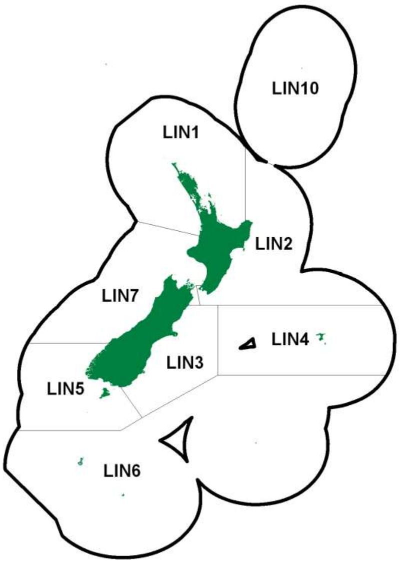
LING

(*Genypterus blacodes*)
Hoka



1. FISHERY SUMMARY

Ling was introduced into the Quota Management System on 1 October 1986. TACs, TACCs, and allowances as of 1 October 2021 are given in Table 1.

Table 1: TACs (t), TACCs (t) and allowances (t) for ling.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other sources of mortality	TACC	TAC
LIN 1	40	20	3	400	463
LIN 2	–	–	–	982	–
LIN 3	0	0	0	2 060	2 060
LIN 4	0	0	0	4 200	4 200
LIN 5	1	1	97	4 735	4 834
LIN 6	0	0	85	8 505	8 590
LIN 7	1	2	68	3 387	3 458
Total	42	22	–	23 182	22 493

1.1 Commercial fisheries

Ling was introduced into the Quota Management System (QMS) on 1 October 1986. Ling are widely distributed throughout the middle depths (200–800 m) of the New Zealand EEZ, particularly south of latitude 40° S. From 1975 to 1980 there was a substantial longline fishery on the Chatham Rise (and to a lesser extent in other areas) carried out by Japanese and Korean longliners. Since 1980 ling have been caught by large trawlers, both domestic and foreign owned, and by small domestic longliners and trawlers. In the early 1990s the domestic fleet was increased by the addition of several larger longliners with autoline equipment, resulting in a large increase in the catches of ling off the east and south of South Island (LIN 3, 4, 5, and 6). Following the 2000–01 fishing year there was a declining trend in catches taken by longline vessels in most areas, offset, to some extent, by increased trawl landings. Potting for ling in LIN 3&4 represented less than 1% of the catch up until 2013; since then, the use of this method has increased, and potting represented 15% of the catch in that area over the 2019–2021 fishing years.

The principal grounds for smaller domestic vessels are off the west coast of South Island (WCSI) and the east coast of both main islands south of East Cape. For the large trawlers the main sources of ling are Puysegur Bank and the slope of the Stewart-Snares shelf and waters in the Auckland Islands area, and the Chatham Rise, primarily as bycatch of target fisheries for hoki. Longliners fish mainly in LIN 3, 4, 5, and 6.

Under the Adaptive Management Programme (AMP), the TACC for LIN 1 was increased to 400 t from 1 October 2002, and it remained at this level when LIN 1 was removed from the AMP on 30 September 2009. In a proposal for the 1994–95 fishing year, TACCs for LIN 3 and 4 were increased to 2810 t and 5720 t, respectively. These stocks were removed from the AMP from 1 October 1998, with TACCs maintained at the increased level. However, from 1 October 2000, the TACCs for LIN 3 and 4 were reduced to 2060 t and 4200 t, respectively. From 1 October 2004, the TACCs for LIN 5 and LIN 6 were increased by about 20% to 3595 t and 8505 t, respectively, and the LIN 5 was increased by a further 10% (to 3955 t) from 1 October 2013. From 1 October 2009, the TACC for LIN 7 was increased from 2225 t to 2474 t, and further increased to 3080 t from 1 October 2013. All other TACC increases since 1986–87 in all stocks are the result of quota appeals. From 1 October 2018, a TACC of 4735 t applies for LIN 5, and from 1 October 2019 a TACC of 3387 t applies for LIN 7.

In 2020–21, landings from Fishstocks LIN 2, LIN 3, LIN 4, and LIN 6 were substantially lower than their TACCs; the LIN 1 and LIN 7 catches were slightly under the TACCs; and the LIN 5 catch was slightly over the TACC. Reported landings for the main QMAs from 1931 to 1982 are given in Table 2.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	LIN 1	LIN 2	LIN 3	LIN 4	LIN 5	LIN 6	LIN 7
1931–32	0	0	11	0	1	0	0
1932–33	0	63	14	0	2	0	35
1933–34	0	146	59	0	1	0	67
1934–35	0	217	70	0	1	0	94
1935–36	0	146	124	0	1	0	66
1936–37	0	133	103	0	1	0	61
1937–38	0	91	320	0	1	0	57
1938–39	0	66	280	0	24	0	37
1939–40	0	40	320	0	16	0	26
1940–41	1	85	286	0	21	0	46
1941–42	0	64	308	0	22	0	40
1942–43	0	54	254	0	24	0	29
1943–44	0	83	264	0	19	0	40
1944	0	103	224	0	13	0	46
1945	1	122	199	0	13	0	80
1946	0	153	348	0	9	0	78
1947	0	203	474	0	24	0	96
1948	0	120	403	0	24	0	66
1949	0	108	402	0	20	0	67
1950	0	84	352	0	29	0	61
1951	0	60	230	0	16	0	34
1952	0	69	235	0	16	0	36
1953	0	62	212	0	19	0	34
1954	0	75	208	0	7	0	44
1955	0	48	160	0	6	0	27
1956	0	27	155	0	4	0	15
1957	0	34	175	0	8	0	19
1958	0	43	178	0	15	0	28
1959	0	39	157	0	13	0	27
1960	0	26	196	0	21	0	19
1961	0	25	230	0	20	0	19
1962	1	27	211	0	13	0	16
1963	1	17	213	0	14	0	11
1964	1	20	223	0	16	0	13
1965	1	21	195	0	24	0	13
1966	5	52	141	0	16	0	17
1967	7	40	106	0	14	0	36
1968	7	55	88	0	11	0	42
1969	5	52	154	0	10	0	23
1970	6	67	167	0	14	0	51
1971	4	49	203	0	20	1	37
1972	6	37	522	6	22	0	33
1973	18	73	1 425	0	23	0	41
1974	9	102	575	42	335	44	82
1975	3	70	1 770	15	1 513	344	224
1976	2	60	1 567	14	2 630	0	1 739
1977	9	100	1 149	466	1 683	0	2 810
1978	24	144	487	0	2 515	391	240
1979	82	228	799	246	4 400	1 431	454
1980	114	205	265	182	4 064	933	928
1981	208	429	427	444	3 576	636	1 020
1982	320	625	924	435	2 109	317	1 208

Reported landings by nation from 1975 to 1987–88 are given in Table 3, and reported landings by Fishstock from 1983–84 onwards are given in Table 4. Figure 1 shows the historical landings and TACC values for the main LIN stocks.

Table 3: Reported landings (t) from 1975 to 1987–88. Data from 1975 to 1983 from MAF; data from 1983–84 to 1985–86 from FSU; data from 1986–87 to 1987–88 from QMS. –, no data available.

Fishing year	New Zealand			Foreign Licensed					Grand total
				Longline	Trawl				
	Domestic	Chartered	Total	(Japan + Korea)	Japan	Korea	USSR	Total	
1975*	486	0	486	9 269	2 180	0	0	11 499	11 935
1976*	447	0	447	19 381	5 108	0	1 300	25 789	26 236
1977*	549	0	549	28 633	5 014	200	700	34 547	35 096
1978–79#	657	24	681	8 904	3 151	133	452	12 640	13 321
1979–80#	915	2 598	3 513	3 501	3 856	226	245	7 828	11 341
1980–81#	1 028	–	–	–	–	–	–	–	–
1981–82#	1 581	2 423	4 004	0	2 087	56	247	2 391	6 395
1982–83#	2 135	2 501	4 636	0	1 256	27	40	1 322	5 958
1983†	2 695	1 523	4 218	0	982	33	48	1 063	5 281
1983–84§	2 705	2 500	5 205	0	2 145	173	174	2 491	7 696
1984–85§	2 646	2 166	4 812	0	1 934	77	130	2 141	6 953
1985–86§	2 126	2 948	5 074	0	2 050	48	33	2 131	7 205
1986–87§	2 469	3 177	5 646	0	1 261	13	21	1 294	6 940
1987–88§	2 212	5 030	7 242	0	624	27	8	659	7 901

* Reported by calendar year.
\# Reported April 1 to March 31(except domestic vessels, which reported by calendar year).
† Reported April 1 to September 30 (except domestic vessels, which reported by calendar year).
§ Reported October 1 to September 30.

Table 4: Reported landings (t) of ling by Fishstock from 1983–84 to present and actual TACCs (t) from 1986–87 to present. Estimated landings for LIN 7 from 1987–88 to 1992–93 include an adjustment for ling bycatch of hoki trawlers, based on records from vessels carrying observers. QMS data from 1986-present. [Continued on next page]

Fishstock	LIN 1		LIN 2		LIN 3		LIN 4		LIN 5	
FMA (s)	1 & 9		2		3		4		5	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	141	–	594	–	1 306	–	352	–	2 605	–
1984–85*	94	–	391	–	1 067	–	356	–	1 824	–
1985–86*	88	–	316	–	1 243	–	280	–	2 089	–
1986–87	77	200	254	910	1 311	1 850	465	4 300	1 859	2 500
1987–88	68	237	124	918	1 562	1 909	280	4 400	2 213	2 506
1988–89	216	237	570	955	1 665	1 917	232	4 400	2 375	2 506
1989–90	121	265	736	977	1 876	2 137	587	4 401	2 277	2 706
1990–91	210	265	951	977	2 419	2 160	2 372	4 401	2 285	2 706
1991–92	241	265	818	977	2 430	2 160	4 716	4 401	3 863	2 706
1992–93	253	265	944	980	2 246	2 162	4 100	4 401	2 546	2 706
1993–94	241	265	779	980	2 171	2 167	3 920	4 401	2 460	2 706
1994–95	261	265	848	980	2 679	2 810	5 072	5 720	2 557	3 001
1995–96	245	265	1 042	980	2 956	2 810	4 632	5 720	3 137	3 001
1996–97	313	265	1 187	982	2 963	2 810	4 087	5 720	3 438	3 001
1997–98	303	265	1 032	982	2 916	2 810	5 215	5 720	3 321	3 001
1998–99	208	265	1 070	982	2 706	2 810	4 642	5 720	2 937	3 001
1999–00	313	265	983	982	2 799	2 810	4 402	5 720	3 136	3 001
2000–01	296	265	1 105	982	2 330	2 060	3 861	4 200	3 430	3 001
2001–02	303	265	1 034	982	2 164	2 060	3 602	4 200	3 295	3 001
2002–03	246	400	996	982	2 529	2 060	2 997	4 200	2 939	3 001
2003–04	249	400	1 044	982	1 990	2 060	2 618	4 200	2 899	3 001
2004–05	283	400	936	982	1 597	2 060	2 758	4 200	3 584	3 595
2005–06	364	400	780	982	1 711	2 060	1 769	4 200	3 522	3 595
2006–07	301	400	874	982	2 089	2 060	2 113	4 200	3 731	3 595
2007–08	381	400	792	982	1 778	2 060	2 383	4 200	4 145	3 595
2008–09	320	400	634	982	1 751	2 060	2 000	4 200	3 232	3 595
2009–10	386	400	584	982	1 718	2 060	2 026	4 200	3 034	3 595
2010–11	438	400	670	982	1 665	2 060	1 572	4 200	3 856	3 595
2011–12	384	400	504	982	1 292	2 060	2 305	4 200	3 649	3 595
2012–13	383	400	579	982	1 475	2 060	2 181	4 200	3 610	3 595
2013–14	380	400	673	982	1 442	2 060	2 373	4 200	3 935	3 955
2014–15	374	400	673	982	1 325	2 060	2 246	4 200	3 924	3 955
2015–16	422	400	702	982	1 440	2 060	2 659	4 200	3 868	3 955
2016–17	404	400	1 022	982	1 808	2 060	2 565	4 200	3 356	3 955
2017–18	415	400	1 106	982	2 171	2 060	2 636	4 200	4 034	3 955
2018–19	383	400	939	982	2 016	2 060	2 044	4 200	4 596	4 735
2019–20	371	400	756	982	1 685	2 060	1 778	4 200	4 678	4 735
2020–21	319	400	645	982	1 489	2 060	2 103	4 200	4 950	4 735

Table 4 [Continued]

Fishstock	LIN 6		LIN 7			LIN 10			Total
FMA (s)	6		7 & 8			10			
	Landings	TACC	Reported Landings	Estimated Landings	TACC	Landings	TACC	Landings§	TACC
1983–84*	869	–	1 552	–	–	0	–	7 696	–
1984–85*	1 283	–	1 705	–	–	0	–	6 953	–
1985–86*	1 489	–	1 458	–	–	0	–	7 205	–
1986–87	956	7 000	1 851	–	1 960	0	10	6 940	18 730
1987–88	1 710	7 000	1 853	1 777	2 008	0	10	7 901	18 988
1988–89	340	7 000	2 956	2 844	2 150	0	10	8 404	19 175
1989–90	935	7 000	2 452	3 171	2 176	0	10	9 028	19 672
1990–91	2 738	7 000	2 531	3 149	2 192	< 1	10	13 506	19 711
1991–92	3 459	7 000	2 251	2 728	2 192	0	10	17 778	19 711
1992–93	6 501	7 000	2 475	2 817	2 212	< 1	10	19 065	19 737
1993–94	4 249	7 000	2 142	–	2 213	0	10	15 961	19 741
1994–95	5 477	7 100	2 946	–	2 225	0	10	19 841	22 111
1995–96	6 314	7 100	3 102	–	2 225	0	10	21 428	22 111
1996–97	7 510	7 100	3 024	–	2 225	0	10	22 522	22 113
1997–98	7 331	7 100	3 027	–	2 225	0	10	23 145	22 113
1998–99	6 112	7 100	3 345	–	2 225	0	10	21 034	22 113
1999–00	6 707	7 100	3 274	–	2 225	0	10	21 615	22 113
2000–01	6 177	7 100	3 352	–	2 225	0	10	20 552	19 843
2001–02	5 945	7 100	3 219	–	2 225	0	10	19 561	19 843
2002–03	6 283	7 100	2 918	–	2 225	0	10	18 903	19 978
2003–04	7 032	7 100	2 926	–	2 225	0	10	18 760	19 978
2004–05	5 506	8 505	2 522	–	2 225	0	10	17 189	21 977
2005–06	3 553	8 505	2 479	–	2 225	0	10	14 184	21 977
2006–07	4 696	8 505	2 295	–	2 225	0	10	16 102	21 977
2007–08	4 502	8 505	2 282	–	2 225	0	10	16 264	21 977
2008–09	2 977	8 505	2 223	–	2 225	0	10	13 137	21 977
2009–10	2 414	8 505	2 446	–	2 474	0	10	12 609	22 226
2010–11	1 335	8 505	2 800	–	2 474	0	10	12 337	22 226
2011–12	2 047	8 505	2 771	–	2 474	0	10	12 953	22 226
2012–13	3 102	8 505	3 010	–	2 474	0	10	14 339	22 226
2013–14	3 221	8 505	3 200	–	3 080	0	10	15 224	23 192
2014–15	3 115	8 505	3 343	–	3 080	0	10	15 002	23 192
2015–16	2 222	8 505	3 340	–	3 080	0	10	14 654	23 192
2016–17	2 473	8 505	3 428	–	3 080	0	10	15 056	23 192
2017–18	4 846	8 505	3 487	–	3 080	0	10	18 694	23 192
2018–19	3 706	8 505	3 059	–	3 080	0	10	16 743	23 972
2019–20	3 972	8 505	3 216	–	3 387	< 1	10	16 456	24 279
2020–21	3 916	8 505	3 308		3 387	< 1	10	16 730	24 279

* FSU data.
§ Includes landings from unknown areas before 1986–87, and areas outside the EEZ since 1995–96.

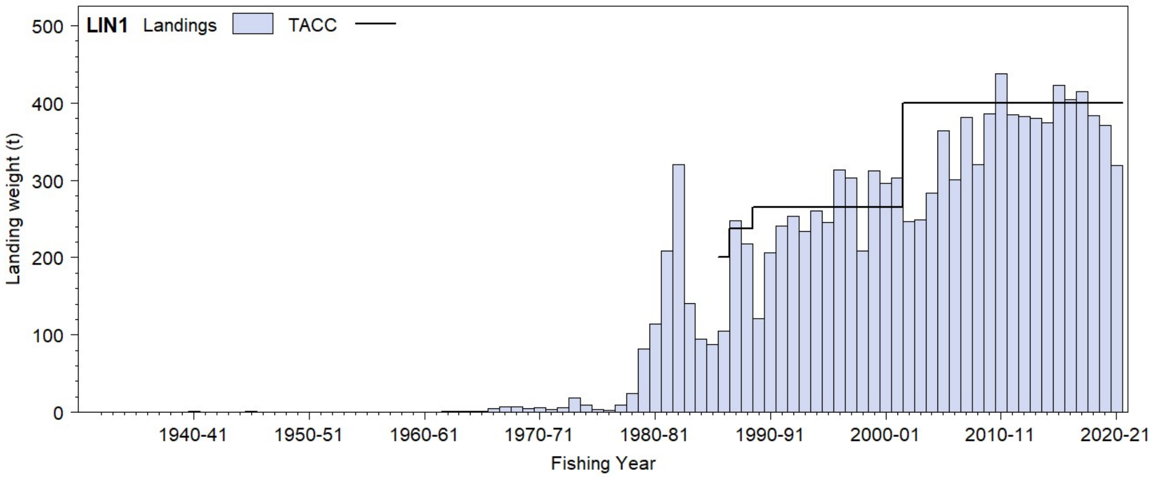


Figure 1: Reported commercial landings and TACC for the seven main LIN stocks. LIN 1 (Auckland East). [Continued on next page]

