New Zealand Fisheries
Assessment Report
2009/42
September 2009
ISSN 1175-1584

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New Zealand Fisheries Assessment Report 2009/42
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Published by Ministry of Fisheries
Wellington
2009

ISSN 1175-1584

McKenzie, A.; Coburn, R.P. (2009).
Stock assessment of smooth oreo in the Bounty Plateau study area (part of OEO 6)
for 2007–08.
New Zealand Fisheries Assessment Report 2009/42. 42 p.

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

EXECUTIVE SUMMARY

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***New Zealand Fisheries Assessment Report 2009/42.* 42 p.**

The Bounty Plateau 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 fishery length-frequency series.

For the standardised CPUE indices either two non-overlapping series were used (early and late period), or a single CPUE series covering both periods. In all preliminary model runs the length-frequency data series were not well fitted to, and gave a strong but contrasting biomass signal, relative to the CPUE indices. Therefore for final model runs the length frequency data were down-weighted by using just the 1999 length frequency.

Biomass estimates are uncertain because of the reliance on commercial CPUE data, because the biological parameter estimates are from oreo stocks in other areas, and because of contrasting biomass signals from using either a single or split CPUE indices.

In the base model with early and late period CPUE indices, and the 1999 length frequency fitted, current mature biomass is estimated to be 33% of a virgin biomass of 17 400 t.

Two sensitivity model runs were done with the 1999 length frequency data dropped from the model, but retaining the fishery selectivity estimated with it in. With the early and late period CPUE indices in the model, current biomass was estimated to be 39% of a virgin biomass of 19 300 t. If a single CPUE series covering the same period is used in the model current biomass is estimated to be 17% of a virgin biomass of 13 900 t.

1. INTRODUCTION

This report describes results for part of the Ministry of Fisheries project OEO200701. It covers objective 4 (stock assessment of smooth oreo from Bounty Plateau), and is the first assessment for this stock. The stock assessment study area is shown in Figure 1.

Throughout this document, year is the fishing year (e.g., 1996 refers to 1 October 1995 to 30 September 1996).

2. STOCK ASSESSMENT

2.1 Model structure

The model structure is very similar to that for the east Pukaki Rise smooth oreo stock assessment (McKenzie 2007), which is in turn based on the OEO 3A smooth oreo stock assessment for 2006 (Doonan et al., NIWA, 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 1–70 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, and mortality (natural and fishing). It is assumed that 50% of the recruits are males, and that year class strengths for 1983–2007 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.

As there is no biological data from the Bounty Plateau study area the values for the life history parameters (Table 1) are the same as those used for the OEO 3A smooth oreo stock assessment for 2006 (Doonan et al. unpublished report). 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 (Doonan et al. 1997). The von Bertalanffy parameters are from fish sampled from the Chatham Rise and Puysegur Bank fisheries (Doonan et al. 1997). The associated c.v.s for the growth curves are model estimated values from a previous smooth oreo stock assessment (Coburn et al. 2003), and are very close to the assumed value of 0.10 used in other smooth oreo assessments. The mean length-at-age curves are plotted in **Error! Reference source not found.** 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 the default value for New Zealand assessments (Francis 1992).

The maturity ogive developed during the 2003 stock assessment of smooth oreo from south Chatham Rise (Table 2) 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).

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 split into an early and late period or a single CPUE series covering the entire period (Table 3).

Methods used to analyse the length-frequency data are very similar to those described by Coburn et al. (2007). Two length-frequency series are used separately in the model runs: core and non-core (Tables 4–

7, Figures 4–6). The core length frequency series is based on tows from a subset of the study area where about 80% of the catch is taken; the non-core length-frequency series used tows from the entire study area.

The standardised CPUEs are 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 standardisations 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, the c.v.s for the year effects were estimated by a nested bootstrapping procedure: vessels were randomly resampled, then tows within the resampled vessels.

Methods used to perform the analyses below are very similar to those described by Coburn et al. (2007); for analysis result details see Tables 8–12. Within the fishery, this same single vessel is the only one that puts in significant continuous effort from 1995–2007 with rest of the vessels' effort confined to mainly either 1995–2000 or 2001–2007 (Table 13). Because of this the standardised CPUE is split into early and late period series, with a mean c.v of 0.55 for the early period series and 0.29 for the late period series (Table 14, Figure 7). As a sensitivity test to the splitting, a model run was done with a single standardised CPUE series for 1995–2007, this series having a mean c.v. of 0.63 (Table 15, Figures 8–9).

The catches taken in the model are given in Table 16 and Figure 10. For the fishing year 2007–08, the previous year's catch was assumed (670 t).

Logistic age-based selectivities were estimated for males and females and applied to the catch, CPUE, and commercial length-frequency data.

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 constants (q1, q2) which scale the early and late period standardised CPUE indices to vulnerable biomass, (3) the four parameters defining the male and female logistic curves for the fishing selectivity, (4) a single value for the process error for the early and late standardised CPUE series, and (5) a single value for the length-frequency series process error. The free parameters are summarised in Table 17.

In one model run the L_{inf} for male and female growth are estimated, as is cv1, the c.v. at age one for the length-at-age relationship. For all model runs interpolation by length is used for intermediate c.v.s between cv1 and cv70 (the c.v. at age 70+ for the length-at-age relationship).

In sensitivity model run a single standardised CPUE series for 1995–2007 was fitted, instead of the separate early and late CPUE series.

Maximum Posterior Density (MPD) estimates were found for the free parameters in the model. The stock assessment program CASAL v2.21 (Bull et al. 2008) was used to implement and fit the models.

2.4 Model fits

2.4.1 Introduction

A sequence of preliminary model runs was conducted (Table 18). In the first two preliminary model runs, both with a split CPUE series, the contrast between using the core and non-core length frequency series is ascertained. Subsequent preliminary model runs all use the core length frequency series, and investigate the direction and strength of the biomass signal given by the series, and how the estimated commercial fishery selectivity varies between years by using subsets of the length frequency series. In the final preliminary model run some of the growth curve parameters are estimated, allowing an evaluation of how much the growth curve would need to differ from the assumed fixed values in order to better fit the length frequency data.

The final base model run chosen by the Deep Water Working group used the 1999 core length-frequency with a split CPUE series (Table 19). Two sensitivity model runs were conducted, both using a fixed commercial fishery selectivity estimated from the base model. In the first sensitivity the split CPUE indices were fitted, while for the second sensitivity a single CPUE index was fitted that covered the same years as the split CPUE series.

2.4.2 Preliminary model runs

The first preliminary model run is fitted using the non-core length frequency series (Table 18). Current mature biomass is estimated to be 21% of virgin biomass, with a steady decline since about 1995 when the fishery started. The fitted biomass trajectory is flatter then the early CPUE series, but steeper then the late CPUE series (Figures 11–12). 1998 and 2001 are particularly difficult to fit as the indices for these years are markedly differently from adjacent years. The length frequency series is poorly fitted, with the observed length frequencies much more peaked then the model length frequencies (Figure 13). Furthermore, the mean male observed lengths are nearly all less then the model mean lengths (see Figure 11).

The second preliminary model used the core length frequencies and gives a current biomass estimated to be 15% of virgin biomass, compared to 21% when using the non-core length frequencies (see Table 18). Similar problems present themselves regarding the fit to the CPUE and length frequency series (see Figures 14–16). However, two differences is that the selectivities are sharper (near the a_{50} value), and both the male and female observed lengths are all less then the model mean lengths (Figure 14).

To investigate the influence of the two CPUE series a run was done in which only they were fitted ("CPUE only"). The fishery selectivities were fixed to those estimated with all years used for the core length frequencies, and the CPUE process error set at zero. With only the CPUE series fitted to current biomass is estimated to be 42% of virgin biomass, compared to 15% when the core length frequencies are included (see Table 18). As in other model runs the initial steep decline in the early CPUE is poorly fitted (Figures 17–18).

The next two preliminary model runs used subsets of the core length frequency series in the model. As is evident from comparing the "Core Lfs" and "CPUE only" model runs, with all years of the length frequency series in the model, the length frequency series gives a strong and contrasting biomass signal compared to the two CPUE series. Fitting to just a single year from the length frequency series gives more weight to the CPUE series as a driver of the biomass trajectory, and using non-adjacent years is useful for evaluating if the selectivity changes over time. The two years chosen by the Deep Water Working Group for this purpose were 1999 and 2006.

Using just the 1999 or 2006 core length frequency data gave an estimated current biomass of 33% or 29% of virgin biomass respectively (see Table 18). Both of these are greater then when all years are used (15%), but less than if just the CPUE data is fitted to with a fixed selectivity (42%). There is a slight increase of 1–2 years for the estimated a_{50} in going from 1999 to 2006. See Figures 19–25 for some plots.

The growth curve assumed for the model is based on fish from the Chatham Rise and Puysegur. In order to evaluate how different this curve would have to be in order to better fit the core length frequency series, a model run was done in which L_{inf} and cv1 (c.v. at age one) were estimated for both the male and female growth curves (Figures 26–27). A model run was also attempted in which cv70 (c.v. at age 70+) was estimated as well as the other growth parameters, but this did not converge well. To enable likelihood comparisons across model runs, the CPUE and length frequency series process errors were set to the estimated values obtained when all years of core length frequency data were included in the model. Estimating the two growth curve parameters indicated that in order to get better fits the male L_{inf} would have to decrease by about 4 cm, and the female L_{inf} decrease by about 2 cm (see Table 18). For both male and female cv1 would have to be close to zero. Assuming these values, the current biomass is estimated to be 35% of virgin, compared to 15% when the growth parameters are not estimated.

2.4.3 Final model runs

The model run using the 1999 core length frequency was chosen as the base model by the Deepwater Working Group (Tables 18–19). Two sensitivities were conducted on this model run: (1) fixing the selectivities at those estimated in the base model, and (2) using a single standardised CPUE in place of the split CPUE series.

For the first sensitivity with the selectivities fixed at the base model values, current biomass is estimated to be greater at 39% of virgin biomass, compared to 33% when they are estimated with the 1999 length frequency in the model (Table 19). This is a similar result to the model run when the selectivities were fixed at the estimated values with all the core length frequencies in the model (42% of virgin biomass).

The second sensitivity, with just a single CPUE series and a fixed selectivity, gives a much lower current biomass at 17% of virgin compared to when the split CPUE series is used (39% of virgin). See Table 19 and Figures 28–29.

3. DISCUSSION

Four problematic aspects that emerged during the model runs were: (1) it is difficult to fit the length-frequency data; (2) the CPUE data and length-frequency data are in conflict regarding the biomass signal, with the length-frequency data indicating a lower initial virgin biomass and steeper subsequent decline compared to the CPUE data; (3) using the single CPUE series in the model gives a steeper decline in the biomass trajectory than using the split CPUE series; and (4) in no runs was the initial steep decline in the CPUE well fitted.

The first two problems are ameliorated to some extent by not fitting to all the length frequency data, but instead using a single year of data. Doing this allows the commercial fishery selectivity to be estimated, but down-weights the biomass signal from it. The particular year chosen (1999) proved to be unproblematic as there was no significant change in the estimated selectivity or biomass trajectory if the 2006 year was used instead. In the base model run with the 1999 length frequency data included, current mature biomass was estimated to be 33% of the virgin biomass of 17 400 t. However, even with just a single year of length data in the model the contrasting biomass signal from it compared to the CPUE data is still non-trivial: dropping the length-frequency data, but retaining the fishing selectivity estimated with it in, gives a current biomass that is 39% of virgin biomass.

Nonetheless, even the 1999 length-frequencies by themselves are badly fitted to (Figure 22). In the model there are slightly more younger fish than observed, and significantly more older fish than observed. This is a pattern observed in nearly every year for the length frequencies (Figure 16). A different estimated growth curve alleviates this to some extent; however a c.v. of close to zero for fish of age one seems implausible, and the fit to the length frequencies is still not good (Figure 27). An alternative model run to consider, which may give more plausible results is to estimate the c.v. for the oldest fish in the model (70+), but leaving the c.v. for the fish of age one fixed.

If a single CPUE series is used instead of a split CPUE series, then current biomass is estimated at 17% and 39% respectively, when the 1999 length-frequency data is omitted from the model (Table 19). The patterns followed by the single and split CPUE series are similar, except following the first year where the decline is much steeper for the single CPUE series, this being the most likely reason for the disparity in biomass estimates (Figure 30). For the single CPUE series there is just a single vessel that links across 1995–2007 (vessel 2 in Table 13), and this vessel appears to drive the steep decline in the first year. Dropping it from the analysis gives a shallower index: with it dropped the decline in the first three years is to 30% of the value in the first year instead of 19%, and the decline from the first to last year is 30% instead of 13% (Figure 30). In this sense vessel 2 is atypical compared to the other vessels, and given the importance of it as a linking vessel, further analysis of it would be fruitful in order to validate the single CPUE series.

Lastly, in no models runs was the initial steep decline in the CPUE well fitted. This was the case whether a split or single CPUE series was used, and just the CPUE indices alone fitted (albeit with a set selectivity from the length data). This is possibly due to the catchability changing over time (e.g. hyperdepletion, whereby catchability decreases with abundance), or model mis-specification. A great deal more further work would be required to untangle just what the reason is for the bad fit to the early part of the CPUE. A simple procedure to evaluate the importance of the initial steep decline would be to do further model runs without the first year.

4. ACKNOWLEDGMENTS

Thanks to the Deep Water Working Group for their input and review of the assessment. The work was funded by the Ministry of Fisheries under project OEO200701.

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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.		0.10	0.09
Length-weight parameters*	a	0.029	0.032
	b	2.90	2.87
Recruitment steepness		0.75	0.75

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

Table 2: Maturity ogive showing predicted probability of maturity for males and females. Ages are in years. Taken from Appendix 2 of Doonan et al. (2003).

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 3: 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). Many of the years are an agglomeration of two or three years, with the year shown representing the approximate centre of the data. The 1995 year for the core length-frequency was omitted in model runs as it is based on only seven tows.

Observational data type	Year	Likelihood
Non-core length frequency	1995, 1999, 2000, 2003, 2005, 2006, 2007	log-normal
Core length-frequency	1999, 2002, 2005, 2006, 2007	log-normal
Standardised CPUE (early)	1995–2000	log-normal
Standardised CPUE (late)	2001–2007	log-normal
Standardised CPUE (single)	1995–2007	log-normal

Table 4: Reported catch (t) of smooth oreo plus unspecified oreo (OEO) by area and fishing year and the number of length frequency samples collected by fishing industry (ORM) and MFish scientific observer programme (SOP) observers. The core stratum was chosen by eye, from a plot of mean length versus axis-position. Other strata are to the west (West) and east (East) of the central fishing area (Core). –, no data.

	SSO catch (t)			Numbers of samples	
	West	Core	East	ORM	SOP
1980–81	–	–	4	–	–
1983–84	9	307	77	–	–
1987–88	8	9	–	–	–
1990–91	–	20	–	–	–
1992–93	–	81	–	–	–
1993–94	–	379	55	–	–
1994–95	–	1 101	153	–	–
1995–96	1	435	306	–	–
1996–97	7	359	192	–	–
1997–98	–	204	34	–	1
1998–99	11	691	165	35	–
1999–00	272	446	7	–	17
2000–01	3	346	2	4	8
2001–02	27	703	54	4	5
2002–03	83	1 228	47	–	9
2003–04	18	1 196	59	–	3
2004–05	558	1 498	19	–	36
2005–06	276	1 218	97	–	38
2006–07	77	509	–	–	19
2007–08	–	–	–	–	2
Totals	1 350	10 730	1 271	43	152

Table 5: Core length analysis Year group, year applied and the number of length frequencies. Smooth oreo sample catch weight, fishery catch and sample catch as percentage of the fishery.

Year group	Year applied	No. of lfs	Catch sampled (t)	Fishery catch (t)	% fishery sampled
1991–92 to 1995–96	1994-95	7	88	1505	6
1998–99 to 1999–2000	1998-99	30	246	1121	22
2000–2001 to 2002–03	2001-02	25	398	2261	18
2003–04 to 2004–05	2004-05	29	261	2280	11
2005–06	2005-06	32	379	1121	34
2006–07 to 2007–08	2006-07	17	168	494	34

Table 6: The non-core length frequencies used in model runs and their c.v.s by sex and for each year. Frequencies are rounded to four decimal places, and c.v.s to two decimal places. These differ from the original non-core length frequencies in that they are input with a common range 22cm to 45cm (no plus group) for males and females, with frequencies then rescaled to sum to one for each year.

