OREOS – OEO 3A BLACK OREO AND SMOOTH OREO

1. FISHERY SUMMARY

This is presented in the Fishery Summary section at the beginning of the Oreos report.

2. BIOLOGY

This is presented in the Biology section at the beginning of the Oreos report.

3. STOCKS AND AREAS

This is presented in the Stocks and Areas section at the beginning of the Oreos report.

4. STOCK ASSESSMENT

The smooth oreo assessment was revised in 2009. The black oreo assessment is unchanged from 2004.

4.1 Introduction

The following assumptions were made in the stock assessment analyses carried out by NIWA to estimate biomasses and yields for black oreo and smooth oreo.

(a) The acoustic abundance estimates were unbiased absolute values.
(b) The CPUE analyses provided indices of abundance for either black oreo or smooth oreo in the whole of OEO 3A. Most of the oreo commercial catches came from the CPUE study areas. Research trawl surveys indicated that there was little habitat for, and biomass of, black oreo or smooth oreo outside those areas.
(c) The ranges used for the biological values covered their true values.
(d) Varying the maximum fishing mortality (F_{MAX}) from 0.5 to 3.5 altered B_0 for smooth oreo in OEO 3A by only about 6% in the 1996 assessment, so only one assumed value (0.9) was used in all the analysis of OEO 3A smooth oreo. Only one assumed value (0.67) for the maximum exploitation rate (E_{MAX}) was used in the NIWA OEO 3A black oreo analysis.
(e) Recruitment was deterministic and followed a Beverton & Holt relationship with steepness of 0.75.
(f) Catch overruns were 0% during the period of reported catch.
(g) The populations of black oreo and smooth oreo in OEO 3A were discrete stocks or production units.
(h) The catch histories were accurate.

4.1.1 Black oreo

The reported assessment was completed in 2004 with the NIWA CASAL software and used an acoustic absolute abundance estimate (and associated length and biological data) made from a survey carried out in 2002.

The 2002 assessment for black oreo in OEO 3A (termed the spatial analysis) used an age-structured population model. Three areas within the study area were modelled, corresponding to an increasing mean length of the catch as seen in the observer length frequency data. Area 1 contained small fish and flat ground while area 3 contained the largest fish and many features where short tows have historically taken place. One-way migration was allowed in the model and area specific selectivity curves were estimated using length frequencies derived from observed tows in the commercial fishery.

The 2004 assessment retained the three areas (revised) and one-way migrations and used updated and new data gathered since 2001.

4.1.2 Smooth oreo

A new assessment of smooth oreo in OEO 3A was completed in 2009. This used a CASAL age-structured population model employing Bayesian methods. Input data included research and observer-collected length data, one absolute abundance estimate from a research acoustic survey carried out in 1997 (TAN9713), and three relative abundance indices from standardised catch per unit effort analyses.

4.2 Black oreo

NIWA CASAL spatial model

An age structured, CASAL model employing Bayesian statistical techniques was developed, to jointly analyse the population dynamics within three areas of the black oreo stock in OEO 3A. A list of the data inputs and main changes between the base case for the assessment model and the previous (2002) spatial model is in Table 1.

Table 1: CASAL model data inputs and method changes compared to the previous (2002) spatial model.

Input	Description of changes and new estimates made
Recruitment	Assumed recruitment to mid-water at age one year and then into area 1 with one-way migration.
Migration	Age-dependent rates.
Fishing selectivities	None.
Growth	New growth, pre- and post-settlement. 1–70 years. Length-at-age CVs estimated.
CPUE abundance	Updated with 2000–01 and 2001–02. New standard errors. 20% process error assumed.
Acoustic abundance	Revised 1997 (target strength) plus 2002 surveys.
Acoustic length frequency	1997 plus 2002 survey data. Lognormal error structure. Process error estimated.
Observer length frequency	Updated with 2001–02 and 2002–03. Lognormal error structure, grouped over years. Process error estimated.
Catch history	Updated with 2000–01 and 2001–02.

It assumed Baranov fishing mortality, but had a maximum exploitation rate (0.80) instead of a maximum instantaneous fishing mortality. Natural mortality was partitioned into recruits and mature mortalities to determine differences that may occur when assuming a higher juvenile mortality. A maturation curve was estimated outside the model by fitting a loess curve through 7 points spread between the ages 18 and 48 years. Deterministic recruitment was assumed although recruitment deviates were estimated in one case. The latter suggested a very high level of recruitment in 1973 followed by very low levels until the late 1990s. This was driven by better fits to the acoustic length frequency data in area 1 and observer length frequency data in area 2. Fish recruit to the population at age one year.

The model estimated initial recruitment (mid-water only), the CV of the length-at-age, migration parameters to move fish from mid-water to area 1, from area 1 to 2, and from area 2 to 3, and process errors on both the observer and acoustic survey length frequency data sets. Input data for each area for the new stock assessment included: new absolute abundance estimates and length data from the 2002 acoustic survey and revised estimates from the 1997 acoustic survey; revised and updated catch history, revised and updated relative abundance estimates from pre-GPS and post-GPS standardised CPUE analyses, revised observer length frequencies, revised growth parameter estimates, and age dependent migration (base case). Observed lengths in the commercial fishery were compiled for each area grouped over years (up to five) where enough data were available and the absolute abundance at length from the acoustic surveys was converted to a length frequency using fixed length-weight parameters.

The base case analysis excluded trawl survey relative abundance data and trawl survey length frequencies. Migration was assumed to be unidirectional, meaning fish could move from mid-water to area 1, or from area 1 to area 2 or from area 2 to area 3 in one year, and not move back. The migration rate was dependent on age and in one run it was dependent on the current biomass of the area the fish were moving to.

Growth was defined by a mean length at each age class in the model (1 to 70 years) for both sexes combined, and an associated CV (estimated as 0.077 from the age-length data) was assumed to be constant over the age classes. Growth data for black oreo split into two groups at about age five years corresponding to the pre- and post-settlement life stages. Mean length-at-age was calculated separately for pre-and post-settlement fish and linear interpolation was used to join the curves. For post-settlement fish a local regression with a width spanning 2/3 of the data was fitted to all fish greater than 20 cm and mean length at ages 7 to 70 years was calculated from this fit. For pre-settlement fish a straight line was taken through the origin and the mean length for fish less than 20 cm length. Linear interpolation was used to calculate the mean length at ages 1 to 4 years. Mean length for ages 5 and 6 years was calculated by linear interpolation between those at 4 and 7 years.

