Ministry for Primary Industries
Manatū Ahu Matua

Assessment of Pukaki Rise (OEO 6) black oreo for 2011–12

New Zealand Fisheries Assessment Report 2013/64

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ISSN 1179-5352 (online)
ISBN 978-0-478-42097-5 (online)

November 2013

New Zealand Government

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EXECUTIVE SUMMARY

Anderson, O.F.; Doonan, I.J. (2013). Assessment of Pukaki Rise (OEO 6) black oreo for 2011–12. *New Zealand Fisheries Assessment Report 2013/64*. 40 p.

A fishery for black oreo on the Pukaki Rise (part of OEO 6) ran for about five years in the early 1980s, followed by several years of little or no fishing. The fishery was re-established in about 1995–96, along with the development of fisheries for orange roughy and smooth oreo. Catches of black oreo grew to a peak of about 2900 t between 2006–07 and 2009–10 then dropped sharply with reduced effort in the following two years.

An updated CPUE analysis was carried out, based on catch and effort data from the post-GPS fishery. The preferred “Core Target” index used a core set of experienced vessels and ignored records that targeted orange roughy or smooth oreo, or were from features where these were the main target species. A reliable CPUE index for the early (pre-GPS) fishery was not possible because of the poor linkage of vessels across the five years.

Fish length data collected by MPI and industry observers were used to produce updated length frequency distributions, scaled by the catch size and weighted by the fishing depth, to represent the size structure of the commercial fishery in ten blocks of fishing years from 1997 to 2012. These frequencies, and an analysis of sample mean lengths, revealed a general decrease in fish size over time.

Biomass of black oreo on the Pukaki Rise was estimated using Bayesian methods in a CASAL age-structured population model. The revised CPUE index and size frequencies were used as input data. Fishery selectivity was estimated in a preliminary model incorporating the observer length data, then fixed at the estimated values, and the length data discarded, for the base case model. Two alternative models were run to examine the influence of assuming lower and higher levels of natural mortality.

The median virgin biomass for the base case was 35 600 t (with a 95% C.I. of 31 000–45 000 t). The median mature 2011–12 (mid-year) biomass estimate was 10 100 t (28% of B_0) with a 95% C.I. of 5600–19 000 t (18–42 % B_0).

The main source of uncertainty in the assessment is with the assumption that the CPUE provides a valid index of abundance for black oreo on the Pukaki Rise. The Deepwater Working Group considered that the CPUE index was unreliable because the CPUE for the associated species, smooth oreo, in the same area indicated a current abundance that was too low to be believed. Until further investigation into the data were done, the working group has set aside the assessment reported here. Other sources of uncertainty arise from the assumption of deterministic recruitment in the model and from fixing the selectivity values in the final model runs.

1. INTRODUCTION

1.1 Objectives

This work addresses the following objectives in MPI project “Stock Assessment of Oreo” (DEE201002 OEO).

Overall objective

1. To carry out a stock assessment of black oreo (*Allocyttus niger*) and smooth oreo (*Pseudocyttus maculatus*), including estimating biomass and sustainable yields.

Specific objectives (2012–13)

1. To update standardised catch per unit effort analyses and stock assessments of oreo, including estimates of biomass, risk and yields for:

   - Black oreo in OEO 3A.
   - Black oreo in OEO 6 (Pukaki Rise).
   - Smooth oreo in OEO 6 (Pukaki Rise).

We report here only on black oreo in OEO 6 (Pukaki Rise).

1.2 Overview

Oreos are managed as a group that includes black oreo (*Allocyttus niger*, BOE), smooth oreo (*Pseudocyttus maculatus*, SSO), spiky oreo (*Neocyttus rhomboidalis*, SOR), and warty oreo (*Allocyttus verrucosus*, WOE). The last two species are not sought by the commercial fleet but are a minor bycatch in some areas.

The Pukaki Rise black oreo fishery is one of several oreo fisheries in the oreo Quota Management Area (QMA) OEO 6; it is the largest oreo fishery (for either species) in this QMA and, alongside the OEO 3A fishery, represents the largest black oreo fishery in New Zealand. The Pukaki Rise also supports the largest smooth oreo fishery in OEO 6 (Coburn & McMillan 2006), and also a fluctuating orange roughy fishery.

Black oreo occur in depths of 600–1300 m, mainly south of about 45° S. They appear to have a 4–5 year pelagic juvenile phase before settling onto the bottom at a length of 21–26 cm Total Length (TL). Spawning occurs from late October to at least December and the mean length at maturity for females is about 34 cm TL.

The Total Allowable Commercial Catch (TACC) for OEO 6 was originally based on average annual catches, but was doubled to 6000 t in 1996–97 to encourage exploratory fishing and has remained at this level (Ministry for Primary Industries 2012).

The purpose of this study was to update the standardised Catch Per Unit Effort (CPUE) indices and the observer length frequency analysis for input into a CASAL (Bull et al. 2012) stock assessment for the Pukaki black oreo fishery. The CPUE analysis updates those of Coburn et al. (2002) and Anderson & Doonan (2010), and the stock assessment updates that of Doonan et al. (2010).

1.3 Assessment area

The Pukaki fishery, for the purposes of stock assessment, is defined by a polygon with vertices at: 46° 26.1' S, 174° 59.2' E; 48° 31.8' S, 177° 00.0' E; 50° 59.6' S, 177° 00.0' E; 50° 59.6' S, 172° 58.4' E; 49° 0.1' S, 168° 58.0' E (after Coburn et al. 2007). This area was further divided into three informal subareas, based on observed breaks in the spatial and temporal distribution of fishing effort, separated by dividing lines at 173.8° E and 49.3° S (Figure 1).

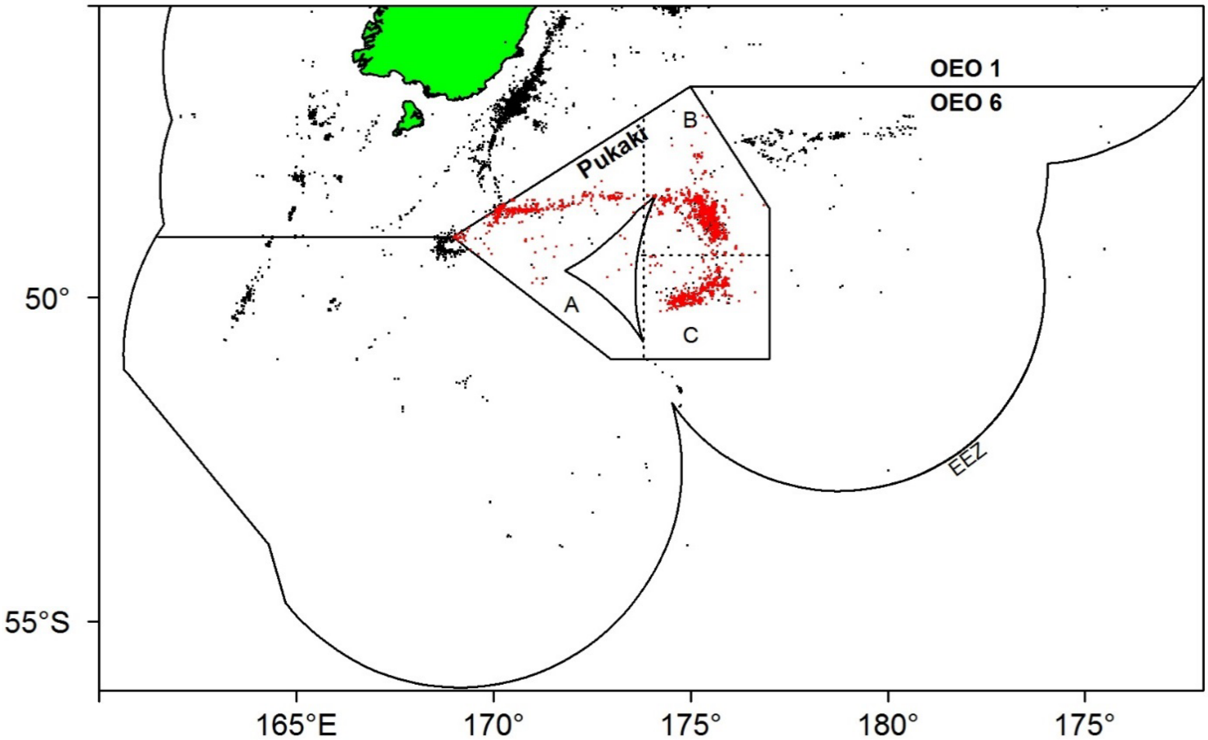

Figure 1: The southern region of the New Zealand Exclusive Economic Zone (EEZ) showing the location of the Pukaki black oreo fishery in relation to the oreo QMAs and historical fishing effort in the region. Dots show the start position of all recorded trawls targeting or catching black oreo from 1978 to 2012; in red for those within the Pukaki region. The letters "A", "B", and "C" indicate the subareas referred to in the report.

2. CPUE ANALYSIS

2.1 Catch effort data

The CPUE analysis used records of commercial catch and effort from the MPI "*Warehou*" database. Very little catch in the Pukaki black oreo fishery was recorded on Catch, Effort and Landing Return (CELR) forms, so tow-by-tow data were available for virtually the entire fishery. Data were groomed and checked for errors as follows: trawl distances were calculated from the recorded start and finish positions; records with trawls longer than 50 km or with missing start or finish coordinates were provided with new coordinates where possible based on "median imputation". This replaces erroneous values with median values from other trawls by the same vessel on the same day. Trawl duration was calculated from start and finish times; the durations of long trawls (over 5.3 h) were recalculated from the recorded trawling speed and the calculated trawl distance, and replaced with this value where the two values differed by more than 50%; median imputation was used to modify extreme values of trawling speed (less than 2 knots and greater than 10 knots) and to resolve multiple values of vessel power and tonnage for a single vessel (in these cases using the most common values rather than medians).

A database of New Zealand seamounts was examined to identify those within the fishery area. Only five seamounts have been recorded by NIWA, in this area, lying close together in the southeast quadrant of the fishery within the "Antipodes" orange roughy fishery (see Dunn et al. 2008). Various levels of fishing effort and catch have taken place in the vicinity of these seamounts since 1995–96.

2.2 Unstandardised CPUE

Data summaries for the unstandardised analyses were based on records for which black oreo were either targeted or caught, and therefore include a number of records associated with target fishing for orange roughy and smooth oreo.

Annual effort and vessel nationality

The fishery was initially based on Soviet vessels of 2100–2600 gross registered tonnage, followed by some smaller Korean vessels, and an intensive fishery operated for about five years, from 1980–81 to 1985–86 (Table 1). Effort by vessels of both nations then fell away sharply and remained low, so that between 1986–87 and 1993–94 only 20 trawls were made, catching a total of 33 t of black oreo. When the fishery resumed in 1994–95 it was dominated by domestic vessels making about 400 trawls per year, increasing to over 1000 by 2007–08 then declining after 2009–10 to less than 500 in 2011–12.

Table 1: Effort (number of trawls) and catch (t) by nation and fishing year for the Pukaki black oreo fishery, 1978–79 to 2011–12. Nation codes: DOM, New Zealand; KOR, Korea; OTH, other (Belize, Japan, Panama, Ukraine, Norway); SOV, Soviet; UNK, unknown.

										Nation
Fishing year	DOM		KOR		OTH		SOV		UNK	
	n.trawls	t	n. trawls	t	n. trawls	t	n. trawls	t	n. trawls	t
1978–79	0	0	0	0	0	0	10	15	0	0
1979–80	0	0	0	0	0	0	2	0	0	0
1980–81	0	0	0	0	1	0	207	934	360	2 199
1981–82	0	0	0	0	0	0	348	1 480	112	351
1982–83	0	0	0	0	0	0	109	423	0	0
1983–84	0	0	36	422	1	0	124	575	0	0
1984–85	0	0	120	1 185	12	3	163	361	0	0
1985–86	0	0	19	27	0	0	7	19	0	0
1986–87	0	0	0	0	0	0	0	0	0	0
1987–88	0	0	0	0	0	0	0	0	0	0
1988–89	0	0	0	0	0	0	0	0	0	0
1989–90	2	0	0	0	0	0	0	0	0	0
1990–91	2	1	0	0	0	0	0	0	0	0
1991–92	2	14	0	0	1	0	0	0	0	0
1992–93	10	18	0	0	2	0	0	0	0	0
1993–94	0	0	0	0	1	0	0	0	0	0
1994–95	29	210	0	0	0	0	0	0	0	0
1995–96	198	1 028	0	0	0	0	0	0	39	103
1996–97	525	1 894	0	0	0	0	0	0	0	0
1997–98	465	1 899	0	0	0	0	0	0	6	13
1998–99	360	1 048	0	0	6	3	0	0	0	0
1999–00	417	975	0	0	0	0	0	0	0	0
2000–01	350	1 048	0	0	0	0	0	0	0	0
2001–02	261	937	0	0	6	2	0	0	0	0
2002–03	427	1 554	0	0	1	0	0	0	0	0
2003–04	434	1 387	0	0	3	0	0	0	0	0
2004–05	522	1 501	5	19	7	0	0	0	0	0
2005–06	723	2 585	0	0	0	0	0	0	0	0
2006–07	906	3 063	0	0	0	0	0	0	0	0
2007–08	1 013	2 950	0	0	0	0	0	0	0	0
2008–09	1 032	2 820	0	0	0	0	0	0	0	0
2009–10	1 178	2 979	0	0	0	0	0	0	0	0
2010–11	608	1 451	0	0	0	0	0	0	0	0
2011–12	489	1 511	0	0	0	0	0	0	0	0

Catch and catch rates

Annual catches in the early phase of the fishery varied considerably, peaking in 1980–81 at just over 3000 t from about 500 trawls (Figure 2). After the resumption of the fishery in 1994–95 annual catches built to a similar level to that of the early period, initially 1000–2000 t but increasing considerably after 2004–05 to about 2500–3000 t before declining again to about 1500 t in each of the last two years. Effort increased steadily between 2001–02 and 2009–10 then fell sharply in 2010–11. Annual catch rates during the earlier years of the fishery fluctuated around a level of 4–6 t/trawl, and in the later period were mostly 2.5–3.5 t/trawl (Figure 2).