Sex& Length (cm)	1995	cvs 1995	1999	cvs 1999	2000	cvs 2000	2003	cvs 2003	2005	cvs 2005	2006	cvs 2006	2007	cvs 2007
m22	0.0001	3.78	0.0002	1.74	0.0007	1.46	0.0001	5.00	0.0014	0.71	0.0000	5.50	0.0002	2.01
m23	0.0005	1.05	0.0001	1.80	0.0001	5.00	0.0001	5.00	0.0021	0.91	0.0000	4.39	0.0001	5.00
m24	0.0014	0.88	0.0003	1.29	0.0001	1.34	0.0001	5.00	0.0037	0.53	0.0003	2.22	0.0003	1.25
m25	0.0022	0.73	0.0002	1.19	0.0003	1.27	0.0001	5.00	0.0018	0.68	0.0001	5.62	0.0001	5.00
m26	0.0045	0.71	0.0004	1.08	0.0001	1.63	0.0001	5.00	0.0057	0.43	0.0000	5.38	0.0001	5.00
m27	0.0054	0.72	0.0012	0.83	0.0027	0.54	0.0001	5.00	0.0039	0.43	0.0002	4.61	0.0010	0.95
m28	0.0029	0.94	0.0038	0.68	0.0040	0.46	0.0007	0.98	0.0054	0.39	0.0005	2.25	0.0007	1.22
m29	0.0049	0.70	0.0075	0.46	0.0104	0.29	0.0030	0.81	0.0093	0.27	0.0024	0.82	0.0017	0.87
m30	0.0127	0.76	0.0145	0.30	0.0217	0.21	0.0061	0.50	0.0081	0.25	0.0029	0.67	0.0044	0.54
m31	0.0182	0.55	0.0193	0.25	0.0382	0.19	0.0139	0.32	0.0132	0.20	0.0094	0.41	0.0137	0.32
m32	0.0282	0.39	0.0277	0.22	0.0605	0.16	0.0422	0.20	0.0322	0.13	0.0254	0.18	0.0195	0.29
m33	0.0565	0.31	0.0380	0.22	0.0614	0.14	0.0417	0.18	0.0466	0.12	0.0546	0.12	0.0490	0.15
m34	0.0902	0.18	0.0477	0.17	0.0569	0.16	0.0650	0.16	0.0598	0.11	0.0716	0.08	0.0625	0.14
m35	0.1177	0.15	0.0648	0.16	0.0607	0.14	0.0695	0.16	0.0747	0.10	0.0989	0.07	0.0875	0.11
m36	0.1217	0.26	0.0792	0.15	0.0526	0.16	0.0632	0.15	0.0645	0.11	0.0903	0.08	0.0810	0.13
m37	0.0713	0.26	0.0645	0.14	0.0463	0.15	0.0610	0.17	0.0531	0.12	0.0642	0.10	0.0504	0.17
m38	0.0449	0.36	0.0471	0.19	0.0339	0.21	0.0514	0.16	0.0344	0.13	0.0410	0.13	0.0472	0.16
m39	0.0179	0.52	0.0380	0.18	0.0237	0.26	0.0312	0.21	0.0240	0.17	0.0223	0.18	0.0237	0.20
m40	0.0149	0.60	0.0278	0.34	0.0082	0.37	0.0172	0.33	0.0110	0.28	0.0153	0.20	0.0157	0.30
m41	0.0056	1.15	0.0134	0.47	0.0062	0.44	0.0049	0.61	0.0063	0.32	0.0049	0.31	0.0039	0.56
m42	0.0014	1.71	0.0090	0.41	0.0030	0.69	0.0031	0.80	0.0014	0.58	0.0020	0.51	0.0036	0.57
m43	0.0001	5.00	0.0057	0.56	0.0026	0.72	0.0031	0.77	0.0016	0.58	0.0012	0.57	0.0016	0.83
m44	0.0006	1.10	0.0018	0.77	0.0001	1.87	0.0015	0.92	0.0004	0.99	0.0002	1.45	0.0012	0.92
m45	0.0068	0.72	0.0013	1.04	0.0002	1.81	0.0001	5.00	0.0005	1.00	0.0002	1.14	0.0002	1.59
f22	0.0010	0.93	0.0001	1.61	0.0001	5.00	0.0001	5.00	0.0008	0.80	0.0000	6.30	0.0001	5.00
f23	0.0010	0.95	0.0001	1.92	0.0001	5.00	0.0001	5.00	0.0017	0.80	0.0000	5.45	0.0001	5.00
f24	0.0013	0.91	0.0000	2.16	0.0002	1.31	0.0001	5.00	0.0019	0.53	0.0001	5.00	0.0001	5.00
f25	0.0015	0.68	0.0002	1.74	0.0001	5.00	0.0001	5.00	0.0043	0.41	0.0002	5.59	0.0001	5.00
f26	0.0034	0.69	0.0008	1.05	0.0017	0.73	0.0004	1.15	0.0033	0.42	0.0005	1.71	0.0001	5.00
f27	0.0045	0.83	0.0010	0.77	0.0014	0.65	0.0001	5.00	0.0040	0.42	0.0004	3.25	0.0003	1.13
f28	0.0053	0.61	0.0022	0.75	0.0043	0.40	0.0017	0.76	0.0077	0.39	0.0011	2.12	0.0006	0.99
f29	0.0060	0.51	0.0047	0.72	0.0087	0.29	0.0042	0.64	0.0059	0.38	0.0010	1.10	0.0003	1.62
f30	0.0061	0.98	0.0091	0.41	0.0141	0.28	0.0044	0.53	0.0056	0.28	0.0010	1.67	0.0073	0.41
f31	0.0055	0.79	0.0111	0.40	0.0194	0.22	0.0116	0.36	0.0129	0.22	0.0047	0.63	0.0102	0.41
f32	0.0088	0.83	0.0173	0.25	0.0338	0.19	0.0280	0.31	0.0208	0.18	0.0131	0.28	0.0223	0.27
f33	0.0248	0.51	0.0333	0.22	0.0406	0.17	0.0364	0.27	0.0333	0.13	0.0286	0.19	0.0312	0.17
f34	0.0181	0.74	0.0340	0.28	0.0527	0.14	0.0523	0.27	0.0502	0.11	0.0406	0.15	0.0473	0.14
f35	0.0377	0.59	0.0408	0.23	0.0526	0.14	0.0485	0.22	0.0654	0.10	0.0596	0.10	0.0747	0.14
f36	0.0406	0.36	0.0326	0.23	0.0481	0.16	0.0505	0.19	0.0607	0.09	0.0651	0.09	0.0788	0.10

Table 6: continued

Sex& Length (cm)	1995	cvs 1995	1999	cvs 1999	2000	cvs 2000	2003	cvs 2003	2005	cvs 2005	2006	cvs 2006	2007	cvs 2007
f37	0.0509	0.26	0.0517	0.15	0.0457	0.17	0.0605	0.25	0.0665	0.11	0.0662	0.11	0.0631	0.14
f38	0.0538	0.27	0.0434	0.19	0.0325	0.18	0.0435	0.18	0.0555	0.15	0.0579	0.12	0.0555	0.15
f39	0.0368	0.43	0.0480	0.15	0.0415	0.19	0.0470	0.18	0.0388	0.14	0.0481	0.13	0.0421	0.33
f40	0.0106	1.09	0.0487	0.20	0.0387	0.23	0.0449	0.18	0.0333	0.12	0.0320	0.15	0.0322	0.20
f41	0.0224	0.52	0.0414	0.22	0.0270	0.22	0.0242	0.27	0.0257	0.17	0.0295	0.17	0.0210	0.20
f42	0.0122	0.57	0.0216	0.39	0.0185	0.32	0.0293	0.21	0.0168	0.18	0.0193	0.18	0.0166	0.29
f43	0.0097	0.85	0.0196	0.36	0.0126	0.39	0.0199	0.31	0.0110	0.23	0.0143	0.22	0.0153	0.24
f44	0.0047	0.93	0.0125	0.46	0.0083	0.57	0.0096	0.43	0.0059	0.30	0.0058	0.34	0.0089	0.37

Table 7: The core length frequencies used in model runs and their c.v.s by sex and for each year. Frequencies are rounded to four decimal places, and c.v.s to two decimal places. These differ from the original core length frequencies in that they are input with a common range 29cm to 45cm (no plus group) for males and females, with frequencies then rescaled to sum to one for each year.

Sex& Length(cm)	1995	cvs 1995	1999	cvs 1999	2002	cvs 2002	2005	cvs 2005	2006	cvs 2006	2007	cvs 2007
m29	0.0014	2.48	0.0026	0.60	0.0012	1.21	0.0001	5.00	0.0019	0.60	0.0017	1.01
m30	0.0105	0.87	0.0106	0.34	0.0041	0.69	0.0006	0.88	0.0024	0.63	0.0044	0.61
m31	0.0170	0.66	0.0175	0.28	0.0119	0.39	0.0056	0.35	0.0090	0.38	0.0144	0.35
m32	0.0259	0.52	0.0308	0.23	0.0388	0.21	0.0232	0.18	0.0260	0.20	0.0201	0.32
m33	0.0588	0.34	0.0420	0.22	0.0338	0.19	0.0422	0.16	0.0578	0.10	0.0485	0.17
m34	0.0948	0.19	0.0527	0.16	0.0585	0.17	0.0571	0.12	0.0723	0.09	0.0628	0.16
m35	0.1264	0.16	0.0691	0.15	0.0709	0.14	0.0737	0.12	0.1003	0.08	0.0861	0.12
m36	0.1345	0.25	0.0799	0.14	0.0685	0.13	0.0715	0.12	0.0902	0.09	0.0825	0.14
m37	0.0766	0.28	0.0650	0.14	0.0672	0.13	0.0631	0.13	0.0602	0.11	0.0512	0.19
m38	0.0446	0.38	0.0501	0.19	0.0551	0.14	0.0442	0.13	0.0434	0.13	0.0485	0.18
m39	0.0193	0.52	0.0364	0.19	0.0355	0.18	0.0320	0.16	0.0222	0.22	0.0232	0.22
m40	0.0165	0.61	0.0249	0.40	0.0160	0.28	0.0157	0.26	0.0179	0.21	0.0171	0.31
m41	0.0063	1.21	0.0119	0.52	0.0077	0.40	0.0090	0.31	0.0058	0.30	0.0042	0.56
m42	0.0012	2.20	0.0076	0.46	0.0042	0.55	0.0019	0.54	0.0026	0.53	0.0041	0.55
m43	0.0001	5.00	0.0052	0.67	0.0037	0.59	0.0021	0.60	0.0016	0.60	0.0016	0.91
m44	0.0001	5.00	0.0009	1.12	0.0010	0.83	0.0005	0.91	0.0003	1.47	0.0014	0.94
m45	0.0077	0.72	0.0001	1.53	0.0002	1.57	0.0007	0.94	0.0002	1.11	0.0003	1.48
f29	0.0001	5.00	0.0021	0.68	0.0003	1.42	0.0004	1.35	0.0008	0.80	0.0003	1.48
f30	0.0042	1.73	0.0049	0.49	0.0031	0.81	0.0007	0.91	0.0002	1.38	0.0081	0.42
f31	0.0043	1.10	0.0076	0.53	0.0068	0.47	0.0054	0.42	0.0034	0.53	0.0098	0.50
f32	0.0065	1.29	0.0200	0.26	0.0161	0.35	0.0156	0.24	0.0133	0.23	0.0224	0.31
f33	0.0246	0.60	0.0334	0.21	0.0284	0.26	0.0240	0.19	0.0291	0.21	0.0293	0.19
f34	0.0165	0.91	0.0389	0.25	0.0465	0.22	0.0435	0.15	0.0413	0.14	0.0475	0.16
f35	0.0394	0.59	0.0430	0.21	0.0483	0.17	0.0687	0.12	0.0633	0.10	0.0744	0.16
f36	0.0432	0.38	0.0392	0.23	0.0538	0.16	0.0637	0.09	0.0658	0.10	0.0783	0.11
f37	0.0541	0.27	0.0535	0.14	0.0630	0.18	0.0784	0.12	0.0662	0.12	0.0637	0.14
f38	0.0573	0.27	0.0436	0.20	0.0463	0.15	0.0694	0.16	0.0564	0.14	0.0528	0.17
f39	0.0399	0.42	0.0474	0.16	0.0548	0.15	0.0523	0.14	0.0450	0.13	0.0422	0.37
f40	0.0108	1.26	0.0510	0.21	0.0557	0.16	0.0454	0.12	0.0329	0.15	0.0321	0.24
f41	0.0248	0.51	0.0429	0.24	0.0323	0.20	0.0363	0.17	0.0268	0.16	0.0201	0.22
f42	0.0136	0.57	0.0227	0.38	0.0305	0.19	0.0229	0.17	0.0195	0.20	0.0175	0.32
f43	0.0107	0.92	0.0203	0.35	0.0204	0.27	0.0172	0.23	0.0128	0.22	0.0174	0.25
f44	0.0048	1.05	0.0110	0.53	0.0124	0.40	0.0087	0.29	0.0061	0.37	0.0094	0.37
f45	0.0033	1.38	0.0113	0.50	0.0032	0.59	0.0040	0.43	0.0031	0.42	0.0028	0.82

Table 8: Summary of non-year variables that could be selected in the initial regression model. All were categorical variables. Df is the number of parameters estimated for that variable; –, not available (depended on the dataset).

Variable	Df	Description
Target	4	Target species, SSO, BOE, OEO, ORH, or other.
Depth	7	Depth at start of a tow. Bins were defined to contain about the same number of tows.
Season	7	The fishing year blocked into 8 periods.
Time	7	Time of day when a tow started, blocked into 8 periods.
Axis-position	7	Axis-position of start of tow, blocked into 8 bins.
Vessel	–	A parameter estimated for each vessel with at least 50 tows. Vessels with fewer than 50 tows were grouped together.
Moon	7	Moon illumination, blocked into 8 bins.
Sun	7	Altitude of the sun, blocked into 8 bins.

Table 9: Unstandardised CPUE for all tows in the assessment area that targeted or caught smooth oreo from 1980–81 to 2006–07. Catch in tonnes (t). Zero tows is the fraction of tows with no smooth oreo reported. Data from 1994–95 to 2006–07 were used for standardised analysis. Combined oreo (SSO plus OEO) t per hr is defined as: sum of catch/sum of hours.

Fishing year	Number of tows	Number of vessels	SSO catch (t)	Mean SSO catch per tow	Combined oreo t per hour	Zero tows (%)
1980–81	8	2	4	0.5	0.3	38
1983–84	26	4	393	15.1	15.9	15
1985–86	1	1	0	0.0	0.0	100
1987–88	2	1	18	8.8	5.6	0
1990–91	7	2	20	2.9	5.4	43
1992–93	10	1	81	8.1	15.3	20
1993–94	24	2	434	18.1	11.4	4
1994–95	155	7	1 254	8.1	7.0	11
1995–96	127	3	742	5.8	7.7	10
1996–97	162	3	559	3.4	2.8	20
1997–98	130	6	239	1.8	2.2	37
1998–99	251	9	867	3.5	3.9	14
1999–00	109	7	725	6.7	4.3	10
2000–01	95	5	351	3.7	4.3	19
2001–02	130	4	784	6.0	5.9	5
2002–03	231	5	1 359	5.9	8.0	8
2003–04	245	6	1 273	5.2	7.0	18
2004–05	410	8	2 075	5.1	4.3	14
2005–06	334	4	1 591	4.8	9.2	23
2006–07	209	5	587	2.8	5.9	16

Table 10: Early period (1994–95 to 1999–2000) CPUE. R2 (%) values for the stepwise (a) zero catch and (b) positive catch model selection of variables for the initial analysis. New variables were added one at a time until R2 failed to increase by more than 1 unit. At each iteration the variable that increased R2 the most was added. Variables considered for the regression are given in Table 8.

