Ministry for Primary Industries
Manatū Ahu Matua

Stock assessment of ling (*Genypterus blacodes*) in Cook Strait for the 2010–11 fishing year

New Zealand Fisheries Assessment Report 2013/7

P.L. Horn
R.I.C.C Francis

ISSN 1179-5352 (online)
ISBN 978-0-478-40513-2 (online)

January 2013

New Zealand Government

Growing and Protecting New Zealand

Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries websites at:
http://www.mpi.govt.nz/news-resources/publications.aspx
http://fs.fish.govt.nz go to Document library/Research reports

Table of Contents

EXECUTIVE SUMMARY

Horn, P.L.; Francis, R.I.C.C. (2013). Stock assessment of ling (*Genypterus blacodes*) in Cook Strait for the 2010–11 fishing year.

***New Zealand Fisheries Assessment Report 2013/7*. 35 p.**

Stock assessments for ling are currently carried out for five biological stocks: Chatham Rise (LIN 3 and LIN 4), Campbell Plateau and Stewart-Snares shelf (LIN 5, and LIN 6 west of 176º E), Bounty Plateau (LIN 6 east of 176º E), west coast South Island (LIN 7 west of Cape Farewell), and Cook Strait (those parts of LIN 2 and LIN 7 making up Statistical Areas 16 and 17 in Cook Strait). These stocks are referred to as LIN 3&4, LIN 5&6, LIN 6B, LIN 7WC, and LIN 7CK, respectively. The stock structure of Cook Strait ling is uncertain.

New model input data for all stocks are reported here. Updated Bayesian assessments are presented for the LIN 7CK (Cook Strait) stock, using the general-purpose stock assessment program CASAL v2.22. The assessment incorporated all relevant biological parameters, the commercial catch histories, updated CPUE series, and series of catch-at-age data from the commercial trawl and line fisheries. The model structure allows the input of catch histories and relative abundance indices attributable to different fishing methods, seasons, and areas.

Current stock size of LIN 7CK is very uncertain. Results of two model runs are presented, but only the base model includes an index of abundance (i.e., a trawl CPUE series using TCEPR data from 1994 to 2009). Preliminary modelling using line fishery CPUE suggested that series to be invalid as an abundance index. There are no fishery-independent indices of relative abundance for this stock. The base model produces very uncertain estimates of biomass; current stock status as a percentage of B_0 is estimated to be 54% B_0 with a 95% confidence bound of 23–80% B_0. The assessment is driven by a long series of trawl fishery catch-at-age data, tuned by the trawl fishery CPUE. The trawl CPUE series is indicative of an overall decline in biomass in the last two decades. Much of the uncertainty in the results is attributable to the estimation of *M* in the model, but it was considered necessary to do this because of the uncertainty of *M* for this stock, and because it was known that biomass of this stock is very sensitive to relatively small changes in this parameter. The trawl fishery selectivity ogives appear to be consistent with the catch-at-age data, but the line fishery selectivity ogive would be expected to have a greater age at peak selectivity than is currently estimated. However, the line fishery ogive is based on only two years of data from the autoline fishery, so may not be applicable to the hand baiting fleet.

The base model run is indicative of a current biomass greater than 40% B_0 and an increasing stock size over the next five years under a scenario of future annual catches equal to the mean of the last four years (owing to recruitment into the fishery of some year classes that are relatively stronger than most since the mid 1990s). However, the biomass estimates were not considered reliable enough to warrant the estimation of any yields. It is not known whether mean catches taken recently are sustainable in the long term, or are at levels that will allow the stock to move towards a size that will support the MSY. Overall, the available data indicate that there are no sustainability issues for the Cook Strait stock in the short to medium term, but this conclusion must be tempered by the uncertainty in the estimates of biomass.

1. INTRODUCTION

This document reports the results of Objective 3 of Ministry of Fisheries Project LIN2009-01. The project objectives were as follows.

1. To carry out a descriptive analysis of the commercial catch and effort data for ling from LIN 2, 3 & 4, 5 & 6, 6B (Bounties), and 7.
2. To update the standardised catch and effort analyses from the ling longline and trawl bycatch fisheries in LIN 3 & 4, 5 & 6, and 7, with the addition of data up to the end of the 2008–09 fishing year.
3. To update the stock assessments of at least two stocks (to be determined by the Middle Depth Species Fisheries Assessment Working Group), including estimating biomass and yields.

The results from Objectives 1 and 2 have been reported by Horn & Ballara (2012).

Ling are managed as eight administrative QMAs, although five of these (LIN 3, 4, 5, 6, and 7) (Figure 1) currently produce about 95% of landings. Research has indicated that there are at least five major biological stocks of ling in New Zealand waters (Horn 2005): the Chatham Rise, the Sub-Antarctic (including the Stewart-Snares shelf and Puysegur Bank), the Bounty Platform, the west coast of the South Island, and Cook Strait.

Stock assessments are currently carried out for the same five biological stocks and are defined as follows: Chatham Rise (LIN 3 and LIN 4), Sub-Antarctic incorporating Campbell Plateau and Stewart-Snares shelf (LIN 5, and LIN 6 west of 176º E), Bounty Plateau (LIN 6 east of 176º E), west coast South Island (LIN 7 west of Cape Farewell), and Cook Strait (those parts of LIN 2 and LIN 7 between latitudes 41° and 42° S and longitudes 174° and 175.4° E, equating approximately to statistical areas 16 and 17). These stocks are referred to as LIN 3&4, LIN 5&6, LIN 6B, LIN 7WC, and LIN 7CK, respectively. The most recently reported assessments of these stocks are as follows: LIN 3&4, LIN 5&6, and LIN 7CK (Horn 2008), LIN 6B (Horn 2007b), and LIN 7WC (Horn 2009). Although Objective 3 of this project is to assess ling in LIN 3, 4, 5, 6, and 7, there was an understanding that not all stocks would be assessed, and that the stocks to be assessed would be determined by the Middle Depth Species Fishery Assessment Working Group. LIN 7CK was the Fishstock chosen for full assessment.

The current assessment used CASAL v2.22, a generalised age- or length-structured fish stock assessment model (Bull et al. 2008). The LIN 7CK assessment incorporates catch-at-age data from line and trawl fisheries, and line and trawl fishery CPUE series were both considered for inclusion.

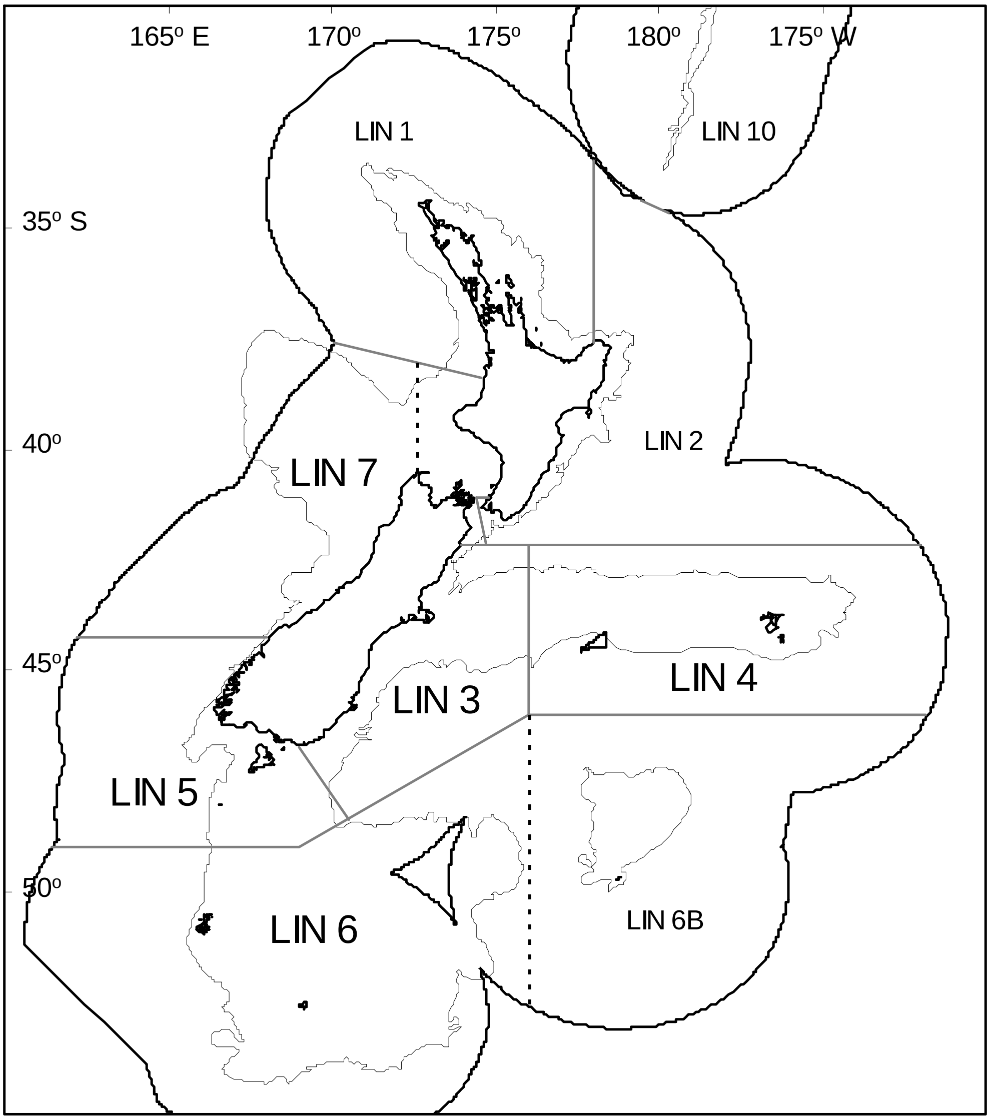

Figure 1: Area of Fishstocks LIN 3, 4, 5, 6, and 7. Adjacent ling fishstock areas are also shown, as is the 1000 m isobath. The boundaries used to separate biological stock LIN 6B from the rest of LIN 6, and the west coast South Island section of LIN 7 from the rest of LIN 7, are shown as broken lines.

2. REVIEW OF THE FISHERY

Reported landings of ling are summarised in Tables 1 and 2. From 1975 to 1980 there was a substantial fishery on the Chatham Rise (and to a lesser extent in other areas) carried out by Japanese and Korean longliners. During the 1980s, most ling were taken by trawl. In the early 1990s a longline fishery developed, with a resulting increase in landings from LIN 3, 4, 5, and 6 (Table 2), although since about 2000 there has been a decline in the line catch in most areas, but most markedly in LIN 5&6 (Horn 2007a). (In some areas this decline in line catches was concurrent with an increase in trawl catches.) Landings on the Bounty Plateau are taken almost exclusively by longline. A small, but important, quantity of ling is also taken by setnet in LIN 3 and LIN 7 (Horn 2007a). In the west coast South Island section of LIN 7, about two-thirds of ling landings are taken as a trawl bycatch, primarily of the hoki fishery. In Cook Strait, about 75% of ling landings are taken as a bycatch of the hoki trawl fishery, with the remaining landings generally made by the target line fishery (Horn 2007a).

Under the Adaptive Management Programme (AMP), TACCs for LIN 3 and 4 were increased by about 30% for the 1994–95 fishing year to a level that was expected to allow any decline in biomass to be detected by trawl surveys of the Chatham Rise (with c.v. 10% or less) over the 5 years following the increase. The TACCs were set at 2810 and 5720 t, respectively. These stocks were removed from the AMP from 1 October 1998, with TACCs maintained at the increased level. Following a decline in catch rates (as indicated from the analysis of longline CPUE data) and assessment model results indicating that current biomass was about 25–30% of B_0, the TACCs for LIN 3 and LIN 4 were reduced to 2060 t and 4200 t, respectively, from 1 October 2000. The sum of these values was at the level of the combined CAY estimate of 6260 t for LIN 3&4 from Horn et al. (2000). Also under the AMP, the TACC for LIN 1 was increased to 400 t from 1 October 2002, within an overall TAC of 463 t.

TACCs for LIN 5 and 6 have been increased by about 20% to 3600 t and 8500 t, respectively, from 1 October 2004. This followed an assessment (Horn 2004) indicating that the level of exploitation during the 1990s had little impact on the size of the Sub-Antarctic stock.

The TACC for LIN 7 has been consistently exceeded throughout the 1990s, sometimes by as much as 50%. It is strongly believed that landings of ling by trawlers off the west coast of South Island (WCSI) were under-reported in fishing years 1989–90 to 1992–93; an adjusted catch history is presented in Table 2. Dunn (2003a) investigated the extent of likely misreporting of hake from HAK 7 to other hake stocks from 1989–90 to 2000–01, and he extended this investigation to ling (Dunn 2003b). He concluded that any misreporting from LIN 7 to LIN 5&6 was minimal, but that the levels of misreporting from LIN 7 to LIN 3&4 could have been about 250–400 t annually in the three fishing years from 1997–98 to 1999–2000. However, the accuracy of these estimates is unknown.

Table 1: Reported landings (t) of ling 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 and 1987–88 from QMS.

				Foreign licensed					
	New Zealand			Longline	Trawl				Grand
Fishing Year	Domestic	Chartered	Total	(Japan + Korea)	Japan	Korea	USSR	Total	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

* Calendar years (1978 to 1983 for domestic vessels only).
\# 1 April to 31 March.
† 1 April–30 Sept 1983.
§ 1 Oct to 30 Sept.

Table 2: Reported landings (t) of ling by Fishstock from 1983–84 to 2008–09 and actual TACCs (t) from 1986–87 to 2008–09. 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.

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	1 104	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	3 294	3 001
2002–03#	246	400	996	982	2 528	2 060	2 997	4 200	2 936	3 001
2003–04#	249	400	1 044	982	1 990	2 060	2 617	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	1 710	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	3 009	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	19 565	19 843
2002–03#	6 283	7 100	2 917	–	2 225	0	10	18 909	19 978
2003–04#	7 032	7 100	2 927	–	2 225	0	10	18 760	19 978
2004–05#	5 506	8 505	2 522	–	2 225	0	10	17 186	21 977
2005–06#	3 553	8 505	2 479	–	2 225	0	10	14 182	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#	3 199	8 505	2 198	–	2 225	0	10	13 113	21 977

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

3. RESEARCH RESULTS

3.1 Catch-at-age

New catch-at-age distributions from the following samples were created as part of Project MID2007/01, and were reported by Horn & Sutton (2010). All the samples extend existing series of catch-at-age data.

LIN 3&4: Trawl survey (TAN1001), Jan 2010
LIN 3&4: Commercial longline, Jun–Oct 2009
LIN 3&4: Commercial trawl, Oct 2008 – May 2009
LIN 5&6: Trawl survey (TAN0911), Dec 2009
LIN 5&6: Commercial longline (non-spawning fishery), Feb–Jul 2009
LIN 5&6: Commercial trawl, Sep 2008 – Apr 2009
LIN 6 (Bounty Plateau): Commercial longline, Nov 2008 – Mar 2009
Cook Strait: Commercial trawl, Jun–Sep 2009

For the first time since 1993 there were insufficient length data and otoliths collected from the LIN 7 commercial trawl fishery off WCSI to enable the estimation of catch-at-age from the winter fishery (i.e., Jun–Sep 2009).

Catch-at-age data for ling from the Cook Strait commercial trawl fishery in June–September 2010 are presented in Appendix B, but were not available for the assessment presented below.

3.2 Catch-at-length

The initial formulation of series of numbers-at-length for ling from various trawl and longline fisheries was described by Horn (2002). These series have been included in stock assessment models where a lack of age data precludes their input as catch-at-age.

