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Assessment of Chatham Rise smooth oreo (OEO 3A and OEO 4) for 1997

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ASSESSMENT OF CHATHAM RISE SMOOTH OREO (OEO 3A AND OEO 4) FOR 1997

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1. EXECUTIVE SUMMARY

Biomass of smooth oreo in OEO 3A was estimated from stock reduction analyses using abundance indices from catch per unit effort (CPUE), and for OEO 4 using abundance indices from research trawl survey data. Yields from both stocks will be low because the productivity of smooth oreo, based on unvalidated age estimates, is low. Estimates of long-term sustainable yield (MCY) for smooth oreo in OEO 3A were 1100–1400 t (95% confidence interval). Estimated long-term sustainable yields for smooth oreo in OEO 4 were 1600–6200 t (trawl catchability constrained within the range 1.8–0.27). The recent catch levels of smooth oreo from OEO 3A were higher than the yield estimates in OEO 3A. For OEO 4, recent catch levels of smooth oreo were higher than the yield estimate where catchability was set to 1.8, but were less than the yield estimate where catchability was 0.27.

2. INTRODUCTION

2.1 Overview

This document presents an updated and revised stock assessment for smooth oreo in OEO 3A (*see* Doonan *et al.* (1996)) using a standardised CPUE analysis as an index of abundance. Catch data were updated from the 1996 assessment, the CPUE analysis was revised by using target species in the New Zealand regressions, and new biological parameters were used in a stock reduction analysis applied to the abundance index. A revised assessment of smooth oreo in OEO 4 is also presented, using the south Chatham Rise trawl survey data (1991–1993, 1995) as an abundance index with the new biological parameters in a stock reduction analysis where catchability of smooth oreo from the trawl surveys was constrained between 0.27 and 1.8.

2.2 Description of the fishery

Smooth oreo are caught by trawling at depths of 800–1300 m in southern New Zealand waters. The south Chatham Rise fishery is on two grounds: in OEO 3A between 172° and 176° E and in OEO 4 from about 178° 20′ E to 174° W (Figure 1). Fishing in the first area has mainly been on undulating terrain (short plateaus or terraces and "drop-offs") with some fishing on hills or seamounts: the second area is a mix of undulating terrain and hills, but at the eastern end it is almost exclusively a hill fishery. Orange roughy is a minor catch element in the western Chatham Rise fishing area, but the proportion increases towards the east along the Chatham Rise.

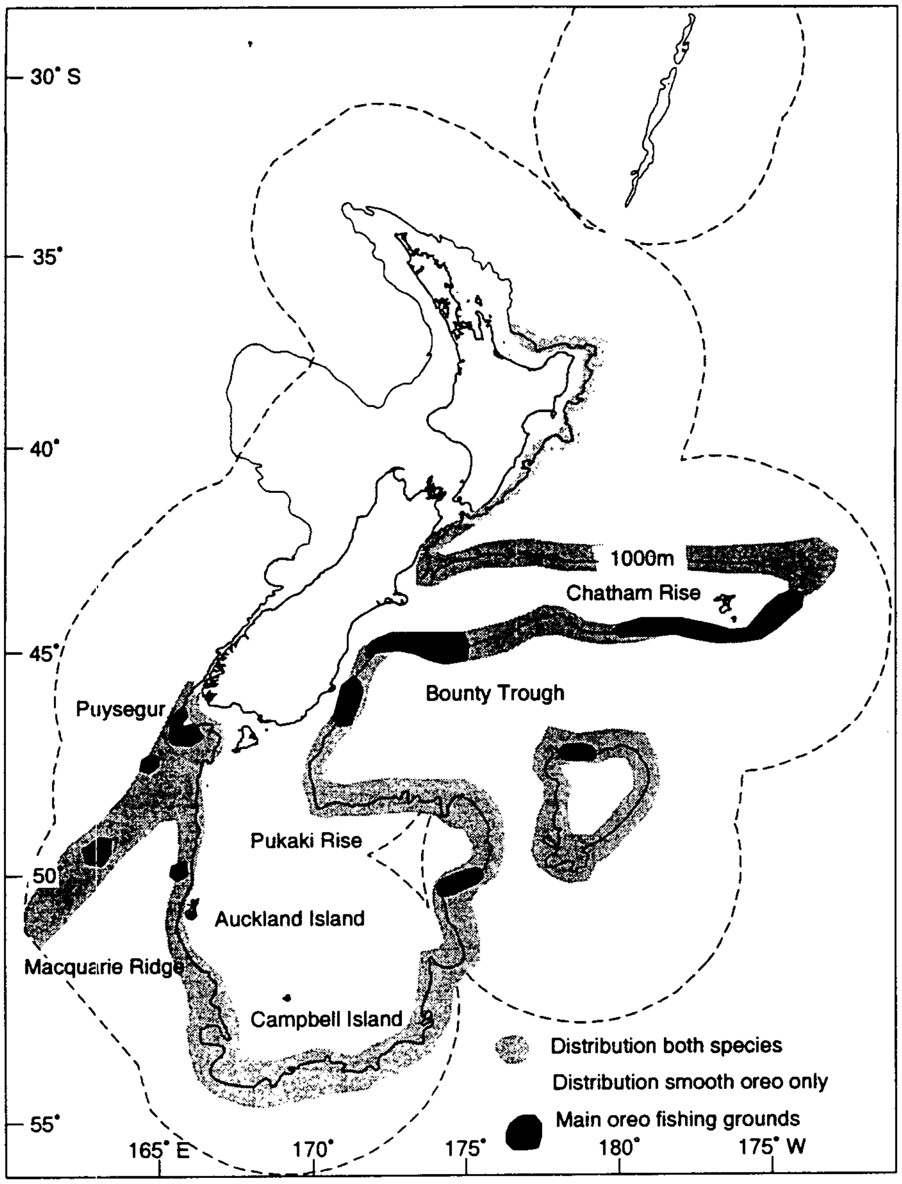

Figure 1: The main fishing grounds and distribution of black oreo and smooth oreo.

2.3 Literature review

The literature was summarised by McMillan *et al.* (1988), McMillan & Hart (1991), Doonan *et al.* (1995a), and Doonan *et al.* (1996). The last stock assessment was given in Annala and Sullivan (1996). Age estimates for Chatham Rise smooth oreo were given by Doonan *et al.* (1995b, 1997). Fincham *et al.* (1991) provided a summary of oreo catches from 1972 to 1988, and McMillan & Hart (1994a, 1994b, 1994c, 1995) and Hart & McMillan (unpubl. results) reported on annual south Chatham Rise biomass trawl surveys from 1990 to 1995.

3. REVIEW OF THE FISHERY

3.1 TACCs, catch, landings, and effort data

Oreos are managed as a group which includes black oreo (*Allocyttus niger*, BOE), smooth oreo (*Pseudocyttus maculatus*, SSO), and spiky oreo (*Neocyttus rhomboidalis*, SOR). The last species is not sought by the commercial fleet and is a minor bycatch in some areas, e.g., the Ritchie Bank orange roughy fishery. The management areas used since October 1986 are shown in Figure 2.