(a) Zero catch model

	Step 1	Step 2	Step 3	Step 4	Step 5
Axis-position	16.4	–	–	–	–
Season	13.0	20.0	–	–	–
Depth	12.1	18.3	21.8	–	–
Vessel	11.9	17.9	21.5	23.5	–
Time	10.7	17.9	21.4	23.5	24.9
Improvement	7.5	3.7	1.8	1.7	1.4

(b) Positive catch model

	Step 1	Step 2	Step 3	Step 4
Depth	14.5	–	–	–
Season	12.6	20.0	–	–
Vessel	12.9	17.8	26.0	–
Axis-position	12.9	16.6	21.8	28.4
Improvement	7.3	5.5	6.0	2.4

Table 11: Late period (2000–01 to 2006–07) CPUE. R2 (%) values for the stepwise (a) zero catch and (b) positive catch model selection of variables for the initial analysis. New variables were added one at a time until R2 failed to increase by more than 1 unit. At each iteration the variable that increased R2 the most was added. Variables considered for the regression are given in Error! Reference source not found.**.**

(a) Zero catch model

	Step 1	Step 2
Season	4.7	–
Axis-position	4.1	6.1
Improvement	2.0	1.4

(b) Positive catch model

	Step 1	Step 2	Step 3	Step 4
Season	4.8	–	–	–
Axis-position	4.2	7.2	–	–
Depth	3.9	7.1	8.8	–
Time	3.7	6.2	8.8	10.1
Improvement	2.6	2.4	1.5	1.4

Table 12: Single period (1995–96 to 2006–07) CPUE. R2 (%) values for the stepwise (a) zero catch and (b) positive catch model selection of variables for the initial analysis. New variables were added one at a time until R2 failed to increase by more than 1 unit. At each iteration the variable that increased R2 the most was added. Variables considered for the regression are given in Table 8.

(a) Zero catch model

	Step 1	Step 2	Step 3
Year	4.6	–	–
Vessel	1.9	6.1	–
Season	0.9	5.8	7.2
Improvement	4.6	1.5	1.2

(b) Positive catch model

	Step 1	Step 2	Step 3	Step 4
Year	4.0	–	–	–
Depth	2.3	7.1	–	–
Vessel	1.9	6.4	9.1	–
Season	2.1	5.6	9.0	10.5
Improvement	4.0	3.1	2.0	1.4

Table 13: Number of tows by vessel and fishing year. Each row (apart from the year row) is a vessel, and single year vessels are excluded. Nine vessels fished for at least three years. 86 is the fishing year 1985–86, etc.

Vessel	86	88	91	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07
1	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	6	10	–	52	7	4	11	47	56	11	16	34	57	186	103	91
3	–	–	–	–	1	14	60	92	51	26	14	–	–	–	–	–	–	–
4	–	–	–	–	23	–	–	–	–	–	–	–	7	–	–	–	–	–
5	–	–	–	–	–	40	–	66	–	–	–	–	–	–	–	–	–	–
6	–	–	–	–	–	20	–	–	15	28	–	–	–	–	–	–	–	–
7	–	–	–	–	–	2	60	–	–	5	19	4	–	–	–	–	–	–
8	–	–	–	–	–	–	–	–	1	–	–	4	–	21	–	–	–	–
9	–	–	–	–	–	–	–	–	–	10	2	–	–	–	–	–	–	–
10	–	–	–	–	–	–	–	–	–	2	3	–	–	27	18	4	–	–
11	–	–	–	–	–	–	–	–	–	–	6	16	36	81	126	139	181	66
12	–	–	–	–	–	–	–	–	–	–	9	–	–	–	–	–	–	10
13	–	–	–	–	–	–	–	–	–	–	–	60	71	68	39	19	33	37
14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	13	17	–

Table 14: Early and late period CPUE combined index estimates by year, and bootstrap c.v. estimates.

Early period	kg/tow	c.v	Late period	kg/tow	c.v
1995–96	3551	0.423	2000–01	850	0.487
1996–97	3322	0.496	2001–02	2976	0.274
1997–98	2306	0.980	2002–03	1489	0.243
1998–99	781	0.391	2003–04	1727	0.260
1999–2000	1536	0.306	2004–05	1604	0.227
			2005–06	1386	0.310
			2006–07	966	0.232

Table 15: Single period CPUE combined index estimates by year, and bootstrap c.v. estimates.

Year	kg/tow	c.v
1994–95	7472	0.286
1995–96	4453	0.735
1996–97	3366	1.264
1997–98	1444	0.406
1998–99	2835	0.286
1999–2000	2817	0.436
2000–01	632	0.680
2001–02	1973	0.663
2002–03	1296	0.615
2003–04	1284	0.445
2004–05	1289	0.563
2005–06	1056	1.200
2006–07	805	0.675

Table 16: Catch history (t) of smooth oreo from the Bounty Plateau 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
1983–84	620	1996–97	610
1984–85	0	1997–98	650
1985–86	0	1998–99	1 200
1986–87	0	1999–00	870
1987–88	10	2000–01	550
1988–89	0	2001–02	980
1989–90	0	2002–03	1 530
1990–91	20	2003–04	1 420
1991–92	0	2004–05	2 190
1992–93	110	2005–06	1 790
1993–94	490	2006–07	670
1994–95	1 450	2007–08	670
1995–96	900		

Table 17: 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
q early CPUE	uniform-log	1
q late CPUE	uniform-log	1
Commercial logistic selectivity (male)	uniform	2
Commercial logistic selectivity (female)	uniform	2
Process error for early and late CPUE	uniform	1
Process error for length-frequency	uniform	1

Table 18: MPD estimates of the free parameters in the preliminary model runs. The less the likelihood, the better the model fit. V2008 refers to the vulnerable biomass in the 2008 fishing year, SSB2008 to the spawning stock biomass in 2008. cv1 is the c.v. at age one, U the exploitation rate (either in 2008 or maximum over all model years).

		Non-core LFs	Core LFs	CPUE only	Core only 1999 LF	Core only 2006 LF	Core Est Linf and cv1
	B_0 (mid-year)	14400	13600	20300	17400	16600	18000
	$B_{current}$ (mid-year)	3000	2000	8500	5800	4800	6300
	$B_{current} (\%B_0)$	21	15	42	33	29	35
	U_{2008}	0.20	0.41	0.08	0.10	0.14	0.17
	U_{max}	0.37	0.58	0.19	0.22	0.29	0.33
	V2008/SSB2008	1.02	0.65	0.95	1.08	0.92	0.59
	q early CPUE	0.16	0.19	0.11	0.12	0.14	0.16
	q late CPUE	0.27	0.40	0.14	0.17	0.21	0.24
	q single CPUE	–	–	–	–	–	–
	CPUE process error	0.0[†]	0.35	0.0[*]	0.0[†]	0.0[†]	0.35[*]
	LF process error	0.80	0.82	–	0.33	1.43	0.82[*]
Male selectivity	a_{50}	20.4	21.1	21.1[*]	19.5	20.5	27.5
	a_{to95}	4.8	0.2	0.2[*]	0.1[†]	0.1[†]	0.1
Female selectivity	a_{50}	20.9	22	22[*]	20.1	22.9	23.5
	a_{to95}	4.7	0.1[†]	0.1[*]	0.1	0.2	0.1
Male growth	Linf	43.6[*]	43.6[*]	43.6[*]	43.6[*]	43.6[*]	39.1
	cv1	0.09[*]	0.09[*]	0.09[*]	0.09[*]	0.09[*]	0.0[†]
Female growth	Linf	50.8[*]	50.8[*]	50.8[*]	50.8[*]	50.8[*]	48.9
	cv1	0.10[*]	0.10[*]	0.10[*]	0.10[*]	0.10[*]	0.0[†]
Likelihoods	*total*	187.8	91.1	0.3	5.2	24.9	15.9
	early CPUE	-0.2	-0.7	0.1	0.0	-0.1	-0.6
	late CPUE	-4.7	-1.3	-5.5	-5.5	-5.3	-3.6
	sum LF	186.3	86.2	–	4.8	24.1	13.5
	sum priors	6.4	7.0	5.7	5.9	6.2	6.5
	catch penalty	0	0	0	0	0	0

† at model bound
* fixed value

Table 19: Sensitivities on the base model run (Core only 1999 LF): MPD estimates of the free parameters. The less the likelihood, the better the model fit. V2008 refers to the vulnerable biomass in the 2008 fishing year, SSB2008 to the spawning stock biomass in 2008. cv1 is the c.v. at age one, U the exploitation rate (either in 2008 or maximum over all model years).

		Core only 1999 LF	CPUE only: fix 99 LF	Non-split CPUE: fix 99 LF
	B_0 (mid-year)	17400	19300	13900
	$B_{current}$ (mid-year)	5800	7600	2400
	$B_{current}(\%B_0)$	33	39	17
	U_{2008}	0.10	0.08	0.25
	U_{max}	0.22	0.19	0.43
	V2008/SSB2008	1.08	1.08	1.0
	q early CPUE	0.12	0.11	–
	q late CPUE	0.17	0.14	–
	q single CPUE	–	–	0.30
	CPUE process error	0.0†	0.0*	0.0*
	LF process error	0.33	–	–
Male selectivity	a_{50}	19.5	19.5*	19.5*
	a_{to95}	0.1†	0.1*	0.1*
Female selectivity	a_{50}	20.1	20.1*	20.1*
	a_{to95}	0.1	0.1*	0.1*
Male growth	Linf	43.6*	43.6*	43.6*
	cv1	0.09*	0.09*	0.09*
Female growth	Linf	50.8*	50.8*	50.8*
	cv1	0.10*	0.10*	0.10*
Likelihoods	*total*	5.2	0.3	7.8
	early CPUE	0.0	0.1	–
	late CPUE	-5.5	-5.5	–
	single CPUE	–	–	-0.5
	sum LF	4.8	–	–
	sum priors	5.9	5.7	8.3
	catch penalty	0	0	0

† at model bound
* fixed value

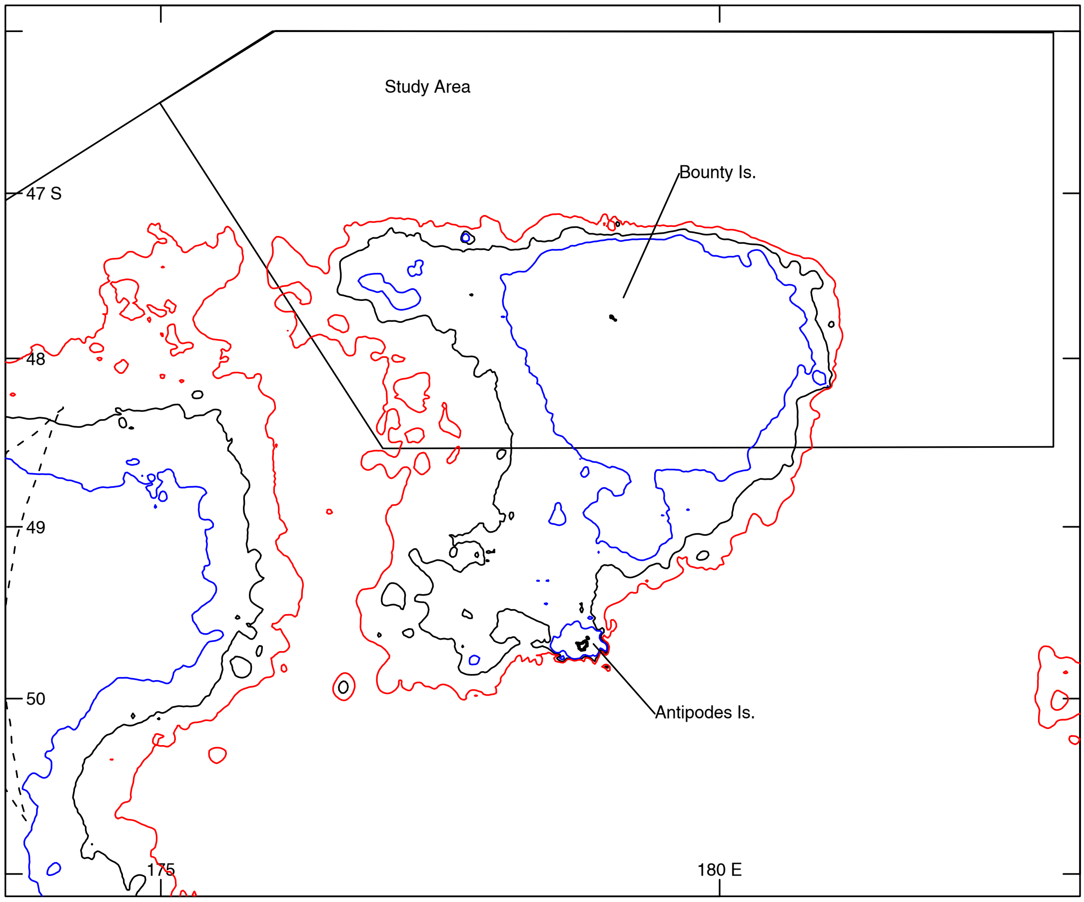

Figure 1: The Bounty Plateau fishery assessment study area.

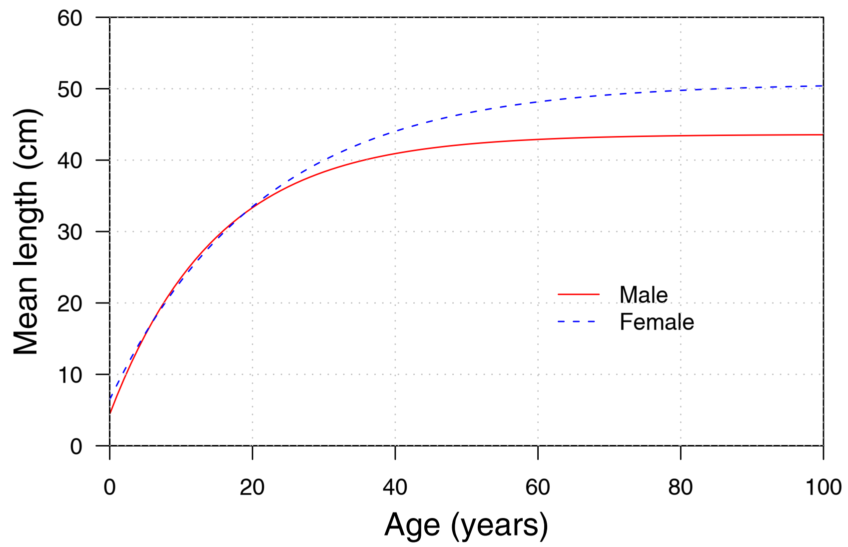

Figure 2: Mean length-at-age for smooth oreo (male and female).

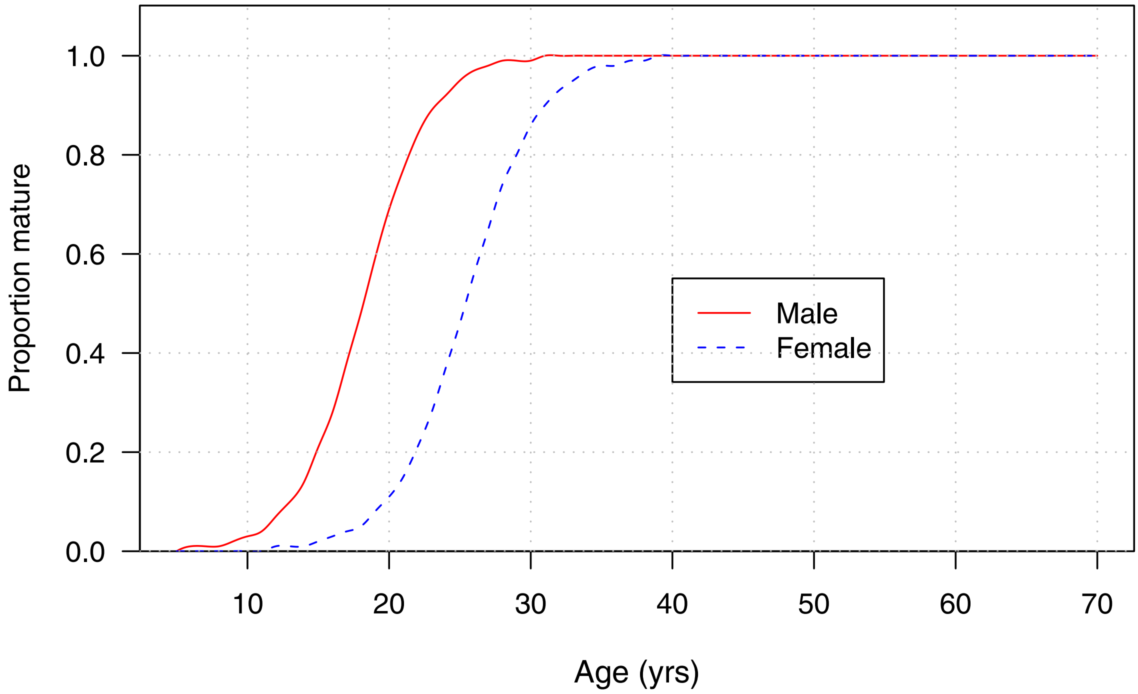

Figure 3: Proportion mature by age (male and female).