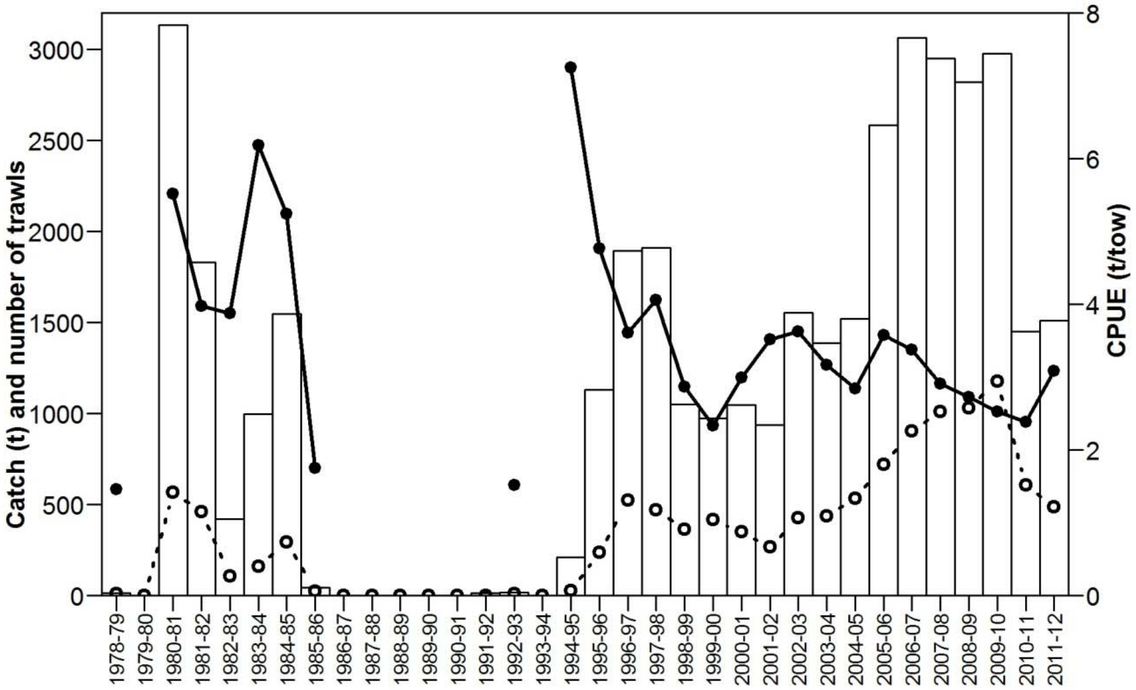

Figure 2: Catch (bars), effort (dashed line, open circles), and unstandardised CPUE (solid line, filled circles) in the Pukaki BOE fishery, 1978–79 to 2011–12. CPUE is plotted only for years where there were two or more vessels and 10 or more trawls.

The number of vessels in this fishery ranged from 7 to 11 in the first phase of the fishery (before 1986–87) and from 2 to 12 in the later period (after 1993–94) (Table 2). A notable feature of this fishery is that the rationalisation of the deepwater fishing fleet in recent years has seen the number of vessels drop substantially, from 12 in 2004–05 to 2 in 2007–08, yet effort and catch nearly doubled during this period. No persistent trend in mean catch per trawl is evident in either the early or late phase of this fishery, but catch rates have generally been lower in more recent years (Table 2). The number of zero trawls (trawls targeting but not catching black oreo) was much higher in the early period than in the later, and may be more to do with differences in recording practices than with failed trawls. The majority of trawls in the early period of the fishery (before 1986–87) and in the most recent five years (since 2007–08) targeted black oreo, whereas in the intervening period trawls which caught black oreo were usually targeting other species (Table 2).

Table 2: **Unstandardised CPUE for all trawls in the Pukaki area that targeted or caught black oreo from 1978–79 to 2011–12. Catch was rounded to the nearest 10 t. Zero trawls is the percentage of trawls with no black oreo catch reported. Catch rates are presented only for years in which there were two or more vessels and 10 or more trawls. '–' insufficient data.**

Fishing year	Number of trawls	Number of vessels	BOE catch (t)	Mean catch per trawl	Zero trawls (%)	BOE target trawls (%)
1978–79	10	2	10	1.5	40	40
1979–80	2	1	<1	–	0	0
1980–81	568	10	3 130	5.5	10	97
1981–82	460	7	1 830	4.0	25	88
1982–83	109	7	420	3.9	46	100
1983–84	161	11	1 000	6.2	14	61
1984–85	295	7	1 550	5.2	37	69
1985–86	26	3	50	1.8	4	92
1986–87	0	0	0	–	–	–
1987–88	0	0	0	–	–	–
1988–89	0	0	0	–	–	–
1989–90	2	2	0	–	–	–
1990–91	2	1	<1	–	0	0
1991–92	3	2	10	–	0	0
1992–93	12	4	20	1.5	0	0
1993–94	1	1	<1	–	0	0
1994–95	29	2	210	7.3	0	0
1995–96	239	4	1 150	4.8	0	0
1996–97	528	6	1 900	3.6	0	0
1997–98	472	7	1 910	4.1	1	8
1998–99	367	10	1 050	2.9	2	12
1999–00	420	8	970	2.3	1	24
2000–01	350	9	1 050	3.0	1	15
2001–02	267	8	940	3.5	1	20
2002–03	428	7	1 550	3.6	1	30
2003–04	437	9	1 390	3.2	0	11
2004–05	534	12	1 520	2.8	0	6
2005–06	723	8	2 580	3.6	0	4
2006–07	906	7	3 060	3.4	1	25
2007–08	1 013	2	2 950	2.9	5	63
2008–09	1 032	3	2 820	2.7	2	77
2009–10	1 178	3	2 980	2.5	4	90
2010–11	608	3	1 450	2.4	2	79
2011–12	489	3	1 510	3.1	1	93

Monthly catch and effort

In the early phase of the fishery effort was compressed into fewer months, with the largest monthly catch (1839 t) occurring in July 1981 (Figure 3). For most of the later period of the fishery, effort and catch were typically spread throughout the year, although from 1984–85 to 2003–04 there was generally less fishing between June and August (Figure 3), when the deepwater fleet tended to focus on the spawning fisheries for orange roughy and hoki in other areas. More recently, since about 2005–06, effort has increased during this period, especially in July and August.

Changes in the relative sizes of the effort and catch circles in Figure 3 indicate that catch rates have tended to decrease over time, with catch circles generally smaller than effort circles in the recent period of the fishery. The increase in annual effort after 2000–01 (see Figure 2) was well spread over the year, although usually low in June, and the decline in effort in the two most recent years was most noticeable in the middle months of the fishing year.

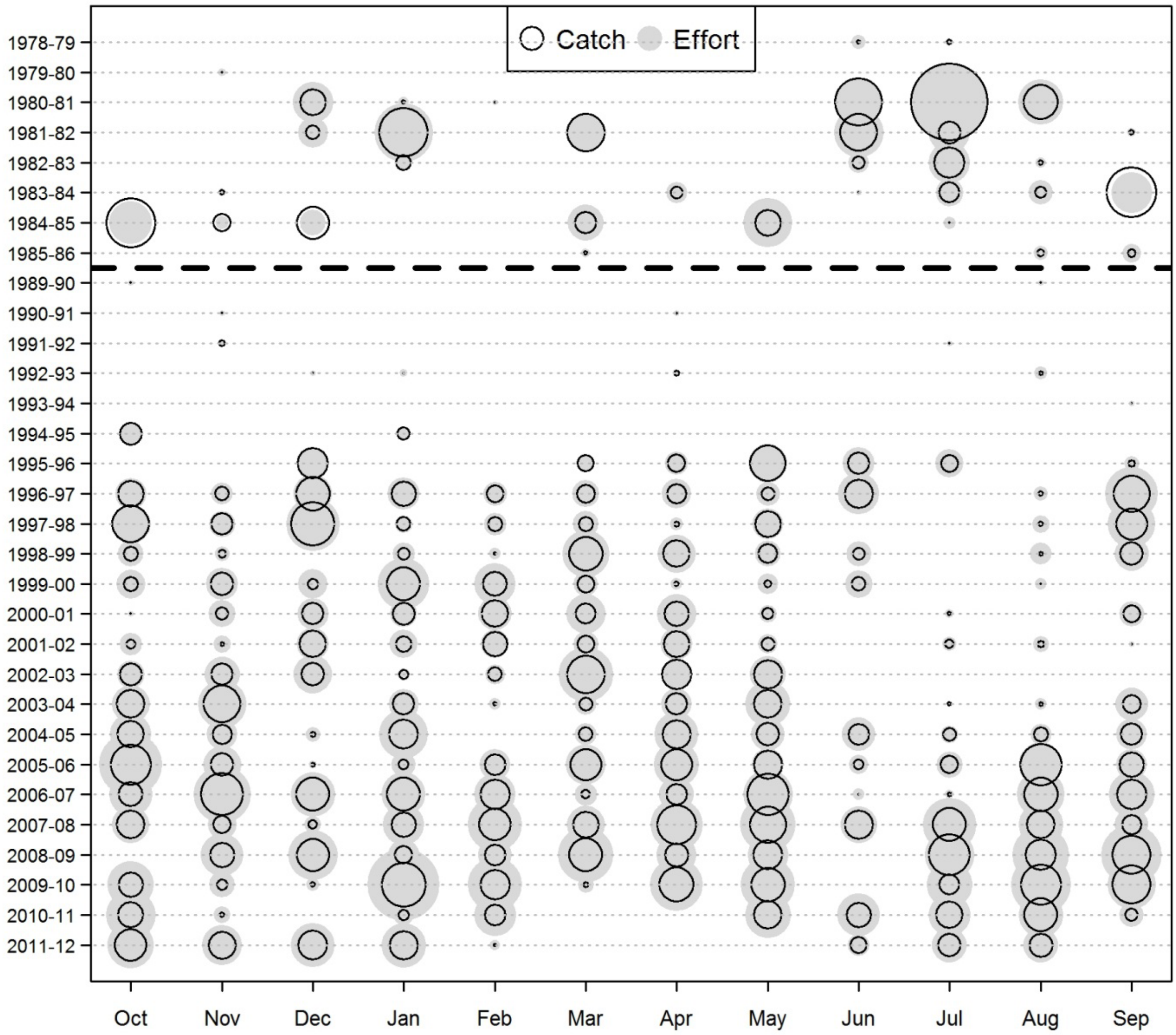

Figure 3: Catch (t) and effort (number of trawls) by month and fishing year in the Pukaki black oreo trawl fishery. Circle area is proportional to the number of trawls or catch, maximum circle size = 1839 t and 295 trawls. The dashed line indicates a break in the time series, between 1985–86 and 1989–90, when no fishing took place.

Spatial distribution of the fishery

The Pukaki black oreo fishery naturally divides into three distinct areas (designated in this report as A, B, and C), each with a distinct fishing history (Figure 4). Between 1980–81 and 1982–83 the fishery was strongly focussed in the northeast (area B), with a small amount of effort in the southeast (area C). In the following two years the focus shifted westward into area A where fishing took place along the depth contour at about 48.5° S; fishing effort in area B continued, but at a more variable level. Some large individual catches of black oreo were made during these five years, the largest in each year ranging from 21 t to 50 t. In 1985–86, the fishery was virtually abandoned and left almost completely unfished for the following nine years.

When fishing resumed in 1994–95 the centre of effort was again in area B, but the fishery rapidly expanded into area C where a new fishery for orange roughy (known as the Antipodes) was being developed. Fishing gradually spread around the curve of the 1000 m depth contour on the eastern edge of the Pukaki Rise in areas B and C, separated by a consistent gap centred at about 49.5° S. This spatial pattern of the fishery remained relatively constant over the following 17 years, although more recently (since 2001–02) some effort has returned to area A, with some large catches at the western boundary of the fishery in particular, and also from trawls near the eastern end of the area at about 173° E.

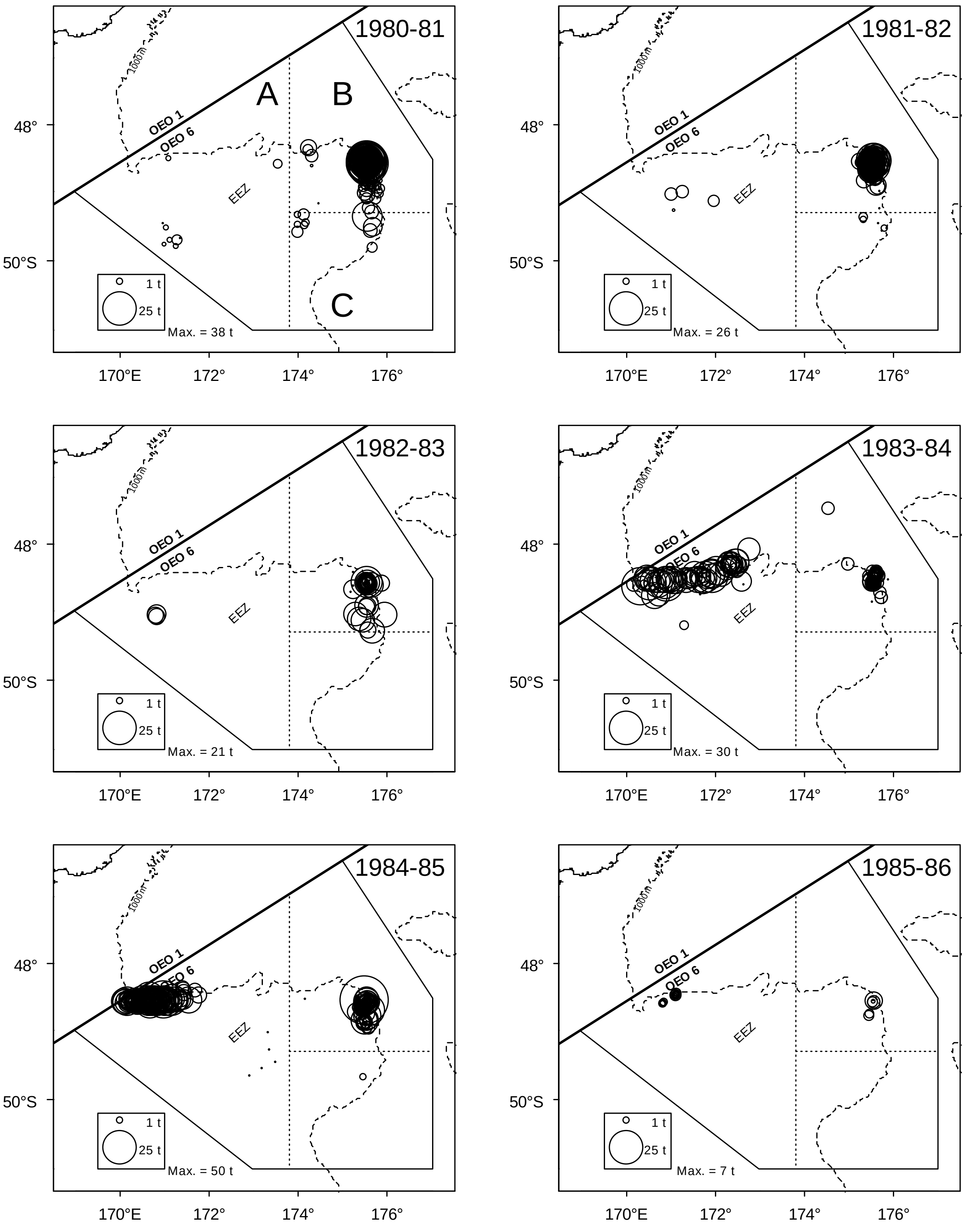

Figure 4: Catches of black oreo in Pukaki for the period 1980–81 to 1985–86. Circle area is proportional to catch size.

