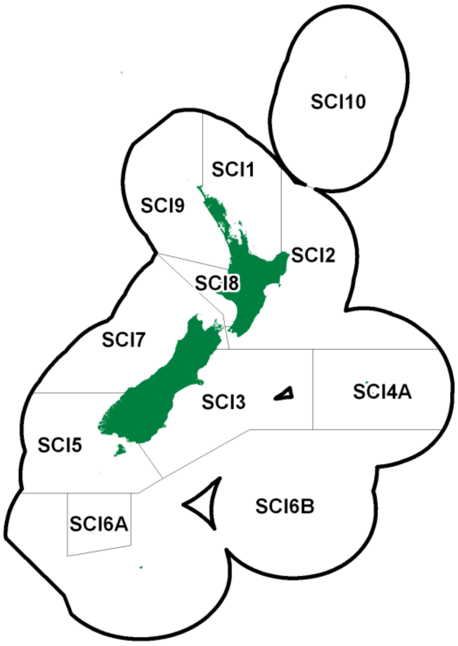
SCAMPI (SCI)

(*Metanephrops challengeri*)



1. FISHERY SUMMARY

Scampi were introduced into the QMS on 1 October 2004. At this time, management areas for scampi on the Chatham Rise (SCI 3 and 4) and in the Sub-Antarctic (SCI 6A and 6B) were substantially modified. Current TACs and TACCs by Fishstock are shown in Table 1.

Table 1: Total allowable catches (TAC, t) allowances for customary fishing, recreational fishing, and other sources of mortality (t) and Total Allowable Commercial Catches (TACC, t) declared for scampi.

			Allowances		
Fishstock	TAC	Customary	Recreational	Other*	TACC
SCI 1	126	0	0	6	120
SCI 2	161	0	0	8	153
SCI 3	428	0	0	20	408
SCI 4A	126	0	0	6	120
SCI 5	42	0	0	2	40
SCI 6A	321	0	0	15	306
SCI 6B	53	0	0	3	50
SCI 7	79	0	0	4	75
SCI 8	5	0	0	0	5
SCI 9	37	0	0	2	35
SCI 10	0	0	0	0	0

1.1 Commercial fisheries

Target trawl fisheries for scampi developed first in the late 1980s and, until the 1999–00 fishing year, there were restrictions on the vessels that could be used in each stock. Between October 1991 and September 2002, catches were restrained using a mixture of competitive and individually allocated catch limits but, between October 2001 and September 2004, all scampi fisheries were managed using competitive catch limits – i.e. there were no individual allocations (Figure 1).

Fishing has been conducted by 20–40 m vessels using light bottom trawl gear but over the last ten years, all vessels are less than 32 m long. All vessels use multiple rigs of two or three nets of very low headline height. The main fisheries are in waters 300–500 m deep in SCI 1 (Bay of Plenty), SCI 2 (Hawke Bay, Wairarapa Coast), SCI 3 (Mernoo Bank) SCI 4A (western Chatham Rise and Chatham Islands) and SCI

6A (Sub-Antarctic). Some fishing has been reported on the Challenger Plateau outside the EEZ. Minimal fishing for scampi has taken place in SCI 5, 6B, 7, 8 and 9.

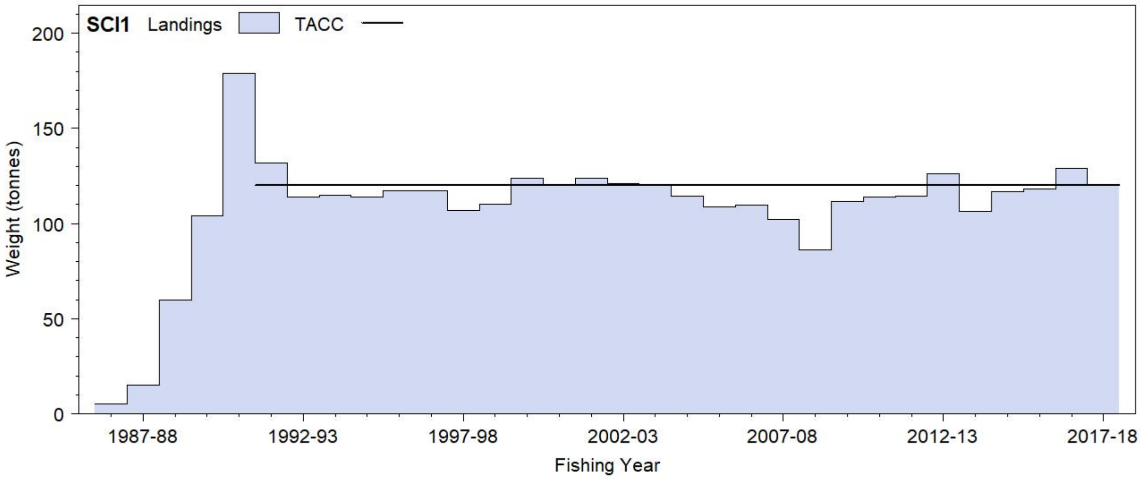
Table 2: Estimated commercial landings (t) from the 1986–87 to present (based on management areas in force since introduction to the QMS in October 2004) and catch limits (t) by Fishstock (from CLR and TCEPR forms and data reported electronically, Fisheries New Zealand landings and catch effort databases, early years may be incomplete). No limits before 1991–92 fishing year, (†) catch limits allocated individually until the end of 2000–01. *Note that management areas SCI 3, 4A, 6A and 6B changed in October 2004, and the catch limits applied to the old areas are not relevant to the landings, which have been reallocated to the revised areas on a pro-rata basis in relation to the TECPR data, which has previously been found to match landings well.

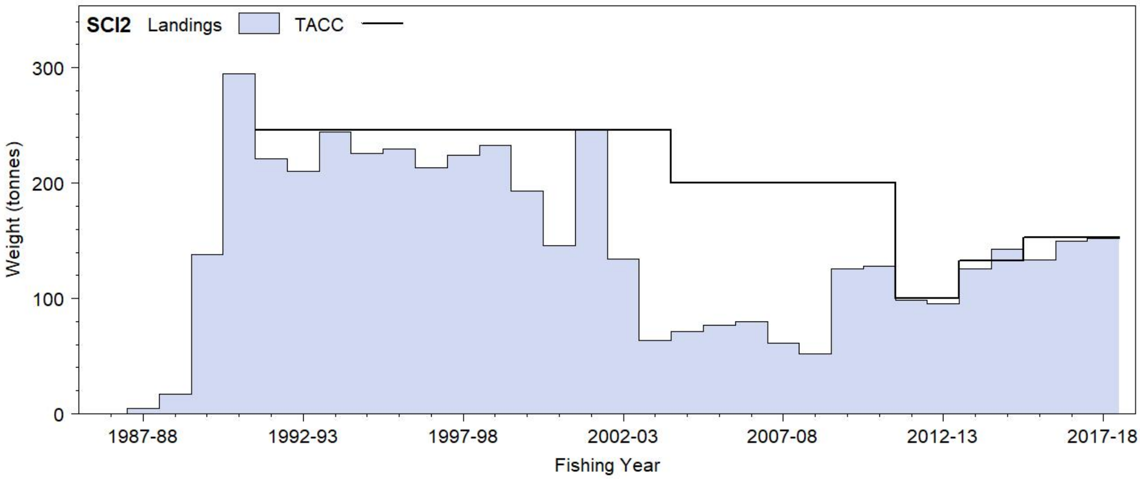
	SCI 1		SCI 2		SCI 3		SCI 4A		SCI 5	
	Landings	Limit (†) /TACC	Landings	Limit (†) /TACC	Landings	Limit (†) /TACC	Landings	Limit(†) /TACC	Landings	Limit (†) /TACC
1986–87	5	–	0	–	0	–	0	–	0	–
1987–88	15	–	5	–	0	–	0	–	0	–
1988–89	60	–	17	–	0	–	0	–	0	–
1989–90	104	–	138	–	0	–	0	–	0	–
1990–91	179	–	295	–	0	–	32	–	0	–
1991–92	132	120	221	246	153	–	78	–	0	60
1992–93	114	120	210	246	296	–	11	–	2	60
1993–94	115	120	244	246	324	–	0	–	1	60
1994–95	114	120	226	246	292	–	0	–	0	60
1995–96	117	120	230	246	306	–	0	–	0	60
1996–97	117	120	213	246	304	–	0	–	2	60
1997–98	107	120	224	246	296	–	0	–	0	60
1998–99	110	120	233	246	292	–	28	–	30	60
1999–00	124	120	193	246	322	–	23	–	9	40
2000–01	120	120	146	246	333	–	0	–	7	40
2001–02	124	120	247	246	304	–	30	–	< 1	40
2002–03	121	120	134	246	264	–	79	–	7	40
2003–04	120	120	64	246	277	–	41	–	5	40
2004–05	114	120	71	200	335	340	101	120	1	40
2005–06	109	120	77	200	319	340	79	120	< 1	40
2006–07	110	120	80	200	307	340	39	120	< 1	40
2007–08	102	120	61	200	209	340	8	120	< 1	40
2008–09	86	120	52	200	190	340	1	120	< 1	40
2009–10	111	120	125	200	302	340	< 1	120	< 1	40
2010–11	114	120	128	100	256	340	43	120	< 1	40
2011–12	114	120	99	100	278	340	41	120	< 1	40
2012–13	126	120	96	100	300	340	55	120	<1	40
2013–14	107	120	125	133	319	340	107	120	<1	40
2014–15	117	120	143	133	374	340	131	120	<1	40
2015–16	118	120	134	153	336	340	114	120	<1	40
2016–17	129	120	150	153	344	340	129	120	<1	40
2017–18	120	120	152	153	337	340	111	120	<1	40

	SCI 6A		SCI 6B		SCI 7		SCI 8		SCI 9	
	Landings	Limit (†) /TACC	Landings	Limit (†) /TACC	Landings	Limit (†) /TACC	Landings	Limit (†) /TACC	Landings	Limit (†) /TACC
1986–87	0	–	0	–	0	–	0	–	0	–
1987–88	0	–	0	–	0	–	0	–	0	–
1988–89	0	–	0	–	0	–	0	–	0	–
1989–90	0	–	0	–	0	–	0	–	0	–
1990–91	2	–	0	–	0	–	0	–	0	–
1991–92	325	–	0	–	0	75	0	60	0	60
1992–93	279	–	0	–	2	75	0	60	2	60
1993–94	303	–	0	–	0	75	0	60	1	60
1994–95	239	–	0	–	2	75	0	60	0	60
1995–96	270	–	0	–	1	75	0	60	0	60
1996–97	275	–	0	–	0	75	0	60	0	60
1997–98	279	–	0	–	0	75	0	60	0	60
1998–99	325	–	< 1	–	1	75	0	60	< 1	60
1999–00	328	–	0	–	1	75	0	5	0	35
2000–01	264	–	0	–	< 1	75	0	5	0	35
2001–02	272	–	0	–	< 1	75	0	5	0	35
2002–03	255	–	0	–	< 1	75	0	5	0	35
2003–04	311	–	0	–	1	75	0	5	0	35
2004–05	295	306	0	50	1	75	0	5	0	35
2005–06	286	306	0	50	1	75	0	5	0	35
2006–07	302	306	0	50	< 1	75	0	5	0	35
2007–08	287	306	0	50	1	75	0	5	0	35
2008–09	264	306	< 1	50	1	75	0	5	0	35
2009–10	144	306	0	50	2	75	0	5	0	35
2010–11	198	306	< 1	50	4	75	0	5	0	35
2011–12	166	306	< 1	50	6	75	0	5	< 1	35

Table 2 [continued]

2012–13	146	306	0	50	7	75	0	5	<1	35
2013–14	107	306	<1	50	4	75	0	5	<1	35
2014–15	102	306	<1	50	9	75	0	5	<1	35
2015–16	263	306	<1	50	9	75	0	5	<1	35
2016–17	300	306	<1	50	3	75	0	5	<1	35
2017–18	295	306	<1	50	4	75	0	5	<1	35





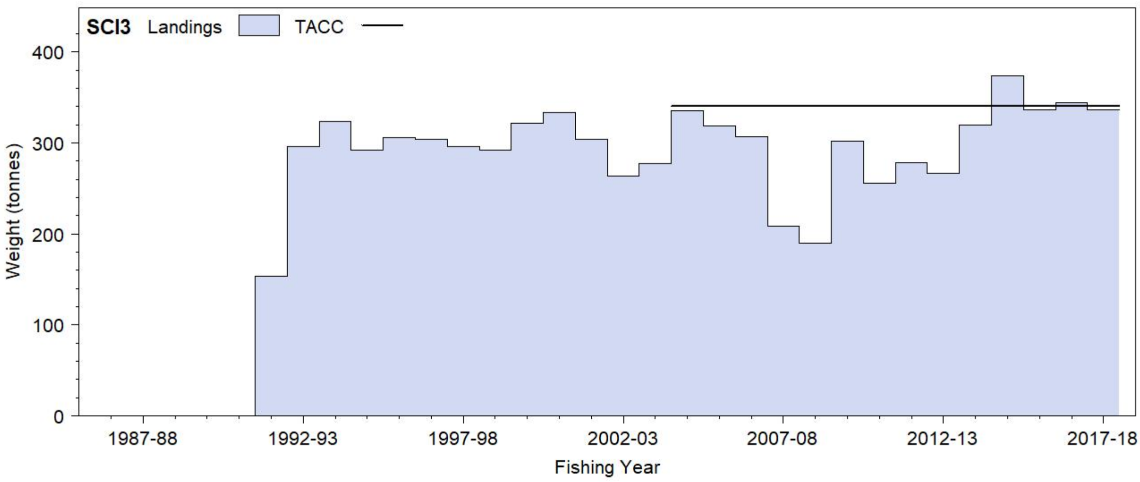
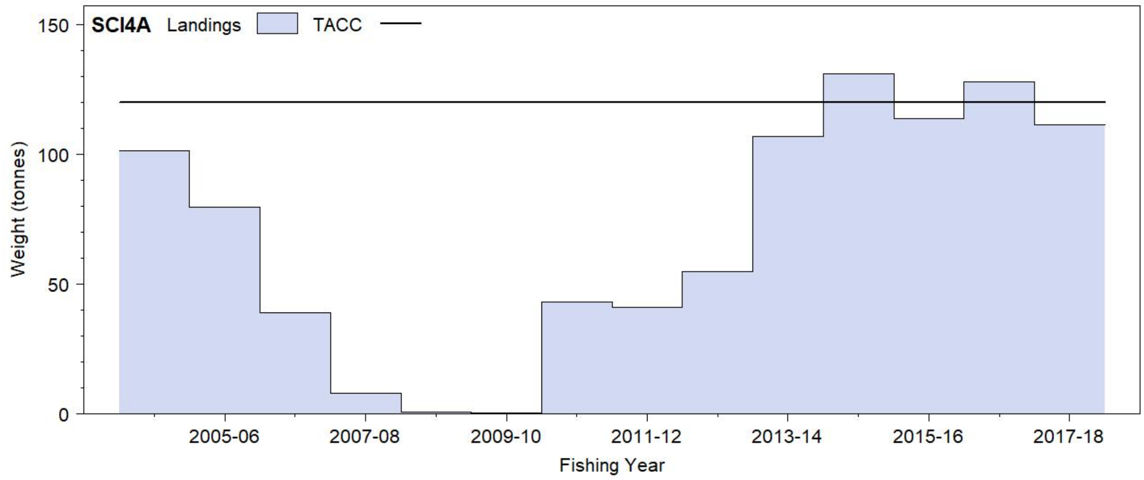


Figure 1: Reported commercial landings and TACCs (or catch limits prior to 2004–05) for the five main SCI stocks from fishing years 1986–87 to present. SCI 1 Bay of Plenty, SCI 2 Wairarapa coast and SCI 3 Chatham Rise [Continued on next page].