The sensitivity of the model to the effects of estimating mature fish natural mortality (M), immature fish M, catchability in Area 1, and recruitment were investigated. Additional runs excluded pre-GPS or post-GPS standardised CPUE and included research trawl survey length frequency data for area 1.

Partition of the main fishery into 3 areas

The main fishery area was split into three areas: a northern area that contained small fish and was generally shallow (area 1), a southern area that contained large fish in the period before 1993 and which was generally deeper (area 3), and a transition area (area 2) that lay between areas 1 and 3 (Figure 1).

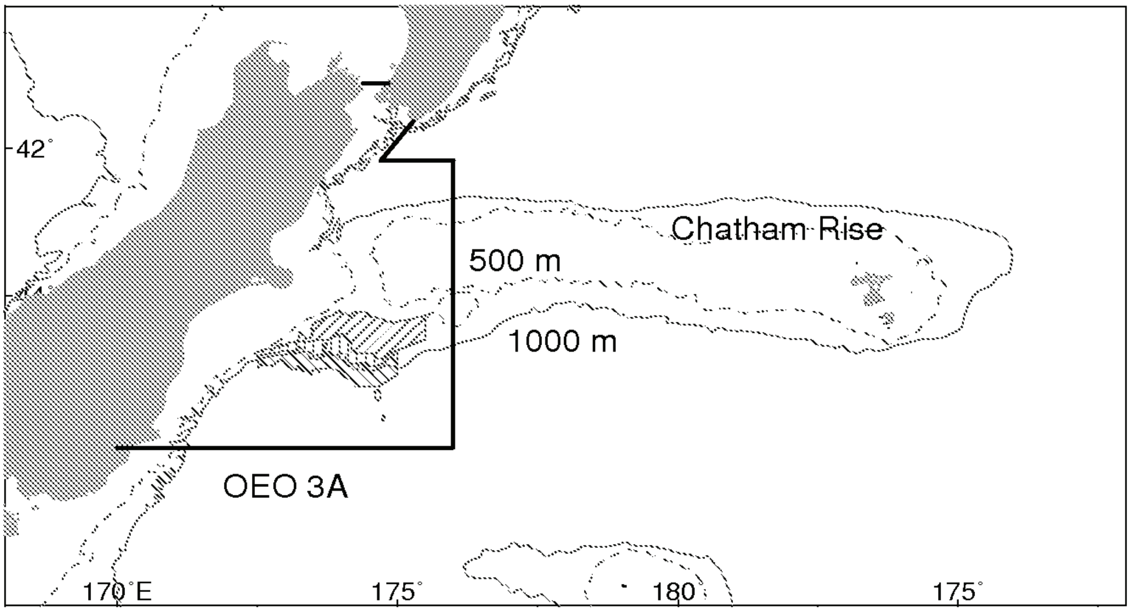

Figure 1: The three spatial areas used in the CASAL model and 2002 acoustic abundance survey. Area one at the top with right sloping shading; area two in the middle with vertical shading; area three at the bottom with left sloping shading. The thick dark line enclosed management area OEO 3A.

The boundary between areas 1 and 2 was defined in terms of the northern edge of the area that enclosed 90% of the total catch from the fishery. Thus, areas 2 and 3 contained most of the fishery while area 1 consisted of lightly fished and unfished ground. The boundary between areas 2 and 3 was defined by the 32.5 cm contour in mean fish length for data before 1993 so that the fishery is split into an area containing smaller fish and another that has larger fish. The population outside the main fishery was assumed to follow the same relative dynamics.

4.2.1 Estimates of fishery parameters and abundance

Catches by area

Catches were partitioned into the three areas by scaling up the estimated catch of black oreo from each area to the total reported catch (see Tables 2 and 3 in the Fishery Summary section at the beginning of the Oreos report) and are given in Table 2.

Table 2: Black oreo catch (t) for each fishing year in the three spatial model areas, rounded to the nearest 10 t.

Year	Total	Area 1	Area 2	Area 3	Year	Total	Area 1	Area 2	Area 3
1972–73	†3 440	110	2 010	1 320	1987–88	3 140	40	1 940	1 160
1973–74	†3 800	130	2 220	1 460	1988–89	3 230	170	2 490	570
1974–75	†5 100	170	2 970	1 960	1989–90	2 830	620	1 050	1 160
1975–76	†1 260	40	730	480	1990–91	4 770	890	2 310	1 580
1976–77	†3 880	130	2 260	1 490	1991–92	3 450	300	1 290	1 870
1977–78	†5 750	190	3 350	2 210	1992–93	4 960	230	2 810	1 920
1978–79	720	20	420	270	1993–94	4 160	340	2 510	1 320
1979–80	5 740	430	2 670	2 650	1994–95	2 400	120	1 560	720
1980–81	12 640	80	8 260	4 300	1995–96	3 760	200	2 530	1 030
1981–82	11 460	100	6 400	4 960	1996–97	3 750	450	2 190	1 110
1982–83	8 290	510	4 940	2 840	1997–98	1 600	170	590	840
1983–84	7 410	300	4 200	2 910	1998–99	3 290	160	2 450	680
1984–85	3 930	150	1 510	2 270	1999–00	4 070	160	2 780	1 120
1985–86	2 190	10	920	1 260	2000–01	2 960	100	2 010	850
1986–87	4 030	30	1 970	2 020	2001–02	2 250	60	1 530	660

† Soviet catch, assumed to be mostly from OEO 3A and to be 50:50 black oreo: smooth oreo.

Observer length frequencies by area

Catch at length data collected by observers in areas 1, 2, and 3 were extracted from the obs_lfs database. Within each area, groups of years were identified where each group spanned no more than five years. This procedure aimed to get adequate sample sizes to derive combined length frequencies and to use as much of the data as possible. Only one sample, from area 1 1995–96, was not included, (Table 3). Derived length frequencies for each group were calculated from the sample length frequencies weighted by the catch weight of each sample.

Research acoustic survey length frequencies by area

The revised 1997, and the new 2002 acoustic survey abundance at length data were converted to a length frequency using the combined sexes fixed length-weight relationship ("unsexed" in Table 1, Biology section above) to convert the abundance to numbers at length. Lengths below 25 cm and greater than 38 were pooled, Table 4.

Table 3: Number of observer commercial tows where black oreo was measured for length frequency. Excluded tows had less than 30 fish measured (13), extreme mean lengths (2) and missing catch information (3). –, no data.

