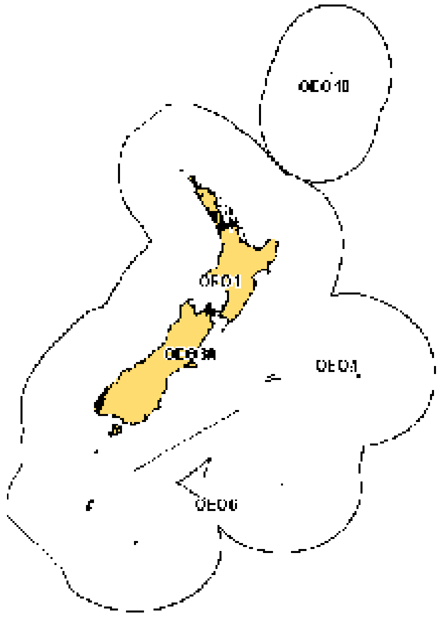
OREOS (OEO)

(*Allocyttus niger*, *Neocyttus rhomboidalis* and *Pseudocyttus maculatus*)



1. INTRODUCTION

The main black oreo and smooth oreo fisheries have been assessed separately and individual reports produced for each as follows:

1. OEO 3A black oreo and smooth oreo
2. OEO 4 black oreo and smooth oreo
3. OEO 1 and OEO 6 black oreo and smooth oreo

2. BIOLOGY

Black oreo

Occurs from 600 to 1300 m depth. The geographical distribution south of about 45° S is not well known. It is a southern species and is abundant on the south Chatham Rise, along the east coast of the South Island, the north and east slope of Pukaki Rise, the Bounty Platform, the Snares slope, Puysegur Bank and the northern end of the Macquarie Ridge. They probably occur right round the slope of the Campbell Plateau.

Spawning occurs from late October to at least December and is widespread on the south Chatham Rise. Mean length at maturity for females, estimated from Chatham Rise trawl surveys (1986–87, 1990, 1991–93) using macroscopic gonad staging, is 34 cm TL.

They appear to have a pelagic juvenile phase, but little is known about this phase because only about 12 fish less than 21 cm TL have been caught. The pelagic phase may last for 4–5 years to lengths of 21–26 cm TL.

Unvalidated age estimates were obtained for Chatham Rise and Puysegur-Snares fish in 1995 and 1997 respectively using counts of the zones (assumed to be annual) observed in thin sections of otoliths. These estimates indicate that black oreo is slow growing and long lived. Maximum estimated age was 153 years (45.5 cm TL fish). Australian workers used the same methods, i.e., sections of otoliths, and reported similar results.

A von Bertalanffy growth curve was fitted to the Puysegur samples only (Table 1). Estimated age at maturity for females was 27 years.

A first estimate of natural mortality (M), 0.044 (yr^{-1}), was made in 1997 using the Puysegur growth data only. This estimate is uncertain because it appeared that the otolith samples were taken from a well fished part of the Puysegur area.

Black oreo appear to settle over a wide range of depths on the south Chatham Rise, but appear to prefer to live in the depth interval 600–800 m that is often dominated by individuals with a modal size of 28 cm TL.

Smooth oreo

Occurs from 650 to about 1500 m depth. The geographical distribution south of about 45° S is not well known. It is a southern species and is abundant on the south Chatham Rise, along the east coast of the South Island, the north and east slope of Pukaki Rise, the Bounty Platform, the Snares slope, Puysegur Bank and the northern end of the Macquarie Ridge. They probably occur right round the slope of the Campbell Plateau.

Spawning occurs from late October to at least December and is widespread on the south Chatham Rise in small aggregations. Mean length at maturity for females, estimated from Chatham Rise trawl surveys (1986–87, 1990, 1991–93) using macroscopic gonad staging, is 40 cm TL.

They appear to have a pelagic juvenile phase, but little is known about this phase because only about six fish less than 16 cm TL have been caught. The pelagic phase may last for 5–6 years to lengths of 16–19 cm TL.

Unvalidated age estimates were obtained for Chatham Rise and Puysegur-Snares fish in 1995 and 1997 respectively using counts of the zones (assumed to be annual) observed in thin sections of otoliths. These estimates indicate that smooth oreo is slow growing and long lived. Maximum estimated age was 86 years (51.3 cm TL fish). Australian workers used the same methods, i.e., sections of otoliths, and reported similar results.

A von Bertalanffy growth curve was fitted to the age estimates from Chatham Rise and Puysegur-Snares fish combined and the parameters estimated for the growth curve are in Table 1. Estimated age at maturity for females was 31 years.

An estimate of natural mortality, 0.063 (yr^{-1}), was made in 1997. The estimate was from a moderately exploited population of fish from the Puysegur region. The Puysegur fishery started in 1989–90 and by August-September 1992 (when the otoliths were sampled) about 24% of the smooth oreo catch from 1989–90 to 1995–96 had been taken. Future estimates of M should, if possible, be made from an unexploited population.

There are concentrations of recently settled smooth oreo south and south west of Chatham Island, although small individuals (16–19 cm TL) occur widely over the south Chatham Rise at depths of 650–800 m.

Table 1: Biological parameters used for black oreo and smooth oreo stock assessments. –, not estimated.

Parameter	Symbol (unit)	Female	Male	Unsexed
(a) Black oreo				
Natural mortality	M (yr^{-1})	0.044	0.044	0.044
Age at recruitment	A_r (yr)	–	–	–
Age at maturity	A_m (yr)	27	–	–
von Bertalanffy parameters	L¥ (cm, TL)	39.9	37.2	38.2
	k (yr^{-1})	0.043	0.056	0.05
	t_0 (yr)	-17.6	-16.4	-17.0
Length–weight parameters	a	0.008	0.016	0.0078
	b	3.28	3.06	3.27
Length at recruitment	(cm, TL)	–	–	–
Length at maturity	(cm, TL)	34	–	–
Recruitment variability	σ_R	0.65	0.65	0.65
Recruitment steepness		0.75	0.75	0.75
Fishing mortality	F_{max} (yr^{-1})	0.9	0.9	–
Max exploitation rate	E_{max} (yr^{-1})	–	–	0.67
(b) Smooth oreo				
Natural mortality	M (yr^{-1})	0.063	0.063	
Age at recruitment	A_r (yr)	21	21	
Age at maturity	A_m (yr)	31	–	
von Bertalanffy parameters	L¥ (cm, TL)	50.8	43.6	
	k (yr^{-1})	0.047	0.067	
	t_0 (yr)	-2.9	-1.6	
Length–weight parameters	a	0.029	0.032	
	b	2.90	2.87	
Length at recruitment	(cm, TL)	34	–	
Length at maturity	(cm, TL)	40	–	
Recruitment variability	σ_R	0.65	0.65	
Recruitment steepness		0.75	0.75	
Fishing mortality	F_{max} (yr^{-1})	0.9	0.9	

3. STOCKS AND AREAS

Black oreo

Stock structure of Australian and New Zealand samples was examined using genetic (allozyme and mitochondrial DNA) and morphological counts (fin rays, etc.). It was concluded that the New Zealand samples constituted a stock distinct from the Australian sample based on “small but significant difference in mtDNA haplotype frequencies (with no detected allozyme differences), supported by differences in pyloric caeca and lateral line counts”. The genetic methods used may not be suitable tools for stock discrimination around New Zealand.

A New Zealand pilot study examined stock relationships using samples from four management areas (OEO 1, OEO 3A, OEO 4 & OEO 6) of the New Zealand EEZ. Techniques used included genetic (nuclear and mitochondrial DNA), lateral line scale counts, settlement zone counts, parasites, otolith microchemistry, and otolith shape. Lateral line scale and pyloric caeca counts were different between samples from OEO 6 and the other three areas. The relative abundance of three parasites differed significantly between all areas. Otolith shape from OEO 3A samples was different to that from OEO 1 and OEO 4, but OEO 1, OEO 4 and OEO 6 otolith samples were not morphologically different. Genetic, otolith microchemistry, and settlement zone analyses showed no regional differences.

Smooth oreo

Stock structure of Australian and New Zealand samples was examined using genetic (allozyme and mitochondrial DNA) and morphological counts (fin rays, etc.). No differences between New Zealand and Australian samples were found using the above techniques. A broad scale stock is suggested by these results but this seems unlikely given the large distances between New Zealand and Australia. The genetic methods used may not be suitable tools for stock discrimination around New Zealand.

A New Zealand pilot study examined stock relationships using samples from four management areas (OEO 1, OEO 3A, OEO 4 & OEO 6) of the New Zealand EEZ. Techniques used included genetic (nuclear and mitochondrial DNA), lateral line scale counts, settlement zone counts, parasites, otolith microchemistry, and otolith shape. Otolith shape from OEO 1 and OEO 6 was different to that from OEO 3A and OEO 4 samples. Weak evidence from parasite data, one gene locus and otolith microchemistry suggested that northern OEO 3A samples were different from other areas. Lateral line scale and otolith settlement zone counts showed no differences between areas.

These data suggest that the stock boundaries given in previous assessment documents should be retained until more definitive evidence for stock relationships is obtained, i.e., retain the areas OEO 1, OEO 3A, OEO 4, and OEO 6 (see the figure on the first page of the Oreos assessment report above).

The three species of oreos (black oreo, smooth oreo and spiky oreo) are managed as if they were one stock. Each species could be managed separately. They have different depth and geographical distributions, different stock sizes, rates of growth, and productivity.

4. FISHERY SUMMARY

(a) Commercial fisheries

Commercial fisheries occur for black oreo (BOE) and smooth oreo (SSO). Oreos are managed as a species group, which includes spiky oreo (SOR). The Chatham Rise (OEO 3A and OEO 4) is the main fishing area, but other fisheries occur off Southland on the east coast of the South Island (OEO 1/OEO 3A), and on the Pukaki Rise, Macquarie Ridge, and Bounty Plateau (OEO 6).

Total reported landings of oreos and TACs are shown in Table 2. Total oreo catch from OEO 4 exceeded the TAC from 1991–92 to 1994–95 and was close to the TAC from 1995–96 to 1999–00 (Table 2). Catch remained high in OEO 4 while the orange roughy fishery has declined. The OEO 4 TAC was reduced from 7000 to 5460 in 2001–02 but was restored to 7000 t in 2003–04. The oreo catch from OEO 3A was less than the TAC from 1992–93 to 1995–96, substantially so in 1994–95 and 1995–96. The OEO 3A TAC was reduced from 10 106 to 6600 t in 1996–97. A voluntary agreement between the fishing industry and the Minister of Fisheries to limit catch of smooth oreo from OEO 3A to 1400 t of the total oreo TAC of 6600 t was implemented in 1998–99. Subsequently the total OEO 3A TAC was reduced to 5900 t in 1999–00, 4400 in 2000–01, 4095 in 2001–02 and 3255 t in 2002–03. Catch from the Subantarctic area (OEO 6) increased substantially in 1994–95 and exceeded the TAC in 1995–96. The OEO 6 TAC was increased from 3000 to 6000 t in 1996–97. There was also a voluntary agreement not to fish for oreos in the Puysegur area which started in 1998–99. OEO 1 was fished under the adaptive management programme up to the end of 1997–98. The OEO 1 TAC reverted back to pre-adaptive management levels from 1998–99.

Reported estimated catches by species from tow by tow data recorded in catch and effort logbooks (Deepwater, TCEPR, and CELR) and the ratio of estimated to landed catch reported are given in Table 3. There was an increase in the amount of catch reported as "OEO" (species not specified) in catch effort statistics dating from the introduction of changes to the QMS in 1988–89.

Table 2: Total reported landings (t) for all oreo species combined by Fishstock from 1978–79 to 2004–05 and TACs (t) from 1982–83 to 2004–05.

Fishing	FISHSTOCK OEO 1		OEO 3A		OEO 4		OEO 6		Totals	
year	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1978–79*	2 808	–	1 366	–	8 041	–	17	–	12 231	–
1979–80*	143	–	10 958	–	680	–	18	–	11 791	–
1980–81*	467	–	14 832	–	10 269	–	283	–	25 851	–
1981–82*	21	–	12 750	–	9 296	–	4 380	–	26 514	–
1982–83*	162	–	8 576	10 000	3 927	6 750	765	–	13 680	17 000
1983–83#	39	–	4 409	#	3 209	#	354	–	8 015	#
1983–84†	3 241	–	9 190	10 000	6 104	6 750	3 568	–	22 111	17 000
1984–85†	1 480	–	8 284	10 000	6 390	6 750	2 044	–	18 204	17 000
1985–86†	5 390	–	5 331	10 000	5 883	6 750	126	–	16 820	17 000
1986–87†	532	4 000	7 222	10 000	6 830	6 750	0	3 000	15 093	24 000
1987–88†	1 193	4 000	9 049	10 000	8 674	7 000	197	3 000	19 159	24 000
1988–89†	432	4 233	10 191	10 000	8 447	7 000	7	3 000	19 077	24 233
1989–90†	2 069	5 033	9 286	10 106	7 348	7 000	0	3 000	18 703	25 139
1990–91†	4 563	5 033	9 827	10 106	6 936	7 000	288	3 000	21 614	25 139
1991–92†	4 156	5 033	10 072	10 106	7 457	7 000	33	3 000	21 718	25 139
1992–93†	5 739	6 044	9 290	10 106	7 976	7 000	815	3 000	23 820	26 160
1993–94†	4 910	6 044	9 106	10 106	8 319	7 000	983	3 000	23 318	26 160
1994–95†	1 483	6 044	6 600	10 106	7 680	7 000	2 528	3 000	18 291	26 160
1995–96†	4 783	6 044	7 786	10 106	6 806	7 000	4 435	3 000	23 810	26 160
1996–97†	5 181	6 044	6 991	6 600	6 962	7 000	5 645	6 000	24 779	25 644
1997–98†	2 681	6 044	6 336	6 600	7 010	7 000	5 222	6 000	21 249	25 644
1998–99†	4 102	5 033	5 763	6 600	6 931	7 000	5 287	6 000	22 083	24 633
1999–00†	3 711	5 033	5 859	5 900	7 034	7 000	5 914	6 000	22 518	23 933
2000–01†	4 852	5 033	4 577	4 400	7 358	7 000	5 932	6 000	22 719	22 433
2001–02†	4 197	5 033	3 923	4 095	4 864	5 460	5 737	6 000	18 721	20 588
2002–03†	3 034	5 033	3 070	3 255	5 402	5 460	6 115	6 000	17 621	19 748
2003–04†	1 703	5 033	2 856	3 255	6 735	7 000	5 811	6 000	17 105	21 288
2004–05†	1 025	5 033	3 061	3 255	7 390	7 000	5 744	6 000	17 220	21 288

Source: FSU from 1978–79 to 1987–88; QMS/MFish from 1988–89 to 2004–05. *, 1 April to 31 March. #, 1 April to 30 September. Interim TACs applied. †, 1 October to 30 September. Data prior to 1983 were adjusted up due to a conversion factor change.

