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Stock assessment of ling (*Genypterus blacodes*) off the west coast of South Island for the 2008–09 fishing year

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EXECUTIVE SUMMARY

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Ling in QMAs 3–7 and part of QMA 2 are treated as five biological stocks for assessment: 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 subsequently referred to as LIN 3&4, LIN 5&6, LIN 6B, LIN 7WC, and LIN 7CK, respectively.

New model input data for all stocks are reported here. Updated Bayesian assessments are presented for the LIN 7WC stock, using the general-purpose stock assessment program CASAL v2.21. The assessment incorporated all relevant biological parameters, the commercial catch histories, updated trawl survey biomass and CPUE series, a series of catch-at-length data from the trawl surveys, and series of catch-at-age and catch-at-length 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 7WC is very uncertain. Results of nine model runs are presented; two produce unrealistically high biomass estimates, but the others are potentially realistic. The assessment is driven by a long series of trawl fishery catch-at-age data, and the fishery selectivity ogives. The trawl survey data or the trawl CPUE provide little information to the model or have trends that are not in conflict with the dominant signal from the trawl catch-at-age series. The line CPUE series appears to be misleading, and is indicative of hyper-stable catches in that fishery. There is still no clearly reliable series of relative abundance indices available for the LIN 7WC stock. Varying M between 0.18 and 0.22 has a relatively slight influence on estimated stock status. The assessment is moderately sensitive to changes in the fishery ogives, and there are some problems with these. The line fishery ogive is very poorly known (being based on only one year of catch-at-age data), and the trawl fishery ogive has unexpectedly high ages at maximum selectivity. Confidence in the assessment will not be achieved until we have confidence in the ogives.

All the realistic model runs are indicative of a current biomass greater than 40% B_0 and an increasing stock size over the next few years (owing to recruitment into the fishery of some relatively strong year classes). This information, along with a relatively constant catch history since 1989 and trawl catch-at-age distributions from recent years that are similar to those taken by the fishery in the early 1990s, suggests that there are no current sustainability issues for the WCSI ling stock. However, none of the biomass estimates were considered reliable enough to warrant the estimation of any yields. It is not known whether the TACC or current catch levels 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.

1. INTRODUCTION

This document reports the results of Objective 3 of Ministry of Fisheries Project LIN2007-01. 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 2006–07 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 (2009).

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 Campbell Plateau (including the Stewart-Snares shelf and Puysegur Bank), the Bounty Platform, the west coast of the South Island, and Cook Strait.

In the stock assessment process, the same five biological stocks of ling are recognised, and are defined as follows: 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 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 2006). 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 7WC was the Fishstock chosen for full assessment. However, input files for all stocks were updated where possible (i.e., catch histories, CPUE series, catch-at-age, and catch-at-length).

The current assessment used CASAL v2.21, a generalised age- or length-structured fish stock assessment model (Bull et al. 2005). The LIN 7WC assessment incorporates trawl survey biomass and proportion-at-length data, catch-at-age and catch-at-length data from line and trawl fisheries, and line and trawl fishery CPUE series.

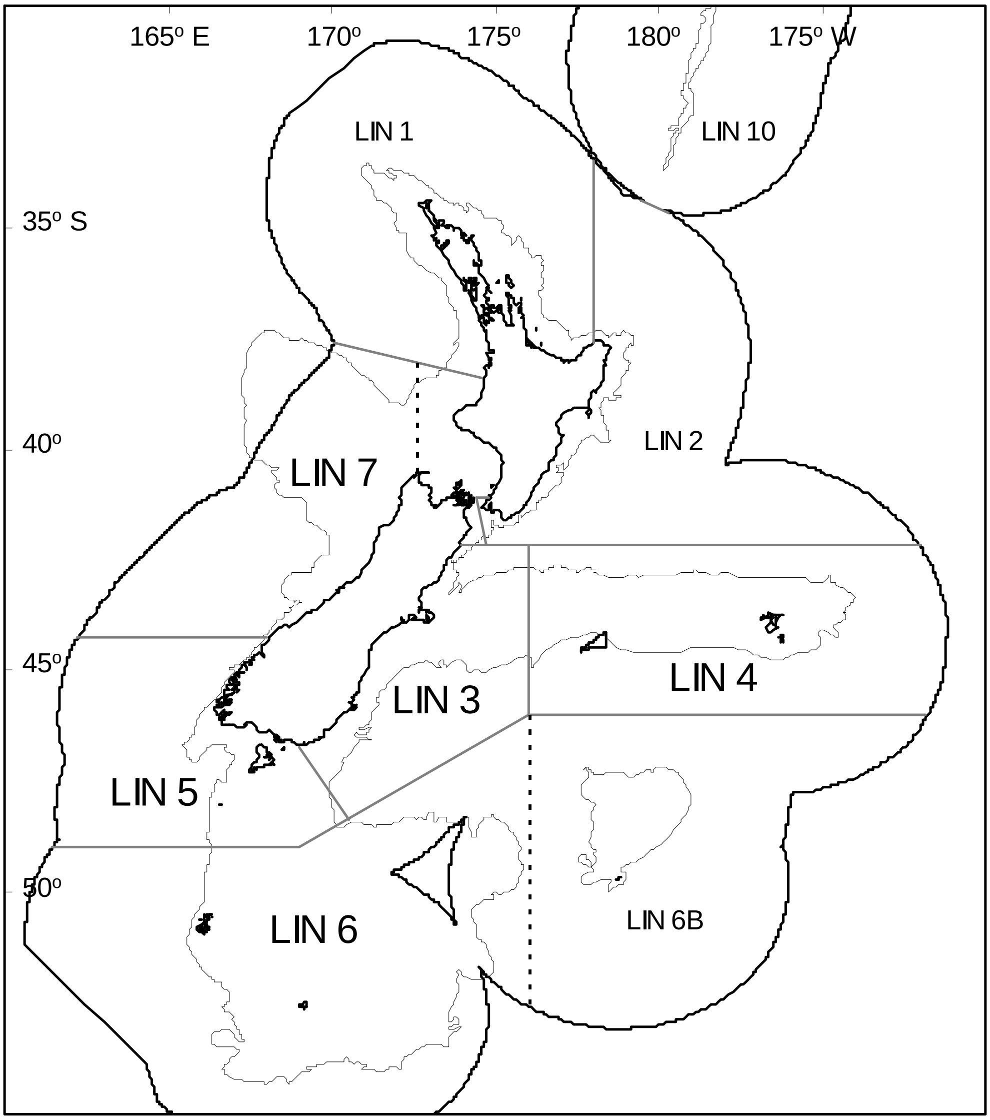

Figure 1: Area of Fishstocks LIN 3, 4, 5, 6, and 7. Adjacent ling fishstock areas are also shown, as is the 1000 m isobath. The boundaries used to separate biological stock LIN 6B from the rest of LIN 6, and the west coast South Island section of LIN 7 from the rest of LIN 7, are shown as broken lines.

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 follows an assessment (Horn 2004) indicating that the level of exploitation during the 1990s had little impact on the size of the Campbell Plateau 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 2006–07 and actual TACCs (t) from 1986–87 to 2006–07. 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

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

* 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 (2008). All the samples extend existing series of catch-at-age data.

LIN 3&4: Trawl survey (TAN0801), Jan 2008
LIN 3&4: Commercial longline, Jul–Oct 2007
LIN 3&4: Commercial trawl, Nov 2006 – May 2007
LIN 5&6: Trawl survey (TAN0714), Dec 2007
LIN 5&6: Commercial longline (Puysegur spawning fishery), Oct–Dec 2006
LIN 5&6: Commercial trawl, Nov 2006 – May 2007
LIN 7 (WCSI): Commercial trawl, Jun–Sep 2007
Cook Strait: Commercial trawl, Jun–Sep 2007
Cook Strait: Commercial longline, Jun–Sep 2007

A single catch-at-age distribution was also estimated for the WCSI line fishery. The length data were derived from three observed trips (in June 2003 and June 2004). A total of 271 ling had been measured and sexed, and the length-frequency from both years combined was applied to an age-length key comprising the trawl fishery age data from winter 2003 and 2004 combined. It is not ideal to use trawl-caught age data to estimate line fishery catch-at-age, or to combine data from two distinct years. However, these were the only available data considered reliable enough to enable a selectivity ogive to be developed in the assessment modelling of the LIN 7WC stock. Some additional length-frequency data were available from the SeaFIC logbook scheme; they are described below in Section 3.2.

A set of 15 catch-at-age distributions is available for ling caught in the trawl fishery for hoki off WCSI (i.e., 1991, and 1994 to 2007). Interestingly, when all the distributions are combined (Figure 2), there is an indication that the left-hand limbs of the selectivity ogives for both sexes are not smooth. For example, for females, it seems likely that 7-year-old fish are less selected, and/or 8-year-old fish are more selected, than would be expected. Consequently, it would be appropriate to complete a model run fitting all-values ogives to the trawl fishery catch-at-age data.

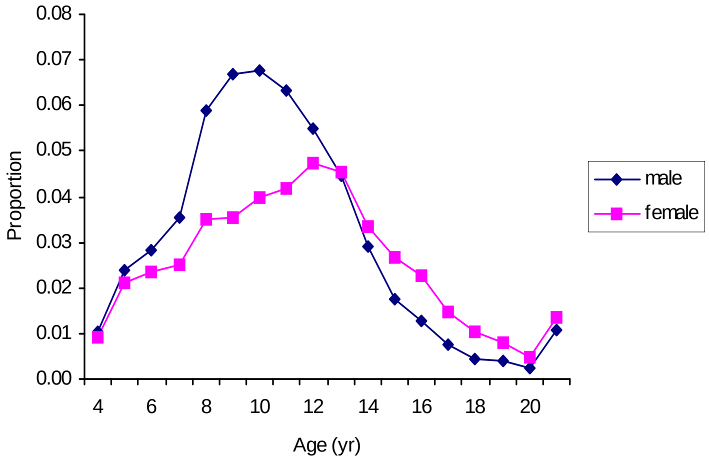

Figure 2: Frequency distributions, by sex, of all catch-at-age data from the LIN 7WC trawl fishery.

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 are included in the stock assessment model 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 (i.e., LIN 3&4 Nov–May, LIN 5&6 Sep–Apr, LIN 7WC Jun–Sep, 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 could be updated.

Some length-frequency data from the LIN 7WC line fishery are available. Data derived from three observed trips were converted into a single catch-at-age distribution (see Section 3.1). Additional length data were collected under the SeaFIC logbook scheme from 16 trips between October 2005 and July 2007. Although most of the logbook fish were sexed there is doubt about some of the determinations; some small females may have been classified as males. Also, some samples were measured into 5 cm or 10 cm bins, and it was not certain how the binned measurements had been made (i.e., was the recorded length to the nearest 5 cm unit, or to the 5 cm unit below actual size). Consequently, the data in 10 cm bins (from five trips) were not used. The remaining data (729 measurements) were combined into 5 cm bins to produce catch-at-length distributions, by sex, that were attributed to the 2006 model year. These data contributed to the estimation of age-based selectivity ogives for the LIN 7WC line fishery. It appears that the trawl fishery takes a greater proportion of smaller fish than the line fishery, and the line fishery selects a greater proportion of larger fish (Figure 3). Similar trends are apparent in other ling stocks where both trawl and line fisheries take significant quantities of ling.

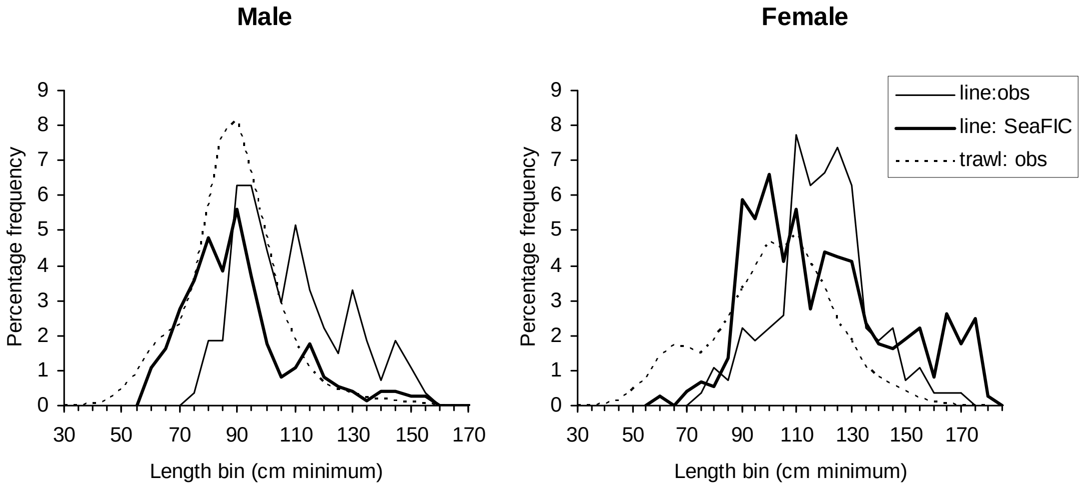

Figure 3: Comparison of unscaled length-frequency distributions from the LIN 7WC line fishery (observer data from 2003 to 2004, *n* = 271; SeaFIC data from 2005 to 2007, *n* = 729) and trawl fishery (data from 1991 to 2007, *n* = 32 742).

3.3 WCSI trawl survey biomass

A series of inshore trawl surveys using RV *Kaharoa* have been conducted off WCSI between Farewell Spit and the Haast River mouth, and within Tasman and Golden Bays, sampling at depths between 20 and 400 m (Stevenson & Hanchet 2000). The series began in March-April 1992, and has been conducted every one to three years since then. Estimates of ling biomass from these surveys are listed in Table 7. It is clear that because of the depths surveyed, this series will be indexing only a small proportion of the ling biomass off WCSI. However, the estimates of biomass and the scaled length-frequency distributions are used as inputs in the assessment modelling below.

A combined acoustic and trawl survey of the hoki fishing grounds off WCSI was conducted in winter 2000 using RV *Tangaroa* (O'Driscoll et al. 2004). The acoustics component of the survey covered depths between 300 and 650 m, from 40° 45' S to about 43° 20' S (Figure 4). However, the random bottom trawl component of the survey covered only the two strata north of the Hokitika Trench (i.e., north of about 42° 24' S). The bottom trawl gear used was the same as is used in the trawl surveys of hoki and middle depth species on the Chatham Rise and Campbell Plateau. Hence, trawl catching ability for ling from the surveys in all three areas would be expected to be quite similar.

