New Zealand Fisheries
Assessment Report
2007/34
September 2007
ISSN 1175-1584

Stock assessment for east Pukaki Rise smooth oreo (part of OEO 6)

A. McKenzie

Stock assessment for east Pukaki Rise smooth oreo (part of OEO 6)

A. McKenzie

NIWA
Private Bag 14901
Wellington

New Zealand Fisheries Assessment Report 2007/34
September 2007

Published by Ministry of Fisheries
Wellington
2007

ISSN 1175-1584

Citation:
McKenzie, A. (2007).
Stock assessment for east Pukaki Rise smooth oreo (part of OEO 6).
New Zealand Fisheries Assessment Report 2007/34. 27 p.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

McKenzie, A. (2007). Stock assessment for east Pukaki Rise smooth oreo (part of OEO 6).

New Zealand Fisheries Assessment Report 2007/34. **27 p.**

The east Pukaki Rise smooth oreo fishery (part of OEO 6) is located off the southeast of the South Island. A first stock assessment is presented for this fishery, with estimates of current and virgin biomass.

Two sets of observational data were investigated for use in the assessment: (1) standardised CPUE indices, and (2) a commercial length-frequency series covering the years 1999–2004. As a series of length-frequency data fitted badly in all preliminary model runs they were omitted for the final model run.

Biomass estimates are uncertain because of the reliance on commercial CPUE data, and because the biological parameter estimates are from oreo stocks in other areas.

Model results suggest that mature virgin biomass was about 24 000 t with very broad 90% confidence intervals (16 000–78 000 t). Current biomass is estimated to be 42% of virgin biomass with a 90% confidence interval of 15–82%. The confidence intervals of the biomass estimates are wide because of the large uncertainties associated with the standardised CPUE series. Because of the broad confidence intervals the current status of the stock is uncertain.

The estimate of median long-term yield (MAY estimate) was 550 t, which is lower than the current catch of 1300 t.

1. INTRODUCTION

This report describes results from part of the Ministry of Fisheries project OEO200502. It covers objective 5 (stock assessment for smooth oreo from east Pukaki Rise). The stock assessment area includes the part of quota management area shown in Figure 1. This is the first assessment for this stock.

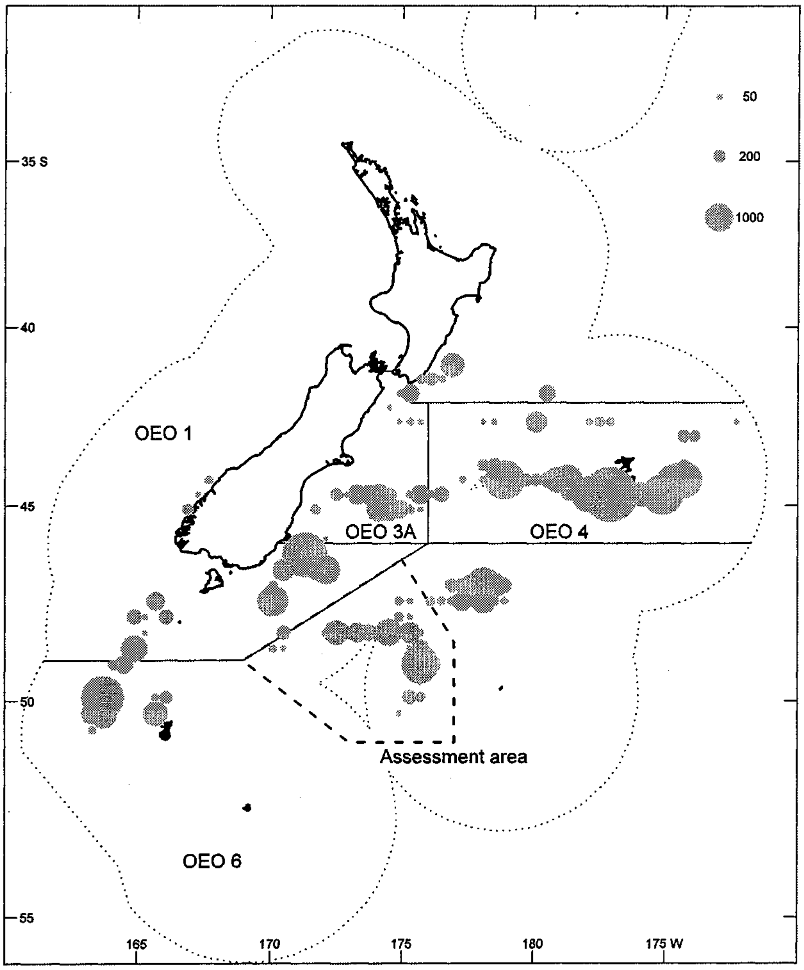

Figure 1: The Pukaki Rise fishery assessment area (within broken lines) abutting the north boundary of OEO 6. The circle areas are proportional to the mean of smooth oreo estimated catches (t) from the last 5 years (2000–01 to 2004–05) for each 0.4 x 0.4 degree rectangle. The dotted line is the EEZ boundary.

2. STOCK ASSESSMENT

2.1 Model structure

The model structure is similar to that used for the OEO 3A smooth oreo stock assessment 2005–06 (Doonan et al. unpublished report).

The observational data were incorporated into an age-based Bayesian stock assessment with deterministic recruitment to estimate stock size. The stock was considered to reside in a single area, with a partition by age and sex, but not by maturity. Age groups were 5–70 years, with a plus group of 70+.

There is a single time step in the model, in which the order of processes is ageing, recruitment, maturation, and mortality (natural and fishing). It is assumed that 50% of the recruits are males, and that year class strengths over 1973–2001 are equal. Mortality was "instantaneous", i.e., half the natural mortality was applied, then all of the fishing mortality, then half the natural mortality. A maximum exploitation rate of 0.58 was permitted.

The values for the life history parameters are the same as those used in a smooth oreo stock assessment off the east coast of the South Island conducted in 2005–06 (Doonan et al. unpublished report)(Table 1). These fixed values were derived from oreo samples taken from a range of areas. The natural mortality estimate is from fish sampled from the Puysegur Bank fishery. The von Bertalanffy parameters and associated length-at-age c.v.s are from fish sampled from the Chatham Rise and Puysegur Bank fisheries (Doonan et al. 1997). The mean length-at-age curves are plotted in Figure 2. The length-weight parameters are from research trawl samples from the south Chatham Rise (Doonan et al. 1995), and the recruitment steepness for the Beverton and Holt recruitment relationship is an assumed value.

Table 1: Fixed life history parameters for smooth oreo.

Parameter	Symbol (unit)	Female	Male
Natural mortality	M (yr^{-1})	0.063	0.063
von Bertalanffy parameters	L_∞ (cm, TL)	50.8	43.6
	k (yr^{-1})	0.047	0.067
	t_0 (yr)	-2.9	-1.6
Length-at-age c.v.		0.1	0.1
Length-weight parameters*	a	0.029	0.032
	b	2.90	2.87
Recruitment steepness		0.75	0.75

* $W(kg) = L(cm)^b$

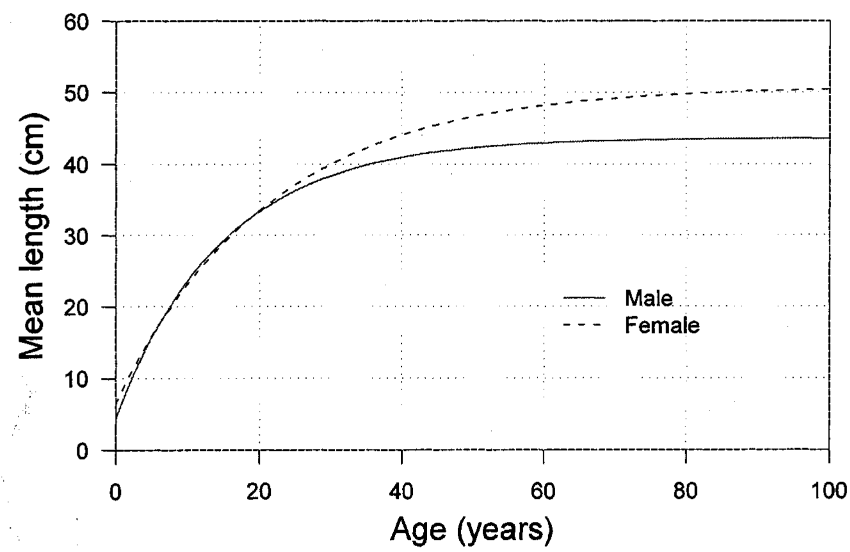

Figure 2: Mean length-at-age for smooth oreo (male and female).

The maturity ogive developed during the 2003 stock assessment of smooth oreo from south Chatham Rise (appendix 2 in Doonan et al. 2003) was used. The age at which 50% are mature is between 18 and 19 years for males and between 25 and 26 years for females (Figure 3).

Figure 3: Proportion mature by age (male and female).

