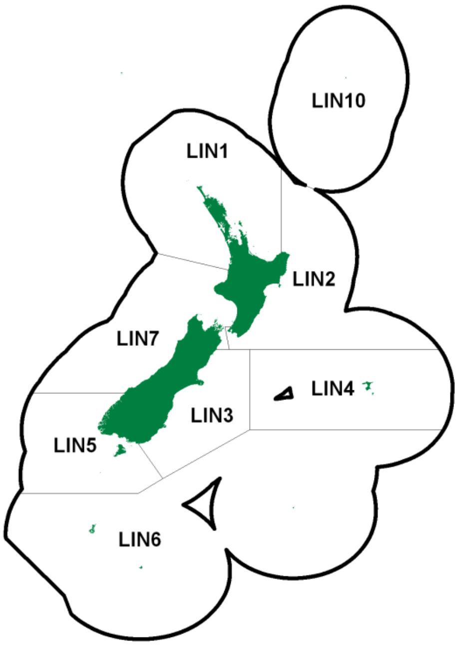
LING

(*Genypterus blacodes*)
Hoka



1. FISHERY SUMMARY

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 to the 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 fitted with autoline equipment. This caused a large increase in the catches of ling off the east and south of the 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.

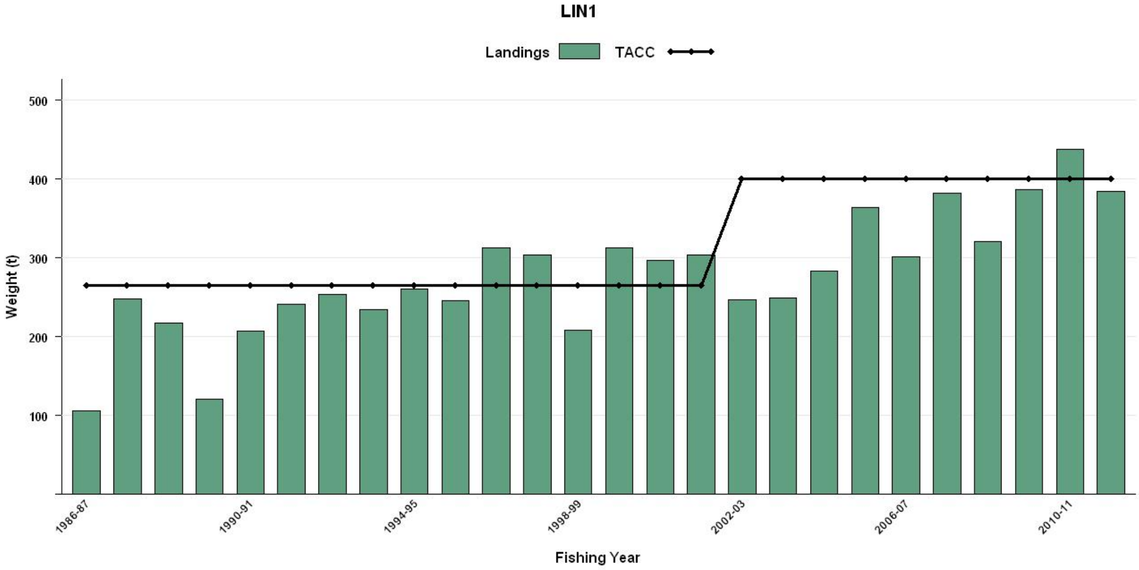
The principal grounds for smaller domestic vessels are the west coast of the South Island (WCSI) and the east coast of both main islands south of East Cape. For the large trawlers the main sources of ling are Puysegur Bank and the slope of the Stewart-Snares shelf and waters in the Auckland Islands area. Longliners fish mainly in LIN 3, 4, 5 and 6. In 2011–12, landings from Fishstocks LIN 2, LIN 3, LIN 4 and LIN 6 were significantly under-caught relative to their TACCs by 49%, 37%, 45% and 76%, respectively. The LIN 5 and LIN 7 TACCs were slightly over-caught (by 2% and 10%, respectively. Reported landings by nation from 1975 to 1987–88 are shown in Table 1, and reported landings by Fishstock from 1983–84 to 2011–12 are shown in Table 2. 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, within an overall TAC of 463 t. All stocks including LIN 1 were removed from the AMP on 30th September 2009. In an earlier proposal for the 1994–95 fishing year, TACCs for LIN 3 and 4 had been increased to 2810 and 5720 t, respectively. These stocks were removed from the AMP from 1 October 1998, with TACCs maintained at the increased level. However, from 1 October 2000, the TACCs for LIN 3 and 4 were reduced to 2060 and 4200 t, respectively. From 1 October 2004, the TACCs for LIN 5 and LIN 6 were increased by about 20% to 3595 t and 8505 t, respectively. From 1 October 2009, the TACC for LIN 7 was increased from 2225 t to 2474 t. All other TACC increases since 1986–87 in all stocks are the result of quota appeals.

Table 1: 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 Longline	Trawl			Total	Grand 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.



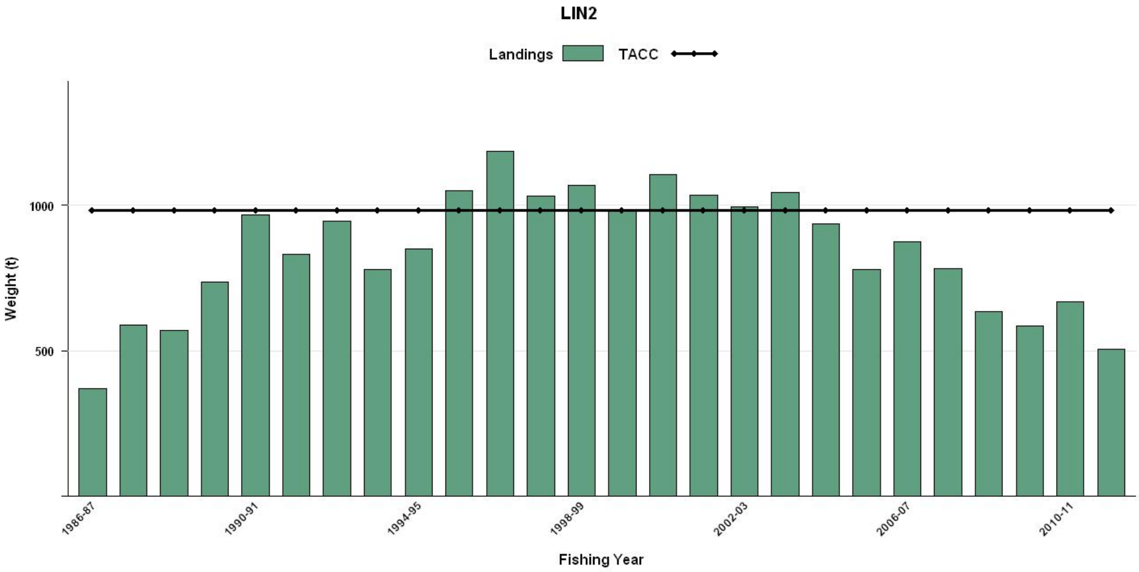
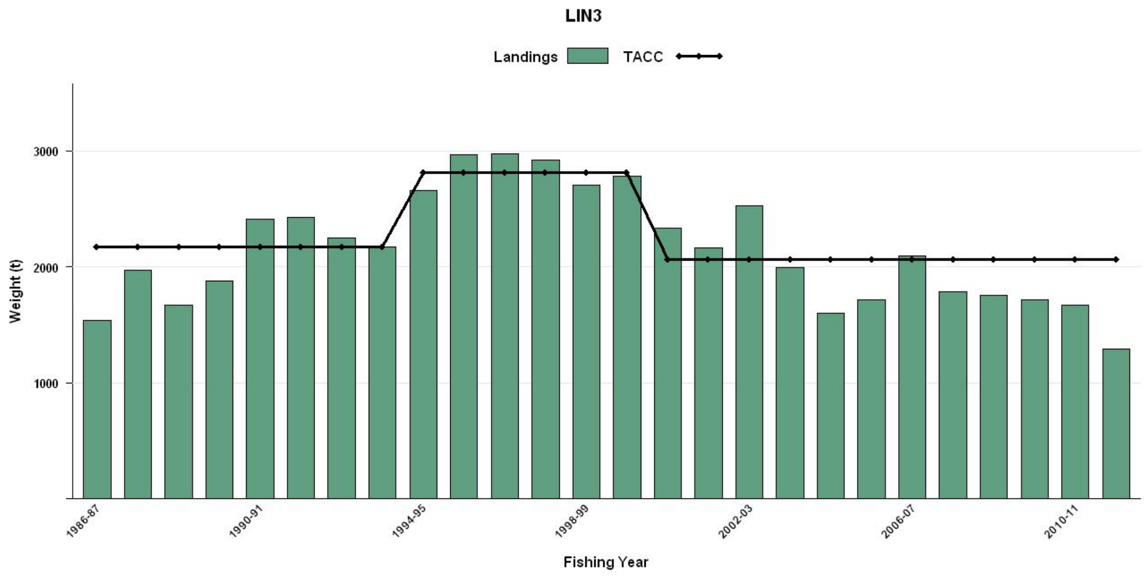
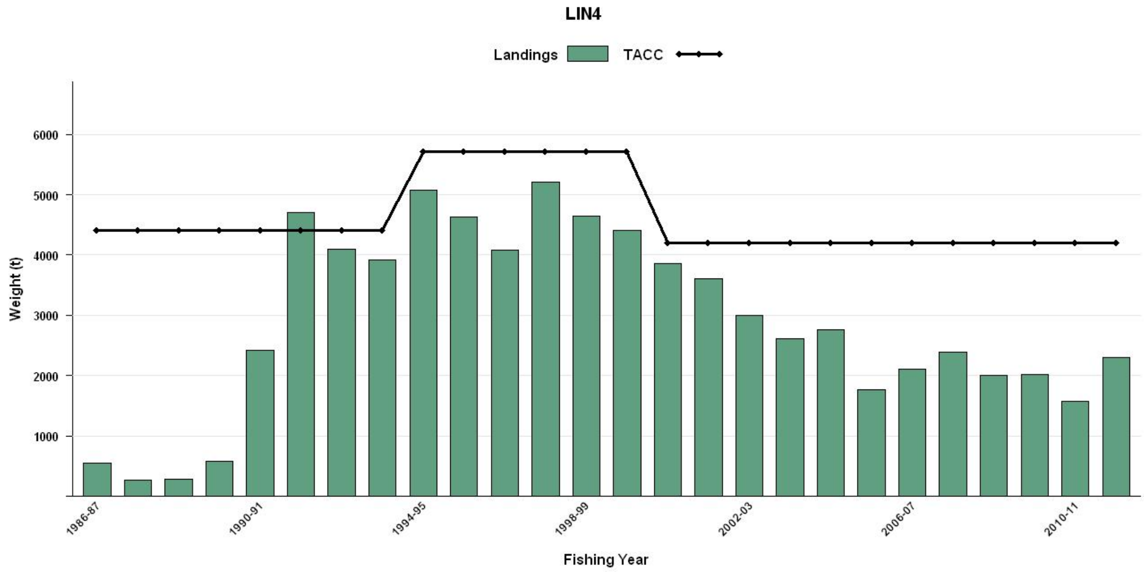


Figure 1: Historical landings and TACC for the seven main LIN stocks. From top to bottom: LIN1 (Auckland East) and LIN2 (Central East). [Continued on next page].