Table 3: Reported estimated catch (t) by species (smooth oreo (SSO), black oreo (BOE) by Fishstock from 1978–79 to 2004–05 and the ratio (percentage) of the total estimated SSO plus BOE, to the total reported landings (from Table 1). –, less than 1.

	SSO				BOE				Total	Estimated:
Year	OEO 1	OEO 3A	OEO 4	OEO 6	OEO 1	OEO 3A	OEO 4	OEO 6	estimated	landings (%)
1978–79*	0	0	0	0	9	0	0	0	9	–
1979–80*	16	5 075	114	0	118	5 588	566	18	11 495	98
1980–81*	1	1 522	849	2	66	8 758	5 224	215	16 637	64
1981–82*	21	1 283	3 352	2	0	11 419	5 641	4 378	26 096	98
1982–83*	28	2 138	2 796	60	6	6 438	1 088	705	13 259	97
1983–83#	9	713	1 861	0	1	3 693	1 340	354	7 971	100
1983–84†	1 246	3 594	4 871	1 315	1 751	5 524	1 214	2 254	21 769	99
1984–85†	828	4 311	4 729	472	544	3 897	1 651	1 572	18 004	99
1985–86†	4 257	3 135	4 921	72	1 060	2 184	961	54	16 644	99
1986–87†	326	3 186	5 670	0	163	4 026	1 160	0	14 531	96
1987–88†	1 050	5 897	7 771	197	114	3 140	903	0	19 072	100
1988–89†	261	5 864	6 427	–	86	2 719	1 087	0	16 444	86
1989–90†	1 141	5 355	5 320	–	872	2 344	439	–	15 471	83
1990–91†	1 437	4 422	5 262	81	2 314	4 177	793	222	18 708	87
1991–92†	1 008	6 096	4 797	2	2 384	3 176	1 702	15	19 180	88
1992–93†	1 716	3 461	3 814	529	3 768	3 957	1 326	69	18 640	78
1993–94†	2 000	4 767	4 805	808	2 615	4 016	1 553	35	20 599	88
1994–95†	835	3 589	5 272	1 811	385	2 052	545	230	14 719	81
1995–96†	2 517	3 591	5 236	2 562	1 296	3 361	364	1 166	20 093	84
1996–97†	2 203	3 063	5 390	2 492	2 578	3 549	530	1 950	21 755	88
1997–98†	1 510	4 790	5 868	2 531	1 027	1 623	811	1 982	20 142	95
1998–99†	2 958	2 367	5 613	3 462	820	3 147	844	1 231	20 442	93
1999–00†	2 533	1 733	5 985	4 306	970	3 943	628	1 043	21 142	94
2000–01†	4 012	1 648	5 924	4 183	332	3 005	799	1 128	21 031	93
2001–02†	2 973	1 769	3 806	4 470	697	2 378	515	983	17 591	94
2002–03†	2 521	1 395	4 105	3 941	481	1 636	868	1 640	16 587	94
2003–04†	1 046	1 244	5 082	3 767	458	1 590	973	1 496	15 656	92
2004–05†	665	1 447	5 848	3 840	234	1 594	851	1 580	16 059	93

Source: FSU from 1978–79 to 1987–88 and MFish from 1988–89 to 2004–05
* 1 April to 31 March. # ,1 April to 30 September. † ,1 October to 30 September.

Descriptive analyses of the main New Zealand oreo fisheries were updated with data from 2004–05 in 2006. The standardised CPUE analysis of black oreo in OEO 3A was updated in 2003. A new smooth oreo OEO 3A standardised CPUE analysis was developed in 2004. Standardised analyses of OEO 4 black oreo were carried out for the 2000 stock assessment and were updated in 2001. Standardised analyses of OEO 4 smooth oreo were updated in 2003. Standardised analyses of the main fisheries in OEO 1 and OEO 6 were developed in 2001. A new standardised CPUE analysis of Pukaki Rise smooth oreo was developed in 2006.

(b) Recreational fisheries

There are no known recreational fisheries for black oreo and smooth oreo.

(c) Maori customary fisheries

There is no known Maori customary fishing for black oreo and smooth oreo.

(d) Illegal catch

Estimates of illegal catch are not available.

(e) Other sources of mortality

Dumping of unwanted or small fish and accidental loss of fish (lost codends, ripped codends, etc.) were features of oreo fisheries in the early years. These sources of mortality were probably substantial in those early years but are now thought to be relatively small. No estimate of mortality from these sources has been made because of lack of hard data and because they now appear to be small. Estimates of discards of oreos were made for 1994–95 and 1995–96 from MFish observer data. This involved calculating the ratio of discarded oreo catch to retained oreo catch and then multiplying the annual total oreo catch from the New Zealand EEZ by this ratio. Estimates were 207 and 270 t for 1994–95 and 1995–96 respectively.

5. FOR FURTHER INFORMATION

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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

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.

Black oreo

The assessment was unchanged from 2004. That assessment used an acoustic absolute abundance estimate (and associated length and biological data) made from a survey carried out in 2002. The assessment used the NIWA CASAL software and Bayesian statistical techniques in line with the 2003 assessment of OEO 4 smooth oreo and replaced the 2002 NIWA assessment.

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.

Smooth oreo

An assessment of smooth oreo in OEO 3A was completed in 2005 and replaced the 1999 assessment. 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 relative abundance indices from a new standardised catch per unit effort analysis.

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 midwater 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 c.v.s 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 (midwater only), the c.v. of the length-at-age, migration parameters to move fish from midwater 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 midwater 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 c.v. (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).

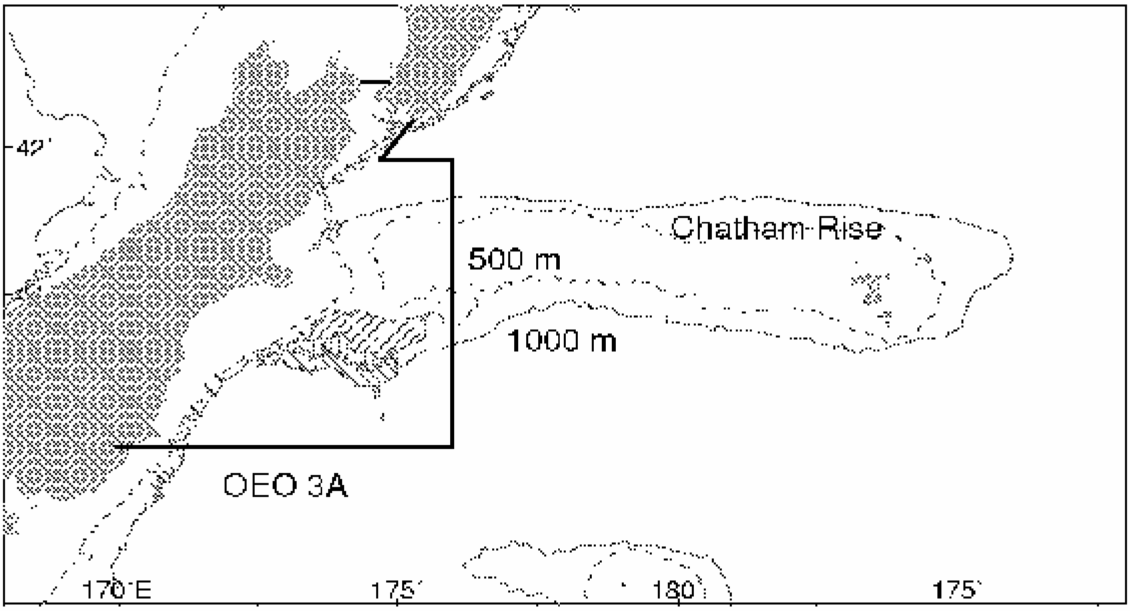

Figure 1: The three spatial areas used in the CASAL model and 2002 acoustic abundance survey. Area one at the top with right sloping shading; area two in the middle with vertical shading; area three at the bottom with left sloping shading. The thick dark line enclosed management area OEO 3A.

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.

(a) 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.

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	–	

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 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	0.030	0.013
27	0.113	0.061	0.029	0.051	0.038	0.018
28	0.165	0.090	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	0.060
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	0.100
36	0.015	0.043	0.091	0.021	0.052	0.104
37	0.006	0.037	0.080	0.015	0.025	0.049
38–50	0.006	0.042	0.131	0.020	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 (c.v., %)	Area 1	Area 2	Area 3	Total
1997	148 000 (29)	10 000 (26)	5 240 (25)	163 000 (26)
2002	43 300 (31)	15 400 (27)	4 710 (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 c.v. 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)

(b) 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			Total		
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	B_0	B_{2003}	B_{2003}/B_0
Mature	71 600	68 400	96	40 500	11 600	29	47 700	3 100	7	159 800	83 200	52
Vulnerable	–	–	–	–	–	–	–	–	–	89 800	15 800	18
Total	92 100	88 200	96	42 000	12 600	30	47 800	3 200	7	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.

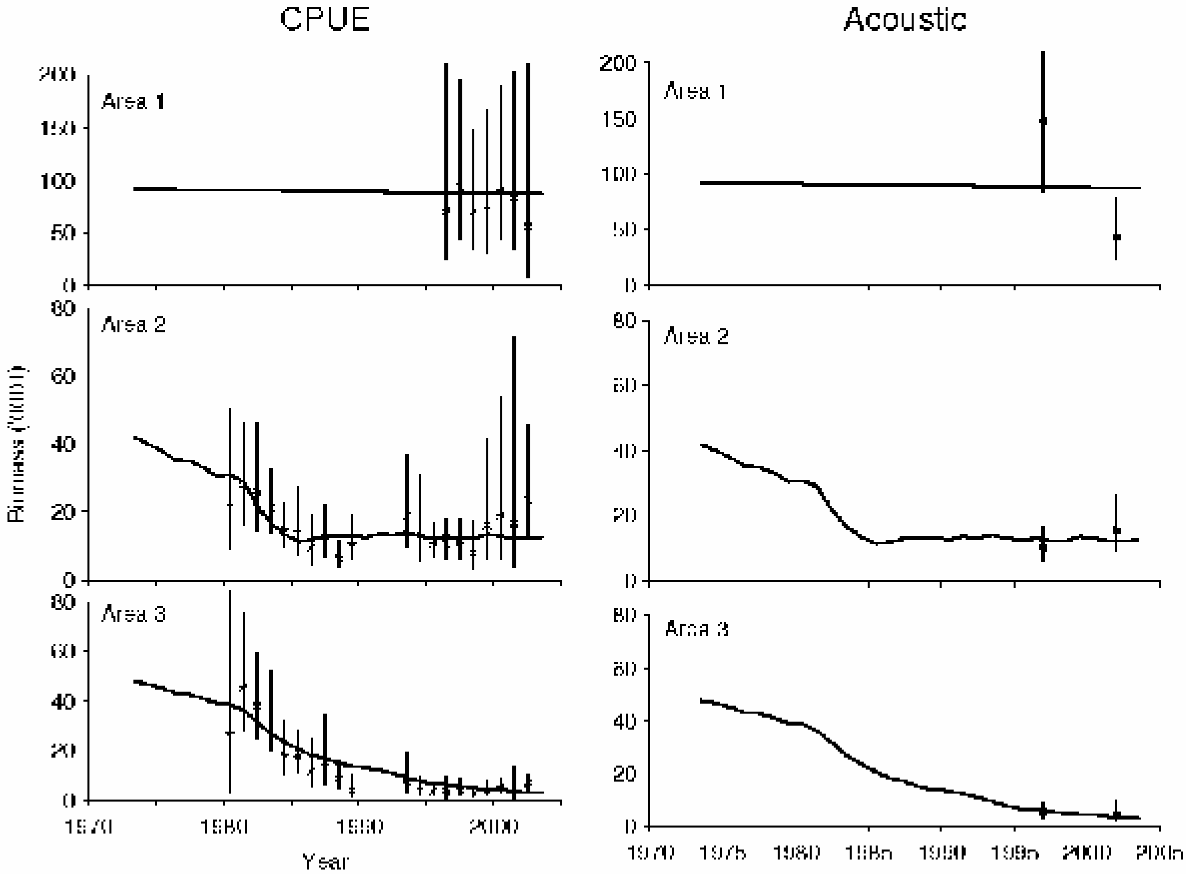

Figure 2: The fit of the abundance observations (CPUE and the absolute acoustic estimates) for each area to the predicted total biomass trajectories for the 2004 assessment of black oreo in OEO 3A (MPD solution, base case). The vertical lines are the 95% confidence intervals. The CPUE series were adjusted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

(c) 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%Bo, and the probability that the projected biomass would exceed B_{MSY} (which was interpreted as being 27%Bo). 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			
1000	1.0	1.0	56
1500	1.0	1.0	55
1855	1.0	1.0	54
2000	1.0	1.0	54
2500	1.0	1.0	52
3000	1.0	1.0	51
(b) Vulnerable biomass (areas 2 & 3)			
1000	1.0	0.06	24
1500	0.88	0.01	22
1855	0.65	0	21
2000	0.51	0	20
2500	0.15	0	18
3000	0.03	0	16

(d) 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

2005 assessment

The stock assessment analyses were conducted using the CASAL age-structured population model employing Bayesian statistical techniques. Changes compared to previous assessments included new pre- and post-GPS standardised CPUE analyses and the inclusion of observer and acoustic survey length data in the population model. 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 subareas were recognised.

(a) 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	1980–81	2 196	1988–89	6 963	1996–97	3 239
1973–74	†3 800	1981–82	1 288	1989–90	6 459	1997–98	4 733
1974–75	†5 100	1982–83	2 495	1990–91	5 054	1998–99	2 474
1975–76	†1 260	1983–84	3 979	1991–92	6 622	1999–00	1 789
1976–77	†3 880	1984–85	4 351	1992–93	4 334	2000–01	1 621
1977–78	†5 750	1985–86	3 142	1993–94	4 942	2001–02	1 673
1978–79	650	1986–87	3 190	1994–95	4 199	2002–03	1 412
1979–80	5 215	1987–88	5 905	1995–96	4 022	2003–04	‡1 410

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

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 3). Only samples where the catch weight was available and where a valid depth was 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 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	15	1 540	2	–
1989–90	0	0	–	–
1990–91	28	3 029	3	Applied
1991–92	9	919	3	–
1992–93	0	0	–	–
1993–94	24	1 454	4	Applied
1994–95	8	778	4	–
1995–96	2	207	4	–
1996–97	3	365	5	–
1997–98	13	1 720	5	–
1998–99	5	770	5	–
1999–00	82	7 700	5	Applied
2000–01	97	9 450	6	Applied
2001–02	22	3 068	7	–
2002–03	25	1 667	7	Applied

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(cv) = 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.