2.2 Model inputs

Two sets of observational data are used in the assessment: (1) a commercial fishery length-frequency series and, (2) a standardised CPUE series (Table 2, Appendix A1). Full details of the analysis for the CPUE and length-frequency data were given by Coburn et al. (2007); brief details are given here.

Table 2: Summary of observational data for the model. The year is the fishing year (e.g. 1996 refers to 1 October 1995 to 30 September 1996). Years in quotation marks include data from adjacent years in which there were few samples. See Appendix A1 for further details.

Observational data type	Year	Likelihood
Length-frequency	"1999", "2001", 2002, and "2004"	log-normal
Standardised CPUE	1996–2005	log-normal

The standardised CPUE is based on tow-by-tow data from trawl catch effort returns where smooth oreo was either targeted or caught. The chosen units for the CPUE were kg/tow, as has been commonly used for other oreo CPUE standardisations. Typically c.v.s for year effects in CPUE standardisation are estimated by a bootstrapping procedure in which tows are resampled, then the year effects recalculated under the original standardisation model. However, as a single vessel dominated the data it was decided to estimate the c.v.s for the year effects by a nested bootstrapping procedure: vessels were randomly resampled, then tows within the resampled vessels. This gave c.v.s about 3–7 times higher those obtained when just the tows were resampled, with a mean c.v. of 0.43.

The catches taken in the model are given in Table A1. For the fishing year 2005–06, the previous year's catch was assumed (1370 t).

Logistic age-based selectivities were estimated for males and females and applied to the catch, CPUE, and commercial length-frequency data. Analysis of the length-frequency data indicates that the distribution depends on depth, with smaller fish caught in shallower waters. Furthermore, the depth at which fishing has occurred has changed over time. Hence it was decided to incorporate a shift-factor for the parameter a_{50} of the logistic selectivities. The selectivity a_{50} is shifted in year Y by $a_{scale}(D_Y - D_{mean})$

where a_{scale} is a scaling factor estimated within the model, D_Y is the median catch depth in year Y, and D_{mean} is the mean of the D_Y values. The D_Y values are in Appendix A2. A similar approach has been used before in the OEO 3A smooth oreo 2005–06 assessment (Doonan et al. unpublished report) and for the 2002 hoki stock assessment (Francis 2003). The median depth associated with a length-frequency observation is that for the year for which most of the data for the observation comes from, though some observations include some data from adjacent years. In a more refined analysis this could be accounted for by appropriately combining median depths across years.

2.3 Methods

Parameters which were made free in the models (but fixed in some) were: (1) the virgin biomass (B_0), (2) the relativity constant (q) which is involved in scaling the standardised CPUE index to a biomass, (3) the four parameters defining the male and female logistic curves for the fishing selectivity, and (4) the scaling parameter a_{scale} that determines how much the a_{50} selectivity is shifted by. The free parameters are summarised in Table 3.

In one model run the L_{inf} for males and females are estimated, as are cv1 and cv2, the c.v. at the minimum and maximum ages for the length-at-age relationship.

Table 3: Free parameters for the models. In some model runs several of these parameters are fixed.

Free parameters	Prior	Number of parameters
B_0	uniform-log	1
Relativity constant (q)	uniform-log	1
Commercial logistic selectivity (male)	uniform	2
Commercial logistic selectivity (female)	uniform	2
Scaling parameter for a_{50} shift	uniform	1

Maximum Posterior Density (MPD) estimates were found for the free parameters in the model. The stock assessment program CASAL v2.08 (Bull et al. 2005) was used to implement and fit the models (see Appendix A3 for the CASAL model files).

In addition, the uncertainty in the estimates was evaluated by Markov Chain Monte Carlo (MCMC) simulations for one model run: only the CPUE data fitted plus the selectivity is set to knife-edge at 19 years.

2.4 Model fits

A sequence of model structures was explored. In the simplest model ("No shift") a common selectivity was estimated for male and females, and no depth shifting was used for the selectivity. This simple model was modified to explore the effect of assuming separate selectivities for male and females ("No shift, M≠F"), and additionally including a depth shifting for the selectivities ("Shifted, M≠F").

For these initial model fits $B_{current}$ (%B_0) varied between 12–14%, with very similar estimates for the selectivities (Table 4, Figure 4–Figure 7). In all of these initial models the fits to the length frequencies were poor, with the observed length frequencies much more peaked than the model length frequencies. Also, before the 2003 fishing year, the model's length frequencies have a greater proportion of long fish then the observed length frequencies. In the "Shifted, M≠F" model a_{scale} was estimated to be 0.032, which corresponds to subtracting 2.2 from a_{50} in 1990–91 when the median catch depth was least, or adding 4.4 to a_{50} in 1987–88 when the median catch depth was most.

It was decided to combine the length frequencies for all years into a single length frequency, centred on the 2001 fishing year, but separated by sex ("LF (comb)" model). However, the fit to the combined length frequencies was also poor (Figure 8). In order to try and fit the length frequencies better for this model L_{inf}, cv1, and cv2 were also estimated within the model. However, the estimated values were implausible with L_{inf} taking values from 38 to 42 cm, and the cv1 values being very close to zero.

As the length frequencies were not well fitted, the Deep Water Working Group decided to drop them from the model and fit only to the CPUE data ("CPUE only" model). The fishery selectivity was set at a knife-edge at 19 years, this value being chosen based on the combined length frequencies. In this model $B_{current}$ (%B_0) was 22%. The fit to the CPUE was very similar to other model runs, with the model unable to track the decline in CPUE to 2000, followed by a rise and subsequent decline from 2002 onwards (Table 4, Figure 9).

Plotting the fit of the model expected mean lengths to the observed mean length shows that, even with depth shifting, the 1999 length observation cannot be fitted to satisfactorily (Figure 10). Furthermore, the observed mean lengths for 2001, 2002, and 2004 show a steeper decline than that for the CPUE only run, which is why the virgin biomass increases when the length-frequency data are dropped.

Of note is that the a_{50} for all estimated selectivities is around 19 yrs, which is about equal to the age at which 50% of males are mature, but is about 6–7 years before the age at which 50% of females are mature. This is reflected in the ratio of the vulnerable biomass to spawning stock biomass in 2006 (V2006/SSB2006 in Table 4) which is about 1.3 for most runs.

Table 4: MPD estimates of the free parameters in the model runs. The less the likelihood, the better the model fit. In all models there is a partition by male and female, and a common selectivity is estimated for male and female (except for runs with M≠F), and the length frequency data are included (except for the CPUE only run). Shifting refers to using a depth-shifted factor added to a_{50}. In the LF (comb) run the length-frequencies are combined for all years, centred on 2001, but separated by sex. V2006 refers to the vulnerable biomass in the 2006 fishing year, SSB2006 to the spawning stock biomass in 2006.

		No shift	No shift M≠F	Shifted M≠F	LF (comb)	CPUE only
	B_0 (mid-year)	14900	14900	15200	14400	17400
	$B_{current}$ (mid-year)	1850	1850	2100	1400	3800
	$B_{current}(\%B_0)$	12	12	14	10	22
	U_{max}	0.48	0.47	0.44	0.58	0.27
	U_{2006}	0.48	0.47	0.44	0.58	0.27
	V2006/SSB2006	1.30	1.31	1.28	1.34	1.18
	q CPUE	0.15	0.15	0.14	0.16	0.11
Male selectivity	a_{50}	19.1	19.0	19.2	19.0	19.0*
	a_{95}	8.0	8.2	8.2	7.9	0*
Female selectivity	a_{50}	19.1†	19.1	19.1	19.0†	19*
	a_{95}	8.0†	7.9	7.9	7.9†	0*
Scaling for shift	a_{scale}	0*	0*	0.032	0*	0*
Likelihoods	*sum*	340.0	340.0	310.6	301.0	2.5
	CPUE	-4.98	-4.98	-3.94	-4.78	-5.10
	LF 1999	196.8	195.6	170.0	-	-
	LF 2001	153.0	152.5	155.8	-	-
	LF 2002	13.1	13.1	5.3	-	-
	LF 2004	-24.8	-23.5	-24.2	-	-
	LF (comb)	-	-	-	297.9	-

