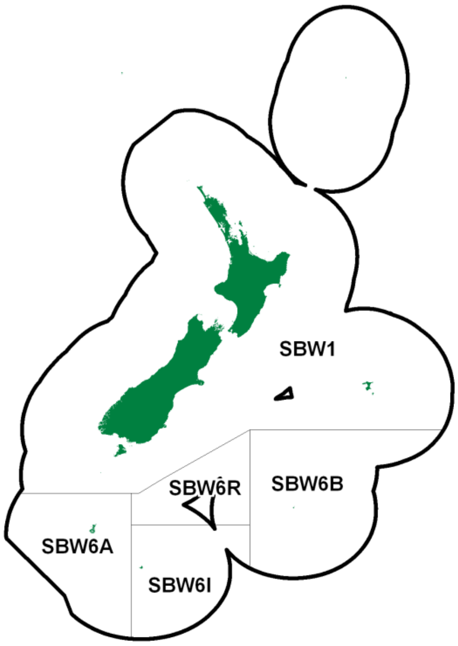
SOUTHERN BLUE WHITING (SBW)
(*Micromesistius australis*)



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 November 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 most years since 2000–01 (Table 2). However, catches increased from 21 t to 86 t in 2016–17. The TACC for SBW 1 was increased to 98 t for the 2017–18 season. Catch was 51 t in 2017–18 and 33 t in 2018–19.

Landings for other stocks have been between 20 000 t and 40 000 t since 2000, with the majority of the catch currently taken by foreign owned 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 only 9 000 t . The TACC on the Campbell Island Rise has been increasingly under-caught since 2014–15, most recently by 20 866 t in 2017–18 and 24 053 t in 2018–19. 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 9 800 t for the 2008–09 season and further increased to 14 700 t for the 2009–10 and 2010–11 seasons but decreased to 6 860 t for the 2011–12 season. In 2013–14, 2 832 t were shelved, leaving the effective catch limit at 4 028 t. The TACC for the Bounty Platform stock was reduced to 2 940 t for the 2015–16 and 2016–17 seasons, further reduced to 2 377 t for the 2017–18 season and then increased to 3 145 t for the 2018–19 season. The TACC for the Campbell Island Rise stock was reduced from 25 000 t to 20 000 t in 2006-07, where it remained until 2009–10. For the 2010–11 season the catch limit for the Campbell stock was raised to 23 000 t, in 2011–12 to 29 400 t, and in 2014–15 it was raised to 39 200 t. Catch limits for Pukaki Rise and Auckland Islands have remained unchanged since 1997.

Table 1: Reported annual landings (t) of southern blue whiting for all areas

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

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.

	SBW6B Bounty Platform		SBW6I Campbell Rise		SBW6R Pukaki Rise		SBW6A Auckland Is.		SBW6I Rest of NZ		Total	
Fish. year	Catch	Limit	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	9	8	24 804	‡35 140
2001–02#	2 262	8 000	29 999	30 000	230	5 500	10	1 640	1	8	31 114	‡45 140
2002–03#	7 564	8 000	33 445	30 000	508	5 500	262	1 640	16	8	41 795	‡45 140
2003–04#	3 812	3 500	23 718	25 000	163	5 500	116	1 640	3	8	27 812	‡35 640
2004–05#	1 477	3 500	19 799	25 000	240	5 500	95	1 640	9	8	21 620	‡35 640
2005–06#	3 962	3 500	26 190	25 000	58	5 500	66	1 640	2	8	30 287	‡35 640
2006–07#	4 395	3 500	19 763	20 000	1 115	5 500	84	1 640	7	8	25 363	‡30 640
2007–08#	3 799	3 500	20 996	20 000	513	5 500	278	1 640	1	8	25 587	‡30 640
2008–09#	9 863	9 800	20 483	20 000	1 377	5 500	143	1 640	21	8	31 867	‡36 948
2009–10#	15 468*	14 700	19 040	20 000	4 853	5 500	174	1 640	5	8	39 540	‡42 148
2010–11#	13 913	14 700	20 224	23 000	4 433	5 500	131	1 640	8	8	38 708	‡44 848
2011–12#	6 660	6 860	30 971	29 400	686	5 500	92	1 640	2	8	38 412	‡43 400
2012–13#	6 827	6 860	21 321	29 400	1 702	5 500	49	1 640	8	8	29 906	‡43 400
2013–14#	4 278~	4 028	28 607	29 400	14	5 500	47	1 640	21	8	32 950	‡43 400
2014–15#	7 054	6 860	24 592	39 200	34	5 500	156	1 640	29	8	31 887	‡53 208
2015–16#	2 405	2 940	22 100	39 200	12	5 500	181	1 640	35	8	24 733	‡49 228
2016–17#	2 569	2 940	19 875	39 200	11	5 500	46	1 640	86	8	22 588	‡49 280
2017–18#	2 423	3 145	18 334	39 200	36	5 500	202	1 640	51	98	20 821	‡49 485
2018–19#	1 101	3 145	15 147	39 200	36	5 500	218	1 640	33	98	16 502	‡49 485

f 1 April–30 September` + 1 October–30 September
† 1 October 1998–31 March 2000 # 1 April–31 March
* 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 6 860 t, the ACE available to balance against catch was limited to 4 028 t as 2 832 t was shelved under a voluntary agreement with industry.

