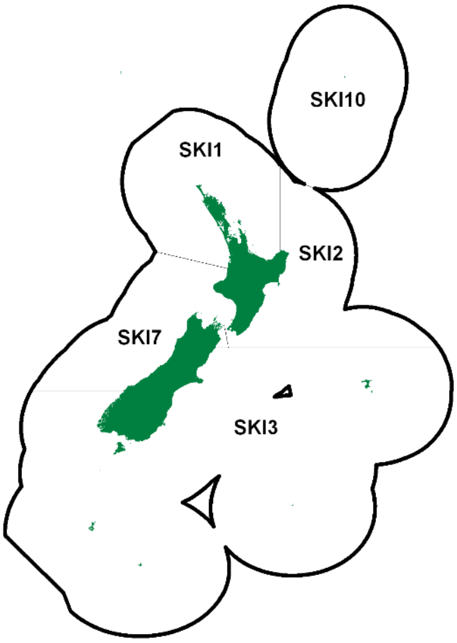
GEMFISH (SKI)

(*Rexea* spp.)
Maka-taharaki, Maka-tikati, Tiikati



1. FISHERY SUMMARY

Gemfish were introduced into the QMS on 1 October 1986. Current allowances, TACCs, and TACs are given in Table 1.

Table 1: Recreational and customary non-commercial allowances (t), TACCs (t), and TACs (t) by Fishstock, as at 1 October 2022.

Fishstock	Recreational allowance	Customary non-commercial allowance	Other sources of fishing related mortality	TACC	TAC
SKI 1	27	3	25	252	307
SKI 2	5	3	0	240	248
SKI 3	0	1	8	839	848
SKI 7	0	1	8	839	848
SKI 10	–	–	–	10	–

1.1 Commercial fisheries

Gemfish are caught in coastal waters around mainland New Zealand down to about 550 m. Historical estimated and recent reported gemfish landings and TACCs are given in Tables 2–4, and Figure 1 shows the historical and recent landings and TACC values for the main gemfish stocks. Annual catches increased significantly in the early 1980s and peaked at about 8250 t in 1985–86 (Table 2). In the late 1980s, annual catches generally ranged from about 4200 t to 4800 t per annum (Table 4). Annual catches declined substantially after 1989–90 and total landings were less than 1200 t from 1998–99 to 2016–17 (Table 4). This decline in catch resulted in successive TACC reductions for SKI 1 and SKI 2 from 1997–98 and SKI 3 and SKI 7 from 1996–97 (Table 4). From 2017–18 annual catches increased to over 2000 t and were substantially in excess of the TACCs for SKI 3 and SKI 7 in 2017–18 and 2018–19, and in 2020–21. TACCs were increased from 2019–20 for SKI 3 and SKI 7 and from 2020–21 for SKI 1 and SKI 2. Despite increases, annual catch has remained well above the TACCs until the most recent fishing year (2021–22).

Most of the recorded catch is taken by bottom trawl (BT), with midwater (MW) trawl catches increasing in recent years in SKI 3 and particularly in SKI 7. There was also some midwater trawl catch in SKI 2 in the mid-1990s. Target gemfish fisheries developed off the eastern and northern coasts of the North Island. From 1993 to 2000, there was a major shift in effort from east of North Cape to the west, and over 50% of the SKI 1 catch was taken from FMA 9 in some years. However, the distribution of fishing changed substantially after 2001 when the SKI 1 and SKI 2 quotas were reduced. The northwest coast fishery virtually disappeared, as did the fishery off East Northland. Although landings were historically concentrated in the months of May and June, they are now spread throughout the year. Most SKI 1 and SKI 2 landings are now bycatch in a range of trawl fisheries, including tarakihi, hoki, scampi, and ling, although targeting of gemfish does occur. Gemfish catches off the west coast of the South Island (SKI 7) are primarily a bycatch of the winter hoki target fishery whereas the majority of the gemfish catch in SKI 3 occurs while fishing for squid on the Stewart-Snares shelf. There is some bycatch of gemfish in the inshore mixed target species trawl fisheries that operate off both the east and the west coasts of the South Island.

Table 2: Reported gemfish catch (t) from 1978–79 to 1987–88. Source - MAF and FSU data.

Fishing	New Zealand		Foreign Licensed			
year	Domestic	Chartered	Japan	Korea	USSR	Total
1978–79*	352	53	1 509	1 079	0	2 993
1979–80*	423	1 174	1 036	78	60	2 771
1980–81*	1 050	N/A	N/A	N/A	N/A	> 1 050
1981–82*	1 223	1 845	391	16	0	3 475
1982–83*	822	1 368	274	567	0	3 031
1983–83†	1 617	1 799	57	37	0	3 510
1983–84‡	1 982	3 532	819	305	0	6 638
1984–85‡	1 360	2 993	470	223	0	5 046
1985–86‡	1 696	4 056	2 059	442	0	8 253
1986–87‡	1 603	2 277	269	76	0	4 225 §
1987–88‡	1 016	2 331	90	35	0	3 472 §

* 1 April–31 March.
‡ 1 October–30 September.
† 1 April–30 September.
§ These totals do not match those in Table 3 due to under-reporting to the FSU.
N/A Unknown.

Table 3: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	SKI 1	SKI 2	SKI 3	SKI 7	Year	SKI 1	SKI 2	SKI 3	SKI 7
1931–32	0	0	0	0	1957	2	12	21	10
1932–33	0	0	0	0	1958	5	34	19	28
1933–34	0	42	0	66	1959	2	40	58	38
1934–35	0	70	0	105	1960	3	61	65	39
1935–36	0	39	0	59	1961	6	42	14	19
1936–37	0	37	13	57	1962	5	58	49	27
1937–38	0	86	19	130	1963	19	72	19	38
1938–39	0	50	47	66	1964	17	48	20	29
1939–40	0	48	47	72	1965	19	96	11	28
1940–41	0	58	72	87	1966	12	102	15	26
1941–42	1	63	50	96	1967	32	173	14	46
1942–43	0	47	22	71	1968	18	183	15	33
1943–44	0	15	15	23	1969	60	308	11	22
1944	0	14	15	23	1970	50	281	22	28
1945	6	19	13	30	1971	52	315	24	59
1946	5	20	30	33	1972	85	261	15	37
1947	0	23	74	32	1973	56	237	46	102
1948	1	28	51	44	1974	21	150	14	89
1949	4	19	48	28	1975	2	96	172	37
1950	15	32	59	30	1976	11	108	8	36
1951	5	29	35	27	1977	22	118	4	74
1952	1	21	45	22	1978	36	235	411	1 069
1953	1	13	42	10	1979	82	235	2 104	628
1954	2	31	12	38	1980	278	287	1 899	924
1955	0	25	22	23	1981	236	350	1 369	1 669
1956	0	31	27	35	1982	546	219	971	676

Notes:
1. The 1931–1943 years are April–March but from 1944 onwards are calendar years.
2. Data up to 1985 are from fishing returns; data from 1986 to 1990 are from Quota Management Reports.
3. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data include both foreign and domestic landings.

Table 4: Reported landings (t) of gemfish by Fishstock from 1983–84 to present and TACCs from 1986–87.

Fishstock	SKI 1		SKI 2		SKI 3		SKI 7		SKI 10		
FMA (s)	1 & 9		2		3, 4, 5, & 6		7 & 8		10	Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	TACC	Landings	TACC
1983–84*	588	–	632	–	3 481	–	1 741	–	† –	6 442 §	–
1984–85*	388	–	381	–	2 533	–	1 491	–	† –	4 793 §	–
1985–86*	716	–	381	–	5 446	–	1 468	–	† –	8 011 §	–
1986–87	773	550	896	860	2 045	2 840	1 069	1 490	†10	4 783	5 750
1987–88	696	632	1 095	954	1 664	2 852	1 073	1 543	†10	4 528	5 991
1988–89	1 023	1 139	1 011	1 179	1 126	2 922	1 083	1 577	†10	4 243	6 827
1989–90	1 230	1 152	1 043	1 188	1 164	3 259	932	1 609	†10	4 369	7 218
1990–91	1 058	1 152	949	1 188	616	3 339	325	1 653	†10	2 948	7 342
1991–92	1 017	1 152	1 208	1 197	287	3 339	584	1 653	†10	3 096	7 350
1992–93	1 292	1 152	1 020	1 230	371	3 345	469	1 663	†10	3 152	7 401
1993–94	1 156	1 152	1 058	1 300	75	3 345	321	1 663	†10	2 616	7 470
1994–95	1 032	1 152	905	1 300	160	3 355	103	1 663	†10	2 169	7 480
1995–96	801	1 152	789	1 300	49	3 355	81	1 663	†10	1 720	7 480
1996–97	965	1 152	978	1 300	58	1 500	238	900	†10	2 240	4 862
1997–98	627	752	671	849	27	300	44	300	†10	1 369	2 211
1998–99	413	460	336	520	17	300	59	300	†10	825	1 590
1999–00	409	460	506	520	62	300	107	300	†10	1 083	1 590
2000–01	335	460	330	520	47	300	87	300	†10	799	1 590
2001–02	201	210	268	240	72	300	123	300	†10	664	1 060
2002–03	206	210	313	240	115	300	268	300	†10	902	1 060
2003–04	221	210	301	240	78	300	542	300	†10	1 142	1 060
2004–05	234	210	259	240	72	300	635	300	†10	1 199	1 060
2005–06	230	210	182	240	27	300	248	300	†10	687	1 060
2006–07	215	210	317	240	26	300	209	300	†10	767	1 060
2007–08	216	210	249	240	18	300	179	300	†10	662	1 060
2008–09	191	210	191	240	11	300	213	300	†10	606	1 060
2009–10	247	210	176	240	20	300	144	300	†10	587	1 060
2010–11	226	210	300	240	33	300	301	300	†10	860	1 060
2012–13	182	210	140	240	23	300	234	300	†10	580	1 060
2013–14	198	210	268	240	39	300	268	300	†10	764	1 060
2014–15	83	210	168	240	21	300	231	300	†10	503	1 060
2015–16	188	210	224	240	80	300	186	300	†10	677	1 060
2016–17	244	210	236	240	248	300	431	300	†10	1 159	1 060
2017–18	277	210	286	240	466	300	583	300	†10	1 612	1 060
2018–19	354	210	328	240	577	300	937	300	†10	2 196	1 060
2019–20	394	210	275	240	514	599	938	599	†10	2 120	1 658
2020–21	284	252	368	240	1 063	599	1 012	599	†10	2 728	1 700
2021–22	313 ‡	252	189	240	881	839	786	839	†10	2 144	2 180
2022–23	335	252	250	240	1318	1091	1 078	1091	†10	2 980	2 732

* FSU data.
† No recorded landings.
‡ Includes 25 t research fishing allowance.
§ The totals do not match those in Table 2 because some fish were not reported by area (FSU data prior to 1986–87).

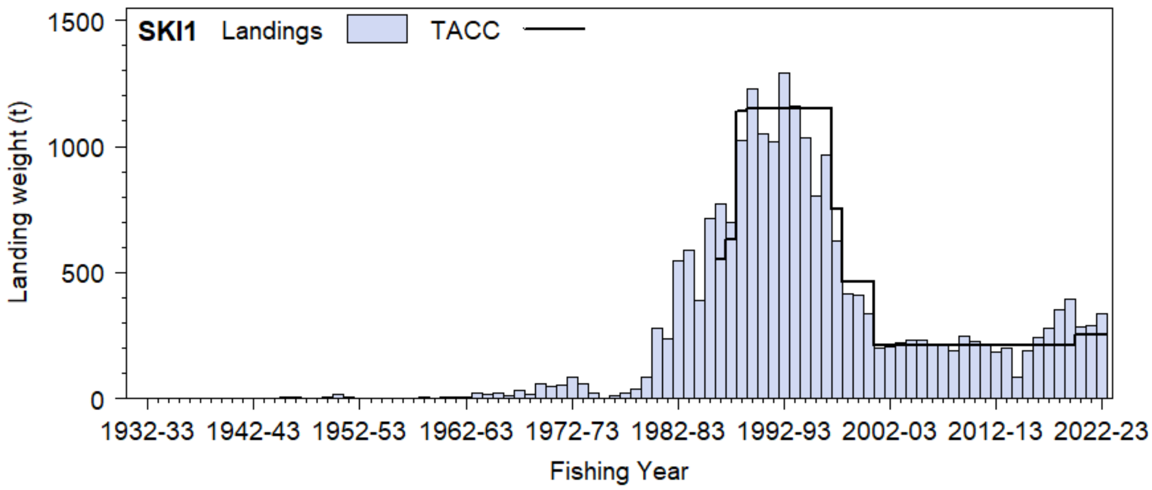


Figure 1: Reported commercial landings and TACC for the four main SKI stocks. SKI 1 (Auckland East). [Continued on next page]