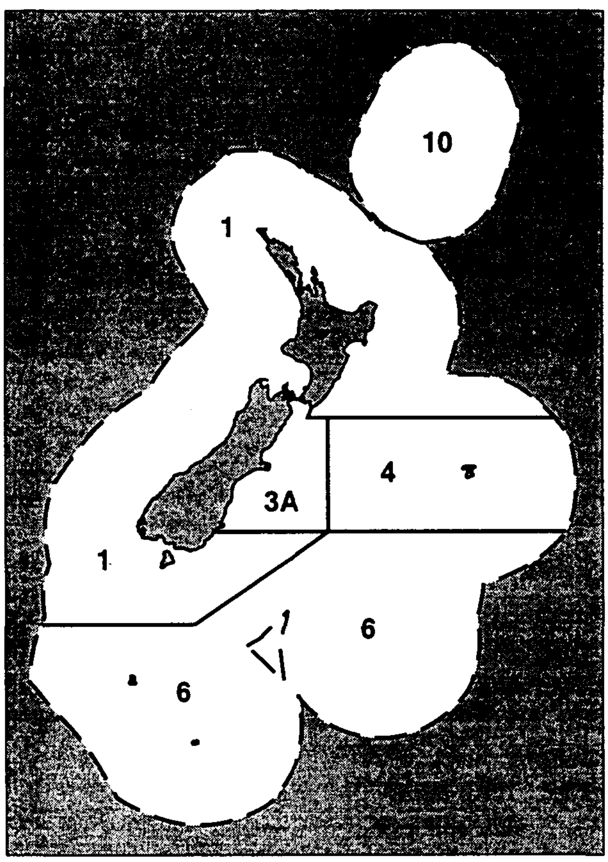

Figure 2: Oreo management areas.

Separate catch statistics for each oreo species were not requested in the version of the catch statistics logbook used when the New Zealand EEZ was formalised in April 1978, so the catch for 1978–79 was not reported by species (the generic code OEO was used instead). From 1979–80 onwards the species were listed and recorded separately. When the ITQ scheme was introduced in 1986, the statutory requirement was only for the combined code (OEO) for the Quota Management Reports, and consequently some loss of separate species catch information has occurred even though most vessels catching oreos are requested to record the species separately in the catch-effort logbooks.

The oreo fishery started in about 1972 when the Soviets reported 7000 t (probably black oreo and smooth oreo combined, *see* Doonan *et al.* (1995a)) from the New Zealand area (Table 1). Reported landings of oreos (combined species) and TACs from 1978–79 until 1995–96 are given in Table 2. The Chatham Rise TAC has been the same from 1982–83 to 1995–96 (about 10 000 t for OEO 3A and 7000 t for OEO 4), but the TACC for OEO 3A was reduced to 6600 t for the 1996–97 fishing year. Reported estimated catches by species from tow by tow data recorded in catch and effort logbooks (Deepwater, TCEPR, and CELR) are given in Table 3. The values recorded as "OEO" have been scaled up to the amounts recorded for each fishstock in Table 2, i.e., SSO + BOE + OEO (Table 3) = fishstock (Table 2).

Table 1: Soviet oreo catch (t) by FAO area from 1972 to 1977 (from Fincham *et al.* 1991)

	FAO area†		
Year	**81.4**	**81.5**	**Total**
1972	121	6 879	7 000
1973	0	7 600	7 600
1974	0	10 200	10 200
1975	87	2 513	2 600
1976	242	7 758	8 000
1977	0	11 500	11 500

† The two FAO areas include waters west of N.Z. (81.4) and east of N.Z. (81.5).

Table 2: Total reported landings (t) for all oreo species combined by Fishstock from 1978–79 to 1995–96 and TACs (t) from 1982–83 to 1995–96

	FISHSTOCK									
	OEO 1		OEO 3A		OEO 4		OEO 6		Total	
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†	4 704	6 044	7 719	10 106	6 801	7 000	4 348	3 000	23 572	26 160

Source: FSU from 1978–79 to 1987–88; QMS/ITD from 1988–89 to 1995–96.
* 1 April to 31 March.
\# 1 April to 30 September. Interim TACs applied.
† 1 October to 30 September.

Note: TAC for OEO 10 (Kermadec) is 10 t but there has been no reported catch.

Table 3: Reported estimated catch (t) by species (smooth oreo (SSO), black oreo (BOE), and unspecified species (OEO)) by Fishstock from 1978–79 to 1995–96

	SSO				BOE				OEO				
Year	OEO 1	OEO 3A	OEO 4	OEO 6	OEO 1	OEO 3A	OEO 4	OEO 6	OEO 1	OEO 3A	OEO 4	OEO 6	TOTAL
1978–79*	0	0	0	0	9	0	0	0	2 799	1 366	8 041	0	12 231
1979–80*	16	5 075	114	0	118	5 588	566	18	0	8	0	0	11 791
1980–81*	1	1 522	849	2	66	8 758	5 224	215	400	4 424	4 142	0	25 851
1981–82*	21	1 283	3 352	2	0	11 419	5 641	4 378	0	41	9	0	26 514
1982–83*	28	2 138	2 796	60	6	6 438	1 088	705	128	0	42	0	13 680
1983–83#	9	713	1 861	0	1	3 693	1 340	354	30	3	9	0	8 015
1983–84†	1 246	3 594	4 871	1 315	1 751	5 524	1 214	2 254	243	72	18	0	22 111
1984–85†	828	4 311	4 729	472	544	3 897	1 651	1 572	103	76	10	0	18 204
1985–86†	4 257	3 135	4 921	72	1 060	2 184	961	54	0	12	0	0	16 820
1986–87†	326	3 186	5 670	0	163	4 026	1 160	0	36	7	0	0	15 093
1987–88†	1 050	5 897	7 771	197	114	3 140	903	0	65	12	0	0	19 159
1988–89†	261	5 864	6 427	–	86	2 719	1 087	0	85	1 608	933	0	19 070
1989–90†	1 141	5 355	5 320	–	872	2 344	439	–	96	1 587	1 589	0	18 744
1990–91†	1 437	4 422	5 262	81	2 314	4 177	793	222	812	1 228	881	0	21 666
1991–92†	1 008	6 096	4 797	2	2 384	3 176	1 702	15	764	800	958	16	21 718
1992–93†	1 716	3 461	3 814	529	3 768	3 957	1 326	69	360	1 871	2 837	217	23 924
1993–94†	2 000	4 767	4 805	808	2 615	4 016	1 553	35	295	323	1 961	140	23 318
1994–95†	835	3 589	5 272	1 811	385	2 052	545	230	263	959	1 863	487	18 291
1995–96†	2 489	3 577	5 142	2 377	1 290	3 342	364	1 147	925	800	1 295	824	23 572

Source: FSU from 1978–79 to 1987–88 and ITD from 1988–89 to 1995–96.
* 1 April to 31 March.
\# 1 April to 30 September.
† 1 October to 30 September.
– Less than 1 t.

3.1.1 CPUE analysis for smooth oreo from OEO 3A

Data

The smooth oreo catch and effort data were restricted to that area within OEO 3A (the "CPUE study area") where the main fishery occurred from 1978–79 to 1995–96 (*see* figure 4 in Doonan *et al.* 1995a). The total estimated catch of smooth oreo from this area was 56 297 t and the smooth oreo catch from the rest of area OEO 3A was 11 000 t between 1978–79 and 1995–96. A catch of about 3500 t, reported from the Waitaki Canyon area in 1991–92, was not typical or sustained in subsequent years and therefore all the smooth oreo data from 1991–92 where excluded when the catch from the CPUE study area and the catch from the rest of area OEO 3A were calculated, i.e., smooth oreo catch totals were 53 700 t from the CPUE study area, and 7500 t from the rest of OEO 3A between 1978–79 and 1995–96.

Method of CPUE analysis

The CPUE analysis method was described by Doonan *et al.* (1995a, 1996). The same selected variables were used in the New Zealand regressions with the addition of target species. The Soviet analysis was unchanged from 1996 (no new data). Two cases are presented below and differ from those in Doonan *et al.* (1995a, 1996): the "base" case used Soviet and New Zealand CPUE data analysed separately while the "New Zealand" case used New Zealand CPUE data only.