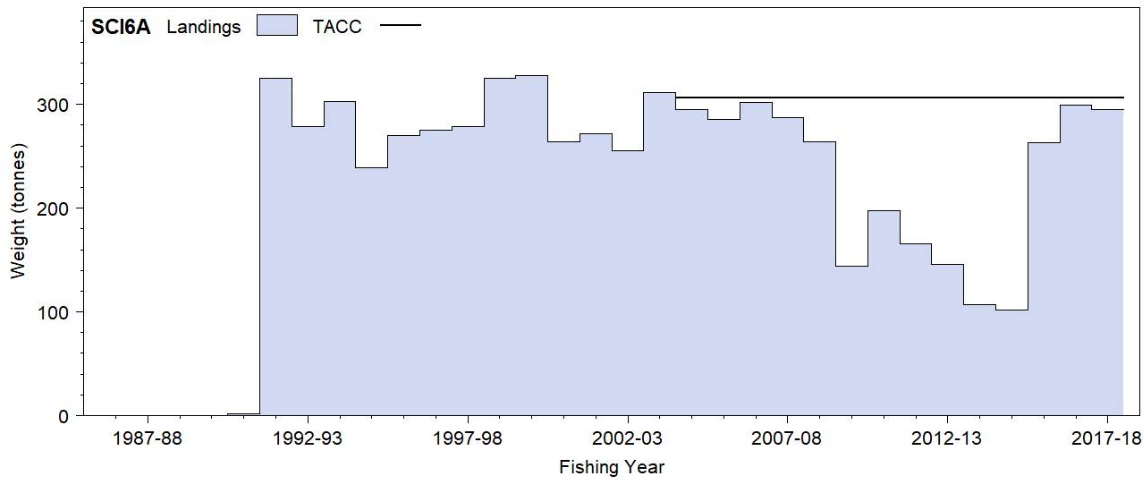


Figure 1: [Continued] Reported commercial landings and TACCs (or catch limits prior to 2004–05) for the five main SCI stocks from fishing years 1986–87 to present: SCI 4A Chatham Islands, and SCI 6A Auckland Islands.

1.2 Recreational fisheries
There is no recreational fishery for scampi.

1.3 Maori customary fisheries
There is no customary fishery for scampi.

1.4 Illegal catch
There is no quantitative information on the level of illegal catch. It is assumed to be zero.

1.5 Other sources of mortality
Other sources of fishing related mortality in scampi could include incidental effects of trawl gear on the animals and their habitat.

2. BIOLOGY

Scampi are widely distributed around the New Zealand coast, principally in depths between 200 and 500 m on the continental slope. Like other species of *Metanephrops* and *Nephrops*, *M. challengeri* builds a burrow in the sediment and may spend a considerable proportion of time within this burrow. From trawl catch rates, it appears that there are daily and seasonal cycles of emergence from burrows onto the sediment surface. Catch rates are typically higher during the hours of daylight than night, and patterns vary seasonally between sexes and areas, dependent on the moult cycle.

Scampi moult several times per year in early life and probably about once a year after sexual maturity (at least in females). Early work suggested that female *M. challengeri* achieve sexual maturity at about 40 mm orbital carapace length (OCL) in the Bay of Plenty and on the Chatham Rise, about 36 mm OCL off the Wairarapa coast, and about 56 mm OCL around the Auckland Islands (approximately age 3 to 4 years). Examination of ovary maturity on more recent trawl surveys suggest that 50% of females were mature at 30 mm OCL in SCI 1 and 2, and at about 38 mm in SCI 6A. The peak of moulting and spawning activity seems to occur in spring or early summer. Larval development of *M. challengeri* is probably very short, and may be less than three days in the wild. The abbreviated larval phase may, in part, explain the low fecundity of *M. challengeri* compared with *N. norvegicus* (that of the former being about 10–20% that of the latter).

Relatively little is known of the growth rate of any of the *Metanephrops* species in the wild. Males grow to a larger size than females. Tagging of *M. challengeri* to determine growth rates was undertaken in the Bay of Plenty in 1995, and the bulk of recaptures were made late in 1996. About 1% of tagged animals were recaptured, similar to the average return rate of similar tagging studies for scampi and prawns in the UK and Australia. Many more females than males were recaptured, and small males were almost entirely absent from the recapture sample. The reasons for this are not understood, but may relate to the timing of moulting in relation to the study, and tag retention. Scampi captured and tagged at night were much more likely to be recaptured than those exposed to sunlight. Estimates from this work of growth rate and mortality for females are given in Table 3. The data for males were insufficient for analysis, although the average annual increment with size appeared to be greater than in females.

Table 3: Estimates of biological parameters.

Population		**Estimate**	**Source**
1. Weight = a(orbital carapace length)^b (weight in g, OCL in mm)			
All males: SCI 1	a = 0.000373	b = 3.145	Cryer & Stotter (1997)
Ovigerous females: SCI 1	a = 0.003821	b = 2.533	Cryer & Stotter (1997)
Other females: SCI 1	a = 0.000443	b = 3.092	Cryer & Stotter (1997)
All females: SCI 1	a = 0.000461	b = 3.083	Cryer & Stotter (1997)
2. von Bertalanffy growth parameters			
	K (yr^{-1})	**L_∞ (OCL, mm)**	
Females: SCI 1 (tag)	0.11–0.14	48.0–49.0	Cryer & Stotter (1999)
Females: SCI 2 (aquarium)	0.31	48.8	Cryer & Oliver (2001)
Males: SCI 2 (aquarium)	0.32	51.2	Cryer & Oliver (2001)
3. Natural mortality (*M*)			
Females: SCI 1		M = 0.20–0.25	Cryer & Stotter (1999)

Estimates of M are based on the relationship between growth rate and natural mortality, and are subject to considerable uncertainty. Analytical assessment models have been examined for M=0.2 and M=0.3.

Scampi from SCI 2 were successfully reared in aquariums for over 12 months in 1999–2000. Results from these growth trials suggested a Brody coefficient of about 0.3 for both sexes, compared with less than 0.15 from the tagging trial. Extrapolating the length-based results to age-based curves suggests that scampi are about 3–4 years old at 30 mm carapace length and may live for 15 years. There are many uncertainties with captive reared animals, however, and these estimates should not be regarded as definitive. In particular, the rearing temperature was 12º C compared with about 10º C in the wild (in SCI 1 and 2), and the effects of captivity are largely unknown.

The maximum age of New Zealand scampi is not known, although analysis of tag return data and aquarium trials suggest that this species may be quite long lived. *Metanephrops* spp in Australian waters may grow rather slowly and take up to 6 years to recruit to the commercial fishery (Rainer 1992), consistent with estimates of growth in *M. challengeri* (Table 3). *N. norvegicus* populations in some northern European populations achieve a maximum age of 15–20 years (Bell et al 2006), consistent with the estimates of natural mortality, *M*, for *M. challengeri*.

A tagging project has been conducted in SCI 6A, with five release events (March 2007, 2008, 2009, 2013 and 2016). Most recaptures occur within a year of release. Tagging work has also more recently been conducted in SCI 1, 2 and 3, although recapture rates have been low. Tag recaptures are fitted within assessment models to estimate growth.

3. STOCKS AND AREAS

Stock structure of scampi in New Zealand waters is not well known. Preliminary electrophoretic analyses suggest that scampi in SCI 6A are genetically distinct from those in other areas, and there is substantial heterogeneity in samples from SCI 1, 2, and 4A. Studies using newer mitochondrial DNA and microsatellite approaches are underway, and are likely to be more sensitive to differences between stocks. The abbreviated larval phase of this species may lead to low rates of gene mixing. Differences among some scampi populations in average size, size at maturity, the timing of diel and seasonal cycles of catchability, catch to bycatch ratios and CPUE trends also suggest that treatment as separate management units is appropriate.

A review of stock boundaries between SCI 3 and SCI 4A and between SCI 6A and SCI 6B was conducted in 2000, prior to introduction of scampi into the Quota Management System. Following the recommendation of this review, the boundaries were changed on 1 October 2004, to reflect the distribution of scampi stocks and fisheries more appropriately.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was last reviewed by the Aquatic Environment Working Group for the May 2012 Fishery Assessment Plenary. Tables were updated and minor corrections to the text were made for the May 2018 Fishery Assessment Plenary. This summary is from the perspective of the scampi fishery; a more detailed summary from an issue-by-issue perspective is available in the 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

Scampi are thought to prey mainly on invertebrates (Meynier et al 2008) or carrion. A 3-year diet study on the Chatham Rise showed that scampi was the first, third and fourth most important item (by IRI, Index of Relative Importance) in the diet of smooth skate, ling and sea perch respectively (Dunn et al 2009). Scampi build and maintain burrows in the sediment and this bioturbation is thought to influence oxygen and nutrient fluxes across the sediment-water boundary, especially when scampi density is high (e.g., Hughes & Atkinson 1997, who studied *Nephrops norvegicus* at densities of 1–3 m^{-2}). Observed densities from photographic surveys in New Zealand have been 0.02–0.1 m^{-2} (Tuck 2010), similar to densities of *N. norvegicus* in comparable depths.

4.2 Bycatch (fish and invertebrates)

In the 2002–03 to 2015–16 fishing years, total annual bycatch was estimated to range from 2400–5600 t compared with total landed scampi catches of 550–893 t, and scampi accounted for 19% of the total estimated catch by weight from all observed tows (Anderson & Edwards 2018). Nearly 500 bycatch species or species groups were identified by observers, and the main bycatch species were javelinfish (18%), rattails (12%), and sea perch (10%), which were mostly discarded. Smaller catches of hoki (5%), ling (4%), dark ghost shark (3%), were also recorded. Invertebrate species made up a much smaller fraction of the bycatch overall (about 7%), with crustaceans (3%), echinoderms (2%) and squid (0.9%) being the main invertebrate bycatch species groups.

Total annual discard estimates from 2002–03 to 2015–16 showed no trend over time, ranging from a low of 940 t in 2003–04 to 4 070 t in the following year (Anderson & Edwards 2018). Non-QMS species were the main group discarded, often at a magnitude of two to three times that of QMS species discards. Annual estimated discards of scampi were generally low but exceeded 10 t in two years (2002–03 and 2009–10). The species discarded in the greatest amounts were those caught in the greatest amounts, javenlinfish (95%), rattails (91%), and sea perch (68%). From 2002–03 to 2015–16, the overall discard fraction value was 3.6 kg, with little trend over time. Discards ranged from 1.2–4.9 kg of discarded fish for every 1 kg of scampi caught.

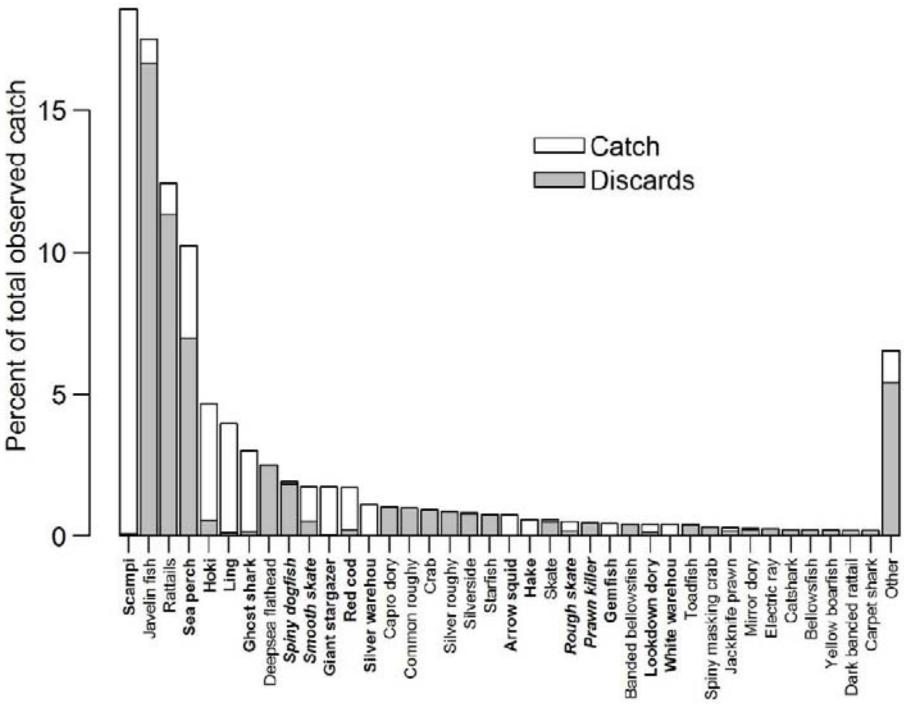


Figure 2: Percentage of the total catch contributed by the main bycatch species (those representing 0.02% or more of the total catch) in the observed portion of the target scampi trawl fishery for fishing years 2002-03 to 2015-16, and the percentage discarded. The Other category is the sum of all bycatch species representing less than 0.02% of the total catch (Anderson & Edwards 2018).

4.3 Incidental Catch (seabirds, mammals, and protected fish)

For protected species, capture estimates presented here 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 but not brought onboard the vessel, Middleton & Abraham 2007). Risk assessments results, which also include estimation of cryptic mortality, are also presented here when relevant.

Marine mammal interactions

Scampi trawlers occasionally catch marine mammals, 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).

In the 2016–17 fishing year there were no observed captures of New Zealand sea lions in scampi trawl fisheries (Table 4). Sea lions captured in previous years were all taken close to the Auckland Islands in SCI 6A (Thompson et al 2011).

In the 2016–17 fishing year there were no observed captures of New Zealand fur seals in scampi trawl fisheries, with 9.5% observer coverage (Table 5). Since 2002–03, only about 0.7% of the estimated total captures of New Zealand fur seals in all commercial fisheries have been taken in scampi fisheries; these have been on the western Chatham Rise and close to the Auckland Islands.

Rates of capture for both sea lions and fur seals have been low and have fluctuated without obvious trend.

Seabird interactions

Observed seabird capture rates in scampi fisheries ranged from about 1 to 20 per 100 tows between 1998–99 and 2008–09 (Baird 2001, 2004 a,b,c, 2005b Thompson & Abraham, 2009, Abraham et al. 2009, Abraham & Thompson 2011, Abraham et al 2013, Abraham et al 2016, Abraham & Richard 2017, 2018) and have fluctuated without obvious trend. In the 2015–16 fishing year there were 3 observed captures of birds in scampi trawl fisheries, with 195 (95% c.i.: 132–283) estimated captures, with the estimates made using a consistent modelling framework (Abraham et al 2016, Abraham & Richard 2017, 2018; Table 6). There were 11 observed captures in the 2016–17, but estimates of total captures are not yet available (Table 6). The estimates are based on relatively low observer coverage and include all bird species and should, therefore, be interpreted with caution. The average capture rate in scampi trawl fisheries over the last thirteen years (all areas combined) is about 4.43 birds per 100 tows, a moderate rate relative to trawl fisheries for squid (13.79 birds per 100 tows) and hoki (2.32 birds per 100 tows) over the same years.

Table 4: Number of tows by fishing year and observed New Zealand sea lion captures in Auckland Islands scampi trawl fisheries (SCI 6A), 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 available via https://data.dragonfly.co.nz/psc. Data for 2002–03 to 2015–16 are based on data version 2018V01.

	Fishing effort			Observed captures		Estimated interactions	
	Tows	No. obs	% obs	Captures	Rate	Mean	95% c.i.
2002–03	1 351	150	11.1	0	0.00	7	2–15
2003–04	1 363	169	12.4	3	1.78	10	5–18
2004–05	1 275	0	0.0	0		8	2–16
2005–06	1 331	118	8.9	1	0.85	8	3–16
2006–07	1 328	101	7.6	1	0.99	8	3–16
2007–08	1 327	93	7.0	0	0.00	8	2–15
2008–09	1 457	61	4.2	1	1.64	10	3–18
2009–10	NA	92	NA	0	0.00	5	1–11
2010–11	1 400	207	14.8	0	0.00	7	2–15
2011–12	NA	119	NA	0	0.00	7	2–14
2012–13	1 093	136	12.4	0	0.00	6	1–12
2013–14	NA	52	NA	0	0.00	5	1–11
2014–15	NA	0	NA	0		3	0–8
2015–16	1 414	66	4.7	0	0.00		
2016–17	1 677	354	21.1	0	0.00		

Table 5: Number of tows by fishing year and observed and model-estimated total NZ fur seal captures in scampi 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 available via https://data.dragonfly.co.nz/psc. Data for 2002–03 to 2015–16 are based on data version 2018v01.

