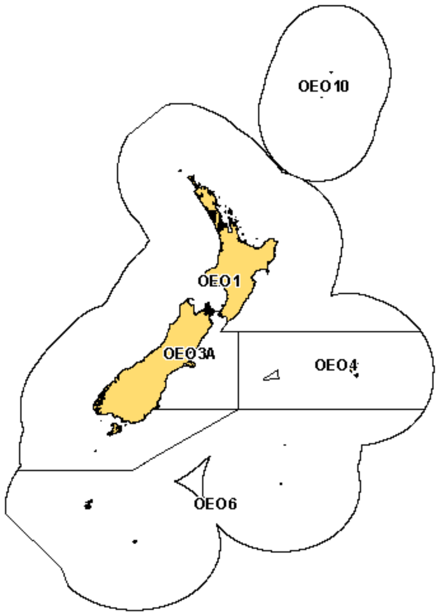
OREOS (OEO)

(*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

2.1 Black oreo

Occur 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.

2.2 Smooth oreo

Occur 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.

Fishstock			Estimate
1. Natural Mortality – M (yr^{1})			
	Females	Males	Unsexed
Black oreo	0.044	0.044	0.044
Smooth oreo	0.063	0.063	
2. Age at recruitment – A_r (yr)			
Black oreo	–	–	–
Smooth oreo	21	21	
3. Age at maturity A_M (yr)			
Black oreo	27	–	–
Smooth oreo	31	–	

4. von Bertalanffy parameters

	Females			Males			Unsexed		
	L¥(cm, TL)	k(yr^{1})	t_0 (yr)	L¥(cm, TL)	k(yr^{1})	t_0 (yr)	L¥(cm, TL)	k(yr^{1})	t_0 (yr)
Black oreo	39.9	0.043	-17.6	37.2	0.056	-16.4	38.2	0.05	-17.0
Smooth oreo	50.8	0.047	-2.9	43.6	0.067	-1.6			

5. Length-weight parameters (Weight = a(length)^{b} (Weight in g, length in cm fork length).)

	Females		Males		Unsexed	
	a	b	a	b	a	b
Black oreo	0.008	3.28	0.016	3.06	0.0078	3.27
Smooth oreo	0.029	2.90	0.032	2.87		

	Females	Males	Unsexed
6. Length at recruitment (cm, TL)			
Black oreo	-	-	-
Smooth oreo	34	-	
7. Length at maturity (cm, TL)			
Black oreo	34	-	-
Smooth oreo	40	-	-
8. Recruitment variability (σ_R)			
Black oreo	0.65	0.65	0.65
Smooth oreo	0.65	0.65	
9. Recruitment seeepness			
Black oreo	0.75	0.75	0.75
Smooth oreo	0.75	0.75	
10. Fishing mortality (F_{max} (yr^{-1}))			
Black oreo	0.9	0.9	–
Smooth oreo	0.9	0.9	
11. Max exploitation (E_{max} (yr^{-1}))			
Black oreo	-	-	0.67

3. STOCKS AND AREAS

3.1 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.

3.2 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

4.1 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 2000–01 (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 10106 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 3100 t in 2002–03. Catch from the Sub-Antarctic 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.Catches have declined since then, and from 1 October 2007 the TACC was reduced to 2500 t.

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.

Table 2: Total reported landings (t) for all oreo species combined by Fishstock from 1978–79 to 2006–07 and TACs (t) from 1982–83 to 2006–07.