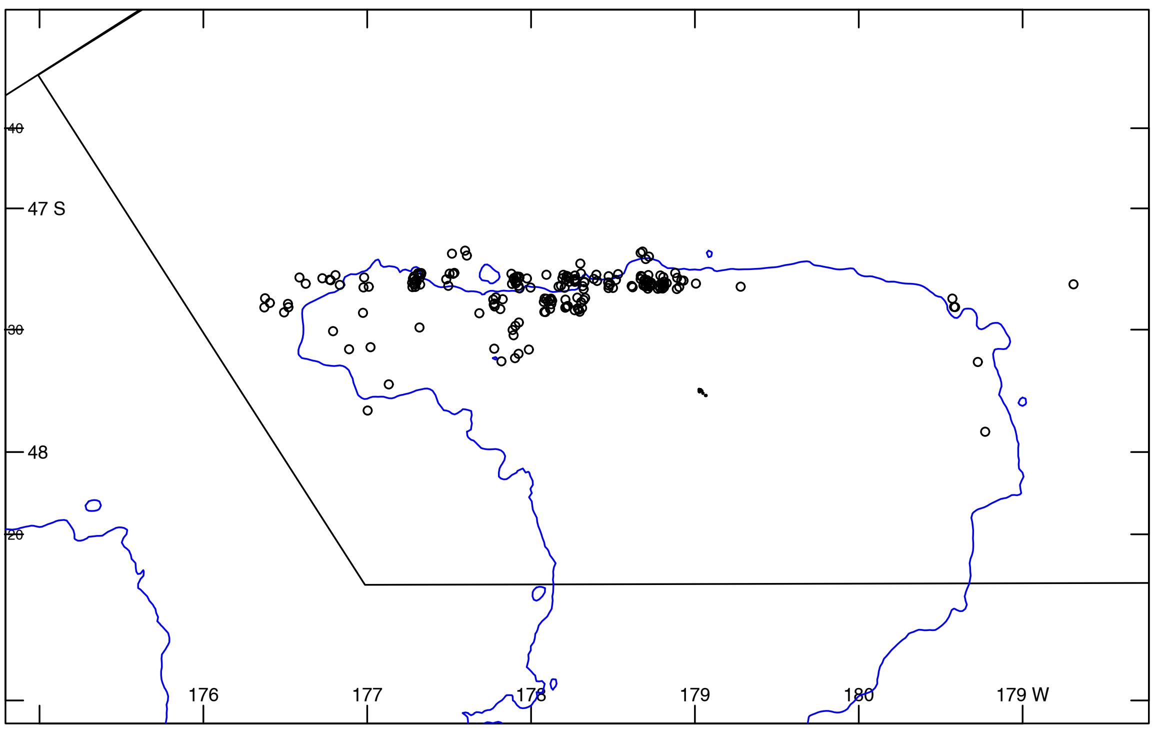

Figure 4: Location of smooth oreo observer length frequency samples where the number of fish per sample was greater than or equal to 30. Positions are shown jittered.

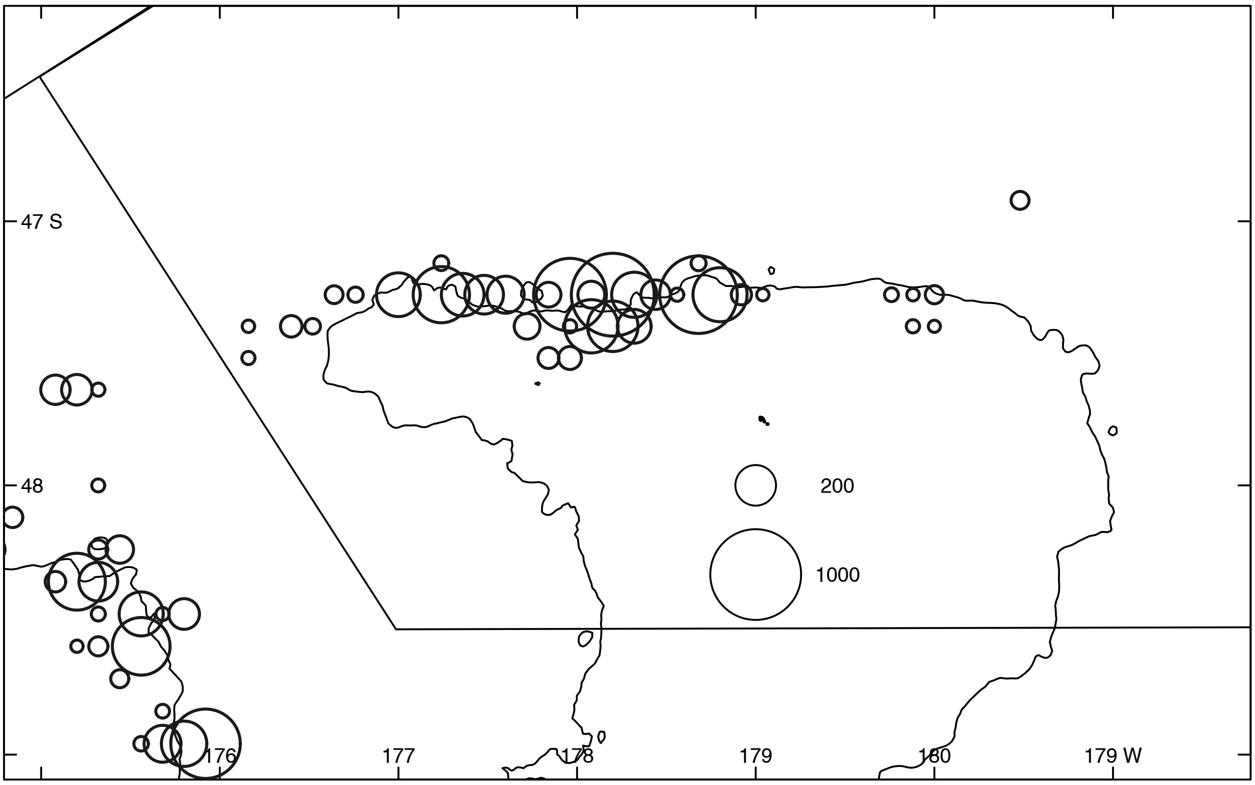

Figure 5: Cumulative catch of smooth oreo (tonnes) from 1980–81 to 2006–07. 1000 m depth contour is shown.

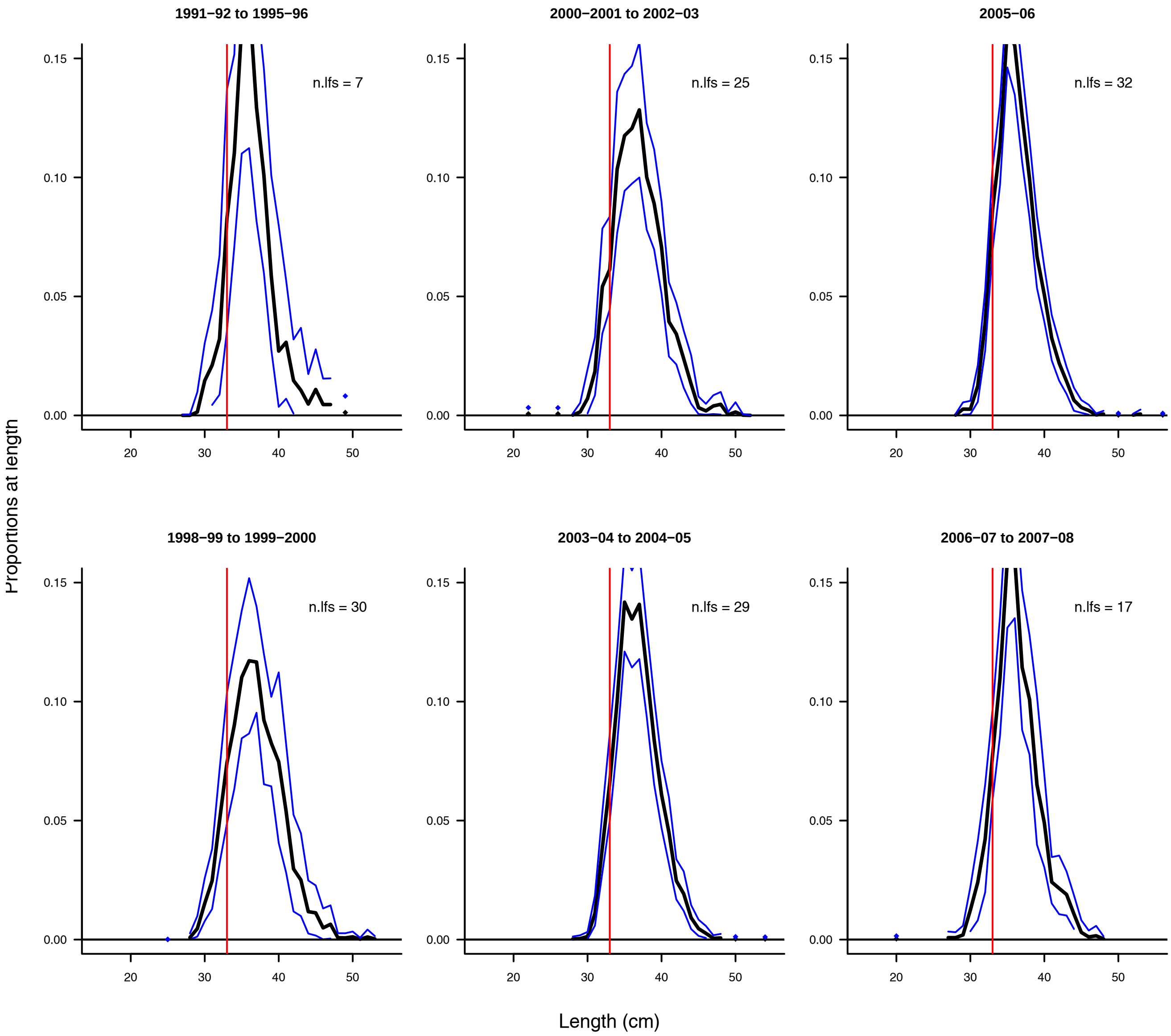

Figure 6: Length frequency distribution plots for core data only.

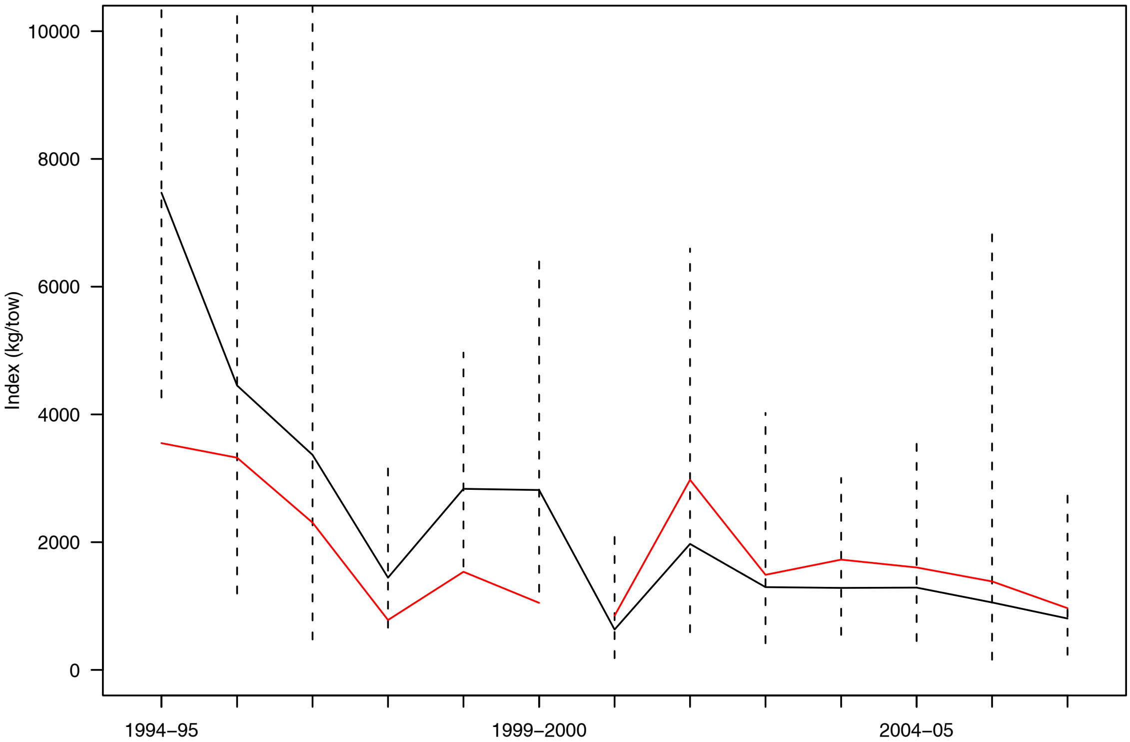

Figure 7: Early and late period CPUE combined indices with bootstrap confidence intervals. The single period CPUE indices are also shown.

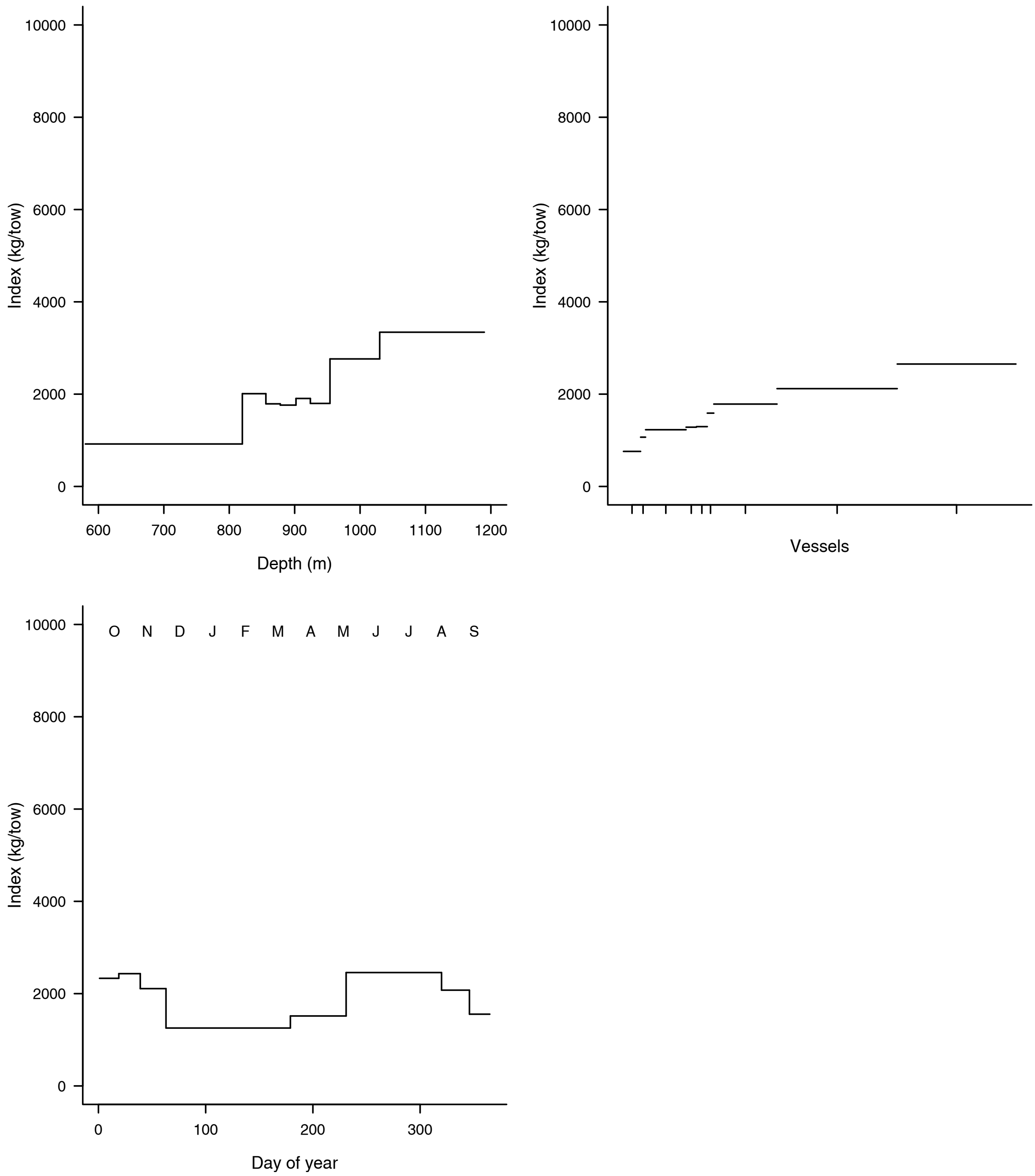

Figure 8: Single period CPUE combined indices. Non-year effects from the final model. The width of each step is proportional to the number of records in each category. The depth effect: steps show the effect on the index at each of the eight bins. The vessel effect: horizontal lines show the effect on the index for each vessel category. The season effect: steps show the effect on the index at each of the eight bins (0 = 1st of October).