* fixed parameter
† forced equal to male value

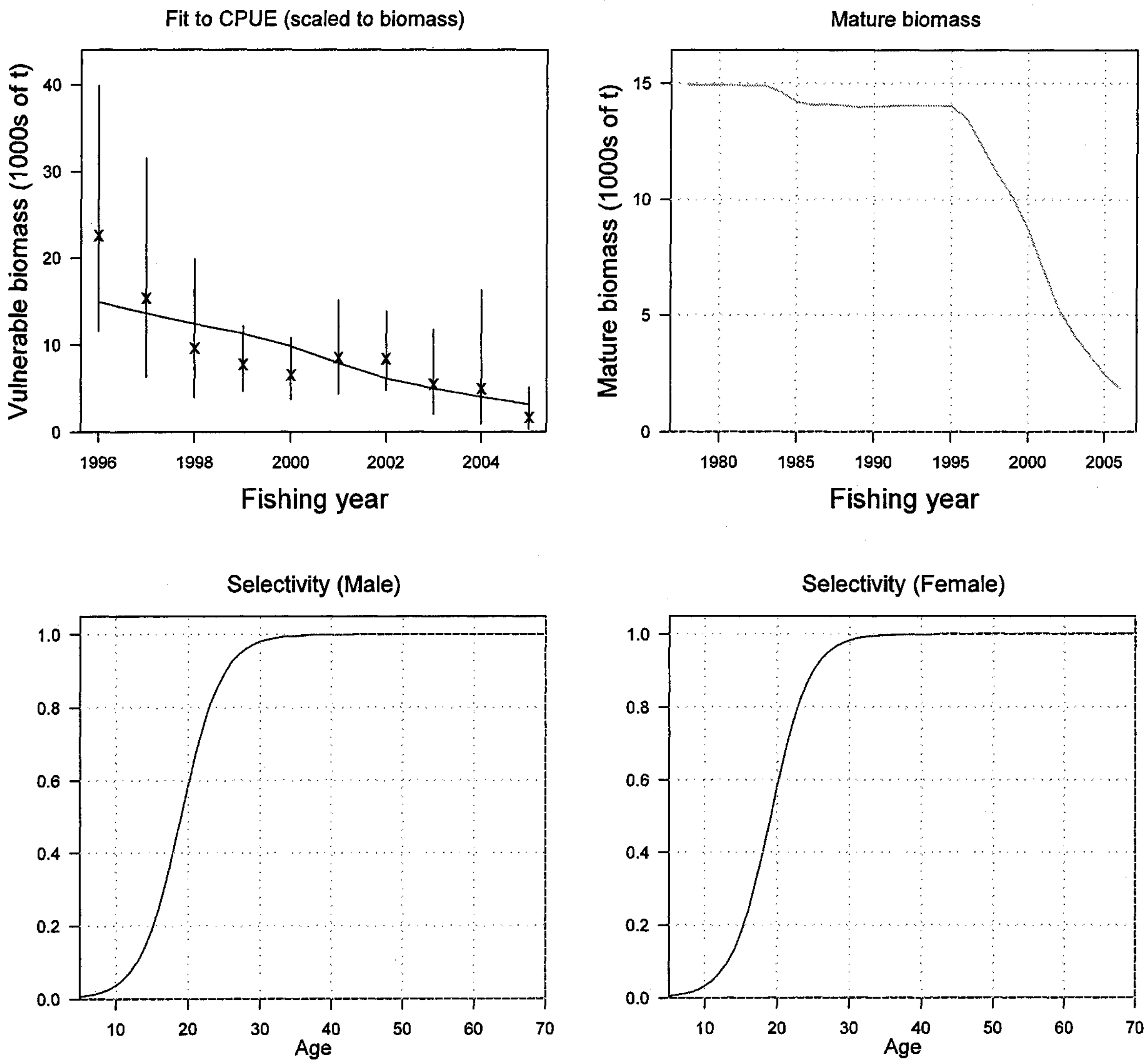

Figure 4: Some fits to the non-depth shifted selectivity model, with separate fishery selectivities for male and female ("No shift, M≠F").

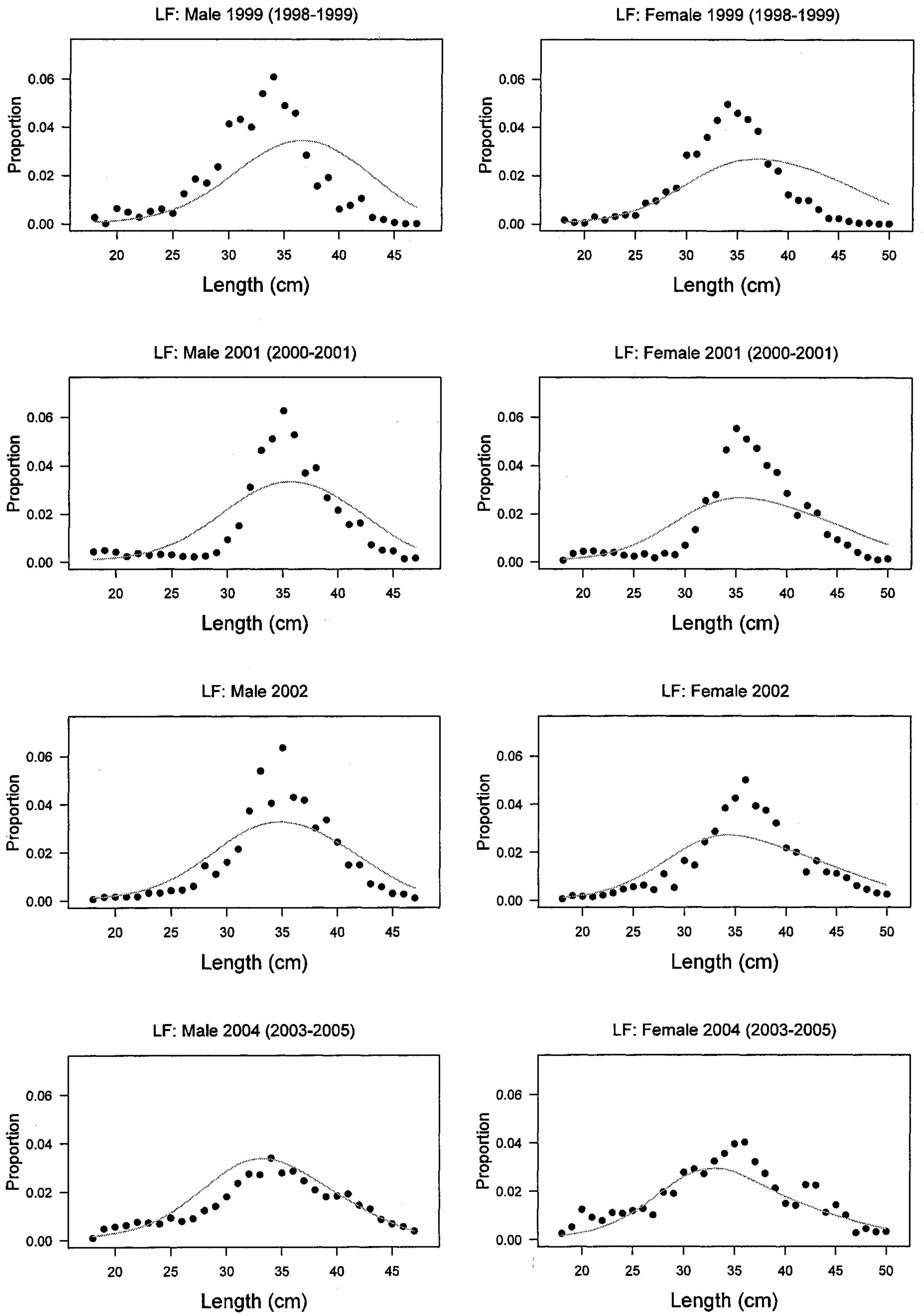

Figure 5: Fits to the length frequencies for the non-depth shifted selectivity model, with separate fishery selectivities for male and female ("No shift, M≠F"). Years in parentheses are years which were combined and assigned to the year shown that is not in parentheses.