Year	Number of tows in the length frequency					
	Area 1	Group no.	Area 2	Group no.	Area 3	Group no.
1978–79	–		–		–	
1979–80	–		9	1	35	1
1980–81	–		–		–	
1981–82	–		–		–	
1982–83	–		–		–	
1983–84	–		–		–	
1984–85	–		–		–	
1985–86	–		–		1	2
1986–87	–		2	2	6	2
1987–88	–		3	2	6	2
1988–89	3	1	32	2	7	2
1989–90	8	1	9	2	2	3
1990–91	1	1	5	2	8	3
1991–92	–		–		11	3
1992–93	–		–		–	
1993–94	–		22	3	4	4
1994–95	–		–	3	6	4
1995–96	1		3	3	3	4
1996–97	–		1	3	1	4
1997–98	13	2	–		7	4
1998–99	2	2	–		1	5
1999–00	2	2	52	4	57	5
2000–01	1	2	83	4	47	5
2001–02	–		18	4	14	5
2002–03	–		12	4	–	

Table 4: Length frequency proportions at length for the model area for the revised 1997 and 2002 acoustic surveys.

	1997			2002		
Length (cm)	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3
1–25	0.015	0.013	0.009	0.022	0.016	0.008
26	0.035	0.027	0.019	0.039	0.03	0.013
27	0.113	0.061	0.029	0.051	0.038	0.018
28	0.165	0.09	0.038	0.085	0.062	0.029
29	0.153	0.104	0.064	0.117	0.091	0.044
30	0.143	0.105	0.065	0.139	0.119	0.06
31	0.131	0.119	0.089	0.123	0.122	0.086
32	0.102	0.121	0.105	0.137	0.133	0.127
33	0.046	0.094	0.098	0.112	0.123	0.141
34	0.041	0.086	0.097	0.065	0.084	0.138
35	0.029	0.058	0.083	0.054	0.064	0.1
36	0.015	0.043	0.091	0.021	0.052	0.104
37	0.006	0.037	0.08	0.015	0.025	0.049
38–50	0.006	0.042	0.131	0.02	0.041	0.083

Absolute abundance estimates from the 1997 and 2002 acoustic surveys

Absolute estimates of abundance for black oreo are available from two acoustic surveys of oreos carried out from 10 November to 19 December 1997 (TAN9713) (Doonan et al., 1998, 1999b) and 25 September to 7 October 2002 (TAN0213). The 1997 survey covered the “flat” with a series of random north-south transects over six strata at depths of 600–1200 m. Seamounts were also sampled using parallel and “starburst” transects. Targeted and some random (background) trawling was carried out to identify targets and to determine species composition. The 1997 estimate used in the previous assessment was updated using revised estimates of target strength for smooth oreo, black oreo and some other species. The 2002 survey was limited to flat ground with 77 acoustic transect and 21 mark identification trawls completed. The estimated total abundance (immature plus mature) for each area is shown in Table 5.

Table 5: Total (immature plus mature) black oreo abundance estimates (t) for the 1997 (revised from the values used in the 2002 assessment) and 2002 acoustic surveys for the three model areas in OEO 3A.

Abundance (CV %)	Area 1	Area 2	Area 3	Total
1997	148 000 (29)	10 000 (26)	5240 (25)	163 000 (26)
2002	43 300 (31)	15 400 (27)	4710 (38)	64 000 (22)

Relative abundance estimates from standardised CPUE analysis

Standardised CPUE indices were obtained for each area. Because of the apparent changes in fishing practise attributable to the introduction of GPS, the data were split into pre- and post-GPS series. The catch and effort data were restricted to all tows that targeted or caught black oreo in OEO 3A up to and including the 2001–02 fishing year. Data were restricted to the spatial analysis study area and were included in the analyses if there were at least three years with more than 50 catches of black oreo. Data were excluded if only one vessel caught 80% or more of the black oreo catch in a year.

The basic analysis used a two-part model which separately analysed the tows that caught black oreo using a linear regression applied to log-transformed data, termed the log-linear regression (positive catch regression), and a binomial part which used a Generalised Linear Model with a logit link for the proportion of successful tows (zero catch regression). The log-linear and binomial index values for each year were multiplied together to give a combined index. The variables considered in the analyses included year, latitude, longitude, depth, season, time, target species, vessel, sun altitude and moon phase. The modified model incorporated an interaction term for year and area that enabled the CPUE from each of the three areas to be analysed. The method was also modified from the previous (2002) analysis to provide a unique index for each year by taking the means of the model predicted values for each combination of year and area for the model with a fishing year-area interaction term.
The following analyses were performed:

1. Analysis for area 1 used a single part model only (log-linear regression). No binomial model analysis was required because there were very few zero tows.
2. Analysis with year/area interaction was applied to areas 2 and 3 for pre- and post-GPS data separately. Two part (log-linear and binomial) models were employed for the pre-GPS series. The single part (log-linear) model was used for the post-GPS series because there was very little post-GPS target fishing for black oreo and therefore very few zero catch tows.

The analysis of area 1 had data from 1979–80, 1989–90, 1990–91 and 1995–96 to 1999–00 but the data from years prior to 1995–96 were poorly linked by common vessels fishing in both periods, so a CPUE index was only provided from 1995–96 onwards (Table 6). For Areas 2 and 3 the pre-GPS combined indices (log-linear and binomial) and the post-GPS log-linear model indices for each area using the modified model with year-area interaction are in Table 6.

Table 6: Summary of the OEO 3A black oreo pre-GPS and post-GPS time series of standardised catch per unit effort indices and jack-knife CV estimates (%). –, no estimate.