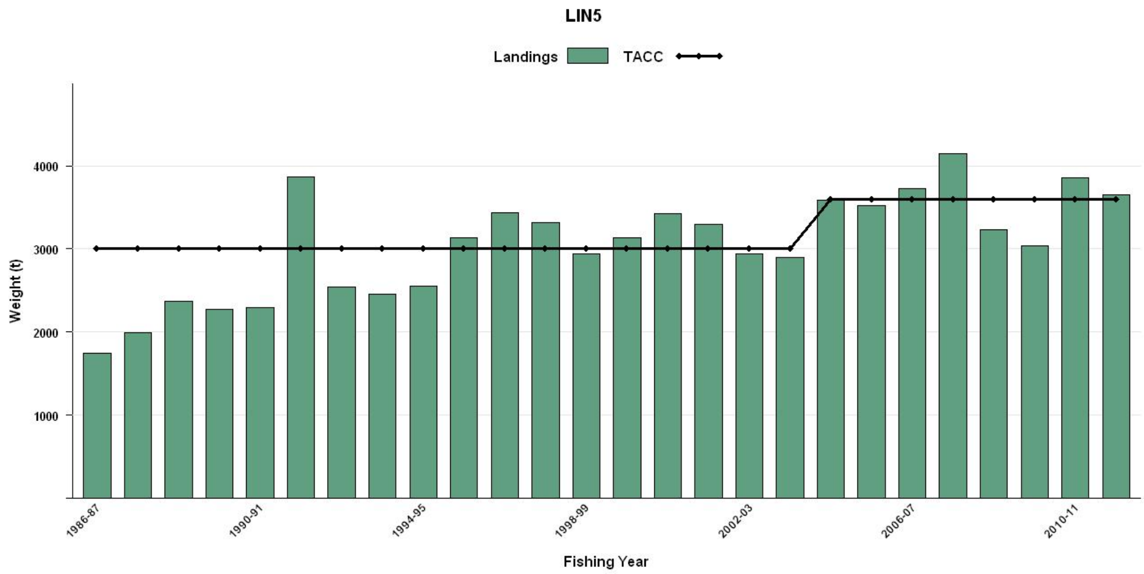
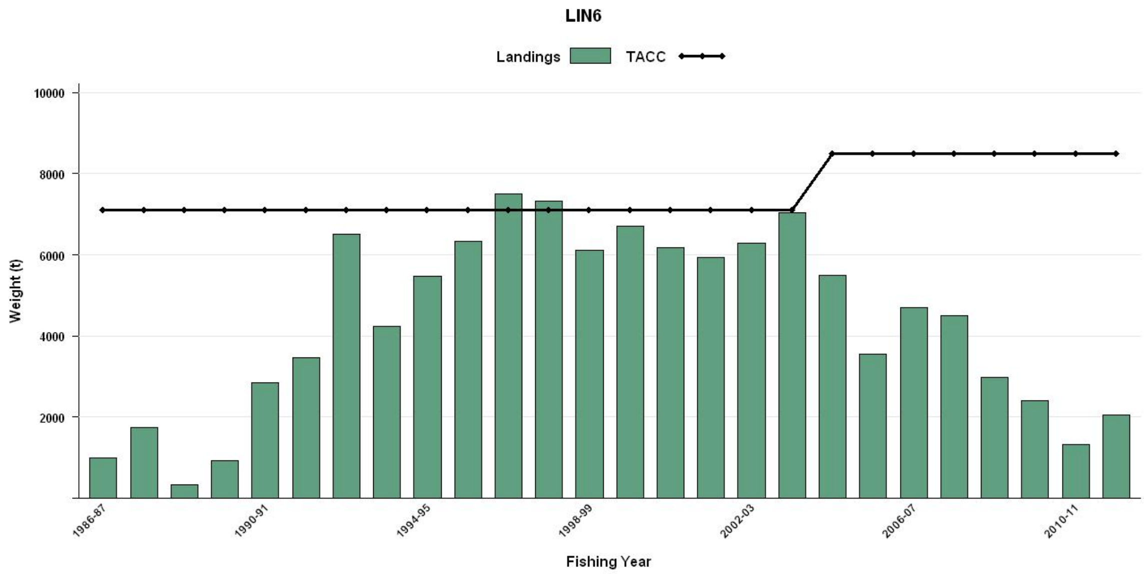


Figure 1 [Continued]: Historical landings and TACC for the seven main LIN stocks. From top to bottom: LIN3 (South East Coast), LIN4 (South East Chatham Rise) and LIN5 (Southland). [Continued on next page].



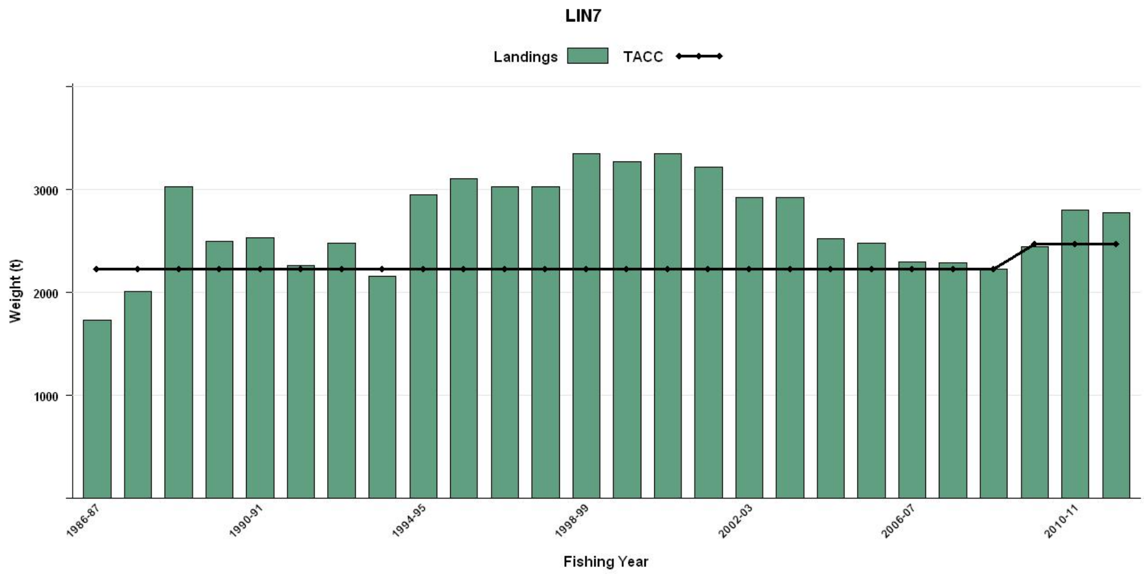


Figure 1 [Continued]: Historical landings and TACC for the seven main LIN stocks. From top: LIN6 (Sub-Antarctic), and LIN7 (Challenger). Note that these figures do not show data prior to entry into the QMS.

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, < 500; LIN 7, < 500) were too low to provide reliable estimates.

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.

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 2 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.

Table 2: Reported landings (t) of ling by Fishstock from 1983–84 to 2011–12 and actual TACCs (t) from 1986–87 to 2011–12. 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.

Fishstock	LIN 1		LIN 2		LIN 3		LIN 4		LIN 5	
QMA (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

Fishstock	LIN 6		LIN 7			LIN 10			
QMA (s)	6		7 & 8			10		Total	
	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

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

2. BIOLOGY

Ling live to a maximum age of about 30 years; fewer than 0.2% 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, Cook Strait) showed that females grew significantly faster and reached a greater size than males in all areas, and that growth rates were significantly different between areas. Ling grow fastest in Cook Strait and slowest on the Campbell Plateau (Horn 2005).

M was initially estimated from the equation $M = \log_e 100$/maximum age, where maximum age is the age to which 1% of the population survives in an unexploited stock. The mean M calculated from 5 samples of age data was 0.18 (range = 0.17–0.20). However, a recent review of M, and results of modelling conducted in 2007, suggests that this parameter may vary between stocks (Horn 2008b). The M for Chatham Rise ling appears to be lower than 0.18, while for Cook Strait and west coast South Island the value is probably higher than 0.18.

Ling in spawning condition have been reported in a number of localities throughout the EEZ (Horn 2005). Time of spawning appears to vary between areas: July to November 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 3.

Table 3: Estimates of biological parameters from Horn (2005). See Section 3 for definitions of Fishstocks.

Fishstock	**Estimate**
1. Natural mortality (M)	
All stocks average (both sexes)	$M = 0.18$

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

	Female		Male		Area
	a	b	a	b	
LIN 3&4	0.00114	3.318	0.00100	3.354	Chatham Rise
LIN 5&6	0.00128	3.303	0.00208	3.190	Southern Plateau
LIN 6B	0.00114	3.318	0.00100	3.354	Bounty Plateau
LIN 7WC	0.00094	3.366	0.00125	3.297	West Coast S.I.
LIN 7CK	0.00094	3.366	0.00125	3.297	Cook Strait

3. von Bertalanffy growth parameters

	Female			Male			Area
	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	West Coast S.I.
LIN 7CK	0.097	–0.54	163.6	0.080	–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 behavior, 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

The stock assessments for two ling stocks (LIN 7WC, west coast South Island; LIN 7CK, Cook Strait) were updated in 2013. Assessments for other stocks were updated in 2007 (LIN 6B, Bounty Plateau), or 2012 (LIN 3&4, Chatham Rise; LIN 5&6, Sub-Antarctic). All assessments 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 4, and other model input parameters are shown in Table 5. Estimates of relative abundance from standardised CPUE analyses (Table 6) and trawl surveys (Table 7) are also presented below.

Table 4: Estimated catch histories (t) for LIN 3&4 (Chatham Rise), LIN 5&6 (Campbell Plateau), LIN 6B (Bounty Platform), LIN 7WC (WCSI section of LIN 7), and LIN7CK (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 3&4		LIN 5&6			LIN 6B	LIN 7WC		LIN 7CK	
	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	1 934	529	3 199	9	4	12	2 205	399	362	121
1991	2 563	2 228	4 534	392	97	33	2 163	364	488	163
1992	3 451	3 695	6 237	566	518	908	1 631	661	498	85
1993	2 375	3 971	7 335	1 238	474	969	1 609	716	307	114
1994	1 933	4 159	5 456	770	486	1 149	1 136	860	269	84
1995	2 222	5 530	5 348	2 355	338	396	1 750	1 032	344	70
1996	2 725	4 863	6 769	2 153	531	381	1 838	1 121	392	35
1997	3 003	4 047	6 923	3 412	614	340	1 749	1 077	417	89
1998	4 707	3 227	6 032	4 032	581	395	1 887	1 021	366	88
1999	3 282	3 818	5 593	2 721	489	563	2 146	1 069	316	216
2000	3 739	2 779	7 089	1 421	1 161	991	2 247	923	317	131
2001	3 467	2 724	6 629	818	1 007	1 064	2 304	977	258	80
2002	2 979	2 787	6 970	426	1 220	629	2 250	810	230	171
2003	3 375	2 150	7 205	183	892	922	1 980	807	280	180
2004	2 525	2 082	7 826	774	471	853	2 013	814	241	227
2005	1 913	2 440	7 870	276	894	49	1 558	871	200	282
2006	1 639	1 840	6 161	178	692	43	1 753	666	129	220
2007	2 322	1 880	7 504	34	651	236	1 306	933	107	189
2008	2 350	1 810	6 990	329	821	503	1 067	1 170	115	110
2009	1 534	2 217	5 225	276	432	232	1 089	1 009	108	39
2010	1 484	2 257	4 270	864	313	1	1 346	1 063	74	14
2011	1 500	2 200	4 500	450	450	53	1 597	1 046	111	38
2012	–	–	–	–	–	2	1 300	1 050	100	40

Table 5: Input parameters for the assessed stocks.

Parameter	LIN 3&4	LIN 5&6	LIN 6B	LIN 7WC	LIN 7CK
Stock-recruitment steepness	0.9	0.9	0.9	0.9	0.9
Recruitment variability c.v.	0.6	0.6	1.0	0.6	0.7
Ageing error c.v.	0.05	0.06	0.05	0.05	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	0.022	0.084	0.27	0.61	0.86	0.96	0.99	1.00	1.0			
Female	0.0	0.001	0.004	0.015	0.06	0.22	0.55	0.84	0.96	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			

*Proportion mature at age

Table 6: Standardised CPUE indices (with CVs) for the ling line and trawl fisheries. Year refers to calendar year.