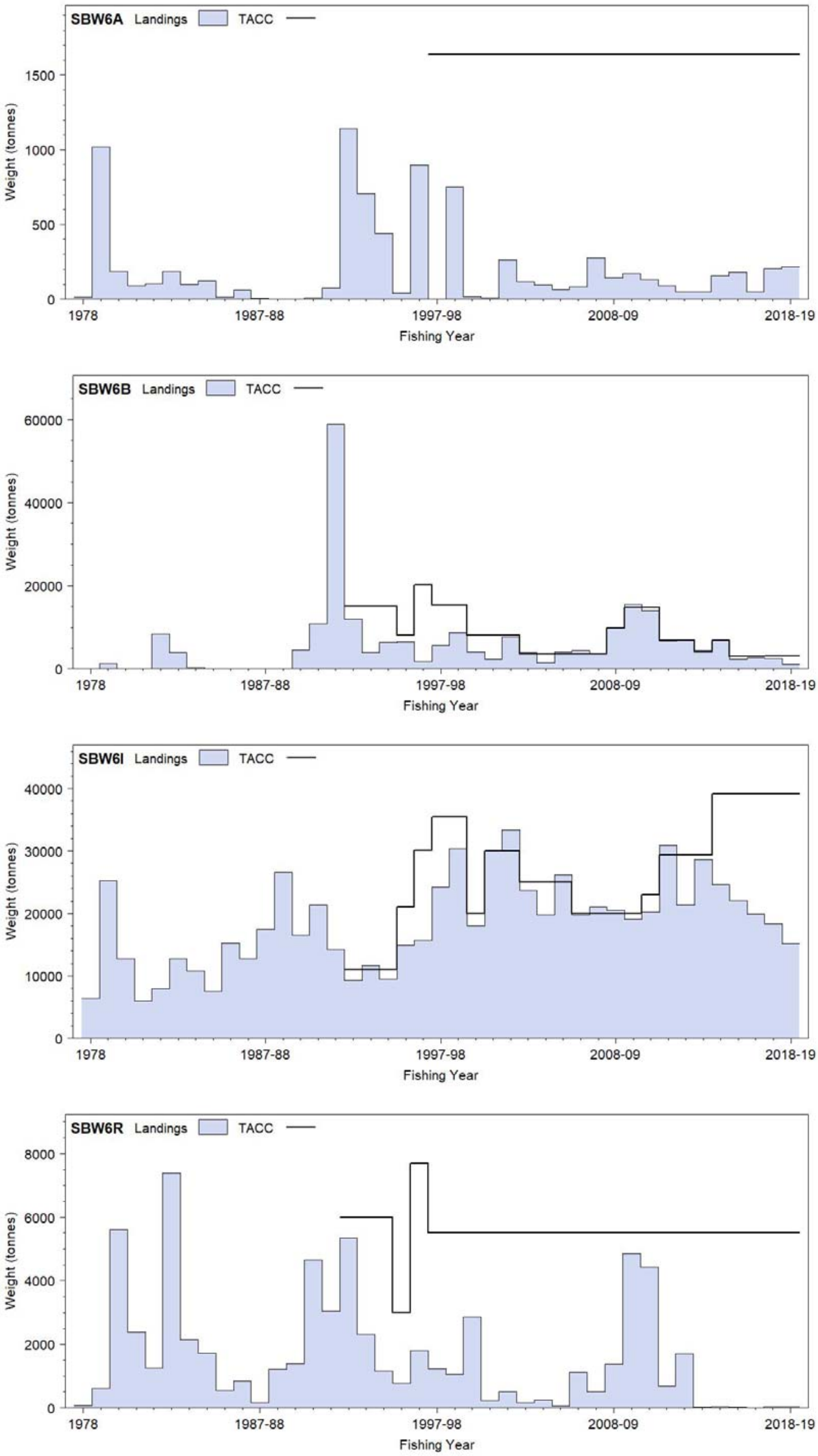


Figure 1: Reported commercial landings and TACC for the four main SBW stocks. From top: SBW 6A (Auckland Islands), SBW 6B (Bounty Platform), SBW 6I (Campbell Island Rise), and SBW 6R (Pukaki Rise). Note that these figures do not show data prior to entry into the QMS.

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 $\log_e(100)$/maximum age, where maximum age is the age to which 1% of the population survives in an unexploited stock. Using a maximum age of 22 years, M was estimated to equal 0.21. 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 and Roberts & Dunn 2017).

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)
			0.17	0.18	Roberts & Hanchet (2018)
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 2018 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 2017 Aquatic Environment & Biodiversity Annual Review (MPI 2017, https://www.mpi.govt.nz/dmsdocument/27471-aquatic-environment-and-biodiversity-annual-review-aebar-2017-a-summary-of-environmental-interactions-between-the-seafood-sector-and-the-aquatic-environment).

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 2011). 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. A total of 109 bycatch species have been recorded by observers, of which the main bycatch species have been ling, hake, and hoki, with smaller amounts of porbeagle shark, opah, silverside, and pale ghost shark (Finucci et al 2019).

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 New Zealand sea lions and New Zealand fur seals (which were classified as “Nationally Critical” and “Not Threatened”, respectively, under the New Zealand Threat Classification System in 2010, Baker et al 2016). 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*, has an estimated total population of around 11 800 sea lions in 2015 Pup production at the main Auckland Island rookeries showed a steady decline between 1998 and 2009 and has subsequently stabilised (details can be found in the Aquatic Environment and Biodiversity Annual Review, MPI 2018).

Sea lions interact with some trawl fisheries which can result in incidental capture and subsequent drowning (Smith & Baird 2009, Thompson et al 2010b, Abraham & Thompson 2011, Abraham et al 2016). Since 1988, incidental captures of sea lions have been monitored by government observers on-board an increasing proportion of the fishing fleet. Since the 2012–13 fishing year effectively 100% of SBW fishing effort has been observed (Table 4).

Specific objectives for the management of New Zealand sea lion incidental captures are outlined in the fishery-specific chapters of the National Deepwater Plan for the fisheries with which New Zealand 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.

Captures of New Zealand sea lions in the Campbell Island southern blue whiting trawl fishery have been variable between years. The sea lion captures occur close to Campbell Island in SBW 6I and are mostly males (91%). There were 21 captures in 2012–13, mostly early in the season, which led to the development of an operational 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 2016–17. 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 (2016) and are available via https://data.dragonfly.co.nz/psc. Estimates for 2002–03 to 2014–15 are based on data version 2018v01.

			Observed captures			Estimated captures	
	Tows	No.obs	%obs	Captures	Rate	Mean	95%c.i.
2002–03	638	275	43.1	0	0.0	1	0-3
2003–04	740	241	32.6	1	0.4	3	1-9
2004–05	870	335	38.5	2	0.6	5	2-13
2005–06	624	217	34.8	3	1.4	10	3-22
2006–07	630	224	35.6	3	1.3	15	6-30
2007–08	816	331	40.6	5	1.5	8	5-14
2008–09	1 189	301	25.3	0	0.0	1	0-7
2009–10	1 113	396	35.6	11	2.8	24	15-37
2010–11	1 171	433	37.0	6	1.4	15	8-25
2011–12	952	669	70.3	0	0.0	1	0-4
2012–13	790	790	100.0	21	2.7	21	21-21
2013–14	802	801	99.9	2	0.2	2	2-2
2014–15	677	670	99.0	6	0.9	6	6-6
2015–16	442	443	100.2	3	0.7		
2016–17	538	538	100.0	0	0.0		

The New Zealand fur seal was classified as "Least Concern" by IUCN in 2008 and as "Not Threatened" under the New Zealand Threat Classification System in 2010 (Baker et al 2016).

Southern blue whiting has one of the highest observed capture rates of New Zealand fur seals for any observed fishery. The capture rate of fur seals in the southern blue whiting fishery has varied considerably between years ranging without trend from a high of 11.8 seals per 100 tows in 2008–09 to a low of 2 seals per 100 tows in 2016-17, (Thompson et al 2010a, Abraham & Thompson 2011, Thompson et al 2012, Thompson et al 2013, Abraham et al 2016) (Table 5). Almost all fur seals captured in this fishery have been caught at the Bounty Platform in August and September when the southern blue whiting are in dense spawning aggregations. Estimated capture rates from Abraham et al (2016) (available via https://data.dragonfly.co.nz/psc) are not reproduced here pending resolution of identified structural issues in the model related to the partition between model strata with contrasting capture rates, resulting in implausibly high estimates of uncertainty despite high observer coverage.

Table 5: Number of tows by fishing year and observed New Zealand fur seal captures in southern blue whiting trawl fisheries, 2002–03 to 2016–17. Abraham et al (2016) and are available via https://data.dragonfly.co.nz/psc

				Observed captures	
	Tows	No.obs	%obs	Captures	Rate
2002–03	638	275	43.1	8	2.9
2003–04	740	241	32.6	13	5.4
2004–05	870	335	38.5	33	9.9
2005–06	624	217	34.8	52	24.0
2006–07	630	224	35.6	13	5.8
2007–08	816	331	40.6	24	7.3
2008–09	1 189	301	25.3	17	5.6
2009–10	1 113	396	35.6	16	4.0
2010–11	1 171	433	37.0	36	8.3
2011–12	952	669	70.3	25	3.7
2012–13	790	790	100.0	27	3.4
2013–14	802	801	99.9	95	11.9
2014–15	677	670	99.0	41	6.1
2015–16	442	443	100.2	51	11.5
2016–17	538	538	100.0	11	2.0

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 each of the 2015–16 and 2016–17 fishing years, there were 6 observed captures of birds in southern blue whiting trawl fisheries at a rate of 1.4 and 1.1 birds per 100 observed tows (Table 6). The average capture rate in southern blue whiting trawl fisheries for the period from 2002–03 to 2016–17 is about 1.33 birds per 100 tows, a low rate relative to other New Zealand trawl fisheries, e.g. for scampi (4.43 birds per 100 tows) and squid (13.79 birds per 100 tows) over the same years.

Overall, the impact that the southern blue whiting fisheries have on seabirds is small. This can be seen in the proportions of the overall fisheries Population Sustainability Threshold (PST) that are attributable to the blue whiting fisheries for each species (Table 7). Observed seabird captures since 2002–03 have been dominated by grey petrels (49 of the 83 observed seabird captures since 2002–03), a negligible risk species where the blue whiting fisheries are estimated to be responsible for 16.6% of the PST (Table 7).