In the current year, the catch from all the major trawl fishery series except LIN 7WC Jun–Sep (i.e., LIN 3&4 Nov–May, LIN 5&6 Sep–Apr, and LIN 7CK Jun–Sep) could be converted into catch-at-age.

Previous length-frequency series for the longline fisheries have been derived using data from a logbook scheme set up in 1995 by SeaFIC (described by Langley 2001). However, the programme essentially ceased to function from the end of the 2005–06 fishing year, so none of the series have been updated since then.

4. MODEL INPUTS, STRUCTURE, AND ESTIMATION

4.1 Model input data

Estimated commercial landings histories for the five stocks are listed in Table 3. Landings up to 1972 are assumed to be zero, although it is very likely that small quantities of ling were taken in various areas before then. The split between method (and pre-spawning and spawning seasons for the LIN 5&6 longline fishery) from 1983 to 2006 was based on reported estimated landings per month, pro-rated to equal total reported landings. Landings before 1983 were split into method and season, based on anecdotal information of fishing patterns at the time, as no quantitative information is available.

Estimates of biological parameters and assumed values for model parameters used in the assessments are given in Table 4. Growth and length-weight relationships were revised most recently by Horn (2006). *M* was initially set at 0.18 for all stocks (Horn 2000), but was revised on a stock by stock basis by Horn (2008). The maturity ogive represents the proportion of fish (in the virgin stock) that are estimated to be mature at each age. Ogives for LIN 3&4, LIN 5&6, and LIN 7WC are from Horn (2005). The LIN 6B and LIN 7CK ogives are assumed to be the same as for LIN 3&4 and LIN 7WC, respectively, in the absence of any data to otherwise determine them. The proportion spawning was assumed to be 1.0 in the absence of data to estimate this parameter. A stock-recruitment relationship (Beverton-Holt, with steepness 0.9) was assumed. Variability in the von Bertalanffy age-length relationship was assumed to be lognormal with a constant c.v. of 0.1.

Standardised and unstandardised CPUE series (see Horn & Ballara 2012) are listed in Tables 5 and 6. CPUE indices were used as relative biomass indices, with associated c.v.s estimated from the generalised linear model used to estimate relative year effects. Series of research trawl survey indices were available for LIN 3&4, LIN 5&6, and LIN 7WC (Table 7). Biomass estimates from the trawl surveys are used as relative biomass indices, with associated c.v.s estimated from the survey analysis.

The *Tangaroa* trawl survey catch data from LIN 3&4 and LIN 5&6 were also available as estimates of catch-at-age. For LIN 3&4, LIN 5&6, LIN 6B, LIN 7WC, and LIN 7CK, various series of catch-at-age data from the commercial trawl and longline fisheries were available (see Horn & Sutton 2010). Catch-at-age data were fitted to the model as proportions-at-age, where estimates of the proportions-at-age and associated c.v.s by age were estimated using the NIWA catch-at-age software by bootstrapping (Bull & Dunn 2002). Zero values of proportion-at-age were replaced with 0.0001. This replacement was because zero values cannot be used with the assumed error distribution for the proportions-at-data (i.e., lognormal). Ageing error for the observed proportions-at-age data was assumed to have a discrete normal distribution with c.v.s as defined in Table 4. The c.v.s varied between stocks because of perceived differences between stocks in the difficulty of reading otoliths (author's unpublished data).

When used, catch-at-length data were fitted to the model as proportions-at-length with associated c.v.s by length class. These data were also estimated using the software described above. Zero values of catch-at-length were replaced with 0.0001.

A summary of all input data series, by stock, is given in Table 8. Data from trawl surveys could be input either as a) biomass and proportions-at-age, or b) numbers-at-age. For the ling assessments the preference was for a), i.e., entering trawl survey biomass and trawl survey proportions-at-age data as separate input series. [Francis et al. (2003) presented an argument against the use of numbers-at-age data for hoki from trawl surveys.] The c.v.s applied to each data set would then give appropriate weight to the signal provided by each series.

Table 3: 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 LIN 7CK (Cook Strait sections of LIN 7 and LIN 2). 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. The 2010 values are required for the current assessment; they are estimated based on recent landings trends. For LIN 6B, all landings up to 1990 were taken by trawl, and over 97% of all landings after 1990 were taken by line.

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	11	2 205	399	362	121
1991	2 563	2 228	4 534	392	97	172	2 163	364	488	163
1992	3 451	3 695	6 237	566	518	1 430	1 631	661	498	85
1993	2 375	3 971	7 335	1 238	474	1 575	1 609	716	307	114
1994	1 933	4 159	5 456	770	486	875	1 136	860	269	84
1995	2 222	5 530	5 348	2 355	338	387	1 750	1 032	344	70
1996	2 725	4 863	6 769	2 153	531	588	1 838	1 121	392	35
1997	3 003	4 047	6 923	3 412	614	333	1 749	1 077	417	89
1998	4 707	3 227	6 032	4 032	581	569	1 887	1 021	366	88
1999	3 282	3 818	5 593	2 721	489	771	2 146	1 069	316	216
2000	3 739	2 779	7 089	1 421	1 161	1 319	2 247	923	317	131
2001	3 467	2 724	6 629	818	1 007	1 153	2 304	977	258	80
2002	2 979	2 787	6 970	426	1 220	623	2 250	810	230	171
2003	3 375	2 150	7 205	183	892	932	1 980	807	280	180
2004	2 525	2 082	7 826	774	471	860	2 013	814	241	227
2005	1 913	2 440	7 870	276	894	50	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	237	1 306	933	107	189
2008	2 350	1 810	6 990	329	821	507	1 067	1 170	115	110
2009	1 534	2 217	5 225	276	432	275	1 089	1 009	108	39
2010	1 950	2 000	6 400	220	700	330	1 100	1 000	120	100

Table 4: Biological and other input parameters used in the ling assessments.

1. Natural mortality (M)

	Female	Male
All stocks (average)	0.18	0.18

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

	Female		Male	
	a	*b*	*a*	*b*
LIN 3&4	0.00114	3.318	0.00100	3.354
LIN 5&6	0.00128	3.303	0.00208	3.190
LIN 6B	0.00114	3.318	0.00100	3.354
LIN 7WC	0.000934	3.368	0.001146	3.318
LIN 7CK[#]	0.000934	3.368	0.001146	3.318

[#] Parameters assumed to be the same as for LIN 7WC, in the absence of data from Cook Strait.

3. von Bertalanffy growth parameters (n, sample size)

	Male				Female			
	n	*k*	t_0	L_∞	*n*	*k*	t_0	L_∞
LIN 3&4	3 964	0.127	–0.70	113.9	4 133	0.083	–0.74	156.4
LIN 5&6	2 884	0.188	–0.67	93.2	4 093	0.124	–1.26	115.1
LIN 6B	296	0.141	0.02	120.5	386	0.101	–0.53	146.2
LIN 7WC	2 366	0.067	–2.37	159.9	2 320	0.078	–0.87	169.3
LIN 7CK	348	0.080	–1.94	158.9	332	0.097	–0.54	163.6

4. Maturity ogives (proportion mature at age)

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 LIN 7CK)													
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			

5. Miscellaneous parameters

Stock	3&4	5&6	6B	7WC	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 by sex at birth	0.5	0.5	0.5	0.5	0.5
Proportion spawning	1.0	1.0	1.0	1.0	1.0
Spawning season length	0	0.25	0	0	0
Maximum exploitation rate (U_{max})	0.6	0.6	0.6	0.6	0.6

Table 5: Unstandardised (Unstd) and standardised (Std, with 95% confidence intervals and c.v.s) year effects for the target ling line fisheries on the Chatham Rise, Sub-Antarctic (Sub-Ant.), Bounty Plateau, and WCSI stocks (from Horn & Ballara 2012). Separate series are presented for the spawning and non-spawning fisheries in the Sub-Antarctic. There are also two separate series for the Bounty Plateau; 1992–2006 (plain text), and 2007–09 (italic text).

Year	Unstd	Std	95% CI	c.v.	Unstd	Std	95% CI	c.v.	Unstd	Std	95% CI	c.v.
	Chatham Rise (LIN 3&4)				Sub-Ant. spawning (LIN 5&6)				Sub-Ant. non-spawn (LIN 5&6)			
1990	0.53	2.07	1.77–2.43	0.08	–	–	–	–	–	–	–	–
1991	0.70	1.66	1.51–1.83	0.05	1.20	1.27	0.91–1.79	0.17	0.63	0.65	0.51–0.83	0.12
1992	1.72	2.09	1.90–2.30	0.05	0.90	1.35	1.07–1.71	0.12	0.75	1.04	0.87–1.25	0.09
1993	1.51	1.54	1.42–1.68	0.04	0.74	1.70	1.38–2.09	0.10	0.69	0.84	0.69–1.03	0.10
1994	1.43	1.48	1.37–1.60	0.04	0.81	1.18	0.97–1.45	0.10	0.63	0.75	0.64–0.89	0.08
1995	2.15	1.47	1.35–1.59	0.04	0.92	1.21	0.88–1.66	0.16	1.09	1.02	0.88–1.19	0.08
1996	1.83	1.23	1.14–1.33	0.04	1.58	1.28	1.03–1.60	0.11	0.84	0.80	0.69–0.94	0.08
1997	1.07	0.85	0.80–0.91	0.03	1.17	1.29	1.06–1.57	0.10	0.95	0.90	0.80–1.02	0.06
1998	1.12	0.81	0.75–0.88	0.04	0.95	0.96	0.79–1.16	0.10	0.85	0.78	0.70–0.87	0.06
1999	0.81	0.71	0.66–0.76	0.04	1.74	1.22	1.00–1.50	0.10	0.70	0.65	0.59–0.72	0.05
2000	1.13	0.82	0.76–0.89	0.04	1.88	1.32	1.08–1.60	0.10	0.77	0.74	0.65–0.85	0.06
2001	1.74	0.81	0.75–0.89	0.04	1.82	1.34	1.10–1.62	0.10	0.85	0.90	0.76–1.06	0.08
2002	1.05	0.72	0.67–0.78	0.04	1.88	1.56	1.27–1.92	0.10	0.77	0.77	0.64–0.94	0.10
2003	1.18	0.87	0.80–0.95	0.04	1.39	1.13	0.88–1.44	0.12	0.42	0.62	0.49–0.77	0.11
2004	1.03	0.73	0.67–0.79	0.04	1.30	0.94	0.79–1.13	0.09	0.50	0.56	0.46–0.67	0.10
2005	0.60	0.81	0.75–0.87	0.04	2.03	1.42	1.11–1.82	0.12	0.60	0.51	0.39–0.66	0.13
2006	0.56	0.69	0.64–0.74	0.04	1.65	1.25	0.99–1.58	0.12	0.68	0.60	0.45–0.79	0.14
2007	0.53	0.74	0.68–0.80	0.04	1.65	1.42	1.14–1.77	0.11	1.14	1.10	0.55–2.21	0.36
2008	0.63	0.83	0.76–0.90	0.04	1.39	1.05	0.79–1.39	0.14	0.56	0.99	0.75–1.30	0.14
2009	0.68	0.66	0.61–0.72	0.04	2.85	2.08	1.41–3.07	0.20	0.74	0.81	0.62–1.06	0.13
	Bounty Plateau (LIN 6B)				WCSI (LIN 7WC)				Cook Strait (LIN 7CK)			
1990	–	–	–	–	0.62	0.92	0.81–1.04	0.06	0.63	0.73	0.53–0.99	0.16
1991	–	–	–	–	0.78	1.18	1.06–1.31	0.05	0.43	1.10	0.85–1.43	0.13
1992	1.05	1.80	1.40–2.32	0.13	0.89	1.16	1.06–1.27	0.04	0.50	1.10	0.87–1.38	0.11
1993	0.97	1.58	1.28–1.96	0.11	1.01	0.92	0.84–1.02	0.05	0.39	0.80	0.64–1.00	0.11
1994	0.85	1.07	0.82–1.41	0.13	1.04	0.93	0.85–1.01	0.04	0.26	0.71	0.57–0.88	0.11
1995	1.11	1.13	0.87–1.47	0.13	1.04	0.95	0.87–1.03	0.04	0.31	0.66	0.52–0.84	0.12
1996	0.90	1.05	0.83–1.33	0.12	0.91	0.78	0.72–0.84	0.04	0.45	0.79	0.60–1.03	0.13
1997	0.81	0.85	0.66–1.11	0.13	1.02	0.85	0.78–0.92	0.04	0.55	1.05	0.72–1.52	0.19
1998	1.42	1.03	0.80–1.32	0.12	1.27	0.93	0.86–1.01	0.04	0.44	0.73	0.54–0.99	0.15
1999	1.33	1.04	0.84–1.30	0.11	1.13	1.02	0.93–1.11	0.04	3.12	1.28	0.89–1.86	0.19
2000	1.23	0.95	0.79–1.16	0.10	1.09	0.98	0.89–1.07	0.04	1.59	1.45	1.00–2.10	0.19
2001	0.96	0.81	0.67–0.99	0.10	1.17	1.12	1.03–1.22	0.04	2.47	1.30	0.87–1.92	0.20
2002	0.94	0.72	0.60–0.88	0.10	0.98	1.06	0.96–1.16	0.05	1.54	1.91	1.52–2.40	0.11
2003	1.05	0.78	0.66–0.94	0.09	0.99	1.12	1.02–1.22	0.04	1.21	1.68	1.35–2.09	0.11
2004	1.05	0.71	0.54–0.94	0.14	1.00	1.10	1.00–1.22	0.05	1.26	1.42	1.16–1.74	0.10
2005	–	–	–	–	0.87	0.85	0.78–0.93	0.04	1.29	1.17	0.94–1.46	0.11
2006	0.61	0.97	0.48–1.94	0.36	0.87	0.86	0.77–0.94	0.05	5.09	0.94	0.68–1.29	0.16
2007	*1.18*	*1.12*	*0.88–1.42*	*0.12*	1.20	1.15	1.06–1.26	0.04	2.06	0.72	0.56–0.92	0.13
2008	*1.04*	*1.12*	*0.92–1.36*	*0.10*	1.24	1.14	1.04–1.25	0.05	3.07	0.90	0.59–1.39	0.22
2009	*0.81*	*0.80*	*0.64–0.99*	*0.11*	1.13	1.15	1.05–1.26	0.05	1.81	0.65	0.36–1.16	0.30

Table 6: Lognormal (Logn), binomial (Bino), and combined (standardised, with c.v.s) year effects from the Cook Strait and WCSI hoki target trawl fisheries. See Horn & Ballara (2012) for further information on the derivation of these series.