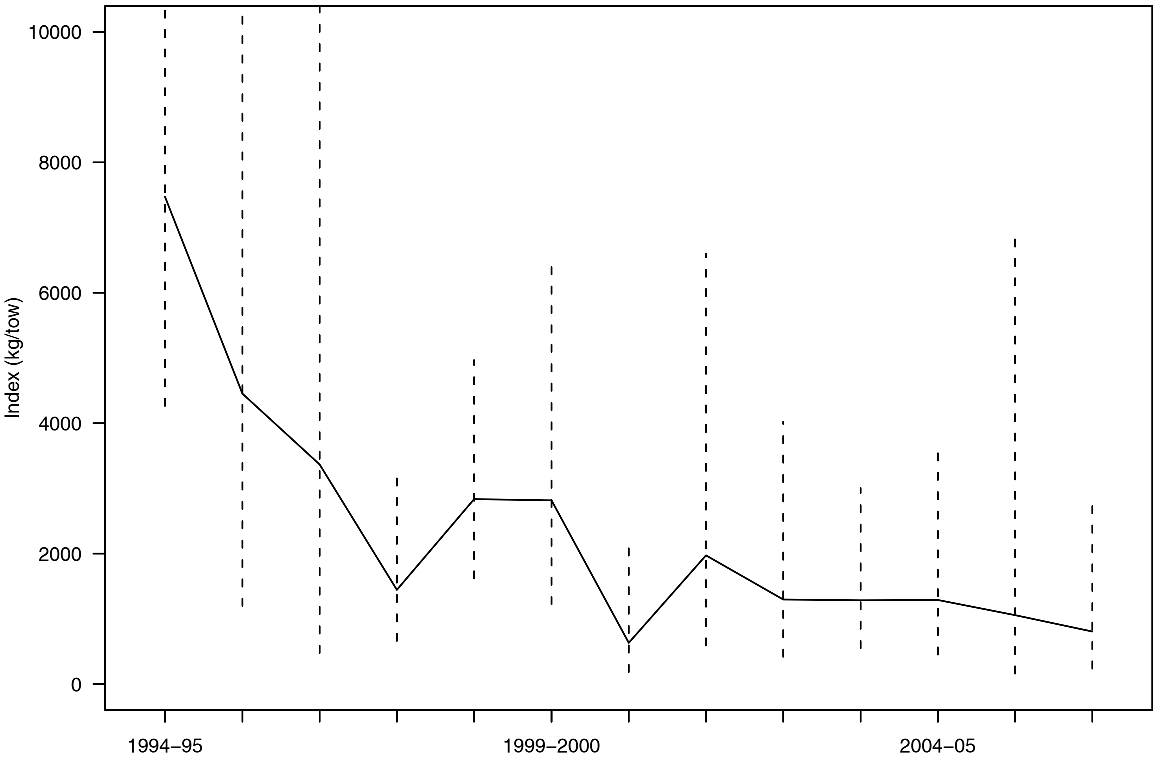

Figure 9: Single period CPUE combined indices with bootstrap confidence interval.

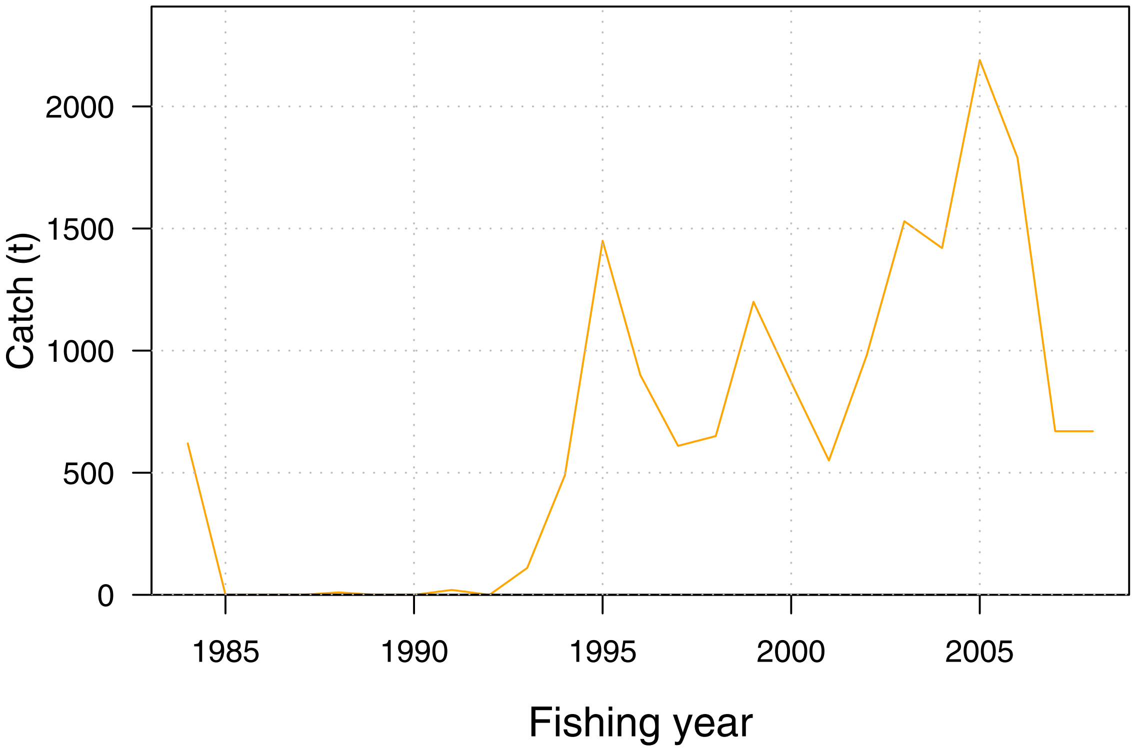

Figure 10: Catch history for smooth oreo from the Bounty Plateau fishery assessment area (Table 16).

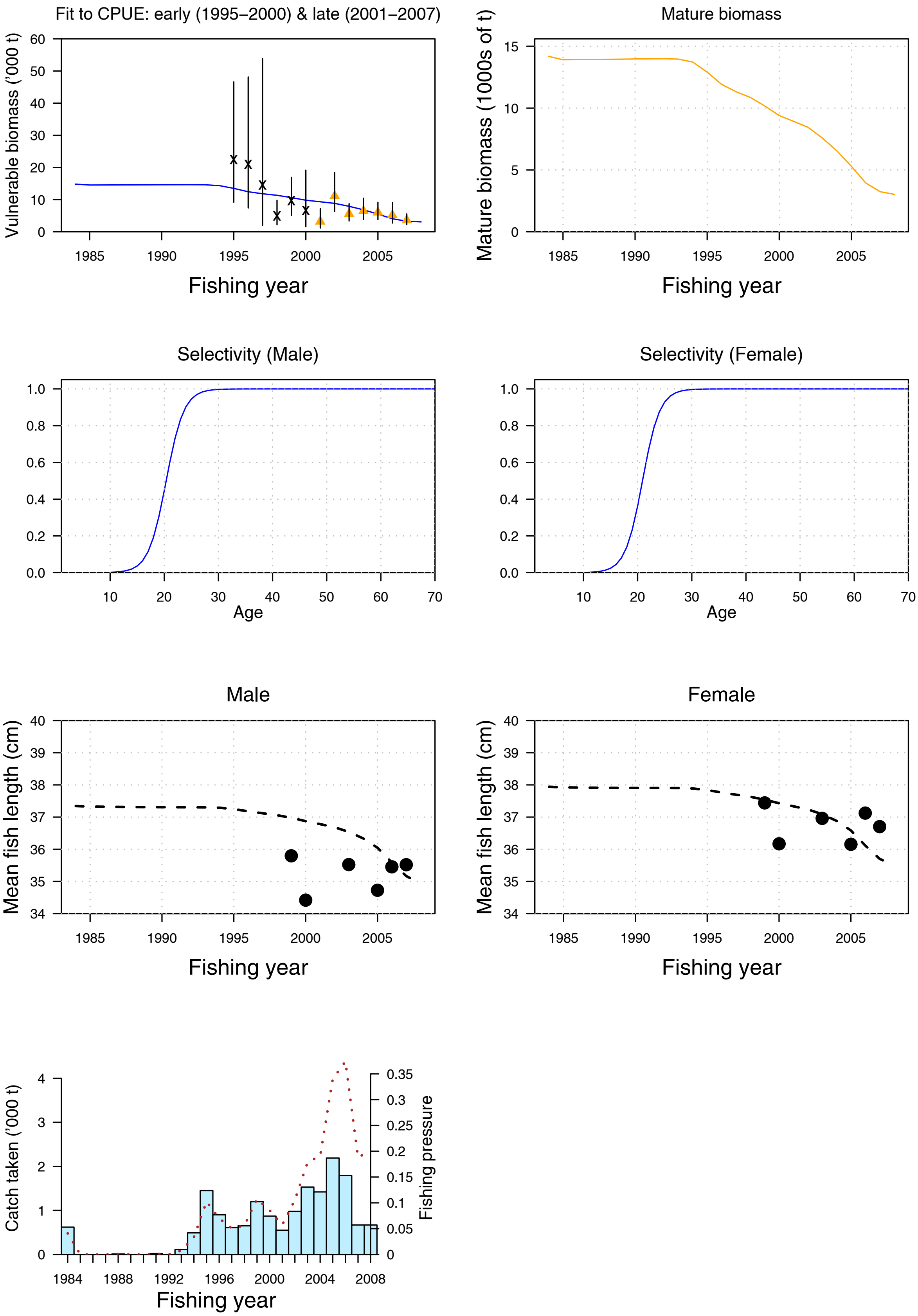

Figure 11: Some fits using the non-core length frequencies ("Non-core LFs"). In the third row the solid dots are the observations and the dashed lines the model output.

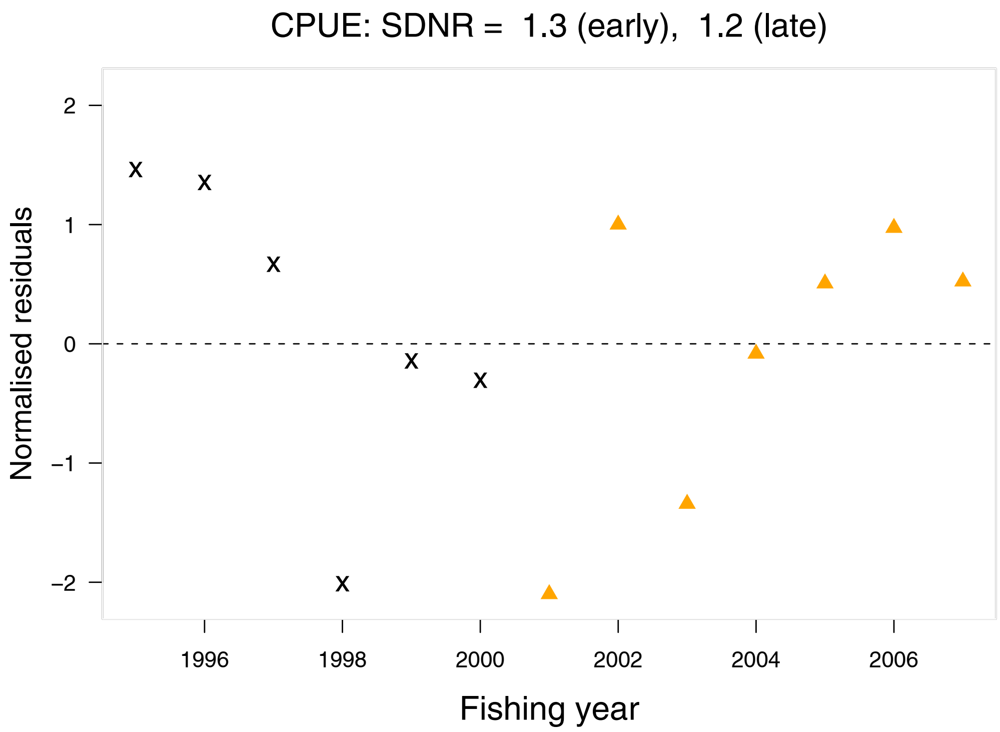

Figure 12: Diagnostics for the CPUE fit for the model run using the non-core length frequencies ("Non-core LFs"). Early CPUE residuals are shown by crosses, late CPUE residuals by triangles.

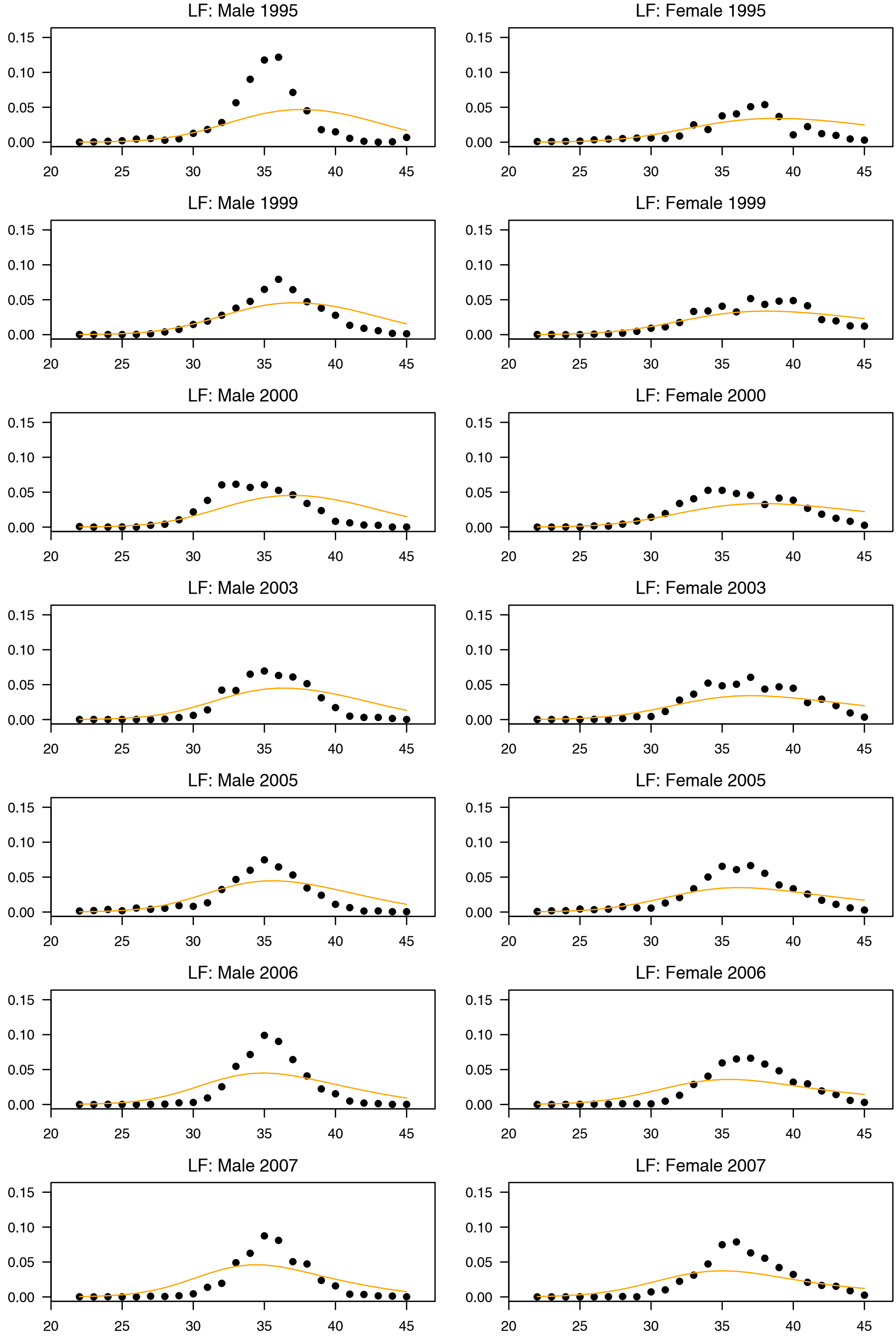

Figure 13: Fits to the non-core length frequencies ("Non-core LFs").