	LIN 3&4 line		LIN 5&6 line (spawn)		LIN 5&6 line (non-spawn)		LIN 7WC line		LIN 7CK line	
Year	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.
1990	–	–	–	–	–	–	0.90	0.07	1.29	0.15
1991	1.66	0.06	1.28	0.17	0.66	0.12	1.07	0.06	1.44	0.13
1992	2.15	0.05	1.75	0.14	1.01	0.09	1.25	0.05	1.43	0.11
1993	1.54	0.05	1.54	0.11	0.84	0.10	0.90	0.05	1.11	0.11
1994	1.54	0.05	1.33	0.11	0.74	0.09	0.88	0.05	0.90	0.11
1995	1.48	0.05	1.40	0.17	1.02	0.08	0.90	0.04	0.83	0.12
1996	1.19	0.04	1.28	0.11	0.85	0.08	0.68	0.04	0.97	0.13
1997	0.82	0.04	1.16	0.10	0.91	0.06	0.80	0.05	1.32	0.18
1998	0.89	0.04	0.99	0.11	0.79	0.06	0.92	0.05	0.83	0.15
1999	0.78	0.04	1.28	0.10	0.64	0.05	0.95	0.05	1.54	0.18
2000	0.92	0.04	1.32	0.10	0.76	0.07	0.96	0.04	1.45	0.19
2001	0.91	0.04	1.34	0.10	0.91	0.09	1.12	0.05	1.27	0.18
2002	0.74	0.04	1.55	0.10	0.79	0.10	1.06	0.05	2.04	0.11
2003	0.90	0.04	1.12	0.12	0.62	0.12	1.10	0.04	1.66	0.10
2004	0.74	0.04	1.03	0.09	0.57	0.09	1.10	0.05	1.45	0.09
2005	0.84	0.04	1.42	0.12	0.50	0.13	0.84	0.04	1.16	0.10
2006	0.71	0.04	1.29	0.12	0.61	0.14	0.84	0.05	0.97	0.15
2007	0.78	0.04	1.35	0.11	0.98	0.36	1.11	0.04	0.70	0.12
2008	0.99	0.05	1.02	0.14	1.05	0.12	1.13	0.05	0.82	0.22
2009	0.71	0.04	2.05	0.19	0.85	0.13	1.14	0.05	0.60	0.28
2010	0.88	0.04	0.69	0.18	0.85	0.09	1.39	0.05	0.35	0.30
2011	–	–	–	–	–	–	1.28	0.07	0.22	0.30

	LIN 7CK trawl		LIN 7WC trawl		LIN 6B line	
Year	**CPUE**	**c.v.**	**CPUE**	**c.v.**	**CPUE**	**c.v.**
1987	–	–	0.49	0.07	–	–
1988	–	–	0.92	0.06	–	–
1989	–	–	1.33	0.06	–	–
1990	–	–	1.27	0.06	–	–
1991	–	–	0.81	0.06	–	–
1992	–	–	0.76	0.07	1.80	0.13
1993	–	–	1.04	0.06	1.58	0.11
1994	1.25	0.05	0.91	0.05	1.07	0.13
1995	1.16	0.04	1.31	0.06	1.13	0.13
1996	1.12	0.04	1.73	0.05	1.05	0.12
1997	1.00	0.04	1.40	0.06	0.85	0.13
1998	1.01	0.04	1.36	0.05	1.03	0.12
1999	1.02	0.03	1.59	0.05	1.04	0.11
2000	1.27	0.04	1.23	0.04	0.95	0.10
2001	1.46	0.04	0.94	0.04	0.81	0.10
2002	1.27	0.05	1.27	0.04	0.72	0.10
2003	1.27	0.04	0.71	0.05	0.78	0.09
2004	1.13	0.04	1.12	0.04	0.71	0.14
2005	1.18	0.04	0.79	0.04	–	–
2006	1.10	0.05	0.73	0.04	0.97	0.36
2007	0.73	0.06	0.55	0.06	*1.12*	*0.12*
2008	0.90	0.06	0.54	0.06	*1.12*	*0.10*
2009	0.44	0.07	0.48	0.06	*0.80*	*0.11*
2010	0.44	0.07	0.63	0.06	–	–
2011	0.23	0.09	1.06	0.06	–	–

Chatham Rise, LIN 3 & LIN 4

LIN 3

4.2 Biomass estimates

Biomass in the core strata (30–400 m) for the east coast South Island trawl survey is consistently lower in recent surveys compared to that in the 1990s (Figure 2). Coefficients of variation are also variable ranging from 17 to 35%, (mean 23%) and overall can be regarded as low. The additional biomass captured in the 10–30 m depth range is negligible.

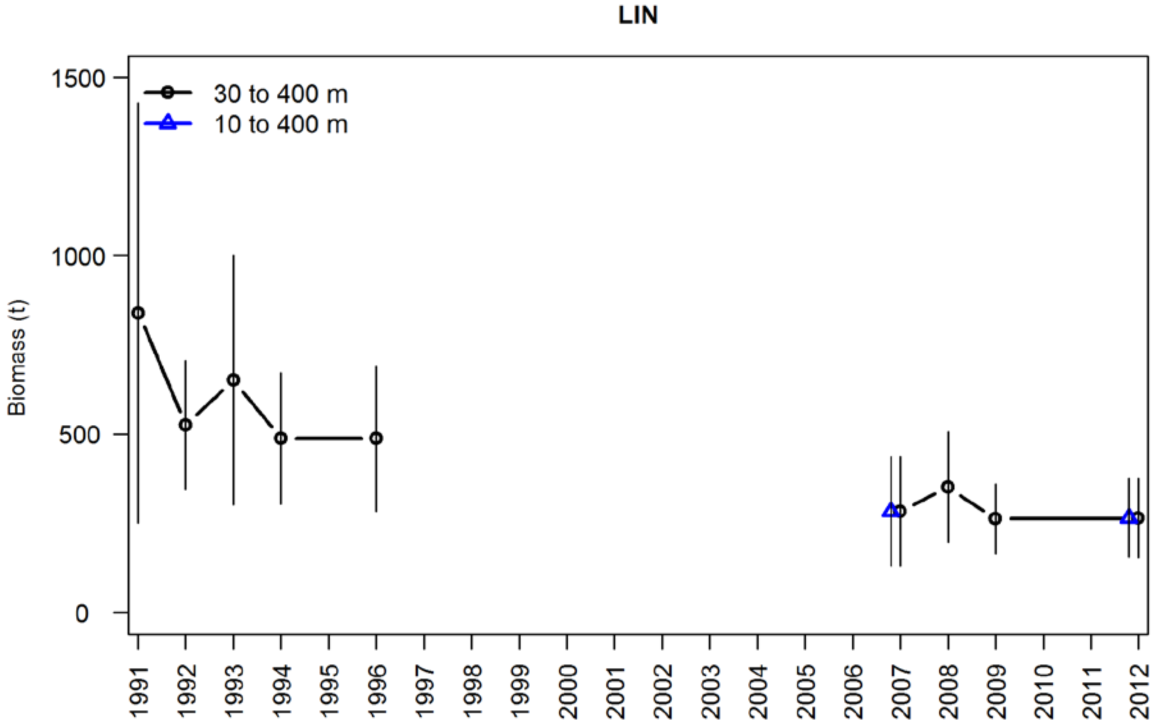


Figure 2: Ling total biomass and 95% confidence intervals for the all ECSI winter surveys in core strata (30–400 m), and core plus shallow strata (10–400 m) in 2007 and 2012.

4.3 Length frequency distributions

The length distributions for the east coast South Island trawl survey show two distinct modes, particularly in the shallower depths, centred at about 50 cm and 90 cm (combined males, females, and unsexed) (Figure 3). Both modes will comprise multiple year classes. Plots of time series length frequency distributions are generally consistent among surveys with indications of fewer larger fish (mode around 90 cm) in recent years. The addition of the 10–30 m depth range has not changed the shape of the length frequency distribution.

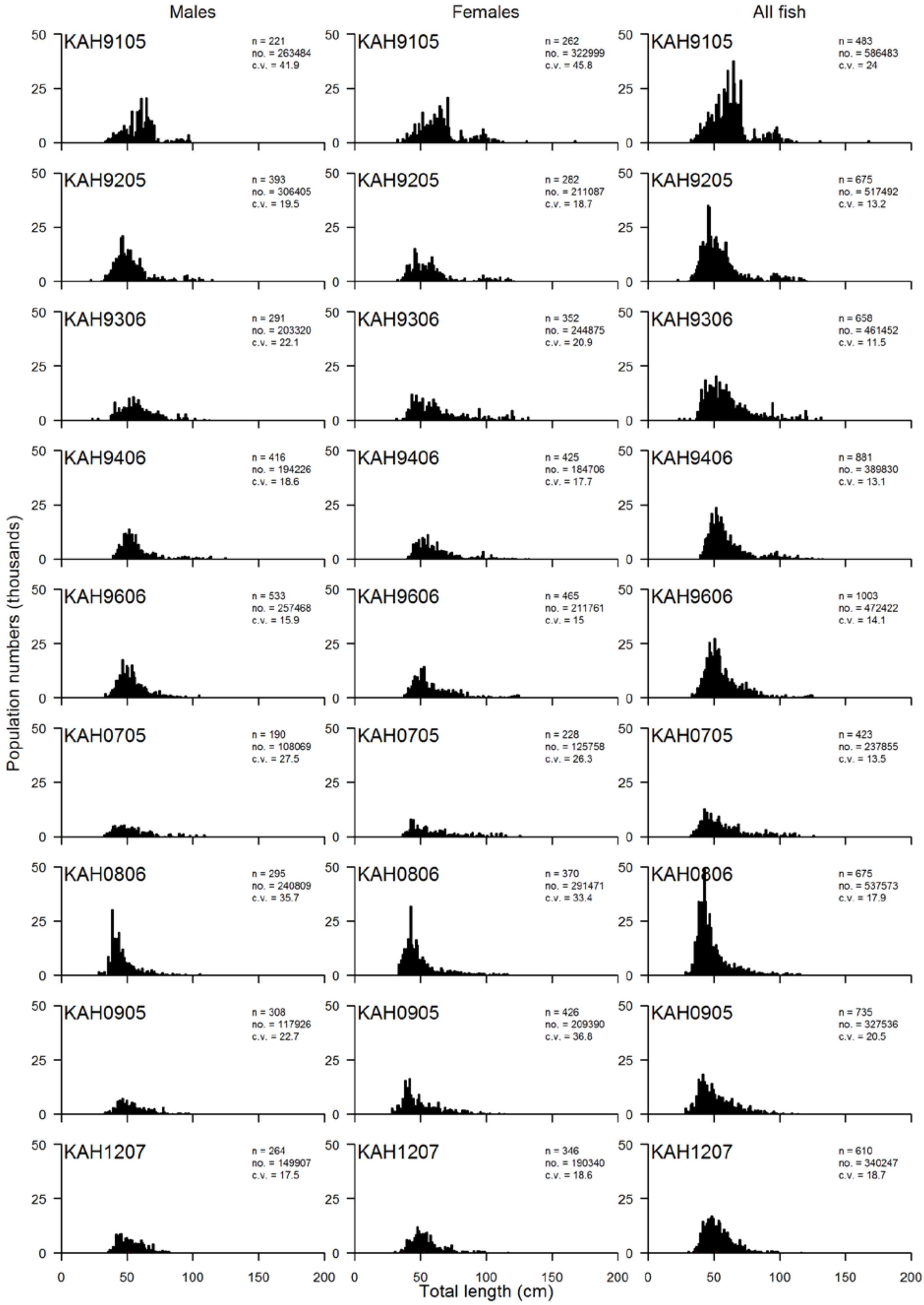


Figure 3: Scaled length frequency distributions for ling in core strata (30–400 m) for all nine ECSI winter surveys. The length distribution is also shown in the 10–30 m depth strata for the 2007 and 2012 surveys overlaid in red for species with many length classes, otherwise in light grey (not stacked). Population estimates are for the core strata only. n, number of fish measured; no., population number; c.v., coefficient of variation.

Table 7: Biomass indices (t) and estimated coefficients of variation (c.v.).

