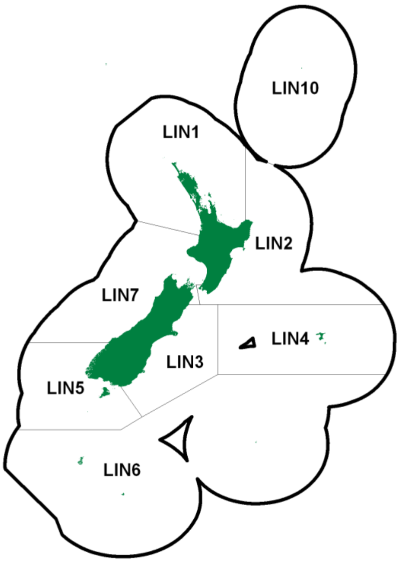
LING

(*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 2017 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	79	3 955	4 036
LIN 6	0	0	85	8 505	8 590
LIN 7	1	1	62	3 080	3 144
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 through 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). However, since about 2000 there has been a declining trend in catches taken by line vessels in most areas, offset, to some extent, by increased trawl landings.

The principal grounds for smaller domestic vessels are 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. In 2016–17, landings from Fishstocks LIN 3, LIN 4 and LIN 6 were substantially under-caught relative to their TACCs, the LIN 5 catch was just under the TACC, and the LIN 1, LIN 2 and LIN 7 TACCs were slightly over-caught. Reported landings for the main QMAs from 1931 to 1982 are given in Table 2, reported landings by nation from 1975 to 1987–88 are given in Table 3, and reported landings by Fishstock from 1983–84 onwards are shown in Table 4. Figure 1 shows the historical landings and TACC values for the main LIN stocks.

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 and 5 720 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 2 060 and 4 200 t, respectively. From 1 October 2004, the TACCs for LIN 5 and LIN 6 were increased by about 20% to 3 595 t and 8 505 t, respectively, and the LIN 5 was increased by a further 10% (to 3 955 t) from 1 October 2013. From 1 October 2009, the TACC for LIN 7 was increased from 2 225 t to 2 474 t, and further increased to 3 080 t from 1 October 2013. All other TACC increases since 1986–87 in all stocks are the result of quota appeals.

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

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

Year	LIN 5	LIN 6	LIN 7	Year	LIN 5	LIN 6	LIN 7
1931–32	1	0	0	1957	8	0	19
1932–33	2	0	35	1958	15	0	28
1933–34	1	0	67	1959	13	0	27
1934–35	1	0	94	1960	21	0	19
1935–36	1	0	66	1961	20	0	19
1936–37	1	0	61	1962	13	0	16
1937–38	1	0	57	1963	14	0	11
1938–39	24	0	37	1964	16	0	13
1939–40	16	0	26	1965	24	0	13
1940–41	21	0	46	1966	16	0	17
1941–42	22	0	40	1967	14	0	36
1942–43	24	0	29	1968	11	0	42
1943–44	19	0	40	1969	10	0	23
1944	13	0	46	1970	14	0	51
1945	13	0	80	1971	20	1	37
1946	9	0	78	1972	22	0	33
1947	24	0	96	1973	23	0	41
1948	24	0	66	1974	335	44	82
1949	20	0	67	1975	1 513	344	224
1950	29	0	61	1976	2 630	0	1 739
1951	16	0	34	1977	1 683	0	2 810
1952	16	0	36	1978	2 515	391	240
1953	19	0	34	1979	4 400	1 431	454
1954	7	0	44	1980	4 064	933	928
1955	6	0	27	1981	3 576	636	1 020
1956	4	0	15	1982	2 109	317	1 208

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			Total	
	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 Sept 30 (except domestic vessels, which reported by calendar year).
§ Reported Oct 1 to Sept 30.

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.

Table 4: Reported landings (t) of ling by Fishstock from 1983–84 to 2016–17 and actual TACCs (t) from 1986–87 to 2016–17. 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

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

* FSU data.

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

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 1 334 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 Maori 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 South and Chatham Islands, ling comprised about 4% (by number) of recovered fish remains.

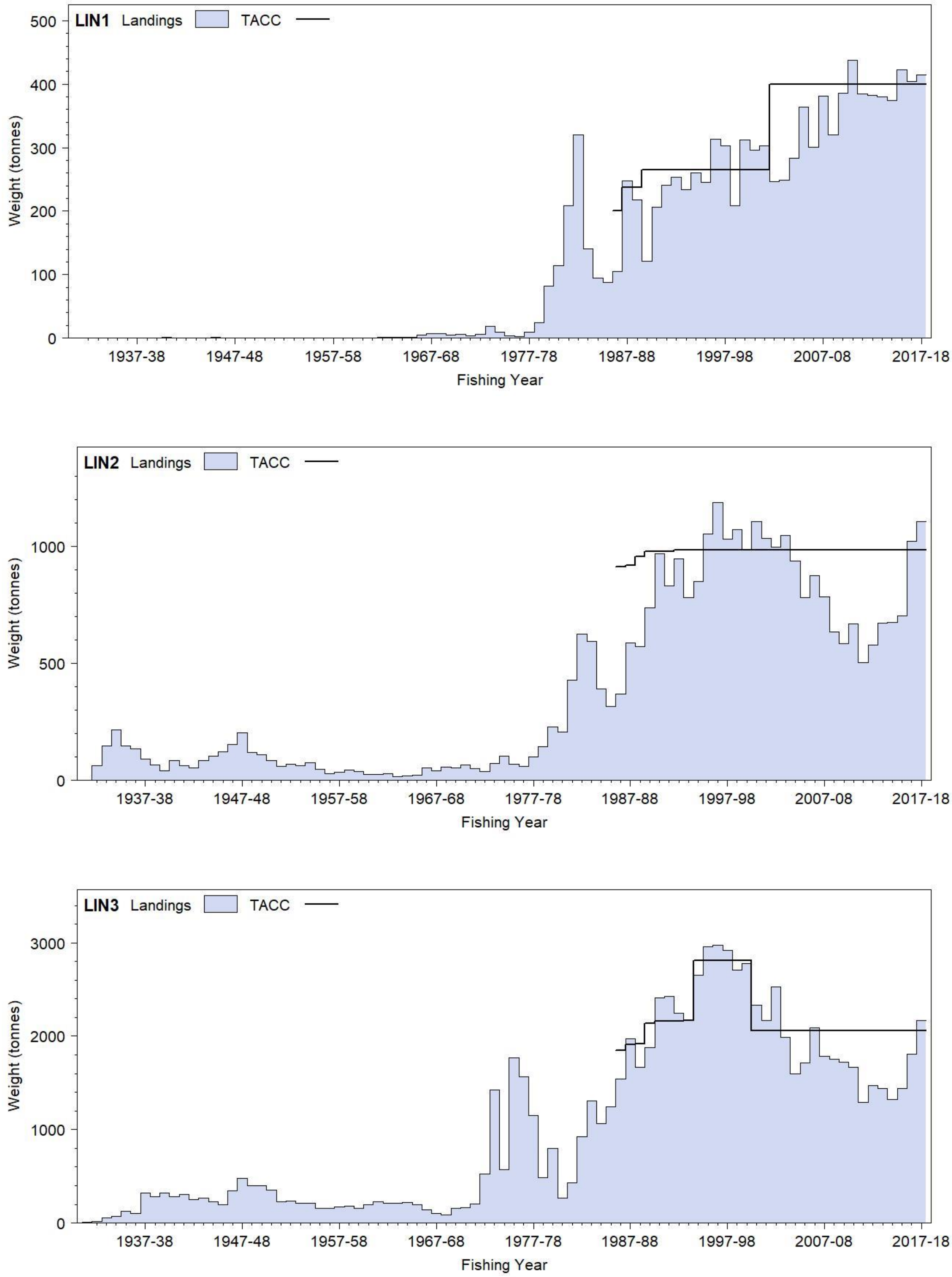


Figure 1: Reported commercial landings and TACC for the seven main LIN stocks. From top to bottom: LIN 1 (Auckland East), LIN 2 (Central East) and LIN 3 (South East Coast) [Continued on next page].

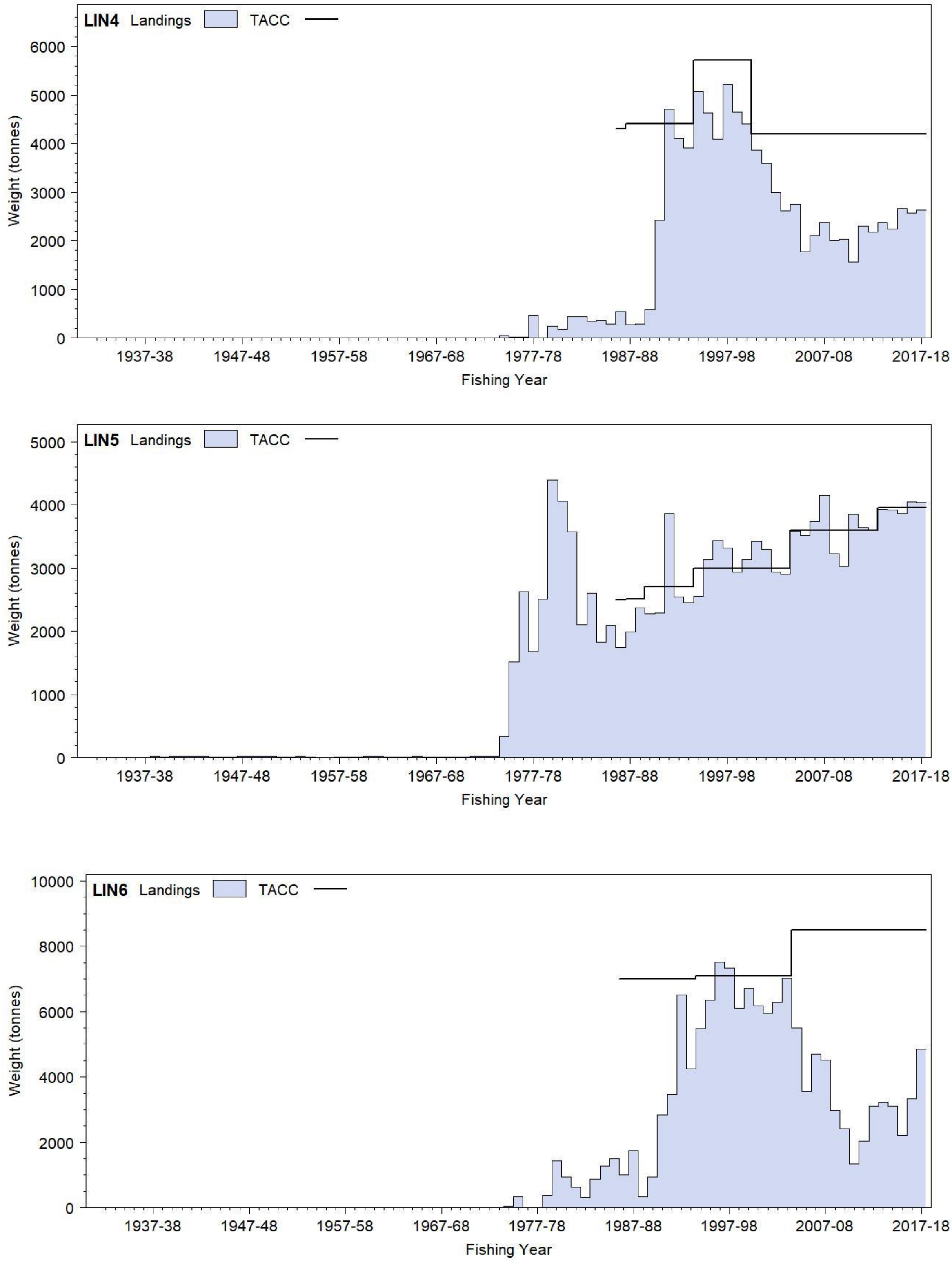


Figure 1 [continued]: Reported commercial landings and TACC for the seven main LIN stocks. From top to bottom: LIN 4 (South East Chatham Rise), LIN 5 (Southland) and LIN 6 (Sub-Antarctic) [Continued on next page].

