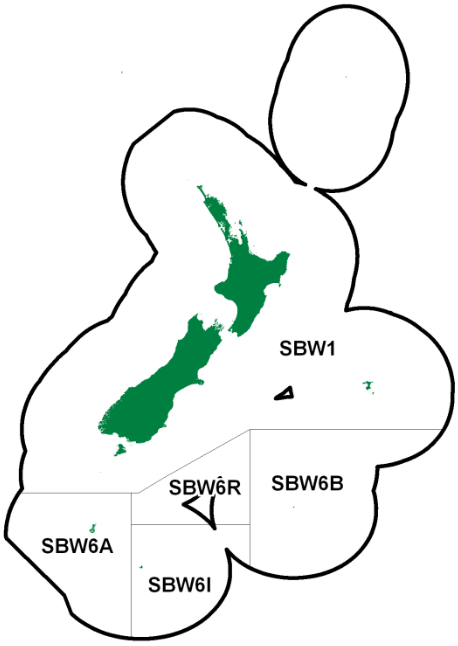
SOUTHERN BLUE WHITING (SBW)

(*Micromesistius australis*)



1. FISHERY SUMMARY

1.1 Commercial fisheries

Southern blue whiting are almost entirely restricted in distribution to Sub-Antarctic 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 the Auckland Islands over depths of 250–600 m. During most years, fish in the spawning fishery range between 35 and 50 cm fork length (FL), although occasionally a smaller size class of males (29–32 cm FL) is also present.

Reported landings for the period 1971 to 1977 are shown in Table 1. Estimated landings by area from the trawl catch and effort logbooks and QMRs are given from 1978 to the present in Table 2, while Figure 1 shows the historical landings and TACC values for the main southern blue whiting stocks. Landings were chiefly taken by the Soviet foreign licensed fleet during the 1970s and early 1980s, and the fishery fluctuated considerably peaking at almost 50 000 t in 1973 and again at almost 30 000 t in 1979. The Japanese surimi vessels first entered the fishery in 1986, and catches gradually increased to a peak of 76 000 t in 1991–92. A catch limit of 32 000 t, with area sub-limits, was introduced for the first time in the 1992–93 fishing year (Table 2). The total catch limit increased to 58 000 t in 1996–97 for three years. The southern stocks of southern blue whiting were introduced to the Quota Management System on 1 Nov 1999, with the TACCs given in Table 2. The fishing year was also changed to 1 April to 31 March to reflect the timing of the main fishing season. TACC changes since 2000–01 are shown in Table 2. A nominal TACC of 8 t (SBW 1) was set for the rest of the EEZ, and typically less than 10 t per year has been reported from SBW 1 since 2000–01.

Landings have been between 25 000 t and 40 000 t since 2000, with the majority of the catch currently taken by foreign charter vessels (predominantly large factory trawlers) producing headed and gutted or dressed frozen product and waste to fishmeal. On the Campbell Island Rise and the Bounty Platform the TACC has been almost fully caught in each year since 2005–06, except on the Campbell Island Rise in 2012–13 where the TACC was significantly under-caught. On the other grounds, the catch limits have often been under-caught in most years since their introduction. This reflects the economic value of the fish and difficulties experienced by operators in both timing their arrival on the grounds and locating the aggregations of fish. On the Pukaki Rise and Auckland Islands Shelf, operators have generally found it difficult to justify expending time to locate fishable aggregations, given the small allocation available in these areas, the small fish size and relatively low value of the product, and the more certain option available to fish southern blue whiting at Campbell Island where aggregations are concurrent.

The TACC for the Bounty Platform stock was increased to 9800 t for the 2008 season and further increased to 14 700 t for the 2009 and 2010 seasons but decreased to 6860 t for the 2011 season. In 2013, 2832 t were shelved, leaving the effective catch limit at 4028 t. From 1 April 2006, the TACC for the Campbell Island Rise stock was reduced from 25 000 t to 20 000 t, where it remained until 2009. For the 2010 season the catch limit for the Campbell stock was raised to 23 000 t, and in 2011 it was further raised to 29 400 t. Catch limits for Pukaki Rise and Auckland Islands have remained unchanged since 1997.

Table 1: Reported annual landings (t) of southern blue whiting from 1971 to 1977.

Fishing year	Total
1971	10 400
1972	25 800
1973	48 500
1974	42 200
1975	2 378
1976	17 089
1977	26 435

Table 2: Estimated catches (t) and actual TACCs (or catch limits) of southern blue whiting by area from vessel logbooks and QMRs. – no catch limit in place. Before 1997–98 there was no separate catch limit for Auckland Is.

	Bounty Platform		Campbell Island Rise		Pukaki Rise		Auckland Is.		Total	
Fishing year	Catch	Limit	Catch	Limit	Catch	Limit	Catch	Limit	Catch	Limit
1978*f*	0	-	6 403	-	79	-	15	-	6 497	-
1978–79+	1 211	-	25 305	-	601	-	1 019	-	28 136	-
1979–80+	16	-	12 828	-	5 602	-	187	-	18 633	-
1980–81+	8	-	5 989	-	2 380	-	89	-	8 466	-
1981–82+	8 325	-	7 915	-	1 250	-	105	-	17 595	-
1982–83+	3 864	-	12 803	-	7 388	-	184	-	24 239	-
1983–84+	348	-	10 777	-	2 150	-	99	-	13 374	-
1984–85+	0	-	7 490	-	1 724	-	121	-	9 335	-
1985–86+	0	-	15 252	-	552	-	15	-	15 819	-
1986–87+	0	-	12 804	-	845	-	61	-	13 710	-
1987–88+	18	-	17 422	-	157	-	4	-	17 601	-
1988–89+	8	-	26 611	-	1 219	-	1	-	27 839	-
1989–90+	4 430	-	16 542	-	1 393	-	2	-	22 367	-
1990–91+	10 897	-	21 314	-	4 652	-	7	-	36 870	-
1991–92+	58 928	-	14 208	-	3 046	-	73	-	76 255	-
1992–93+	11 908	15 000	9 316	11 000	5 341	6 000	1 143	-	27 708	32 000
1993–94+	3 877	15 000	11 668	11 000	2 306	6 000	709	-	18 560	32 000
1994–95+	6 386	15 000	9 492	11 000	1 158	6 000	441	-	17 477	32 000
1995–96+	6 508	8 000	14 959	21 000	772	3 000	40	-	22 279	32 000
1996–97+	1 761	20 200	15 685	30 100	1 806	7 700	895	-	20 147	58 000
1997–98+	5 647	15 400	24 273	35 460	1 245	5 500	0	1 640	31 165	58 000
1998–00†	8 741	15 400	30 386	35 460	1 049	5 500	750	1 640	40 926	58 000
2000–01#	3 997	8 000	18 049	20 000	2 864	5 500	19	1 640	24 804	‡35 140
2001–02#	2 262	8 000	29 999	30 000	230	5 500	10	1 640	31 114	‡45 140
2002–03#	7 564	8 000	33 445	30 000	508	5 500	262	1 640	41 795	‡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	19 799	25 000	240	5 500	95	1 640	21 620	‡35 640
2005–06#	3 962	3 500	26 190	25 000	58	5 500	66	1 640	30 287	‡35 640
2006–07#	4 395	3 500	19 763	20 000	1 115	5 500	84	1 640	25 363	‡30 640
2007–08#	3 799	3 500	20 996	20 000	513	5 500	278	1 640	25 587	‡30 640
2008–09#	9 863	9 800	20 483	20 000	1 377	5 500	143	1 640	31 867	‡36 948
2009–10#	15 468*	14 700	19 040	20 000	4 853	5 500	174	1 640	39 540	‡42 148
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	30 971	29 400	686	5 500	92	1 640	38 412	‡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	4 278˜	4 028	28 607	29 400	14	5 500	47	1 640	32 950	‡43 400
2014–15	7 054	6 860	24 592	39 200	34	5 500	156	1 640	31 887	53 208

f 1 April–30 September` + 1 October–30 September
† 1 October 1998–31 March 2000 # 1 April–31 March
‡ SBW 1 (all EEZ areas outside QMA6) had a TACC of 8 t, and reported catches of 9 t in 2000–01, 1 t in 2001–02, 16 t in 2002–03, 3 t in 2003–04, 9 t in 2004–05, 2 t in 2005–06, 7 t in 2006–07, 1 t in 2007–08, 21 t in 2008–09, 5 t in 2009–10, 8 t in 2010–11, 2 t in 2011–12, and 8 t in 2012–13.
* Reported catch total for 2009–10 does not include fish lost when *FV Oyang 70* sank on 18 August 2010.
˜In 2013, while the TACC remained at 6860 t, the ACE available to balance against catch was limited to 4028 t as 2832 t was shelved under a voluntary agreement with industry.

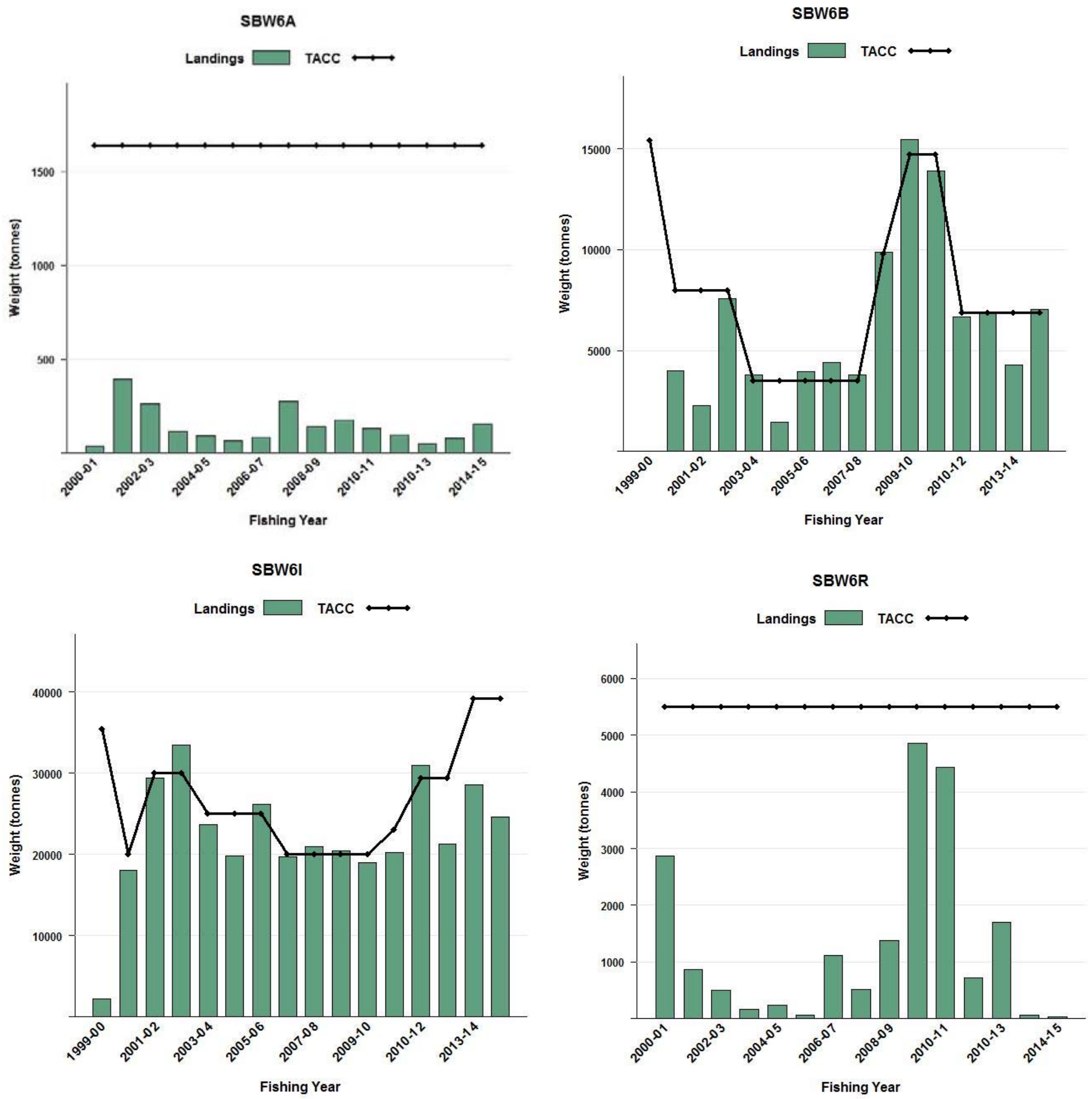


Figure 1: Reported commercial landings and TACC for the four main SBW stocks. From top left to bottom right: SBW 6A (Auckland Islands), SBW 6B (Bounty Platform), SBW 6I (Campbell Island Rise), and SBW 6R (Pukaki Rise). Note that these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries

There is no recreational fishery for southern blue whiting.