Fishstock	Area	Vessel	Trip code	Date	Biomass	c.v. (%)
LIN 3	ECSI (winter)	*Kaharoa*	KAH9105	1991	1 009	35
			KAH9205	1992	525	17
			KAH9306	1993	651	27
			KAH9406	1994	488	19
			KAH9606	1996	488	21
			KAH0705	2007	283	17
			KAH0806	2008	351	22
			KAH0905	2009	262	19
			KAH1207	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	15.3
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 1991	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
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	*Kaharoa*	KAH9204	Mar-Apr 1992	286	19
			KAH9404	Mar-Apr 1994	261	20
			KAH9504	Mar-Apr 1995	367	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	235	43

4.4.1 Model structure and inputs

The stock assessment for LIN 3&4 (Chatham Rise) was updated in 2012. 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_{2011}) 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. 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 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. The catch history, biological input parameters, and estimates of relative abundance used in the model are shown in Tables 4–7. 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 8.

Table 8: 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) Line CPUE Line catch-at-age/length Trawl catch-at-age	0.2 0.5
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.

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

Investigative model runs identified a conflict between the line fishery CPUE and the trawl survey biomass index, where the line fishery biomass index declined between 1991 and 1997, but the trawl survey index remained relatively flat throughout. This difference could not be resolved in a single model run by assuming different selectivity ogives for each biomass index. Therefore, to remove this conflict, a base case model run (Base) used all the observational data except those from the line fishery; the trawl survey biomass index being preferred in the base case because these data were fishery independent. A sensitivity run (NoTrawl) then included the line fishery data, and excluded the trawl survey data.

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 0.2 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 then adjusted using the reweighting procedure of Francis (2011). Reweighting of the at-age and at-length data was completed for the base and sensitivity runs separately.

4.4.2 Model estimates

The fits to the biomass indices, catch-at-age and catch-at-length data, were reasonable to good in all model runs, with generally balanced residuals. Posterior distributions of year class strength estimates from the base case model run are shown in Figure 4; the distribution from the NoTrawl run differed little from the base case. Since 1980, year class strengths were below average except for a period between 1994 and 1999, and in 2007. 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 (mean selectivity A_{50} of 5.2 years), then the trawl fishery (mean A_{50} of 8.0 years), and then the line fishery (A_{50} of 11.0 years). Males were estimated to be less vulnerable than females to the trawl and line fisheries. The estimated median *M* was 0.15.

The assessment is driven by the catch history, and by catch-at-age data, which contain information indicative of a stock decline during the 1990s. This is supported by a declining trend in the line fishery CPUE index during that time.

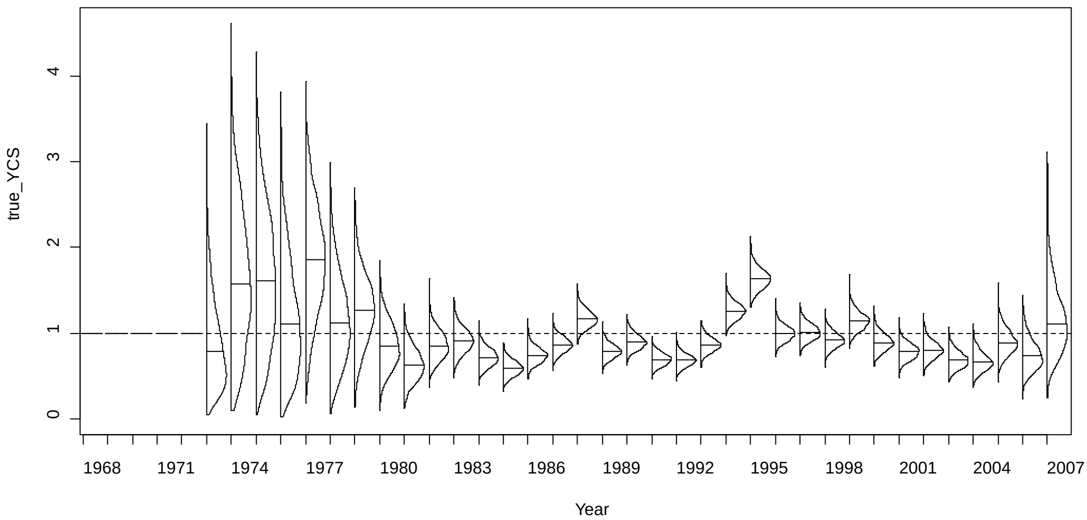


Figure 4: LIN 3&4 — Estimated posterior distributions of year class strength for the base model. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

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, and very likely that biomass in 2011 was greater than 44% of B_0 (Table 9).

Table 9: LIN 3&4 — Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2011} (in tonnes), and B_{2011} as a percentage of B_0 for both model runs.

Model run	B_0		B_{2011}		B_{2011} (% B_0)	
Base	127 400	(110 400–170 300)	70 800	(48 600–121 900)	55	(44–71)

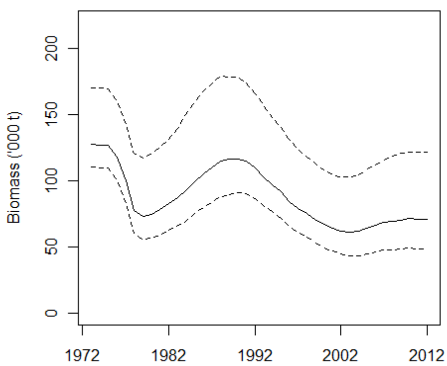


Figure 5: LIN 3&4 — Estimated posterior distributions of the biomass trajectory (in tonnes) from the base run. Broken lines show the 95% credible intervals and the solid line the median.

The model indicated an increasing biomass since 2004 (driven by a reduction in catch). Annual landings from the LIN 3&4 stock have been less than 4600 t since 2004, markedly lower than the 6000–8000 t taken annually between 1992 and 2003. Biomass projections derived from this assessment are shown below (Section 4.9).

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

4.5.1 Model structure and inputs

The stock assessment for LIN 5&6 (Sub-Antarctic) was updated in 2012. 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_{2011}) 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.

MCMC chains were constructed using a burn-in length of $5x10^5$ iterations, with every 2500th sample taken from the next $2.5x10^6$ iterations (i.e., a final sample of length 1000 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 model run that incorporated all the data except the CPUE series is presented, with a sensitivity run that included the CPUE series. 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 12.

Table 10: 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	Recruitment Non-spawning fisheries (trawl & line)	0.75	0.4	Trawl survey (summer) Trawl survey (autumn) Line CPUE (non-spawn) Line (non-spawn) catch-at-age Trawl catch-at-age	0.1 0.5 0.7
2	Sep–Nov	Increment ages Spawning fishery (line)	0.25	0.0	Line CPUE (spawning) Line (spawning) 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.

Lognormal errors, with known CVs, were assumed for all relative biomass, proportions-at-age, and proportions-at-length observations. The CVs available for those observations of relative abundance and catch data allow for sampling error only. However, additional variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance. The additional variance, termed process error, was estimated in MPD runs of the model (Table 13) and fixed in all subsequent runs.

The assumed prior distributions used in the assessment are given in Table 14. 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 11: LIN 5&6 — Summary of the relative abundance series applied in the models, including source years (Years), and the estimated process error (c.v.) added to the observation error.

Data series	Years	Process error c.v.
Trawl survey proportion at age (*Amaltal Explorer*, Nov)	1990	0.15
Trawl survey biomass (*Tangaroa*, Nov–Dec)	1992–94, 2001–10	0.01
Trawl survey proportion at age (*Tangaroa*, Nov–Dec)	1992–94, 2001–10	0.15
Trawl survey biomass (*Tangaroa*, Mar–May)	1992–93, 1996, 1998	0.01
Trawl survey proportion at age (*Tangaroa*, Mar–May)	1992–93, 1996, 1998	0.01
CPUE (longline, spawning fishery)	1991–2010	0.18
CPUE (longline, non-spawning fishery)	1991–2010	0.18
Commercial longline proportion-at-age (spawning, Oct–Dec)	2000–08, 2010	0.3
Commercial longline proportion-at-age (non-spawn, Feb–Jul)	1999, 2001, 2003, 2005, 2009, 2010	0.3
Commercial trawl proportion-at-age (Sep–Apr)	1992–94, 1996, 1998, 2001–10	0.3

Table 12: 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 c.v.

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*
Process error c.v.	Uniform-log	–	–	0.001	2
M (x_0, y_0, y_1, y_2)	Uniform	–	–	3, 0.01, 0.01, 0.01	15, 0.6, 1.0, 1.0

* A range of maximum values were 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 4–7.

4.5.2 Model estimates

Descriptions of two model runs reported are as follows.

- Base case — catch history, all relative abundance series listed in Tables 4, 6, and 7, *M* estimated as an ogive independent of sex, double-normal selectivity ogives for the trawl fishery, logistic ogives for the line fisheries and the resource survey series.
- CPUE — the base case model, but incorporating the two line fishery CPUE series.

Three other sensitivities were investigated: (1) splitting the summer survey series into early (1992–2006) and recent (2007–09) series with independent *q*s, (2) excluding the 2001 survey biomass point, and (3) fitting the survey ogives as double-normal. These models all produced estimates of stock status that were little different to those from the reported models.

Posterior distributions of year class strength estimates from the base case model run are shown in Figure 4; the distribution from the CPUE model run differed little from the base case. Year classes were generally weak from 1982 to 1992, strong from 1993 to 1996, and average since then (although 2005 may be strong). Overall, estimated year class strengths were not widely variable, with all medians being between 0.5 and 2. Consequently, biomass estimates for the stock declined through the 1990s, but have exhibited an upturn during the last 12 years (Figure 5). The biomass trajectory from the CPUE model was little different to that derived from the base case.

Biomass estimates for the stock appear very healthy, with estimated current biomass from the two reported models at about 89% of B_0 (Figure 5, Table 15). Annual exploitation rates (catch over vulnerable biomass) were low (less than 0.06) in all years as a consequence of the high estimated stock size in relationship to the level of relative catches.

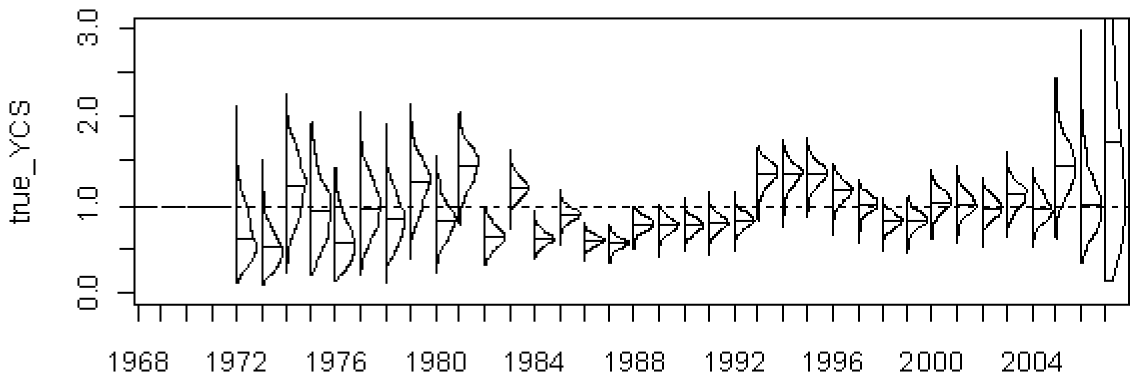


Figure 4: LIN 5&6 — Estimated posterior distributions of year class strength from the base case run. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

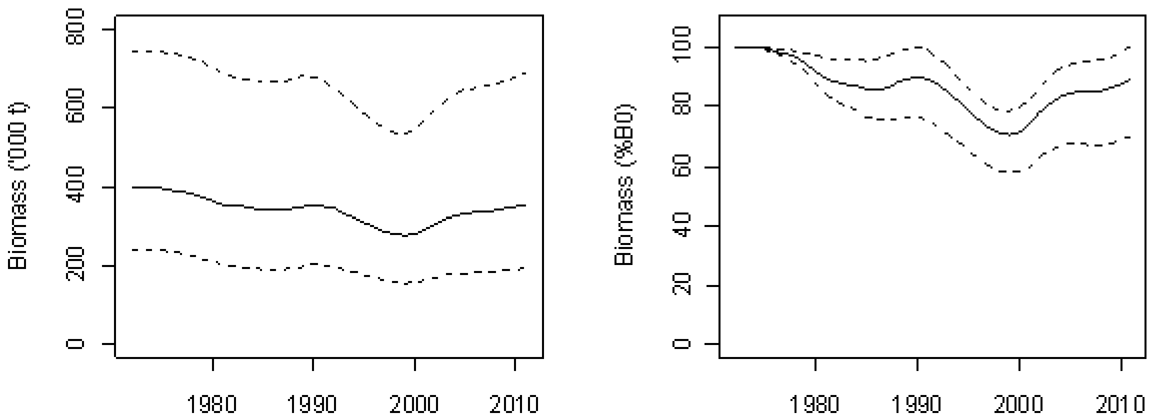


Figure 5: LIN 5&6 — Estimated median trajectories (with 95% credible intervals shown as dashed lines) for absolute biomass and biomass as a percentage of B_0 from the base case model run.