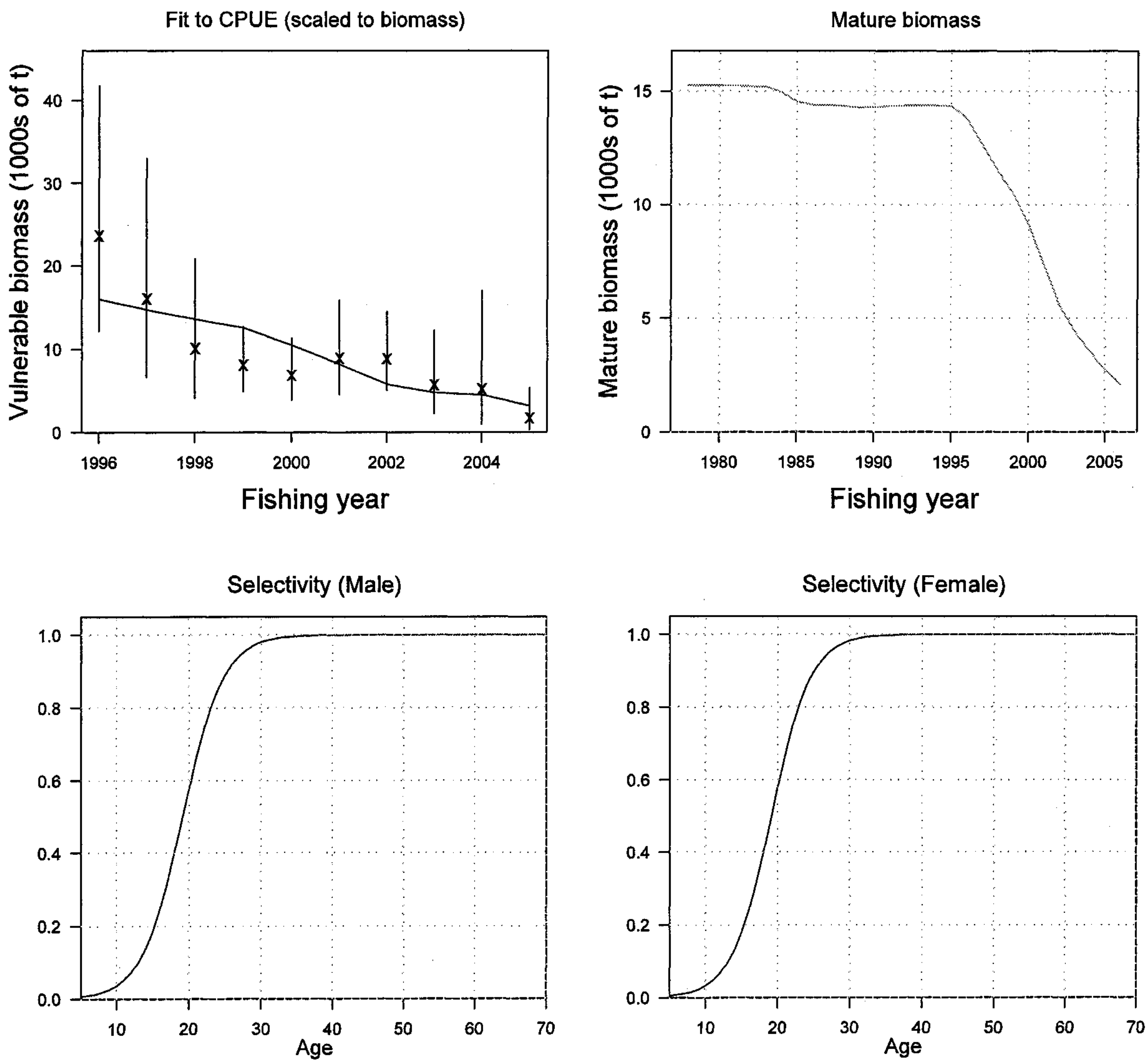

Figure 6: Some fits to the depth-shifted selectivity model, with separate fishery selectivities for male and female ("Shift, M≠F").

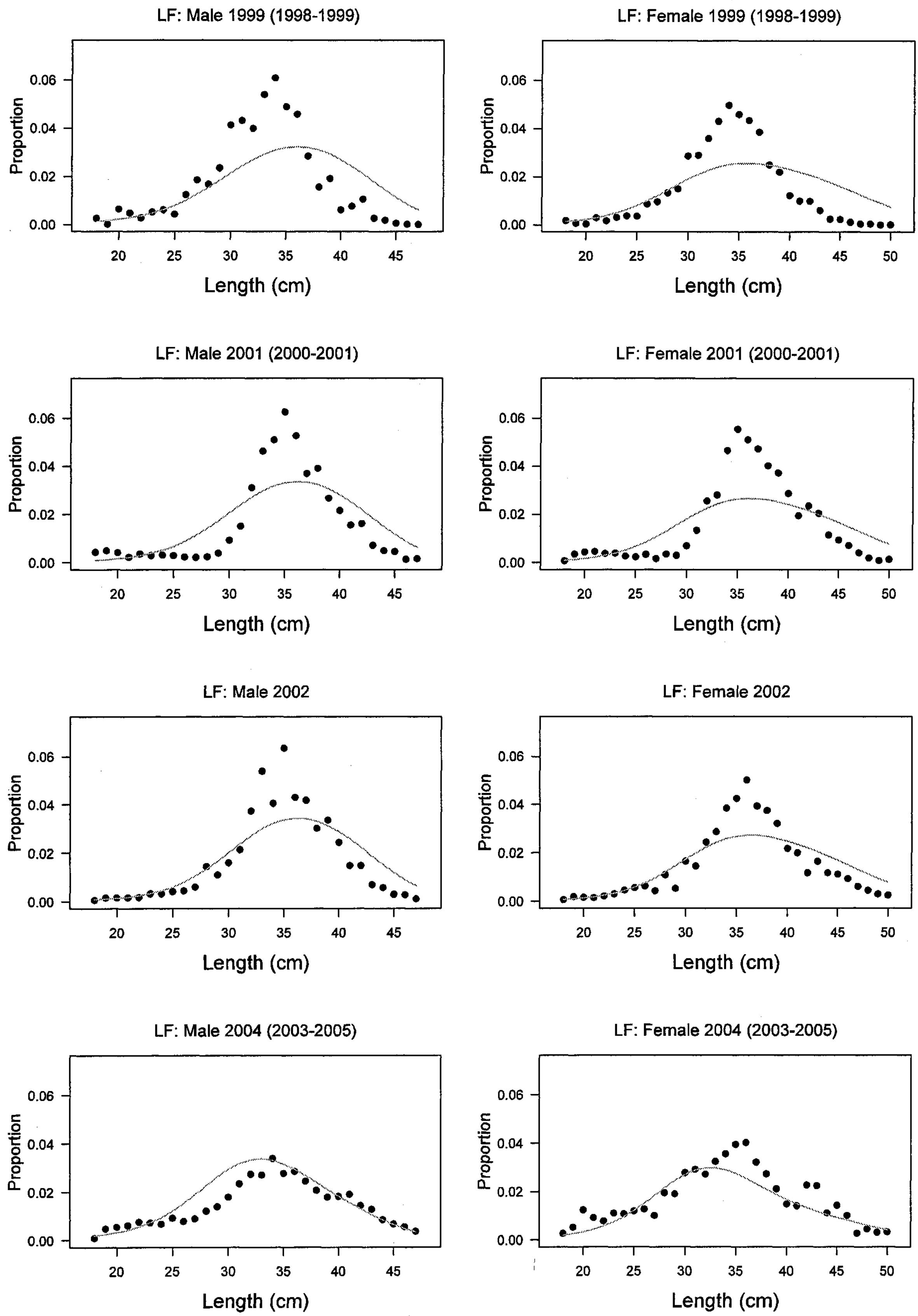

Figure 7: Fits to the length-frequencies for the depth-shifted selectivity model, with separate fishery selectivities for male and female ("Shift, M≠F"). Years in parentheses are years which were combined and assigned to the year shown that is not in parentheses.