	Cook Strait (TCEPR data)				Cook Strait (observer data)			
Year	Logn	Bino	Combined	c.v.	Logn	Bino	Combined	c.v.
1990	2.28	0.82	2.17	0.05			–	
1991	1.91	0.86	1.79	0.04			–	
1992	1.67	0.91	1.63	0.05			–	
1993	1.69	1.01	1.50	0.05			–	
1994	1.14	1.03	1.03	0.05			–	
1995	1.01	1.11	0.84	0.04			–	
1996	0.99	1.19	0.80	0.04			–	
1997	0.90	1.12	0.78	0.03			–	
1998	0.84	1.07	0.77	0.03	1.24	0.96	1.16	0.11
1999	0.83	0.96	0.81	0.03	1.12	1.07	1.01	0.11
2000	0.98	0.98	0.93	0.03	1.75	0.87	1.69	0.11
2001	1.06	0.95	1.06	0.03	1.34	1.04	1.23	0.11
2002	1.00	0.96	0.98	0.04	1.35	1.00	1.25	0.14
2003	1.02	1.00	1.00	0.04	1.44	1.02	1.32	0.15
2004	0.85	0.99	0.81	0.04	1.26	0.94	1.19	0.14
2005	0.93	1.01	0.88	0.04	0.77	0.97	0.72	0.18
2006	0.88	0.96	0.85	0.04	1.10	1.15	0.97	0.20
2007	0.59	1.09	0.53	0.05	0.54	0.99	0.50	0.15
2008	0.70	0.97	0.55	0.06	0.56	1.09	0.51	0.16
2009	0.38	1.07	0.30	0.06	0.49	0.94	0.46	0.17

	WCSI (TCEPR data)				WCSI (observer data)			
Year	Logn	Bino	Combined	c.v.	Logn	Bino	Combined	c.v.
1987			–		0.53	1.34	0.46	0.06
1988			–		0.93	1.12	0.86	0.05
1989			–		1.38	1.12	1.28	0.06
1990	0.86	1.05	0.84	0.08	1.29	0.96	1.25	0.06
1991	0.95	0.99	0.92	0.08	0.80	1.14	0.74	0.06
1992	1.64	1.06	1.59	0.09	0.75	1.07	0.70	0.07
1993	1.24	1.05	1.21	0.08	1.01	1.07	0.95	0.07
1994	1.25	0.99	1.22	0.08	0.94	0.99	0.89	0.05
1995	1.00	0.97	0.98	0.06	1.23	0.90	1.20	0.06
1996	0.99	1.06	0.96	0.08	1.44	0.93	1.40	0.05
1997	1.31	1.04	1.26	0.09	1.49	1.01	1.41	0.06
1998	0.77	1.00	0.76	0.06	1.38	0.95	1.33	0.05
1999	1.17	1.00	1.18	0.04	1.59	0.96	1.53	0.05
2000	0.99	1.01	0.96	0.03	1.24	0.97	1.19	0.04
2001	0.97	1.00	0.96	0.03	0.99	0.96	0.96	0.04
2002	0.82	0.96	0.81	0.03	1.28	0.93	1.24	0.04
2003	0.78	1.02	0.76	0.03	0.73	1.01	0.70	0.05
2004	0.90	0.98	0.89	0.03	1.27	0.92	1.24	0.04
2005	0.87	1.02	0.86	0.03	0.86	0.91	0.84	0.04
2006	0.83	0.98	0.83	0.03	0.88	0.91	0.86	0.05
2007	0.94	0.98	0.93	0.05	0.70	0.96	0.67	0.06
2008	0.87	0.94	0.86	0.05	0.61	1.01	0.58	0.06
2009	1.25	0.92	1.24	0.06	0.74	0.98	0.71	0.06

Table 7: Series of relative biomass indices (t) from *Tangaroa* (TAN) and *Kaharoa* (KAH) trawl surveys (with coefficients of variation, c.v.) available for the assessment modelling.

Fishstock	Area	Trip code	Date	Biomass (t)	c.v. (%)
LIN 3&4	Chatham Rise	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	8.3
		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
LIN 5&6	Campbell Plateau	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	9.0
		TAN0414	Dec 2004	23 790	12.2
		TAN0515	Dec 2005	19 700	9.0
		TAN0617	Dec 2006	19 640	12.0
		TAN0714	Dec 2007	26 490	8.0
		TAN0813	Dec 2008	22 840	9.5
		TAN0911	Dec 2009	22 710	9.6
LIN 5&6	Campbell Plateau	TAN9204	Mar-Apr 1992	42 330	5.8
		TAN9304	Apr-May 1993	33 550	5.4
		TAN9605	Mar-Apr 1996	32 130	7.8
		TAN9805	Apr-May 1998	30 780	8.8
LIN 7WC	WCSI	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

Table 8: Summary of the relative abundance series available for the assessment modelling, including source years (Years). The process error that was added to the observation error in the stock that was modelled is also listed.

Data series	Years	Process error c.v.
LIN 3&4		
Trawl survey proportion at age (*Amaltal Explorer*, Dec)	1990	
Trawl survey biomass (*Tangaroa*, Jan)	1992–2010	
Trawl survey proportion at age (*Tangaroa*, Jan)	1992–2010	
CPUE (longline, all year)	1990–2009	
Commercial longline proportion-at-age (Jun–Oct)	2002–09	
Commercial longline length-frequency (Jun–Oct)	1995–2006	
Commercial trawl proportion-at-age (Oct–May)	1992, 1994–2009	
LIN 5&6		
Trawl survey proportion at age (*Amaltal Explorer*, Nov)	1990	
Trawl survey biomass (*Tangaroa*, Nov–Dec)	1992–94, 2001–10	
Trawl survey proportion at age (*Tangaroa*, Nov–Dec)	1992–94, 2001–10	
Trawl survey biomass (*Tangaroa*, Mar–May)	1992–93, 1996, 1998	
Trawl survey proportion at age (*Tangaroa*, Mar–May)	1992–93, 1996, 1998	
CPUE (longline, all year)	1991–2009	
Commercial longline length-frequency (spawning, Oct–Dec)	1993, 96, 1999–2006	
Commercial longline proportion-at-age (spawning, Oct–Dec)	2000–08	
Commercial longline length-frequency (non-spawn, Feb–Jul)	1998–2005	
Commercial longline proportion-at-age (non-spawn, Feb–Jul)	1998–99, 2001, 2003, 2005, 2009	
Commercial trawl proportion-at-age (Sep–Apr)	1992–94, 1996, 1998, 2001–09	
LIN 6B		
CPUE (longline, all year)	1992–2004, 2006, 2007–09	
Commercial longline proportion-at-age (Nov–Mar)	1993, 2000–01, 2004, 2008–09	
LIN 7CK		
CPUE (hoki trawl, Jun–Sep)	1990–2009	0.2
CPUE (longline, all year)	1990–2009	0.2
Commercial trawl proportion-at-age (Jun–Sep)	1999–2009	1.1
Commercial longline proportion-at-age (May–Sep)	2006–2007	1.1
LIN 7WC		
CPUE (hoki trawl, Jun–Sep)	1999–2009	
CPUE (longline, all year)	1990–2009	
Commercial trawl proportion-at-age (Jun–Sep)	1991, 1994–2008	
Commercial longline proportion-at-age	2003	
Commercial longline length-frequency	2006	
Trawl survey biomass (*Kaharoa*, Mar–Apr)	1992, 94, 95, 97, 2000, 03, 05, 07, 09	
Trawl survey proportion-at-length (*Kaharoa*, Mar–Apr)	1992, 94, 95, 97, 2000, 03, 05, 07, 09	
Trawl survey biomass (*Tangaroa*, July)	2000	

4.2 Model structure

The LIN 7CK (Cook Strait) stock was assessed in 2010. The stock assessment model partitions the Cook Strait population into sexes and age groups 3–25, with a plus group. There are two fisheries (trawl and longline). The model's annual cycle for the stock is described in Table 9.

The selectivity ogives for the commercial trawl and line fisheries were age-based and were estimated in the model, separately by sex. The trawl fishery ogives were estimated using a double normal parameterisation; the estimated line fishery ogives were assumed to be logistic. In all cases, male selectivity curves were estimated relative to female selectivity. The parameterisations of the double normal and logistic curves were given by Bull et al. (2008). In both fisheries, selectivities were assumed constant over all years, i.e., there was no allowance for annual changes in selectivity.

The maximum exploitation rate was assumed to be 0.6 for the stock. The choice of the maximum exploitation rate has the effect of determining the minimum possible virgin biomass allowed by the model. This value was set relatively high as there was little external information from which to determine it.

Table 9: Annual cycles of the LIN 7CK 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.

4.3 Model estimation

Model parameters were estimated using Bayesian estimation implemented using the CASAL v2.22 software. However, only the mode of the joint posterior distribution (MPD) was estimated in preliminary runs. For final runs, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Full details of the CASAL algorithms, software, and methods were detailed by Bull et al. (2008).

Lognormal errors, with known c.v.s, were assumed for all relative biomass and proportions-at-age observations. The c.v.s available for those observations of relative abundance and catch allow for sampling error only. However, additional process variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance. Process error was added to CPUE series so that the final point c.v.s were approximately 0.2, as recommended by Francis et al. (2001). Process error for catch-at-age series was initially estimated as 0.01 in early MPD runs of the model, using all available data. However, it was subsequently found that process error of 1.1 on the at-age data was necessary to ensure that all the 95% confidence intervals around observed mean ages overlapped with the expected mean age from the model incorporating the trawl CPUE data (see Section 4.4). Hence, the overall c.v. assumed in the model runs for each observation was calculated by adding process error and observation error. The process errors added to each input series are listed in Table 8.

Year class strengths were assumed known (and equal to 1) for years before 1983 and after 2005, when inadequate or no catch-at-age data were available for any year. Otherwise, year class strengths were estimated under the assumption that the estimates from the model must average 1. The Haist parameterisation for year class multipliers is used here (see Bull et al. (2008) for details).

Yields (MCY or CAY) were not calculated in this assessment as the estimates of biomass were considered to be too unreliable.

4.4 Developing a base model

The most recent previous assessment of the Cook Strait ling stock found that estimated biomass was very sensitive to relatively small changes in *M* (Horn 2008). It also appeared likely that the true *M* for the Cook Strait stock was probably higher than the ‘default’ value of 0.18 that has been used in many ling assessments (Horn 2008). Consequently, there is a need to incorporate the effect of this uncertainty in *M* in the current assessment.

There are also some possible problems with the three available CPUE series for Cook Strait ling (see Tables 5 and 6), and this is critical as these series are the only available indices of relative abundance for this stock. The line fishery series is data poor and may be biased upwards owing to the potential to post-select the target species after the catch is onboard (Horn & Ballara 2012). The observer trawl series is also data poor. The TCEPR trawl series appears to suffer from some change in fleet fishing or reporting behaviour between 1993 and 1994 that the model cannot standardise for. Consequently, Horn & Ballara (2012) recommended that TCEPR trawl indices from 1994 to 2009 only be used in any stock modelling.

An initial model using the fishery catch-at-age data only (i.e., no CPUE indices), and allowing *M* to be estimated produced an estimate of 0.21. A likelihood profile for this model showed that while the priors on *M*, as well as other priors and penalties, supported values around 0.18, the fishery catch-at-age data encouraged much higher values of *M* (Figure 2). This profiling also confirmed that estimated biomass was sensitive to small changes in *M*, particularly as this parameter increased (Figure 3).

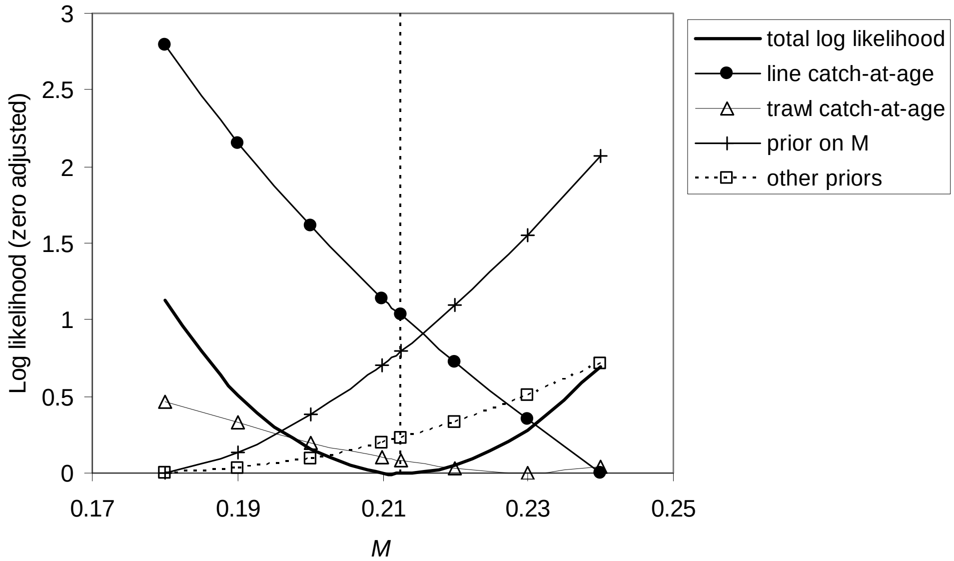

Figure 2: Likelihood profile on *M* for the initial model, showing both the total likelihood (heavy line) and those for individual data series. Vertical dashed line shows the model estimate of *M*.

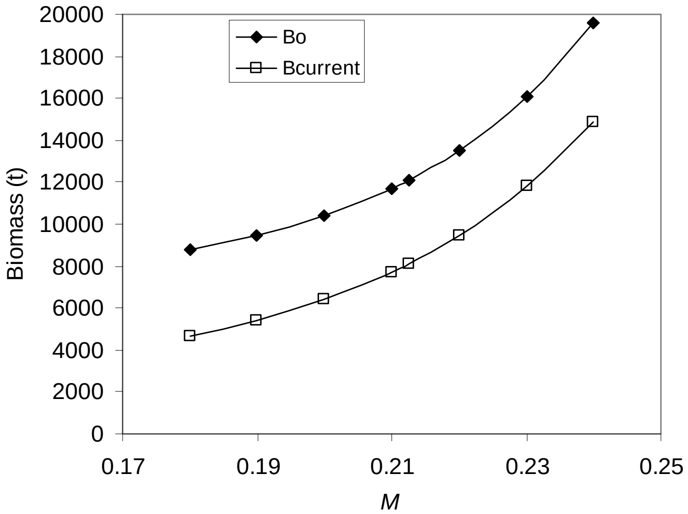

Figure 3: Estimated virgin and current biomass from the initial model for a range of *M* values.

The initial model was then run with each of the four CPUE series, i.e., TCEPR trawl 1994–2009, TCEPR trawl 1990–2009, observer trawl, and line. Model fits to the CPUE series are shown in Figure 4. Inclusion of the line CPUE produced slightly better fits to the line fishery catch-at-age data, while the TCEPR 1990–2009 trawl CPUE series encouraged markedly worse fits to the line fishery age data and slightly worse fits to the trawl age data (Table 10). Including the trawl observer or TCEPR 1994–2009 series resulted in little change in the fits to the catch-at-age data. Consequently, the 1990–2009 TCEPR series was rejected as the first four data points were particularly poorly fitted (see Figure 4); these are the data that were considered particularly questionable in the evaluation of the CPUE series (Horn & Ballara 2012). Of the remaining trawl CPUE sets, the 1994–2009 TCEPR series was considered preferable to the observer series as it was based on a much greater volume of data (Horn & Ballara 2012).