Results of CPUE analysis

For the Soviet abundance series, the data used were from 1982–83 to 1987–88. The variables year, vessel, area, depth, and season were used for the positive catch regression (R^2 = 29%), and also for the zero catch regression (R^2 = 14%). Data from 1980–81 to 1981–82 were dropped because there were fewer than 50 tows per year. The 1979–80 data were dropped because those data caused the regression to fail (when vessel was a variable in the regression, the matrix, which was used in its inverse form, was singular and so the inverse could not be formed and no regression solution was possible). The data from 1988–89 were dropped because only one vessel fished in that year. No relationship was seen between the number of vessels fishing in a year and the *c.v.* of the indices so the mean *c.v.*, 61%, was taken as the *c.v.* for the abundance index series.

For the New Zealand abundance series, the data used were from 1986–87 to 1995–96. The variables year, vessel, area, depth, target species, and season were used for the positive catch regression (R^2 = 31%), but only year, vessel, and season were used for the zero catch regression (R^2 = 8%). Data from 1982–83 to 1985–86 were dropped because they had fewer than 50 tows per year. The reference year (1990–91) was chosen because it provided the most data and gave the relative indices with the lowest *c.v.*s compared to other years. No relationship was seen between the number of vessels fishing in a year and the *c.v.* of the indices so the mean *c.v.*, 57%, was taken as the *c.v.* for the abundance index series.

The time series of abundance indices for the Soviet and New Zealand data are given in Table 4 and both series show a decline which is more marked in the Soviet data.

Table 4: Smooth oreo, OEO 3A. Soviet and New Zealand time series of abundance indices from CPUE. –, no data

Year	Soviet	New Zealand
1982–83	6.92	–
1983–84	1.75	–
1984–85	3.41	–
1985–86	2.55	–
1986–87	1.00	2.21
1987–88	0.61	1.92
1988–89	–	1.24
1989–90	–	1.23
1990–91	–	1.00
1991–92	–	1.64
1992–93	–	1.16
1993–94	–	1.23
1994–95	–	0.97
1995–96	–	0.69

3.2 Other information

Mean length (total length) data for smooth oreo

OEO 3A

Observer mean length data from commercial vessels fishing this area were analysed and presented by Doonan *et al.* (1995a). The analysis was not updated here because there were too few new observer data.

OEO 4

The smooth oreo mean length data collected by observers on New Zealand commercial vessels fishing on the flat and on hills were updated from those presented by Doonan *et al.* (1996). The data were scaled by catch and included all lengths, i.e., pre-recruit and recruited fish. The data were sparse in some years, e.g., 1988 and 1989 had only one tow each and were therefore excluded. Sample sizes are presented in Table 5. Data were divided into four areas to try to stratify the fishing areas along the south Chatham Rise based on closeness (discrete fishing areas) and consistent sampling, i.e., over the history of the fishery. Area 1 at the western end was fished first on the flat and on hills, while Area 4 at the eastern end was fished last and supported almost solely hill fishing. There may have been changes in fishing patterns within each area, e.g., a switch to mainly hill fishing, and this may have influenced trends.

Table 5: Smooth oreo: number of tows sampled by observers (number of fish lengths measured in parentheses) on New Zealand vessels from four areas within OEO 4 from 1990 to 1996. Areas are: 1, 178° 20′ to 177° 15′ W; 2, 177° 08′ to 176° 16′ W; 3, 176° 04′ to 175° 00′ W; 4, 175° 00′ to 174° 00′ W

Year	Area 1	Area 2	Area 3	Area 4
1990	4 (747)	2 (210)	18 (2 070)	0 (0)
1991	6 (714)	5 (495)	4 (684)	36 (4 132)
1992	0 (0)	0 (0)	3 (328)	9 (986)
1993	1 (111)	10 (1 104)	30 (2 905)	39 (3 993)
1994	5 (516)	29 (3 154)	17 (1 544)	39 (4 325)
1995	7 (691)	13 (1 435)	8 (952)	4 (744)
1996	0 (0)	5 (678)	0 (0)	1 (196)

Mean lengths are shown in Figure 3. There were no trends in areas 1 and 3 (and no new data). In area 2, the means for two of the three years at the end of the series were lower than the means for the first two years. Area 4 showed a decline of about 3 cm from values that were initially higher than in the other areas.

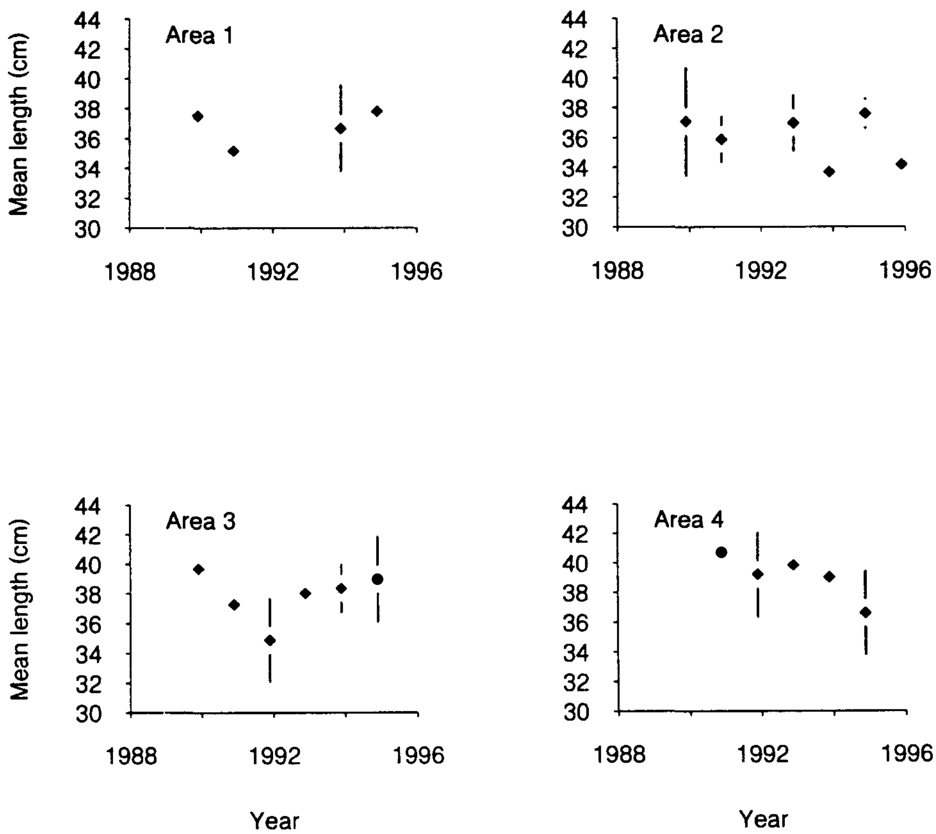

Figure 3: Smooth oreo, OEO 4. Observer length frequency data scaled to catch. Mean length (◆). Vertical lines are ± 2 s.e., dark (females), pale (males). Areas are: 1, 178° 20′ to 177° 15′ W; 2, 177° 08′ to 176° 16′ W; 3, 176° 04′ to 175° 00′ W; 4, 175° 00′ to 174° 00′ W.

3.3 Recreational and Maori customary Fisheries

There is no known recreational or Maori customary catch of oreos.

3.4 Other sources of fishing mortality

Dumping of unwanted or small fish and accidental loss of fish (lost, ripped codends, etc.) were features of the fisheries, particularly in the early years. These sources of mortality were probably substantial but are thought to be relatively small for the last few years. No estimate of mortality from these sources has been made because of lack of hard data and because they now appear to be small.