Table 6: Number of tows by fishing year and observed seabird captures in southern blue whiting trawl fisheries, 2002–03 to 2016–17. 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 (2016) and Abraham & Richard (2017, 2018) and are available via https://data.dragonfly.co.nz/psc. Estimates for 2002–03 to 2015–16 are based on data version 2018v01.

	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	3	0-9	100.0
2003–04	740	241	32.6	1	0.4	6	1-13	100.0
2004–05	870	335	38.5	2	0.6	11	4-23	100.0
2005–06	624	217	34.8	1	0.5	5	1-11	100.0
2006–07	630	224	35.6	3	1.3	7	3-14	100.0
2007–08	816	331	40.6	3	0.9	8	4-15	100.0
2008–09	1 189	301	25.3	0	0	10	2-22	100.0
2009–10	1 113	396	35.6	11	2.8	29	18-46	100.0
2010–11	1 171	433	37.0	11	2.5	23	15-34	100.0
2011–12	952	669	70.3	3	0.4	6	3-12	100.0
2012–13	790	790	100.0	19	2.4	19	19-19	100.0
2013–14	802	801	99.9	16	2	16	16-16	100.0
2014–15	677	670	99.0	7	1	7	7-9	100.0
2015–16	442	443	100.2	6	1.4	6	6-6	100.0
2016–17	538	538	100.0	6	1.1	6	6-7	100.0

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 2014–15, showing seabird species with a risk ratio of at least 0.001 of PST. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Population Sustainability Threshold, PST (from Richard et al 2017, where full details of the risk assessment approach can be found). The DOC threat classifications are shown (Robertson et al 2017 at http://www.doc.govt.nz/documents/science-and-technical/nztcs19entire.pdf).

Species	PST (mean)	Risk ratio SBW trawl	Risk ratio Total	Risk category	DOC Threat Classification
Salvin's albatross	3599.5	0.009	0.780	High	Threatened: Nationally Critical
Grey petrel	5524.1	0.006	0.037	Negligible	At Risk: Naturally Uncommon
Campbell black-browed albatross	1980.5	0.002	0.077	Low	At Risk: Naturally Uncommon

4.4 Benthic interactions

Southern blue whiting is principally taken using midwater trawls (99% for fishing years 2012-13 to 2015-16). 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 2012) 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).

During 1989–90 to 2015–16, about 15 470 southern blue whiting bottom-contacting trawls were reported on TCEPRs (Baird & Wood 2018): about 1000–2000 tows were reported annually during 1989–90 to 1991–92; 300–500 in most other years, except in 1997–98 and 1998–99 and 2009–10 and 2010–11 when about 700 tows were reported each year. The total footprint generated from these tows was estimated at about 21 000 km2. This footprint represented coverage of 0.5% of the seafloor of the combined EEZ and the Territorial Sea areas; 1.5% of the 'fishable area', that is, the seafloor area open to trawling, in depths of less than 1600 m. For the 2016–17 fishing year, 307 southern blue whiting bottom tows had an estimated footprint of 748 km2 which represented coverage of < 0.1% of the EEZ and Territorial Sea and 0.1% of the fishable area.

The overall trawl footprint for southern blue whiting (1989–90 to 2015–16) covered 3.0% of seafloor in 200–400 m, 6% in 400–600 m, and 0.2% of 600–1600 m seafloor (Baird & Wood 2018). In 2016–

17, the southern blue whiting footprint contacted < 0.1%, 0.3%, and < 0.01% of those depth ranges, respectively (Baird & Mules 2019). The BOMEC areas with the highest proportion of area covered by the southern blue whiting footprint were classes F (sub-Antarctic island shelves), I (Chatham Rise slope and shelf edge of the east coast South Island), and L (deeper waters off the Stewart-Snares shelf and around the main sub-Antarctic islands). The 2016–17 southern blue whiting footprint covered 0.25% of the 38 608 km2 of class F, 0.02% of the 52 224 km2 of class I, and almost 1% of the 198 577 km2 of class L (Baird & Mules 2019).

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 2018.

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 does not have a policy definition (MPI, 2013). 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 2018, using research time series of abundance indices from wide-area acoustic surveys from 1993 to 2016 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 2016, which produced a biomass estimate of 97 000 t. The general purpose stock assessment program, CASAL (Bull et al 2012) was used and the approach, which used Bayesian estimation, differed from previous assessments (e.g. Dunn & Hanchet 2017) in that year class strengths were estimated from 1958 (instead of 1977), the catch history was extended back to 1971, the first year of reported catches (1979 previously; see Table 1) and an initial equilibrium age structure was assumed in 1960 (instead of a non-equilibrium age structure in 1979) (Roberts & Hanchet 2018). The new model produced similar estimates of status to the old model, though also produced stable estimates of natural mortality when using Markov Chain Monte Carlo (MCMC) methods.

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. The general purpose stock assessment program, CASAL (Bull et al 2012) with Bayesian estimation was used. 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. Development of the assessment then focused on evaluating models with different assumptions that allowed a comparison of the extent to which the high biomass and subsequent decline were fitted. However, these have not proven successful, and the stock assessment has now been rejected by the Working Group in favour of developing a harvest control rule. An HCR that would lead to a low risk of the stock falling below the soft limit reference point was developed, and used the most recent acoustic index of abundance as an absolute measure of abundance. Four further acoustic surveys have been completed at the Bounty Platform (from 2014 to 2017).

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 2016, a series of local area aggregation surveys has been carried out from industry vessels fishing the Bounty Platform (O'Driscoll 2015, O'Driscoll & Dunford 2017, O'Driscoll & Ladroit 2017, Large et al. in prep). The fishing vessels 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 2015). 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 2004–2016 (O'Driscoll 2015, O'Driscoll & Dunford 2017, O'Driscoll & Ladroit 2017); and the proportion of catch that occured 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
2014		-	11 852 (31%)	0.75
2015		-	6 726 (42%)	0.44
2016		-	6 201 (35%)	0.93
2017			7 719 (24%)	0.61

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, but since then biomass estimates have progressively declined, supporting the view that biomass has declined in this stock. Acoustic data collected in 2018 could not be used for estimates of abundance as aggregations seen later in August had dispersed before an acoustic snapshot could be made. It is possible that the first spawning in 2018 was earlier than in recent years, and therefore that the acoustic data collection was too late (Large et al., in prep).

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 Working Group 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 2016 (O'Driscoll et al 2018). Estimates of mature biomass suggested an increase in biomass since 2011, similar to the highest estimate from 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 1993–2016 (from Fu et al 2013, O'Driscoll et al 2018). 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%)
2016	4 456 (19%)	97 117 (16%)

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 (2009 to 2012) 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 (2017 stock assessment)

The stock assessment model

An updated stock assessment for the Campbell Island stock was completed for the 2016–17 year (Roberts & Hanchet 2018).

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 1960–2016. Five year projections were run for the years 2017–2021. 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 2016.

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 updated model was started in 1960 and assumed an equilibrium age distribution, differing from recent assessments, which estimated numbers-at-age in the population at a model starting year of 1979. The new model estimated year class strengths back to 1958, which allowed the flexibility to fit to strongly non-equilibrium age composition observed in the commercial trawl catches since 1979. Catches for the Campbell Rise in years 1971–1977 were estimated by assuming the proportion of the catch from all areas taken at the Campbell Rise was equal to the proportion across the period since 1978, following Roberts & Dunn (2017) (See Table 12).

Table 12: Estimated catches for Campbell Rise from 1971 to 1977 (see Roberts & Hanchet 2018).

Fishing year	Estimated catch
1971	7 260
1972	18 010
1973	33 856
1974	29 458
1975	1 660
1976	11 929
1977	18 453

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 2016. 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 by bootstrap using the NIWA catch-at-age software (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 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). To improve mixing at MCMC (following the approach of Roberts & Doonan 2016) the covariance matrix was recalculated empirically from the 100 samples obtained from a single MCMC chain of length 1×10^6 iterations (no burn in).