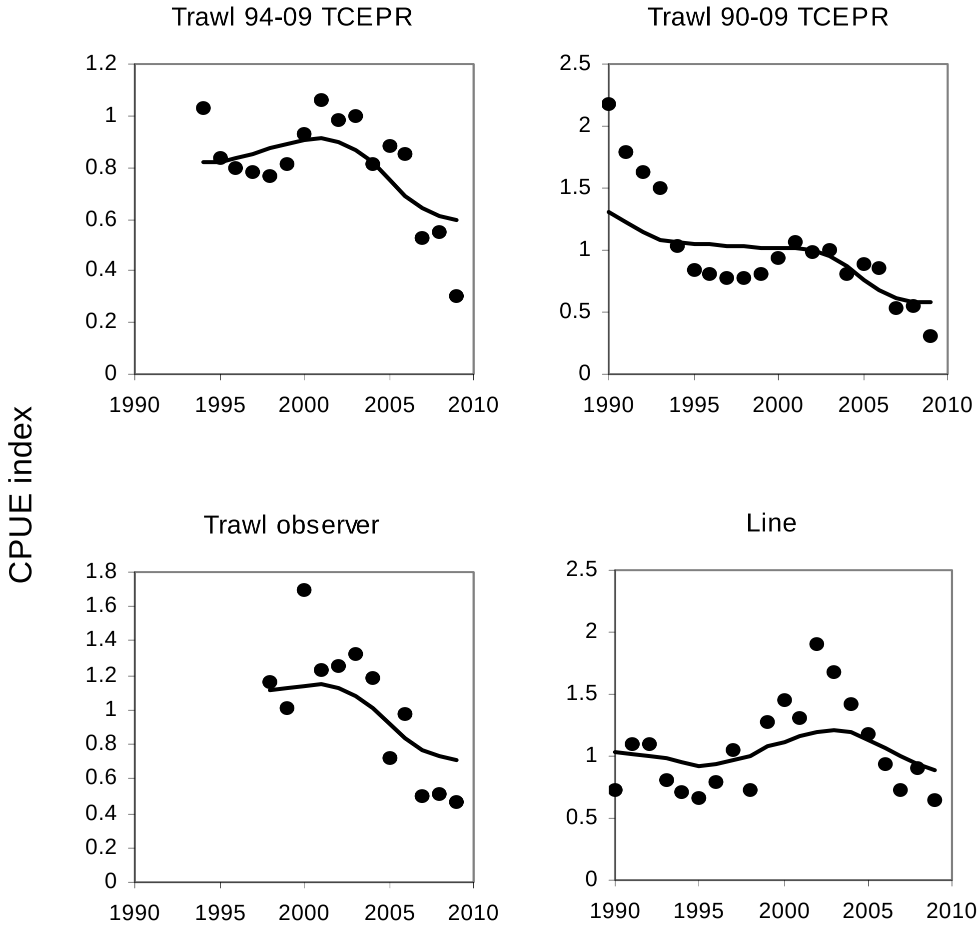

Figure 4: MPD model fits to the four CPUE series.

Table 10: Negative log likelihood of data series showing the effect on the initial model of adding individual CPUE series.

Data series	Initial model (no CPUE)	Selected CPUE series: Line	Trawl 94–09	Trawl 90–09	Trawl observer
Line catch-at-age	-6.34	-7.97	-6.81	-2.39	-6.64
trawl catch-at-age	-89.93	-89.45	-89.68	-88.88	-89.18
priors & penalties	4.54	-3.20	-3.29	-3.01	-3.08
CPUE	–	-17.82	-17.20	-13.80	-10.17
Total log likelihood	-91.73	-118.44	-116.97	-108.08	-109.08

The choice of a CPUE series for the Base assessment model (i.e., either the trawl 1994–2009 TCEPR series, or the line fishery series) was based on beliefs about the likely reliability of these series, and on the quality of the MPD fits to them. As noted above, the line fishery indices are based on low data volumes and have the potential to be biased in a way that might maintain CPUE even though actual ling abundance is declining (Horn & Ballara 2012). No obvious sources of bias are apparent for the trawl series. However, the fits to both these series clearly had unbalanced residuals (see Figure 4), indicating that there was conflict in the biomass signals from the at-age data and the CPUE series.

An examination of the mean expected age of ling (in a model using the 1994–2009 TCEPR CPUE series) and the observed mean age from the trawl at-age data indicated that the amount of process error added to the at-age data (c.v. of 0.01, derived from initial MPD runs) was insufficient to explain the true variability in the estimated ages (Figure 5a). It was necessary to add considerably more process error (i.e., c.v. of 1.1) to ensure that all the 95% confidence intervals around observed mean ages overlapped with the expected mean age from the model run (Figure 5b). Consequently, this amount of process error was added to both at-age data sets in all future model runs.

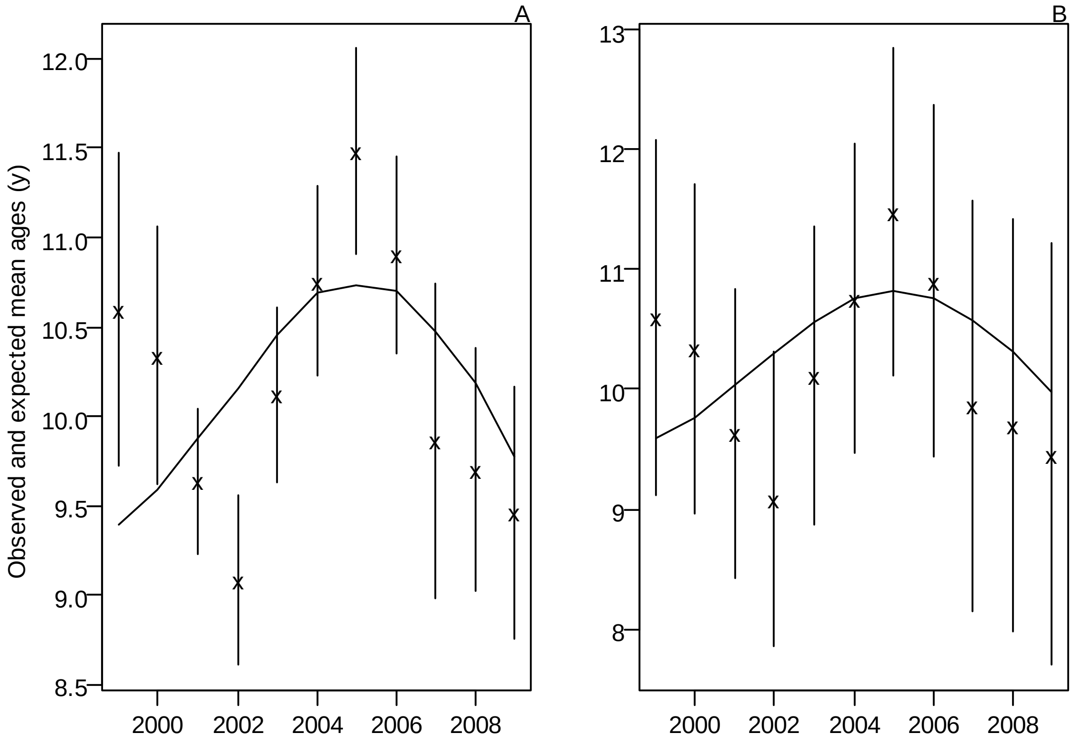

Figure 5: Observed ('×', with 95% confidence intervals shown as vertical lines) and expected mean age from (A) the initial model with 1994–2009 trawl CPUE, and (B) the same model but with the at-age data down-weighted by adding a process error with a c.v. of 1.1. The 95% confidence intervals are as implied by the assumed error distribution for the at-age data.

Given that the addition of substantial process error considerably down-weighted the at-age data, the MPD models were re-run to see what effect this had on the fits to the line and 1994–2009 trawl CPUE. For the line fishery CPUE, it was clear that even if the at-age data were down-weighted and the CPUE was up-weighted (by removing any process error), the model fit was still unsatisfactory (Figure 6). In addition, both models incorporating the line CPUE estimated B_0 to be 60 000 t, which is the upper bound of the prior distribution, and considered a highly unlikely value. We conclude, therefore, that the line CPUE is not a valid index of relative abundance for this stock.

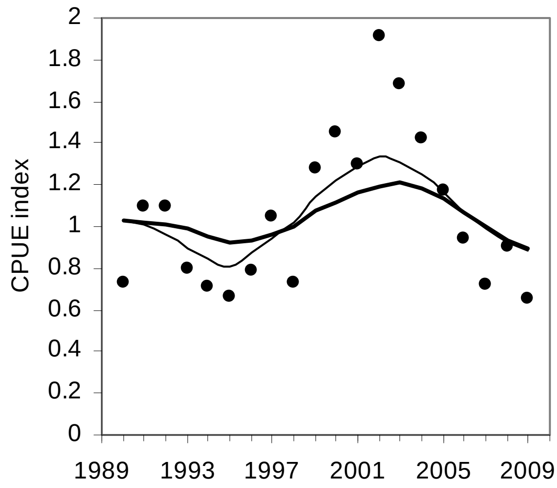

Figure 6: MPD model fits to the line fishery CPUE series. Thick line, process error of 0.01 and 0.2 on the at-age and CPUE data, respectively; thin line, process error of 1.1 and 0.0 on the at-age and CPUE data, respectively.

Two additional models were tested using the trawl CPUE series — one that down-weighted the at-age data by adding process error of 1.1, and another with both this down-weighting and an up-weighting of the CPUE by setting its process error to 0 (Figure 7). The first had little impact on the expected CPUE fit. The second did markedly improve the CPUE fit, particularly the steep downward trend in the observed indices after 2000. The residuals are still unbalanced for both models. It was also apparent that the model with only the at-age data down-weighted still fitted the at-age data relatively well and quite similarly to the unforced model (Figure 8). However, when the at-age data are down-weighted and the CPUE data are up-weighted, the at-age data are not fitted as well, particularly some relatively strong younger year classes apparent in the 2006–2009 distributions (see Figure 8). In addition, the 'down-weight age, up-weight CPUE' model also selected a B_0 at the upper bound of the prior distribution (i.e., 60 000 t) and required biomass levels close to 80 000 t in the early 2000s (Figure 9). Biomasses of this size are believed to be highly unlikely for the Cook Strait stock.

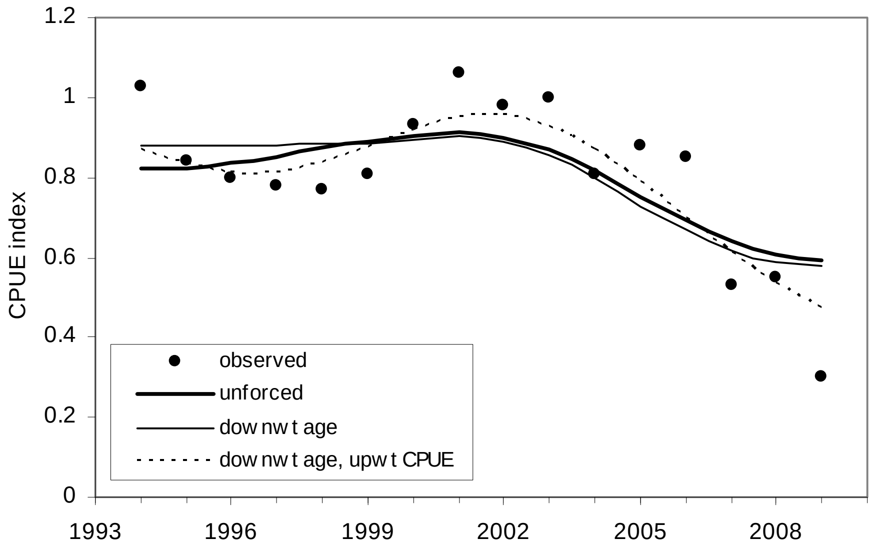

Figure 7: Effect on the fit to the trawl CPUE of changing data weights, showing the observed (points) and expected (lines) CPUE for three models. Unforced, model with process error of 0.01 and 0.2 on the at-age and CPUE data, respectively; downwt age, at-age data are down-weighted by adding a process error of 1.1; downwt age upwt CPUE, at-age data are down-weighted by adding a process error of 1.1 and CPUE data are up-weighted by removing all process error.

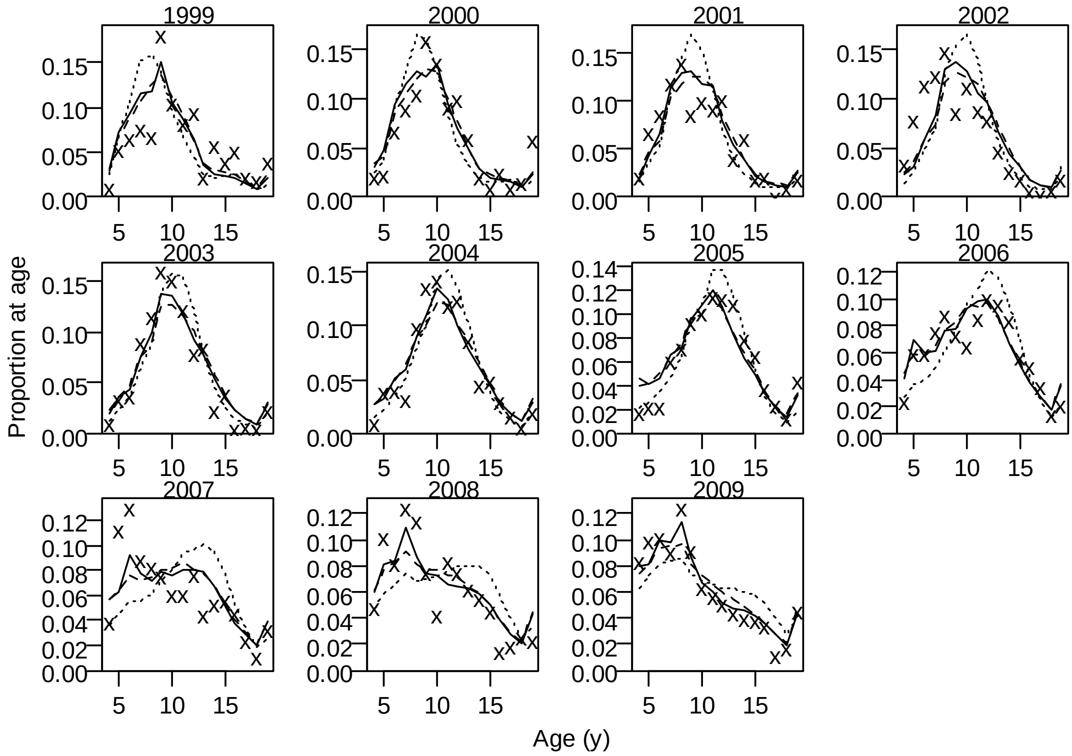

Figure 8: Effect on the fit to trawl fishery at-age data of changing data weights, showing the observed ('×') and expected (lines) proportions at age (sexes combined) for three models. Unforced model (solid lines), with process error of 0.01 and 0.2 on the at-age and CPUE data, respectively; downwt age model (broken lines), at-age data are down-weighted by adding a process error of 1.1; downwt age upwt CPUE model (dotted lines), at-age data are down-weighted by adding a process error of 1.1 and CPUE data are up-weighted by removing all process error.

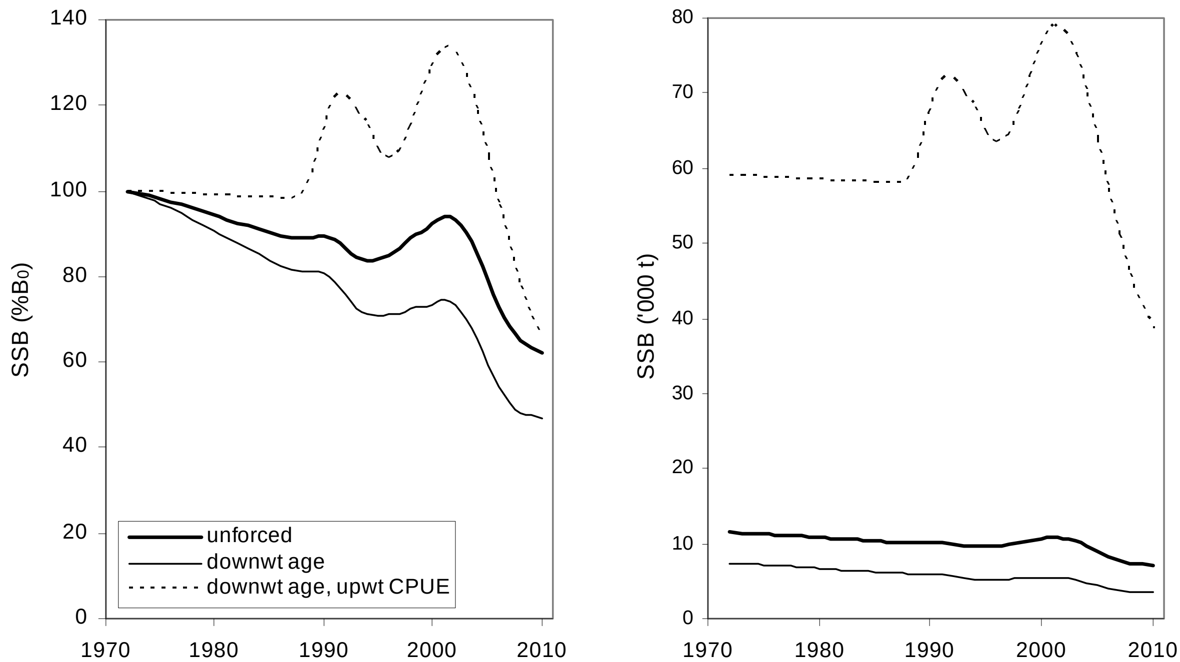

Figure 9: Plots of estimated spawning stock biomass (SSB) as a percentage of B_0 and in '000 t, for three models. Unforced, with process error of 0.01 and 0.2 on the at-age and CPUE data, respectively; downwt age, at-age data are down-weighted by adding a process error of 1.1; downwt age upwt CPUE, at-age data are down-weighted by adding a process error of 1.1 and CPUE data are up-weighted by removing all process error.