4. RESEARCH

4.1 Stock structure

The Chatham Rise oreo fishery is managed as two Fishstocks, OEO 3A and OEO 4. These management areas were introduced in 1982–83 to define what appeared to be two separate fisheries (*see* figure 3 in Doonan *et al.* (1995a) for a discussion of separate fishing areas on the south Chatham Rise).

The three species of oreos (black, smooth, and spiky) are managed as if they were one stock. It would be desirable to manage each species separately. They have different depth and geographical distributions, growth, and productivity (McMillan 1985, Doonan *et al.* 1995b).

There are no genetic data to define stock structure on the Chatham Rise. Ward *et al.* (1996) were not able to detect genetic differences between New Zealand and Australian smooth oreo using allozyme and mDNA tests, but it is unlikely that there would be one stock given the large distance separating the populations.

4.2 Resource surveys

Trawl surveys have been carried out in most years since 1986 (Table 6). The abundance estimates from the surveys before 1991 were not considered to be comparable with the *Tangaroa* series because different vessels were used. Other results from those early surveys were used, e.g., gonad staging to determine length at maturity. The 1991–93 and 1995 "standard" (flat, undulating, and drop-off ground) surveys are comparable, though major changes to survey design were put in place for the 1992 survey. Six hills were chosen at random from a list of 14 known fishing hills and these were sampled using random trawl methods in 1992 and 1993 (the "hill" survey), but hill abundance estimates are not reported here because there are only two sets of estimates and they have high individual *c.v.*s.

Table 6: Random stratified trawl surveys (standard, i.e. flat tows only) for oreos on the south Chatham Rise (OEO 3A & OEO 4)

Year	Area (km²)	Vessel	Survey area	No. of stations
1986	47 137	*Arrow*	South	186
1987	47 496	*Amaltal Explorer*	South	191
1990	56 841	*Cordella*	South, southeast	189
1991	56 841	*Tangaroa*	South, southeast	154
1992	60 503	*Tangaroa*	South, southeast	146
1993	60 503	*Tangaroa*	South, southeast	148
1995	60 503	*Tangaroa*	South, southeast	172

Mean length (total length) data for smooth oreo

OEO 3A

Research mean length data from this area were analysed and presented by Doonan *et al.* (1995a). The analysis was not updated because there was little new research data from voyage TAN9511.

OEO 4

The smooth oreo mean length data collected from the standard research trawl survey (i.e., flat tows only) were scaled to represent the biomass (Figure 4). The female and male mean length research data showed no trend from 1986 to 1992, but then declined by about 3 cm for females and 2 cm for males in 1993 and remained at the lower level in 1995. The mean length of males was less than that of females from 1986 to 1992, but was close to the female value in 1993 and 1995. These declines could be due to substantial new recruitment or a real decline in mean length of the population, possibly because fishing has removed larger individuals.

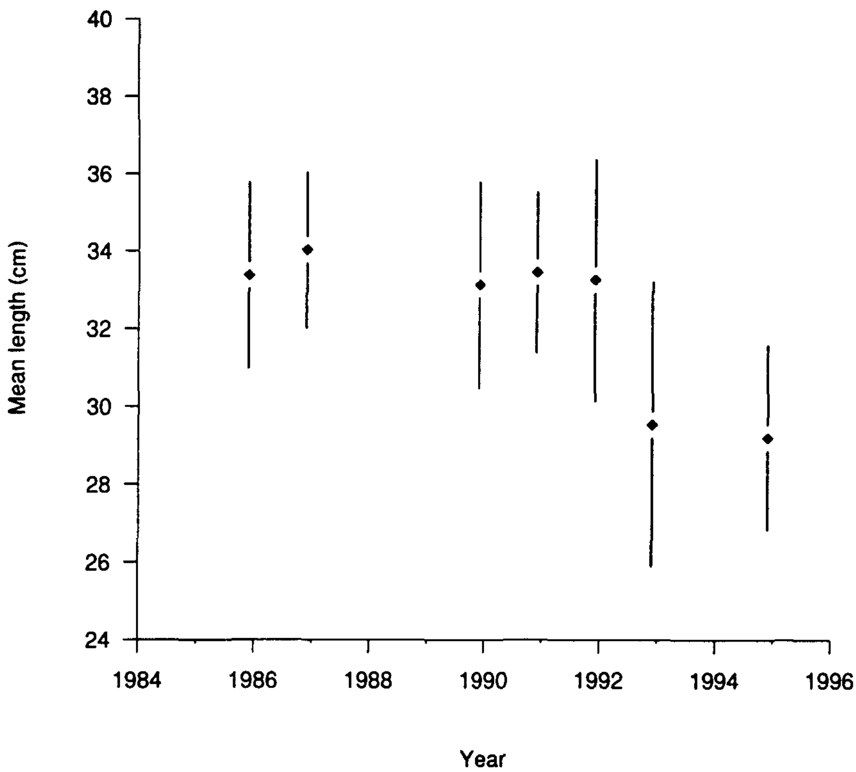

Figure 4: Smooth oreo, OEO 4. Research length frequency data scaled to biomass. Mean length (◆). Vertical lines are ± 2 s.e., dark (females), pale (males).

4.3 Other studies

Catchability (q) of smooth oreo from the trawl surveys of OEO 3A and OEO 4

Inconsistent estimates of q, resulting from stock reduction analyses of the abundance estimates from the *Tangaroa* trawl surveys carried out in OEO 3A and OEO 4, were identified at the 1996 stock assessment plenary meeting. Analyses were therefore subsequently carried out to resolve the following:

(a) what were the reasons for the differences in estimated q between the *Tangaroa* trawl surveys of OEO 3A and OEO 4?

(b) what would be reasonable bounds for estimates of q for these surveys?

<u>The differences in estimated q between the *Tangaroa* trawl surveys</u>

All seven trawl surveys (including *Tangaroa* and non-*Tangaroa*, *see* Table 6) were considered in this analysis of catchability. The 1986 and 1987 surveys covered only 26 000 km^2 in OEO 4 compared to 39 000 km^2 in the later surveys, so biomass estimates were increased by 1.2 to make them comparable with later estimates. The scaling factor (1.2) was calculated from the ratio of biomass from the total area of the 1990 survey to the biomass in the survey area of the 1986 and 1987 surveys. The same net design and a similar net setup and towing method were used on all surveys.

Catchability (and virgin biomass) are usually estimated in a stock reduction analysis, but q is generally poorly estimated by that method. For OEO 3A and OEO 4, stock reduction analyses gave estimates of q of 0.14 and 4 respectively (wingspread estimates from *Tangaroa* surveys only). The surveys used in this analysis covered both areas consecutively so the difference in q may indicate an inconsistency between the surveys in OEO 3A and OEO 4. Note that qs from hoki surveys were from doorspread estimates.

To investigate the inconsistency, an implied q (denoted by q_i in the text to distinguish it from the estimate of q that comes out of the trawl survey stock reduction) for each survey, i, was calculated using

$$q_i = \frac{I_i}{B_i'}$$

where I_i is the estimate of biomass from the trawl survey, and B' is the estimated biomass from the stock reduction analysis. Differences between these q_is were due to differences in catchability (between vessel, yearly variations, and differences in areal availability in OEO 3A and OEO 4) and also to sample variability in the I_is. The q_i values also depended on the B_i' s being unbiased. Both stock reduction analyses estimated virgin biomass at B_{min}. The OEO 3A analysis included two abundance series from CPUE data plus the *Tangaroa* trawl surveys, but the OEO 4 analysis used only the *Tangaroa* trawl surveys.