While the estimate of ling biomass from strata 1, 2, and 4 is relatively precise (i.e., 1454 t with a c.v. of 17%), ling from the WCSI stock are clearly distributed to the north and south of the surveyed area, and also inshore of the 300 m contour (Horn 2007a). It was estimated that the area of seabed between 200 and 650 m depth in the LIN 7WC stock area, excluding the Challenger Plateau (see Figure 1), is about 20 100 km^2. This is three times the area that was surveyed using bottom trawl in the 2000 survey (i.e., 6619 km^2). Consequently, the estimated biomass from strata 1, 2, and 4 was input into the model using appropriate priors on trawl *q* to account for the unsurveyed area (see Section 4.4).

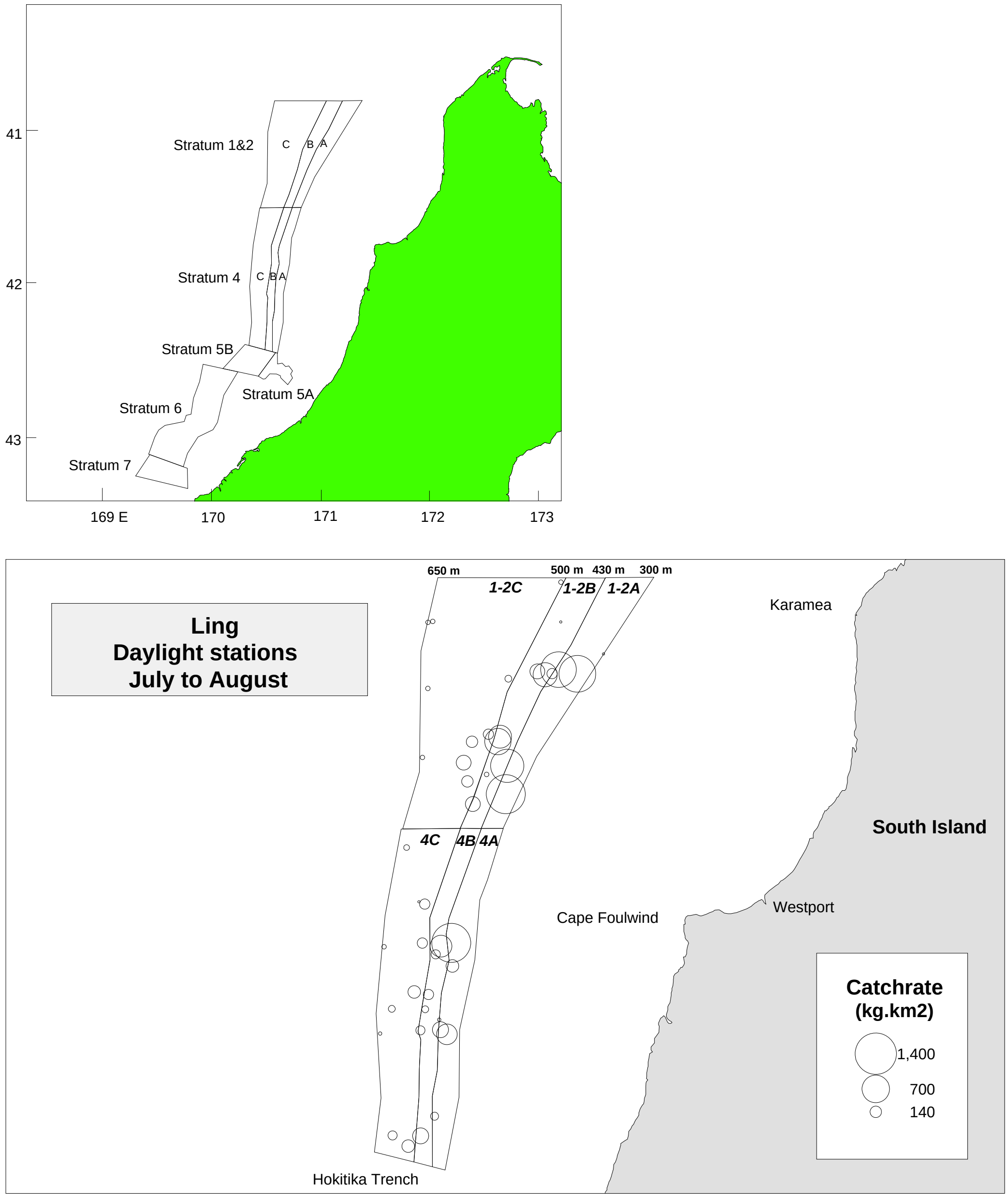

Figure 4: Stratum boundaries for the 2000 acoustic survey of hoki off WCSI, and the catch rates of ling in daytime random bottom trawls carried out in Strata 1&2 and 4 (from O'Driscoll et al. 2004).

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 2009) 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 7WC, 15 years of commercial trawl catch-at-age data, and one year of commercial line catch-at-age data were available. For LIN 3&4, LIN 5&6, LIN 6B, and LIN 7CK, various series of catch-at-age and catch-at-length data from the commercial trawl and longline fisheries were available. 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).

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/length, or b) numbers-at-age/length. For the ling assessments the preference was for a), i.e., entering trawl survey biomass and trawl survey proportions-at-age/length 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. A summary of all available sets of catch-at-age data is given in Appendix B.

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 2008 values are required for the current assessment; they are set equal to the current TACC, split between fisheries 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	–	–	–	–	–	–	1 225	800	–	–

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
LIN 7WC (current assessment)	0.22	0.22

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) CPUE year effects for the ling target line fisheries on the Chatham Rise, Campbell Plateau, Bounty Plateau, and WCSI. –, insufficient data to calculate a useful index.

Year	Unstd	Std	95% CI	c.v.	Unstd	Std	95% CI	c.v.
			Chatham Rise (LIN 3&4)				Campbell Plateau (LIN 5&6)	
1990	0.24	2.11	1.83–2.44	0.07	–	–	–	–
1991	0.49	1.54	1.41–1.68	0.04	0.82	0.90	0.73–1.11	0.10
1992	1.74	2.01	1.83–2.20	0.05	0.86	1.22	1.04–1.42	0.08
1993	1.52	1.48	1.36–1.60	0.04	0.77	1.30	1.12–1.51	0.08
1994	1.45	1.42	1.32–1.53	0.04	0.74	0.95	0.84–1.09	0.07
1995	2.17	1.41	1.31–1.53	0.04	1.15	1.29	1.13–1.48	0.07
1996	1.85	1.18	1.10–1.28	0.04	1.08	1.04	0.91–1.19	0.07
1997	1.08	0.83	0.77–0.89	0.03	1.07	1.20	1.08–1.33	0.05
1998	1.13	0.80	0.74–0.87	0.04	0.93	0.99	0.90–1.10	0.05
1999	0.82	0.70	0.65–0.75	0.04	0.86	0.83	0.75–0.92	0.05
2000	1.14	0.81	0.75–0.88	0.04	1.04	0.97	0.86–1.09	0.06
2001	1.76	0.80	0.74–0.87	0.04	1.21	1.09	0.96–1.24	0.07
2002	1.01	0.69	0.64–0.74	0.04	1.22	1.07	0.93–1.24	0.07
2003	1.21	0.85	0.78–0.93	0.04	0.79	0.81	0.68–0.96	0.09
2004	0.94	0.70	0.65–0.76	0.04	0.78	0.73	0.63–0.85	0.07
2005	0.61	0.77	0.72–0.84	0.04	1.11	0.84	0.69–1.01	0.10
2006	0.60	0.64	0.59–0.70	0.04	1.27	0.89	0.74–1.07	0.09
2007	0.61	0.71	0.65–0.78	0.04	1.73	1.10	0.89–1.36	0.11
			Bounty Plateau (LIN 6B)				WCSI (LIN 7WC)	
1990	–	–	–	–	0.63	0.90	0.80–1.03	0.06
1991	–	–	–	–	0.79	1.16	1.05–1.29	0.05
1992	1.05	1.80	1.40–2.32	0.13	0.90	1.15	1.05–1.26	0.05
1993	0.97	1.58	1.28–1.96	0.11	1.03	0.92	0.84–1.02	0.04
1994	0.85	1.07	0.82–1.41	0.13	1.06	0.93	0.85–1.02	0.04
1995	1.11	1.13	0.87–1.47	0.13	1.06	0.96	0.88–1.04	0.04
1996	0.90	1.05	0.83–1.33	0.12	0.93	0.79	0.73–0.86	0.04
1997	0.81	0.85	0.66–1.11	0.13	1.03	0.87	0.80–0.94	0.04
1998	1.42	1.03	0.80–1.32	0.12	1.29	0.97	0.89–1.05	0.04
1999	1.33	1.04	0.84–1.30	0.11	1.14	1.04	0.96–1.14	0.04
2000	1.23	0.95	0.79–1.16	0.10	1.10	1.00	0.91–1.09	0.04
2001	0.96	0.81	0.67–0.99	0.10	1.19	1.14	1.05–1.25	0.04
2002	0.94	0.72	0.60–0.88	0.10	1.02	1.10	1.00–1.21	0.05
2003	1.05	0.78	0.66–0.94	0.09	1.01	1.14	1.04–1.25	0.04
2004	1.05	0.71	0.54–0.94	0.14	1.03	1.13	1.02–1.25	0.05
2005	–	–	–	–	0.88	0.86	0.79–0.94	0.04
2006	0.61	0.97	0.48–1.94	0.36	0.90	0.89	0.81–0.99	0.05
2007	–	–	–	–	1.26	1.15	1.05–1.26	0.04
			Cook Strait (LIN 7CK)					
1990	0.69	0.71	0.52–0.97	0.15				
1991	0.47	1.07	0.82–1.38	0.13				
1992	0.56	1.09	0.87–1.36	0.11				
1993	0.43	0.78	0.63–0.98	0.11				
1994	0.28	0.69	0.56–0.85	0.10				
1995	0.34	0.64	0.51–0.81	0.12				
1996	0.49	0.76	0.59–0.99	0.13				
1997	0.60	1.01	0.70–1.45	0.18				
1998	0.48	0.69	0.52–0.94	0.15				
1999	3.43	1.23	0.85–1.79	0.19				
2000	1.75	1.41	0.98–2.05	0.19				
2001	2.72	1.27	0.85–1.90	0.20				
2002	1.69	1.85	1.48–2.32	0.11				
2003	1.33	1.63	1.32–2.03	0.11				
2004	1.39	1.35	1.10–1.66	0.10				
2005	1.42	1.14	0.91–1.42	0.11				
2006	5.60	0.92	0.66–1.28	0.17				
2007	2.28	0.69	0.53–0.90	0.13				

Table 6: Unstandardised (Unstd) and standardised (Std, with 95% confidence intervals and c.v.s) CPUE year effects for the ling bycatch in the Cook Strait hoki target trawl fishery, and lognormal (Logn), binomial (Bino), and combined (with c.v.s) year effects from theWCSI hoki target trawl fishery. See Horn (2009) for further information on the derivation of these series.

	Cook Strait (LIN 7CK)				LIN 7WC (combined model)			
Year	Unstd	Std	95% CI	c.v.	Logn	Bino	Combined	c.v.
1990	2.06	2.11	1.91–2.34	0.05			–	
1991	1.51	1.75	1.62–1.89	0.04			–	
1992	1.36	1.53	1.40–1.67	0.04			–	
1993	1.51	1.62	1.48–1.75	0.04			–	
1994	1.14	1.04	0.96–1.11	0.04			–	
1995	0.98	0.87	0.82–0.93	0.03			–	
1996	0.98	0.87	0.82–0.92	0.03			–	
1997	0.84	0.75	0.71–0.79	0.03			–	
1998	0.82	0.78	0.73–0.82	0.03			–	
1999	0.74	0.77	0.73–0.81	0.03	1.43	1.21	1.26	0.10
2000	0.75	0.86	0.82–0.91	0.03	1.23	1.04	1.20	0.09
2001	0.80	0.98	0.92–1.04	0.03	1.09	1.00	1.08	0.07
2002	0.97	1.01	0.94–1.08	0.04	0.97	1.27	0.83	0.06
2003	0.99	1.05	0.99–1.12	0.03	0.93	0.99	0.93	0.06
2004	0.89	0.84	0.79–0.90	0.03	1.03	1.29	0.87	0.07
2005	0.85	0.80	0.74–0.85	0.03	0.90	0.91	0.94	0.07
2006	0.85	0.79	0.73–0.85	0.04	0.82	0.77	0.95	0.07
2007	0.76	0.65	0.60–0.71	0.04	0.76	0.69	0.93	0.08

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
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

(*continues*)

Table 7 ctd.

Fishstock	Area	Trip code	Date	Biomass (t)	c.v. (%)
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

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)	1992–2008	
Trawl survey proportion at age (*Tangaroa*, Jan)	1992–2008	
CPUE (longline, all year)	1990–2007	
Commercial longline proportion-at-age (Jul–Oct)	2002–07	
Commercial longline length-frequency (Jul–Oct)	1995–2006	
Commercial trawl proportion-at-age (Nov–May)	1992, 1994–2007	
LIN 5&6		
Trawl survey proportion at age (*Amaltal Explorer*, Nov)	1990	
Trawl survey biomass (*Tangaroa*, Nov–Dec)	1992–94, 2001–08	
Trawl survey proportion at age (*Tangaroa*, Nov–Dec)	1992–94, 2001–08	
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)	1991–2007	
Commercial longline length-frequency (Puysegur, Oct–Dec)	1993, 96, 1999–2006	
Commercial longline proportion-at-age (Puysegur, Nov–Dec)	2000–07	
Commercial longline length-frequency (Campbell, Apr–Jul)	1998–2005	
Commercial longline proportion-at-age (Campbell, Jun)	1999, 2001, 2003, 2005	
Commercial trawl proportion-at-age (Jan–Jul)	1992–94, 1996, 1998, 2001–07	
LIN 6B		
CPUE (longline, all year)	1992–2004, 2006	
Commercial longline proportion-at-age (Nov–Feb)	1993, 2000–01, 2004	
Commercial longline length-frequency (Nov–Feb)	1996, 2000–2004	
LIN 7CK		
CPUE (hoki trawl, all year)	1990–2007	
CPUE (longline, all year)	1990–2007	
Commercial trawl proportion-at-age (May–Sep)	1999–2007	
Commercial longline proportion-at-age (May–Sep)	2006–2007	
Commercial longline length-frequency (May–Sep)	2001–2004	
LIN 7WC		
CPUE (hoki trawl, Jun–Sep)	1999–2007	0.2
CPUE (longline, all year)	1990–2007	0.2
Commercial trawl proportion-at-age (Jun–Sep)	1991, 1994–2007	0.25
Commercial longline proportion-at-age	2003	0.15
Commercial longline length-frequency	2006	0.25
Trawl survey biomass (*Kaharoa*, Mar–Apr)	1992, 94, 95, 97, 2000, 03, 05, 07	0.3
Trawl survey proportion-at-length (*Kaharoa*, Mar–Apr)	1992, 94, 95, 97, 2000, 03, 05, 07	0.35
Trawl survey biomass (*Tangaroa*, July)	2000	0.2

4.2 Model structure

The LIN 7WC stock was assessed in 2008. The stock assessment model partitions the WCSI population into sexes and age groups 3–28, with a plus group. There are two fisheries (trawl and longline). The model's annual cycle for the stock is described in Table 9.