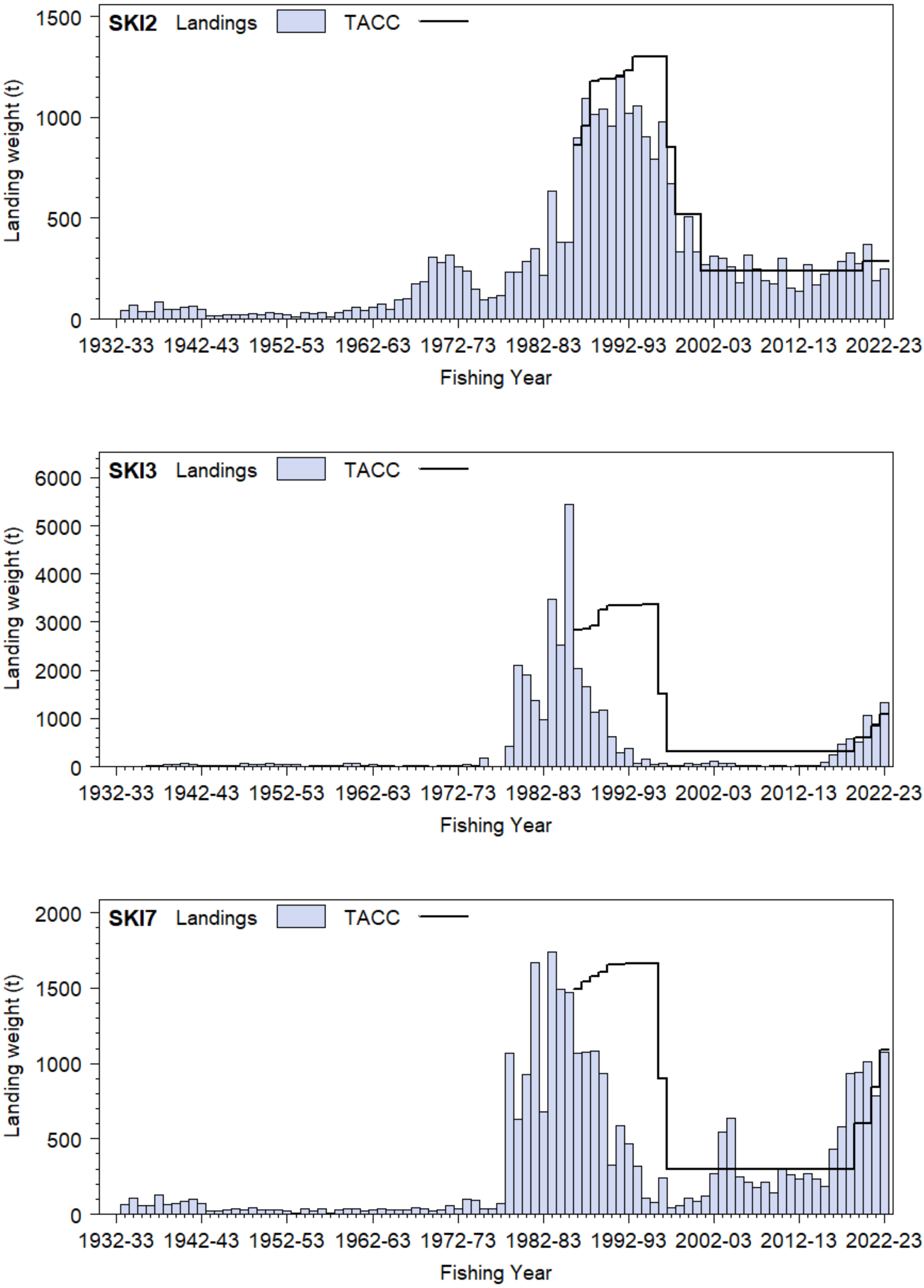


Figure 1 [Continued]: Reported commercial landings and TACC for the four main SKI stocks. SKI 2 (Central East), SKI 3 (South East Coast), and SKI 7 (Challenger).

1.2 Recreational fisheries

Little or no recreational catch was reported in marine recreational fishing telephone/diary surveys between 1992 and 2001, but the harvest estimates provided by these surveys are no longer considered reliable. A Recreational Technical Working Group concluded that these harvest estimates should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and c) the 2000 and 2001 estimates are implausibly high for many important fisheries. In response to these problems and the cost and scale challenges associated with onsite methods, a national panel survey was conducted for the first time throughout the 2011–12 fishing year (Wynne-Jones et al 2014). The panel survey used face-to-face interviews of a random sample of 30 390 New Zealand households to recruit a panel of fishers and non-fishers for a full year. The panel members were contacted regularly about their fishing activities and harvest information in standardised phone interviews. The national panel survey was repeated during the 2017–18 and 2022–23 fishing years using very similar methods to produce directly comparable results (Wynne-Jones et al 2019; Heinemann & Gray, in prep). Recreational catch estimates from the three national panel surveys are given in Table 4. Note that national panel survey estimates do not include recreational harvest taken on charter vessel trips or under s111 general approvals.

Table 5: Recreational harvest estimates for gemfish stocks (Wynne-Jones et al 2014, 2019, Heinemann & Gray, in prep). Mean fish weights were not available from boat ramp surveys so catches cannot be converted to weight.

Stock	Year	Method	Number of fish	Total weight (t)	CV
SKI 1	2011–12	Panel survey	2476	–	0.45
	2017–18	Panel survey	4756	–	0.39
	2022–23	Panel survey	1952	–	0.91
SKI 2	2011–12	Panel survey	0	–	–
	2017–18	Panel survey	1 299	–	0.53
	2022–23	Panel survey	657	–	0.64
SKI 3	2011–12	Panel survey	0	–	–
	2017–18	Panel survey	0	–	–
	2022–23	Panel survey	99	–	1.02
SKI 7	2011–12	Panel survey	137	–	1.03
	2017–18	Panel survey	27	–	1.09
	2022–23	Panel survey	89	–	1.01

1.3 Customary non-commercial fisheries
Quantitative information on the current level of customary non-commercial take is not available and is assumed to be negligible.

1.4 Illegal catch
No data on the scale of misreporting are available but misreporting is assumed to be negligible.

1.5 Other sources of mortality
There may have been some gemfish discarded prior to the introduction of the EEZ, but this is likely to have been minimal since the early 1980s because gemfish is a medium value species.

2. BIOLOGY

Silver gemfish (*Rexea solandri*) occur on the continental shelf and slope, from about 50–550 m depth. They are known to undertake spawning migrations and the pre-spawning runs have formed the basis of winter target fisheries, but exact times and locations of spawning are not well known. Spawning probably takes place about July near North Cape and late August/September off the west coast of the South Island.

Ageing of southern gemfish indicates that fish attain about 30 cm at the end of the first year, 45 cm at the end of the second year, 53 cm at the end of the third year, and 63 cm at the end of the fourth year. Both sexes display similar growth rates until age 5, but subsequently females grow larger. The maximum ages recorded for gemfish (from 1989 to 1994) are 17 years for both sexes. In the northern fishery (SKI 1, SKI 2), males and females appear to recruit into the fishery from age 3 but are probably not fully recruited until about age 5 (SKI 2) or age 7 or 8 (spawning fishery in SKI 1). In the southern fishery, gemfish start to recruit at age 2 into spawning and non-spawning fisheries, but age at full recruitment is difficult to determine because of large variation in year class strength.

Recruitment variability in SKI 3 and SKI 7 (during the 1980s and early 1990s) has been correlated with wind and sea surface temperature patterns during the spawning season (Renwick et al 1998). Patterns of recruitment for 2000–2015 in SKI 3 and SKI 7 do not appear to be consistent with the previous correlation with SST (Langley 2020). No significant correlations were found between SKI 1 and SKI 2 recruitment indices and a range of climate variables (Hurst et al 1999).

Biological parameters relevant to stock assessment are given in Table 6.

Table 6: Estimates of biological parameters for gemfish.

Fishstock							**Source**
1. Natural mortality (M)							
All stocks	$M = 0.25\ y^{-1}$ considered best estimate for all areas for both sexes						Horn & Hurst (1999)
2. Weight = a (length)^b (Weight in g, length in cm fork length)							
		Male			Female		
		a	b		a	b	
SKI 1		0.0008	3.55		0.0034	3.22	Langley et al (1993)
SKI 3		0.0012	3.41		0.0095	3.47	Hurst & Bagley (1998)
3. von Bertalanffy growth parameters							
		Male			Female		
	L_∞	k	t_0	L_∞	k	t_0	
East Northland	90.7	0.204	-0.49	122.7	0.114	-1.1	Langley et al (1993)
East Northland	88.4	0.235	-0.54	108.5	0.167	-0.71	Horn & Hurst (1999)
Wairarapa	90.8	0.287	0.00	103.4	0.231	-0.1	Horn & Hurst (1999)
West Northland	86.3	0.295	-0.11	103.4	0.209	-0.37	Horn & Hurst (1999)
North combined	87.4	0.266	-0.35	105	0.194	-0.55	Horn & Hurst (1999)
Southland	88.5	0.242	-0.66	104.2	0.178	-0.88	Horn & Hurst (1999)

3. STOCKS AND AREAS

When introduced to the QMS in 1986, the gemfish stock was defined as comprising only silver gemfish, *Rexea solandri*. In 1996, the species definition was amended to *Rexea* spp. (section 319 of the Fisheries Act 1996) and separate research codes were established for *Rexea solandri* (RSO), *Rexea prometheoides* (REP), and *Rexea antefurcata* (LFG). The statutory reporting code remained SKI, but with the meaning amended to *Rexea* spp. (Fisheries (Reporting) Amendment Regulations 2005, clause 10(3)). A small number of landings and estimated catches have been reported using all three of the species-specific codes, but all observer and research records in Fisheries New Zealand databases are recorded as *Rexea solandri*. Unless otherwise noted, all references to gemfish in this chapter are considered to be to *Rexea solandri*.

In previous assessments, analysis of seasonal trends in gemfish fisheries indicated that there may be at least two stocks:

1. A southern/west coast stock (SKI 3 & 7) caught on Pukaki Rise and the Stewart-Snares shelf in spring, summer, and autumn, which appears to migrate to the west coast of the South Island to spawn and is caught there mainly in August–September. Spawning is thought to occur in late August/early September (Hurst 1988, Horn & Hurst 1999).
2. A northern/east coast stock (SKI 1E & SKI 2) caught mainly off the North Island east coast in spring and summer, which then migrates in May–June to spawn north of the North Island and is intercepted in the Bay of Plenty and East Northland. Seasonal trends in commercial catch and length frequency data from SKI 1E (FMA 1) are consistent with pre- and post-spawning migrations through the area; similar data from SKI 2 are inconclusive but indicate lower catches during the peak spawning months, although this could be partly due to target fishing on other species, particularly orange roughy, at this time.

The relationship of the pre-spawning fishery in SKI 1W (FMA 9) to the pre-spawning fishery in SKI 1E was investigated by Horn & Hurst (1999). They presented age frequency distributions from commercial catches for SKI 1E, SKI 1W, and SKI 2 and from research sampling for SKI 3. Age distributions for the two SKI 1 spawning fisheries appeared to be similar, with year classes in 1980, 1982, 1984, 1986, and 1991 strong relative to other year classes. The SKI 2 distribution also exhibited the same pattern, although the relative dominance of the 1991 year class was greater, as might be expected from an area in which pre-recruit fish occur. The age distribution from SKI 3 gemfish showed that the 1982, 1984, 1985, and 1989 year classes were strong. There were no significant differences in the von Bertalanffy growth parameters calculated for northern and southern gemfish (Horn & Hurst 1999).

Biochemical analyses of Australasian gemfish suggested that there may be a very low level of mixing between eastern Australian and New Zealand gemfish, but not high enough to treat them as a single stock (Colgan & Paxton 1997). There was also a suggestion of a difference between north-eastern and southern New Zealand gemfish.

Two alternative hypotheses have been proposed: that both SKI 1 and SKI 2 are one stock, or that SKI 1W is separate from SKI 1E and SKI 2. The Working Group concluded that based on the close similarity in declines in CPUE indices and in age distributions from commercial catches that the northern gemfish should be assessed using SKI 1 and 2 combined.

4. STOCK ASSESSMENT

4.1 Auckland (SKI 1) and Central East (SKI 2)

The northern gemfish stock has been assessed assuming SKI 1 and SKI 2 represent a single biological stock. Previously, stock assessments for northern gemfish were conducted in 2008 (Fu et al 2008). In 2020, 2021 and 2022, trends in stock abundance were assessed using standardised CPUE indices (Middleton et al 2023). In 2023, a new fully quantitative stock assessment was completed for northern gemfish, incorporating the standardised CPUE indices and age composition data, including recent (2021–22) catch-at-age from the SKI 1 fishery.

4.1.1 Combined landings and TACCs for SKI 1 and SKI 2

Figure 2 shows the landings and TACCs for SKI 1 and SKI 2 combined.