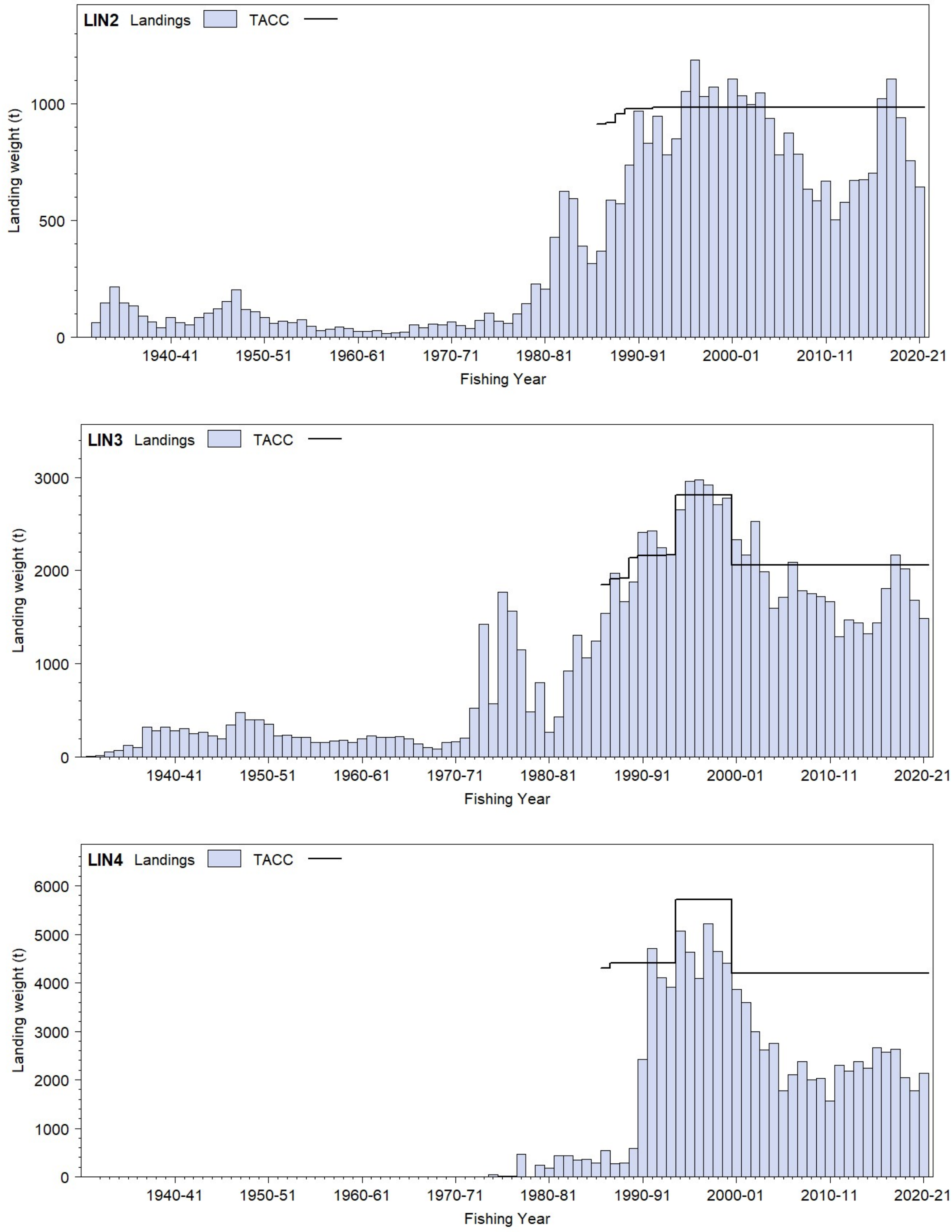


Figure 1: [Continued] Reported commercial landings and TACC for the seven main LIN stocks. From top to bottom: LIN 2 (Central East), LIN 3 (South East Coast), and LIN 4 (South East Chatham Rise). [Continued on next page]

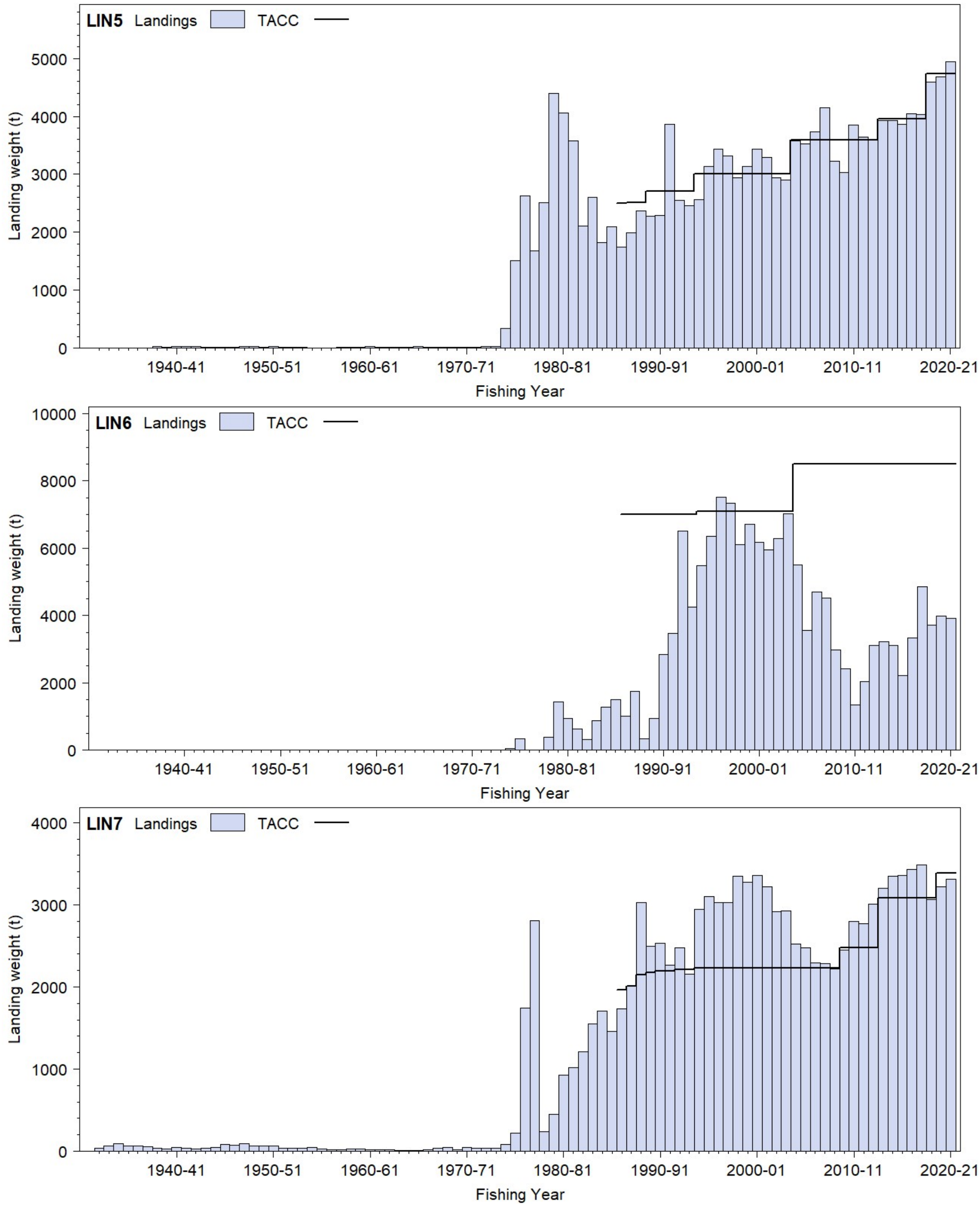


Figure 1: [Continued] Reported commercial landings and TACC for the seven main LIN stocks. From top to bottom: LIN 5 (Southland), LIN 6 (Sub-Antarctic), and LIN 7 (Challenger).

1.2 Recreational fisheries

The 1993–94 North region recreational fishing survey (Bradford 1996) estimated the annual recreational catch from LIN 1 as 10 000 fish (CV 0.23). With a mean weight likely to be in the range of 1.5 to 4 kg, this equates to a harvest of 15–40 t. Recreational catch was recorded from LIN 1, 5, and 7 in the 1996 national diary survey. The estimated harvests (LIN 1, 3000 fish; LIN 5, less than 500; LIN 7, less than 500) were too low to provide reliable estimates.

The harvest estimates provided by telephone/diary surveys between 1993 and 2001 are no longer considered reliable for various reasons. 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. 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 (Wynne-Jones et al 2014). The panel members were contacted regularly about their fishing activities and harvest information collected in standardised phone interviews. The national panel survey was repeated during the 2017–18 fishing year using very similar methods to produce directly comparable results (Wynne-Jones et al 2019). In 2011–12, only three fishers reported catching ling in LIN 1 (4 trips) and only four fishers reported catching ling in LIN 2 (5 trips). In 2017–18, only two fishers reported catching ling in LIN 2 (2 trips), one fisher reported catching ling in LIN 3 (1 trip), and three fishers reported catching ling in LIN 7 (3 trips). Estimates of total nationwide catch were 1334 and 320 fish in 2011–12 and 2017–18, respectively, both with wide CVs. Note that national panel survey estimates do not include recreational harvest taken under s111 general approvals.

1.3 Customary non-commercial fisheries

Quantitative information on the level of Māori customary non-commercial take is not available. Ling bones have been recovered from archaic middens throughout the South Island and southern North Island, and on Chatham Island (Leach & Boocock 1993). In the South Island and Chatham Island, ling comprised about 4% (by number) of recovered fish remains.

1.4 Illegal catch

It is believed that up to the mid-1990s some ling bycatch from the west coast hoki fishery was not reported. Estimates of total catch including non-reported catch are given in Table 4 for LIN 7. It is believed that in the early 1990s, some catch from LIN 7 was reported against other ling stocks (probably LIN 3, 5, and 6). The likely levels of misreporting are moderate, being about 250–400 t in each year from 1989–90 to 1991–92 (Dunn 2003).

1.5 Other sources of mortality

There is likely to be some mortality associated with escapement from trawl nets, mostly from small fish that can escape through the trawl mesh. The mortality of ling associated with escapement is not known. In the Sub-Antarctic, the catch and effort records for ling suggest that small ling are uncommon in areas where the hoki/hake/ling fishery occurs with only very low proportions of small ling recorded by observers (Mormede et al 2021a). Hence the level of mortality of ling associated with escapement is likely to be low over the history of the fishery and is assumed to be negligible. The other sources of mortality from the longline fishery are likely to be insignificant.

2. BIOLOGY

The maximum age recorded for New Zealand ling is 46 years, although only 0.5% of successfully aged ling have been older than 30 years. A growth study of ling from five areas (west coast South Island, Chatham Rise, Bounty Plateau, Campbell Plateau, and Cook Strait) showed that females grew significantly faster and reached a greater size than males in all areas, and that growth rates were significantly different between areas. Ling grow fastest in Cook Strait and slowest on the Campbell Plateau (Horn 2005).

M was initially estimated from the equation $M = \log_e 100$/maximum age, where maximum age is the age to which 1% of the population survives in an unexploited stock. The mean M calculated from five samples of age data was 0.18 (range = 0.17–0.20) (Horn 1993). However, a review of M and results of modelling conducted in 2007 suggested that this parameter may vary between stocks (Horn 2008). The M for Chatham Rise ling was estimated to be lower than 0.18, whereas for Cook Strait and west coast South Island the value was potentially higher than 0.18. M was evaluated again in 2017 (Edwards 2017). In the new study all available life-history data were re-analysed and sex-specific M values derived. For a variety of reasons female M values were estimated with much greater confidence than those for males, the results for females being: west coast South Island 0.15, Cook Strait 0.12, Chatham Rise 0.13, and Sub-Antarctic 0.16. However, all credibility intervals overlapped such that assuming a common value of 0.14 in all areas was also credible. M has been estimated in assessment model runs for some stocks (see section 4).

Ling in spawning condition have been reported in a number of localities throughout the EEZ (Horn 2005, 2015). Time of spawning appears to vary between areas: August to October on the Chatham Rise, September to December on Campbell Plateau and Puysegur Bank, September to February on the Bounty Plateau, and July to September off west coast South Island and in Cook Strait. Little is known about the distribution of juveniles until they are about 40 cm total length, when they begin to appear in trawl samples over most of the adult range.

Ling appear to be mainly bottom dwellers, feeding on crustaceans such as *Munida* and scampi and also on fish, with commercial fishing discards being a significant dietary component (Dunn et al 2010). However, they may at times be caught well above the bottom, for example when feeding on hoki during the hoki spawning season.

Biological parameters relevant to the stock assessment are shown in Table 5. These were updated in 2021 for LIN 5&6 (Mormede et al 2021a), and in 2022 for LIN 3&4 (Mormede et al in prep a), and showed no indication of change in the length-weight or growth parameters over time for LIN 3&4 or LIN 5&6.

Table 5: Estimates of biological parameters. See section 3 for definitions of Fishstocks.

1. Natural mortality

	Both
FMA	
All stocks	0.18

2. Weight = *a* (length)^{b} (Weight in g, length in cm total length)

			Male		Combined		Area
FMA	*a*	*b*	*a*	*b*	*a*	*b*	
LIN 3&4	0.0013	3.271	0.00128	3.294	–	–	Chatham Rise
LIN 5&6	0.0013	3.293	0.00213	3.179	–	–	Southern
LIN 6B	0.0011	3.318	0.001	3.354	–	–	Bounty Plateau
LIN 7W	0.0009	3.368	0.001146	3.318	0.0010	3.318	West Coast S.I.
LIN 7CK	0.0009	3.368	0.001146	3.318	–	–	Cook Strait

3. von Bertalanffy growth

	Female				Male				Combined			Area
FMA	*K*	t_0	L_∞	CV	*K*	t_0	L_∞	CV	*K*	t_0	L_∞	
LIN 3&4	0.090	-0.71	153.3	0.09	0.130	-0.65	112.2	0.09	–	–	–	Chatham Rise
LIN 5&6	0.14	-1.09	111.2	0.08	0.14	-0.71	91.2	0.07	–	–	–	Southern Plateau
LIN 6B	0.101	-0.53	146.2		0.141	0.02	120.5		–	–	–	Bounty Plateau
LIN 7WC	0.078	-0.87	169.3		0.067	-2.37	159.9		0.07	-1.5	168.5	West Coast S.I.
LIN 7CK	0.097	-0.54	163.6		0.08	-1.94	158.9		–	–	–	Cook Strait

3. STOCKS AND AREAS

A review of ling stock structure (Horn 2005) examined diverse information from studies of morphometrics, genetics, growth, population age structures, and reproductive biology and behaviour, and indicated that there are at least five ling stocks, i.e., west coast South Island, Chatham Rise, Cook Strait, Bounty Plateau, and the Southern Plateau (including the Stewart-Snares shelf and Puysegur Bank). Stock affinities of ling north of Cook Strait are unknown, but spawning is known to occur off Northland, Cape Kidnappers, and in the Bay of Plenty.

An analysis of the length and sex structure in space of ling suggested LIN 6B could be considered a part of the LIN 5&6 stock but did not suggest any other changes to the stock structured proposed above (Mormede et al 2021a).

4. STOCK ASSESSMENT

LIN 1 was previously managed and assessed under the Adaptive Management Programme, and the stocks off the east and west coasts (LIN 1E and LIN 1W) have been assessed separately. An updated CPUE analysis for the eastern part of the stock (LIN 1E) was attempted in 2020 but was not accepted as an index of abundance due to sparse data, the influence of vessels with particularly low catch rates in the early part of the series, and inconsistent trends in different statistical areas. A CPUE analysis for the ling target bottom longline fishery in LIN 2 was conducted in 2014. The characterisation and stock assessments for the ling stock in LIN 3&4 (Chatham Rise) was updated in 2022, and that for LIN 5&6 (Sub-Antarctic) was last updated in 2021. Assessments for other stocks were updated in 2007 (LIN 6B, Bounty Plateau, with a CPUE update in 2014), 2010 (LIN 7CK, Cook Strait, with an assessment in 2013 rejected), and 2020 (LIN 7WC, west coast South Island). All assessments (excluding LIN 1 and LIN 2) were updated using a Bayesian stock model implemented using the general-purpose stock assessment program CASAL (Bull et al 2012). The stock assessment of ling in LIN 5&6 was also run in Stan (Webber et al 2021).

Catch histories by stock and fishery are presented in Table 6, and other model input parameters are given in Table 7. Estimates of relative abundance from standardised CPUE analyses (Table 8) and trawl surveys (Table 9) are also presented below.

In 2022, the Deepwater Working Group recommended that the model year start for all current and future ling assessments be set at 1st January, matching the calendar year. This matches the biology and fisheries better and allows uniformity in the assessments rather than a different model year for each stock.

Table 6: Estimated catch histories (t) for LIN 2 (ECNI), LIN 3&4 (Chatham Rise), LIN 5&6 (Campbell Plateau), LIN 6B (Bounty Platform), LIN 7WC (WCSI section of LIN 7), and LIN 7CK (Cook Strait). Landings have been separated by fishing method (trawl or longline). The catch histories for LIN 5&6 are expressed in model years, whereby 1990 is the model year from 1st September 1989 to 31st August 1990. The catch histories for LIN 3&4 are expressed in calendar year. '–' denotes no update to the stock assessment and therefore catch histories. [Continued on next page]

	LIN 2		LIN 3&4			LIN 5&6		LIN 6B	LIN 7WC		LIN 7CK	
Year	trawl	line	trawl	line	pot	trawl	line	line	trawl	line	trawl	line
1972	–	–	0	0	0	0	0	0	0	0	0	0
1973	–	–	250	0	0	500	0	0	85	20	45	45
1974	–	–	382	0	0	1 120	0	0	144	40	45	45
1975	–	–	953	8 439	0	900	118	0	401	800	48	48
1976	–	–	2 100	17 436	0	3 402	190	0	565	2 100	58	58
1977	–	–	2 055	23 994	0	3 100	301	0	715	4 300	68	68
1978	–	–	1 400	7 577	0	1 945	494	10	300	323	78	78
1979	–	–	2 380	821	0	3 707	1 022	0	539	360	83	83
1980	–	–	1 340	360	0	5 200	0	0	540	305	88	88
1981	–	–	673	160	0	4 427	0	10	492	300	98	98
1982	–	–	1 183	339	0	2 402	0	0	675	400	103	103
1983	–	–	1 210	326	0	2 778	5	10	1 040	710	97	97
1984	–	–	1 366	406	0	3 203	2	6	924	595	119	119
1985	–	–	1 351	401	0	4 480	25	2	1 156	302	116	116
1986	–	–	1 494	375	0	3 182	2	0	1 082	362	126	126
1987	–	–	1 313	306	0	3 962	0	0	1 105	370	97	97
1988	–	–	1 636	290	0	2 065	6	0	1 428	291	107	107
1989	–	–	1 397	488	0	2 923	10	9	1 959	370	255	85
1990	85	134	3 170	243	2	2 795	11	12	2 205	399	362	121
1991	162	185	3 979	1 786	16	4 311	187	33	2 163	364	488	163
1992	110	299	3 851	3 388	37	6 229	637	908	1 631	661	498	85
1993	97	381	2 836	3 963	13	7 445	1 280	969	1 609	716	307	114
1994	96	397	2 374	4 241	11	4 475	1 066	1 149	1 136	860	269	84
1995	97	398	2 680	5 391	7	6 060	2 497	396	1 750	1 032	344	70
1996	149	350	3 375	4 699	1	6 194	1 932	381	1 838	1 121	392	35
1997	168	269	3 901	4 182	38	7 394	3 386	340	1 749	1 077	417	89
1998	148	387	5 140	3 299	40	7 278	3 932	395	1 887	1 021	366	88
1999	169	257	4 306	2 994	41	5 364	2 887	563	2 146	1 069	316	216
2000	166	286	3 826	3 228	23	6 839	2 179	991	2 247	923	317	131
2001	216	344	2 941	3 082	2	7 005	2 181	1 064	2 304	977	258	80
2002	212	366	3 637	2 330	1	7 164	1 692	629	2 250	810	230	171
2003	124	344	3 563	2 150	1	7 513	1 135	922	1 980	807	280	180
2004	82	420	2 714	1 731	4	7 468	1 195	853	2 013	814	241	227
2005	54	335	2 250	2 259	10	7 562	1 153	49	1 558	871	200	282
2006	45	365	1 890	1 489	54	6 517	887	43	1 753	666	129	220
2007	87	425	2 841	1 571	55	8 021	770	236	1 306	933	107	189

Table 6 [continued]

	LIN 2		LIN 3&4			LIN 5&6		LIN 6B	LIN 7WC		LIN 7CK	
Year	**trawl**	**line**	**trawl**	**line**	**pot**	**trawl**	**line**	**line**	**trawl**	**line**	**trawl**	**line**
2008	37	457	2 432	2 034	15	7 295	1 243	503	1 067	1 170	115	110
2009	49	394	1 459	1 897	12	5 372	661	232	1 089	1 009	108	39
2010	37	409	1 530	1 973	39	4 498	1 358	1	1 346	1 063	74	14
2011	51	426	1 030	1 658	33	4 392	795	51	1 733	1 011	115	67
2012	57	288	1 470	2 087	11	4 372	1 524	2	1 744	976	96	47
2013	44	317	1 125	2 394	24	6 222	474	3	1 915	1 045	104	106
2014	78	337	1 349	2 443	58	5 856	1 195	265	1 420	1 190	71	71
2015	68	385	1 513	1 685	46	5 830	1 067	23	1 561	1 157	68	63
2016	69	386	1 551	2 695	164	5 439	816	220	1 669	1 149	52	81
2017	–	–	1 811	2 432	201	4 783	1 226	–	1 998	1 187	–	–
2018	–	–	1 330	2 870	543	7 971	1 340	–	1 940	1 230	–	–
2019	–	–	1 347	1 877	674	6 821	1 465	–	1 487	1 347	–	–
2020	–	–	1 060	1 627	402	6 565	1 988	–	–	–	–	–
2021	–	–	765	1 598	360	–	–	–	–	–	–	–

Table 7: Input parameters for the assessed stocks.