Fishing			Pre-GPS			Post-GPS
year	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3
1979–80	–	1.45 (39)	1.50 (125)	–	–	–
1980–81	–	1.84 (17)	2.52 (15)	–	–	–
1981–82	–	1.72 (22	2.13 (9)	–	–	–
1982–83	–	1.41 (8)	1.79 (14)	–	–	–
1983–84	–	0.98 (8)	1.02 (19)	–	–	–
1984–85	–	0.94 (27)	0.97 (12)	–	–	–
1985–86	–	0.63 (31)	0.68 (33)	–	–	–
1986–87	–	0.82 (22)	0.87 (36)	–	–	–
1987–88	–	0.47 (20)	0.48 (23)	–	–	–
1988–89	–	0.70 (21)	0.24 (44)	–	–	–
1989–90	–	–	–	–	–	–
1990–91	–	–	–	–	–	–
1991–92	–	–	–	–	–	–
1992–93	–	–	–	–	1.45 (28)	1.50 (42)
1993–94	–	–	–	–	1.84 (39)	2.52 (24)
1994–95	–	–	–	–	1.72 (12)	2.13 (22)
1995–96	–	–	–	0.95 (54)	1.41 (19)	1.79 (53)
1996–97	–	–	–	1.23 (32)	0.98 (16)	1.02 (21)
1997–98	–	–	–	0.93 (32)	0.94 (36)	0.97 (21)
1998–99	–	–	–	0.95 (38)	0.63 (46)	0.68 (29)
1999–00	–	–	–	1.19 (32)	0.82 (52)	0.87 (17)
2000–01	–	–	–	1.11 (41)	0.47 (82)	0.48 (62)
2001–02	–	–	–	0.73 (113)	0.70 (27)	0.24 (8)

4.2.2 Biomass estimates

A MCMC chain of 8000 was used which was derived from systematically sub-sampling every 1000th point after a burn-in of 860 iterations. The chain converged, but only after two parameters were set to their MPD values (i.e., age at 50% selection for the mid-water to area 1 migration, and ages for 50 to 95% selection in the area 1 to area 2 migration). The process errors in the acoustic and observer length frequencies were also set to their MPD values. Base case biomass estimates (medians of the posterior distribution) are in Table 7. The vulnerable biomass estimates are the same as the total biomass estimates in areas 2 plus 3.

Table 7: Base case biomass estimates (rounded to nearest 100 t). Vulnerable biomass is the sum of the total biomass in areas 2 and 3. All estimates are mid-year. – not estimated.

			Area 1			Area 2			Area 3
Biomass	B_0	B_{2003}	B_{2003}/B_0	B_0	B_{2003}	B_{2003}/B_0	B_0	B_{2003}	B_{2003}/B_0
Mature	71 600	68 400	96	40 500	11 600	29	47 700	3 100	7
Vulnerable	–	–	–	–	–	–	–	–	–
Total	92 100	88 200	96	42 000	12 600	30	47 800	3 200	7

			Total
Biomass	B_0	B_{2003}	B_{2003}/B_0
Mature	159 800	83 200	52
Vulnerable	89 800	15 800	18
Total	181800	104 000	57

The fits of the abundance estimates to the MPD solution of the base case are generally good (Figure 2), but they do not fit to the last year of the CPUE indices in areas 2 and 3, or to the acoustic estimates in area 1.

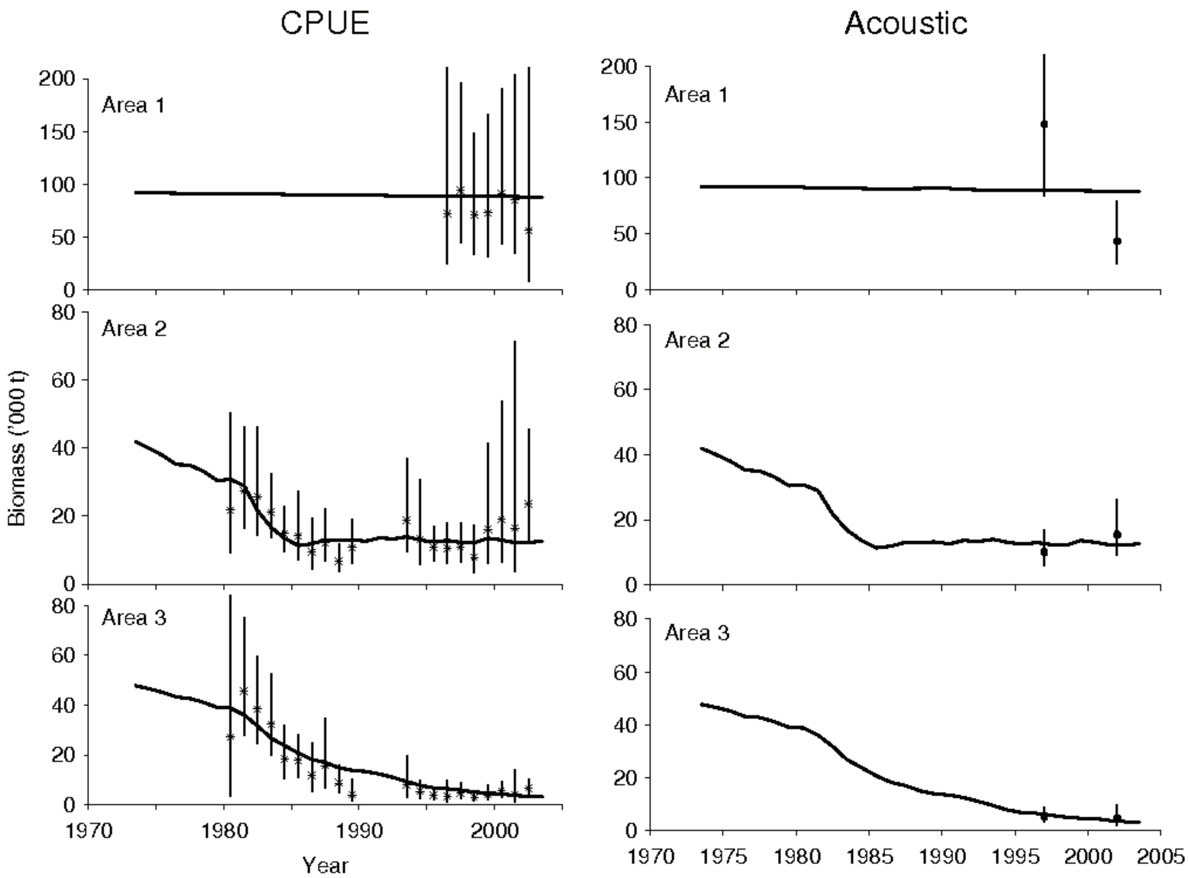

Figure 2: The fit of the abundance observations (CPUE and the absolute acoustic estimates) for each area to the predicted total biomass trajectories for the 2004 assessment of black oreo in OEO 3A (MPD solution, base case). The vertical lines are the 95% confidence intervals. The CPUE series were adjusted by their estimated catchability so that they are in absolute biomass units.

Biomass estimates from all the sensitivity runs were not substantially different from the base case, Table 8.

Table 8: Estimated mature $B_{2002–03}/B_0$ (%) for the MPD sensitivity runs. Runs were ranked (small values at the top) by summing the absolute percentage differences for each area for each run compared to the base case.