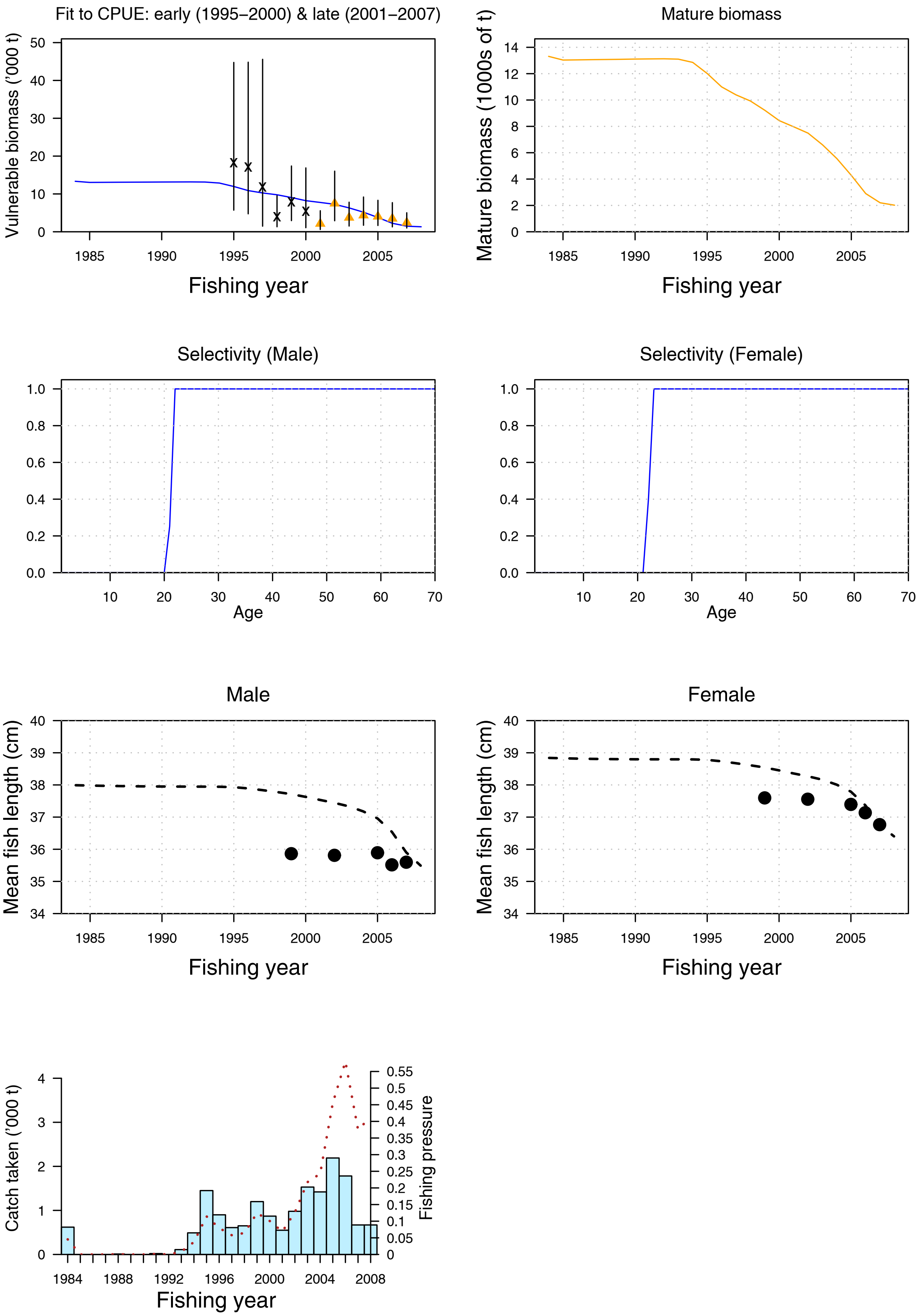

Figure 14: Some fits for the core length frequencies model run ("Core LFs").

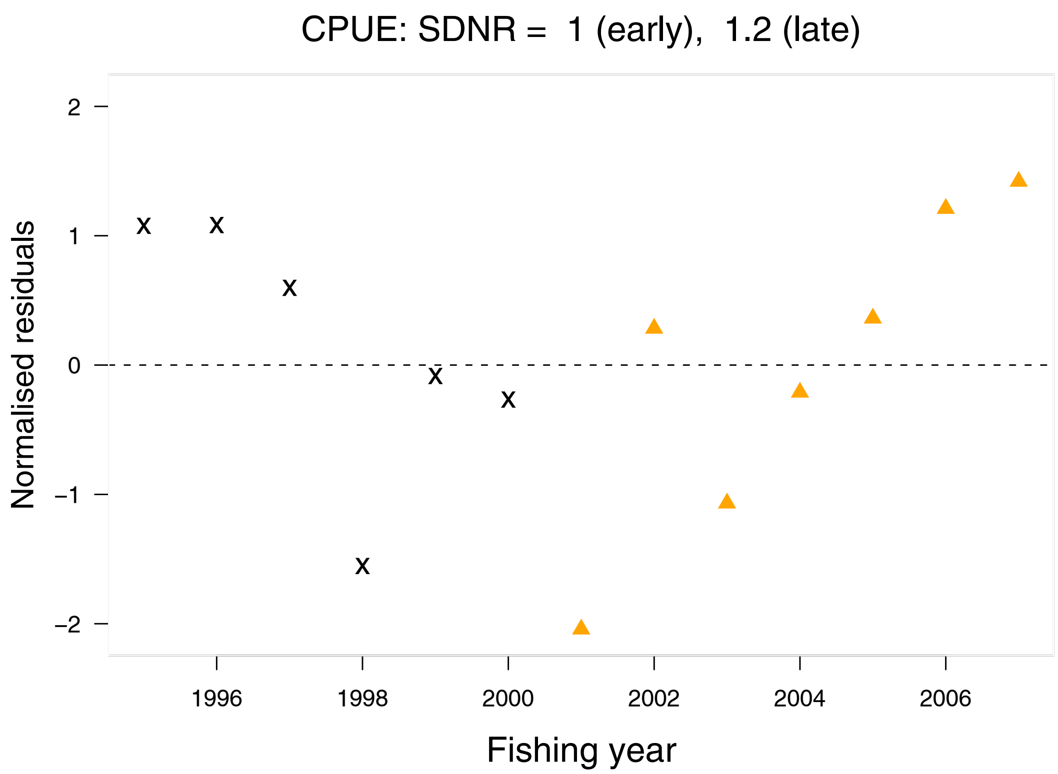

Figure 15: Diagnostics for the CPUE fit for the model run using the core length frequencies ("Core LFs"). Early CPUE residuals are shown by crosses, late CPUE residuals by triangles.

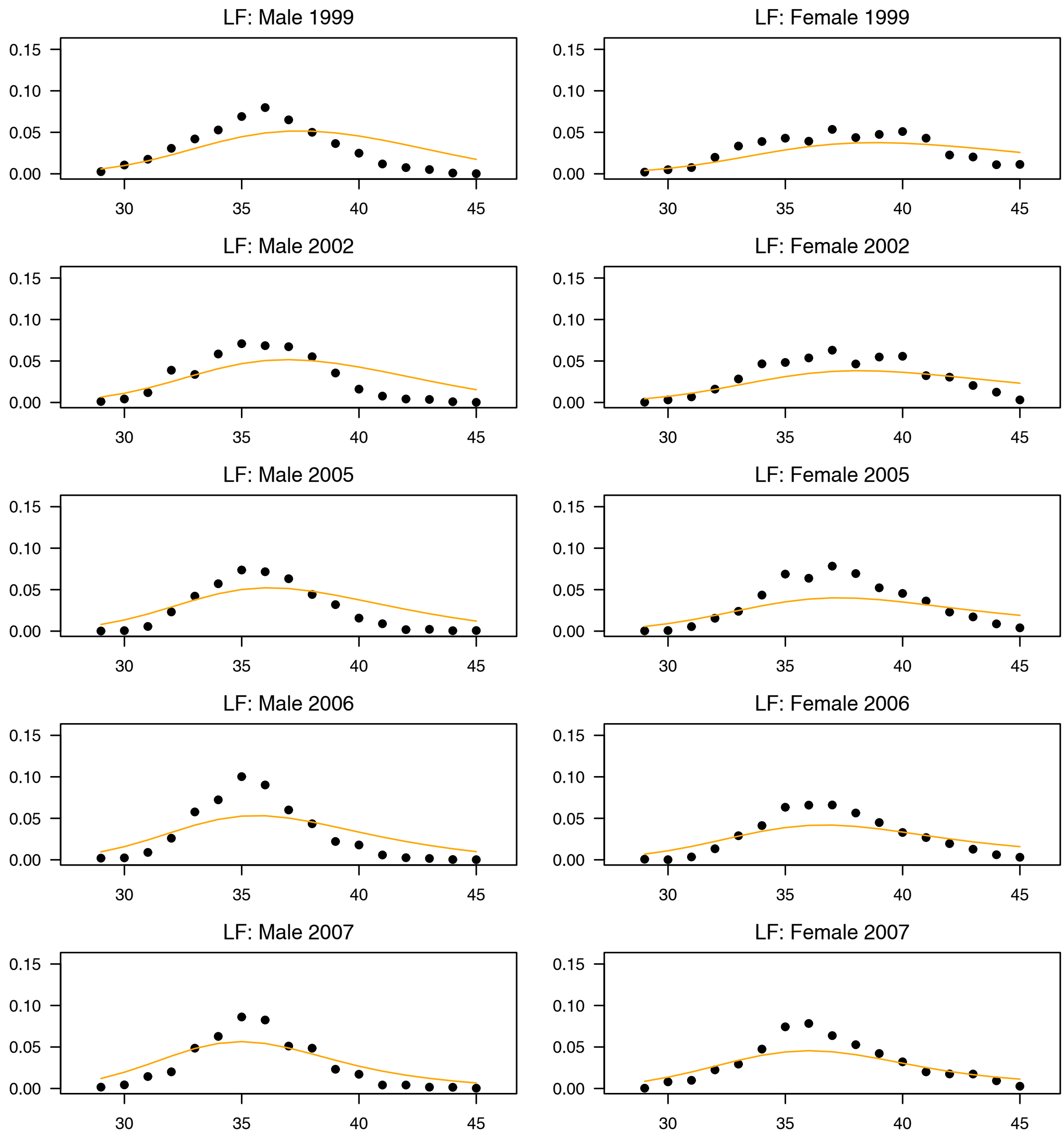

Figure 16: Fits to the core length frequencies ("Core LFs").

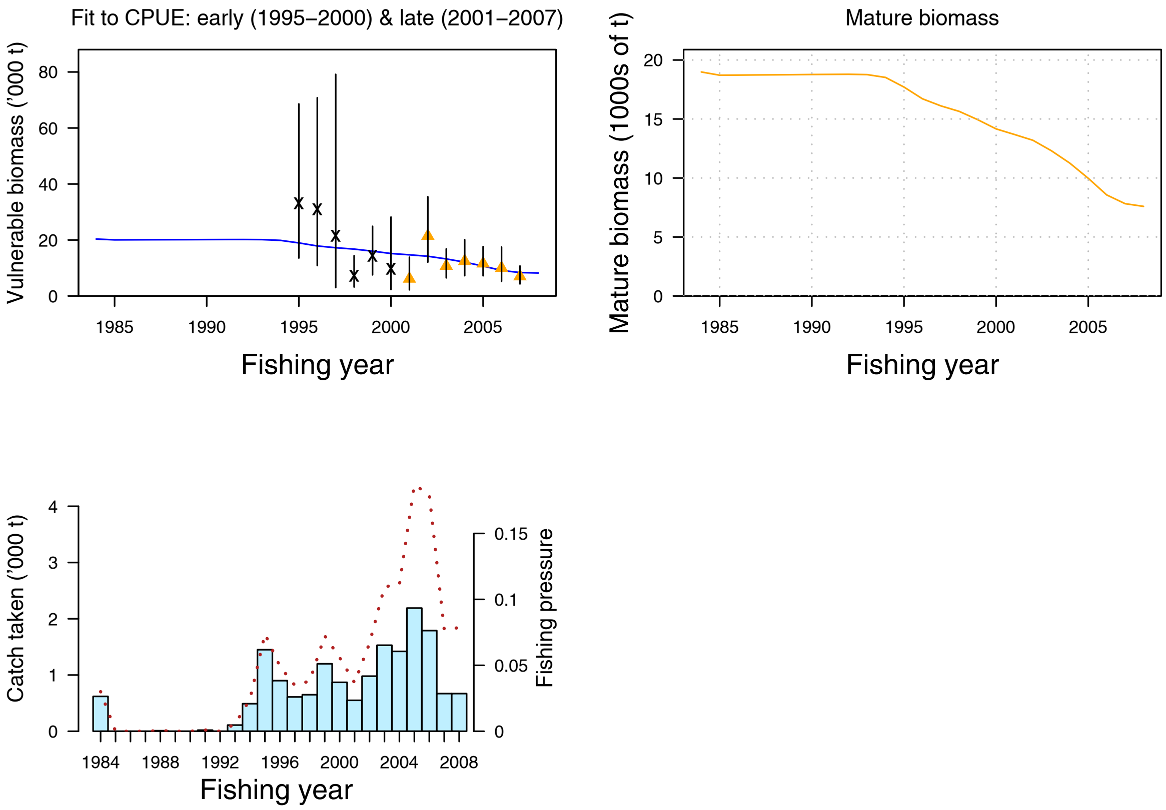

Figure 17: Model fits for the CPUE data only model with process error set at zero.

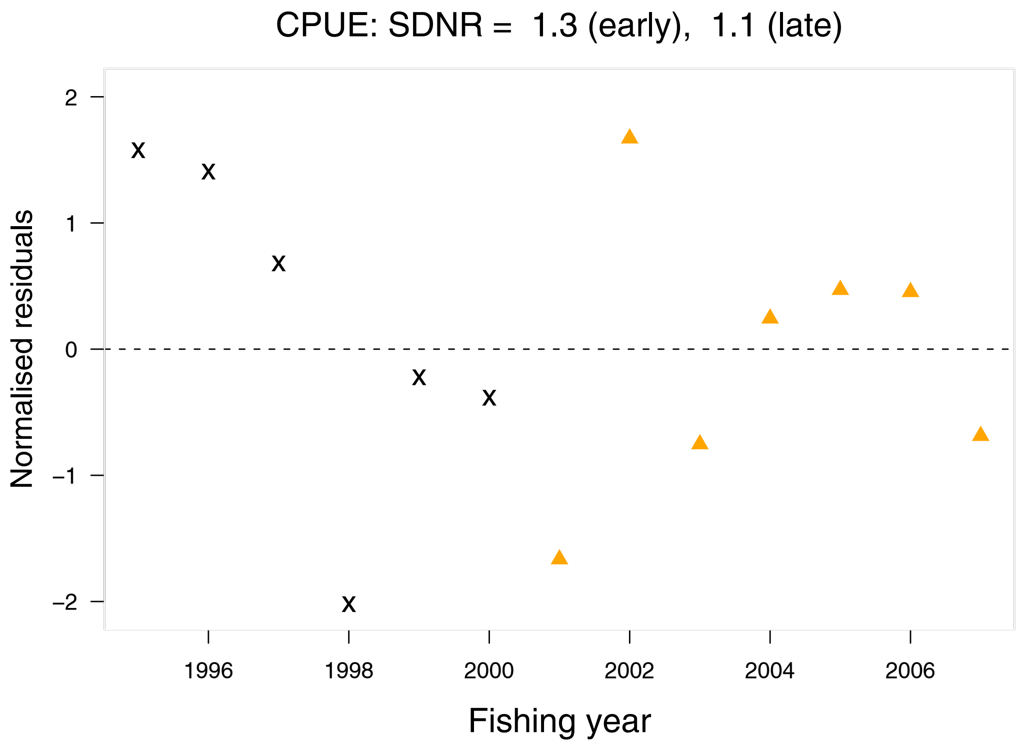

Figure 18: Diagnostics for the CPUE data only model with process error set at zero. Early CPUE residuals are shown by crosses, late CPUE residuals by triangles.