1.3 Customary non-commercial fisheries

Customary non-commercial take is not known to occur for southern blue whiting.

1.4 Illegal catches

The level of illegal and unreported catch is thought to be low. However, a number of operators have been convicted for area misreporting; where the catch returns have been revised, the corrected totals by area are shown in Table 2. In addition, the operators of a vessel were convicted for discarding fish without reporting the catch in 2004, and crew members estimated that between 40 and 310 t of southern blue whiting were illegally discarded during the two and a half week period fishing on the Campbell Island Rise.

1.5 Other sources of mortality

Scientific observers have occasionally reported discards of undersize fish and accidental loss from torn or burst codends. The amount of possible discarding was 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 southern blue whiting catch over all the 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 occur primarily because most catch came from vessels that targeted spawning aggregations.

In August 2010, the F.V. *Oyang 70* sank while fishing for SBW 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.

2. BIOLOGY

Southern blue whiting is a schooling species that is confined to Sub-Antarctic waters. 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. 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 a maximum age of 25 years.

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 the majority do not mature until age 3 or 4, usually at a length of 33–40 cm FL. The majority of 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.

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 respectively. 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.

Natural mortality (M) was estimated using the equation loge(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. The value of 0.2 is assumed to reflect the imprecision of this value. Recent Campbell Island stock assessments have estimated M within the model, using an informed prior with a mean of 0.2 (see Table 3).

Table 3: Estimates of biological parameters for the Campbell Island Rise southern blue whiting stock.

Fishstock				Estimate	Source
1. Natural mortality (*M*)					
			Males	Females	
Campbell Island Rise			0.2	0.2	Hanchet (1991)
2. Weight = a (length)^b (Weight in g, length in cm fork length)					
	Males		Females		
	a	b	a	b	
Campbell Island Rise	0.00515	3.092	0.00407	3.152	Hanchet (1991)

Note: Estimates of natural mortality and the length-weight coefficients are assumed to be the same for the other stocks. Observed length-at-age data are used for all stocks.

3. STOCKS AND AREAS

Hanchet (1999) reviewed the stock structure of southern blue whiting. He examined historical data on southern blue whiting distribution and abundance, reproduction, growth, and morphometrics. There appear to be four main spawning grounds of southern blue whiting; on the 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. The Plenary concluded that this constitutes strong evidence that fish in these areas return to spawn on the grounds to which they first recruit. No genetic studies have been carried out, but given their close proximity, it is unlikely that there would be detectable genetic differences in the fish between these four areas.

For the purposes of 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 stock.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the May 2016 Fishery Assessment Plenary. This summary is from the perspective of the southern blue whiting fishery; a more detailed summary from an issue-by-issue perspective is available in the Aquatic Environment & Biodiversity Annual Review ().

4.1 Role in the ecosystem

Southern blue whiting are one of the dominant (in terms of biomass) middle depth fish species found on the Campbell Plateau and Bounty Platform, over depths of 250–600 m. Francis et al (2002) categorised southern blue whiting as part of an upper slope assemblage and estimated its distribution to be centred on about 500 m depth and latitude 51° S. During August and September, southern blue whiting form large dense spawning aggregations on the Campbell Island Rise and Bounty Platform and, to a lesser extent, on the Pukaki Rise and near the Auckland Islands. The species is also found in much lower numbers on the Snares Shelf and Chatham Rise.

These stocks are characterised by highly variable year class strengths, with the strong year classes growing at a significantly lower rate than others (i.e., showing signs of density dependent growth). Their substantial abundance suggests that southern blue whiting are probably an important part of the Campbell Rise and Bounty Platform ecosystems, but their variability suggests that these systems may function differently at different times. For instance, very large changes have been observed in the abundance of southern blue whiting on the Bounty Plateau recently, with a 7-fold increase between 2005 and 2007 followed by a 4-fold decrease to 2009 (Dunn & Hanchet 2011a). The large increase was due to the very strong 2002 year class recruiting to the fishery but the rapid decline is not easily explained. Whatever the reason, there are likely to be implications for the role of the southern blue whiting population in the ecosystem during such events.

4.1.1 Trophic interactions

Crustaceans and teleosts are the dominant prey groups for southern blue whiting. Stevens et al (2011) showed that in the Sub-Antarctic (and similarly from the Chatham Rise), crustaceans occurred in 70% of stomachs, mainly euphausiids (37%), natant decapods (24%) and amphipods (11%). Teleosts occurred in 32% of stomachs, mainly myctophids (10%). Salps (7%) and cephalopods (2%) were of lesser importance.

Predation by marine mammals and large teleosts is probably the main source of mortality for adults, and juveniles are frequently taken by seabirds (MPI 2013). Large hake and ling taken as bycatch in the fishery have usually been feeding on southern blue whiting and large hoki caught during Sub-Antarctic trawl surveys have occasionally been feeding on juvenile southern blue whiting. Juvenile (90–130 mm FL) southern blue whiting were found to be the main prey item of black-browed albatross at Campbell Island during its chick rearing period in January 1997 (Cherel et al 1999) and are also regularly taken by grey-headed albatross and rockhopper penguins breeding at Campbell Island (Cherel et al 1999).

4.1.2 Ecosystem Indicators

Tuck et al (2009) used data from the Sub-Antarctic trawl survey series to derive fish-based ecosystem indicators using diversity, fish size, and trophic level. This trawl survey has run almost continually using the same vessel since 1991 and covers much of the area inhabited by southern blue whiting. Tuck et al (2009) showed generally increasing trends in the proportion of threatened fish species and those with low resilience (from FishBase, Froese & Pauly 2000) and indices of fish diversity often showed positive trends. The proportion of piscivorous and demersal species and the mean trophic level generally declined over the time period, especially in areas where southern blue whiting are more common. Highly variable recruitment of dominant species like southern blue whiting may strongly influence such trends. Changes in fish size were less consistent, and Tuck et al (2009) did not find size-based indicators as useful as they have been overseas. Routine measurement of all fish species in New Zealand trawl surveys since 2008 may increase the utility of size-based indicators in the future.

4.2 Bycatch (fish and invertebrates)

4.2.1 Fish

The southern blue whiting fishery is characterised by large, "clean" catches of the target species with minimal fish bycatch. Anderson (2009) estimated that southern blue whiting accounted for more than 99% of the total estimated catch recorded by observers and more than 99% of the total reported catch from the fishery based on catch-effort forms. The main bycatch species recorded have been ling, hake, and hoki, with smaller amounts of porbeagle shark, jack mackerels, rattails, Ray's bream, and silverside (see also Clark *et. al*. 2000; Anderson 2004).

4.2.2 Invertebrates

There is little invertebrate bycatch in this fishery even though most trawls are on or close to the seabed for at least part of the time (Cole et al 2007). Protected coral bycatch has been negligible in this fishery (Ramm 2012).

4.3 Incidental Capture of Protected Species (seabirds, mammals, and protected fish)

Southern blue whiting trawlers occasionally capture marine mammals (pinnipeds), including NZ sea lions and NZ fur seals (which were classified as "Nationally Critical" and "Not Threatened", respectively, under the NZ Threat Classification System in 2010, Baker et al 2010). Vessels in the southern blue whiting fishery also interact with and incidentally capture seabirds.

Ramm (2012) summarised observer data for bottom trawl fisheries of Seabirds, Mammals, and Coral Catch for the 2010–11 fishing year. Coral impacts are discussed under Invertebrates (Section 4.2.2).

4.3.1 Marine mammal interactions

The New Zealand sea lion (rāpoka) *Phocarctos hookeri*, is the rarest sea lion in the world. The estimated total population of around 11,800 sea lions in 2015 is classified by the Department of Conservation as 'Nationally Critical.' under the New Zealand Threat Classification System (Baker et al 2010). New Zealand sea lions were classified in 2015 as Endangered' by the International Union for Conservation of Nature (IUCN) on the basis of a projected ongoing decline in pup production of 4% per year at the largest breeding colonies on the Auckland Islands. Pup production at the main Auckland Island rookeries showed a steady decline between 1998 and 2009 but has been stable since.

Sea lions interact with some trawl fisheries which can result in incidental capture and subsequent drowning (Smith & Baird 2005a, 2007a & b, Thompson & Abraham 2010a, Abraham & Thompson 2011). Since 1988, incidental captures of sea lions have been monitored by government observers on-board a proportion of the fishing fleet [1].

Specific objectives for the management of NZ sea lion incidental captures are outlined in the fishery-specific chapters of the National Deepwater Plan for the fisheries with which NZ sea lions are most likely to interact. These fisheries include trawl fisheries for southern blue whiting (SBW). The southern blue whiting chapter of the National Deepwater Plan includes Operational Objective 2.2: Ensure that incidental New Zealand sea lion mortalities, in the southern blue whiting fishery at Campbell Island (SBW 6I), do not impact the long term viability of the sea lion population and captures are minimised through good operational practices.

[1] As part of its data reconciliation processes, MPI has identified that less than 2% of observed protected species captures between 2002 and 2015 were not recorded in Centralised Observer Database (COD). Steps are being taken to update the database and estimates of protected species captures and associated risks.

NZ sea lions forage to depths of up to 600 m within the habitat and depth range where spawning southern blue whiting are found (MPI, 2013). There is seasonal variation in the distribution overlap (MPI, 2013).

There has been a steady increase in the number of observed and estimated captures of NZ sea lions in the Campbell Island southern blue whiting trawl fishery from close to zero before year 2000 to an estimated 25 captures in 2009–10 (Abraham & Thompson 2011, Thompson & Abraham 2012). A total of 11 sea lions were observed captured in 2009–10 of which 2 were released alive (Ramm 2012). The sea lion captures were all close to Campbell Island in SBW 6I and were almost all males (91%). There were 21 captures in 2012–13 (Table 4), mostly early in the season which led to the development of an operation plan that includes observers being placed on all trips and compulsory use of sea lion exclusion devices (SLEDs) on all tows in SBW 6I (MPI 2015).

Table 4: Number of tows by fishing year and observed and model-estimated total New Zealand sea lion captures in southern blue whiting trawl fisheries, 2002–03 to 2014–15. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described in Thompson et al**. (2013) and are available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 2002–03 to 2013–14 and preliminary data for 2014–15 are based on data version 2016v01.**

		Observed captures				Estimated captures		
	Tows	No.ob	%obs	Captures	Rate	Captures	95%c.i.	%inc.
2002–03	638	275	43.1	0	0.00	0	0–3	100.0
2003–04	740	241	32.6	1	0.41	3	1–9	100.0
2004–05	870	335	38.5	2	0.60	5	2–12	100.0
2005–06	624	217	34.8	3	1.38	10	4–21	100.0
2006–07	630	224	35.6	3	1.34	15	6–29	100.0
2007–08	819	331	40.4	5	1.51	8	5–14	100.0
2008–09	1 189	301	25.3	0	0.00	1	0–7	100.0
2009–10	1 114	396	35.5	11	2.78	24	15–36	100.0
2010–11	1 171	433	37.0	6	1.39	14	8–24	100.0
2011–12	951	669	70.3	0	0.00	1	0–3	100.0
2012–13	790	790	100	21	2.66	21	21 – 21	100.0
2013–14	805	804	99.9	2	0.25	1	1–1	100.0
2014–15†	678	670	98.8	6	0.90			

† Provisional data, no model estimates available.