Fishing	OEO 1		OEO 3A		OEO 4		OEO 6	
year	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1978–79*	2 808	–	1 366	–	8 041	–	17	–
1979–80*	143	–	10 958	–	680	–	18	–
1980–81*	467	–	14 832	–	10 269	–	283	–
1981–82*	21	–	12 750	–	9 296	–	4 380	–
1982–83*	162	–	8 576	10 000	3 927	6 750	765	–
1983–83#	39	–	4 409	#	3 209	#	354	–
1983–84†	3 241	–	9 190	10 000	6 104	6 750	3 568	–
1984–85†	1480	–	8 284	10 000	6 390	6 750	2 044	–
1985–86†	5 390	–	5 331	10 000	5 883	6 750	126	–
1986–87†	532	4 000	7 222	10 000	6 830	6 750	0	3 000
1987–88†	1 193	4 000	9 049	10 000	8 674	7 000	197	3 000
1988–89†	432	4 233	10 191	10 000	8 447	7 000	7	3 000
1989–90†	2 069	5 033	9 286	10 106	7 348	7 000	0	3 000
1990–91†	4 563	5 033	9 827	10 106	6 936	7 000	288	3 000
1991–92†	4 156	5 033	10 072	10 106	7 457	7 000	33	3000
1992–93†	5 739	6 044	9 290	10 106	7 976	7 000	815	3 000
1993–94†	4 910	6 044	9 106	10 106	8 319	7 000	983	3 000
1994–95†	1 483	6 044	6 600	10 106	7 680	7 000	2 528	3 000
1995–96†	4 783	6 044	7 786	10 106	6 806	7 000	4 435	3 000
1996–97†	5 181	6 044	6 991	6 600	6 962	7 000	5 645	6 000
1997–98†	2 681	6 044	6 336	6 600	7 010	7 000	5 222	6 000
1998–99†	4 102	5 033	5 763	6 600	6 931	7 000	5 287	6 000
1999–00†	3 711	5 033	5 859	5 900	7 034	7 000	5 914	6 000
2000–01†	4 852	5 033	4 577	4 400	7 358	7 000	5 932	6 000
2001–02†	4 197	5 033	3 923	4 095	4 864	5 460	5 737	6 000
2002–03†	3 034	5 033	3 070	3 100	5 402	5 460	6 115	6000
2003–04†	1 703	5 033	2 856	3 100	6 735	7 000	5 811	6 000
2004–05†	1 025	5 033	3 061	3 100	7 390	7 000	5 744	6 000
2005–06†	850	5 033	3 333	3 100	6 829	7 000	6 463	6 000
2006–07†	903	5 033	3 073	3 100	7 211	7 000	5 926	6 000

Fishing	Totals	
year	Landings	TAC
1978–79*	12 231	–
1979–80*	11 791	–
1980–81*	25 851	–
1981–82*	26 514	–
1982–83*	13 680	17 000
1983–83#	8 015	#
1983–84†	22 111	17 000
1984–85†	18 204	17 000
1985–86†	16 820	17 000
1986–87†	15 093	24 000
1987–88†	19 159	24 000
1988–89†	19 077	24 233
1989–90†	18 703	25 139
1990–91†	21 614	25 139
1991–92†	21 718	25 139
1992–93†	23 820	26 160
1993–94†	23 318	26 160
1994–95†	18 291	26 160
1995–96†	23 810	26 160
1996–97†	24 779	25 644
1997–98†	21 249	25 644
1998–99†	22 083	24 633
1999–00†	22 518	23 933
2000–01†	22 719	22 433
2001–02†	18 721	20 588
2002–03†	17 621	19 593
2003–04†	17 105	21 133
2004–05†	17 220	21 133
2005–06†	17 475	21 133
2006–07†	17 113	21 133

Source: FSU from 1978–79 to 1987–88; QMS/MFish from 1988–89 to 2005–06. *, 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 2006–07 and the ratio (percentage) of the total estimated SSO plus BOE, to the total reported landings (from Table 1). –, less than 1.