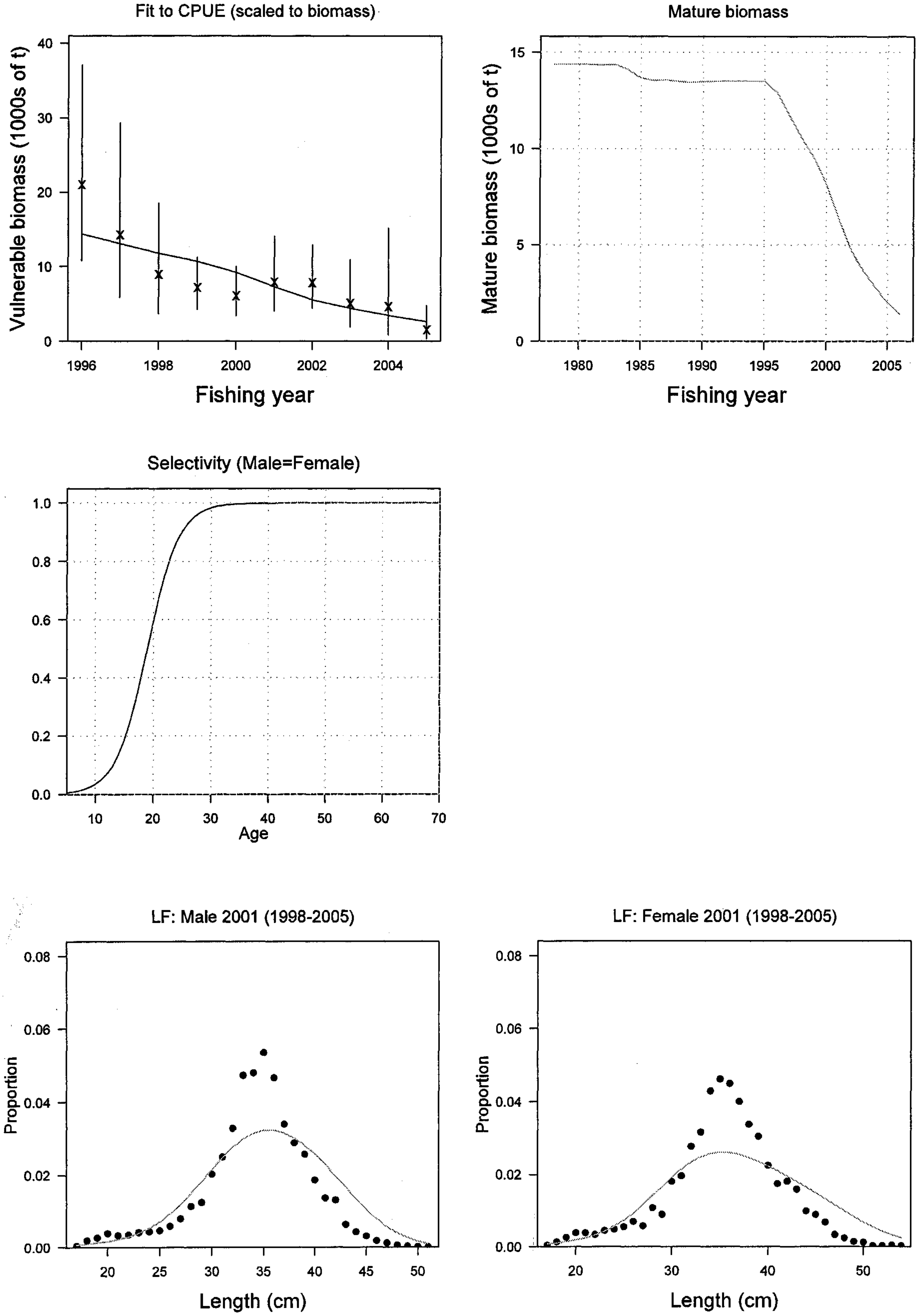

Figure 8: LF (comb) model run fits. Years in parentheses denotes years which were combined and assigned to the year 2001.

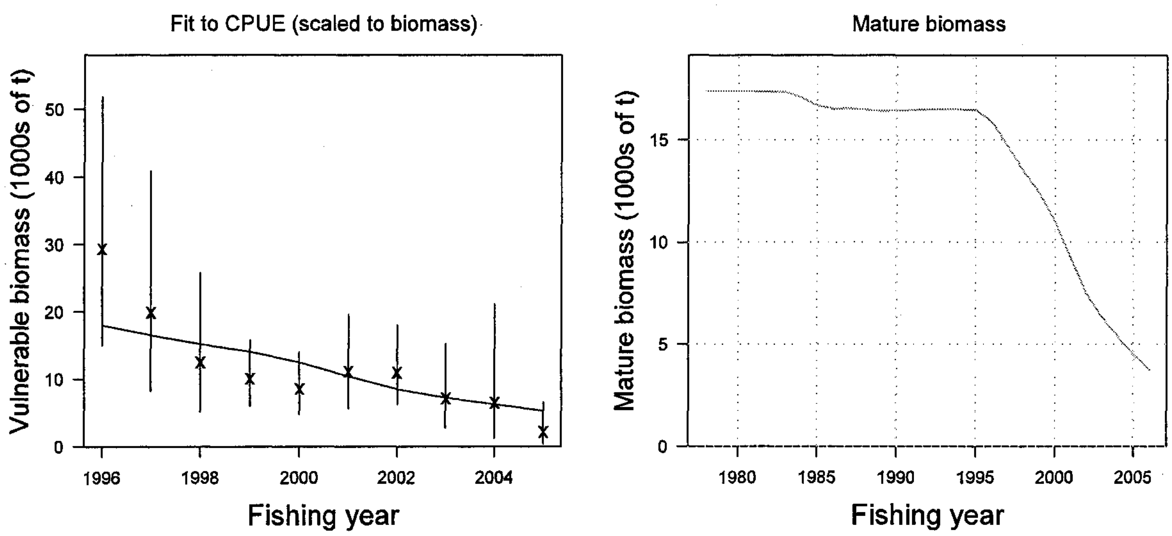

Figure 9: CPUE only model run fits. The fishery selectivity is knife-edge at 19 years for male and female.

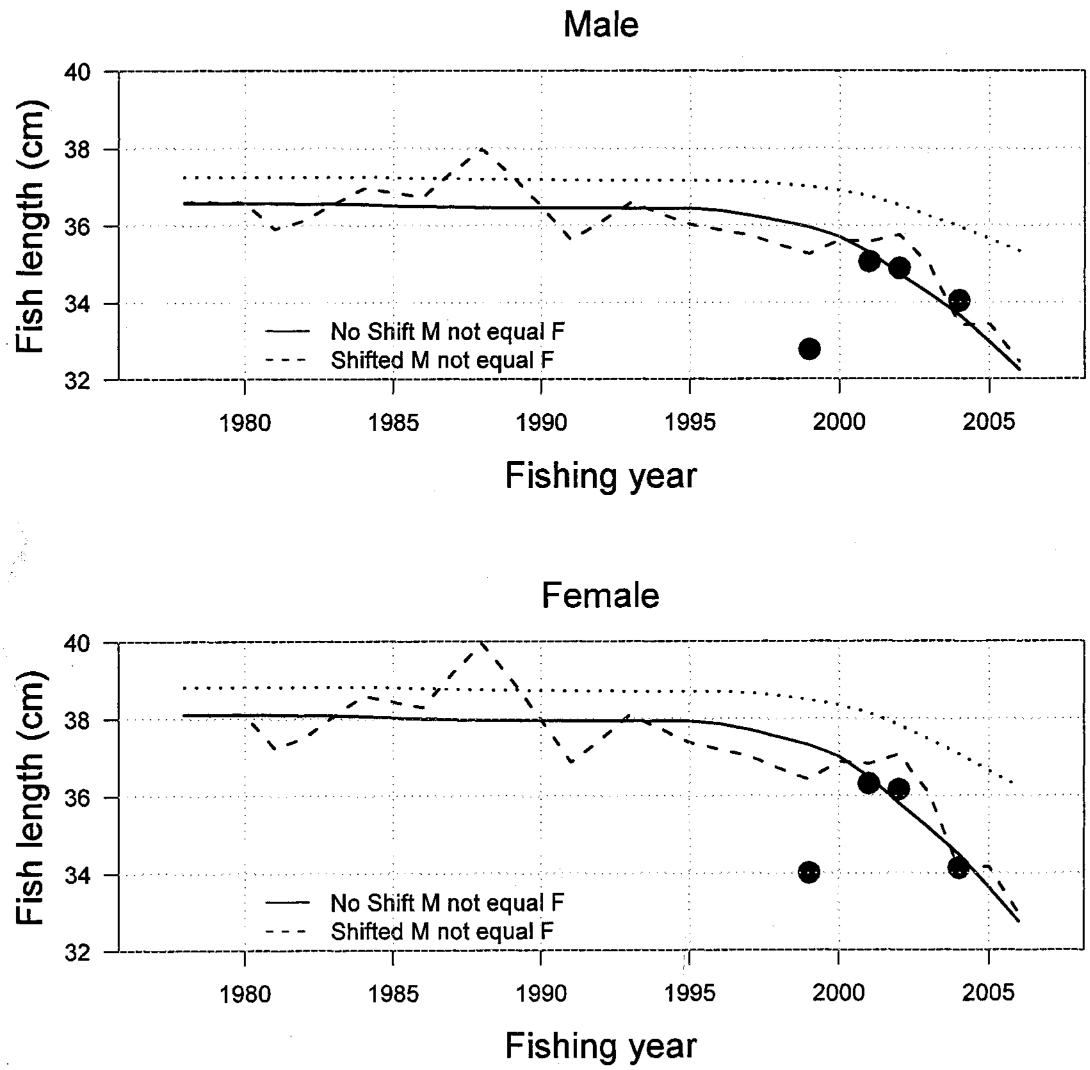

Figure 10: Fit of the model expected mean lengths to the observed mean lengths (black dots). The observed lengths are in the fishing years 1999, 2001, 2002, and 2004.

2.5 CPUE only model Monte Carlo Markov Chain (MCMC)

A chain of length 3 100 000 was used with a burn-in of 100 000, and every 1000th sample used, giving a total of 3000 samples. The initial chain had an upper bound on B_0 of a million tonnes, but the MCMC chain gave very skewed distributions of B_0 and $B_{current}$, with right tails extending to very high biomasses. This is a consequence of the high c.v.s of the CPUE index, which imply that a high virgin biomass which is mostly unaffected by subsequent catch is possible. To ameliorate this it was decided to set an upper bound on B_0 of 100 000 t, based on comparisons with other smooth oreo stocks.

The resulting posterior densities also have long right tails for B_0 and $B_{current}$ (Figure 11). The median virgin biomass is 24 000 t with a 90% confidence interval of 16 000 t to 78 000 t (Table 5). The median current biomass is 42% of virgin biomass with a confidence interval of 15–82%. The same results were obtained when the posterior densities were estimated directly from the likelihood versus B_0 via a posterior profile on B_0, as can be done for a one parameter model, showing that the long tails are not an artefact of the MCMC estimation algorithm.

Table 5: Mid-year mature biomass estimate (median, with 90% confidence interval in parentheses) for the model run with only CPUE data. $B_{current}$ is the mid-year mature biomass in 2006.