The New Zealand fur seal was classified as "Least Concern" by IUCN in 2008 and as "Not Threatened" under the NZ Threat Classification System in 2010 (Baker et al 2010).

Southern blue whiting has one of the highest observed capture rates of NZ fur seals for any observed fishery. The capture of fur seals in the southern blue whiting fishery has varied considerably between years ranging from an estimated low of 20 seals in 2002–03 to an estimated high of 140 seals in 1998–99, but has showed no overall trend through time (Abraham & Thompson 2011, Thompson et al 2012, Thompson et al 2013) (Table 5). Almost all fur seals have been caught at the Bounty Platform in August and September when the southern blue whiting are in dense spawning aggregations. Recent changes in the management of foreign charter vessels has led to an increase in the observer coverage in these fisheries, with almost all effort observed from 2012–13 to 2014–15 (Tables 4 and 5).

Table 5: Number of tows by fishing year and observed and model-estimated total NZ fur seal captures in southern blue whiting trawl fisheries, 2002–03 to 2014–2015. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described in Thompson et al (2013) and are available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 2002–03 to 2013–14 and preliminary data for 2014–15 are based on data version 20160001.

		Observed				Estimated		
	Tows	No.obs	%obs	Captures	Rate	Captures	95%c.i.	%inc.
2002–03	638	275	43.1	8	2.91	20	8 – 66	100.0
2003–04	740	241	32.6	13	5.39	34	14 – 108	100.0
2004–05	870	335	38.5	33	9.85	102	35 – 436	100.0
2005–06	624	217	34.8	52	23.96	67	52 – 121	100.0
2006–07	630	224	35.6	13	5.80	24	13 – 67	100.0
2007–08	819	331	40.4	24	7.25	111	25 – 570	100.0
2008–09	1 189	301	25.3	17	5.65	120	24 – 418	100.0
2009–10	1 114	396	35.5	16	4.04	106	21–416	100.0
2010–11	1 171	433	37.0	36	8.31	72	37–224	100.0
2011–12	951	669	70.3	25	3.74	69	25 – 281	100.0
201213	790	790	100.09	27	3.42	27	27–27	100.0
2013¬14	805	804	99.9	95	11.82	96	94–112	
2014¬15†	678	670	98.8	41	6.12			

† Provisional data, no model estimates available.

4.3.2 Seabird interactions

Vessels are legally required to use seabird mitigation devices and also to adhere to industry Operating Procedures in regards to managing risk of environmental interactions. For protected species, capture estimates presented include all animals recovered to the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds struck by a warp or caught on a hook but not brought on board the vessel, Middleton & Abraham 2007, Brothers et al 2010).

Mitigation methods such as streamer (tori) lines, Brady bird bafflers and offal management are used in the southern blue whiting trawl fishery. Warp mitigation was voluntarily introduced from about 2004 and made mandatory in April 2006 (Department of Internal Affairs 2006). The 2006 notice mandated that all trawlers over 28 m in length use a seabird scaring device while trawling (being "paired streamer lines", "bird baffler" or "warp deflector" as defined in the Notice).

In the 2014–2015 fishing year, there were 7 observed captures of birds in southern blue whiting trawl fisheries at a rate of 1.13 birds per 100 observed tows (Table 6). The average capture rate in southern blue whiting trawl fisheries for the period from 2002–03 to 2014–15 is about 1.13 birds per 100 tows, a low rate relative to other New Zealand trawl fisheries, e.g. for scampi (4.64 birds per 100 tows) and squid (13.96 birds per 100 tows) over the same years.

Overall, the impact that the southern blue whiting fisheries have on seabirds is very small. This can be seen in the proportions of the overall fisheries Potential Biological Removals (PBR) that are attributable to the blue whiting fisheries for each species, where all are less than 2% of the total (Table 7). Observed seabird captures since 2002–03 have been dominated by grey petrels (46 of the 77 observed seabird captures since 2002–03), a medium risk species where the blue whiting fisheries are estimated to be responsible for 1.8% of the PBR (Table 7).

Table 6: Number of tows by fishing year and observed seabird captures in southern blue whiting trawl fisheries, 2002–03 to 2014–15. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described in Abraham et al **(2013) and are available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 2002–03 to 2013–14 and preliminary data for 2014–15 are based on data version 2016v01.**

	Fishing effort			Observed captures		Estimated captures		
	Tows	**No. Obs**	**% obs**	**Captures**	**Rate**	**Mean**	**95% c.i.**	**% included**
2002–03	638	275	43.1	0	0.00	3	0–8	100.0
2003–04	740	241	32.6	0	0.00	5	1–12	100.0
2004–05	870	335	38.5	2	0.60	10	4–17	100.0
2005–06	624	217	34.8	2	0.92	6	2–12	100.0
2006–07	630	224	35.6	3	1.34	7	3–13	100.0
2007–08	819	331	40.4	3	0.91	7	3–13	100.0
2008–09	1 187	299	25.2	0	0.00	8	2–16	100.0
2009–10	1 114	396	35.5	10	2.53	27	18–40	100.0
2010–11	1 171	433	37.0	10	2.31	23	15–34	100.0
2011–12	952	669	70.3	4	0.60	7	4–11	100.0
2012–13	790	790	100.0	19	2.41	19	19–19	100.0
2013¬14	810	801	99.9	17	2.10	19	19–20	100.0
2014¬15†	677	669	98.8	7	1.05			

† Provisional data, no model estimates available.

Table 7: Risk ratio for seabirds predicted by the level two risk assessment for the target southern blue whiting (SBW) fishery and all fisheries included in the level two risk assessment, 2006–07 to 2012–13, showing seabird species with a risk ratio of at least 0.001 of PBR_{rho}. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR_{rho} (from Richard and Abraham 2015 where full details of the risk assessment approach can be found). The DOC threat classifications are shown (Robertson et al 2013 at http://www.doc.govt.nz/documents/science-and-technical/nztcs4entire.pdf). The numbers of observed seabird captures by species in the southern blue whiting trawl fisheries, 2002–03 to 2014–15 (http://www.fish.govt.nz/en-nz/Environmental/Seabirds/, version 2016v01) are also shown.

		Risk ratio				
Species	**PBR_1 (mean)**	**SBW trawl**	**Total**	**Risk category**	**DoC Threat Classification**	**Total Captures**
Salvin's albatross	1024.6	0.020	3.384	Very high	Threatened: Nationally Critical	18
Southern Buller's albatross	449.3	0.001	1.683	Very high	At Risk: Naturally Uncommon	
Gibson's albatross	673.2	0.007	0.254	Very high	Threatened: Nationally Critical	0
NZ white-capped albatross	2152.4	0.012	0.071	Very high	At Risk: Declining	0
Antipodean albatross	386.6	0.004	0.066	High	Threatened: Nationally Critical	0
Campbell black-browed albatross	1024.6	0.020	3.384	High	At Risk: Naturally Uncommon	5
Northern giant petrel	180.8	0.003	1.144	Medium	At Risk: Naturally Uncommon	0
Grey petrel	4044.8	0.001	1.078	Low	At Risk: Naturally Uncommon	87
Southern royal albatross	136.5	0.006	0.786	Low	At Risk: Naturally Uncommon	2
Unidentified storm petrel[1]	-	-	-	-	-	1

[1] Released alive, species identity undefined.

4.4 Benthic interactions

Southern blue whiting is principally taken using midwater trawls (94% for calendar years 2011–2013). About 55% of the trawl effort is fished on or near to the seabed (0–<5m off the seabed). Target southern blue whiting tows accounted for only 1% of all tows reported on TCEPR forms to have been fished on or close to the bottom between 1989–90 and 2004–05 (Baird et al 2011). Almost all southern blue whiting catch is reported on TCEPR forms (Black et al 2013). Tows are located in Benthic Optimised Marine Environment Classification (BOMEC, Leathwick et al 2009) classes F (upper slope), I, L (mid-slope), and M (mid-deep slope) (Baird & Wood 2012), and 95% were between 300 and 600 m depth (Baird et al 2011).

Where trawls for southern blue whiting are fished on the bottom, they are likely to have effects on benthic community structure and function (e.g., Cole et al 2007, Rice 2006) and there may be consequences for benthic productivity (e.g., Jennings 2001, Hermsen et al 2003, Hiddink et al 2006, Reiss et al 2009). However, any consequences from southern blue whiting fishing, due to the gear type and scale of the fishery (typically less than 600 tows fished on the bottom per year) , are likely to be relatively minor. A more general review of habitat interactions can be found in the Aquatic Environment and Biodiversity Annual Review 2013 (MPI, 2013).

The NZ EEZ contains 17 Benthic Protection Areas (BPAs) that are closed to bottom fishing and include about 52% of all seamounts over 1500 m elevation and 88% of identified hydrothermal vents.

4.5 Other considerations

4.5.1 Spawning disruption

Fishing during spawning may disrupt spawning activity or success. Canadian research carried out on Atlantic cod (*Gadus morhua*) concluded that “Cod exposed to a chronic stressor are able to spawn successfully, but there appears to be a negative impact of this stress on their reproductive output, particularly through the production of abnormal larvae”, Morgan et al (1999). Morgan et al (1997) also reported disruption of a spawning shoal of Atlantic cod: “Following passage of the trawl, a 300-m-wide "hole" in the aggregation spanned the trawl track. Disturbance was detected for 77 min after passage of the trawl.” There has been no research carried out on the disruption of spawning southern blue whiting by fishing in New Zealand but fishing occurs almost entirely on spawning aggregations.

4.5.2 Genetic effects

Fishing, environmental changes such as altered average sea temperatures (climate change), or pollution could alter the genetic composition or diversity of a species. There are no known studies of the genetic diversity of southern blue whiting from New Zealand. Genetic studies for stock discrimination are reported above under “Stocks and Areas”.

4.5.3 Habitat of particular significance to fisheries management

Habitat of particular significance for fisheries management (HPSFM) does not have a policy definition (MPI, 2013) although work is currently underway to generate one. Studies have identified areas of importance for spawning and juvenile southern blue whiting where distribution plots highlight hotspot areas for the 0+, 1+, immature, and adult fish (O’Driscoll et al 2003). These are the Campbell Plateau and Bounty Platform, with minimal numbers recorded on the Chatham Rise.

5. STOCK ASSESSMENT

An updated assessment of the Campbell Island Rise stock was completed in 2014, using research time series of abundance indices from wide-area acoustic surveys from 1993 to 2013 and proportion-at-age data from the commercial fishery. New information included a wide area acoustic survey of the Campbell Island Rise carried out in August–September 2013. The general purpose stock assessment program, CASAL (Bull et al 2012) was used and the approach, which used Bayesian estimation, was similar to that in previous assessments (Dunn & Hanchet 2011a,b).

A stock assessment was also completed for the Bounty Platform stock in 2014 using data up to 2013 from local area acoustic surveys of aggregations. Data from the most recent survey in 2013 were broadly consistent with observations in 2007–2008, but not consistent with the observed abundances in 2009–2012. The general purpose stock assessment program, CASAL (Bull et al 2012) was used, with Bayesian estimation.

No new assessment is available for the Pukaki Rise stock due to the paucity of useful abundance data. No assessment has been made of the Auckland Islands Shelf stock. The years given in the biomass and yield sections of this report refer to the August–September spawning/fishing season.

5.1 Estimates of fishery parameters and abundance indices

Between 1993 and 2001, a series of wide area acoustic surveys for southern blue whiting were carried out by the *R/V Tangaroa* on the Bounty Platform. From 2004 to 2013, a series of local area aggregation surveys has been carried out from industry vessels fishing the Bounty Platform (O'Driscoll et al in prep b). The fishing vessels have opportunistically collected acoustic data from the Bounty Platform fishing grounds using a random survey design over an ad-hoc area that encompassed an aggregation of southern blue whiting (O'Driscoll et al in prep b). The local area aggregation surveys have had mixed levels of success (Table 8).