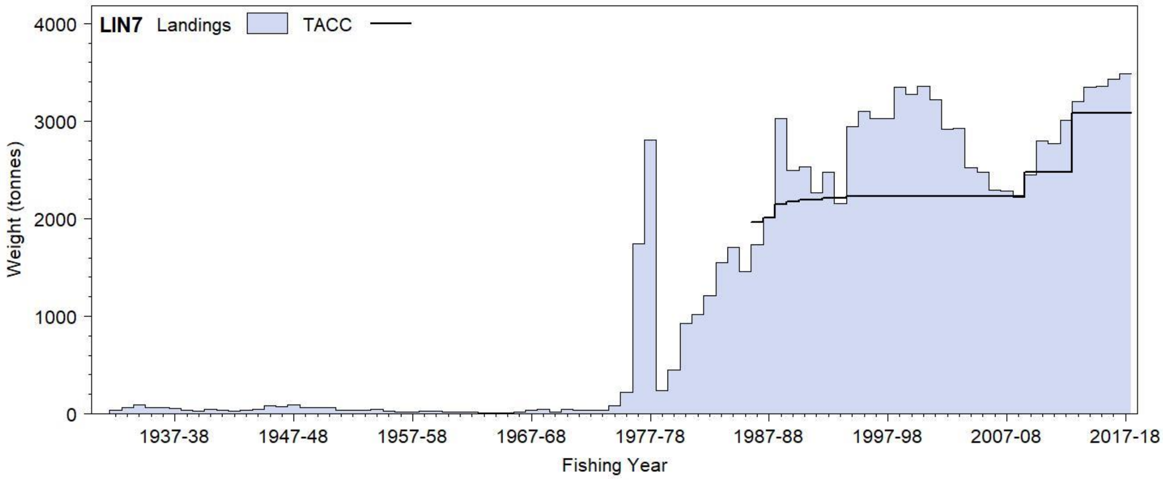


Figure 1 [continued]: Reported commercial landings and TACC for the seven main LIN stocks. LIN 7 (Challenger).

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 recent years, some catch from LIN 7 has been 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

The extent of any other sources of mortality is unknown.

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 $M = \log_e 100/\text{maximum age}$, 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, while 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 Straight 0.12; Chatham Rise 0.13; 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; 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.

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

1. Natural mortality (M)

FMA	Both sexes
All stocks	*0.18*

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

	Female		Male		Combined		Area
FMA	a	b	a	b	a	b	
LIN 3&4	0.00114	3.318	0.001	3.354	–	–	Chatham Rise
LIN 5&6	0.00128	3.303	0.00208	3.19	–	–	Southern Plateau
LIN 6B	0.00114	3.318	0.001	3.354	–	–	Bounty Plateau
LIN 7WC	0.000934	3.368	0.001146	3.318	0.00104	3.318	West Coast S.I.
LIN 7CK	0.000934	3.368	0.001146	3.318	–	–	Cook Strait

3. von Bertalanffy growth parameters

	Female			Male			Combined			Area
FMA	K	t_0	L_{∞}	K	t_0	L_{∞}	K	t_0	L_{∞}	
LIN 3&4	0.083	–0.74	156.4	0.127	–0.70	113.9	–	–	–	Chatham Rise
LIN 5&6	0.124	–1.26	115.1	0.188	–0.67	93.2	–	–	–	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.

4. STOCK ASSESSMENT

LIN 1 was previously managed and assessed under the Adaptive Management Programme (see Section 5) and an updated CPUE analysis for this Fishstock was conducted in 2017. A CPUE analysis for the ling target bottom longline fishery in LIN 2 was conducted in 2014. The stock assessments for two ling stocks (LIN 3&4, Chatham Rise; LIN 5&6, Sub-Antarctic) were updated in 2015. Assessments for other stocks were updated in 2007 (LIN 6B, Bounty Plateau, with a CPUE update in 2014), 2013 (LIN 7CK, Cook Strait), or 2017 (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).

4.1 Estimates of fishery parameters and abundance

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

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 line), and, for the LIN 5&6 line fishery, by pre-spawning (Pre) and spawning (Spn) season.

Year	LIN 2		LIN 3&4		LIN 5&6			LIN 6B	LIN 7WC		LIN 7CK	
	trawl	line	trawl	line	trawl	line Pre	line Spn	line	trawl	line	trawl	line
1972	–	–	0	0	0	0	0	0	0	0	0	0
1973	–	–	250	0	500	0	0	0	85	20	45	45
1974	–	–	382	0	1 120	0	0	0	144	40	45	45
1975	–	–	953	8 439	900	118	192	0	401	800	48	48
1976	–	–	2 100	17 436	3 402	190	309	0	565	2 100	58	58
1977	–	–	2 055	23 994	3 100	301	490	0	715	4 300	68	68
1978	–	–	1 400	7 577	1 945	494	806	10	300	323	78	78
1979	–	–	2 380	821	3 707	1 022	1 668	0	539	360	83	83
1980	–	–	1 340	360	5 200	0	0	0	540	305	88	88
1981	–	–	673	160	4 427	0	0	10	492	300	98	98
1982	–	–	1 183	339	2 402	0	0	0	675	400	103	103
1983	–	–	1 210	326	2 778	5	1	10	1 040	710	97	97
1984	–	–	1 366	406	3 203	2	0	6	924	595	119	119
1985	–	–	1 351	401	4 480	25	3	2	1 156	302	116	116
1986	–	–	1 494	375	3 182	2	0	0	1 082	362	126	126
1987	–	–	1 313	306	3 962	0	0	0	1 105	370	97	97
1988	–	–	1 636	290	2 065	6	0	0	1 428	291	107	107
1989	–	–	1 397	488	2 923	10	2	9	1 959	370	255	85
1990	85	134	1 934	529	3 199	9	4	12	2 205	399	362	121
1991	162	185	2 563	2 228	4 534	392	97	33	2 163	364	488	163
1992	110	299	3 451	3 695	6 237	566	518	908	1 631	661	498	85
1993	97	381	2 375	3 971	7 335	1 238	474	969	1 609	716	307	114
1994	96	397	1 933	4 159	5 456	770	486	1 149	1 136	860	269	84
1995	97	398	2 222	5 530	5 348	2 355	338	396	1 750	1 032	344	70
1996	149	350	2 725	4 863	6 769	2 153	531	381	1 838	1 121	392	35
1997	168	269	3 003	4 047	6 923	3 412	614	340	1 749	1 077	417	89
1998	148	387	4 707	3 227	6 032	4 032	581	395	1 887	1 021	366	88
1999	169	257	3 282	3 818	5 593	2 721	489	563	2 146	1 069	316	216
2000	166	286	3 739	2 779	7 089	1 421	1 161	991	2 247	923	317	131
2001	216	344	3 467	2 724	6 629	818	1 007	1 064	2 304	977	258	80
2002	212	366	2 979	2 787	6 970	426	1 220	629	2 250	810	230	171
2003	124	344	3 375	2 150	7 205	183	892	922	1 980	807	280	180
2004	82	420	2 525	2 082	7 826	774	471	853	2 013	814	241	227
2005	54	335	1 913	2 440	7 870	276	894	49	1 558	871	200	282
2006	45	365	1 639	1 840	6 161	178	692	43	1 753	666	129	220
2007	87	425	2 322	1 880	7 504	34	651	236	1 306	933	107	189
2008	37	457	2 350	1 810	6 990	329	821	503	1 067	1 170	115	110
2009	49	394	1 534	2 217	5 225	276	432	232	1 089	1 009	108	39
2010	37	409	1 484	2 257	4 270	864	313	1	1 346	1 063	74	14
2011	51	426	1 191	2 046	4 404	567	169	51	1 733	1 011	115	67
2012	57	288	1 407	2 190	4 384	934	376	2	1 744	976	96	47
2013	44	317	1 113	2 543	6 234	135	340	3	1 915	1 045	104	106
2014	78	337	1 340	2 250	5841	785	247	265	1 420	1 190	71	71
2015	68	385	1 064	1 608	6176	611	229	23	1 561	1 157	68	63
2016	69	386	936	2 189	5228	440	190	220	1 669	1 149	52	81
2017					5816	633	153					

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	0.7	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*

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	0.027	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	0.001	0.003	0.006	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	1.0			
Female	0.0	0.00	0.05	0.10	0.30	0.50	0.80	1.00	1.00	1.0			
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	1.0			
Female	0.0	0.004	0.017	0.06	0.18	0.39	0.65	0.85	0.94	1.0			
Combined	0.0	0.010	0.056	0.23	0.48	0.67	0.83	0.93	0.97	1.0			

*Horn 2005

Table 8: Standardised CPUE indices (with CVs) for the ling line and trawl fisheries. Year refers to calendar year; sp=spawning fishery; nsp=non-spawning fishery.

	LIN 2 line		LIN 3&4 line		LIN 5&6 line (sp)		LIN 5&6 line (nsp)		LIN 6B line	
Year	**CPUE**	**CV**	**CPUE**	**CV**	**CPUE**	**CV**	**CPUE**	**CV**	**CPUE**	**CV**
1991	–	–	1.67	0.06	–	–	–	–	–	–
1992	1.64	0.09	2.43	0.06	1.03	0.13	1.15	0.1	1.74	0.15
1993	1.40	0.08	1.73	0.05	1.76	0.09	1.16	0.11	1.41	0.13
1994	1.55	0.09	1.65	0.05	1.59	0.1	1.02	0.09	0.95	0.16
1995	1.54	0.07	1.68	0.05	1.26	0.08	1.44	0.08	1.24	0.13
1996	1.34	0.07	1.31	0.05	1.33	0.11	1.05	0.08	1.15	0.12
1997	1.29	0.07	0.88	0.04	1.27	0.08	1.3	0.06	0.92	0.14
1998	1.27	0.07	0.90	0.05	1.15	0.07	1.1	0.06	1.06	0.12
1999	1.13	0.07	0.80	0.04	1.03	0.09	0.74	0.06	1.07	0.11
2000	0.80	0.07	0.93	0.05	1.07	0.1	0.86	0.07	0.95	0.10
2001	0.60	0.08	0.93	0.04	1.29	0.08	1.03	0.09	0.76	0.11
2002	0.97	0.08	0.77	0.04	1.36	0.09	0.99	0.13	0.69	0.11
2003	0.88	0.07	0.85	0.05	1.49	0.1	0.64	0.17	0.78	0.10
2004	1.07	0.07	0.81	0.04	0.78	0.11	0.71	0.07	0.74	0.16
2005	1.00	0.08	0.85	0.04	1.02	0.08	0.71	0.11	–	–
2006	0.88	0.07	0.74	0.05	1.46	0.11	0.78	0.14	–	–
2007	0.95	0.07	0.81	0.04	1.19	0.11	0.76	0.45	–	–
2008	0.85	0.07	1.04	0.04	1.27	0.1	0.75	–	–	–
2009	0.89	0.08	0.73	0.04	1.03	0.14	0.92	0.17	–	–
2010	0.90	0.07	0.84	0.04	2.05	0.19	1.18	0.09	–	–
2011	0.82	0.06	0.65	0.04	0.69	0.18	0.76	0.1	–	–
2012	0.56	0.07	0.79	0.05	1.04	0.14	0.99	0.08	–	–
2013	0.65	0.08	0.80	0.07	1.1	0.15	0.9	–	–	–
2014					0.87	0.16	0.84	0.09		
2015					0.65	0.16	0.84	0.08		
2016					0.58	0.16	0.52	0.1		
2017					0.64	0.27	0.72	0.09		

	LIN 7WC line		LIN 7CK line		LIN 7CK trawl		LIN 7WC trawl	
Year	**CPUE**	**CV**	**–**	**–**	**CPUE**	**CV**	**CPUE**	**CV**
1987	–	–	–	–	–	–	0.58	0.07
1988	–	–	–	–	–	–	1.01	0.06
1989	–	–			–	–	1.43	0.07
1990	0.87	0.07	1.29	0.15	–	–	1.37	0.06
1991	1.04	0.06	1.44	0.13	–	–	0.88	0.07
1992	1.23	0.05	1.43	0.11	–	–	0.95	0.08
1993	0.88	0.05	1.11	0.11	–	–	1.10	0.07
1994	0.86	0.05	0.90	0.11	1.25	0.05	0.94	0.06
1995	0.87	0.05	0.83	0.12	1.16	0.04	1.29	0.07
1996	0.65	0.04	0.97	0.13	1.12	0.04	1.71	0.05
1997	0.77	0.05	1.32	0.18	1.00	0.04	1.62	0.06
1998	0.89	0.04	0.83	0.15	1.01	0.04	1.32	0.05
1999	0.92	0.05	1.54	0.18	1.02	0.03	1.60	0.04
2000	0.94	0.05	1.45	0.19	1.27	0.04	1.22	0.04
2001	1.09	0.05	1.27	0.18	1.46	0.04	0.98	0.04
2002	1.02	0.05	2.04	0.11	1.27	0.05	1.22	0.04
2003	1.08	0.04	1.66	0.10	1.27	0.04	0.70	0.05
2004	1.08	0.05	1.45	0.09	1.13	0.04	1.21	0.04
2005	0.81	0.04	1.16	0.10	1.18	0.04	0.83	0.04
2006	0.81	0.05	0.97	0.15	1.10	0.05	0.77	0.04
2007	1.08	0.04	0.70	0.12	0.73	0.06	0.57	0.06
2008	1.10	0.05	0.82	0.22	0.90	0.06	0.57	0.06
2009	1.09	0.05	0.60	0.28	0.44	0.07	0.54	0.06
2010	1.33	0.04	0.35	0.30	0.44	0.07	0.75	0.06
2011	1.15	0.05	0.22	0.30	0.23	0.09	1.10	0.05
2012	1.18	0.05					0.88	0.05
2013	1.32	0.05					0.98	0.03
2014	1.23	0.05					0.94	0.03
2015	1.06	0.05					1.09	0.03
2016	1.03	0.06					1.32	0.03

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.