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. Year class strengths were estimated for all years from 1958 to 2013, 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 13). 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 new log-normal prior was developed for the wide area acoustic survey catchability coefficient obtained using the approach of Cordue (1996). The main difference between the revised prior and the original prior used in the 2013 assessment (Dunn & Hanchet 2015) was the inclusion of uncertainty over the tilt angle of southern blue whiting. Individual priors were developed for the key factors, including target strength, acoustic system calibration, target identification, shadow or dead zone correction, and spatial availability and these were then aggregated to develop an overall lognormal prior which had a mean of 0.54 and CV of 0.44.

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 13: 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	-	-	30 000	800 000
Male maturity	4	Uniform	-	-	0.001	0.999
Female maturity	4	Uniform	-	-	0.001	0.999
Year class strength	56	Lognormal	1.0	1.3	0.001	100
Wide area catchability mature *q*	1	Lognormal	0.54	0.44	0.1	1.5
Wide area catchability immature *q*	1	Uniform	-	-	0.01	1.5
*Natural mortality (average)	1	Lognormal	0.2	0.2	0.075	0.325
*Natural mortality (difference)	1	Normal	0.0	0.05	-0.05	0.05

*Natural mortality was estimated for a sensitivity run

Model runs

The Working Group considered a base case and 4 sensitivities (Table 14). The base case assumed a fixed natural mortality of 0.2 and an equilibrium age distribution in 1960. The sensitivities included an update of the 2015–16 base case model (with non-equilibrium age estimated in the model start year of 1979) and models with alternative assumptions of natural mortality, including estimated. Model outputs were relatively insensitive to alternative catch histories for the period 1971–1977 and sensitivities with respect to acoustic biomass estimates for 2016 (not shown here).

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 runs using all the available data, and fixed at these values for the MCMCs. 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 at MPD).

Table 14: Model run labels and descriptions.

Model type	Model label	Description
Sensitivity	1.1	Model estimating age-specific population size (C_{inital}) parameters for the year 1979, YCSs estimated for years 1977–2013, catch history for years 1979–2016 and natural mortality equal to 0.20.
Base case	2.1	Model with equilibrium age distribution for the year 1960, YCSs estimated for years 1958–2013, catch history for years 1971–2016, natural mortality equal to 0.20.
Sensitivity	3.1	Model 2.1, but with natural mortality equal to 0.15.
Sensitivity	3.2	Model 2.1, but with natural mortality equal to 0.25.
Sensitivity	3.3	Model 2.1, but with natural mortality estimated.

Results

The estimated MCMC marginal posterior distributions for spawning stock biomass trajectories are shown for the base case model run in Figure 2, and the results summarised in Table 15 and 16. The run suggests that the stock biomass increased above B_0 in the mid-1970s, due to strong year classes in the mid-1960. This was followed by 20 years of below average recruitment which led to a steep decline in stock biomass. This was followed by a large increase from 1994 to 1996 in response to the very 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 stabilised in recent years as the stronger 2006, 2009 and 2011 year classes recruited to the fishery. The most recent estimable year classes in 2012 and 2013 are both weak. 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 base case model run (2.1) and sensitivities 1.1 (2015 base case assuming non-equilibrium starting age structure in 1979), 3.1 (M fixed to 0.15), 3.2 (M fixed to 0.25) and 3.3 (*M* estimated)

Model	B_0	B_{2016}	B_{2016} (% B_0)
2.1 (base)	345 100 (311 100–389 800)	239 700 (173 100–328 600)	70 (54–86)
1.1	370 300 (327 000–428 500)	246 700 (175 600–340 100)	67 (54–80)
3.1	333 600 (311 400–360 800)	186 400 (138 100–254 500)	56 (44–71)
3.2	424 100 (361 800–521 000)	324 800 (230 300–479 500)	77 (59–100)
3.3	335 200 (307 500–380 500)	209 300 (146 000–313 100)	62 (45–84)

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 the base case model run and the sensitivity cases.

Model	Catchability		Natural mortality	
	Immature	Mature	Male	Female
2.1 (base)	0.26 (0.21–0.31)	0.36 (0.29–0.42)	–	–
1.1	0.26 (0.21–0.31)	0.35 (0.28–0.42)	–	–
3.1	0.39 (0.33–0.46)	0.48 (0.41–0.56)	–	–
3.2	0.16 (0.12–0.20)	0.25 (0.18–0.32)	–	–
3.3	0.32 (0.21–0.45)	0.42 (0.30–0.54)	0.17 (0.13–0.21)	0.18 (0.14–0.22)

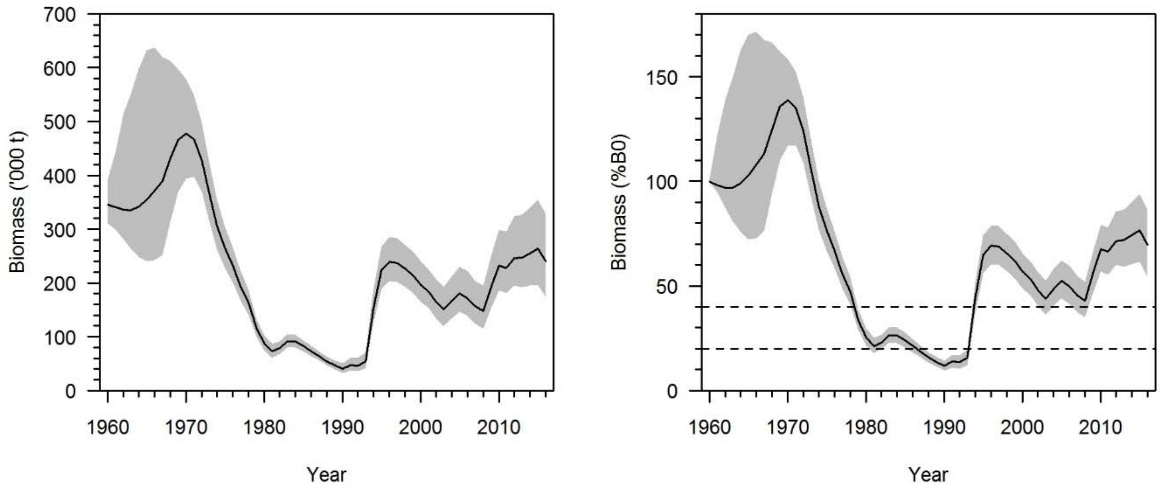


Figure 2: MCMC posterior plots of the trajectories of biomass (left) and current stock status (%B_{2013}/B_0) (right) for the Campbell Island stock for the base case model. The shaded regions are the 95% CIs.

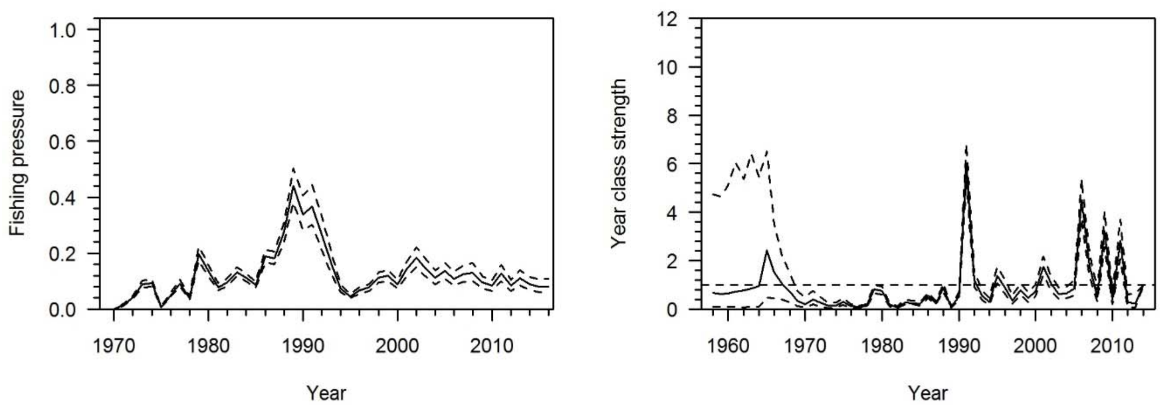


Figure 3: Estimated posterior distributions of exploitation rates (left) and relative year class strength (right) for the Campbell Island stock for the base case model.