	Area 1	Area 2	Area 3
Base case	96	29	7
Estimate juvenile natural mortality	95	29	7
Treat area 1 acoustic absolute estimates as relative	96	28	7
Exclude post-GPS CPUE series	96	28	7
Migration rates: not age dependence	96	30	9
Exclude pre-GPS CPUE series	95	32	7
Add in trawl survey length frequencies (area 1)	95	28	4
Age and density dependent migration	95	20	7
Estimate mature fish M	97	37	6
Estimate recruitment deviates with 6 degrees of freedom	132	41	7
Estimate recruitment deviates	131	42	6

Comparison of the CASAL spatial model with previous stock assessments

The 1999 assessment used a single area, but both the SeaFIC and NIWA models were unable to explain some of the data (Table 9) and also produced conflicting assessment results. When stock assessment models cannot satisfactorily predict what appear to be valid observations for fish populations, it may be that the model is mis-specified, the observations are incorrect, or both. In response to these problems, a spatial model based on splitting the population into three areas was produced in 2002. This solved most of the problems with the 1999 assessment (Table 9) and was accepted. The 2004 model built on the 2002 model and solved more of the problems (Table 9) as well as using methods employed by NIWA for other recent oreo assessments, e.g., 2003 OEO 4 smooth oreo.

Table 9: The main problems with OEO 3A black oreo stock assessment models (1999, 2002, 2004). Yes –explained the data to an acceptable level. No - unable to explain the data to an acceptable level. NA, not applicable or not used.

Observation	1999 NIWA	1999 SeaFIC	2002	2004
Whole area				
Soviet CPUE declined steeper than the predicted biomass trajectory	No	NA	Yes	Yes
Annual length frequency switched from large to small fish and vice versa	No	No	Yes	Yes
Large acoustic abundance of small fish in area 1	No	No	Yes†	Yes
Spatial areas (1–3)				
Area 1 acoustic and observer length frequencies	NA	NA	No	Yes
Area 2 observer length frequencies	NA	NA	No	Yes
Area 3 observer length frequencies	NA	NA	No	Yes

† only when juvenile natural morality was estimated

The 2004 model produced more optimistic biomass estimates compared to the 2002 analysis. The more optimistic estimates appear to be due, in part, to density dependent migration being selected in the 2002 model.

Projections

Forward projections over the next five years were performed to determine the probability that the projected biomass would exceed the current biomass, the probability that the projected biomass would exceed 20%B_0, and the probability that the projected biomass would exceed B_{MSY} (which was interpreted as being 27%B_0). A catch split of 5%, 68%, and 27% was used for areas 1–3 respectively and recruitment variability (lognormal with $\sigma_r = 0.67$) and parameter variability were introduced. The probabilities for the base case projected under different catch levels are presented in Table 10.

Table 10: Probability that biomass in 5 years ($B_{2007–08}$) is greater than the reference biomass (20% and 27%B_0) and the median biomass in 5 years as a %B_0 ($Bmed_{2007–08}$) under different constant catch scenarios. The 2002–03 catch limit for black oreo in OEO 3A was 1855 t.

Annual catch (t)	P($B_{2007–2008}$>20%Bo)	P($B_{2007–2008}$>27%Bo)	$Bmed_{2007–08}$
(a) Mature biomass Areas 1–3			
1 000	1	1	56
1 500	1	1	55
1 855	1	1	54
2 000	1	1	54
2 500	1	1	52
3 000	1	1	51
(b) Vulnerable biomass (areas 2 & 3)			
1 000	1	0.06	24
1 500	0.88	0.01	22
1 855	0.65	0	21
2 000	0.51	0	20
2 500	0.15	0	18
3 000	0.03	0	16

4.2.4 Other factors

Yield estimates would be under-estimated if reported catch was less than the actual catch. Low reported catch could be caused by discarding of unwanted and small fish, particularly black oreo in the early days of the fishery and also by lost bags. Estimates of discards of oreos were made for 1994–95 and 1995–96 from MFish observer data and were 207 and 270 t, respectively. Estimates of discards at other times were not made but may have been substantial for black oreo in the mid 1980s. Yield estimates may also be under-estimated if there was a change over time in the proportion of oreo catch that was not reported.

4.3 Smooth oreo

2009 assessment

The stock assessment analyses were conducted using the CASAL age-structured population model employing Bayesian statistical techniques. The 2005 assessment was updated by including five more years of catch, CPUE and observer length data, and used two new series of post-GPS standardised CPUE, one before and the second after major TACC and catch limit changes. The modelling took account of the sex and maturity status of the fish and treated OEO 3A as a single smooth oreo fishery, i.e., no sub-areas were recognised. The base case model used the 1997 absolute acoustic abundance estimate, pre-GPS and early and late post-GPS series of standardised CPUE indices, and the mean natural mortality estimate (0.063 yr^{-1}). Acoustic and observer length frequencies were used in a preliminary model run to estimate selectivity and the base case fixed these selectivity estimates but did not use the length frequencies. Other cases investigated the sensitivity of the model to data sources including: use of the upper and lower 95% confidence interval values for estimates of natural mortality (0.042–0.099 yr^{-1}); use of only the left hand limb of the 1994 observer length frequency (plus the 1997 acoustic survey length frequency) with growth not estimated by the model.

4.3.1 Estimates of fishery parameters and abundance

Catch history

The estimated catches were scaled up to the total reported catch (see Tables 2 and 3 in the Fishery Summary section at the beginning of the Oreos report) and are given in Table 11.

Table 11: Reconstructed catch history (t)

Year	Catch	Year	Catch	Year	Catch	Year	Catch
1972–73	†3 440	1981–82	1 288	1990–91	5 054	1999–00	1 789
1973–74	†3 800	1982–83	2 495	1991–92	6 622	2000–01	1 621
1974–75	†5 100	1983–84	3 979	1992–93	4 334	2001–02	1 673
1975–76	†1 260	1984–85	4 351	1993–94	4 942	2002–03	1 412
1976–77	†3 880	1985–86	3 142	1994–95	4 199	2003–04	1 254
1977–78	†5 750	1986–87	3 190	1995–96	4 022	2004–05	1 457
1978–79	650	1987–88	5 905	1996–97	3 239	2005–06	1 445
1979–80	5 215	1988–89	6 963	1997–98	4 733	2006–07	1 306
1980–81	2 196	1989–90	6 459	1998–99	2 474	2007–08	1 526

† Soviet catch, assumed to be mostly from OEO 3A and to be 50 : 50 black oreo : smooth oreo.