Table 8: Estimates of biomass (t) for immature and mature fish from wide-area acoustic surveys of the Bounty Platform from 1993–2001 (from Fu et al 2013); and mature fish from local aggregation surveys in 2004–2013 (O'Driscoll et al. in prep b); and the proportion of fishing mortality that was assumed to occur before the biomass estimate in each year (based on catch effort data, and sample dates for the acoustic snapshots). Sampling CVs for the surveys are given in parentheses.

	Wide area surveys		Local aggregation surveys	
Year	Immature	Mature	Mature	Proportion
1993	15 269 (33%)	43 338 (58%)	-	-
1994	7 263 (27%)	17 991 (25%)	-	-
1995	0 (-)	17 945 (24%)	-	-
1997	3 265 (54%)	27 594 (37%)	-	-
1999	344 (37%)	21 956 (75%)	-	-
2001	668 (28%)	11 784 (35%)	-	-
2004		-	8 572 (69%)	0.73
2005		-	-	-
2006		-	11 949 (12%)	0.78
2007		-	79 285 (19%)	0.93
2008		-	75 889 (34%)	0.68
2009		-	16 640 (21%)	0.29
2010		-	18 074 (36%)	0.35
2011		-	20 990 (28%)	0.89
2012		-	16 333 (7%)	0.84
2013		-	28 533 (27%)	0.76

Acoustic data collected in 2005 could not be used because of inadequate survey design and acoustic interference from the scanning sonar used by the vessel for searching for fish marks. There was some concern that the surveys in 2006 and 2009 may not have sampled the entire aggregation as fish marks extended beyond the area being surveyed on some transects. However, the surveys in 2010–2012 appeared to have sampled the entire aggregation and gave a similar estimate of biomass to that in 2009. The 2013 aggregation survey was higher than the preceding four surveys, and was more consistent with the hypothesis that the surveys from 2009 to 2012 did not cover the entire population of southern blue whiting on the Bounty Platform

O'Driscoll (2011a) explored various reasons for the much lower observed biomass estimates from the surveys in 2009 and 2010 compared with 2007 and 2008. No reason in the survey methodology, equipment (including calibration), or changes in timing and extent of survey coverage could be found to explain the observed reduction in these estimates.

A standardised CPUE analysis was carried out for the Bounty Platform for data up to 2002. However, the results of this analysis were not consistent with the acoustic survey estimates, and the model structure and assumptions were inadequate to reliably determine the indices or associated variance. The indices were therefore rejected by the WG as indices of abundance and have not been used in assessments.

A wide-area survey of the Campbell Island Rise was carried out in August–September 2013 O'Driscoll et al (in prep a). Estimates of mature biomass suggested an increase in biomass since 2011, although the point estimates were not as high as the 2009 survey. (Table 9).

Table 9: Estimates of biomass (t) for immature and mature fish from wide-area acoustic surveys of the Campbell Island Rise 1993–2001 (from Fu et al 2013 and O'Driscoll et al. in prep a). Sampling CVs for the surveys are given in parentheses.

	Wide area surveys	
Year	**Immature**	**Mature**
1993	35 208 (25%)	16 060 (24%)
1994	8 018 (38%)	72 168 (34%)
1995	15 507 (29%)	53 608 (30%)
1998	6 759 (20%)	91 639 (14%)
2000	1 864 (24%)	71 749 (17%)
2002	247 (76%)	66 034 (68%)
2004	5 617 (16%)	42 236 (35%)
2006	3 423 (24%)	43 843 (32%)
2009	24 479 (26%)	99 521 (27%)
2011	14 454 (17%)	53 299 (22%)
2013	8 004 (55%)	65 801 (25%)

A standardised CPUE analysis of the Campbell Island stock was completed up until the 2002 fishing season. In the past there has been concern that because of the highly aggregated nature of the fishery, and the associated difficulty in finding and maintaining contact with the highly mobile schools in some years, the CPUE series may not be monitoring abundance. The indices have therefore not been used in the stock assessment since 1998.

Wide-area surveys of the Pukaki Rise were carried out between 1993 and 2000 (Fu et al 2013), and more recently local area aggregation estimates by industry vessels (Table 10). The biomass estimates from the last two surveys (2010, 2012) were considered too small to be plausible (Table 10).

Table 10: Estimates of biomass (t) for immature and mature fish from wide-area acoustic surveys of the Pukaki Rise 1993–2000 (from Fu et al 2013 and O'Driscoll 2013) and local area aggregation surveys from 2009–2012. Sampling CVs for the surveys are given in parentheses.

	Wide area surveys				Local aggregation surveys		
Year	**Immature**		**Mature**	**Vessel**	**Transects**	**Area (km^2)**	**Biomass (%cv)**
1993	9 558 (25%)		26 298 (32%)			-	
1994	125 (100%)	3 591 (48%)	21 506 (44%)			-	
1995	0 (-)		6 552 (18%)			-	
1997	1 866 (12%)		16 862 (34%)			-	
2000	1 868 (62%)	8 363 (74%)	6 960 (37%)			-	
2009			-	*Meridian 1*	4	50	188 (29%)
			-		5	283	9 459 (30%)
			-		5	71	6 272 (41%)
			-	*Aleksandr Buryachenko*	6	60	2 361 (12%)
			-		7	117	7 903 (26%)
			-		6	19	11 321 (38%)
2010			-	*Meridian 1*	10	364	1 085 (17%)
2012			-	*San Waitaki*	-	-	3 272 (21%)

5.2 Biomass estimates

(i) Campbell Island stock (2014 stock assessment)

The stock assessment model

An updated stock assessment for the Campbell Island stock was completed in 2014.

Table 11: Annual cycle of the stock model, showing the processes taking place at each step, and the available observations. Fishing mortality (F) and natural mortality (*M*) that occur within a time step occur after all other processes. *M*, proportion of *M* occurring in that time step.

Period	Process	*M*	Length at age	Observations
1. Nov–Aug	Natural mortality	0.9	-	-
2. Sep–Oct	Age, recruitment, F, M	0.1	Matrix applies here	Proportion at age, acoustic indices

A two-sex, single stock and area Bayesian statistical catch-at-age model for the Campbell Island southern blue whiting stock was implemented in CASAL (Bull et al 2012). The model partitioned the stock into immature and mature fish with two sexes and age groups 2–15, with a plus group at age 15. The model was run for the years 1979–2013. Five year projections were run for the years 2014–2018. The annual cycle was partitioned into two time steps. In the first time step (nominally the non-spawning season), 90% of natural mortality was assumed to have taken place. In the second time step (spawning season), fish matured, and were migrated to a spawning area where fish ages were incremented; the 2-year-olds were recruited to the population, and mature fish were subjected to fishing mortality. The remaining 10% of natural mortality was then applied to the entire population following fishing. A two sex model was used because there are significant differences observed between males and females in both the proportions at age in the commercial catch for fished aged 2–4 (see later) and their mean size at age (Hanchet & Dunn 2010). The stock recruitment relationship was assumed to be Beverton-Holt with a steepness of 0.9, with the proportion of males at recruitment (at age 2) assumed to be 0.5 of all recruits.

Southern blue whiting exhibit large inter-annual differences in growth, presumably caused by local environmental factors but also closely correlated with the occurrence of strong and weak year classes. Hence, an empirical size-at-age matrix was used which was derived by qualitatively reviewing the empirically estimated mean sizes-at-age from the commercial catch-at-length and -age data (Hanchet & Dunn 2010). Missing mean sizes in the matrix were inferred from the relative size of their cohort and the mean growth of similar ages in other years; and cohorts with unusually small or large increments were similarly adjusted. For projections, the mean sizes-at-age were assumed to be equal to the estimated sizes-at-age in 2013.

In general, southern blue whiting on the Campbell Island Rise are assumed to be mature when on the fishing ground, as they are fished during spawning. Hence, it was assumed that all mature fish were equally selected by fishing, and that no immature fish were selected. The maximum exploitation rate (U_{max}) was assumed to be 0.8. The proportion of immature fish that mature in each year was estimated for ages 2–5, with fish aged 6 and above assumed to be fully mature.

The model was started in 1979 and the numbers in the population at the start of the model were estimated for each age separately (i.e., described as a $C_{initial}$ starting state in Bull et al 2012). Estimates of the initial age structure were constrained so that the number of males within each age class was equal to the number of females within that age class.

Observations

The model was fitted to a single time series of acoustic biomass estimates and the catch-at-age data from the fishery; the time series of acoustic biomass estimates came from a wide area survey series conducted by the research vessel Tangaroa for immature and for mature fish. The acoustic survey estimates were used as relative estimates of mid-season biomass (i.e., after half the catch has been removed), with associated CVs estimated from the survey analysis (Table 9).

Catch-at-age observations by sex were available for most years from the commercial fishery for the period 1979 to 2013. These catch-at-age data were fitted to the model as proportions-at-age, where estimates of the proportions-at-age and associated CVs by age were estimated using the NIWA catch-at-age software by bootstrap (Bull & Dunn 2002).

Estimation

Model parameters were estimated using Bayesian methods implemented using the NIWA stock assessment program CASAL v2.30 (Bull et al 2012). For initial runs only the mode of the joint posterior distribution was estimated. For the final runs presented here, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm.

MCMC chains were estimated using a burn-in length of 1 million iterations, with every 10 000th sample taken from the next 10 million iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior).

Equilibrium “virgin” biomass is equal to the population that there would have been if all the YCS were equal to one and there was no fishing. However, there was a period of unknown (and possibly large) catches from the Campbell Island stock before 1979, and there is high recruitment variability in the stock, so the initial 1979 biomass was allowed to differ from the equilibrium virgin biomass. The initial population in 1979 (ages 2 to 15+) was estimated for each of the ages in the initial population, and assumed to be equal by sex. Year class strengths were estimated for all years from 1977 to 2010, under the assumption that the estimates from the model should average one.

Prior distributions and penalty functions

In general, the assumed prior distributions used in the assessment were intended to be non-informative with wide bounds (Table 12). The exceptions to this were the priors and penalties on the biomass catchability coefficient and on relative year class strengths. The prior assumed for the relative year class strengths was lognormal, with mean 1.0 and CV 1.3.

A log-normal prior was developed for the wide area acoustic survey catchability coefficient with mean 0.87 and C.V. 0.3, obtained using the approach of Cordue (1996), derived by P. Cordue (pers. comm., 2013). Various factors were included in the derivation of the prior including, mean target strength, acoustic system calibration, target identification, shadow or dead zone correction, and spatial availability (Table 13). While the analysis indicated a lower bound of 0.39, this did not account for recent updates to the target strength of southern blue whiting based on *in situ* measurements using an acoustic-optical system (AOS) (O'Driscoll et al 2013). The AOS target strength estimate was based on observations of fish in the mouth of a trawl, which had a mean swimming angle of 16° and standard deviation of 15° (O'Driscoll et al 2013). This may have over-estimated target strength of fish in spawning aggregations, as spawning fish are likely to have a different tilt angle distribution to those being herded by a trawl. Hence, the assessment models assumed a lower bound on the catchability prior of 0.1 to account for possibility of this bias.

Natural mortality was parameterised by the average of male and female, with the difference estimated with an associated normal prior with mean zero and standard deviation 0.05. Penalty functions were used to constrain the model so that any combinations of parameters that did not allow the historical catch to be taken were strongly penalised. A small penalty was applied to encourage the estimates of year class strengths to average to 1.

Table 12: The distributions, priors, and bounds assumed for the various parameters being estimated for the Campbell Island stock assessment.