Projections were made assuming fixed catch levels of 23 000 t and 40 000 t for the years 2018 to 2021. Projections were made using the MCMC samples, with recruitments drawn randomly from the distribution of year class strengths for the period 1958–2013 estimated by the model and applied from year 2014 onwards. For projections, the mean sizes-at-age were assumed to be equal to the estimated sizes-at-age in 2016.

For each scenario, the probability that the mid-season biomass for the specified year will be less than the soft limit (20% B_0) is given in Table 17. The probability of dropping below the soft limit at annual catch levels of 23 000 t is less than 1% for all models and all years. Under average recruitment conditions the biomass is expected to decline over the next 5 years, although remain above the soft limit.

Table 17: Probability that the projected mid-season vulnerable biomass for 2017–2021 will be less than 20% B_0, and the median projected biomass (%B_0), at a projected catch of 23 000 t or 40 000 t, for the base case model assuming average recruitment over the period 1958–2013 for 2014+.

Model	Catch (t)	Pr (SSB < 0.2B_0)					Median SSB (%B_0)				
		2017	2018	2019	2020	2021	2017	2018	2019	2020	2021
2.1 (base)	23 000	0.000	0.000	0.000	0.000	0.004	66	61	56	53	50
	40 000	0.000	0.000	0.002	0.038	0.138	66	59	50	42	35

(ii) Bounty Platform stock

A 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. Development of the assessment then focused on evaluating models with different assumptions that allowed a comparison of the extent to which the high biomass and subsequent decline were fitted. However, these have not proven successful, and the stock assessment was rejected by the Working Group and a harvest control rule was developed.

Development of a harvest control rule (HCR)

An HCR that would lead to a low risk of the stock falling below the soft limit reference point was developed, and used the most recent acoustic index of abundance as an absolute measure of abundance. In the HCR, risk was defined as the probability of the SSB being below 20% SSB0 (the soft limit). The HCR is given by TACC t+1 = HCR-p (B_t – C_t/ 2), where B_t is acoustic abundance, C_t is catch, and HCR-p is a fixed proportion in year *t*.

Results of simulations for different levels of harvest (HCR-p) and assumptions of natural mortality are given in Table 18 (Doonan 2017).

Table 18: Case-2: Risk for a combination of M and HCR-p values with steepness set to 0.90 and survey process CV at 0% (probability of SSB_0 being below 0.20 B_0 over a 120-year projection). Risk is the probability of SSB_0 being below 0.2 B_0 over a 120-year projection. Mean over 2 runs. Standard simulation error was about 0.0025. Acceptable risks are below the thick black border.

M	HCR-p				
	0.1	0.15	0.2	0.25	0.3
0.1	0.037	0.151	0.305	0.460	0.589
0.15	0.010	0.053	0.131	0.229	0.332
0.2	0.003	0.021	0.058	0.113	0.180
0.25	0.002	0.012	0.035	0.070	0.117
0.3	0.001	0.007	0.020	0.042	0.071

For 2017, the currently accepted HCR for SBW 6B, Bounty Platform, was applied using the abundance estimate from the industry acoustic survey completed in the 2017 fishing season. THE HCR depends on the values of natural mortality and steepness and these were specified by MPI to be $0.2y^{-1}$ and 0.9, respectively. The HCR gave a yield for the 2018 fishing season of 3209 t (Doonan, 2018). This yield assumes that there will not be a very large cohort entering the mature population. No further work was conducted developing or exploring assumptions underlying the current HCR, e.g. what procedures should be undertaken to detect and respond to another very large recruitment event (which is excluded from the current HCR), or, whether the HCR is more robust if it is based on the end-of-year biomass rather than that at the start of the fishing season.

(iii) Pukaki Rise stock

An assessment of the Pukaki Rise stock was carried out in 2002. The age structured separable Sequential Population Analysis (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 19, 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 20. 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 20.

Table 19: 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 20: 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 Working Group did not accept this initial run as a base case assessment, but agreed to present a range of possible biomass estimates. The Plenary 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 21, Figure 4). 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.

An assessment was planned for the Pukaki Rise stock in 2014 but the Working Group did not accept that the 2012 acoustic survey provided an acceptably realistic biomass estimate for the stock, so an assessment was not possible.

Table 21: 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

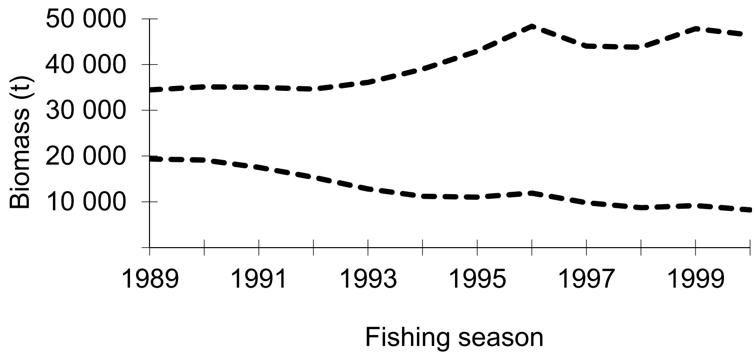


Figure 4: Mid-season spawning stock biomass trajectory bounds for the Pukaki Rise stock. Bounds based on acoustic *q* of 0.65 and 2.8.

(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 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	Unknown

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 relatively low fish bycatch when this was a substantial target fishery during the mid-1990s.

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

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	Harvest control rule simulations
Reference Points	Management Target: A fishing mortality rate calculated from the harvest control rule Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: A fishing mortality rate calculated from the harvest control rule
Status in relation to Target	Likely (> 60%) to be below the target *F*
Status in relation to Limits	Unknown
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status
-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown

Recent Trend in Fishing Intensity or Proxy	Fishing mortality is likely to have fluctuated around the target *F* in recent years.
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	Unknown
Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Harvest Control Rule based on simulations of an age structured model	
Assessment Dates	Latest assessment: 2018	Next assessment: 2020
Overall assessment quality rank	2 – Medium Quality	
Main data inputs (rank)	- Wide area acoustic abundance indices	1 – High Quality
	- Acoustic abundance indices from local area aggregation surveys	2 – Medium Quality (uncertainty in the proportion of the spawning aggregation covered by the surveys)
	- Proportions at age data from the commercial fisheries and trawl surveys	1 – High Quality
	- Estimates of biological parameters	1 – High Quality
	- Estimates of acoustic target strength	1 – High Quality
Data not used (rank)	- Commercial CPUE	3 – Low Quality: does not track stock biomass
Changes to Model Structure and Assumptions	- Previous (2014) assessment rejected and replaced with a harvest control rule	
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. - Estimates of fishing mortality assume the catchability coefficient of the acoustic biomass estimates is known.	

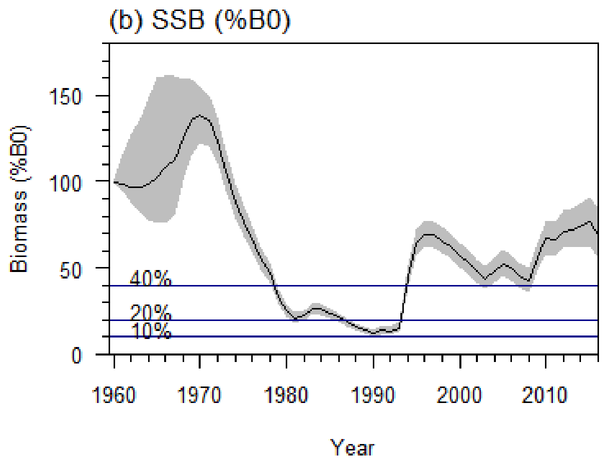
Qualifying Comments
Three surveys from 2014 to 2016 showed a progressive decline in stock biomass to low levels, but increased slightly in 2017.

