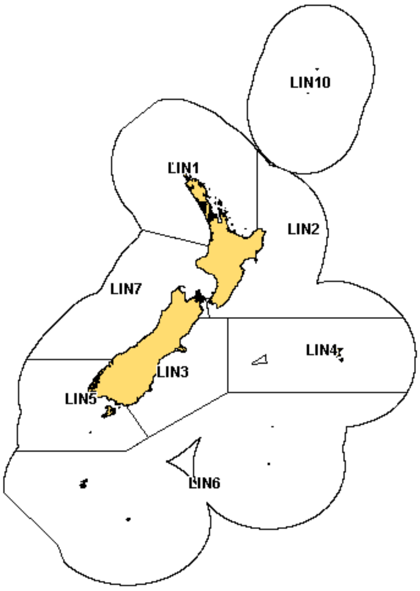
(LING)

(*Genypterus blacodes*)
Hoka



1. FISHERY SUMMARY

1.1 Commercial fisheries

Ling are widely distributed through the middle depths (200–800 m) of the New Zealand EEZ, particularly to the south of latitude 40° S. From 1975 to 1980 there was a substantial longline fishery on the Chatham Rise (and to a lesser extent in other areas), carried out by Japanese and Korean longliners. Since 1980 ling have been caught by large trawlers, both domestic and foreign owned, and by small domestic longliners and trawlers. In the early 1990s the domestic fleet was increased by the addition of several larger longliners fitted with autoline equipment. This caused a large increase in the catches of ling off the east and south of the South Island (LIN 3, 4, 5 and 6). However, since about 2000 there has been a declining trend in catches taken by line vessels in most areas, offset, to some extent, by increased trawl landings.

The principal grounds for smaller domestic vessels are the west coast of the South Island (WCSI) and the east coast of both main islands south of East Cape. For the large trawlers the main sources of ling are Puysegur Bank and the slope of the Stewart-Snares shelf and waters in the Auckland Islands area. Longliners fish mainly in LIN 3, 4, 5 and 6. Landings in 2006–07 were close to the TACCs in Fishstocks LIN 3 and 7, above the TACC in LIN 5, but under-caught in LIN 1, 2, 4 and 6. Reported landings by nation from 1975 to 1987–88 are shown in Table 1, and reported landings by Fishstock from 1983–84 to 2006–07 are shown in Table 2.

Under the Adaptive Management Programme (AMP), the TACC for LIN 1 was increased to 400 t from 1 October 2002, within an overall TAC of 463 t. In an earlier proposal for the 1994(95 fishing year, TACCs for LIN 3 and 4 had been increased to 2810 and 5720 t, respectively. These stocks were removed from the AMP from 1 October 1998, with TACCs maintained at the increased level. However, from 1 October 2000, the TACCs for LIN 3 and 4 were reduced to

2060 and 4200 t, respectively. From 1 October 2004, the TACCs for LIN 5 and LIN 6 were increased by about 20% to 3600 t and 8520 t, respectively.

All other TACC increases since 1986–87 in all stocks are the result of quota appeals.

Table 1: Reported landings (t) from 1975 to 1987–88. Data from 1975 to 1983 from MAF; data from 1983–84 to 1985–86 from FSU; data from 1986–87 to 1987–88 from QMS. –, no data available.

				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).
\# April 1 to March 31.
† April 1 to Sept 30.
§ Oct 1 to Sept 30.

1.2 Recreational fisheries

The 1993–94 North region recreational fishing survey (Bradford 1996) estimated the annual recreational catch from LIN 1 as 10 000 fish (CV 23%). With a mean weight likely to be in the range of 1.5 to 4 kg, this equates to a harvest of 15–40 t.

Recreational catch was recorded from LIN 1, 5, and 7 in the 1996 national diary survey. The estimated harvests (LIN 1, 3000 fish; LIN 5, <500; LIN 7, <500) were too low to provide reliable estimates.

1.3 Customary non-commercial fisheries

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

1.4 Illegal catch

It is believed that up to the mid 1990s some ling bycatch from the west coast hoki fishery was not reported. Estimates of total catch including non-reported catch are given in Table 2 for Fishstock LIN 7.

It is believed that in recent years, some catch from LIN 7 has been reported against other ling stocks (probably LIN 3, 5, and 6). The likely levels of misreporting are moderate, being about 250–400 t in each year from 1989–90 to 1991–92 (Dunn 2003).

1.5 Other sources of mortality

The extent of any other sources of mortality is unknown.

Table 2: Reported landings (t) of ling by Fishstock from 1983–84 to 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	1 105	982	2 330	2 060	3 861	4 200	3 430	3 001
2001–02#	303	265	1 034	982	2 164	2 060	3 602	4 200	3 294	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	1 711	2 060	1 769	4 200	3 522	3 595
2006–07#	301	400	874	982	2 089	2 060	2 113	4 200	3 731	3 595

Fishstock	LIN 6		LIN 7			LIN 10			
QMA (s)	6		7 & 8			10		Total	
	Landings	TACC	Reported Landings	Estimated Landings	TACC	Landings	TACC	Landings§	TACC
1983–84*	869	–	1 552	–	–	0	–	7 696	–
1984–85*	1 283	–	1 705	–	–	0	–	6 953	–
1985–86*	1 489	–	1 458	–	–	0	–	7 205	–
1986–87#	956	7 000	1 851	–	1 960	0	10	6 940	18 730
1987–88#	1 710	7 000	1 853	1 777	2 008	0	10	7 901	18 988
1988–89#	340	7 000	2 956	2 844	2 150	0	10	8 404	19 175
1989–90#	935	7 000	2 452	3 171	2 176	0	10	9 028	19 672
1990–91#	2 738	7 000	2 531	3 149	2 192	<1	10	13 506	19 711
1991–92#	3 459	7 000	2 251	2 728	2 192	0	10	17 778	19 711
1992–93#	6 501	7 000	2 475	2 817	2 212	<1	10	19 065	19 737
1993–94#	4 249	7 000	2 142	–	2 213	0	10	15 961	19 741
1994–95#	5 477	7 100	2 946	–	2 225	0	10	19 841	22 111
1995–96#	6 314	7 100	3 102	–	2 225	0	10	21 428	22 111
1996–97#	7 510	7 100	3 024	–	2 225	0	10	22 522	22 113
1997–98#	7 331	7 100	3 027	–	2 225	0	10	23 145	22 113
1998–99#	6 112	7 100	3 345	–	2 225	0	10	21 034	22 113
1999–00#	6 707	7 100	3 274	–	2 225	0	10	21 615	22 113
2000–01#	6 177	7 100	3 352	–	2 225	0	10	20 552	19 843
2001–02#	5 945	7 100	3 219	–	2 225	0	10	19 561	19 843
2002–03#	6 283	7 100	2 917	–	2 225	0	10	18 903	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	17 189	21 977
2005–06#	3 553	8 505	2 479	–	2 225	0	10	14 184	21 977
2006–07#	4 696	8 520	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.

2. BIOLOGY

Ling live to a maximum age of about 30 years; fewer than 0.2% of successfully aged ling have been older than 30 years. A growth study of ling from five areas (west coast South Island, Chatham Rise, Bounty Plateau, Campbell Plateau, Cook Strait) showed that females grew significantly faster and reached a greater size than males in all areas, and that growth rates were significantly different between areas. Ling grow fastest in Cook Strait and slowest on the Campbell Plateau (Horn 2005b).

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

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

Ling appear to be mainly bottom dwellers, feeding on crustaceans such as *Munida* and scampi and also on fish. However, they may at times be caught well above the bottom, for example when feeding on hoki during the hoki spawning season.