Parameter	**LIN 3&4**	**LIN 5&6**	**LIN 6B**	**LIN 7WC**	**LIN 7CK**
Stock-recruitment steepness	0.84	0.84	0.9	0.84	0.9
Recruitment variability CV	0.6	0.6	1.0	0.7	0.7
Ageing error CV	0.05	0.06	0.05	0.1	0.07
Proportion male at birth	0.5	0.5	0.5	0.5	0.5
Proportion of mature that spawn	1.0	1.0	1.0	1.0	1.0
Maximum exploitation rate (U_{max})	0.6	0.6	0.6	0.6	0.6

Maturity ogives (from Horn 2005)

Age	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
LIN 3&4 (and assumed for LIN 6B)													
Male	0.0	0.03	0.063	0.14	0.28	0.48	0.69	0.85	0.93	0.97	0.99	1.00	1.0
Female	0.0	0.00	0.003	0.01	0.014	0.033	0.08	0.16	0.31	0.54	0.76	0.93	1.0
LIN 5&6													
Male	0.0	0.00	0.10	0.30	0.50	0.80	1.00	1.00	1.00	1.00			
Female	0.0	0.00	0.05	0.10	0.30	0.50	0.80	1.00	1.00	1.00			
LIN 7WC (and assumed for LIN7CK)													
Male	0.0	0.015	0.095	0.39	0.77	0.94	1.00	1.00	1.00	1.00			
Female	0.0	0.004	0.017	0.06	0.18	0.39	0.65	0.85	0.94	1.00			
Combined	0.0	0.010	0.056	0.23	0.48	0.67	0.83	0.93	0.97	1.00			

Table 8: Standardised CPUE indices (with CVs) for the ling longline and trawl fisheries. Year refers to calendar year, apart from LIN 5&6 where year refers to model year (1st September to 31st August). '–' denotes no update to the stock assessment and therefore catch histories. Note that the LIN 3&4 line CPUE was not standardised to 1 to avoid minimisation issues in CASAL (Mormede et al 2021b, Webber et al 2021) but instead expressed in standardised catch in kilograms per hook. [Continued on next page]

	LIN 2 line		LIN 3&4 line		LIN 5&6 line		LIN 6B line	
Year	**CPUE**	**CV**	**CPUE**	**CV**	**CPUE**	**CV**	**CPUE**	**CV**
1991	–	–	6 520	0.03	1.18	0.08	–	–
1992	1.64	0.09	9 090	0.02	1.09	0.06	1.74	0.15
1993	1.40	0.08	6 520	0.02	1.42	0.04	1.41	0.13
1994	1.55	0.09	6 010	0.02	1.42	0.04	0.95	0.16
1995	1.54	0.07	5 450	0.03	1.28	0.04	1.24	0.13
1996	1.34	0.07	4 350	0.03	1.11	0.05	1.15	0.12
1997	1.29	0.07	2 830	0.04	1.34	0.04	0.92	0.14
1998	1.27	0.07	2 810	0.04	1.14	0.04	1.06	0.12
1999	1.13	0.07	2 430	0.05	0.87	0.05	1.07	0.11
2000	0.80	0.07	2 710	0.04	0.91	0.04	0.95	0.10
2001	0.60	0.08	2 700	0.04	1.11	0.04	0.76	0.11
2002	0.97	0.08	2 360	0.04	1.05	0.04	0.69	0.11
2003	0.88	0.07	2 640	0.04	1.14	0.04	0.78	0.10
2004	1.07	0.07	2 430	0.04	0.69	0.07	0.74	0.16
2005	1.00	0.08	2 600	0.04	0.65	0.07	–	–
2006	0.88	0.07	2 230	0.05	0.76	0.06	–	–
2007	0.95	0.07	2 400	0.04	0.90	0.07	–	–
2008	0.85	0.07	3 100	0.03	1.00	0.05	–	–
2009	0.89	0.08	2 150	0.04	0.94	0.06	–	–
2010	0.90	0.07	2 590	0.04	1.17	0.04	–	–
2011	0.82	0.06	1 900	0.05	0.78	0.05	–	–
2012	0.56	0.07	2 420	0.04	0.93	0.04	–	–
2013	0.65	0.08	2 660	0.04	0.74	0.07	–	–
2014	–	–	2 400	0.04	0.84	0.05	–	–
2015	–	–	2 150	0.05	0.85	0.05	–	–
2016	–	–	2 350	0.04	0.62	0.07	–	–
2017	–	–	2 380	0.04	0.87	0.04	–	–

Table 8 [Continued]

	LIN 2 line		LIN 3&4 line		LIN 5&6 line		LIN 6B line	
Year	**CPUE**	**CV**	**CPUE**	**CV**	**CPUE**	**CV**	**CPUE**	**CV**
2018	–	–	2 400	0.04	1.02	0.05	–	–
2019	–	–	2 170	0.05	1.06	0.04	–	–
2020	–	–	2 260	0.05	1.09	0.04	–	–
2021	–	–	3 030	0.04	–	–	–	–

	LIN 7WC line		LIN 7CK line		LIN 7CK trawl		LIN 7WC trawl	
Year	**CPUE**	**CV**	**CPUE**	**CV**	**CPUE**	**CV**	**CPUE**	**CV**
1987	0.34	0.07	–	–	–	–	0.58	0.07
1988	0.7	0.06	–	–	–	–	1.01	0.06
1989	1.45	0.07	–	–	–	–	1.43	0.07
1990	1.39	0.06	1.29	0.15	–	–	1.37	0.06
1991	0.77	0.07	1.44	0.13	–	–	0.88	0.07
1992	0.82	0.08	1.43	0.11	–	–	0.95	0.08
1993	0.96	0.08	1.11	0.11	–	–	1.10	0.07
1994	0.74	0.06	0.90	0.11	1.25	0.05	0.94	0.06
1995	1.14	0.07	0.83	0.12	1.16	0.04	1.29	0.07
1996	1.28	0.05	0.97	0.13	1.12	0.04	1.71	0.05
1997	1.24	0.06	1.32	0.18	1.00	0.04	1.62	0.06
1998	1.23	0.05	0.83	0.15	1.01	0.04	1.32	0.05
1999	1.69	0.04	1.54	0.18	1.02	0.03	1.60	0.04
2000	0.96	0.04	1.45	0.19	1.27	0.04	1.22	0.04
2001	0.99	0.04	1.27	0.18	1.46	0.04	0.98	0.04
2002	1.26	0.04	2.04	0.11	1.27	0.05	1.22	0.04
2003	0.67	0.05	1.66	0.10	1.27	0.04	0.70	0.05
2004	1.28	0.04	1.45	0.09	1.13	0.04	1.21	0.04
2005	0.95	0.04	1.16	0.10	1.18	0.04	0.83	0.04
2006	0.71	0.04	0.97	0.15	1.10	0.05	0.77	0.04
2007	0.53	0.06	0.70	0.12	0.73	0.06	0.57	0.06
2008	0.55	0.06	0.82	0.22	0.90	0.06	0.57	0.06
2009	0.42	0.06	0.60	0.28	0.44	0.07	0.54	0.06
2010	0.80	0.06	0.35	0.30	0.44	0.07	0.75	0.06
2011	1.05	0.05	0.22	0.30	0.23	0.09	1.10	0.05
2012	0.97	0.04	–	–	–	–	0.88	0.05
2013	1.04	0.03	–	–	–	–	0.98	0.03
2014	0.96	0.03	–	–	–	–	0.94	0.03
2015	1.06	0.03	–	–	–	–	1.09	0.03
2016	1.44	0.03	–	–	–	–	1.32	0.03
2017	1.05	0.03	–	–	–	–	–	–
2018	1.30	0.03	–	–	–	–	–	–
2019	1.26	0.03	–	–	–	–	–	–

Table 9: Trawl survey biomass indices (t) and estimated coefficients of variation (CV). [Continued on next page]

Fishstock	**Area**	**Vessel**	**Trip code**	**Date**	**Biomass**	**CV (%)**
LIN 3	ECSI (winter)	*Kaharoa*	KAH9105*	May–Jun 1991	1 009	35
			KAH9205*	May–Jun 1992	525	17
			KAH9306*	May–Jun 1993	651	27
			KAH9406*	May–Jun 1994	488	19
			KAH9606*	May–Jun 1996	488	21
			KAH0705*	May–Jun 2007	283	17
			KAH0806*	May–Jun 2008	351	22
			KAH0905*	May–Jun 2009	262	19
			KAH1207*	May–Jun 2012	265	21
LIN 3 & 4	Chatham Rise	*Tangaroa*	TAN9106	Jan–Feb 1992	8 930	5.8
			TAN9212	Jan–Feb 1993	9 360	7.9
			TAN9401	Jan 1994	10 130	6.5
			TAN9501	Jan 1995	7 360	7.9
			TAN9601	Jan 1996	8 420	8.2
			TAN9701	Jan 1997	8 540	9.8
			TAN9801	Jan 1998	7 310	8.0
			TAN9901	Jan 1999	10 310	16.1
			TAN0001	Jan 2000	8 350	7.8
			TAN0101	Jan 2001	9 350	7.5
			TAN0201	Jan 2002	9 440	7.8
			TAN0301	Jan 2003	7 260	9.9
			TAN0401	Jan 2004	8 250	6.0
			TAN0501	Jan 2005	8 930	9.4
			TAN0601	Jan 2006	9 300	7.4
			TAN0701	Jan 2007	7 800	7.2
			TAN0801	Jan 2008	7 500	6.8
			TAN0901	Jan 2009	10 620	11.5
			TAN1001	Jan 2010	8 850	10.0
			TAN1101	Jan 2011	7 030	13.8
			TAN1201	Jan 2012	8 098	7.4
			TAN1301	Jan 2013	8 714	10.1
			TAN1401	Jan 2014	7 489	7.2

Table 9 [continued]

Fishstock	Area	Vessel	Trip code	Date	Biomass	CV (%)
LIN 3 & 4	Chatham Rise	*Tangaroa*	TAN1601	Jan 2016	10 201	7.2
			TAN1801	Jan 2018	8 758	11.5
			TAN2001	Jan 2020	7 577	7.9
			TAN2201	Jan 2022	7 293	10.7
LIN 5 & 6	Southern Plateau	*Amaltal Explorer*	AEX8902*	Oct–Nov 1989	17 490	14.2
			AEX9002*	Nov–Dec 1990	15 850	7.5
LIN 5 & 6	Southern Plateau (summer)	*Tangaroa*	TAN9105	Nov–Dec 1992	24 090	6.8
			TAN9211	Nov–Dec 1992	21 370	6.2
			TAN9310	Nov–Dec 1993	29 750	11.5
			TAN0012	Dec 2000	33 020	6.9
			TAN0118	Dec 2001	25 060	6.5
			TAN0219	Dec 2002	25 630	10.0
			TAN0317	Nov–Dec 2003	22 170	9.7
			TAN0414	Nov–Dec 2004	23 770	12.2
			TAN0515	Nov–Dec 2005	19 700	9.0
			TAN0617	Nov–Dec 2006	19 640	12.0
			TAN0714	Nov–Dec 2007	26 492	8.0
			TAN0813	Nov–Dec 2008	22 840	9.5
			TAN0911	Nov–Dec 2009	22 710	9.6
			TAN1117	Nov–Dec 2011	23 178	11.8
			TAN1215	Nov–Dec 2012	27 010	11.3
			TAN1412	Nov–Dec 2014	30 010	7.7
			TAN1614†	Nov–Dec 2016	26 656	16.0
			TAN1811	Nov–Dec 2018	21 276	10.4
			TAN2014	Nov–Dec 2020	22 343	12.4
LIN 5 & 6	Southern Plateau (autumn)	*Tangaroa*	TAN9204	Mar–Apr 1992	42 330	5.8
			TAN9304	Apr–May 1993	37 550	5.4
			TAN9605	Mar–Apr 1996	32 130	7.8
			TAN9805	Apr–May 1998	30 780	8.8
LIN 7WC	WCSI	*Tangaroa*	TAN0007	Aug 2000	1 861	17.3
			TAN1210	Aug 2012	2 169	14.8
			TAN1308	Aug 2013	2 000	18.4
			TAN1608	Aug 2016	1 635	12.7
			TAN1807	Jul–Aug 2018	1 682	18.3
LIN 7WC	WCSI	*Kaharoa*	KAH9204*	Mar–Apr 1992	280	19
			KAH9404*	Mar–Apr 1994	261	20
			KAH9504*	Mar–Apr 1995	373	16
			KAH9701*	Mar–Apr 1997	151	30
			KAH0004*	Mar–Apr 2000	95	46
			KAH0304*	Mar–Apr 2003	150	33
			KAH0503*	Mar–Apr 2005	274	37
			KAH0704*	Mar–Apr 2007	180	27
			KAH0904*	Mar–Apr 2009	291	37
			KAH1104*	Mar–Apr 2011	234	43
			KAH1305*	Mar–Apr 2013	405	44
			KAH1503*	Mar–Apr 2015	472	53

* Not used in the reported assessment.

† The core survey strata were unable to be completed and biomass estimates were scaled up using factors based on the proportion of biomass of each species in 'missing strata' in previous surveys from 2000–14 (O'Driscoll et al 2018).

4.1 LIN 1

In October 2002, the TACC for LIN 1 was increased from 265 t to 400 t within an Adaptive Management Plan (AMP). Reviews of the LIN 1 AMP were carried out in 2007 and 2009. The AMP programme was discontinued by the Minister of Fisheries in 2009–10. Updates of LIN 1 CPUE analyses were carried out in 2013, 2017, and 2020. The early CPUE analyses were given a reduced data quality ranking; in 2020 the Inshore Working Group concluded that the CPUE analyses did not provide a reliable index of abundance.

4.1.1 Fishery characterisation

- Around two thirds of LIN 1 landings come from the LIN target bottom longline fishery with most of the remainder from a mixed target bottom trawl fishery. The proportion of the catch taken by longline increased in 2005.
- The ling longline fishery has operated consistently in the Bay of Plenty (primarily Statistical Areas 009 and 010). Longline catches increased in East Northland from the mid-1990s, then off the west coast of the North Island from 2008.

- The majority of bottom trawl catches are taken in Statistical Areas 008 to 010, although there have been significant bottom trawl catches of ling off the west coast of the North Island in Statistical Areas 045 to 047. There were substantial ling bycatches made by trawl off the North Island west coast from 1996–97 to 2000–01 in the gemfish fishery (which has since ceased).
- Target bottom trawl catches of LIN 1 have increased since 2005 and represent about a third of trawl catches. Bycatch in the gemfish trawl fishery was important from the mid-1990s to early 2000s. Prior to 1995, bycatch of ling in the scampi fishery represented the majority of ling trawl catches, and, though the volume has reduced, the scampi fishery remains a consistent part of the LIN 1 trawl fishery. Ling catches in the hoki target trawl fishery have increased since 2010.
- The bottom longline landings of LIN 1 are taken mainly in the final two months of the fishing year, probably due to the economics of the vessels switching from tuna longlining to cleaning up available quota at the end of the fishing year. Bottom trawl catches of ling tend to be more evenly distributed across the year and reflect the fishing patterns of the diverse trawl targets, such as scampi which is also a consistent fishery over the entire year. Both the major fishing methods which take ling have sporadic seasonal patterns, reflecting the small landings in most years and the bycatch nature of many of the fisheries, although the ling target longline fishery has operated more consistently since 2005.
- The depth distribution of ling catches in the trawl fisheries show two main depths associated with the target species. Most ling are caught in the scampi/hoki/ling fisheries at about 400 m depth, but some are taken in the tarakihi/snapper/barracouta/trevally fisheries around 100 m depth. Bottom longline depth records indicate that target ling fishing (as well as target bluenose fishing) takes place at even deeper depths, with most of the records at between 500 and 600 m.

4.1.2 Abundance indices

A variety of different CPUE analyses have been carried out for LIN 1 (see Starr & Kendrick 2017) but no indices are currently accepted.

4.2 East Coast North Island, (LIN 2, Statistical Areas 011–015)

In 2014 a catch-per-unit-effort (CPUE) analysis was conducted on data from the LIN 2 fishery (Roux 2015). Estimated catch data and effort data from bottom longliners that fished in FMA 2 Statistical Areas 011–015 (ECNI) targeting ling where there was a positive catch were used. The estimated catch and effort data were rolled up by vessel/day/statistical area after a filter was applied to individual fishing events to retain estimated catch from the top five species together with all effort.

A GLM model (model 1) was fitted using a core vessel fleet where individual vessels had to have fished for four or more years in the fishery and fished a minimum of 10 days per year. One auto-longlining vessel was excluded because it was an outlier in terms of numbers of hooks set and created patterns in the residuals.

The sensitivity of the CPUE time series was tested for a range of alternative sets of input data: vessels using very large numbers of hooks per day (over 10 000) were either included or excluded; changes in fishing power and fleet were minimised by fitting only the most recent time series (2000–2013); data from Statistical Area 016 (Cook Strait) were either included or excluded; and fitting was carried out with or without the use of interaction terms. An all-target model using bottom longline data that targeted or caught ling was also developed with ‘target species’ included as an explanatory variable. The GLM trend was robust to all sensitivities investigated.

The standardised CPUE index for ling from the ECNI demonstrates an initial decline consistent with the previous assessment (Horn 2004), followed by a period of stability (2002–2010) with lower CPUE in 2011–12 and 2012–13 (Figure 2). This pattern was consistent across all GLM scenarios examined.