Fishery Interactions
There is relatively low fish bycatch in the fishery and, as this is primarily a pelagic fishery, very little benthic impact. Protected species interactions have been recorded for New Zealand fur seals and seabirds.

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

Stock Status	
Year of Most Recent Assessment	2017
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_{2016} was estimated at 70% B_0 and is Very Likely (> 90%) to be at or above the target
Status in relation to Limits	B_{2016} 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 spawning biomass (%B_0) for the Campbell Island Rise southern blue whiting stock from the start of the assessment period in 1960 to 2016. The blue horizontal lines show the management target (40% B_0), the hard limit (10% B_0) and soft limit (20% B_0) in stock status. Biomass estimates are based on MCMC 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, 2009 and 2011 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 TACC of 39 200 t, the biomass of the Campbell stock is expected to decrease slightly over the next 1–2 years. At current catches, the biomass will remain above the target (40% B_0) for the next 5 years.
Probability of Current Catch or TACC causing Biomass to remain below, or to decline below, Limits	At both the catch and the TACC: 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	At the current catch: Very Unlikely (< 10%) At the TACC: Unlikely (< 40%)

Assessment Methodology		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2017	Next assessment: 2020
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	- Equilibrium age distribution assumed in 1960 instead of non-equilibrium age in previous model start year of 1979 - Catch history from 1971–1977 was added - Year class strengths from 1958 to 1976 were estimated	
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
-

Fishery Interactions
The main protected species incidental captures are of New Zealand sea lions, New Zealand fur seals and seabirds. There is relatively low fish bycatch in the fishery and, as it is primarily 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 relatively low fish bycatch, and negligible benthic impact or marine mammal incidental captures in the target fishery.

6. FUTURE RESEARCH

For Campbell Island Rise southern blue whiting, a candidate for further research or investigation would be to determine how to best represent mean weights at age in the projections given the negative relationship between year class strength and growth.

7. FOR FURTHER INFORMATION

Abraham, E R; Richard, Y; Berkenbusch, K; Thompson, F (2016) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 2002–03 to 2012–13. *New Zealand Aquatic Environment and Biodiversity Report* No. 169. 205 p

Abraham, E R; Richard, Y (2017) Summary of the capture of seabirds in New Zealand commercial fisheries, 2002–03 to 2013–14. *New Zealand Aquatic Environment and Biodiversity Report* No. 184. 88 p.

Abraham, E R; Richard, Y (2018) Estimated capture of seabirds in New Zealand trawl and longline fisheries, 2002–03 to 2014–15. *New Zealand Aquatic Environment and Biodiversity Report* No. 197. 97 p.

Abraham, E R; Thompson, F N (2011) Summary of the capture of seabirds, marine mammals, and turtles in New Zealand commercial fisheries, 1998–99 to 2008–09. *New Zealand Aquatic Environment and Biodiversity Report* No. 80.

Anderson, O F (2009) Fish and Invertebrate Bycatch and Discards in Southern Blue Whiting Fisheries, 2002–07. *New Zealand Aquatic Information and Biodiversity Report No. 43.*

Baird, S J (2004a) Estimation of the incidental capture of seabird and marine mammal species in commercial fisheries in New Zealand waters, 1999–2000. *New Zealand Fisheries Assessment Report 2004/41*. 56 p.

Baird, S J (2004b) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2000–01. *New Zealand Fisheries Assessment Report 2004/58*. 63 p.

Baird, S J (2004c) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2001–02. *New Zealand Fisheries Assessment Report 2004/60*. 51 p.

Baird, S J (2005) Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2002–03. *New Zealand Fisheries Assessment Report 2005/2*. 50 p.

Baird, S.J.; Mules, R. (2019). Extent of bottom contact by New Zealand commercial trawl fishing for deepwater Tier 1 and Tier 2 target species determined using CatchMapper software, 2008–17. Draft New Zealand Aquatic Environment and Biodiversity Report prepared for Fisheries NZ project BEN201701.

Baird, S J; Smith, M H (2007) Incidental capture of New Zealand fur seals (*Arctocephalus forsteri*) in commercial fisheries in New Zealand waters, 2003–04 to 2004–05. *New Zealand Aquatic Environment and Biodiversity Report* No. 14. 98 p.

Baird, S J; Wood, B A (2012) Extent of coverage of 15 environmental classes within the New Zealand EEZ by commercial trawling with seafloor contact. *New Zealand Aquatic Environment and Biodiversity Report* No. 89. 43 p.

Baird, S.J.; Wood, B.A. (2018). Extent of bottom contact by New Zealand commercial trawl fishing for deepwater Tier 1 and Tier 2 target fishstocks, 1989–90 to 2015–16. *New Zealand Aquatic Environment and Biodiversity Report No. 193.* 102 p.

Baird, S J; Wood, B A; Bagley, N. W. (2011) Nature and extent of commercial fishing effort on or near the seafloor within the New Zealand 200 n. mile Exclusive Economic Zone, 1989–90 to 2004–05. *New Zealand Aquatic Environment and Biodiversity Report* No. 73. 143 p.

Baker, C S; Chilvers, B L; Childerhouse, S; Constantine, R; Currey, R; Mattlin, R; van Helden, A; Hitchmough, R; Rolfe, J (2016) Conservation status of New Zealand marine mammals, 2013. *New Zealand Threat Classification Series 14*. Department of Conservation, Wellington. 18 p

Black, J; Wood, R; Berthelsen, T; Tilney, R (2013) Monitoring New Zealand's trawl footprint for deepwater fisheries: 1989–1990 to 2009–2010. *New Zealand Aquatic Environment and Biodiversity Report* No. 110. 57 p.

Brothers, N; Duckworth, A R; Safina, C; Gilman, E L (2010) Seabird bycatch in pelagic longline fisheries is grossly underestimated when using only haul data. *PLoS One, 5(8)*, e12491.

Bull, B; Dunn, A (2002) Catch-at-age: User manual v1.06.2002/09/12. *NIWA Internal Report 114*. 23 p.

Bull, B; Francis, R I C C; Dunn, A; Gilbert, D J; Bian, R; Fu, D (2012) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.30.2012/03/21. *NIWA Technical Report* 135. 280 p.

Cherel, Y; Waugh, S; Hanchet, S (1999) Albatross predation of juvenile southern blue whiting (*Micromesistius australis*) on the Campbell Plateau. *New Zealand Journal of Marine and Freshwater Research, 1999, Vol. 33*: 437–41

Childerhouse, S; Burns, T; French, R; Michael, S; Muller, C (2017). Report for CSP Project New Zealand sea lion monitoring at the Auckland Islands 2016/17. Document Reference Number: BPM-17-FINAL-Report for CSP Project NZSL Auckland Island monitoring 2016-17 v1.1. 24 p.

Cole, R; Stevenson, M G; Hanchet, S; Gorman, R M; Rickard, G J; Morrisey, D; Handley, S (2007) Information on benthic impacts in support of the Southern Blue Whiting Fishery Plan, National Institute of Water and Atmospheric Research. Final Research Report for Ministry of Fisheries Research Project ZBD2005-16 Objectives 1-6. 33 p. (Unpublished report held by FNZ Wellington.)

Cordue, P L (1996) A model-based method for bounding virgin biomass using a catch history, relative biomass indices, and ancillary information. New Zealand Fisheries Assessment Research Document 1996/8. 48 p. (Unpublished report held by NIWA library, Wellington.)

Department of Internal Affairs. (2006) Seabird Scaring Devices – Circular Issued Under Authority of the Fisheries (Commercial Fishing) Amendment Regulations 2006 (No. F361). *New Zealand Gazette 6 April 2006*: 842–846.

Doonan, I J (2018) Objective 2: To apply the agreed harvest control rule to SBW6B, 2018. Final Research Report, unpublished manuscript held by FNZ. 2 p.