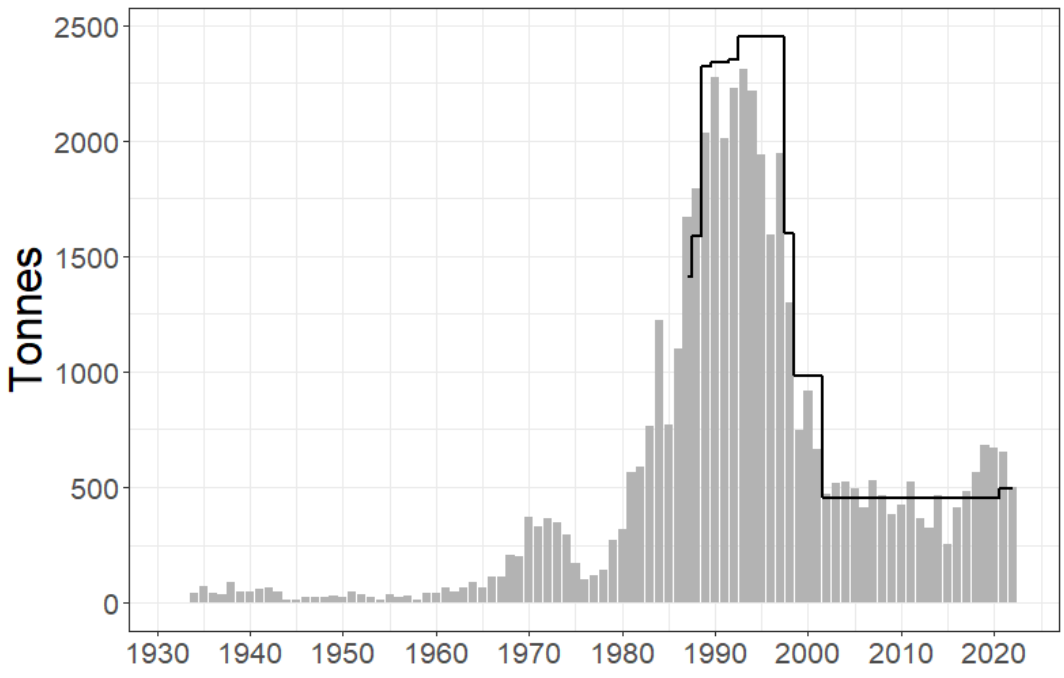


Figure 2: Combined landings (bars) and TACC (line) for SKI 1 and SKI 2.

For the 2023 assessment, annual catches were partitioned between the target (defined here as SKI and HOK target trawling) and bycatch (predominantly bycatch of the tarakihi trawl fishery) fisheries in SKI 1 and SKI 2.

Recreational catches of gemfish are small and there is no information available regarding customary catches. The assessment model only included reported catch from the commercial fishery.

4.1.2 Standardised CPUE analysis

During 2020–2022, new CPUE indices for SKI 1 and SKI 2 were developed and used for a partial quantitative assessment of the stock. A trip-resolution index based on tarakihi target effort throughout SKI 1 and SKI 2 and beginning in 1990 is considered to index the sub-adult and adult fish, while an event-resolution index of adult stock abundance beginning in 1994 was developed using gemfish and hoki target effort off the North Island east coast (Middleton et al 2023).
For the 2023 assessment, the TAR target index was updated with data to the 2022 fishing year. The HOK-SKI event resolution index was revised to ensure that effort carried out using the Precision Seafood Harvesting bottom trawl (PRB) was included in addition to conventional bottom trawl (BT) and midwater trawl (MW) effort. Target species is a key standardisation variable in this model, so a sensitivity was conducted where target species was not offered. However, this resulted in only a minor change to the indices (Figure 3), with depth and area replacing target species as key standardisation variables.

A daily-resolution index was also developed in 2023 to provide a target fishery index that extended back to 1990. This used data that was aggregated to "pseudo CELR" resolution with daily aggregated effort assigned to the modal Statistical Area, and estimated catches constrained to the top 5 species caught each day. Records were included where the modal target species for the day was HOK or SKI.

This BT-TAR trip resolution series showed a steep decline from 1990 to 1999, a stable period to 2016, and then a rapid increase to a peak in 2020 after which the index declined somewhat to 2022 (Figure 3). The various HOK-SKI target series all declined to a low point in the early 2000s, then increased until around 2008. They then showed a slight decline to 2015 then increased rapidly from 2017 to 2022. The event-resolution indices showed a particularly marked increase from 2019 to 2020 and increased further to 2022. The daily-resolution index also increased in this period, but with a more modest increase from 2019 to 2022 than that exhibited by the event-resolution index (Figure 3).

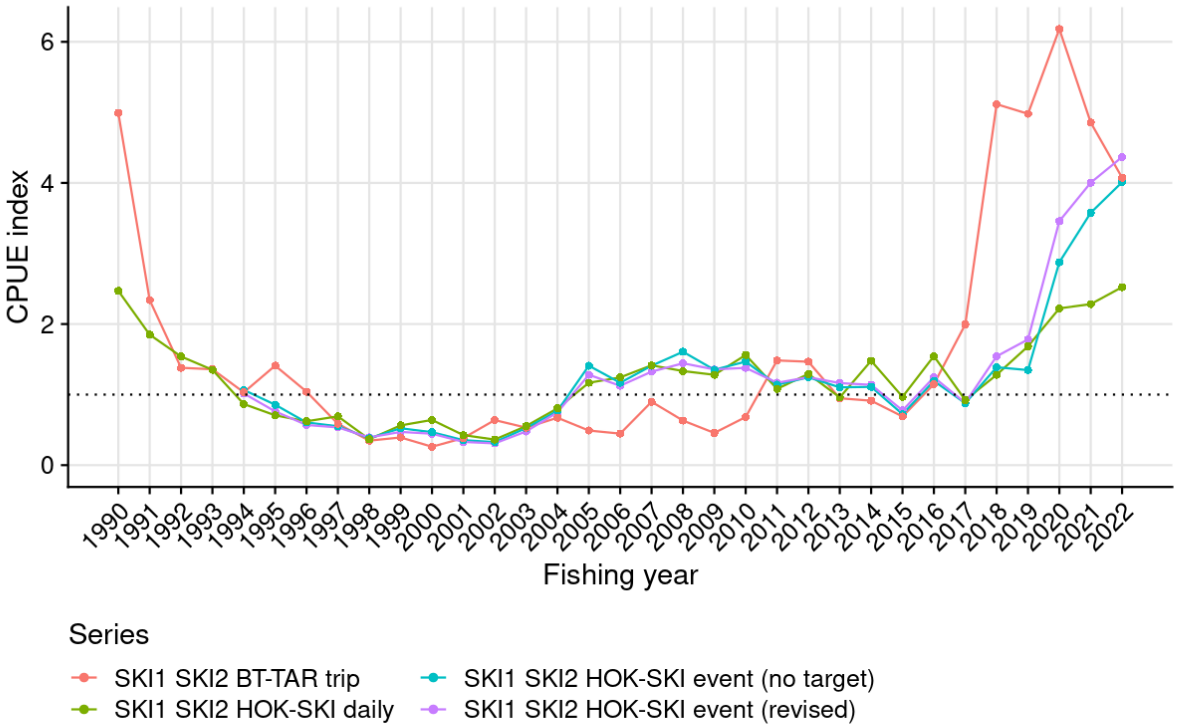


Figure 3: The SKI 1 and SKI 2 CPUE series for mixed sub-adult/adult gemfish (SKI1 SKI2 BT-TAR trip - trip-resolution index from the tarakihi-target bottom trawl fishery), and for adult gemfish: SKI1 SKI2 HOK-SKI event (revised) - event-resolution index from HOK and SKI target trawl events in the Bay of Plenty and SKI 2; SKI1 SKI2 HOK-SKI event (no target) - a sensitivity where target species was not offered as an explanatory variable; SKI1 SKI2 HOK-SKI daily - daily-resolution index from trawling in the Bay of Plenty and SKI 2 where HOK or SKI was the modal target.

The reasons for the difference in recent trend in the event- and daily-resolution series are not clear; however, the working group noted that proportion of HOK and SKI target tows carried out on days included in the daily-resolution series showed a decline from the early 1990s to 2010. The working group considered that the event-resolution series was the preferred series for monitoring the abundance of adult gemfish in SKI 1 and SKI 2 but agreed that the event and daily resolution series should be investigated as alternative indices in the stock assessment modelling.

4.1.3 Age composition of commercial catches

Commercial catch-at-age data included in the assessment were: SKI 1 (SKI 1E and 1W combined) for 1989–1994, 1997–1999, 2002, 2006, 2010, 2012, 2014, and 2022 and SKI 2 for 1996–2005, 2007, and 2008. Age compositions from SKI 1 were from the main target fishery (SKI or HOK). Age compositions from SKI 2 were assigned to either the bycatch or target fishery based on the predominant annual catch; samples from 1996 to 2000 were assigned to the target fishery and subsequent samples were assigned to the bycatch fishery.

4.1.4 Assessment model

The assessment model included the SKI 1 and SKI 2 catch history from 1950 and assumed that the initial population age structure was in an equilibrium, unexploited state. The population structure included 20 age classes for each sex, the oldest age class representing an aggregated "plus" group (20 years and older). The model data period extended to the 2023 year (2022–23 fishing year). The catch in 2023 was assumed to be equivalent to 2022.

The key biological parameters for the assessment are presented in Table 7.

The model was structured with an annual time-step comprising two seasons (October–April and May–September). The seasonal structure partitions the spawning period and main SKI 1 commercial catch (season 2). A Beverton-Holt spawning stock-recruitment relationship (SRR) was assumed with a fixed value of steepness (*h*). Recruitment deviates (1975–2017) from the SRR were estimated assuming a standard deviation of the natural logarithm of recruitment (σ_R) of 0.8. More recent recruitments were derived from the SRR (i.e., rec dev 0).

The maturity ogive was derived from parameters estimated by Fu et al (2008) to determine the age-specific movement from SKI 2 to SKI 1 (associated with spawning). For the current assessment, the age-specific relationship for female gemfish was approximated using a logistic function and assumed to represent age-specific maturity.

Table 7: Biological parameters and priors for the interim base case model.

Component	Parameters	Value, Priors	Fixed/Estimated (N*)
Biology	*M*	0.25	Fixed
	VB Growth	*Len1* = 26.8 cm	Fixed
	Males	*k* = 0.235, *Linf* = 88.4 cm	Fixed
	Females	*k* = 0.167, *Linf* = 108.5 cm	Fixed
	CV length-at-age	0.10	Fixed
	Length-wt		Fixed
	Males	*a* = 8.0e-7, *b* = 3.55	
	Females	*a* = 3.4e-6, *b* = 3.22	
	Maturity	A50 7.2 Width 3.5	Fixed
Recruitment	LnR_0		Estimated (1)
	B-H SRR steepness *h*	0.90	Fixed
	SigmaR σR	0.8	Fixed
	Recruitment deviates	Lognormal deviates (1975–2017)	Estimated (43)

* N, Number of parameters estimated

Age composition data were available from the SKI 1 target fishery (16 observations), SKI 2 target fishery (5 observations), and SKI 2 bycatch fishery (7 observations) (Table 8). For all age compositions, an ageing error, specified with a CV at age of 0.08, was used (from Fu et al 2008). Separate logistic age-based selectivity functions were estimated for the two target fisheries, with sex-specific selectivity estimated for the SKI 1 target fishery. The selectivity to the SKI 2 bycatch fishery was estimated using a double normal function and the selectivity of the SKI 1 bycatch fishery was assumed to be equivalent.

Preliminary modelling revealed that the performance of models incorporating the Daily SKI1-SKI2 HOK-SKI target CPUE indices was better than corresponding models incorporating the Trawl event based CPUE indices. The Daily CPUE indices were adopted as the primary abundance index for the base model and assumed to have an equivalent selectivity to the SKI 1 target fishery.

The main data inputs were assigned relative weightings based on the approach of Francis (2011). The CPUE indices were assumed to have a lognormal distribution with observation error specified as the standard error of the individual CPUE indices. Based on initial model fits the indices were assigned an additional process error of 0.1. For the three sets of fisheries age compositions, the individual age compositions were each assigned an Effective Sample Size (ESS) following Method TA1.8 of Francis (2011) (Table 8).

Table 8: Summary of input data sets for the Base Case assessment model. The relative weighting includes the Effective Sample Size (ESS) of age composition data and the coefficient of variation (CV) associated with the abundance data.

Data set	Model years	Nobs	Error structure	Observation error/ESS	Process error
CPUE indices	1990–2022	33	Lognormal	0.05–0.26	0.1
SKI1 age comp	1989–1994, 1996–1999, 2002, 2006, 2010, 2012, 2014, 2022	16	Multinomial	ESS 6–20	
SKI2 target age comp	1996–2000	5	Multinomial	ESS 21–82	
SKI2 bycatch age comp	2001–2005, 2007, 2008	7	Multinomial	ESS 7–23	

Table 9: Estimated parameters and structural assumptions for the base model.

Parameter	Number of parameters	Parameterisation, priors, constraints
LnR_0	1	Uniform, uninformative
Rec devs (1975–2017)	43	SigmaR 0.8
Selectivity SKI1 target	4	Logistic, sex specific
Selectivity SKI2 target	2	Logistic
Selectivity SKI2 bycatch	4	Double Normal
Selectivity SKI1 bycatch	-	Equivalent to SKI 2 bycatch
CPUE q	2	Uniform, uninformative

Model uncertainty was determined using Markov chain Monte Carlo (MCMC) implemented using the Metropolis-Hastings algorithm. For each model option, 1000 MCMC samples were drawn at 1000 intervals from a chain of 1.1 million following an initial burn-in of 100 000. The performance of the MCMC sample was evaluated using a range of diagnostics.

Stock status was determined relative to the equilibrium, unexploited spawning (mature) biomass of female fish (SB_0). Current biomass was defined as the biomass in the 2023 model year (2022–23 fishing year) ($SB_{CURRENT}$ or SB_{2023}).