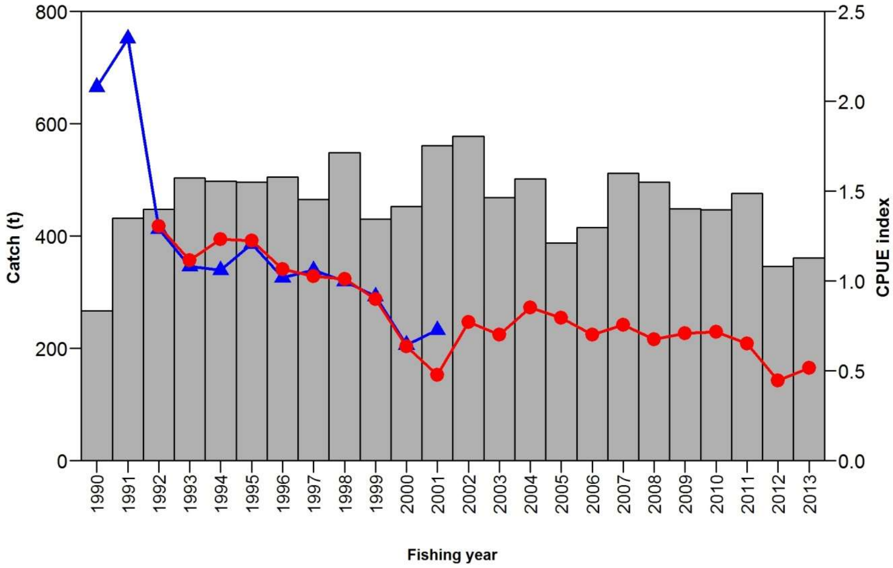


Figure 2: Estimated ling catch (bars) and standardised CPUE indices for LIN 2. Blue line and triangles from Horn (2004). Red line and circles for ECNI Statistical Areas 011–015 for core bottom longline vessels targeting ling, from Roux (2015). The two CPUE series were normalised to the overlapping fishing years (1992–2001).

4.3 Chatham Rise, LIN 3 & LIN 4

4.3.1 Model structure and inputs

The stock assessment for LIN 3&4 (Chatham Rise) was updated in 2022 (Mormede et al in prep b). For final model runs, the full posterior distribution was sampled using Markov chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Bounded estimates of spawning stock virgin (B_0) and current (B_{2022}) biomass were obtained. Year class strengths and fishing selectivity ogives were estimated in the model. All selectivities were fitted as logistic curves. Trawl fishery and research survey selectivity ogives used to be fitted as double normal curves (Holmes 2019) but the right-hand limb was highly uncertain and estimated towards logistic, hence the change. Due to the low numbers of young fish aged in the fishery, the age frequency was truncated at age 5 for both commercial fisheries and age 3 for the trawl survey. The trawl fishery male left-hand limb of the selectivity was fixed at its MPD values due to its high uncertainty (the trawl fishery selects fish younger than 5 years old which is when the age frequency starts). Because only one potting trip was observed and no age data are available, the potting fishery was assumed to have the same selectivity as the longline fishery based on the trip length frequency (Mormede et al in prep b). Selectivities were assumed constant over all years in each fishery/survey. Instantaneous natural mortality (M) was estimated as sex specific and constant at ages in the model, parameterised as the average morality value (M_{avg}) and the male-female difference (M_{diff}). MCMCs were estimated using a burn-in length of 1×10^6 iterations, with every 1000th sample kept from the next 4×10^6 iterations (i.e., a final sample of length 3000 was taken from the Bayesian posterior).

For LIN 3&4, model input data included catch histories for trawl, longline, and pot fisheries separately, biomass, and sexed catch-at-age data from a summer trawl survey series, sexed catch-at-age from the trawl and longline fisheries, and longline fishery standardised CPUE used in a sensitivity run (Table 10). Data used in the base case model are shown in bold. The catch history, biological input parameters, and estimates of relative abundance used in the model are given in Tables 5–9. The stock assessment model partitioned the population into two sexes, and age groups 3 to 25 with age 25 being a plus group. The survey age frequency was provided as ages 3 to 25 (with 25 as a plus group) and in the fishery as ages 5 to 25 (with 25 as a plus group). The longline age frequency for 2019 was not included due to low sample size and large uncertainty. To align more closely with the spawning season and seasons of the fishery of the various ling stocks, the model year was set as January to December, rather than the fishing year (October to September) as previously done. The model's annual cycle is described in Table 11.

Table 10: LIN 3&4: Summary of the relative abundance series applied in the models, including source years (Years). Data used in the base case model are shown in bold.

Data series	Years
Trawl survey biomass (*Tangaroa*, Jan)	**1992–2014, 2016, 2018, 2020, 2022**
Trawl survey proportion at age (*Tangaroa*, Jan), sexed	**1992–2014, 2016, 2018, 2020**
CPUE (longline, all year)	1991–2021
Commercial longline proportion-at-age (Jun–Oct), sexed	**2002–09, 2013–2018, 2020**
Commercial trawl proportion-at-age (Oct–May), sexed	**1992, 1994–2020**

Table 11: LIN 3&4: Annual cycle of the stock model, 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 within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

					Observations	
Step	Period	Processes	*M**	Age†	Description	%*Z*‡
1	Jan-Jun	Recruitment	0.9	0.5	Trawl survey (summer)	0.2
2	Jul-Dec	Spawning	0.1	0	–	
		fisheries			Longline CPUE	0.5
		(longline & trawl)			Longline catch-at-age/length	
					Trawl catch-at-age	
		Increment in ages		0.5		

* *M* is the proportion of natural mortality that was assumed to have occurred in that time step.
† Age is the age fraction, used for determining length-at-age, that was assumed to occur by the start of that time step.
‡ %*Z* is the percentage of the total mortality in the step that was assumed to have taken place at the time each observation was made.

The error distributions assumed were multinomial for the at-age data, and lognormal for all other data. The weight assigned to each data set was controlled by the error coefficient of variation (CV). The multinomial observation error CVs for the at-age data were adjusted using the reweighting procedure of Francis (2011). In a change to the previous assessment, but in line with the assessment of ling in LIN 5&6, additional process errors for the trawl survey biomass index and longline fishery CPUE were estimated within the model at MPD level only (fixed at MCMC level) after the age frequency datasets were reweighted.

Most priors were intended to be uninformed and were specified with wide bounds. One exception was an informative prior for the trawl survey *q*. The prior on *q* for all the *Tangaroa* trawl surveys was estimated assuming that the catchability constant was a product of areal availability (0.5–1.0), vertical availability (0.5–1.0), and vulnerability between the trawl doors (0.03–0.40). The resulting (approximately lognormal) distribution had mean 0.13 and CV 0.70, with bounds assumed to be 0.02 to 0.30. Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was strongly penalised. A penalty was applied to the estimates of year class strengths to encourage estimates that averaged to 1.

In all model runs, the catchability coefficients (*q*s) were estimated as free parameters. Models that included the longline CPUE as an index standardised to 1 had difficulty converging at MCMC with *q* estimated as a free parameter, but this was tracked to the instability of the minimisation routine within CASAL for very low parameter values (Webber et al 2021). The longline CPUE was input as standardised catch in kilograms per hook, allowing the *q* value to be estimated at about 0.08 (instead of 10^{-4}) as a free parameter with a stable model.

There is a conflict between the longline fishery CPUE and the trawl survey biomass index, in which the longline fishery biomass index declined between 1991 and 1997, but the trawl survey index remained relatively flat throughout. Furthermore, MPD profiles of initial biomass (B_0) showed that the age frequency series were in agreement with the longline fishery CPUE series rather than the trawl survey biomass series which has no information on maximum B_0. The base case model run (Base) used all the age frequency data and the trawl survey biomass series rather than the longline fishery CPUE because this was deemed the most reliable index of abundance. A sensitivity run was carried out with all the age frequency data and the longline CPUE series (CPUE sensitivity). A final sensitivity run was carried out using the Base model but fixing mortality values to those estimated in the CPUE sensitivity model run.

Spatial-temporal standardisations of the longline fishery CPUE and the survey biomass series were carried out to further investigate this conflict (Mormede et al in prep c). The resulting spatial series were similar to the corresponding series that were used in the model and insufficient to explain the discrepancy between the CPUE and trawl survey series between 1991 and 1997.

4.3.2 Model estimates

The fits to the catch-at-age data were all reasonable, and almost indistinguishable between model runs. The fits to the survey biomass series (Base model) or the CPUE series (sensitivity) were reasonable. Estimated year class strengths were not widely variable, although they were poorly estimated prior to 1980 (Figure 3). Fixing year class strengths to 1 prior to 1980 resulted in almost identical model results (see Mormede et al in prep b). All year class strengths estimated from 2000 have been less than 1, apart from that for 2007.

Ling are first caught by the trawl survey (age at full selectivity 5–6 years), then the trawl fishery (age 6–8 years), and then the longline fishery (age 12–15 years). Males were estimated to be less vulnerable than females to the trawl and longline fisheries but equally vulnerable as females in the survey. The estimated median M_{avg} was 0.156 and M_{diff} -0.015 (male-female difference) for the base case model, and 0.137 and -0.011, respectively, for the sensitivity run with CPUE series. A further sensitivity run was carried out using the base case model observations but fixing mortality values to those estimated in the CPUE sensitivity run.

Lag correlation of the MCMC for the base case model were above 1 for all lags instead of below 1 from lag two onwards, highlighting the conflict between the datasets within the model. Lag correlation was acceptable for the model with fixed *M* values and for the sensitivity run. Median relative jump size was acceptable for all models once the selectivities were set to logistic.

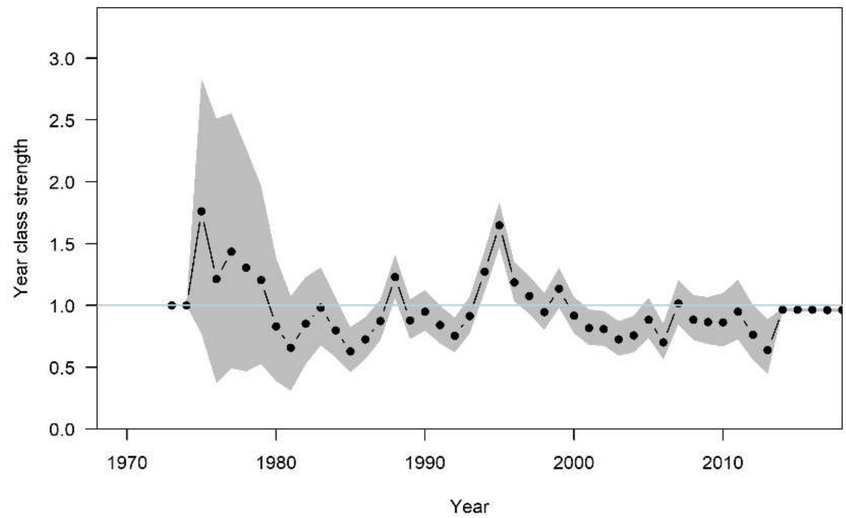


Figure 3: LIN 3&4. Estimated posterior distributions of year class strength from the base case run, with median (line and individual points) and 95% credible interval (grey band). The horizontal line indicates a year class strength of one.

Base case estimates indicated that it was unlikely that B_0 was lower than 100 000 t for this stock, or that biomass in 2022 was less than 46% of B_0 (Table 12, Figure 4). Annual exploitation rates (catch over vulnerable biomass) were estimated to be lower than 0.15 (often much lower) since 1979 (Figure 5). The sensitivity model based on the longline CPUE estimated a lower initial biomass (88 450–96 520 t), with biomass in 2022 estimated between 27 and 41% B_0.

The WG considered the sensitivity run not likely to be a reliable representation of the biomass because the longline fishery CPUE showed a sharp drop in the early 1990s when the trawl survey biomass showed no such trend. Although the trawl survey biomass index was in conflict with the age data in the model (including the survey age data), the survey is considered of high quality and therefore should be trusted over the longline CPUE or the age data. Further spatial-temporal analyses of the survey data did not indicate a change in ling distribution or any other process which might have rendered the survey biomass calculation inadequate. Furthermore, the CV on the survey biomass estimation is low (Table 9), indicating the survey is likely to be adequate for this species.

The CPUE sensitivity model estimated natural mortality at a lower value of M than was estimated in the base case. An additional sensitivity run of the base case model but with natural mortality fixed at the sensitivity estimates of M_{avg} = 0.137 and M_{diff} = -0.011 resulted in a lower biomass estimate and status than the base case model, with the biomass in 2022 estimated at about 45% of initial biomass rather than 56% as estimated by the base case model. This model also presented acceptable diagnostics in terms of lag, which the base case did not. A natural mortality of 0.137 is akin to that estimated by Edwards (2017) but much lower than that estimated by Horn (2008) at 0.18. Simulations were carried out whereby natural mortality was fixed at either MPD or MCMC values, 100 simulated observations derived, and then used to back-estimate mortality parameters. Those simulations showed neither the base case model nor the CPUE sensitivity model showed bias in the estimate of the natural mortality parameters or undue uncertainty (Mormede et al 2022 in prep b).

Table 12: LIN 3&4: Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2022} (in tonnes, and as a percentage of B_0) for the Base model run and two sensitivities, and the probability that B_{2022} is below 40% of B_0 from the Base model run.

Model run	B_0		B_{2022}		B_{2022} (% B_0)		P(>40% B_0)	P(<20% B_0)
Base case model (survey)	110 040	(100 660–129 890)	61 380	(47 400–85 810)	55.8	(46.9–66.3)	1.000	0.000
Sensitivity (CPUE)	92 190	(88 450–96 520)	30 860	(24 720–39 080)	33.5	(27.1–41.2)	0.052	0.000

The model indicated a relatively flat biomass trajectory from about 2009 (Figure 4). Annual landings from the LIN 3&4 stock have been less than 4600 t since 2004, markedly lower than the 6000–8000 t taken annually between 1992 and 2003. Biomass projections derived from this assessment are shown below (section 4.3.3).

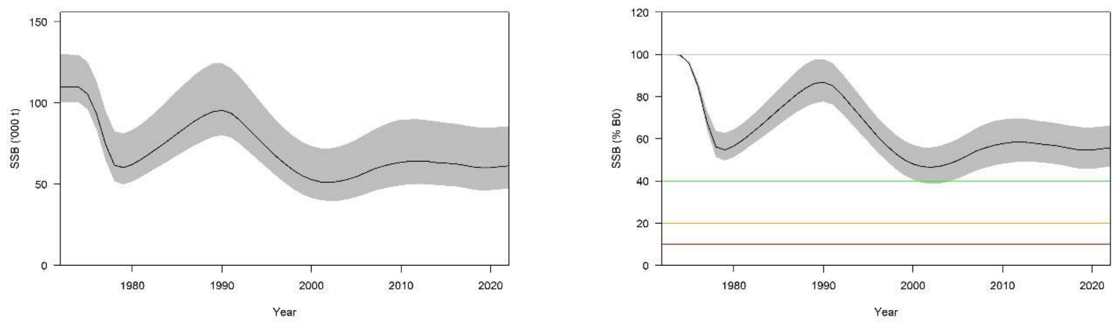


Figure 4: LIN 3&4 base model. Estimated median trajectories (with 95% credible intervals shown as grey band) for absolute biomass and biomass as a percentage of B_0. The red horizontal line at 10% B_0 represents the hard limit, the orange line at 20% B_0 is the soft limit, and the green line is the % B_0 target (40% B_0).

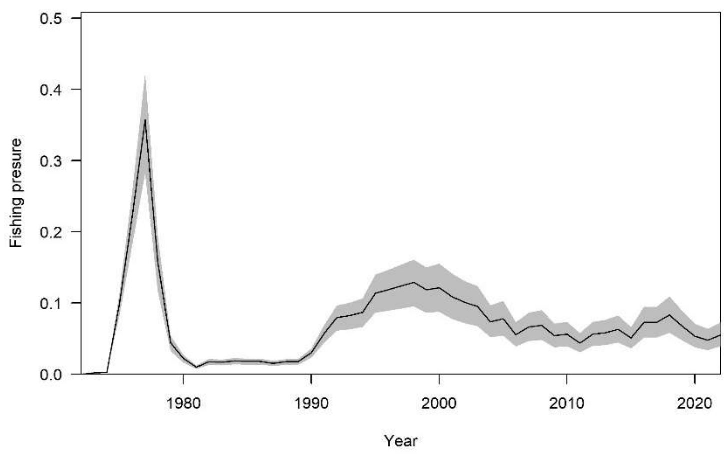


Figure 5: LIN 3&4 base model: Exploitation rates (catch over vulnerable biomass) with 95% credible intervals shown in grey.

Prior to the introduction of the QMS and before the establishment of the EEZ, catch reporting was not required and as such catches are uncertain but are assumed to have been low during this period. A sensitivity model was run based on the base case model that assumed 5% additional fishery mortality for years before the introduction of the QMS (1986) and 2% thereafter. The inclusion of estimates of incidental mortality and pre-QMS unreported catch resulted in very similar status, and biomass in 2022 from the base model.

4.3.3 Projections

Four scenarios were carried out, all using the base case model. Recent catches have been much lower than the TACC so the future catches were assumed to be either the average of the 2019–2021 catches or the TACC, keeping the ratio of catches between the fisheries to that of the 2019–2021 fisheries (52% longline, 33% trawl, and 15% pot). Furthermore, year class strengths have been mostly low since 2000 so the year class strengths for the projections were either resampled from the full 1975–2013 range, or from the 2003–2013 range.

For LIN 3&4, using the base case model, stock size is likely to remain about the same or increase by about 5%, assuming future catches equal recent catch levels and year class strengths are consistent with recent (2003–2013) or all year class strengths, respectively, or decrease to around 83–89% of the 2022 biomass by 2027 if catches reach the TACC with the same year class strength assumptions (Table 13).

The probability of biomass in 2027 being above 40% B_0 is 0.85–1.0 and the probability of being below 20% B_0 is zero for all projection scenarios.

Table 13: LIN 3&4. Bayesian median and 95% credible intervals (in parentheses) of projected B_{2027}, B_{2027} as a percentage of B_0, and as a percentage of B_{2022} for the base case run and various assumptions of future catches and year class strengths (YCS). The probability of B_{2027} being above 40% B_0 (p_{40}) and of B_{2027} being below 20%B_0 (p_{20}) are also reported.

YCS	Catch	Future catch (t)										
range	range	Trawl	Line	Pot	B_{2027} (t)		B_{2027} (%B_0)		B_{2027} (%B_{2022})		p_{40}	p_{20}
All	2019–2021	1 057	1 701	479	65 150	(49 150–91 170)	59	(48–72)	105	(95–119)	1.00	0
2003–2013	2019–2021	1 057	1 701	479	60 620	(46 160–84 560)	55	(45–66)	99	(93–106)	0.90	0
All	TACC	2 044	3 290	926	55 150	(39 050–81 380)	50	(38–64)	89	(78–103)	0.95	0
2003–2013	TACC	2 044	3 290	926	50 560	(35 980–74 560)	46	(35–58)	83	(74–91)	0.85	0

4.4 Sub-Antarctic, LIN 5 & LIN 6 (excluding Bounty Plateau)

4.4.1 Model structure and inputs

An age-based total catch history stock assessment model assuming a Beverton-Holt stock-recruit relationship for LIN 5&6 (Sub-Antarctic) was updated in 2021 (Mormede et al 2021b). For final runs, the full posterior distribution was sampled using Markov chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Bounded estimates of spawning stock virgin (B_0) and current (B_{2021}) biomass were obtained. Year class strengths and fishing selectivity ogives were also estimated in the model. Trawl fishery selectivity ogives were fitted as double normal curves with the right-hand limb fixed at 100 (i.e., a flat-topped selectivity); longline fishery and research survey ogives were fitted as logistic curves. Selectivities were assumed constant over all years in each fishery/survey.