Run	B_0(t)	$B_{current}$(t)	$B_{current}$(% B_0)
Only CPUE	24 000 (16 000-78 000)	9 800 (2 400-64 000)	42 (15-82)

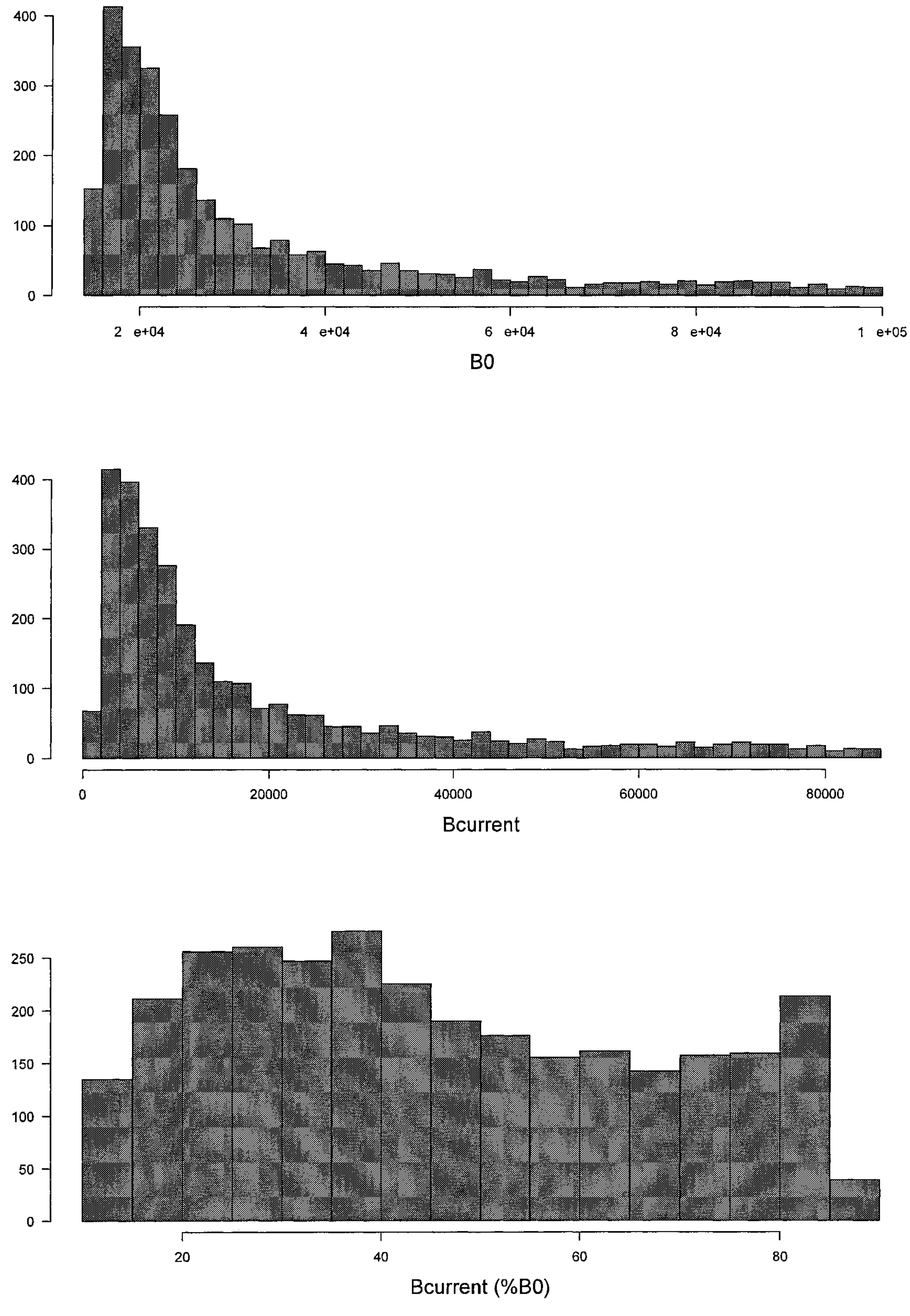

Figure 11: Estimated posterior densities for CPUE only model run with an upper bound on B_0 of 100 000 t.

2.6 Yield estimates

Estimates of the Maximum Average Yield (MAY) were based on calculations performed for the Southland smooth oreo stock which used the same life history characteristics for natural mortality, recruitment steepness, length-age and weight-age (Coburn et al. 2003). For the Southland stock, the MAY was estimated to be 2.3% of the median mature virgin biomass. Applying this value to the estimates of B_0 in Table 5 gives a median estimate of MAY for Pukaki smooth oreo of 550 t, with a 90% confidence interval of 370–1800 t.

3. MANAGEMENT IMPLICATIONS

Model results suggest that mature virgin biomass was about 24 000 t with very wide 90% confidence intervals (16 000–78 000 t). Current biomass is estimated to be 42% of virgin biomass with a 90% confidence interval of 15–82%.

The estimated confidence intervals around the biomass estimates are very broad so it is not possible to determine the current stock status. However, based on CPUE trends and the catch history, the current annual catch levels seem unlikely to be maintained in the future.

The model estimates suggest a median long-term yield (MAY estimate) of about 550 t, which is lower than the current catch of 1300 t.

4. ACKNOWLEDGMENTS

Thank you to Ralph Coburn for providing the CASAL scripts from the 2005–06 OEO 3A smooth oreo assessment, and giving guidance for the stock assessment. Chris Francis reviewed the document, making a number of helpful suggestions that helped to clarify some explanations.

5. REFERENCES

Bull, B.; Francis, R.I.C.C.; Dunn, A.; McKenzie, A.; Gilbert, D.J.; Smith, M.H. (2005). CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.07-2005/08/21. *NIWA Technical Report 127*. 272 p.

Coburn, R.P.; Doonan, I.J.; McMillan, P.J. (2003) Stock assessment of smooth oreo in the Southland fishery (OEO 1 and 3A) for 2003. *New Zealand Fisheries Assessment Report 2003/62*. 32 p.

Coburn, R.P.; McMillan, P.J.; Gilbert, D. (2007). Inputs for a stock assessment of smooth oreo, Pukaki Rise (part of OEO 6). *New Zealand Fisheries Assessment Report 2007/23*. 32 p.

Doonan, I.J.; McMillan, P.J.; Coburn, A.C., Hart, A.C. (2003). Assessment of OEO 4 smooth oreo for 2002–03. *New Zealand Fisheries Assessment Report 2003/50*. 55 p.

Doonan, I.J.; McMillan, P.J.; Kalish, J.M., Hart, A.C. (1995). Age estimates for black oreo and smooth oreo. New Zealand Fisheries Assessment Research Document 95/14. 26 p. (Unpublished report held in NIWA library, Wellington.)

Doonan, I.J.; McMillan, P.J.; Hart, A.C. (1997). Revision of smooth oreo life history parameters. New Zealand Fisheries Assessment Research Document 97/9. 11 p. (Unpublished report held in NIWA library, Wellington.)

Doonan, I.J.; Coburn, R.P.; McMillan, P.J.; Hart, A.C. Assessment of OEO 3A smooth oreo for 2005–06. 53 p. (Unpublished report)

Francis, R.I.C.C. (2003). Analyses supporting the 2002 stock assessment of hoki. *New Zealand Fisheries Assessment Report 2003/5*. 34 p.

APPENDIX A1: DATA INPUTS FOR THE MODEL

For details of the catch history, CPUE analysis, and length frequencies see Coburn et al. (2007). The maturity ogive is from Appendix 2 of Doonan et al. (2003).

Table A1: Catch history of smooth oreo from the Pukaki Rise fishery assessment area. Catches are rounded to the nearest 10 t. The catch history is derived from the declared catch of oreo in OEO 6, with tow-by-tow records used to estimate the proportion of smooth oreo and area breakdown for the catch. See Figure A1 for a plot of the catch history.