		Observed				Estimated	
	Tows	No. obs	% obs	Captures	Rate	Captures	95% c.i.
2002–03	5 130	512	10.0	2	0.39	7	2-18
2003–04	3 753	412	11.0	1	0.24	6	1-14
2004–05	4 652	143	3.1	0	0.00	12	1-36
2005–06	4 867	331	6.8	0	0.00	6	0-18
2006–07	5 135	389	7.6	0	0.00	7	1-20
2007–08	4 804	524	10.9	1	0.19	8	1-20
2008–09	3 975	396	10.0	1	0.25	5	1-14
2009–10	4 248	348	8.2	1	0.29	7	1-19
2010–11	4 447	536	12.1	0	0.00	4	0-12
2011–12	4 509	459	10.2	1	0.22	7	1-19
2012–13	4 566	270	5.9	0	0.00	5	0-15
2013–14	4 421	254	5.7	0	0.00	3	0-11
2014–15	4 423	342	7.7	1	0.29	7	1-18
2015–16	5 210	144	2.8	0	0.00	5	0-15
2016–17	4 709	447	9.5	1	0.22		

Observed seabird captures since 2002–03 have been dominated by four species: Salvin's and white-capped albatrosses make up 44% and 28% of the albatrosses captured respectively; white chinned petrel, flesh-footed shearwaters and common diving petrel make up 29%, 23%, and 19% of other birds respectively, and the total and fishery risk ratios are presented in Table 7. Most of the captures occur near the Auckland Islands (39%), Bay of Plenty (36%), or Chatham Rise (21%). These numbers should be regarded as only a general guide on the distribution of captures because observer coverage is not uniform across areas and may not be representative.

Table 6: Number of tows by fishing year and observed and model-estimated total NZ seabirds captures in scampi 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, % inc, percentage of total effort included in the statistical model. Estimates are based on methods described in Abraham et al (2016) and Abraham & Richard (2017, 2018) and available via https://data.dragonfly.co.nz/psc. Data for 2002–03 to 2016–17 are based on data version 2018-001.

		Observed				Estimated		
	Tows	No. obs	% obs	Captures	Rate	Captures	95% c.i.	% inc.
2002–03	5 130	512	10.0	7	1.37	192	123-304	100.0
2003–04	3 753	412	11.0	7	1.70	137	87-213	100.0
2004–05	4 648	143	3.1	9	6.29	186	124-279	100.0
2005–06	4 867	331	6.8	11	3.32	195	128-288	100.0
2006–07	5 135	389	7.6	24	6.17	205	140-301	100.0
2007–08	4 805	524	10.9	10	1.91	173	112-263	100.0
2008–09	3 974	396	10.0	19	4.80	173	115-261	100.0
2009–10	4 249	348	8.2	5	1.44	156	96-245	100.0
2010–11	4 446	536	12.1	109	20.34	296	222-403	100.0
2011–12	4 510	459	10.2	10	2.18	164	107-245	100.0
2012–13	4 565	270	5.9	6	2.22	185	118-282	100.0
2013–14	4 421	254	5.7	6	2.36	172	112-254	100.0
2014–15	4 423	342	7.7	7	2.05	168	108-257	100.0
2015–16	5 210	144	2.8	3	2.08	203	135-300	100.0
2016–17	4 710	447	9.5	11	2.46	169	111-255	100.0

Table 7: Risk ratio of seabirds predicted by the level two risk assessment for the SCI target trawl 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 (inclusive of cryptic mortality) 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).

		Risk ratio			
Species name	PST (mean)	SCI target trawl	TOTAL	Risk category	DOC Threat Classification
Salvin's albatross	3 599.5	0.077	0.780	High	Threatened: Nationally Critical
Flesh-footed shearwater	1 452.8	0.033	0.669	High	Threatened: Nationally Vulnerable
Northern Buller's albatross	1 627.4	0.030	0.253	Medium	At Risk: Naturally Uncommon
Black petrel	437.1	0.011	1.153	Very high	Threatened: Nationally Vulnerable
Northern giant petrel	335.4	0.008	0.138	Medium	At Risk: Naturally Uncommon
New Zealand white-capped albatross	10 900.3	0.008	0.353	High	At Risk: Declining
Southern Buller's albatross	1 368.4	0.007	0.392	High	At Risk: Naturally Uncommon
White-chinned petrel	25 614.6	0.006	0.055	Negligible	At Risk: Declining
Chatham Island albatross	425.2	0.003	0.362	High	At Risk: Naturally Uncommon
Campbell black-browed albatross	1 980.5	0.003	0.077	Low	At Risk: Naturally Uncommon

4.4 Benthic interactions

The spatial extent of seabed contact by trawl fishing gear in New Zealand's EEZ and Territorial Sea has been estimated and mapped in numerous studies for trawl fisheries targeting deepwater species (Baird et al 2011, Black et al 2013, Black and Tilney 2015, Black and Tilney 2017, and Baird and Wood 2018) and species in waters shallower than 250m (Baird et al 2015). The most recent assessment of the deepwater trawl footprint was for the period 2007-08 to 2016-17 (Baird & Mules 2019).

Bottom trawl effort for scampi peaked in 2001–02 at over 6 500 tows (roughly 10% of all TCEPR bottom trawls in that year) but has typically been 4000–5000 tows per year since 1989–90 (Baird & Wood 2018). Most scampi effort is reported on TCEPR forms (Baird et al 2011, Black et al 2013). Tows are located in Benthic-optimised Marine Environment Classification (BOMEC, Leathwick et al 2012) classes F, G (upper slope), H, J, and L (mid-slope) (Baird & Wood 2012), and 95% were between 300 and 500 m depth (Baird et al 2011).

During 1989–90 to 2015–16, about 117 850 scampi bottom trawls were reported on TCEPRs (Baird & Wood 2018). The total footprint generated from these tows was estimated at about 22 537 km2. This footprint represented coverage of 0.5% of the seafloor of the combined EEZ and the Territorial Sea areas; 1.6% 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, 4705 scampi bottom tows had an estimated footprint of 3715 km2 which represented coverage of 0.1% of the EEZ and Territorial Sea and 0.3% of the fishable area (Baird & Mules 2019).

The overall trawl footprint for scampi (1989–90 to 2015–16) covered < 1.0% of seafloor in depths less than 200 m, 10% in 200–400 m, and 3% of 400–600 m seafloor (Baird & Wood 2018). In 2016–17, the scampi footprint contacted < 0.1%, 3%, and 1% of those depth ranges, respectively (Baird & Mules 2019). The BOMEC areas with the highest proportion of area covered by the scampi footprint were classes H (Chatham Rise) and L (deeper waters off the Stewart-Snares shelf and around the main sub-Antarctic islands). In 2016–17, the scampi footprint covered ≤ 0.01% of each BOMEC class (Baird & Mules 2019).

Bottom trawling for scampi, like trawling for other species, is likely to have effects on benthic community structure and function (e.g., Cryer et al 2002 for a specific analysis and Rice 2006 for an international review) and there may be consequences for benthic productivity (e.g., Jennings et al. 2001, Hermsen et al 2003, Hiddink et al 2006, Reiss et al 2009). These consequences are not considered in detail here but are discussed in the Aquatic Environment and Biodiversity Annual Review (2018).

4.5 Other considerations
None considered by the AEWG.

5. STOCK ASSESSMENT

In 2011 the SFWG accepted the stock assessments for SCI 1 and SCI 2, undertaken using the length-based population model. A length based assessment was also accepted for SCI 3 in 2015, and for SCI 6A in 2017. Section 5.2 summarises the stock assessments that have to date been accepted by the SFWG.

Attempts have been made to index scampi abundance using CPUE and trawl survey indices and, more recently, photographic surveys of visible scampi and scampi burrows. There is some level of agreement between the relative trends shown, and all three indices are included in the length based assessment model.

5.1 Estimates of fishery parameters and abundance
Standardised CPUE indices are calculated for each stock every three years, as part of the stock assessment process. Annual unstandardised CPUE indices for each area (total catch divided by total effort in hours of trawling) are updated annually, using the data from all vessels that fished (Figure 2). The Shellfish Fishery Assessment Working Group (SFWG) has raised concerns in the past that potential variability in catchability between years mean that standardised CPUE may not provide a reliable index of abundance, although consistent changes shown by different types of indices for the same area provide more confidence in the data. The standardised indices for areas SCI 3, 4A 6A and 6B have been recalculated over the time series in light of the alterations of some stock boundaries, following the review mentioned in Section 3. All discussions below relate to standardised CPUE.

In SCI 1, CPUE increased in the early 1990s, and then declined between 1995–96 and 2001–02, showed a slight increase in 2002–03 and 2003–04, but has generally remained stable since 2001–02, with a slight increase in 2017–18. In SCI 2, CPUE increased in 1994–95, then declined steadily to 2001–02, remained at quite a low level until 2007–08, increased until 2013–14 (with CPUE comparable to that recorded in the mid–1990s), declining slightly after this to levels comparable with the late 1990s, and remaining stable since 2015–16. In SCI 3, CPUE rose steadily through the early 1990s, fluctuated around a slowly declining trend in the late 1990s and early 2000s, showed a steeper decline to 2007–08, increased to 2010–11, and then remained stable until increasing in 2016–17 to a level that has been maintained in 2017–18. In SCI 4A, CPUE observations were intermittent between 1991–92 and 2002–

03, showing a dramatic increase over this period. Since 2002–03 CPUE has been far lower, but since 2010–11 data show an increase on the mid–2000s. In SCI 6A, after an initial decline in the early 1990s, CPUE remained relatively stable until 2007–08, shows a decline until 2013–14, and a slight increase since. With the revision of the stock boundaries, data are only available for one year for SCI 6B, and are therefore not presented. For both SCI 5 and SCI 7, observations have been intermittent, and consistently low.

A time series of trawl surveys designed to measure relative biomass of scampi in SCI 1 and 2 ran between January 1993 and January 1995 (Table 8). Research trawling for other purposes has been conducted in both SCI 1 and SCI 2 in several other years, and catch rates from appropriate hauls within these studies have been plotted alongside the dedicated trawl survey data in Figure 3 and Figure 4. In SCI 1 the additional trawling was conducted in support of a tagging programme (in 1995 and 1996), which was conducted by a commercial vessel in the peak area of the fishery, while work to assess trawl selectivity (1996) and in support of photographic surveys (since 1998) may have been more representative of the overall area. In SCI 2 the additional trawling was conducted in support of a growth investigation using length frequency data (1999 and 2000) and in support of photographic surveys (since 2003). All the work was carried out by the same research vessel, but while the work in support of photographic surveys was carried out over the whole area, the work related to the growth investigation was concentrated in a small area in the south of the SCI 2 area. Only the additional trawl survey work in support of photographic surveys has been included in Table 8, since the other studies did not have comparable spatial coverage. The trends observed are similar to the trends in commercial CPUE (Figure 2) for both stocks.

Surveys have been conducted in SCI 3 in 2001 (two surveys, pre- and post- fishery), 2009, 2010, 2013 and 2016. The trawl component of the surveys did not suggest any difference between the pre and post fishery periods in 2001, but the photographic survey observed more scampi burrows after the fishery. Trawl, photographic and CPUE data indicate a significant decline in scampi abundance between 2001 and 2009, but an increase in more recent years (Figure 5).

Table 8: Trawl survey indices of biomass (t) for scampi in survey strata within SCIs 1, 2, 3 and 6A. CVs of estimates in parenthesis.

	SCI 1	SCI 2	SCI 3	SCI 6A	Comments
1993	217.3 (0.12)	238.2 (0.12)			Dedicated trawl survey
1994	288.2 (0.19)	170.0 (0.16)			Dedicated trawl survey
1995	391.6 (0.18)	216.2 (0.18)			Dedicated trawl survey
1996					
1997					
1998	174.0 (0.17)				Trawling in support of photo survey
1999					
2000	181.3 (*)				Trawling in support of photo survey
2001	179.5 (0.27)		272.5 (0.24) (strata 902–3)		Trawling in support of photo survey SCI 3 pre-season survey
2002	130.6 (0.24)				Trawling in support of photo survey
2003		28.0 (*)			Trawling in support of photo survey
2004		46.9 (0.20)			Trawling in support of photo survey
2005		50.8 (0.35)			Trawling in support of photo survey
2006		22.9 (0.19)			Trawling in support of photo survey
2007				1073.5 (0.18)	Trawling in support of photo survey
2008	211.9 (*)			1229.1 (0.18)	Trawling in support of photo survey
2009			40.2 (0.37) (strata 902–3) 418.1 (0.26)	821.6 (0.09)	Trawling in support of photo survey
2010			49.0 (0.11) (strata 902–3) 596.1 (0.04)		Trawling in support of photo survey
2011					
2012	150.0 (0.25)	164.2 (0.28)			Trawling in support of photo survey
2013			126.5 (0.27) (strata 902–3) 551.3 (0.12)	1258.0 (0.06)	Trawling in support of photo survey
2014					
2015	118.5 (0.17)	224.5 (0.19)			Trawling in support of photo survey
2016			139.6 (0.14) (strata 902–3) 913.1 (0.12)	593.3 (0.09)†	Trawling in support of photo survey
2017					
2018	188.6 (0.21)	183.3 (0.29)			Trawling in support of photo survey

* - where no CV is provided, one stratum had only one valid station. Strata included: SCI 1 – 302,303, 402, 403; SCI 2 – 701, 702, 703, 801, 802, 803; SCI 3 – 902, 903, 904; SCI 6A (main area) – 350 m, 400 m, 450 m, 500 m. SCI 3 survey in 2009 and 2010 split into area surveyed in 2001, and new area (strata 902A–C & 903A). † - 2016 survey in SCI 6A conducted with a different vessel from previous surveys in this area.

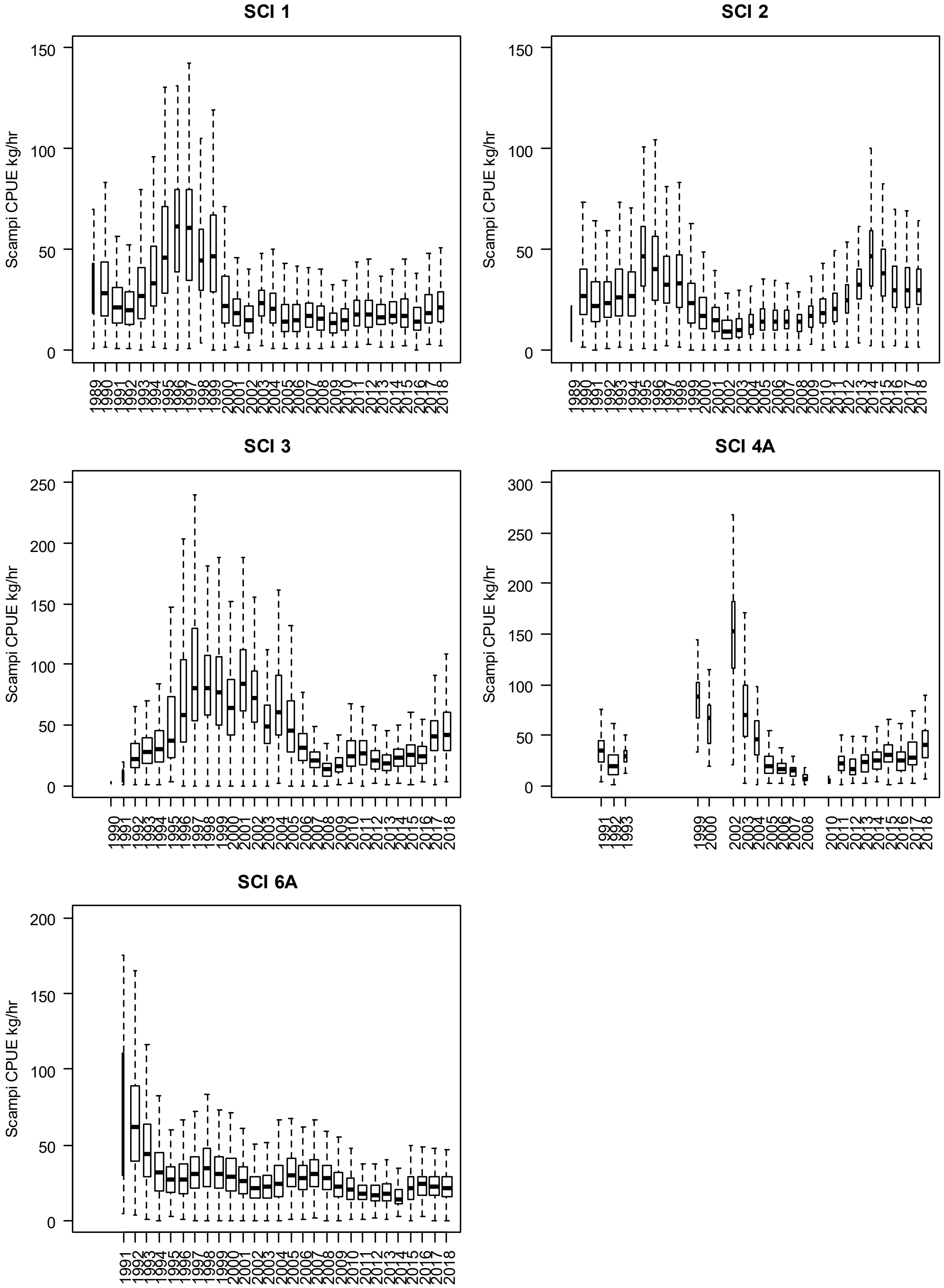


Figure 2: Box plots (with outliers removed) of individual observations of unstandardised catch rate for scampi (tow catch (kg) divided by tow effort (hours)) with tows of zero scampi catch excluded, by fishing year for main stocks. Box widths proportional to square root of the number of observations. Note different scales between plots. Horizontal bars within boxes represent distribution median. Upper and lower limits of boxes represent upper and lower quartiles. Whisker extends to largest (or smallest) observation which is less than or equal (greater than or equal) to the upper quartile plus 1.5 times the interquartile range (lower quartile less 1.5 times the interquartile range). Outliers (removed from this plot) are values outside the whiskers. Box width proportional to square root of number of observations.