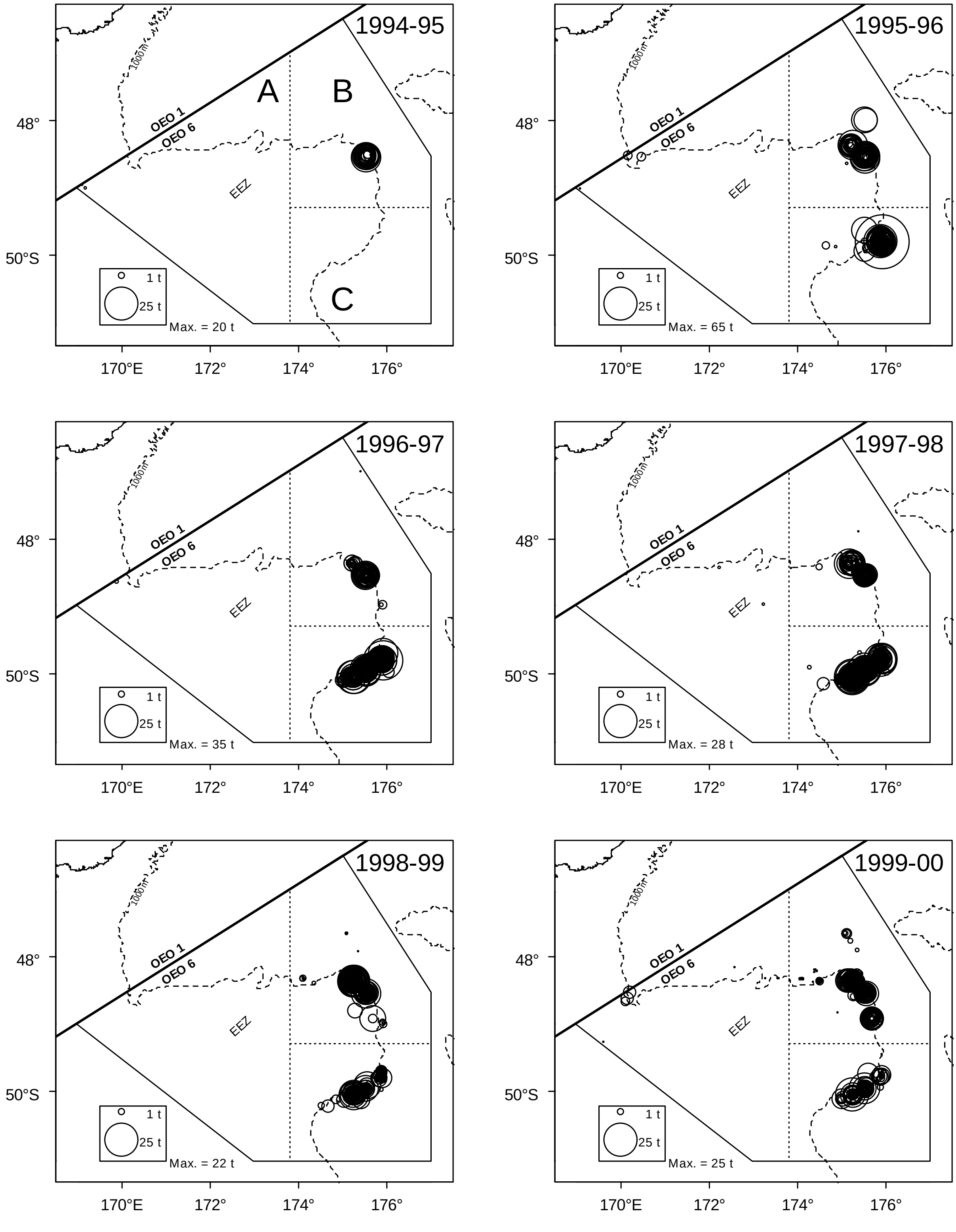

Figure 4—*Continued*: 1994–95 to 1999–2000.

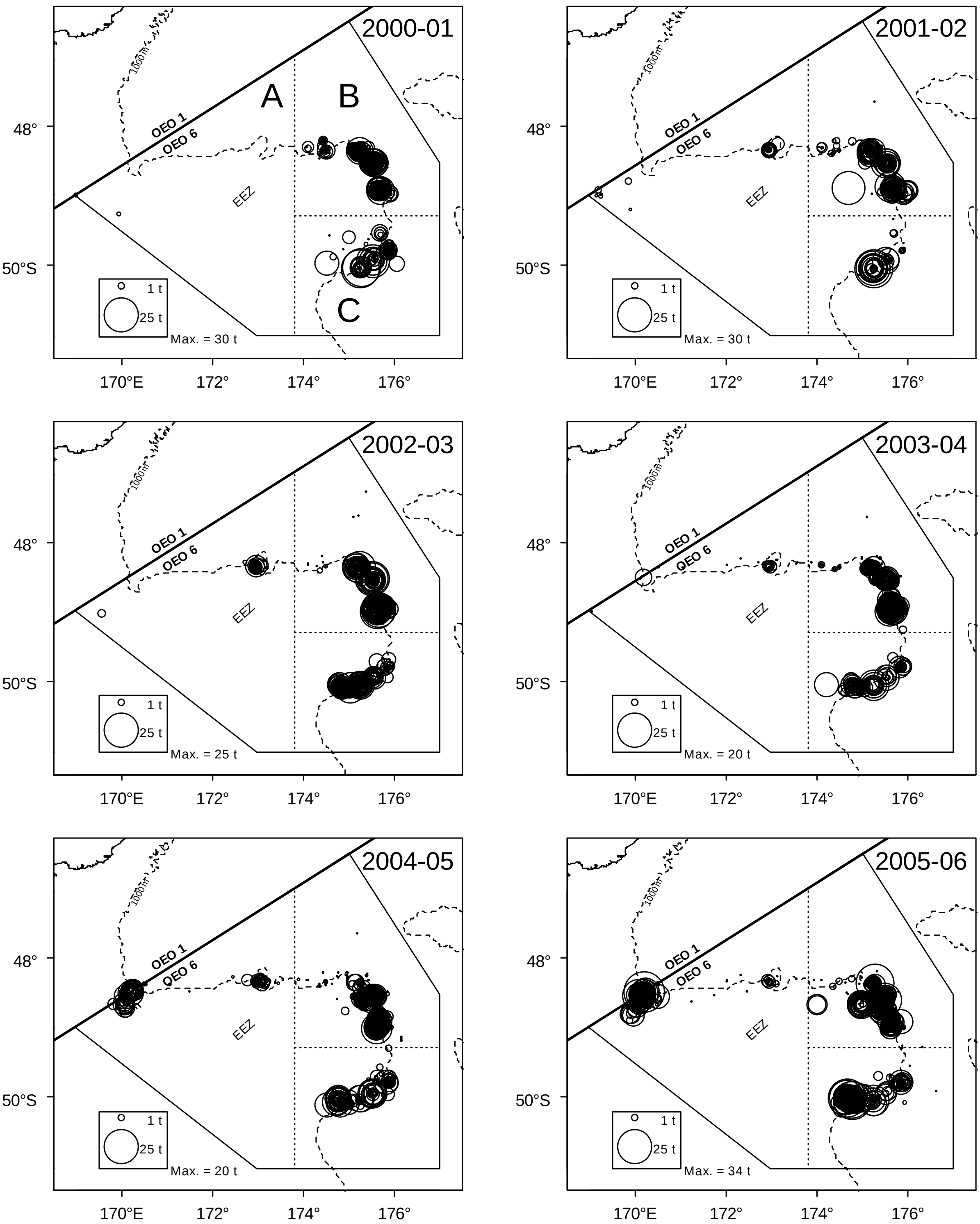

Figure 4—*Continued*: 2000–01 to 2005–06.

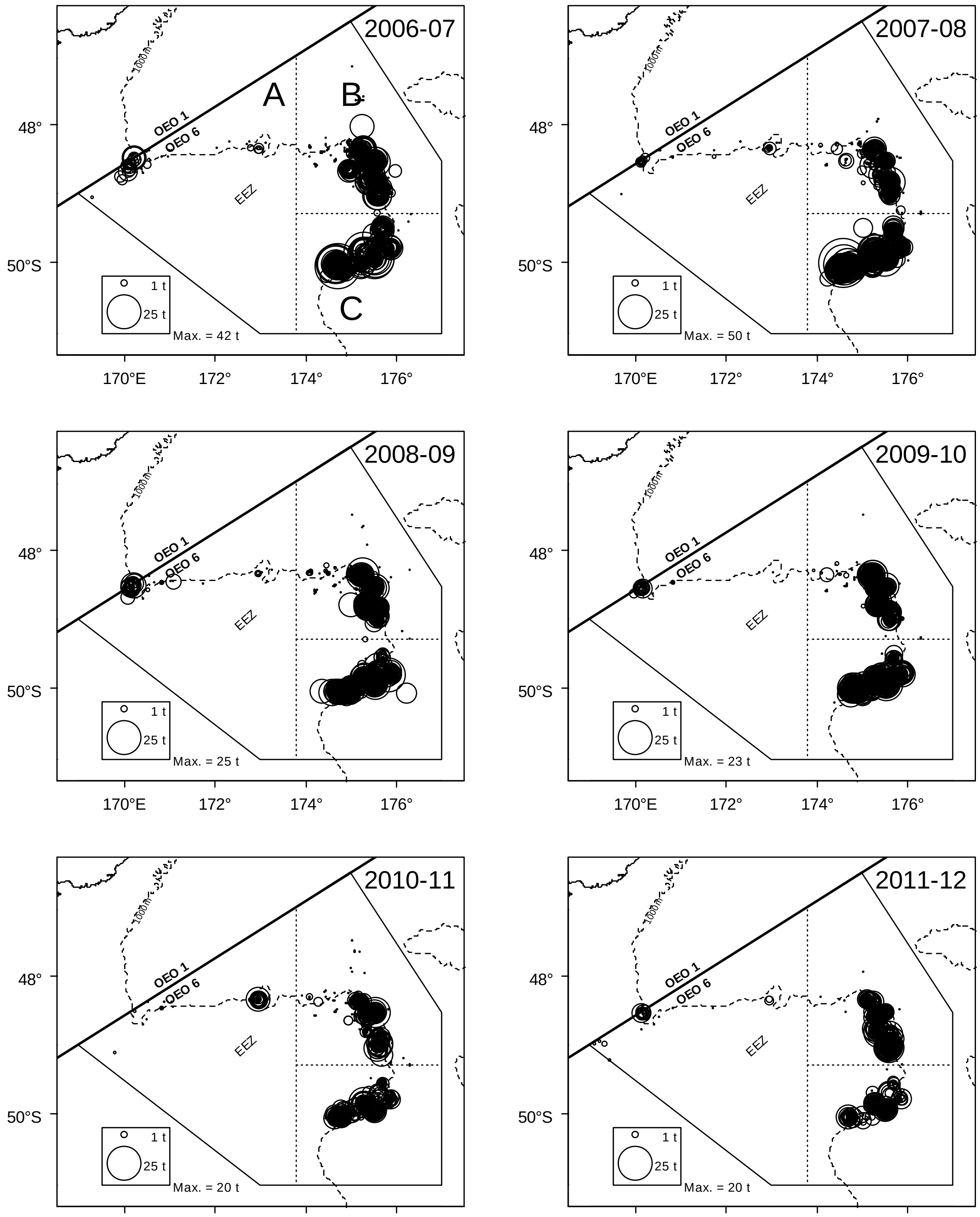

Figure 4—*Continued*: 2006–07 to 2011–12.

2.3 Standardised CPUE

For the purposes of calculating CPUE indices, the fishery was split into two time series either side of the period when the fishery was rested—which included the period of introduction of GPS (the fishing years 1989–90 to 1991–92 (Coburn et al. 2002)). The early (pre-GPS) time series covered the period 1980–81 to 1984–85; no update of the existing CPUE index for this period (Anderson and Doonan 2010) was made. The later (post-GPS) CPUE index of Anderson & Doonan (2010) was updated with the addition of data from four subsequent fishing years, now covering the period 1995–96 to 2011–12.

The post-GPS period

The resumption of the black oreo fishery in 1995–96 and 1996–97 was strongly linked to the development of the Antipodes orange roughy fishery, and so trawls catching black oreo at this time were mostly a result of targeting orange roughy, with no specific targeting of black oreo recorded (Table 3). Despite this, catch rates of black oreo were high in these years and, as the orange roughy fishery subsequently diminished, targeting for oreos (BOE, SSO, and OEO) predominated—with increasing effort. For the last five years, 2007–08 to 2011–12, black oreo was the most commonly recorded targeted species.

Table 3: Percentage of trawls by target species and total number of trawls, by fishing year, in the Pukaki black oreo fishery (trawls targeting or catching black oreo), for the post-GPS period. BOE, black oreo; OEO, unspecified oreo; ORH, orange roughy; SSO, smooth oreo.

	Percentage of trawls by target species				
	BOE	OEO	ORH	SSO	Total number of trawls
1995–96	0	28	68	3	237
1996–97	0	11	86	3	525
1997–98	8	54	33	6	468
1998–99	11	71	13	6	360
1999–00	23	53	6	18	411
2000–01	14	50	2	32	347
2001–02	19	66	0	12	263
2002–03	29	58	0	13	422
2003–04	11	76	3	9	437
2004–05	6	62	8	24	532
2005–06	4	78	9	9	722
2006–07	25	52	11	11	901
2007–08	62	24	8	6	967
2008–09	76	0	9	15	1 008
2009–10	89	0	6	5	1 134
2010–11	79	0	5	16	597
2011–12	93	0	1	5	484

Although there are few seamounts or other topographical features recorded in the Pukaki area, recorded trawl coordinates in the post-GPS period clustered strongly around a number of discrete positions. By examining these positions graphically it was possible to identify 35 such "features" in subareas B and C, with a location defined by the approximate centre of the cluster of associated trawls. Thus a "feature trawl" variable was created, based on proximity of the trawl start position to a cluster (within 1 n.mile) and trawl duration (less than 0.5 h), similar to the "hill trawls" definition used in CPUE analyses for other New Zealand deepwater fisheries (e.g., Anderson 2005, Mormede 2009). Of the 8864 records in the post-GPS data, 3163 (36%) were feature trawls under this definition. Analysis of these features showed that a number were primarily orange roughy or smooth oreo fisheries, with a large fraction of trawls targeting one or both of these species (Table 4).

Tables 3 and 4 show that there has been an overlap of recorded target fisheries for three species in this area, with different species predominating at different times in different locations. In order to produce a meaningful time series of black oreo catch rates for this fishery, it is necessary to either explicitly take into account target species in the CPUE model, or to redefine the black oreo fishery to better separate it from those of smooth oreo and orange roughy. Both approaches were taken by forming a subset of the post-GPS data which excluded trawls from the ten non-black oreo features and trawls which did not record BOE or OEO as the target species. Therefore CPUE models were built for two sets of data:

- **All Target**. Including all features and all target species; target species included as a predictor.
- **Core Target**. Excluding non-black oreo features and targeting of SSO and ORH.

Table 4: Summary of orange roughy and smooth oreo targeting by feature in the post-GPS black oreo fishery in Pukaki. Feature numbers marked with an asterisk are those on which 50% or more of trawls were targeting orange roughy or smooth oreo, and excluded from the "Core Target" CPUE model.