Consequently, owing to the degraded fits to the at-age data and the unrealistically high estimates of biomass when the CPUE series is up-weighted, the chosen Base model for the assessment incorporated the trawl 1994–2009 TCEPR CPUE series (with process error of 0.2) and the trawl and line fishery catch-at-age (with process error of 1.1), with *M* estimated in the model. In addition, a model excluding any CPUE data was also investigated using MCMC to examine what information on trends in biomass was provided by the fishery catch-at-age data.

4.5 Model estimation using MCMC

Model parameters were estimated using Bayesian estimation implemented using the CASAL software. For final runs, the full posterior distribution was sampled using Monte Carlo Markov Chain (MCMC) methods, based on the Metropolis-Hastings algorithm. MCMCs were estimated using 24×10^6 iterations, a burn-in length of 4×10^6 iterations, and with every 20 000th sample kept from the final 20×10^6 iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior). Year class strengths were estimated as in the MPD runs except that the value for 2006 was no longer fixed at 1. In this situation the unknown year class strengths were assumed to have a lognormal distribution with mean 1.0 and standard deviation set equal to the standard deviation of the previously estimated year class strengths from the particular stock.

4.6 Prior distributions and penalty functions

The assumed prior distributions used in the assessment are given in Table 11. Most priors were intended to be relatively uninformed, and were specified with wide bounds. The exception was natural mortality. The priors for natural mortality assumed that *M* can vary between stocks, but is very probably between 0.1 and 0.3 for all stocks (following Horn 2008). Consequently, the chosen prior distribution was lognormal with a mean at 0.18 (the value previously used as *M* for all stocks) and a moderately high c.v.

Table 11: Assumed prior distributions and bounds for estimated parameters in the assessment. Parameter values are mean (in natural 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*
Process error c.v.	uniform-log	–	–	0.001	2
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 average to 1.

5. MODEL ESTIMATES

Base case (i.e., the trawl 1994–2009 TCEPR CPUE model) estimates of biomass, year class strengths, and *M* were derived using the fixed parameters (see Table 4) and the model input parameters described earlier. One sensitivity (i.e., no CPUE) was investigated.

MCMC estimates of the posterior distribution were obtained for both model runs, and are presented below. In addition, MCMC estimates of the median posterior and 95% percentile credible intervals are reported for the key output parameters. A comparison of the MCMC chains for estimates of B_0 from the two models shows that both have a clear concentration of estimates between about 7 000 and 20 000 t, but also frequent higher estimates (Figure 10). Although neither chain appears to be well converged in Figure 10, the distributions of estimates of B_0 and B_{2010} (as $\%B_0$) from the trawl CPUE model are reasonably consistent between the first, middle, and last thirds of the chain (Figure 11), and hence convergence is probably adequate for stock-assessment purposes.

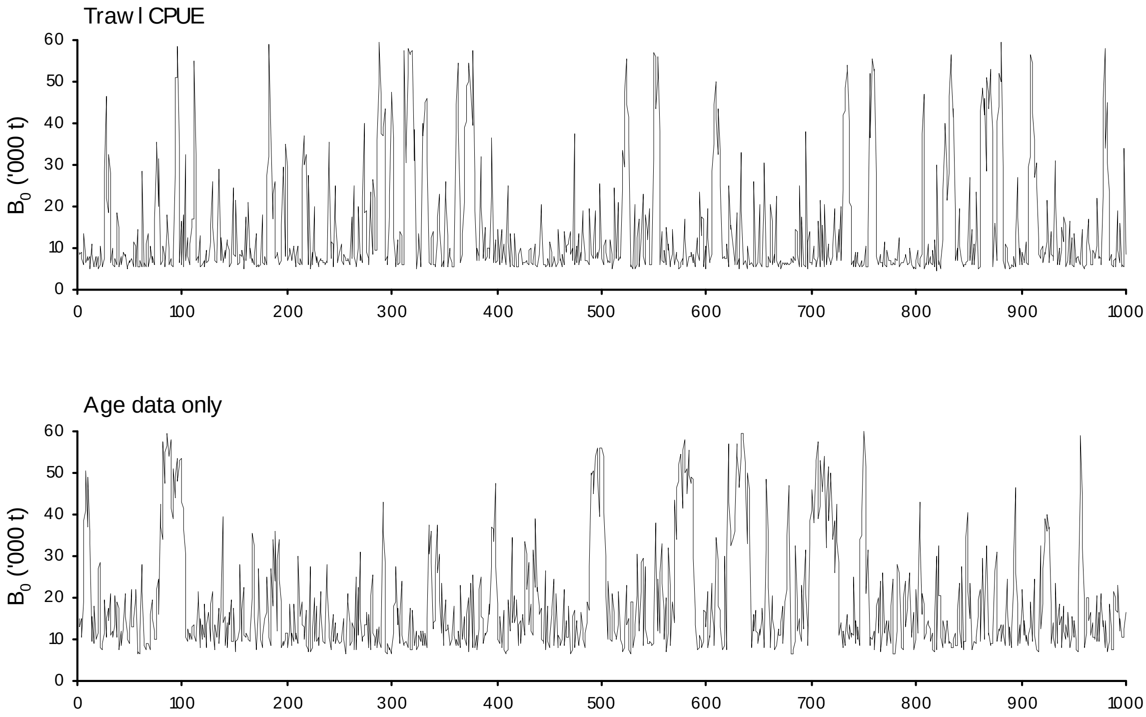

Figure 10: Trace diagnostic plot of the MCMC chains for estimates of B_0 for both the Cook Strait stock model runs.

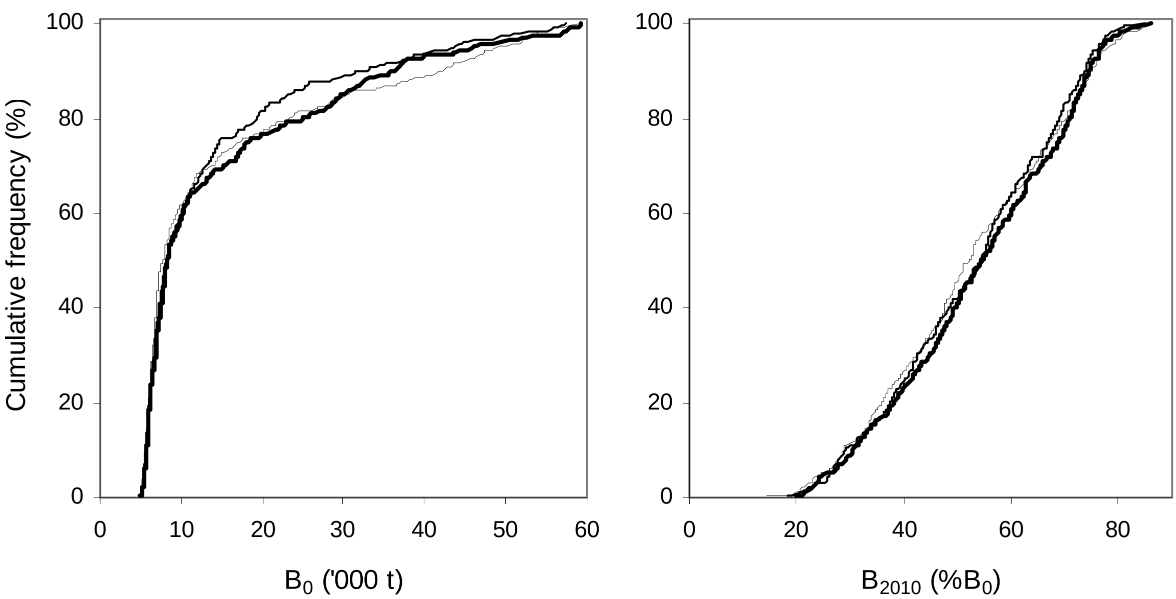

Figure 11: MCMC diagnostic plot showing the cumulative frequencies of B_0 and B_{2010} ($\%B_0$) for the first (thick line), middle (medium line), and last (thin line) third of the MCMC chain for the base model.

The MPD fits, and diagnostic plots, for the trawl 1994–2009 TCEPR CPUE series are shown in Figure 12. The fit is reasonable to all points except 2009, but the residuals are clearly auto-correlated.

The estimated MCMC marginal posterior distributions for selected parameters from the Base model are shown in Figures 13–17. Instantaneous natural mortality (M) was estimated as a constant independent of sex (Figure 13). The posterior distribution had a median of 0.24, and a 95% credible interval of 0.16–0.30; clearly there is information in the model encouraging an M much higher than the 'default' value of 0.18 that has been used in most previous ling stock assessments. The posterior distribution is clearly limited by the upper bound on the prior. The estimation of M is confounded with the estimation of fishery selectivities, so although it is likely that M for the Cook Strait stock is higher than 0.18 we can not be confident that the true value has been determined here.

Fishery selectivity ogives were relatively tightly defined (Figure 14). Fishing selectivities indicated that ling were fully selected in the trawl fishery by about age 11–15 years, compared to age 7–12 in the line fishery. This is not consistent with selectivity ogives for other assessed ling stocks where age at full selectivity is higher in the line fishery relative to the trawl fishery (e.g., Horn 2008). In both fisheries, females appear to be fully selected at younger ages than males, which is consistent with selectivity by size as females are larger at age than males. There is no information outside the model that allows the shape of the estimated selectivity ogives to be verified.

Year class strengths were poorly estimated (and consequently have wide confidence bounds) for years where only older fish were available to determine age class strength (i.e., before 1993) (Figure 15). There were no exceptionally strong or weak year classes from 1983 to 1992. More recent year class strengths appear well estimated, with estimated median recruitment from 1995 to 2004 being consistently lower than average (particularly from 1997 to 2000, where all the posterior distributions are almost completely below 1). Overall, estimated year class strengths were not widely variable, with the medians for almost all years being between 0.5 and 2.

Estimated biomass for the Cook Strait stock increased throughout the late 1990s owing to the relatively strong recruitment from 1988 to 1994 (Figure 16). Biomass then steadily declined from 2001 to the present owing to generally poor recruitment. Bounds around the median biomass estimates are wide, particularly the upper bounds. Current stock size is estimated to be about 54% of B_0 (95% credible interval 23–80%) (see Figure 16 and Table 12.) 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 17).

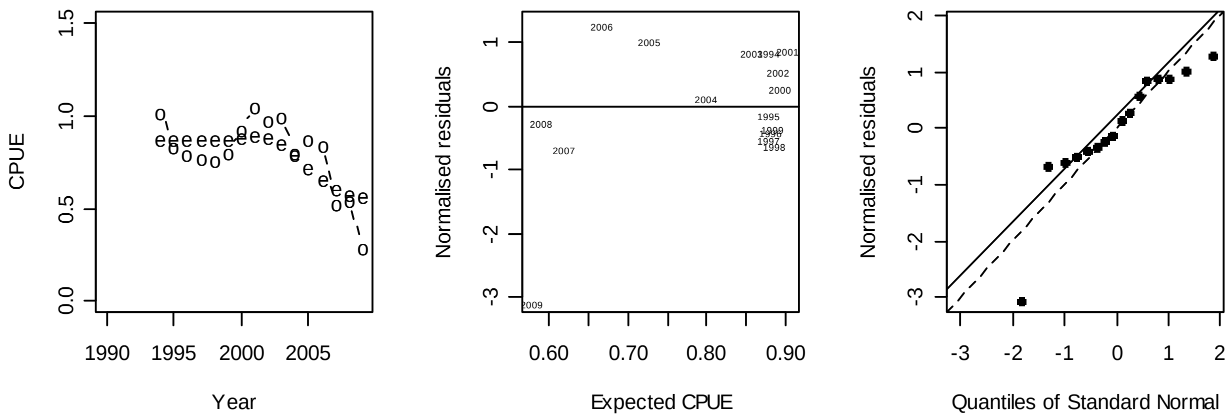

Figure 12: Base model — MPD fit ('e') to the observed trawl CPUE series ('o'), and diagnostic plots of normalised residuals for this series.

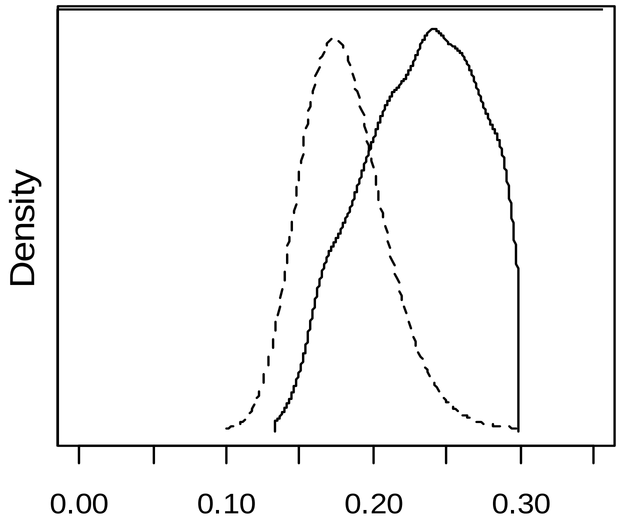

Figure 13: Base model — Comparison of estimated posterior (solid line) and prior (broken line) distributions for instantaneous natural mortality (*M*).