Observer length frequencies

Observer length data were extracted from the observer database. These data represent proportional catch at length and sex. All length samples were from the CPUE study area (see Figure 4). Only samples where 30 or more fish were measured, and the catch weight and a valid depth were recorded, were included in the analysis. Data from adjacent years were pooled because of the paucity of data in some years. The pooled length frequencies were applied in the model at the year that the median observation of the grouped samples was taken (Table 12).

Table 12: Observer length frequencies; numbers of length samples (tows sampled), number of fish measured, groups of pooled years, and the year that the length data were applied in the stock assessment model. –, not applicable.

Year	Number of length samples	Number of fish measured	Year group code	Year the grouped data were applied
1979–80	32	3 499	1	Applied
1980–81	0	0	–	–
1981–82	0	0	–	–
1982–83	0	0	–	–
1983–84	0	0	–	–
1984–85	0	0	–	–
1985–86	1	106	2	–
1986–87	4	387	2	–
1987–88	10	1 300	2	Applied
1988–89	14	1 512	2	–
1989–90	0	0	–	–
1990–91	26	2 978	3	Applied
1991–92	9	919	3	–
1992–93	0	0	–	–
1993–94	13	1 365	4	Applied
1994–95	7	752	4	–
1995–96	2	207	4	–
1996–97	3	365	5	–
1997–98	13	1 720	5	–
1998–99	5	770	5	–
1999–00	77	7 595	5	Applied
2000–01	93	9 389	6	Applied
2001–02	20	3 030	7	Applied
2002–03	14	1 427	8	Applied
2003–04	4	321	8	–
2004–05	9	840	8	–
2005–06	26	3 207	9	Applied
2006–07	2	205	9	–
2007–08	8	816	9	–

Length frequency data from the 1997 acoustic survey

Length data collected during the 1997 survey were used to generate a population length frequency by sex. A length frequency was generated from the trawls in each mark-type and also for the seamounts. These frequencies were combined using the fraction of smooth oreo abundance in each mark-type. The overall frequency was normalised over both male and female frequencies so that the sum of the frequencies over both sexes was 100%. The c.v. for each length class was given by the regression, log(c.v.) = 0.86 + 8.75/log(proportion). This regression was estimated from the c.v.s obtained by bootstrapping the data and provides a smoothed estimate of the c.v.s. The estimated length frequency is in Figure 3.

Absolute abundance estimates from the 1997 acoustic survey

Absolute estimates of abundance for smooth oreo are available from the acoustic survey on oreos carried out from 10 November to 19 December 1997 (TAN9713) using the same approach as described for OEO 3A black oreo. The abundance estimates used in the 1999 OEO 3A smooth oreo assessment were revised in 2005 using new target strength estimates for smooth oreo, black oreo and a number of bycatch species. The revised estimate was 25 200 t with a c.v. of 23% (1999 estimate was 35 100 t with c.v. of 27%). There is uncertainty in the estimates of biomass because the acoustic estimate includes smooth oreo in layers that are a mixture of species for which the acoustic method has potential bias problems.

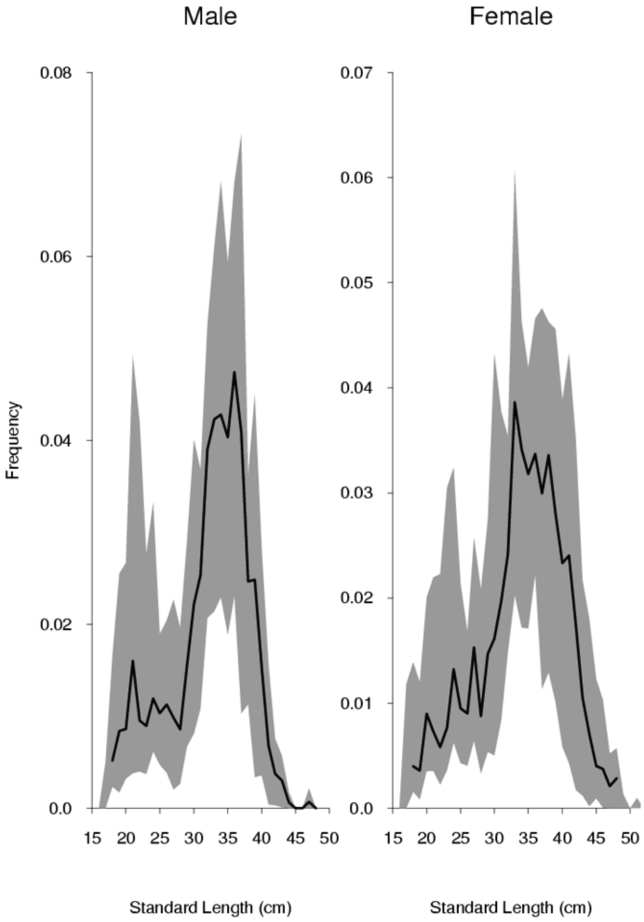

Figure 3: Population length frequency derived from the 1997 acoustic survey data. The bold line is the estimated value and the shaded area is the spread from 300 bootstraps.

Relative abundance estimates from standardised CPUE analysis

The CPUE study area is shown in Figure 4. Three analyses were carried out; a pre-GPS analysis (unchanged from 2005) that included data from 1980–81 to 1988–89 and two new post-GPS analyses that included data from 1992–93 to 1997–98 and 2002–03 to 2007–08. The years from 1998–99 to 2001–02 were not included because a voluntary smooth oreo of catch limit (1400 t) was introduced and substantial oreo TACC reductions were made during that time (6600 to 3100 t). The pre-GPS series trends down, and declines to approximately a third of the initial level over the nine-year period. The early post-GPS trends down but the late post-GPS series trends up and flattens. The base case stock assessment used all three indices (Table 13).

Table 13: CPUE indices by year and jackknife c.v. (%) estimates from the pre-GPS and the two post-GPS analyses.

		Pre-GPS						Post-GPS
Year	Index	c.v.	Year	Index	c.v.	Year	Index	c.v.
1980–81	1.00	27	1992–93	1.00	24	2002–03	0.55	23
1981–82	0.82	26	1993–94	0.88	11	2003–04	0.77	22
1982–83	0.72	62	1994–95	0.74	14	2004–05	0.99	22
1983–84	0.59	61	1995–96	0.48	17	2005–06	0.96	31
1984–85	0.72	22	1996–97	0.56	15	2006–07	1.00	20
1985–86	0.61	19	1997–98	0.50	19	2007–08	0.92	21
1986–87	0.46	16						
1987–88	0.42	16						
1988–89	0.26	28						

Fishing Industry members of the Deepwater Fishery Assessment Working Group expressed concern about the accuracy of the historical Soviet catch and effort data (pre-GPS series) and felt that it was inappropriate to use those data in the stock assessment.