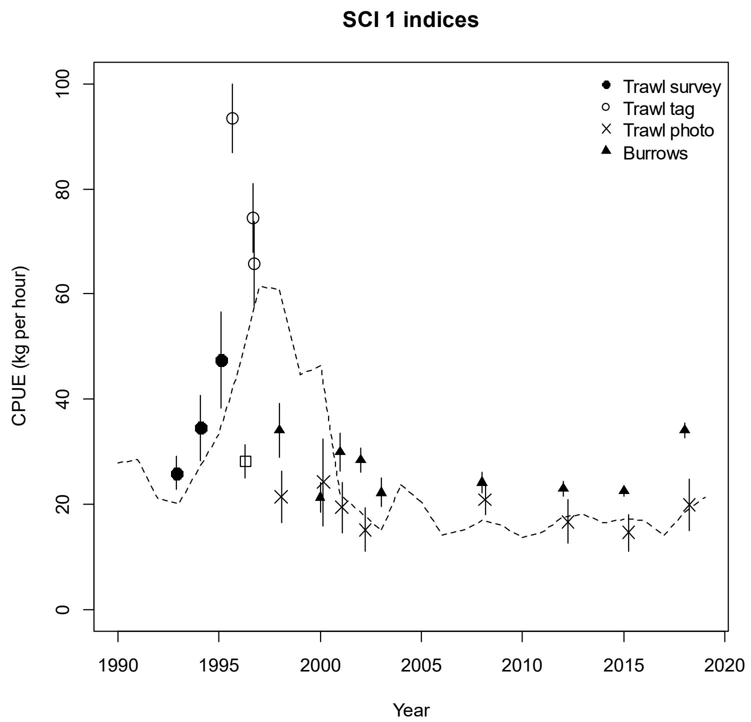


Figure 3: Mean catch rates and relative abundance (± one standard error) of research trawling and photo survey counts in the core area of SCI 1. Symbols represent different aims of survey work (● – trawl survey, ○ – tagging work, □ – trawl selectivity, ×- trawling within photo survey, ▲-scaled photo survey abundance). Dotted line represents median of annual unstandardised CPUE for SCI 1 from Figure 2.

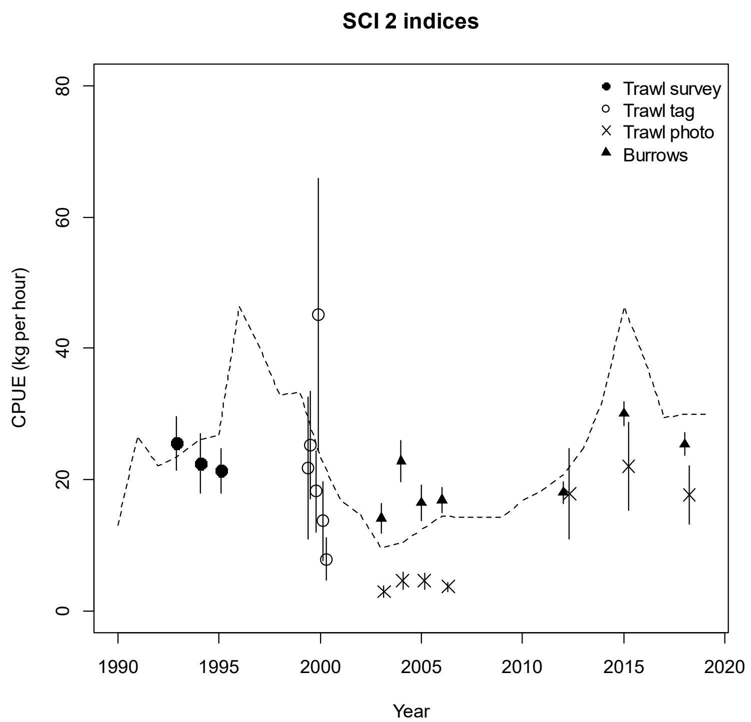


Figure 4: Mean catch rates and relative abundance (± one standard error) of research trawling and photo survey counts in the core area of SCI 2. Symbols represent different aims of survey work (● – trawl survey, ○ – tagging work, ×- trawling within photo survey, ▲-scaled photo survey abundance). Dotted line represents median of annual unstandardised CPUE for SCI 2 from Figure 2.

Table 9: Photographic survey estimates of abundance (millions) based on major openings and visible scampi in survey strata within SCIs 1, 2, 3 and 6A. CVs of estimates in parenthesis. Major burrow openings are openings on the seabed that are considered to be main entrance of a scampi burrow. Visible scampi represents all scampi seen in photographs (either in a burrow entrance, or walking free on the seabed).

	SCI 1		SCI 2		SCI 3		SCI 6A		Comments
	Major openings	Visible scampi	Major openings	Visible scampi	Major openings	Visible scampi	Major openings	Visible scampi	
1998	154.6 (0.15)	27.9 (0.22)							
1999									
2000	96.8 (0.13)	18.2 (0.18)							
2001	135.9 (0.12)	12.3 (0.26)			224.0 (0.09) (strata 902–3)	48.2 (0.16) (strata 902–3)			
2002	128.7 (0.08)	16.7 (0.21)							
2003	101.0 (0.12)	14.4 (0.21)	93.1 (0.16)	10.0 (0.39)					
2004			150.2 (0.14)	20.6 (0.28)					
2005			108.5 (0.17)	14.6 (0.20)					
2006			111.3 (0.11)	13.3 (0.23)					
2007							305.5 (0.11)	60.4 (0.14)	SCI 6A estimate for main area*
2008	109.8 (0.08)	12.5 (0.13)					132.3 (0.08)	55.4 (0.08)	
2009					54.4 (0.14) (strata 902–3) 285.8 (0.07) (larger survey)	18.4 (0.17) (strata 902–3) 122.6 (0.10) (larger survey)	288.8 (0.10)	36.6 (0.14)	SCI 3, estimates provided for 2001 survey coverage (strata 902–3) and new larger survey
2010					72.0 (0.11) (strata 902–3) 378.0 (0.05) (larger survey)	8.7 (0.22) (strata 902–3) 92.8 (0.11) (larger survey)			SCI 3, estimates provided for 2001 survey coverage (strata 902–3) and new larger survey
2012	104.0 (0.06)	23.9 (0.09)	118.7 (0.09)	32.0 (0.11)					
2013					144.1 (0.11) (strata 902–3) 592.6 (0.06) (larger survey)	20.5 (0.17) (strata 902–3) 130.8 (0.09) (larger survey)	126.5 (0.09)	32.8 (0.16)	
2015	102.2 (0.07)	18.0 (0.14)	197.8 (0.06)	40.0 (0.09)					
2016					152.1 (0.10) (strata 902–3) 747.5 (0.05) (larger survey)	36.7 (0.16) (strata 902–3) 206.9 (0.08) (larger survey)	146.6 (0.12)	48.7 (0.14)	
2018	154.7 (0.05)	45.3 (0.06)	167.2 (0.07)	48.9 (0.29)					

* - SCI 6A estimate provided for main area as future surveys may not survey secondary area. SCI 1 estimate provided for strata 302, 303, 402, 403.

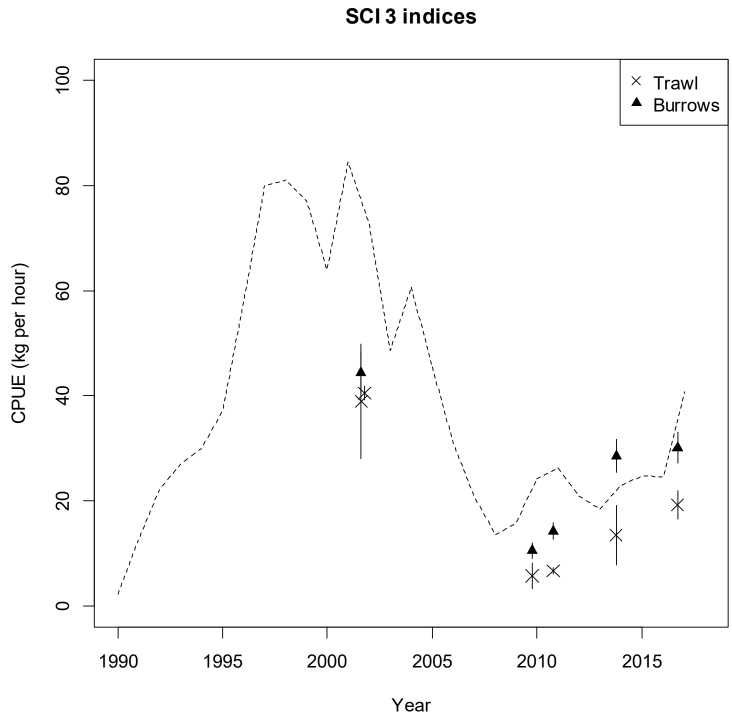


Figure 5: Mean catch rates and relative abundance (± one standard error) of research trawling and photo survey counts in the core area of SCI 3. Symbols represent different aims of survey work (×- trawling within photo survey, ▲-scaled photo survey abundance). Dotted line represents median of annual unstandardised CPUE for SCI 3 from Figure 2.

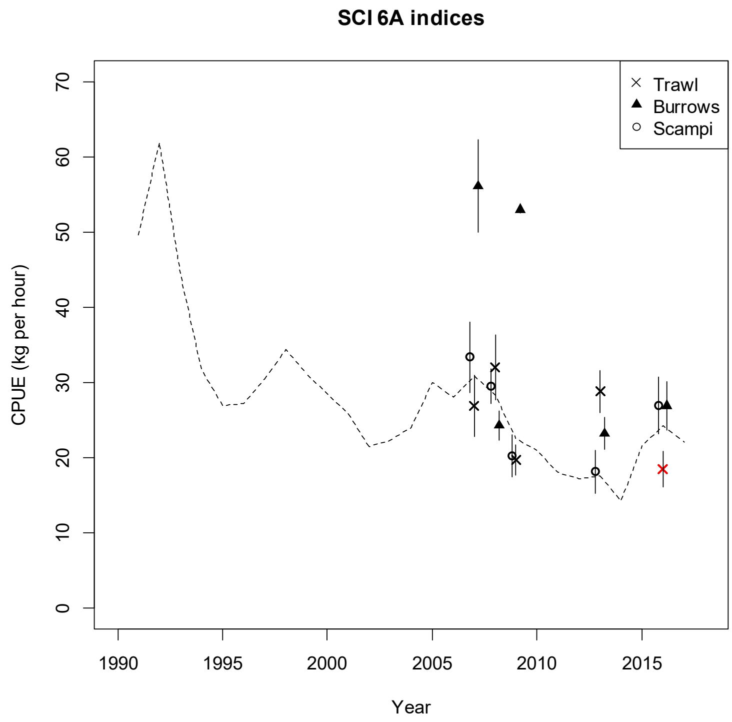


Figure 6: Mean catch rates and relative abundance (± one standard error) of research trawling and photo survey counts in the core area of SCI 6A. Symbols represent different aims of survey work (×- trawling within photo survey, ▲-scaled photo survey abundance). The 2016 trawl index point (denoted by a red ×) was excluded from the SCA 6A assessment model because a different vessel was used for the trawl survey in this year. The dotted line represents median of annual unstandardised CPUE for SCI 6A from Figure 2.

Surveys have been conducted in SCI 6A in 2007–2009, 2013 and 2016 (although with a different vessel in the most recent year). The trawl component of the photo surveys suggests that the biomass has fluctuated in recent years, although modelling indicated that the fishing power of the vessel used in 2016 was substantially less than that of the vessel used in earlier years. The most recent index point was therefore excluded from the trawl survey index fitted in the stock assessment model. The photographic survey (burrows) suggested a considerable decline in abundance between 2007 and 2008, an increase in 2009 back towards the 2007 level, followed by a decline to lower levels of abundance in 2013 and 2016. Over the longer term, the CPUE data indicate a rapid decline in the early 1990s, followed by a slower decline in abundance between 1995 and 2014, with evidence of a recent increase in abundance (Figure 6).

Photographic surveying (usually by video) has been used extensively to estimate the abundance of the European scampi *Nephrops norvegicus*. In New Zealand, development of photographic techniques, including surveys, has been underway since 1998. To date, nine surveys have been undertaken in SCI 1 (between Cuvier Island and White Island at a depth of 300 to 500 m), seven surveys have been undertaken in SCI 2 (Mahia Peninsula to Castle Point 200 to 500 m depth), five surveys have been undertaken in SCI 3 (north eastern Mernoo Bank only, 200 to 600 m depth), and five surveys in SCI 6A (to the east of the Auckland Islands, 350–550 m depth). The association between scampi and burrows in SCI 6A appears to be different to other areas examined, and it is assumed that the burrow abundance index for this stock does not provide a reliable index of scampi abundance, given the poor relationship between the scampi and burrow abundance indices (Figure 6) and the marked degree of decline in abundance it suggests (Table 8)

Two indices are calculated from photographic surveys: the density of visible scampi and the density of major burrow openings (counts of which are now consistent among experienced readers, and repeatable, following development of a between reader standardisation process). Both of these can be used to estimate indices of biomass, using estimates of mean individual weight or the size distribution of animals in the surveyed population. The Bayesian length based assessment model used for SCI 1, SCI 2 and SCI 3 uses the estimated abundance of major burrow openings as an abundance index, but only the visible scampi index was used in the SCI 6A assessment.

Estimates of major burrow opening and visible scampi abundance are provided in Table 9. Acoustic tagging approaches (undertaken during surveys) have been used, in conjunction with burrow and scampi density estimates, to estimate emergence patterns and priors for scampi catchability. A revised approach to estimating priors on the basis of this data, taking greater account of uncertainty in observed burrow and animal density and emergence rates, was adopted in 2016 (Tuck et al 2015).

Length frequency distributions from trawl surveys and from scientific observers do not show a consistent increase in the proportion of small individuals in any SCI stock following the development of significant fisheries for scampi. Analyses of information from trawl survey and scientific observers in SCI 1 and 6A, up to about 1996, suggested that the proportion of small animals in the catch declined markedly in both areas, despite the fact that CPUE declined markedly in SCI 6A and increased markedly in SCI 1. Where large differences in the length frequency distribution of scampi measured by observers have been detected (as in SCIs 1 and 6A), detailed analysis has shown that the spatial coverage of observer samples has varied with time, and this may have influenced the nature of the length frequency samples. The length composition of scampi is known to vary with depth and geographical location, and fishers may deliberately target certain size categories.

Some commercial fishers reported that they experienced historically low catch rates in SCI 1 and 2 between 2001 and 2004. They further suggest that this reflects a decrease in abundance of scampi in these areas. Other fishers consider that catch rates do not necessarily reflect changes in abundance because they are influenced by management and fishing practices.

5.2 Stock Assessment Methods

SCI 1 and SCI 2

In 2011 the SFWG accepted the stock assessments for SCI 1 and SCI 2, undertaken using the length-based population model that had been under development for several years (Tuck & Dunn 2012), and updated assessments were accepted in 2013 and 2016. Provisional assessment results in 2019 do not indicate and change in status for either stock. The text below applies to the 2016 assessment.