Table 9: Annual cycles of the assessment model for the LIN 7WC stock, showing the processes taking place at each time step, their sequence within each time step, and the available observations of relative abundance. Any fishing and natural mortality within a time step occur after all other processes, with half of the natural mortality fraction for that time step occurring before and after the fishing mortality. An age fraction of 0.5 for a time step means that a 6+ fish is treated as being of age 6.5 in that time step. Trawl surveys and CPUE indices occur during the fishing time step. The last column (%*M*) shows the proportion of that time step's mortality that is assumed to have taken place when each observation is made (see Table 8 for descriptions of the observations).

					Observations	
Stock/Step	Approx. months	Processes	*M* fraction	Age fraction	Description	%*M*
LIN 7WC						
1	Oct–May	recruitment fishery (line)	0.75	0.5	Line CPUE Line catch-at-age/length *Kaharoa* survey series	0.5
2	Jul–Sep	increment ages fishery (trawl)	0.25	0	Trawl CPUE Trawl catch-at-age *Tangaroa* survey	0.5

The selectivity ogives for the commercial trawl and line fisheries and the *Kaharoa* trawl survey were age-based and were estimated in the model, separately by sex. The trawl survey and trawl fishery ogives were estimated using a double normal parameterisation. The estimated line fishery ogives were assumed to be logistic. In one model run an 'all-values' ogive (allowing independent selectivity values for each age) was fitted to the trawl fishery data. In all cases, male selectivity curves were estimated relative to female selectivity. The parameterisations of the double normal, logistic, and all-values curves were given by Bull et al. (2005). In each fishery, 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.

4.3 Model estimation

Model parameters were estimated using Bayesian estimation implemented using the CASAL v2.21 software (Bull et al. 2005). 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.

Lognormal errors, with known c.v.s, were assumed for all relative biomass, proportions-at-age, and proportions-at-length 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 and catch-at-length series was estimated in early runs of the model, using all available data, from MPD fits. 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) when inadequate (i.e., fewer than three data points) or no catch-at-age data were available for that year. Otherwise, year class strengths were estimated under the assumption that the estimates from the model must average 1. However, in biomass projections, the assumption that the recent unknown year class strengths were equal to 1 was relaxed. 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.

Yields were not calculated in this assessment as the estimates of biomass were considered to be too unreliable.

4.4 Prior distributions and penalty functions

The assumed prior distributions used in the assessment are given in Table 10. Most priors were intended to be relatively uninformed, and were specified with wide bounds. The exceptions were the choice of informative priors for the *Tangaroa* trawl survey *q*, and natural mortality (when estimated). The priors on *q* for the *Tangaroa* trawl surveys of the Chatham Rise and Sub-Antarctic 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 c.v. 0.70, with bounds assumed to be 0.02 to 0.30. However, the *Tangaroa* survey off WCSI is estimated to have covered only one-third of the likely ling habitat. Consequently, for this survey, the priors were a lognormal distribution with a mean of 0.043 (i.e., 0.13 × 0.33), c.v. of 0.7, and bounds of 0.01 to 0.20. The priors for natural mortality assumed that *M* varies between stocks, but is very probably between 0.1 and 0.3 for all stocks (following Horn 2008). Consequently, the chosen prior distribution was normal with a mean at 0.2 and a standard deviation that produced a relatively flat distribution between the bounds of 0.1 to 0.3.

Table 10: Assumed prior distributions and bounds for estimated parameters in the assessments. 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	–	–	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
Kaharoa survey *q*	uniform-log	–	–	0.001	10
CPUE *q*	uniform-log	–	–	1e-8	1e-3
Selectivities	uniform	–	–	0	20–200*
Process error c.v.	uniform-log	–	–	0.001	2
M	normal	0.20	0.07	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. A penalty was applied to the all-values ogives to encourage their right-hand limbs to approximate a third order polynomial.

5. MODEL ESTIMATES

Estimates of spawning stock biomass and year class strengths were derived for the LIN 7WC stock using the fixed parameters (see Table 4) and the series of input data (see Table 8) described earlier. A selection of models was run for each stock. For each model run, MPD fits were obtained and quantitatively evaluated; objective function values (negative log-likelihood) for these are presented. MCMC estimates of the posterior distributions were then obtained for all model runs.

Convergence diagnostics were run on MCMC chains of final length 4×10^6 iterations (following a burn-in period of 2×10^6 iterations), after systematically subsampling ("thinning") to 1000 samples. The Geweke (1992) convergence diagnostic is based on a test that compares the means of the first 10% and last 50% of a Markov chain. Under the assumption that the samples were drawn from the stationary distribution of the chain, the two means are equal and Geweke's statistic has an asymptotically standard normal distribution. The resulting test statistic is a standard Z-statistic, with the standard error estimated from the spectral density at zero. Values of the Z-statistic that have a *p*-value less than 0.05 indicate that, at the 5% significance level, there is evidence that the samples were not drawn from a stationary distribution. The test diagnostics were calculated using the Bayesian Analysis Output software (Smith 2005).

Heidelberger & Welch (1983) proposed two linked tests. The first is a stationarity test that uses the Cramer-von-Mises statistic to test the null hypothesis that the sampled values come from a stationary distribution. The test is successively applied, first to the whole Markov chain, then after discarding the first 10, 20, etc, percent of the chain until, either the null hypothesis is accepted, or 50% of the chain has been discarded. If more than 50% of the chain is discarded, then the test returns a failure of the stationarity test. Otherwise, the number of iterations to keep is reported. The second test is the half-width test that calculates a 95% confidence interval for the chain mean, using the portion of the chain that passed the Heidelberger & Welch stationarity test. Half the width of this interval is compared with the estimate of the mean. If the ratio between the half-width and the mean is lower than 2% of the mean, the half width test is passed.

For LIN 7WC several model runs were completed as follows.

- Estimate *M* — catch history, trawl and line fishery catch-at-age, with double-normal ogives for the trawl fishery and logistic ogives for the line fishery, and estimating a single *M* for both sexes.
- Base case — the Estimate *M* model, but with *M* set constant at 0.22 for both sexes.
- *Tangaroa* survey — the base case model, but including the *Tangaroa* biomass estimate.
- All-values ogive — the base case model, but fitting all-values ogives to the trawl fishery catch-at-age data.
- Sensitivity for *M* — the base case model, but testing three different *M* values (i.e., *M* of 0.15, 0.18, and 0.20).
- CPUE — the base case model, but including both the trawl and line CPUE series.
- Trawl CPUE — the base case model, but including the trawl CPUE series only, and with no process error applied to this series.
- Two surveys — the base case model, but including the *Tangaroa* and *Kaharoa* biomass estimates, and the *Kaharoa* numbers-at-length data.

For each model run, MPD fits were obtained and quantitatively evaluated. Objective function values (negative log-likelihood) for the model runs are shown in Table 11. Summary plots of the residuals for the MPD model fits to the proportion-at-age series are presented in Appendix A. MCMC estimates of the posterior distributions were obtained for all model runs; some of these are presented below.

Convergence diagnostics for the model runs are given in Table 12. Trace diagnostics of B_0 from five of the model runs are shown in Figure 5. There are two clear groups of runs. One group has most B_0

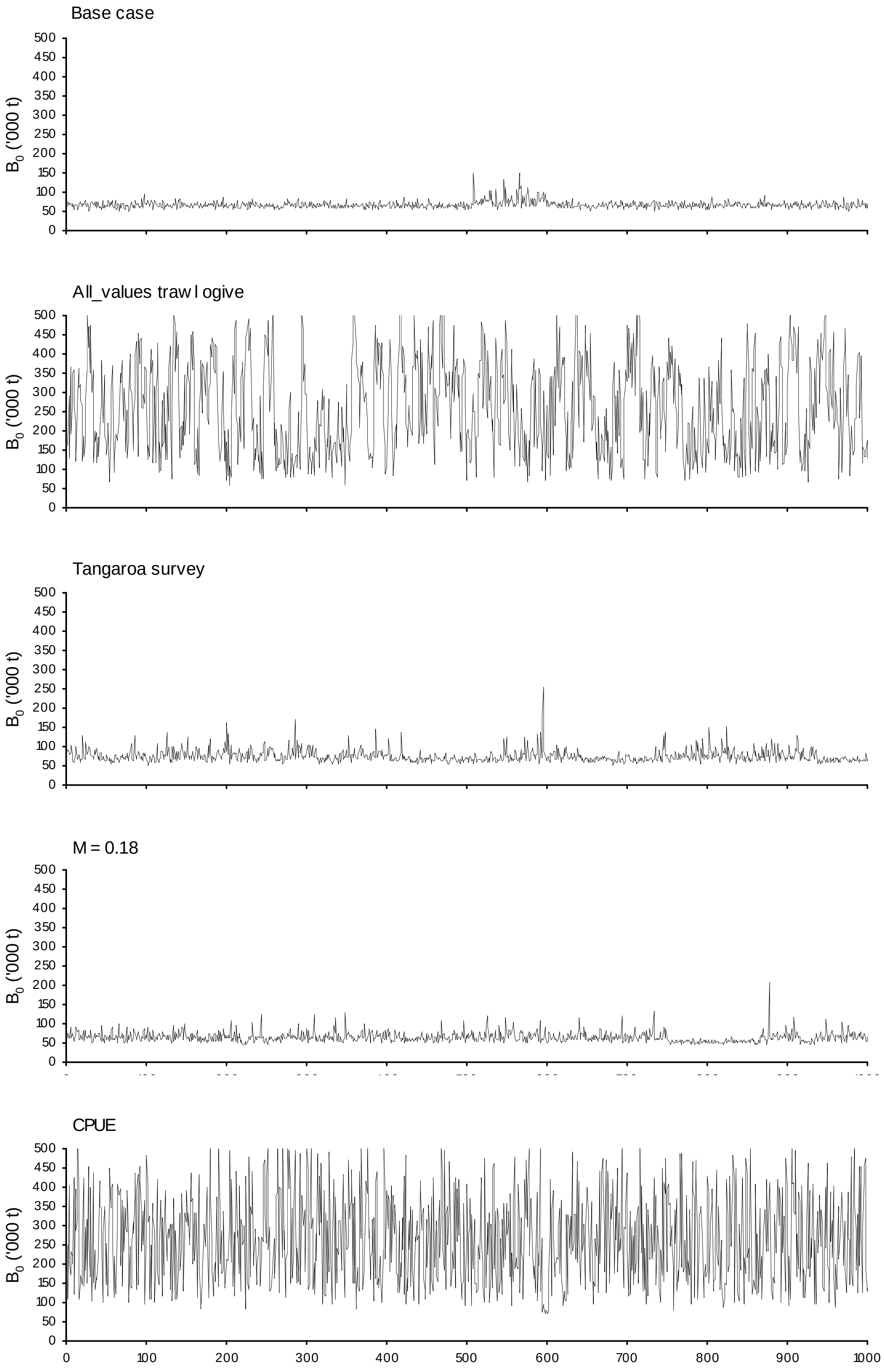

Figure 5: Trace diagnostic plots of the final sample MCMC chains for estimates of B_0 for selected LIN 7WC model runs.

values in the range 50 000–100 000 t, with little evidence of a lack of convergence. The other group has widely varying B_0 estimates from about 100 000 to 450 000 t. No evidence of lack of convergence was found in the estimates of B_0 from any of the model runs (Table 12). Most estimates of YCS and selectivity parameters appeared to have converged in all model runs. The estimate of *M* exhibited convergence under the stationarity and half width tests, but not the Geweke test.

The posterior distribution of the estimate of instantaneous natural mortality (*M*), shown in Figure 6, had a median value of 0.22, with a 95% confidence interval of 0.15 to 0.29. The posterior distribution is clearly limited by the upper bound on the prior. *M* was set at 0.22 for both sexes in all subsequent model runs (except those testing the sensitivity of the model to changes in *M*).

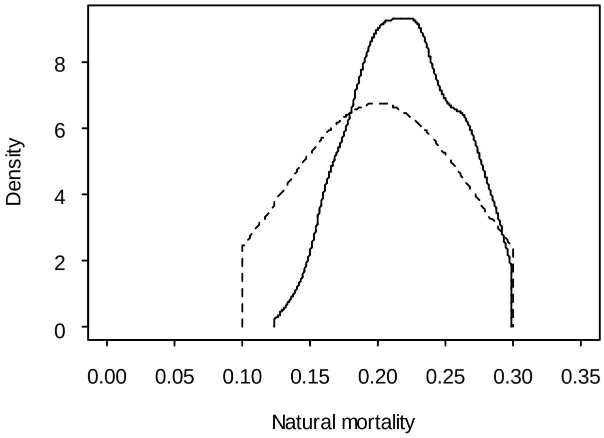

Figure 6: Estimated posterior distribution (solid line) of instantaneous natural mortality (*M*), and distribution of priors (broken line), from the Estimate *M* run.

Table 11: Objective function values (negative log-likelihood) for MPD fits to data, priors, penalties resulting from penalties to catch (Catch), to year class strengths averaging to one (YCS), and to smoothing the all-values ogives (Ogive), and the total objective function (negative log-likelihood) value.