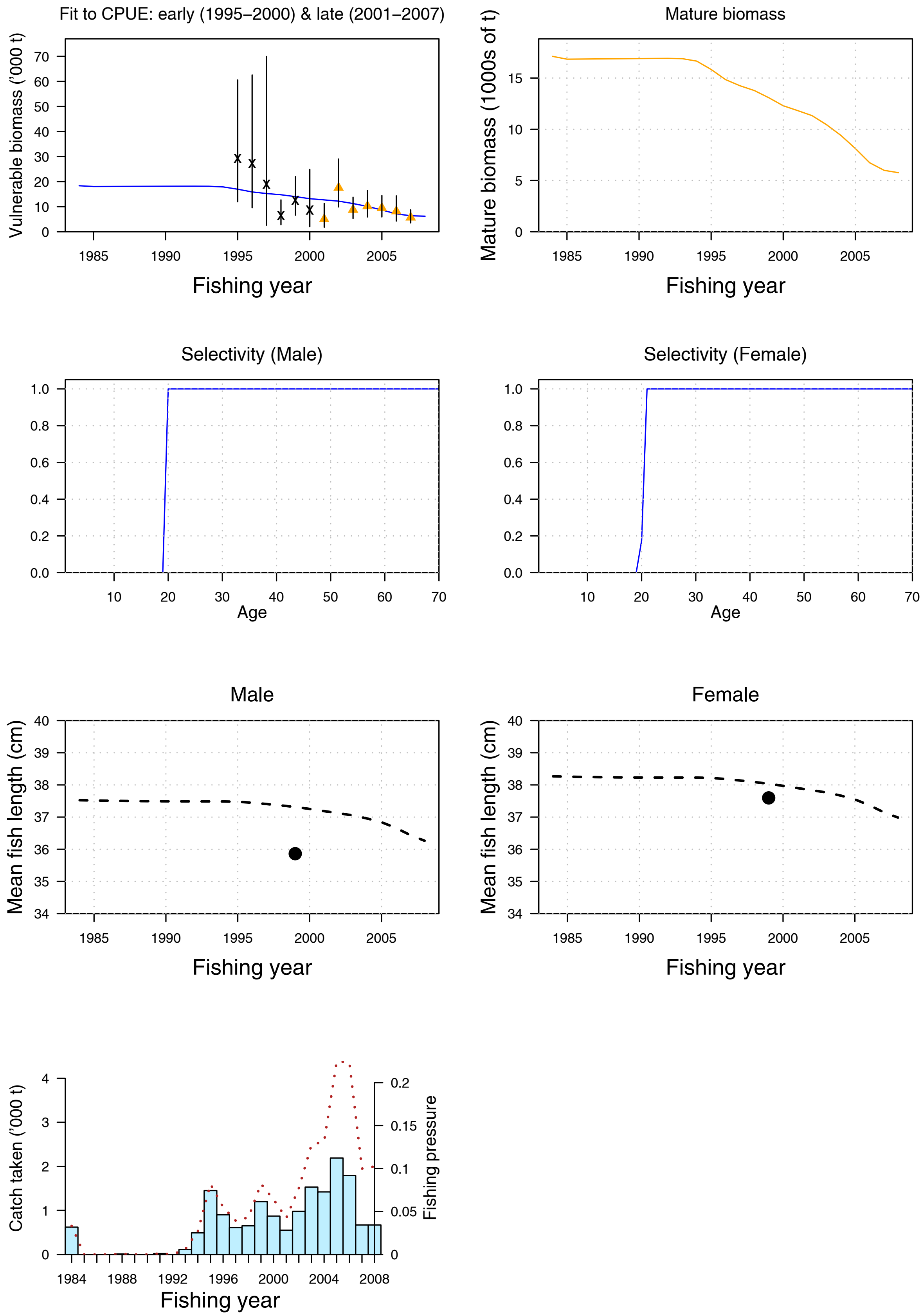

Figure 19: Some fits using only the core 1999 length frequencies ("Core only 1999 LF").

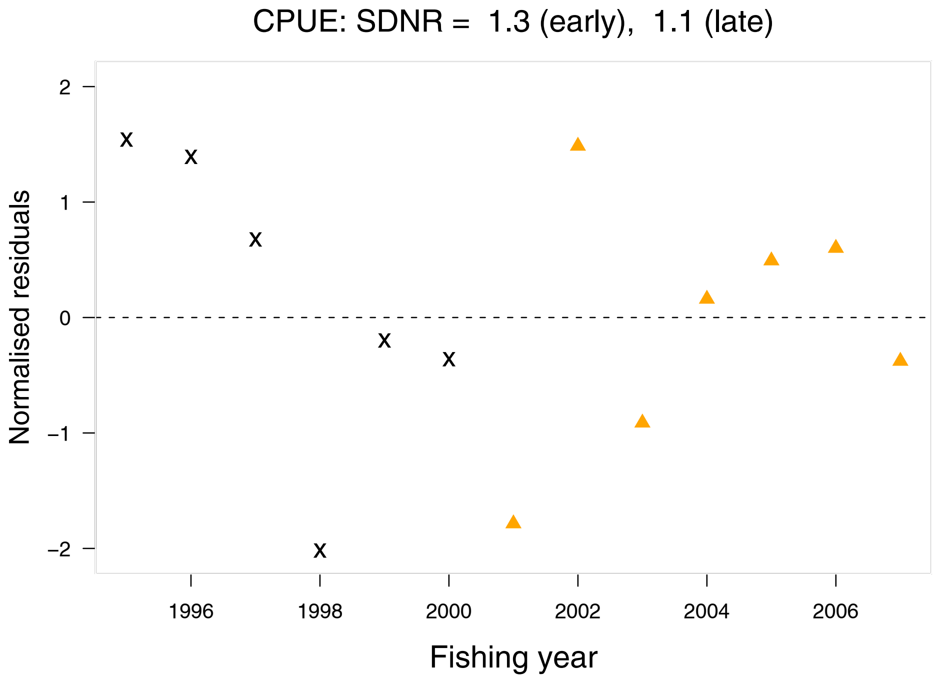

Figure 20: Diagnostics for the CPUE fit ("Core only 1999 LF" model). Early CPUE residuals are shown by crosses, late CPUE residuals by triangles.

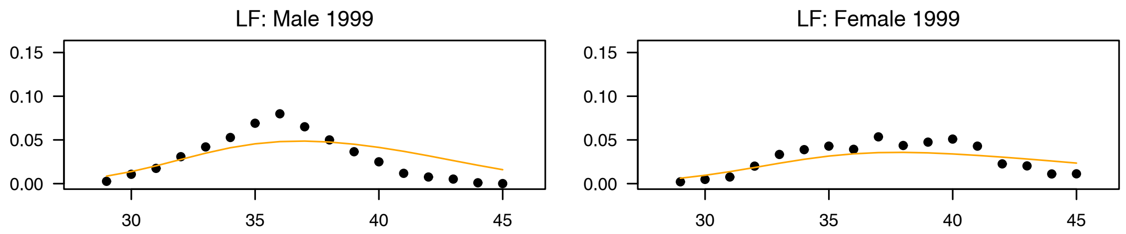

Figure 21: Fits to the 1999 core length frequencies ("Core only 1999 LF").

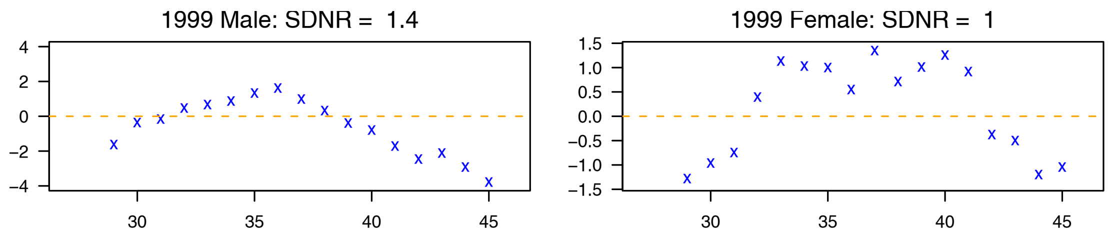

Figure 22: Diagnostics for the 1999 core length frequencies ("Core only 1999 LF").

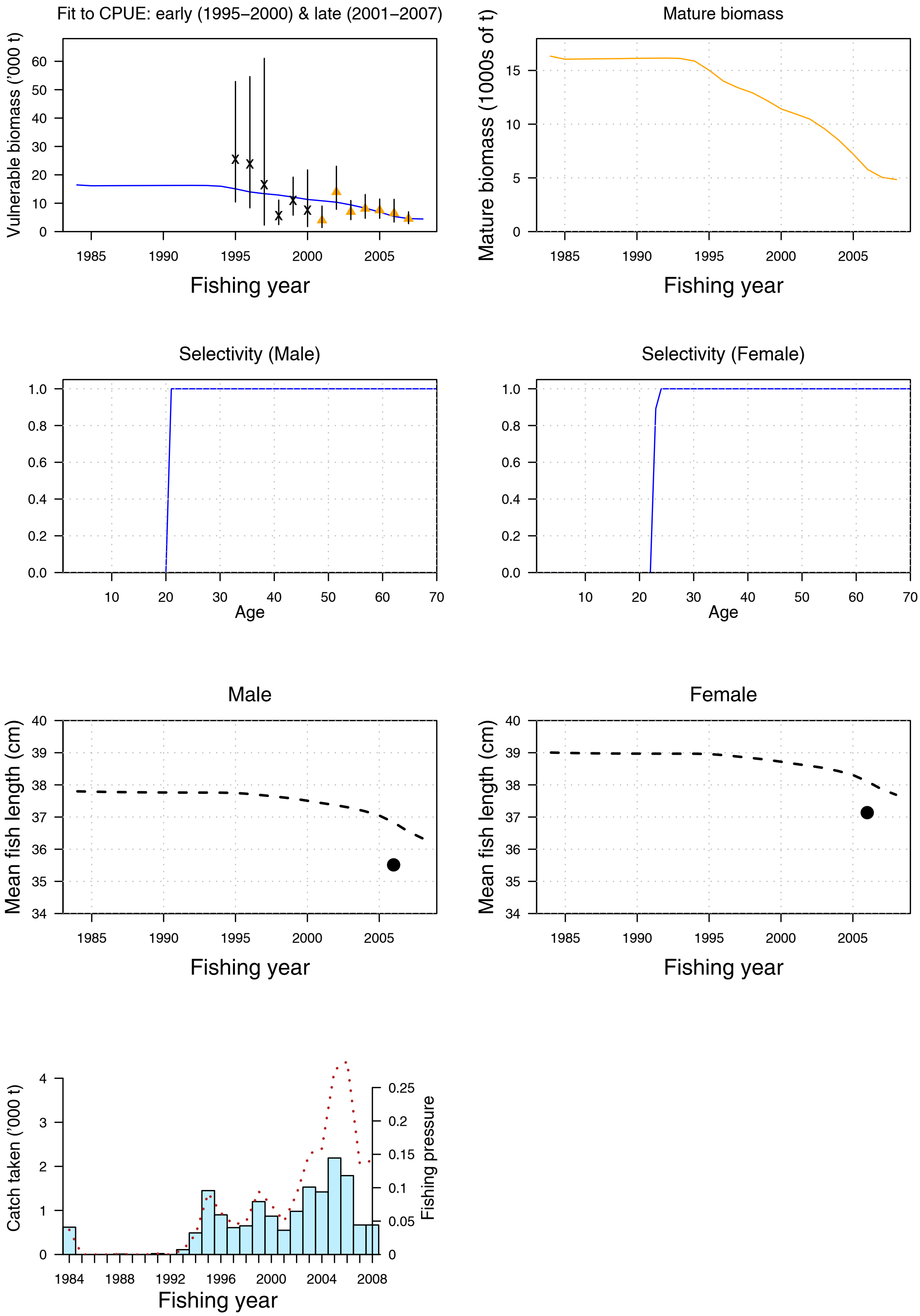

Figure 23: Some fits using only the core 2006 length frequencies ("Core only 2006 LF").

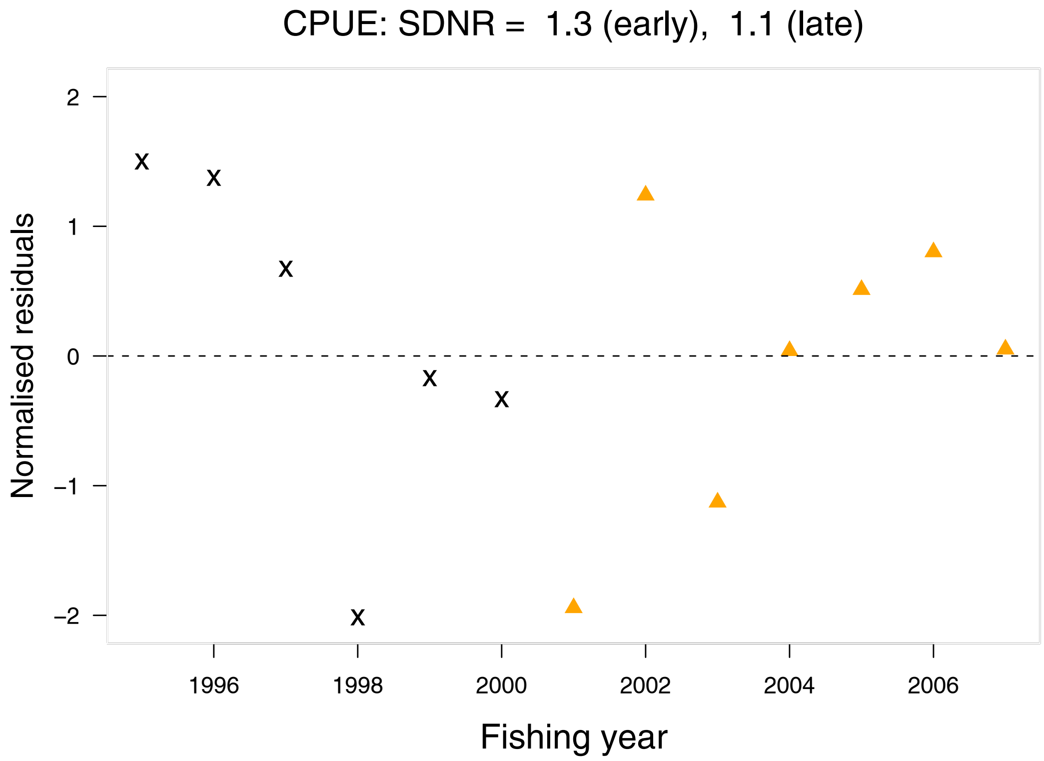

Figure 24: Diagnostics for the CPUE fit ("Core only 2006 LF"). Early CPUE residuals are shown by crosses, late CPUE residuals by triangles.

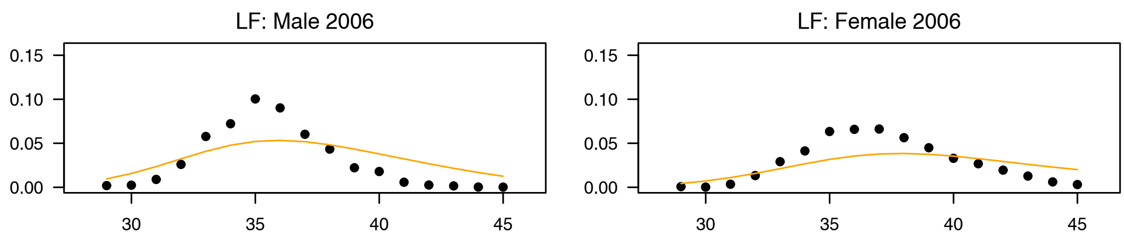

Figure 25: Fits to the 2006 core length frequencies ("Core only 2006 LF").