A number of model runs were presented, examining sensitivities to M, data weighting, and a combined area model (two stock model with no migration, sharing growth and selectivity parameters). For SCI 1 assessments, the absolute biomass levels and the state of the stock relative to B_0 was relatively consistent between models, but for SCI 2, both absolute biomass levels and the state of the stock relative to B_0 increased with M. Base models were agreed upon with M=0.3, although outputs from M=0.25 and M=0.35 models are also presented.

The model's annual cycle is based on the fishing year and is divided into three time-steps (Table 10). The choice of three time steps was based on the current understanding of scampi biology and the sex ratio in catches. Note that model references to "year" within this report refer to the modelled or fishing year, and are labelled as the most recent calendar year, i.e., the fishing year 1998–99 is referred to as "1999" throughout.

Table 10: Annual cycle of the population model for SCI 1, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur together within a time step occur after all other processes, with 50% of the natural mortality for that time step occurring before and 50% after the fishing mortality.

Step	Period	Process	Proportion in time step
1	Oct–Jan	Growth (both sexes)	
		Natural mortality	0.33
		Fishing mortality	From TCEPR
2	Feb–April	Recruitment	1.0
		Maturation	1.0
		*Growth (males)**	
		Natural mortality	0.25
		Fishing mortality	From TCEPR
3	May–Sept	Natural mortality	0.42
		Fishing mortality	From TCEPR

* - the main period of male moulting appears to be from February to April. In the model both sexes are assumed to grow at the start of step 1, and this male growth period (February to April) is ignored.

Investigations into factors affecting scampi catch rates and size distributions (Cryer & Hartill 2000, Tuck 2010) have identified significant depth and regional effects, and regional (strata) and depth stratification were applied in previous models. Preliminary examination of patterns in CPUE indices and other input data suggested that this may not be necessary, and a simplified single area model was developed in 2013. Catches generally occur throughout the year, and were divided among the time-steps according to the proportion of estimated catches recorded on Trawl Catch, Effort, and Processing Returns (TCEPR). Recreational catch, customary catch, and illegal catch are ignored. The maximum exploitation rate (i.e., the ratio of the maximum catch to biomass in any year) is not known, but was constrained to no more than 0.9 in a time-step. Individuals are assumed to recruit to the model at age 1, with the mean expectation of recruitment success predicted by a Beverton Holt stock-recruitment relationship. Length at recruitment is defined by a normal distribution with mean of 10 mm OCL with a CV of 0.4. Relative year class strengths are encouraged to average 1.0. Growth is estimated in the model, fitting to the tag (Cryer & Stotter 1997, Cryer & Stotter 1999) and aquarium data (Cryer & Oliver 2001) from SCI 1 and SCI 2.

The model uses logistic length-based selectivity curves for commercial fishing, research trawl surveys and photographic surveys, assumed constant over years but allowed to vary with sex, time step. While the sex ratio data suggest that the relative catchability of the sexes vary through the year (hence the model time structure adopted), there is no reason to suggest that (assuming equal availability) selectivity-at-size would be different between the sexes. Therefore the selectivity implementation used allowed the L_{50} and a_{95} selectivity parameters to be estimated as single values shared by both sexes in a particular time step, but allowed for different availability between the sexes through estimation of different a_{max} values for each sex. In SCI 1 and SCI 2 selectivity is assumed to be the same in time steps 1 and 3, owing to the relative similarity in sex ratio.

Data inputs included CPUE, trawl and photographic survey indices, and associated length frequency distributions.

The assessment reports B_0 and $B_{current}$ and used the ratio of current and projected spawning stock biomass ($B_{current}$ and B_{2018}) to B_0 as preferred indicators. Projections were conducted up to 2021 on the basis of a range of catch scenarios. The probability of exceeding the default Harvest Strategy Standard target and limit reference points are reported.

SCI 3

In 2015 the SFWG accepted a stock assessment for SCI 3, undertaken using the length-based population model, and an updated assessment was accepted in 2018. A number of model runs were presented, examining sensitivities to assumptions about process error on the CPUE indices and M. The absolute biomass levels were sensitive to the process error and M, but the state of the stock relative to B_0 was consistent between models. A base model was taken with M = 0.25 and CPUE process error = 0.2, with sensitivities to these assumptions considered..

The model's annual cycle is slightly adjusted from the fishing year and is divided into two time-steps (Table 11). The choice of two time steps was based on the current understanding of scampi biology and the sex ratio in catches. Note that model references to "year" within this report refer to the modelled year, and are labelled as the most recent calendar year, i.e., the modelled year 1998–99 is referred to as "1999" throughout.

Table 11: Annual cycle of the population model for SCI 3, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur together within a time step occur after all other processes, with 50% of the natural mortality for that time step occurring before and 50% after the fishing mortality.

Step	Period	Process	Proportion in time step
1	Jul–Dec	Growth (both sexes)	
		Natural mortality	0.5
		Fishing mortality	From TCEPR
2	Jan–Jun	Recruitment	1.0
		Maturation	1.0
		Natural mortality	0.5
		Fishing mortality	From TCEPR

The SCI 3 fishery is focussed in three distinct areas on the Chatham Rise (an area to the west of 176° E on the Mernoo Bank – MO; an area to the west of 176° E on the Mernoo Bank – MW; and a separate region to the north east, centred about 177° E - MN), and differences in management between these areas over time have led to different fishing histories. Scampi are not thought to undertake large scale migrations, and so these three areas were considered distinct stocks within the assessment model, sharing some parameters (growth, selectivity and catchability). The seasonal patterns of catches vary between stocks and over time through the fishery, and were divided among the stocks and time-steps according to the proportion of estimated catches recorded on Trawl Catch, Effort, and Processing Returns (TCEPR). Recreational catch, customary catch, and illegal catch are ignored. The maximum exploitation rate (i.e., the ratio of the maximum catch to biomass in any year) is not known, but was constrained to no more than 0.9 in a time-step. Individuals are assumed to recruit to the model at age 1, with the mean expectation of recruitment success predicted by a Beverton-Holt stock-recruitment relationship. Length at recruitment is defined by a normal distribution with mean of 10 mm OCL with a CV of 0.4. Relative year class strengths are encouraged to average 1.0. Growth is estimated in the model.

As with the SCI 1 and SCI 2 models, the SCI 3 model uses logistic length-based selectivity curves for commercial fishing, research trawl surveys and photographic surveys, assumed constant over years and stocks, but allowed to vary with sex and time step. Data inputs for each stock included CPUE, trawl and photographic survey indices, and associated length frequency distributions.

The assessment reported B_0 and B_{2017} (at both the individual stock and overall FMA level) and used the ratio of current and projected spawning stock biomass (B_{2017t} and B_{2020}) to B_0 as preferred indicators. Projections were conducted up to 2020 on the basis of a range of catch scenarios. The probability of exceeding the default Harvest Strategy Standard target and limit reference points are reported.

SCI 6A

In 2016 the Plenary accepted a stock assessment for SCI 6A, undertaken using the length-based population model. A number of model runs were presented, examining sensitivities to two alternative CVs for YCS priors (0.4 and 0.7), and two values of M (0.20 and 0.25). All four models produced similar estimates of absolute biomass and stock status. Slightly higher estimates of B_0 were produced when a higher CV was used for the YCS prior and when a higher value was used for M, and estimates of stock status relative to B_0 were slightly higher when a higher M was assumed. The SFWG accepted that all four models were equally representative of the status of the SCI 6A stock, with results provided by one model (M = 0.25, YCS prior CV = 0.4) being indicative of those produced by the other three.

The model's annual cycle is slightly adjusted from the fishing year and is divided into three time-steps (Table 12). The choice of the three time steps was based on the current understanding of scampi biology and the sex ratio in catches. Note that model references to "year" within this report refer to the modelled year, and are labelled as the most recent calendar year, i.e., the modelled year 1998–99 is referred to as "1999" throughout.

Table 12: Annual cycle of the population model for SCI 6A, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur together within a time step occur after all other processes, with 50% of the natural mortality for that time step occurring before and 50% after the fishing mortality.

Step	Period	Process	Proportion in time step
1	Mid Nov – mid Apr	Growth (both sexes)	
		Maturation	1.0
		Natural mortality	0.417
		Fishing mortality	From TCEPR
2	mid Apr–Jun	Recruitment	1.0
		Natural mortality	0.208
		Fishing mortality	From TCEPR
3	Jul–mid Nov	Natural mortality	0.375
		Fishing mortality	From TCEPR

The SCI 6A fishery occurs south east of the Auckland Islands (between 166°E and 168°E, and between 50°15′ S and 51°15′ S). Scampi are not thought to undertake large scale migrations, and this is considered to be a distinct stock, for which a simplified single area model was developed in 2016. Catches generally occur throughout the year, and were divided among the time-steps according to the proportion of estimated catches recorded on Trawl Catch, Effort, and Processing Returns (TCEPR). Recreational catch, customary catch, discards and illegal catch are thought to be zero and are therefore ignored in the model. The maximum exploitation rate (i.e., the ratio of the maximum catch to biomass in any year) is not known, but was constrained to no more than 0.9 in a time-step. Individuals were assumed to recruit to the model at 10 mm, with the mean expectation of recruitment success predicted by a Beverton-Holt stock-recruitment relationship. Length at recruitment was defined by a normal distribution with mean of 10 mm OCL and a CV of 0.4. There was no penalty on year class strength. Growth is estimated in the model from tag recapture data.

The model used logistic length-based selectivity curves for commercial fishing and research trawl surveys, which were assumed to be constant over years but allowed to vary with sex and time step. While the sex ratio data suggest that the relative catchability of the sexes varies through the year (hence the model time structure adopted), there is no reason to suggest that (assuming equal availability) selectivity-at-size would be different between the sexes. Therefore the selectivity implementation used allowed the L_{50} and a_{95} selectivity parameters to be estimated as single values shared by both sexes in a particular time step, but allowed for different availability between the sexes through estimation of different a_{max} values for each sex. The value for L_{50} in time step 3 was fixed at 42 mm as the model estimated unrealistically high values for this parameter. A combined sex double normal selectivity curve was used when fitting photo survey length frequency data for visible scampi.

The assessment reported B_0 and $B_{current}$ and used the ratio of current and projected spawning stock biomass ($B_{current}$ and B_{2020}) to B_0 as preferred indicators. Projections were conducted up to 2020 for two future catch scenarios. The probability of exceeding the default Harvest Strategy Standard target and limit reference points are reported.

5.3 Stock Assessment Results

SCI 1 and SCI 2

For SCI 1, model outputs suggest that spawning stock biomass (SSB) increased to a peak in about 1995, declined to the early 2000s, and has remained relatively stable since this time. The SSB in SCI 1 in 2015 was estimated to be about 75% of B_0 (Figure 7, Table 13). Historical changes in biomass in SCI 1 appear to be related to fluctuations in recruitment rather than catches, and likelihood profiles suggest that the priors have more influence than the abundance indices in determining B_0. Estimated year class strength seems to be driven largely by the abundance indices with little signal from the length-frequency distributions. Post-Plenary investigations into the sensitivity of excluding the survey indices showed that removing the photo survey reduced the estimate of B_0, while removing the trawl survey had the opposite effect, although stock trajectory and current status ($B_{current}/B_0$) was only slightly affected. For SCI 2, model outputs suggest that spawning stock biomass (SSB) decreased slightly until 1990, increased to a peak in the early 1990s, declined to the early 2000s, increased slightly until about 2008, but increased more rapidly to 2014, declining slightly by 2015. The SSB in SCI 2 in 2015 was estimated to be 89%–113% B_0 (Figure 8, Table 14).

Table 13: Results from MCMC runs showing B_0, B_{curr} and B_{curr}/B_0 estimates for the base model (M=0.3) and sensitivities for SCI 1.

Model	M=0.25	M=0.3	M=0.35
B_0	5 572	6 009	6 148
B_{curr}	3 974	4 507	4 604
B_{curr}/B_0	0.72	0.75	0.75

Table 14: Results from MCMC runs showing B_0, B_{curr} and B_{curr}/B_0 estimates for the base model (M=0.3) and sensitivities for SCI 2.

Model	M=0.25	M=0.3	M=0.35
B_0	2 728	2 867	3 005
B_{curr}	2 431	2 888	3 391
B_{curr}/B_0	0.89	1.01	1.13

The default management target for scampi of 40% B_0 is below the range of % B_0 estimated for both stocks.

SCI 3

For SCI 3, a base model was taken with M = 0.25 and CPUE process error = 0.2, with sensitivities to these assumptions considered. Model outputs suggest that spawning stock biomass (SSB) increased to a peak in about 1999, declined to 2010, and then remained more stable, increasing after 2014 (Figure 9). The SSB in SCI 3 in 2017 was estimated to be 76% (95% CI 69–83%) of B_0 at the FMA level for the base case, with median estimates ranging between 0.75 to 0.81 for the three sensitivities (Figures 9, Table 15).

The default management target for scampi of 40% B_0 is below the range of %B_0 estimated for the SCI 3 base model, or any of the sensitivities (Figure 10).

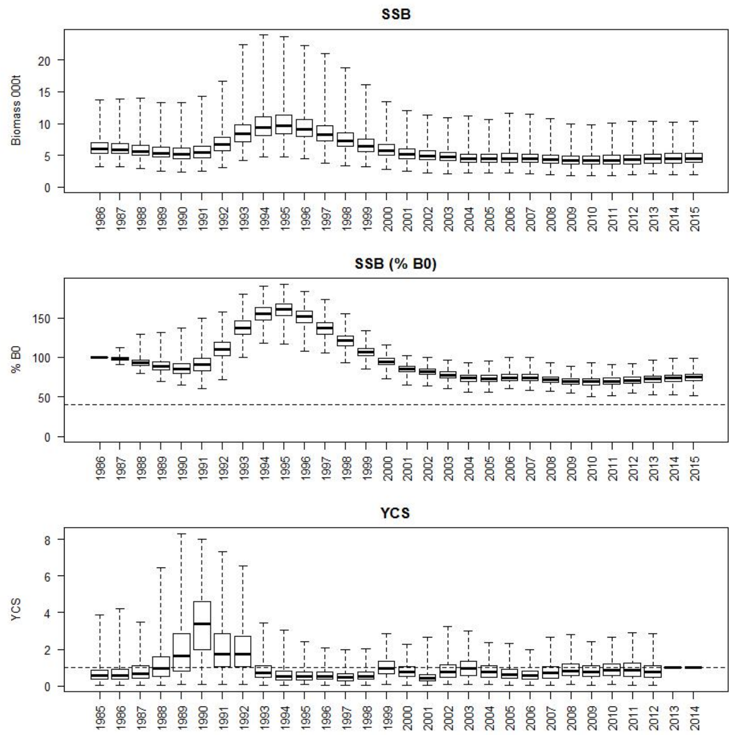


Figure 7: Posterior trajectory from SCI 1 base model (M=0.3) of spawning stock biomass and YCS. Upper plot shows boxplots of SSB, while the middle plot shows SSB as a percentage of B_0. On the middle plot, target and limit reference points are shown in grey solid and dashed lines. Box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.

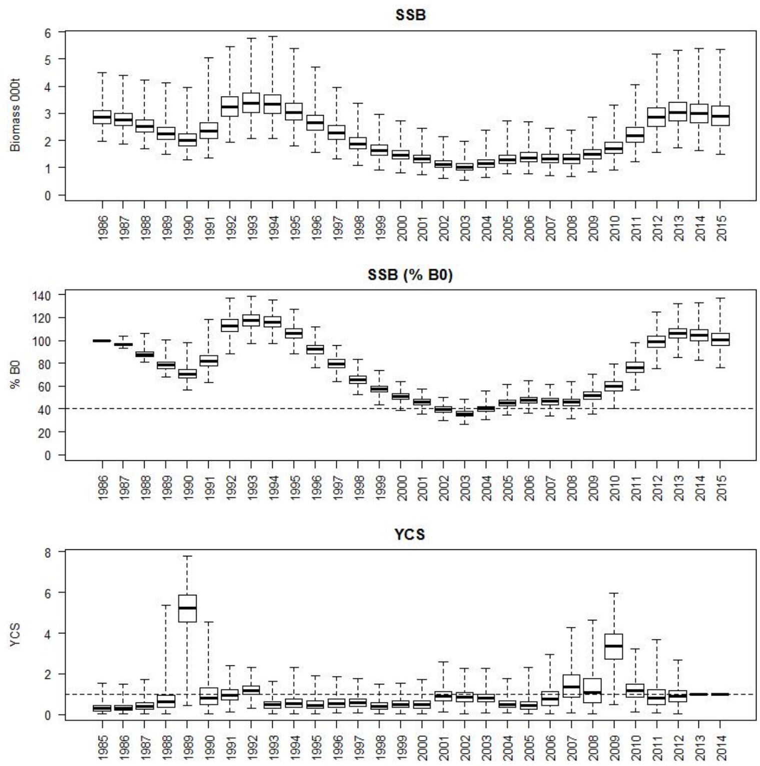


Figure 8: Posterior trajectory from the SCI 2 base model (M=0.3) of spawning stock biomass and YCS. Upper plot shows boxplots of SSB, while middle plot shows SSB as a percentage of B_0. On middle plot, target and limit reference points are shown in grey solid and dashed lines. Box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.