Table 13: LIN 5&6 — Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2011} (in tonnes), and B_{2011} as a percentage of B_0 for both model runs.

Model run	B_0		B_{2011}		B_{2011} (% B_0)	
Base case	395 660	(240 210–740 790)	355 190	(195 430–689 960)	89.2	(69.8–100.6)
CPUE	442 400	(258 010–763 190)	399 260	(214 270–703 600)	89.8	(74.1–100.3)

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. 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 assessment relied on biomass data from the Sub-Antarctic trawl survey series. The summer survey series was not particularly well fitted and had clear patterns in the residuals (Figure 6). It was also apparent that there can be marked changes in catchability between adjacent pairs of surveys. Estimated trawl survey catchability constants were moderately low (about 4–15% based on doorspread swept area estimates), but are consistent with the priors.

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. Probabilities that current and projected biomass will drop below selected management reference points are shown in Table 16.

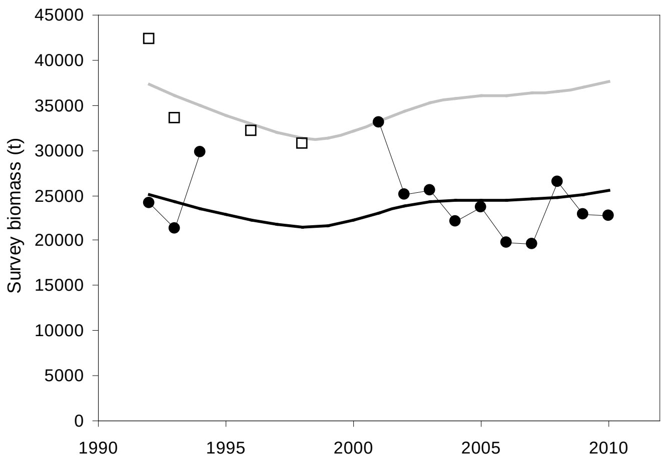


Figure 6: LIN 5&6 — Observed relative biomass from the autumn (open squares) and summer (filled circles) research trawl surveys. Survey biomass trajectories estimated in the base case model are also shown for the autumn (grey line) and summer (black line) surveys.

Table 14: LIN 5&6 — Probabilities that current (B_{2011}) and projected (B_{2016}) biomass will be less than 40%, 20% or 10% of B_0. Projected biomass probabilities are presented for the base case model using two scenarios of future annual catch (i.e., 5900 t, and 12 100 t).

Biomass	Management reference points		
	40% B_0	20% B_0	10% B_0
B_{2011}	0.000	0.000	0.000
B_{2016}, 5900 t catch	0.000	0.000	0.000
B_{2016}, 12 100 t catch	0.000	0.000	0.000

Estimates of biomass projections derived from this assessment are shown below (Section 4.9). The relatively high level of uncertainty in the model precluded any updated estimation of *MCY* and *CAY* (although an *MCY* was estimated in the 2007 assessment, as is reported below).

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

4.6.1 Model structure and inputs

The stock assessment for the Bounty Plateau stock (part of LIN 6) was updated in 2007. 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_{2007}) 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 16.

Lognormal errors, with known CVs, were assumed for all relative biomass, proportions-at-age, and proportions-at-length observations. The CVs available for those observations of relative abundance and catch data allow for sampling error only. However, additional variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance. The additional variance, termed process error, was estimated in MPD runs of the model (Table 17) and fixed in all subsequent runs.

Table 15: 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	0.9	0.5	Line CPUE	0.5
		fisher y (line)			Line catch-at-age/length	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 16: LIN 6B — Summary of the relative abundance series applied in the models, including source years (Years), and the estimated process error (c.v.) added to the observation error.

Data series	Years	Process error c.v.
CPUE (longline, all year)	1992–2004	0.15
Commercial longline length-frequency (Nov–Feb)	1996, 2000–04	0.5
Commercial longline proportion-at-age (Dec–Feb)	2000–01, 2004	0.4

The assumed prior distributions used in the assessment are given in Table 18. All priors were intended to be relatively uninformed, and were estimated with wide bounds.

Table 17: 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	–	–	5000	100 000
Year class strengths	lognormal	1.0	0.7	0.01	100
CPUE *q*	uniform-log	–	–	1e-8	1e-3
Selectivities	uniform	–	–	0	20–200
Process error CV	uniform-log	–	–	0.001	2

* A range of maximum values were 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 4–7.

4.6.2 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 7.

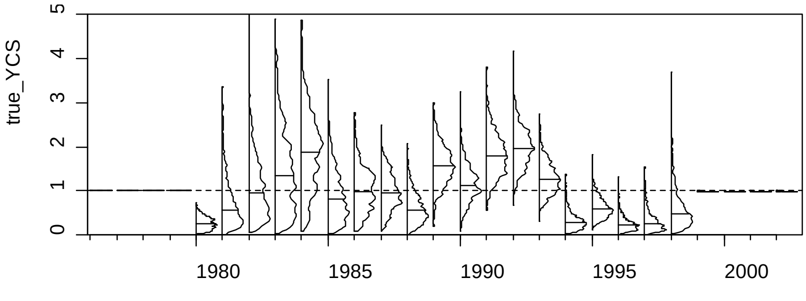


Figure 7: LIN 6B — Estimated posterior distributions of year class strength from the base case run. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

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 19 and the biomass trajectory is shown in Figure 8. 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 18: 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)

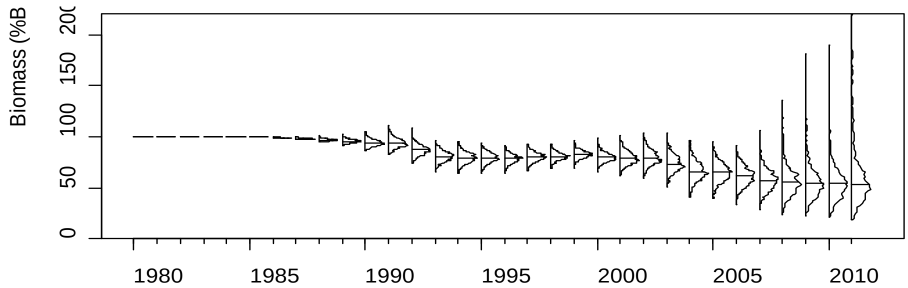


Figure 8: LIN 6B — Estimated posterior distributions of biomass trajectories as a percentage of B_0, from the base case model run (including 5-year projections through to 2011 with assumed constant annual catch of 400 t). Distributions are the marginal posterior distribution, with horizontal lines indicating the median.

Estimates of *MCY*, *CAY*, and biomass projections derived from this assessment are shown below (Sections 4.7–4.9).

4.7 West coast South Island, LIN 7WC

4.7.1 Model structure and inputs

The stock assessment for LIN 7WC (west coast South Island) was updated in 2013. The assessment model partitions the population into age groups 3 to 28 with a plus group, with no sex in the partition. The model's annual cycle is described in Table 19.

The chosen base case was developed following the investigation of numerous previous models. It was found that the model could not reconcile some differences in sex ratios of the age-frequency data, so sex was removed from the partition.

Year class strengths and fishing selectivity ogives were also estimated in the model. Commercial trawl and research survey selectivities were fitted as double normal curves; the line fishery ogive was fitted as a 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_{2008}) biomass were obtained. MCMC chains were constructed using a burn-in length of $2{\times}10^6$ iterations, with every 4000th sample taken from the next $4{\times}10^6$ iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior). Single chain convergence tests were applied to resulting chains to determine evidence of non-convergence. No evidence of lack of convergence was found in the estimates of B_0 or $B_{current}/B_0$ from the base case model run.

For LIN 7WC, model input data include 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 comparable *Tangaroa* surveys in 2000 and 2012, and estimates of biological parameters (Table 20). A line fishery CPUE series was available, but was rejected as unlikely to be indexing stock abundance. The base case estimated instantaneous natural mortality, *M*, as a constant.

Table 19: 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 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, with additional process error of 0.2. 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 survey a relatively high weighting.

Table 20: LIN 7WC — Summary of the relative abundance series applied in the models, including source years (Years).

Data series	Years
CPUE (hoki trawl, Jun–Sep)	1987–2011
Commercial trawl proportion-at-age (Jun–Sep)	1991, 1994–2008
Commercial longline proportion-at-age	2003, 2012
Trawl survey biomass (*Tangaroa*, July)	2000, 2012
Trawl survey age data	2000, 2012

The assumed prior distributions used in the assessment are given in Table 21. 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 4.3.1) 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 × 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 21: 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	20–200*
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 4–7.

4.7.2 Model estimates

MCMC runs of the base case and one sensitivity (where *M* was fixed at 0.18) were conducted.

Posterior distributions of year class strength estimates from the base case model run are shown in Figure 9. The YCS distribution from the sensitivity run was not visually different and is not shown.

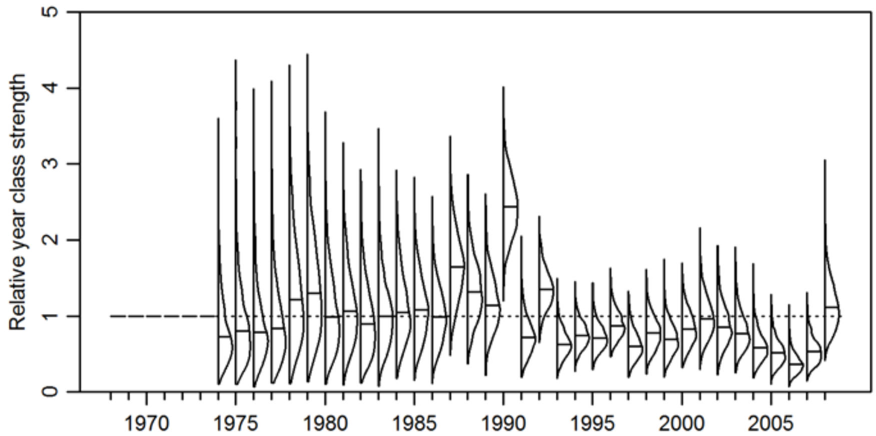


Figure 9: LIN 7WC — Estimated posterior distributions of year class strength. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

Both model runs were indicative of a B_0 greater than about 50 000 t. The upper bound on B_0 is highly uncertain and dependent on the priors on the survey q and *M*. Both model runs also indicated a biomass decline from 2000-2012 (Table 22, Figure 10). The model fit to the CPUE series was poor (Figure 11). Model estimates suggest a period of higher recruitment from 1978 to 1990 followed by lower recruitment since 1992. There was also some evidence for stronger recruitment in the most recent year for which an estimate can be made but this is highly uncertain (Figure 9).

Table 22: LIN 7WC — Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2011} (in tonnes), and B_{2012} as a percentage of B_0 for all model runs. The base case estimates *M*.