Biological parameters relevant to the stock assessment are shown in Table 3.

Table 3: Estimates of biological parameters from Horn (2006b). See Section 3 for definitions of Fishstocks.

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

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

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

3. von Bertalanffy growth parameters

	Female			Male			Area
	K	t_0	L_∞	K	t_0	L_∞	
LIN 3&4	0.083	–0.74	156.4	0.127	–0.70	113.9	Chatham Rise
LIN 5&6	0.124	–1.26	115.1	0.188	–0.67	93.2	Southern Plateau
LIN 6B	0.101	–0.53	146.2	0.141	0.02	120.5	Bounty Plateau
LIN 7WC	0.078	–0.87	169.3	0.067	–2.37	159.9	West Coast S.I.
Cook Strait	0.097	–0.54	163.6	0.080	–1.94	158.9	Cook Strait

3. STOCKS AND AREAS

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

4. STOCK ASSESSMENT

Stock assessments for three ling stocks (LIN 3&4, Chatham Rise; LIN 5&6, Southern Plateau; and Cook Strait, parts of LIN 2 and 7) were updated in 2007 using a Bayesian stock model implemented using the general-purpose stock assessment program CASAL v2.09 (Bull *et al.* 2005). For final runs, the full posterior distribution was sampled using Markov Chain Monte Carlo (MCMC) methods, based on the Metropolis-Hastings algorithm. Bounded estimates of spawning stock virgin (B_0) and current (B_{2007}) biomass were obtained. Year class strengths and fishing selectivity ogives were also estimated in the model. Trawl selectivity ogives were fitted as double normal curves; line fishery ogives were fitted as logistic curves. Research survey selectivity was fitted as either double normal or logistic, dependent on stock and model run. Assessments for other stocks (LIN 6B, Bounty Plateau; and LIN 7WC, west coast South Island) are not updated here.

MCMC chains were constructed using a burn-in length of 5(10^5 iterations, with every 1000th sample taken from the next 10^6 iterations (i.e., a final sample of length 1000 was taken from the Bayesian posterior). Single chain convergence tests were applied to resulting chains to determine evidence of non-convergence. No evidence of lack of convergence was found in the estimates of B_0 from the base case model runs, or in most of the sensitivity runs, but some estimates of selectivity parameters and YCS showed evidence of lack of convergence.

For LIN 3&4, model input data include catch histories, biomass and catch-at-age data from a summer trawl survey series, line fishery CPUE, catch-at-age and catch-at-length from the line fishery, catch-at-age data from the trawl fishery, and estimates of biological parameters. A base case model run is presented (i.e., a re-run of the most recently reported assessment model, with updated catch history and abundance series), plus two sensitivity runs (to investigate the effect of using a lower *M*, and estimating *M* in the model). The stock assessment model partitions the population into two sexes, and age groups 3 to 25 with a plus group. The model's annual cycle is described in Table 4.

For LIN 5&6, model input data include catch histories, biomass and catch-at-age data from summer and autumn trawl survey series, line fishery CPUE, catch-at-age and catch-at-length from the spawning ground and home ground line fisheries, catch-at-age data from the trawl fishery, and estimates of biological parameters. A base case model run is presented, with sensitivity runs investigating the effect of estimating *M* in the model, and encouraging the series of recent declining summer survey biomass indices to be well fitted. The stock assessment model partitions the population into two sexes, and age groups 3 to 25 with a plus group. The model's annual cycle is described in Table 4.

For LIN 7CK, model input data include catch histories, trawl and line fishery CPUE, catch-at-age data from the trawl fishery, catch-at-age and catch-at-length from the line fishery, and estimates of biological parameters. In the absence of sufficient stock-specific data, maturity ogives were assumed to be the same as for LIN 7WC, a stock with comparable growth parameters to Cook Strait ling. A base case model run is presented, with sensitivity runs placing different weightings on the trawl CPUE series, and investigating the effect of estimating *M* in the model. The stock assessment model partitions the population into two sexes, and age groups 3 to 25 with a plus group. The model's annual cycle is described in Table 4.

Table 4: Annual cycle of the assessment model for LIN 3&4, LIN 5&6, and Cook Strait, 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 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. The last column shows the proportion of that time step's mortality that is assumed to have taken place when each observation is made (see Table 5 for descriptions of the observations).

					Observations	
Step	Approx. months	Processes	*M* fraction	Age fraction	Description	%*M*
LIN 3&4						
1	Dec-Aug	recruitment non-spawning fisheries (trawl & line)	0.9	0.5	Trawl survey (summer)	0.2
					Line CPUE	0.5
					Line catch-at-age/length	
					Trawl catch-at-age	
2	Sep-Nov	increment ages	0.1	0	–	
LIN 5&6						
1	Dec-Aug	recruitment non-spawning fisheries (trawl & line)	0.75	0.4	Trawl survey (summer)	0.1
					Trawl survey (autumn)	0.5
					Line CPUE	0.7
					Line catch-at-age/length	
					Trawl catch-at-age	
2	Sep-Nov	increment ages spawning fishery (line)	0.25	0	Line catch-at-age/length	
Cook Strait						
1	Oct–May	recruitment fishery (line)	0.67	0.5	Line CPUE	0.5
					Line catch-at-age/length	
2	Jul-Sep	increment ages fishery (trawl)	0.33	0	Trawl CPUE	0.5
					Trawl catch-at-age	

Lognormal errors, with known CVs, were assumed for all relative biomass, proportions-at-age, and proportions-at-length observations. The CVs available for those observations of relative abundance and catch data allow for sampling error only. However, additional variance, assumed to arise from differences between model simplifications and real world variation, was added to the sampling variance. The additional variance, termed process error, was estimated in MPD runs of the model (see Table 5) and fixed in all subsequent runs.

Table 5: Summary of the relative abundance series applied in the models, including source years (Years), and the estimated process error (c.v.) added to the observation error.

Data series	Years	Process error c.v.
LIN 3&4		
Trawl survey proportion at age (*Amaltal Explorer*, Dec)	1990	0.001
Trawl survey biomass (*Tangaroa*, Jan)	1992–2007	0.05
Trawl survey proportion at age (*Tangaroa*, Jan)	1992–2007	0.3
CPUE (longline, all year)	1990–2006	0.1
Commercial longline proportion-at-age (Jul–Oct)	2002–06	0.05
Commercial longline length-frequency (Jul–Oct)	1995–2005	0.6
Commercial trawl proportion-at-age (Nov–May)	1992, 1994–2006	0.25
LIN 5&6		
Trawl survey proportion at age (*Amaltal Explorer*, Nov)	1990	0.1
Trawl survey biomass (*Tangaroa*, Nov–Dec)	1992–94, 2001–07	0.15
Trawl survey proportion at age (*Tangaroa*, Nov–Dec)	1992–94, 2001–07	0.1
Trawl survey biomass (*Tangaroa*, Mar–May)	1992–93, 1996, 1998	0.01
Trawl survey proportion at age (*Tangaroa*, Mar–May)	1992–93, 1996, 1998	0.2
CPUE (longline, all year)	1991–2006	0.15
Commercial longline length-frequency (Puysegur, Oct–Dec)	1993, 96, 1999–2006	0.3
Commercial longline proportion-at-age (Puysegur, Nov–Dec)	2000–06	0.3
Commercial longline length-frequency (Campbell, Apr–Jul)	1998–2005	0.4
Commercial longline proportion-at-age (Campbell, Jun)	1999, 2001, 2003, 2005	0.35
Commercial trawl proportion-at-age (Jan–Jul)	1992–93, 1996, 1998, 2003	0.4
Cook Strait		
CPUE (hoki trawl, all year)	1990–2006	0.2
CPUE (longline, all year)	1990–2006	0.2
Commercial trawl proportion-at-age (May–Sep)	1999–2006	0.01
Commercial longline proportion-at-age (May–Sep)	2006	0.01
Commercial longline length-frequency (May–Sep)	2001–2004	0.1

The assumed prior distributions used in the assessment are given in Table 6. Most priors were intended to be relatively uninformed, and were specified with wide bounds. The exceptions were the choice of informative priors for the trawl survey q, and natural mortality (when estimated). The priors on q for all the *Tangaroa* trawl surveys were estimated assuming that the catchability constant was a product of areal availability (0.5–1.0), vertical availability (0.5–1.0), and vulnerability between the trawl doors (0.03–0.40). The resulting (approximately lognormal) distribution had mean 0.13 and CV 0.70, with bounds assumed to be 0.02 to 0.30. The prior for natural mortality assumed that the current estimate of M (0.18) was a reasonable approximation to the true value, but that the true value could differ from the current point estimate by about 0.1.