Model run	Data			Priors	Penalties		Total
	Survey	Catch-at-age/length	CPUE		Catch & YCS	Ogive	
Estimate *M*	–	-121.0	–	3.4	0	–	-117.4
Base case	–	-119.1	–	4.5	0	–	-114.6
Tangaroa survey	-1.4	-119.1	–	1.0	0	–	-119.5
All-values ogive	–	-134.5	–	4.7	0	0.3	-129.4
M = 0.15	–	-120.7	–	3.2	0	–	-117.5
M = 0.18	–	-120.8	–	3.8	0	–	-117.0
M = 0.20	–	-120.1	–	4.2	0	–	-115.9
CPUE	–	-116.0	-35.6	-16.8	0	–	-168.4
Trawl CPUE only	–	-117.6	-14.8	-6.6	0	–	-139.0
Two surveys	-4.2	-72.4	–	-3.9	0	–	-80.5

Table 12: Percentage of parameters that passed the Geweke (1992) and Heidelberger & Welch (1983) convergence diagnostics tests for selected parameters from the MCMC chains. *n*, number of parameters estimated.

Stock	Model run	Parameter	*n*	Geweke (%)	Heidelberger & Welch (%)	
					Stationarity	Half width
LIN 7WC	Estimate *M*	B_0	1	100	100	100
		Selectivity	12	42	58	92
		YCS	30	87	90	100
		M	1	0	100	100
	Base case	B_0	1	100	100	100
		Selectivity	12	83	92	100
		YCS	30	87	90	100
	All-values ogive	B_0	1	100	100	100
		Selectivity	45	96	89	100
		YCS	30	97	100	100
	Tangaroa survey	B_0	1	100	100	100
		Selectivity	12	83	75	92
		YCS	30	97	100	100
	M = 0.15	B_0	1	100	100	100
		Selectivity	12	100	100	100
		YCS	30	80	83	100
	CPUE	B_0	1	100	100	100
		Selectivity	12	100	100	100
		YCS	30	100	100	100

The calculated ogives for the trawl and line fisheries are reasonably well estimated in the base case run (Figure 7). However, the male and female ogives for the trawl fishery differ in shape; the female ogive is essentially logistic, while selectivity declines with age after 13 years for males. The addition of any trawl survey data had little effect on the base case selectivity ogives. However, fitting the trawl fishery selectivity ogive using the all-values parameterisation resulted in a marked change in both the trawl and line fishery ogives (Figure 7). The steps in the younger section of the catch-at-age distributions (see Figure 2) are apparent in the new ogives. But more significantly, relative to the base case, age at peak selectivity in the trawl fishery reduces for both sexes (markedly so for females, from 16 to 12 years), and age at 50% selectivity in the line fishery reduces by about 2 years. Female selectivity in the trawl fishery declines with increasing age after the age of full selectivity (as occurs for males in this run and in the base case). The spread in the posterior distributions of selectivity at individual ages for the all-values ogive is greater than in the base case (particularly for females), indicating that the all-values ogives are not well estimated. It is clear that the differences in the ogives from the base case and all-values ogive models have a marked influence on absolute estimates of biomass (see Figure 5). Also, the relatively poorly estimated all-values ogives produce the wide variation in individual biomass estimates from that model run. Changes in *M* also have a moderate influence on the shape and location of the selectivity ogives. For the line fishery ogives, reductions in *M* simply shift the ogives to the left, but have little influence on their shape (i.e., a reduction in *M* from 0.22 to 0.18 reduces the age at 50% selectivity by 1.5 years for females and 2.5 years for males). For the trawl fishery ogives, reductions in *M* have a slight influence on the estimated ages at full selectivity, but do result in males being relatively more selected than females (Figure 8). There is no information outside the model that allows the shape of any of the fishery ogives to be verified.

The estimated selectivity ogives for the *Kaharoa* trawl survey are as would be expected for samples comprising mainly juvenile (age classes 1+ to 5+) fish, with peak selectivity occurring before age 3 and selectivity being close to zero by age 15 (Figure 9). However, the model fits to the survey proportion-at-length data are quite poor for some of the smaller (and most abundant) length classes (Appendix A, Figure A4).

The relative abundance series available for the WCSI stock are a single *Tangaroa* trawl survey index, a series of *Kaharoa* biomass indices, and trawl and line fishery CPUE indices. The estimated *Tangaroa* trawl q had a very tight distribution with a median at 0.025 (Figure 10). The *Kaharoa* trawl q had a similarly tight distribution, but a much lower median of 0.008 (Figure 10). Both q values are very low, particularly for the *Kaharoa* series, confirming that neither survey series is comprehensively sampling the WCSI ling population. The MPD fit to the *Kaharoa* biomass series is poor (Figure 11), but this is not surprising given that the individual indices varied widely and have relatively high c.v.s. Confidence in both the CPUE series is not great (Horn 2009), and neither series is well fitted by the CPUE model run (Figure 12). The trawl CPUE is indicative of a reasonable decline from 1999 to 2002 (which is not fitted by the model), while the line CPUE indicates a relatively constant (but rather variable) level of biomass throughout its entire series. The trend in the line series is in contradiction to the signal from the inputs to the base case model (i.e., a steady decline in biomass between 1990 and 2004), so to produce a reasonable fit to the line CPUE it is necessary to start with a relatively high level of biomass. To encourage a better fit to the trawl CPUE, the trawl CPUE only model fitted this series without any process error (Figure 13). A slightly steeper biomass decline than occurred in the base case was achieved, but overall changes in biomass were slight. The objective function values for the age and length data in both the CPUE models show that the inclusion of the CPUE data result in worse fits to the age and length data than in all but the two surveys model run (see Table 11).

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 all runs. The objective function values attributable to the catch-at-age and -length data are fairly robust over all but the two surveys model run (see Table 11).

Year class strengths were sometimes poorly estimated, particularly before about 1981 when only data from older fish were available, and since 2000 (Figure 14). Year class trends varied little across all model runs, and indicate generally below average YCS from 1980 to 1997, and above average from 2000 to 2003 (the last estimated year class). The only markedly different pattern of estimated YCS is produced in the two surveys model run, where the proportion-at-length data from the *Kaharoa* surveys series provides some additional data that changes the pattern of YCS since 1993 (Figure 14). Variation of the median estimated year class strengths is moderate for this stock; the medians range from 0.5 to 2.3.

Estimated exploitation rates were quite similar in all the model runs producing estimates of median B_0 in the range 62 000–71 000 t, with the rate seldom being more than 0.15 in any year for either fishery (Figure 15). Overall, exploitation rates were very low up to the late 1980s in the trawl fishery and early 1990s for the line fishery (except for two years of heavy foreign longline pressure in 1976–77). However, concurrent with the development of the hoki fishery, estimated fishing pressure on ling by the trawl fishery then steadily increased to peak about 2002, and has since declined. Estimated fishing pressure by the line fishery increased during the early-mid 1990s, but has been relatively constant since about 1996. As M is progressively reduced it has the effect of increasing the exploitation by the trawl fishery and decreasing the line fishery exploitation, as a consequence of the resulting changes in the estimated selectivity ogives (Figure 15).

Biomass trajectories from most of the model runs indicate a general decline from 1992, with a minimum biomass in 2005, and a slight recovery since then (Figure 16). Depending on the model inputs, median B_{2008} is estimated to range from 43% to 94% of B_0 (Table 13). The periods of most marked decline occurred after the development of the hoki fishery from the late 1980s, with a consequent bycatch of ling, and the short period of intensive foreign longlining in 1975–77. All of the model runs indicate that the stock recovery apparent since 2005 is likely to continue over the next five years at catch levels of 2225 t annually (Figure 17, Table 14). Median B_{2013} is estimated to be at least 55% B_0 in all model runs.

Table 13: Bayesian median and 95% credible intervals (in parentheses) of B_0, B_{2008}, and B_{2008} as a percentage of B_0 for all LIN 7WC model runs.

Model run	B_0		B_{2008}		B_{2008} (% B_0)	
Base case	66 110	(55 100–88 500)	45 960	(30 810–72 570)	69	(56–85)
Tangaroa survey	70 630	(56 570–119 160)	51 240	(33 490–102 300)	72	(58–89)
All-values ogive	251 510	(79 430–488 320)	207 810	(52 930–435 740)	83	(64–96)
M = 0.15	57 210	(46 060–77 600)	24 800	(13 870–44 690)	43	(29–58)
M = 0.18	62 420	(48 730–96 290)	35 560	(20 350–70 890)	57	(42–74)
M = 0.20	62 740	(51 400–104 890)	39 770	(26 280–81 820)	63	(50–82)
CPUE	258 890	(95 770–492 970)	246 820	(78 370–483 810)	94	(79–104)
Trawl CPUE	64 980	(55 100–88 820)	42 900	(32 400–67 490)	66	(57–76)
Two surveys	69 120	(57 590–122 480)	46 500	(32 630–88 510)	67	(56–81)

Table 14: Bayesian median and 95% credible intervals (in parentheses) of projected B_{2013}, B_{2013} as a percentage of B_0, and B_{2013}/B_{2008} (%) for all LIN 7WC model runs. Future annual catches are assumed equal to the TACC (1425 t by trawl and 800 t by line).

Model run	Future catch (t)	B_{2013}		B_{2013} (% B_0)		B_{2013}/B_{2008} (%)	
Base case	2225	58 900	(37 580–97 670)	89	(67–112)	127	(108–150)
Tangaroa survey	2225	65 920	(41 830–133 050)	93	(71–118)	127	(111–151)
All-values ogive	2225	258 060	(65 250–542 550)	102	(78–126)	123	(109–148)
M = 0.15	2225	31 620	(15 200–61 350)	55	(33–80)	127	(104–151)
M = 0.18	2225	46 010	(24 470–98 850)	74	(50–102)	128	(111–152)
M = 0.20	2225	51 870	(32 060–110 430)	82	(61–108)	128	(112–150)
CPUE	2225	308 280	(96 120–619 180)	118	(97–140)	126	(110–146)
Trawl CPUE	2225	54 310	(37 670–86 270)	83	(66–101)	125	(108–148)
Two surveys	2225	64 310	(42 330–130 600)	93	(73–119)	137	(119–161)

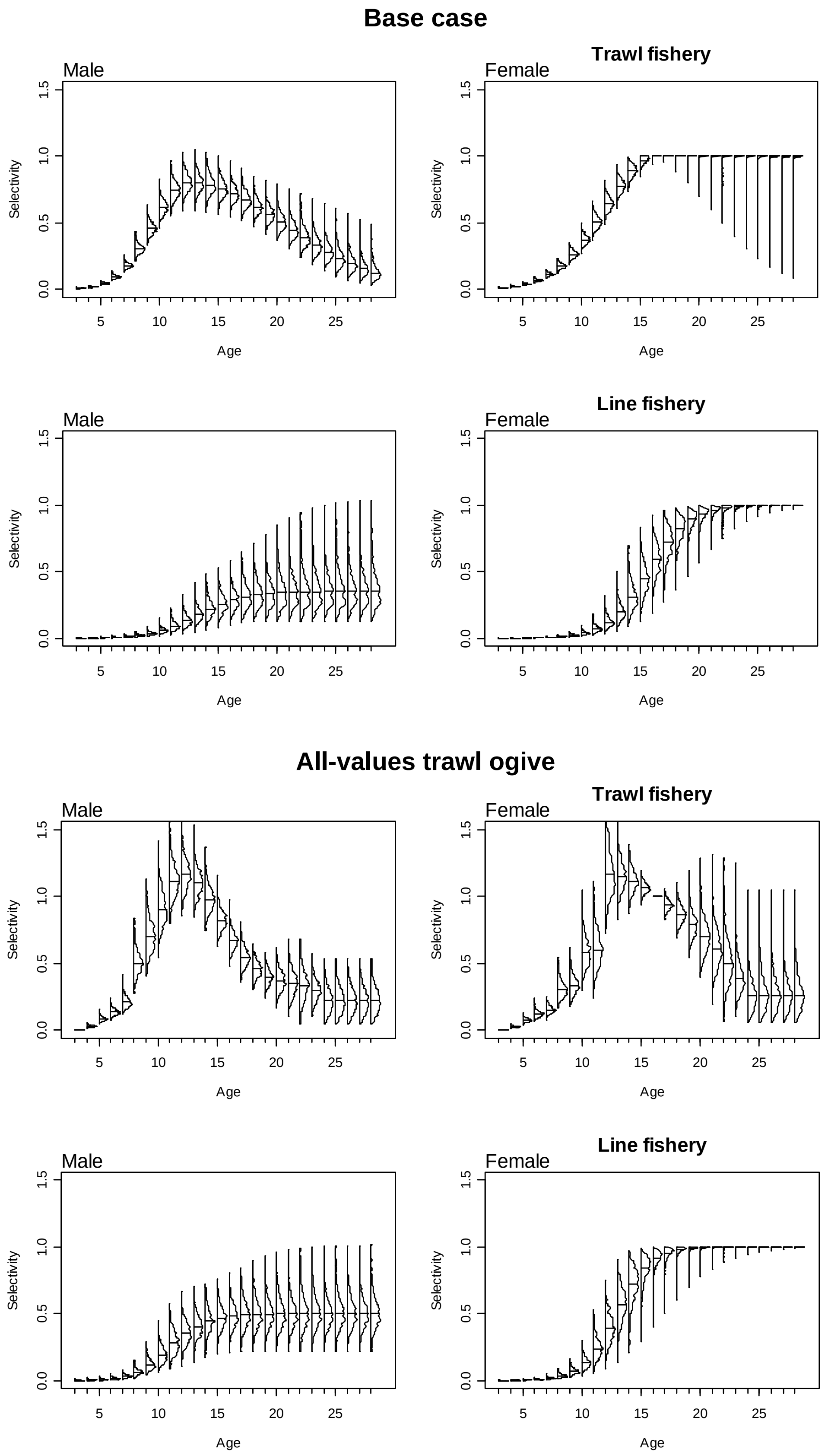

Figure 7: Estimated posterior distributions of relative selectivity, by age and sex, for the commercial trawl and line fisheries from the base case and all-values ogive model runs. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