The results showed wide variations in q_i but there were some marked differences between q_is for OEO 3A and OEO 4 and also between the *Tangaroa* and the vessels used in the first three surveys (Figure 5 and Tables 7 and 8). For OEO 3A, q_i values from the first three non-*Tangaroa* surveys were similar, ranging from 0.9 to 1.5, but were about 5 times those for the 1991–93 surveys and 38 times that for 1995 (Table 7). To test for statistical significance (assuming a normal distribution), the surveys were grouped into non-*Tangaroa* and *Tangaroa* (first 3 only) and the mean q_i from each group compared (Table 8). The mean difference was significant at the 5% level (Student's t-distribution).

For OEO 4, the differences in q_i between the first three non-*Tangaroa* and all four *Tangaroa* surveys was only a factor of two, but the mean q_i for the non-*Tangaroa* surveys was significantly different (5% level, assuming a normal distribution, Student's t-distribution) from the mean for the *Tangaroa* surveys (Table 8).

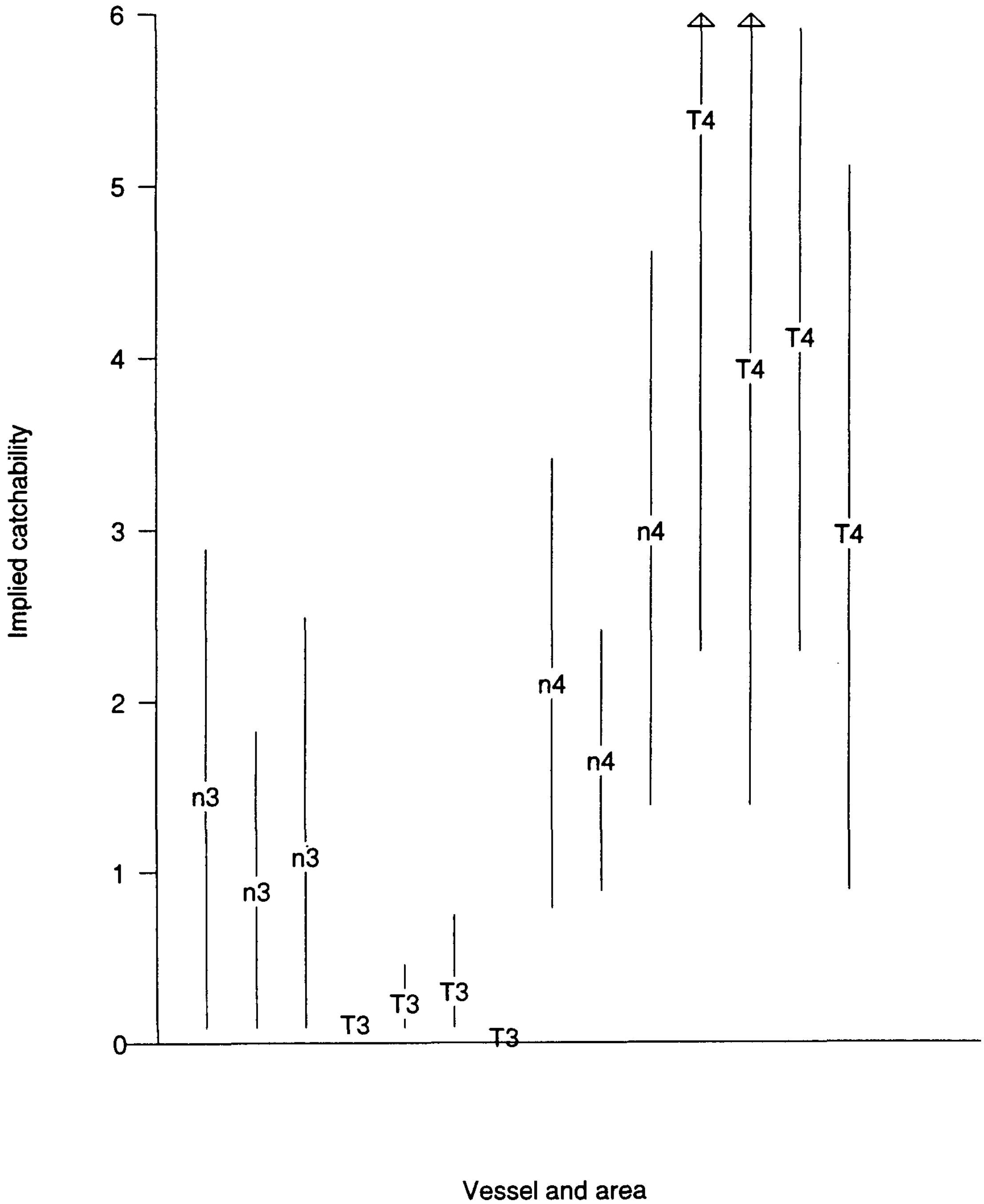

Figure 5: Implied catchabilities (q_i) for trawl surveys in OEO 3A and OEO 4, where n = mean value for each non-*Tangaroa* survey, T = mean value for each *Tangaroa* survey, 3 = OEO 3A, and 4 = OEO 4. The vertical lines are 2 standard errors using the *c.v.*s from the trawl biomass estimates, and they are cut off at 6.0 (marked by arrows).

The non-*Tangaroa* surveys have about half the value of implied q_is for OEO 3A compared to OEO 4. The mean q_is were significantly different (but only just at the 5% level, Table 8). This suggested that the areal availability was different between the two regions, or, that the estimated biomass from the OEO 4 stock reduction analysis was too low, assuming that the OEO 3A stock reduction analysis was correct.

Table 7: Implied catchabilities (q_i) for trawl surveys in OEO 3A and OEO 4. Biomass in tonnes

		Trawl estimated		Stock reduction	
Year	**Vessel**	**Biomass (I_i)**	*c.v.* **(%)**	**Biomass (B_i')**	**q_i**
a) OEO 3A					
1986	*Arrow*	48.1	53	33.2	1.45
1987	*A. Explorer*	27.8	59	31.4	0.89
1990	*Cordella*	21.5	69	19.8	1.09
1991	*Tangaroa*	1.8	73	16.6	0.11
1992	*Tangaroa*	3.5	73	15.5	0.23
1993	*Tangaroa*	4.2	93	14.0	0.30
1995	*Tangaroa*	0.3	30	9.6	0.03
b) OEO 4					
1986	*Arrow*	107	34	50.9	2.10
1987	*A. Explorer*	76	27	46.1	1.65
1990	*Cordella*	85	29	28.4	2.99
1991	*Tangaroa*	134	30	24.9	5.38
1992	*Tangaroa*	84	33	21.4	3.93
1993	*Tangaroa*	72	23	17.5	4.11
1995	*Tangaroa*	27	37	9.1	2.97

Table 8: Mean implied catchabilities (q_i) for trawl surveys in OEO 3A and OEO 4 for the non-*Tangaroa* series (1986–90), for the first 3 *Tangaroa* surveys (1991–93), for the fourth *Tangaroa* survey (1995) or for all the *Tangaroa* surveys (1991–95). N is the number of surveys

Surveys	**N**	**Mean q_i**
a) OEO 3A		
1986–90	3	1.20
1991–93	3	0.21
1995	1	0.03
b) OEO 4		
1986–90	3	2.3
1991–95	4	4.1

These differences suggested that the *Tangaroa* surveys in OEO 3A were inconsistent with other smooth oreo surveys and that the survey is now flawed for smooth oreo in OEO 3A. The low catchability values for the 1991–95 OEO 3A *Tangaroa* surveys means that they missed most of the recruited stock. A possible explanation for this is that these surveys had a very small chance of randomly "hitting" one of the few schools in the area. Adults of this species school and most of the recruited population is thought to be contained in schools. An analysis of the number of smooth oreo schools observed during the TAN9511 echo-sounder survey in OEO 3A suggested that about 695 trawl stations would have been needed in 1995 to achieve a 30% *c.v.* for the biomass estimate (Doonan *et al.*, unpubl. results). This contrasts with the 24–44 carried out each year during the four *Tangaroa* surveys. Another indication that these surveys were not sampling the adult fish adequately was that the research survey mean lengths were 10 cm lower than the mean from observer data (taken on fishing vessels which may try to target large fish).