Table 6: Assumed prior distributions and bounds for estimated parameters in the assessments. The parameters are mean (in log space) and c.v. for lognormal.

Parameter description	Distribution	Parameters		Bounds	
B_0 (LIN 3&4)	uniform-log	–	–	30 000	500 000
B_0 (LIN 5&6)	uniform-log	–	–	50 000	800 000
B_0 (Cook Strait)	uniform-log	–	–	2 000	60 000
Year class strengths	lognormal	1.0	0.7	0.01	100
Trawl survey q	lognormal	0.13	0.70	0.02	0.3
CPUE q	uniform-log	–	–	1e-8	1e-3
Selectivities	uniform	–	–	0	20–200*
Process error c.v.	uniform-log	–	–	0.001	2
M	lognormal	0.18	0.18	0.05	0.5

* A range of maximum values were used for the upper bound

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

4.1 Estimates of fishery parameters and abundance

The catch history used in the model is presented in Table 8, and other input parameters are shown in Table 7.

Table 7: Input parameters for the assessed stocks.

Parameter	LIN 3&4	LIN 5&6	Cook Strait
Stock-recruitment steepness	0.9	0.9	0.9
Recruitment variability c.v.	0.6	0.6	0.7
Ageing error c.v.	0.05	0.06	0.07
Proportion by sex at birth	0.5	0.5	0.5
Proportion spawning	1.0	1.0	1.0
Spawning season length	0	0.25	0
Maximum exploitation rate (U_{max})	0.6	0.6	0.6

Maturity ogives*

Age	3	4	5	6	7	8	9	10	11	12	13	14	15
LIN 3&4													
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 Cook Strait)													
Male	0.0	0.015	0.095	0.39	0.77	0.94	1.00	1.00	1.00	1.0			
Female	0.0	0.004	0.017	0.06	0.18	0.39	0.65	0.85	0.94	1.0			

*Proportion mature at age

Table 8: 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 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.

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

Table 8 (*Continued*):

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
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*	2 000	2 100	7 000	300	700	100	1 800	750	200	250

* Assumed catches.

Estimates of relative abundance from trawl surveys (Table 9) and standardised analyses of CPUE (Table 10) are presented below. The Cook Strait trawl and line CPUE series exhibit conflicting trends in recent years. The trawl series from the hoki target fishery is believed to provide the more reliable index of abundance series because it is derived from a data rich fishery with relatively constant behaviour, reasonably accurate tow-by-tow catch records, and with little incentive to target or avoid ling. The line fishery series is data poor in some years, and, because it uses data from target ling sets only, may be biased owing to the reported target species being determined after the catch is onboard.

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

Fishstock	Area	Vessel	Trip code	Date	Biomass	c.v. (%)
LIN 3 & 4	Chatham Rise	*Tangaroa*	TAN9106	Jan-Feb 1992	8 930	5.8
			TAN9212	Jan-Feb 1993	9 360	7.9
			TAN9401	Jan 1994	10 130	6.5
			TAN9501	Jan 1995	7 360	7.9
			TAN9601	Jan 1996	8 420	8.2
			TAN9701	Jan 1997	8 540	9.8
			TAN9801	Jan 1998	7 310	8.0
			TAN9901	Jan 1999	10 310	16.1
			TAN0001	Jan 2000	8 350	7.8
			TAN0101	Jan 2001	9 350	7.5
			TAN0201	Jan 2002	9 440	7.8
			TAN0301	Jan 2003	7 260	9.9
			TAN0401	Jan 2004	8 250	6.0
			TAN0501	Jan 2005	8 930	9.4
			TAN0601	Jan 2006	9 300	7.4
			TAN0701	Jan 2007	7 800	7.2
			TAN0801	Jan 2008	7 503	6.8
LIN 5 & 6	Southern Plateau	*Amaltal Explorer*	AEX8902	Oct–Nov 1989	17 490	14.2
			AEX9002	Nov–Dec 1990	15 850	7.5
LIN 5 & 6	Southern Plateau	*Tangaroa*	TAN9105	Nov-Dec 1991	24 090	6.8
			TAN9211	Nov-Dec 1992	21 370	6.2
			TAN9310	Nov-Dec 1993	29 750	11.5
			TAN0012	Dec 2000	33 020	6.9
			TAN0118	Dec 2001	25 060	6.5
			TAN0219	Dec 2002	25 630	10.0
			TAN0317	Nov-Dec 2003	22 170	9.7
			TAN0414	Nov-Dec 2004	23 770	12.2
			TAN0515	Nov-Dec 2005	19 700	9.0
			TAN0617	Nov-Dec 2006	19 640	12.0
			TAN07xx	Nov-Dec 2007	26 492	8.0
LIN 5 & 6	Southern Plateau	*Tangaroa*	TAN9204	Mar-Apr 1992	42 330	5.8
			TAN9304	Apr-May 1993	37 550	5.4
			TAN9605	Mar-Apr 1996	32 130	7.8
			TAN9805	Apr-May 1998	30 780	8.8
LIN 7WC	WCSI	*Kaharoa*	KAH9204	Mar-Apr 1992	286	19
			KAH9404	Mar-Apr 1994	261	20
			KAH9504	Mar-Apr 1995	367	16
			KAH9701	Mar-Apr 1997	151	30

KAH0004	Mar-Apr 2000	95	46
KAH0304	Mar-Apr 2003	150	33
KAH0503	Mar-Apr 2005	274	37
KAH0704	Mar-Apr 2007	180	27

Table 10: Standardised CPUE indices (with c.v.s) for the trawl and line fisheries in LIN 3&4, LIN 5&6, and Cook Strait. Year refers to calendar year.

	LIN 3&4 line		LIN 5&6 line		Cook Strait line		Cook Strait trawl	
Year	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.
1990	1.99	0.07	–	–	0.74	0.16	2.06	0.05
1991	1.49	0.04	0.91	0.10	1.08	0.13	1.70	0.04
1992	1.96	0.05	1.23	0.08	1.08	0.11	1.49	0.04
1993	1.44	0.04	1.31	0.07	0.79	0.11	1.55	0.04
1994	1.39	0.04	0.96	0.06	0.69	0.10	1.01	0.04
1995	1.38	0.14	1.30	0.07	0.62	0.11	0.87	0.03
1996	1.16	0.04	1.05	0.06	0.75	0.13	0.85	0.03
1997	0.82	0.03	1.21	0.05	0.97	0.18	0.73	0.03
1998	0.79	0.04	1.00	0.05	0.68	0.15	0.74	0.03
1999	0.69	0.04	0.84	0.05	1.23	0.19	0.74	0.03
2000	0.80	0.04	0.98	0.06	1.39	0.19	0.84	0.03
2001	0.79	0.04	1.10	0.07	1.28	0.21	0.95	0.03
2002	0.67	0.04	1.09	0.07	1.76	0.11	0.98	0.04
2003	0.84	0.04	0.80	0.09	1.51	0.11	1.03	0.03
2004	0.69	0.04	0.73	0.08	1.28	0.11	0.82	0.03
2005	0.76	0.04	0.83	0.10	1.06	0.12	0.79	0.03
2006	0.63	0.04	0.89	0.10	0.89	0.17	0.78	0.04

Posterior distributions of year class strength estimates from the base case model runs for each assessed stock are shown in Figure 1; distributions from the other model runs differed little from these examples.