Following the Harvest Strategy Standard (HSS), current biomass was assessed relative to the default soft limit of 20% SB_0 and hard limit of 10% SB_0 (Ministry of Fisheries 2008). The HSS includes a default target biomass level of 40% SB_0 for stocks with low productivity where an operational ("real world") SB_{MSY} has not been fully evaluated. The Inshore Fisheries Working Group accepted 40% SB_0 as an appropriate SB_{MSY} proxy for SKI1&2. Current stock biomass is reported relative to the default target biomass level ($SB_{40\%}$) and current levels of fishing mortality are reported relative to the level of fishing mortality that result in $SB_{40\%}$ under equilibrium conditions (i.e., $F_{SB40\%}$). The reference level of age specific fishing mortality is determined from the composite age specific fishing mortality from the last year of the model data period (2022–23).

Results

The model provided a coherent fit to all the main datasets, although the scale of the recent increase in the CPUE indices is under-estimated by the assessment model and there are deficiencies in the fit to the most recent (2022) age composition. This indicates a degree of conflict between the two sets of data from the recent period.

The estimated annual recruitments are cyclical with periods of higher recruitment occuring at approximately 15 year intervals and low recruitment during the intervening years. Spawning biomass was depleted in the late 1990s and early 2000s following a period of higher catches during the early 1990s and lower overall recruitment during the early-mid 1990s. Spawning biomass increased during the 2000s following higher recruitment in the late 1990s and early 2000s, while catches remained at a relatively low level. Spawning biomass is estimated to have increased further during 2019–2023 following higher recruitments in 2013–2017 (Figure 4). Estimates of current (2023) spawning biomass approximate the SB_0 level. However, there is considerable uncertainty associated with the estimate of stock status, reflecting the uncertainty associated with the estimates of those recent higher recruitments.

Correspondingly, with the high stock biomass and relatively low catches, fishing mortality over the last 10 years (including 2023) is estimated to be well below the rate that equates to the target biomass level (under equilibrium conditions i.e., $F_{SB40\%}$).

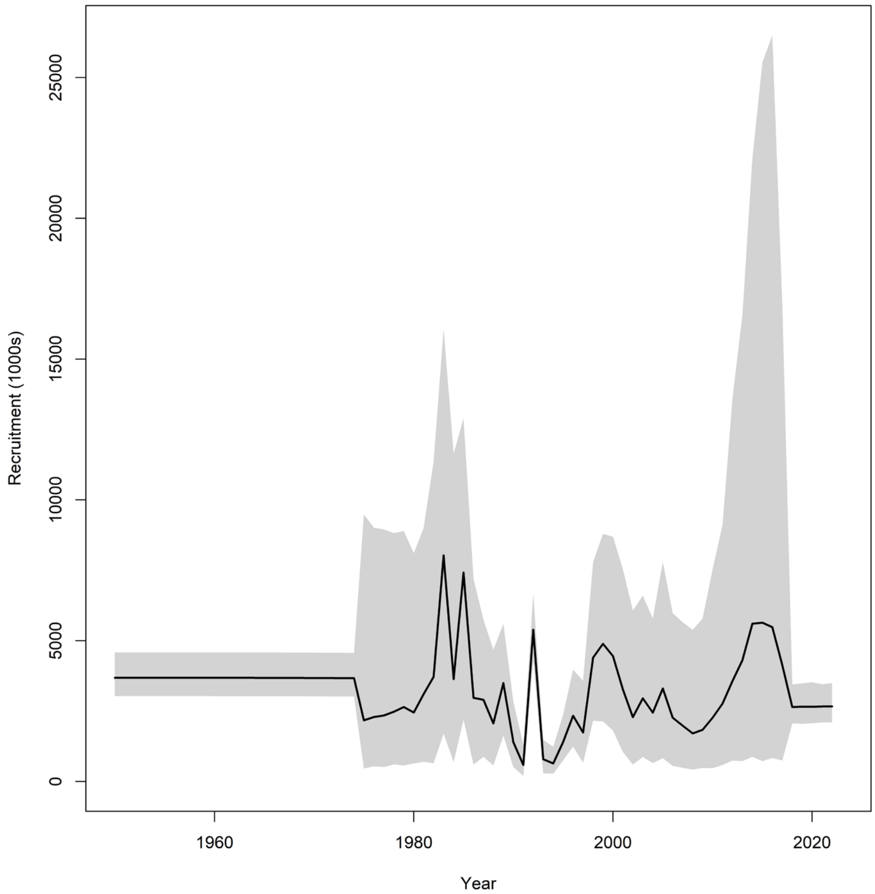


Figure 4: Annual estimates of recruitment (numbers of fish, thousands) from the base case model (MCMCs). The black line represents the median of the MCMC estimates and the shaded error represents the 95% confidence interval.

Sensitivities

A number of key assumptions of the model were investigated as (single change) sensitivities to the base case model. The sensitivity options included alternative values for key biological parameters and alternative CPUE assumptions (Table 10).

A number of the sensitivities were excluded from the final set of model options as they were either not considered plausible (SigmaR 1.5) or did not differ appreciably from the base case model (Recruit1965, TargetDay_SelectSKI2, TargetEvent_SelectSKI2). The estimates of stock status were relatively robust to the final set of model sensitivities (Table 11).

Table 10: Model sensitivities.

Sensitivity	Description
M 0.20	Natural mortality, both sexes 0.20
M 0.30	Natural mortality, both sexes 0.30
Maturity Ogive	Maturity ogive A50 shifted to 5 y
Recruit1965	Extend recruitment estimation period back to 1965
SigmaR 1.5	SigmaR for rec devs to 1.5
Steepness 0.7	Steepness of SRR 0.7
TargetDay_SelectSKI2	Link Daily CPUE indices to selectivity from SKI 2 target fishery
TargetEvent_SelectSKI1	Replace Daily CPUE indices with Event based CPUE indices
TargetEvent_SelectSKI2	Replace Daily CPUE indices with Event based CPUE indices, linked to SKI2 taget fishery

Table 11: Estimates of current (2023 = FY 2022–23) and virgin spawning biomass (median and the 95% confidence interval from the MCMCs) and probabilities of current biomass being above specified levels and probability of fishing mortality being below the level of fishing mortality associated with the interim target biomass level. The potential yield in 2023 was derived by applying the $F_{SB40\%}$ fishing mortality rate to the current (2023) biomass.

						Pr (SB_{2023} > $X\%SB_0$)		
Model option	SB_0	SB_{2023}	$SB_{40\%}$	SB_{2023}/SB_0	$SB_{2023}/SB_{40\%}$	**40%**	**20%**	**10%**
Base	9 041	9 401	3 616	1.036	2.591	1.00	1.00	1.00
	(7 442–11 244)	(6 312–14 825)	(2 977–4 498)	(0.756–1.494)	(1.89–3.736)			
M 0.20	9 077	7 764	3 631	0.853	2.132	1.00	1.00	1.00
	(7 832–10 639)	(5 166–11 620)	(3 133–4 255)	(0.62–1.211)	(1.549–3.028)			
M 0.30	9 943	12 088	3 977	1.199	2.999	1.00	1.00	1.00
	(7 959–13 092)	(7 773–19 325)	(3 183–5 237)	(0.878–1.718)	(2.194–4.295)			
Maturity Ogive	11 431	12 412	4 572	1.079	2.697	1.00	1.00	1.00
	(9 479–13 840)	(8 277–19 942)	(3 792–5 536)	(0.789–1.629)	(1.972–4.073)			
Steepness 0.7	9 751	9 344	3 901	0.968	2.419	1.00	1.00	1.00
	(8 141–11 950)	(6 295–15 138)	(3 257–4 780)	(0.698–1.416)	(1.745–3.541)			
TargetEvent_SelectSKI1	9 397	13 705	3 759	1.448	3.62	1.00	1.00	1.00
	(7 693–11 845)	(8 696–24 035)	(3 077–4 738)	(1.009–2.295)	(2.522–5.738)			

Model option	$F_{SB40\%}$	$F_{2023}/F_{SB40\%}$	Pr(F_{2023}<$F_{SB40\%}$)
Base	0.105	0.167	1.00
	(0.103–0.108)	(0.103–0.243)	
M 0.20	0.096	0.237	1.00
	(0.094–0.098)	(0.153–0.352)	
M 0.30	0.112	0.114	1.00
	(0.109–0.115)	(0.071–0.178)	
Maturity Ogive	0.130	0.134	1.00
	(0.127–0.134)	(0.081–0.199)	
Steepness 0.7	0.092	0.189	1.00
	(0.090–0.094)	(0.113–0.285)	
TargetEvent_SelectSKI1	0.105	0.120	1.00
	(0.103–0.107)	(0.066–0.190)	

Projections

Five-year stock projections (to the 2027–28 fishing year) were conducted using the base case model assuming annual catches equivalent to the 2021–22 catch; i.e., a commercial catch of 508 t (approximating the current combined TACCs for SKI 1 and SKI 2 of 492 t).

Two options were considered for annual recruitment for the 5-year projection period (2024–2028): recruitment at the long-term (1975–2017) average level or recruitment at the average of 2002–2010 (64% of long term average), representing a recent period of lower recruitment.

The projections indicate that the stock biomass reaches a peak in the next few years and then declines slightly, following the progression of the strong 2013–2017 year classes through the fishery. Nonetheless, for all recruitment assumptions the stock remains well above the target biomass level throughout the projection period (Figure 5 & Table 12).

Qualifying comments

For the current assessment, recent trends in stock abundance are strongly informed by the recent Daily SKI-HOK target CPUE indices. The general trend in these indices is consistent with other recent observations from the fisheries, although the extent of the increase in the indices is considerably less than the increase in the Event (Trawl) based SKI-HOK target CPUE indices. There are likely to have been changes in the operation of the fishery in response to the recent increase in gemfish targeting, particularly when the fishery has been constrained by the relatively low TACCs for SKI 1 and SKI 2. Consequently, the Daily CPUE indices may under-estimate the extent of the increase in gemfish abundance, particularly where there has been an increase non-target trawls during more recent years. Conversely, an increase in the effective targeting of gemfish by individual trawls may over-estimate the increase in the Trawl-based abundance indices. The Daily CPUE indices were selected for the base case model because they resulted in a better overall fit to the data.

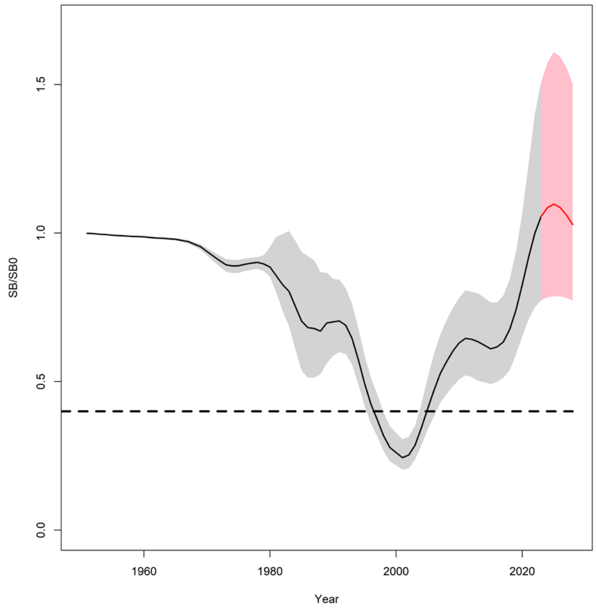


Figure 5: Annual spawning biomass relative to virgin biomass (equilibrium, unexploited) estimated from the base case model (black) and the five-year projection (red) assuming annual catches equivalent to the 2023 catch with recent recruitment at the long term average level (1975-2017). The solid line represents the median of the MCMCs and the shaded area represents the 95% confidence interval. The horizontal dashed line represents the default target biomass level.

Table 12: Projected spawning biomass relative to virgin biomass (and 95% confidence interval) and the probability of the spawning biomass being above default biomass limits and interim target level in 2028 (FY 2027–28) for the base case at the current level of catch with different recruitment assumptions.

		Pr (SB_{2028} > $X\%SB0$)		
Recruitment option	SB_{2028}/SB_0	**10%**	**20%**	**40%**
Avg 1975–2017	1.03 (0.77–1.50)	1.00	1.00	1.00
Avg 2002–2010	0.91 (0.66–1.35)	1.00	1.00	1.00

The CPUE indices provide a composite trend in abundance from the SKI-HOK target fisheries in SKI 1 and SKI 2. However, there are differences in the selectivity of gemfish for the target fisheries operating in the two areas, with the SKI 2 fishery catching gemfish from a younger age. For the purpose of the stock assessment, the CPUE indices were associated with the SKI 1 target fishery as that provided a more direct linkage between the recent CPUE indices and the most recent age composition (2022). There was no appreciable difference in the model results when the alternative selectivity (SKI 2 target) was assumed for mediating the CPUE indices.

The maturity ogive assumed for the current assessment was derived from a series of estimated parameters from the previous quantitative stock assessment (Fu et al 2008). This stock assessment equated maturity with estimated movement from SKI 2 to SKI 1. As such, those parameters may be sensitive to the structural assumptions of the previous assessment model (e.g., constant selectivity of the SKI 1 fishery and the spatial separation of the two SKI QMAs) and may be unreliable as estimates of female age-specific maturity.