Year	Catch	Year	Catch
1980–81	30	1993–94	0
1981–82	20	1994–95	130
1982–83	0	1995–96	1 360
1983–84	640	1996–97	1 650
1984–85	340	1997–98	1 340
1985–86	10	1998–99	1 370
1986–87	0	1999–00	2 270
1987–88	180	2000–01	2 580
1988–89	0	2001–02	2 020
1989–90	0	2002–03	1 340
1990–91	10	2003–04	1 660
1991–92	0	2004–05	1 370
1992–93	70		

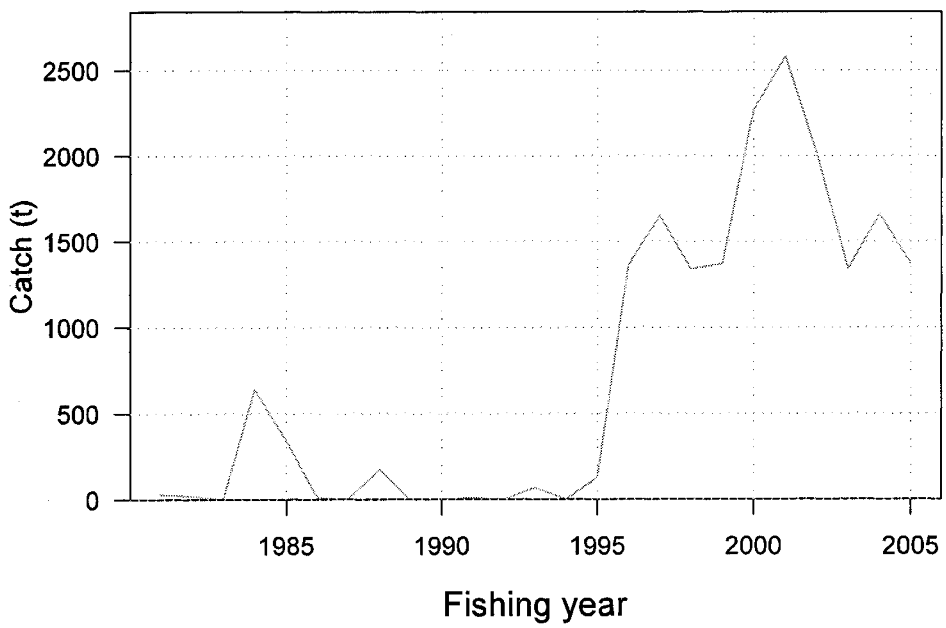

Figure A1: Catch history for smooth oreo (see Table A1).

Table A2: Maturity ogive showing predicted probability of maturity for male and female.

age	male	female	age	male	female
5	0.00	0.00	38	1.00	0.99
6	0.01	0.00	39	1.00	1.00
7	0.01	0.00	40	1.00	1.00
8	0.01	0.00	41	1.00	1.00
9	0.02	0.00	42	1.00	1.00
10	0.03	0.00	43	1.00	1.00
11	0.04	0.00	44	1.00	1.00
12	0.07	0.01	45	1.00	1.00
13	0.10	0.01	46	1.00	1.00
14	0.14	0.01	47	1.00	1.00
15	0.21	0.02	48	1.00	1.00
16	0.28	0.03	49	1.00	1.00
17	0.38	0.04	50	1.00	1.00
18	0.48	0.05	51	1.00	1.00
19	0.59	0.08	52	1.00	1.00
20	0.69	0.11	53	1.00	1.00
21	0.77	0.15	54	1.00	1.00
22	0.84	0.21	55	1.00	1.00
23	0.89	0.28	56	1.00	1.00
24	0.92	0.37	57	1.00	1.00
25	0.95	0.46	58	1.00	1.00
26	0.97	0.56	59	1.00	1.00
27	0.98	0.65	60	1.00	1.00
28	0.99	0.74	61	1.00	1.00
29	0.99	0.80	62	1.00	1.00
30	0.99	0.86	63	1.00	1.00
31	1.00	0.90	64	1.00	1.00
32	1.00	0.93	65	1.00	1.00
33	1.00	0.95	66	1.00	1.00
34	1.00	0.97	67	1.00	1.00
35	1.00	0.98	68	1.00	1.00
36	1.00	0.98	69	1.00	1.00
37	1.00	0.99	70	1.00	1.00

Table A3: CPUE index estimates by year, and bootstrap c.v. estimates.

	kg/tow	c.v
1995–96	3 339	0.316
1996–97	2 266	0.417
1997–98	1 421	0.421
1998–99	1 143	0.243
1999–2000	969	0.272
2000–01	1 260	0.319
2001–02	1 247	0.270
2002–03	804	0.451
2003–04	735	0.829
2004–05	243	0.768

Table A4: The length frequencies and their c.v.s by by sex and for each year.

Sex&Length(cm)	1999	cvs_1999	2001	cvs_2001	2002	cvs_2002	2004	cvs_2004
M18	0.0026	1.15	0.0043	0.71	0.0006	0.66	0.0010	0.93
M19	0.0001	2.25	0.0050	0.52	0.0016	0.59	0.0049	0.50
M20	0.0064	0.83	0.0042	0.47	0.0017	0.52	0.0057	0.39
M21	0.0048	0.60	0.0023	0.68	0.0017	0.52	0.0062	0.40
M22	0.0028	0.55	0.0036	0.49	0.0017	0.60	0.0077	0.37
M23	0.0052	0.52	0.0030	0.49	0.0033	0.64	0.0073	0.36
M24	0.0061	0.60	0.0032	0.60	0.0033	0.52	0.0069	0.39
M25	0.0043	0.59	0.0030	0.52	0.0042	0.48	0.0093	0.35
M26	0.0124	0.49	0.0024	0.59	0.0045	0.48	0.0079	0.33
M27	0.0185	0.39	0.0022	0.58	0.0060	0.46	0.0090	0.30
M28	0.0168	0.43	0.0025	0.51	0.0145	0.40	0.0122	0.28
M29	0.0235	0.17	0.0040	0.45	0.0111	0.34	0.0140	0.27
M30	0.0413	0.24	0.0093	0.30	0.0160	0.30	0.0179	0.23
M31	0.0432	0.14	0.0150	0.21	0.0214	0.25	0.0235	0.23
M32	0.0399	0.15	0.0310	0.16	0.0374	0.29	0.0274	0.21
M33	0.0539	0.13	0.0462	0.13	0.0539	0.16	0.0271	0.22
M34	0.0608	0.11	0.0509	0.12	0.0405	0.19	0.0339	0.20
M35	0.0488	0.14	0.0626	0.10	0.0634	0.16	0.0277	0.22
M36	0.0458	0.16	0.0527	0.11	0.0430	0.12	0.0286	0.17
M37	0.0284	0.18	0.0369	0.14	0.0418	0.17	0.0245	0.24
M38	0.0156	0.23	0.0390	0.13	0.0302	0.19	0.0208	0.21
M39	0.0191	0.26	0.0267	0.16	0.0336	0.17	0.0180	0.24
M40	0.0061	0.32	0.0215	0.18	0.0244	0.24	0.0182	0.29
M41	0.0077	0.31	0.0155	0.20	0.0148	0.48	0.0191	0.28
M42	0.0105	0.52	0.0162	0.33	0.0148	0.34	0.0144	0.39
M43	0.0027	0.61	0.0072	0.33	0.0070	0.42	0.0129	0.34
M44	0.0018	0.95	0.0049	0.44	0.0057	0.43	0.0085	0.42
M45	0.0006	0.81	0.0045	0.44	0.0030	0.54	0.0067	0.54
M46	0.0001	1.76	0.0014	0.66	0.0028	0.68	0.0056	0.37
M47	0.0001	5.00	0.0017	0.76	0.0012	0.76	0.0038	0.68
F18	0.0017	1.05	0.0008	1.70	0.0007	0.64	0.0027	0.67
F19	0.0007	1.08	0.0035	0.69	0.0020	0.55	0.0053	0.46
F20	0.0004	1.58	0.0044	0.50	0.0017	0.56	0.0125	0.40
F21	0.0029	0.55	0.0046	0.35	0.0015	0.56	0.0093	0.36
F22	0.0017	0.57	0.0038	0.47	0.0022	0.55	0.0079	0.39
F23	0.0031	0.77	0.0040	0.43	0.0031	0.51	0.0111	0.32
F24	0.0037	0.51	0.0027	0.42	0.0046	0.42	0.0108	0.32
F25	0.0036	0.53	0.0024	0.47	0.0056	0.42	0.0120	0.39
F26	0.0086	0.50	0.0034	0.35	0.0063	0.38	0.0128	0.35
F27	0.0096	0.35	0.0017	0.52	0.0044	0.38	0.0102	0.30
F28	0.0133	0.28	0.0035	0.44	0.0109	0.39	0.0195	0.29
F29	0.0149	0.21	0.0030	0.42	0.0053	0.33	0.0191	0.36
F30	0.0286	0.18	0.0069	0.37	0.0165	0.33	0.0278	0.29
F31	0.0290	0.15	0.0134	0.28	0.0146	0.26	0.0292	0.22
F32	0.0359	0.17	0.0256	0.15	0.0243	0.20	0.0272	0.19
F33	0.0430	0.15	0.0280	0.16	0.0287	0.25	0.0324	0.19

Table A4: continued

Sex&Age (y)	1999	cvs_1999	2001	cvs_2001	2002	cvs_2002	2004	cvs_2004
F34	0.0497	0.13	0.0465	0.15	0.0384	0.16	0.0356	0.23
F35	0.0459	0.12	0.0554	0.11	0.0424	0.19	0.0395	0.20
F36	0.0434	0.14	0.0510	0.14	0.0501	0.16	0.0403	0.19
F37	0.0385	0.17	0.0472	0.13	0.0393	0.16	0.0322	0.22
F38	0.0249	0.22	0.0402	0.12	0.0374	0.17	0.0273	0.22
F39	0.0220	0.23	0.0372	0.14	0.0321	0.23	0.0212	0.24
F40	0.0123	0.30	0.0286	0.15	0.0218	0.26	0.0149	0.28
F41	0.0099	0.31	0.0194	0.15	0.0199	0.29	0.0141	0.31
F42	0.0098	0.31	0.0235	0.19	0.0117	0.36	0.0226	0.29
F43	0.0061	0.49	0.0204	0.16	0.0165	0.35	0.0224	0.32
F44	0.0024	0.54	0.0115	0.21	0.0118	0.40	0.0112	0.33
F45	0.0023	0.45	0.0094	0.25	0.0111	0.35	0.0143	0.30
F46	0.0011	0.59	0.0071	0.28	0.0093	0.36	0.0101	0.29
F47	0.0004	0.91	0.0040	0.43	0.0061	0.46	0.0028	0.58
F48	0.0005	1.18	0.0019	0.51	0.0046	0.43	0.0045	0.56
F49	0.0000	1.59	0.0009	0.59	0.0030	0.53	0.0032	0.62
F50	0.0001	1.08	0.0014	0.64	0.0026	0.73	0.0034	0.57

APPENDIX A2: EXOGENOUS MEDIAN DEPTH VARIABLE FOR SHIFTING SELECTIVITES

Table A5: Median fishing depth (half the catch is caught below this depth, half above) as a function of the fishing year. There were insufficient data to calculate the median depth for some years, and the median depth for these years was estimated by linear interpolation from their neighbours (estimated median depths are shaded).