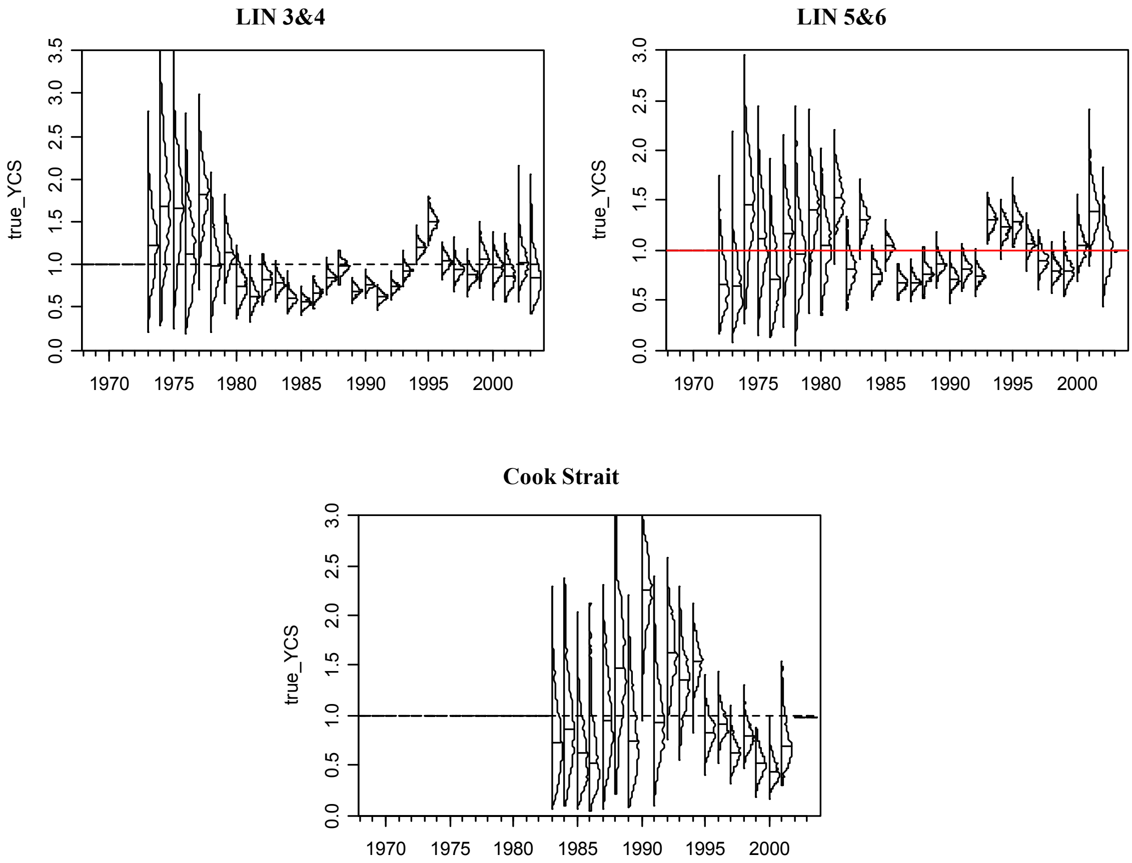


Figure 1: Estimated posterior distributions of year class strength for each assessed stock. The horizontal line indicates a year class strength of one. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

4.2 Biomass estimates

LIN 3&4

Descriptions of the two model runs presented are as follows.

- Fixed *M* — catch history, all relative abundance series listed in Tables 5, 9, and 10, *M* = 0.18, double-normal selectivity ogives for research and commercial trawl, logistic ogives for the line fishery.
- Estimate *M* — the base case model, but estimating a single *M* for both sexes.

The two model runs indicate that the estimation of biomass (both absolute and stock status) is quite sensitive to changes in *M* (Figure 2, Table 11). Both assessments are driven by the catch-at-age data, which contains information indicative of a stock decline during the 1990s, supported by a declining trend in the line fishery CPUE indices during that time. The Estimate *M* model is more pessimistic than the Fixed *M*, and the variance around the biomass trajectory is smaller in the Estimate *M* run. The estimated median *M* was 0.14. The fits to the survey biomass, CPUE, catch-at-age and catch-at-length series are reasonable to good in all model runs, with generally balanced residuals for all series. However, the run with the lower *M* has the lowest negative log-likelihood, attributable mainly to it being better able to fit the line fishery catch-at-length data. The only abundance series fitted best by the Fixed *M* model is the research survey biomass.

Table 11: Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2007} (in tonnes), and B_{2007} as a percentage of B_0 for both model runs for LIN 3&4.

Model run	B_0		B_{2007}		B_{2007} (% B_0)	
Fixed *M*	141 790	(128 540–160 260)	88 960	(74 820–108 180)	68	(58–82)
Estimate *M*	112 690	(107 870–120 440)	50 940	(43 760–63 080)	45	(40–53)

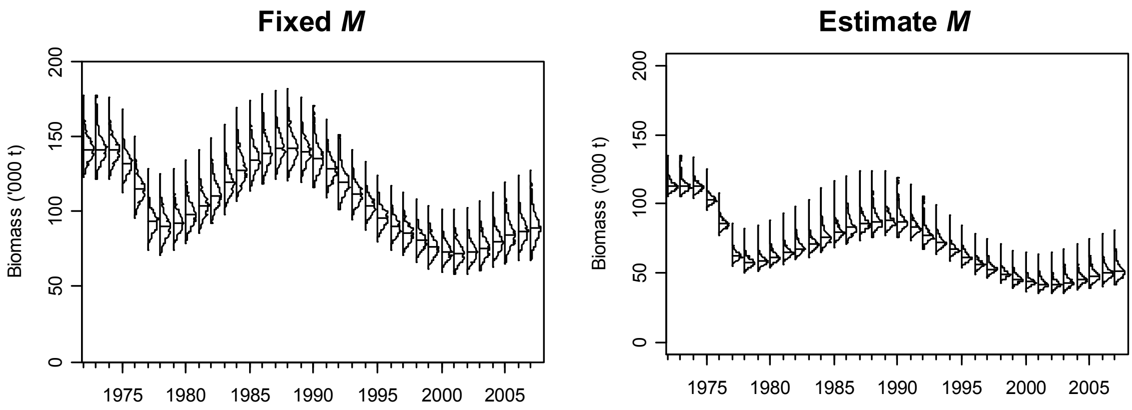


Figure 2: LIN 3&4 — Estimated posterior distributions of the biomass trajectory (in tonnes) from the Fixed *M* and Estimate *M* runs. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

Both model runs indicated an increasing biomass since 2001 (driven by a reduction in catch, and the recruitment of some average to strong year classes). Estimates of current and virgin stock size are reasonably precise, assuming that the estimated *M* of 0.14 is reasonably precise. Annual landings from the LIN 3&4 stock have been less than 4600 t since 2004, markedly lower than the 6000–8000 t taken annually between 1992 and 2003.