Feature number	Approx. Latitude	Approx. Longitude	Total number of trawls	Number of trawls targeting ORH	Percentage of trawls targeting ORH	Number of trawls targeting SSO	Percentage of trawls targeting SSO
1	174.7	-50.0	35	0	0	0	0
2	174.8	-50.1	131	0	0	0	0
3	174.8	-50.0	100	0	0	0	0
4	174.9	-50.1	86	0	0	4	5
5	175.0	-50.1	94	4	4	13	14
6	175.2	-50.1	202	13	6	8	4
7	175.3	-49.9	138	0	0	0	0
8	175.5	-49.9	511	65	13	15	3
9	175.8	-49.8	93	14	15	14	15
10*	175.9	-49.8	196	112	57	11	6
11*	175.9	-49.7	33	19	58	3	9
12	175.7	-49.6	4	0	0	0	0
13	175.5	-48.5	327	12	4	15	5
17	175.5	-48.6	2	0	0	0	0
18	175.7	-49.0	24	0	0	0	0
19	175.6	-48.9	28	0	0	0	0
20	175.2	-48.4	138	2	1	26	19
21	175.3	-48.4	34	0	0	6	18
22*	175.9	-49.0	74	2	3	36	49
23*	174.5	-48.4	36	0	0	24	67
24	175.7	-48.9	72	0	0	8	11
25*	174.4	-48.4	6	1	17	2	33
26*	175.8	-48.9	22	0	0	16	73
27	175.3	-48.6	23	1	4	1	4
28	175.6	-49.0	123	0	0	1	1
29	175.6	-49.0	80	0	0	0	0
30*	175.1	-48.6	141	131	93	0	0
31	175.6	-48.9	87	0	0	2	2
32	175.3	-48.5	41	3	7	7	17
33	175.0	-48.7	33	0	0	0	0
34	175.4	-48.8	55	0	0	1	2
36*	175.0	-48.3	22	20	91	0	0
37*	174.1	-48.3	20	0	0	14	70
38	175.1	-48.4	140	5	4	23	16
39*	174.1	-48.3	12	0	0	10	83

Data from subarea A were excluded from this analysis as this area contributed to the fishery only sporadically during the 17-year period, with effort limited mostly to the western extremity of the defined Pukaki area, on the boundary between OEO 6 and OEO 1 (see Figure 4), and accounting for 5% or less of the total catch of black oreo in all but two years.

The regression methods used here are based on those used previously for oreo fisheries (e.g., Coburn et al. 2007), and the analysis updates that of Anderson & Doonan (2010) for Pukaki black oreo. Generalised Linear Models (GLMs) were used for the regression models, with forward stepwise selection. The variable of interest, *fishing year*, was forced into the model, and the order of additional predictors was chosen by calculating the increase in the model R^2 (the reduction in residual deviance relative to the null deviance) for each predictor variable in turn and selecting that with the highest value. The process was then repeated with the remaining variables until none were able to improve the model R^2 by at least 1%. Interaction terms were not used. A measure of the overall influence of each selected variable on the standardisation of CPUE, i.e., the extent to which it causes the series trajectory to deviate from the unstandardized series, was calculated from the model coefficients for that variable (Bentley et al., 2012). Annual CVs for the index series were derived from the model standard errors.

Because the fraction of zero-catch trawls was low for the post-GPS period (see Table 2), a positive catch model was used, i.e., all records with a zero catch of black oreo were discarded. Catch per trawl, expressed as log(kg/trawl), was chosen as the unit of CPUE and regressed against a set of predictor variables available from the operational data records. A combination of categorical and continuous predictor variables was used (Table 5), with continuous variables constructed in the models as 3rd order polynomials.

Table 5: Summary of predictor variables used in the post-GPS CPUE models.

Variable	Degrees of freedom		Description
	All target model	Core target model	
Categorical			
Fishing year	16	16	1 Oct–30 Sep
Subarea	1	1	See Figure 4
Month	11	11	Month of year
Depthbin	7	7	Bottom depth at start of trawl, binned
Vessel	6	4	Individual vessels
Target species	3	1	ORH*, SSO*, OEO, BOE (* all target model only)
Trawl duration	7	7	Trawl duration (h), binned
Feature	1	1	Trawls ≤0.5 h and ≤1 n.mile from a "feature"
Start time	11	11	Start time, binned
Continuous			
Vessel power	2	2	Recorded vessel power (Kw)
Speed	2	2	Vessel speed during trawl (knots)

All Target model

This model used data only from years in which there were more than 40 records with catches of black oreo and only from vessels with a minimum of 20 black oreo catches in at least three years. This vessel experience criterion reduced the number of vessels in the model from 34 to 7 yet retained 94% of the catch.

There is a good linkage of vessels between years in this series, with between two and five of the seven vessels linking each adjacent pair of years (Table 6). One vessel (vessel A) fished in every one of the 17 years of the series and two other vessels (vessels B and G) fished in more than half of the years.

Table 6: Number of trawls by fishing year for vessels in the All Target post-GPS dataset. The vessels are sorted from left to right according to the average date of their trawls, from earliest to most recent.

							Vessel
	C	E	F	B	D	A	G
1995–96	0	21	0	0	0	174	0
1996–97	43	26	56	0	0	299	0
1997–98	47	0	62	1	0	334	0
1998–99	22	6	0	32	0	223	0
1999–00	0	47	0	123	0	151	14
2000–01	0	12	0	84	97	92	35
2001–02	0	0	0	70	53	77	19
2002–03	0	0	0	167	57	147	12
2003–04	0	0	0	67	135	166	37
2004–05	0	0	26	55	118	210	2
2005–06	0	0	0	29	145	373	31
2006–07	0	0	0	11	131	507	206
2007–08	0	0	0	0	0	907	25
2008–09	0	0	0	0	0	830	126
2009–10	0	0	0	140	0	888	80
2010–11	0	0	0	0	0	484	68
2011–12	0	0	0	0	0	431	33

The CPUE model selected, in addition to *fishing year*, the variables *target species*, *duration*, *depth*, and *vessel* (Table 7). In this case *fishing year* accounted for a relatively small amount of the variability in catch rates, and *target species* was the most important predictor, explaining an additional 20.5% of the model deviance and annually adjusting unstandardized CPUE by an average of 51.7%. The other three variables together explained an additional 7.2% of the model deviance; although *vessel* increased R^2 by only 1.4% this variable had greater influence on the CPUE index, with a value of 10.2%. Overall, the model explained 30.2% of the total variability in catch rates.

Table 7: All Target model fits for the post-GPS period GLM for Pukaki black oreo in the stepwise order determined by R^2. Df, degrees of freedom. Variables below the line did not meet the additional R^2 criteria required for inclusion in the final model.

	Df	R^2 (%)	Additional R^2 (%)	Overall Influence (%)
Fishing year		2.6	2.6	–
Target species	3	23.1	20.5	51.7
Duration	7	26.6	3.5	6.4
Depth	7	28.8	2.3	4.1
Vessel	6	30.2	1.4	10.2
Month	11	30.8	0.6	–

The standardised CPUE shows a fairly typical pattern for a stock undergoing substantial fishing pressure, with high values at the beginning of the series (1995–96 and 1996–97) followed by a sharp decrease then a slow decline over a longer period (Figure 5). The influence of *target species* on CPUE is most significant at the beginning of the series (Figure 5). This is because overall the model predicted higher catch rates when the target species was BOE and lower catch rates when the target species was ORH (Figure 6), but in the first few years of the time series catch rates were high despite the fishery mostly targeting ORH (Table 8). The effect on the index of the remaining variables, duration, depth, and vessel, is also mainly restricted to the first three years in the series (Figure 6).

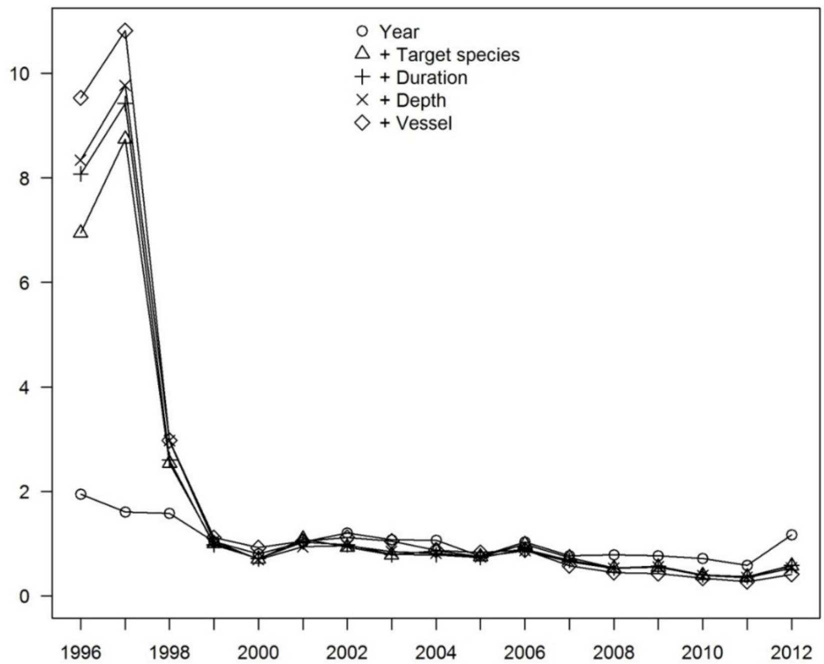

Figure 5: Step plot for Pukaki black oreo All Target model, showing the CPUE index at each step in the stepwise selection of variables (top to bottom in legend on plot). The line for vessel (diamonds) indicates the final step.

Predicted catch rates by target species are as might be expected, with the highest catch rate when targeting black oreo, followed by unspecified oreo, smooth oreo, and lastly orange roughy (Figure 6). The change in targeting pattern over time is clearly shown in the bubble plot which, combined with the degree of variability in the coefficients, results in large changes in annual influence with a decreasing trend over time. CPUE increased with increasing trawl duration, with similar variation in the coefficients for this factor to that for target species, but there was far less inter-annual variability in trawl duration (apart from the first three years in the series when trawl duration was noticeably shorter) and therefore it has less influence on the index. The influence of vessel on CPUE is limited by the restriction of the dataset to a core set of vessels, but there is a gradual replacement of vessels with lower catch rates by vessels with higher catch rates after 2000 causing a trend of increasing influence, which remains high over several of the more recent years. Fishing depth also has greater influence in the more recent years, with increasing effort in depths with higher catch rates, but overall the annual depth distribution is relatively stable and there is low variation in the coefficients across the depth bins, leading to a low overall influence.

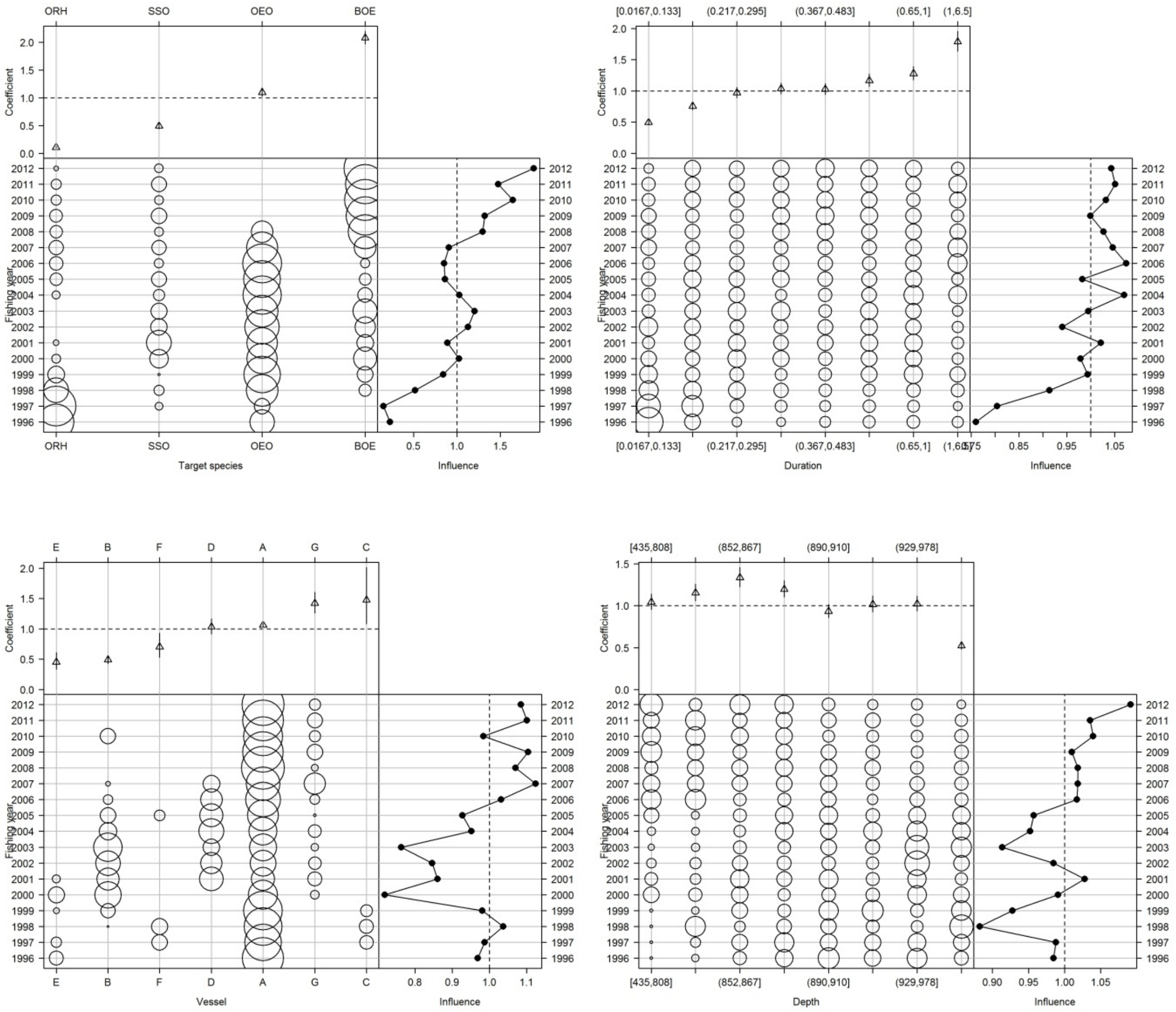

Figure 6: Influence plots for each accepted predictor in the All Target model. In each panel the top plot shows the normalised coefficients (with standard errors) for each level; the bottom left plot shows the distribution of the variable levels in each year; and the bottom right plot shows the annual level of influence of the variable on CPUE. See Bentley et al. (2012) for more details.

Table 8: Catch rates (t/tow) by target species and fishing year for the All Target dataset in the Pukaki black oreo fishery.

	BOE	OEO	ORH	SSO
1995–96	NA	7.4	4.2	NA
1996–97	NA	5.1	3.7	2.1
1997–98	2.4	5.4	2.5	3.9
1998–99	6.9	3.4	0.7	0.0
1999–00	3.4	3.3	2.3	0.6
2000–01	3.5	4.1	0.8	1.8
2001–02	3.9	4.3	NA	3.2
2002–03	3.1	4.9	NA	1.7
2003–04	2.8	3.8	0.5	1.2
2004–05	2.3	3.0	1.2	2.3
2005–06	3.3	4.0	0.3	1.3
2006–07	4.8	4.0	0.3	1.4
2007–08	3.7	3.0	0.1	1.4
2008–09	3.2	NA	0.2	2.2
2009–10	2.9	NA	0.1	1.4
2010–11	3.0	NA	0.1	0.3
2011–12	3.3	NA	0.3	1.7

Examination of the model residuals show a relatively poor fit to the data (Figure 7). The log of the residuals is mostly negative for high levels of the fitted values, the model underestimates CPUE for extreme values, and the annual distribution of residuals tend to be skewed to the right.