Table 9: Biomass indices (t) and estimated coefficients of variation (CV).

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
			TAN1601	Jan 2016	10 201	7.2
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
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
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

Table 9 [continued]

KAH1305*	Mar–Apr 2013	405	44
KAH1503*	Mar–Apr 2015	472	53

* Not used in the reported assessment.

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.

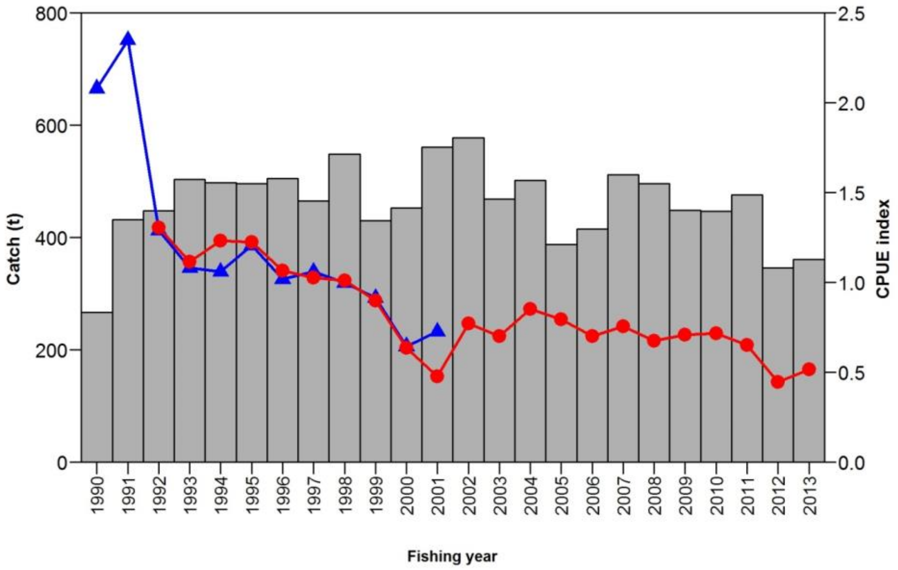


Figure 2: Estimated ling catch (bars) and standardized CPUE indices for LIN 2. Blue line and triangles from Horn (2004). Red line and circles for ECNI Statistical Areas 011–015 for core bottom longline vessels targeting ling, from Roux (2015). The two CPUE series were normalised to the overlapping fishing 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 2015 (McGregor 2015). 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_{2014}) biomass were obtained. Year class strengths and fishing selectivity ogives were estimated in the model. Trawl fishery and research survey selectivity ogives were fitted as double normal curves; line fishery ogives were fitted as logistic curves. Selectivities were assumed constant over all years in each fishery/survey. Instantaneous natural mortality (M) was estimated as a constant in the model. MCMCs were estimated using a burn-in length of 2×10^5 iterations, with every 1000th sample kept from the next 6×10^6 iterations (i.e., a final sample of length 6000 was taken from the Bayesian posterior).

For LIN 3&4, model input data included catch histories, biomass and sexed catch-at-age data from a summer trawl survey series, sexed catch-at-age from the trawl fishery, line fishery CPUE, unsexed catch-at-age and catch-at-length from the line fishery, and estimates of biological parameters (Table 10). The catch history, biological input parameters, and estimates of relative abundance used in the model are shown in Tables 5–9. The stock assessment model partitioned the population into two sexes, and age groups 3 to 25 with a plus group. 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 series	Years
Trawl survey proportion at age (*Amaltal Explorer*, Dec)	1990
Trawl survey biomass (*Tangaroa*, Jan)	1992–2014
Trawl survey proportion at age (*Tangaroa*, Jan)	1992–2014
CPUE (longline, all year)	1991–2013
Commercial longline proportion-at-age (Jun–Oct)	2002–09, 2013
Commercial longline length-frequency (Jun–Oct)	1995–2002
Commercial trawl proportion-at-age (Oct–May)	1992, 1994–2013

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^1	Age[2]	Description	$\%Z^3$
1	Dec–Aug	Recruitment fisheries (line & trawl)	0.9	0.5	Trawl survey (summer)	0.2
					Line CPUE	0.5
					Line catch-at-age/length	
					Trawl catch-at-age	
2	Sep–Nov	Spawning and increment ages	0.1	0	–	

1. *M* is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction, used for determining length-at-age, that was assumed to occur by the start of that time step.
3. %*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 and at-length data, and lognormal for all other data. The weight assigned to each data set was controlled by the error coefficient of variation (CV). The observation-error CVs were calculated using standard formulae. An additional process error CV of 0.15 was added to the trawl survey biomass index following Francis et al (2001), and a process error CV for the line fishery CPUE was estimated at 0.15 following Francis (2011). The multinomial observation error CVs for the at-age and at-length data were adjusted using the reweighting procedure of Francis (2011).

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. The other exception was the normal prior on p_male with μ=0.5, CV=0.15. 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 free, unless there were difficulties in convergence, in which case they were set as nuisance variables (they were integrated out). The runs that included the longline CPUE had difficulty converging.

There is a conflict between the line fishery CPUE and the trawl survey biomass index, in which the line fishery biomass index declined between 1991 and 1997, but the trawl survey index remained relatively flat throughout. To remove this conflict, a base case model run (Base) used all the observational data except the line fishery CPUE. The trawl survey biomass index was preferred in the base case because these data were fishery independent, and there was evidence that the longline fishery *q* had changed over time as very large fish were removed from the population (Horn 2015). A sensitivity run (Longline) then included the line fishery CPUE, and excluded the trawl survey biomass series; this model is considered a likely 'worst case' scenario. Additional models included both biomass indices (All), tested logistic, rather than double normal, selectivity ogives for trawl survey and fishery (Selectivity), and estimated a separate natural mortality for each sex (M), but these models are not reported in detail here.

4.3.2 Model estimates

The fits to the biomass indices, catch-at-age and catch-at-length data, were all reasonable, and almost indistinguishable between model runs. Year class strength estimates (Figure 3) were generally average or below average since 1980, except for 1994 and 1995. Estimated year class strengths were not widely variable, with all medians being between 0.5 and 2. Ling were first caught by the trawl survey (age at full selectivity 6 years), then the trawl fishery (age 8 years), and then the line fishery (age 16 years). Selectivities for the trawl fishery and survey tended towards a logistic distribution, although a double normal distribution was offered. Males were estimated to be less vulnerable than females to the trawl fishery. The estimated median *M* (for sexes combined) was 0.15.

The assessment was driven by the catch history, and by catch-at-age data, which contain information indicative of a stock decline during the 1990s.

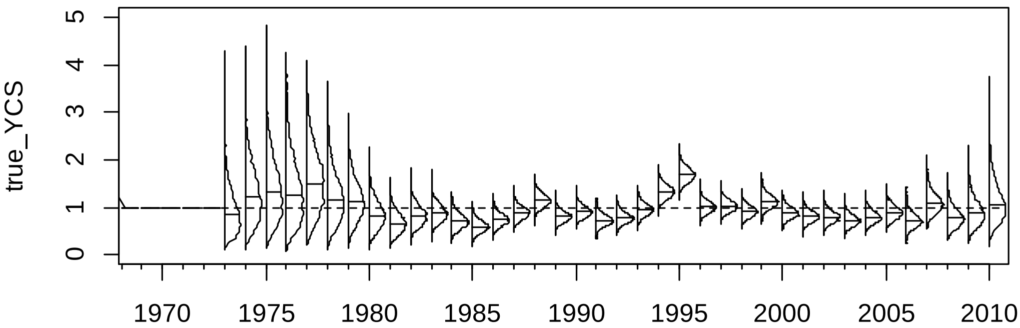


Figure 3: LIN 3&4: Estimated posterior distributions of year class strength for the base model. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

Although estimates of current and virgin stock size were imprecise, it was unlikely that B_0 was lower than 110 000 t for this stock, or that biomass in 2014 was less than 44% 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).

Table 12: LIN 3&4: Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2014} (in tonnes, and as a percentage of B_0) for the Base model run, and the probability that B_{2014} is above 40% of B_0.

Model run		B_0		B_{2014}		B_{2014} (%B_0)	P(40% B_0)
Base	126 600	(110 700–165 100)	71 800	(50 500–115 200)	57	(45–71)	0.003

The model indicated a relatively flat biomass trajectory since about 2006 (Figure 4). Annual landings from the LIN 3&4 stock have been less than 4 600 t since 2004, markedly lower than the 6 000–8 000 t taken annually between 1992 and 2003. Biomass projections derived from this assessment are shown below (Section 4.9).

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

4.4.1 Model structure and inputs

The stock assessment for LIN 5&6 (Sub-Antarctic) was updated in 2018 (Masi in prep). 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_{2018}) 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; line fishery and research survey ogives were fitted as logistic curves. Selectivities were assumed constant over all years in each fishery/survey.

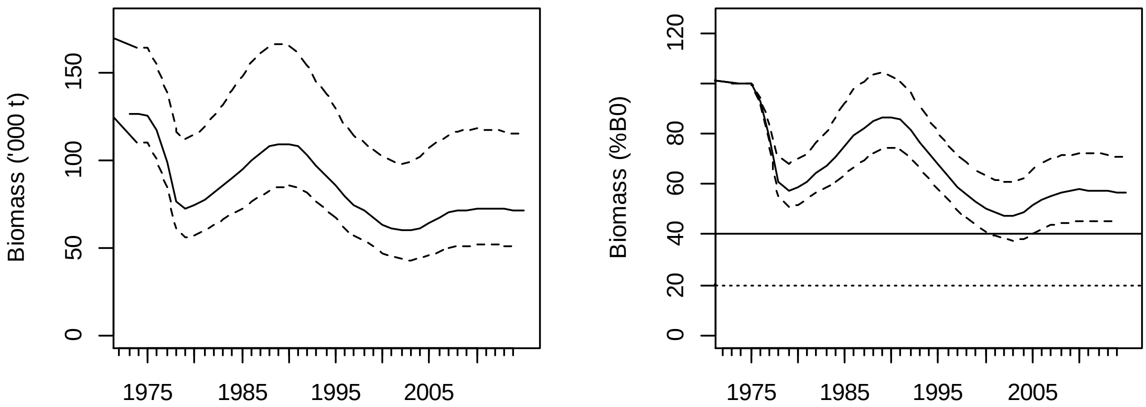


Figure 4: LIN 3&4 base model: Estimated median trajectories (with 95% credible intervals shown as dashed lines) for absolute biomass and biomass as a percentage of B_0.

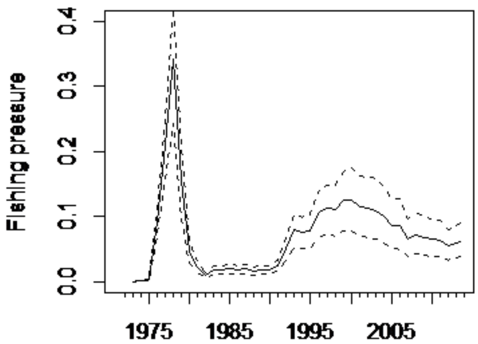


Figure 5: LIN 3&4 base model: Exploitation rates (catch over vulnerable biomass) with 95% credible intervals shown as dashed lines.

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, two line fishery CPUE series (from the spawning and home ground fisheries), catch-at-age from the spawning ground and home ground line fisheries, catch-at-age data from the trawl fishery, and estimates of biological parameters. A base case run is presented, which had a constant, estimated natural mortality with respect to age and a revised annual cycle for the spawn and non-spawn line fisheries. 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 13.