LIN 5&6

Descriptions of the two model runs reported are as follows.

- Fixed *M* — catch history, all relative abundance series listed in Tables 5, 9, and 10, *M* = 0.18, double-normal selectivity ogives for the trawl fishery, logistic ogives for the line fishery and the resource survey series.
- Estimate *M* — the base case model, but estimating a single *M* for both sexes.

The model runs indicate that the estimation of absolute biomass is very sensitive to changes in *M* (Figure 3, Table 12). Changing *M* from 0.18 (Fixed *M*) to 0.20 (Estimate *M*) increases the point estimates of biomass by 70–90%. Both runs have similar biomass trajectory shapes, driven by the catch-at-age data, which contains information indicative of a slight stock decline during the 1990s. The Estimate *M* run is more optimistic, but also more imprecise, than the Fixed *M* run. The fits to the CPUE, catch-at-age and catch-at-length series are reasonable to good in both model runs, with generally balanced residuals for all series. However, the run estimating *M* has the lower negative log-likelihood, attributable to slightly better fits to the catch-at-age data.

Neither of the models fit the summer research survey biomass well (Figure 4). Consequently, an additional model was run aimed at strongly encouraging a fit to the series of declining summer survey biomass indices from 2001 to 2007 by allowing this part of the series to have a separate *q*, and by removing the line CPUE (which has a relatively flat trend during the 2000s). However, the resulting fit was little different to the base case, with only a slight downward trend. This run was slightly more pessimistic than the Fixed *M* results.

A further model run estimated *M* as a double exponential ogive. The estimated ogive was biologically sensible, with *M* being greater for very old (*M* ~ 0.4) and very young (~0.24) fish, and lowest (~0.13) at age 13 years. Biomass estimates from this run were between those derived from the Fixed *M* and Estimate *M* models.

Table 12: Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2007} (in tonnes), and B_{2007} as a percentage of B_0 for both model runs for LIN 5&6.

Model run	B_0		B_{2007}		B_{2007} (%B_0)	
Fixed *M*	265 770	(219 600–345 320)	198 380	(145 190–288 460)	75	(66–84)
Estimate *M*	445 750	(272 530–740 110)	369 840	(199 020–660 420)	82	(72–91)

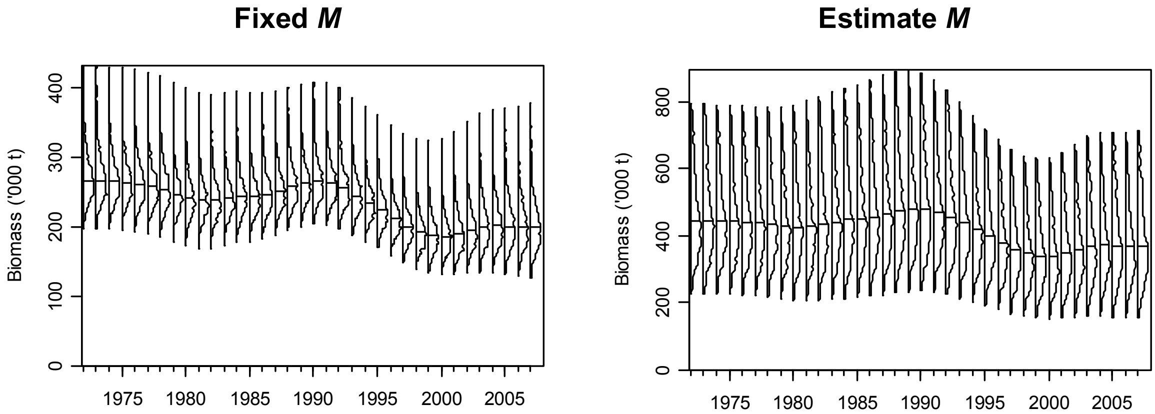


Figure 3: LIN 5&6 — Estimated posterior distributions of the biomass trajectory (in tonnes) from both model runs. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

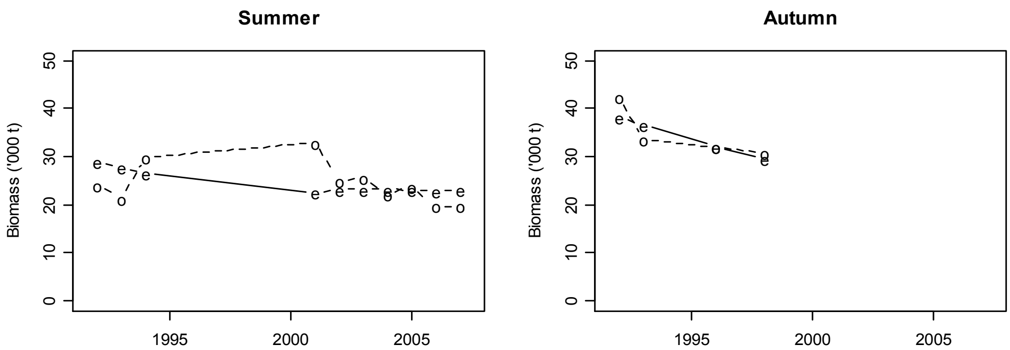


Figure 4: LIN 5&6 — MDP fits to the summer and autumn trawl survey series, from the Fixed *M* run. Points are observed (o) and expected (e).

Previous assessments of the LIN 5&6 stock (the last one conducted in 2003) have required strong (and possibly unrealistic) priors to force the summer survey *q* to be close to the *q* value estimated for the LIN 3&4 summer survey series, and thereby produce believable absolute biomass estimates. The only sound conclusion that could previously be drawn was that fishing had had little impact on the stock. The current assessment uses uninformed or realistic informed priors to produce biomass trajectories, admittedly with very wide variance, indicating that the abundance series now available are starting to show some contrast.

All assessments indicated a biomass trough about 2000, and some recovery since then. However, it is uncertain whether biomass in recent years has increased, decreased, or remained stable. Estimates of current and virgin stock size are very imprecise, but it is most unlikely that B_0 was lower than 200 000 t for this stock, and it is very likely that current biomass is greater than 60% of B_0. The parameter having the greatest influence on biomass estimates is *M*; small increases in *M* can produce large increases in estimated biomass. The mean 'true' *M* for LIN 5&6 may be slightly higher than the base case value of 0.18.

Cook Strait

A description of the reported model run is as follows.

- Split trawl CPUE — catch history, all relative abundance series listed in Tables 5 and 10 excluding the line CPUE, *M* = 0.18, double-normal selectivity ogives for the trawl fishery, logistic ogives for the line fishery, but splitting the trawl CPUE into an early (1990–1993) and a recent (1994–2006) series.

The four additional models described below were completed, and are discussed here, but their numerical results are not reported.

- Trawl CPUE only — the Split trawl CPUE model, but including trawl CPUE as a single series.
- Up-weighted trawl CPUE — the 'Trawl CPUE only' model, but with no process error added to the trawl CPUE series.
- Both CPUE series — the 'Trawl CPUE only' model, but including the line CPUE.
- Estimate *M* — the Both CPUE series model, but with logistic ogives for both the trawl and line fishery, and estimating a single *M* for both sexes.