The assessment estimated strong recruitments for 2013–2017, although the magnitude of those recruitments is uncertain. Gemfish stocks appear to sustained by periods of higher recruitment occuring intermittently, at 10–15 year intervals. The magnitude of more recent recruitments is unknown.

4.2 South-East/Southland (SKI 3) and Challenger/Central (West) (SKI 7)

A stock assessment of the southern stock (SKI 3 & 7) was conducted in 1997 using the MIAEL procedure (Hurst & Bagley 1998). This analysis was considered highly uncertain by the Middle Depths Working Group, which only accepted the minimum and maximum ranges for B_0, stock status, and yields. Langley (2020) incorporated CPUE indices derived from the west coast South Island (WCSI) hoki fishery, length composition data from the main commercial fisheries (from observers), and trawl surveys of the west coast of the South Island by *Kaharoa* and *Tangaroa* into a preliminary stock assessment model for the southern stock. However, the Deepwater Working Group (DWWG) concluded that this preliminary stock assessment model was not sufficiently reliable to estimate current stock status. Starr et al (in press) conducted an extensive analysis of all available catch and effort data for SKI 3 and SKI 7, reporting ten CPUE series covering three SKI 3 and SKI 7 fisheries which were based on four distinct data sets (event-based CPUE, daily CPUE, and daily processed catch, using the statutory catch, effort, and landings data, and observed catch CPUE using data from fisheries observers).

4.2.1 Trawl survey biomass indices

The relative abundance of gemfish in the Southland area (SKI 3) was monitored by trawl surveys conducted by *Shinkai Maru* (early 1980s) and *Tangaroa* (early 1990s) (Table 13). Since the early 1990s, a regular series of inshore trawl surveys off the west coast South Island (SKI 7) has been conducted by *Kaharoa* during April–May. Although gemfish is not considered to be a target species for the survey, the survey appears to monitor the relative abundance of juvenile gemfish in the survey area. The more recent series of offshore trawl surveys off the west coast South Island by *Tangaroa* overlaps the main distribution of gemfish and may occur during the early part of the spawning period. The survey appears to monitor the adult and juvenile components of the gemfish stock in the WCSI.

4.2.2 Exploratory population modelling

Langley (2020) developed CPUE analyses based on data derived from the bycatch of gemfish from the WCSI hoki fishery. Two analyses were put forward, one a negative binomial series based on all catch and effort data from the target HOK trawls conducted by the WCSI trawl (BT and MW) fishery during July–September from 1989–90 to 2017–18. The other, using a delta-lognormal procedure, was a pared down data set limited to New Zealand domestic vessel effort in a 250–600 m depth range within the northern area of the hoki fishery during late August–September. The Deepwater Working Group considered these indices to be qualitatively reflecting a recent increase in biomass but were unlikely to be directly proportional to abundance. Nevertheless, these CPUE series were used in a preliminary age-structured stock assessment model to test the implications of the apparent increase in southern gemfish abundance (Langley 2020).

This preliminary age-structured population model was configured to integrate the various data sets available from SKI 7 and was extended to include the entire southern gemfish stock (SKI 3 and SKI 7). The data sets included trawl survey biomass estimates and age composition data available from the *Tangaroa* Southland surveys (4 surveys 1993–1996) and biomass estimates from three earlier *Shinkai Maru* trawl surveys (1981–1983). Total annual catches were available from SKI 3 and SKI 7 for 1975 to 2017–18. Additional observer sampled length composition data were also available from the gemfish sampled from the Southland squid fishery (SKI 3) (14 years of observations).

The model was implemented in Stock Synthesis and configured as follows.

- Model period 1975–2018 (2018 = 2017–18 fishing year).
- Initial conditions equilibrium, unexploited in 1975 with the first year of catch in 1975.
- Population structure: two sexes, 15 age classes (1–15+), 1 cm length bins (10–110 cm).

- Biological parameters (natural mortality, growth, maturity, length-weight) as documented in Table 6.
- Single model region, i.e., spatial structure of fisheries not explicitly modelled.
- Beverton-Holt spawner-recruitment relationship (steepness *h* 0.85). Recruitment deviates 1975–2016, with models using sigmaR from 1.0 to 2.0.
- Abundance indices: four sets of trawl survey indices and SKI 7 CPUE indices *(all data or partial data* indices, with CV 0.30).
- Annual catches from two fisheries (SKI 3 and SKI 7) with allowance for under reporting pre- and post-QMS.
- Length-based selectivity functions. Logistic selectivities estimated for two commercial fisheries. Southland trawl surveys were assumed to have the equivalent selectivity to the SKI 3 fishery selectivity. Double normal selectivities estimated for *Kaharoa* and *Tangaroa* WCSI trawl surveys.

Table 13: Biomass indices (t) and coefficients of variation (CV) from trawl surveys (assuming area availability, vertical availability, and vulnerability = 1).

Fishhstock	Area	Vessel	Trip code	Date	Biomass	% CV
SKI 3	Southland	*Shinkai Maru*	SHI8102	Feb 1981	3 900	17
			SHI8201	Mar–Apr 1982	3 100	31
			SHI8303	Apr 1983	5 500	33
SKI 3	Southland	*Tangaroa*	TAN9301	Feb–Mar 1993	1 066	17
			TAN9402	Feb–Mar 1994	406	18
			TAN9502	Feb–Mar 1995	539	25
			TAN9604	Feb–Mar 1996	529	23
SKI 7	WCSI	*Kaharoa*	KAH9204	Mar–Apr 1992	130	19
			KAH9404	Mar–Apr 1994	68	29
			KAH9504	Mar–Apr 1995	21	55
			KAH9701	Mar–Apr 1997	704	83
			KAH0004	Mar–Apr 2000	120	30
			KAH0304	Mar–Apr 2003	137	23
			KAH0503	Mar–Apr 2005	474	49
			KAH0704	Mar–Apr 2007	101	19
			KAH0904	Mar–Apr 2009	143	29
			KAH1104	Mar–Apr 2011	101	34
			KAH1305	Mar–Apr 2013	113	28
			KAH1503	Mar–Apr 2015	186	17
			KAH1703	Mar–Apr 2017	545	28
			KAH1902	Mar–Apr 2019	559	22
			KAH2103	Mar–Apr 2021	433	26
SKI 7	WCSI	*Tangaroa*	TAN1210	Jul–Aug 2012	14	32
			TAN1308	Aug 2013	11	43
			TAN1609	Aug 2016	127	23
			TAN1807	Jul–Aug 2018	702	33
			TAN2107	Jul–Aug 2021	754	18

Note: *Tangaroa* WCSI survey in 2000 was not used because the survey in that year did not extend inshore of 300 m depth.

In general, the model provided a reasonable fit to most of the data sets. However, the fit to the *all data CPUE* indices was poor because the short period of high CPUE indices in 2003–04 and 2004–05 appeared to be inconsistent with the annual catches and fishery length composition data from the following years (given the biological parameters of the species). The model yielded a much better fit to the *partial data CPUE* indices throughout the time series (1997–2018).

The model estimated a period of relatively high recruitment in the late 1970s-early 1980s, minimal recruitment during the late 1980s to 1990s and intermittent recruitment during the 2000s. The model estimated exceptionally high recruitment estimates in 2014 and 2015 to fit the recent large increases in the CPUE indices and WCSI trawl survey biomass indices and the higher recent catches. The magnitude of these recent recruitment estimates was not consistent with that for the recruitment estimates for the entire preceding period. Further, the magnitudes of the recent recruitment estimates were inconsistent with the individual year classes evident in the length compositions from the 2018 WCSI fishery and *Tangaroa* trawl survey. It was only possible to appreciably improve the fit to the recent length compositions by excluding the last few years of CPUE indices and trawl survey biomass estimates and by reducing the catches in the terminal year.

The Deepwater Working Group considered that the model was not sufficiently reliable to provide estimates of current biomass and stock status. Nonetheless, the DWWG considered that there was sufficient information available from the trawl surveys and commercial fisheries data to conclude that there has been a considerable increase in stock abundance in recent years due to strong cohorts from the 2014, 2015, and 2016 year classes.

4.2.3 2021 SKI 3 & 7 CPUE analysis

Starr et al (in press) conducted detailed analyses of all available catch and effort data for SKI 3 and SKI 7, extending the preliminary CPUE analyses conducted by Langley (2020). They identified the following three southern gemfish fisheries:

- SKI 7 target HOK: a target HOK fishery operating in the winter (May–September) off the west coast of the South Island (Statistical Areas 034 and 035) based on bottom trawl (BT) gear or midwater gear fished within 10 m of the bottom (MB);
- SKI 3 Stewart-Snares shelf: a mixed target (SQU, BAR, HOK, SWA, SKI, LIN) fishery operating year round on the Stewart-Snares shelf and Pukaki Rise (Statistical Areas 025–030 and 504) based on bottom trawl (BT) gear or midwater gear fished within 10 m of the bottom (MB);
- SKI 3 East coast: a mixed target (SQU, BAR, HOK, RCO, TAR) fishery operating year round off the east coast South Island (Statistical Areas 020 and 022) based on bottom trawl (BT) gear or midwater gear fished within 10 m of the bottom (MB);

For each of these fisheries, they considered four data sets:

- event: tow-by-tow event-based data, based on TCEPR, TCER, and ERS-trawl forms, with estimated catches scaled to landings and constrained to report only the top five species caught in each tow (to conform to the requirements of the TCEPR form);
- daily processing: based on processing data from large factory trawlers, where the processed catch for the day was assumed to have been caught on that day; effort was the sum of the hours fished on that day, depth was the mean depth fished, and the modal statistical area and target species for the day was used;
- observer: tow-by-tow observer data; there was no concern about missing SKI in each tow with the assumption that the observer would find gemfish if it was present in the tow;
- daily rollup: the catch for the day was summed, along with the hours fished; the modal statistical area and target species for the day was used and the catch was constrained to be the top five species caught for the day; this 'roll-up' was meant to emulate the CELR form requirements and was intended to include inshore vessels into the analysis; all MW catch and effort were included because depth is not a valid CELR field.

Although the event and daily rollup data sets will have considerable data overlap, the catch data in the daily processing data set should be relatively independent from the event data set and the observer data set. This latter data set is based on many of the same events, but the data are recorded independently from the statutory catch and effort logs.

CPUE series were developed for the following ten fishery/data-set combinations, showing the years covered, the core vessel selection criteria, and the depth range used:

	Data set			
Fishery	**Event**	**Daily processing**	**Observer**	**Daily roll-up**
SKI 7 target HOK	1990–2020 5 year/1 trip 250–600 m	1990–2020 4 year/1 trip 250–600 m	2000–2020 5 year/1 trip 250–600 m	1990–2020 4 year/1 trip
SKI 3 Stewart/Snares shelf	1990–2020 5 year/1 trip 50–600 m	1990–2020 3 year/1 trip 50–600 m	2000–2020 5 year/1 trip 50–600 m	1990–2020 3 year/1 trip
SKI 3 East coast	1996–2020 3 year/1 trip 50–600 m	2001–2020 2 year/1 trip 50–600 m	insufficient data	insufficient data

A standardised lognormal GLM was fitted to the positive gemfish catches from each series and a binomial GLM was fitted to the presence/absence of gemfish observations in the same data set. Explanatory variables appropriate to the data set were offered to each model, including vessel, depth, duration of fishing, season-day, start latitude, start longitude, hour of day, speed, headline height, method of capture, and statistical area. However, most models only accepted a few of these variables, primarily the vessel key and the season-day variable. The binomial and lognormal models were then combined into a single series using the multiplicative delta-lognormal procedure.

The Deepwater Working Group accepted that all ten series indicated a considerable increase in apparent relative biomass compared with the low levels of gemfish observed during the period 1989–90 to the mid-2010s, assuming these series were indexing biomass. This was true for all three evaluated fisheries: SKI 7 target HOK (Figure 6), the SKI 3 Stewart-Snares shelf (Figure 7, top panel), and the SKI 3 Banks (East coast, Figure 7, bottom panel). The DWWG also noted that the correspondence between the SKI 7 target HOK series with the *Kaharoa* survey was poor (Figure 6, top panel), but this was acceptable because this survey primarily indexes gemfish recruitment. The DWWG also noted that the gemfish index from the 2018 *Tangaroa* survey showed an increase that was consistent with several of the SKI 7 target HOK series (Figure 6, bottom panel). This observation corroborates the SKI 7 CPUE series, despite the short series for this survey, given the assumption that this survey is more likely to be indexing recruited gemfish.

The DWWG preferred the daily processing series because these series were not affected by the limitations of the species reporting requirements of the TCEPR forms and were longer than the observer CPUE series. All three daily processing series are presented with error bars in Figure 8. The DWWG also accepted the SKI 7 target HOK daily processing series as the primary abundance indicator for southern gemfish because it operates during the spawning period in the primary location where this stock is presumed to spawn. The SKI 3 Stewart-Snares shelf series was viewed as a corroborative series which operates in the feeding and migratory region for this stock.