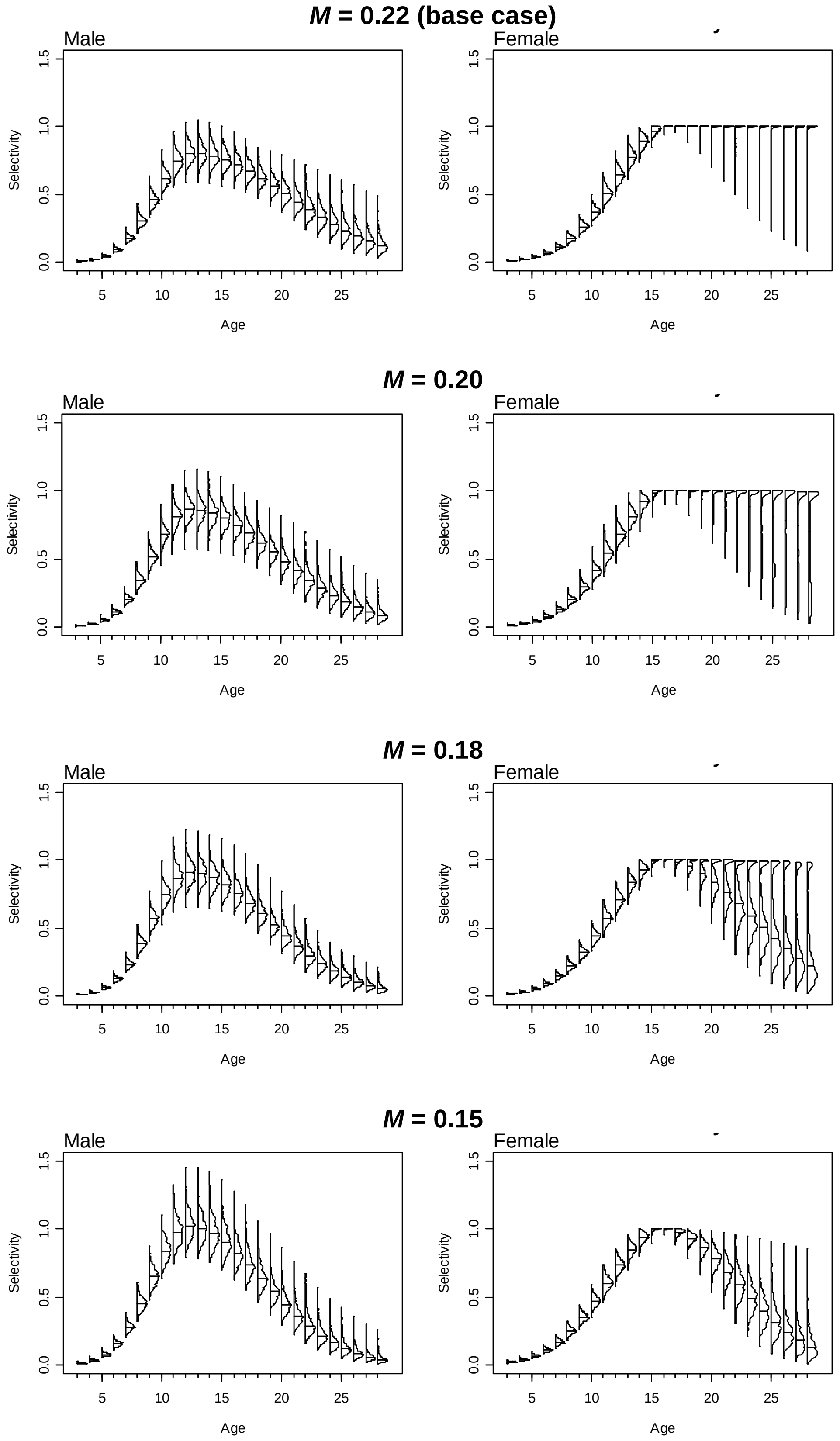

Figure 8: Estimated posterior distributions of relative selectivity, by age and sex, for the commercial trawl fishery from the model runs investigating sensitivity to changes in *M*. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

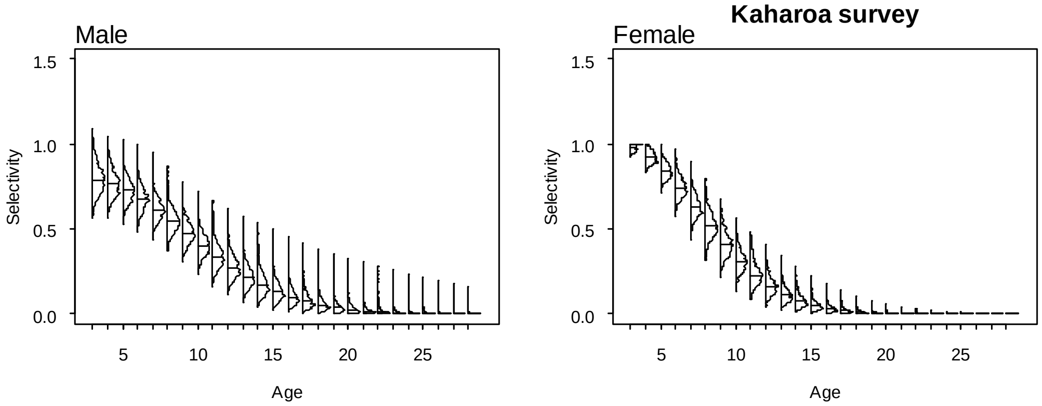

Figure 9: Estimated posterior distributions of relative selectivity, by age and sex, for the *Kaharoa* trawl survey from the two surveys model run. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

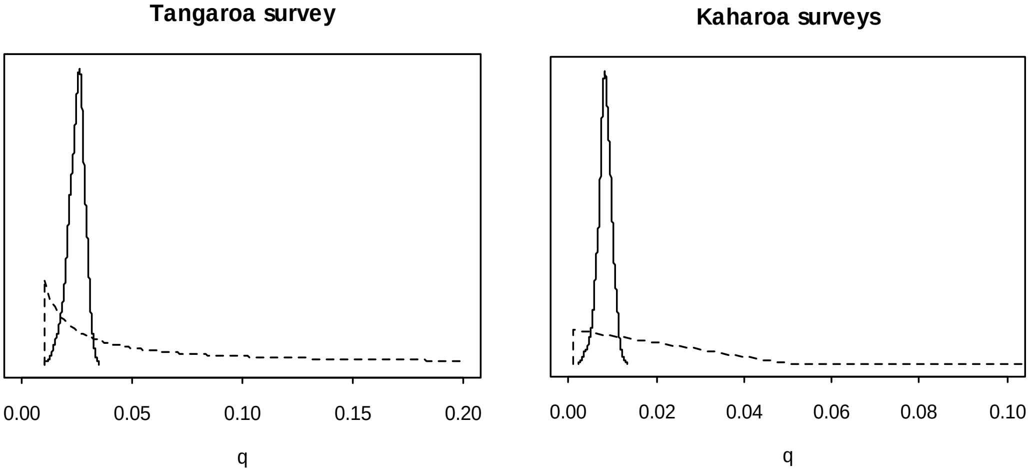

Figure 10: Estimated posterior distributions (solid lines) of trawl *q*, and distributions of priors (broken lines), for the *Tangaroa* survey (*Tangaroa* survey model) and the *Kaharoa* survey (two surveys model).

Figure 11: MDP fits to the *Kaharoa* trawl biomass series from the two surveys model run.

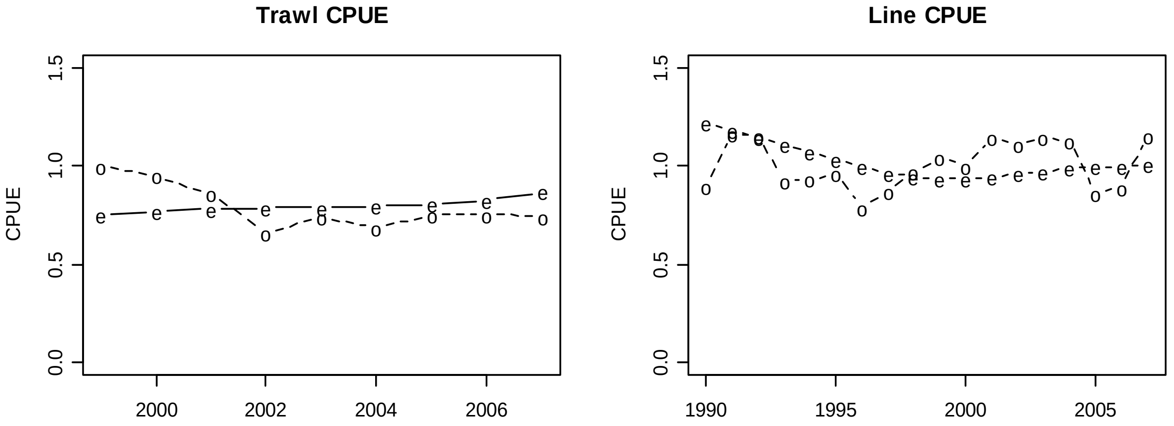

Figure 12: MDP fits to the trawl and line fishery CPUE series from the CPUE model run.

Figure 13: MDP fits to the trawl CPUE series from the Trawl CPUE only model run.

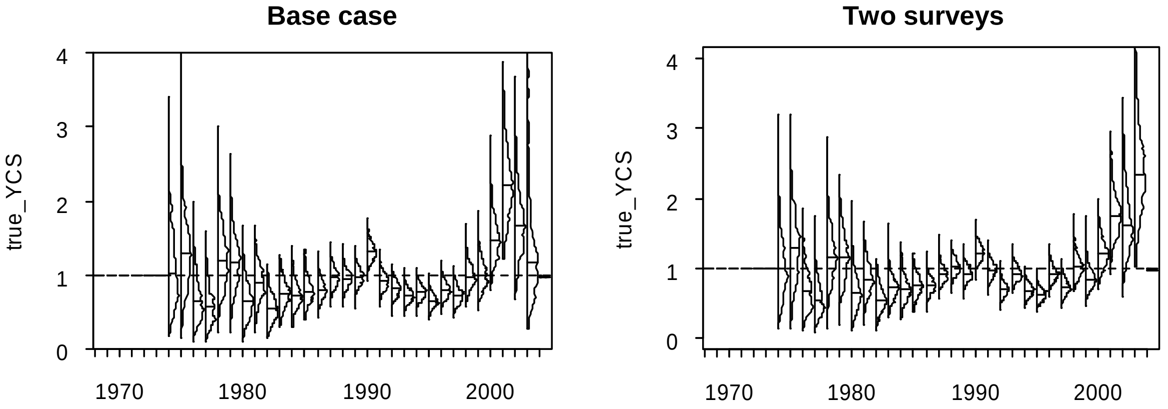

Figure 14: Estimated posterior distributions of year class strength from the base case and two surveys model runs. The horizontal line indicates a year class strength of 1. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

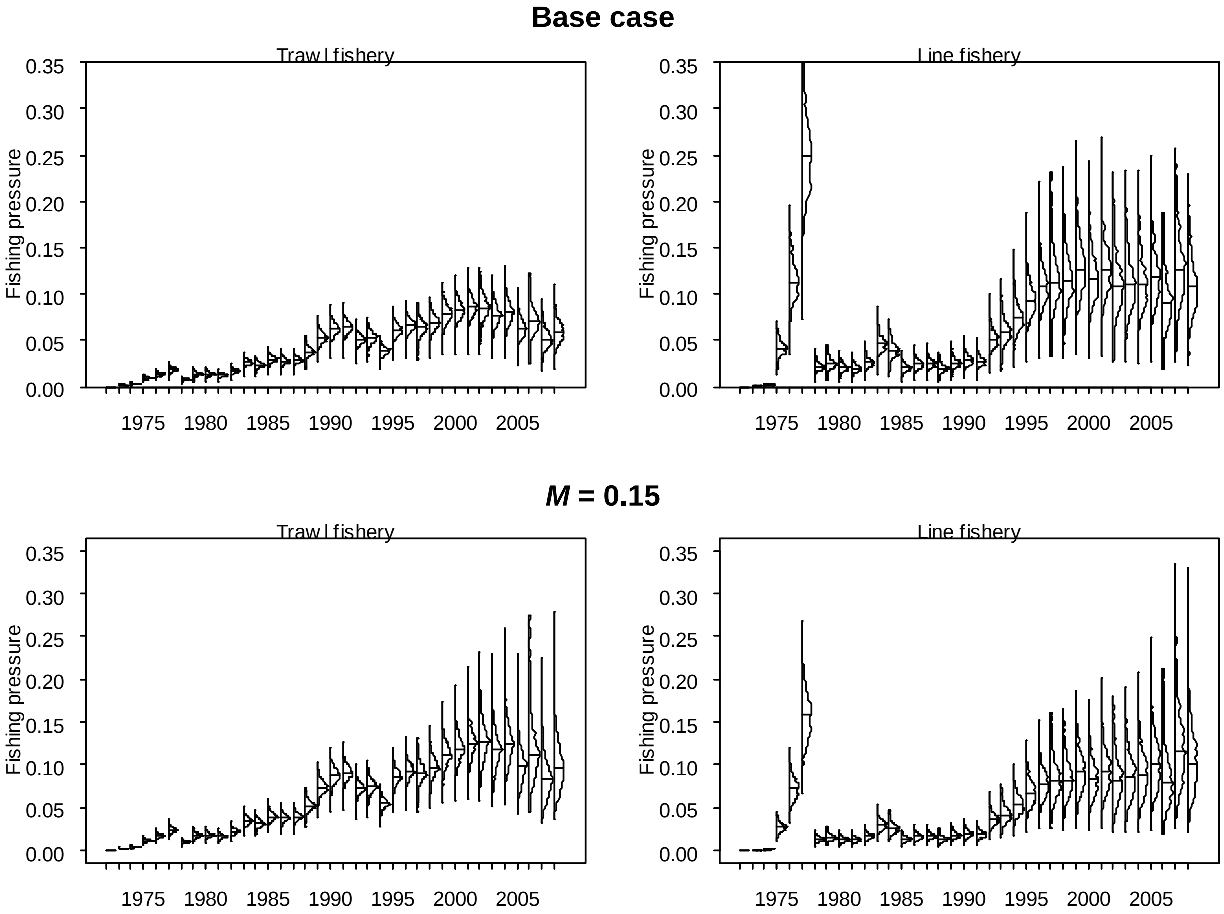

Figure 15: Estimated posterior distributions of exploitation rates from the base case and *M* = 0.15 model runs. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