The first run model (Both CPUE series) included all available data, but showed that fits to both CPUE series were poor (Figure 5). The two series exhibit conflicting trends. For the reasons given earlier (section 4.1) the Cook Strait trawl CPUE is believed to be a more reliable relative abundance series than the line CPUE. However, the fit to the trawl CPUE was little improved when the line series was excluded (i.e., the Trawl CPUE only model). Consequently, two additional models were run excluding the line CPUE and encouraging the trawl CPUE to be better fitted. The Up-weighted trawl CPUE model fitted the CPUE series very well, but produced an unsatisfactory q-q plot for the CPUE series, poor negative log-likelihood values, and illogical trawl selectivity ogives. Hence, this model is probably unrealistic. The Split trawl CPUE model also fitted the two CPUE sub-series well, and indicated that catchability was about 50% higher in 1990–93 relative to 1994–2006. The possibility that the early and recent parts of the trawl CPUE series may not be comparable was suggested in the most recent CPUE analysis (Horn in prep. a). Consequently, this model is considered the most believable, and its results are presented here (Figure 6, Table 13). All the models are driven by the trawl and line fishery catch-at-age and catch-at-length data, which contain information indicative of a stock decline from the late 1980s to 1993, a period of rebuilding to 2002, and a subsequent decline.

When fitting trawl selectivity as double-normal ogives, the selectivity for both sexes tended to peak at about ages 14–16, whereas line selectivity ogives, fitted as logistic functions, produced full selectivity at ages 12–13. 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. A model run where both trawl and line fishery ogives were estimated as logistic curves (the Estimate *M* model) produced ages at full selectivity that were also lower in the line fishery than the trawl fishery. The reason for the "aberrant" selectivity ogives for Cook Strait fisheries in not known.

It was assumed in all but the Estimate *M* model run that *M* is 0.18 y^{-1} for both sexes. However, information outside the model indicated that *M* is likely to be higher than 0.18 for the LIN 7CK stock. A model run estimating a constant *M* produced a posterior distribution with a median at 0.22, and a 95% credible interval of 0.18–0.26. This run produced the most optimistic stock status, but also the most variable estimates of absolute biomass. The Cook Strait assessment is clearly quite sensitive to relatively small changes in *M*.

In summary, the LIN 7CK assessment has several shortfalls. First, there are no fishery-independent indices of relative abundance. Second, the line and trawl CPUE series exhibit conflicting trends, and although the trawl series is probably the more reliable of the two, early and recent parts of this series may not be comparable. 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 their association with ling off the lower east coast of the North Island is unknown. Fourth, the catch-at-length and 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. And finally, the model is moderately sensitive to small changes in *M*. But notwithstanding all these shortfalls, Cook Strait ling appears likely to have a B_0 in the range 7000–8000 t, and a current biomass in excess of 40% of B_0.

Table 13: Bayesian median and 95% credible intervals (in parentheses) of B_0 and B_{2007} (in tonnes), and B_{2007} as a percentage of B_0 for the Split trawl CPUE model run for Cook Strait ling.

Model run	B_0		B_{2007}		B_{2007} (%B_0)	
Split trawl CPUE	7 150	(6 500–7 890)	3 360	(2 740–4 080)	47	(42–52)

Figure 5: Cook Strait — MDP fits to the trawl and line fishery CPUE series from the Both CPUE series run.

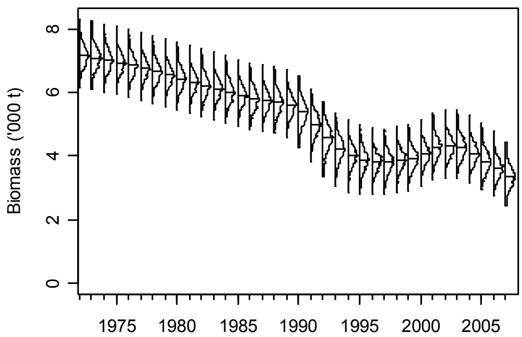


Figure 6: Cook Strait — Estimated posterior distributions of biomass trajectories (in tonnes) for the Split trawl CPUE model run. Individual distributions show the marginal posterior distribution, with horizontal lines indicating the median.

4.3 Estimation of Maximum Constant Yield (MCY)

Two methods were used to estimate MCY.

(i) MCY = cY_{av}, where c = 0.8 based on M = 0.18 and Y_{av} is the mean catch for the years 1983–84 to 1990–91.

(ii) MCY = pB_0 where p is determined for each stock using the simulation method of Francis (1992) such that the spawning biomass does not go below 20% B_0 more than 10% of the time. MCY estimates and related parameters are listed in Table 14.

Auckland (LIN 1)

An MCY for LIN 1 was estimated from the equation MCY = cY_{av}, and is 101 t. It has not been re-estimated since the 1992 Plenary Report.

Central (East), including Cook Strait (LIN 2)

An MCY for all of LIN 2 (394 t) was estimated from the equation MCY = cY_{av} in 1992. Modelling of the Cook Strait stock (parts of LIN 2 and LIN 7) was completed in 2007, and estimates of MCY were derived from this assessment using a variant of method (ii) above. About 75% of the Cook Strait landings are from Fishstock LIN 2 (the rest being from LIN 7), and in recent years they have accounted for about 40% of the LIN 2 landings.

South-East (Coast), and South-East (Chatham Rise) (LIN 3 & 4)

Estimates of MCY are presented from several LIN 3&4 CASAL runs using a variant of method (ii) above. They were derived from the 2007 assessment.

Southland, and Sub-Antarctic (LIN 5 & 6)

Estimates of MCY are presented from several LIN 5&6 CASAL runs using a variant of method (ii) above. They were derived from the 2007 assessment. B_0 and current biomass for this stock are poorly known, so the yield estimates are very uncertain.

An estimate of MCY for the Bounty Plateau stock (LIN 6B) was derived from the 2006 CASAL assessment using a variant of method (ii) above. B_0 and current biomass for this stock are poorly known, so the yield estimate is very uncertain.

Challenger, and Central (West) (LIN 7)

Estimates of MCY for ling off west coast South Island are presented from several CASAL runs, but they are based on assessments that are very uncertain. They were derived from the 2005 assessment. See LIN 2 (above) for yield estimates for the Cook Strait stock.

Table 14: Estimates of B_{MCY} and MCY from base case and sensitivity model runs.

Fishstock	Model run	B_{MCY} (t)	MCY (t)	B_{MCY} (% of B_0)	MCY (% of B_0)
LIN 3&4	Fixed *M*	57 170	8 240	40.3	5.8
	Estimate *M*	45 750	4 960	40.6	4.4
LIN 5&6	Fixed *M*	122 510	16 640	46.1	6.3
	Estimate *M*	267 240	25 880	60.0	5.8
LIN 6B	Base case	7 520	720	55.4	5.3
Cook Strait	Split trawl CPUE	3 140	390	43.9	5.5
LIN 7WC	TCEPR CPUE	15 490	2 360	37.6	5.7
	Observer CPUE	28 250	3 090	48.0	5.3
	Trawl & line CPUE	21 170	2 670	43.4	5.5
	Kaharoa survey	14 550	2 360	35.8	5.8
	No CPUE	13 430	2 100	36.9	5.8

4.4 Estimation of Current Annual Yield (CAY)

The simulation method of Francis (1992) was also used to estimate CAY with the same definition of risk. CAY estimates from the reported model runs for LIN 3&4, 5&6, 6B, and Cook Strait are given in Table 15. There are no reliable CAY estimates for any other stocks.

Table 15: CAY estimates and associated parameters for the model runs for LIN 3&4, LIN 5&6, and LIN 7CK (from the 2007 assessment), and for LIN 6B (from the 2006 assessment).