MCMC chains with a total length of 4×10^6 iterations were constructed. A burn-in length of 1×10^6 iterations was used, with every 1000th sample taken from the final 3×10^6 iterations (i.e., a final sample of length 3000 was taken from the Bayesian posterior). For LIN 5&6, model input data include catch histories, biomass and catch-at-age data from summer and autumn trawl survey series, longline fishery CPUE series, catch-at-age data from the longline and trawl fisheries, and estimates of biological parameters. The stock assessment model partitions the population into two sexes and age groups 3 to 25 with a plus group. The base model's annual cycle is described in Table 14. To align more closely with the spawning season (September to December), and to the season of the fishery (particularly in the early years), the model year was set as September to August, rather than the fishing year (October to September).

A summary of all observations used in this assessment and the associated time series is given in Table 15. Lognormal errors, with known CVs, were assumed for all relative biomass observations. The CVs available for those observations of relative abundance allow for sampling error only. However, additional variance, assumed to arise from differences between model simplifications and real-world variation, was added to the sampling variance. The additional variance, termed process error, was estimated in the models at MPD-level only. Multinomial errors were assumed for all age composition observations. The effective sample sizes for the composition samples were estimated following method TA1.8 as described in appendix A of Francis (2011).

Table 14: LIN 5&6. Annual cycle of the stock model, 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 within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

					Observations	
Step	**Period**	**Processes**	***M*****	**Age**†	**Description**	**%*Z*‡**
1	Sep–Dec	Recruitment	0.33	0.0	Longline CPUE	0.5
		Trawl and longline fisheries			Longline catch-at-age	0.5
		Increment ages			Trawl catch-at-age	0.5
					Trawl survey (summer)	0.9
2	Jan–Aug		0.67	0.5	Trawl survey (autumn)	0.5

* *M* is the proportion of natural mortality that was assumed to have occurred in that time step.
† Age is the age fraction, used for determining length-at-age, that was assumed to occur in that time step.
‡ %*Z* is the percentage of the total mortality in the step that was assumed to have taken place at the time each observation was made.

Table 15: LIN 5&6. Summary of the relative abundance series applied in the models, including source years (Model years).

Data series	**Model years**
Trawl survey biomass (*Tangaroa*, Nov–Dec)	1992–94, 2001–10, 2012–13, 2015, 2017, 2019, 2021
Trawl survey proportion at age (*Tangaroa*, Nov–Dec)	1992–94, 2001–10, 2012–13, 2015, 2017, 2019
Trawl survey biomass (*Tangaroa*, Mar–May)	1992–93, 1996, 1998
Trawl survey proportion at age (*Tangaroa*, Mar–May)	1992–93, 1996, 1998
CPUE (longline)	1991–2020
Commercial longline proportion-at-age	1994, 1996, 1998–2012, 2014, 2017, 2018
Commercial trawl proportion-at-age	1992, 1994, 1996, 1998–2019

The assumed prior distributions used in the assessment are given in Table 16. Most priors were intended to be relatively uninformed and were specified with wide bounds. The exceptions were the choice of informative priors for the trawl survey *q*. The priors on *q* for all the *Tangaroa* trawl surveys were estimated assuming that the catchability constant was a product of areal availability (0.5–1.0), vertical availability (0.5–1.0), and vulnerability between the trawl doors (0.03–0.40). The resulting (approximately lognormal) distribution had mean 0.13 and CV 0.70, with bounds assumed to be 0.02 to 0.30. The prior for *M* was chosen based on a 2017 study of ling mortality (Edwards 2017).

Table 16: LIN 5&6. Assumed prior distributions and bounds for estimated parameters in the assessments. The parameters for lognormal priors are mean (in log space) and CV.

Parameter description	**Distribution**	**Parameters**		**Bounds**	
B_0	Uniform-log	–	–	50 000	800 000
Year class strengths	Lognormal	1.0	0.70	0.01	100
Trawl survey *q*	Lognormal	0.13	0.70	0.02	0.3
Trawl survey process error	Uniform-log	–	–	0.001	2
CPUE *q*	Uniform-log	–	–	1e-6	1e-3
Selectivities	Uniform	–	–	0	20–200*
M†	Lognormal	0.16	0.2	0.05	0.5

* A range of maximum values were used for the upper bound.
† Constant, estimated natural mortality used in some sensitivity models.

Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was strongly penalised. A small penalty was applied to the estimates of year class strengths to encourage estimates that averaged to 1. The catch history, biological input parameters, and estimates of relative abundance used in the model are given in Tables 5–9.

The base model for 2021 was quite different from that of the previous assessment in 2018 (Masi 2019). In 2018 the base case had three fisheries, estimated natural mortality, a revised annual cycle for the spawning and non-spawning longline fisheries, free survey *q* parameters, and excluded the longline CPUE index. In 2021, the base case run had two fisheries (and associated updated annual cycle), a fixed natural mortality of 0.18 y^{-1}, nuisance survey *q* parameters, fixed the right-hand limb trawl selectivity parameters, and included the longline standardised CPUE index. The process which led to these changes in parameters are detailed below.

- Two fisheries – New spatial analyses carried out in 2021 concluded that splitting the LIN 5&6 stock between trawl and longline fisheries would achieve more consistent length frequencies and sex ratios in those two fisheries over time than the previous split of trawl, spawning, and home ground longline fisheries (Mormede et al 2021a). These new splits also cover the entire year rather parts of the year as previously done (Ballara 2019). The models were therefore updated to have a longline and a trawl fishery as opposed to two longline (spawning and non-spawning) and a trawl fishery. The effect of this change was minor at the MPD level.

- Fixed *M* – *M* used to be estimated as a U-shaped natural mortality (Roberts 2016), then a single natural mortality with uniform prior (Masi 2019). The models run in 2021 with an estimated mortality parameter presented very poor MCMC diagnostics (including mixing and stability) and were deemed unacceptable by the Deepwater Working Group (DWWG). The base case model and sensitivities reverted to fixed *M* values. Values of 0.16 y^{-1} (based on Edwards 2017), 0.18 y^{-1} (based on Horn 2005 and value previously used in models), and 0.20 y^{-1} (MPD estimated value) were used as bounding values. A simulation was also carried out whereby *M* was fixed at 0.17 y^{-1}, observations simulated using the MCMC parameters, and *M* then back-estimated at MPD level; *M* was over-estimated by about 0.015 on average. Therefore, *M* of 0.18 y^{-1} was the chosen base case.

- Nuisance *q*s – The survey *q*s were set as nuisance in 2015 (Roberts 2016) and then changed to free *q*s in 2018 (Masi 2019). The models run in 2021 with free survey *q*s presented poor MCMC diagnostics, which were greatly improved when switching back to nuisance *q*s. Fixing the right-hand limb trawl selectivity to 100 (mean of the MCMC values) stabilised the models further and was adopted by the Deepwater Working Group. The effect of changing from free *q*s to nuisance *q*s increased the initial biomass slightly, as was seen in 2018 (Masi 2019, table 12).

- Longline CPUE index – The ling longline fishery is a target fishery which almost exclusively catches ling. The DWWG felt it was a suitable index of abundance to use in the models, if the MCMC for these models converged adequately. Furthermore, the DWWG felt that the 2018 model presented a very large confidence interval on the value of B_0 due to the lack of information about how large the stock might be. Further investigations through MPD profiles showed that the CPUE index did contain some bounding information on stock size. The longline CPUE index was added to the model with annual CVs calculated from the CPUE standardisation (Table 8) and a process error estimated within CASAL at about 0.16. This compares favourably with the process error of the trawl survey which CASAL estimated at about 0.13, confirming that the CPUE series is consistent with the expected biomass trajectory of the model. In 2018 the longline CPUE was included in some sensitivity runs but not kept in the base case model because the spawning CPUE was not well fitted; this could have been a spatial issue and was resolved by grouping non-spawning and spawning together (see 'Two fisheries' above). A sensitivity run was carried out without the CPUE index and with *M* fixed at 0.18.

4.4.2 Model estimates

Description of the base model run reported is as follows:
The base case is considered to be a reference model because it was the most stable model obtained and uses all of the trusted information available. Other model runs which led to this base case (e.g., with estimated *M* values, free *qs*) are not reported here. The base case model comprised two fisheries (and associated updated annual cycle), a fixed natural mortality of 0.18 y^{-1}, nuisance survey *q* parameters, fixed the right-hand limb trawl selectivity parameters, and the longline standardised CPUE series.

Three sensitivities are reported: (1) *M* fixed at 0.16, (2) *M* fixed at 0.20, and (3) *M* fixed at 0.18 and excluding the longline standardised CPUE series. From the sensitivity runs trialled, MPD estimates of current stock status were between 61–80% B_0. Steepness was assumed to be 0.84 (Table 7); sensitivities to this were not conducted due to the consistently high stock status.

Posterior distributions of year class strength estimates from the base case model run are shown in Figure 6; the distribution from the base case model differed little from the sensitivity models. Year classes were generally weak from 1985 to 1992, strong from 1994 to 1996 and 2005 to 2010, and average since then. Overall, estimated year class strengths were not widely variable, with all medians being between 0.5 and 1.5. Biomass estimates for the stock declined through the 1990s but have been stable since the early 2000s (Figure 7). The biomass trajectory from the base case model was little different to those derived from the sensitivity models, although the 95% credible interval varied between model runs (see Table 17).

Stock status estimates for 2021 from three reported models were between 61–80% of B_0 (Figure 7, Table 17), with the lowest stock status linked to the lowest value of *M*. Annual exploitation rates (catch over vulnerable biomass) were low (less than 0.1) in all years as a consequence of the high estimated stock size in relationship to the level of relative catches (Figure 8).

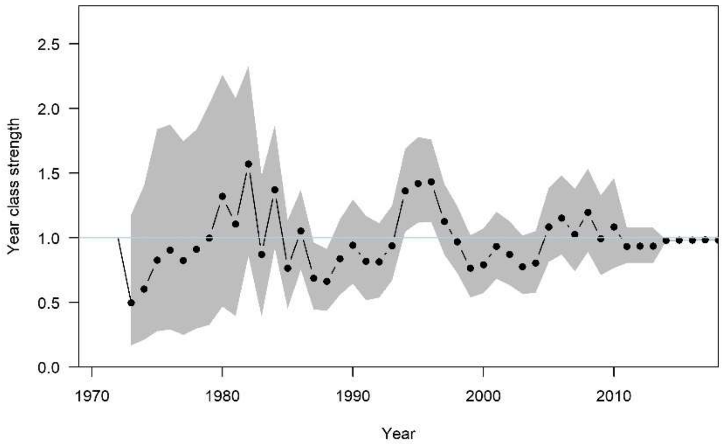


Figure 6: LIN 5&6. Estimated posterior distributions of year class strength from the base case run, with median (line and individual points) and 95% credible interval (grey band). The horizontal line indicates a year class strength of one.

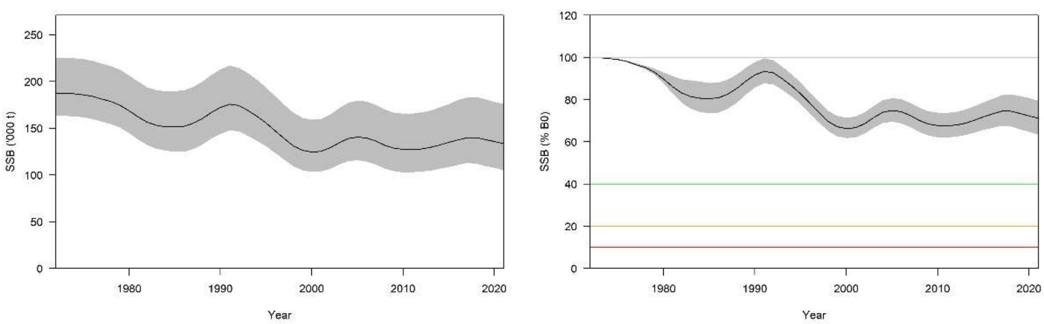


Figure 7: LIN 5&6 base model. Estimated median trajectories (with 95% credible intervals shown as grey band) for absolute biomass and biomass as a percentage of B_0. The red horizontal line at 10% B_0 represents the hard limit, the orange line at 20% B_0 is the soft limit, and the green line is the % B_0 target (40% B_0).

Table 17: LIN 5&6. Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2021} (in tonnes), and B_{2021} as a percentage of B_0, and the probability that B_{2021} is above 40% and below 20% of B_0 from the Base model and sensitivity runs with TACC as future catches.

Model run	B_0		B_{2021}		B_{2021} (% B_0)		P(>40 % B_0)	P(<20 % B_0)
Base case model	187 350	(163 190–226 090)	132 780	(104 630–177 230)	70.8	(63.1–79.3)	0.934	0.000
M = 0.16	157 800	(144 500–175 820)	96 520	(79 080–119 840)	61.2	(54.1–69.1)	0.671	0.008
M = 0.20	258 770	(203 270–361 080)	208 840	(150 460–318 790)	80.6	(72.2–89.7)	0.995	0.000
M = 0.18 and no CPUE	197 130	(166 520–246 370)	147 690	(109 610–209 350)	75.0	(64.8–86.0)	0.962	0.000

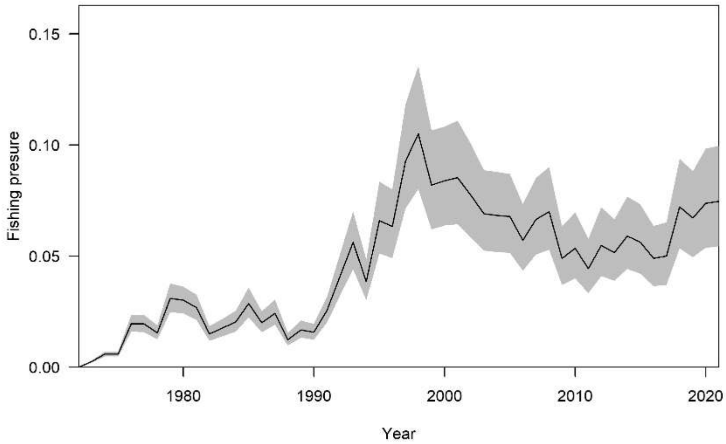


Figure 8: LIN 5&6 base model exploitation rate (catch over vulnerable biomass) with 95% credible intervals shown in grey.

Resource survey and fishery selectivity ogives were relatively tightly defined. The survey ogive suggested that ling were fully selected by the research gear at about age 7–9 years. Estimated fishing selectivities indicated that ling were fully selected by the trawl fishery at about age 9 years, and by the longline fisheries at about age 12–16.

The assessments indicated a general drop in biomass to 2000, and a flat trend since then. Fixing M, the trawl right-hand limb trawl selectivities have reduced the uncertainty around the estimate of biomass which was present in the 2018 assessment (Masi 2019), although this uncertainty increases with the value of M in the model (Table 17). Biomass projections derived from this assessment are shown below.

The effect of possible incidental mortality associated with escapement from trawl nets and potential unreported catch from before the introduction of the QMS was evaluated in a sensitivity model. Discards from the hoki/hake/ling target fishery were likely to be very low (< 0.3%, Anderson 2019).

Incidental mortality of small fish associated with escapement also is assumed to be low because the ling fishery occurs in areas away from locations where small ling are found. Unreported catch prior to the introduction of the QMS is not known but assumed to be low due to the high commercial value of ling at that time. A sensitivity model was run that assumed 5% additional fishery mortality for years before the introduction of the QMS (1986) and 2% thereafter. The inclusion of estimates of incidental mortality and pre-QMS unreported catch resulted in a very similar status, and similar estimates of current biomass.

4.4.3 Projections

For LIN 5&6, the probability of B_{2021} being below 40% of B_0 is very small when assuming either one of two future annual catch scenarios (the average catch of 6320 t for trawl and 1370 t for longline between 2016 and 2020 or the TACC of 13 240 t split 82% trawl and 18% longline reflecting the average proportion of catches between the two fisheries between 2016 and 2020) (Table 18).

Table 18: LIN 5&6. Bayesian median and 95% credible intervals (in parentheses) of projected B_{2026}, B_{2026} as a percentage of B_0, and B_{2026}/B_{2021}(%) for the base case runs.

Stock and model run		Future catch (t) Trawl	Longline	B_{2026} (t)		B_{2026} (% B_0)		B_{2026}/B_{2021} (%)	
LIN 5&6	Base	6 320	1 370	129 080	(81 670–205 590)	68	(46– 104)	95	(72–133)
		10 860	2 380	110 340	(63 330–186 650)	58	(36 – 94)	81	(57–117)

4.5 Bounty Plateau, LIN 6B (Bounty Plateau only)

4.5.1 Model structure and inputs

The stock assessment for the Bounty Plateau stock (part of LIN 6) was updated in 2007 (Horn 2007b). For final runs, the full posterior distribution was sampled using Markov chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Bounded estimates of spawning stock virgin (B_0) and current (B_{2006}) biomass were obtained. Year class strengths and fishing selectivity ogives were also estimated in the model. Longline fishery ogives were fitted as logistic curves.

MCMC chains were constructed using a burn-in length of 5×10^5 iterations, with every 1000th sample taken from the next 10^6 iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior).

For LIN 6B, model input data include catch histories, longline fishery CPUE, catch-at-age, and catch-at-length from the longline fishery, and estimates of biological parameters. In the absence of sufficient stock-specific data, maturity ogives were assumed to be the same as for LIN 3&4, a stock with comparable growth parameters to LIN 6B. Only a base case model run is presented. The stock assessment model partitions the population into two sexes and age groups 3 to 35 with a plus group. There is one fishery (longline) in the stock. The model's annual cycle is described in Table 19.

Lognormal errors, with observation-error CVs, were assumed for all relative biomass, proportions-at-age, and proportions-at-length observations. Additional process error was estimated in MPD runs of the model (Table 20) and fixed in all subsequent runs.

The assumed prior distributions used in the assessment are given in Table 21. All priors were intended to be relatively uninformed and were estimated with wide bounds.

Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was strongly penalised. A small penalty was applied to the estimates of year class strengths to encourage estimates that averaged to 1.

The catch history, biological input parameters, and estimates of relative abundance used in the model are shown in Tables 5–8.

Table 19: LIN 6B. Annual cycle of the stock model, 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 within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

Step	Period	Processes	M*	Age†	Observations Description	%Z‡
1	Dec–Sep	Recruitment	0.9	0.5	Longline CPUE	0.5
		fishery (line)			Longline catch-at-age/length	0.5
2	Oct–Nov	increment ages	0.1	0	–	

* M is the proportion of natural mortality that was assumed to have occurred in that time step.
† Age is the age fraction, used for determining length-at-age that was assumed to occur in that time step.
‡ %Z is the percentage of the total mortality in the step that was assumed to have taken place at the time each observation was made.

Table 20: LIN 6B. Summary of the relative abundance series applied in the models, including source years (Years), and the estimated process error (CV) added to the observation error.

Data series	Years	Process error CV
CPUE (longline, all year)	1992–2004	0.15
Commercial longline length-frequency (Nov–Feb)	1996, 2000–04	0.50
Commercial longline proportion-at-age (Dec–Feb)	2000–01, 2004	0.40

Table 21: LIN 6B. Assumed prior distributions and bounds for estimated parameters for the assessments. The parameters are mean (in log space) and CV for lognormal.