4.2.5 SKI 3 and SKI 7 observer length frequency data (2021)

Starr et al (in press) also summarised the available observer length frequency data for SKI 3 and SKI 7. These summaries show clear progressions of length modes in all observer regions where southern gemfish occur for both bottom trawl (Figure 9) and midwater trawl (Figure 10). These progressions are most evident in the Challenger (west coast South Island) observer region where there is better observer coverage. Both capture methods in the Challenger region show a broadening of the length frequency distributions in 2019 and particularly in 2020 with fish smaller than 30 cm seen, which probably indicates that additional new recruitment has been entering these fisheries.

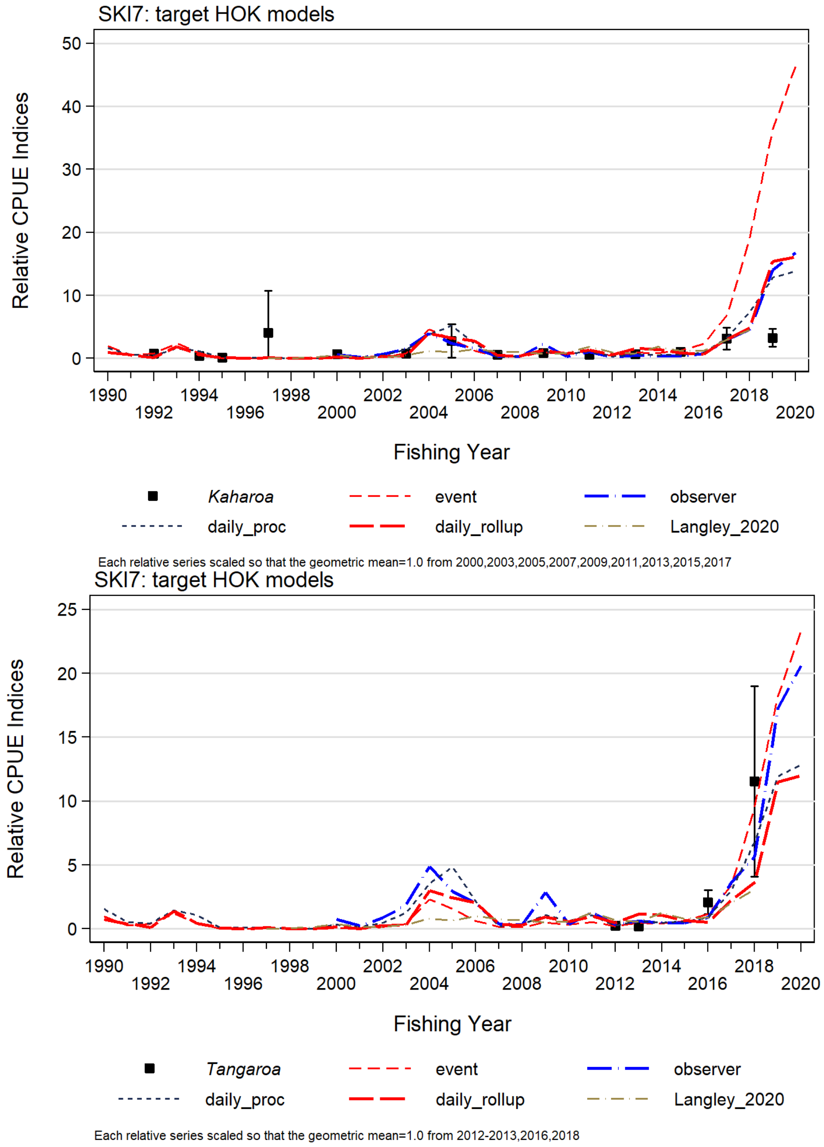
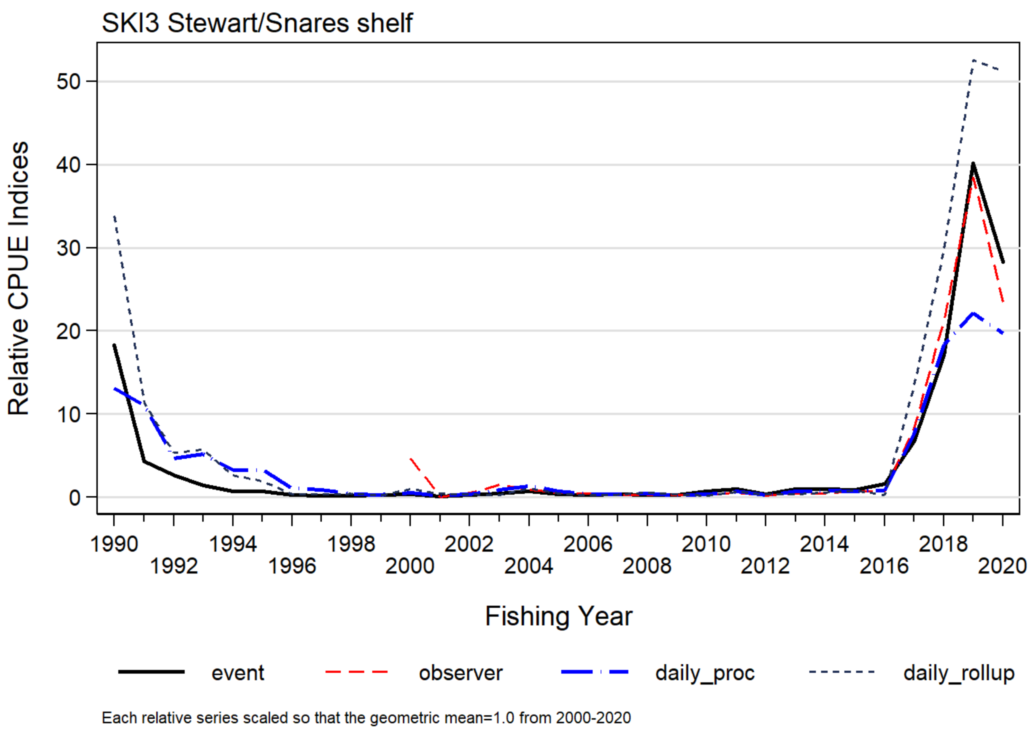


Figure 6: Comparison of the four SKI 7 HOK target combined delta-lognormal CPUE models and the Langley (2020) *partial data* CPUE model with the *Kaharoa* survey indices (top) and with the *Tangaroa* survey indices (bottom), showing approximate 95% confidence intervals for the survey indices.



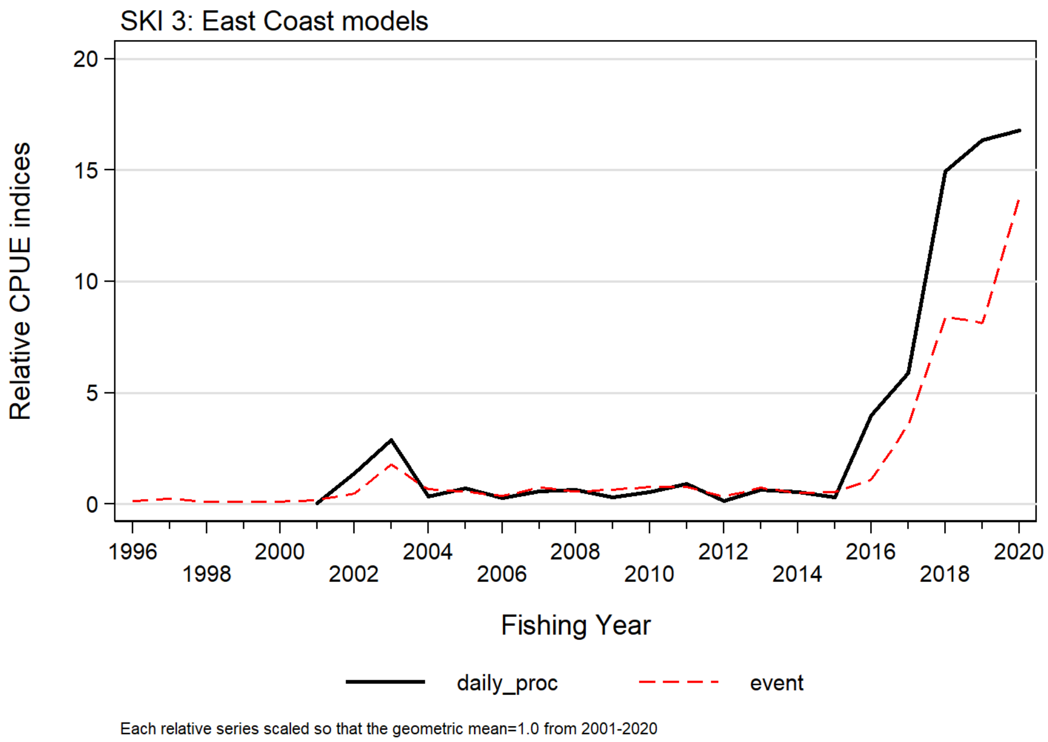


Figure 7: Comparison of the four SKI 3 Stewart-Snares shelf combined delta-lognormal CPUE models (top panel) and the two East coast CPUE series (bottom panel).

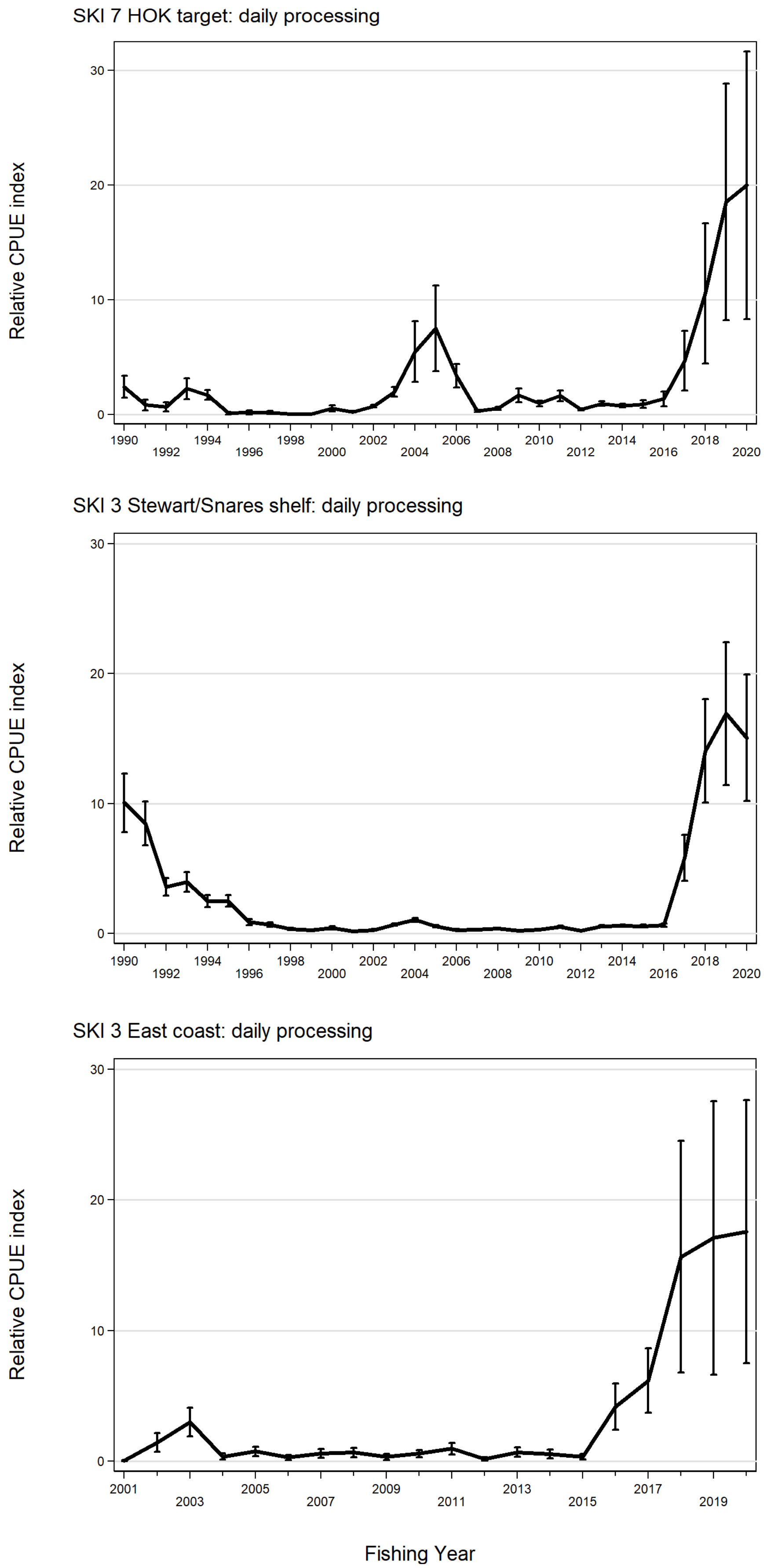


Figure 8: Daily processing combined delta-lognormal CPUE indices for the SKI 7 HOK target fishery (1990–2020), SKI 3 Stewart-Snares shelf fishery (1990–2020), and SKI 3 East coast southern gemfish (2001–2020), showing approximate 95% confidence intervals.