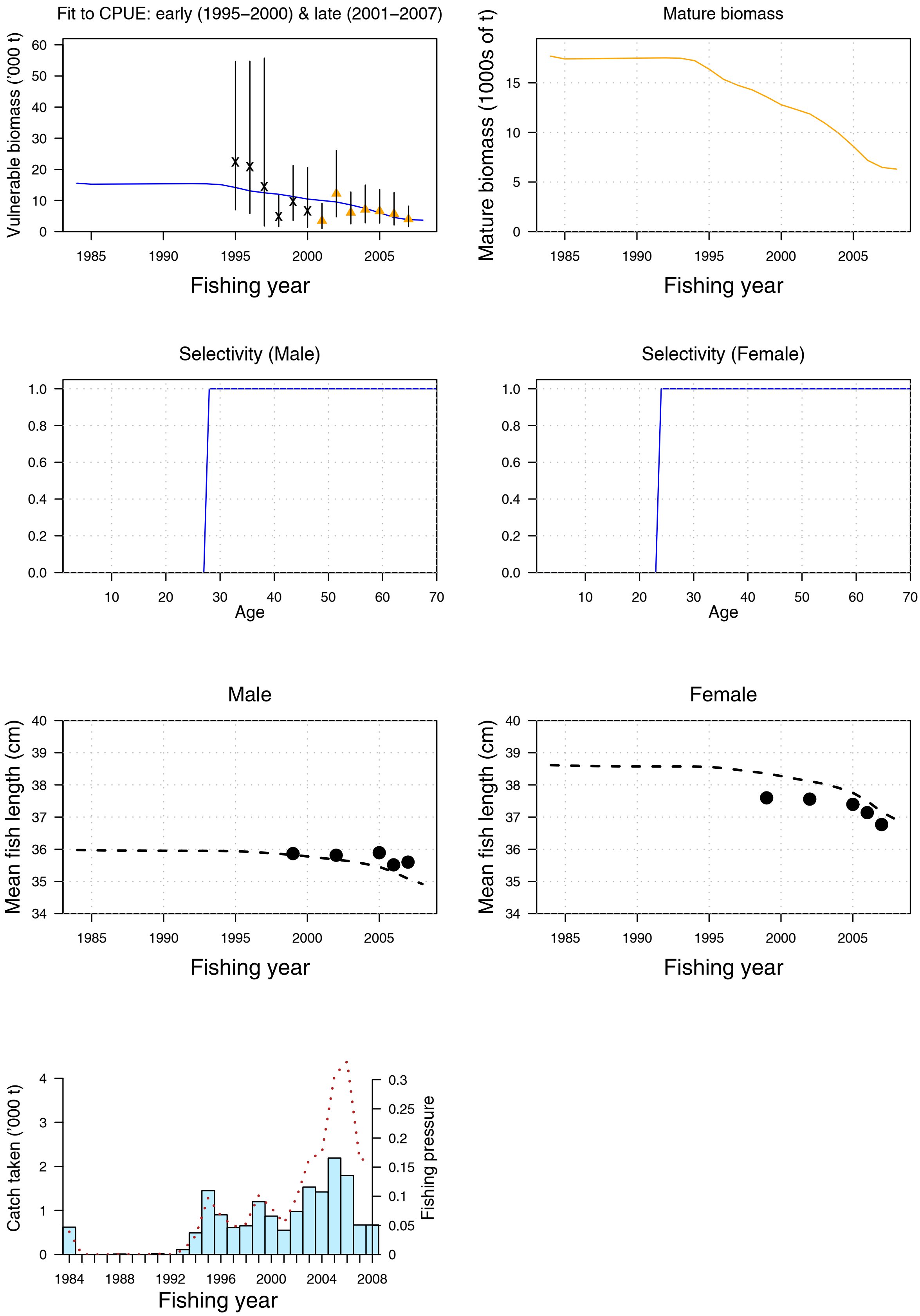

Figure 26: Some model fits using the core length frequencies with Linf and cv1 estimated ("Core Est Linf and cv1").

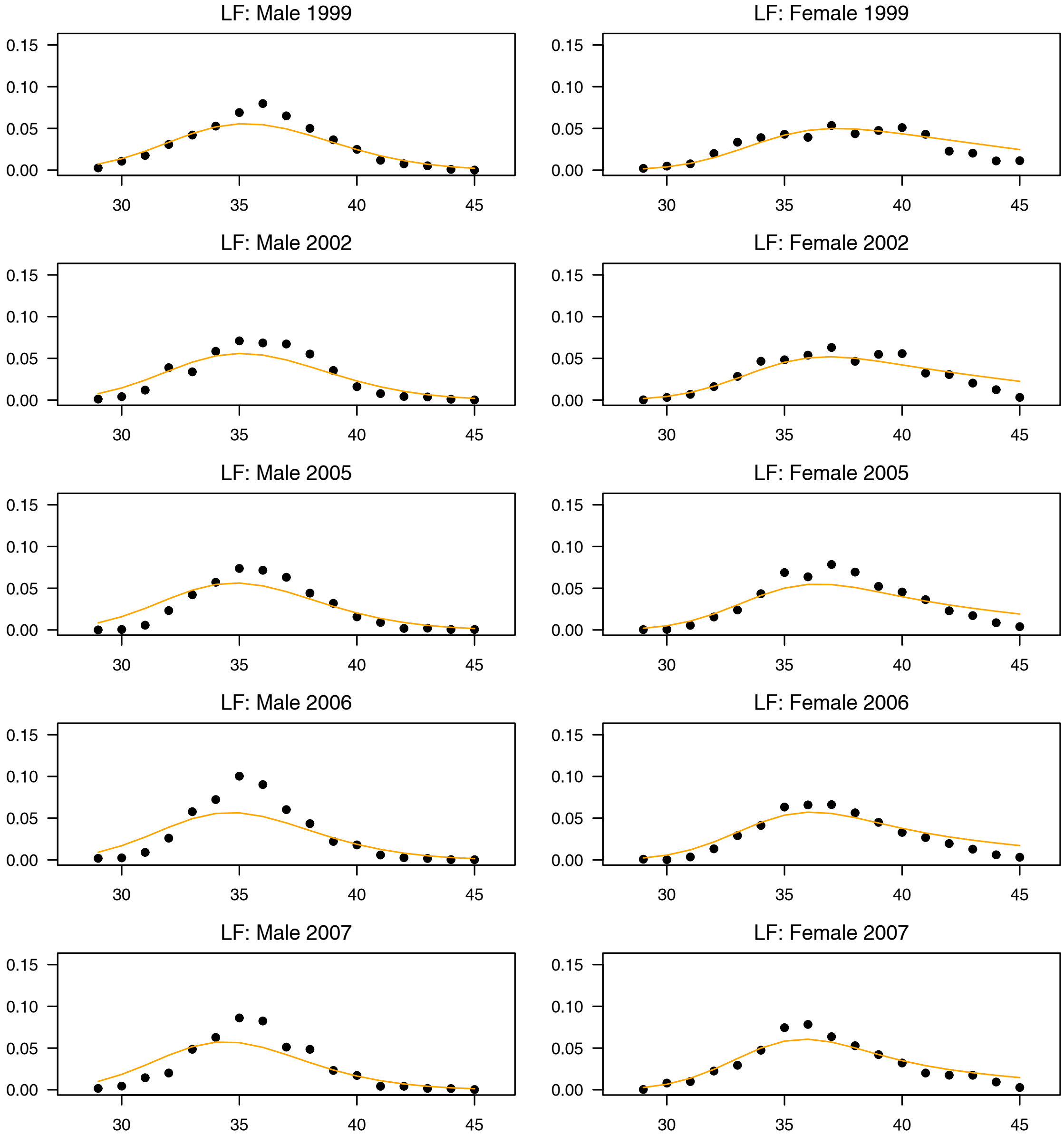

Figure 27: Fits to the core length frequencies with Linf and cv1 estimated ("Core Est Linf and cv1").

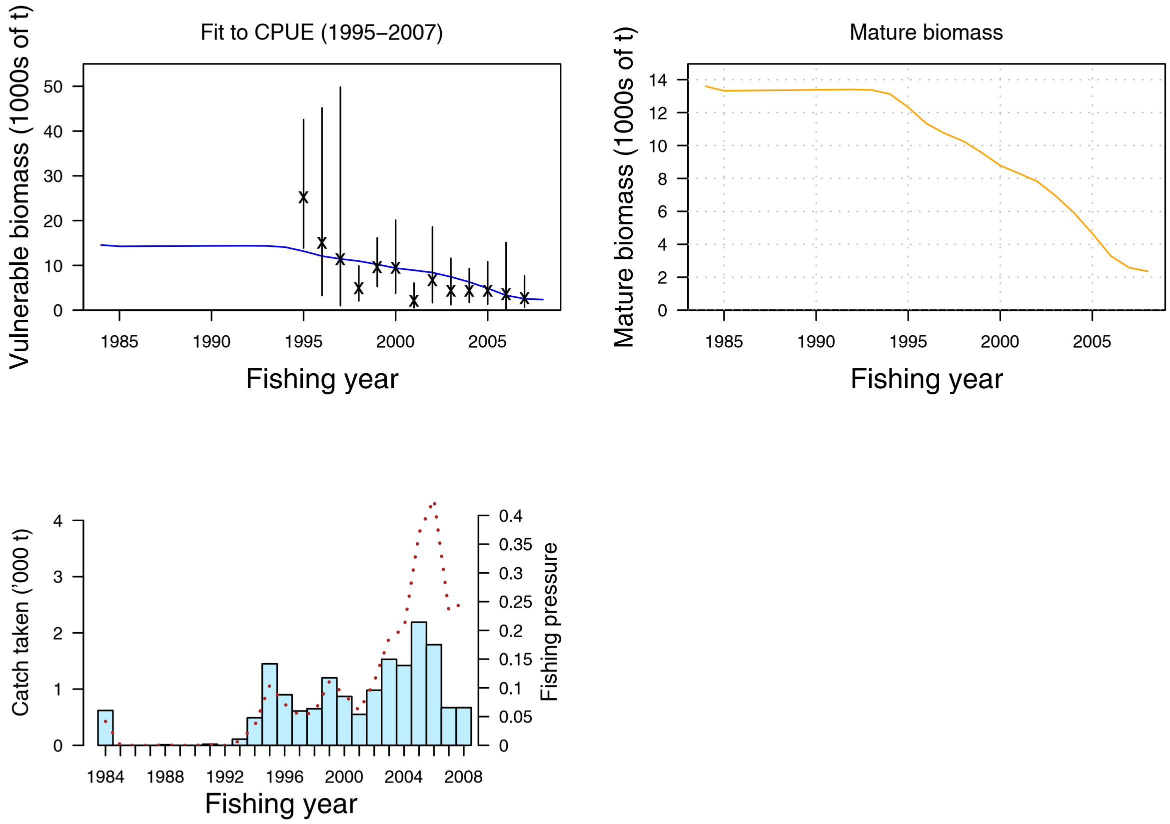

Figure 28: Model fits for the non-split CPUE only model.

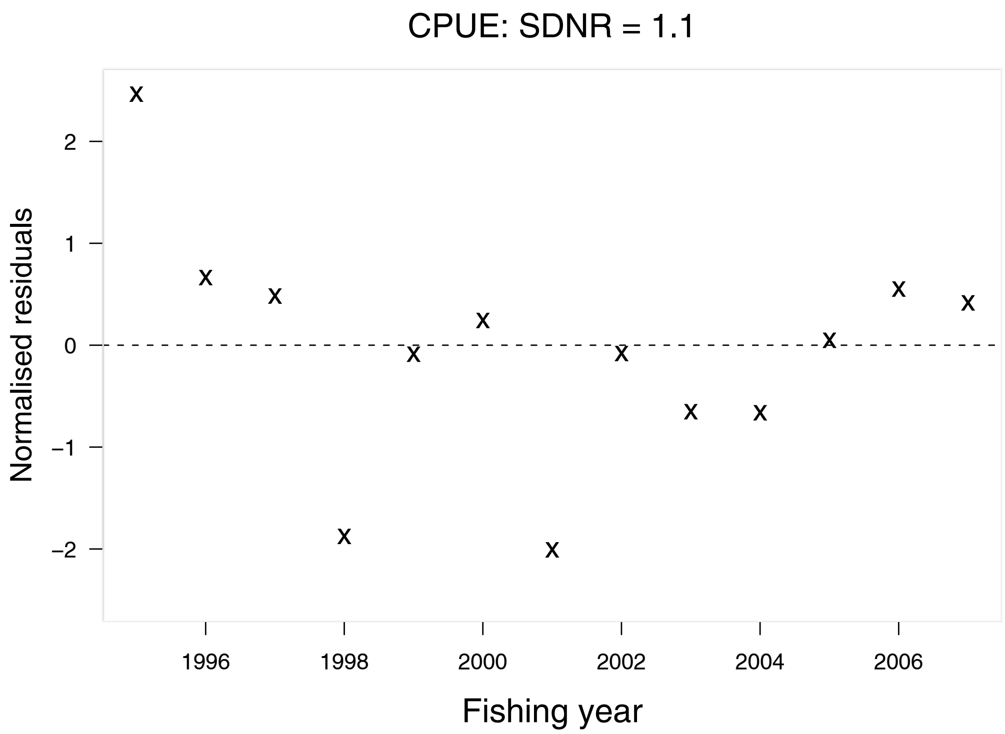

Figure 29: Diagnostics for the non-split CPUE only model.

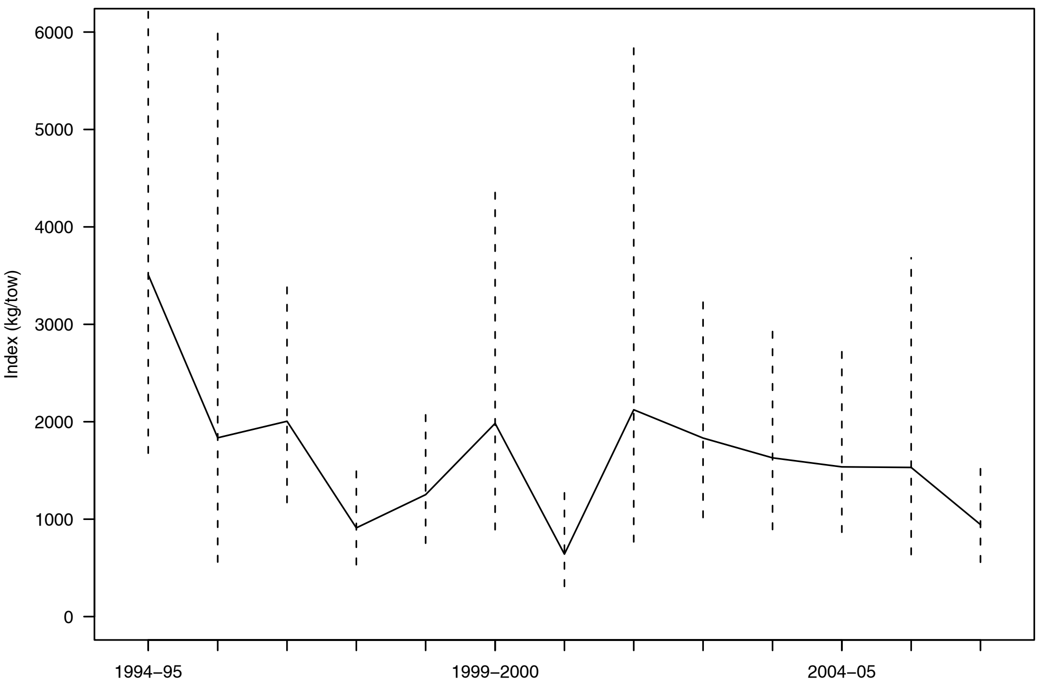

Figure 30: Single period CPUE minus data from one vessel combined indices with bootstrap confidence interval.