Parameter	*N*	Distribution	Values		Bounds	
			Mean	CV	Lower	Upper
B_0	1	Uniform-log	-	-	20 000	250 000
Initial population (by sex)	14	Uniform	-	-	2e0	2e9
Male maturity	4	Uniform	-	-	1	20
Female maturity	4	Uniform	-	-	0.02	20
Year class strength	34	Lognormal	1.0	1.3	0.001	100
Wide area catchability mature *q*	1	Lognormal	1.0	0.2	0.1	1.71
Wide area catchability immature *q*	1	Uniform	-	-	0.1	1.71

Table 13: Estimated 'best' and lower and upper bounds for the factors for the acoustic catchability prior (P. Cordue, pers. comm., 2013). The combined estimate corresponds to a lognormal prior with mean 0.87 and CV 0.3.

Factor	Estimate		
	Lower	Best	Upper
Target strength	0.72	0.90	1.13
Target identification	0.90	1.15	1.45
Vertical availability	0.75	0.85	0.95
Areal availability	0.90	0.95	1.00
System calibration	0.90	1.00	1.10
Combined	0.39	0.84	1.71

Model runs

The Working Group considered a base case and 2 sensitivities (Table 14). The base case included all of the acoustic biomass indices, the sensitivities excluded the 2009 acoustic biomass index and allowed for the estimation of the natural mortality rate for males and females.

Lognormal errors, with known CVs, were assumed for the relative biomass indices, while multinomial errors were assumed for the proportions-at-age data. However, the error terms allowed for sampling error only and additional variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance. This additional variance, termed process error, was estimated in the initial MPD run for the first model using all the available data, and assumed for the other two models. Process errors were estimated separately for the proportion-at-age data using the method of Francis (2011), and for the acoustic estimates from the wide area surveys (but was estimated to be nil).

Table 14: Model run labels and descriptions.

Model run	Description
1.1	Base case model
1.2	Model 1.1, but excluding the 2009 biomass index
1.3	Model 1.1, but with natural mortality estimated

Results

The estimated MCMC marginal posterior distributions for spawning stock biomass trajectories are shown for the base case (model 1.1) in Figure 2, and the results summarised in Table 15 and 16. The run suggests that the stock biomass showed a steady decline from the early 1980s until 1993, followed by a large increase to 1996 as a result of the strong 1991 year class. The population then declined until a moderate year class in 2003 and then a strong year class in 2006 resulted in a relatively stable stock size until 2009, and then increased in recent years as the 2006 and 2009 year classes recruited to the fishery. Exploitation rates and relative year class strengths are shown in Figure 3. Estimates of the adult acoustic q and M are given in Table 16.

Table 15: Bayesian median and 95% credible intervals of equilibrium (B_0), initial, and current biomass for the model runs 1.1 (base case), 1.2 (exclude 2009 index), and 1.3 (estimate M)

Model	B_0	B_{2013}	B_{2013} (% B_0)
1.1 (Base case)	342 290 (307 800–391 080)	205 532 (145 856–284 562)	60 (48–74)
1.2	327 020 (295 550–368 730)	175 098 (123 444–239 085)	54 (42–65)
1.3	346 990 (297 650–433 560)	262 977 (167 817–406 478)	76 (54–97)

Table 16: Bayesian median and 95% credible intervals of the catchability coefficients (q) and natural mortality parameters for the wide area acoustic biomass indices for model runs 1.1 (base case) and the sensitivity cases.

Model	Catchability		Natural mortality	
	Mature	Immature	Male	Female
1.1 (Base case)	0.41 (0.34–0.48)	0.28 (0.22–0.34)	–	–
1.2	0.41 (0.34–0.48)	0.26 (0.20–0.33)	–	--
1.3	0.31 (0.21–0.43)	0.17 (0.10–0.29)	0.26 (0.19–0.32)	0.26 (0.18–0.33)

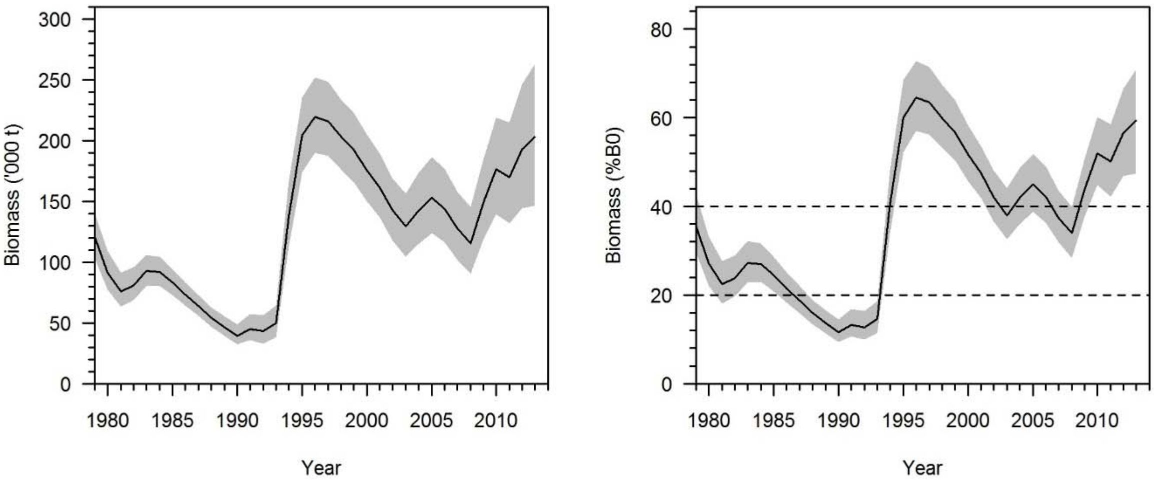
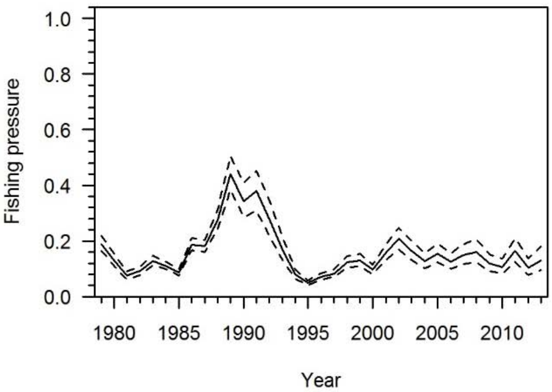


Figure 2: MCMC posterior plots of the trajectories of biomass (left) and current stock status (% B_{2013}/B_0) (right) for the Campbell Island stock for the base case model. The shaded regions are the 95% CIs.



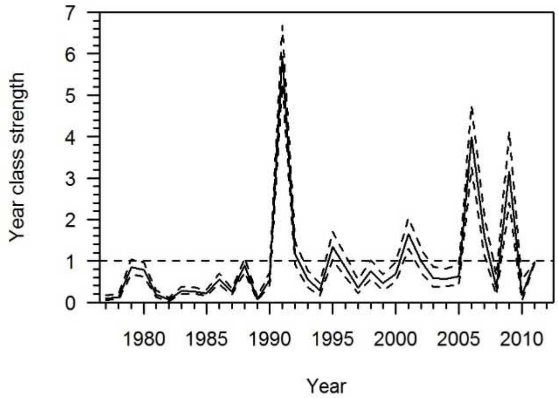


Figure 3: Estimated posterior distributions of exploitation rates (left) and relative year class strength (right) for the Campbell Island stock for the base case model.

Projections were made assuming fixed catch levels of 30 000 t. Projections were made using the MCMC samples, with recruitments drawn randomly from the distribution of year class strengths for the period 1977–2010 estimated by the model and applied from year 2011 onwards. For projections, the mean sizes-at-age were assumed to be equal to the estimated sizes-at-age in 2013.

For each scenario, the probability that the mid-season biomass for the specified year will be less than the threshold level (20% B_0) is given in Table 17. The probability of dropping below the threshold biomass at catch levels of 30 000 t is less than 10% for all models and all years. Under average recruitment conditions the biomass is expected to increase in the next year, then decline.

Table 17: Probability that the projected mid-season vulnerable biomass for 2014–2018 will be less than 20% B_0, and the median projected biomass (%B_0), at a projected catch of 30 000 t, 35 000 t, and 40 000 t, for the base case model assuming average recruitment over the period 1997–2010 for 2010+.

Model	Catch (t)	Pr (SSB < 0.2B_0)					Median SSB (%B_0)				
		2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
1.1 (base)	30 000	0.00	0.00	0.00	0.01	0.05	65	61	55	51	46
	35 000	0.00	0.00	0.00	0.02	0.09	64	59	52	46	41
	40 000	0.00	0.00	0.00	0.05	0.18	64	57	49	42	35

(ii) Bounty Platform stock (2014 assessment)

An updated stock assessment for the Bounty Platform stock was completed for 2014. Preliminary model runs did not provide a satisfactory fit to both the high local area aggregation acoustic biomass estimates observed in 2007–2008 and the lower local area aggregation biomass estimates observed since 2009. Hence, the development of the assessment focused on evaluating models with different assumptions that allowed a comparison of the extent to which the high biomass and subsequent decline were fitted. The Working Group considered that the model that allowed for the larger biomass in 2007 and 2008 with a subsequent decline to 2013 was the most plausible, based on the observed changes in biomass in recent years and the fits to the age data. This model was developed as the base case, with sensitivities on the nature of the catchability prior that was assumed for the acoustic surveys.

Population dynamics and model structure

A two-sex, single stock and area Bayesian statistical catch-at-age model for the Bounty Platform southern blue whiting stock was implemented in CASAL (Bull et al 2012). The model partitioned the stock into immature and mature fish with two sexes and age groups 2–15, with a plus group at age 15. The model was run for the years 1979–2013. Five year projections were run for the years 2014–2018. The annual cycle was partitioned into two time steps. In the first time step (nominally the non-spawning season), 90% of natural mortality was assumed to have taken place. In the second time step (spawning season), fish matured, and were migrated to a spawning area where fish ages were incremented; the 2-year-olds were recruited to the population, and mature fish were subjected to fishing mortality. The remaining 10% of natural mortality was then applied to the entire population following fishing. A two sex model was used because there are significant differences observed between males and females in both the proportions at age in the commercial catch for fished aged 2–4 (see later) and their mean size at age (Hanchet & Dunn 2010). The stock recruitment relationship was assumed to be Beverton-Holt with a steepness of 0.9, with the proportion of males at recruitment (at age 2) assumed to be 0.5 of all recruits.

Southern blue whiting exhibit large inter-annual differences in growth, presumably caused by local environmental factors but also closely correlated with the occurrence of strong and weak year classes. Hence, an empirical size-at-age matrix was used which was derived by qualitatively reviewing the empirically estimated mean sizes-at-age from the commercial catch-at-length and catch-at-age data (Hanchet & Dunn 2010). Missing mean sizes in the matrix were inferred from the relative size of their cohort and the mean growth of similar ages in other years; and cohorts with unusually small or large increments were similarly adjusted. For projections, the mean sizes-at-age were assumed to be equal to the estimated sizes-at-age in 2013. Estimates of the initial age structure were constrained so that the number of males within each age class was equal to the number of females within that age class.

The proportion of immature fish that mature in each year was estimated for ages 2–5, with fish aged 6 and above assumed to be fully mature. In addition, in order to account for years when slower growing cohorts potentially matured later, an annual shift parameter was estimated that varied the probability of fish maturing in that year, and was estimated for the years 2005–2010.
However, in developing the models for southern blue whiting on the Bounty Platform, it was found that in the exploratory model runs the estimates of the very large year class observed in 2002 were strongly confounded with model estimates of the overall mean recruitment, equilibrium (B_0), and initial abundance ($C_{initial}$). To resolve this issue, the mean year class strength constraint was modified to exclude the 2002 year class, i.e., the constraint that the mean of the relative year class strengths for years 1988–2010 equals one was replaced with the constraint that the mean of the relative year class strengths for the years 1988–2001 and 2003–2010 combined equals one. This modification removed most of the confounding between those parameters, and resulted in a more numerically stable model.