Bounds on values of catchability

Cordue (1996) gave a method to put bounds on catchability values estimated from trawl surveys. Catchability is the product of three terms: vertical availability (u_v, the proportion of fish herded down below the headline of the net), areal availability (u_a, the proportion of fish that is in the survey area at the time of the survey), and vulnerability (v, the average proportion of fish that is available to the net that is caught). Bounds were placed separately on the three terms in such a way that the investigators were all comfortable that the true value for each term was included in the range. The lower bound for catchability is the product of the three lower bounds of the terms, and the upper bound is the product of the three upper bounds.

Bounds on catchability were considered by the Deepwater Stock Assessment Working Group. The resulting proposed values plus those from the literature were:

(a) Smooth oreo: 0.42–2.0 (OEO 3A) and 0.27–1.8 (OEO 4). These preliminary bounds were derived using the Cordue method. Estimates of the individual elements were:

	Low	High
u_v	0.8	1.0
u_a		
OEO 3A	0.8	1.0
OEO 4	0.5	0.9
v	0.67	2.0

The reasoning behind these estimates for smooth oreo was:

1) u_v The high value assumed complete herding. The low value (0.8) was chosen because this species forms schools which extend up from the bottom and all fish may not be herded down into the net. A check on the lower bound was made by analysing the frequency of marks observed at the net mouth during research trawls.

During research trawls, marks observed on the net monitor were coded as no marks, marks that were all under the headline, or marks above and below the headline. The first survey with data was the *Cordella* in 1990 where 44 trawls (10 catches of over 2 t) had marks on the net monitor of which 9 (20%) had marks above the headline. There were no big catches when no marks were observed on the net monitor. For the four *Tangaroa* surveys, 169 trawls had marks on the net monitor, but only one trawl had marks above the headline. The chance of a big catch was 30% if a mark was seen on the net monitor,

and 7% if no marks were observed.
Thus, the lower limit for vertical availability is given by the *Cordella* data, i.e., 0.80.

2) u_a For OEO 3A the low value (0.8) assumed that about 20% of the survey area was not trawlable and the high value assumed that all the survey area was trawlable. For OEO 4 we estimated that about 20% of the fish were on the hills (McMillan *et al.* 1996) and perhaps another 20% was not trawlable, i.e., a low of 0.6. The high value assumed that 20% of fish were not available because they were on the hills and that all other ground was trawlable, i.e., 0.8.

3) v The low value for *v* was taken as the ratio of the distance between the ends of the ground rope to that between the ends of the wingtips. The absence of lower wings leaves a gap on the side of the net through which fish can potentially escape. The wingtip distance was 26 m, the ground rope length was 22.4 m, and the groundrope extension was 13.1 m (each side). To calculate distance between the ends of the groundrope we assumed that the groundrope and its extension were a parabola. The estimated distance between the ends of the groundrope was 17.3 m. The lower limit for vulnerability is 17.3/26 = 0.67. The upper value for v was 2 which assumes that the effective herding of fish is about halfway between the area swept by the doors (v = 4) and between the wings of the net.

(b) Hoki 0.17–2.9 (Cordue (1996), corrected to wingtip)

(c) Ling 0.13–3.0 (Cordue (1996), corrected to wingtip)

(d) Orange roughy, a range of 0.6–1.7. For the Chatham Rise, the estimated value was 0.6–0.7 (in which two vessels were treated as one). For the Challenger Plateau, the implied q for two surveys that were not used in the assessment (based on CPUE) was 1.4 and 1.7. For Puysegur, q was estimated at 1.3 for the winter surveys and 0.6 for the spring surveys in the stock reduction analysis which included a CPUE abundance series.

The main conclusions from these analyses of catchability were that:

1 The *Tangaroa* surveys in OEO 3A probably did not sample recruited smooth oreo very well. They produced q values that were inconsistent with the estimated q values from other non-*Tangaroa* surveys in OEO 3A and OEO 4. The abundance estimates of smooth oreo for OEO 3A from the *Tangaroa* surveys should therefore be removed from the stock reduction analysis because the q value estimates from the series were too low.

2 Preliminary bounds on q for smooth oreo in OEO 4 were 0.27–1.8.

4.4 Biomass estimates

Biomass estimates for smooth oreo in OEO 3A and OEO 4 were made using deterministic stock reduction analyses (*after* Francis 1990). The following important assumptions were made in these analyses:

(a) the CPUE analysis indexed the abundance of smooth oreo in the CPUE study area in OEO 3A and the trawl survey biomass estimates indexed the abundance of most of the smooth oreo in OEO 4;
(b) the ranges used for the biological values covered their true values;
(c) the bounds on q for the OEO 4 trawl survey encompass the true value of q;
(d) varying the maximum fishing mortality (F_{max}) from 0.5 to 3.5 altered B_0 for smooth oreo in OEO 3A only by about 6% in the 1996 assessment, so one assumed value (0.9) was used in all the analyses below;
(e) recruitment was deterministic and recruitment steepness was 0.75;
(f) catch overruns were 0% during the period of reported catch.

Other minor assumptions were:

(a) the populations of smooth oreo in OEO 3A (in the main fishing ground at least) and OEO 4 were discrete stocks or production units;
(b) the exploitation rates for smooth oreo in OEO 3A were the same in the CPUE study area and in the rest of OEO 3A and the exploitation rates for smooth oreo in OEO 4 were the same in the trawl survey area and in the rest of OEO 4;
(c) the trawl surveys occurred in the first few months of the fishing year and so were assumed to index beginning-of-year biomass;
(d) the catch histories are accurate.

In OEO 3A most of the smooth oreo commercial catch taken from 1978–79 to 1995–96 came from the CPUE study area and research trawl surveys indicate that there is little habitat for, and biomass of, smooth oreo outside that area. For OEO 4, research trawl surveys indicate that the main biomass of smooth oreo in the area is contained within the trawl survey area.

Input data for the stock reduction analyses included revised life history parameters (Doonan *et al.* 1997), Table 9, catch history, Table 10, and the trawl survey abundance estimates and their *c.v.*s (Table 11). Catch history for the years 1972 (1972–73) to 1977 (1977–78) was based on reported Soviet catch (*see* Doonan *et al.* 1995a, p. 23). For subsequent years the estimated catch amounts from catch effort returns were scaled to the QMR reported catch of oreo from the CPUE study area or survey area. "OEO" (unspecified oreo) reported catch was apportioned to species by the ratio of estimated smooth oreo to black oreo catch from the catch effort data. Catches from 1977–78 to 1982–83 were adjusted to the 1 October-30 September fishing year.

Biomass estimates from the stock reduction analyses (and yield estimates) were scaled up from the OEO 3A CPUE study area and OEO 4 trawl survey area to the respective total fishstock management areas. The calculations used for each area are given below.