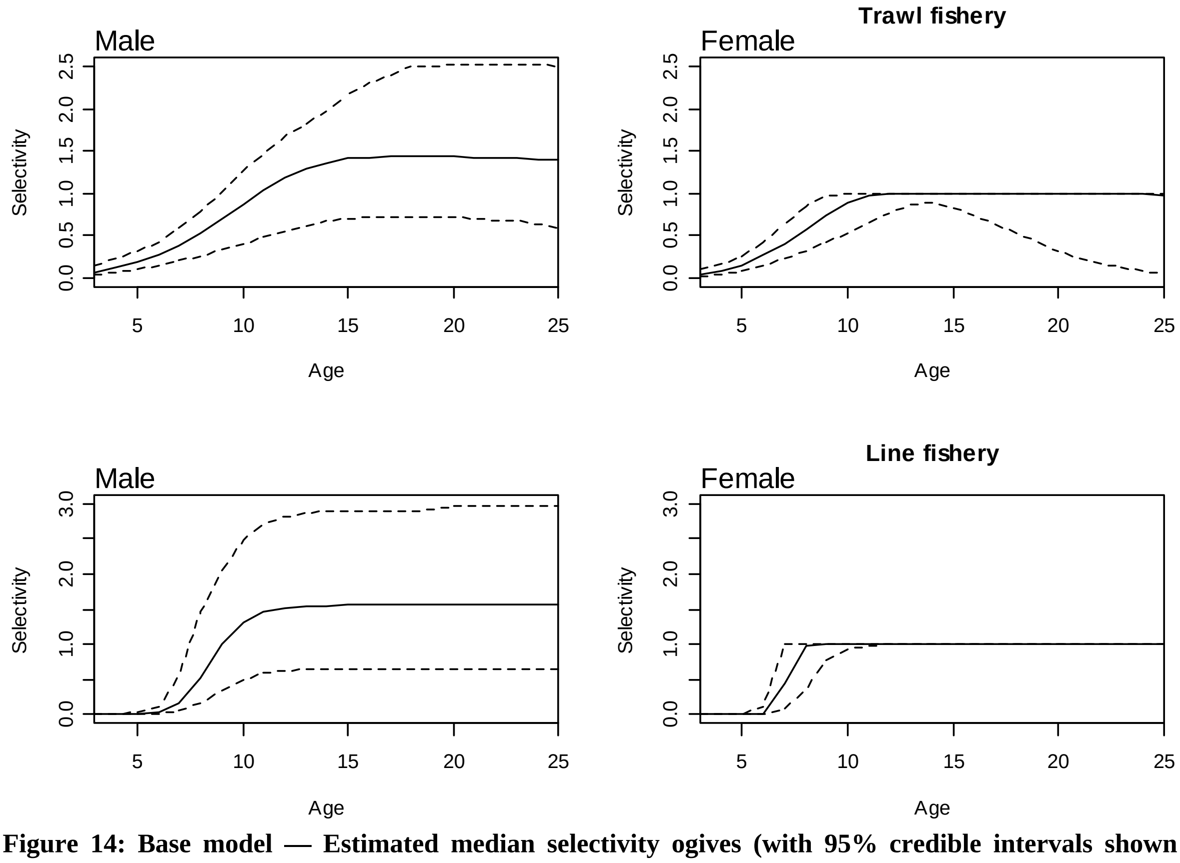

Figure 14: Base model — Estimated median selectivity ogives (with 95% credible intervals shown as dashed lines) for the trawl fishery and the line fishery, for the Cook Strait stock.

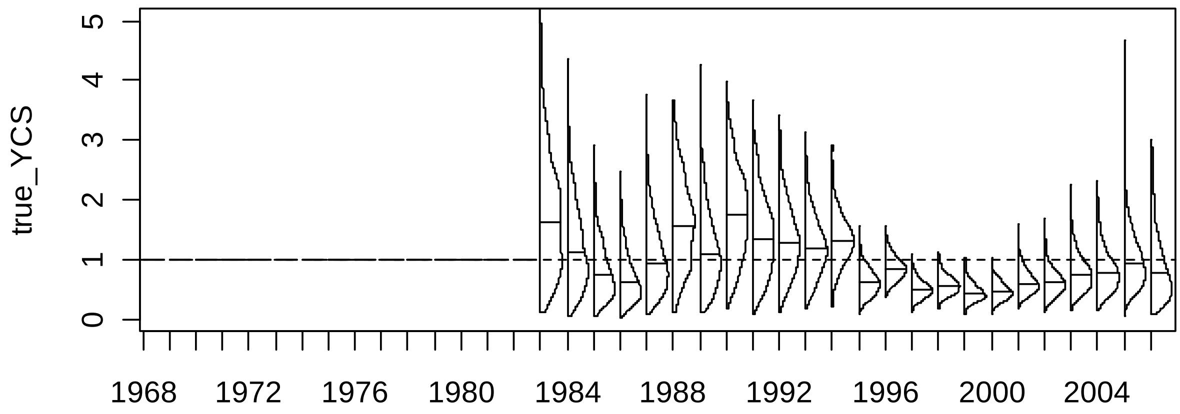

Figure 15: Base model — Estimated posterior distributions of year class strengths for the Cook Strait stock. The dashed horizontal line indicates the year class strength of one. Individual distributions are the marginal posteriors, with horizontal lines indicating the median.

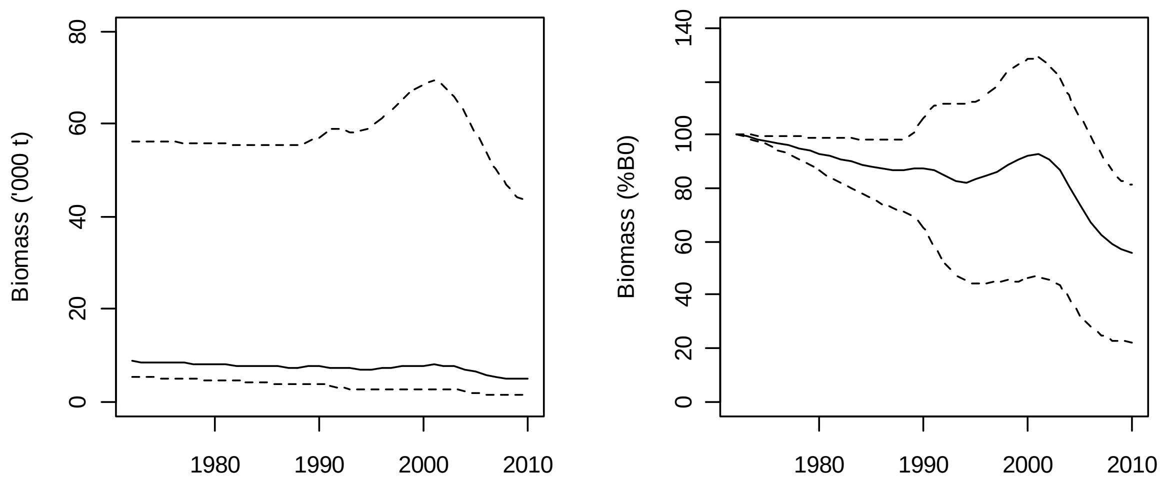

Figure 16: Base model — Estimated median trajectories (with 95% credible intervals shown as dashed lines) for absolute biomass and biomass as a percentage of B_0, for the Cook Strait stock.

Table 12: Bayesian median and 95% credible intervals of B_0, B_{2010}, and B_{2010} as a percentage of B_0 for the Cook Strait model runs.

Model run	B_0		B_{2010}		B_{2010} (%B_0)	
Base model	8 070	(5 290–53 080)	4 370	(1 250–40 490)	53.6	(23.1–79.7)
No CPUE	13 610	(7 150–54 070)	9 580	(3 210–44 280)	70.2	(44.3–86.9)

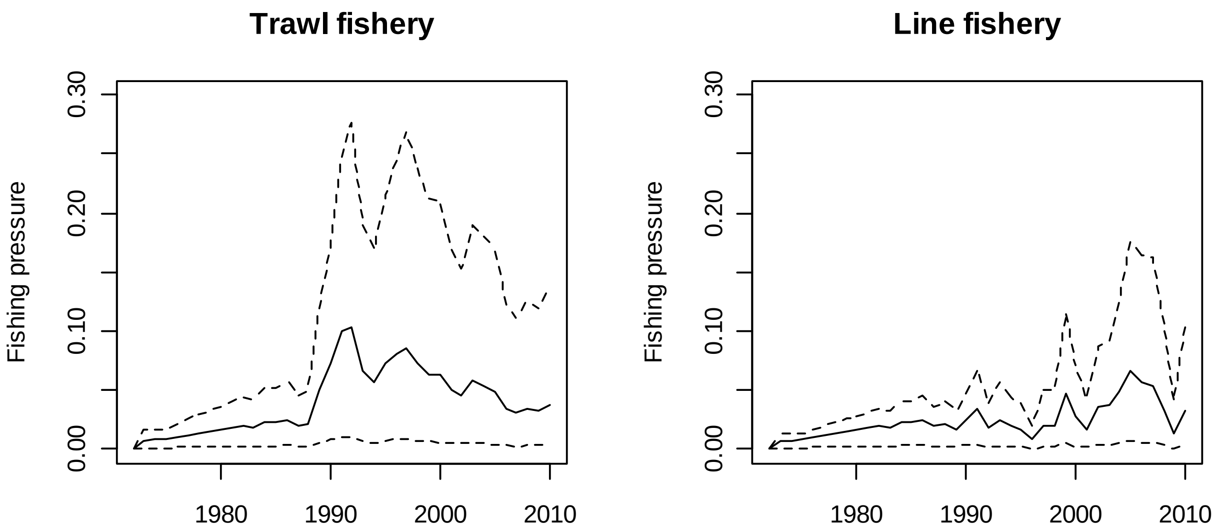

Figure 17: Base model — Estimated median trajectories (with 95% credible intervals shown as dashed lines) of fishery exploitation rates for the Cook Strait stock.

The residuals from the MPD fits to the proportion-at-age data from the trawl fishery exhibit no trends across the years (Appendix A, Figure A1), suggesting that these series are reasonably well fitted (Appendix A, Figure A3). The fits to this series and to the line fishery proportion-at-age (Appendix A, Figure A2) vary little between the two models.

The No CPUE sensitivity model was identical to the base model except that no CPUE series were included. Consequently, this model had no series of relative abundance so was reliant on the two fishery catch-at-age series to provide information on absolute and relative biomass.

The posterior distribution for estimated M had a median of 0.24 and a 95% credible interval of 0.19–0.28 (Figure 18). The fishery selectivity ogives were little different to those estimated for the base model. The pattern of year class strength estimates was also quite similar to the base model (Figure 19), with the main difference being a series of slightly higher estimates for 2001–05 in the No CPUE model.

The estimated biomass (as a percentage of B_0) trajectory from the No CPUE model had a similar shape to that from the other two models, but with the main differences being a flattening out of biomass in the last two years (Figure 20). Bounds around the median biomass estimates are wide, particularly the upper bounds. Current stock size is estimated to be about 70% of B_0 (95% credible interval 44–87%) (see Figure 20 and Table 12.) Exploitation rates (catch over vulnerable biomass) were very low up to the late 1980s, and have been low to moderate (up to about 0.07 yr^{-1}) since then.

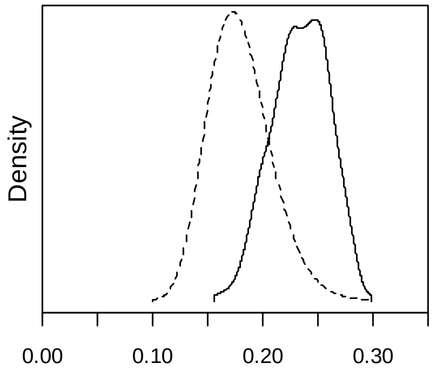

Figure 18: No CPUE model — Estimated posterior distribution (solid line) of instantaneous natural mortality (*M*), and distribution of priors (broken line).

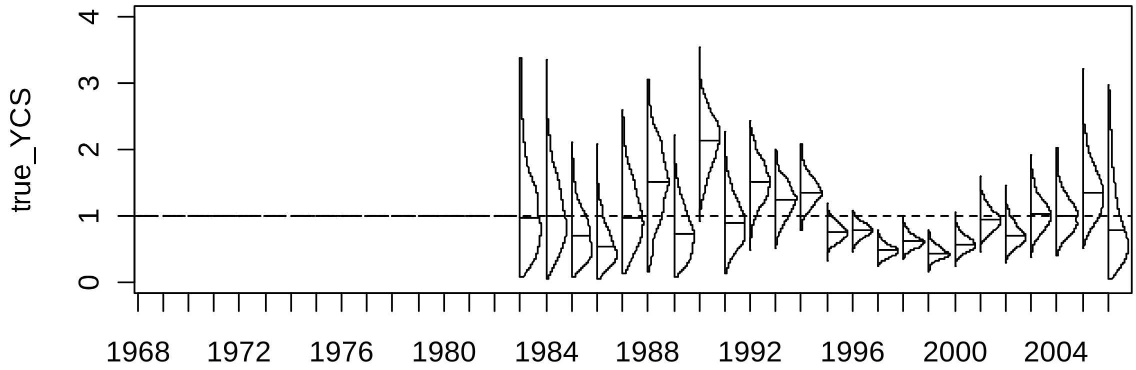

Figure 19: No CPUE model — Estimated posterior distributions of year class strengths for the Cook Strait stock. The dashed horizontal line indicates the year class strength of one. Individual distributions are the marginal posteriors, with horizontal lines indicating the median.

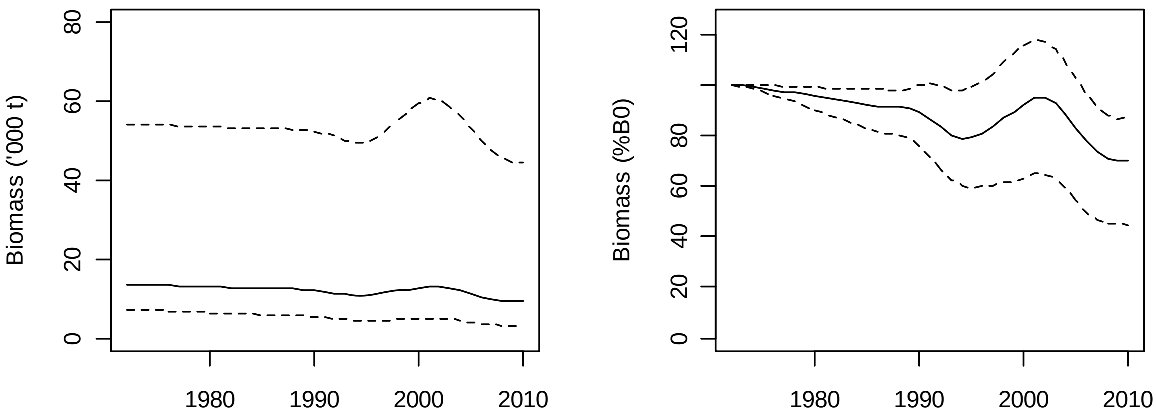

Figure 20: No CPUE model — Estimated median trajectories (with 95% credible intervals shown as dashed lines) for absolute biomass and biomass as a percentage of B_0, for the Cook Strait stock.

5.1 Biomass projections

Biomass projections from the base model were made under two assumed future catch scenarios (220 t or 420 t annually from 2011 to 2015). The low catch scenario (220 t) approximates the catch level from recent years (since 2007). The high catch scenario (420 t) is the average catch from Cook Strait since 1990. Biomass projections from the No CPUE model were made under the low catch scenario only.

In the projections, the assumption that unestimated year class strengths were equal to one was rejected. Here, relative year class strengths from 2006 onwards were selected randomly from the previously estimated year class strengths from 1990 to 2005. It was considered prudent to base the projections more on recent recruitment levels because these had generally been lower than the long term average (see Figure 15).

Projections from the Base model suggested that biomass in 2010 will increase slightly to be about 59% of B_0 (lower catch) or decrease slightly to be about 52% of B_0 (higher catch) by 2015 (Table 13, Figure 21). The main difference between the two scenarios is that the lower bound on B_{2015} is much lower under the higher catch. Similarly, under the sensitivity model, biomass was projected to increase under the lower future catch scenario. The extent of the projected increase (i.e., to about 82% of B_0 by

2015) is greater than for the Base model (Table 13, Figure 22). The projected increase in biomass is a consequence of recruitment into the fishery of some year classes (i.e., 2003–05) that are relatively stronger than most others since 1995.

Table 13: Bayesian median and 95% credible intervals of projected B_{2015}, B_{2015} as a percentage of B_0, and B_{2015}/B_{2010} (%) for the Cook Strait model runs, under two future annual catch scenarios.