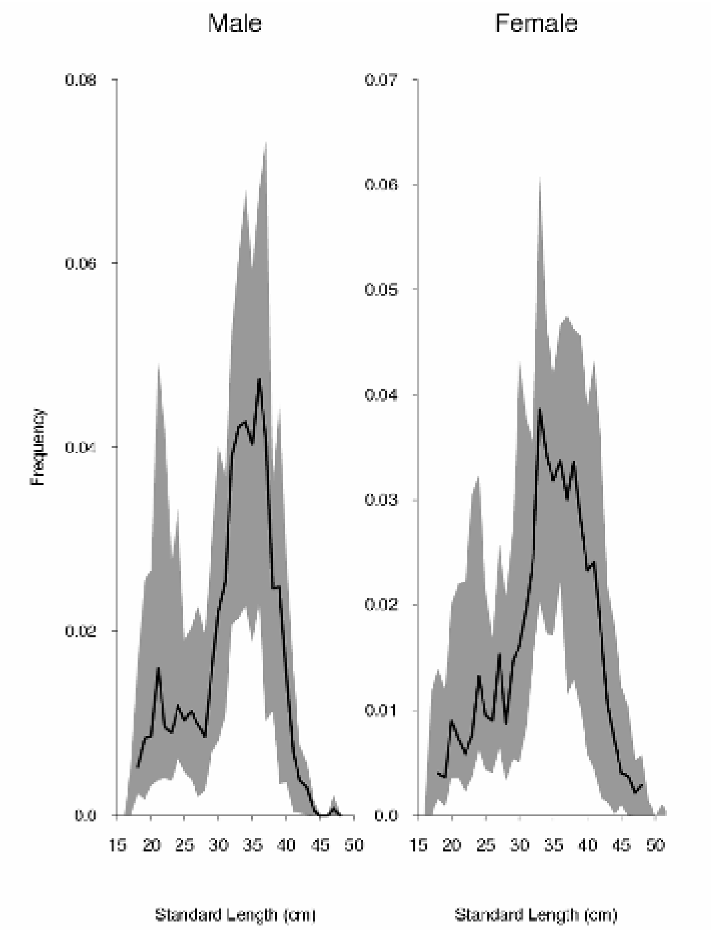

Figure 3: Population length frequency derived from the 1997 acoustic survey data. The bold line is the estimated value and the shaded area is the spread from 300 bootstraps.

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 previous OEO 3A smooth oreo assessment were revised using new target strength estimates for smooth oreo, black oreo and a number of by-catch species. The new estimate was 25 200 t with a c.v. of 23% (previously 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.

Relative abundance estimates from standardised CPUE analysis

The CPUE study area is shown in Figure 4. Two analyses were carried out; a pre-GPS analysis that included data from 1980–81 to 1988–89 and a post-GPS analysis that included data from 1992–93 to2002–03. The pre-GPS indices trend down, are fairly linear, and decline to approximately a third of the initial level over the eight-year period. The post-GPS indices trend downward from the start of the series to 2000–01 declining to approximately a third of the initial level over these eight years. Since 2000–01 the trend is upward to nearly match the initial year in 2002–03. The base case stock assessment analysis used the indices from both the pre- and post-GPS series (Table 15).

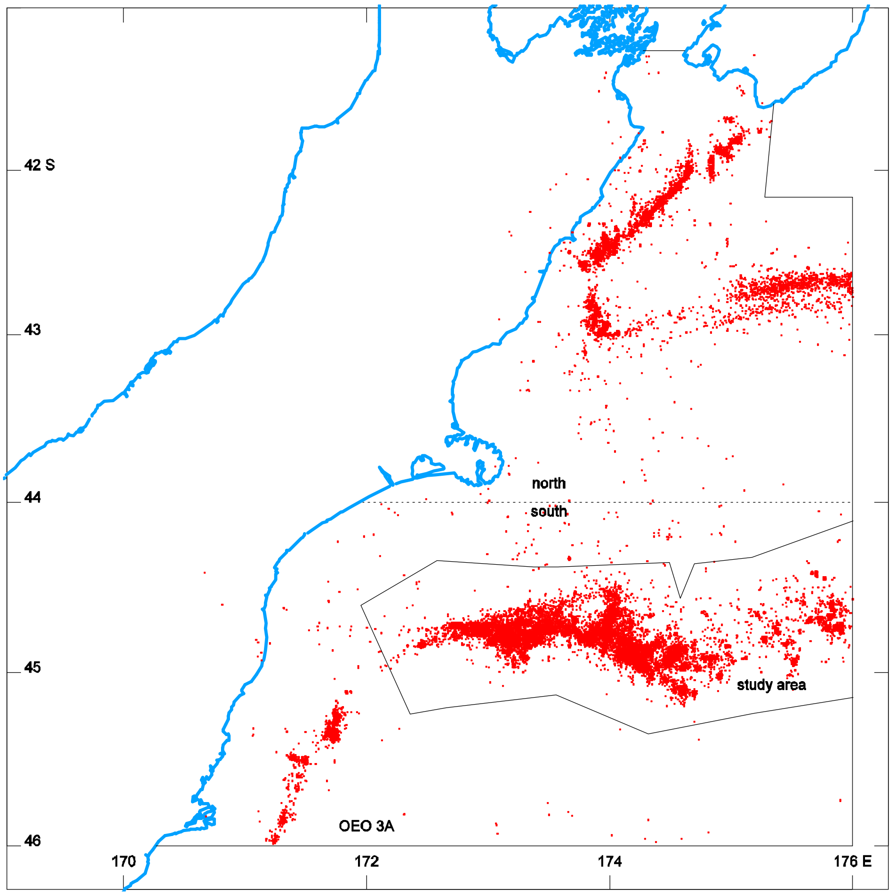

Figure 4: Locations of all tows in OEO 3A with a reported catch of smooth oreo from 1979–80 to 2002–03 (dots). The study area is shown along with the line chosen to split north from south Chatham rise catches.

Table 15: CPUE indices by year and jackknife c.v. estimates from the pre-GPS and the post-GPS analyses.

	Pre-GPS			Post-GPS	
	CPUE	Jackknife cv %		CPUE	Jackknife cv %
1980–81	1.00	27	1992–93	1.00	35
1981–82	0.82	26	1993–94	0.93	47
1982–83	0.72	62	1994–95	0.76	81
1983–84	0.59	61	1995–96	0.55	53
1984–85	0.72	22	1996–97	0.61	67
1985–86	0.61	19	1997–98	0.69	25
1986–87	0.46	16	1998–99	0.53	18
1987–88	0.42	16	1999–00	0.46	42
1988–89	0.26	28	2000–01	0.36	16
			2001–02	0.52	18
			2002–03	0.81	33

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.

(b) Biomass estimates

The Markov Chain Monte Carlo analysis for the base case produced a total chain length of 38 million. The first 5 million points were discarded (burn-in) and then every 10 000th point was retained. Convergence diagnostics were run on the resulting sample of 3300 points. Autocorrelations, and single chain convergence tests were applied to the chain to test for non-convergence. The tests showed that the MCMC runs converged.

The fit of the basecase biomass trajectory (MPD solution) to the abundance estimates is satisfactory (Figure 5).

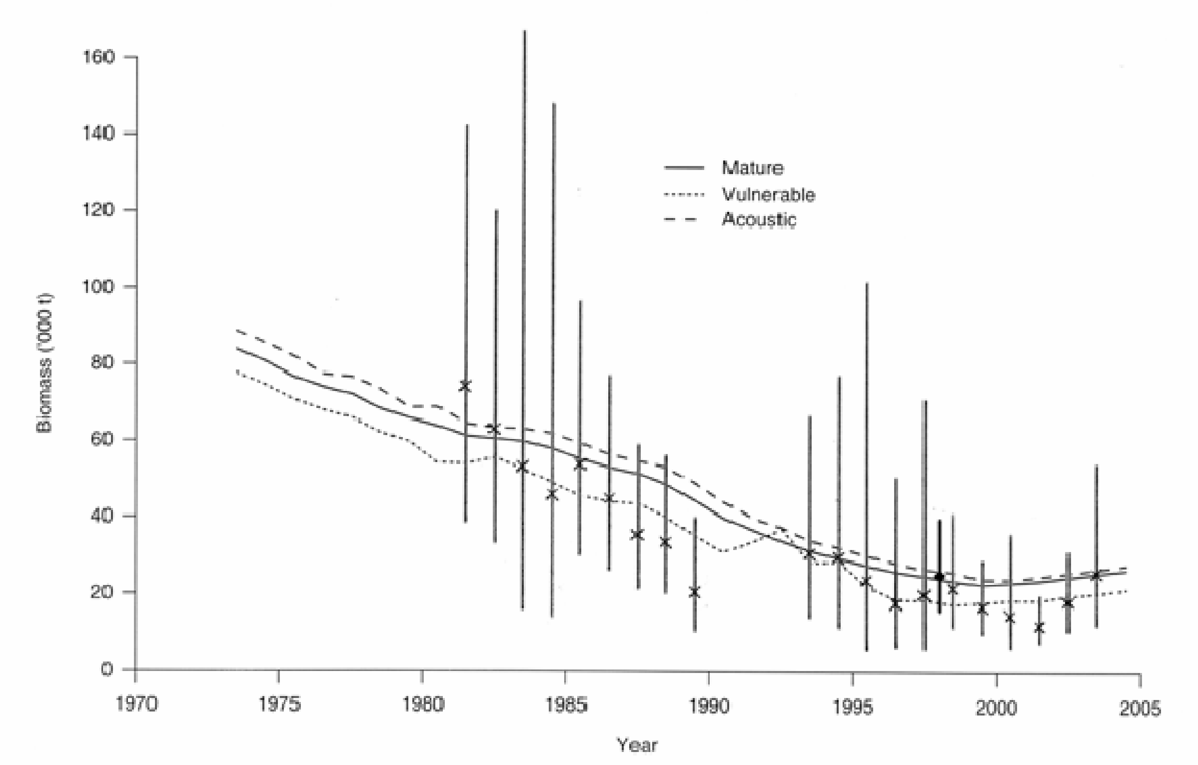

Figure 5: Smooth oreo 3A: fit of the abundance observations, CPUE (Xs), and the absolute acoustic estimate (®), to the predicted total biomass trajectories (MPD base case). The vertical lines are the 95% confidence intervals. The CPUE series were adjusted by their estimated catchability so that they are in absolute biomass units.

A random sample of 1000 points from the MCMC was used to derive estimates of biomass (Table 16). Total mature biomass for 2003–04 was estimated to be 29% of the initial biomass (B_0), which is greater than B_{MAY} (25%B_0). Several sensitivities were conducted for MPD runs only. Except for two cases all gave estimates of current biomass between 27% and 36% of virgin biomass. When CPUE data only was included biomass was much lower (12% B_0); when acoustic data only was included current stock status was higher (47%B_0).

Table 16: Basecase biomass and yield estimates.

Mature biomass estimates (t)

Smooth oreo 3A	Median	90% C.I.
Virgin biomass	81 000	77 000–86 000
2003–04 mid-year	24 000	19 000–29 000
2003–04 mid-year/B_0 (%)	29	25–33
	Mean	
B_{MAY}	20 400‡	
B_{MAY} /B_0(%)	25‡	

‡ mid-year mature biomass.

(c) Projections

Forward projections over the next five years were performed to determine the probability that the projected biomass would exceed 20%B_0, and the probability that the projected biomass would exceed B_{MAY} (25% B_0). Recruitment variability (lognormal with σ_r = 0.67) and parameter variability were considered (1000 random draws from the posterior distribution). The probabilities for the base case projected under different catch levels are presented in Table 17.

Table 17: Probability that the mature biomass in 5 years ($B_{2008–09}$) is greater than the reference biomass (20% and 25%B_0) and the median biomass in 5 years as a %B_0 ($Bmed_{2008–09}$) under different constant catch scenarios. The 2003–04 catch limit for smooth oreo in OEO 3A was 1400 t.

Annual catch (t)	$P(B_{2008–2009}>20\%B_0)$	$P(B_{2008–2009}>25\%B_0)$	$Bmed_{2008–09}$ (%)
1 000	1	1	36
1 400	1	1	35
2 000	1	1	32
2 500	1	0.98	30
3 000	1	0.87	28
4 000	0.93	0.32	24

(d) 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 that might be caused by the application of a single TACC to separate species in OEO 3A.

Model biomass estimates are uncertain because of a range of factors, including sensitivity to the target strength of black oreo and uncertainty in the estimates of M. However, the Plenary considered that for smooth oreo the model underestimates uncertainty. The lack of uncertainty results from model assumptions that recruitment is deterministic, and that the acoustic index can be considered as an absolute estimate of abundance. In addition, the Plenary 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. The sex ratio information will be investigated more fully inter-sessionally.

5. STATUS OF THE STOCKS

Black oreo, OEO 3A

Current and virgin biomass for black oreo in OEO 3A were estimated using a CASAL spatial stock assessment which estimated higher levels of stock status than the 2002 assessment for the same Fishstock. 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 B_0 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.

Smooth oreo, OEO 3A

The most recent assessment was completed in 2005. Total mature biomass for 2003–04 was estimated to be 29% of the initial biomass (B_0), which is greater than B_{MAY} (25%B_0). Five-year projections to estimate future mature biomass were carried out at different constant annual catches. An annual catch of 1400 t, the maximum catch of smooth oreo under the current management arrangements, gave a 100% probability that mature biomass would be greater than both 20% B_0 and 25%B_0 (B_{MAY}) to 2008–09.

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 sex ratio of the mature biomass (see section 4.3d "Other factors" above). The Plenary considered that the model underestimates uncertainty.

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	2004–05 estimated catch
Black oreo	1 605
Smooth oreo	1 457

6. FOR FURTHER INFORMATION

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OREOS – OEO 4 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

4.1 Introduction

Black oreo

The assessment was updated by NIWA in 2000 but not included in this report until 2001. This was the first stock assessments for OEO 4 that included the results from the 1998 acoustic survey.

Smooth oreo

Assessments were developed by NIWA and SeaFIC in 2003. The assessments included revised abundance estimates from the 1998 and new estimates from the 2001 acoustic surveys.

NIWA assessments of black oreo and smooth oreo

The following assumptions were made in the stock assessment analyses carried out to estimate biomasses and yields.

(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 4. 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. (Smooth oreo growth was estimated by the model).
(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 analyses of black oreo and smooth oreo below.
(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 4 were discrete stocks or production units.
(h) The catch histories were accurate.

SeaFIC assessment of smooth oreo

An assessment was conducted by SeaFIC in 2002 but was not reported. This assessment was repeated in 2003 with modified input data, but the catch and the CPUE data were not updated to include data from the 2001–02 commercial fishery.

The following assumptions were made in the stock assessment analyses carried out to estimate biomasses and yields for smooth oreo.
(a) The acoustic abundance estimates were unbiased absolute values.
(b) The CPUE analyses provided indices of abundance for smooth oreo in the whole of OEO 4.
(c) An assumed value (0.95) was used for maximum allowed harvest rate.
(d) Recruitment was deterministic and followed a Beverton & Holt relationship with steepness of 0.75.
(e) Catch overruns were 0% during the period of reported catch.
(f) The catch histories were accurate.