Note that in other, similar assessment models, the equilibrium unexploited spawning biomass (B_0) is typically defined as being equal to the spawning biomass that there would have been if the mean relative year class strength was equal to one over some defined period and there was no fishing (see Bull et al 2012 for rationale). Here, as we ignore the 2002 year class in the averaging process, we define the equilibrium unexploited spawning biomass as being equal to the spawning biomass that there would have been if the mean relative year class strength was equal to one over the period 1998–2001 and 2003–2009 combined with no fishing. This modification has consequences, specifically projections that assume a mean relative year class strength of one ignore the possibility of a very strong year class such as that observed in 2002. Estimated biomass reference points would also be lower. To correct for this, the mean year class strength was recalculated when including the 2002 year class, and applied as an adjustment to estimates of B_0.

Observations
The model was fitted to two time series of acoustic biomass estimates and the proportion-at-age data from the fishery. One time series of acoustic biomass estimates came from a wide area survey series conducted by the research vessel Tangaroa (Hanchet & Dunn 2010) for immature and for mature fish. The acoustic survey estimates were used as relative estimates of mid-season biomass (i.e., after half the catch has been removed), with associated CVs estimated from the survey analysis (Table 8).

The second time series of acoustic biomass estimates came from a series of southern blue whiting local area aggregation surveys carried out from industry vessels fishing the Bounty Platform (Table 8). It was assumed that the local area aggregation survey estimates were relative estimates of mature stock biomass after a proportion of the catch had been removed (see Table 8) and with a CV equal to the sampling CV estimated from the survey. These estimates were based on the revised target strength estimates of O'Driscoll et al 2013. However, as the coverage by the survey of the population was likely to have been different in each year, the series was assumed to be a time series with non-constant catchability. Hence the catchability coefficient (q) for each year was allowed to be an independent parameter in the model. In order to use these survey estimates as a time series (allowing the biomass estimates to provide some information to the model) it was assumed that the local area aggregation survey catchability coefficients were related to the wide area acoustic survey estimates via a q ratio prior (see Section 6.5.7 of Bull et al 2012 for detail). Hence a prior distribution on the ratio of each individual survey and the *R/V Tangaroa* wide area surveys were specified, with the ratio prior assumed to be lognormally distributed and parameterised by a mean and CV.

Catch-at-age observations by sex were available from the commercial fishery for the period 1990–2012. These catch-at-age data were fitted to the model as proportions-at-age, where estimates of the proportions-at-age and associated CVs by age were estimated using the NIWA catch-at-age software by bootstrap (Bull & Dunn 2002).

Estimation

Model parameters were estimated using Bayesian methods implemented using the NIWA stock assessment program CASAL v2.30 (Bull et al 2012). Model fits were evaluated at the maximum of the posterior density (MPD) by investigating model fits and residuals and also by examining the full posterior distributions sampled using Markov Chain Monte Carlo (MCMC) methods.

Prior distributions and penalty functions

In general, the assumed prior distributions used in the assessment were intended to be non-informative with wide bounds (Table 18 and 19). The exceptions to this were the priors and penalties on biomass catchability coefficients (including the ratio priors) and on relative year class strengths. The prior assumed for the relative year class strengths was lognormal, with mean 1.0 and CV 1.3, for all year classes except for the 2002 year class. To allow for the possibility that the 2002 year class was much stronger than average, the lognormal prior CV was modified to be less constraining and set to 10.

A log-normal prior was developed for the wide-area acoustic survey catchability coefficient, derived from the posterior estimates of catchability in the base case Campbell Island assessment model above (Table 13). However, as the catchability in the Bounty Platform is unlikely to be identical to that from the Campbell Rise, the prior was broadened from the posterior by increasing the CV, and a lognormal prior with μ=0.43 and CV=0.2 was used as the base case.

Priors for the local area aggregation surveys were non-informative, but a q-ratio prior was added to provide some limitation on the ratios between the local area aggregation surveys and the wide area acoustic catchability coefficient (Table 19). The specification of the q ratio prior was based on the assumption that (i) the wide area surveys covered all of the mature population, (ii) the 2004, 2007–2013 local area aggregation surveys also covered all of the mature population, and (iii) the 2006 survey missed a large, but unknown, proportion of the mature population.

Table 18: The distributions, priors, and bounds assumed for the various parameters being estimated for the Bounty Platform stock assessment (*q* ratio priors are given in Table 19).

Parameter	*N*	Distribution	Values		Bounds	
			Mean	CV	Lower	Upper
B_0	1	Uniform-log	-	-	20 000	250 000
Initial population (by sex)	14	Uniform	-	-	2e2	2e9
Male maturity	4	Uniform	-	-	1	20
Female maturity	4	Uniform	-	-	0.02	20
Maturity shift parameters	6	Uniform	-	-	-20	20
Year class strength	23	Lognormal	1.0	1.3 [1]	0.001	100
Wide area catchability mature *q*	1	Lognormal	0.41	0.2	0.1	1.71
Wide area catchability immature *q*	1	Uniform	-	-	0.1	1.71
2004 local area catchability *q*	1	Uniform	-	-	0.1	1.71
2006 local area catchability *q*	1	Uniform	-	-	0.1	1.71
2007 local area catchability *q*	1	Uniform	-	-	0.1	1.71
2008 local area catchability *q*	1	Uniform	-	-	0.1	1.71
2009 local area catchability *q*	1	Uniform	-	-	0.1	1.71
2010 local area catchability *q*	1	Uniform	-	-	0.1	1.71
2011 local area catchability *q*	1	Uniform	-	-	0.1	1.71
2012 local area catchability *q*	1	Uniform	-	-	0.1	1.71
2013 local area catchability *q*	1	Uniform	-	-	0.1	1.71

Note 1: Except for 2002. Here the CV = 10.

Table 19: Aggregation survey biomass estimates for the Bounty Platform and the assumed *q* ratio prior, 2004–2013.

Year	Biomass (CV%)†	*q* ratio prior Down-weight 2009–2013	
		μ	CV
2004	8 572 (69%)	1.00	0.050
2006	11 949 (12%)	0.50	0.50
2007	79 285 (19%)	1.00	0.05
2008	75 889 (34%)	1.00	0.05
2009	16 640 (21%)	1.00	0.50
2010	18 074 (36%)	1.00	0.50
2011	20 990 (28%)	1.00	0.50
2012	16 333 (7%)	1.00	0.50
2013	28 533 (27%)	1.00	0.50

† Biomass data from Table 8.

Based on the observations and preliminary model fits, the Working Group considered the most plausible model runs were those that down-weighted the acoustic observations from 2009 to 2013 relative to those in 2007 and 2008. The recent biomass observations and age structure were not consistent with those models that down weighted the 2007–2008 observations. However, the 2013 biomass observation and recent age structures were consistent with the observed biomass in 2007 and 2008, after taking account of fishing and natural mortality, if we assume that the 2009–2012 observations underestimated the true biomass.

These model results were found to be sensitive to the choice of the relative catchability coefficient, and hence two sensitivity runs were considered. The first up-weighted the prior, and assumed a lognormal prior with mean 0.41 and CV 0.1; the second down-weighted the prior and assumed a lognormal prior with mean 0.41 and CV 0.3. These model runs are described in Table 20.

Lognormal errors, with known CVs, were assumed for the relative biomass and proportions-at-age data. The CVs available for these data allow for sampling error only. However, additional variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance. The additional variance, termed process error, was estimated in each of the initial runs (MPDs) using all the available data. Process errors were estimated separately for the proportion-at-age data, and for the acoustic estimates from the wide area and local area aggregation surveys.

Table 20: Model base case (6.3) and four sensitivity runs (4.2, 4.3, 6.6 and 6.7)

Model	Description
6.3 Base case	Down weight 2009–2013 acoustic indices and estimated catchability with lognormal prior mean = 0.41, CV =0.2
4.2	Down weight 2007–2008 acoustic indices (ignore the high acoustic biomass estimates in these years)
4.3	Down weight 2009–2013 acoustic indices (ignore the recent low acoustic biomass estimates)
6.6	Down weight 2009–2013 acoustic indices and estimated catchability with lognormal prior mean = 0.41, CV =0.1
6.7	Down weight 2009–2013 acoustic indices and estimated catchability with lognormal prior mean = 0.41, CV =0.3

Results

The estimated MCMC marginal posterior distributions for spawning stock biomass trajectories are shown for the base case (model 6.3) in Figure 4, and the results are summarised in Table 21 and 22. The run suggests that the stock biomass was relatively low from the early 1990s till the arrival of the large 2002 year class into the fishery in 2007. Since 2007, the population has declined, even with the arrival of a moderately sized year class in 2007. Exploitation rates and relative year class strengths are shown in Figure 5. Estimates of the adult acoustic *q* are given in Table 22.

Table 21: Bayesian median and 95% credible intervals of equilibrium initial biomass (B_0), current biomass (B_{2014}) and stock status (%B_{2014} B_0) for the model runs 6.3 (base case), 6.6 (*q* prior CV=0.1) and 6.7 (*q* prior CV=0.3). Models 4.2 and 4.3 had *q* fixed at 0.5).

Model	B_0	B_{2014}	B_{2014} (%B_0)
6.3 Base case	150 120 (126 140–189 050)	66 977 (46 837–102 237)	45 (36–54)
4.2	126 350 (118 880–140 110)	46 208 (42 635–50 294)	36 (34–39)
4.3	164 300 (151 770–179 920)	77 370 (64 240–94 477)	47 (42–54)
6.6	180 060 (159 890–205 860)	91 383 (73 509–114 100)	51 (45–57)
6.7	133 170 (112 380–169 380)	52 358 (34 126–82 344)	39 (30–50)

Table 22: Bayesian median and 95% credible intervals of the catchability coefficients (q) for the wide area acoustic biomass indices for model runs 6.3 (base case), 6.6 (*q* prior CV=0.1) and 6.7 (*q* prior CV=0.3). Models 4.2 and 4.3 had fixed values of *q*, with the mature acoustic *q* for these surveys set at 0.5,

Model	Catchability	
	Mature	Immature
6.3 (Base case)	0.55 (0.43–0.67)	0.12 (0.10–0.15)
6.6	0.43 (0.39–0.48)	0.11 (0.10–0.15)
6.7	0.65 (0.48–0.80)	0.13 (0.10–0.16)

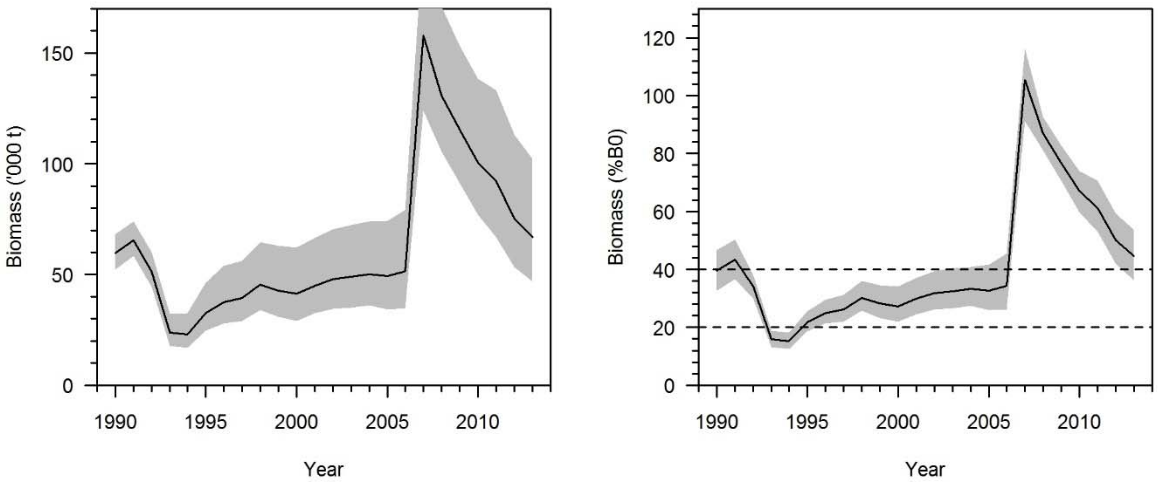


Figure 4: MCMC posterior plots of the biomass trajectories of (left) B_0 and (right) current biomass (%B_{2014}/B_0) for the Bounty Platform stock for the base case.