Table 13: 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*[1]**	**Age[2]**	**Description**	**%*Z*[3]**
1	Dec–Aug	Trawl and Spawning fishery (line) fisheries Increment ages	0.33	0.0	Trawl survey (summer)	0.1
					Trawl survey (autumn)	0.5
					Trawl catch-at-age	0.7
					Line CPUE (spawning)	
					Line (spawning) catch-at-age	
	Sep–Nov	Recruitment	0.67		Line CPUE (non-spawn)	
2		Non-spawning (line) fishery		0.5	Line (non-spawn) catch-at-age	0.5

1. *M* is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction, used for determining length-at-age, that was assumed to occur in that time step.
3. %*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.

A summary of all observations used in this assessment and the associated time series is given in Table 14. 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 fixed to 0.11 for the base model run, following the recommendations of Francis (2011). 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: Summary of the relative abundance series applied in the models, including source years (Years).

Data series	Model Years
Trawl survey biomass (*Tangaroa*, Nov–Dec)	1992–94, 2001–10, 2012–13, 2015, 2017
Trawl survey proportion at age (*Tangaroa*, Nov–Dec)	1992–94, 2001–10, 2012–13, 2015, 2017
Trawl survey biomass (*Tangaroa*, Mar–May)	1992–93, 1996, 1998
Trawl survey proportion at age (*Tangaroa*, Mar–May)	1992–93, 1996, 1998
CPUE (longline, spawning fishery)	1991–2017
CPUE (longline, non-spawning fishery)	1991–2017
Commercial longline proportion-at-age (spawning, Oct–Dec)	2000–08, 2010, 2017
Commercial longline proportion-at-age (non-spawn, Feb–Jul)	1999, 2001, 2003, 2005, 2009–12, 2014
Commercial trawl proportion-at-age (Sep–Apr)	1992–94, 1996, 1998, 2001–17

The assumed prior distributions used in the assessment are given in Table 15. 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.

Table 15: 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
CPUE *q*	Uniform-log	–	–	1e-8	1e-3
Selectivities	Uniform	–	–	0	20–200[1]
M[2]	Uniform			0.01	0.6

1. A range of maximum values were used for the upper bound
2. Constant, estimated natural mortality used in base model

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.

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, except process error for both summer and autumn trawl surveys was set to 0.11, a constant, estimated natural mortality with respect to age was applied and a revised annual cycle for the spawn and non-spawn line fisheries was used.

Five sensitivities were investigated: (1) the updated 2015 model using free q's (hereafter referred to as the reference model) (2) using nuisance *q*'s, (3) logistic selectivity ogive for longline spawn only, (4) doubled the mean of the prior for *q* for the trawl surveys, and (5) halved multinomial weightings associated with age composition estimates. An additional trial of fitting to CPUE was investigated, however this model was found to have potential structural issues. The MPD run with the CPUE index predicted $\%B_0$ was still above the 40% threshold, but the CPUE spawn index was not adequately reflecting abundance due to a decline in catch in recent years. Therefore, there was uncertainty as to the CPUE index being a reliable measure of abundance. From the five sensitivity runs trialled, MPD estimates of stock status were between 86–94% B_0.

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 reference model. Year classes were generally weak from 1982 to 1992, strong from 1994 to 1996, 2005 to 2006, 2008 and 2010, and average since then. Overall, estimated year class strengths were not widely variable, with all medians being between 0.5 and 1.5. Consequently, biomass estimates for the stock declined through the 1990s, but have exhibited an upturn during the last 17 years (Figure 7). The biomass trajectory from the base case model was little different to that derived from the reference model.

Biomass estimates for the stock appear very healthy, with estimated current biomass from three reported models at 88–90% of B_0 (Figure 7, Table 16). Annual exploitation rates (catch over vulnerable biomass) were low (less than 0.05) in all years as a consequence of the high estimated stock size in relationship to the level of relative catches (Figure 8).

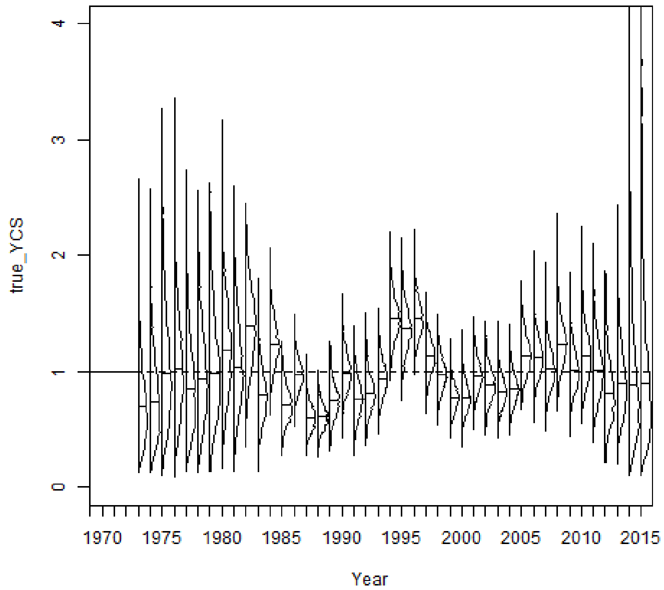


Figure 6: LIN 5&6: Estimated posterior distributions of year class strength from the base case run. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

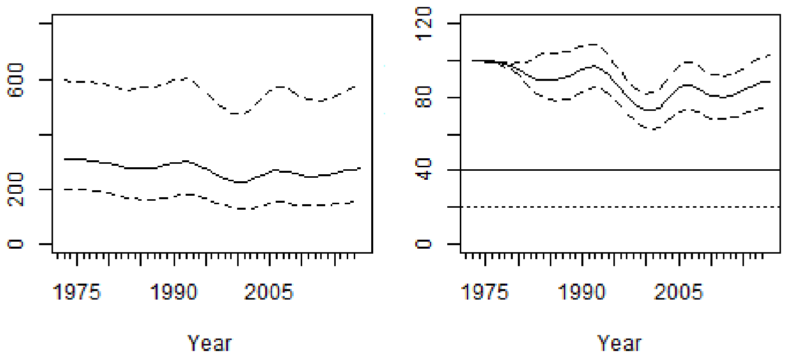


Figure 7: LIN 5&6 base model: Estimated median trajectories (with 95% credible intervals shown as dashed lines) for absolute biomass and biomass as a percentage of B_0. The management target of 40% B_0 is represented as a solid line and the dashed line is the soft limit (20% B_0).

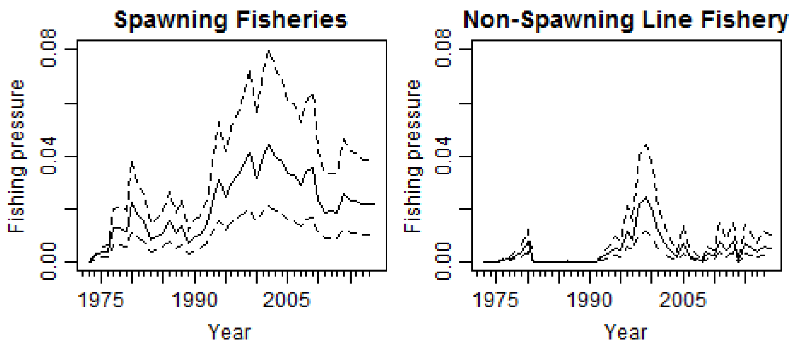


Figure 8: LIN 5&6 base model: Exploitation rates (catch over vulnerable biomass) with 95% credible intervals shown as dashed lines.

Table 16: LIN 5&6: Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2018} (in tonnes), and B_{2018} as a percentage of B_0, and the probability that B_{2018} is above 40% of B_0 from the Base model, Reference model and Base model with nuisance q's.

Model run	B_0		B_{2018}		B_{2018} (% B_0)		P(40% B_0)
Base case model	305 306	(206 265–568 452)	271 900	(164 127–498 668)	88.4	(75.4 –101.1)	0.000
Reference model	278 469	(185 556–507 129)	253 822	(142 119–508 076)	90.3	(74.1–104.7)	0.000
Nuisance q's model	373 544	(233 061–657 266)	339 627	(190 132–638 935)	91.4	(79.4–103.1)	0.000

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. Estimated fishing selectivities indicated that ling were fully selected by the trawl fishery at about age 9 years, and by the line fisheries at about age 12–16.

The assessments indicated a biomass trough about 1999, and some recovery since then. Although estimates of current and virgin stock size are very imprecise, it is most unlikely that B_0 was lower than 200 000 t for this stock, and it is very likely that current biomass is greater than 70% of B_0. Biomass projections derived from this assessment are shown below (Section 4.9).

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. Line 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, line fishery CPUE, catch-at-age and catch-at-length from the line 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 17.

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 18) and fixed in all subsequent runs.

Table 17: 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.

					Observations	
Step	**Period**	**Processes**	***M*[1]**	**Age[2]**	**Description**	**%*Z*[3]**
1	Dec–Sep	Recruitment fisher y (line)	0.9	0.5	Line CPUE Line catch-at-age/length	0.5 0.5
2	Oct–Nov	increment ages	0.1	0	–	

1. M is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction, used for determining length-at-age, that was assumed to occur in that time step.
3. $\%Z$ 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 18: 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

The assumed prior distributions used in the assessment are given in Table 19. All priors were intended to be relatively uninformed, and were estimated with wide bounds.

Table 19: 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

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.

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.

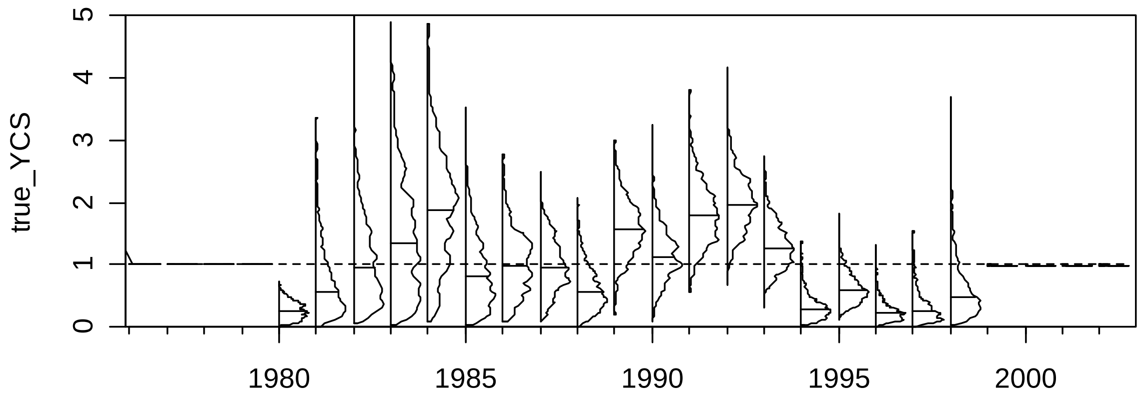


Figure 9: LIN 6B: Estimated posterior distributions of year class strength from the base case run. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

The assessment was driven largely by the catch-at-age and catch-at-length series from the line fishery; the first two years of CPUE data were not well fitted. Biomass estimates are listed in Table 20 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 20: 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)

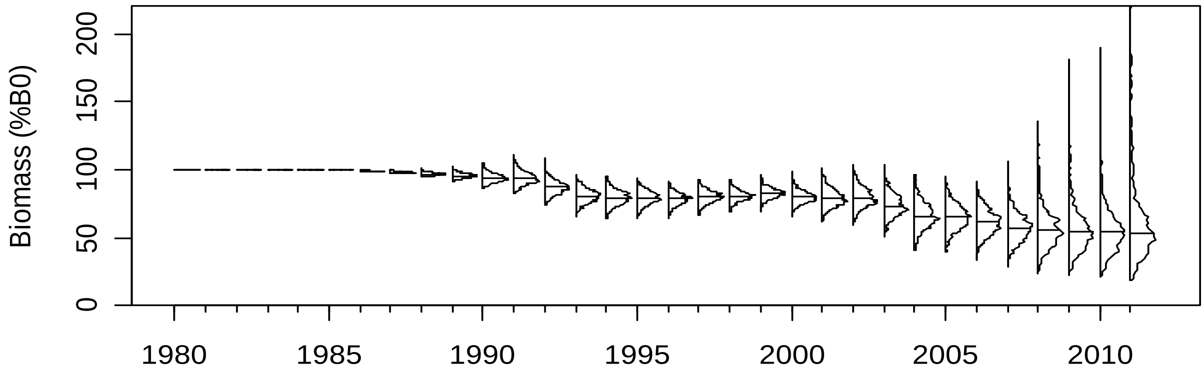


Figure 10: LIN 6B: Estimated posterior distributions of biomass trajectories as a percentage of B_0, from the base case model run (including 5-year projections through to 2011 with assumed constant annual catch of 400 t). Distributions are the marginal posterior distribution, with horizontal lines indicating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

Biomass projections derived from this assessment are shown below (Section 4.9).