4.2 Black oreo

NIWA assessment

Biomass estimates were made in 2000 using a stock reduction analysis incorporating deterministic recruitment, acoustic absolute abundance estimates from the 1998 survey, relative abundance estimates from new standardised CPUE analyses, relative abundance indices from the south Chatham Rise *Tangaroa* trawl surveys (1991–93 and 1995), life history parameters from Table 1 of the Biology section at the beginning of the Oreos report, and catch history.

(a) <u>Estimates of fishery parameters and abundance</u>

Absolute abundance estimates from the 1998 acoustic survey

Absolute estimates of abundance were available from an acoustic survey on oreos which was carried out from 26 September to 30 October 1998 on *Tangaroa* (voyage TAN9812). Transects on flat ground were surveyed to a stratified random design and a random sample of seamounts were surveyed with either a random transect (large seamounts) or a systematic “star” transect design. For some seamounts the flat ground nearby was also surveyed to compare the abundance of fish on and near the seamount either by extending the length of the star transects or by extra parallel transects. Acoustic data were collected concurrently for flat and seamounts using both towed and hull mounted transducers. The OEO 4 survey covered 59 transects on the flat and 29 on seamounts. A total of 95 tows was carried out for target identification and to estimate target strength and species composition. In situ and swimbladder samples for target strength data were collected and these have yielded revised estimates of target strength for both black oreo and smooth oreo.

Acoustic abundance estimates for recruit black oreo from seamounts and flat for the whole of OEO 4 are in Table 1. About 59% of the black oreo abundance came from the background mark-type. This mark-type is not normally fished by the commercial fleet and this implies that the abundance estimate did not cover the fish normally taken by the fishery. In addition the scaling factor to convert the acoustic area estimate to the trawl survey area estimate was 4.3, i.e., the acoustic survey area only had about 23% of the abundance. The magnitude of this ratio suggests that the size of the area surveyed was borderline for providing a reliable abundance estimate.

Table 1: OEO 4 recruit black oreo seamount, flat, and total acoustic abundance estimates (t) and recruit c.v. (%) based on knife-edge recruitment (23 years).

	Abundance (t)	c.v. (%)
Seamount	127	91
Flat	13 800	56
Total	13 900	55

Relative abundance estimates from standardised CPUE analyses

The CPUE analysis method was the same as that used for analyses of standardised CPUE for black oreo in OEO 3A and involved regression based methods where the zero catch tow and the positive catch tow data were analysed separately to produce positive catch and zero catch indices. For target fishing a combined index (positive catch and zero catch indices) was calculated. Only the positive catch index was calculated for analysis of bycatch data because the zero catch index was only important for target fishing. The mean c.v.s for the combined and positive indices (all years) were estimated using a jackknife technique. Data were divided into those from target fishing or from catch taken as bycatch during target fishing for other species, e.g., orange roughy; pre- and post-global positioning system (GPS) time periods, 1979–80 to 1988–89 and 1992–93 to 1998–99 respectively.

Two (of four) potential analyses were chosen where data were adequate and because target was preferred over bycatch analyses (Table 2).

Table 2: OEO 4 black oreo standardised CPUE analyses. Overall c.v.s of 66 and 104% were calculated for the target and bycatch series respectively.

	Index	c.v.
(a) Target pre-GPS combined index and jackknife c.v. (%)		
1980–81	2.80	122.0
1981–82	2.72	94.8
1982–83	1.02	68.1
1983–84	1.00	0.0
1984–85	0.64	60.8
1985–86	0.46	127.0
1986–87	0.41	63.4
(b) Bycatch post-GPS positive index and jackknife c.v. (%)		
1992–93	1.32	39.2
1993–94	1.31	75.4
1994–95	1.00	0.0
1995–96	0.63	88.1
1996–97	0.95	45.9
1997–98	0.63	39.2
1998–99	0.37	332.0

Relative abundance estimates from trawl surveys

The estimates, and their c.v.s, from the four standard *Tangaroa* south Chatham Rise trawl surveys were treated as relative abundance indices (Table 3).

Table 3: OEO 4 black oreo research survey abundance estimates (t). N is the number of stations. Estimates were made using knife-edge recruitment set at 33 cm TL. Previously knife-edge recruitment was set at 27 cm and estimates of abundance based on that value are also provided for comparison.

	Mean abundance		c.v. (%)	N
	27 cm	33 cm		
1991	34 407	13 065	40	105
1992	29 948	12 839	46	122
1993	20 953	6 515	30	124
1995	29 305	9 238	30	153

(b) Biomass estimates

The stock assessment of OEO 4 black oreo was considered unreliable and was not accepted because:

1. The acoustic abundance estimate is uncertain. The acoustic survey was aimed at smooth oreo and consequently the black oreo areas in OEO 4 received only minimal coverage. The estimate of recruit abundance is low and is largely based on background abundance, where the acoustic method performed poorly, rather than from black oreo schools. The poor coverage of black oreo areas by the

acoustic survey was compensated by multiplying the acoustic survey area abundance by a scaling factor of 4.3 (based on research surveys) to make the estimate equivalent to the trawl survey area and then by a further 1.06 to estimate a total abundance for OEO 4. In addition only small acoustic abundance estimates were made from the seamounts which suggests that either black oreo abundance on seamounts was low or the estimate was biased low.

2. The CPUE abundance estimates are uncertain. There is only a small fishery for black oreo in OEO 4 (about 1100 t per year from 1989–90 to 1998–99) with target fishing largely confined to the west end during the late 1980s and early 1990s.

No estimates of biomass are reported because they were considered unreliable.

(c) Estimation of Maximum Constant Yield (MCY)

MCY was estimated using the equation, MCY = c^*Y_{av} (Method 4). There was no trend in the annual catches, nominal CPUE, or effort from 1982–83 to 1987–88 so that period was used to calculate the MCY estimate (1200 t).

(d) Estimation of Current Annual Yield (CAY)

CAY cannot be estimated because of the lack of current biomass estimates.

4.3 Smooth oreo (new in 2003)

Bayesian procedures were used in the NIWA and SeaFIC assessments to estimate the uncertainties in model estimates of current biomass and in future projections (SeaFIC only) for all model runs. These procedures were conducted with the following steps:

1. Model parameters were estimated using maximum likelihood and the prior probabilities;
2. Samples from the joint posterior distribution of parameters were generated with the Monte Carlo Markov Chain procedure (MCMC) using the Hastings-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, 5 and 95 percentiles for parameters of interest.

NIWA assessment

The area was split at 178° 20′ W into a west and an east fishery based on an analysis of commercial catch, standardised CPUE, and research trawl and acoustic results which suggested distinct fisheries and fish distribution patterns for the west and east parts of OEO 4. Oreo catch data showed marked changes in fishing patterns over time. This involved a progression of high catches over time starting in the west and moving east and appeared to represent successive exploitation of new areas. Areas in the west previously exploited did not later return to sustained high catches. The target species and the type of fishing changed over time with smooth oreo the target species in the west on flat, dropoff, and seamounts from the late 1970s, with a gradual change to target fishing for orange roughy on seamounts in the east from the late 1980s on.

Biomass and yield estimates for smooth oreo were made using a CASAL age-structured population model with Bayesian estimation, incorporating deterministic recruitment, life history parameters from Table 1 of the Biology section at the beginning of the Oreos report, and catch history. Data fitted in the analysis were the 1998 and 2001 acoustic abundance estimates (Table 7), standardised combined CPUE indices (a, c, & d, Table 9), observer length data (Table 8), and the 2001 acoustic survey length data.

The base case used an east/west split for all data inputs and assumed that a fixed proportion of year 1 fish went to the west area with no migration from the east to the west area and a fixed M (0.063). Estimated model parameters included two growth parameters (L_∞ and the c.v. of the length distribution) with the third growth parameter (k) fixed at the values in Table 1 of the Oreo biology section (it was not possible at the time to incorporate length and age data into the model). Selectivities were modelled as a two-parameter age-based logistic function with separate functions for the east and west areas but the same for each sex (for both the commercial and acoustic survey) and were mainly determined by the length frequencies. All sets of length data were fitted to the model using a log-normal likelihood with process errors. The model had a tendency to improve the fit to the east data at the expense of the west data, so the process error for the west acoustic length data was set to a c.v. of 0.015. Process error for the CPUE series was set to a c.v. of 0.20.

Bayesian estimates were based on the median of a 3886 long MCMC (the first 300 values were excluded). Estimated model parameters and priors are presented in Table 4.

Table 4: Estimated parameters and priors of the NIWA CASAL assessment model. U, uniform distribution. –, no value or not applicable.

Parameter	Both	Male	Female	Number	Prior
Virgin biomass	Estimated	–	–	1	ln B_0 ~U[0, ln (500 000)]
West catchability coefficient [pre-GPS CPUE]	Estimated	–	–	1	U[0, 1]
East catchability coefficient [post-GPS CPUE]	Estimated	–	–	1	U[0, 1]
West catchability coefficient [post-GPS CPUE]	Estimated	–	–	1	U[0, 1]
Age-based selectivity: commercial fishery:					
Age at 50% selected (east & west)	Estimated	–	–	2	U[1, 50]
Extra years to 95% selected (east & west)	Estimated	–	–	2	U[1, 35]
Age-based selectivity: acoustic survey:					
Age at 50% selected (east & west)	Estimated	–	–	2	U[1, 50]
Extra years to 95% selected (east & west)	Estimated	–	–	2	U[1, 35]
Von Bertalanffy parameters:					
L_∞	–	Estimated	Estimated	2	1U[30, 60 cm]
C.v. of length-at-age distribution	–	Estimated	Estimated	2	U[0, 0.3]
C.v. of proportion of year 1 fish going to the west	Estimated	–	–	1	U[0, 1]
Process errors					
Commercial length data	Estimated	–	–	2	U[0,1.5]
Acoustic length data (east)	Estimated	–	–	1	U[0,1.5]

SeaFIC assessment

The SeaFIC assessment did not use an east/west area split for OEO 4 and was based on model input data that were appropriate for all of OEO 4. This assessment was fitted to the 1998 and 2001 acoustic survey estimates (Table 7) and two CPUE abundance indices (Table 9 a & b). Two sets of length frequency data were used: one set from the 2001 acoustic survey and the other from the commercial fishery sampled by MFish observers (Table 8). A set of age-length pairs (142 males and 164 females) was used to estimate the von-Bertalanffy growth parameters. The model was run as a single area population represented by the biomass indices and a single fishery was assumed, mediated through an age-based selectivity function. A length-based selectivity function was used to interpret the acoustic survey that was estimated from the acoustic length frequency data. The acoustic surveys were assumed to be absolute and the CPUE indices were introduced into the model as relative estimates.
The CVs for the CPUE biomass indices were not modified from the values provided in Table 9. This was because a residual analysis incorporating the base CVs indicated that the CPUE data already had lower relative weights than other data sets. The acoustic survey CVs were left unchanged from the values provided in Table 7 for similar reasons. The model was tuned to catches.

A robust multinomial likelihood was used to fit the length data. The number of tows from which the length data were derived was used as the sample weight for each data set. Growth was estimated within the model, based on paired age-length data constructed from samples taken from the Chatham Rise. These data are the same as were used to estimate the von-Bertalanffy parameters in Table 1 of the Biology section at the beginning of the Oreos report, except that a few non-Chatham Rise data pairs were dropped from the sample. A log-normal likelihood was used to fit these data in the model.

Estimated model parameters and priors are presented in Table 5. Fixed model parameters are presented in Table 6. The left-side selectivity parameter values were fixed to knife-edge values and only the age or length at full selectivity was estimated due to convergence problems when running the Bayesian procedures described above. The age or length at full selectivity was the same for both sexes. The right-side parameters for both selectivity functions were fixed at large values to ensure that there was no decreasing selectivity with increasing age or length.

Several runs were investigated in this assessment, but only one is reported. Sensitivities included dropping the commercial length frequency data, looking at the effect of fixing all growth parameters at the values estimated when fitting to the age-length data alone and estimating the natural mortality parameter in addition to the six growth parameters estimated in the reference run.

Table 5: Estimated parameters and priors of the OEO 4 smooth oreo SeaFIC assessment model. U: uniform distribution. The prior for R_0 is in millions of age 1 recruits.

Parameter	Both	Male	Female	Prior
Average recruitment	Estimated	–	–	U[1, 1,000]
Catchability coefficient [pre-GPS CPUE]	Estimated	–	–	$\ln q \sim U[-20, 20]$
Catchability coefficient [post-GPS CPUE]	Estimated	–	–	$\ln q \sim U[-20, 20]$
Age-based selectivity: commercial fishery				
Age at full recruitment	Estimated			U[3, 30]
Length-based selectivity: acoustic survey				
Length at full recruitment	Estimated			U[2, 80]
Von Bertalanffy parameters:				
L_{80}	–	Estimated	Estimated	U[30, 60 cm]
k	–	Estimated	Estimated	U[0, 0.2yr^{-1}]
CV_{80}/CV_1	–	Estimated	Estimated	U[0, 2]

Table 6: Fixed parameters of the OEO 4 smooth oreo SeaFIC assessment model.

Parameter	Both	Male	Female
Natural mortality	–	0.063	0.063
Recruitment steepness	–	0.75	0.75
Plus-group age	–	80	80
Initial age structure	Fixed	–	–
Recruitment deviations	Fixed		
Catchability coefficient [survey]	Absolute	–	–
Von-Bertalanffy parameters			
L_1	–	7.4	7.7
CV_1	–	0.10	0.15
Length-weight parameters			
a	–	0.032	0.029
b	–	2.87	2.9
Age-based selectivity parameters, commercial fishery			
Left side standard deviation		0	0
Right side standard deviation		15	15
Length-based selectivity parameters, acoustic survey			
Left side standard deviation		0	0
Right side standard deviation		15	15

[1] Fixed at values estimated when fitting growth model only to the age-length data

(a) Estimates of fishery parameters and abundance

Absolute abundance estimates from the 1998 and 2001 acoustic surveys

Absolute estimates of abundance were available from an acoustic survey carried out from 26 September to 30 October 1998 on *Tangaroa* (voyage TAN9812) and from an acoustic survey carried out between 16 October and 14 November 2001 using *Tangaroa* for acoustic work (voyage TAN0117) and *Amaltal Explorer* (voyage AEX0101) for trawling.

Acoustic abundance estimates for total smooth oreo from seamounts and flat for the whole of OEO 4 are in Table 7. The NIWA assessment used the estimates for the east and west areas separately, while the SeaFIC assessment used the estimates for all of OEO 4.

Table 7: Estimated absolute abundance (t) from acoustic surveys in 1998 and 2001 by east, west and for the combined area. C.v.s are in brackets (%). -, not estimated.