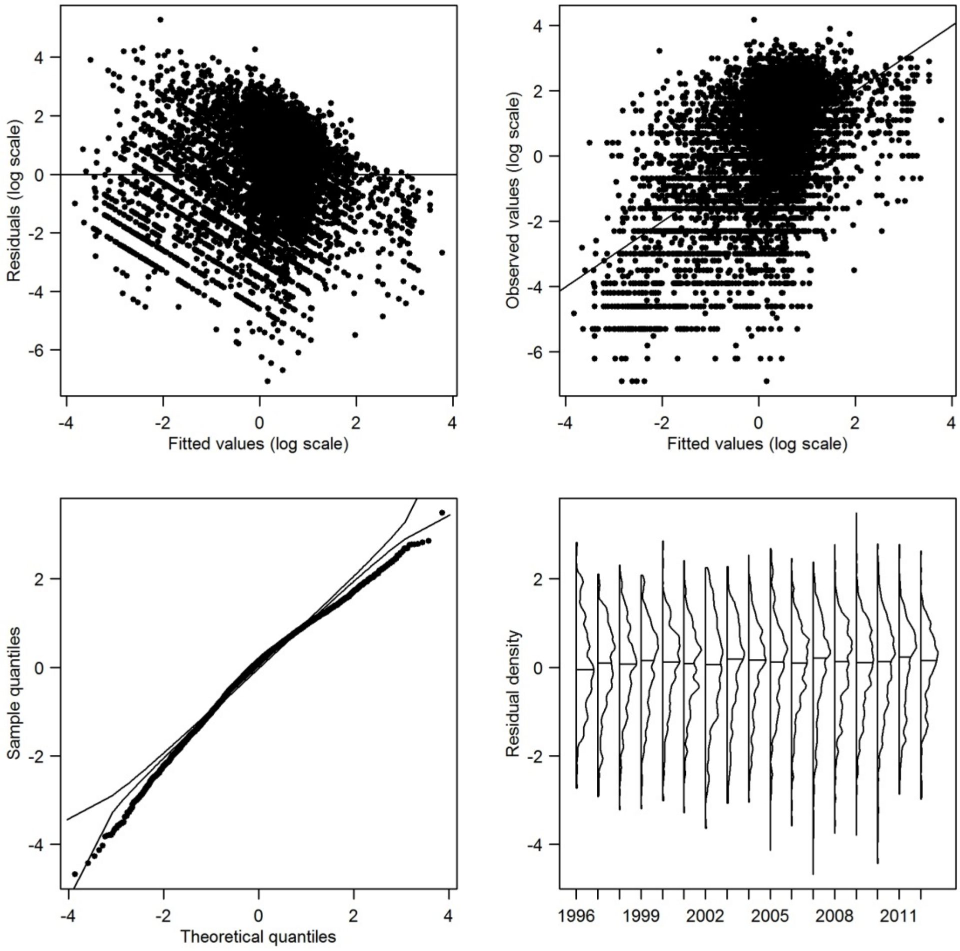

Figure 7: All Target model – diagnostics.

Core Target model

This model is based on the All Target dataset but excludes records associated with the non-black oreo features identified above (see Table 4) and records for which target species was not BOE or OEO. In addition, vessels with fewer than 15 black oreo catches in each of at least three years were excluded. This vessel experience criterion reduces the number of vessels from the All Target dataset from seven to five while retaining 85% of the catch.

Linkage of vessels between years in the Core Target series is similar to that for the All Target series (Table 9). Each adjacent pair of years is linked by either three or four vessels for half of the series, and by at least two vessels in all but one pair. As in the All Target series, one vessel fished in each of the 17 years, and two of the remaining vessels fished in more than half the years.

Table 9: Number of trawls by fishing year for vessels in the Core Target post-GPS dataset. The vessels are sorted from left to right according to the average date of their trawls, from earliest to most recent.

	Vessel				
	E	B	D	A	G
1995–96	21	0	0	42	0
1996–97	16	0	0	39	0
1997–98	0	1	0	218	0
1998–99	5	32	0	198	0
1999–00	46	60	0	146	0
2000–01	10	32	56	90	11
2001–02	0	61	36	70	8
2002–03	0	110	57	142	11
2003–04	0	45	126	156	16
2004–05	0	27	94	187	1
2005–06	0	2	142	309	28
2006–07	0	10	123	440	77
2007–08	0	0	0	782	13
2008–09	0	0	0	692	42
2009–10	0	129	0	806	44
2010–11	0	0	0	391	59
2011–12	0	0	0	402	28

The CPUE model selected, in addition to *fishing year*, the variables *duration, depth*, and *subarea* (Table 10). Two other variables, *start time* and *month*, also had a small influence on catch rates but did not meet the selection criteria for inclusion in the final model. As in the All Target model, *fishing year* accounted for only a small amount of the variability in catch rates. In this case *duration* and *depth* were the most important factors, together explaining an additional 9.2% of the model deviance. The last variable to be selected, *subarea*, explained a relatively small amount of the variability in catch rates (2.2%), but had more influence (9.9%) than the other additional variables. Overall, the model explained a modest 13.9% of the total variability in catch rates.

Table 10: Core Target model fits for the post-GPS period GLM for Pukaki black oreo in the stepwise order determined by R^2. Df, degrees of freedom. Variables below the line did not meet the additional R^2 criteria required for inclusion in the final model.

	Df	R^2 (%)	Additional R^2 (%)	Overall influence (%)
Fishing year		2.4	2.4	
Duration	-7	9.0	6.5	5.0
Depth	-7	11.6	2.7	7.9
Subarea	-1	13.9	2.2	9.9
Start time	-11	14.5	0.6	
Month	-11	15.1	0.6	

The standardised CPUE for this model shows a distinctly different trajectory to the All Target model, with the standardisation process having far less effect. Removal of the records associated more with the smooth oreo and orange roughy fisheries has led to a down-weighting of the indices for the initial part of the series and while the initial decline is still steep it indicates a more credible decline in relative abundance over the period as a whole, with a small increase in the final two values (Figure 8). The effect of the additional variables in the index is relatively minor, with CPUE slightly down-weighted by the influence of trawl duration in the first few years, depth having an influence only in one or two years, and subarea having the effect of slightly steepening the overall decline in CPUE.

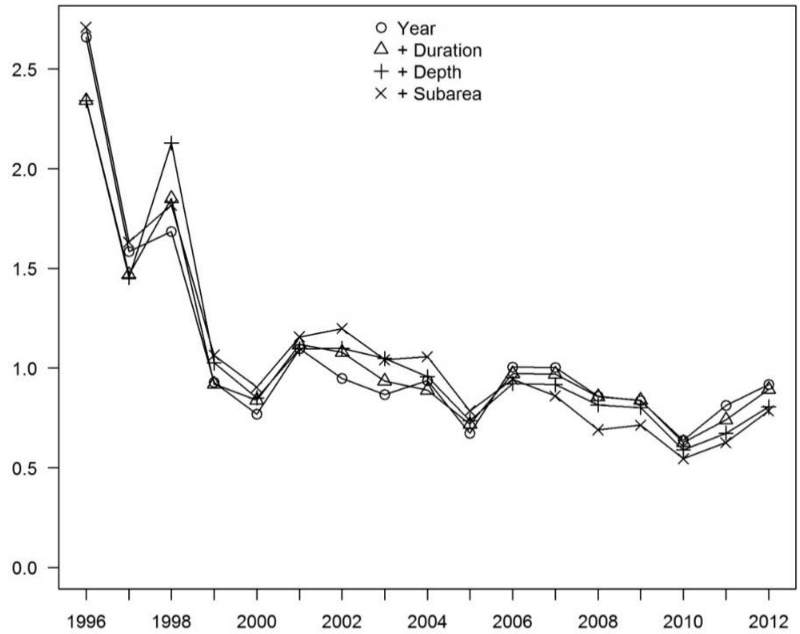

Figure 8: Step plot for Pukaki black oreo Core Target model, showing the CPUE index at each step in the stepwise selection of variables (top to bottom in legend on plot). The line for subarea (×) indicates the final step.

As in the All Target model CPUE increased with increasing trawl duration, but with little inter-annual variability in the distribution of trawl duration the influence on the index is slight (Figure 9). The influence of depth on CPUE is stronger, with decreasing effort in deeper, less productive areas, and more inter-annual variability in the depth distribution of fishing early in the time series. The influence of subarea on CPUE early in the time series is due to overall higher catch rates in area C than area B coupled with a large shift in effort from area B in 1995–96 and 1996–97 to area C in 1997–98.

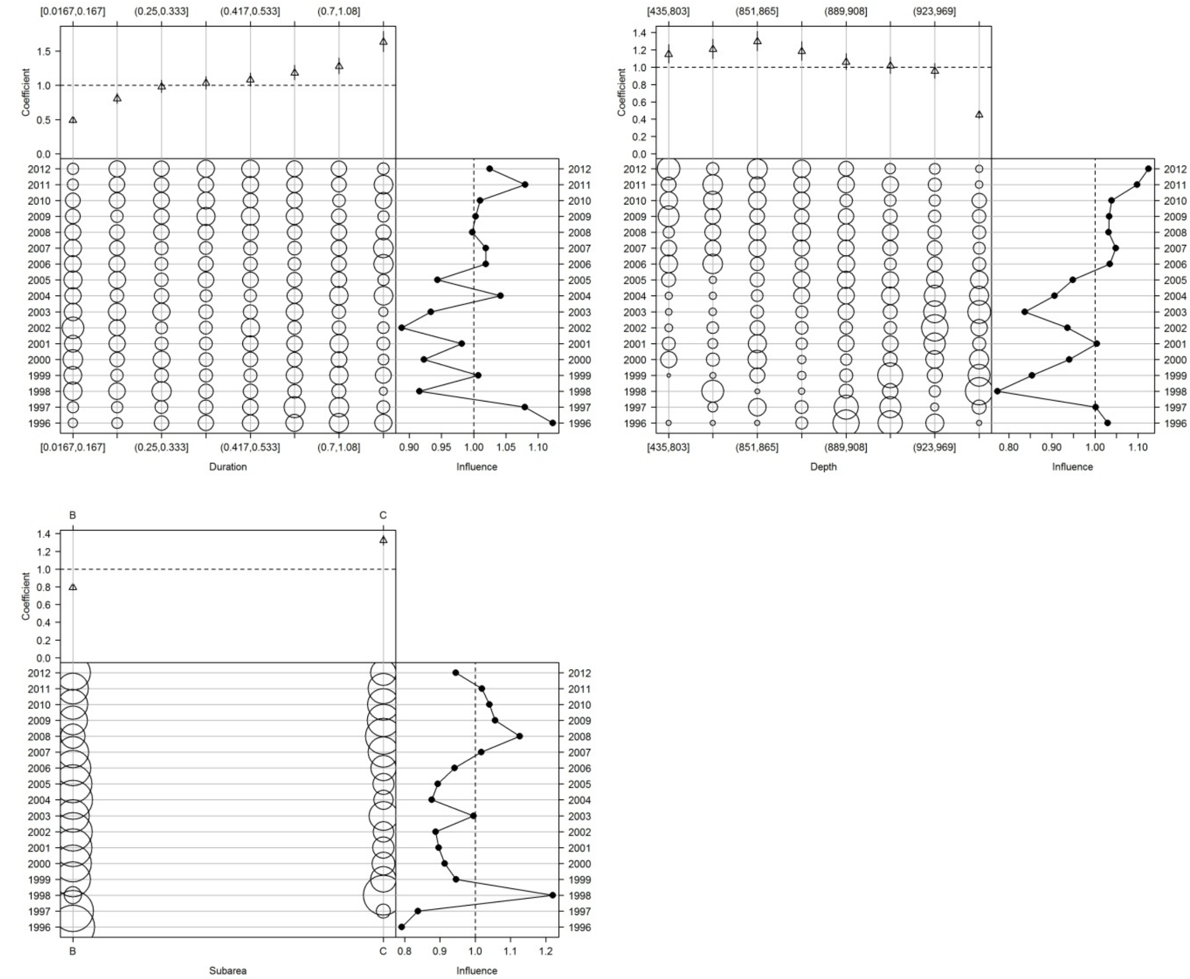

Figure 9: Influence plots for each accepted predictor in the Core Target model. See Figure 6 for more details.

Examination of the model residuals show a relatively poor fit to the data, similar to that illustrated for the All Target model (see Figure 7). Although the log of the residuals is more evenly spread around zero over the range of the fitted values, especially for higher values, the model again underestimates CPUE for extreme values, and the annual distribution of residuals are generally skewed to the right (Figure 10).

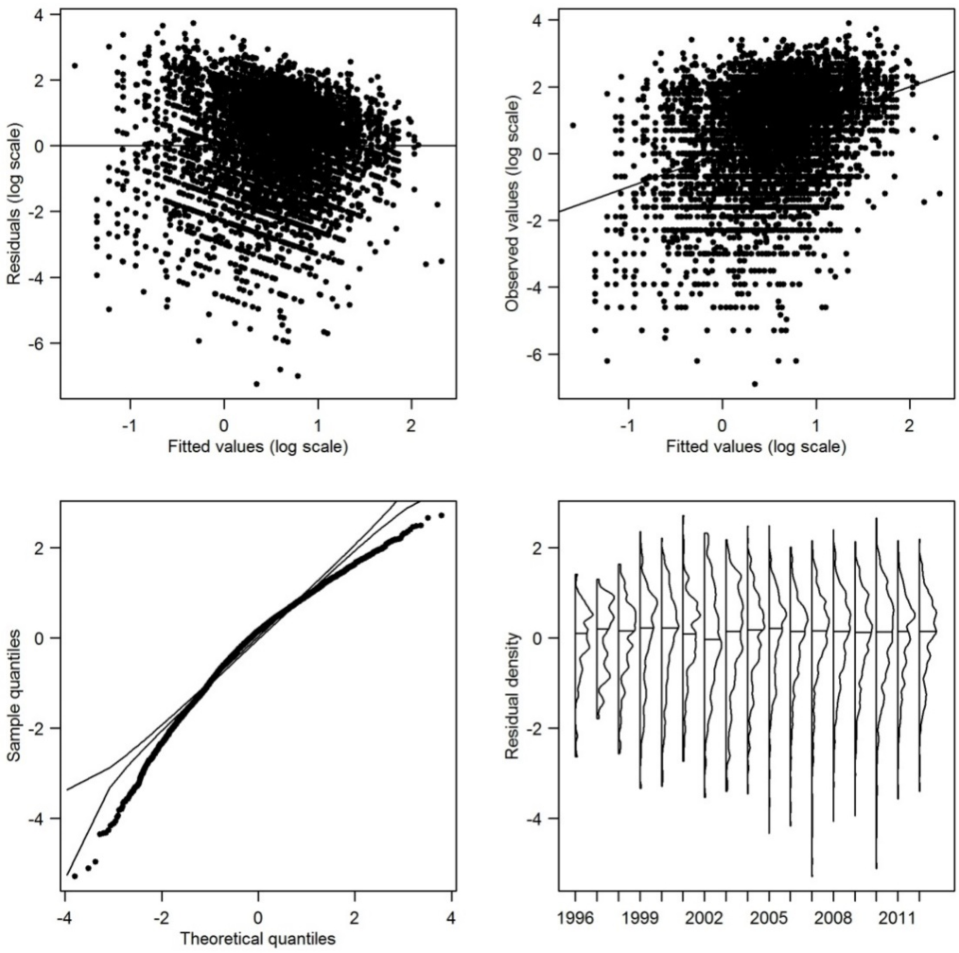

Figure 10: Core Target model – diagnostics.