Table 9: Life history parameters for smooth oreo. –, not estimated

Parameter	Symbol (unit)	1996 estimates		Revised estimates	
		Female	Male	Female	Male
Natural mortality	M (yr^{-1})	0.05	0.05	0.063	0.063
Age at recruitment	A_r (yr)	20	20	21	21
Age at maturity	A_m (yr)	30	30	31	–
von Bertalanffy parameters	L_∞ (cm, TL)	52	41	50.8	43.6
	k (yr^{-1})	0.046	0.080	0.047	0.067
	t_0 (yr)	-2.9	-1.0	-2.9	-1.6
Length–weight parameters	a	0.029	0.032	0.029	0.032
	b	2.90	2.87	2.90	2.87
Recruitment variability		0.65	0.65	0.65	0.65
Recruitment steepness		0.75	0.75	0.75	0.75
Length at recruitment	(cm, TL)	34	–	34	–
Length at maturity	(cm, TL)	40	–	40	–

Table 10: Reconstructed catch history (t) of smooth oreo from the CPUE study area in OEO 3A used for the base and New Zealand cases and from flat and hills for the trawl survey area in OEO 4 used in the stock reduction analysis. All OEO 4 data are for the 1 October to 30 September fishing year. –, no data

Year	OEO 3A	OEO 4
1972–73	†3 440	–
1973–74	†3 800	–
1974–75	†5 100	–
1975–76	†1 300	–
1976–77	†4 000	–
1977–78	†5 750	4 020
1978–79	650	100
1979–80	5 215	1 829
1980–81	2 196	1 334
1981–82	1 288	1 928
1982–83	2 495	1 997
1993–84	3 395	4 764
1984–85	4 301	4 689
1995–86	2 529	4 711
1986–87	3 011	5 562
1987–88	4 394	7 569
1988–89	5 597	6 987
1989–90	5 643	6 648
1990–91	4 743	4 929
1991–92	2 804	5 165
1992–93	3 174	5 552
1993–94	4 244	5 566
1994–95	3 614	6 407
1995–96	3 427	6 018
1996–97	‡3 300	–
1997–98	‡3 300	–

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

Table 11: The 95% confidence intervals (lower and upper bounds) for smooth oreo standard (tows on flat only) research survey recruited abundance estimates (t) from OEO 4 on the south Chatham Rise. N, number of stations

	Mean abundance	Lower bound	Upper bound	*c.v.* (%)	N
1991	133 492	52 951	214 034	30	110
1992	83 550	27 619	139 481	33	122
1993	71 982	38 673	105 290	23	124
1995	27 187	7 029	47 346	37	149

4.4.1 Smooth oreo, OEO 3A

The two time series of combined CPUE abundance indices and their mean *c.v.*s, the catch history from the CPUE study area, and the life history parameters for smooth oreo were used in a deterministic stock reduction analysis to produce biomass estimates (the "base" case). Estimates were also made using just the New Zealand CPUE index of abundance (the "New Zealand" case).

The biomass estimates (and the yield estimates below) were adjusted up to the total OEO 3A area using the ratio of estimated catch from the "rest of area" OEO 3A (7500 t) to the estimated catch from the CPUE study area (53 700 t), from 1978–79 to 1995–96, i.e., 1.14.

Biomass estimates, including the 95% confidence intervals and the maximum likelihood ("best") value (in parentheses), are given in Table 12. The 95% confidence interval estimates of B_0 for the base case from this analysis were 68 000–89 000 t, based on bootstrap simulation that used the *c.v.* from the CPUE indices and assumed deterministic recruitment. Biomass estimates are uncertain because the variability of the CPUE data resulted in a 61% *c.v.* for the Soviet index series and a 57% *c.v.* for the New Zealand index.

Table 12: Biomass estimates (t) for smooth oreo from the stock reduction model for OEO 3A. Base and New Zealand case estimates are given for the CPUE study area and adjusted to the total area by multiplying by 1.14. The point estimate is the "best" estimate and the range in parentheses is the 95% confidence limits

		B_0	Mid-year $B_{1995-96}$	
			(t)	%B_0
OEO 3A	CPUE study area	61 000 (60 000–78 000)	6 000 (4 900–24 000)	10 (8–30)
Base case	Total area	70 000 (68 000–89 000)	6 900 (5 600–27 000)	10 (8–30)
OEO 3A	CPUE study area	71 000 (60 000–1 000 000)	17 000 (4 900–950 000)	23 (8–95)
New Zealand case	Total area	81 000 (68 000–1 140 000)	19 000 (5 600–1 079 000)	23 (8–95)

4.4.2 Smooth oreo OEO 4

Estimates of biomass were made with a deterministic stock reduction analysis which used the trawl survey abundance estimates as a relative abundance index, the catch history, and the revised life history parameters.

The smooth oreo catch history used in the analysis was from the south Chatham Rise trawl survey area (176° E to 174° W) only. These data include catch from the hills as well as from the flat, so it was assumed that the trawl survey indexes the fish abundance on both hills and flat.

Biomass estimates (and yield estimates below) for the trawl survey area were adjusted up to the total OEO 4 area using the ratio of the catches from the rest of area OEO 4 not indexed by the trawl survey (4098 t) to the catch from the survey area (60 403 t) from the fishing years 1986–87 to 1995–96 (*see* Table 10), i.e., a ratio of 1.07. The 1986–87 season was chosen as the start of the adjusted catch data series because the Quota Management System was introduced in that year.

Biomass estimates were made using a stock reduction analysis with q bounded by 0.27 and 1.8 (Table 13). No confidence limits were estimated but the q bounds gave plausible lower and upper limits (B_{min} and B_{max} in Table 13), i.e., B_0 range was 100 000 to 386 000 t. The decline in the trawl survey abundance index can not be modelled within these bounds (for F_{max} = 0.9), which implies that the true value of B_0 is probably at the lower end of the range given above.

Table 13: Biomass estimates (t) for smooth oreo from the stock reduction model for OEO 4. Estimates are given for the trawl survey area and adjusted for the total OEO 4 area by multiplying by 1.07. Estimates were made using q values of 0.27 and 1.8

		B_0	Mid-year $B_{1995-96}$ (t)	$\%B_0$
OEO 4	Trawl survey area			
	B_{min} (q = 1.8)	93 000	31 000	33
	B_{max} (q = 0.27)	361 000	300 000	83
	Total area			
	B_{min} (q = 1.8)	100 000	33 000	33
	B_{max} (q = 0.27)	386 000	321 000	83

4.4.3 Sensitivity of biomass estimates

Smooth oreo, OEO 3A

The CPUE index series used in the analysis did not greatly affect B_0 but had a large effect on mid-year $B_{1995-96}$ (Table 14). Increasing M by 2 standard errors resulted in a 23% reduction in B_0, but reducing M by 2 standard errors resulted in a 17% increase, i.e., the estimates are sensitive to M values. Catch history is also important, e.g., B_0 was reduced by 10% when catch history was 10% lower (Table 14). The ratio of $B_{1995-96}$ to B_0 was not sensitive to M or catch history.

Table 14: Sensitivity of smooth oreo virgin (B_0) and mid-year ($B_{1995-96}$) biomass estimates (t) to changes in the CPUE index, i.e., base (NZ plus Soviet) and New Zealand cases, natural mortality (M) and catch history for OEO 3A. se is standard error

Change in parameters	B_0	$B_{1995-96}$	(% B_0)
Base case	70 000	6 900	10
New Zealand case	81 000	19 000	23
M - 2 se (0.042)	82 000	9 300	11
M + 2 se (0.099)	†54 000	4 800	9
Catch + 10%	76 000	7 400	10
Catch - 10%	63 000	6 300	10

† indicates value is at B_{min}

Smooth oreo, OEO 4

Increasing M by 2 standard errors resulted in an 8% reduction in B_0, but reducing M by 2 standard errors resulted in a 5% increase, i.e., the estimates are not very sensitive to M values (Table 15). Changing the catch history by 10% resulted in a change of 5% in B_0. The ratio of $B_{1995-96}$ to B_0 is not sensitive to M or catch history. When the stock reduction model was run with no bounds on q the virgin biomass estimate was lower than the range of plausible values and was at B_{min} (the minimum biomass that is consistent with both the catch history and F_{max}), and the estimate of q was high (3.4).