			Mark Type
Area	**All**	**Layers**	**Schools**
1998			
West	34 900 (52)	20 300 (77)	14 600 (61)
East	192 000 (37)	136 000 (57)	56 3000 (28)
All	222 000 (34)	–	–
2001			
West	51 700 (35)	37 800 (48)	12 300 (34)
East	236 000 (22)	163 000 (29)	70 000 (25)
All	279 000 (22)	–	–

One of the major uncertainties in the assessment is from the large contribution to the total acoustic abundance estimate from smooth oreo estimated to be in the layers (about 70% of the total biomass for both surveys). The contribution of large (greater than 31 cm) smooth oreo to the total backscatter in these layers was typically less than 10% of the total biomass, with the remainder composed of a number of associated bycatch species and smaller smooth oreo. The layer acoustic abundance could be biased because the contribution made by the suite of other fish species present in the layers may be mis-specified, thus adding to the overall uncertainty in the biomass estimates from the assessment. The contribution of large smooth oreo to the total backscatter in the schools was typically greater than 75%. Therefore, the acoustic smooth oreo biomass estimates from the schools were considered to be better estimated than the equivalent acoustic estimates from the layers. Smooth oreo in schools made up only about 30% of the total smooth oreo biomass.

Observer length frequencies

Observer length data were extracted from the observer database. These data were stratified by season (October-March and April-September) and into west and east parts. The length frequencies were combined over strata by the proportion of catch in each stratum.

The NIWA assessment used data for strata in which there were more than 5 tows for the year for both strata combined, more than 30 fish were measured in the stratum, and there were data for both females and males in the stratum (Table 8). The SeaFIC assessment used data from 1991, 1992, 1996–1998, and 2001 (Table 8).

Table 8: Observer length frequencies for the west, east and combined areas: percentage catch and number of tows with length data by season strata, and whether a length frequency was used in the NIWA and SeaFIC stock assessments. The SeaFIC assessment combined the length data from the West and East areas into a single area.

	Catch percentage		Number of tows		Assessment	
Year	**October-March**	**April-September**	**October-March**	**April-September**	**NIWA**	**SeaFIC**
West area						
1987	72.6	27.4	2	2		
1989	70.1	29.9	10	5	Yes	
1990	80.5	19.5	4	0		
1991	70.6	29.4	16	0		Yes
1992	55.9	44.1	6	0		Yes
1993	34.0	66.0	0	0		
1994	56.5	43.5	1	0		
1995	41.9	58.1	1	0		
1996	75.7	24.3	9	10	Yes	Yes
1997	74.2	25.8	11	0		Yes
1998	60.2	39.8	2	9	Yes	Yes
1999	78.8	21.2	0	7		
2000	72.6	27.4	3	15	Yes	
2001	70.1	29.9	9	15	Yes	Yes

	Catch percentage		Number of tows		Assessment	
Year	**October-March**	**April-September**	**October-March**	**April-September**	**NIWA**	**SeaFIC**
East area						
1987	61.9	38.1	0	0		
1989	60.3	39.7	1	0		
1990	71.0	29.0	0	0		
1991	65.9	34.1	25	4	Yes	Yes
1992	55.6	44.4	45	8	Yes	Yes
1993	61.4	38.6	13	15	Yes	
1994	43.8	56.2	62	32	Yes	
1995	46.8	53.2	42	28	Yes	
1996	67.4	32.6	6	6	Yes	Yes
1997	85.9	14.1	28	3	Yes	Yes
1998	91.3	8.7	20	9	Yes	Yes
1999	83.5	16.5	30	21	Yes	
2000	65.9	34.1	14	0		
2001	51.5	48.5	50	4	Yes	Yes

Acoustic survey length frequencies

Length data collected during the 2001 acoustic survey were used to generate population length frequencies for the east and west areas separately and both areas combined. Each frequency was estimated using the length data from trawls in each mark-type sub-stratum weighted by the catch rates and the proportion of acoustic abundance in the sub-stratum. These frequencies were normalised over both male and female frequencies so that the sum of the frequencies over both sexes summed to 1. The data for the two areas separately and the combined data were used in the NIWA and SeaFIC assessments, respectively.

Relative abundance estimates from standardised CPUE analyses

The CPUE analysis method was the same as that described above (Section 4.2) for OEO 4 black oreo except that a revised method was used to convert the index values to a canonical form by dividing each value by the geometric mean of the index series following the suggestion of Francis (1999) and resulted in the index value for the reference year being a value other than 1. Annual c.v.s for the combined indices were estimated using a jackknife technique (Doonan et al., 1995a) but the method was revised by using the canonical index values to calculate the jackknife c.v. values and resulted in the reference year c.v. having a value other than 0. The target SSO pre-GPS series (Table 9 a) used data from the both east and west areas but most of the data were from the west. The SeaFIC assessment used the indices that indexed the whole area (Table 9 a & b). The NIWA assessment used east and west indices (Table 9 a, c, & d).

Table 9: OEO 4 smooth oreo time series of combined and positive catch abundance indices from standardised CPUE analyses. Used in NIWA (†) and SeaFIC (‡) assessments.

Year	Combined index	Jackknife c.v.
(a) Target SSO pre-GPS (east + west but mainly west data) †, ‡		
1981–82	1.40	14.7
1982–83	1.36	19.2
1983–84	1.04	20.7
1984–85	0.84	20.2
1985–86	1.00	43.7
1986–87	0.99	28.1
1987–88	0.89	20.3
1988–89	0.68	21.7
(b) Target OEO/SSO post-GPS (east + west)‡		
1992–93	1.00	31.1
1994–95	1.23	28.5
1995–96	0.73	63.5
1996–97	1.06	21.7
1997–98	0.87	109.3
1998–99	0.92	27.8
1999–00	1.17	34.0
2000–01	1.10	42.8
(c) Target OEO/SSO post-GPS (west)†		
1992–93	0.66	25.6
1995–96	0.77	53.1
1996–97	1.16	27.9
1997–98	1.05	44.6
1998–99	1.01	15.9
1999–00	1.34	31.9
2000–01	1.20	19.6
(d) Bycatch post-GPS (east)†		
Year	**Positive catch index**	**Jackknife c.v.**
1992–93	1.50	39.1
1993–94	1.13	16.1
1994–95	1.06	16.6
1995–96	0.99	31.3
1996–97	1.19	92.4
1997–98	0.85	28.7
1998–99	0.90	14.7
1999–00	0.85	28.4
2000–01	0.72	39.2

(b) Biomass estimates

NIWA assessment

The estimates of biomass and yield from the base case analysis are dominated by the acoustic absolute abundance estimates and observer length data. All estimated parameters achieved MCMC convergence. The distribution of mature virgin biomass estimates is shown in Figure 1 and biomass point estimates are in Table 10.

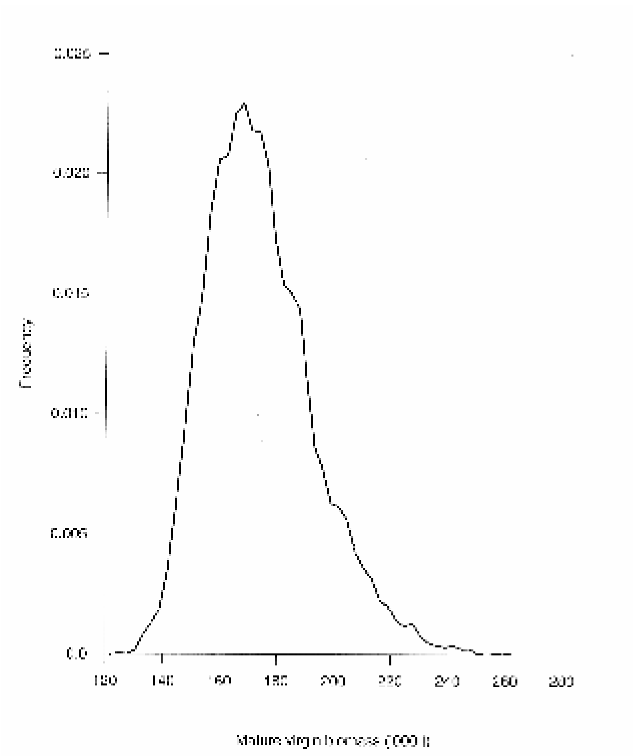

Figure 1: Bayesian posterior distribution of mature virgin biomass (t) estimates for the NIWA OEO 4 smooth oreo assessment. Based on 3886 Monte Carlo Markov Chain runs.

Table 10: Biomass, yield, and Current Surplus Production estimates (t). –, not estimated or na. (a) Biomass estimates

OEO 4	**Median**	**90% C.I.**	**% mid-year OEO 4 B_0**
Mature virgin	172 000	147 000–209 000	–
Mature 2001–02 mid-year	90 400	67 000–127 000	55
Vulnerable virgin	140 000	119 000–174 000	–
Vulnerable 2001–02 mid-year	65 100	44 500–98 200	46
East			% mid-year east B_0
Mature 2001–02 mid-year	77 000	54 300–113 000	62
Vulnerable 2001–02 mid-year	60 700	39 900–93 400	57
West			% mid-year west B_0
Mature 2001–02 mid-year	13 300	11 700–15 400	32
Vulnerable 2001–02 mid-year	4 390	3 390–5 500	13

(b) Yield estimates	**Mean**	**% mid-year OEO 4 B_0**
$MCY_{long\text{-}term}$	4 200	–
B_{MCY}	†37 000	34
B_{MAY}	†23 000	21
CAY	7 700	

† mid-year vulnerable biomass.

(c) CSP estimate	
CSP	3 500

For the two areas combined, the median estimate of current mature biomass was 55% B_0 and of vulnerable biomass was 46% B_0. For the two areas considered separately, both mature and vulnerable biomass are more depleted in the west than in the east.

SeaFIC assessment

The median estimate of stock status from the SeaFIC assessment is that the current biomass is above 50% B_0 and there is no probability that the beginning year vulnerable biomass in 2001–02 is less that 34% B_0. (Table 11; Figure 2). Most of the sensitivity runs gave similar results to the reported run except for the sensitivity option which fixed the growth parameters at the values which were estimated when the growth data are analysed independently of the stock assessment model. This run also estimated that the stock size was relatively high (between 30 and 40% B_0), but these values are lower than the other sensitivity runs. The fits to the data for the fixed growth parameter run are much poorer than for the other runs, particularly to the acoustic data (biomass indices and the 2001 length frequency data) and to the commercial length frequency data. The Working Group agreed that either the growth parameters or the natural mortality (M) had to be estimated in order to fit the available data and it indicated a preference towards estimating the growth parameters.

Note that, because of the way the UW/SeaFIC model has been constructed, spawning biomass levels are reported for females only, while vulnerable biomass is reported for both sexes.

Table 11: OEO 4 smooth oreo vulnerable and spawning mid-year biomass estimates (t) for the run described in Table 5. Values shown are the median, 5% and 95% of the posterior distributions for the three biomass indicators and the probability that B_{2002} will be greater than 21% B_0 and 34% B_0. Note that the spawning biomass estimate is expressed in terms of females only.

	Vulnerable biomass (t)			Female spawning biomass (t)		
	Median	5%	95%	Median	5%	95%
B_0	187 000	149 000	238 000	85 000	69 000	108 000
B_{2002}	111 000	73 000	162 000	45 000	29 000	69 000
$100 * B_{2002}/B_0$	59	49	68	53	43	63
$P(B_{2002})>0.21B_0$	1.0					
$P(B_{2002})>0.34B_0$	1.0					

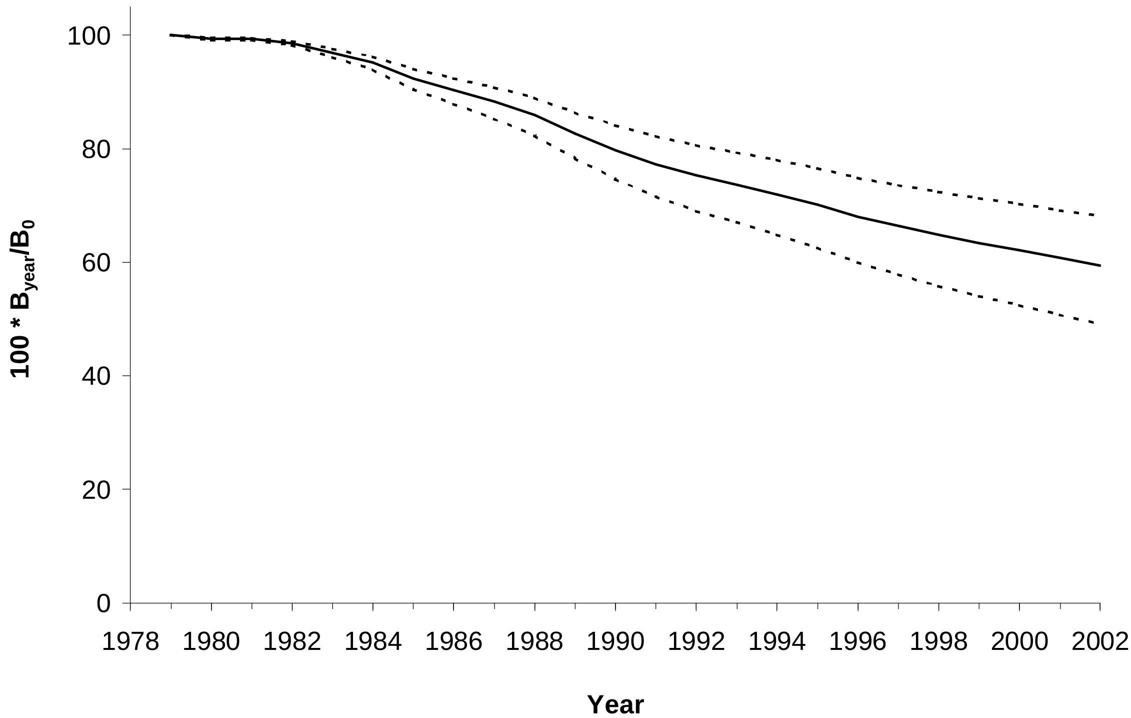

Figure 2: Mid-year biomass trajectory for OEO 4 smooth oreo for vulnerable biomass from the SeaFIC assessment expressed as a percentage of B_0. The solid line indicates the median of the posterior for each year and the lower and upper dashed lines indicate the 5% and 95% of the distribution respectively.

(c) Estimation of Maximum Constant Yield (MCY)

NIWA assessment

The method of Francis (1992), extended by Bull (2002) was used. B_{MCY} is 34% of vulnerable B_0. Base case estimates using vulnerable biomass are in Table 10.