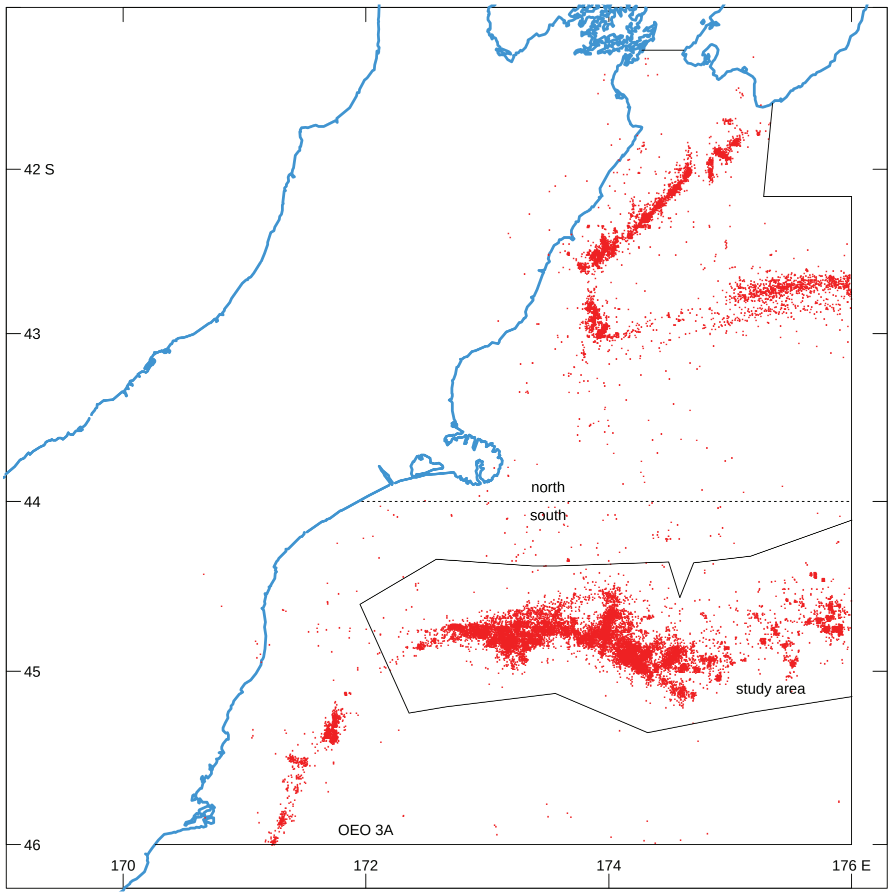

Figure 4: Locations of all tows in OEO 3A with a reported catch of smooth oreo from 1979–80 to 2002–03 (dots). The study area is shown along with the line chosen to split north from south Chatham rise catches.

4.3.2 Biomass estimates

The posterior distributions from the MCMC on the base case are shown in Figure 5. The probability that the current mature biomass (2008–09) and the biomass 5 years out (2013–14) are above 20% B_0 is 1 for both.

Biomass estimates derived from the MCMC are in Table 14. Total mature biomass for 2008–09 was estimated to be 36% of the initial biomass (B_0). Sensitivity case results for the base case using the lower and upper 95% confidence interval value estimates for M gave estimates of current biomass between 26% and 49% of B_0. The sensitivity case that used the left hand limb of the 1994 observer length frequency (plus the 1997 acoustic survey length frequency) with growth not estimated by the model gave estimates of current biomass for the mean estimate of M (0.063 yr^{-1}) of 30 % of B_0 while estimates using the lower and upper 95% confidence interval value estimates for M gave estimates of current biomass between 12% and 59% of B_0.

Projections were carried out for 5 years with the current catch limit of 1400 t. The trajectory shows increasing biomass (Figure 5).