The Deepwater Working Group selected the Core Target CPUE index to use in the base case CASAL stock assessment model, reasoning that the Pukaki black oreo fishery was best represented by fishing effort in which the recorded target species was limited to BOE and OEO.

The updated CPUE series in Table 11 are similar to those produced in 2009 for the overlapping years (Anderson & Doonan 2010), although for the All Target data set the decline in CPUE is markedly stronger in the updated model than in the 2009 version (Figure 11). The two updated series contrast substantially in the level of decline in abundance between 1995–96 and 2011–12; the final index in the All Target model is 4% of the initial index value, compared to 37% in the Core Target model.

Table 11: Summary of data used as input to the standardised CPUE models, and CPUE index values and CVs by year.

All target

Year	No. of trawls	No. of vessels	Estimated catch (t)	CPUE index	CV
1995–96	195	2	1 024	9.53	0.07
1996–97	424	4	1 635	10.82	0.06
1997–98	444	4	1 824	2.97	0.05
1998–99	283	4	979	1.12	0.06
1999–00	335	4	922	0.92	0.06
2000–01	320	5	1 007	1.05	0.06
2001–02	219	4	888	1.11	0.07
2002–03	383	4	1 483	1.05	0.05
2003–04	405	4	1 363	0.87	0.05
2004–05	411	5	1 125	0.83	0.05
2005–06	578	4	2 001	0.88	0.04
2006–07	855	4	2 975	0.58	0.04
2007–08	932	2	2 927	0.44	0.04
2008–09	956	2	2 699	0.43	0.04
2009–10	1 108	3	2 940	0.34	0.04
2010–11	552	2	1 387	0.27	0.05
2011–12	464	2	1 472	0.41	0.05

Core target

Year	No. of trawls	No. of vessels	Estimated catch (t)	CPUE index	CV
1995–96	63	2	465	1.94	0.09
1996–97	55	2	283	1.44	0.13
1997–98	219	2	1 191	1.53	0.07
1998–99	235	3	946	0.98	0.11
1999–00	252	3	841	0.82	0.12
2000–01	199	5	807	1.11	0.10
2001–02	175	4	760	1.07	0.11
2002–03	320	4	1 382	0.91	0.10
2003–04	343	4	1 303	0.97	0.09
2004–05	309	4	942	0.73	0.13
2005–06	481	4	1 941	0.88	0.09
2006–07	650	4	2 789	0.80	0.09
2007–08	795	2	2 844	0.62	0.12
2008–09	734	2	2 385	0.61	0.12
2009–10	979	3	2 831	0.33	0.21
2010–11	450	2	1 362	0.51	0.16
2011–12	430	2	1 419	0.72	0.12

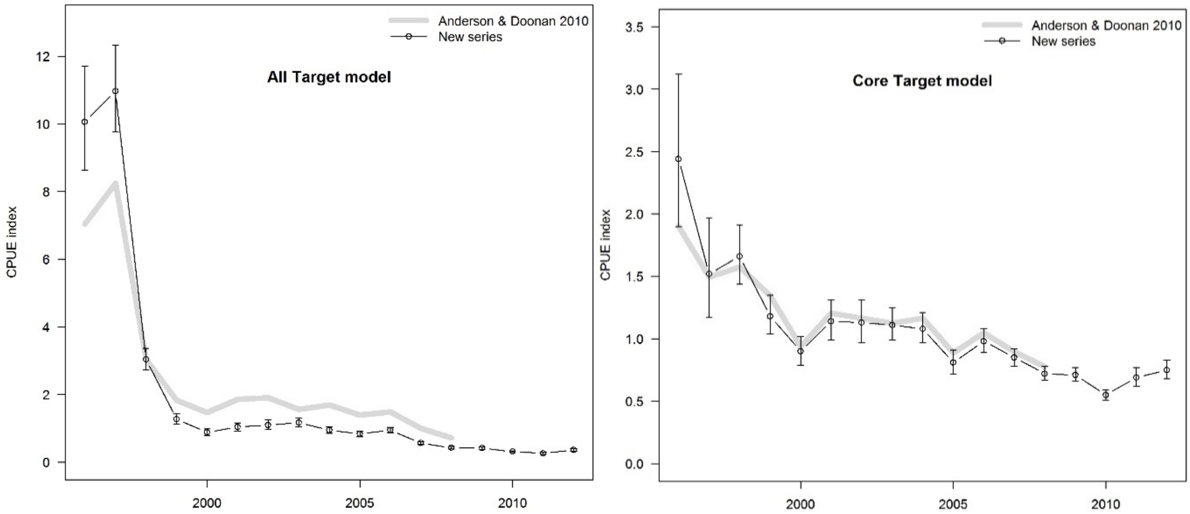

Figure 11: Comparison of CPUE indices for the All Target and Core Target models from the previous analysis (Anderson & Doonan 2010) and from the current analysis.

3. OBSERVER LENGTH FREQUENCIES

3.1 Summary of available data

Black oreo length frequency data collected by MPI observers (SOP) and fishing industry (ORMC) observers were available from 1996–97 to 2011–12. The MPI observer programme stores these data on the *COD* database, and 926 individual samples were retrieved from this source. The ORMC samples come from two programmes: ORM, (1998–2002) which has data stored in *COD* (98 samples), and OTS, (2005–2008) with data stored by SeaFIC (76 samples). Data were selected from trawls which caught at least 1 t of black oreo and at least 10 fish of each sex. These selection criteria reduced the total number of available samples from 1100 to 827.

There was a good spatial coverage of observer length sampling in the Pukaki area, covering the core fishing localities, with each programme collecting samples from areas B and C and the SOP and OTS programmes also collecting samples from area A (Figure 12).

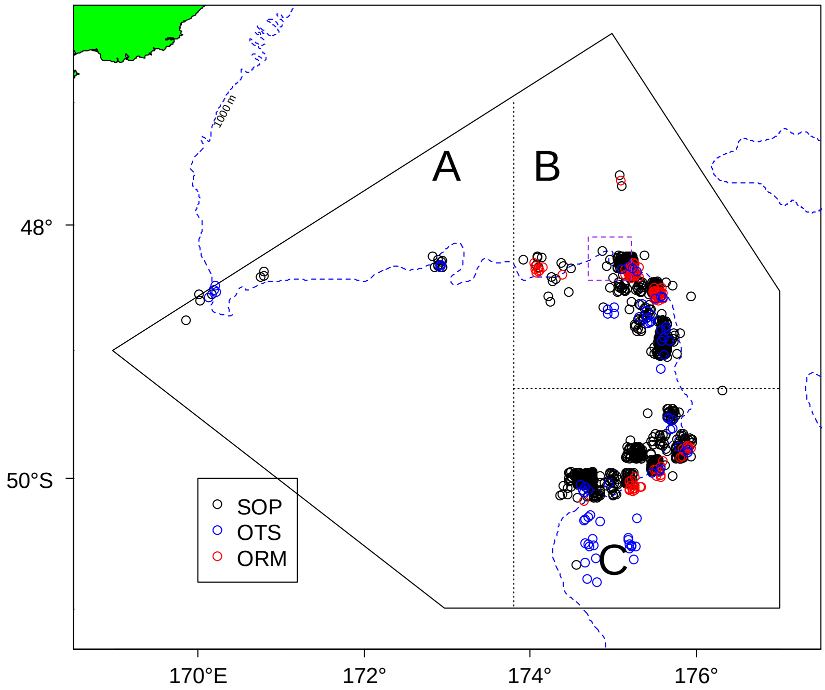

Figure 12: Location of black oreo catches in the Pukaki fishery from which observer length samples were measured.

3.2 Analysis of sample mean lengths

The overall mean lengths from each observer sample were calculated as a simple average of the sample male and female mean lengths, and a GLM model was used to identify any factors having an influence on the mean size of the sampled fish. To remove the effect of any differences between vessels, only data from vessel A (which provided nearly three quarters of the samples) were used in the model. The model was run with stepwise selection (forward and backward) and predictors chosen by AIC; predictors were accepted only if they explained more than 1% additional deviance. The available predictor variables used were: *fishing year*, *month*, *bottom depth*, *subarea*, *sampling programme*, and *catch weight*. This process selected *fishing year* as the first predictor, with 41% deviance explained, followed by *bottom depth* (explaining an additional 5.3% deviance) and *month* (5.1%) (Table 12).

Table 12: Model fits for a GLM predicting black oreo observer sample mean lengths for vessel A. Predictors are in the stepwise order determined by AIC. Df, degrees of freedom. Only selected predictors, those explaining more than 1% additional deviance, are shown.

	Df	Residual deviance	Percentage deviance explained	Additional deviance explained
NULL		673		
Fishing year	15	397	41.0	
Depth	1	362	46.3	5.3
Month	11	327	51.4	5.1

3.3 Calculation of length frequencies

To account for any variability in the depths fished by the sampled fleet between years, the length data were post stratified by depth. Two strata: shallow (less than or equal to 900 m); and deep (deeper than 900 m) were chosen, based on the average fishing depth for black oreo so as to represent an approximately even division of the catch. Length frequencies were calculated for each depth range and then combined, weighted by the catch in each depth range for the year(s) being considered. In addition, to give greater weight to samples from larger catches, the length data were scaled to the total weight of the black oreo catch from which the samples were taken. This was done by multiplying the numbers at length in each sample by the catch weight divided by the sample weight. Missing sample weights (all the industry samples) were calculated using the sample length distribution and a published length-weight function for black oreo (Ministry for Primary Industries 2012). To overcome the uneven spread of samples across years, length data were grouped into ten blocks of adjacent years, in such a way that each block contained at least 10 samples in each depth strata (Table 13). Altogether 611 samples were used, based on 67 238 measured fish.

Table 13: Summary of observer black oreo length frequency data used in the stock assessment model for the Pukaki fishery.

		Number of trawls sampled			
Year	Year group	SOP	ORM/OTS	All	Total number of fish measured
1996–97	97–98	7	0	7	784
1997–98	97–98	25	0	25	2 366
1998–99	99–00	7	44	51	5 000
1999–00	99–00	6	0	6	580
2000–01	01–02	8	18	26	2 541
2001–02	01–02	2	8	10	1 035
2002–03	03–05	7	2	9	948
2003–04	03–05	18	0	18	1 675
2004–05	03–05	21	0	21	2 494
2005–06	06	21	42	63	7 103
2006–07	07	154	11	165	19 064
2007–08	08	61	9	70	7 337
2008–09	09	46	0	46	6 171
2009–10	10	57	0	57	5 889
2010–11	11–12	13	0	13	1 524
2011–12	11–12	24	0	24	2 722
Total	–	477	134	611	67 238

The resulting length frequency distributions show a relatively constant structure throughout the series, exhibiting a strongly uni-modal shape, but this mode shifts gradually to the left after the third block of years, indicating a decrease in the average size of the sampled fish over time (Figure 13).

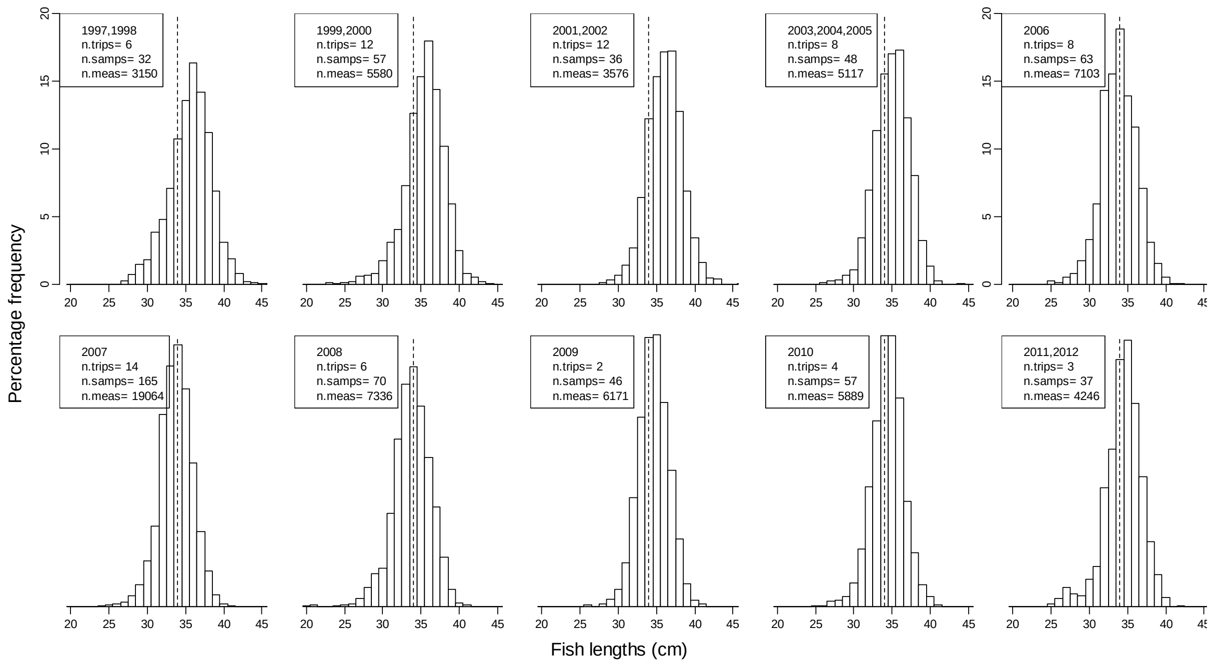

Figure 13: Observer length frequencies for Pukaki Rise black oreo, stratified by depth (see text), and grouped by years (in the legends 1997=1996–97 etc.). The vertical dashed lines indicate the approximate overall mean length as an aid to comparing the distributions.

4. STOCK ASSESSMENT MODEL

4.1 Population dynamics

4.1.1 Partition of the population

The stock assessment model partitioned the Pukaki Rise black oreo population into one sex group, and age groups of 5–70 years, with a plus group. There was a single area.

4.1.2 Annual cycle

The nominal unit of time in the model was one year, during each of which processes such as recruitment and mortality were applied. Since these processes cannot be modelled simultaneously they were carried out in a specified sequence (Table 14). Events were given a specified time within the year (month) through the specification of the percentage of natural mortality that was applied, assuming that it was applied uniformly throughout the year. Observations were fitted to model predictions specified by the time step and the time within the year (Table 14).

Table 14: Stock assessment model: timing within a year for processes and when data were fitted.

Model time step

Time	Process (in the order applied)
October	Increment age
October	Recruitment
Oct-September	Fishing and natural mortality

Observations fitted

Time	Description
March	CPUE indices
March	Observer length data

4.2 Selectivities, ogives, and other assumptions

Fishing selectivity

One age-based selectivity ogive was estimated for the sexes combined for the commercial fishery (catch) data. The ogive was a logistic curve with parameters for the age of 50% selection and for the ages from 50 to 95% selection.

Maturity

The revised maturity ogive of Doonan et al. 2009 was used, in which maturity rates were represented by a capped logistic curve with parameters A_m (rates cap), A50 (age at 50% of A_m), and A50.95 (ages from 50% to 95% level). The estimated parameters were: A50 = 37.7 yr, and A50.95= 0.47 yr. This age ogive is almost knife-edge at about 38 yr.