Fishing year	Median depth (m)	Fishing year	Median depth (m)
1981	898	1994	941
1982	916	1995	918
1983	952	1996	911
1984	988	1997	909
1985	981	1998	901
1986	973	1999	896
1987	1033	2000	937
1988	1093	2001	961
1989	1024	2002	1008
1990	955	2003	994
1991	887	2004	933
1992	923	2005	972
1993	964		

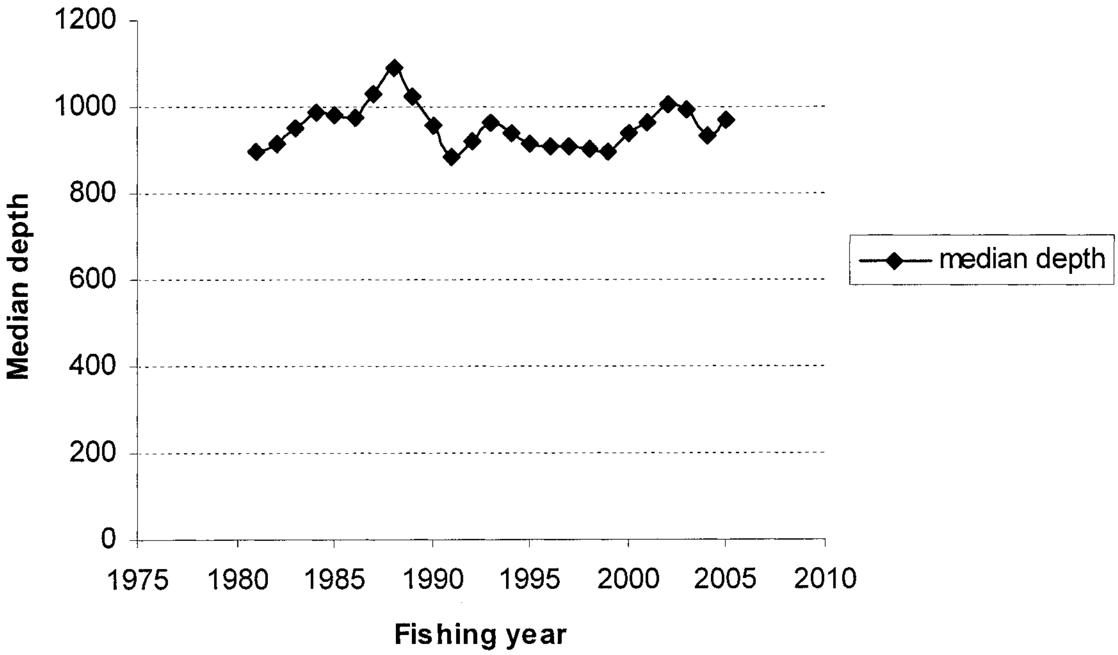

Figure A1: The median fishing depth versus fishing year (see Table A5).

APPENDIX A3: CASAL MODEL FILES

The following are the CASAL files for the CPUE only model.

A3.1 The population file

@initialization
B0 30000

@size_based false

@min_age 5
@max_age 70
@plus_group true

@sex_partition True
@mature_partition False
@n_areas 1

@initial 1978 # first year of catch history
@current 2006
@final 2011

@annual_cycle
time_steps 1
aging_time 1
recruitment_time 1
maturation_times 1

fishery_times 1
fishery_names Pukaki_rise_east

spawning_time 1
spawning_p 1
spawning_part_mort 0.50

M_props 1 # proportion of natural mortality that occurs in each time step
baranov False

@y_enter 5
@recruitment
#YCS_years from initial year - y_enter (= 1978 - 5 = 1973) to current year - y_enter (= 2006 - 5 = 2001)
YCS_years 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986
1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001
YCS 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1
p_male 0.5
sigma_r 0.65 # only important for randomised projections

SR BH
steepness 0.75

#RECRUITMENT VARIABILITY #for MCY/CAY & projections
@randomisation_method lognormal

#MATURATION
@maturity_props

#from GLM results using 0.4 and 1 as the GSI for males and females respectively

```
#probs for ages 5-70
#age  5 6  7  8  9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25  26
27  28  29  30  31 32  33  34  35  36  37  38  39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56
57 58 59 60 61 62 63 64 65 66 67 68 69 70

#rates_male allvalues
male allvalues 0  0.01  0.01  0.01  0.02  0.03  0.04  0.07  0.1  0.14  0.21  0.28  0.38  0.48  0.59  0.69  0.77  0.84
0.89  0.92  0.95  0.97  0.98  0.99  0.99  0.99  1  1  1  1  1  1  1  1  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

#rates_female allvalues
female allvalues 0 0  0  0  0  0  0  0.01 0.01 0.01 0.02 0.03 0.04 0.05 0.08 0.11 0.15 0.21 0.28
0.37 0.46 0.56 0.65 0.74 0.8  0.86 0.9 0.93 0.95 0.97 0.98 0.98 0.99 0.99 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

@natural_mortality
all     0.063

@fishery Pukaki_rise_east
# where years: 1978=1977-78 fishing year
years     1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
catches   0  0  0  30  20  0  640  340  10  0  180  0  0  10  0  70  0  130  1360 1650 1340 1370
2270 2580 2020 1340 1660 1370 1370
selectivity trawl_common
U_max 0.58
future_years    2007  2008  2009  2010  2011
future_catches    0    0    0    0    0

#SELECTIVITIES
@selectivity_names trawl_common

@selectivity trawl_common
all knife_edge 19

#SIZE AT AGE
@size_at_age_type von_Bert
@size_at_age_dist normal

@size_at_age
k_male 0.067
t0_male -1.6
Linf_male 43.6
cv_male 0.1
k_female 0.047
t0_female -2.9
Linf_female 50.8
cv_female 0.1

#SIZE WEIGHT
@size_weight
a_male    3.2e-8
b_male    2.87
a_female  2.9e-8
b_female  2.90
#verify_size_weight   40  .5  3    #check that 40 cm fish weights between .5 & 3 kgs
```

A3.2 The estimation file

```
@estimator Bayes
@max_iters 300
@max_evals 1000
@grad_tol 1e-6

@MCMC
start 0     # 0 implies start chain at point estimate
length 3200000
keep 1000   # keep every 1000th sample
burn_in 200  # burn in for 1000*200=200 000 steps of the chain
systematic True  # if False then randomly sample from the chain
adaptive_stepsize  True
adapt_at 50000 100000

#-----------------------------------------------------------------
#
# Standardised CPUE 1996-2005
#
#-----------------------------------------------------------------

@relative_abundance CPUE
step 1
q CPUE
years 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
proportion_mortality 0.5
biomass true
ogive trawl_common
dist lognormal

1996 3339
1997 2266
1998 1421
1999 1143
2000  969
2001 1260
2002 1247
2003  804
2004  735
2005  243

cv_1996 0.316
cv_1997 0.417
cv_1998 0.421
cv_1999 0.243
cv_2000 0.272
cv_2001 0.319
cv_2002 0.270
cv_2003 0.451
cv_2004 0.829
cv_2005 0.768

@estimate
parameter q[CPUE].q
lower_bound 1e-3
upper_bound 1
prior uniform-log

@q_method  nuisance
```

```
#----------------------------------------------------------------------
#
# Estimated parameters
#
#----------------------------------------------------------------------

@estimate
parameter initialization.B0
lower_bound 1e2
upper_bound 1e6
prior uniform-log

#---------------------------------------------
#
# Profile B0
#
#--------------------------------------------

@profile
parameter initialization.B0
l 10000
u 100000
n 99

#PENALTIES

@catch_limit_penalty
label     CatchMustBeTaken
fishery    Pukaki_rise_east
log_scale    true
multiplier    1000
```