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

Dunford, A (2003) Review and revision of southern blue whiting (*Micromesistius australis*) target strength. Final Research Report for Ministry of Fisheries Research Project SBW2001/02 Objective 2. 16 p. (Unpublished report held by FNZ, Wellington.)

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

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

Dunn, A; Hanchet, S M (2011) Southern blue whiting (*Micromesistius australis*) stock assessment for the Bounty Platform for 2009–10. *New Zealand Fisheries Assessment Report 2011/26*. 30 p.

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

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

Finucci, B; Edwards, C T T; Anderson, O F (2019). Fish and invertebrate bycatch in New Zealand deepwater fisheries from 1990–91 until 2016–17. *New Zealand Aquatic Environment and Biodiversity Report No. 210*.

Francis, R I C C (1992) Recommendations concerning the calculation of maximum constant yield (*MCY*) and current annual yield (*CAY*). New Zealand Fisheries Assessment Research Document 1992/8. 27 p. (Unpublished document held at NIWA library, Wellington.)

Francis, R I C C (2011) Data weighting in statistical fisheries stock assessment models. *Canadian Journal of Fisheries and Aquatic Sciences* 68: 15.

Francis, M P; Hurst, R J; McArdle, B H; Bagley, N W; Anderson, O F (2002) New Zealand demersal fish assemblages. *Environmental Biology of Fishes*, 65(2), 215–234.

Froese, R; Pauly, D (Eds.). (2000) FishBase 2000: concepts, design and data sources (No. 1594). WorldFish.

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

Gauthier, S; Fu, D; O'Driscoll, R L; Dunford, A (2011) Acoustic estimates of southern blue whiting from the Campbell Island Rise, August–September 2009. *New Zealand Fisheries Assessment Report 2011/09*. 40 p.

Grimes, P; Fu, D; Hanchet, S M (2007) Estimates of biomass and CVs of decomposed age classes of southern blue whiting from previous acoustic surveys from 1993 to 2004 using a new target strength - fish length relationship. Final Research Report for Ministry of Fisheries Research Project SBW2005-01. 34 p. (Unpublished report held by FNZ, Wellington.)

Hanchet, S M (1991) Southern blue whiting fishery assessment for the 1991–92 fishing year. New Zealand Fisheries Assessment Research Document 1991/7. 48 p. (Unpublished document held by NIWA library, Wellington.)

Hanchet, S M (1999) Stock structure of southern blue whiting (*Micromesistius australis*) in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research* 33(4): 599–610.

Hanchet, S M (2002) Southern blue whiting (*Micromesistius australis*) stock assessment for the Bounty Platform for 2002 and 2003. *New Zealand Fisheries Assessment Report 2002/53*. 23 p.
Hanchet, S M (2005a) Southern blue whiting (*Micromesistius australis*) stock assessment update for the Campbell Island Rise for 2005. *New Zealand Fisheries Assessment Report 2005/40*. 40 p.
Hanchet, S M (2005b) Southern blue whiting (*Micromesistius australis*) stock assessment for the Bounty Platform for 2004–05. *New Zealand Fisheries Assessment Report 2005/45*. 36 p.
Hanchet, S M; Blackwell, R G (2005) Development and evaluation of catch-per-unit-effort indices for southern blue whiting (*Micromesistius australis*) on the Campbell Island Rise (1986–2002) and the Bounty Platform (1990–2002). *New Zealand Fisheries Assessment Report 2005/55*. 60 p.
Hanchet, S M; Blackwell, R G; Dunn, A (2005) Development and evaluation of catch-per-unit-effort indices for southern blue whiting (*Micromesistius australis*) on the Campbell Island Rise New Zealand. *ICES Journal of Marine Sciences. 62:* 1131–1138.
Hanchet, S M; Blackwell, R G; Stevenson, M L (2006) Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for 2006. *New Zealand Fisheries Assessment Report 2006/41*. 45 p.
Hanchet, S M; Dunn, A (2010) Review and summary of the time series of input data available for the assessment of southern blue whiting (*Micromesistius australis*) stocks. *New Zealand Fisheries Assessment Report 2010/32*. 37 p.
Hanchet, S M; Dunn, A; Stevenson, M L (2003a) Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for 2003. *New Zealand Fisheries Assessment Report 2003/59*. 42 p.
Hanchet, S M; Grimes, P J; Coombs, R F (2002a) Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, August 2001. *New Zealand Fisheries Assessment Report 2002/58*. 35 p.
Hanchet, S M; Grimes, P J; Coombs, R F; Dunford, A (2003b) Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) for the Campbell Island Rise, August–September 2002. *New Zealand Fisheries Assessment Report 2003/44*. 38 p.
Hanchet, S M; Grimes, P J; Dunford, A; Ricnik, A (2002b) Classification of fish marks from southern blue whiting acoustic surveys. Final Research Report for Ministry of Fisheries Research Project SBW2000/02 Objective 2. 55 p. (Unpublished report held by FNZ, Wellington.)
Hanchet, S M; Haist, V; Fournier, D (1998) An integrated assessment of southern blue whiting (*Micromesistius australis*) from New Zealand waters using separable Sequential Population Analysis. *In* Funk, F et al (Eds.). Alaska Sea Grant College Program Report No. AK-SG-98-01. University of Alaska, Fairbanks, 1998.
Hanchet, S M; Renwick, J A (1999) Prediction of southern blue whiting (*Micromesistius australis*) year class strength in New Zealand waters. New Zealand Fisheries Assessment Research Document 1999/51. 24 p. (Unpublished document held in NIWA library, Wellington.)
Hermsen, J M; Collie, J S; Valentine, P C (2003) Mobile fishing gear reduces benthic megafaunal production on Georges Bank. *Marine Ecology Progress Series* 260: 97–108.
Hiddink, J G; Jennings, S; Kaiser, M J; Queiros, A M; Duplisea, D E; Piet, G J (2006) Cumulative impacts of seabed trawl disturbance on benthic biomass, production, and species richness in different habitats. *Canadian Journal of Fisheries and Aquatic Science*s 63:721–36.
Jennings, S; Dinmore, T A; Duplisea, D E; Warr, K J; Lancaster, J E (2001) Trawling disturbance can modify benthic production processes. *Journal of Animal Ecology, 70*: 459–475.
Large, K.; O'Driscoll, R. L.; Schimel, A. (In prep.) Review and summary of the time series of input data available for the assessment of southern blue whiting (*Micromesistius australis*) stocks up to and including the 2018 season. Draft New Zealand Fisheries Assessment Report held by FNZ.
Large, K. (2019) Review and summary of the time series of input data available for the assessment of southern blue whiting (*Micromesistius australis*) stocks up to and including the 2017 season. Draft New Zealand Fisheries Assessment Report held by FNZ.
Large, K; Hanchet, S M (2017) Review and summary of the time series of input data available for the assessment of southern blue whiting (*Micromesistius australis*) stocks up to and including the 2016 season. *New Zealand Fisheries Assessment Report 2017/35*. 44 p.
Leathwick, J.R.; Rowden, A.; Nodder, S.; Gorman., R.; Bardsley, S.; Pinkerton, M.; Baird, S.J.; Hadfield, M.; Currie, K.; Goh, A. (2012). A Benthic–optimised Marine Environment Classification (BOMEC) for New Zealand waters. *New Zealand Aquatic Environment and Biodiversity Report No. 88*. 54 p.
MacKenzie, D; Fletcher, D (2006) Characterisation of seabird captures in commercial trawl and longline fisheries in New Zealand 1997/98 to 2003/04. Final Research Report for Ministry of Fisheries project ENV2004/04. (Unpublished report held by FNZ, Wellington.) 102 p.
McClatchie, S; Macaulay, G; Hanchet, S; Coombs, R F (1998) Target strength of southern blue whiting (*Micromesistius australis*) using swimbladder modelling, split beam and deconvolution. *ICES Journal of Marine Science* 55: 482–493.
McClatchie, S; Thorne, R; Grimes, P J; Hanchet, S (2000) Ground truth and target identification for fisheries acoustics. *Fisheries Research* 47: 173–191.
Middleton, D A; Abraham, E R (2007) The efficacy of warp strike mitigation devices: trials in the 2006 squid fishery. Final Research Report for Ministry of Fisheries research project IPA2006/02. (Unpublished report held by FNZ Wellington.)
Monstad, T; Borkin, I; Ermolchev, V (1992) Report of the joint Norwegian-Russian acoustic survey on blue whiting, spring 1992. *ICES C.M. 1992/H:6*, Pelagic Fish Committee. 26 p.
Morgan, M J; DeBlois, E M; Rose, G A (1997) An observation on the reaction of Atlantic cod (*Gadus morhua*) in a spawning shoal to bottom trawling. *Canadian Journal of Fisheries and Aquatic Sciences, 54(S1)*, 217–223.
Morgan, M J; Wilson, C E; Crim, L W (1999) The effect of stress on reproduction in Atlantic cod. *Journal of Fish Biology, 54(3)*: 477–488.
MPI (2013) Aquatic Environment and Biodiversity Annual Review 2013. Compiled by the Fisheries Management Science. Ministry for Primary Industries, Wellington, New Zealand. 538 p.
MPI (2015) Aquatic Environment and Biodiversity Annual Review 2015. Compiled by the Fisheries Management Science. Ministry for Primary Industries, Wellington, New Zealand. 682 p.
MPI (2017) Aquatic Environment and Biodiversity Annual Review 2015. Compiled by the Fisheries Management Science. Ministry for Primary Industries, Wellington, New Zealand.
O'Driscoll, R L (2011a) Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2010. NIWA Client Report WLG2011-01 for The Deepwater Group Ltd, January 2011. 28 p. (Unpublished report held by NIWA, Wellington).
O'Driscoll, R L (2011b) Industry acoustic surveys of spawning southern blue whiting on the Bounty Platform and Pukaki Rise 2004–09. *New Zealand Fisheries Assessment Report 2011/17*. 53 p.
O'Driscoll, R L (2012) Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2011. *New Zealand Fisheries Assessment Report 2012/16*. 29 p.
O'Driscoll, R L (2013) Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2012. *New Zealand Fisheries Assessment Report 2013/4*. 26 p.
O'Driscoll, R L (2015) Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2014. *New Zealand Fisheries Assessment Report 2015/02*. 28 p