Model run	B_0		B_{2012}		B_{2012} (% B_0)	
Base case	99 200	(58 400–304 600)	70 350	(33 000–248 400)	71	(56–85)
M = 0.18	66 100	(50 300–142 900)	39 580	(23 600–109 200)	59	(46–79)

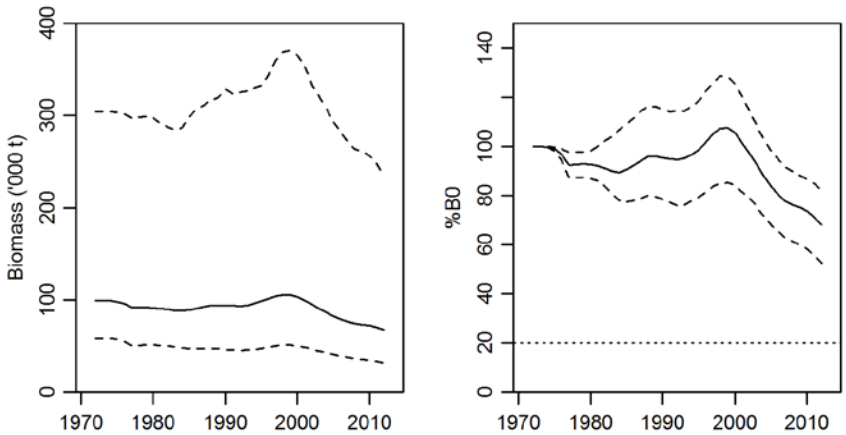


Figure 10: LIN 7WC — Estimated posterior distributions of the biomass (t) trajectory and % B_0 for the base case. The solid lines are the median values and the dashed lines are the 95% CIs.

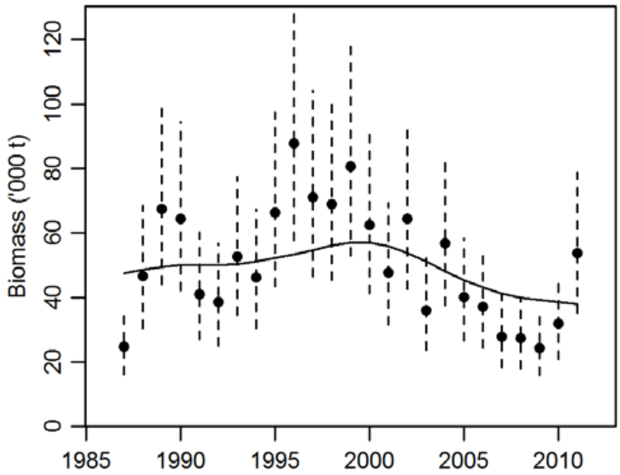


Figure 11: LIN 7WC —The fit of the base case model (MPD) to the commercial trawl CPUE index. The CPUE index has been scaled to the biomass using the estimated q.

4.8 Cook Strait, LIN 7CK

4.8.1 Model structure and inputs

A stock assessment of ling in Cook Strait (LIN 7CK) was completed in 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, 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 24. 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 known CVs, were assumed for all CPUE and proportions-at-age observations. The CVs available for those observations allow for sampling error only. However, additional variance (termed process error), assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance (Table 25).

Table 23: 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 24: LIN 7CK — Summary of the available data including source years (Years), and the estimated process error (c.v.) added to the observation error.

Data series	Years	Process error c.v.
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	2006–7	1.1

The assumed prior distributions used in the assessment are given in Table 26. Most priors were intended to be relatively uninformed, and were specified with wide bounds.

Table 25: LIN 7CK — Assumed prior distributions and bounds for estimated parameters in the assessments. The parameters are mean (in log space) and c.v. 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 4–7.

4.8.2 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 12.

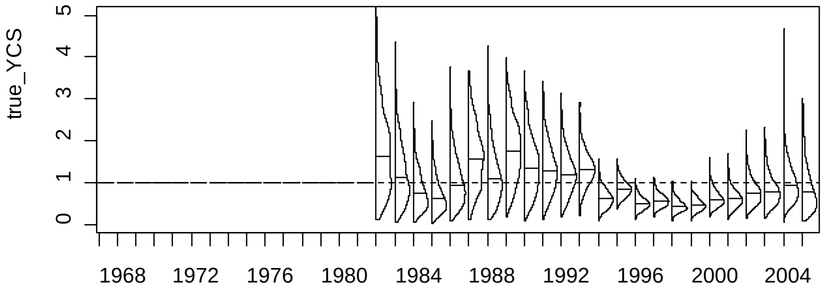


Figure 12: LIN 7CK — Estimated posterior distributions of year class strength. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

The assessment is driven by the trawl fishery catch-at-age data and tuned by the trawl CPUE. Both input series contain information indicative of an overall stock decline in the last two decades. The confidence bounds around biomass estimates are wide (Table 27, Figure 13). Probabilities that current and projected biomass will drop below selected management reference points are shown in Table 28. 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 (Figure 14). Since the early 1990s, trawl fishing pressure has generally declined, while line pressure has generally increased.

Table 26: 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 27: 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

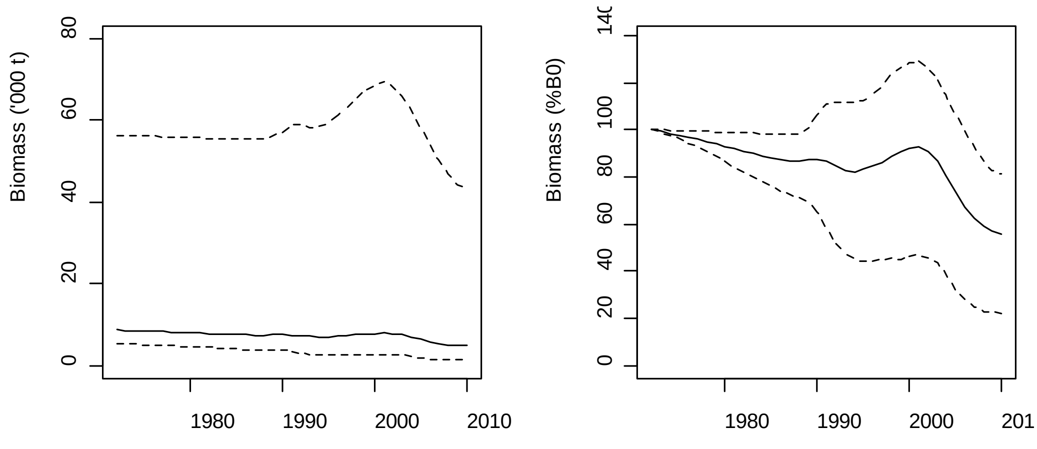


Figure 13: LIN 7CK — Estimated median trajectories (with 95% credible intervals shown as dashed lines) for absolute biomass and biomass as a percentage of B_0.

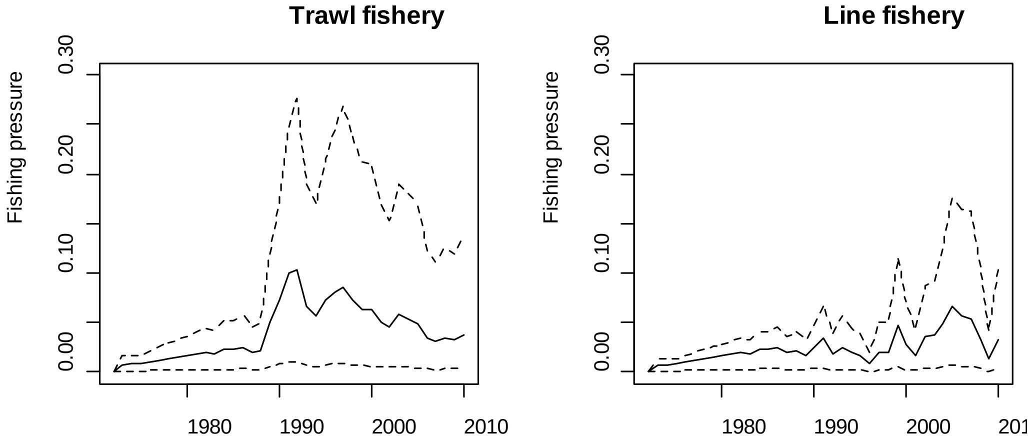


Figure 14: LIN 7CK — Estimated median trajectories (with 95% credible intervals shown as dashed lines) of fishery exploitation rates.

Estimates of biomass projections derived from this assessment are shown below (Section 4.9). The relatively high level of uncertainty in the model precluded any updated estimation of *MCY* and *CAY* (although an *MCY* was estimated in the 2007 assessment, as is reported below).

4.9 Yield estimates and projections

No estimate for *MCY* or *CAY*

Projections for LIN 6B from the 2006 assessment are shown in Table 28. The LIN 6B stock (Bounty Plateau) is likely to decline out to 2011, but probably will still be higher than 50% of B_0. Projections out to 2015 for LIN 7CK indicate that biomass is likely to increase with future catches equal to recent catch levels, or decline slightly if catches are equal to the mean since 1990 (Table 29). New projections made in 2011 out to 2016 for LIN 3&4 and 5&6, assuming future annual catches equal to recent catch levels, are shown in Table 30. For LIN 3&4, stock size is likely to remain about the same. For LIN 5&6, stock size is likely to increase slightly. For LIN 7 WC the Working Group did not consider that projections using either run were reliable and so no projections are shown.

Table 28: 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 base case.

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

Table 29: 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 case	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 30: LIN 3&4 and 5&6 Bayesian median and 95% credible intervals (in parentheses) of projected B_{2016}, B_{2016} as a percentage of B_0, and B_{2016}/B_{2011} (%) for the base case and sensitivity run.

Stock and model run		Future catch (t)	B_{2016}		B_{2016} (%B_0)		B_{2016}/B_{2011} (%)	
LIN 3&4	Base	3 900	69 900	(45 500–122 000)	55	(41–72)	98	(87–111)
LIN 5&6	Base case	5 900	409 400	(210 350–963 680)	103	(84–149)	114	(94–211)
	CPUE	5 900	464 310	(213 840–973 870)	104	(85–141)	114	(94–181)

5. ANALYSIS OF ADAPTIVE MANAGEMENT PROGRAMMES (AMP)

The Ministry of Fisheries revised the AMP framework in December 2000. The AMP framework is intended to apply to all proposals for a TAC or TACC increase, with the exception of fisheries for which there is a robust stock assessment. In March 2002, the first meeting of the new Adaptive Management Programme Working Group was held. Two changes to the AMP were adopted:

- a new checklist was implemented with more attention being made to the environmental impacts of any new proposal;
- the annual review process was replaced with an annual review of the monitoring requirements only. Full analysis of information is required a minimum of twice during the 5 year AMP.

LIN 1

In October 2002, the TACC for LIN 1 was increased from 265 t to 400 t within the AMP. A full-term review of the LIN 1 AMP was carried out in 2007.

Mid-term Review 2009 (AMP WG/09/09).

Fishery Characterization

- LIN1 entered the QMS in 1986-87 at a TACC of 200 t, which was increased to 238 t in 1988–89 and 265 t in 1989–90, probably due to the quota appeal process. LIN 1 catches remained slightly under the TACC up to 1994–94, but then exceeded the TACC, reaching ~300 t over most of the period 1996–97 to 2001–02. LIN 1 entered the AMP programme in 2002–03, with a TACC increase from 265 t to 400 t.
- After implementation of the AMP, catches dropped back to the previous TACC level for two years, and then increased to 364 t by 2005–06, dipped to 201 t in 2006–07, and increased to 381 t in 2007–08, the highest catch level over the data series.
- 53% of LIN 1 landings come from the bottom trawl fishery and a further 46% by bottom longline since 1989–90. The remaining methods account for < 2% of the total landings.
- 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 some years 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 longline landings increased after about 2000 in East Northland Area 002, but have fallen off considerably in 2007–08.
- There is a small targeted ling trawl fishery, while trawl catches of LIN1 are mainly made in the scampi and gemfish targeted fisheries. The gemfish fishery mainly contributed catches from 1996–97 to 2000–01 and has since considerably diminished with the reduction of the SKI 1 TACC. The Bay of Plenty scampi fishery has also changed considerably during this period, 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, ~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.