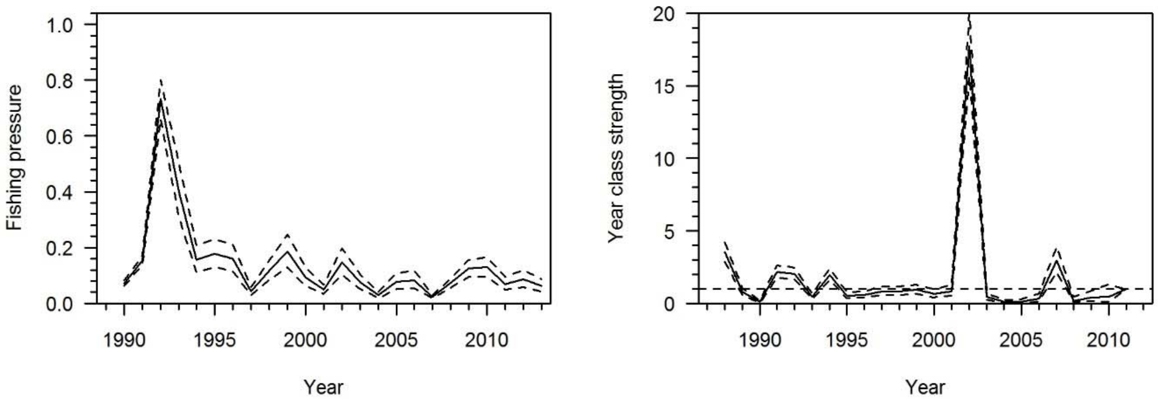


Figure 5: Estimated posterior distributions of exploitation rates (left) and relative year class strength (right) for the Bounty Platform stock for the base case.

Projections were made assuming fixed catch levels of 6860, 8000 and 10 000 t. They used the MCMC samples, with recruitments drawn from a lognormal distribution with mean of 1 and σ_R of 1.1 and applied from year 2011 onwards. For projections, the mean sizes-at-age were assumed to be equal to the estimated sizes-at-age in 2013.

For each scenario, the probability that the mid-season biomass for the specified year will be less than the threshold level (20% B_0) is given in Table 23. The probability of dropping below the threshold biomass at a catch level of 6860 t is less than 5% for all years and for catch levels of 8000 and 10 000 t is less than 10% for all years. Under average recruitment conditions the biomass is expected to decline slowly.

Table 23: Probability that the projected mid-season vulnerable Bounty Platform southern blue whiting biomass for 2014–2016 will be less than 20% B_0, and the median projected biomass (%B_0), at a projected catch of 6860t, 8000 t, and 10 000 t, for the base case model and four sensitivities, assuming average recruitment over the period 1988–2010 for 2011 onwards.

Model	Catch (t)	Pr (SSB < 0.2B_0)			Median SSB (%B_0)		
		2014	2015	2016	2014	2015	2016
	6 860	0.00	0.00	0.00	47	44	43
6.3 (base)	8 000	0.00	0.00	0.00	47	43	41
	10 000	0.00	0.00	0.00	47	42	38
	6 860	0.00	0.00	0.00	54	54	54
4.2	8 000	0.00	0.00	0.00	53	52	51
	10 000	0.00	0.00	0.00	52	48	45
	6 860	0.00	0.00	0.00	71	72	72
4.3	8 000	0.00	0.00	0.00	70	69	68
	10 000	0.00	0.00	0.00	69	67	65
	6 860	0.00	0.00	0.00	77	73	71
6.6	8 000	0.00	0.00	0.00	77	72	69
	10 000	0.00	0.00	0.00	77	70	65
	6 860	0.00	0.00	0.00	60	56	54
6.7	8 000	0.00	0.00	0.00	60	54	51
	10 000	0.00	0.00	0.01	59	51	46

(iii) Pukaki Rise stock

An assessment for 2014 was planned for the Pukaki Rise stock but the Working Group did not accept that the 2012 acoustic survey provided an acceptably realistic biomass estimate for the stock, so no assessment was possible.

An assessment of the Pukaki Rise stock was carried out in 2002. The sSPA model was used to estimate the numbers at age in the initial population in 1989 and subsequent recruitment. The model estimates selectivity for ages 2, 3, and 4 and assumes that the selectivity after age 4 is 1.0. No stock-recruitment relationship is assumed in the sSPA.

Preliminary runs of the model were fitted to proportion-at-age data from 1989 to 2000, and the acoustic indices given in Table 24, which differ from those in Table 8 because they were calculated with an older estimate of target strength and sound absorption. The indices were fitted in the model as relative estimates of mid-season biomass (i.e., after half the catch has been removed), with the CVs as shown in Table 25. The proportion-at-age data are assumed to be multinomially distributed with a median sample size of 50 (equivalent to a CV of about 0.3). Details of the input parameters for the initial and sensitivity runs are given in Table 25.

Table 24: R.V. *Tangaroa* age 2, 3 and 4+ acoustic biomass estimates (t) for the Pukaki Rise used in the 2002 assessment. Estimates differ from those in Table 8 because they were calculated with old estimates of target strength and sound absorption.

Year	Age 1	Age 2	Age 3	Age 4+
1993	578	26 848	9 315	31 152
1994	13	1 193	6 364	35 969
1995	0	102	775	11 743
1997	22	2 838	864	34 086
2000	58	7 268	5 577	24 931

Table 25: Values for the input parameters to the separable Sequential Population Analysis for the initial run and sensitivity runs for the Pukaki Rise stock.

Parameter	Initial run	Sensitivity runs
M	0.2	0.15, 0.25
Acoustic age 3 and 4+ indices *CV*	0.3	0.1, 0.5
Acoustic age 1, 2 indices *CV*	0.7	0.5, 1.0
Weighting on proportion-at-age data	50	5, 100
Years used in analysis	1989–2000	1979–2000
Acoustic *q*	estimated	0.68, 1.4, 2.8

Biomass estimates in the initial run and also in the sensitivity runs all appeared to be over-pessimistic because the adult (4+) acoustic *q* was very high. For example, for the initial run the 4+ acoustic *q* was estimated to be 2.7. The WG did not accept this initial run as a base case assessment, but agreed to present a range of possible biomass estimates. The Plenary also agreed to present a range, based on assumptions concerning the likely range of the value for the acoustic *q*.

Bounds for the adult (4+) acoustic *q* were obtained using the approach of Cordue (1996). Uncertainty over various factors including mean target strength, acoustic system calibration, target identification, shadow or dead zone correction, and areal availability were all taken into account. In addition to obtaining the bounds, a 'best estimate' for each factor was also calculated. The factors were then multiplied together. This independent evaluation of the bounds on the acoustic *q* suggested a range of 0.65–2.8, with a best estimate of 1.4. Clearly the *q* from the initial run is almost at the upper bound and probably outside the credible range. When the model was run fixing the acoustic *q* at 0.65 and 2.8, estimates of B_0 were 18 000 t and 54 000 t, and estimates of B_{2000} were 8000 t and 48 000 t respectively (Table 26, Figure 6). Within these bounds current biomass is greater than B_{MAY}. Assuming the 'best estimate' of *q* of 1.4 gave B_0 equal to 22 000 t and B_{2000} equal to 13 000 t.

Based on the range of stock biomass modelled in the assessment, the average catch level since 2002 (380 t) is unlikely to have made much impact on stock size. A more intensive fishery or more consistent catches from year to year would seem to be required to provide any contrast in the biomass indices. This stock has been only lightly exploited since 1993, when over 5000 t was taken in the spawning season.

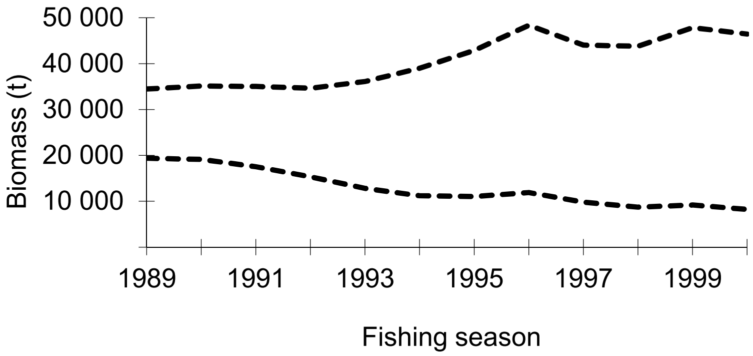


Figure 6: Mid-season spawning stock biomass trajectory bounds for the Pukaki Rise stock. Bounds based on acoustic *q* of 0.65 and 2.8.

Table 26: Parameter estimates for the Pukaki stock as a result of fixing the adult 4+ acoustic *q* at various values. B_{mid}, mid-season spawning stock biomass; $N_{2,1992}$ size of the 1990 year class (millions). All values in t x 10^3.

Fixing the acoustic *q* value	B_0	$B_{mid\ 89}$	$B_{mid\ 00}$	$N_{2,1992}$	$B_{mid\ 00}$ (%B_0)	$B_{mid\ 00}$ (%B_{may})
q = 0.65	54	36	48	63	88	246
q = 1.4	22	22	13	28	58	161
q = 2.8	18	19	8	23	44	123

(iv) Auckland Islands stock

No estimate of current biomass is available for the Auckland Islands Shelf stock. The acoustic estimate of the adult biomass in 1995 was 7800 t.

5. STATUS OF THE STOCKS

Stock Structure Assumptions

Southern blue whiting are assessed as four independent biological stocks, based on the presence of four main spawning areas (Auckland Islands Shelf, Bounty Platform, Campbell Island Rise, and Pukaki

Rise), and some differences in biological parameters and morphometrics between these areas (Hanchet 1999).

The four main stocks SBW 6A (Auckland Islands), SBW 6B (Bounty Platform), SBW 6I (Campbell Island Rise), and SBW 6R (Pukaki Rise) cover the four main bathymetric features in the Sub-Antarctic QMA6. SBW 1 is a nominal stock covering the rest of the New Zealand EEZ where small numbers of fish may occasionally be taken as bycatch.

- **Auckland Islands (SBW 6A)**

Stock Status	
Year of Most Recent Assessment	-
Assessment Runs Presented	-
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	
Historical Stock Status Trajectory and Current Status	
Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Catches have fluctuated without trend
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	No reliable indices of abundance
Trends in Other Relevant Indicators or Variables	Catch in 2007 and 2008 was dominated by large (40–50 cm long) fish - no sign of recent strong year classes.

Projections and Prognosis	
Stock Projections or Prognosis	-
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	-

Assessment Methodology		
Assessment Type	Level 4 - Low information	
Assessment Method	None	
Assessment Dates	-	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs	Catch history - erratic catches with no trend Limited catch-at-age data (1993–1998) and 2008	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- No reliable time series of data available. - Catches have been erratic for the past 10 years and have been taken as bycatch in other middle depth fisheries so unlikely to provide reliable CPUE indices.	

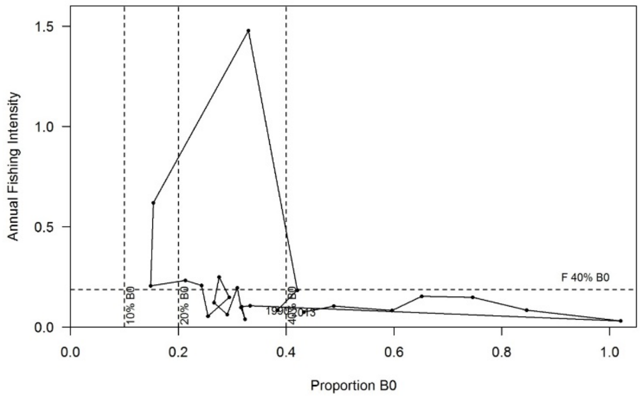
Qualifying Comments
There were several years of high catches (700–1100 t) during the mid 1990s but since then annual catches have averaged about 100 t. Good recruitment in southern blue whiting tends to be episodic and it is likely that the period of high catches was due to the presence of the strong year 1991 year class. Catches will probably remain low until another strong year class enters the fishery.