Model run	Future catch (t)	B_{2015}	B_{2015} (%B_0)	B_{2015}/B_{2010} (%)
Base model	220	5 030 (1 310–43 340)	59.3 (23.8–97.2)	110 (82–158)
	420	4 320 (590–42 910)	51.7 (11.2–92.4)	95 (45–136)
No CPUE	220	11 250 (3 720–51 810)	81.5 (51.5–103.9)	117 (98–138)

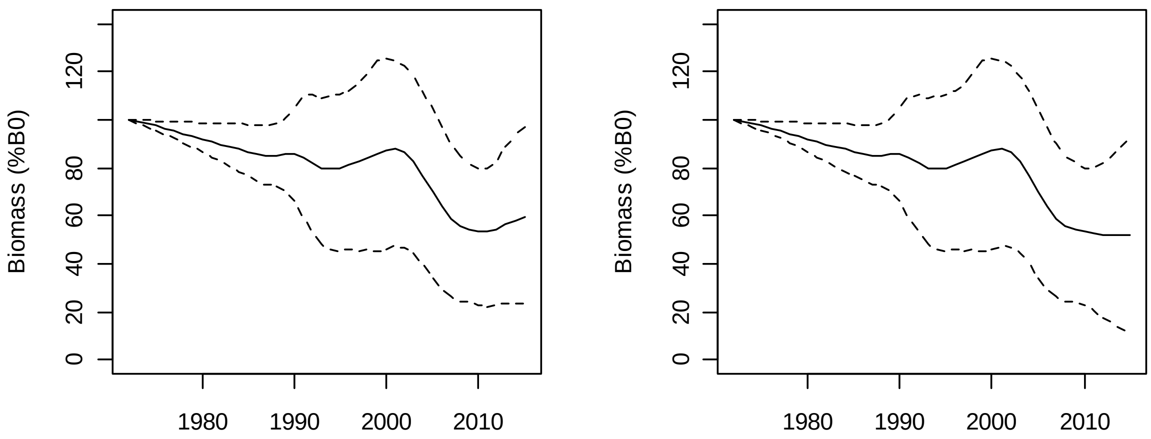

Figure 21: Base model — Estimated median trajectories (with 95% credible intervals shown as dashed lines) for biomass as a percentage of B_0, for the Cook Strait stock, projected to 2015 with future catches assumed to be 220 t (left panel) or 420 t (right panel) annually.

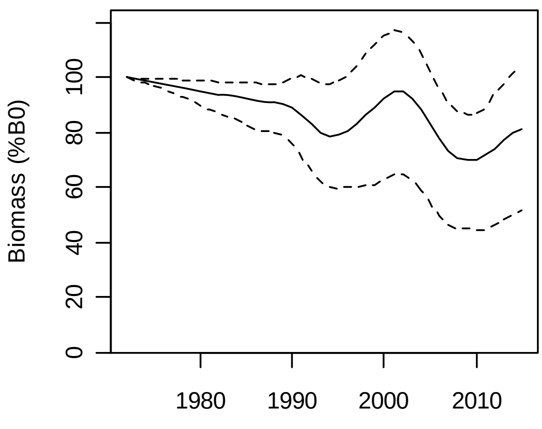

Figure 22: No CPUE model — Estimated median trajectories (with 95% credible intervals shown as dashed lines) for biomass as a percentage of B_0, for the Cook Strait stock, projected to 2015 with future catches assumed to be 220 t.

5.2 Management biomass targets

Probabilities that current and projected biomass will drop below selected management reference points (i.e., target, 40%B_0; soft limit, 20%B_0; hard limit, 10%B_0) are shown, for the base model run, in Table 14. It appears very unlikely (i.e., less than 10%) that B_{2015} will be lower than the soft target of 20%B_0.

Table 14: 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

5.3 Estimates of sustainable yields

Absolute estimates of biomass from any of the models are neither precise enough nor considered reliable enough to justify the estimation of sustainable yields (i.e., MCY or CAY).

6. DISCUSSION

Ling in Cook Strait are believed to comprise a distinct biological stock (Horn 2005), but it does not have a separate TACC. It is a ‘trans-boundary’ stock, being partially in Fishstocks LIN 7 and LIN 2. The Cook Strait stock is data poor. Model inputs are confined to a catch history, CPUE indices, and series of catch-at-age data. No fishery-independent series of relative abundance are available.

The assessment (and clearly, the shape of the biomass trajectory) is dominated by the catch-at-age data from the trawl and line fisheries rather than the CPUE series. The CPUE series essentially tune the estimates of biomass and year class strengths derived from the catch-at-age data. Unfortunately, none of the CPUE series are fitted particularly well. Horn & Ballara (2012) concluded that the trawl CPUE series using TCEPR data from 1994 to 2009 was a more reliable relative abundance series than the line CPUE because it was based on more data and was less likely to be biased by changes in fishing practice and catch recording. From the modeling presented above it was concluded that the line CPUE series should be rejected as an index of abundance for the Cook Strait stock.

The Base model run, which includes the trawl CPUE, is indicative of a B_0 in Cook Strait that is small (i.e., about 8 000 t) when compared with virgin biomass estimates for stocks covering much larger geographic areas (e.g., 110 000–140 000 t for Chatham Rise (Horn 2008)). However, when geographical area is taken into account (the Chatham Rise ling grounds are about 40 times the area of the assumed Cook Strait stock distribution), the unfished density of Cook Strait ling is estimated to be about 2–3 times that of the Chatham Rise. But, the actual geographic area encompassed by the ‘Cook Strait’ biological stock is unknown. For the purposes of generating data inputs for the model, the ‘stock’ is assumed to comprise the area between latitudes 41° and 42° S and longitudes 174° and 175.4° E, equating approximately to Statistical Areas 16 and 17. However, ling as far south as the Kaikoura Peninsula, and north towards Hawke Bay could easily be part of this biological stock. While this would markedly increase the area, it would increase the landings from the stock by only about a factor of 2.

Much of the uncertainty in the results presented here for Cook Strait ling is attributable to the estimation of *M* in the models. However, it was considered necessary to do this because of the uncertainty of *M* for this stock, and because it was known that biomass of this stock is very sensitive to relatively small changes in this parameter (Horn 2007b, 2008). Fixing *M* as a constant would be likely to produce strongly converging MCMC analyses with relatively narrow bounds around estimated biomass (see Horn 2008), but in doing this we would be ignoring some known and influential uncertainty in this assessment. Lower estimates of biomass in the posterior distributions are generally associated with lower estimates of *M* (an expected result, based on the information in Figure 3). The lowest and highest thirds of the posterior biomass estimates (both B_0 and B_{2010}) have mean *M* estimates of 0.20 and 0.27, respectively.

Trawl selectivity for both sexes tended to peak at about ages 11–15, while for the line fishery full selectivity is at about age 7–12 years, with females selected at younger ages than males in both fisheries. It is unusual for age at full selectivity in a line fishery to be less than age at full selectivity in a trawl fishery in the same area (e.g., Horn 2008). Raw length data were examined to see whether they indicated that the trawl fishery did take proportionally more larger fish than the line fishery. Clearly, smaller fish (less than 75–80 cm, or about 6 years of age) are selected in greater numbers by the trawl fishery (Figure 23), and this is reflected in a comparison of the trawl and line fishery ogives (see Figure 14). However, the modal lengths are slightly greater in the line, relative to the trawl fishery for both sexes, although the right-hand limbs appear quite similar. This suggests that age at full selectivity (by sex) for the two fisheries should be slightly greater for the line fishery. The length-frequency peaks from the trawl fishery catch correspond to an expected age of about 10 years for both sexes. However, the "aberrant" selectivity ogives for the line fishery in Cook Strait, where age at full selectivity would be expected to be about 12–14 years, are not explained. This problem should be addressed when the stock is next assessed.

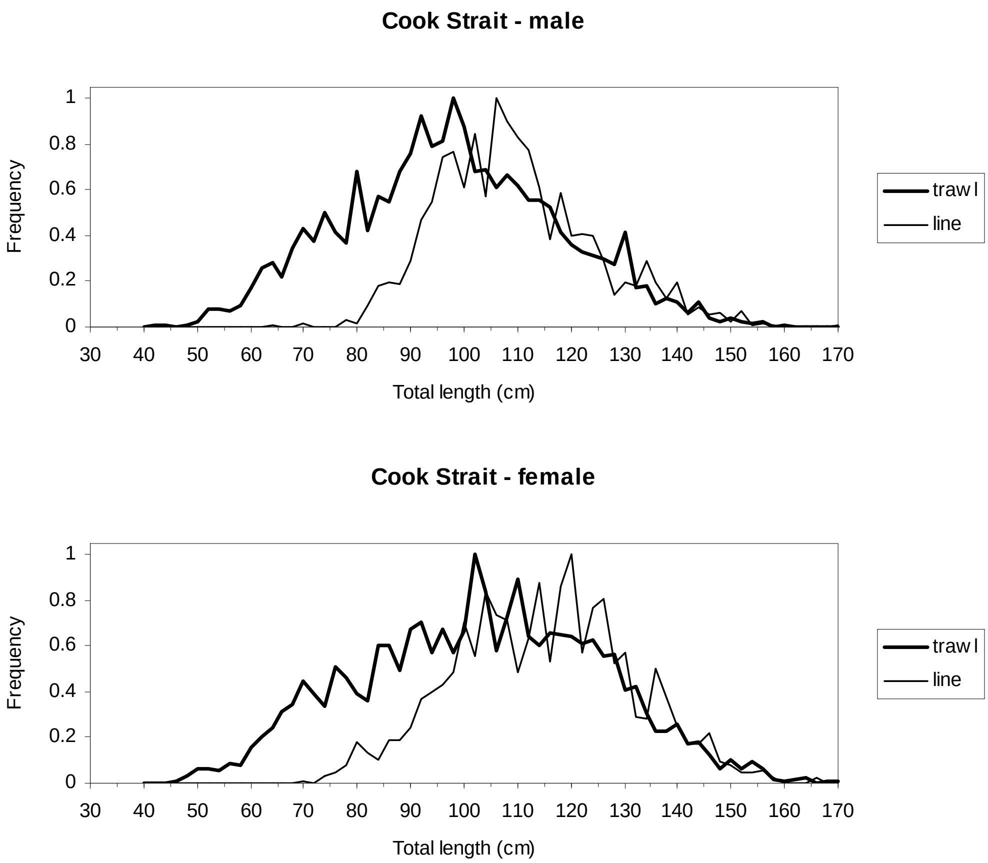

Figure 23: Length-frequency distribution (in 2 cm bins) of ling measured from the Cook Strait ling target autoline fishery (line, 2006–07) and the hoki trawl fishery (trawl, 1999–2009), by sex.

The size and status of the Cook Strait stock is not well known, but it is likely to be small relative to the Chatham Rise or Sub-Antarctic stocks. The confidence interval around estimated B_0 is very wide, a consequence of the assessment model's sensitivity to small changes in *M*. The shape of the biomass trajectory is driven by the at-age data, with the rate of biomass decline modified by the trawl CPUE. The CPUE series is not well fitted, particularly the most recent point (2009). The estimate of current stock status is 54% of B_0 (with a lower bound of 23%), and the model is projecting an improvement in stock status over the next five years with future catches equal to recent landings levels. The projected improvement in stock status is a consequence of recruitment into the fishery of some year classes relatively stronger than most since the mid 1990s. Therefore, the available data indicate that there are no sustainability issues for the Cook Strait stock in the short to medium term, but this conclusion must be tempered by the uncertainty in the estimates of biomass.

The assessment of Cook Strait is confounded by several difficulties. First, there are no fishery-independent indices of relative abundance. Second, the two fishery-dependent abundance series (i.e., the trawl and line CPUE series) exhibit some conflicting trends (Horn & Ballara 2012), although, as noted above, the line series is now strongly considered to be unreliable. Third, the stock structure of Cook Strait ling is uncertain. While ling in this area are almost certainly biologically distinct from the west coast South Island and Chatham Rise stocks (Horn 2005), their association with ling off the lower east coast of the North Island is unknown. Fourth, the catch-at-age data used to estimate the line fishery selectivity ogives are from the autoline sector of this fishery only. All the line catch before 1998, and about half of the line catch since then, has been taken by smaller 'hand-baiting' vessels that often fish in areas different to the autoliners. No length-frequency data are available from the 'hand-baiting' fishery, so it is not known if its catch composition differs from the autoline catch. Also, the line fishery ogives are based on only two years of data, and the shape of the ogives does not appear to be consistent with the length-frequency data. Confidence in the assessment will not be achieved if we have no confidence in the ogives. And finally, the model is sensitive to small changes in *M*, a parameter that is poorly known for this stock.

It is recommended that future assessments of the Cook Strait stock maintain the estimation of *M*, as this is believed to provide a greater degree of biological reality for a parameter that clearly has a marked influence on biomass estimation. Future work should also continue to rely on the trawl, rather than line, CPUE. It would also be desirable to have more information to better define the line fishery ogives.

7. ACKNOWLEDGMENTS

We thank members of the Middle Depth Fishery Assessment Working Group for comments and suggestions on this assessment. This work was funded by the Ministry of Fisheries under project LIN2009-01.

8. REFERENCES

Bull, B.; Dunn, A. (2002). Catch-at-age: User manual v1.06.2002/09/12. NIWA Internal Report 114. 23 p. (Unpublished report held in NIWA library, Wellington.)

Bull, B.; Francis, R.I.C.C.; Dunn, A.; McKenzie, A.; Gilbert, D.J.; Smith, M.H.; Bian, R. (2008). CASAL (C++ algorithmic stock assessment laboratory): CASAL user manual v2.20-2008/02/14. *NIWA Technical Report 130*. 275 p.

Dunn, A. (2003a). Revised estimates of landings of hake (*Merluccius australis*) for the west coast South Island, Chatham Rise, and sub-Antarctic in the fishing years 1989–90 to 2000–01. *New Zealand Fisheries Assessment Report 2003/39.* 36 p.

Dunn, A. (2003b). Investigation of evidence of area misreporting of landings of ling in LIN 3, 4, 5, 6, & 7 from TCEPR records in the fishing years 1989–90 to 2000–01. Final Research Report for

Ministry of Fisheries Research Project HAK2001/01, Objective 8. 21 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Francis, R.I.C.C.; Hurst, R.J.; Renwick, J.A. (2001). An evaluation of catchability assumptions in New Zealand stock assessments. *New Zealand Fisheries Assessment Report 2001/1*. 37 p.

Francis, R.I.C.C.; Haist, V.; Bull, B. (2003). Assessment of hoki (*Macruronus novaezelandiae*) in 2002 using a new model. *New Zealand Fisheries Assessment Report 2003/6.* 69 p.

Horn, P.L. (2000). Catch-at-age data, and a review of natural mortality, for ling. Final Research Report for Ministry of Fisheries Research Project MID9801, Objectives 1, 3, 4, & 5. 26 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Horn, P.L. (2002). Stock assessment of ling (*Genypterus blacodes*) around the South Island (Fishstocks LIN 3, 4, 5, 6, and 7) for the 2001–02 fishing year. *New Zealand Fisheries Assessment Report 2002/20*. 53 p.

Horn, P.L. (2004). Stock assessment of ling (*Genypterus blacodes*) on the Campbell Plateau (LIN 5 and 6) and off the west coast of the South Island (LIN 7) for the 2003–04 fishing year. *New Zealand Fisheries Assessment Report 2004/7*. 45 p.

Horn, P.L. (2005). A review of the stock structure of ling (*Genypterus blacodes*) in New Zealand waters. *New Zealand Fisheries Assessment Report 2005/59*. 41 p.

Horn, P.L. (2006). Stock assessment of ling (*Genypterus blacodes*) off the west coast of the South Island (LIN 7) for the 2005–06 fishing year. *New Zealand Fisheries Assessment Report 2006/24*. 47 p.