O'Driscoll, R L (In prep) Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2017. Draft New Zealand Fisheries Assessment Report. 28 p

O'Driscoll, R L; Bagley, N W (2003) Trawl survey of middle depth species in the Southland and Sub-Antarctic areas, November–December 2002 (TAN0219). *New Zealand Fisheries Assessment Report 2003/1*, 53 p.

O'Driscoll, R L; Dunford, A J (2017) Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2015. *New Zealand Fisheries Assessment Report 2017/19*. 29 p.

O'Driscoll, R L; Dunford, A J; Ladroit, Y (2014). Acoustic estimates of southern blue whiting from the Campbell Island Rise, August–September 2013 (TAN1309). *New Zealand Fisheries Assessment Report 2014/22.* 46 p.

O'Driscoll, R L; Grimes, P J; Hanchet, S M; Dunford, A (2005) Acoustic estimates of southern blue whiting from the Campbell Island Rise, August–September 2004. *New Zealand Fisheries Assessment Report 2005/41*. 29 p.

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

O'Driscoll, R L; Hanchet, S M; Gauthier, S; Grimes, P J (2007) Acoustic estimates of southern blue whiting from the Campbell Island Rise, August–September 2006. New Zealand Fisheries Assessment Report 2007/20. 34 p.

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

O'Driscoll, R L; Large, K; Marriott, P (2018) Acoustic estimates of southern blue whiting from the Campbell Island Rise, August–September 2016. *New Zealand Fisheries Assessment Report 2018/56.* 60 p.

O'Driscoll, R L; Macaulay, G J; Gauthier, S (2006) Biomass estimation of spawning southern blue whiting from industry vessels in 2006. NIWA Client Report WLG2006-xx for the Deepwater Stakeholders' Group. 39 p. (Unpublished report held by NIWA, Wellington.)

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

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

Ramm, K. (2012) Conservation Services Programme Observer Report: 1 July 2010 to 30 June 2011. New Zealand Department of Conservation, Wellington, New Zealand. 121 p.

Reiss, H; Greenstreet, S P R; Seibe, K; Ehrich, S; Piet, G J; Quirijns, F; Robinson, L; Wolff, W K; Kronke, I (2009) Effects of fishing disturbance on benthic communities and secondary production within an intensively fished area. *Marine Ecology Progress Series* 394:201–213.

Rice, J (2006) Impacts of Mobile Bottom Gears on Seafloor Habitats, Species, and Communities: A Review and Synthesis of Selected International Reviews. Canadian Science Advisory Secretariat Research Document 2006/057. 35 p. (available from http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2006/RES2006_057_e.pdf).

Richard, Y; Abraham, E R (2015) Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2012–13.*New Zealand Aquatic Environment and Biodiversity Report* 162. 85 p

Richard, Y; Abraham, E R; Berkenbusch, K (2017) Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2014–15. *New Zealand Aquatic Environment and Biodiversity Report No 191.* 133 p.

Roberts, J; Doonan, I (2016) Quantitative Risk Assessment of Threats to New Zealand Sea Lions. *New Zealand Aquatic Environment and Biodiversity Report* No. 166. 111 p.

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

Roberts, J; Hanchet, S (2018) Southern blue whiting (*Micromesistius australis*) stock assessment for the Campbell Island Rise for 2017. Draft New Zealand Fisheries Assessment Report held by Fisheries New Zealand.

Roberts, J; Lalas, C (2015) Diet of New Zealand sea lions (*Phocarctos hookeri*) at their southern breeding limits. *Polar Biology, 38*: 1483–1491.

Robertson, H A; Baird, K; Dowding J E; Elliott, G P; Hitchmough, R A; Miskelly, C M; McArthur, N; O'Donnell, C F J; Sagar, P M; Scofield, R P; Taylor, G A (2017) Conservation status of New Zealand birds, 2016. *New Zealand Threat Classification Series 19.* . Department of Conservation, Wellington. 23 p.

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

Smith, M H; Baird, S J (2009) Model-based estimation of New Zealand fur seal (*Arctocephalus forsteri*) incidental captures and strike rates for trawl fishing in New Zealand waters for the years 1994–95 to 2005–06. *New Zealand Aquatic Environment and Biodiversity Report* No. 40. 92 p.

Stevens, D W; O'Driscoll, R L; Dunn, M R; MacGibbon, D; Horn, P L; Gauthier, S (2011) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2010 (TAN1001). *New Zealand Fisheries Assessment Report 2011/10*, 112 p.

Thompson, F N; Abraham, E R; Berkenbusch, K (2012) Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2010–11. Final Research Report for Ministry for Primary Industries project PRO2010-01 (Unpublished report held by Fisheries New Zealand, Wellington). 90 p.

Thompson, F N; Abraham, E R; Oliver, M D (2010a) Estimation of fur seal bycatch in New Zealand trawl fisheries, 2002–03 to 2007–08. *New Zealand Aquatic Environment and Biodiversity Report* No. 56. 29 p.

Thompson, F N; Berkenbusch, K; Abraham, E R (2013) Marine mammal bycatch in New Zealand trawl fisheries, 1995–96 to 2010–11. Final Research Report for Ministry for Primary Industries project PRO2010-01 (Unpublished report held by Fisheries New Zealand, Wellington).

Thompson, F N; Oliver, M D; Abraham, E R (2010b) Estimation of the capture of New Zealand sea lions (*Phocarctos hookeri*) in trawl fisheries, from 1995–96 to 2007–08. *New Zealand Aquatic Environment and Biodiversity Report* No. 52. 25 p.

Tuck, I D; Cole, R; Devine, J A (2009) Ecosystem indicators for New Zealand fisheries. *New Zealand Aquatic Environment and Biodiversity Report* No. 42. 188 p.