Table 15: Sensitivity of smooth oreo virgin (B_0) and mid-year ($B_{1995-96}$) biomass estimates (t) to changes in natural mortality (M) and catch history for OEO 4 for the base case (q constrained by 1.8) and where q was not constrained (No bounds). se is standard error

Change in parameters	B_0	$B_{1994-95}$	(%B_0)
Base case (q =1.8)	100 000	33 000	33
M - 2 se (0.042)	105 000	31 000	30
M + 2 se (0.099)	92 000	37 000	40
Catches + 10%	105 000	32 000	30
Catches - 10%	95 000	36 000	37
No bounds on q	78 000	11 000	14

Biomass results were more sensitive to M and catch history for the OEO 3A analysis than for OEO 4. This was because q was not fixed for OEO 3A but was constrained to 1.8 for OEO 4, i.e., for the OEO 3A analysis q and B_0 were both estimated, but only B_0 was estimated for OEO 4.

4.5 Yield estimates

4.5.1 Smooth oreo, OEO 3 and OEO 4

Using the method of Francis (1992), the maximum constant catch that can be taken indefinitely (without reducing the population below 20% B_0 more than 10% of the time) from a population with life history parameters as in Table 9 is 1.6% B_0. Under continued fishing at this level the mean biomass was 44% B_0.

Yield estimates for smooth oreo from OEO 3A (Table 16) and OEO 4 (Table 17) were calculated from the results of the stock reduction analyses reported above, using the "depressed stocks" method from Francis (1992). Where stocks are depressed (below 20% B_0), the MCY for 1997–98 was scaled down.

The level of risk to the stocks by harvesting the populations at the estimated MCY values has not been determined.

Table 16: Yield estimates (t) for smooth oreo for OEO 3A. Base and New Zealand case estimates are given for the CPUE study area and adjusted to the total area by multiplying by 1.14. The point estimates are the "best" estimates. The ranges (in parentheses) are the 95% confidence limits

		$MCY_{1997-98}$	$MCY_{long\ term}$	$CAY_{1997-98}$
OEO 3A	CPUE study area	480 (390–1 200)	970 (960–1 200)	270 (220–1 100)
Base case	Total area	550 (450–1 400)	1 100 (1 100–1 400)	310 (250–1 300)
OEO 3A	CPUE study area	1 100 (390–16 000)	1 100 (960–16 000)	790 (220–46 000)
New Zealand case	Total area	1 300 (450–18 000)	1 300 (1 000–18 000)	900 (250–52 000)

Table 17: Yield estimates (t) for smooth oreo for OEO 4. Estimates are given for the trawl survey area and adjusted for the total area by multiplying by 1.07. "No q bounds" is the estimate made with no bounds on q and estimates are also made using q values of 0.27 and 1.8. No ranges are given because the q values used uniquely define the range of estimates

		$MCY_{1997-98}$	$MCY_{long\ term}$	$CAY_{1997-98}$
OEO 4	Trawl survey area			
	B_{min} (q = 1.8)	1 500	1 500	1 400
	B_{max} (q = 0.27)	5 800	5 800	14 000
	Total area			
	B_{min} (q = 1.8)	1 600	1 600	1 400
	B_{max} (q = 0.27)	6 200	6 200	15 000

4.5.2 Sensitivity of MCY to M and steepness for smooth oreo, OEO 3A and OEO 4

M was varied by plus or minus 2 standard errors, and steepness values were changed to 0.5 and 0.95 from the 0.75 used in the yield estimates above. Long term MCY, as a percentage of virgin biomass, varied widely with changes in M and steepness (Table 18). For the base case for OEO 3A this resulted in a range of estimates from 780 to 1300 t (Table 19). For OEO 4, long term MCY varied from 1100 t to 2100 (Table 20).

Table 18: Sensitivity of long term MCY (% virgin biomass) to M and "steepness" for OEO 3A and OEO 4. –, not estimated

	Steepness		
M	**0.50**	**0.75**	**0.95**
0.042	–	1.14	–
0.063	1.12	1.60	1.94
0.099	–	2.30	–

Table 19: Sensitivity of long term MCY (t) to M and "steepness" for the base case, OEO 3A. –, not estimated

	Steepness		
M	**0.50**	**0.75**	**0.95**
0.042	–	940	–
0.063	780	1 100	1 300
0.099	–	1 200	–

Table 20: Sensitivity of long term MCY (t) to M and "steepness" for OEO 4, q = 1.8. –, not estimated

	Steepness		
M	**0.50**	**0.75**	**0.95**
0.042	–	1 200	–
0.063	1 100	1 600	1 900
0.099	–	2 100	–

5. MANAGEMENT IMPLICATIONS

This stock assessment is limited to smooth oreo on the Chatham Rise (areas OEO 3A and OEO 4). It is based on deterministic stock reduction analyses using updated CPUE data and a revised standardised CPUE analysis which provided abundance indices for OEO 3A, and research trawl survey abundance indices, constrained by catchability values of 0.27 to 1.8, for OEO 4.

The following conclusions can be drawn from this assessment.

Smooth oreo, OEO 3A, base case

1. A 95% confidence interval for estimates of B_0 was 68 000 to 89 000 t. (This interval would widen if stochastic recruitment was included in the analysis.)

2. The biomass at the start of 1997–98 is likely to be less than 20% of B_0 and also less than B_{MCY} (44% B_0).

3. Yields from this stock will be low because the productivity of smooth oreo is low, based on unvalidated age estimates. The long-term MCY estimates from a stock of

between 68 000 and 89 000 t are 1100–1400 t, 30–38% less than the mean catch of smooth oreo in OEO 3A (about 3700 t per year, from Table 3). Therefore, it seems likely that the recent catch levels of smooth oreo from OEO 3A are higher than the long term sustainable yield and will not allow the stock to move towards B_{MCY} or B_{MAY}.

Smooth oreo, OEO 4

1. The estimates of biomass and yields are uncertain because of the uncertain value of smooth oreo catchability from the trawl surveys. B_0 estimates were between 100 000 and 386 000 t for catchability values of 0.27 to 1.8.

2. Yields from this stock will be low because the productivity of smooth oreo is low, based on unvalidated age estimates. If $q = 1.8$, which is the maximum likelihood estimate, then the long-term MCY = 1600 t, substantially less than the mean catch of smooth oreo in OEO 4 (about 4200 t per year), and the stock size is less than B_{MCY} but greater than B_{MAY}. If $q = 0.27$, long-term MCY = 6200 t and the stock is greater than both B_{MCY} and B_{MAY}.

The main sources of uncertainty for these assessments are as follows.

Smooth oreo, OEO 3A and OEO 4

1. The age estimates and recruitment steepness. Smooth oreo age estimates are not validated, though Australian workers using the same method achieved similar results. Small smooth oreo are not available to known sampling methods and other ageing methods are needed to validate age estimates from otolith sections. There are no data available to check the assumed value of recruitment steepness.

Smooth oreo, OEO 3A

1. Stock discreteness for smooth oreo in areas OEO 3A and OEO 4 was assumed, based on the separation of the two fisheries by about 100 n. miles. There are no other data to help define stocks.

Smooth oreo, OEO 4

1. We are uncertain about the relationship between smooth oreo on hills and on the flat. The trawl survey samples the flat (flat, undulating, and drop-offs) and probably covers most of the population, but since 1991–92 most of the smooth oreo catch has come from hills. We assume that the proportion of fish on the flat relative to the hills has been the same over the years covered by the trawl surveys (1991–93, 1995).

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