Parameter description	Distribution	Parameters		Bounds	
B_0	uniform-log	–	–	5 000	100 000
Year class strengths	lognormal	1	0.7	0.01	100
CPUE q	uniform-log	–	–	1.00E-08	1.00E-03
Selectivities	uniform	–	–	0	20–200*
Process error CV	uniform-log	–	–	0.001	2

4.5.2 Model estimates

Only a base case model run was completed.

Posterior distributions of year class strength estimates from the base case model run are shown in Figure 9.

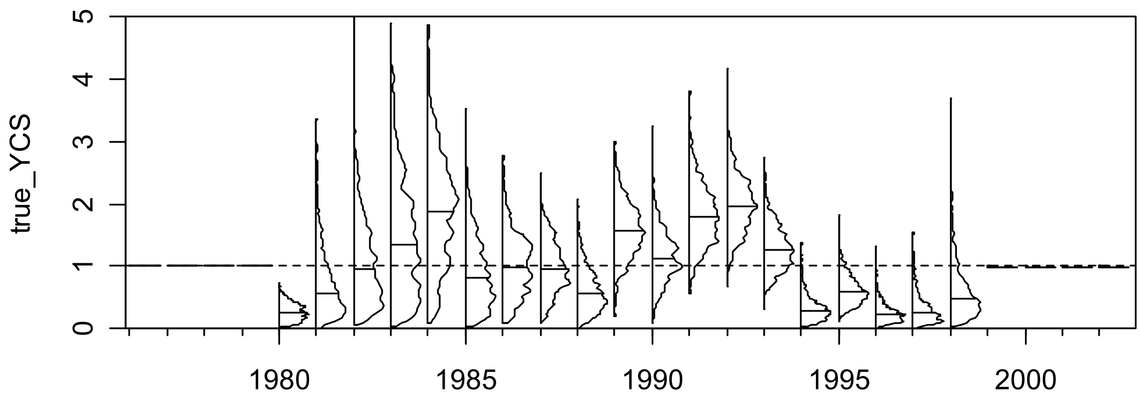


Figure 9: LIN 6B. Estimated posterior distributions of year class strength from the base case run. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

The assessment was driven largely by the catch-at-age and catch-at-length series from the longline fishery; the first two years of CPUE data were not well fitted. Biomass estimates are listed in Table 22 and the biomass trajectory is shown in Figure 10. The assessment indicates a declining biomass throughout the history of the fishery. Estimates of current and virgin stock size are not well known, but current biomass is very likely to be above 50% of B_0.

Table 22: LIN 6B. Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2006} (in t), and B_{2006} as a percentage of B_0 for the base case model run.

Model run	B_0	B_{2006}	B_{2006} (%B_0)
Base case	13 570 (10 850–19 030)	8 330 (4 860–14 730)	61 (45–79)

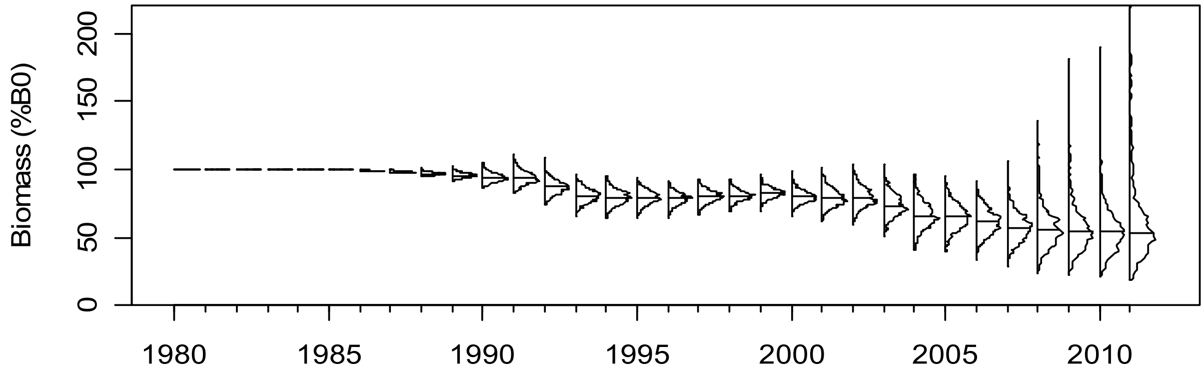


Figure 10: LIN 6B. Estimated posterior distributions of biomass trajectories as a percentage of B_0, from the base case model run (including 5-year projections through to 2011 with assumed constant annual catch of 400 t). Distributions are the marginal posterior distribution, with horizontal lines indicating the median.

4.5.3 Projections

Projections for LIN 6B from the 2006 assessment are given in Table 23. The LIN 6B stock (Bounty Plateau) was projected to decline out to 2011, but probably still be higher than 50% of B_0.

Table 23: LIN 6B. Bayesian median and 95% credible intervals (in parentheses) of projected B_{2011}, B_{2011} as a percentage of B_0, and B_{2011}/B_{2006} (%) for the 2006 base case.

Stock and model run		Future catch (t)	B_{2011}		B_{2011} (% B_0)		B_{2011}/B_{2006} (%)	
LIN 6B	Base	600	7 460	(2 950–18 520)	53	(26–116)	86	(51–168)

4.6 West coast South Island, LIN 7WC

4.6.1 Model structure and inputs

The stock assessment for LIN 7WC (west coast South Island) was updated in 2020 (Kienzle 2021). The assessment model partitioned the population into age groups 3 to 28 with a plus group, and immature and mature fish, with no sex in the partition. The model's annual cycle is described in Table 24.

The reported model runs were developed following the investigation of numerous previous model runs. These evaluated the sensitivity of the model fit to assumptions about indices of abundance, natural mortality rate, trawl survey and fishery selectivity ogives, and weights assigned to different observational data sets.

Year class strengths and fishing selectivity ogives were estimated in the model. The longline fishery and mature fish research trawl survey selectivity ogives were assumed to be logistic. The selectivity of immature fish by the research trawl survey was estimated as a capped logistic curve. Commercial trawl fishery selectivity ogive was set as a double normal function.

Two analyses were carried to test the sensitivity of the results of the LIN 7 stock assessment (base case) to some of the assumptions (Table 25): models 2 and 3 were used to investigate the effect of using alternative indices of abundance into the assessment; models 4 and 5 assessed the effect of using different values of natural mortality.

Table 24: LIN 7WC. Annual cycle of the stock model, 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 within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

					Observations	
Step	Period	Processes	M*	Age†	Description	%Z‡
1	Oct–May	Recruitment fishery (longline)	0.75	0.5	Longline catch-at-age	0.5
2	Jul–Sep	fishery (trawl)	0.25	0.8	Trawl catch-at-age Trawl CPUE Trawl survey biomass and catch-at-age	0.5
3	End of Sep	Increment ages	0	0		

* M is the proportion of natural mortality that was assumed to have occurred in that time step.
† Age is the age fraction, used for determining length-at-age, that was assumed to occur in that time step.
‡ %Z is the percentage of the total mortality in the step that was assumed to have taken place at the time each observation was made.

Table 25: LIN 7WC. Settings of the models exploring the sensitivity of the base case stock assessment to the index of abundance (columns) and the value of natural mortalities (rows).

	Indices of abundance		
Natural mortality (per year)	Survey	Survey + CPUE	CPUE
0.14	Model 4		
0.18	Base case	Model 2	Model 3
0.22	Model 5		

The full posterior distributions of the parameters of the base case model and model 15 were sampled using Markov chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Bounded estimates of spawning stock virgin (B_0) and current (B_{2020}) biomass were obtained. Four MCMC chains were constructed using a burn-in length of 2×10^6 iterations, with every 2000th sample taken from the next 6×10^6 iterations (i.e., four final samples of length 2000 each were taken from the Bayesian posterior totally 8000 samples to describe the posterior distributions of the models parameters). Visual inspections of the chains were used to determine the acceptability of the MCMC procedure. The final model runs (section 4.6.2) were considered acceptable for providing management advice.

For LIN 7WC, available data to model the fishery included catch histories, trawl fishery CPUE, extensive catch-at-age data from the trawl fishery, sparse catch-at-age data from the longline fishery, biomass estimates, proportion-at-age from *Tangaroa* surveys in 2000, 2012, 2013, 2016, and 2018, and estimates of constant biological parameters (Table 26 and Table 5). A longline fishery CPUE series was available but was rejected as unlikely to be indexing stock abundance. The *Kaharoa* inshore trawl survey biomass estimates and proportion-at-length estimates were not considered to be useful because they have been rejected in previous sittings of the DWWG because few ling older than age nine were caught in surveys, and inclusion of the data made negligible contribution to the estimation of model parameters.

The error distributions assumed were multinomial for the proportions-at-age and lognormal for all other data. Biomass indices had assumed CVs set equal to the sampling CV plus an additional process error of 0.4, estimated following Francis (2011). The multinomial observation error effective sample sizes for the trawl fishery at-age data were adjusted using the reweighting procedure of Francis (2011). An *ad hoc* procedure was used for the at-age data from the longline fishery and *Tangaroa* survey at-age data, giving the longline fishery a relatively low weighting and the trawl survey a relatively high weighting.

The assumed prior distributions used in the assessment are given in Table 27. Most priors were intended to be relatively uninformed and were specified with wide bounds. The prior for the survey q was informative and was estimated using the Sub-Antarctic ling survey priors as a starting point because the survey series in both areas used the same vessel and fishing gear. However, the WCSI survey area in the 200–650 m depth range in strata 0004 A–C and 0012 A–C comprised 6619 km^2; seabed area in that depth range in the entire LIN 7 WC biological stock area (excluding the Challenger Plateau) is estimated to be about 20 100 km^2. So, because biomass from only 33% of the WCSI ling habitat was included in the indices, the Sub-Antarctic prior on μ was modified accordingly (i.e., $0.13 \times 0.33 = 0.043$), and the bounds were also reduced from [0.02, 0.30] to [0.01, 0.20]. Priors for survey selectivity parameters, both immature and mature ling, and trawl fishery were changed from uninformed to informed because of lack of convergence in the MCMC. The prior for those parameters was set to a lognormal distribution with mean set at the estimate from a log-likelihood minimisation fit and coefficient of variation of 0.2. The prior distributions for the longline fishery selectivity parameters were assumed to be uniform.

Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was strongly penalised. A small penalty was applied to the estimates of year class strengths to encourage estimates that averaged to 1.

The catch history, biological input parameters, and estimates of relative abundance used in the model are shown in Tables 5–9.

Table 26: LIN 7WC. Summary of the relative abundance and stock composition series applied in the models, including source years (Years).

Data series	Years
CPUE (hoki trawl, Jun–Sep)	1987–2019
Commercial trawl proportion-at-age (Jun–Sep)	1991, 1994–2008, 2012–2019
Commercial longline proportion-at-age	2003, 2006, 2007, 2012, 2015
Trawl survey biomass (*Tangaroa*, Jul)	2000, 2012–13, 2016, 2018
Trawl survey age data	2000, 2012–13, 2016, 2018

Table 27: LIN 7WC. Assumed prior distributions and bounds for parameters estimated in the models. For lognormal distributions the figures are the log-space mean and the CV, and for normal distributions the figures are the mean and standard deviation.

Parameter description	Distribution	Parameters		Bounds	
B_0	uniform-log	–	–	10 000	500 000
Year class strengths	lognormal	1.0	0.7	0.01	100
Tangaroa survey *q*	lognormal	0.043	0.70	0.001	1
CPUE *q*	uniform-log	–	–	1e-8	1e-3
Trawl fishery selectivity par 1	Lognormal	10	0.2	1	30
Trawl fishery selectivity par 2	Lognormal	5.5	0.2	1	30
Trawl survey selectivity immature par 1	Lognormal	2.8	0.2	1	30
Trawl survey selectivity immature par 2	Lognormal	0.77	0.2	0.1	30
Trawl survey selectivity immature par 3	Lognormal	0.03	0.2	0.001	0.20
Trawl survey selectivity mature par 1	Lognormal	13.6	0.2	1	30
Trawl survey selectivity mature par 2	Lognormal	7.2	0.2	1	30
Longline fishery selectivity	uniform	–	–	0	30–200*

* A range of maximum values was used for the upper bound.

4.6.2 Model estimates

The results of the sensitivity analyses showed that the stock assessment model is not sensitive to using alternative indices of abundance. Spawning stock biomass estimates do vary as a function of the magnitude of natural mortality assumed in the model in a predictable way: the best estimate of *M* is 0.18. Of the five models presented in this section, only two were brought to MCMC. Those two models estimated the median virgin biomass to be equal between 55 000–56 000 t (Table 28), and the ling *SSB* to have declined by 2020 to approximately 50% of its virgin biomass (B_0) (Figure 11).

Table 28: LIN 7WC Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2020} (in tonnes) and B_{2020} as a percentage of B_0 for all model runs.

Model run	B_0		B_{2020}		B_{2020} (% B_0)	
Base case	54 546	(50 463–59 833)	25 556	(17 877–35 527)	47	(35–60)
Adding CPUE index of abundance (model 2)	56 159	(51 964–61 580)	28 393	(21 034–38 047)	50	(40–62)

Model run	$P(B_{2020} > 0.4B_0)$	$P(B_{2020} < 0.2B_0)$	$P(B_{2020} < 0.1B_0)$
Base case	87	0	0
Adding CPUE index of abundance (model 2)	97	0	0

Figure 11: LIN 7WC. Estimated posterior distribution of the spawning stock biomass (*SSB* in tonnes) trajectory and estimated virgin spawning stock biomass reference points (40%, 20%, and 10% B_0) for the base case model (left panel) and the model 2 (right panel). The solid black line represents the median values and the shaded areas the 95% confidence intervals.

4.6.3 Projections

Projections out to 2022 for LIN 7WC indicated that biomass was likely to remain about the same with future catches equal to the average of catch in 2012–2016 (2980 t), or if catches for LIN 7WC were to increase modestly (by around 10%, 3300 t) to the overall LIN 7 fishstock level (Table 29).

Table 29: LIN 7WC. Bayesian median and 95% credible intervals (in parentheses) of projected B_{2022}, B_{2022} as a percentage of B_0, and B_{2022}/B_{2016} (%) for the model runs.

Stock and model run		Future catch (t)	B_{2022}		B_{2022} (% B_0)		B_{2022}/B_{2016} (%)	
LIN 7WC	Combined CPUE	2 980	77 300	(37 800–185 500)	79	(56–106)	100	(83–126)
		3 300	76 600	(35 500–183 700)	78	(54–104)	98	(80–123)
	Lognormal CPUE	2 980	47 400	(21 600–97 300)	70	(41–100)	104	(81–134)
		3 300	45 900	(20 700–96 900)	68	(37–97)	102	(77–133)
	Lognormal CPUE	2 980	38 100	(17 300–97 900)	57	(33–85)	100	(76–126)
	& M = 0.18	3 300	36 400	(15 900–95 900)	54	(32–82)	97	(73–124)

4.7 Cook Strait, LIN 7CK

4.7.1 Model structure and inputs

A stock assessment of ling in Cook Strait (LIN 7CK) was completed in 2013 (Dunn et al 2013). Because it is believed that the true M for the Cook Strait stock is higher than the 'default' value of 0.18, it was considered desirable to estimate M in the model, and so incorporate the effect of this uncertainty in M in the assessment. However, the simultaneous estimation of B_0 and M was not successful owing to the adoption of a multinomial likelihood (rather than lognormal) for proportions-at-age. Consequently, models with fixed M values were run, and, although the age data were reasonably well fitted, the model failed to accurately represent declines in resource abundance that appear evident from CPUE values, which have been declining since 2001. The model was considered unsuitable for the provision of management advice.

The last stock assessment for LIN 7CK (Cook Strait) accepted by the Working Group was completed in 2010 (Horn & Francis 2013), and it is reported here. The stock assessment model partitions the population into two sexes and age groups 3 to 25 with a plus group. The model's annual cycle is described in Table 30. Year class strengths and fishing selectivity ogives were also estimated in the model. Commercial trawl selectivity was fitted as double normal curves; longline fishery ogives were fitted as logistic curves.

For final runs, the full posterior distribution was sampled using Markov chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Bounded estimates of spawning stock virgin (B_0) and current (B_{2008}) biomass were obtained. MCMC chains were constructed using a burn-in length of 4×10^6 iterations, with every 2000th sample taken from the next 20×10^6 iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior).

For LIN 7CK, model input data include catch histories, trawl and longline fishery CPUE, extensive catch-at-age data from the trawl fishery, sparse catch-at-age data from the longline fishery, and estimates of biological parameters. Initial modelling investigations found that the longline CPUE produced implausible results; this series was rejected as a useful index. The base case used all catch-at-age data from the fisheries, and the trawl CPUE series. Instantaneous natural mortality was estimated in the model.

Lognormal errors, with observation-error CVs, were assumed for all CPUE and proportions-at-age observations. Additional process error, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance (Table 31).

Table 30: LIN 7CK. Annual cycle of the stock model, 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 within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

					Observations	
Step	Period	Processes	M*	Age†	Description	%Z‡
1	Oct–May	Recruitment fishery (line)	0.67	0.5	Longline CPUE Longline catch-at-age	0.5
2	Jun–Sep	increment ages fishery (trawl)	0.33	0	Trawl CPUE Trawl catch-at-age	0.5

* M is the proportion of natural mortality that was assumed to have occurred in that time step.
† Age is the age fraction, used for determining length-at-age, that was assumed to occur in that time step.
‡ %Z is the percentage of the total mortality in the step that was assumed to have taken place at the time each observation was made.

Table 31: LIN 7CK. Summary of the available data including source years (Years), and the estimated process error (CV) added to the observation error.

Data series	Years	Process error CV
CPUE (hoki trawl, Jun–Sep)	1994–2009	0.2
Commercial trawl proportion-at-age (Jun–Sep)	1999–2009	1.1
Commercial longline proportion-at-age	2006–07	1.1

The assumed prior distributions used in the assessment are given in Table 32. Most priors were intended to be relatively uninformed and were specified with wide bounds.

Table 32: LIN 7CK: Assumed prior distributions and bounds for estimated parameters in the assessments. The parameters are mean (in log space) and CV for lognormal, and mean and standard deviation for normal.

Parameter description	Distribution	Parameters		Bounds	
B_0	uniform-log	–	–	2 000	60 000
Year class strengths	lognormal	1.0	0.9	0.01	100
CPUE *q*	uniform-log	–	–	1e-8	1e-2
Selectivities	uniform	–	–	0	20–200*
M	lognormal	0.18	0.16	0.1	0.3

* A range of maximum values was used for the upper bound.

Penalty functions were used to constrain the model so that any combination of parameters that did not allow the historical catch to be taken was strongly penalised. A small penalty was applied to the estimates of year class strengths to encourage estimates that averaged to 1.

The catch history, biological input parameters, and estimates of relative abundance used in the model are shown in Tables 5–8

4.7.2 Model estimates

A single model was presented incorporating a catch history, trawl and longline fishery catch-at-age, trawl CPUE series, with double-normal ogives for the trawl fishery and logistic ogives for the longline fishery, and *M* estimated in the model.

Posterior distributions of LIN 7CK year class strength estimates from the base case model run are shown in Figure 12.