	SSO				BOE			
Year	OEO 1	OEO 3A	OEO 4	OEO 6	OEO 1	OEO 3A	OEO 4	OEO 6
1978–79*	0	0	0	0	9	0	0	0
1979–80*	16	5 075	114	0	118	5 588	566	18
1980–81*	1	1 522	849	2	66	8 758	5 224	215
1981–82*	21	1 283	3 352	2	0	11 419	5 641	4 378
1982–83*	28	2 138	2 796	60	6	6 438	1 088	705
1983–83#	9	713	1 861	0	1	3 693	1 340	354
1983–84†	1 246	3 594	4 871	1 315	1 751	5 524	1 214	2 254
1984–85†	828	4 311	4 729	472	544	3 897	1 651	1 572
1985–86†	4 257	3 135	4 921	72	1 060	2 184	961	54
1986–87†	326	3 186	5 670	0	163	4 026	1 160	0
1987–88†	1 050	5 897	7 771	197	114	3 140	903	0
1988–89†	261	5 864	6427	–	86	2 719	1 087	0
1989–90†	1 141	5 355	5 320	–	872	2 344	439	–
1990–91†	1 437	4 422	5 262	81	2 314	4 177	793	222
1991–92†	1 008	6 096	4 797	2	2 384	3 176	1 702	15
1992–93†	1 716	3 461	3 814	529	3 768	3 957	1 326	69
1993–94†	2 000	4 767	4 805	808	2 615	4 016	1 553	35
1994–95†	835	3 589	5 272	1 811	385	2 052	545	230
1995–96†	2 517	3 591	5 236	2 562	1 296	3 361	364	1 166
1996–97†	2 203	3 063	5 390	2 492	2 578	3 549	530	1 950
1997–98†	1 510	4 790	5 868	2 531	1 027	1 623	811	1 982
1998–99†	2 958	2367	5 613	3 462	820	3 147	844	1 231
1999–00†	2 533	1 733	5 985	4 306	970	3 943	628	1 043
2000–01†	4 012	1 648	5 924	4 183	332	3 005	799	1 128
2001–02†	2 973	1 769	3806	4 470	697	2 378	515	983
2002–03†	2 521	1 395	4 105	3 941	481	1 636	868	1 640
2003–04†	1 046	1 244	5 082	3 767	458	1 590	973	1 496
2004–05†	665	1 447	5 848	3 840	234	1 594	851	1 580
2005–06†	529	1 354	5 145	3 289	265	1 770	763	2 616
2006–07†	530	1 220	5 863	2 214	263	1 651	795	3 071

Year	Total estimated	Estimated landings (%)
1978–79*	9	–
1979–80*	11 495	98
1980–81*	16 637	64
1981–82*	26 096	98
1982–83*	13 259	97
1983–83#	7 971	100
1983–84†	21 769	99
1984–85†	18 004	99
1985–86†	16 644	99
1986–87†	14 531	96
1987–88†	19 072	100
1988–89†	16 444	86
1989–90†	15 471	83
1990–91†	18 708	87
1991–92†	19 180	88
1992–93†	18 640	78
1993–94†	20 599	88
1994–95†	14 719	81
1995–96†	20 093	84
1996–97†	21 755	88
1997–98†	20 142	95
1998–99†	20 442	93
1999–00†	21 142	94
2000–01†	21 031	93
2001–02†	17 591	94
2002–03†	16 587	94
2003–04†	15 656	92
2004–05†	16 059	93
2005–06†	15 731	90
2006–07†	15 607	91

Source: FSU from 1978–79 to 1987–88 and MFish from 1988–89 to 2006–07
* 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 2005–06 in 2007. 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 2007. 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.

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

4.3 Customary non-commercial fisheries
There is no known customary non-commercial fishing for black oreo and smooth oreo.

4.4 Illegal catch
Estimates of illegal catch are not available.

4.5 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

There are no new assessment results from 2008 for these oreo stocks.