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 2017 (Dunn & Ballara 2018). 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 21.

Table 21: 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[1]**	**Age[2]**	**Description**	**%Z[3]**
1	Oct–May	Recruitment	0.75	0.5		0.5
		fishery (line)			Line catch-at-age	
2	Jul–Sep	increment ages	0.25	0	Trawl survey biomass and catch at age	0.5
		fishery (trawl)			Trawl catch-at-age	
					Trawl CPUE	

1. M is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction, used for determining length-at-age, that was assumed to occur in that time step.
3. %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 reported model runs were developed following the investigation of numerous previous model runs. These evaluated the sensitivity of the model fit to assumptions such as growth rate, natural mortality rate, CPUE index, the *Tangaroa* biomass survey q prior, inclusion of the *Kaharoa* inshore trawl survey, trawl survey and fishery selectivity ogives, weights assigned to different observational data sets, the priors on year class strength estimates, and the choice of stock-recruitment model.

Year class strengths and fishing selectivity ogives were estimated in the model. Commercial trawl fishery and mature fish research trawl survey selectivities were fitted as double normal curves; the line fishery ogive was fitted as a logistic curve. The selectivity of immature fish by the research trawl survey was estimated as a capped logistic curve.

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_{2017}) biomass were obtained. MCMC chains were constructed using a burn-in length of 1×10^6 iterations, with every 1000th sample taken from the next 20×10^6 iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior). Multiple chain convergence tests were applied to determine the acceptability of the estimates. The final model runs (Section 4.6.2) were considered acceptable for providing management advice. The lower bound of the biomass distributions appeared well determined, however the upper bounds were highly uncertain.

For LIN 7WC, model input data included catch histories, trawl fishery CPUE, extensive catch-at-age data from the trawl fishery, sparse catch-at-age data from the line fishery, biomass estimates and proportion-at-age from *Tangaroa* surveys in 2000, 2012, 2013, and 2016, and estimates of constant biological parameters (Table 22). A line 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 also available, but rejected 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 line fishery and *Tangaroa* survey at-age data, giving the line fishery a relatively low weighting, and the trawl survey a relatively high weighting.

Table 22: 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)	1987–2016
Commercial trawl proportion-at-age (Jun–Sep)	1991, 1994–2008, 2012–2015
Commercial longline proportion-at-age	2003, 2006, 2007, 2012, 2015
Trawl survey biomass (*Tangaroa*, July)	2000, 2012, 2013, 2016
Trawl survey age data	2000, 2012, 2013, 2016

The assumed prior distributions used in the assessment are given in Table 23. 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 (see Section 4.4.1) 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]. The prior for M was informed and based on expert opinion. Priors for all selectivity parameters were assumed to be uniform.

Table 23: LIN 7WC: Assumed prior distributions and bounds for parameters estimated in the models. For lognormal distributions the figures are the logspace 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	0.01	0.2
CPUE q	uniform-log	–	–	1e-8	1e-3
Selectivities	uniform	–	–	0	30–200*
M	normal	0.20	0.025	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 5–9.

4.6.2 Model estimates

MCMC runs of three alternative models were conducted, assuming different CPUE indices and *M* assumptions (Table 24). There was no accepted 'base' case, rather the three model runs were chosen to represent the key alternative assumptions, and the range of model outcomes. The alternative CPUE indices were a 'combined' index, where CPUE was estimated as the product of the probability of catching ling and, when ling were caught, the catch, or a 'lognormal' index, where only the positive ling catch data were used. The runs either estimated *M*, or assumed it to be fixed at 0.18.

Posterior distributions of year class strength estimates from the Combined CPUE model run are shown in Figure 11. The YCS distribution from the other runs were not visually different and are not shown.

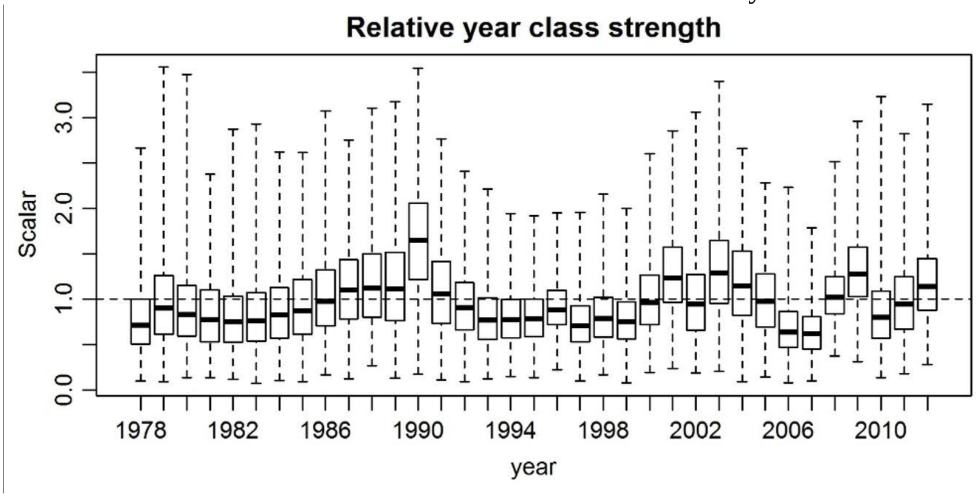


Figure 11: LIN 7WC: Estimated posterior distributions of year class strength for the Combined CPUE model run. The horizontal dashed line indicates a year class strength of one. Individual boxes show for each estimated cohort the median (solid horizontal line), inter-quartile range (box; half of the estimates were within this range), and overall range of estimates (broken vertical lines).

All model runs were indicative of a B_0 greater than about 60 000 t (Table 24). The upper bound on B_0 was highly uncertain and largely dependent on the weight assigned to the trawl survey proportions-at-age, and the prior on *M*. The Combined CPUE model run indicated a biomass decline until 1992, followed by fluctuating but stable biomass until 2016, whereas the Lognormal CPUE model runs both indicated slow overall biomass declines (Figure 12). The model fit to the trawl survey biomass series was good, but to the CPUE series (both lognormal and combined indices) was poor (Figure 13). All model runs estimated recent trawl and longline fishing pressure to be stable (Figure 14). All model runs estimated a period of higher recruitment around 1990, and in several years since 2001 (Figure 11); the relatively strong year classes since 2001 were estimated to have started recruiting to the fishery from around 2010 (at age nine).

Table 24: LIN 7WC: Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2017} (in tonnes), and B_{2017} as a percentage of B_0 for all model runs.

Model run	B_0		B_{2017}		B_{2017} (% B_0)	
Combined CPUE	99 300	(63 500–198 200)	77 400	(39 600–183 000)	79	(61–96)
Lognormal CPUE	69 300	(51 600–122 000)	46 300	(26 100–98 000)	66	(50–83)
Lognormal CPUE and *M* = 0.18	62 800	(48 900–114 500)	34 000	(19 500–84 100)	54	(39–74)

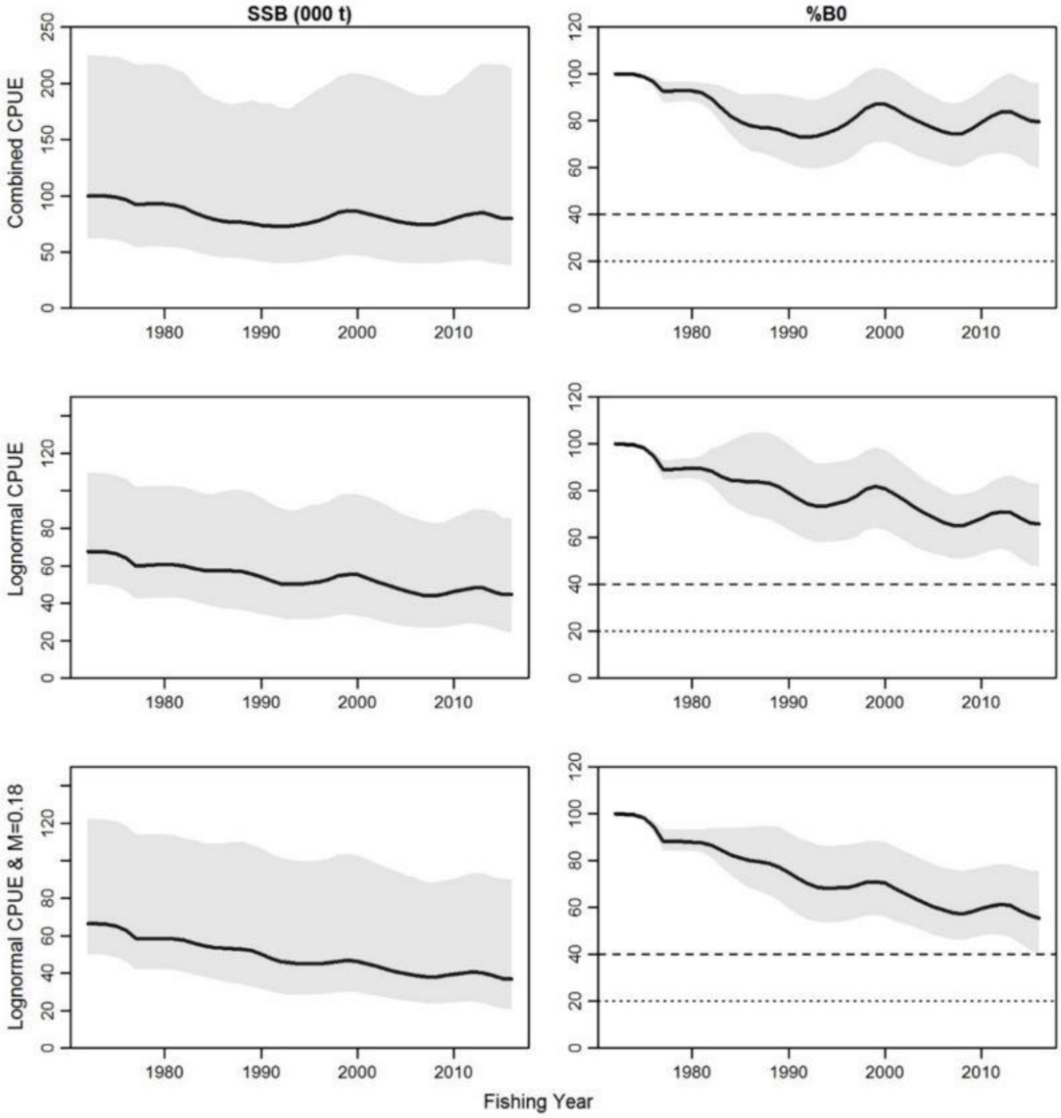


Figure 12: LIN 7WC: Estimated posterior distributions of the spawning stock biomass (t) trajectory and % B_0 for the three model runs. The solid lines are the median values and the shaded area the 95% CIs.

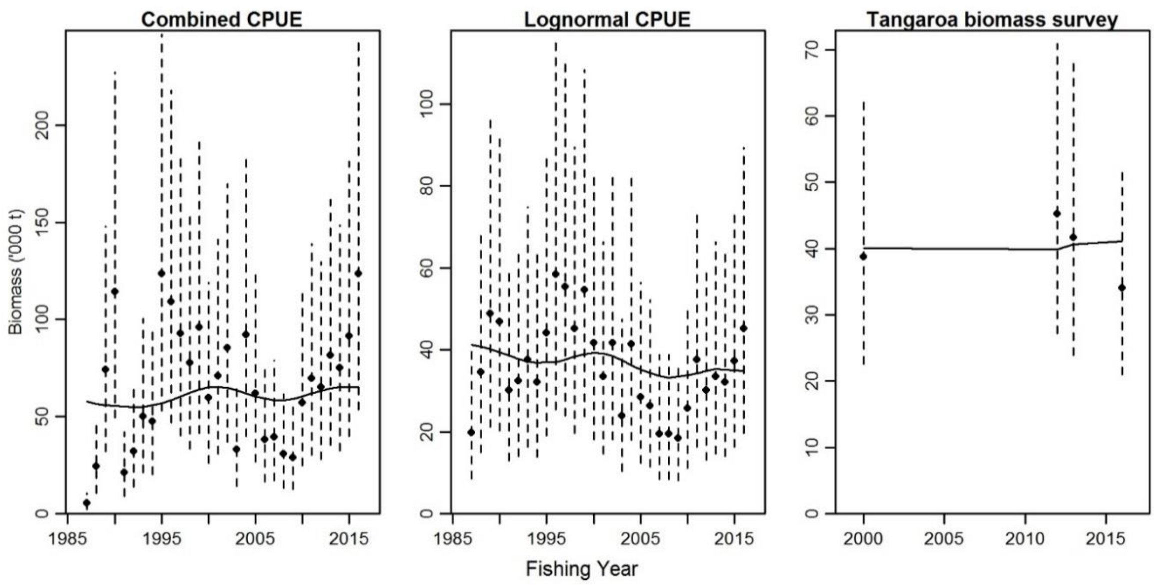


Figure 13: LIN 7WC: The fit (MPD; lines) of the Combined CPUE and Lognormal CPUE model runs to the alternative CPUE indices (solid points; vertical lines show 95% CI). The CPUE index has been scaled to the biomass using the estimated *q*.