Model run		B_{MAY} (t)	MAY (t)	F_{CAY}	CAY (t)	B_{MAY} (% of B_0)	MAY (% of B_0)
LIN 3&4	Fixed *M*	38 710	9 320	0.22	21 160	27.3	6.6
	Estimate *M*	30 230	5 650	0.18	9 560	26.8	5.0
LIN 5&6	Fixed *M*	75 220	20 710	0.27	55 830	28.3	7.8
	Estimate *M*	134 480	39 930	0.29	114 620	30.2	8.9
Cook Strait	Split trawl CPUE	2 040	460	0.22	740	28.5	6.4
LIN 6B	Base case	4 780	940	0.18	1 680	35.2	6.9

4.5 Other yield estimates and stock assessment results

Projections for LIN 6B from the 2006 assessment are shown in Table 16. The LIN 6B stock (Bounty Plateau) is likely to decline out to 2011, but probably will still be higher than 50% of B_0. New projections out to 2012 for LIN 3&4, 5&6, and Cook Strait, assuming future annual catches equal to recent catch levels, are shown in Table 17. For LIN 3&4 and LIN 5&6, stock size is likely to increase slightly. For Cook Strait ling, stock size is likely to decline, but probably will still be higher than 50% of B_0.

Table16: Bayesian median and 95% credible intervals (in parentheses) of projected B_{2011}, B_{2011} as a percentage of B_0, and B_{2011}/B_{2006}(%) for the base case LIN 6B.

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

Table 17: Bayesian median and 95% credible intervals (in parentheses) of projected B_{2012}, B_{2012} as a percentage of B_0, and B_{2012}/B_{2007}(%) for the LIN 3&4, 5&6, and 7CK base case and sensitivity runs.

Stock and model run		Future catch (t)	B_{2012}		B_{2012} (%B_0)		B_{2012}/B_{2007} (%)	
LIN 3&4	Fixed M	4 100	95 890	(76 200–124 250)	68	(58–82)	108	(96–127)
	Estimate *M*	4 100	54 770	(43 900–71 250)	49	(40–60)	106	(94–125)
LIN 5&6	Fixed *M*	8 000	208 250	(138 230–315 690)	77	(62–101)	103	(88–132)
	Estimate *M*	8 000	394 120	(204 070–725 870)	86	(69–112)	104	(89–133)
Cook Strait	Split trawl CPUE	450	2 520	(1 520–4 260)	35	(22–57)	74	(50–120)

5. ANALYSIS OF ADAPTIVE MANAGEMENT PROGRAMMES (AMP)

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

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

LIN 1

In October 2002, the TACC for LIN 1 was increased from 265 t to 400 t within the AMP. The AMP was reviewed in 2007.

Full-term Review of LIN 1 AMP in 2007

In 2007 the AMP FAWG reviewed the performance of the AMP after 4 years at the higher TACC (SeaFIC, 2007).

Fishery Characterization

- Ling catches remained slightly under the TACC up to 1995–96, but then exceeded the TAC, reaching ~300t over most of the period 1996–97 – 2001–02, prompting the AMP proposal.
- After implementation of the AMP, catches dropped back to the previous TACC level for two years, and then increased slowly to reach 364t in 2005–06, 36t under the AMP TACC.
- 54% of the QMA1 ling catch is taken by bottom trawl, and 44% in the ling bottom longline fishery, with catches by both methods mainly coming from the Bay of Plenty (statistical areas 8 to 10). There were substantial ling bycatches made by trawl on the North Island west coast from 1996–97 - 2000–01 in the gemfish fishery, and longline catches have increased from the East Northland area.
- The WG noted that there are substantial problems with the quality of LIN 1 data, and that this is one of the worst data sets analysed under the AMPs. Catches are substantially under-reported compared to landings, with large landings declared in apparently incorrect areas (statistical areas possibly instead of QMA). Individual trips appear to circumnavigate the entire North Island, and a substantial proportion of some catches are retained on board, and so are excluded from the analyses.
- The trawl fishery spans much of the year, with some emphasis from 1996 on fishing in late winter/spring from June to December. The longline fishery is strongly seasonal, taking much of its catch in spring from Aug - Oct each year.
- There is a small targeted ling trawl fishery, and trawl catches of LIN 1 are mainly made in the scampi and gemfish fisheries. The gemfish fishery mainly contributed catches from 1996–97 - 2000–01, with the scampi fishery dominating before and after that.
- In contrast, ~75% of the ling longline catch is taken in the targeted longline fishery, with only minor bycatches coming from the bluenose, ribaldo and hapuka targeted longline fisheries.
- Depth distribution of ling catches in the trawl fisheries shows two main depths associated with specific fisheries. Most ling are caught in the scampi / hoki / ling fishery at ~400 m

depth, but some are taken in the tarakihi / snapper / barracouta / trevally fisheries around 100 m depth.

CPUE Analysis

- The diverse nature and broad geographic range of the LIN 1 fisheries has complicated the selection of representative CPUE indices. Eight potential fisheries were previously identified as potential CPUE indices, but none of the analyses were considered to be robust due to the relative paucity of data.
- Two fishery definitions were explored this year as candidates for LIN 1 standardised indices: the scampi-targeted bottom trawl fishery in the Bay of Plenty (BT (SCI) and the ling targeted bottom longline fishery from the east North Island to Bay of Plenty (BLL (LIN).
- CPUEs for these fishery definitions were standardised using a lognormal model based on non-zero catches. In additional, a binomial model was used to investigate the effect of changing proportion of non-zero catches.
- The two standardised indices show conflicting trends. The BLL index appears to show two periods of gently declining CPUE from 1990–91 - 1996–97 and 1999–00 - 2005–06, but separated by a strong, highly uncertain and likely anomalous peak in 1998–99. In contrast, the BT index appears to be stable until 1997–98, rises to a peak in 2000–01 and then declines slowly back to about the previous level by 2005–06.
- The two indices appear to agree to some extent on a gradual decline since 2000–01, and perhaps on a period of stability around the mid 1990s, but the WG was concerned that the substantial and apparently anomalous peak in BLL indicated that this series is not reliable.
- The WG noted that BLL reporting rates greatly exceed landed catch weights, reaching 700% in 1998–99. The high CPUE peak in the BLL index in 1998–99 also appeared to result from one high landing in one month, suggesting that this might have been a discharge of a large amount of catch retained on board. Although 43% of landings do not have catch estimates, the WG concluded that landed catch should not be used, and that the BLL CPUE analysis should be repeated using estimated catches.
- The WG also noted that many new participants have entered and left this fishery, and questioned whether analyses should focus on e.g. the one vessel that has been in the fishery throughout. The group concluded that the vessel effect needed to be investigated further.
- The WG also recognised many other problems related to possible changes in net width in the scampi fishery, and questions regarding the effectiveness of scampi nets in catching ling. However, it was unclear how this might alter trends, given the relatively sparse data.
- Following the requested re-analysis of the BLL CPUE data using estimated catches, the standardised target LIN 1 BLL CPUE index removed the big peak in 1998–99 and now shows a strong declining trend, but is based on only 700 records.

Logbook Programme

- Only one vessel has participated in the bottom trawl logbook programme implemented in 2002–03, and coverage has been very low, averaging <1% over the four years. The number of fish sampled has increased slightly from 132 to 361 fish in the last year.
- At this low coverage level, the programme has not been able to obtain representative coverage of either areas or seasons.

- Most length samples came from area 9 in the Bay of Plenty, and the length ranges differ somewhat between years, with the range in 2002–03 being smaller and that in 2003–04 being larger. Two modes are apparent in data from 2003–04 onwards, with some evidence of progression of a mode of very small fish (55 cm – 65 cm) from 2003–04 to 2005–06.
- The WG questioned whether the size of ling bycatch in the scampi fishery was at all useful to assessing the state of the stock, and recommended that efforts focus on sampling the target ling fishery.