(d) Estimation of Current Annual Yield (CAY)

NIWA assessment

CAY was estimated (Table 10) using the methods given by Francis (1992), extended by Bull (2002) using a catch split of 29% taken from the west (mean of the catch splits from 1996–97 to 2000–01). B_{MAY} is 21% of vulnerable B_0. F_{CAY}, the maximum constant fishing exploitation rate (F) that can be applied to the vulnerable population (without reducing the mature population below 20% B_0 more than 10% of the time), to a population with the life history parameters as in Table 1 of the Biology section is 0.081. The mean catch when fishing at F = 0.081 was 4100 t.

(e) Estimation of Current Surplus Production (CSP)

NIWA assessment

The CSP estimate was 3500 t and was the catch that ensured that the vulnerable biomass at the end of the 2002–03 fishing year was the same as the vulnerable biomass at the end of 2001–02.

(f) Other yield estimates

SeaFIC assessment

Vulnerable biomass levels at the beginning of 2007–08 have a greater than 50% probability of being more than 34% B_0 for projected catch levels up to 12,000 t per year (Table 12). The median stock status does not decline much for the 6000 t catch level and increases for the 3000 t catch level, indicating that the available surplus production lies between these two catch levels. All projected catch levels assume no allowance for overruns.

Table 12: Median stock status estimates and projection probabilities for OEO 4 smooth oreo mid-year vulnerable biomass from 2002-03 (coded 2003) to 2007-08 (coded 2008).

	2002	2003	2004	2005	2006	2007	2008
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3000	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6000	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9000	1.00	1.00	1.00	0.99	0.98	0.95	0.91
12000	1.00	1.00	0.99	0.95	0.88	0.77	0.64
15000	1.00	1.00	0.96	0.85	0.68	0.48	0.32

(g) Discussion

The NIWA and SeaFIC assessments used very similar models, similar input sources and produced similar results for estimates involving the mature (spawning) biomass. For instance, the NIWA and SeaFIC models estimated the current stock status at 55 and 53% of the mature B_0 respectively. However, the two models differed in their estimates of the status and size of the vulnerable biomass, with the NIWA and SeaFIC models estimating the current status at 46 and 59% of the vulnerable B_0, with estimates of vulnerable B_0 of 140 000 t and 187 000 t, respectively. There was insufficient time available to explore the reasons which led to these different estimates for vulnerable biomass between the two models, but they presumably arise because of the different handling of selectivity and growth in these two assessments.

Both models needed to estimate growth or natural mortality (M) within the model in order to fit the available data, particularly to fit the commercial and acoustic length frequency data and, in the SeaFIC case, the acoustic biomass indices. This result implies that these data are inconsistent with the estimate of M derived from the ageing data or with the growth rate estimates obtained from the age-length data. It is possible that either the age-length data or the commercial length frequency data are biased, but it is not possible to determine which data set is incorrect. Alternatively there could be a misspecification in the structure or assumptions of the assessment model. An example of the latter might be migration of fish to an area outside the area considered by the model.

Another uncertainty is that in the NIWA model the east and west areas behaved differently, i.e., the west area mid-year (2001–02) mature biomass was 32% B_0 while the east area was 62% B_0. Vulnerable biomass from the west was 13% of the west B_0, below the 21% ratio of B_{MAY} for OEO 4, while the east estimate was 57% of the east B_0 much greater than the 34% ratio of B_{MCY} for OEO 4. This suggests that the effects of fishing weren't spatially uniform along the Chatham Rise.

Assessment results from the SeaFIC model for mature biomass for the total area are very similar to the results obtained from the NIWA model, even though each model made different assumptions about stock structure. This indicates that model results for mature biomass are not sensitive to the area assumptions, at least within the context of the other model assumptions, including deterministic recruitment and an equilibrium biomass at the beginning of the assessment period. Sensitivity analyses and model diagnostics indicated that the assessment conclusions were robust to many of the data problems, except to the growth rate misspecification.

There are a number of structural assumptions in both models that result in the true uncertainty of the model biomass estimates being underestimated. These include the assumption that the acoustic biomass estimates for smooth oreo are absolute (scaling coefficient = 1) and that there was no variability in recruitment (deterministic recruitment was used). Also, there are a number of factors that are outside the model and the analyses that add uncertainty to the model estimates of biomass. These include the large smooth oreo acoustic abundance estimated to be in layers which are not normally fished by the commercial fleet, sensitivity of the acoustic biomass estimate to the low value of the target strength of smooth oreo, and uncertainty in the estimates of M and growth rates.

The smooth oreo acoustic biomass in the schools is considered to be better estimated than in the layers. The smooth oreo acoustic biomass estimates from the schools (71 000 t in 1998 and 82 000 t in 2001) lie between the median estimates of vulnerable biomass in 2001–02 from the NIWA (65 000 t) and SeaFIC (111 000 t) models.

5. STATUS OF THE STOCKS

Black oreo

The stock assessment of OEO 4 black oreo was considered unreliable and was not accepted. However, abundance indices from standardised CPUE analysis suggests that there has been a decline in the stock over time. It is not known if recent catch levels or the current TACC are sustainable or if they are at levels that will allow the stock to move towards a size that will support the maximum sustainable yield.

Smooth oreo

NIWA assessment

The mid-year estimate of mature biomass in 2001–02 was 55% of mature B_0. The mid-year estimate of vulnerable biomass in 2001–02 was 46% of vulnerable B_0, larger than the B_{MCY} of 34% of vulnerable B_0. The long-term MCY estimate is 4200 t, and the CAY estimate for 2002 is 7700 t. The smooth oreo catch in OEO 4 from 2001–02 was 4284 t, about the same as long-term MCY.

SeaFIC stock assessment

The assessment of smooth oreo in OEO 4 suggests that both the vulnerable biomass and spawning (mature) biomass at the beginning of 2001–02 were greater than 50% B_0. Catch projections show a probability of 64% of the vulnerable biomass remaining above 34% vulnerable B_0 in 2007–08 at constant catch levels up to 12 000 t. Projections suggest that, at a constant catch of 6000 t, the vulnerable biomass would remain above 50% vulnerable B_0 in 2007–08.

OEO 4: Summary of yield estimates (t) and 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. –, not available.

Species	CAY	Long-term MCY	2004–05 estimated catch
Black oreo	–	1 200	939
Smooth oreo	7 700	4 200	6 451

6. FOR FURTHER INFORMATION

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OREOS – OEO 1 AND OEO 6 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

4.1 Introduction

Assessments are available for Southland Smooth oreo and Pukaki Smooth Oreo as follows

Southland smooth oreo fishery (OEO 1/OEO 3A)

This assessment was developed in 2004 using a CASAL model and applies only to the study area as defined in Figure 1 and does not include areas to the north (Waitaki) and east (Eastern canyon) of the main fishing grounds.

This fishery is mostly in OEO 1 on the east coast of the South Island but catches at the northern end of the fishery straddle and cross the boundary line between OEO 1 and OEO 3A at 46ºS. This is an old fishery with catch and effort data available from 1977–78 and mean annual catches of about 1000 t of smooth oreo. There were no fishery-independent abundance estimates, so relative abundance estimates from pre- and post-GPS standardised CPUE analyses and length frequency data collected by MFish (SOP) and Orange Roughy Management Company (ORMC) observers were used. Two fisheries were modelled: an early fishery (before 1989–90) that was mainly carried out by Soviet vessels and a late fishery (1989–90 on) consisting mainly of New Zealand vessels.

The following assumptions were made in this analysis.

1. The CPUE analysis indexed the abundance of smooth oreo in the study area of OEO 1/3A.
2. The length frequency samples were representative of the population being fished.
3. The ranges used for the biological values covered their true values.
4. Recruitment was deterministic and followed a Beverton & Holt relationship with steepness of 0.75.
5. The population of smooth oreo in the study area was a discrete stock or production unit.
6. Catch overruns were 0% during the period of reported catch.
7. The catch histories were accurate.
8. The maximum fishing pressure (U_{max}) was 0.58.

Pukaki Rise smooth oreo fishery (part of OEO 6)

This is the first assessment for this fishery and was carried out using a CASAL model applied only to the assessment area as defined in Figure 3. This is the main smooth oreo fishery in OEO 6 with mean annual catches of about 1700 t from 1995–96 to 2004–05, taken mainly by New Zealand vessels. There was also a small early Soviet fishery (1980–81 to 1985–86) with mean annual catches of less than 100 t. There were no fishery-independent abundance estimates, so relative abundance estimates from a post-GPS standardised CPUE analysis and length frequency data collected by MFish (SOP) and Orange Roughy Management Company (ORMC) observers were considered. Biological parameter values estimated for Chatham Rise and Puysegur Bank smooth oreo were used in the assessment because there are no research data from Pukaki Rise.

The following assumptions were made in this analysis.

1. The CPUE analysis indexed the abundance of smooth oreo in the Pukaki Rise (OEO 6) assessment area.
2. The length frequency samples were representative of the population being fished.
3. The ranges used for the biological values covered their true values.
4. Recruitment was deterministic and followed a Beverton & Holt relationship with steepness of 0.75.
5. The population of smooth oreo in the assessment area was a discrete stock or production unit.
6. Catch overruns were 0% during the period of reported catch.
7. The catch histories were accurate.
8. The maximum exploitation rate (E_{max}) was 0.58.
9. The prior for stock size was bounded at an upper limit of 100 000 t.

Other oreo fisheries in OEO 1 and OEO 6

No information (other than catch) was available to enable assessments to be made for black oreo and smooth oreo for other fisheries within OEO 1 and OEO 6. Estimates of MCY could be given based on the use of average annual catch methods (MCY = c^*Y_{av}) where appropriate.

4.2 Southland smooth oreo fishery

Assessment

A new age-structured CASAL model employing Bayesian statistical techniques was developed. A two-fishery model was employed by defining and analysing an early fishery, up to and including 1988–89 (pre-GPS), and a late fishery from 1989–90 onwards (post-GPS). This was required because the depth distribution of the catches was very different between the pre-GPS and post-GPS periods, so the CPUE indices needed different selectivity values because depth is related to fish length and therefore the age distribution of the catch. Data inputs for the early and late fisheries models included catch history, relative abundance estimates from standardised CPUE analyses, and length data from SOP and ORMC observers. The model was partitioned by the sex and maturity status of the fish and used population parameters previously estimated from fish sampled on the Chatham Rise and Puysegur Bank fisheries. The maturity ogive used was estimated from Chatham Rise research samples.

(a) <u>Estimates of fishery parameters and abundance</u>

Catch history

A catch history (Table 1) was derived using declared catches of OEO from OEO 1 (see Table 2 in the Fishery Summary section at the beginning of the Oreos report) and tow-by-tow records of catch from the study area (Figure 1). The tow-by-tow data were used to estimate the species ratio (SSO/BOE) and therefore the SSO taken. It was assumed that the reported landings provided the best information on total catch quantity and that the tow-by-tow data provided the best information on the species and area breakdown of catch.

Table 1: Catch history of smooth oreo from Southland. Rounded to the nearest 10 t.

Year	1978–79	1979–80	1980–81	1981–82	1982–83	1983–84	1984–85	1985–86	1986–87	1987–88
Catch	200	10	30	0	10	1 130	690	4 230	190	990
Year	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94	1994–95	1995–96	1996–97	1997–98
Catch	240	640	830	910	660	370	230	1 100	500	550
Year	1998–99	1999–00	2000–01							
Catch	1 090	1 130	1 010							

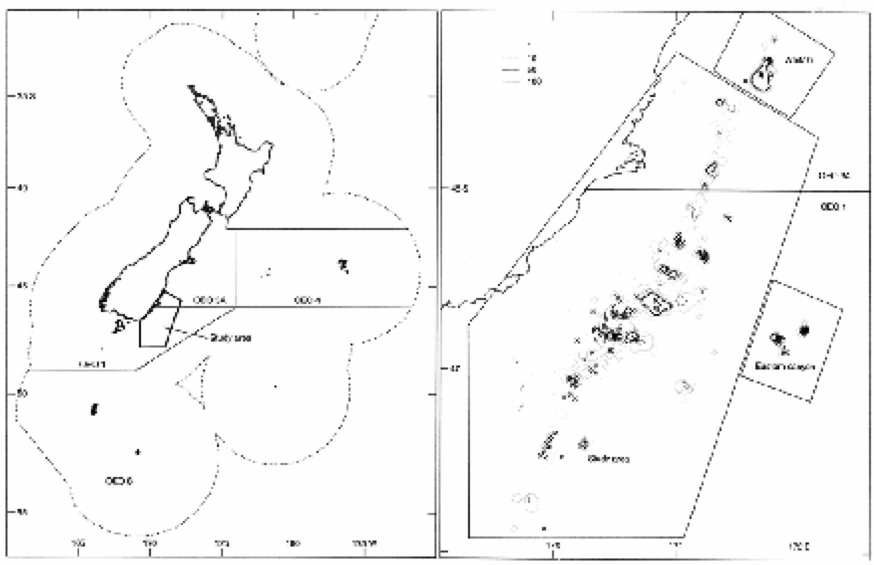

Figure 1: The Southland fishery study area in relation to management areas (left panel) and expanded (large polygon, right panel) with small polygons around the Waitaki and eastern canyon areas (not included in this study). Smooth oreo catch contours from 1977–78 to 2000–01 were plotted by summing the catches over a roughly square grid with cell size of about 10km^2. The contours are at 1, 10, 50 and 100 t per cell (therefore approximately 0.1, 1, 5, and 10 t per km^2). The study area polygon has corners at 45º 13.6' S, 171º 0.3' E; 45º 42.3' S, 172º 9.4' E; 47º 55.2' S, 171º 3.7' E; 47º 55.6' S 169º 19.2' E; 46º 45.8' S 169º 18.5' E. Xs mark the location of length frequency samples of smooth oreo.

Length data

Smooth oreo length frequency data collected by SOP and ORMC observers were stratified by depth (less than 975 m and greater than or equal to 975 m) and weighted by the sample catch(Table 2). The variability of the length data was expressed as c.v.s by length class derived from a linear regression of log c.v. (bootstrap c.v. values from the 1999–2000 length data) versus proportion at length. Process error was always applied to all the length frequency inputs to the extent that the residuals became approximately standardised normal. Because process error was large relative to the above bootstrap derived c.v.s, the precise derivation of the latter was not critical. Length samples collected by ORMC observers from one vessel for 2000–01 appeared to be biased upwards and could not be reconciled with the other data, so data collected by ORMC observers on that vessel were eliminated from the analysis.

Table 2: Summary of length frequency data for smooth oreo available for the study area. The table shows the number of tows sampled by year, source, and depth zone (deep >= 975 m). Note that ORMC samples from one vessel were excluded. –, no data.