Table 15: Results from MCMC runs showing B_0, B_{2017} and B_{2017}/B_0 estimates for the base model and three sensitivities for SCI 3.

Base: M=0.25, CV=0.20	MN	MO	MW	SCI 3
SSB_0	6204 (3845–11 349)	4035 (2348–7593)	4905 (2911–9253)	15162 (9086–28 092)
SSB_{2017}	4611 (2451–9305)	3164 (1806–6034)	3783 (2130–7400)	11599 (6420–22 713)
SSB_{2017}/SSB_0	0.74 (0.62–0.86)	0.78 (0.70–0.87)	0.77 (0.68–0.86)	0.76 (0.69–0.83)
P(SSB_{2017} > 40% SSB_0)	1	1	1	1
P(SSB_{2017} < 20% SSB_0)	0	0	0	0
Sensitivity: M=0.20, CV=0.20	MN	MO	MW	SCI 3
SSB_0	5625 (3770-9767)	3668 (2275-6650)	4335 (2738-7833)	13643 (8820-24 188)
SSB_{2017}	3946 (2184-7769)	3002 (1804-5538)	3304 (1954-6224)	10248 (6022-19 366)
SSB_{2017}/SSB_0	0.7 (0.57-0.82)	0.82 (0.75-0.89)	0.76 (0.68-0.85)	0.75 (0.67-0.82)
P(SSB_{2017} > 40% SSB_0)	1	1	1	1
P(SSB_{2017} < 20% SSB_0)	0	0	0	0
Sensitivity: M=0.20, CV=0.25	MN	MO	MW	SCI 3
SSB_0	5910 (3754–10426)	3728 (2193–6987)	4546 (2722–8316)	14168 (8710–25 614)
SSB_{2017}	4449 (2311–8941)	3127 (1776–5953)	3647 (2031–7097)	11220 (6215–21 827)
SSB_{2017}/SSB_0	0.75 (0.61–0.88)	0.84 (0.77–0.91)	0.80 (0.71–0.89)	0.79 (0.70–0.86)
P(SSB_{2017} > 40% SSB_0)	1	1	1	1
P(SSB_{2017} < 20% SSB_0)	0	0	0	0
Sensitivity: M=0.25, CV=0.25	MN	MO	MW	SCI 3
SSB_0	6235 (3810–11 609)	3947 (2265–7553)	4939 (2896–9388)	15118 (9013–28 337)
SSB_{2017}	4961 (2601–10 285)	3228 (1797–6242)	4013 (2211–7991)	12217 (6704–24 213)
SSB_{2017}/SSB_0	0.79 (0.66–0.92)	0.82 (0.73–0.90)	0.81 (0.72–0.92)	0.81 (0.72–0.88)
0.88)P(SSB_{2017} > 40% SSB_0)	1	1	1	1
P(SSB_{2017} < 20% SSB_0)	0	0	0	0

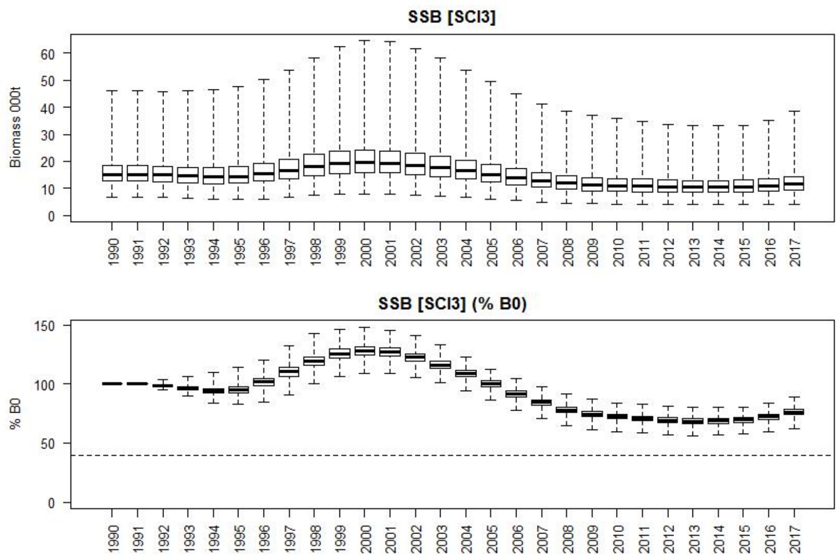


Figure 9: Posterior trajectory from SCI 3 base model (*M*=0.25, CV=0.2) of spawning stock biomass. Upper plot shows boxplots of SSB, while the lower plot shows SSB as a percentage of B_0. On the lower plot, target reference point is shown in as dashed line. Box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.

SCI 6A

For SCI 6A, model outputs suggest that spawning stock biomass (SSB) declined between 1991 and 2004, and again between 2007 and 2012, and has increased since. The SSB in SCI 6A in 2016 was estimated to be 67 and 72% of B_0 for the range of sensitivities considered (Figure 11, Table 16). Historical changes in biomass in SCI 6A before 2010 appear to be related to small fluctuations in recruitment rather than catches, but landings have been far lower than the TACC in recent years, coinciding with an increase in recent year class strengths. The strength of these recent year classes is a key source of uncertainty in the assessment however, as their estimated strength is largely determined by variance specified for the year class strength prior. Nonetheless, all four of the models considered produce similar estimates of current stock status, which are well above the default management target of 40% B_0.

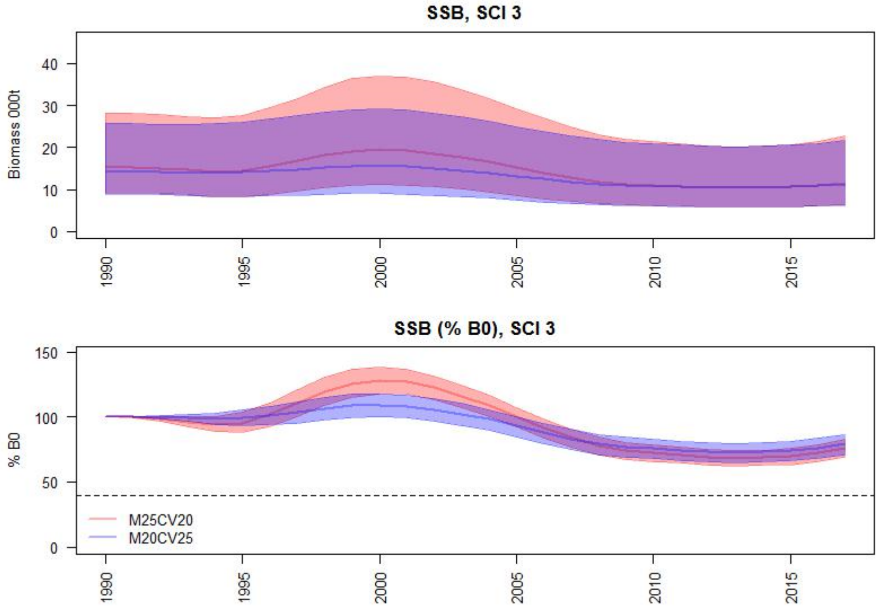


Figure 10: Posterior trajectory of spawning stock biomass from the SCI 3 base model and one of the sensitivities (M=0.2, CV=0.25). Upper plot shows boxplots of SSB, while the lower plot shows SSB as a percentage of *B_0*. On the bottom plot, the target reference point is shown as a dashed line. 95% CI shown as shaded area around each line.

Table 16: Results from MCMC runs showing B_0, B_{curr} and B_{curr}/B_0 estimates for four alternative models for SCI 6A.

Model	*M*=0.20 CV=0.4	*M*=0.20 CV=0.7	*M=0.25 CV=0.4*	*M*=0.25 CV=0.7
B_0	4 664	4 918	4 464	4 766
B_{2017}	3 175	3 308	3 220	3 406
B_{2017}/B_0	0.68	0.67	0.72	0.72

Biomass estimates for SCI also include estimates made using the area swept method from trawl surveys (Table 8). Trawl survey estimates can be considered to be minimum estimates of biomass as it is unlikely that there will be any herding effect of sweeps and bridles. Vertical availability to trawls can be expected to be less than 1 as many scampi will be found in burrows during the day. A preliminary estimate of scampi abundance for an area off the Auckland Islands has been generated from tag return data, although it should be noted that this programme was not designed to estimate biomass and violates many of the assumptions of the Petersen method. The estimated density of scampi for the Petersen method was similar to that estimated for visible scampi over the whole survey area from the photographic survey, although no account was taken of mortality or tag loss.

5.4 Yield estimates and projections

SCI 1

Projections were examined for the base models, with constant annual catch scenarios varying between 116 and 156 t, and projections conducted for 5 years (out to 2021). Median estimates of stock status from the projections are presented in Table 17, and suggest that the stock would remain above 68% B_0 by 2021 in all the scenarios examined.

On the basis of the outputs for SCI 1, and annual catches at the TACC (120 tonnes), the probability of SSB in SCI 1 being below either of the limits by 2021 is very low, and for all catches examined, the probability of remaining above the 40% B_0 target remains high (Table 18).

For the annual catches examined, the probability of SSB remaining above the 40% B_0 target remains high until 2021 (Table 18). For the highest catch examined (156 tonnes), the models suggest that there is a 98% probability that B_{2021} would be above 40% B_0. This catch is likely to reduce the SSB below 2015 levels, and depending on the model examined, the probability of B_{2021} being above B_{2015} ranges from 35% to 41%.

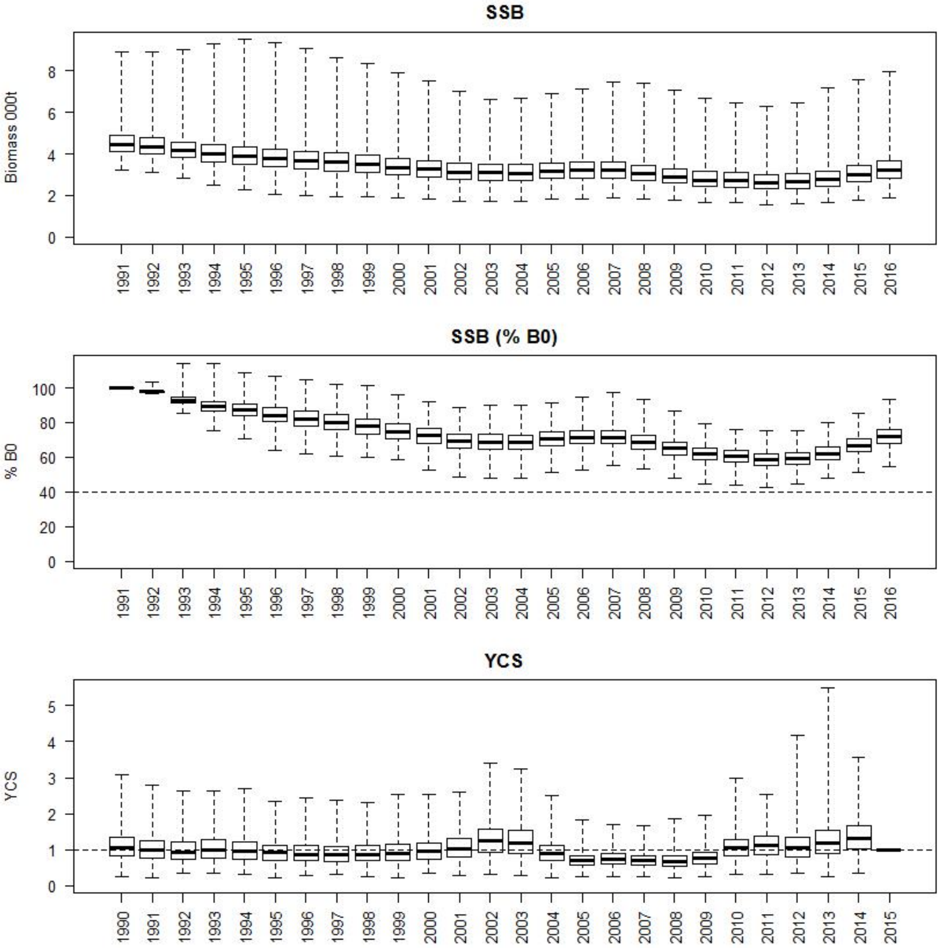


Figure 11: Posterior trajectory from an indicative SCI 6A model (M=0.25, YCS prior CV=0.4) of spawning stock biomass and YCS. Upper plot shows boxplots of SSB, while the middle plot shows SSB as a percentage of B_0. On the middle plot, target and limit reference points are shown in grey solid and dashed lines. Box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.

Table 17: Results from MCMC runs showing B_0, B_{curr} B_{2019} and B_{2021} estimates at varying catch levels for the base model (M=0.3) and sensitivities for SCI 1.

Catch level	Model	M=0.25	M=0.3	M=0.35
	B_0	5 572	6 009	6 148
	B_{curr}	3 974	4 507	4 604
	B_{curr}/B_0	0.72	0.75	0.75
116 tonnes	B_{2019}/B_0	0.71	0.73	0.72
(Status quo)	B_{2019}/B_{curr}	0.98	0.99	0.99
	B_{2021}/B_0	0.70	0.72	0.72
	B_{2021}/B_{curr}	0.98	0.97	0.98
120 tonnes	B_{2019}/B_0	0.70	0.73	0.72
(TACC)	B_{2019}/B_{curr}	0.98	0.98	0.98
	B_{2021}/B_0	0.70	0.72	0.72
	B_{2021}/B_{curr}	0.98	0.97	0.98
132 tonnes	B_{2019}/B_0	0.70	0.72	0.72
	B_{2019}/B_{curr}	0.97	0.98	0.98
	B_{2021}/B_0	0.69	0.71	0.72
	B_{2021}/B_{curr}	0.97	0.96	0.97
156 tonnes	B_{2019}/B_0	0.69	0.71	0.71
	B_{2019}/B_{curr}	0.95	0.96	0.96
	B_{2021}/B_0	0.68	0.70	0.70
	B_{2021}/B_{curr}	0.95	0.94	0.96

Table 18: Results from MCMC runs for the base model (M=0.3) and sensitivities for SCI 1, showing probabilities of projected spawning stock biomass exceeding the default Harvest Strategy Standard target and limit reference points.

	116 tonnes	120 tonnes (TACC)	132 tonnes	156 tonnes
M=0.25				
2019				
P(SSB<10% B0)	0.00	0.00	0.00	0.00
P(SSB<20% B0)	0.00	0.00	0.00	0.00
P(SSB>40% B0)	1.00	1.00	1.00	0.99
P(B2019 > B2015)	0.45	0.44	0.41	0.36
2021				
P(SSB<10% B0)	0.00	0.00	0.00	0.00
P(SSB<20% B0)	0.00	0.00	0.00	0.00
P(SSB>40% B0)	0.99	0.99	0.99	0.98
P(B2021 > B2015)	0.45	0.44	0.41	0.35
M=0.3				
2019				
P(SSB<10% B0)	0.00	0.00	0.00	0.00
P(SSB<20% B0)	0.00	0.00	0.00	0.00
P(SSB>40% B0)	0.99	0.99	0.99	0.98
P(B2019 > B2015)	0.45	0.44	0.41	0.35
2021				
P(SSB<10% B0)	0.00	0.00	0.00	0.00
P(SSB<20% B0)	0.00	0.00	0.00	0.00
P(SSB>40% B0)	1.00	0.99	0.99	0.99
P(B2021 > B2015)	0.43	0.42	0.40	0.36
M=0.35				
2019				
P(SSB<10% B0)	0.00	0.00	0.00	0.00
P(SSB<20% B0)	0.00	0.00	0.00	0.00
P(SSB>40% B0)	1.00	1.00	1.00	0.99
P(B2019 > B2015)	0.47	0.46	0.45	0.41
2021				
P(SSB<10% B0)	0.00	0.00	0.00	0.00
P(SSB<20% B0)	0.00	0.00	0.00	0.00
P(SSB>40% B0)	0.99	0.99	0.99	0.98
P(B2021 > B2015)	0.46	0.46	0.44	0.41

SCI 2

Projections were examined for the base models, with constant annual catch scenarios varying between 118 and 200 t, and projections conducted for 5 years (out to 2021). Median estimates of stock status from the projections are presented in Table 19, and suggest that the stock would remain above 83% B_0 by 2021 in all the scenarios examined.