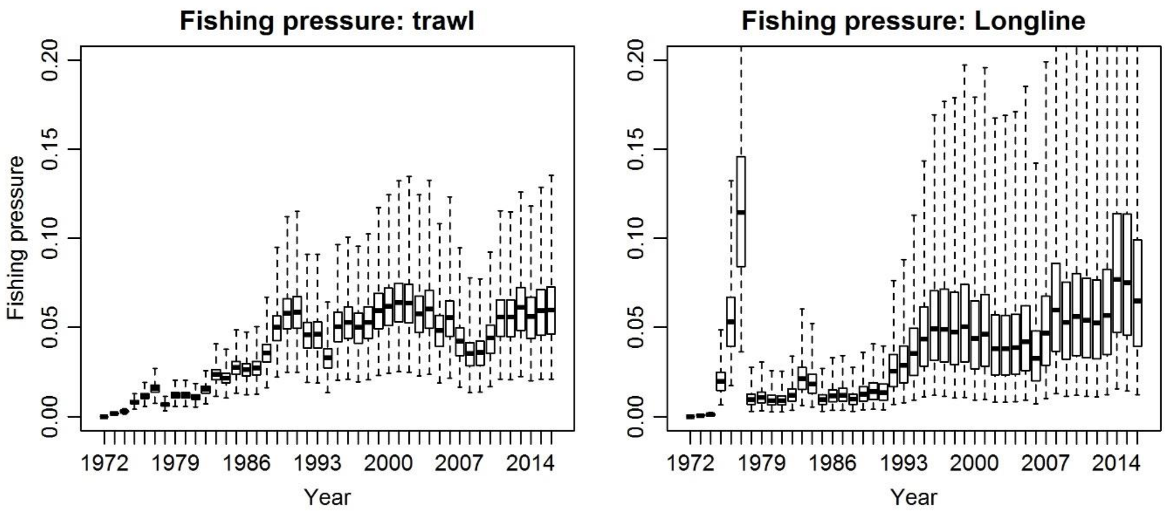


Figure 14: LIN 7WC: Estimated posterior distributions of the fishing pressure for the trawl and longline fleets, for the Combined CPUE model run. For each estimated year the pots show the median (solid horizontal line), inter-quartile range (box; half of the estimates were within this range), and overall range of estimates (broken vertical lines). Note that the y-axis has been truncated at 0.2 in these plots.

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. As a consequence 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 25. Year class strengths and fishing selectivity ogives were also estimated in the model. Commercial trawl selectivity was fitted as double normal curves; line 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 line fishery CPUE, extensive catch-at-age data from the trawl fishery, sparse catch-at-age data from the line fishery, and estimates of biological parameters. Initial modelling investigations found that the line 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 26).

Table 25: 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***[1]	**Age**[2]	**Description**	**%*Z***[3]
1	Oct–May	Recruitment fishery (line)	0.67	0.5	Line CPUE Line catch-at-age	0.5
2	Jun–Sep	increment ages fishery (trawl)	0.33	0	Trawl CPUE Trawl catch-at-age	0.5

1. *M* is the proportion of natural mortality that was assumed to have occurred in that time step.
2. Age is the age fraction, used for determining length-at-age, that was assumed to occur in that time step.
3. %*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 26: 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 27. Most priors were intended to be relatively uninformed, and were specified with wide bounds.

Table 27: 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 5–9.

4.7.2 Model estimates

A single model was presented incorporating a catch history, trawl and line fishery catch-at-age, trawl CPUE series, with double-normal ogives for the trawl fishery and logistic ogives for the line 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 15.

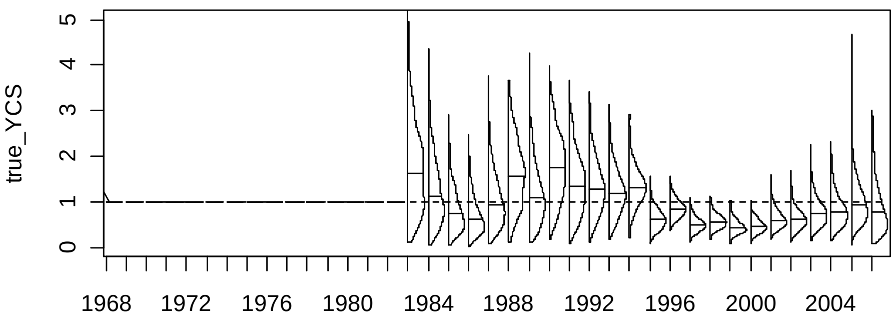


Figure 15: LIN 7CK: Estimated posterior distributions of year class strength. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

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 28, Figure 16). Probabilities that current and projected biomass will drop below selected management reference points are shown in Table 29. 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 yr^{-1}) since then. Since the early 1990s, trawl fishing pressure has generally declined, while line pressure has generally increased.

Table 28: 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)

Table 29: 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).

Biomass	Management reference points		
	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

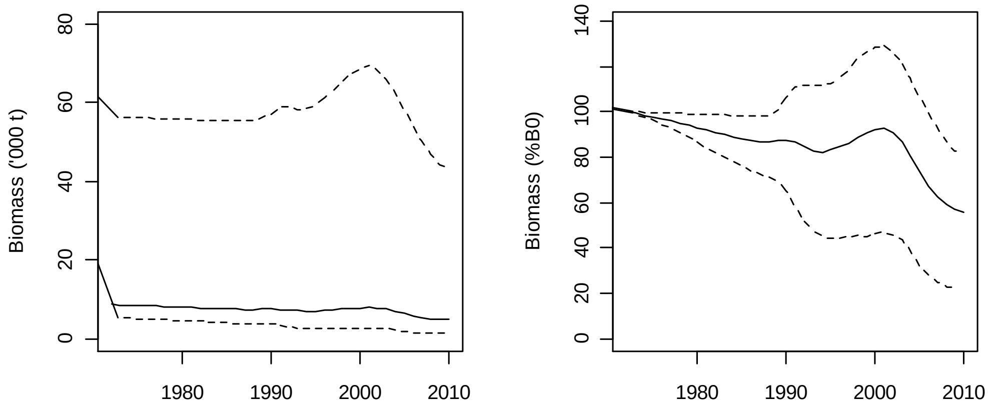


Figure 16: LIN 7CK: Estimated median trajectories (with 95% credible intervals shown as dashed lines) for absolute biomass and biomass as a percentage of B_0.

Estimates of biomass projections derived from this assessment are shown below (Section 4.9).

4.8 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. An update of the LIN 1 CPUE analyses was commissioned by MPI in 2013 and again in 2017, the latter is reported here.

4.8.1 Fishery Characterisation

- 51% of LIN 1 landings come from the bottom longline fishery and a further 47% by bottom trawl fishery from 1989–90 to 2015–16. The remaining methods account for less than 1.5% of the total landings. These ratios are changing, with longline landings exceeding 60% of the catch after 2012–13 and trawl landings dropping to below 40% of the catch in the same years.
- Most BT and BLL landings come from the Bay of Plenty. The majority of bottom trawl catches are taken in Statistical Areas 008 to 010, although there have been significant bottom trawl catches of ling on the west coast of the North Island in Areas 046 to 048. There were substantial ling by-catches made by trawl on the North Island west coast from 1996–97 to 2000–01 in the gemfish fishery (which has since ceased), and longline catches have increased from the East Northland area.

- Ling are caught in small quantities across many fisheries. The distribution of BT effort is broader than the distribution of catch, with effort taking some LIN 1 in East Northland and the west coast in most years. Bottom longline landings of LIN 1 have a wider distribution and are more sporadic, with the Bay of Plenty landings coming primarily from Areas 009 and 010.
- Bottom trawl catches of LIN1 are mainly made in the scampi and gemfish targeted fisheries and recently in growing hoki, tarakihi and ling target fisheries. The bycatch of ling in the gemfish fishery has considerably diminished with the reduction of the SKI 1 TACC after a peak period from 1996–97 to 2000–01. The Bay of Plenty scampi fishery has also changed, particularly after SCI entered the QMS, moving from a competitive fishery requiring multiple vessels to a more rationalised fishery requiring only a single vessel. In contrast, about 75% of the ling longline catch is taken in a targeted ling fishery, with only minor by-catches coming from bluenose, ribaldo and hapuku targeted longline fisheries.
- 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 of the major fishing methods which take ling have sporadic seasonal patterns, reflecting the small landings in most years and the by-catch nature of many of the fisheries.
- The depth distribution of ling catches in the trawl fisheries shows two main depths associated with the target species. Most ling are caught in the scampi / hoki / ling fishery 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 lying between 500 and 600 m.

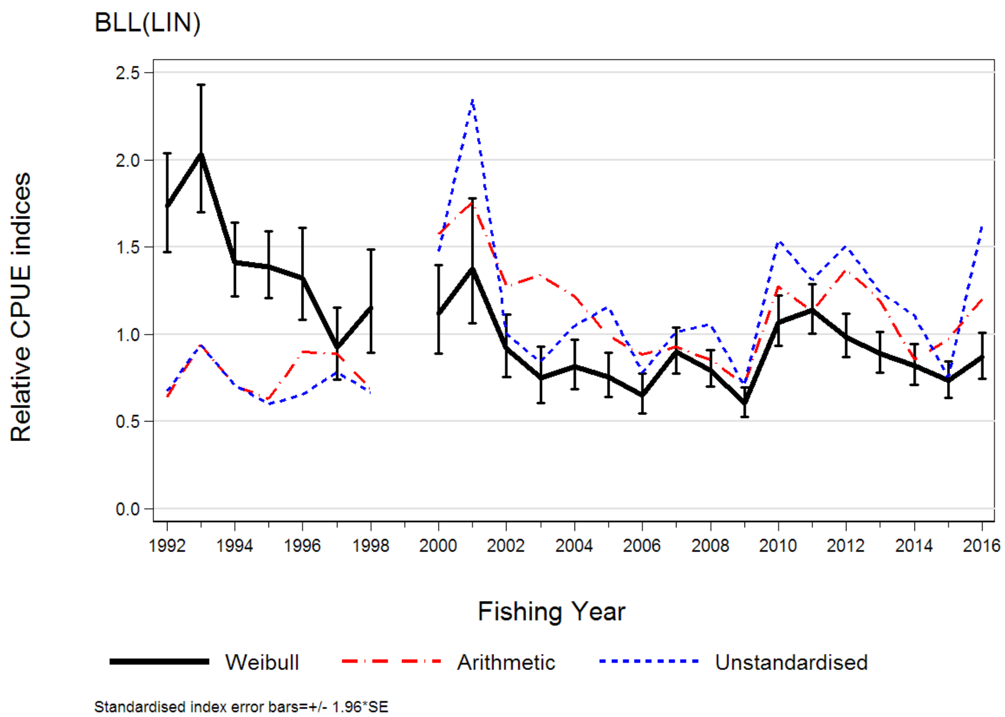


Figure 17: LIN 1 CPUE analyses based on target ling bottom longline data stratified by day, assigning the modal target species and statistical area to that day. Data were restricted to Statistical Areas 002, 003, 004, 008, 009 and 010 and standardised with respect to fishing year, vessel, month and statistical area. As ling is target species, there are no records with zero catch and only the Weibull model is presented. Fishing years 1989–90 and 1990–91 are omitted because of lack of data and 1999–2000 is omitted per agreement of the Working Group because of non-representativeness of the data in that year.