4.3 Modelling methods, parameters, assumptions about parameters

The stock assessment analyses were conducted using CASAL (Bull et al. 2012). This was implemented as an age-structured population model, employing the Bayesian estimator. The model incorporated deterministic recruitment, life history parameters, and catch history. Data fitted in the analysis were standardised post-GPS CPUE indices. Preliminary models also fitted the observer length data, from which fishery selectivities were estimated. These estimated selectivities were then used in a final model, which was used to estimate biomass. These procedures were conducted with the following steps.

1. Models were explored and fits assessed using maximum likelihood and the prior probabilities to estimate parameters (MPD runs).
2. From (1) above, a base case and two sensitivity cases were selected and a Bayesian analysis was performed. Samples for the posterior distribution of parameters were generated with the Markov Chain Monte Carlo (MCMC) procedure using the Metropolis algorithm.
3. A marginal posterior distribution was found for each quantity of interest by integrating the product of the likelihood and the priors over all model parameters. The posterior distribution was described by its median, 2.5, and 97.5 percentiles for parameters of interest. The median was used as the “point” estimate.

The following assumptions were made in the analyses carried out to estimate biomass.

1. CPUE provided a relative index of abundance for black oreo in the whole of the Pukaki Rise.
2. The ranges used for the biological values covered their true values.
3. One assumed value (0.58) of the maximum fishing mortality (U_{max}) was used in all the analyses of black oreo below.
4. Recruitment was deterministic and followed a Beverton & Holt relationship with steepness of 0.75.
5. Catch overruns were assumed to be zero during the period of reported catch.
6. The population of black oreo in the Pukaki Rise formed a discrete stock or production unit.
7. The catch history was accurate.

4.4 Observations and model inputs

4.4.1 Catch history

Catch history is presented in Table 15 and includes the annual total catch for Pukaki Rise derived from the OEO 6 reported data as follows.

1. From 1978–79 to 2011–12, the landings were calculated by multiplying the OEO 6 reported landings by the proportion of estimated black oreo in the Pukaki Rise to black oreo and smooth oreo estimated catch in OEO 6.
2. The last year of the catch history (2012–13) is assumed projected catch, equal to that calculated for the previous year.

Table 15: Reconstructed catch history (t) of black oreo from Pukaki Rise. ‡ projected catch.

Fishing Year	BOE catch (t)	Fishing year	BOE catch (t)
1978–79	17	1996–97	2 413
1979–80	5	1997–98	2 244
1980–81	283	1998–99	1 181
1981–82	4 180	1999–00	1 061
1982–83	1 084	2000–01	1 158
1983–84	1 150	2001–02	988
1984–85	1 704	2002–03	1 701
1985–86	46	2003–04	1 530
1986–87	0	2004–05	1 588
1987–88	0	2005–06	2 811
1988–89	0	2006–07	3 434
1989–90	0	2007–08	3 346
1990–91	15	2008–09	2 818
1991–92	27	2009–10	3 093
1992–93	27	2010–11	1 641
1993–94	10	2011–12	1 671
1994–95	242	2012–13	‡1 671
1995–96	1 352		

4.4.2 Relative abundance estimates from CPUE analyses

The Core Target CPUE index (see Section 2.3) was used in the assessment model. The All Target series was rejected as a portion of the data it was based on was primarily from target fishing for orange roughy and smooth oreos. The annual CVs for the index series were derived from the model standard errors.

4.4.3 Observer length frequencies

The analysis of observer length frequency data is shown in Section 3. The assessment model used observer size frequencies grouped into ten blocks of years (each incorporating 1–3 years of data), covering the period 1996–97 to 2011–12 (see Figure 13). In the model, the size frequencies were assigned to a single year, based on the year in each block with the most number of samples.

These blocks of length data were fitted to the model using a multinomial likelihood with process errors. For the multinomial, the sample size for each block was set to the number of tows sampled. For the process error, the sample size was set to the value that made the qqnorm plot of the residuals close to 1:1, i.e., N=500.

4.4.4 Biological data

As the model was not sex-specific, combined sex parameters were used (Table 16).

Table 16: Fixed life history parameters for black oreo.

Parameter	Symbol (unit)	Estimate
Natural mortality	M (yr^{-1})	0.044
Length-at-age CV		0.10
Length-weight parameters	a	0.0078 (g)
	b	3.27
Recruitment variability		0.65
Recruitment steepness		0.75

Growth was assumed to be the same as that estimated from fish sampled from the Chatham Rise (McMillan et al. 1997). It was defined by a mean length at each age class in the model (5 to 70 years), with an assumed constant CV over the age classes. Mean length-at-age was calculated separately for pre-and post-settlement fish and linear interpolation was used to join the curves (for details see Doonan et al. 2009, Doonan et al. 2010).

4.5 Base case and MPD sensitivity runs

The base case used the fixed biological parameter values (see Table 16), catch history (see Table 15), and Core Target post-GPS standardised CPUE relative abundance indices (see Table 11). Selectivities were estimated using a preliminary run (phase 1) of the model that included the observer length data (see Table 13), which were then excluded from subsequent (phase 2) model runs following the procedure agreed by the Deepwater Working Group for the previous assessment for this fishery (Doonan et al. 2010).

Two sensitivity models runs were also conducted using low (0.029 yr^{-1}) and high (0.066 yr^{-1}) values for natural mortality and the same phased approach with the observer length data. The low value was based on the lower 95% confidence interval on the mean estimated value of M, and the high value was calculated using a factor of 1.5 on the mean estimated M value (McMillan et al. 1997). The MPD model runs are summarised in Table 17, and the parameters estimated and their priors are shown in Table 18.

Table 17: CASAL MPD assessment model runs. The base case is in bold. –, not applicable.

Code	Data changes relative to the Phase_1.04 case	Other	Directory and file holding results
Phase_1.04	–	M = 0.044	\CASAL\Base.04
Phase_1.02	–	M = 0.029	\CASAL\Base.02
Phase_1.06:	–	M = 0.066	\CASAL\Base.06
Phase_2.04	**No observer lfs**	**M = 0.044, selectivity set to that estimated in Phase_1.04**	**\CASAL\NoLF.04**
Phase_2.02	No observer lfs	M = 0.029, selectivity set to that estimated in Phase_1.02	\CASAL\NoLF.02
Phase_2.06	No observer lfs	M = 0.066, selectivity set to that estimated in Phase_1.06	\CASAL\NoLF.06

Table 18: Estimated parameters and uniform priors of the base case. The base case had two phases. In phase 1, the selectivities were estimated and this included growth and process error on the length frequency data. In phase 2, the selectivities were fixed to that estimated in phase 1 and the length frequency data excluded from the fitting.

Parameter type	Phase	Parameter	Distribution	Lower Bound	Upper bound
Abundance	1+2	B_0 (t), virgin biomass	Uniform-log	100	1 000 000
Fishery selectivity	1	Age at 50% selection	Uniform	1	50
	1	Ages 50–95% selection	Uniform	0.1	35
Growth	1	CV of length-at-age	Uniform	0	0.4
Catchability	1+2	CPUE post-GPS	Uniform-log	1×10^{-10}	1

4.6 Bayesian biomass estimates

The base case was used to develop the Markov Chain Monte Carlo (MCMC) analysis, but MCMCs were also estimated for the two other phase 2 models to assess the effect of the alternative values of natural mortality. Biomass was estimated as the median of the posterior distributions.

4.7 Results

4.7.1 MPD results

The MPD model parameter and log-likelihood estimates are listed in Table 19 and biomass estimates in Table 20.

Table 19: MPD fits. Free parameter and log-likelihood estimates. The base case is in bold. –, not estimated or not applicable.

Estimated parameters						
Parameter	Phase_1.04	Phase_1.02	Phase_1.06	**Phase_2.04**	Phase_2.02	Phase_2.06
B_o (mid-year)	31 800	35 800	30 200	**35 100**	40 900	31 200
$B_{current}$ (mid-year)	6 700	6 900	9 000	**9 600**	11 600	9 900
B_{2012} (%B_0)	21	19	30	**27**	28	32
B_{2007} (%B_0)	46	46	52	**51**	52	54
Selectivity						
Age at 50% selection	35.9	29.8	43.1	**–**	–	–
Age for 50–95% selection	15.2	12.6	15.9	**–**	–	–
Size_at_age						
CV	0.032	0.036	0.036	**–**	–	–
Log-likelihood values for the data sets						
Log likelihood component	Phase_1.04	Phase_1.02	Phase_1.06	**Phase_2.04**	Phase_2.02	Phase_2.06
Total	187	224	173	**-16.2**	-15.9	-16.5
CPUE	-16.1	-14.9	-17.3	**-16.6**	-16.3	-17.3
Observer lengths	202	238	189	**–**	–	–
Priors						
Initial B_0	10.4	10.5	10.3	**10.5**	10.6	10.3
Selectivity	0	0	0	**–**	–	–
Size_at_age CV	0	0	0	**–**	–	–
q_CPUE	-9.8	-9.98	-9.49	**-10.0**	-10.2	-9.5
CatchMustBeTaken	0	0	0	**0**	0	0

The fits to the CPUE data are relatively constant between cases (Table 19). The fits to the observer data are slightly better when natural mortality is lower which also moves the selectivity to younger fish. When the observer length data are excluded, the estimated mature biomass increases, but less so for the high M run (Phase_1.06 compared with Phase_2.06).

Estimates of current biomass (%B_0) are sensitive to higher (but not lower) values of natural mortality and to the removal of observer length data, and in these cases current biomasses are more optimistic (Table 19). All runs show a decline in current biomass as a percentage of B_0 between 2006–07 and 2011–12 of 20–30 percentage points.

The fit of the post-GPS Core Target CPUE indices in the base case (Phase_2.04) is shown in Figure 14. The confidence intervals (plus or minus 2 standard deviations) for the first and last indices in the series are entirely above the model trajectory of vulnerable biomass, and the model fits well only to the central period of the index (from about 1998–99 to 2009–10). In particular, the increase in the index after 2009–10 is not matched by the model trajectory—which continues a decline begun in about 1995–96.

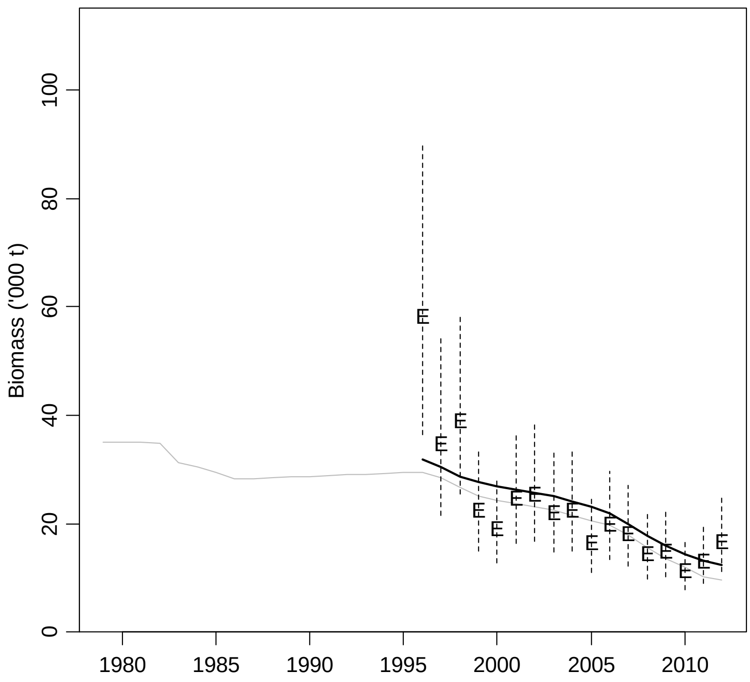

Figure 14: Fits of CPUE in the MPD base case with observer data excluded and M=0.044 (Phase_2.04) to the biomass trajectories in the assessment model. The CPUE indices were scaled by their associated catchabilities to provide abundance. The trajectories are model estimates of mid-year vulnerable biomass (i.e., selected to the fishery, in grey) and mature biomass (in black). Vertical error bars for the CPUE estimates are ± 2 s.d.

For phase 1 of the base case (Phase_1.04) the model fits to the observer length frequency data were variable (Figure 15). The mode of the model fit was relatively constant compared with the observer frequencies, and predicted frequencies indicated more small fish than were observed in the first and last few years. The fits were better for some of the central years sampled (e.g., 2003–04 and 2007–08) but a shoulder on the right-hand side of many of the fitted distributions was not matched by the observer data.

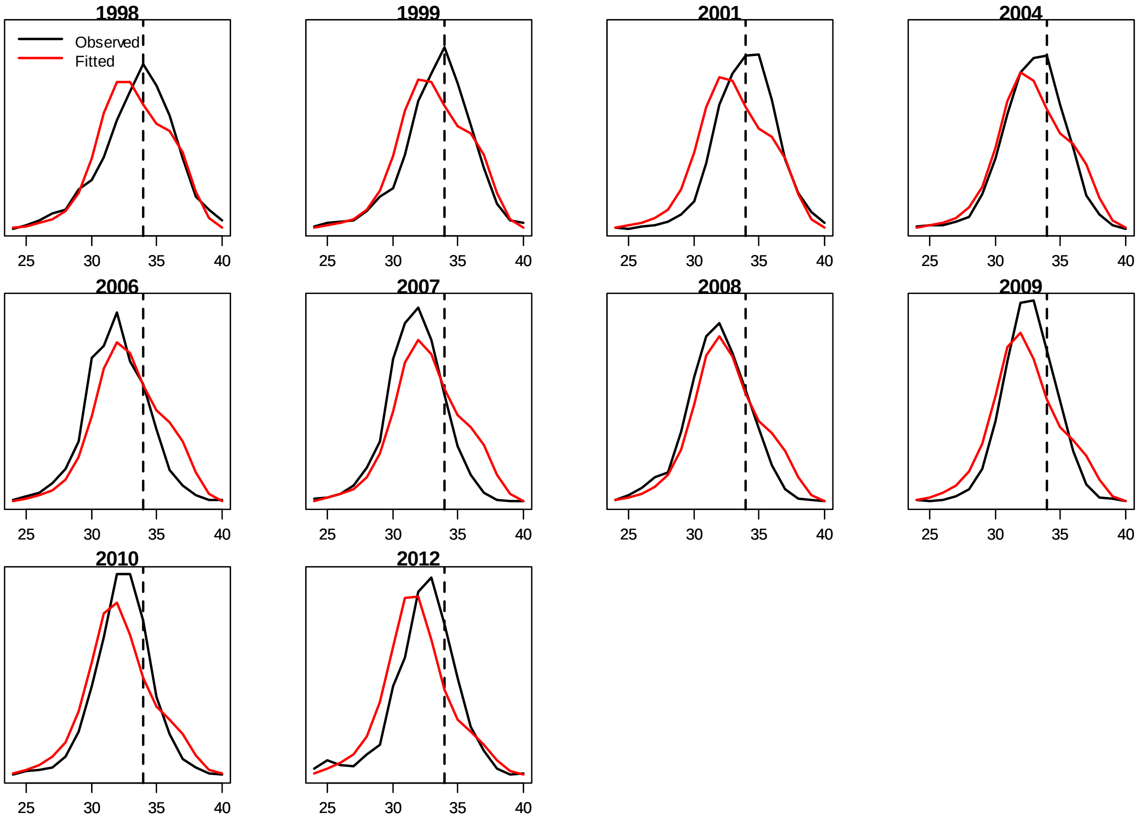

Figure 15: Density plots showing fits of the observer length frequency data (black) to the model estimates (red) for the Phase_1.04 model MPD fit. The number above each plot refers to the year represented, 1998=1997–98, etc. (see Table 13 and Section 4.4.3).