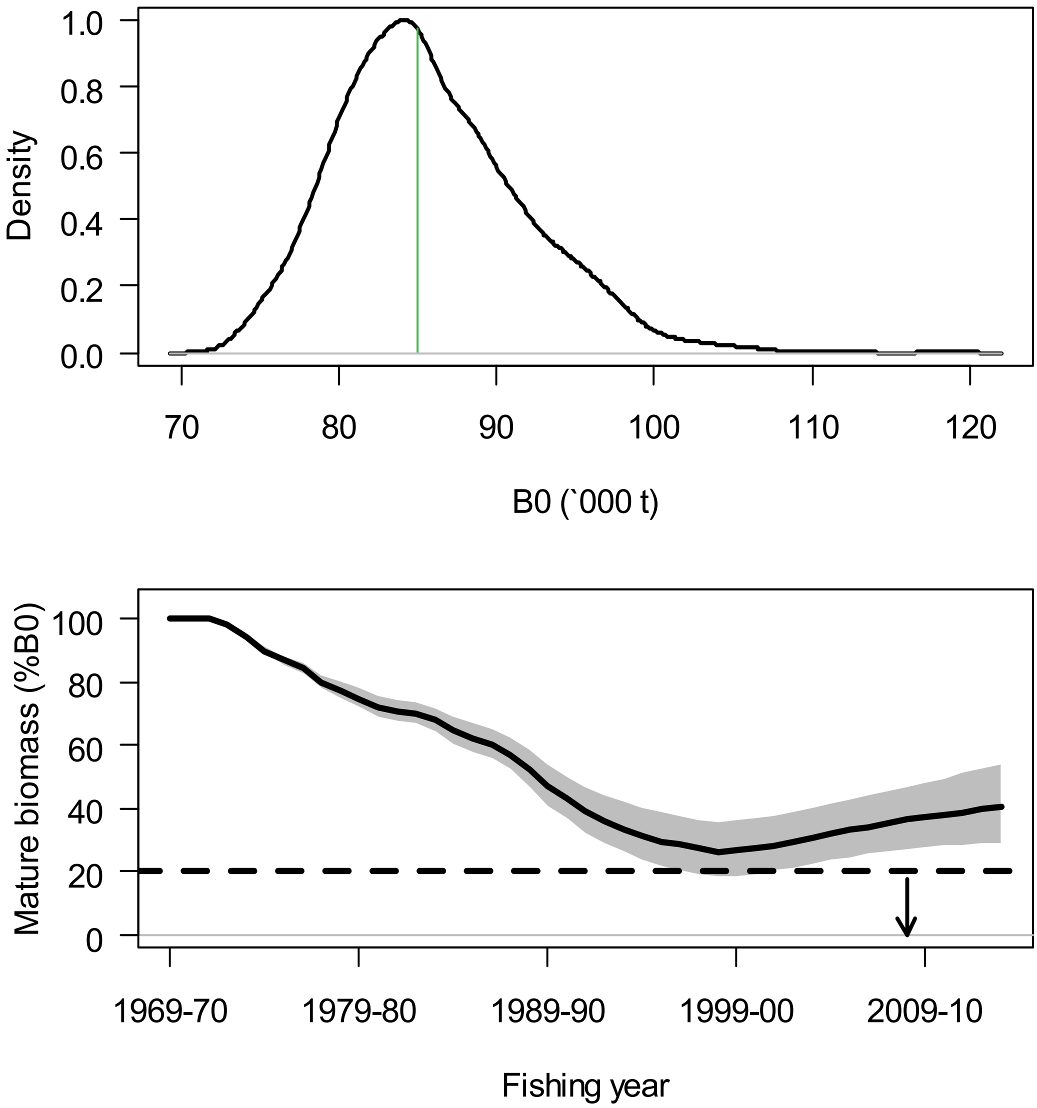

Figure 5: Smooth oreo OEO 3A: posterior distribution for the virgin biomass (top plot) and the mature biomass trajectories as a percentage of virgin biomass (bottom plot) from the MCMC analysis of the "NoLF" case with M = 0.063 (base case). In the top plot, the vertical line is the median of the distribution. In the bottom plot, the grey area is the point-wise 95% confidence intervals of the trajectories and the solid line is the median.

Table 14: Base case (bold) and sensitivity (†) case biomass estimates.

	M=0.063			†M=0.042			†M=0.099		
	Median	**CI.05**	**CI.95**	Median	CI.05	CI.95	Median	CI.05	CI.95
B_0	**85 000**	**77 300**	**96 500**	97 700	90 100	110 000	68 500	60 300	79 600
B_cur	**30 900**	**22 400**	**43 000**	26 300	18 000	38 800	33 800	25 000	45 500
B_cur(%B_0)	**36**	**29**	**45**	27	20	35	49	41	57

Left hand limb of the 1994 observer length frequency (plus the 1997 acoustic survey length frequency) with growth not estimated by the model:

	†M=0.063			†M=0.042			†M=0.099		
	Median	CI.05	CI.95	Median	CI.05	CI.95	Median	CI.05	CI.95
B_0	77 400	74 800	80 200	82 800	81 600	84 200	82 300	76 700	89 200
B_cur	23 100	19 900	26 400	10 200	8 480	12 100	48 800	42 900	56 200
B_cur(%B_0)	30	27	33	12	10	14	59	56	63

4.3.3 Other factors

Because of differences in biological parameters between the species, it would be appropriate to split the current TACC for black oreo and smooth oreo. The WG noted that separate species catch limits are in place to reduce the risk of over- or under-fishing either smooth oreo or black oreo.

The model estimates of uncertainty are unrealistically low. Uncertainties that are not included in the model include:

- the assumption that recruitment is deterministic
- the acoustic index is assumed to be an absolute estimate of abundance
- the selectivity in the base case is fixed at the MPD estimate from the preliminary case where all length data is used
- uncertainty in the estimate of M.

In addition, the growth is fixed and known, while the selectivity . The WG has previously noted the impact of the different ages of maturity for males and females. Due to the fact that males mature at a much smaller size than females (age at 50% maturity is 18–19 years for males and 25–26 for females), the sex ratio needs to be taken into account when assessing the sustainability of any particular catch level.

5. STATUS OF THE STOCKS

The smooth oreo stock assessment was updated in 2009. The black oreo stock assessment is unchanged from 2004.

5.1 Black oreo, OEO 3A

The current and virgin biomass for black oreo in OEO 3A were estimated using a CASAL spatial stock assessment. Total mature biomass for 2002–03 was estimated to be 52% of the initial biomass (B_0), which is greater than B_{MSY} (27%B_0). However, the size of the current biomass relative to initial biomass is not equal across the three sub-areas, with Areas 2 and 3 being 29% and 7% of their respective mature equilibrium virgin biomass levels while Area 1 is estimated to be at 96%. There is uncertainty in the estimates of biomass in Area 1 because the acoustic estimate is based on black oreo in layers that are a mixture of species for which the acoustic method has potential bias problems.

Five year projections to estimate future mature and vulnerable biomass were carried out at different constant annual catches assuming the current catch split between areas. An annual catch of 1885 t, the likely maximum catch of black oreo for the fished areas (areas 2 and 3), given the current management arrangements, gave a 100% probability that mature biomass would be greater than both 20% B_0 and 27%B_0 (B_{MSY}). The corresponding probabilities for vulnerable biomass are a 65 % probability that it would be greater than 20% B_0 and a 0 % probability that it would be greater than 27 %B_0 (B_{MSY}). The difference between the mature and vulnerable biomass status is a consequence of the current stock assessment that estimates a large biomass of mature black oreo in area 1 that is not fished.

Model biomass estimates are uncertain because of a range of factors, including sensitivity to the target strength of black oreo, uncertainty in the estimates of M, and the assumption that recruitment is deterministic.

5.2 Smooth oreo, OEO 3A

This assessment was updated in 2009. Total mature biomass for 2008–09 was estimated to be 36% (29–45 % 95% confidence interval) of the initial biomass (B_0). The projections showed that biomass should increase at catch levels of 1400 t over the next 5 years.

Model biomass estimates are uncertain because of a range of factors, including the assumption that recruitment is deterministic, that the acoustic index is assumed to be an absolute estimate of abundance, uncertainty in the estimates of M, and the sex ratio of the mature biomass (see section 4.3.3 “Other factors” above).

OEO 3A: Summary of estimated catch (t) for the most recent fishing year. Estimated catch was scaled to the reported oreo landings for each fishstock using the reported estimated catch of black or smooth oreo from Tables 2 and 3 of the Fishery Summary section at the beginning of the Oreos report. Reported landings and TACCs for both oreo species combined are in Table 2 of the Fishery Summary section at the beginning of the Oreos report.

Species	2007–08 estimated catch
Black oreo	1 566
Smooth oreo	1 526

6. FOR FURTHER INFORMATION

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