CPUE Analysis

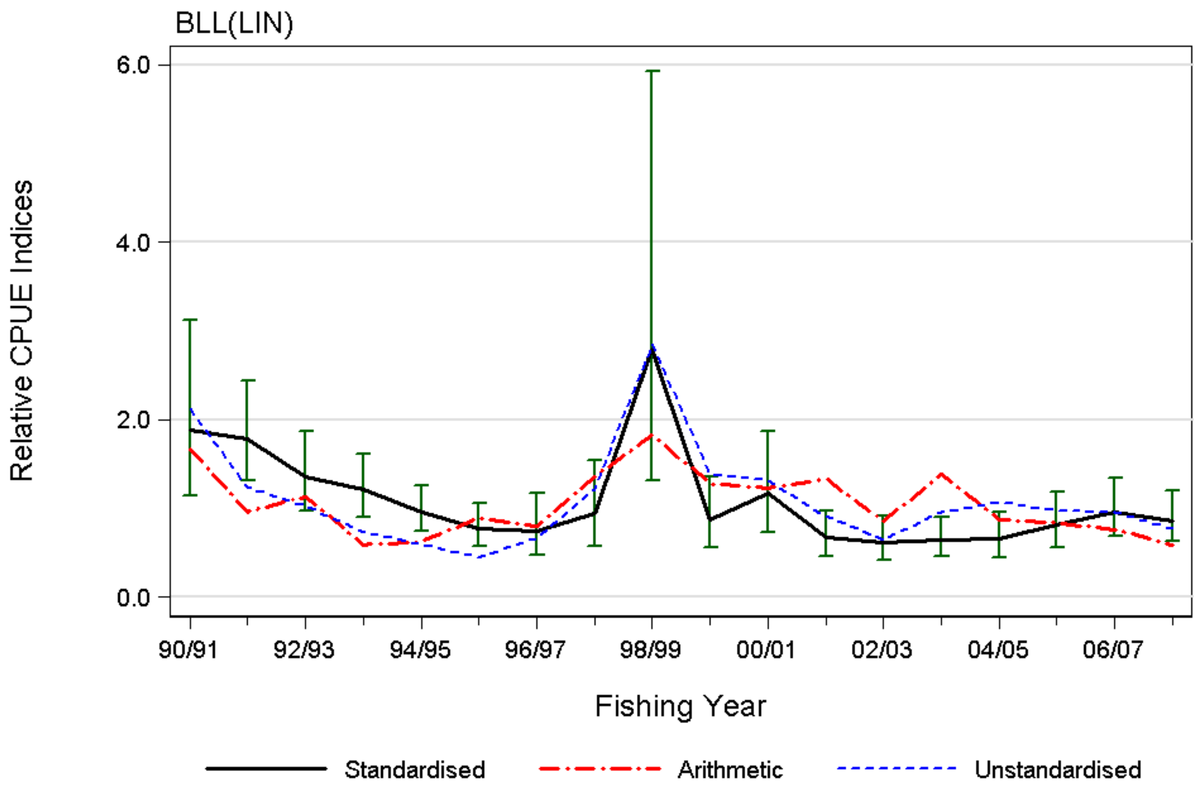


Figure 15: LIN 1 CPUE analysis based on target ling bottom longline data stratified by trip, target species and statistical area for Statistical Areas 002, 003, 004, 008, 009 and 010 standardised with respect to fishing year, number of hooks, vessel, month and number of lines set. Indices from two unstandardised analyses are presented for comparison: a) "arithmetic", the annual sum of landings divided by the total annual number of hooks; and b) "unstandardised", the geometric mean of landings per hook by trip-stratum.

- 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 ~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.
- The WG has previously noted substantial problems with the quality of LIN 1 data. Estimated catches tend to be less than landed greenweight (the median landed greenweight is about 25% greater than the estimated catch in the same trip), but only 4% of trips by weight neglect to report estimated catches of ling when there are landings. The biggest problem with this data set is the confusion, largely confined to the period prior to about 1995–96, where the FMA has been reported as the statistical area of capture rather than the true statistical area. This is a problem for a LIN 1 analysis because (for instance) FMA 4 (Chatham Rise) will be included in this dataset because statistical area 004 is valid for LIN 1. It is not possible to independently validate such a report because the CELR reporting form used by these vessels does not require a noon position or some other corroborating evidence of location. This problem is further exacerbated because many trips which apparently are legitimately fishing in FMAs 1 and 9 (the two LIN 1 FMAs) also tend to range widely, circumnavigate the entire North Island and venture into South Island waters. There is a large amount of landings made to the intermediate destination code R (retained on board) which further confounds the analysis because this breaks the continuity of the landings with the effort section of the form, resulting in much of the data being excluded and severely limiting the amount of data available for CPUE analyses.
- The diverse nature and broad geographic range of the LIN 1 fisheries has further complicated the selection of representative CPUE indices. Eight potential fisheries were previously identified as potential CPUE indices, but none of the analyses were considered to be robust due to the diverse

nature of the fisheries and relative paucity of data. The AMP WG concluded in 2007, when it last reviewed the LIN 1 fishery, that landed catch data were particularly unreliable, and recommended that estimated catch data should be used instead.

- The 2007 review of the LIN 1 CPUE indices concluded that the LIN bycatch fishery in the target scampi bottom trawl fishery in the Bay of Plenty and the target ling bottom longline fishery in the Bay of Plenty and East Northland had sufficient information to warrant attempting standardised CPUE analyses (Starr *et al*. 2007).
- These two candidate CPUE analyses were updated for this review. However, noting that there is now only one vessel in the scampi fishery, and that the amount of LIN catch data from the scampi bycatch fishery continues to decrease, the WG concluded that the only candidate index of LIN 1 abundance worth considering in this review was the BLL(LIN) index (target ling fishing using bottom longline). The WG recommended that future analyses which included mixed target species bottom trawl effort should be investigated to replace the BT(SCI) index.
- In 2009, the BLL(LIN) index was updated to exclude vessels which only fished in a single year, and calculated alternately using estimated and landed catches. The updated BLL index essentially remains unchanged from the one presented in 2007, consisting of two periods of slowly declining CPUE from 1990–91 to 1996–97 and 1999–00 to 2005–06, separated by a strong, highly uncertain and likely anomalous peak in 1998–99.
- In 2007, the WG noted that BLL reporting rates greatly exceed landed catch weights, reaching 700% in 1998–99. The high CPUE peak in 1998–99 appeared to result from landings which occurred in a single month by two vessels which typically had high catch rates. Many new participants have entered and left this fishery and the vessel effect needs to be investigated further.
- The WG made a number of recommendations for additional data selection procedures and analyses to investigate vessel effects on the BLL(LIN) index (see below).

Status of the Stock

<u>Analysis Recommendations</u>
The following analyses were conducted or recommended during the 2009 review:

- The WG requested that the vessels which only fished in one year be removed from the analysis. This was done and updated analyses were presented to the review.
- At the next review, BLL index standardisations need to further explore the reasons for the peak in 1998–99 (which resulted only from 2 vessels which fished only 2 and 4 trip strata respectively). The linkage of core fleet vessels across this and the effect of inclusion of large autoliners in the BLL index also needs to be investigated.
- Other options should be explored for excluding autoliners or vessels which do not belong in FMA 1 during data extraction, and then modifying grooming procedures to retain a higher proportion of data for the remaining vessels.
- For future analyses, a mixed target BT(HOK,LIN,SKI) index should be calculated to replace the BT(SCI) index.

<u>Abundance Indices</u>
The WG 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. The BLL(LIN) target index appears to have more potential as an index for LIN 1, but shows an apparently anomalous peak in 1998-99 and also has a relatively small amount of data. If this anomalous peak is excluded, the BLL(LIN) index has been stable without trend since 1995/96. However, until the reasons for the peak in BLL CPUE are understood, the WG concluded that the CPUE indices from this series are not reliable indices of LIN 1 abundance.

<u>Sustainability of Current Catches</u>
In the absence of a representative index of abundance, it is not known whether current LIN 1 catches or the TACC are sustainable.

<u>Stock Status</u>
The state of the stock in relation to B_{MSY} is unknown.

6. STATUS OF THE STOCKS

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

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.

- **LIN 1 Stock**

Stock Status	
Year of Most Recent Assessment	2009
Assessment Runs Presented	None. Fishstock LIN 1 has been managed under an AMP programme since 2003.
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Historical Stock Status Trajectory and Current Status	-

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Unknown
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	Two CPUE series have been estimated (scampi-targeted bottom trawl, and a ling targeted bottom longline), but neither are considered reliable.
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Level 3 – Qualitative evaluation	
Assessment Method	Evaluation of fishery trends.	
Main data inputs	- CPUE series	
Period of Assessment	Latest assessment: 2009	Next assessment: Unknown
Changes to Model Structure and Assumptions	No modeling completed.	
Major Sources of Uncertainty	Only fishery dependent abundance series were available (CPUE), and these were not considered reliable.	

	The biological stock affinities of ling in LIN 1 are unknown.

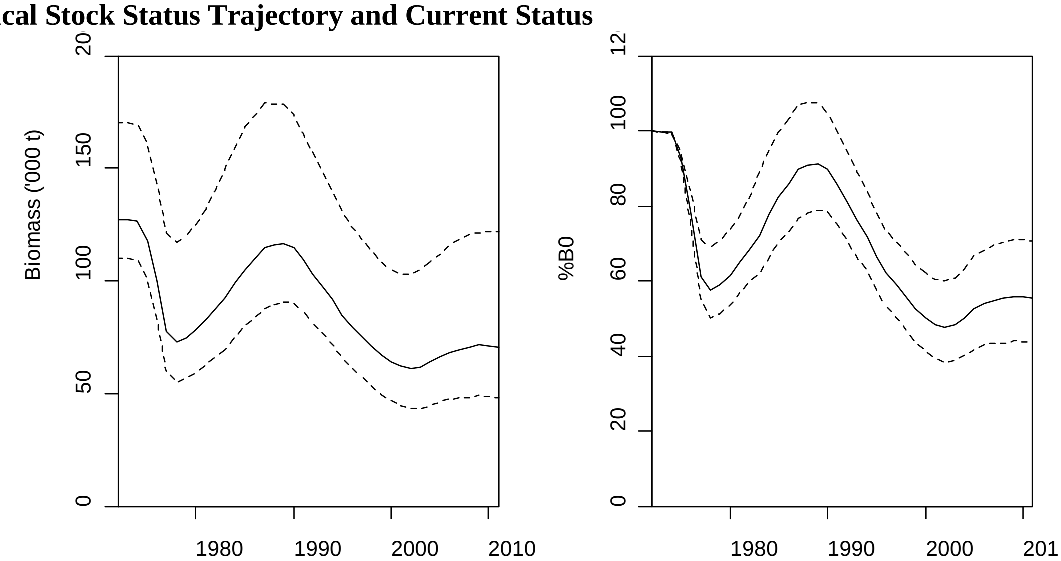
Qualifying Comments
In the absence of a representative and useful index of abundance, it is not known whether current LIN 1 catches or the TACC can be maintained without reducing the stock size. Current stock status is unknown.

Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries, and scampi target trawl fisheries off northern New Zealand. Target line fisheries for ling have the main bycatch species of spiny dogfish, sea perch, sharks and skates and ribaldo. Bycatch species of concern include sharks, skates, fur seals and seabirds (trawl fisheries), and sharks, skates and seabirds (longline fisheries).

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

Stock Status	
Year of Most Recent Assessment	2011
Assessment Runs Presented	A base case and one sensitivity run.
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2011} was estimated to be about 55% B_0; Very Likely (> 90%) to be above the target
Status in relation to Limits	B_{2011} is Exceptionally Unlikely (< 1%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit.

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 2011. 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	Biomass is very unlikely to have been below 40% B_0. Biomass is estimated to have been increasing since 2003.
Recent Trend in Fishing Mortality or Proxy	Fishing pressure is estimated to have been declining since 1999.
Other Abundance Indices	–
Trends in Other Relevant Indicators or Variables	Recruitment since the early 1990s is estimated to have been fluctuating slightly around the long-term average for this stock.

Projections and Prognosis (2011)	
Stock Projections or Prognosis	Biomass is uncertain but current catch is unlikely to cause decline.