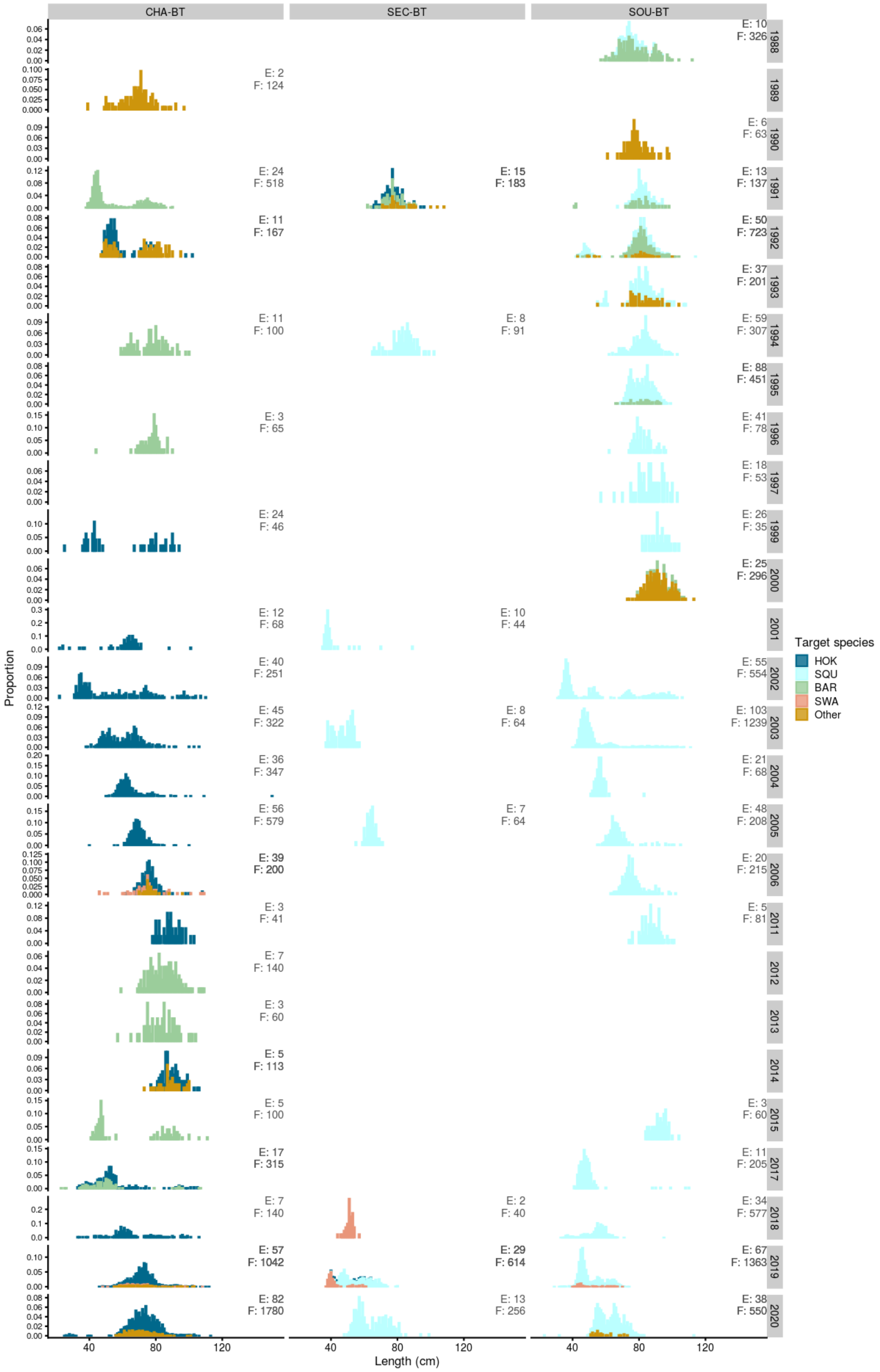


Figure 9: Unweighted aggregate observer length-frequency distributions for gemfish caught in the bottom trawl fishery, by observer region (CHA: Challenger; SEC: Chatham Rise/East coast; SOU: Southland), year, and target species (E: Events sampled; F: number of measured fish).

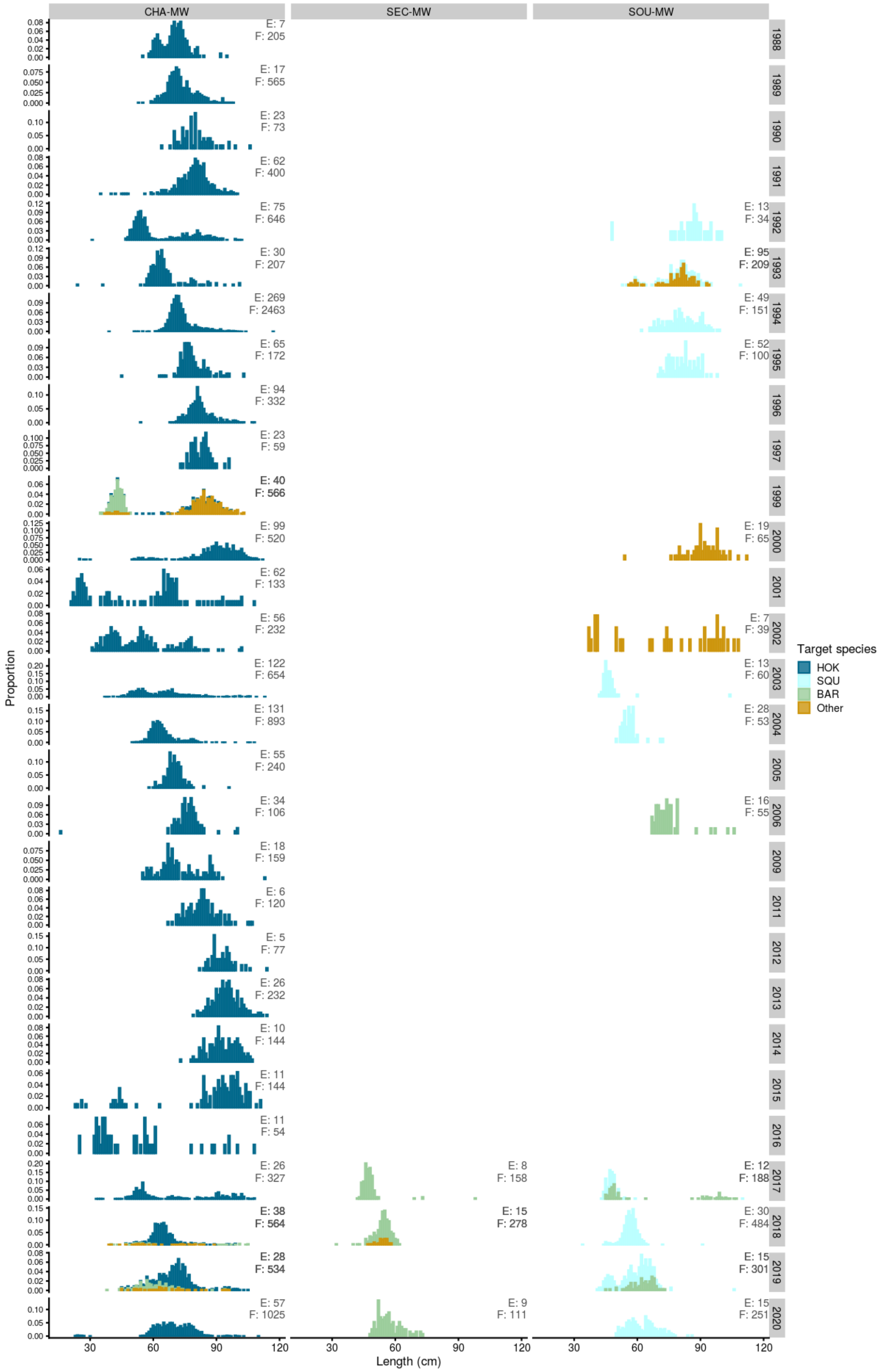


Figure 10: Unweighted aggregate observer length-frequency distributions for gemfish caught in the midwater trawl fishery, by observer region (CHA: Challenger; SEC: Chatham Rise/East coast; SOU: Southland), year, and target species (E: Events sampled; F: number of measured fish).

4.3 Future research considerations

All stocks

- Evaluate potential environmental influences on SKI distribution and recruitment.
- Assess records of *Rexea* spp. other than *Rexea solandri* in New Zealand waters.

SKI 1 and SKI 2:

- Sample the age composition of the catch from the SKI 1 HOK-SKI target fishery and the SKI 2 target and bycatch fisheries. Simultaneous seasonal sampling in both areas (SKI 1 and SKI 2) has the potential to provide evidence of age-specific movement of gemfish.
- Explore the utility of standardisation of age frequencies for gemfish data.
- Refine the recent SKI 1 HOK-SKI target fishery CPUE indices to resolve discrepancies between the Event (trawl) and Daily aggregated CPUE indices. This may involve examination of alternative criteria for model selection, cross validation, and re-balancing data.
- Develop a spatially structured assessment model to explicitly incorporate movement dynamics (spawning migration) between SKI 2 and SKI 1.
- Improve estimates of age-specific maturity of gemfish in SKI 1 and 2.

SKI 3 and SKI 7:

- The southern gemfish stock merits an age-based full quantitative stock assessment, given the strong CPUE response observed in ten analyses across three defined fisheries, as well as the corroborative increase in the 2018 WCSI *Tangaroa* survey biomass estimate and the modal length frequency progression observed in the observer samples from three fisheries and two capture methods.
- Because the abundance increase is likely driven by more than one recruitment event, this stock assessment must be informed with age data. There have been variable collections of gemfish otoliths by observers from three defined fisheries (Challenger (CHA), Chatham Rise/East coast (SEC), Southland (SOU)) as well the possible collection of otoliths from the WCSI *Tangaroa* survey series. For an age-based stock assessment to be conducted, these historical otoliths need to be sourced, catalogued, and aged.
- It is vital to arrange for the collection of sufficient otoliths from WCSI *Tangaroa* surveys to construct a gemfish age-length key so that the age composition of the gemfish biomass can be estimated. This collection will be an important component to any future southern gemfish stock assessment, regardless of when it is undertaken.
- Reanalyse the data collected during the *Kaharoa* WCSI inshore trawl survey series to develop weight- and number-based juvenile abundance indices for RSO.
- Determine whether the *new_FSU* database has data that can be used to extend the CPUE series backwards.

5. STATUS OF THE STOCKS

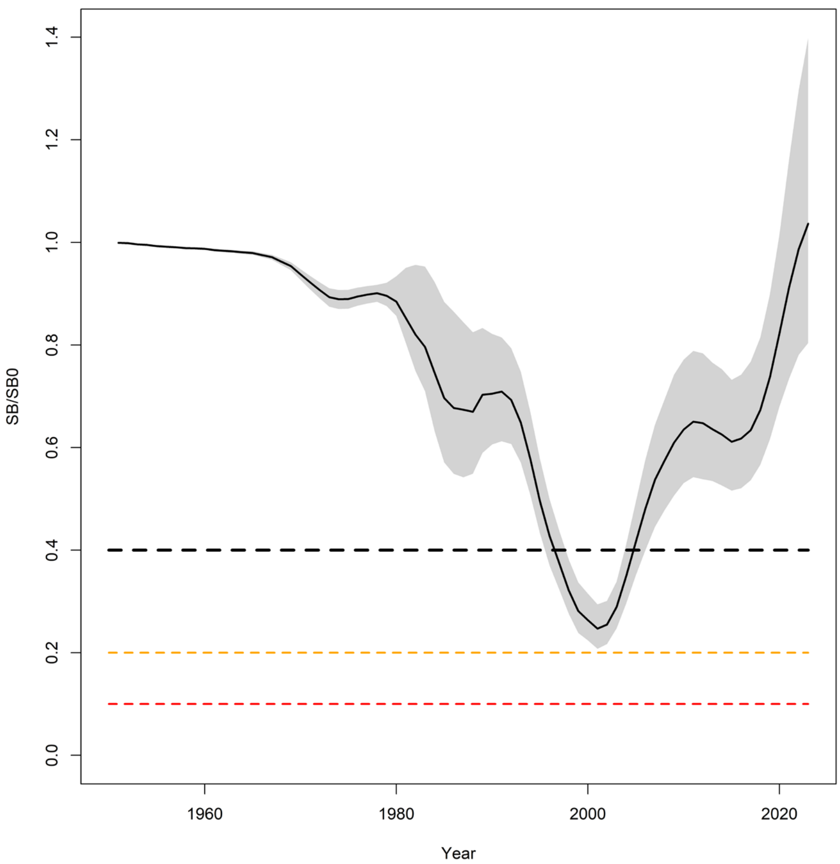
Stock Structure Assumptions

Gemfish are assessed as two biological stocks, based on spawning migration and timing and the location of spawning grounds. These stocks are managed and assessed separately and are assumed to be non-mixing. The SKI 1&2 stock is found off the east and west coasts of the North Island, with adults migrating north to spawn north of the North Island during May–June. The SKI 3&7 stock occurs in the south of New Zealand and migrates to the west coast South Island to spawn in August–September.