For SCI 2, on the basis of annual catches at the TACC (133 tonnes), the probability of SSB being below either of the limits is very low (Table 20).

For the annual catches examined, the probability of SSB remaining above the 40% B_0 target remains high until 2021 (Table 20). For the highest catch examined (200 t), the models suggest that there is a 97% to 98% probability that B_{2021} would be above 40% B_0. This catch is likely to reduce the SSB below 2015 levels, with models suggesting the probability of B_{2021} being above B_{2015} ranges from 27 to 32%.

SCI 3

Projections were examined for the base model, with constant annual catch remaining at current levels, approximately the TACC (status quo; average of the last 5 years), or increasing to 10% or 20% above the current TACC. For the 20% increase in TACC, two scenarios were examined, either with catches taken in the same proportion by subarea as current catches, or with the increased allocation (68 tonnes) taken from the MO subarea (which currently has minimal fishing). These two scenarios were considered to encompass the potential extremes of catch patterns. Median estimates of stock status from the projections are presented in Table 21, and suggested that under the current TACC scenario the stock would be around 81% B_0 by 2021. Sensitivities ranged from 80% to 86%.
On the basis of the outputs for the base model for SCI 3, and the annual catches examined, the probability of SSB being below either of the limits is very low, and the probability of remaining above the 40% B_0 target remains very high until 2021 (Table 22).

Table 19: Results from MCMC runs showing B_0, B_{curr}, B_{2019} and B_{2021} estimates at varying catch levels for the base model (M=0.3) and sensitivities for SCI 2.

Catch	Model	M=0.2	M=0.3	M=0.35
	B_0	2 728	2 867	3 005
	B_{curr}	2 431	2 888	3 391
	B_{curr}/B_0	0.89	1.01	1.13
118 tonnes	B_{2019}/B_0	0.87	0.95	1.04
(Status quo)	B_{2019}/B_{curr}	0.97	0.93	0.91
	B_{2021}/B_0	0.89	0.97	1.03
	B_{2021}/B_{curr}	1.00	0.95	0.90
133 tonnes	B_{2019}/B_0	0.85	0.93	1.03
(TACC)	B_{2019}/B_{curr}	0.95	0.92	0.90
	B_{2021}/B_0	0.87	0.95	1.01
	B_{2021}/B_{curr}	0.98	0.93	0.89
146 tonnes	B_{2019}/B_0	0.84	0.92	1.02
	B_{2019}/B_{curr}	0.94	0.91	0.89
	B_{2021}/B_0	0.85	0.94	1.00
	B_{2021}/B_{curr}	0.95	0.91	0.88
173 tonnes	B_{2019}/B_0	0.81	0.90	1.00
	B_{2019}/B_{curr}	0.91	0.88	0.87
	B_{2021}/B_0	0.82	0.90	0.97
	B_{2021}/B_{curr}	0.91	0.88	0.85
200 tonnes	B_{2019}/B_0	0.79	0.88	0.98
	B_{2019}/B_{curr}	0.87	0.86	0.85
	B_{2021}/B_0	0.78	0.87	0.95
	B_{2021}/B_{curr}	0.87	0.85	0.83

Table 20: Results from MCMC runs for the base model (M=0.3) and sensitivities for SCI 2, showing probabilities of projected spawning stock biomass exceeding the default Harvest Strategy Standard target and limit reference points.

	118 tonnes (Status quo)	133 tonnes (TACC)	146 tonnes	173 tonnes	200 tonnes
M=0.25					
2019					
P(SSB<10% B0)	0.00	0.00	0.00	0.00	0.00
P(SSB<20% B0)	0.00	0.00	0.00	0.00	0.00
P(SSB>40% B0)	1.00	1.00	1.00	1.00	0.99
P(B2019 > B2015)	0.45	0.42	0.40	0.35	0.32
2021					
P(SSB<10% B0)	0.00	0.00	0.00	0.00	0.00
P(SSB<20% B0)	0.00	0.00	0.00	0.00	0.00
P(SSB>40% B0)	1.00	1.00	0.99	0.98	0.97
P(B2021 > B2015)	0.50	0.46	0.44	0.38	0.32
M=0.3					
2019					
P(SSB<10% B0)	0.00	0.00	0.00	0.00	0.00
P(SSB<20% B0)	0.00	0.00	0.00	0.00	0.00
P(SSB>40% B0)	1.00	1.00	1.00	1.00	1.00
P(B2019 > B2015)	0.41	0.39	0.38	0.35	0.32
2021					
P(SSB<10% B0)	0.00	0.00	0.00	0.00	0.00
P(SSB<20% B0)	0.00	0.00	0.00	0.00	0.00
P(SSB>40% B0)	1.00	1.00	1.00	0.99	0.98
P(B2021 > B2015)	0.43	0.40	0.38	0.34	0.31
M=0.35					
2019					
P(SSB<10% B0)	0.00	0.00	0.00	0.00	0.00
P(SSB<20% B0)	0.00	0.00	0.00	0.00	0.00
P(SSB>40% B0)	1.00	1.00	1.00	1.00	1.00
P(B2019 > B2015)	0.37	0.35	0.34	0.31	0.29
2021					
P(SSB<10% B0)	0.00	0.00	0.00	0.00	0.00
P(SSB<20% B0)	0.00	0.00	0.00	0.00	0.00
P(SSB>40% B0)	1.00	1.00	0.99	0.99	0.98
P(B2021 > B2015)	0.36	0.34	0.33	0.31	0.27

Table 21: Results from MCMC runs showing B_0, B_{2017} and B_{2021} estimates at varying catch levels for SCI 3 for the base model.

Catch		MN	MW	MO	SCI 3
340 tonnes (TACC & Status quo)	B0	6 204	4 905	4 035	15 162
	B2017	4 612	3 862	3 160	11 585
	B2017/B0	0.74	0.79	0.78	0.76

	B2021/B0	0.78	0.78	0.84	0.81
	B2021/B2017	1.05	0.99	1.07	1.05
375 tonnes (+10% TACC)	B2021/B0	0.77	0.78	0.84	0.8
	B2021/B2017	1.04	0.99	1.07	1.05
408 tonnes (+20% TACC)	B2021/B0	0.76	0.77	0.84	0.79
	B2021/B2017	1.02	0.99	1.07	1.04
408 tonnes (+20% TACC Additional MO)	B2021/B0	0.78	0.78	0.8	0.79
	B2021/B2017	1.05	0.99	1.02	1.04

Table 22: Results from MCMC runs the base model and three sensitivities for SCI 3, showing probabilities of projected spawning stock biomass exceeding the default Harvest Strategy Standard target reference point and being below the limit reference points. [Continued next page]

Base: (M=0.25, CV=0.20)	340 tonnes (TACC)				375 tonnes (+10% TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B2021< 10%B0)	0	0	0	0	0	0	0	0
P(B2021< 20%B0)	0	0	0	0	0	0	0	0
P(B2021> 40%B0)	1	1	1	1	0.999	1	1	1
P(B2021> B2017)	0.684	0.465	0.819	0.821	0.630	0.456	0.819	0.781

	408 tonnes (+20% TACC)				408 tonnes (+20% TACC, MO)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B2021< 10%B0)	0	0	0	0	0	0	0	0
P(B2021< 20%B0)	0	0	0	0	0	0	0	0
P(B2021> 40%B0)	0.999	1	1	1	1	1	1	1
P(B2021> B2017)	0.577	0.445	0.819	0.741	0.684	0.465	0.574	0.741

Sensitivity: (M=0.20, CV=0.20)	340 tonnes (TACC)				375 tonnes (+10% TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B2021< 10%B0)	0	0	0	0	0	0	0	0
P(B2021< 20%B0)	0	0	0	0	0	0	0	0
P(B2021> 40%B0)	0.999	1	1	1	0.998	1	1	1
P(B2021> B2017)	0.703	0.534	0.908	0.884	0.629	0.515	0.908	0.839

	408 tonnes (+20% TACC)				408 tonnes (+20% TACC, MO)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B2021< 10%B0)	0	0	0	0	0	0	0	0
P(B2021< 20%B0)	0	0	0	0	0	0	0	0
P(B2021> 40%B0)	0.997	1	1	1	0.991	1	1	1
P(B2021> B2017)	0.557	0.500	0.908	0.794	0.703	0.534	0.639	0.793

Sensitivity: (M=0.20, CV=0.25)	340 tonnes (TACC)				375 tonnes (+10% TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B2021< 10%B0)	0	0	0	0	0	0	0	0
P(B2021< 20%B0)	0	0	0	0	0	0	0	0
P(B2021> 40%B0)	1	1	1	1	1	1	1	1
P(B2021> B2017)	0.757	0.585	0.948	0.936	0.696	0.570	0.948	0.913

	408 tonnes (+20% TACC)				408 tonnes (+20% TACC, MO)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B2021< 10%B0)	0	0	0	0	0	0	0	0
P(B2021< 20%B0)	0	0	0	0	0	0	0	0
P(B2021> 40%B0)	0.999	1	1	1	1	1	1	1
P(B2021> B2017)	0.632	0.556	0.948	0.877	0.757	0.585	0.732	0.877

Table 22 [Continued]

Sensitivity: (M=0.25, CV=0.25)	340 tonnes (TACC)				375 tonnes (+10% TACC)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B2021< 10%B0)	0	0	0	0	0	0	0	0
P(B2021< 20%B0)	0	0	0	0	0	0	0	0
P(B2021> 40%B0)	1	1	1	1	1	1	1	1
P(B2021> B2017)	0.742	0.500	0.871	0.880	0.688	0.489	0.871	0.851

	408 tonnes (+20% TACC)				408 tonnes (+20% TACC, MO)			
	MN	MW	MO	SCI 3	MN	MW	MO	SCI 3
P(B2021< 10%B0)	0	0	0	0	0	0	0	0
P(B2021< 20%B0)	0	0	0	0	0	0	0	0
P(B2021> 40%B0)	0.999	1	1	1	1	1	1	1
P(B2021> B2017)	0.639	0.478	0.871	0.819	0.742	0.500	0.659	0.819

SCI 6A

Projections were examined for all four sensitivity models, with constant annual catch remaining at current levels (status quo; catch in 2016), or at the current TACC. Median estimates of stock status from the projections are presented in Table 23, and suggest that under a TACC scenario the stock would be from 65% to 78% B_0 by 2020, depending on the model considered.

For all four models, for both of the catch levels considered, the probability of SSB being below either of the limits is very low, and the probability of remaining above the 40% B_0 target remains very high until 2020 (Table 24).

Table 23: Results from MCMC runs showing B_0, B_{curr} and B_{2020} estimates at varying catch levels for all four sensitivity models for SCI 6A.

Catch level	Model	*M*=0.20 CV=0.4	*M*=0.20 CV=0.7	*M*=0.25 CV=0.4	*M*=0.25 CV=0.7
	B_0	4 665	4 908	4 464	4 766
	B_{curr}	3 175	3 308	3 220	3 406
	B_{curr}/B_0	0.68	0.67	0.72	0.72
252 tonnes	B_{2020}/B_0	0.68	0.77	0.72	0.81
(Status quo)	B_{2020}/B_{curr}	1.00	1.13	0.99	1.12
306 tonnes	B_{2020}/B_0	0.65	0.74	0.69	0.78
(TACC)	B_{2020}/B_{curr}	0.96	1.09	0.95	1.07

5.5 Future research considerations

- Examine the potential use of catch grading data as an alternative descriptor of changes in population length composition.
- The priors have a substantial influence in scaling the assessment model, and they appear to be using the same data as the assessment itself. The trawl and photo survey data should be removed from the development of the catchability priors, so that model data is not used in the priors. This could be achieved by bringing calculations relating emergence and detectability to burrow counts and catches inside the model; however, this probably cannot be conducted inside CASAL and may require tailor-made software.
- For example, develop a model which incorporates the components of the existing prior into the model by making the acoustic tag information the central part of the model and have a prior on emergence.
- The q priors and weighting of abundance indices need to be reviewed.
- Investigate trends in CPUE residuals relative to the modelled population abundance, with a view to understanding possible causes of changes in catchability.
- Investigate the utility of including a spatial variable in the CPUE standardisations.
- Investigate the consequences of increasing process errors (or estimating them) for trawl and photo surveys.
- Investigate the utility of developing Management Strategy Evaluations for one or more SCI stocks.

- Conduct additional tagging to improve growth estimates.
- Investigate the utility of developing an index of, or proxy for, bottom roughness and incorporating this into the CPUE analysis. One potential proxy might be cumulative fishing effort or a running average of fishing effort over some appropriate number of years. Species composition from observer data sets could also be examined to determine whether this could be indicative of bottom roughness. This index may need to be calculated on a fine scale.
- Recruitment patterns should be examined in more detail by obtaining better information on size composition. This could be accomplished by:
  - re-examining the photo survey data to allocate the animals seen into size ranges;
  - investigating the utility of grade data for elucidating recruitment patterns;
  - obtaining records from fishermen who have caught large numbers of juveniles in the past (assuming these were actually juveniles, rather than dwarf populations);
  - investigating the utility of exploratory fishing in shallower areas to obtain a recruitment index;
  - investigating the potential for developing a juvenile index from ling and sea perch stomach contents.
- Develop methods in CASAL to directly estimate sex ratios rather than indirectly via relative selectivity ogives.

Table 24: Results from MCMC runs and sensitivities for the "representative model" for SCI 6A, showing probabilities of projected spawning stock biomass exceeding the default Harvest Strategy Standard target and limit reference points.

	252 tonnes (status quo)	306 tonnes (TACC)
M=0.20		
CV=0.4		
P(SSB<10% B0)	0.00	0.00
P(SSB<20% B0)	0.00	0.00
P(SSB>40% B0)	1.00	1.00
P(B2020 > B2016)	0.51	035
M=0.20		
CV=0.7		
P(SSB<10% B0)	0.00	0.00
P(SSB<20% B0)	0.00	0.00
P(SSB>40% B0)	1.00	1.00
P(B2020 > B2016)	0.78	0.69
M=0.25		
CV=0.4		
P(SSB<10% B0)	0.00	0.00
P(SSB<20% B0)	0.00	0.00
P(SSB>40% B0)	0.99	0.99
P(B2020 > B2016)	0.48	0.36
M=0.25		
CV=0.7		
P(SSB<10% B0)	0.00	0.00
P(SSB<20% B0)	0.00	0.00
P(SSB>40% B0)	1.00	1.00
P(B2020 > B2016)	0.72	0.64

<u>For SCI 2</u>

- Investigate whether the decline in SCI 2 in the 1990s is reflected in the monthly CPUE data.

<u>For SCI 3</u>

- Conduct sensitivities on the use of shared q's between areas for the trawl, CPUE and photo data, as well as year class strengths.
- Test for the possibility that it is the abundance indices rather than the length-frequency data that are driving differences in year class strength in the three sub-regions: use the same abundance indices in all three models so that the only difference between the three is the length-frequency

data. This will determine whether the abundance indices or the length-frequency data is the driving factor in determining year class strength.