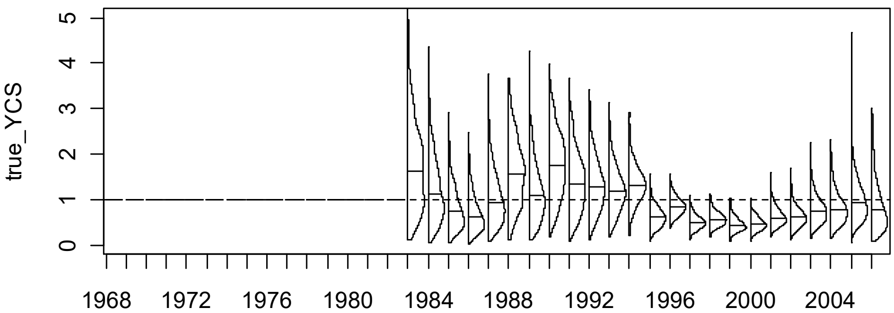


Figure 12: LIN 7CK. Estimated posterior distributions of year class strength. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

The assessment is driven by the trawl fishery catch-at-age data and tuned by the trawl CPUE. Both input series contain information indicative of an overall stock decline in the last two decades. The confidence bounds around biomass estimates are wide (Table 33, Figure 13). Probabilities that current and projected biomass will drop below selected management reference points are given in Table 34. Median *M* was estimated to be 0.24 (95% confidence interval 0.16–0.30). Estimates of biomass are very sensitive to small changes in *M*, but clearly there is information in the model encouraging an *M* higher than the ‘default’ value of 0.18. The model indicated a slight overall biomass decline to about 2000, followed by a much steeper decline from 2000 to 2010. Exploitation rates (catch over vulnerable biomass) were very low up to the late 1980s and have been low to moderate (up to about 0.12 y^{-1}) since then. Since the early 1990s, trawl fishing pressure has generally declined, whereas longline pressure has generally increased.

Table 33: LIN 7CK. Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2010} (in tonnes), and B_{2010} as a percentage of B_0 for all model runs.

Model run	B_0		B_{2010}		B_{2010} (% B_0)	
Base case	8 070	(5 290–53 080)	4 370	(1 250–40 490)	54	(23–80)

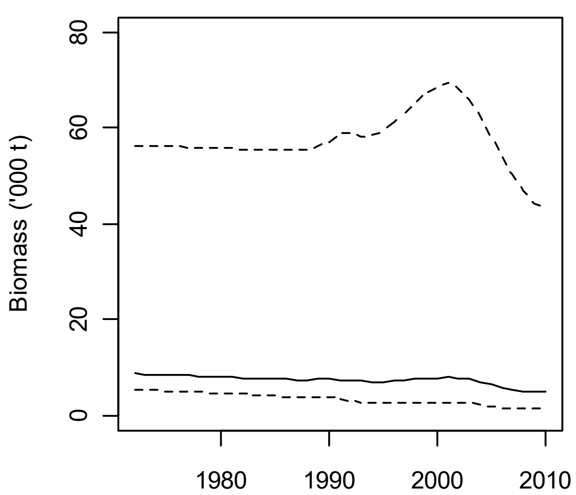


Figure 13: LIN 7CK. Estimated median trajectories (with 95% credible intervals shown as dashed lines) for absolute biomass and biomass as a percentage of B_0.

Table 34: LIN 7CK. Probabilities that current (B_{2010}) and projected (B_{2015}) biomass will be less than 40%, 20%, or 10% of B_0. Projected biomass probabilities are presented for two scenarios of future annual catch (i.e., 220 t and 420 t).

	Management reference points		
Biomass	40% B_0	20% B_0	10% B_0
B_{2010}	0.248	0.006	0.000
B_{2015}, 220 t catch	0.179	0.010	0.000
B_{2015}, 420 t catch	0.328	0.094	0.019

4.7.3 Projections

Projections out to 2015 for LIN 7CK indicated that biomass was likely to increase with future catches equal to recent previous catch levels or decline slightly if catches were equal to the mean since 1990 (Table 35).

Table 35: LIN 7CK. Bayesian median and 95% credible intervals (in parentheses) of projected B_{2015}, B_{2015} as a percentage of B_0, and B_{2015}/B_{2010} (%) for the base case.

Stock and model run		Future catch (t)	B_{2015}		B_{2015} (% B_0)		B_{2015}/B_{2010} (%)	
LIN 7CK	Base	220	5 030	(1 310–43 340)	59	(24–97)	110	(82–158)
		420	4 320	(590–42 910)	52	(11–92)	95	(45–136)

5. FUTURE RESEARCH CONSIDERATIONS

For all stocks, the potential change in growth or spawning over time should be investigated to keep track of potential climate change signals.

LIN 2

- A review of the ling stock structure for LIN 2 should be completed before further assessments are conducted for this QMA.

LIN 3&4

- The potting fishery has been developing since 2018. One trip was observed in 2020 and length data collected. Additional observer length data and age readings are required in order to develop an age-frequency and associated selectivity for this fishery.
- Spatial-temporal standardisation of commercial and Chatham Rise survey data provided different indices worthy of further investigation.

LIN 5&6

- It would be beneficial to improve biological understanding and species distribution for this area. Further work on the spatial-temporal structure of LIN 5&6 needs to be carried out to refine the spatial structure used for modelling this stock.
- The relationship of this stock with LIN 6B needs further investigation.
- The longline CPUE standardisation should be investigated further, in particular with regards to the spatial structure defined.
- If future models continue fixing M, further work on the most appropriate value of M should also be considered.
- Additional representative longline length frequency and age data would be useful.
- Given that making adjustments to correct the *Tangaroa* Sub-Antarctic trawl survey biomass estimate for 2017 will introduce some undefinable uncertainty, the Working Group recommends that this single data point is excluded in all future stock assessments.

6. STATUS OF THE STOCKS

Stock Structure Assumptions
Ling are assessed as six independent biological stocks, based on the presence of spawning areas and some differences in biological parameters between areas (Horn 2005). A spatial length and sex ratio analysis suggested that LIN 6B might be part of the LIN 5&6 stock but otherwise did not suggest any change to the stock assumptions for ling (Mormede et al 2021b).

The Chatham Rise biological stock comprises all of Fishstock LIN 4, and LIN 3 north of the Otago Peninsula. The Sub-Antarctic biological stock comprises all of Fishstock LIN 5, all of LIN 6 excluding the Bounty Plateau, and LIN 3 south of the Otago Peninsula. The Bounty Plateau (part of Fishstock LIN 6) holds another distinct biological stock. The WCSI biological stock occurs in Fishstock LIN 7 west of Cape Farewell. The Cook Strait biological stock includes those parts of Fishstocks LIN 7 and LIN 2 between the northern Marlborough Sounds and Cape Palliser. Ling around the northern North Island (Fishstock LIN 1) are assumed to comprise another biological stock, but there is no information to support this assumption. The stock affinity of ling in LIN 2 between Cape Palliser and East Cape is unknown.

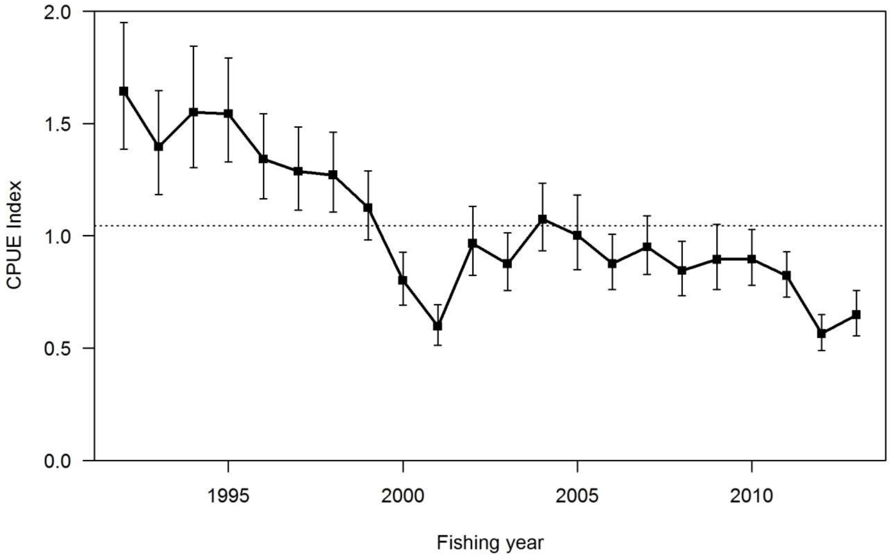
East and west coast LIN 1 are regarded as separate stocks, but no assessments are available for either stock.

- **East coast North Island (part of LIN 2, Statistical Areas 011–015)**

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	CPUE time series based on bottom longline ling target fishing
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F corresponding to 40% B_0
Status in relation to Target	Unknown. CPUE has declined by between about 50–60% since the start of the time series in 1992.

Status in relation to Limits	B_{2014} is Unlikely (< 40%) to be below the Soft Limit and Very Unlikely (< 10%) to be below the Hard Limit
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Standardised CPUE index (± 95% CI) for bottom longline vessels targeting ling from the ECNI Statistical Areas 011–015 (1992–2013). The dashed horizontal line is the time series mean.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is estimated to have declined from 1992 by 50–60%.
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis (2014)	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	CPUE has declined while catches have been below the TACC. There is some probability that fishing at the TACC or current catch may lead to overfishing.

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Evaluation of a CPUE time series from 1992–2013 for bottom longliners targeting ling in Statistical Areas 011–015.	
Assessment Dates	Latest assessment: 2014	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Bottom longline effort& estimated catch	1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	- It is assumed that the longline CPUE time series tracks the entire biomass of ling in this stock. - The boundaries of this biological stock, particularly towards Cook Strait, are uncertain.	

Qualifying Comments
-

Fishery Interactions
Ling are often taken as bycatch in hoki target trawl fisheries in this region. The main bycatch species of hoki-hake-ling-silver warehou-white warehou target fisheries are rattails, javelinfish, and spiny dogfish. Additional information on trawl bycatch can be found in the Environmental and Ecosystem Considerations section of the hoki plenary chapter. Model-based analysis of observer and effort data shows that, in the target longline fisheries for ling across all stocks, the main bycatch species (those constituting over 1% of the observed catch) are: spiny dogfish, ribaldo, skates (smooth and rough), black cod, sea perch, pale ghost shark, red cod, and shovelnose dogfish. Incidental captures of protected species are reported for seabirds.

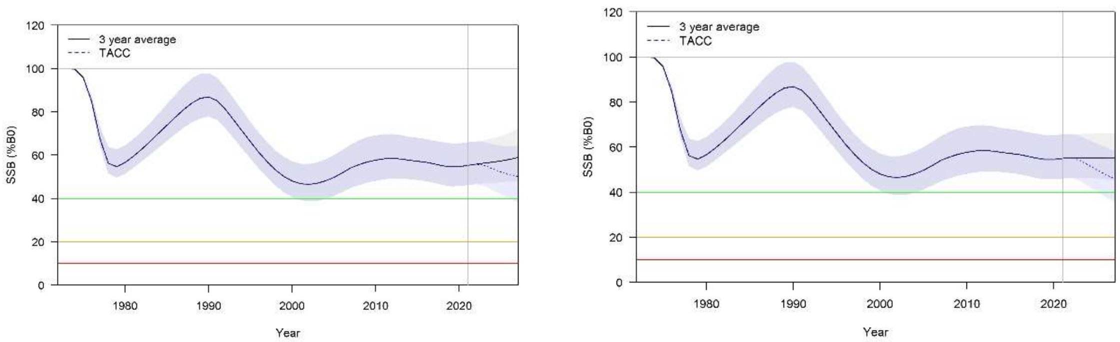
- **Chatham Rise (LIN 3 & 4)**

Stock Status	
Year of Most Recent Assessment	2022
Assessment Runs Presented	Base case
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $U_{40\%}$
Status in relation to Target	B_{2022} was estimated to be 56% B_0; Very Likely (> 90%) to be at or above the above the target
Status in relation to Limits	B_{2022} is Exceptionally Unlikely (< 1%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

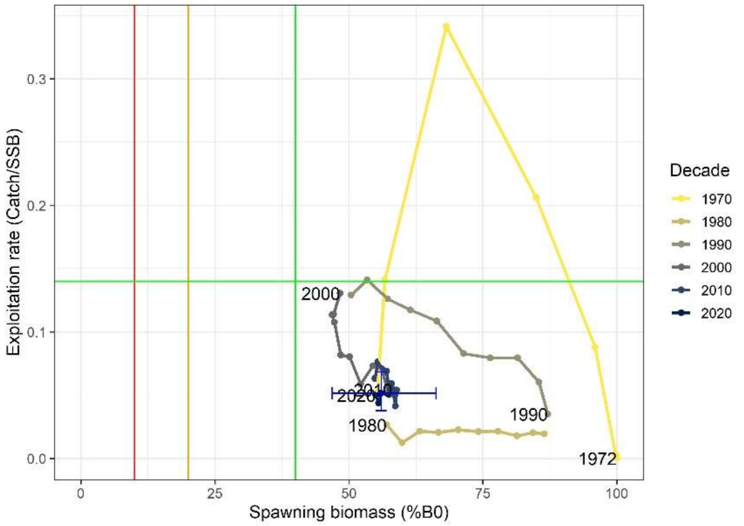
Historical Stock Status Trajectory and Current Status

(a) Resampling all year class strengths

(b) Resampling 2003-13 year class strengths



Trajectory over time of relative spawning biomass (with 95% credible intervals in grey or blue) for the base case model for the Chatham Rise ling stock from the start of the assessment period in 1972 to the most recent assessment in 2022 (vertical grey line) and projected to 2027 with future catches as either the average of the catch from 2019-2021 (solid) or TACC (dashed). Biomass estimates are based on MCMC results. The red horizontal line at 10% B_0 represents the hard limit, the orange line at 20% B_0 is the soft limit, and green line is the %B_0 target (40% B_0). Projections were undertaken by resampling all year class strengths (left) or from the 2003 to 2013 year class strengths (right).



Trajectory over time of exploitation rate (*U*) and spawning biomass (% B_0), for the LIN 3&4 base model from the start of the assessment period in 1972 to 2022. The red vertical line at 10% B_0 represents the hard limit, the orange line at 20% B_0 is the soft limit, and green lines are the % B_0 target (40% B_0) and the corresponding exploitation rate (U_{40} = 0.14 calculated using CASAL *CAY* function). Biomass and exploitation rate estimates are medians from MCMC posteriors for the base model. The blue cross represents the limits of the 95% confidence intervals of the estimated ratio of the *SSB* to B_0 and exploitation rate in 2022.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is estimated to have been increasing or stable since 2003.
Recent Trend in Fishing Mortality or Proxy	Fishing pressure is estimated to have been stable since about 2008.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Recruitment since about 2000 is estimated to have been lower than the long-term average for this stock.

Projections and Prognosis (2022)	
Stock Projections or Prognosis	Current catch or catches at the TACC are Very Unlikely to cause the stock to decline below the target by 2027.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) at current catch Hard Limit: Exceptionally Unlikely (< 1%) at current catch Soft Limit: Exceptionally Unlikely (< 1%) at TACC Hard Limit: Exceptionally Unlikely (< 1%) at TACC
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	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2022	Next assessment: 2025
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Summer research trawl survey series, 1992–2014, 2016, 2018, 2020, 2022	1 – High Quality
	- Proportions-at-age data from the commercial fisheries and trawl survey	1 – High Quality
	- Longline fishery CPUE series (annual indices since 1991): series	2 – Medium or Mixed Quality: likely

	not used in the base assessment model - Estimates of biological parameters (but note that *M* was estimated in the models)	unreliable in the early 1990s. 1 – High Quality
Data not used (rank)	*Kaharoa* ECSI trawl survey abundance index	3 – Low Quality: inadequate spatial coverage of the stock distribution
Changes to Model Structure and Assumptions	- Commercial age frequencies age 5–25 - Commercial selectivities logistic rather than double normal	
Major Sources of Uncertainty	- Lack of contrast in survey indices	

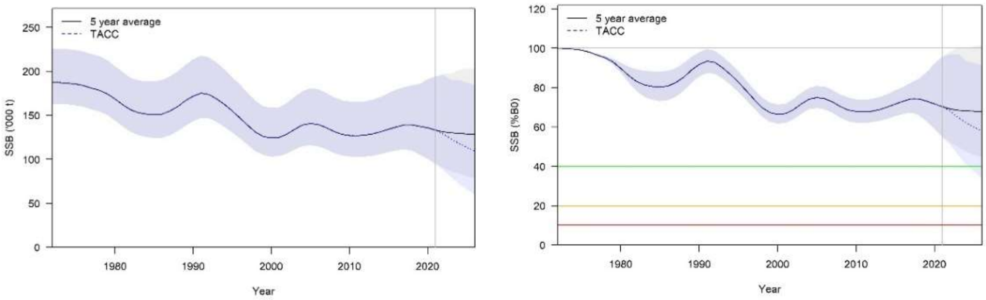
Qualifying Comments
-

Fishery Interactions
Ling are often taken as bycatch in hoki target trawl fisheries in this region. The main bycatch species of hoki-hake-ling-silver warehou-white warehou target fisheries are rattails, javelinfish, and spiny dogfish. Additional information can be found in the Environmental and Ecosystem Considerations section of the hoki plenary chapter. Model-based analysis of observer and effort data shows that, in the target longline fisheries for ling across all stocks, the main bycatch species (those making up over 1% of the observed catch) are: spiny dogfish, ribaldo, skates (smooth and rough), black cod, sea perch, pale ghost shark, red cod, and shovelnose dogfish. All these species are a significant part of the longline fishery bycatch on the Chatham Rise. Spiny dogfish is particularly represented in the longline bycatch (14.8% of catch across all LIN QMAs), with an estimated average annual catch of 1238 t (minimum 281 t, maximum 2405 t) between 2002–03 and 2017–18 in LIN 3 & 4. In the 2019–20 fishing year, protected species captures consisted of 4 seabirds and no marine mammals.