SKI 1&2

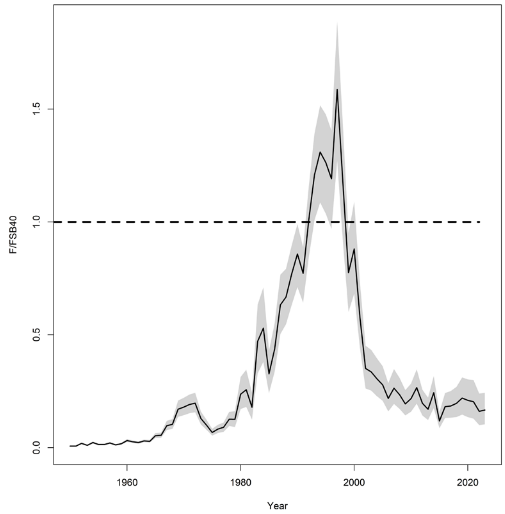
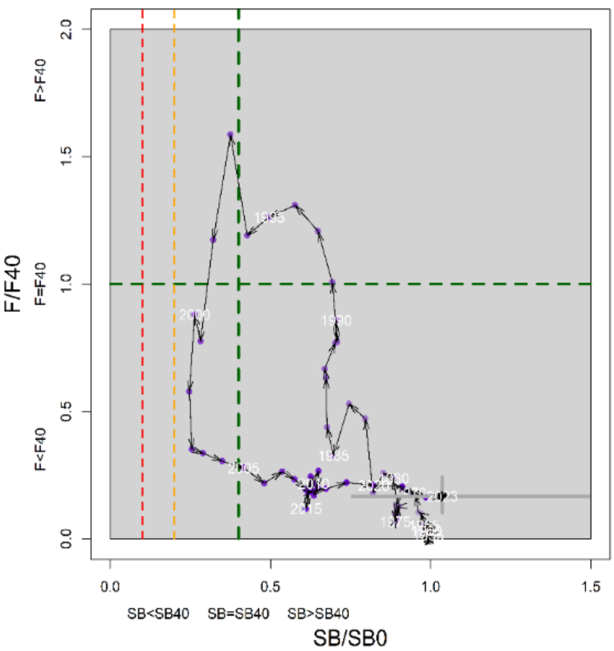
Stock Status		
Most Recent Assessment Plenary Publication Year	2023	
Catch in most recent year of assessment	Year: 2021–22	Catch: 502 t
Assessment Runs Presented	Base case, age-structured population model	
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{SB40\%}$	
Status in relation to Target	Very Likely (> 90%) to be at or above the target in 2023	
Status in relation to Limits	Soft Limit: Very Unlikely (< 10%) to be below Hard Limit: Exceptionally Unlikely (< 1%) to be below	
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring	

Historical Stock Status Trajectory and Current Status



Annual trend in spawning biomass relative to the 40% SB_0 interim target biomass level for the base model. The line represents the median and the shaded area represents the 95% credible interval. The dashed line represents the target level. The red and orange dashed lines represent the hard and soft biomass limits, respectively.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Spawning biomass was estimated to be at a low level in the early 2000s. Spawning biomass increased considerably over the subsequent years and continued to increase between 2017–18 and 2021–22 (in response to strong recruitment during 2012–13 and 2016–17).

Recent Trend in Fishing Mortality or Proxy	Fishing mortality rates have been well below the threshold ($F_{SB40\%}$) since about 2002.  **Annual fishing mortality compared to the *SB40%* interim threshold fishing mortality level (dashed line) for the base case model (median values from MCMCs).**  **Annual spawning biomass and fishing mortality compared with the *SB40%* interim target biomass level and corresponding fishing mortality reference for the base case model (median values from MCMCs). The green dashed lines represent the biomass and fishing mortality target levels. The red and orange dashed lines represent the hard and soft biomass limits, respectively.**
Other Abundance Indices	Relative abundance of pre-recruits (TAR index) increased six-fold between 2016–17 and 2019–20, preceding the large increase in the adult index. The pre-recruit index declined in 2020–21 and 2021–22.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Abundance is estimated to remain well above the target over the next 5 years at the current level of catch.

Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	For current (2021–22) catch and combined TACCs: Soft Limit: Very Unlikely (< 10%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%) for current catch and combined TACCs

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-structured Bayesian stock assessment implemented with Stock Synthesis software and uncertainty estimated by MCMC	
Assessment Dates	Latest assessment Plenary publication year: 2023	Next assessment: 2026
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Commercial catch - Estimates of biological parameters (e.g., growth, length-weight, maturity) - Standardised CPUE index of abundance - Proportions-at-age data from the commercial fisheries	1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	Partial quantitative stock assessment replaced by full quantitative stock assessment. Event-based trawl CPUE indices replaced with Daily index in the base case.	
Major Sources of Uncertainty	- The extent of the recent increase in the CPUE indices - Insufficient age data to corroborate recent year class strengths	

Qualifying Comments
The HOK-SKI target index was restricted to the Bay of Plenty and FMA 2 due to reduced fisheries off east Northland and the west coast and therefore may not be indexing the whole stock. Stock relationship between SKI 1 and SKI 2. The current assessment assumes equivalent population dynamics for fish in the two areas, mediated by differences in fishery selectivity.

Fishery Interactions
Gemfish are common bycatch in the hoki, tarakihi, rubyfish, and scampi target fisheries and are also taken in gemfish target fishing. Bycatch of gemfish target fishing is variable but includes hoki and tarakihi.

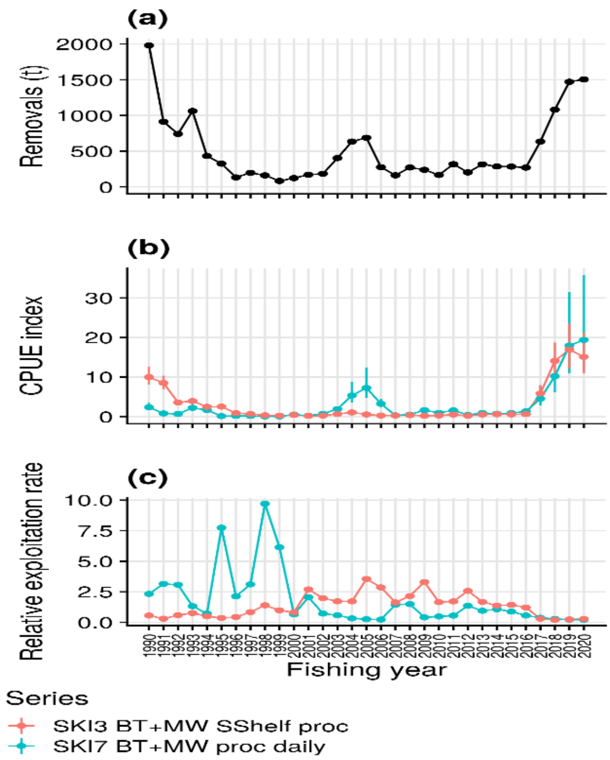
- **SKI 3 & 7**

Updated CPUE analyses were conducted for SKI 3 & 7 in 2021.

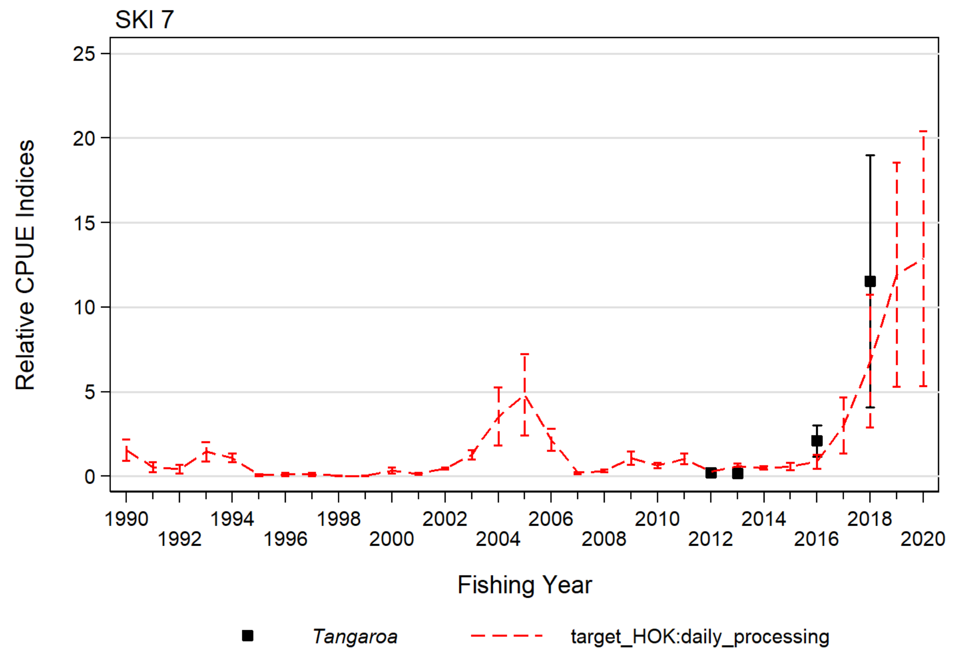
Stock Status		
Most Recent Assessment Plenary Publication	2021	
Catch in most recent year of assessment	Year: 2019–20	Catch: 1 452 t

Assessment Runs Presented	Standardised CPUE indices (SKI 7 target HOK daily process CPUE and SKI 3 Stewart-Snares shelf daily process CPUE), and *Tangaroa* WCSI trawl surveys (2012–2018).
Reference Points	Target: 40% SB_0 Soft Limit: 20% SB_0 Hard Limit: 10% SB_0 Overfishing threshold: $F_{SB40\%}$
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unlikely (< 40%) to be below
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



(a) annual removals for SKI 3 and SKI 7; (b) the standardised catch per unit effort (CPUE) indices for SKI 3 and SKI 7 from daily processing records; (c) annual relative exploitation rate (catch/CPUE) for gemfish in SKI 3 and SKI 7 implied by the two CPUE indices.



Daily processing combined delta-lognormal CPUE indices showing approximate 95% confidence intervals for the SKI 7 HOK target fishery and *Tangaroa* WCSI trawl survey.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass has increased about ten-fold from 2015 following improved recruitment.
Recent Trend in Fishing Intensity or Proxy	Catches have increased with increased biomass over the last few years. Fishing intensity has decreased since about 2015.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	The length compositions from the recent east and west coast South Island *Kaharoa* trawl surveys revealed three consecutive year classes that have started to recruit to the commercial fishery. Recent length frequencies from the commercial fishery indicate one or two additional year classes have begun recruiting to the fishery in 2019 and 2020.

Projections and Prognosis	
Stock Projections or Prognosis	Given recent recruitments, stock size is likely to increase over the short term (1–3 years).
Probability of Current Catch or TACC causing biomass to remain below or to decline below Limits	Current Catch or TACC Soft Limit: Unknown Hard Limit: Unlikely (< 40%)
Probability of Current Catch or TACC causing overfishing to continue or to commence	TACC: Unknown Current catch: Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE indices, trawl survey biomass indices	
Assessment Dates	Latest assessment Plenary publication year: 2021	Next assessment: 2024
Overall assessment of quality rank	1 – High Quality	
Main data inputs (rank)	- Commercial catch history	1 – High Quality

	- CPUE indices - *Tangaroa* trawl survey abundance estimates - Recent commercial length frequency	1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	*Kaharoa* trawl surveys CPUE series based on event or daily roll-up CPUE series based on observer data CPUE series for Banks area	2 – Medium or Mixed Quality: recruitment index only 2 – Medium or Mixed Quality: affected by limitations of species reporting requirements 2 – Medium or Mixed Quality: shorter series with patchy coverage 2 – Medium or Mixed Quality: not adult population
Changes to Model Structure and Assumptions	- The 2021 CPUE analyses were extended to include the catch of gemfish in a mixed target fishery on the Stewart-Snares shelf. - The Plenary accepted the CPUE series defined by the daily processing data for the SKI 7 HOK target fishery and the SKI 3 mixed species target Stewart-Snares shelf fishery.	
Major Sources of Uncertainty	- Reliability of CPUE (potentially biased low) in late 1990s when catches were very low - Although the CPUE indices and trawl survey biomass indices indicate that stock abundance has increased considerably in recent years, the indices do not provide an estimate of the size of current stock biomass relative to historical (unfished) levels (SSB_0). - The scale of the increase in biomass relative to the lowest observed levels, based on the recent CPUE indices, is poorly determined. - Although it is thought that gemfish reside on the Stewart-Snares shelf and migrate to the west coast of the South Island to spawn, it is not known if there are other spawning areas. There are recruiting gemfish off the west and east coasts of the South Island, and the relationship of the latter populations to the main population of southern gemfish is not known. - The magnitude of the recent increase in stock biomass is dependent on the strength of the recent year classes which are poorly determined.	

Qualifying Comments
- The *Kaharoa* WCSI trawl survey monitors the juvenile component of the stock. The survey does not fully monitor the adult component of the stock due to the timing and limited depth range of the survey. - The time series of WCSI *Tangaroa* trawl surveys is short. - Standardised CPUE indices from the WCSI hoki fishery are likely to be influenced by changes in the operation of the hoki fishery.

Fishery Interactions
Gemfish is predominantly caught as a bycatch of the WCSI hoki fishery (SKI 7) and the Southland squid trawl fishery (SKI 3). There is also a catch of gemfish taken by the WCSI inshore trawl fishery (SKI 7). The associated species in these fisheries are the same as for the relevant target fisheries (e.g., squid and hoki).

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