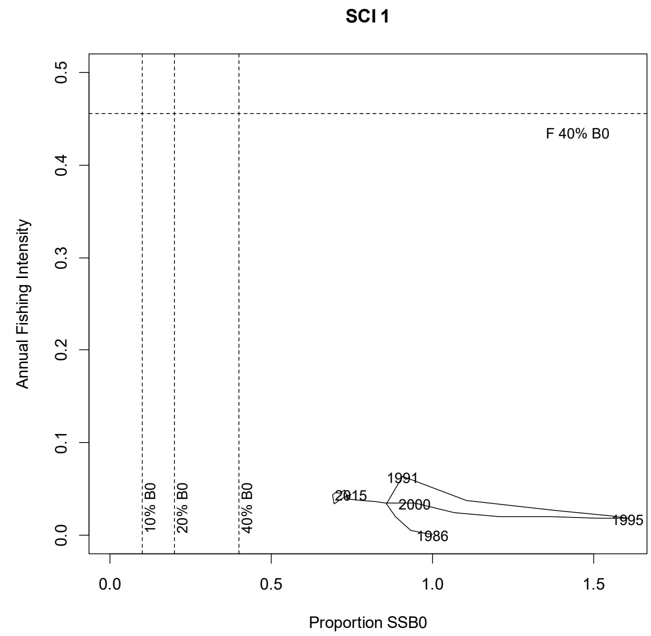
6. STATUS OF THE STOCKS

Stock Structure Assumptions
Assessments have been conducted for areas considered to be the core regions of SCI 1, SCI 2, SCI 3, and SCI 6A .

- **SCI 1**

Stock Status	
Year of Most Recent Assessment	2016
Assessment Runs Presented	Bayesian length based model with M=0.3
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Very Likely (> 90%) to be at or above target
Status in relation to Limits	Exceptionally Unlikely (< 1%) to be below the soft or hard limits
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Trajectories of biomass as a proportion of B_0 and annual equivalent fishing intensity for SCI 1 (M=0.3).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Spawning stock biomass increased to a peak in about 1995, declined to the early 2000s, and has remained relatively stable since this time. 2018 photo survey shows a slight increase in the biomass and the CPUE shows a slight increase too. Trawl survey remains stable between 2018.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has fluctuated without trend since the early 1990s.
Other Abundance Indices	-

Trends in Other Relevant Indicators or Variables	-
Projections and Prognosis	
Stock Projections or Prognosis	The stock is predicted to remain above 40% B_0 up to 2021 under current catches and TACC.
Probability of Current Catch or TACC causing biomass to remain below or to decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Overfishing: Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Length-based Bayesian Model	
Assessment Dates	Latest assessment: 2016	Next assessment: 2020
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Standardised catch and effort data (TCEPR) from MPI	1 – High Quality
	- Length frequency data from MPI observer sampling	2 – Medium or Mixed Quality: data not representative in some years
	- Photographic survey abundance index	1 – High Quality
	- Trawl survey abundance index	1 – High Quality
	- Length frequency data from research sampling	1 – High Quality
	- Length frequency predicted from burrow sizes	2 – Medium or Mixed Quality: estimation of length structure uncertain, and not fitted well in model
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Revised catchability priors developed - Change in weighting of abundance indices	
Major Sources of Uncertainty	- Growth, burrow occupancy and catchability - Early CPUE (potential time varying q) - Early (large) YCSs - Absolute biomass determined by the q prior - Calculation of equivalent annual Fs and reference points	

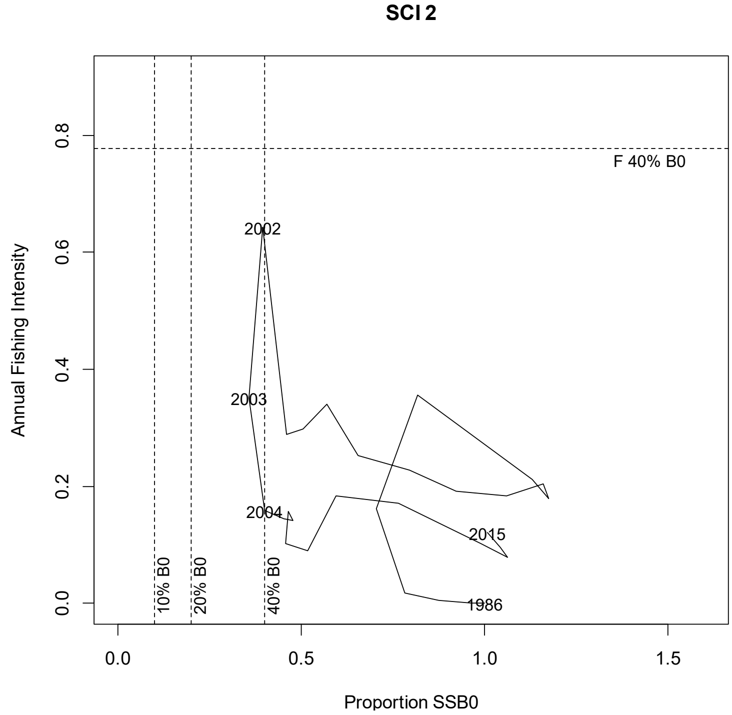
Qualifying Comments
Likelihood profiles suggest priors, rather than abundance indices, are overly important in determining B_0, probably due to a lack of contrast in the abundance data. While this reduces the level of confidence in the assessment, there is nothing to indicate that stock status is poor or declining. Provisional updated done in 2019 shows similar issues with no change of the status.

Fishery Interactions
Main QMS bycatch species include ling, hoki, sea perch, red cod, silver warehou and giant stargazer. Discards are dominated by rattails, javelinfish, skates and crabs, ling, red cod, hoki, spiny dogfish and sea perch. Interactions with seabirds have been recorded. A wide range of benthic invertebrate species are taken as bycatch.

- **SCI 2**

Stock Status	
Year of Most Recent Assessment	2016
Assessment Runs Presented	Bayesian length based model with M=0.3
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Very Likely (> 90%) to be at or above target
Status in relation to Limits	Exceptionally Unlikely (< 1%) to be below the soft or hard limits
Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (< 1%) to be occurring

Historical Stock Status Trajectory and Current Status



Trajectories of biomass as a proportion of B_0 and annual equivalent fishing intensity for SCI 2 (M=0.3).

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass increased during the early 1990s, but declined steadily after this until the early 2000s. Biomass increased steadily between 2008 and 2014, declining slightly since then.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality increased through the 1990s, peaking in the early 2000s, but declined considerable by 2005, and has fluctuated without trend since this time.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	The stock is predicted to remain well above 40% B_0 under recent catches and TACCs.
Probability of Current Catch or TACC causing biomass to remain below or to decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%)

Probability of Current Catch or TACC causing Overfishing to continue or to commence	Overfishing: Very Unlikely (< 10%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Length-based Bayesian Model	
Assessment Dates	Latest assessment: 2016	Next assessment: 2020
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Standardised catch and effort data (TCEPR) from MPI - Length frequency data from MPI observer sampling - Photographic survey abundance index - Trawl survey abundance index - Length frequency data from research sampling - Length frequency predicted from burrow sizes	1 – High Quality 2 – Medium or Mixed Quality: data not representative in some years 1 – High Quality 1 – High Quality 1 – High Quality 2 – Medium or Mixed Quality: estimation of length structure uncertain
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Revised catchability priors developed	
Major Sources of Uncertainty	- Growth, burrow occupancy and catchability - Early CPUE (potential time varying q) - Early and recent (large) YCSs - Absolute biomass determined by the q prior - Calculation of equivalent annual Fs and reference points	

Qualifying Comments
Only preliminary results of the 2019 stock assessment are available. There are some issues with the prior for qPhoto.

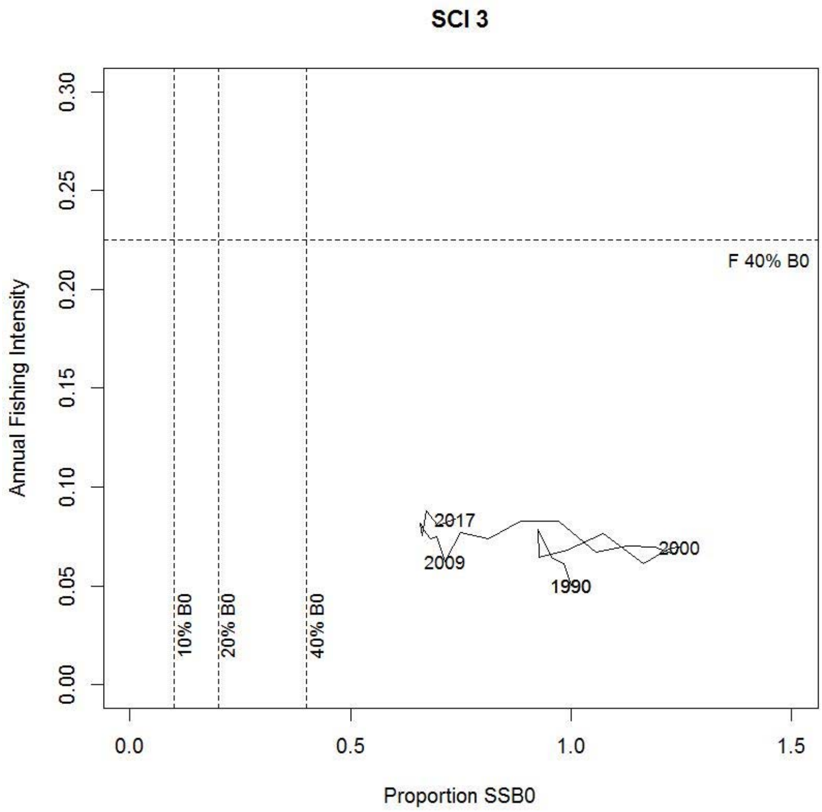
Fishery Interactions
Main QMS bycatch species include ling, hoki, sea perch, red cod, silver warehou and giant stargazer. Discards are dominated by rattails, javelinfish, skates and crabs, ling, red cod, hoki, spiny dogfish and sea perch. In interactions with seabirds have been recorded. A wide range of benthic invertebrate species are taken as bycatch.

- **SCI 3**

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	- Bayesian length based model, base model: M=0.25, CPUE CV=0.2
Reference Points	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_{2017} was estimated to be 76% B_0. Very Likely (> 90%) to be at or above the target.

Status in relation to Limits	B_{2017} is Very Unlikely (< 10%) to be below the soft or hard limits (both models)
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Trajectories of biomass as a proportion of B_0 and annual equivalent fishing intensity for SCI 3.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Estimated spawning stock biomass increased to a peak in about 1999, declined to the late 2000s, and has increased in the most recent years.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has been low and without trend throughout the time series
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	The stock is predicted to remain above 40% B_0 up to 2021 under current catches (TACC) and increases in TACC of up to 20%.
Probability of Current Catch or TACC causing biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

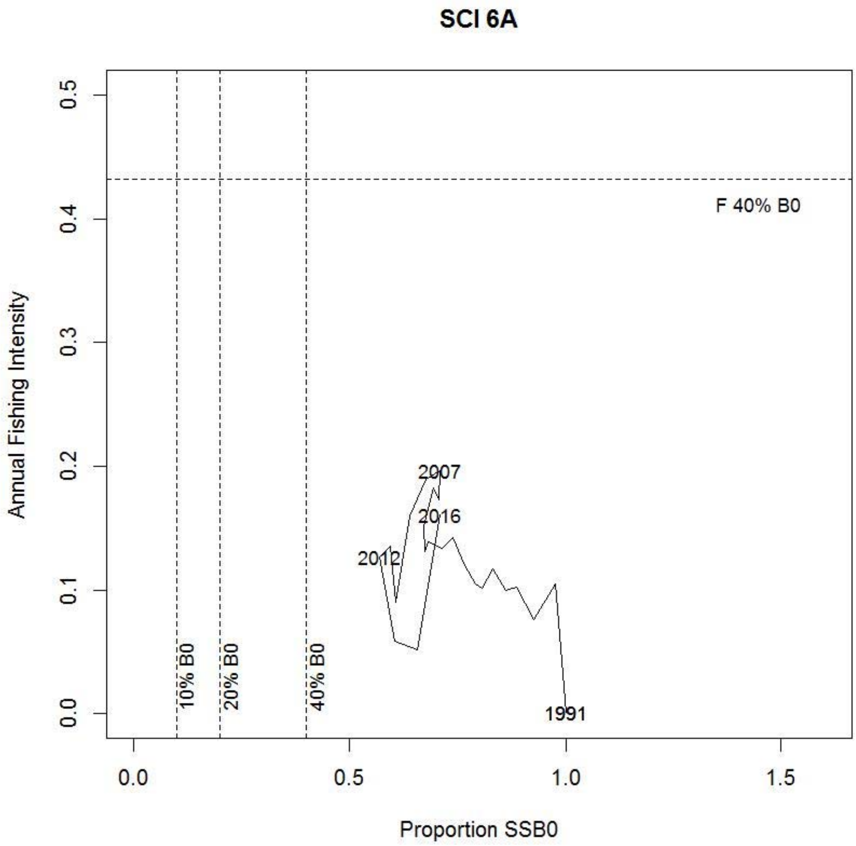
Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Length-based Bayesian model	
Assessment Dates	Latest assessment: 2018	Next assessment: 2021
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Standardised catch and effort data (TCEPR) from MPI - Length frequency data from MPI observer sampling - Photographic survey abundance index - Trawl survey abundance index - Length frequency data from research sampling - Length frequency predicted from burrow sizes	1 – High Quality 2 – Medium or Mixed Quality: data not representative in some years 1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- Changed YCS strengths parameterisation - Revised priors - Revised model time steps - Separate YCSs (rather than shared) - Shared q's between areas	
Major Sources of Uncertainty	- Growth, burrow occupancy and catchability - Early CPUE (potential time varying q) - Early (large) YCSs - Absolute biomass determined by the q prior - Calculation of equivalent annual Fs and reference points	

Qualifying Comments
Model scaling is highly dependent on the q priors without much updating by posteriors. Their influence should be investigated further. CPUE is highly influential and may be driving recruitment. This contributes to generating large early YCS(s) that are not fully supported by data.

Fishery Interactions
Main QMS bycatch species include ling, hoki, sea perch, red cod, silver warehou and giant stargazer. Discards are dominated by rattails, javelinfish, skates and crabs, ling, red cod, hoki, spiny dogfish and sea perch. Interactions with seabirds have been recorded. A wide range of benthic invertebrate species are taken as bycatch.

- **SCI 6A**

Stock Status	
Year of Most Recent Assessment	2017
Assessment Runs Presented	Bayesian length based model with M=0.25 and YCS prior CV of 0.4 (indicative model run)
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	Very Likely (> 90%) to be at or above target
Status in relation to Limits	Exceptionally Unlikely (< 1%) to be below the soft or hard limits
Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (< 1%) to be occurring

Historical Stock Status Trajectory and Current Status

Trajectories of biomass as a proportion of B_0 and annual equivalent fishing intensity for SCI 6A (*M*=0.25, CV for YCS prior = 0.4). The trajectories for this model are indicative of those derived from other model sensitivities.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Estimated spawning stock biomass has been increasing for the last 4 years.
Recent Trend in Fishing Intensity or Proxy	Fishing mortality fell from 2009 until 2015, followed by a large increase in 2016.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	The stock is predicted to remain above 40% B_0 up to 2020 at current levels of catch and the TACC. Projected stock status when catches are at the TACC level is predicted to be about 69% B_0 in 2020.
Probability of Current Catch or TACC causing biomass to remain below or to decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Overfishing Exceptionally Unlikely (< 1%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Length-based Bayesian model	
Assessment Dates	Latest assessment: 2017	Next assessment: 2020

Overall assessment quality rank	1 – High Quality	
Main data inputs	- Standardised catch and effort data (TCEPR) from MPI - Length frequency data from MPI observer sampling - Photographic survey abundance index - Trawl survey abundance index - Length frequency data from trawl survey abundance index - Length frequency data from photos of visible scampi - Growth rates predicted from tag release recapture data	1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality, but estimate from 2016 not used 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	Trawl survey abundance index for 2016	3 – Low Quality: different vessel used in 2016
Changes to Model Structure and Assumptions	No previous accepted assessment	
Major Sources of Uncertainty	- Growth, differential selectivity by sex, and sex ratios - Relationship between CPUE and abundance (potential time varying q) -YCS estimation	

Qualifying Comments
Photo surveys in SCI 6A observe a higher number of scampi out of burrows, relative to burrows counted, than has been observed in other areas. This may be related to animal size or sediment characteristics. If emergence is greater, this may imply that scampi in SCI 6A are more vulnerable to trawling than in other areas.

Fishery Interactions
Main QMS bycatch species include ling, hoki, sea perch, red cod, silver warehou and giant stargazer. Discards are dominated by rattails, javelinfish, skates and crabs, ling, red cod, hoki, spiny dogfish and sea perch. Interactions with seabirds and mammals (fur seals and sea lions) have been recorded. A wide range of benthic invertebrate species are taken as bycatch.

7. FOR FURTHER INFORMATION

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