Horn, P.L. (2007a). A descriptive analysis of commercial catch and effort data for ling from New Zealand waters in Fishstocks LIN 2, 3, 4, 5, 6, and 7. *New Zealand Fisheries Assessment Report 2007/22*. 71 p.

Horn, P.L. (2007b). Stock assessment of ling (*Genypterus blacodes*) on the Bounty Plateau and in Cook Strait for the 2007–08 fishing year. Final Research Report for Ministry of Fisheries Research Project LIN2005-01, Objective 3. 51 p. (Unpublished report held by Ministry for Primary Industries, Wellington.)

Horn, P.L. (2008). Stock assessment of ling (*Genypterus blacodes*) on the Chatham Rise, Campbell Plateau, and in Cook Strait for the 2007–08 fishing year. *New Zealand Fisheries Assessment Report 2008/24*. 76 p.

Horn, P.L. (2009). Stock assessment of ling (*Genypterus blacodes*) off the west coast of South Island for the 2008–09 fishing year. *New Zealand Fisheries Assessment Report 2009/16*. 42 p.

Horn, P.L.; Ballara, S.L. (2012). A descriptive analysis and CPUE from commercial fisheries for ling (*Genypterus blacodes*) in Fishstocks LIN 2, 3, 4, 5, 6, and 7 from 1990 to 2009. *New Zealand Fisheries Assessment Report 2012/13*. 69 p.

Horn, P.L.; Sutton, C.P. (2010). Catch-at-age for hake (*Merluccius australis*) and ling (*Genypterus blacodes*) in the 2008–09 fishing year and from trawl surveys in summer 2009–10, with a summary of all available data sets. *New Zealand Fisheries Assessment Report 2010/30.* 52 p.

Horn, P.L.; Harley, S.J.; Ballara, S.L.; Dean, H. (2000). Stock assessment of ling (*Genypterus blacodes*) around the South Island (Fishstocks LIN 3, 4, 5, 6, and 7). *New Zealand Fisheries Assessment Report 2000/37*. 70 p.

Langley, A.D. (2001). Summary of biological data collected by the ling longline logbook programme, 1994–95 to 1999–2000. *New Zealand Fisheries Assessment Report 2001/71*. 37 p.

Appendix A: Summary residual plots and fits for the MPD Base model run for Cook Strait ling

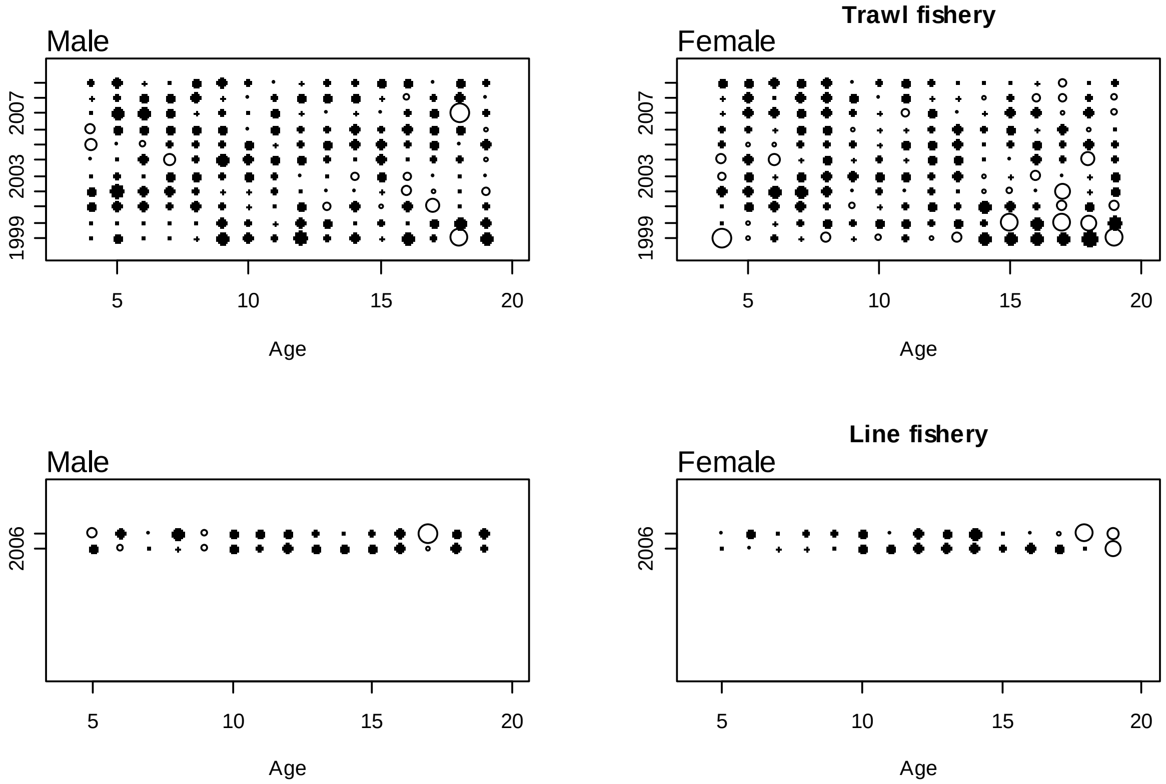

Figure A1: MPD residual values for the proportions-at-age data for the commercial trawl (top two panels) and commercial line (bottom two panels) fishery series. Symbol area is proportional to the absolute value of the residual, with black circles indicating positive residuals and open circles indicating negative residuals.

Figure A2: MPD model fits to the proportion-at-age data from the commercial line fishery. o, observed data; e, expected value.

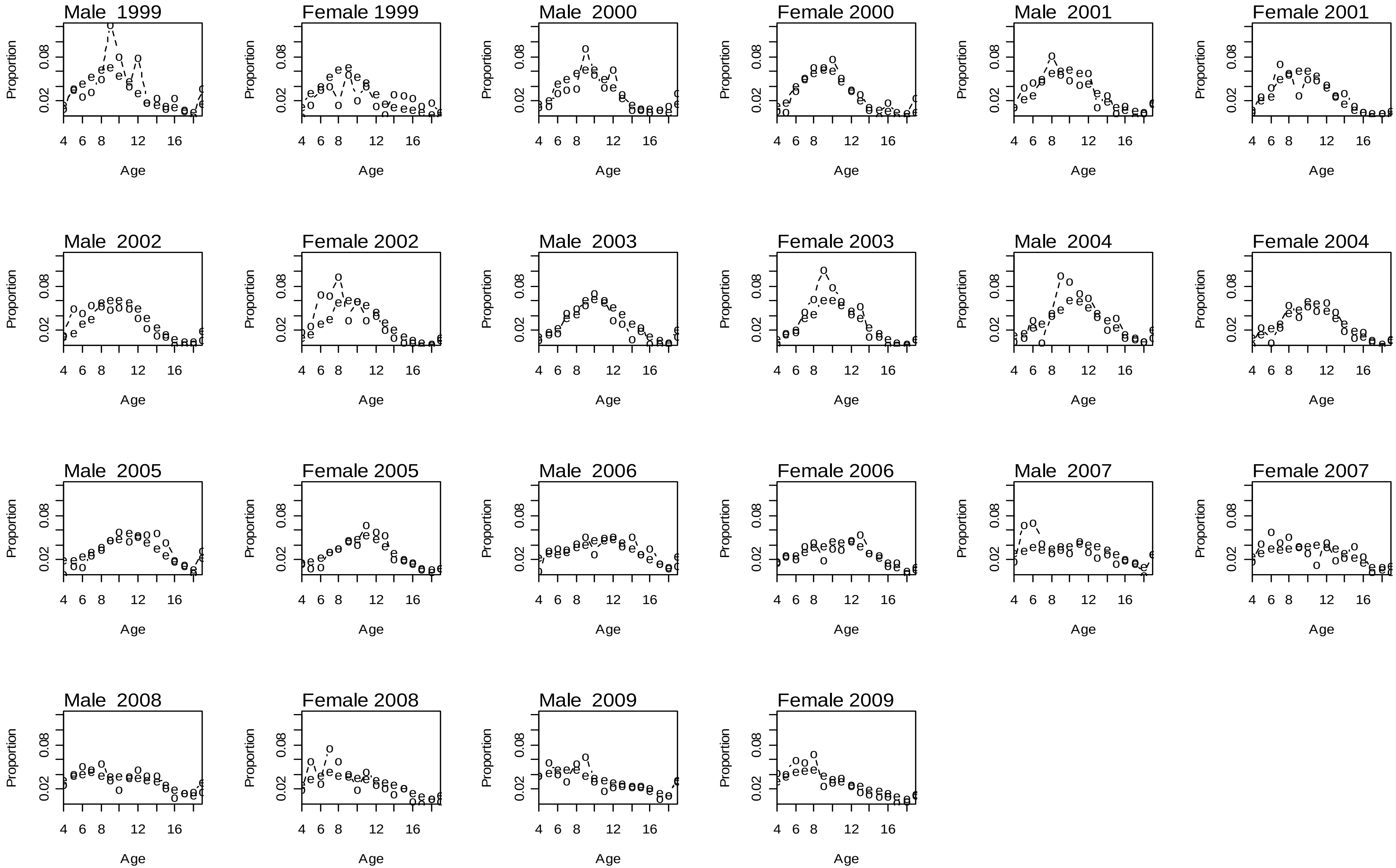

Figure A3: MPD model fits to the proportion-at-age data from the commercial trawl fishery. o, observed data; e, expected value.

Appendix B: Estimated catch at age for ling from the Cook Strait trawl fishery in 2010

These data are the results from project MID200701C, objective 6. The trawl fishery in Cook Strait is analysed using a single area stratum (i.e., those parts of FMAs 2, 7, and 8 between 41° and 42° S and 174° and 175.4° E), and a time stratum of 1 June to 30 September.

Table B1 summarises the quantities of data used each year to produce the catch at age distributions, and also lists the resulting mean weighted c.v.s. The details of the estimated catch at age distribution for Cook Strait trawl-caught ling in the 2009–10 fishing year are given in Table B2. The mean weighted c.v. of 37.1% was higher than the target value of 30%. However, this value cannot be improved as all available length data and otoliths were used in the analysis. Estimated proportion at age distributions from the Cook Strait trawl fishery from the last five years are presented in Figure B1.

Table B1: Numbers of measured and aged male and female ling, and the number of sampled tows and estimated mean weighted c.v. (%) by age, for the Cook Strait trawl fishery.

	Males		Females			Mean c.v.
Year	Measured	Aged	Measured	Aged	Tows	
1999	226	75	189	54	59	47.9
2000	197	95	191	93	62	40.9
2001	610	205	550	208	72	24.5
2002	583	219	644	241	58	27.9
2003	430	282	437	308	56	24.2
2004	609	269	645	241	48	27.2
2005	617	272	561	264	75	26.4
2006	729	248	539	226	26	26.4
2007	327	143	300	137	19	42.0
2008	569	280	470	226	44	27.0
2009	241	180	219	164	62	33.4
2010	274	195	250	196	41	37.1

Table B2: Calculated numbers at age, separately by sex, with c.v.s, for ling caught during commercial trawl operations in Cook Strait during June–September 2010.

Age	Male	c.v.	Female	c.v.
3	0	–	267	1.336
4	946	0.534	767	0.584
5	1 684	0.292	2 274	0.304
6	1 532	0.379	1 360	0.342
7	828	0.454	1 202	0.402
8	825	0.360	1 065	0.353
9	1 301	0.340	758	0.379
10	856	0.419	595	0.469
11	704	0.447	937	0.417
12	556	0.461	753	0.571
13	307	0.635	695	0.502
14	465	0.531	337	0.680
15	685	0.504	636	0.473
16	309	0.731	33	1.515
17	372	0.794	33	1.793
18	253	1.043	0	–
19	169	1.197	122	1.077
20	255	0.810	0	–
21	0	–	0	–
22	101	1.406	34	1.750
23	0	–	184	1.221
24	0	–	0	–
25+	184	1.174	60	1.282

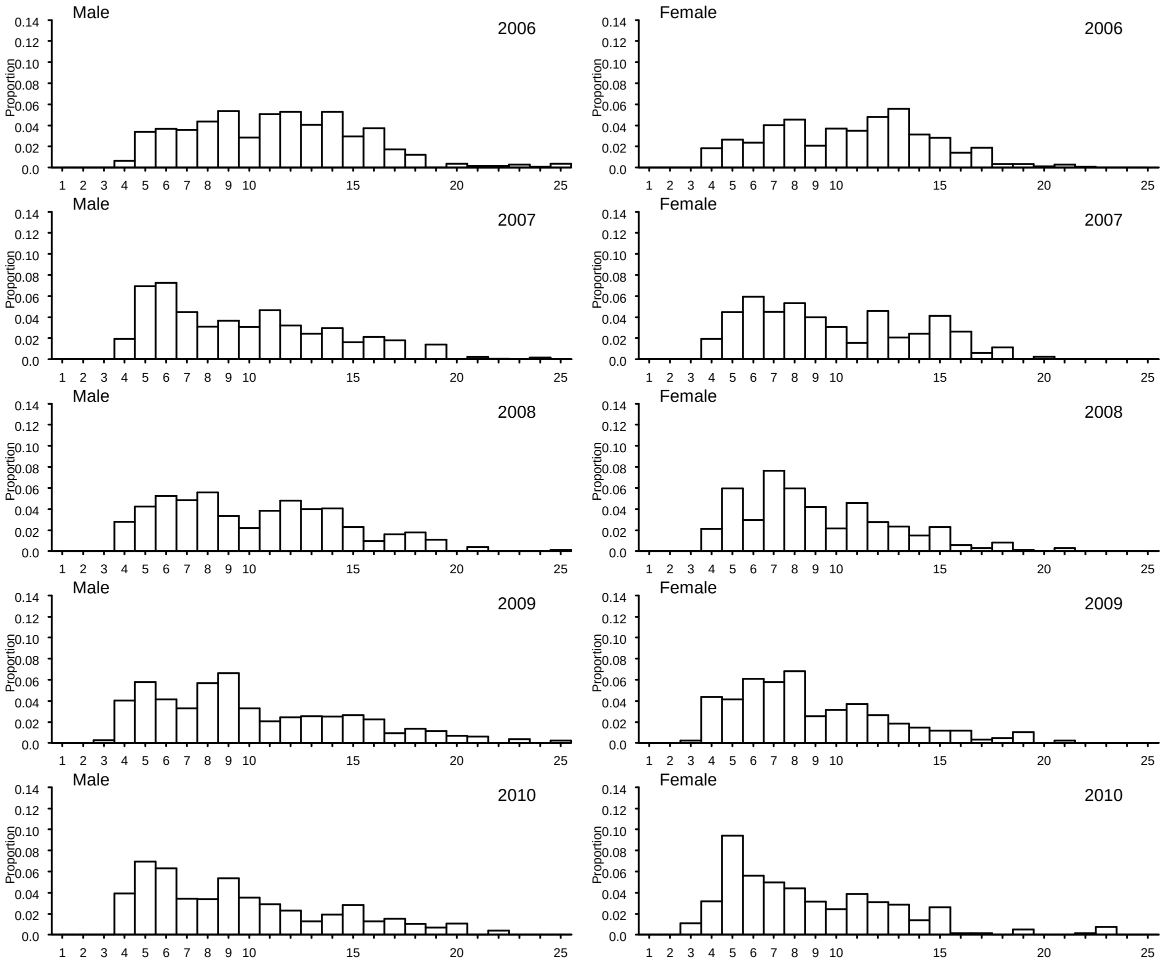

Figure B1: Available age frequencies of ling from commercial catch-at-age data in the Cook Strait trawl fishery, 2006 to 2010.