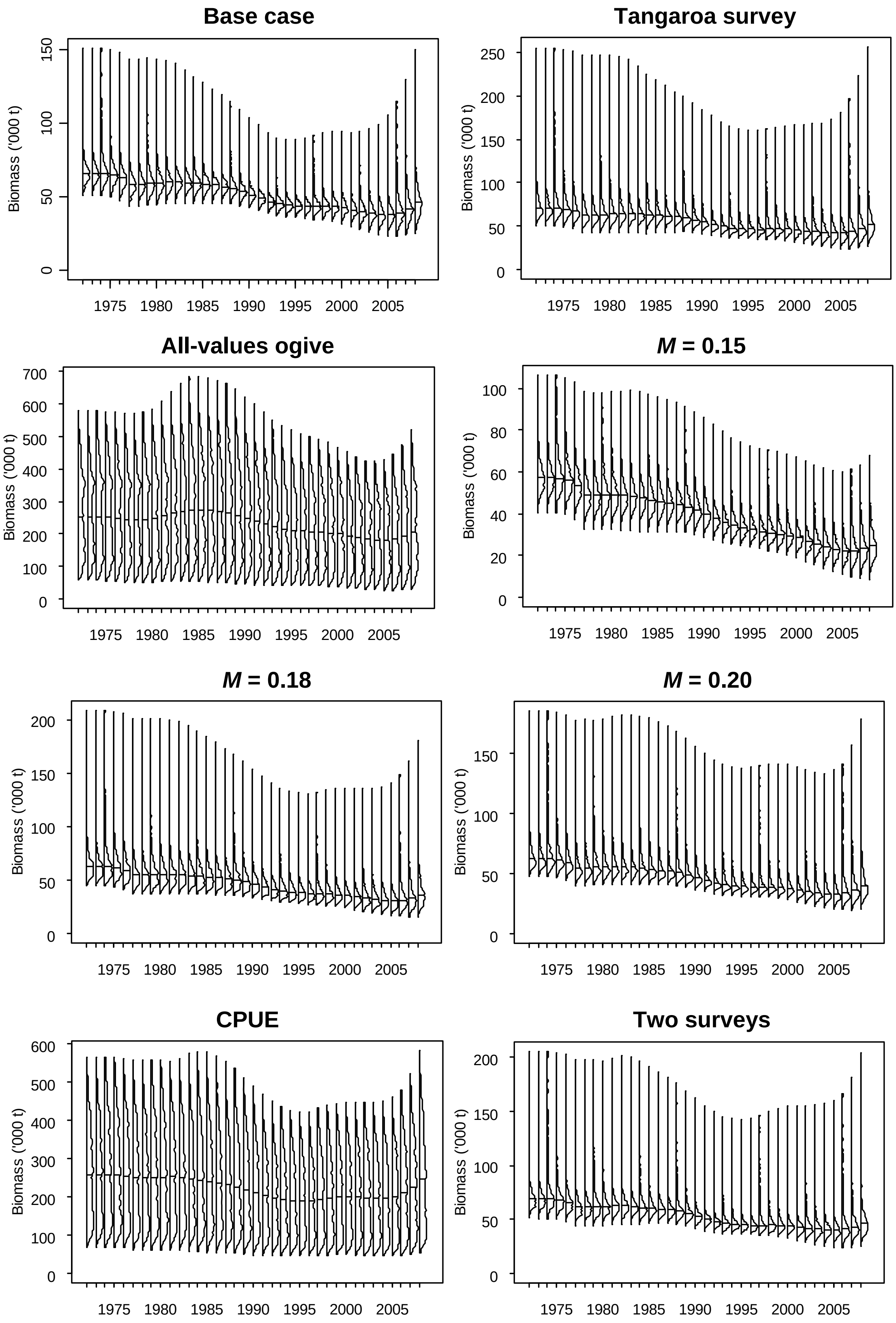

Figure 16: Estimated posterior distributions of biomass trajectories (in tonnes) for all model runs. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

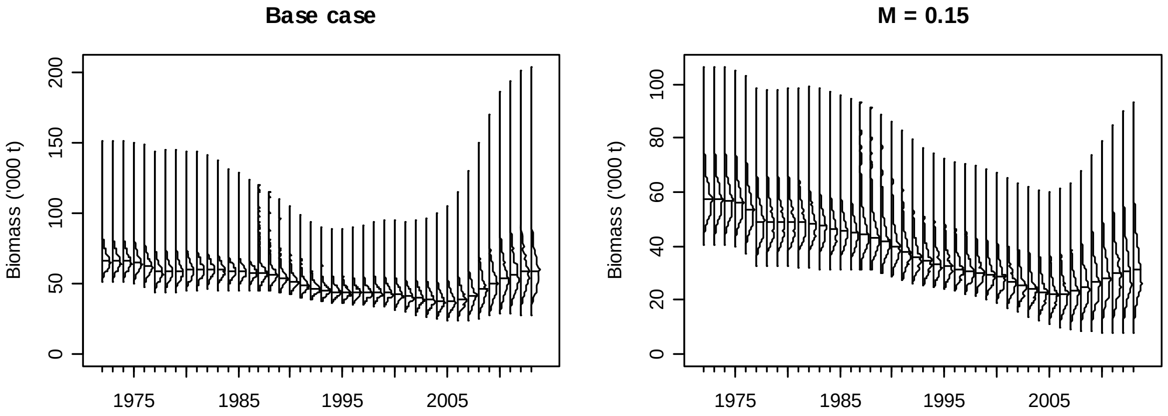

Figure 17: Estimated posterior distributions of projected biomass trajectories (as %B_0) from the base case and $M = 0.15$ model runs. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median. Projections (2009–2013) are based on future annual catches of 2225 t.

6. DISCUSSION

The previous assessment of the LIN 7WC stock concluded that stock status was poorly known, primarily because the assessment was driven by trawl fishery catch-at-age moderated by CPUE indices that may have unreliably indexed abundance (Horn 2006). That assessment also assumed that the line fishery ogive was the same as that estimated for the Chatham Rise line fishery. The small amount of WCSI line fishery length and age data that was available for the current assessment indicates that the WCSI line fishery ogives are shifted further to the right than the Chatham Rise ones (i.e., smaller/younger fish are less selected off WCSI). Also, males are relatively less selected by line off WCSI than on the Chatham Rise. Because the model was found to be moderately sensitive to shifts in the line fishery ogive, it is not surprising to find that the current assessment runs are more optimistic, both absolutely and relatively, than those presented by Horn (2006).

The assessment of LIN 7WC is still very uncertain. The only comprehensive and likely reliable input data series is the trawl fishery catch-at-age. Other data series provide little information or are considered unreliable because they are data poor (i.e., the *Tangaroa* survey, the line fishery catch-at age/length), they do not index a significant proportion of the stock (i.e., the *Kaharoa* survey series), or simply that there are major doubts about their reliability as an abundance index (i.e., the two CPUE series). In summary, there is no reliable series of relative abundance indices for the stock.

An examination of the likelihood profiles associated with each data series shows that there is a set of input series indicative of a very large biomass (i.e., the line fishery CPUE, the line fishery age and length data, and the *Kaharoa* proportion-at-length data), and a set indicative of a B_0 in the range 40 000 to 100 000 t (i.e., the *Tangaroa* and *Kaharoa* biomass estimates, the trawl fishery catch-at-age, and the trawl CPUE) (Figure 18). These two sets of data are clearly at odds, so we consider here what virgin biomass we might logically expect for the LIN 7WC stock. Based on seabed area of likely ling habitat, and assuming that the biomass density of unfished ling stocks around the South Island were all about equal, we would expect that the WCSI virgin biomass would be about two-thirds of that on the Chatham Rise and about four times that on the Bounty Plateau. Best estimates of B_0 in these areas are 100 000–140 000 t on the Chatham Rise (Horn 2008) and 14 000 t on the Bounty Plateau (Horn 2007b). Hence, a WCSI B_0 in the range 40 000 to 100 000 t appears to be sensible. It is probably valid, therefore, to reject the model runs indicative of median B_0 greater than 200 000 t, i.e., the CPUE and all-values ogive runs.

Under the base case model, B_0 was estimated to be about 66 000 t, current biomass was estimated to be 69% of B_0, and stock size is projected to increase in the short term with catches at the TACC. This model included only the catch history, catch-at-age and -length series from the two fisheries, and a value of 0.22 for instantaneous natural mortality for both sexes. The trawl catch-at-age data were reasonably well fitted, and the single year of line fishery catch-at-age data was (as would be expected) very well fitted (see Appendix A, Figure A2).

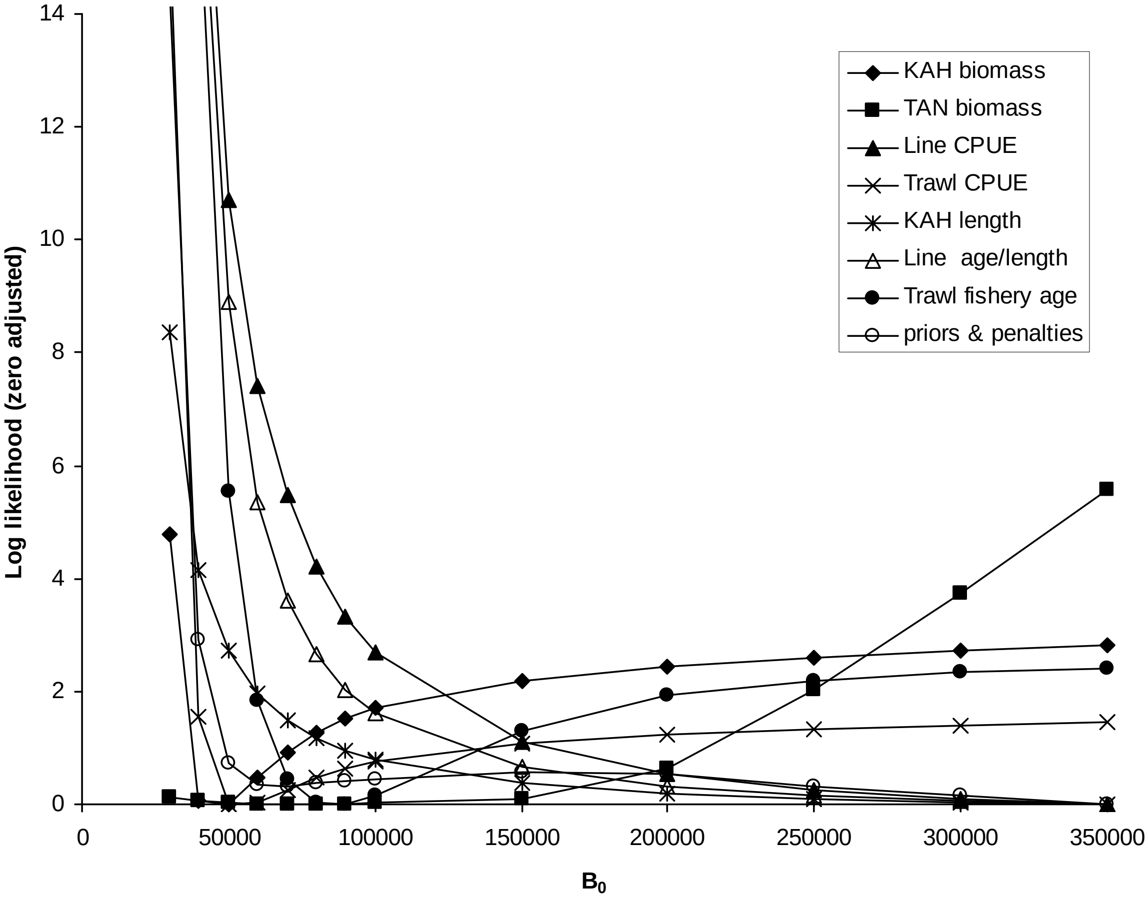

Figure 18: Likelihood profiles for B_0 from a model run assuming logistic line and double-normal trawl selectivity ogives.

Sensitivity runs were conducted to investigate the influence of the available abundance series and the effects of changes in *M*.

The incorporation of the single *Tangaroa* biomass estimate slightly raised the biomass trajectory, but also increased the variability around these estimates. In particular, there was an increased possibility of some relatively high biomasses (i.e., B_0 values greater than 80 000 t). Including the *Kaharoa* biomass and proportion-at-length data in the model had little influence on the estimates of biomass, but did result in some changes to estimated year class strengths. However, because of the relatively poor fits to the *Kaharoa* survey proportion-at-length data, the modifications to the YCS may be erroneous. In summary, the available trawl survey data appear to add little to the model. Both series (but particularly the *Kaharoa* survey) sample a small fraction of the WCSI population, and the *Tangaroa* series is a single estimate. Relative to the base case run, inclusion of the survey data result in little change to estimates of relative or absolute biomass, and variability in the credible range of estimates is increased.

Inclusion of the line fishery CPUE series markedly increased estimates of biomass, but to an improbably high level. The line CPUE series is long (1990–2007), and while the individual indices can vary markedly between adjacent years (see Figure 12) the overall trend is flat. This trend is in contrast to the signal from the trawl catch-at-age data that indicates a steadily declining biomass between 1990 and 2005. Consequently, to accommodate both these signals and allow reasonable fits to both series simultaneously, it is necessary to start with a very high biomass. The trawl CPUE is a shorter series (1999–2007), but, in contrast to the line series, it is indicative of an overall decline. However, the trawl series is poorly fitted when it is input with the recommended level of process error; the total error around the points is sufficient to allow the model to fit a flat, or even increasing, trend through the series. A model run fitting the trawl CPUE without any process error was completed to gauge the effect of forcing the CPUE to have some influence. This resulted in the series being reasonably well fitted with a decreasing trend (see Figure 13), but the biomass estimates were only slightly more pessimistic than in the base case run. In summary, the line CPUE series provides an improbably constant signal, and is indicative of hyper-stable catch rates being maintained in that fishery. The trend in the trawl CPUE series is in concert with that indicated by the extensive trawl catch-at-age data. Based on the modelling reported here, it appears likely that the trawl CPUE series is a more reliable abundance index for the WCSI ling stock than the line CPUE series.

An initial model run estimated M (as a constant for both sexes) to be 0.22; this is in line with the suggestion by Horn (2008) that M for the WCSI ling stock was likely to be higher than the value of 0.18 that had been used in the past for all ling stocks. However, information from the trawl fishery selectivity ogives indicates that the ‘true’ M differs between sexes. In most model runs the trawl fishery ogives show males to be almost fully selected at all ages after the age at peak selectivity, while selectivity of females declines with increasing age. It seems unrealistic to expect that the fishery could cause this difference. However, if ‘true’ M for males is greater than that for females (as is often the case for teleosts (Pauly 1980)) then, by forcing the parameter to be constant between sexes, the model will compensate for the difference by reducing the selectivity of females relative to males in the estimated selectivity ogives.