	Catches at level of the TACC have unknown prognosis.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) at current catch Hard Limit: Exceptionally Unlikely (< 1%) at current catch

Assessment Methodology		
Assessment Type	Level 1 – Quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.	
Main data inputs	- Summer research trawl survey series, annually since 1992. - Proportions-at-age data from the commercial fisheries and trawl survey. - Line fishery CPUE series (annual indices since 1990). - Estimates of biological parameters	
Period of Assessment	Latest assessment: 2011	Next assessment: 2014
Changes to Model Structure and Assumptions	No significant changes since the previous assessment, except that the line fishery CPUE index and composition data were excluded from the base case run.	
Major Sources of Uncertainty	Estimates of current and virgin stock size are very imprecise.	

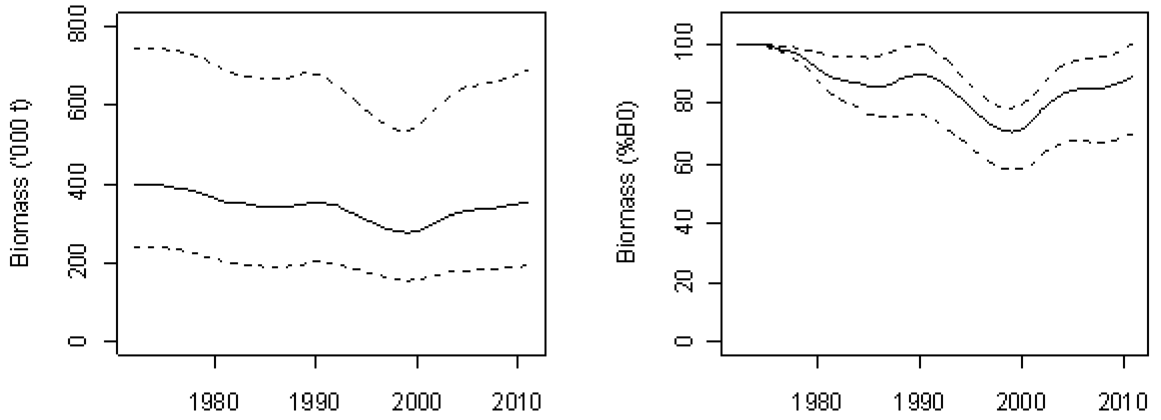
Qualifying Comments
-

Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries. Target line fisheries for ling have the main bycatch species of spiny dogfish, sea perch, sharks and skates and ribaldo. Bycatch species of concern include sharks, skates, fur seals and seabirds (trawl fisheries), and sharks, skates and seabirds (longline fisheries).

- **Sub-Antarctic (LIN 5 & 6)**

Stock Status	
Year of Most Recent Assessment	2011
Assessment Runs Presented	A base case and one sensitivity run.
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	B_{2011} was estimated to be between 70% and 101% B_0; Virtually Certain (> 99%) to be at or above the target
Status in relation to Limits	B_{2011} is Exceptionally Unlikely (< 1%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit

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 2007, for the base case model run. 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	Biomass appears to have been increasing since 2000.
Recent Trend in Fishing Mortality or Proxy	Fishing pressure is estimated to have always been low, and declining since 1998.
Other Abundance Indices	–
Trends in Other Relevant Indicators or Variables	Recruitment throughout the 1980s was low relative to the long-term average for this stock, but has been average or better since 1993.

Projections and Prognosis	
Stock Projections or Prognosis	Stock status is predicted to improve over the next 5 years at catch levels equivalent to that from recent years (i.e., 5900 t per year) or equivalent to the TACC (i.e., 12 100 t).
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Exceptionally Unlikely (< 1%) at current catch Hard Limit: Exceptionally Unlikely (< 1%) at current catch

Assessment Methodology		
Assessment Type	Level 1 – Quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.	
Main data inputs	- Summer and autumn *Tangaroa* trawl survey series. - Proportions-at-age data from the commercial fisheries and trawl surveys. - Line fishery CPUE series (annual indices since 1991). - Estimates of biological parameters (but note that *M* was estimated in the models)	
Period of Assessment	Latest assessment: 2011	Next assessment: 2014
Changes to Model Structure and Assumptions	No significant changes since the previous assessment, except that *M* was estimated as an ogive rather than being fixed at 0.18.	
Major Sources of Uncertainty	The summer trawl survey biomass estimates are variable and catchability clearly varies between surveys. The general lack of contrast in this series (the main relative abundance series) makes it difficult to accurately estimate past and current biomass. The assumption of a single Sub-Antarctic stock (including the Puysegur Bank), independent of ling in all other areas, is the most parsimonious interpretation of available information. However,	

	this assumption may not be correct. 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.

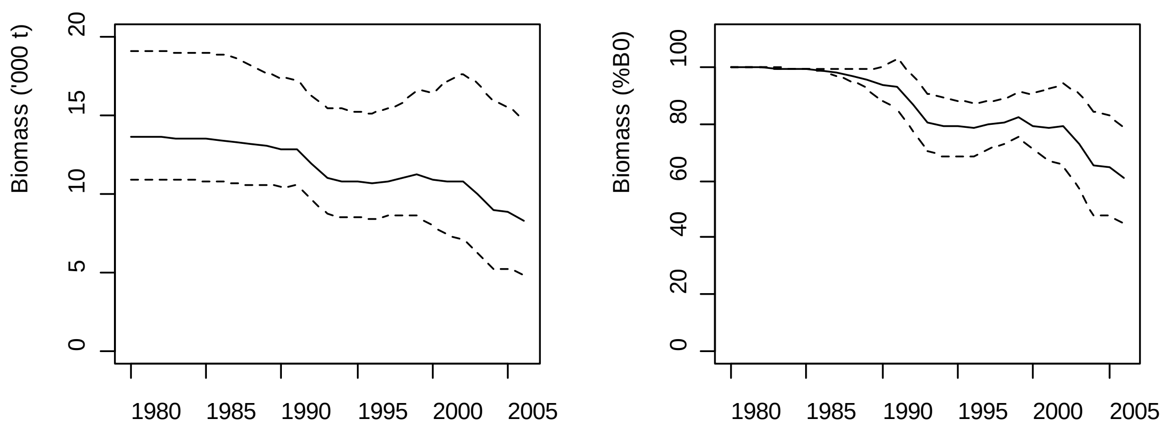
Qualifying Comments
Although estimates of absolute current and reference biomass are unreliable, B_0 was probably over 200 000 t. The stock has probably only been lightly fished.

Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries. Target line fisheries for ling have the main bycatch species of spiny dogfish, sea perch, sharks and skates and ribaldo. Bycatch species of concern include sharks, skates, fur seals and seabirds (trawl fisheries), and sharks, skates and seabirds (longline fisheries).

- **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
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.

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 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%)

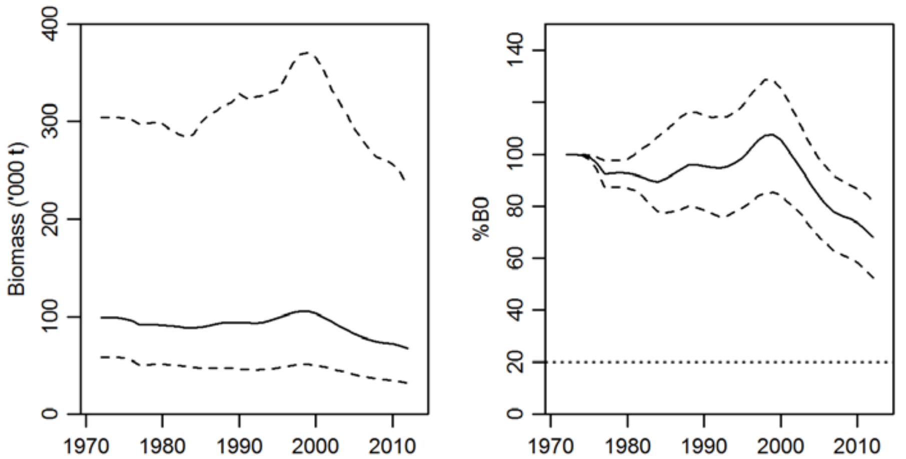
Assessment Methodology		
Assessment Type	Level 1 – Quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions.	
Main data inputs	- Proportions-at-age data from the commercial line fishery. - Line fishery CPUE series (annual indices since 1992). - Estimates of biological parameters.	
Period of Assessment	Latest assessment: 2006	Next assessment: Unknown
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, sharks and skates and ribaldo. Bycatch species of concern include sharks, skates and seabirds.

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

Stock Status	
Year of Most Recent Assessment	2013
Assessment Runs Presented	A base case and one sensitivity model run.
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_{2012} was estimated to be about 71% B_0; Very Likely (> 90%) to be at or above the target.
Status in relation to Limits	B_{2012} 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	Unknown

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 WCSI ling stock from the start of the assessment period in 1972 to the most recent assessment in 2013. 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	Biomass is estimated to have been declining
Recent Trend in Fishing Intensity or Proxy	Unknown
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	No projections were reported
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 1 - Full quantitative stock assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2013	Next assessment: 2016
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Catch history - Abundance index from two WCSI trawl surveys (2000, 2012) - 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	3 – Low Quality: does not track stock

	fishery CPUE Kaharoa trawl survey abundance index	biomass 3– Low Quality: inadequate spatial coverage of the stock distribution
Changes to Model Structure and Assumptions	Single sex model *M* estimated in the base case with an informed prior Reweighted sample sizes for age frequency data Inclusion of a relative trawl survey index with an informed prior on q.	
Major Sources of Uncertainty	There is inadequate contrast in the biomass indices to inform on the magnitude of the 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. Trawl survey selectivity. YCS estimation for recent year classes is highly uncertain because it is based on only one survey.	

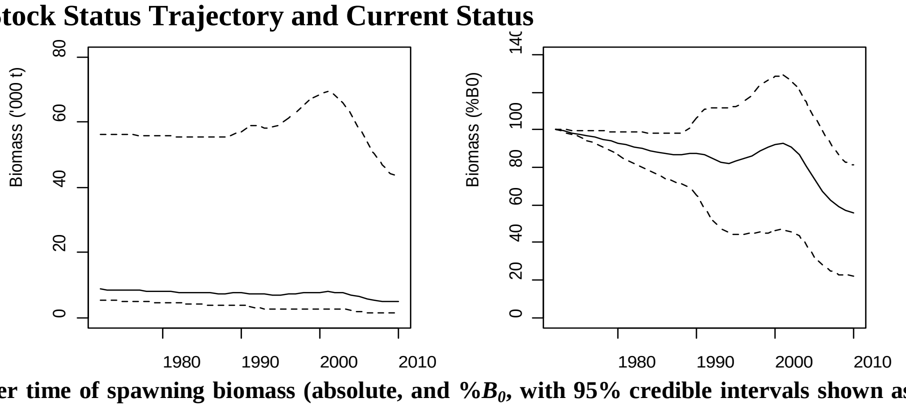
Qualifying Comments
This assessment is very uncertain but it is highly probable that B_{2012} is greater than 40% B_0 and it could be much higher.

Fishery Interactions
Ling are often taken as a bycatch in hoki target trawl fisheries. Target line fisheries for ling have the main bycatch species of spiny dogfish, sea perch, sharks and skates and ribaldo. Low productivity species taken as incidental bycatch include sharks and skates. Protected species interactions are reported for seabirds and fur seals.

- **Cook Strait (LIN 2 & 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 "1995" representing the 1994–95 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: 2015
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 2 – Medium Quality 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 autoline 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. Target line fisheries for ling have the main bycatch species of spiny dogfish, sea perch, sharks and skates. Low productivity species taken as incidental bycatch include sharks and skates. Protected species interactions are reported for seabirds and fur seals.

Table 32: Summary of TACCs (t), and reported landings (t) for the most recent fishing year.

Fishstock	QMA		TACC	Landings
LIN 1	Auckland	1 & 9	400	384
LIN 2	Central (East)	2	982	504
LIN 3	South-East (Coast)	3	2 060	1 292
LIN 4	South-East (Chatham Rise)	4	4 200	2 305
LIN 5	Southland	5	3 595	3 649
LIN 6	Sub-Antarctic	6	8 505	2 047
LIN 7	Challenger, Central (West)	7 & 8	2 474	2 771
LIN 10	Kermadec	10	10	0
Total			22 226	12 953

7. FOR FURTHER INFORMATION

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