4.7.2 Bayesian estimates

A summary of the estimated parameters from the MCMC runs for the three phase 2 cases is shown in Table 20 (see Appendix A for trace plots for these runs). In each case the estimated parameters (B_0, $B_{current}$, and $B_{current}$ $(\%B_0)$) from the MCMC runs were slightly greater than the equivalent MPD estimates.

The base case model (Phase_2.04) gave a median estimate for B_0 of 35 600 t with a 95% confidence interval of 31 000–45 000 t; current mature biomass was estimated to be 10 100 t and 28% B_0 (range 18–42%). The model assuming a greater level of M predicted a lower B_0 but a similar $B_{current}$, (and therefore a more favourable $B_{current}$ $(\%B_0)$); and the model assuming lower M predicted slightly higher values of both B_0 and $B_{current}$ and a similar $B_{current}$ $(\%B_0)$. The confidence intervals for $B_{current}$ $(\%B_0)$ are quite wide (between 18% and 46% taking into account all three cases) making the current status of the stock highly uncertain.

Table 20: Bayesian parameter estimates: summary statistics of the posterior distributions for the three phase 2 cases.

Phase_2.04

Parameter	Median	C.I.05	C.I.95	MPD
B_0	35 600	31 000	45 000	35 100
$B_{current}$	10 100	5 600	19 000	9 600
$B_{current}$ (%B_0)	28	18	42	27

Phase_2.02

Parameter	Median	C.I.05	C.I.95	MPD
B_0	41 600	36 000	52 000	40 900
$B_{current}$	12 100	7 300	23 000	11 6000
$B_{current}$ (%B_0)	29	20	43	28

Phase_2.06

Parameter	Median	C.I.05	C.I.95	MPD
B_0	31 300	26 000	40 000	31 200
$B_{current}$	10 100	5 700	18 000	9 900
$B_{current}$ (%B_0)	32	22	46	32

4.7.3 Yield estimates

No yield estimates were made.

4.7.4 Projections

No projections were made.

4.8 Interpretation of uncertainty

There are large potential biases in the data that could shift the assessment substantially. These include the assumption of constant recruitment, and the assumption of a linear relationship between standardised CPUE and abundance. The Deepwater Working Group considered that the CPUE index used in these models provided an unreliable measure of relative abundance because the CPUE for the associated species, smooth oreo, in the same area indicated a current abundance that was too low to be believed. Until further investigation into the data were done, the working group has set aside the assessment reported here. The Working Group concluded that determination of reliable CPUE indices for each of the deepwater fisheries in the Pukaki region of OEO 6 should be based on a single, spatially stratified, analysis which would assess black oreo catches together with those of smooth oreo and orange roughy.

5. DISCUSSION AND CONCLUSIONS

This assessment provides the first update of the estimation of current and virgin biomass of black oreo on the Pukaki Rise made initially in 2010 (Doonan et al. 2010). These estimates continue to be uncertain for the same reasons as the first assessment, i.e., there are no black oreo biological parameter estimates specific to this region, and the lack of fishery-independent abundance information means that there is a reliance on commercial CPUE data. In addition, further uncertainty is caused by the assumption of constant recruitment and the fixing of the fishery size selectivity to values estimated in phase 1 model runs.

The use of CPUE to index abundance in this stock assessment is limited to the post-GPS period of the fishery; the lack of linkage between vessels across years in the early, pre-GPS, period has prevented the construction of a sensible CPUE index for this short but productive period of the fishery. The primary inputs for the historical reconstruction of the population in the stock assessment model are therefore limited to the recorded catch history and a CPUE index for the later, post-GPS, time period. The CPUE index for this later period may also be unreliable, due to the perceived difficulty of disentangling the black oreo target fishery from significant, overlapping fisheries for smooth oreo and orange roughy.

A step towards finding an acceptable CPUE index was taken with the rejection of the All Target model, which considered records with black oreo catches from trawls targeting orange roughy and smooth oreo as well as from those targeting black oreo and unspecified oreo. Records for all Pukaki deepwater target fisheries had been retained for this model due to inconsistency in how target species has been recorded over time and between vessels, but high catch rates of black oreo when targeting orange roughy in the mid-1990s were in strong conflict with the relationship in later years, resulting in an implausible decline in abundance.

Further analysis of catch and effort data for this multi-species fishery, incorporating a finer spatial examination of effort, may be necessary to produce an index of abundance which will satisfy the requirements of the Working Group and be reliably applied in a stock assessment model.

The updated assessment model results indicate that mature virgin biomass was between about 31 000 t and 42 000 t, depending on the model choice (i.e., the value of M used), with an overall confidence interval of 26 000–52 000 t. Each of the three models suggested a substantial decline in the current biomass relative to virgin biomass over the last five years of the model, with biomass in 2012 at 28–32% of virgin biomass.

Because of the uncertainty in the model inputs and structure, and the model options, it is not possible to make definitive statements about the stock status; but if the current low catch level and increasing CPUE were maintained, the biomass would be likely to increase.

6. ACKNOWLEDGMENTS

This work was carried out for the Ministry for Primary Industries under project DEE201002OEO. We thank Vidette McGregor (NIWA, Wellington) for providing helpful comments on the manuscript, and the members of the Deepwater Fisheries Assessment Working Group for their critical analysis of the research.

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8. APPENDICES

APPENDIX A: Bayesian Trace Plots

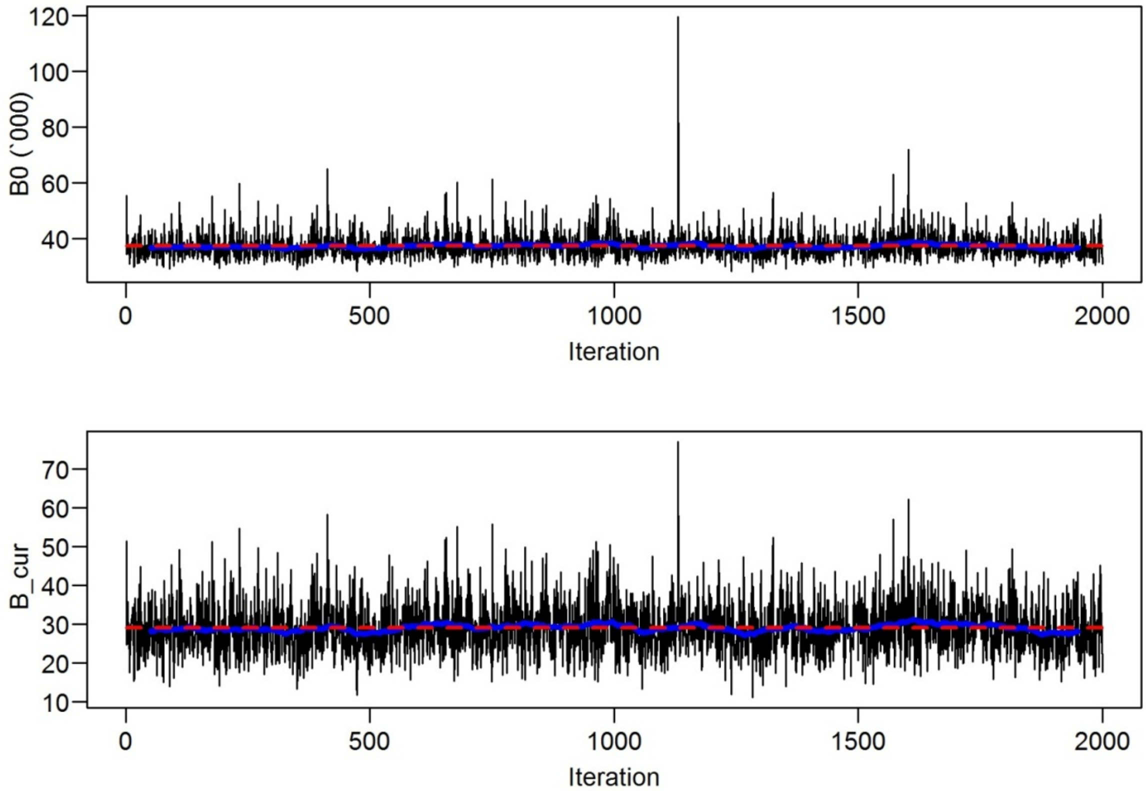

Figure A1: Time series of MCMC estimates for B_0 (top) and current mature biomass as a percentage of virgin biomass (bottom) for the NoLF case with M=0.044 (NoLF.04). The continuous line is a running average of estimates using a window of 50. The dashed line is the mean over the series.

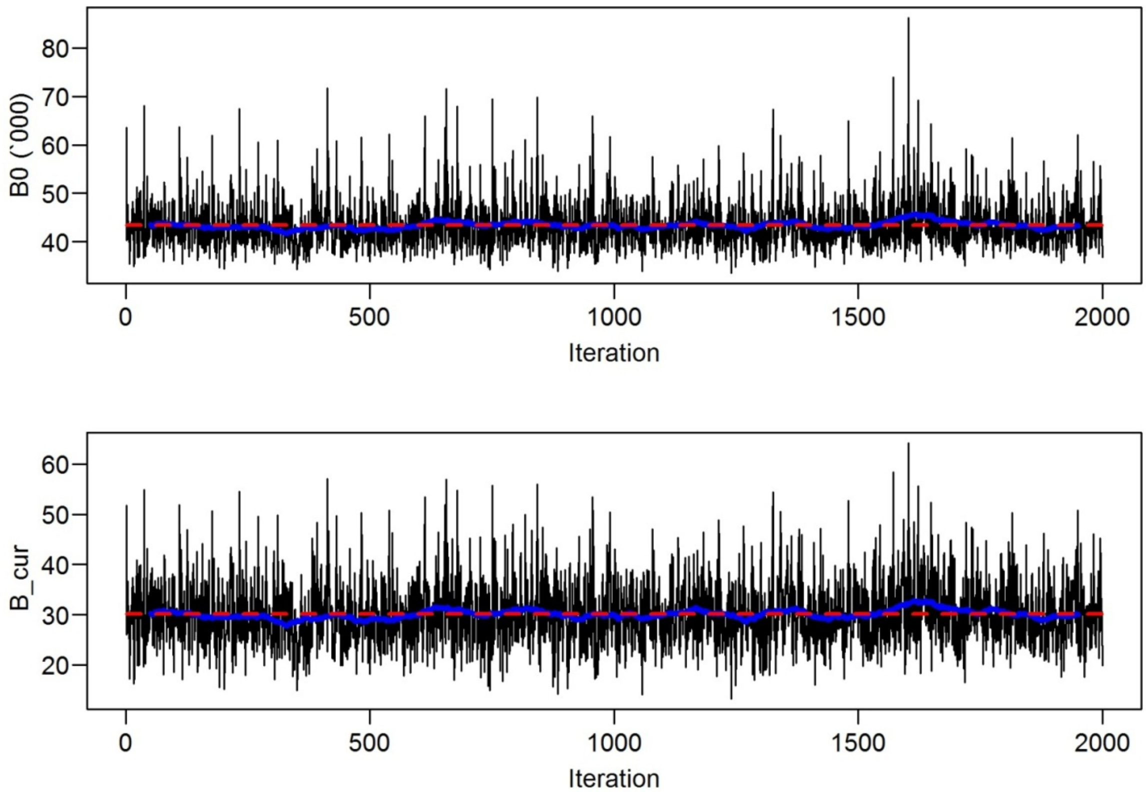

Figure A2: Time series of MCMC estimates for B_0 (top) and current mature biomass as a percentage of virgin biomass (bottom) for the NoLF case with M=0.029 (NoLF.02). The continuous line is a running average of estimates using a window of 50. The dashed line is the mean over the series.

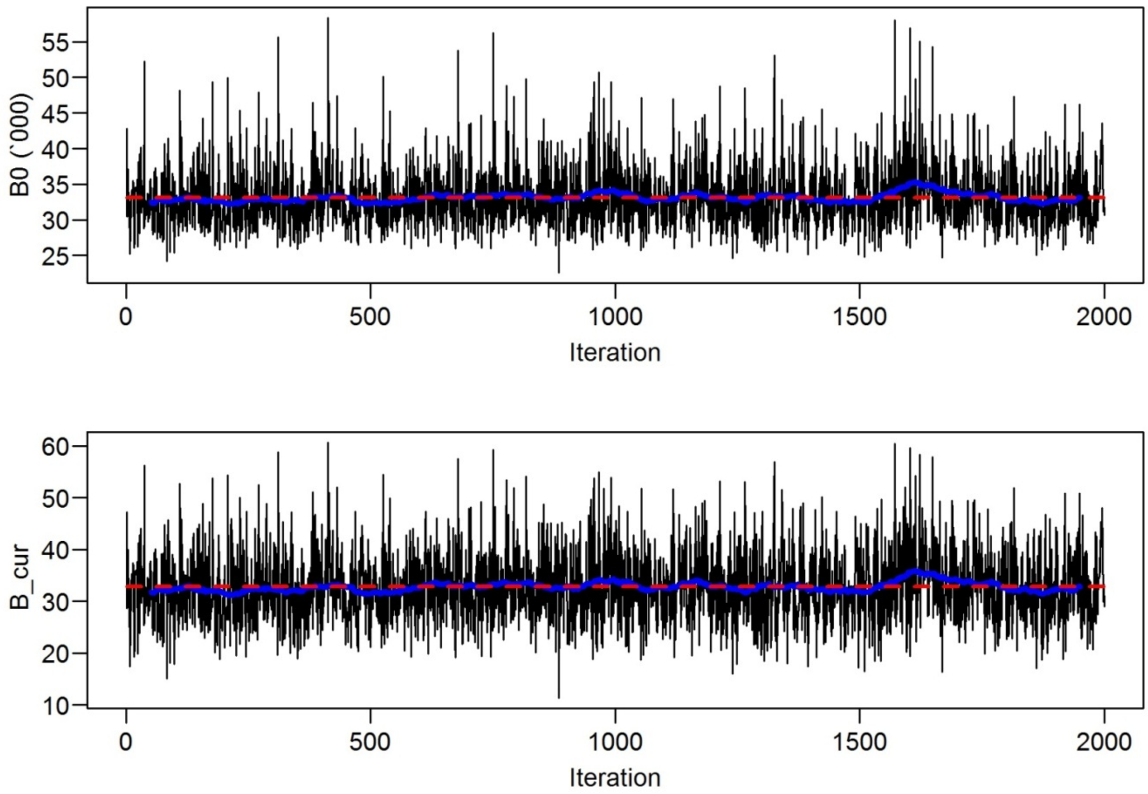

Figure A3: Time series of MCMC estimates for B_0 (top) and current mature biomass as a percentage of virgin biomass (bottom) for the NoLF case with M=0.066 (NoLF.06). The continuous line is a running average of estimates using a window of 50. The dashed line is the mean over the series.