Fishery Interactions
There was virtually no fish bycatch when it was a target fishery during the mid 1990s.

- **Bounty Platform (SBW 6B)**

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	MCMC estimates from integrated stock assessment model scenarios with different prior weighting of the time series of acoustic survey estimates.
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	B_{2013} was estimated to be between 40% B_0 and 50% B_0. About as Likely As Not (40–60%) to be at or above the target
Status in relation to Limits	Unlikely (< 40%) that the current biomass is below the Soft Limit Very Unlikely (< 10%) that the current biomass is below the Hard Limit
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring.

Historical Stock Status Trajectory and Current Status



Trajectory over time of fishing intensity (*U*) and spawning biomass (%*B*$_0$), for the Bounty Platform southern blue whiting stock from the start of the assessment period in 1990 to 2013. The dotted vertical lines show the management target (40% *B*$_0$) in stock status and fishing intensity, and the hard limit (10% *B*$_0$) and soft limit (20% *B*$_0$) in stock status. Biomass estimates are based on MCMC results, while fishing intensity is based on corresponding MPD results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass was below the target level from 1993 to 2005 but, with the recruitment of the very strong 2002 year class, the stock increased to be at or above pre-exploitation levels until 2008 but has subsequently declined.
Recent Trend in Fishing Intensity or Proxy	Fluctuating at levels below the overfishing threshold, since 2002.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Recruitment was estimated to be low from 1995 to 2001 but was extremely high in 2002 and has been low since then. The 2007 year class appears to be above average.

Projections and Prognosis	
Stock Projections or Prognosis	The biomass of the Bounty stock is expected to decrease over the next 3 years at the current catch level as the 2002 and 2007 year classes are fished down.
Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits	Soft Limit: Very Unlikely (< 10%) over next 3 years Hard Limit: Exceptionally unlikely (< 1%) over next 3 years
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 1 – Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2014	Next assessment: 2017
Overall assessment quality rank	2 – Medium Quality	
Main data inputs (rank)	- Wide area acoustic abundance indices - Acoustic abundance indices from local area aggregation surveys - Proportions at age data from the commercial fisheries and trawl surveys - Estimates of biological parameters - Estimates of acoustic target strength	1 – High Quality 2 – Medium Quality (uncertainty in the proportion of the spawning aggregation covered by the surveys) 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	Commercial CPUE	3 – Low Quality: does not track stock biomass
Changes to Model Structure and Assumptions	New model, with revised estimate of acoustic target strength.	
Major Sources of Uncertainty	The proportion of the spawning biomass that is indexed by the local area aggregation survey in each year is variable and uncertain.	

Qualifying Comments
The catch-at-age data for the last seven years have been dominated by the strong 2002 year class. Local area aggregation acoustic surveys carried out in 2007 and 2008 suggested that this was an extremely strong year class, and suggested biomass of 73 000–76 000 t. However, surveys from 2002 to 2012 suggested a lower biomass. The observed decline between 2008 and 2009 was too great to be explained solely by fishing and average levels of natural mortality of the 2002 year class. While the high abundance observed in 2007 and 2008 was not seen by the aggregation surveys from 2009–2012, the higher observed abundance in 2013 is consistent with the abundance observed in the 2007 and 2008 surveys after accounting for natural and fishing mortality.

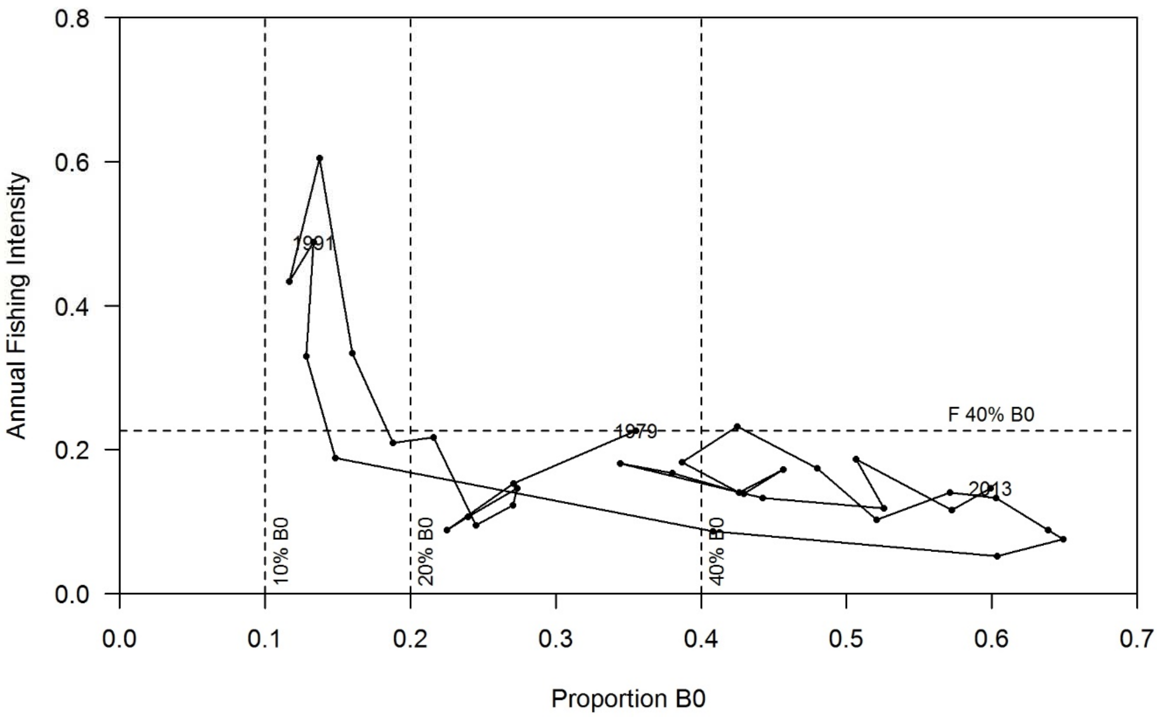
Fishery Interactions
There is virtually no fish bycatch in the fishery and, as this is principally a pelagic fishery, very little benthic impact. Protected species interactions are largely restricted to NZ fur seals and seabirds.

- **Campbell Island Rise (SBW 6I)**

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Base Case Stock Assessment Model
Reference Points	Management Target: 40% B_0

	Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%\ B0}$
Status in relation to Target	B_{2014} was estimated to be at or above 50% B_0 and is Very Likely (> 90%) to be at or above the target.
Status in relation to Limits	B_{2014} is Exceptionally Unlikely (< 1%) to be below soft or hard limits.
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring.

Historical Stock Status Trajectory and Current Status



Trajectory over time of fishing intensity (*U*) and spawning biomass (%*B*$_0$), for the Campbell Island Rise southern blue whiting stock from the start of the assessment period in 1979 to 2013. The dotted vertical lines show the management target (40% *B*$_0$) in stock status and fishing intensity, and the hard limit (10% *B*$_0$) and soft limit (20% *B*$_0$) in stock status. Biomass estimates are based on MCMC results, while fishing intensity is based on corresponding MPD results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	With strong recent recruitment the biomass has increased well above the management target.
Recent Trend in Fishing Intensity or Proxy	Fishing pressure has declined with the increase in stock size.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	The 2006 and 2009 year classes appear to be very strong, but not as strong as the 1991 year class.
Projections and Prognosis	
Stock Projections or Prognosis	At a TAC of 40 000 t, the biomass of the Campbell stock is expected to decrease slightly over the next 1–2 years.
Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits	Soft Limit: Exceptionally Unlikely (< 1%) over next 2–3 years Hard Limit: Exceptionally Unlikely (< 1%) over next 2–3 years
Probability of Current Catch or TACC causing Overfishing to continue or commence	Unlikely (< 40%)

Assessment Methodology		
Assessment Type	Level 1 - Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2014	Next assessment: 2017
Overall assessment quality rank	1–High Quality	
Main data inputs (rank)	- Research time series based on acoustic indices - Proportions-at-age data from the commercial fisheries and trawl surveys - Estimates of biological parameters	1–High Quality 1–High Quality 1–High Quality
Data not used (rank)	Commercial CPUE	3 – Low Quality: does not track stock biomass
Changes to Model Structure and Assumptions	- Target strength was revised resulting in revised biomass estimates. - Plus group increased from11 to 15.	
Major Sources of Uncertainty	- Uncertainty about the size of future age classes affects the reliability of stock projections. - Future mean weight at age in the projections.	

Qualifying Comments
The prior for the wide-area acoustic surveys was based on the previous target strength estimates relationship, which is likely to have led to underestimates of spawning stock biomass, as well as possible biases in stock status estimates.
Fishery Interactions
The principal protected species incidental captures are of New Zealand sea lions, New Zealand fur seals and seabirds. There is virtually no fish bycatch in the fishery and, as it is principally a pelagic fishery, very little benthic impact.

- **Pukaki Rise (SBW 6R)**

Stock Status	
Year of Most Recent Assessment	2002
Assessment Runs Presented	The results of three runs were presented assuming different values for the adult acoustic *q*.
Reference Points	Interim Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: -
Status in relation to Target	Current status unknown. Believed to be only lightly exploited between 1993 and 2002
Status in relation to Limits	Current status unknown. Believed to be only lightly exploited between 1993 and 2002
Status in relation to Overfishing	-
Historical Stock Status Trajectory and Current Status -	
Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Catches over the last 10 years have fluctuated without trend.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	No current reliable indices of abundance (wide area surveys were discontinued in 2000)
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis (2002)	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	-

Assessment Methodology		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age structured separable Sequential Population Analysis (sSPA) with maximum likelihood estimation	
Assessment Dates	Last assessment: 2002	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	- Abundance indices from wide area acoustic surveys - Catch-at-age data	
Data not used (rank)	-	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	The adult acoustic q was estimated in the model to be 2.7 which the Working Group thought was unrealistically high. A run based on a more plausible value for *q* suggested the 2000 biomass was above 50% B_0.	

Qualifying Comments
Fishers reported large aggregations of fish and made good catches in 2009. However, aggregation surveys by industry vessels in 2009 yielded generally low biomass estimates which were at a level consistent with that during the 1990s. The Sub-Antarctic trawl surveys may provide an index of abundance for this stock, but this has yet to be determined. Catch at age data are available for 2007 and 2009 and suggest the catch is dominated by relatively young fish from the 2003–2006 year classes.

Fishery Interactions
There is negligible fish bycatch, benthic impact or marine mammal incidental captures in the target fishery.

Table 27: Summary of TACCs and preliminary estimates of landings (t) (1 April–31 March fishing year).

Area	2014–15 Actual TACC	2014–15 Landings
SBW 1 (EEZ excluding Sub-Antarctic)	8	29
Campbell Island	39200	24 592
Bounty Platform	6 860	4 278
Pukaki Rise	5 500	34
Auckland Islands Shelf	1 640	156
Total	53 208	31 867

6. FUTURE RESEARCH

For Campbell Island Rise southern blue whiting, the following issues were identified as candidates for further research or investigation:

- acoustic biomass estimates are based on a simple average of snapshots, the revision of the acoustic time series should be investigated with respect to weighting the snapshots by the inverse of the CVs;
- the prior for the Campbell wide-area surveys needs to be reconstructed to incorporate the revised target strength relationship;

- determine how to best represent mean weights at age in the projections given the negative relationship between year class strength and growth.

For Bounty Platform southern blue whiting, the following issues were identified as candidates for further research or investigation:

- acoustic biomass estimates are based on a simple average of snapshots, the revision of the acoustic time series should be investigated with respect to weight the snapshots by the inverse of the CVs;
- consider the utility of developing a standardised CPUE index for the Bounties stock for the purpose of corroborating the biomass time series;
- consider starting the Bounties model earlier to obtain a better estimate of B_0;
- determine how to best represent mean weights at age in the projections given the negative relationship between year class strength and growth.

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