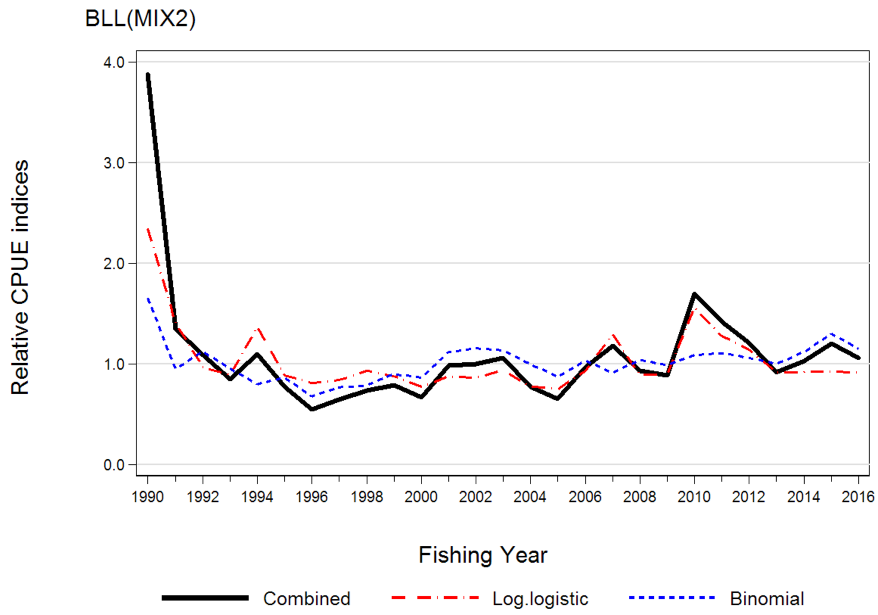


Figure 18: LIN 1 CPUE analyses based on ling bottom longline data stratified by day, assigning the modal target species and statistical area to that day. Data were restricted to Statistical Areas 002, 003, 004, 008, 009 and 010 and standardised with respect to fishing year, target species, vessel, month and statistical area. Three sets of standardised indices are presented: a) a positive catch series using the log.logistic distribution to predict log(catch/day); b) a binomial series predicting catch success per day; c) a combined series, using the delta-lognormal method (Vignaux 1994) to combine the log.logistic and binomial series.

4.8.2 Abundance Indices

In 2009, the Working Group concluded that the BT(SCI) index was not an appropriate index for LIN 1, and had numerous shortcomings related to limited number of vessels, particularly in the most recent 4 years and poor linkage across years. In 2013, the NINSWG agreed with these conclusions, which also applied to the alternative BT(LINHOK, TAR) series developed in response to a 2009 Working Group recommendation. Consequently the NINSWG agreed that neither BT series was adequate for monitoring LIN 1 CPUE and should be discarded. The Working Group requirement that CPUE index values should be determined by at least 3 vessels furthermore resulted the discarding of a large number of index values from both BT series.

In 2009, the Working Group concluded that the BLL(LIN) target index appeared to have more potential as an index for LIN 1, but thought that the anomalous peak in 1998–99 was troubling and was also concerned about the relatively small amount of data in this analysis. Closer examination of the data in 2013 showed that the anomalous 1998–99 peak was caused by a small amount of very localised fishing by two experienced vessels. The NINSWG concluded that this pattern was non-representative of the fishery and the standardisation model was unable to use these data to estimate a credible year index. While this solved the mystery of the “anomalous 1998–99 index”, the problem of very small amount of data in this analysis remains. The NINSWG tentatively accepted in 2013 the BLL(LIN) index with the 1998–99 index value removed as an index of LIN 1 abundance with a research quality ranking of “2” (Figure 17).

When this series was updated in 2017, the Plenary additionally accepted a new bottom longline standardised series (BLL(MIX2), spanning four target species and operating in East Northland and the Bay of Plenty, as an abundance series for LIN 1. Both series were accepted with a quality ranking of “2” because of the sparseness of the data and the strong standardisation effect in both series. The inclusion of more target species greatly increased the amount of data in the BLL(MIX2) analysis, allowing for two earlier years to be incorporated and obviating the need to drop the anomalous peak in 1998–99. However, this analysis had a high proportion of fishing days without ling in the estimated catch: consequently a binomial presence/absence series was estimated from the data set and combined with a log.logistic positive catch series using the delta-lognormal method (Vignaux 1994). The Plenary dropped the 1989–90 index year in the BLL(MIX2) series where there was a four-fold drop between the first and second years of the series, a drop that was considered unlikely to have been caused by a corresponding drop in abundance.

4.9 Projections

Projections for LIN 6B from the 2006 assessment are shown in Table 30. The LIN 6B stock (Bounty Plateau) was projected to decline out to 2011, but probably still be higher than 50% of B_0. 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 31). New projections made in 2014 out to 2019 for LIN 3&4 and 5&6 are shown in Table 32. For LIN 3&4, stock size is likely to remain about the same assuming future catches equal to recent catch levels, or decrease to around 90% of the 2018 biomass by 2023 if catches reach the TACC. For LIN 5&6, the probability of B_{2019} being below 40% of B_0 is very small when assuming either one of two future annual catch scenarios (the recent catch level of 6650 t or the TACC of 12 100 t) (Table 33). 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 34).

Table 30: 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)

Table 31: 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)

Table 32: LIN 3&4 Bayesian median and 95% credible intervals (in parentheses) of projected B_{2024}, B_{2024} as a percentage of B_0, and B_{2024}/B_{2019}(%) for the base case runs.

Stock and model run		Future catch (t)	B_{2024}		B_{2024} (% B_0)		B_{2024}/B_{2019} (%)	
LIN 3&4	Base (future YCS from all estimated YCS)	6 260	54 200	(37 500–81 500)	49	(37–63)	86	(75–98)
	Base (future YCS from last 10 YCS)	6 260	54 000	(37 000–81 600)	49	(36–63)	86	(75–98)
	Base (future YCS from all estimated YCS)	3 883	63 300	(46 600–90 400)	57	(56–70)	101	(92–111)
	Base (future YCS from last 10 YCS)	3 883	63 100	(46 400–90 200)	57	(46–70)	100	(91–111)

Table 33: LIN 5&6 Bayesian median and 95% credible intervals (in parentheses) of projected B_{2023}, B_{2023} as a percentage of B_0, and B_{2023}/B_{2018}(%) for the base case runs.

Stock and model run		Future catch (t)	B_{2024}		B_{2023} (% B_0)		B_{2023}/B_{2018} (%)	
LIN 5&6	Base	6 650	269 600	(135 100–551 200)	86	(67–110)	97	(80–127)
		12 100	247 000	(120 400–553 600)	81	(58–106)	90	(72–123)

Table 34: 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_{2017} (%) 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	2980	77 300	(37 800–185 500)	79	(56–106)	100	(83–126)
		3300	76 600	(35 500–183 700)	78	(54–104)	98	(80–123)
	Lognormal CPUE	2980	47 400	(21 600–97 300)	70	(41–100)	104	(81–134)
		3300	45 900	(20 700–96 900)	68	(37–97)	102	(77–133)
	Lognormal CPUE & M = 0.18	2980	38 100	(17 300–97 900)	57	(33–85)	100	(76–126)
		3300	36 400	(15 900–95 900)	54	(32–82)	97	(73–124)

5. STATUS OF THE STOCKS

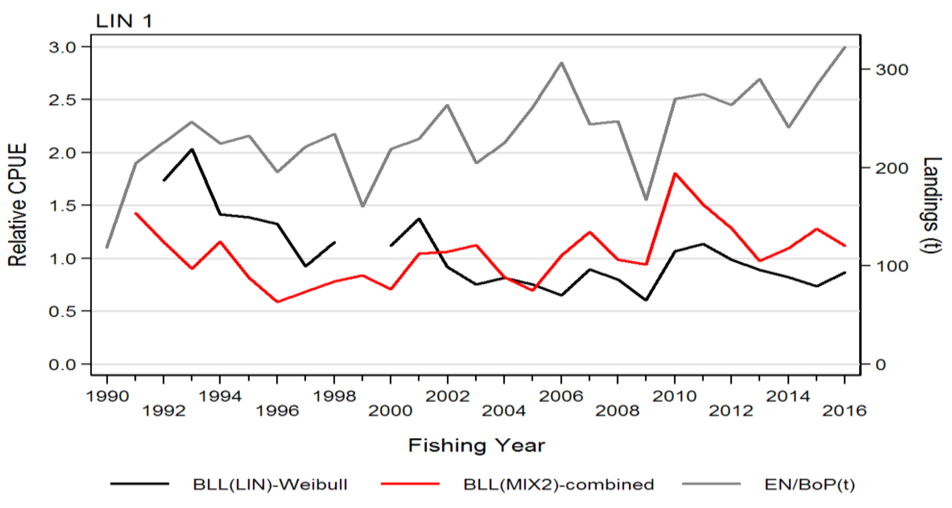
Stock Structure Assumptions
Ling are assessed as six independent biological stocks, based on the presence of spawning areas and some differences in biological parameters between areas (Horn 2005).

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 for the purpose of this assessment.

- **LIN 1 East coast only**

Stock Status	
Year of Most Recent Assessment	2017
Assessment Runs Presented	- Standardised Bottom Longline target LIN CPUE, operating in East Northland or the Bay of Plenty Weibull positive catch model - Standardised Bottom Longline CPUE targeting LIN, BNS, RIB or HPB and operating in East Northland or the Bay of Plenty (BLL MIX2); combined log.logistic (positive catches) and binomial (probability of capture)
Reference Points	Target: Not defined Soft Limit: Not defined Hard Limit: Not defined Overfishing threshold: Not defined
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown
Historical Stock Status Trajectory and Current Status	



Comparison of the Weibull BLL(LIN) CPUE series and the combined BLL(MIX2) CPUE series with the East Northland/Bay of Plenty landings for LIN 1. The 1990 index year for the BLL(MIX2) series has been omitted. The two CPUE series have been standardised to a common geometric mean.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	The BLL(MIX2) CPUE series has been gradually increasing since the mid-1990s, while the other has been relatively stable.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity has fluctuated without trend since 2012
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Not evaluated
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	CPUE analyses	
Assessment Dates	Latest assessment: 2017	Next assessment: Unknown
Overall assessment quality rank	2 – Medium or Mixed Quality: based on Medium or Mixed Quality CPUE indices	
Main data inputs (rank)	- Bottom longline target LIN CPUE series, operating in East Northland or the Bay of Plenty Weibull positive catch model - Bottom longline CPUE series, target LIN, BNS, HPB and RIB, East Northland, Bay of Plenty LIN 1 statistical areas	2 – Medium or Mixed Quality: poor vessel continuity and sparse data 2 – Medium or Mixed Quality: strong impact of target species on standardisation
Data not used (rank)	Two bottom trawl CPUE series: - SCI target - combined LIN, HOK, TAR target	3 – Low Quality: do not track stock biomass and lack data
Changes to Model Structure and Assumptions	- Additional new time series with range of target species developed	
Major Sources of Uncertainty	- Large area spanning two coasts with multiple fisheries with small catches	

Qualifying Comments
The accepted indices of abundance are based on longline fisheries operating only on the east coast of the upper North Island (East Northland and Bay of Plenty).

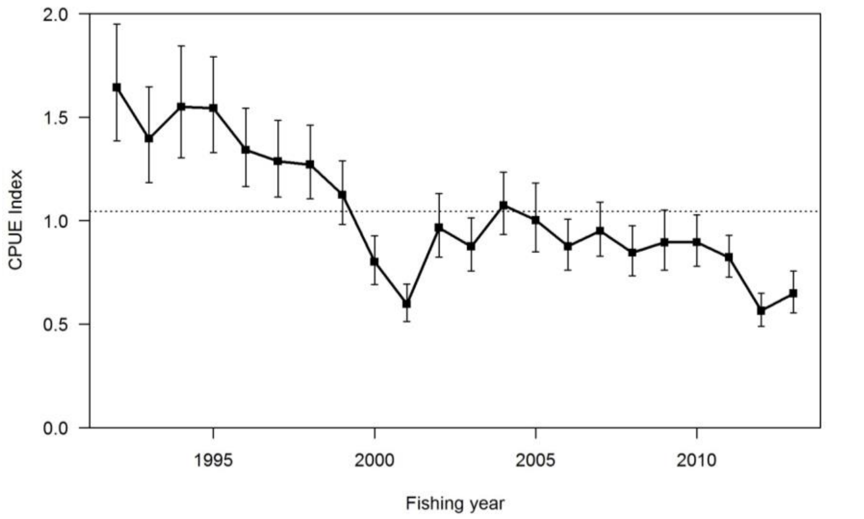
Fisheries Interactions
The top five species (excluding ling) that are recorded among the estimated catch of trawl trips associated with LIN 1 are snapper, trevally, tarakihi, gurnard and orange roughy. The top five species (excluding ling) that are recorded among the estimated catch of bottom longline trips associated with LIN 1 are bluenose, hapuku, school shark, ribaldo and bass. Interactions with other species are currently being characterised.