Effects of Fishing

- There is a specific problem with seabird bycatches in the bottom longline fisheries. Previous studies (McKenzie & Fletcher, unpub. 2006) on seabird captures in commercial trawl and longline fisheries from 1997–98 - 2003–02 concluded that 5% of seabirds killed in New Zealand waters were caught by small bottom longline vessels in FMAs 1 and 2.
- Observer coverage of the LIN 1 fisheries has never been adequate to provide reliable estimates of seabird interactions. We are also still awaiting publication of the DOC report on past observer evaluation of seabird catches.
- Following identification of the ling fishery in the seabird NPOA as a fishery with known seabird interactions, the industry has implemented a Code of Practice specifically for the ling longline fishery. This code includes use of tori lines, restrictions on offal discharge, thawing of bait and minimisation of lights when setting at night.
- The draft observer plan for 2007–08 has a target of 20% coverage (251 observer days) of the inshore ling, bluenose and hapuku fisheries in FMAs 1, 3, 5 and 7. The target for inshore trawl is 10% (258 days), and it was recently proposed that this be increased to 400 days.
- The WG noted that actual catch increases under the AMP were small, and had probably had little effect on the extent or magnitude of impacts. In fact, ling bycatch in the scampi and gemfish trawl fisheries has decreased.
- The WG noted that it is not possible to generating adequate maps of fishing effort to evaluate changes in area of impact, as most data are provided on CELR returns which do not provide fine-scale positional information.
- The WG emphasized the need to improve fishing position reporting, particularly in bottom trawl and longline fisheries, to enable the production of accurate maps of fishing effort distribution, and how this may have changed over time.

Conclusions

- The WG agreed with previous observations that CPUE data for the various ling fisheries do not appear to provide any reliable index of ling abundance. Indices remain highly variable and uncertain, with very limited ling catch data available for each series.
- Efforts to resolve problems using landed catches did seem to improve performance of the longline CPUE index. However, use of estimated catches further reduced the already limited data, further increasing uncertainty around these indices.
- Both indices investigated showed similarly declining CPUE over the past 5 years, which may be of concern. However, the paucity of data and high uncertainty results in low confidence in the CPUE trends in general.

- Re-analysis of CPUE data for the targeted ling longline fishery removed the big peak 1998–99 seen in the analysis of landings data. The standardised longline CPUE now shows a strong declining trend, but is based on only 700 records.

AMP review Checklist

1. The potential CPUE indices explored to date for the LIN 1 fishery do not appear to be adequately robust or reliable to serve as indicators of abundance. Data on actual ling catches in the many fisheries that catch ling are sparse. There are substantial problems with data quality related to under-reporting of catch, reporting against incorrect areas and retaining catch on board for later landing. Further work is needed to ascertain whether any of the ling fisheries can provide a reliable CPUE-based index of abundance.
2. Logbook coverage is inadequate in terms of coverage of fisheries, catch and effort, areas and seasons.
3. The WG suggested the following additional analyses:
   - In future it would be useful to analyse the ratio of ling catches to other target species to explore e.g.,whether ling bycatches increased due to increased gemfish catches, or an actual increase in ling targeting / abundance. However, it was noted that this would be a substantial analysis.
   - Historic information on the size-frequency of ling in the scampi fishery should be summarised and tabled.
4. Given the high levels of uncertainty and variability in the two CPUE series explored, the WG was not able to draw any conclusions regarding whether current catches might be sustainable or not. Recent declines in both standardised CPUE indices investigated are of concern, but it is not clear to what extent these might reflect abundance declines.
5. The state of the stock in relation to B_{MSY} is unknown.
6. Effects of fishing are not adequately monitored.
7. Rates of non-fish bycatch were not reported.
8. This AMP does not need to be reviewed by the Plenary.

6. STATUS OF THE STOCKS

Since the 2007 Plenary report was published, new stock assessments have been produced for the Chatham Rise (LIN 3&4), Campbell Plateau (LIN 5&6), and Cook Strait biological stocks. Cook Strait ling is a trans-boundary stock split between Fishstocks LIN 7 and LIN 2.

LIN 1

The current stock size is considered to be above B_{MSY} based on an analysis of CPUE from the longline fisheries. In October 2002, the TACC for LIN 1 was increased to 400 t within the AMP. The biological stock affinities of ling in LIN 1 are unknown.

LIN 2 (including Cook Strait ling)

LIN 2 comprises waters off east coast North Island from East Cape to Cook Strait. The biological stock affinities of ling in LIN 2 are unknown. In recent years about 40% of the LIN 2 landings have been taken in Cook Strait (i.e., west of Cape Palliser). The model results from a Cook Strait assessment suggest that the stock has declined, particularly since the late 1980s. Based on the 2007 stock assessment current stock size is estimated to be above B_{MAY} but is likely to continue to decline at current catch levels. It is not known if recent landings and the current TACCs are sustainable, or are at levels which will allow the stocks to move towards a size that will support the MSY.

LIN 3 & 4

Based on the 2007 stock assessment current stock size is estimated to be well above B_{MAY} and building. Catches at the level of the current TACC are likely to be sustainable.

LIN 5 & 6

Based on the 2007 assessment ling stocks LIN 5 and LIN 6 (but excluding fish on the Bounty Plateau) are probably only lightly fished and current stock sizes are estimated to be well above B_{MAY}. Estimates of absolute current and reference biomass are unreliable, although B_0 is very unlikely to have been lower than 200 000 t. It is likely that the current TACC is sustainable, as current catches appear to be having only a small impact on biomass levels. The assessment is indicative of surplus ling production being available, at least in the short to medium term.

LIN 6B (Bounty Plateau)

The ling stock on the Bounty Plateau (part of the LIN 6 Fishstock) is estimated to be well above B_{MAY}. Average annual landings since the line fishery began are slightly higher than the MCY estimate. Annual extractions have never exceeded the 2006 estimate of CAY. There is no separate TACC for this stock.

LIN 7WC (west coast South Island only)

The assessment did not include ling from the Cook Strait section of QMA 7, which produces about 5% of the LIN 7 landings and is believed to be a distinct biological stock. Based on the 2005 assessment the status of the LIN 7WC stock is highly uncertain. It is not known if recent landings are sustainable, or are at levels which will allow the stocks to move towards a size that will support the MSY. The stock assessment model results did not provide reliable estimates of current biomass as a percentage of B_0. The relatively constant catch history since 1989 and the relatively flat CPUE indices suggest that future catches at the current level are probably sustainable, at least in the short term. (See LIN 2 above for the stock status of the Cook Strait component of Fishstock LIN 7.)

Summary of yields (t), TACCs (t), and reported landings (t) for the most recent fishing year. Where a range of yield estimates has been presented above, the minimum yield is listed here.

Fishstock	QMA		MCY#	CAY	2006–07 Actual TACC	2006–07 Reported landings
LIN 1	Auckland	1 & 9	101	–	400	301
LIN 2	Central (East)	2	394	–	982	874
LIN 3	South-East (Coast)	3	(	(	2 060	2 089
LIN 4	South-East (Chatham Rise)	4	4 950 (	9 460 (	4 200	2 113
LIN 5	Southland	5	(	(	3 600	3 731
LIN 6§	Sub-Antarctic	6	14 880 (	45 370 (	8 520	4 696
LIN 7†	Challenger, Central (West)	7 & 8	2 100	–	2 225	2 295
LIN 10	Kermadec	10	–	–	10	0
Total					21 997	16 102

\# Based on cY_{av} for LIN 1 & 2, and CASAL estimates for LIN 3 & 4, 5 & 6, and 7.
§ MCY and CAY include ling stock on the Bounty Plateau.
† MCY excludes ling stock in Cook Strait.

7. FOR FURTHER INFORMATION

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