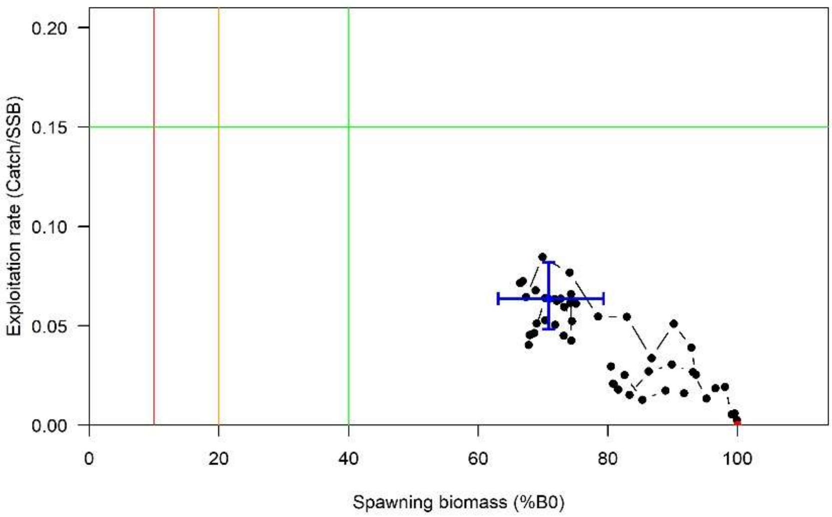
- **Sub-Antarctic (LIN 5 & 6, excluding the Bounty Plateau)**

Stock Status	
Year of Most Recent Assessment	2021
Assessment Runs Presented	One base case
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	B_{2021} was estimated to be 71% B_0; Virtually Certain (> 99%) to be above the target
Status in relation to Limits	B_{2021} is Exceptionally Unlikely (< 1%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit
Status in relation to Overfishing	Overfishing is Exceptionally Unlikely (< 1%) to be occurring

Historical Stock Status Trajectory and Current Status

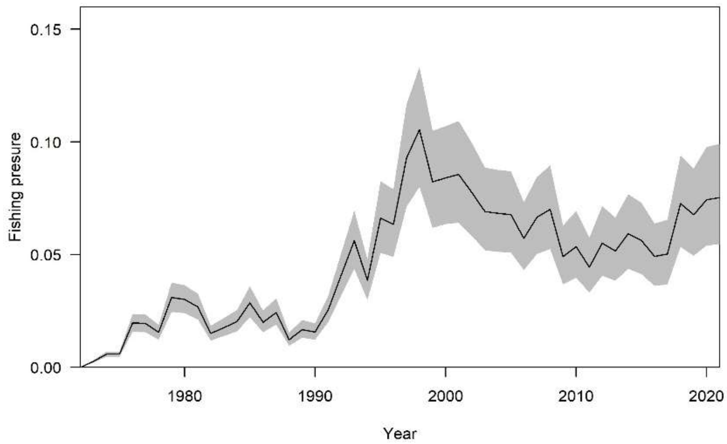


Trajectory over time of relative spawning biomass (with 95% credible intervals in grey or blue) for the base case model for the Sub-Antarctic ling stock from the start of the assessment period in 1972 to the most recent assessment in 2021 (vertical grey line) and projected to 2026 with future catches as either the average of the catch from 2016-2020 (7690 t) (black) or TACC (13 240 t)(blue). Years on the x-axis are model year with '1990' representing the 1989–90 model year from 1 September 1989 to 31 August 1990. Biomass estimates are based on MCMC results. The red horizontal line at 10% B_0 represents the hard limit, the orange line at 20% B_0 is the soft limit, and green line is the %B_0 target (40% B_0). Projections were undertaken by resampling all year class strengths for 2014–2026.



Trajectory over time of exploitation rate (*U*) and spawning biomass (% B_0), for the LIN 5&6 base model from the start of the assessment period in 1972 (represented by a red point), to 2021 (in blue). The red vertical line at 10% B_0 represents the hard limit, the orange line at 20% B_0 is the soft limit, and green lines are the % B_0 target (40% B_0) and the corresponding exploitation rate (U_{40} = 0.15 calculated using CASAL *CAY* calculation). Biomass and exploitation rate estimates are medians from MCMC results. The blue cross represents the limits of the 95% confidence intervals of the estimated ratio of the *SSB* to B_0 and exploitation rate in 2021.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass appears to have changed little in recent years.
Recent Trend in Fishing Mortality or Proxy	Fishing pressure is estimated to have been low, with little change.



LIN 5&6 base model: Exploitation rates (catch over vulnerable biomass) with 95% credible intervals shown as dashed lines.

Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Stock status is unlikely to change over the next 5 years at recent catch levels (7690 t) or the level of the TACC (13 240 t).
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) at current catch or catches at the level of the catch limit Hard Limit: Exceptionally Unlikely (< 1%) at current catch or TACC
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Exceptionally Unlikely (< 1%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2021	Next assessment: 2024
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Summer and autumn *Tangaroa* trawl survey series	1 – High Quality
	- Proportions-at-age data from the commercial fisheries and trawl surveys	1 – High Quality
	- Estimates of biological parameters (but note that *M* was estimated in the models)	1 – High Quality
	- Longline fishery CPUE series (annual indices since 1991)	1 – High Quality
Data not used (rank)	-	
Changes to Model Structure and Assumptions	- The longline fishery was assumed to be a single fishery (it was previously split as spawning and non-spawning) - *M* was fixed at 0.18 - Nuisance *q*s were used instead of free *q*s - The longline CPUE index was used in the base case	
Major Sources of Uncertainty	- The value at which M is fixed has the biggest bearing on the estimate of past and current biomass.	

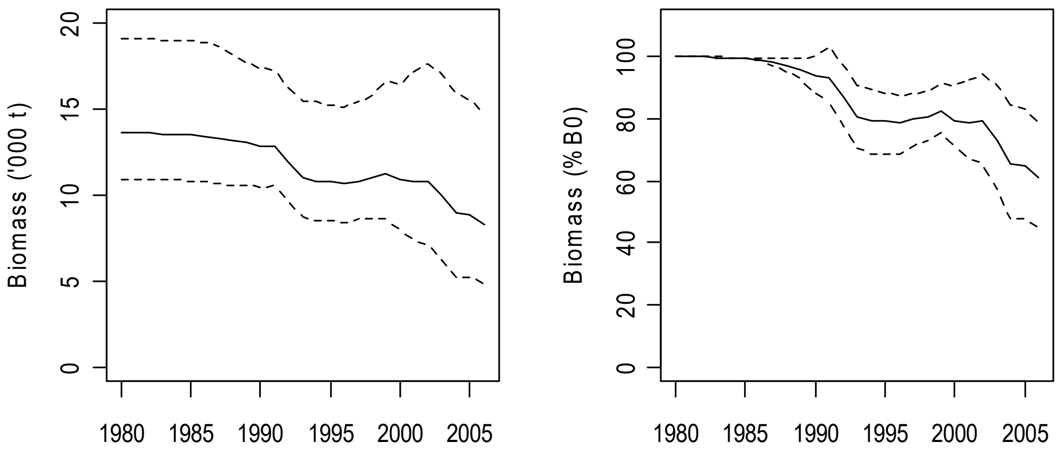
Qualifying Comments
The current assessment assumes that LIN 5 and LIN 6 (except Bounty Islands LIN 6B) are a single biological stock.

Fishery Interactions
Ling are often taken as bycatch in hoki target trawl fisheries in this region. The main bycatch species of hoki-hake-ling-silver warehou-white warehou target trawl fisheries are rattails, javelin fish, and spiny dogfish. Additional information can be found in the Environmental and Ecosystem Considerations section of the hoki plenary. Model-based analysis of observer and effort data shows that, in the target longline fisheries for ling across all stocks, the main bycatch species (those comprising over 1% of the observed catch) are: spiny dogfish, ribaldo, skates (smooth and rough), black cod, sea perch, pale ghost shark, red cod, and shovelnose dogfish.

- **Bounty Plateau (part of LIN 6)**

Stock Status	
Year of Most Recent Assessment	2006
Assessment Runs Presented	A single model run
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Not defined
Status in relation to Target	B_{2006} was estimated to be 61% B_0; Very Likely (> 90%) to be at or above the target
Status in relation to Limits	B_{2006} is Very Unlikely (< 10%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit.
Status in relation to Overfishing	-

Historical Stock Status Trajectory and Current Status



Trajectory over time of spawning biomass (absolute, and % B_0, with 95% credible intervals shown as broken lines) for the Bounty Plateau ling stock from the start of the assessment period in 1980 to the most recent assessment in 2006. Years on the x-axis are fishing year with "1995" representing the 1994–95 fishing year. Biomass estimates are based on MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Median estimates of biomass are unlikely to have been below 61% B_0. Biomass is estimated to have been declining since 1999.
Recent Trend in Fishing Mortality or Proxy	Fishing pressure is estimated to have been low, but erratic, since 1980.

Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Recruitment was above average in the early 1990s, but below average in the late 1990s. No estimates of recruitment since 1999 are available.

Projections and Prognosis (2006)	
Stock Projections or Prognosis	Stock status is predicted to continue declining slightly over the next 5 years at a catch level equivalent to the average since 1991 (i.e., 600 t per year).
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Note that there is no specific TACC for the Bounty Plateau stock. Soft Limit: Very Unlikely (< 10%) Hard Limit: Very Unlikely (< 10%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	-

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2006	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Proportions-at-age data from the commercial longline fishery - Longline fishery CPUE series (annual indices since 1992) - Estimates of biological parameters	1 – High Quality 3 – Low Quality: fishery-dependent with possible changes in *q* over time 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	- No significant changes since the previous assessment	
Major Sources of Uncertainty	- There are no fishery-independent indices of relative abundance, so the assessment is driven largely by the longline fishery CPUE series. - Stock projections are based on a constant future catch of 600 t per year. However, historic catches from this fishery have fluctuated widely, so future catches could be markedly different from 600 t per year.	

Qualifying Comments
There is no separate TACC for this stock; it is part of the LIN 6 Fishstock that has a TACC of 8505 t.

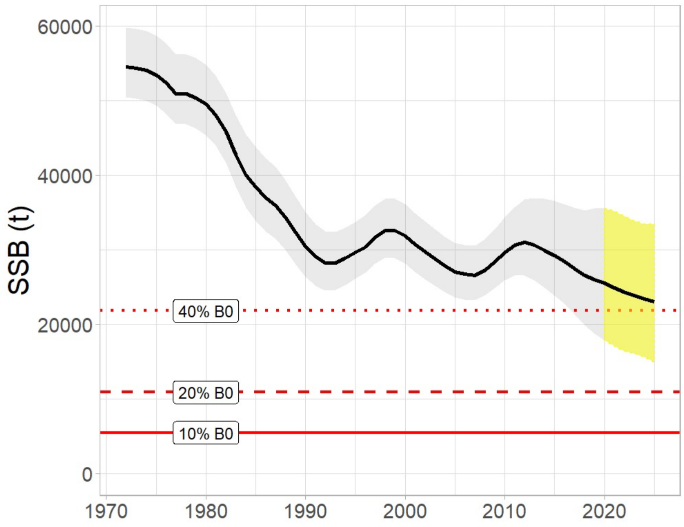
Fishery Interactions
Target longline fisheries for ling have the main bycatch species of spiny dogfish, ribaldo, skates (smooth and rough), sea perch, and sharks (school shark and shovelnose dogfish).

- **West coast South Island (LIN 7)**

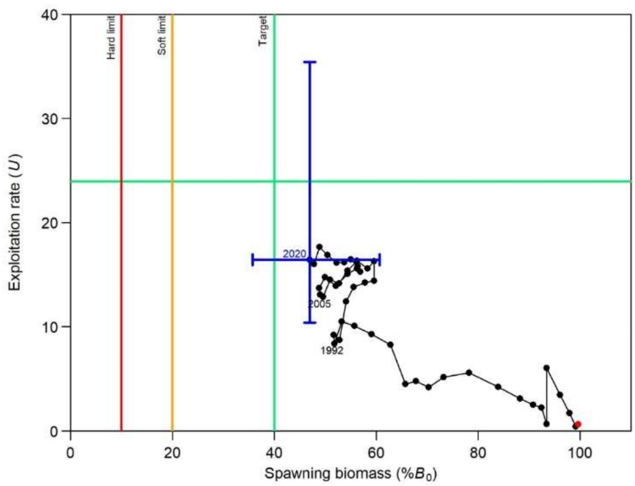
Stock Status	
Year of Most Recent Assessment	2020
Assessment Runs Presented	Base case
Reference Points	Target: 40% B_0

	Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $U_{40\%B0}$
Status in relation to Target	B_{2020} was estimated to be about 47% B_0. Likely (> 60%) to be at or above the target
Status in relation to Limits	B_{2020} is Very Unlikely (< 10%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring

Historical Stock Status Trajectory and Current Status



Trajectory over time of relative spawning biomass (with 95% credible intervals in grey) for the base case model for the WCSI ling stock from the start of the assessment period in 1972 to the most recent assessment in 2020 and projected to 2025 (in yellow). Years on the x-axis are fishing year with '1990' representing the 1989–90 fishing year. Biomass estimates are based on MCMC results.



Trajectory over time of exploitation rate (*U*) and spawning biomass (% B_0), for the LIN 7 base model from the start of the assessment period in 1974 (represented by a red point), to 2020 (in blue). The red vertical line at 10% B_0 represents the hard limit, the orange line at 20% B_0 is the soft limit, and green lines are the %B_0 target (40% B_0) and the corresponding exploitation rate (U_{40}). Biomass and exploitation rate estimates are medians from MCMC results. The blue cross represents the limits of the 95% confidence intervals of estimated the ratio of the *SSB* to B_0 and exploitation rate in 2020.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is estimated to have slowly declined since 2012.
Recent Trend in Fishing Intensity or Proxy	Exploitation rates have been increasing bout are well below the overfishing threshold.
Other Abundance Indices	Inclusion of the trawl fishery CPUE led to the same conclusions.

Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Stock status is declining but Likely (> 60%) to remain above the target over the next 5 years at the current TACC.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	At TACC Soft Limit: Very Unlikely (< 10%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	About as Likely as Not (40–60%)

Assessment Methodology and Evaluation		
Assessment Type	Level 1 - Full Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2020	Next assessment: 2023
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch history - Abundance index from WCSI trawl surveys - Proportions at age data from the commercial fisheries and trawl surveys - Estimates of fixed biological parameters	1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	- Abundance index from the commercial trawl hoki-hake-ling target fishery CPUE - Commercial longline fishery CPUE - *Kaharoa* trawl survey abundance index	1 – High Quality: used in sensitivity 3 – Low Quality: does not track stock biomass 3– Low Quality: inadequate spatial coverage of the stock distribution
Changes to Model Structure and Assumptions	-time step added to place the age increment at the end of the year cycle -changed survey and trawl fishery selectivity to improve the behaviour of the model at MCMC	
Major Sources of Uncertainty	- There is a lack of contrast in the biomass indices to inform the absolute level of biomass. - Although the catch history used in the assessment has been corrected for some misreported catch (see Section 1.4), it is possible that additional misreporting exists. - Age data do not track cohorts well.	

Qualifying Comments
- Longline age data may not be representative of fishery

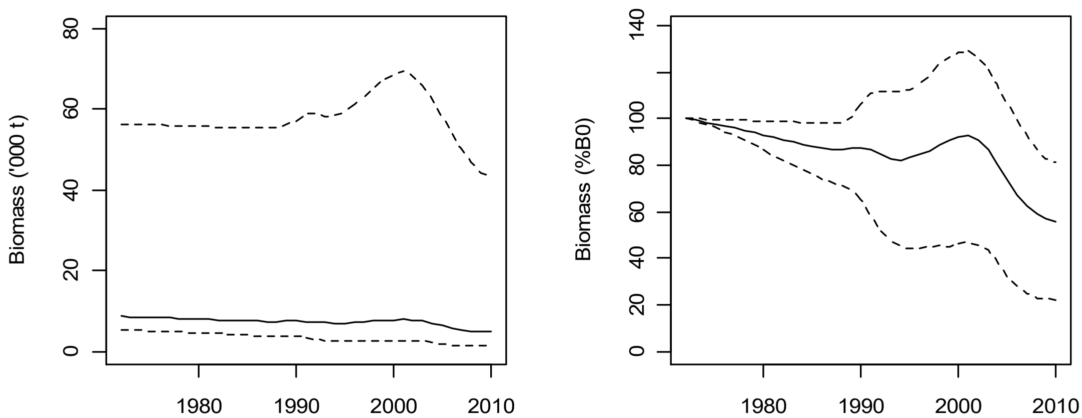
Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries in this region. The main bycatch species of hoki-hake-ling-silver warehou-white warehou target trawl fisheries are rattails, javelinfish, and spiny dogfish. Additional information can be found in the Environmental and Ecosystem Considerations section of the hoki plenary.

Model-based analysis of observer and effort data shows that, in the target longline fisheries for ling across all stocks, the main bycatch species (those comprising over 1% of the observed catch) are: spiny dogfish, ribaldo, skates (smooth and rough), black cod, sea perch, pale ghost shark, red cod, and shovelnose dogfish.

- **Cook Strait (LIN 2 [Statistical Area 016] & part of LIN 7)**

Stock Status	
Year of Most Recent Assessment	2010 (an assessment in 2013 was rejected)
Assessment Runs Presented	Base case
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: F corresponding to 40% B_0
Status in relation to Target	B_{2010} was estimated to be 54% B_0; Likely (> 60%) to be at or above the target
Status in relation to Limits	B_{2010} is Exceptionally Unlikely (< 1%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit
Status in relation to Overfishing	Overfishing is Very Unlikely (< 10%) to be occurring

Historical Stock Status Trajectory and Current Status



Trajectory over time of spawning biomass (absolute, and % B_0, with 95% credible intervals shown as broken lines) for the Cook Strait ling stock from the start of the assessment period in 1972 to the most recent assessment in 2010. Years on the x-axis are fishing year with '1990' representing the 1989–90 fishing year. Biomass estimates are based on MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is estimated to have been declining since 1999, but is unlikely to have dropped below 30% B_0.
Recent Trend in Fishing Intensity or Proxy	Overall fishing pressure is estimated to have been relatively constant since the mid-1990s, but has trended down for trawl and up for longline.
Other Abundance Indices	–
Trends in Other Relevant Indicators or Variables	Recruitment from 1995 to 2006 was low relative to the long-term average for this stock. There are no estimates for the more recent year classes.

Projections and Prognosis	
Stock Projections or Prognosis	Stock status is predicted to improve slightly over the next 5 years at a catch level equivalent to that since 2006 (i.e., 220 t per year), or remain relatively constant at a catch equivalent to the mean since 1990 (i.e., 420 t per year).

Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Note that there is no specific TACC for the Cook Strait stock. Soft Limit: Catch 220 t, Very Unlikely (< 10%); Catch 420 t, Very Unlikely (< 10%) Hard Limit: Catch 220 t, Exceptionally Unlikely (< 1%); Catch 420 t, 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	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2010	Next assessment: 2020
Overall assessment quality rank	3 – Low Quality: The only accepted relative abundance series (trawl fishery CPUE) was not well fitted. A subsequent assessment in 2013 was rejected by the Working Group.	
Main data inputs (rank)	- Proportions-at-age data from the commercial trawl fishery - Proportions-at-age data from the commercial longline fishery - Trawl fishery CPUE series (annual indices since 1994) - Estimates of biological parameters	1 – High Quality 3 – Low Quality: not representative of entire fishery 2 – Medium or Mixed Quality: not well-fitted by model 1 – High Quality
Data not used (rank)	Longline fishery CPUE	3 – Low quality: does not track stock biomass
Changes to Model Structure and Assumptions	- No significant changes since the previous assessment.	
Major Sources of Uncertainty	- There are no fishery-independent indices of relative abundance. It is not known if the trawl CPUE series is a reliable abundance index. - The stock structure of Cook Strait ling is uncertain. While ling in this area are almost certainly biologically distinct from the WCSI and Chatham Rise stocks, their association with ling off the lower east coast of the North Island is unknown. - It is possible that trawl selectivity has varied over time, resulting in poor fits to some age classes in some years. - Longline fishery selectivity is based on only two years of catch-at-age data from the auto longline fishery. No information is available from the 'hand-baiting' longline fishery. - The model is moderately sensitive to small changes in *M*, and *M* is poorly estimated.	

Qualifying Comments
There is no separate TACC for this stock; it comprises parts of Fishstocks LIN 7 and LIN 2.

Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries in this region. The main bycatch species of hoki-hake-ling-silver warehou-white warehou target trawl fisheries are rattails, javelinfish, and spiny dogfish. Additional information can be found in the Environmental and Ecosystem Considerations section of the hoki plenary. Model-based analysis of observer and effort data shows that, in the target longline fisheries for ling across all stocks, the main bycatch species (those comprising over 1% of the observed catch) are: spiny dogfish, ribaldo, skates (smooth and rough), black cod, sea perch, pale ghost shark, red cod, and shovelnose dogfish.

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