- **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



Standardized 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 11–15.	
Assessment Dates	Latest assessment: 2014	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	

Main data inputs (rank)	- Bottom longline effort and 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.	

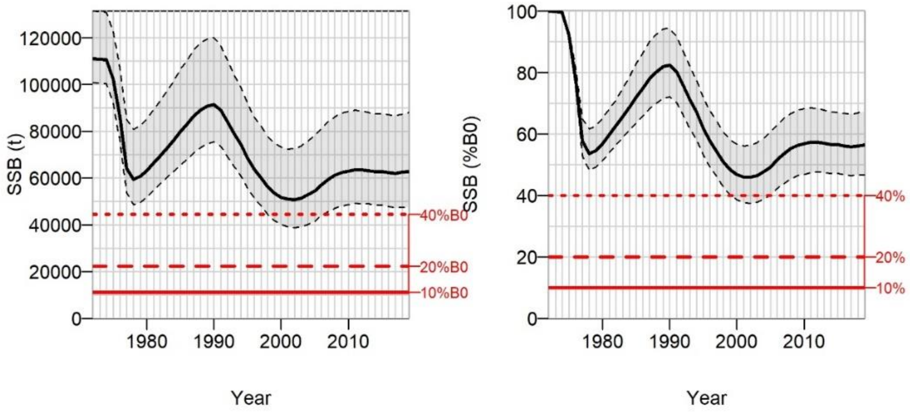
Qualifying Comments
-

Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries. 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 chapter. Target line 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). Low productivity species taken as incidental bycatch include sharks and skates. Incidental captures of protected species are reported for seabirds.

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

Stock Status	
Year of Most Recent Assessment	2019
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: $U_{40\%}$
Status in relation to Target	B_{2019} was estimated to be about 57% B_0; Very Likely (> 90%) to be above the target
Status in relation to Limits	B_{2019} 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 Chatham Rise ling stock from the start of the assessment period in 1972 to the most recent assessment in 2019, for the base case model run. Years on the x-axis are fishing year with "2010" representing the 2009–10 fishing year. Biomass estimates are based on MCMC results.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass is very unlikely to have been below 40% B_0. 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 constant since about 2008.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Recruitment since about 2008 is estimated to have been fluctuating around the long-term average for this stock.

Projections and Prognosis (2019)	
Stock Projections or Prognosis	Current catch is unlikely to cause the stock to decline. Catches at level of the TACC are likely to cause the stock to decline to about 50% B_0 in 5 years.
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: 2019	Next assessment: 2021
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Summer research trawl survey series, 1992-2014, 2016, 2018	1 – High Quality
	- Proportions-at-age data from the commercial fisheries and trawl survey	1 – High Quality
	- Line fishery CPUE series (annual indices since 1991): series not used in the base assessment model	2 – Medium or Mixed Quality: likely change in q over time
	- Estimates of biological parameters (but note that M was estimated in the models)	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	- Longline fishery proportions at length removed as data inputs. - Longline fishery proportions at age changed from combined sex to separated male and female. Natural mortality estimated by sex instead of combined over sexes.	
Major Sources of Uncertainty	- Lack of contrast in survey indices	

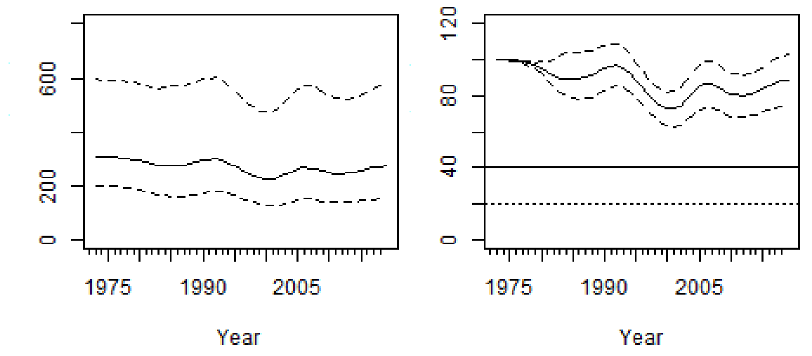
Qualifying Comments
-

Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries. 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. Target line 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). Interactions with other species are currently being characterised.

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

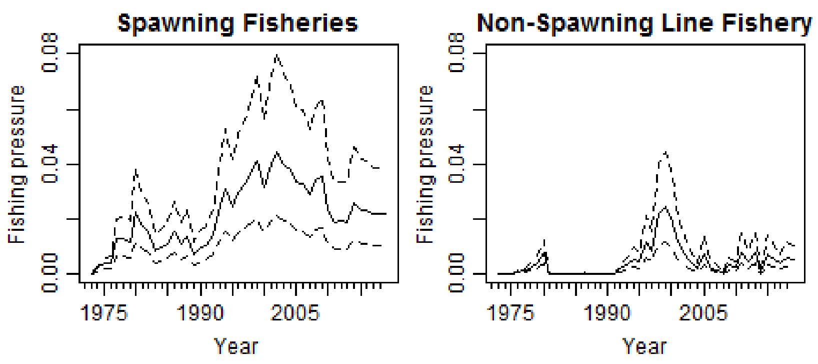
Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	One base case
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	B_{2018} was estimated to be between 75% and 101% B_0; Virtually Certain (> 99%) to be above the target
Status in relation to Limits	B_{2018} 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 spawning biomass (absolute, and % B_0, with 95% credible intervals shown as broken lines) for the Sub-Antarctic ling stock from the start of the assessment period in 1972 to the most recent assessment in 2018, for the base case model run. 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 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 or the level of the TACC (i.e., 12 100 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: 2018	Next assessment: 2021
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Summer and autumn *Tangaroa* trawl survey series - Proportions-at-age data from the commercial fisheries and trawl surveys - Estimates of biological parameters (but note that *M* was estimated in the models)	1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	- Line fishery CPUE series (annual indices since 1991).	2 – Medium Quality: uncertainty in its ability to index abundance
Changes to Model Structure and Assumptions	- *M* was estimated as a constant - The annual cycle of the model and fishery catches were aligned - Free q's were used instead of nuisance q's	
Major Sources of Uncertainty	- The lack of contrast in the summer trawl series (the main relative abundance series) makes it difficult to accurately estimate the upper bound 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.

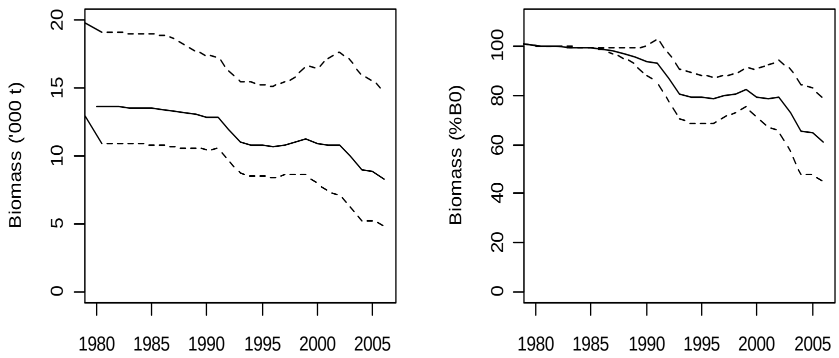
Fishery Interactions
The main bycatch species of hoki-hake-ling-silver warehou-white warehou target trawl fisheries are rattails, javelinfish, and spiny dogfish. Additional information can be found in the Environmental and Ecosystem Considerations section of the hoki plenary. Target line fisheries for ling have the main bycatch species of spiny dogfish, ribaldo, skates (smooth and rough), sea perch, and sharks (school shark and shovelnose dogfish). Interactions with other species are currently being characterised.

- **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 line fishery - Line 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 line 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.	

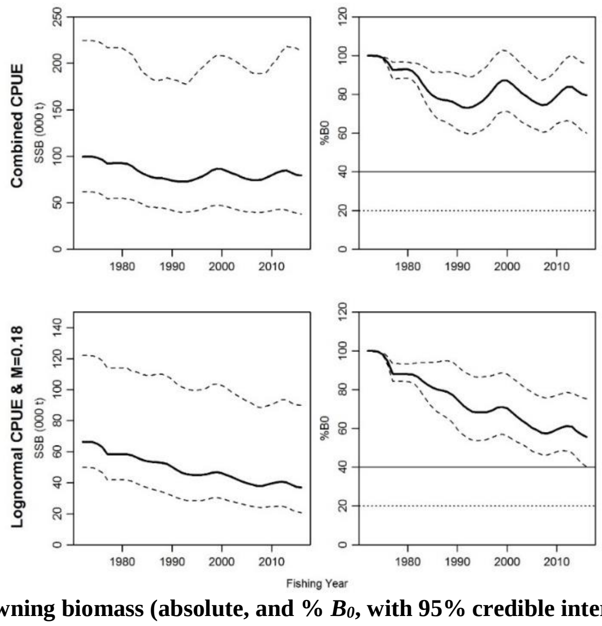
Qualifying Comments
There is no separate TACC for this stock; it is part of the LIN 6 Fishstock that has a TACC of 8505 t.

Fishery Interactions
Target line 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). Interactions with other species are currently being characterised.

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

Stock Status	
Year of Most Recent Assessment	2017
Assessment Runs Presented	Three alternative model runs
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%B0}$
Status in relation to Target	B_{2017} was estimated to be about 79% B_0, 66% B_0, and 54% B_0; in all cases Very Likely (> 90%) to be at or above the target
Status in relation to Limits	B_{2017} 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	Very Unlikely (< 10%)

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 most optimistic (Combined CPUE) and pessimistic (Lognormal CPUE & M = 0.18) model runs for the WCSI ling stock from the start of the assessment period in 1972 to the most recent assessment in 2017. 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 stable or slowly decreasing.
Recent Trend in Fishing Intensity or Proxy	Stable (trawl and longline)
Other Abundance Indices	A CPUE index was available from the line (target) fishery but was not considered reliable. The time series of the inshore *Kaharoa* survey does not adequately cover the distribution of ling on the west coast.
Trends in Other Relevant Indicators or Variables	The age structures of both the commercial catch and trawl survey catch are broad, indicating a low exploitation rate.

Projections and Prognosis	
Stock Projections or Prognosis	Stock status is unlikely to change over the next 5 years at recent catch levels.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	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: 2017	Next assessment: 2020
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch history - Abundance index from WCSI trawl surveys - Abundance index from the commercial trawl hoki-hake-ling target fishery CPUE - 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 1 – High Quality
Data not used (rank)	- Commercial line fishery CPUE - *Kaharoa* trawl survey abundance index	3 – Low Quality: does not track stock biomass 3– Low Quality: inadequate spatial coverage of the stock distribution
Changes to Model Structure and Assumptions	- Reweighted sample sizes for age frequency data	
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. - It is assumed in the assessment models that natural mortality is constant over all ages. - The model estimates that a relatively high proportion of ling biomass is not vulnerable to fishing around the age of first maturity.	

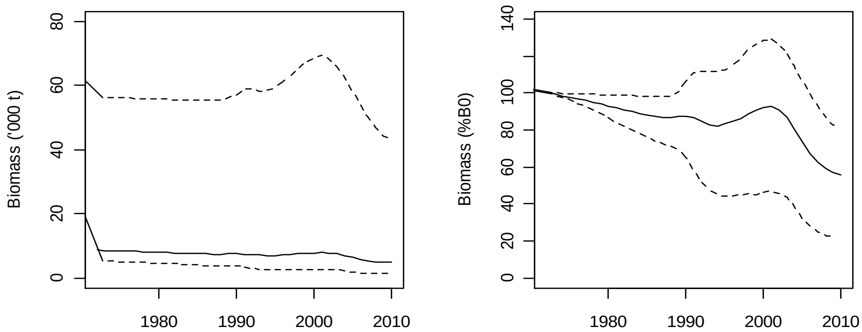
Qualifying Comments
This assessment is very uncertain but it is highly probable that B_{2017} is greater than 40% B_0 and it could be much higher.

Fishery Interactions
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. Target line 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). Interactions with other species are currently being characterised.

- **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	A 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 line.
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 line 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)	Line 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. - Line 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’ line 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. 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. Target line 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). Interactions with other species are currently being characterised.

6. FUTURE RESEARCH

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

7. FOR FURTHER INFORMATION

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