	SOP		ORMC	
Year	Shallow	Deep	Shallow	Deep
1986–87	–	1	–	–
1988–89	–	2	–	–
1993–94	2	–	–	–
1994–95	3	–	–	–
1995–96	2	–	–	–
1996–97	4	–	–	–
1997–98	2	1	–	–
1998–99	–	–	12	19
1999–00	30	6	–	3
2000–01	4	–	1	1

Relative abundance estimates from CPUE analyses

The standardised CPUE analyses used a two part model which separately analysed the tows which caught smooth oreo using a log-linear regression (referred to as the positive catch regression) and a binomial part which used a Generalised Linear Model with a logit link for the proportion of successful tows (referred to as the zero catch regression). The binomial part used all the tows, but considered only whether or not the species was caught and not the amount caught. The yearly indices from the two parts of the analysis (positive catch index and zero catch index) were multiplied together to give a combined index. The pre-GPS data covered the years from 1983–84 to 1987–88 and the post-GPS data covered 1992–93 to 2000–01.

The pre-GPS and post-GPS indices and jackknife c.v. results are in Tables 3 and 4. The pre-GPS combined indices showed a steep decline over time The post-GPS indices were more variable but overall showed a slight decline.

Table 3: Smooth oreo pre-GPS combined index estimates by year, and jackknife c.v. estimates from analysis of all tows in the study area that targeted smooth oreo, black oreo, or unspecified oreo.

	Combined index	Jackknife c.v. (%)
1983–84	1.75	22
1984–85	1.65	29
1985–86	1.19	33
1986–87	0.48	23
1987–88	0.61	27

Table 4: Smooth oreo post-GPS combined index estimates by year, and jackknife c.v. estimates from analysis of all tows in the study area that targeted smooth oreo, black oreo, or unspecified oreo.

	Combined index	Jackknife c.v. (%)
1992–93	1.27	39
1993–94	1.09	78
1995–96	1.62	103
1996–97	0.52	84
1997–98	1.14	27
1998–99	0.90	17
1999–00	0.93	21
2000–01	0.89	38

(b) Biomass estimates

Biomass estimates were made based on a Markov Chain Monte Carlo analysis which produced a total chain length of 500 000. The first 10 000 points were discarded (burn-in) and then every 100th point was retained. The final converged chain had a length of 4900 points.

Biomass estimates for the base case are given in Table 5. Biomass trajectories for the base case and the fit to the CPUE series are shown in Figure 2. These biomass estimates are uncertain because of the paucity of observer length frequency data, the uncertain quality of recent catch data resulting from area mis-reporting, and the lack of fishery-independent abundance estimates and the consequent reliance on commercial CPUE data for abundance indices. The estimates of biomass and depletion levels were also sensitive to which observer length frequency data sets were included in the model runs. Given the estimate of B_0 relative to the total catch taken during the history of this fishery, the estimate of B_0 is likely to be close to a minimum estimate of the unexploited biomass .

Table 5: Biomass estimates (t) for the base case.

(a) Mid-year biomass estimates

	Median	90% C.I.
Mature virgin	15 900	13 800–20 700
Mature 2001–02 mid-year	4 800	2 800–9 500
Mature 2001–02 mid-year (% B_0)	30	20–46
Vulnerable virgin	16 700	13 900–22 400
Vulnerable 2001–02 mid-year	5 300	2 800–10 800
Vulnerable 2001–02 mid-year (% B_0)	32	21–48

	Mean
B_{MCY}	†7 800
B_{MAY}	†4 300

† mid-year vulnerable biomass.

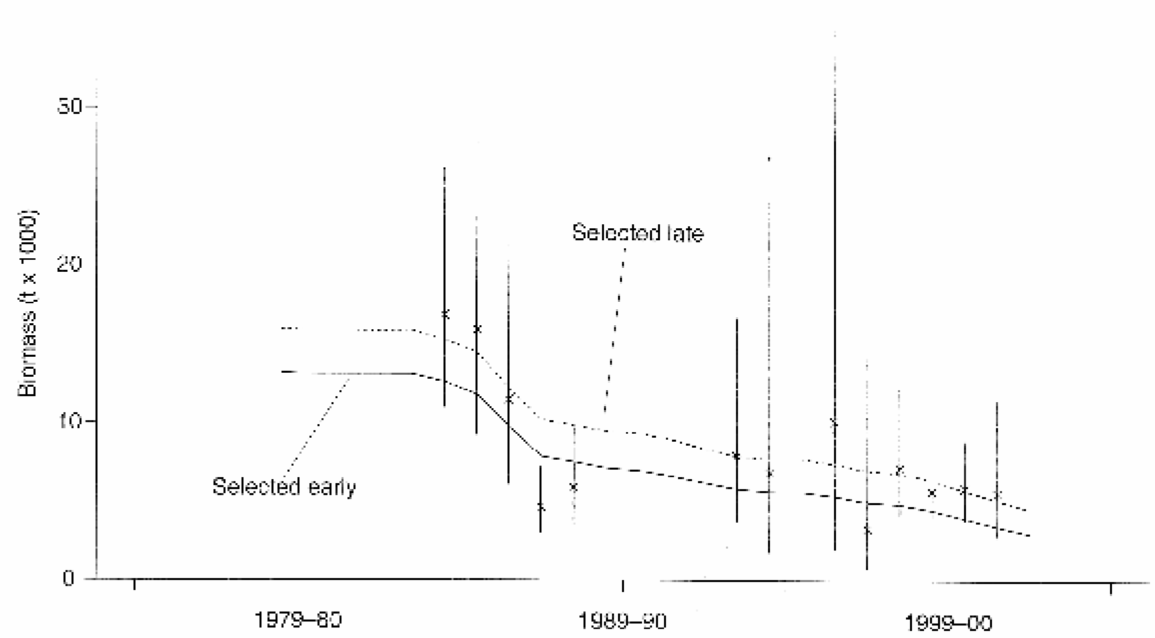

Figure 2: Predicted biomass trajectories for the base case. Selected biomass for the early (before 1989–90) and late (from 1989–90 on) fisheries. Also shown are the CPUE indices from the pre- and post-GPS analyses with 2 s.e. confidence interval indicated by the vertical lines.

(c) Projections

The model was used to project stock status into the future using stochastic recruitment. The simulations used randomised year class strengths with an assumed lognormal distribution (mean = 1, σ_r = 0.65). Biomass projections for 5 years into the future were made under a range of constant catch regimes to determine the probability that the projected biomass would exceed the current biomass, the probability that the projected biomass would exceed 20%Bo, and the probability that the projected biomass would exceed B_{MSY} (estimated to be 26%Bo). Projections were made based on a random sub-sample of 500 values from the posterior distribution (Table 6).

Five year projections to estimate future mature and vulnerable biomass were subject to the same data problems as the biomass estimates. However, the Plenary concluded that catches at the level of the 2000–01 annual catch (1010 t) are probably not sustainable.

Table 6: Probability that biomass in 5 years ($B_{2006–07}$) is greater than the reference biomass (20% and 26%B_0) and the median biomass in 5 years as a %B_0 ($Bmed_{2006–07}$) under different constant catch scenarios. The 2000–01 catch for smooth oreo in the Southland fishery was 1010 t.

Catch (t)	P($B_{2006–07}$ > 20%Bo)	P($B_{2006–07}$ > 26%Bo)	$Bmed_{2006–07}$
1010	0.31	0.15	15
800	0.48	0.23	20
600	0.69	0.41	24
500	0.80	0.50	26
400	0.89	0.62	28
300	0.94	0.71	31
200	0.99	0.84	33

4.3 Pukaki Rise smooth oreo fishery (part of OEO 6)

Assessment

Data inputs included catch history, relative abundance estimates from a standardised CPUE analysis, and length data from SOP and ORMC observers. The observational data were incorporated into an age-based Bayesian stock assessment (CASAL) with deterministic recruitment to estimate stock size. The stock was considered to reside in a single area, with a partition by sex. Age groups were 5–70 years, with a plus group of 70+ years.

The length-weight and length-at-age population parameters are from fish sampled on the Chatham Rise and Puysegur Bank fisheries (Table 1, Biology section). Fish sampled from the Puysegur Bank fishery are used for the natural mortality estimate (Table 1). The maturity ogive is from fish sampled on the Chatham Rise, and the age at which 50% are mature is between 18 and 19 years for males and between 25 and 26 years for females.

(a) Estimates of fishery parameters and abundance

Catch history

A catch history was derived using declared catches of OEO from OEO 6 (Table 2 in the "Fishery summary" section of the Oreos report above) and tow-by-tow records of catch from the assessment area (Figure 3). The tow-by-tow data were used to estimate the species ratio (SSO/BOE) and therefore the SSO taken. It was assumed that the reported landings provided the best information on total catch quantity and that the tow-by-tow data provided the best information on the species and area breakdown of catch. There may be unreported catch from before records started, although this is thought to be small. Before the 1983–84 fishing year the species catch data were combined over years to get an average figure that was then applied in each of those early years. For the years from 1983–84 onwards, each year's calculation was made independently. The catch history used in the population model is given in Table 7.

Table 7: Catch history of smooth oreo from the Pukaki Rise fishery assessment area. Catches are rounded to the nearest 10 t.

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

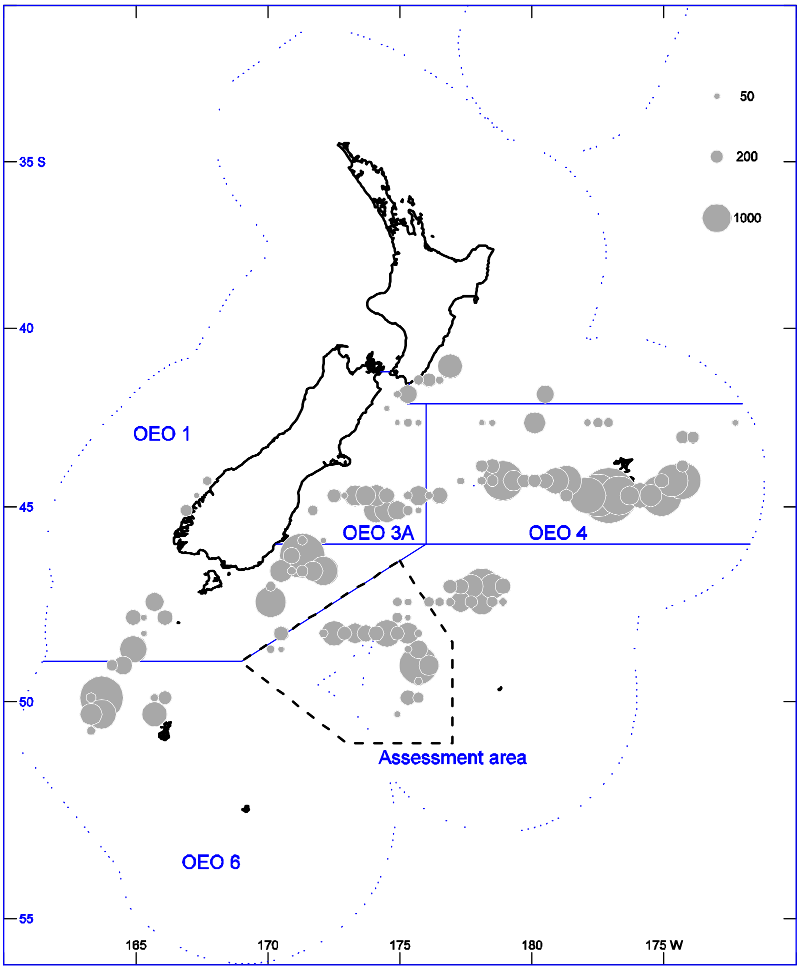

Figure 3: The Pukaki Rise fishery assessment area (polygon) abutting the north boundary of OEO 6. The circles are proportional to the mean of smooth estimated catches (t) from the last 5 years (2000–01 to 2004–05) plotted by summing the catches over 0.4 x 0.4 degree grids. The dotted line is the EEZ.

Length data

Smooth oreo length frequency data collected by SOP and ORMC observers are available from the last eight years (Table 8). An in-depth analysis indicated that these data were reasonably representative of the fishery in terms of spatial, depth and temporal coverage in those years that had adequate data. The depths fished by the sampled fleet varied between years so the length data were stratified by depth resulting in shallow (less than 900 m), middle (900–990 m) and deep strata (greater than 990 m). The data from adjacent years were also grouped because some years had few samples. The resulting length frequencies are shown in Figure 4. There is a trend towards a flatter distribution over the last three grouped distributions (00–01, 02, and 03–05).

Table 8: Summary of length frequency data for smooth oreo available for the assessment area. The table shows the number of tows sampled by year, the sample source, and the year group. –, no data.

	Year group	Number of tows sampled		
Year		ORMC	SOP	All
1997–98	98–99	–	15	15
1998–99	98–99	64	9	73
1999–2000	00–01	5	36	41
2000–01	00–01	37	17	54
2001–02	02	42	22	64
2002–03	03–05	4	12	16
2003–04	03–05	–	19	19
2004–05	03–05	–	19	19
Totals		152	149	301

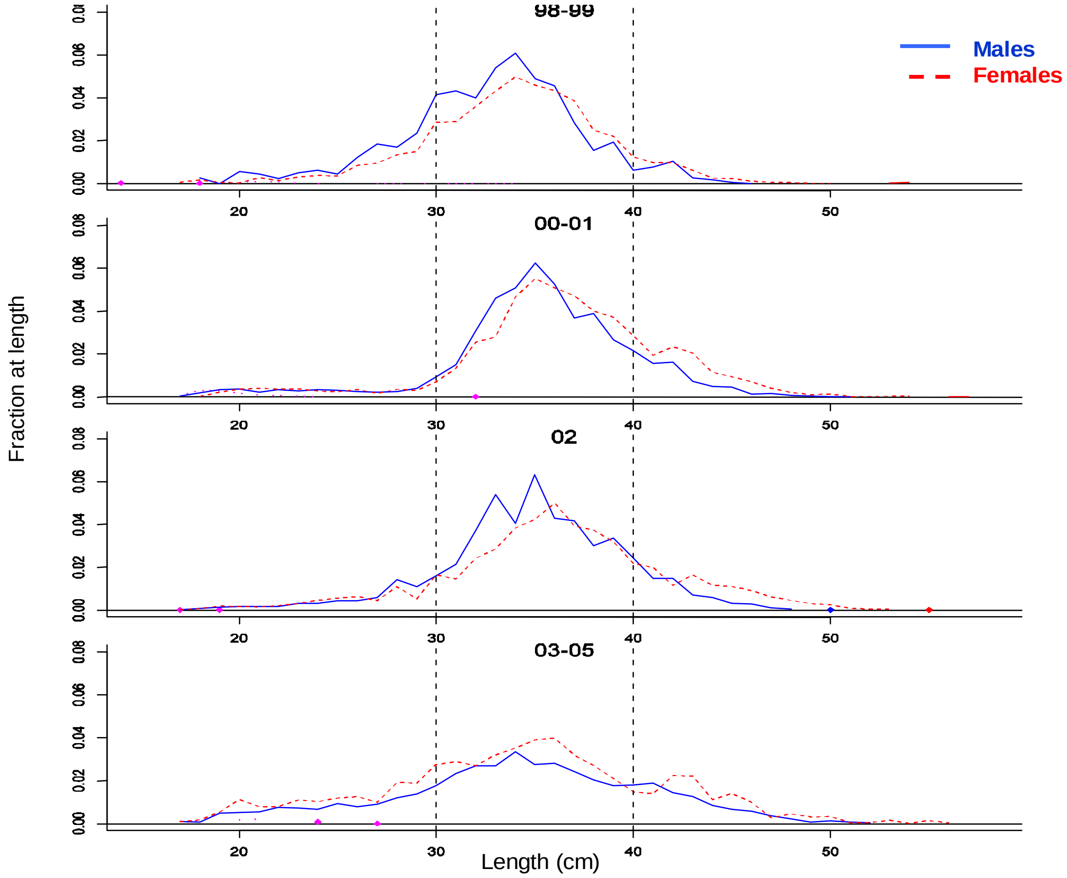

Figure 4: Length frequencies for Pukaki Rise smooth oreo, stratified by depth (see text), and grouped by years.