The series of model runs testing the influence of changes to M showed that as M is reduced, biomass (absolute and relative to B_0) also declines. However, even after a reduction from 0.22 to 0.18, current stock status (B_{2008} as a percentage of B_0) has only reduced from 69% to 57%. The most pessimistic model, where M was set at 0.15, still estimated median current biomass to be 43% of B_0. An M of 0.15 is considered to be at the lowest extreme of the likely M values for this stock (see Figure 6).

The estimates of stock size rely partially on the shape of the selectivity ogives. Age at peak selectivity in the trawl fishery is 12–17 years when fitting double-normal ogives. This fishery is essentially exploiting a spawning population, and age at 100% maturity has been estimated to be about 9–12 years for WCSI fish. Hence, ages at full selectivity lower than 12–17 years would be expected, and it is not apparent why they are not achieved. A smoothed all-values ogive parameterisation was tested for the trawl fishery selectivity. This ogive did fit the apparent kinks in the trawl fishery selectivity of ling younger than 10 (see Figures 2 and 7) and, more significantly, age at peak selectivity reduced to values that are more believable than those produced from the double-normal ogive fit (i.e., 12 years). However, even with an ogive smoothing penalty, the variability around the all-values ogive was wide, which allowed a very wide variation in the estimates of absolute biomass. Most of the estimates of B_0 were greater than the perceived ‘logical’ maximum of 100 000 t, and the posterior distributions on the biomass trajectory were clearly bimodal (see Figure 16). In addition, the improvements in the fits to the trawl catch-at-age data (as measured by the improvement in negative log-likelihood) did not justify the use of the all-values parameterisation. In conclusion, the model run using the all-values trawl fishery ogives is rejected.

The assessment of LIN 7WC is confounded by several difficulties. The available fishery-independent relative abundance data (i.e., trawl surveys) are derived from only a small proportion of the ling habitat in LIN 7WC and consequently provide little data to inform the model. CPUE series are available from the trawl and line fisheries, but they exhibit different trends. It appears likely that the longer of the two series (the line CPUE) is misleading, so future assessment work should probably rely more on the trawl CPUE data. Little age or length data are available from the line fishery, so the fishery ogive is based on tenuous data (although this is likely to be more satisfactory than adopting an ogive estimated from a line fishery in another area). The assessment is sensitive to relatively small changes in the line fishery ogive, so it is imperative that more data be obtained to better define its parameters. It is also known that the trawl fishery catch was under-reported in some years; some corrections to the catch history have been made to account for this, but it is unknown how accurate they are. The relatively high estimates of age at peak selectivity for the trawl fishery are also troubling.

Current stock size of LIN 7WC is uncertain. Results of nine model runs are presented above. Two of these (i.e., the CPUE and all-values models) have been rejected because the biomass estimates are unrealistically high. The remaining model runs are potentially realistic. Runs including the trawl survey data or the trawl CPUE are little different to the base case because the relative abundance series either provide little information or have trends that are not in conflict with the dominant signal from the trawl catch-at-age series. There is still no clearly reliable series of relative abundance indices available for this stock. Varying *M* between 0.22 and 0.18 has a relatively slight influence on estimated stock status. The assessment is moderately sensitive to changes in the fishery ogives, and there are some problems with these. The line fishery ogive is very poorly known, and the trawl fishery ogive has unexpectedly high ages at maximum selectivity. Confidence in the assessment will not be achieved if we have confidence in the ogives. However, all the model runs are indicative of a current biomass greater than 40% B_0, and all indicate that stock size is likely to increase over the next few years (owing to recruitment into the fishery of some relatively strong year classes). This information, along with a relatively constant catch history since 1989 and trawl catch-at-age distributions from recent years that are similar to those taken by the fishery in the early 1990s (see Appendix A, Figure A3), suggests that there are no current sustainability issues for the WCSI ling stock. Nevertheless, the uncertainty of this assessment means it is not known whether the TACC or current catch levels 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.

7. ACKNOWLEDGMENTS

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Appendix A: Summary residual plots and fits for the MPD base case model run for LIN 7WC

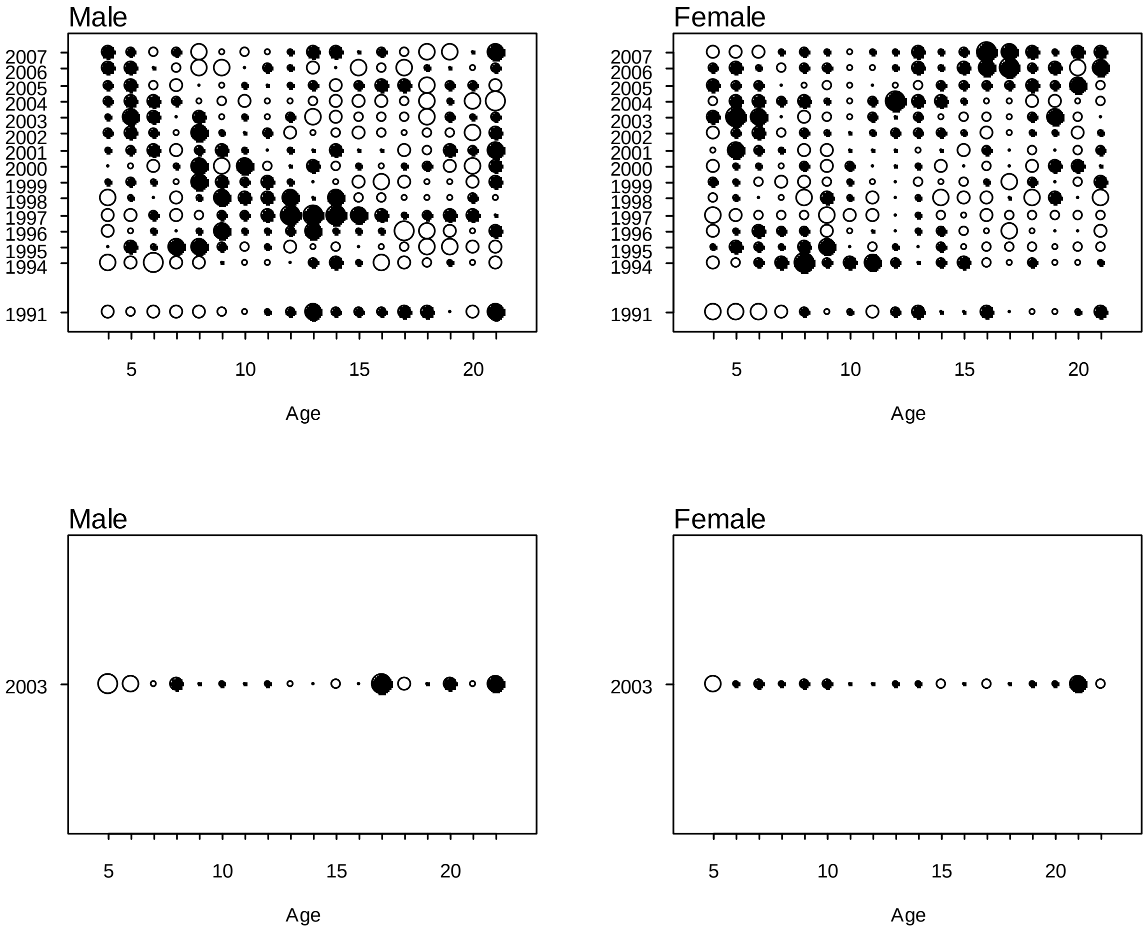

Figure A1: MPD residual values for the proportions-at-age data for the commercial trawl (top two panels) and commercial line (bottom two panels) fishery series. Symbol area is proportional to the absolute value of the residual, with black circles indicating positive residuals and open circles indicating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

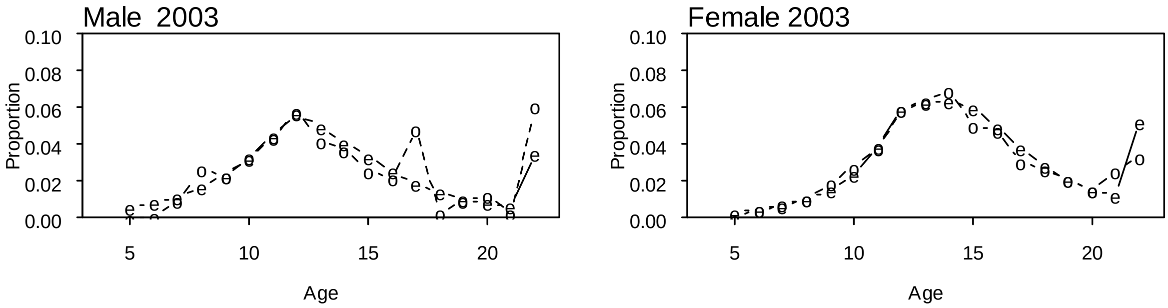

Figure A2: MPD model fits to the proportion-at-age data from the commercial line fishery. o, observed data; e, expected value.

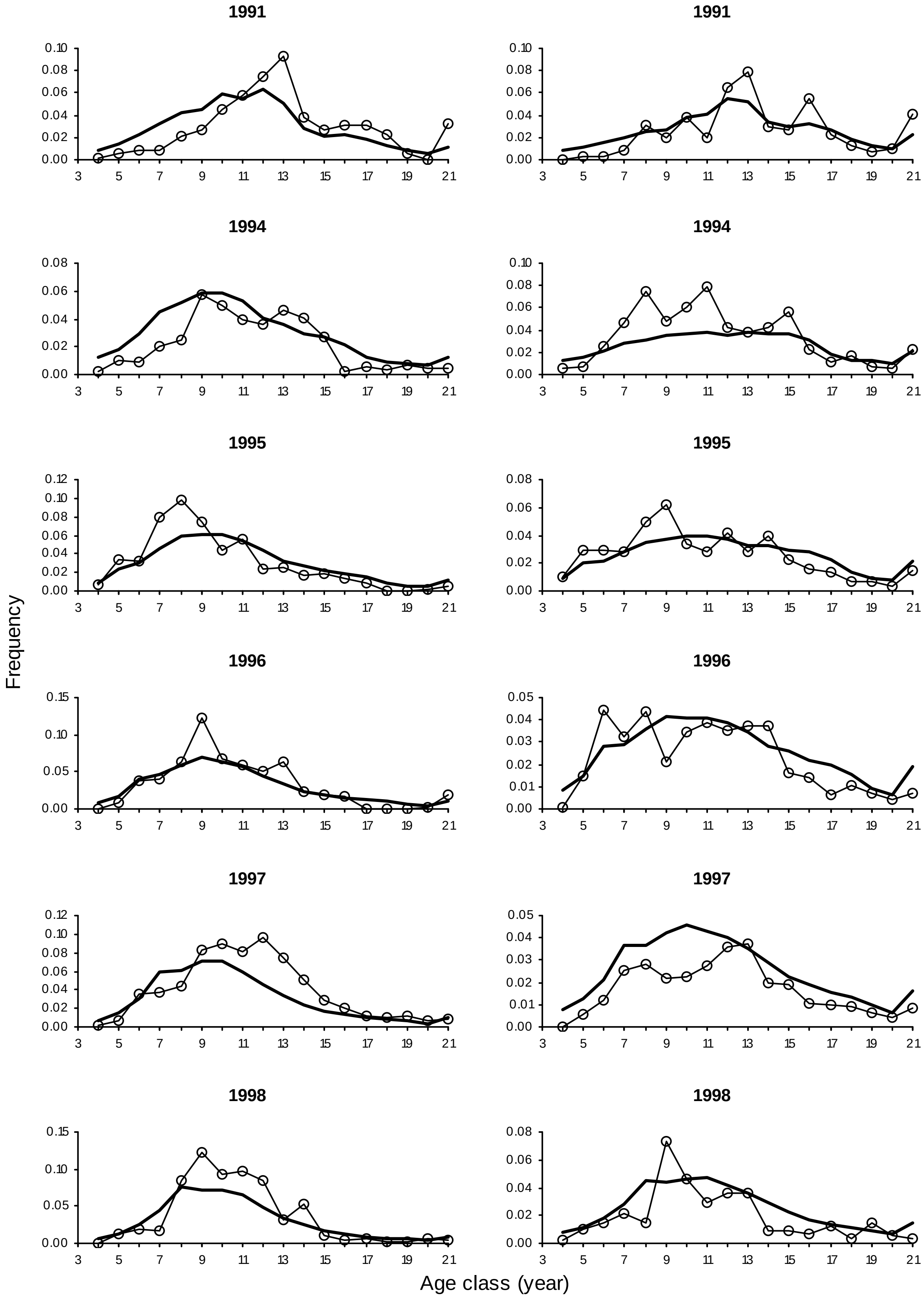

Figure A3: MPD model fits to the proportion-at-age data from the commercial trawl fishery. o and thin line, observed data; thick line, expected values.