4.1 Introduction

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

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

4.1.1 Black oreo

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

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

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

4.1.2 Smooth oreo

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

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

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

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

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

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

Partition of the main fishery into 3 areas

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

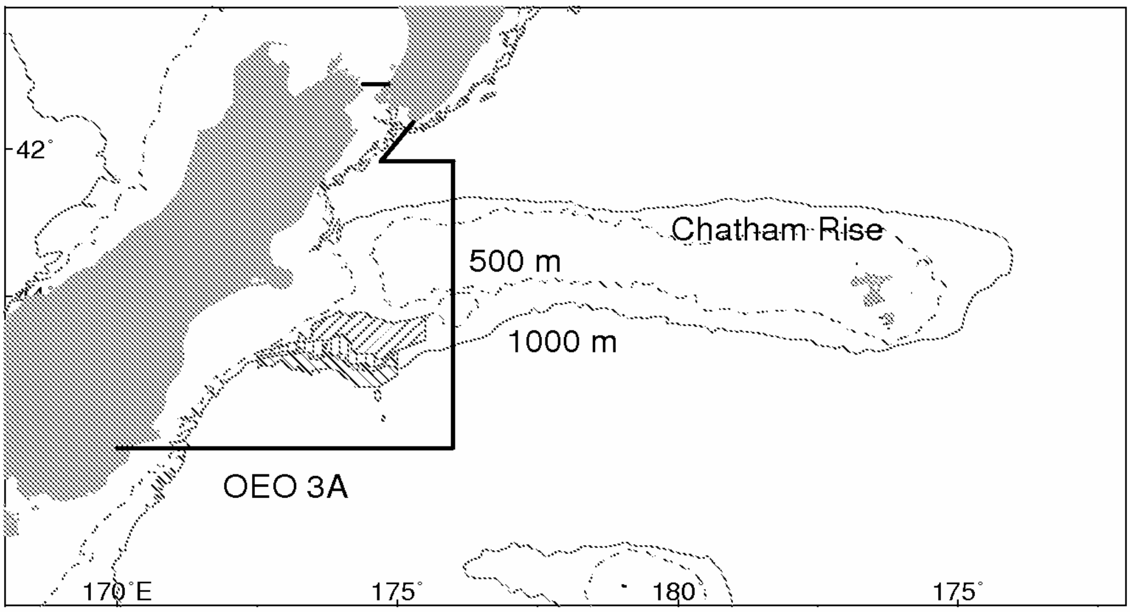

Figure 1: The three spatial areas used in the CASAL model and 2002 acoustic abundance survey. Area one at the top with right sloping shading; area two in the middle with vertical shading; area three at the bottom with left sloping shading. The thick dark line enclosed management area OEO 3A.

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

4.2.1 Estimates of fishery parameters and abundance

Catches by area

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

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

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

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

Observer length frequencies by area

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

Research acoustic survey length frequencies by area

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

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

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

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

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

Absolute abundance estimates from the 1997 and 2002 acoustic surveys

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

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

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

Relative abundance estimates from standardised CPUE analysis

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

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

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

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

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

Fishing			Pre-GPS			Post-GPS
year	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3
1979–80	–	1.45 (39)	1.50 (125)	–	–	–
1980–81	–	1.84 (17)	2.52 (15)	–	–	–
1981–82	–	1.72 (22	2.13 (9)	–	–	–
1982–83	–	1.41 (8)	1.79 (14)	–	–	–
1983–84	–	0.98 (8)	1.02 (19)	–	–	–
1984–85	–	0.94 (27)	0.97 (12)	–	–	–
1985–86	–	0.63 (31)	0.68 (33)	–	–	–
1986–87	–	0.82 (22)	0.87 (36)	–	–	–
1987–88	–	0.47 (20)	0.48 (23)	–	–	–
1988–89	–	0.70 (21)	0.24 (44)	–	–	–
1989–90	–	–	–	–	–	–
1990–91	–	–	–	–	–	–
1991–92	–	–	–	–	–	–
1992–93	–	–	–	–	1.45 (28)	1.50 (42)

Table 6 (*Continued*):

1993–94	–	–	–	–	1.84 (39)	2.52 (24)
1994–95	–	–	–	–	1.72 (12)	2.13 (22)
1995–96	–	–	–	0.95 (54)	1.41 (19)	1.79 (53)
1996–97	–	–	–	1.23 (32)	0.98 (16)	1.02 (21)
1997–98	–	–	–	0.93 (32)	0.94 (36)	0.97 (21)
1998–99	–	–	–	0.95 (38)	0.63 (46)	0.68 (29)
1999–00	–	–	–	1.19 (32)	0.82 (52)	0.87 (17)
2000–01	–	–	–	1.11 (41)	0.47 (82)	0.48 (62)
2001–02	–	–	–	0.73 (113)	0.70 (27)	0.24 (8)