Relative abundance estimates from CPUE analyses

There was a small early Soviet fishery (1980–81 to 1985–86) with too few data for a standardised CPUE analysis. The New Zealand vessel fishery (1995–96 to 2004–05) was used to analyse standardised CPUE.

This new standardised CPUE analysis of Pukaki Rise smooth oreo used regression based methods similar to those in previous oreo CPUE analyses but because the fraction of zero tows were low (Table 9) only a positive catch model was used. The annual c.v.s for the index were estimated using bootstrap methods. The data used are summarised in Table 9.

Table 9: Summary of data used as input to the standardised CPUE analysis for New Zealand vessels.

Year	No. of tows	No. of vessels	Estimated catch (t)	Mean t/tow	Zero catch tows (%)
1995–96	278	9	1 170	4.2	1
1996–97	402	10	1 490	3.7	1
1997–98	356	10	1 190	3.4	5
1998–99	377	12	1 230	3.3	7
1999–00	591	9	2 070	3.5	7
2000–01	651	9	2 310	3.5	8
2001–02	415	7	1 920	4.6	1
2002–03	533	9	1 240	2.3	5
2003–04	585	9	1 520	2.6	2
2004–05	712	12	1 300	1.8	5

The regression model chosen as the final run included vessel, time of year (day), depth, and axis-position (point on a line drawn through the fishery that follows the 1000 m contour around the Pukaki Rise), and excluded data from vessels that fished for less than three years. Target species was chosen as a predictor variable in initial runs but was excluded in the final run because it is believed that it is not accurately reported. The final run index declines (Table 10).

Table 10: Final run CPUE index estimates by year, and bootstrap c.v. estimates from analysis of all tows in the assessment area that caught smooth oreo.

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

(b) Biomass estimates

In all model runs the length-frequency data were poorly fitted, even if selectivity was allowed to vary with depth. This may be due to the use of growth parameters that were derived from another area or to other modelling problems, and is an issue that should be further investigated in the future. In the meantime, the length frequency data were omitted from the stock assessment and the model was fitted to the CPUE data alone. The age at 50% selectivity (a_{50}) was assumed to be knife-edged at 19 yr, corresponding to a fish size of approximately 33 cm. For this model, the MPD estimate of virgin mature biomass (B_0) was 17 400 t, and the current mature biomass was 22% B_0 (Figure 5).

MCMC runs resulted in extremely skewed distributions of B_0 and $B_{current}$ with right hand tails extending to very high biomass levels. Based on comparisons with other smooth oreo stocks (e.g. OEO 4), and the observation that the standardised CPUE has declined rapidly even though catches have been relatively small, a modified prior which truncated B_0 at an upper limit of 100 000 t was adopted. This gave a median estimate of B_0 of 24 000 t (90% confidence intervals 16 000-78 000 t) and a median estimate of $B_{current}$ of 9 800 t (2 400-64 000 t). Because of the wide confidence intervals, the current status (%B_0) is highly uncertain with a median of 42% but 90% confidence intervals of 15-82% (Table 11 and Figure 6).

Table 11: Mid-year mature biomass estimate (median, with 90% confidence intervals in parentheses) for the model run with only CPUE data. $B_{current}$ is the mid-year mature biomass in 2006.

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

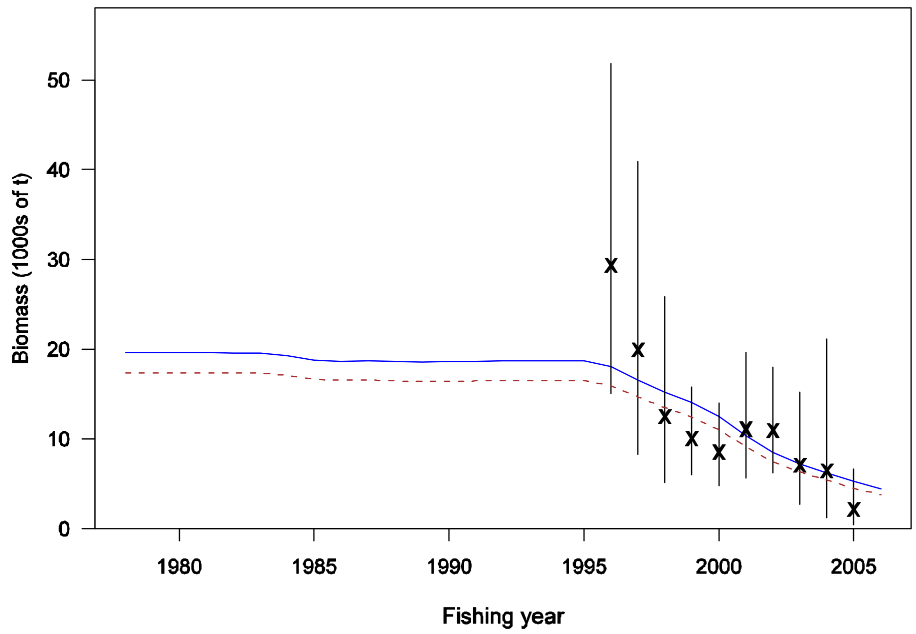

Figure 5: Model run based on CPUE data only, with a_{50} set at 19 yr. The crosses show the CPUE data (vertical lines are the 95% confidence intervals for the indices) and their fits to the vulnerable biomass trajectory (solid line). The dashed line shows the mature biomass trajectory. Fits and trajectories are from MPD estimates.

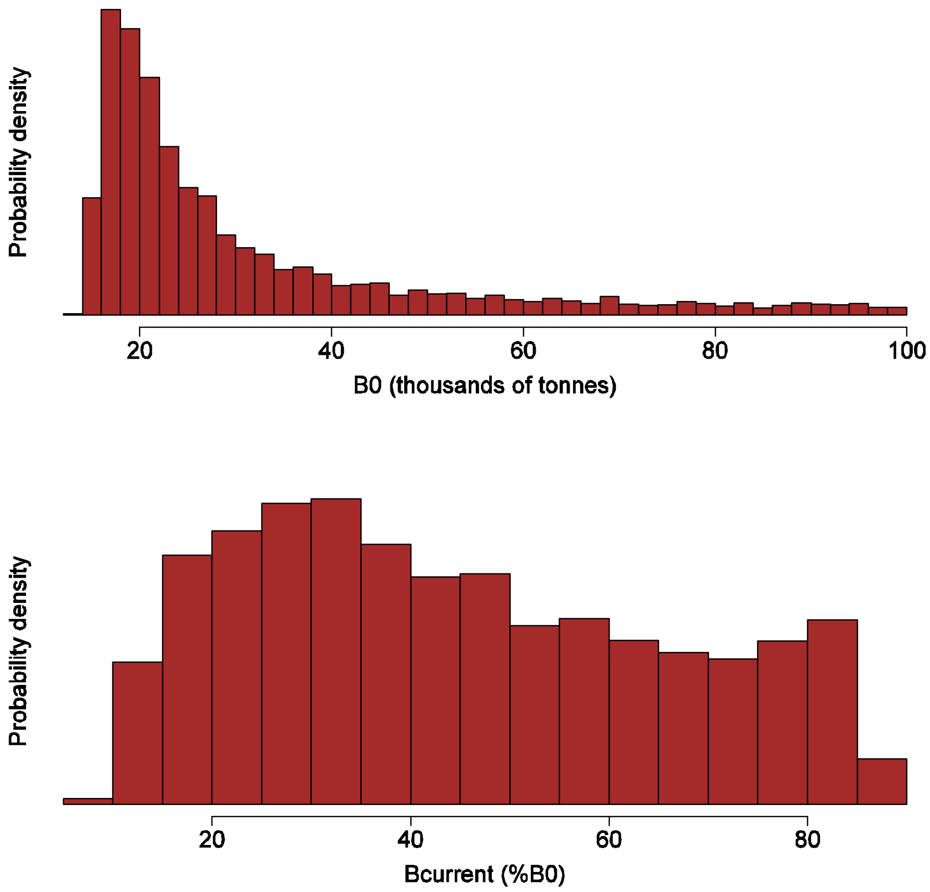

Figure 6: Posterior densities for mature biomass estimates (virgin biomass, and current biomass as a percentage of virgin biomass).

(c) Yield estimates

Estimates of the Maximum Average Yield (MAY) were based on calculations performed for the Southland
smooth oreo stock, which has similar life history characteristics (e.g. assumed natural mortality and steepness, and length-age and weight-age relationships) (Coburn et al. 2003). For Southland, the MAY was estimated to be 2.3% of the median mature virgin biomass. Applying this value to the estimates of B_0 in Table 11 gives a median estimate of MAY for Pukaki smooth oreo of 550 t, with 90% confidence intervals 370-1800 t.

(d) Projections

No projections were made because of the uncertainty in this assessment.

4.4 Other oreo fisheries in OEO 1 and OEO 6

(a) Estimates of fishery parameters and abundance

Relative abundance estimates from trawl surveys

Two comparable trawl surveys were carried out in the Puysegur area of OEO 1 (TAN9208 and TAN9409). The 1994 oreo abundance estimates are markedly lower than the 1992 values (Table 7).

Table 7: OEO 1. Research survey abundance estimates (t) for oreos from the Puysegur and Snares areas. N is the number of stations. Estimates for smooth oreo were made based on a recruited length of 34 cm TL. Estimates for black oreo were made using knife-edge recruitment set at 27 cm TL.

Smooth oreo					
Puysegur area (strata 0110–0502)					
	Mean biomass	**Lower bound**	**Upper bound**	c.v.**(%)**	**N**
1992	1 397	736	2 058	23	82
1994	529	86	972	41	87
Snares area (strata 0801–0802)					
	Mean biomass	**Lower bound**	**Upper bound**	c.v.**(%)**	**N**
1992	2 433	0	5 316	59	8
1994	118	0	246	54	7
Black oreo					
Puysegur area (strata 0110–0502)					
	Mean biomass	**Lower bound**	**Upper bound**	c.v.**(%)**	**N**
1992	2 009	915	3 103	27	82
1994	618	0	1 247	50	87
Snares area (strata 0801–0802)					
	Mean biomass	**Lower bound**	**Upper bound**	c.v.**(%)**	**N**
1992	3 983	0	8 211	53	8
1994	1 564	0	3 566	64	7

(b) Biomass estimates

Estimates of virgin and current biomass are not yet available.

(c) Estimation of Maximum Constant Yield (MCY)

MCY cannot be estimated because of the lack of current biomass estimates for the other stocks.

(d) Estimation of Current Annual Yield (CAY)

CAY cannot be estimated because of the lack of current biomass estimates for the other stocks.

(e) Other factors

Recent catch data from this fishery may be of poor quality because of area misreporting.

5. STATUS OF THE STOCKS

Southland smooth oreo fishery (OEO 1/OEO 3A)

Current and virgin biomass for smooth oreo in Southland (OEO 1/OEO 3A) were estimated in 2004 using a new CASAL stock assessment. These biomass estimates are uncertain because of the paucity of observer length frequency data, the poor quality of recent catch data resulting from area mis-reporting, and the lack of fishery-independent abundance estimates and the consequent reliance on commercial CPUE data for abundance indices. Therefore, quantitative biomass estimates are not reported here and are not considered suitable as a basis for providing management advice. But the analysis suggested that the mature virgin biomass was probably small, less than 21 000 t, and that the stock was unlikely to be able to support a large fishery.

Five year projections to estimate future mature and vulnerable biomass were subject to the same data problems as the biomass estimates. However, the Plenary concluded that catches at the level of the 2000–01 annual catch (1010 t) are probably not sustainable.

Pukaki Rise smooth oreo fishery (part of OEO 6)

Current and virgin biomass for smooth oreo on Pukaki Rise (part of OEO 6) were estimated for the first time in 2006. These biomass estimates are uncertain because of the lack of fishery-independent abundance estimates and the consequent reliance on commercial CPUE data, and because of the lack of biological parameter estimates specific to smooth oreo in this assessment area.

Model results suggest that mature virgin biomass is about 24 000 t with wide 90% confidence intervals (16 000-78 000 t). The Plenary noted that large stock sizes were unlikely, particularly because standardised CPUE has declined rapidly under catch levels that have been small relative to other smooth oreo fisheries. Smooth oreo life history parameters suggest a median long-term yield (MAY estimate) of about 550 t, which is lower than the current catch of 1300 t.

The estimated confidence intervals around $\%B_0$ were so wide that it is not possible to make a definitive statement about stock status. However, based on CPUE trends and the catch history, the Plenary agreed that current annual catch levels are unlikely to be maintained in the future.

No projections were made because of the uncertain biomass estimates.

OEO 1 black oreo and smooth oreo

The TACC was increased from 5033 t to 6044 t in 1992–93 under the adaptive management programme but reverted to 5033 t in 1998–99. It is not known if recent catch levels or the current TACC are sustainable or will allow the stock to move towards a size that will support the maximum sustainable yield.

OEO 6 black oreo and smooth oreo

The current TACC increased from 3000 to 6000 t in 1996–97 and is not based on historical catch levels or on estimates of biomass and productivity. It is not known if recent catch levels or the current TACC are sustainable or if they are at levels that will allow this stock to move towards a size that will support the maximum sustainable yield.

OEO 1: Summary of yield estimates (t) and 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. –, not available.

Species	CAY	Long-term MCY	2004–05 estimated catch
Black oreo	–	–	267
Smooth oreo	–	–	758

OEO 6: Summary of yield estimates (t) and 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. –, not available.

Species	CAY	Long-term MCY	2004–05 estimated catch
Black oreo	–	–	1 675
Smooth oreo	–	–	4 070

6. FOR FURTHER INFORMATION

Coburn, R.P; Doonan, I.J.; McMillan, P.J. (2002). CPUE analyses for the Southland black oreo and smooth oreo fisheries, 1977–78 to 1999–2000. *New Zealand Fisheries Assessment Report 2002/3*. 28 p.

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