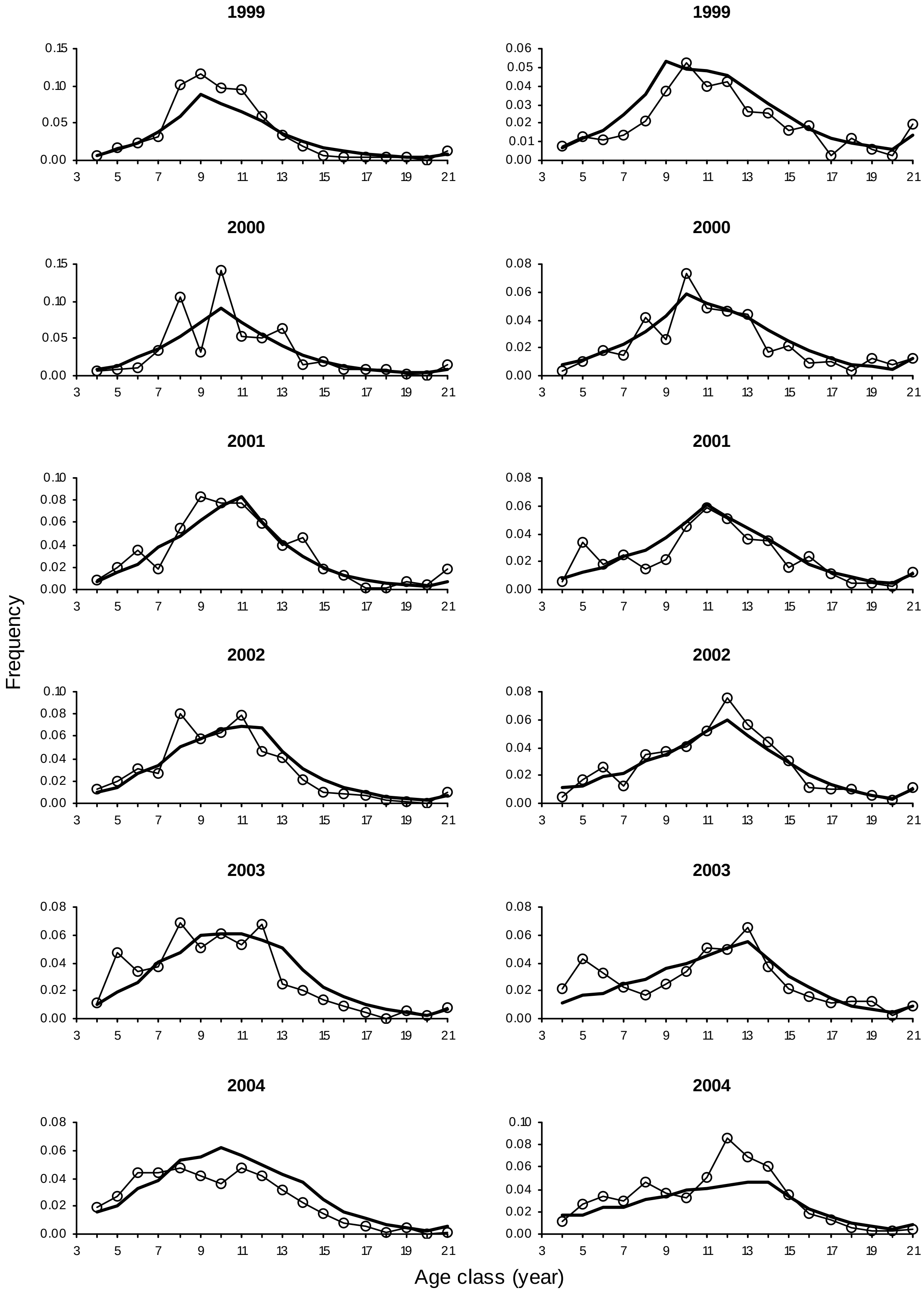

Figure A3 ctd.

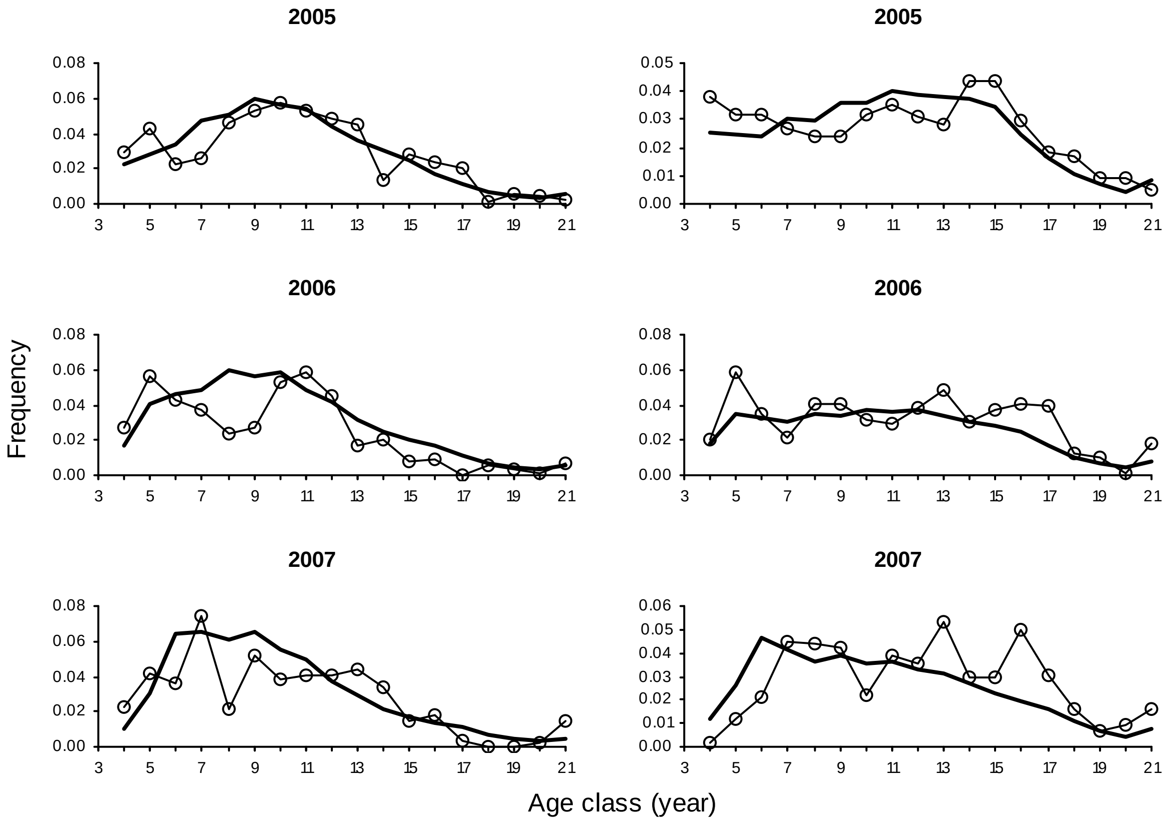

Figure A3 ctd.

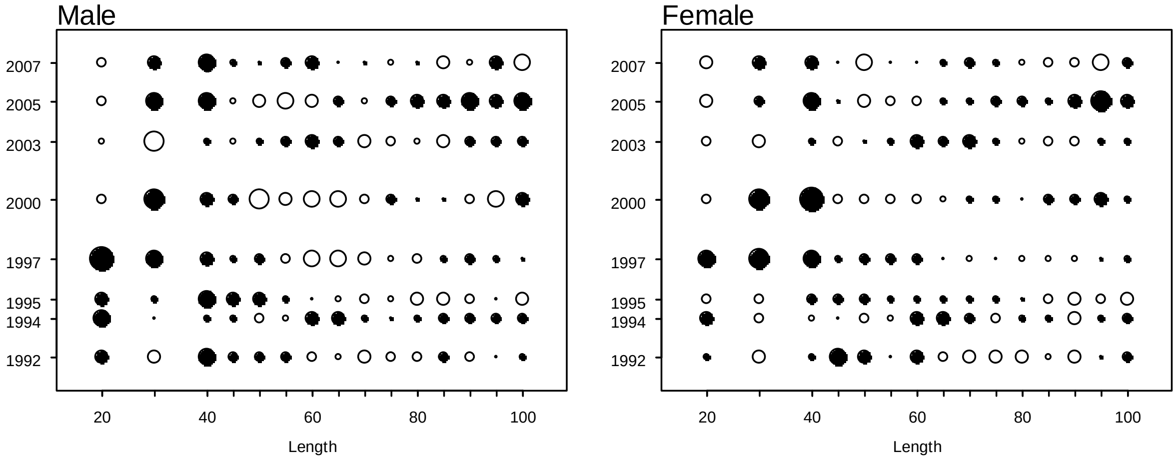

Figure A4: MPD residual values for the numbers-at-length data for the *Kaharoa* trawl survey series. Symbol area is proportional to the absolute value of the residual, with black circles indicating positive residuals and open circles indicating negative residuals.

Appendix B: Summaries of the proportions-at-age data from trawl surveys and commercial fishery samples

Table B1: Numbers of measured and aged fish by data source for male and female ling, and the number of sampled sets/tows and estimated mean weighted c.v. (%) by age for the Chatham Rise stock (LIN 3&4).

	Males		Females			
Source	Measured	Aged	Measured	Aged	Sets/Tows	Mean c.v.
Trawl surveys						
AEX8903	743	303	613	296	130	26.0
TAN9106	1 208	252	1 189	281	174	22.4
TAN9212	1 229	286	1 108	313	177	21.7
TAN9401	1 541	302	1 349	302	157	21.5
TAN9501	583	236	578	201	114	28.1
TAN9601	556	306	509	284	79	27.7
TAN9701	837	317	601	242	98	24.3
TAN9801	665	348	492	280	88	24.5
TAN9901	1 071	336	848	318	111	23.8
TAN0001	1 080	322	969	326	113	22.0
TAN0101	1 145	312	1 084	341	108	20.5
TAN0201	1 053	294	1 170	334	102	19.7
TAN0301	813	317	808	347	98	20.6
TAN0401	865	303	752	302	101	20.2
TAN0501	845	310	801	326	98	22.5
TAN0601	1 007	328	880	330	90	21.0
TAN0701	733	310	732	330	94	21.0
TAN0801	610	317	623	325	92	22.3
Commercial trawl fishery						
1991–92	2 151	252	2 653	281	143	27.0
1993–94	1 127	302	768	302	126	32.9
1994–95	359	236	302	201	59	45.1
1995–96	453	306	399	284	87	30.0
1996–97	162	317	240	242	31	41.1
1997–98	3 463	348	3 117	280	497	18.7
1998–99	3 306	336	2 469	318	312	20.0
1999–2000	887	322	1 013	326	161	24.8
2000–01	1 000	312	988	341	188	21.0
2001–02	642	294	708	334	129	23.8
2002–03	694	317	764	347	114	24.3
2003–04	356	303	600	302	99	30.1
2004–05	869	310	666	326	194	27.9
2005–06	251	328	291	330	54	34.5
2006–07	699	310	687	330	135	22.9
Commercial line fishery						
2002	4 966	284	2 998	309	538	20.4
2003	3 038	337	2 071	289	429	19.1
2004	1 066	302	747	293	139	21.8
2005	889	356	479	234	137	21.6
2006	266	95	294	141	48	36.6
2007	351	174	268	139	62	31.1

Table B2: Numbers of measured and aged fish by data source for male and female ling, and the number of sampled sets/tows and estimated mean weighted c.v. (%) by age for the Campbell Plateau stock (LIN 5&6).

	Males		Females			
Source	Measured	Aged	Measured	Aged	Sets/Tows	Mean c.v.
Trawl surveys						
AEX8902	760	160	1 067	234	133	29.0
TAN9105	1 563	213	2 079	348	151	19.6
TAN9211	1 249	227	1 668	354	146	21.1
TAN9310	1 520	254	1 894	351	127	22.3
TAN0012	1 761	244	1 696	351	85	18.8
TAN0118	1 316	268	1 290	326	95	19.6
TAN0219	1 661	224	1 606	350	88	20.6
TAN0317	1 270	243	1 156	333	70	22.1
TAN0414	1 433	256	1 146	339	79	27.0
TAN0515	1 095	279	988	300	82	22.0
TAN0617	969	250	1 011	355	80	23.1
TAN0714	1 014	229	1 288	353	79	21.7
TAN9204	1 570	221	1 498	310	90	21.5
TAN9304	1 353	261	1 344	373	97	21.1
TAN9605	1 129	325	902	303	88	21.9
TAN9805	809	271	765	296	64	22.9
Commercial trawl fishery						
1991–92	1 466	437	1 652	667	141	22.0
1992–93	1 337	235	1 615	363	164	28.3
1993–94	686	256	1 059	357	129	29.2
1995–96	881	366	779	297	83	24.5
1997–98	1 408	274	1 717	302	218	29.0
2000–01	2 192	247	1 947	351	267	28.1
2001–02	1 887	264	2 579	327	424	24.8
2002–03	1 164	434	1 828	625	263	20.9
2003–04	853	246	1 397	337	202	22.9
2004–05	2 324	254	2 415	339	218	21.5
2005–06	2 739	288	2 618	305	252	20.4
2006–07	1 644	225	1 446	382	191	24.3
Commercial line fishery (Puysegur)						
2000	4 044	242	4 231	278	83	20.6
2001	2 084	131	1 962	143	55	28.7
2002	670	197	898	284	157	22.6
2003	1 250	211	1 687	307	214	20.0
2004	887	208	1 129	289	168	22.5
2005	193	88	362	179	54	28.6
2006	233	108	707	345	94	23.3
2007	412	191	418	217	82	25.1
Commercial line fishery (Campbell)						
1998	608	73	2 763	395	34	23.1
1999	3 316	214	7 535	428	136	18.3
2001	674	103	2 040	235	58	25.3
2003	304	128	611	273	43	29.3
2005	413	114	716	307	113	25.9

Table B3: Numbers of measured and aged fish by data source for male and female ling, and the number of sampled sets and estimated mean weighted c.v. (%) by age for the Bounty Plateau stock (LIN 6B).

	Males		Females			
Source	Measured	Aged	Measured	Aged	Sets	Mean c.v.
Commercial line fishery						
1993	201	52	237	69	24	50.4
2000	1 102	106	2 184	185	41	26.9
2001	405	50	713	66	20	43.6
2004	1 155	200	1 628	300	272	20.0

Table B4: Numbers of measured and aged fish by data source for male and female ling, and the number of sampled sets/tows and estimated mean weighted c.v. (%) by age for the WCSI stock (LIN 7WC).

	Males		Females			
Source	Measured	Aged	Measured	Aged	Sets/Tows	Mean c.v.
Commercial trawl fishery						
1991	563	176	440	220	65	34.8
1994	873	172	1 096	221	141	27.9
1995	1 051	238	794	268	111	24.3
1996	485	247	448	201	83	28.0
1997	1 532	442	901	399	173	19.5
1998	1 063	349	700	279	155	23.6
1999	1 862	285	1 126	263	221	23.7
2000	829	269	783	264	168	26.8
2001	1 106	256	924	307	178	29.6
2002	1 401	283	1 405	321	332	21.4
2003	1 157	293	1 290	302	286	23.3
2004	1 003	243	1 540	352	334	21.4
2005	908	282	899	355	184	24.9
2006	763	276	844	361	154	29.0
2007	228	148	258	158	65	38.7
Commercial line fishery						
2003	123	427	148	561	27	26.9

Table B5: Numbers of measured and aged fish by data source for male and female ling, and the number of sampled sets/tows and estimated mean weighted c.v. (%) by age for the Cook Strait stock (LIN 7CK).

	Males		Females			
Source	Measured	Aged	Measured	Aged	Sets/Tows	Mean c.v.
Commercial trawl fishery						
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
Commercial line fishery						
2006	607	319	538	275	116	19.3
2007	238	125	180	92	43	33.8