4.2.2 Biomass estimates

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

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

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

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

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

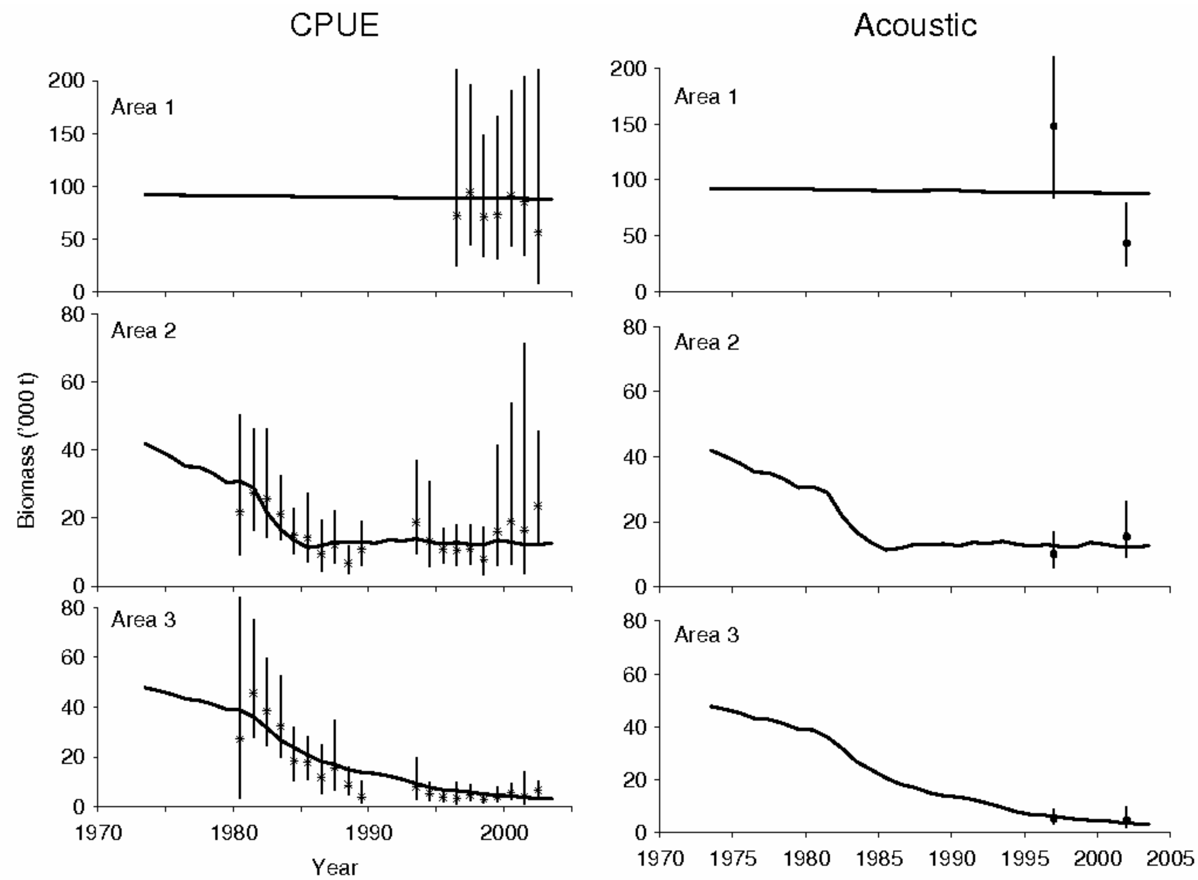

Figure 2: The fit of the abundance observations (CPUE and the absolute acoustic estimates) for each area to the predicted total biomass trajectories for the 2004 assessment of black oreo in OEO 3A (MPD solution, base case). The vertical lines are the 95% confidence intervals. The CPUE series were adjusted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

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

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

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

Comparison of the CASAL spatial model with previous stock assessments

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

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

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

† only when juvenile natural morality was estimated

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

4.2.3 Projections

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

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

Annual catch (t)	$P(B_{2007–2008}>20\%Bo)$	$P(B_{2007–2008}>27\%Bo)$	$Bmed_{2007–08}$
(a) Mature biomass Areas 1–3			
1000	1	1	56
1500	1	1	55
1855	1	1	54
2000	1	1	54
2500	1	1	52
3000	1	1	51
(b) Vulnerable biomass (areas 2 & 3)			
1000	1	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

4.2.4 Other factors

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

4.3 Smooth oreo

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 sub-areas were recognised.

4.3.1 Estimates of fishery parameters and abundance

Catch history

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

Table 11: Reconstructed catch history (t)

Year	Catch	Year	Catch	Year	Catch	Year	Catch
1972–73	†3 440	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