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Assessment of smooth oreo for 1995

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1. EXECUTIVE SUMMARY

The biomass of smooth oreo in OEO 3A was estimated from a stock reduction analysis that used abundance indices from catch per unit effort (CPUE), and research trawl survey data. The analysis suggests that the original smooth oreo stock size in the main fishing ground of OEO 3A was small. Yields from the fishery will probably be low because the productivity of smooth oreo based on unvalidated age estimates is likely to be low. The maximum likelihood estimate of long-term yield for smooth oreo in OEO 3A is 1000 t. The recent catch levels of smooth oreo from OEO 3A are higher than the long term sustainable yield.

2. INTRODUCTION

2.1 Overview

This document presents new life history parameters for Chatham Rise smooth oreo, trawl survey biomass indices, a standardised CPUE analysis for smooth oreo from the main oreo fishing ground in OEO 3A, a stock reduction analysis, and stock assessment for smooth oreo from OEO 3A. Assessment of the other oreo stocks has not been carried out. Smooth oreo in OEO 3A was analysed first because that fishery is not based on hill fishing like the other oreo fisheries and because we are more confident about the estimates of smooth oreo biological parameters than of the estimates of black oreo parameters.

2.2 Description of the fishery

Black oreo and smooth oreo are caught by trawling at depths of 800–1300 m in southern New Zealand waters. The main fishery is on the south Chatham Rise where three main grounds occur, the first between 172° and 176° E, the second from about 178° 20′ E to 176° W, and the third on the southeast and east slopes, east of 176° W (Figure 1). Fishing in the first two areas has mainly been on undulating terrain (short plateaus or terraces and "drop-offs") with some hill fishing: the southeast and east Chatham Rise is exclusively a hill fishery. Orange roughy is a minor catch element in the western Chatham Rise fishing area but its catch proportion increases towards the east along the Chatham Rise.

There are smaller fisheries for oreos off the Otago/Southland coast and in the Puysegur Bank and Macquarie Ridge areas. Orange roughy is a major catch element in the Puysegur area.

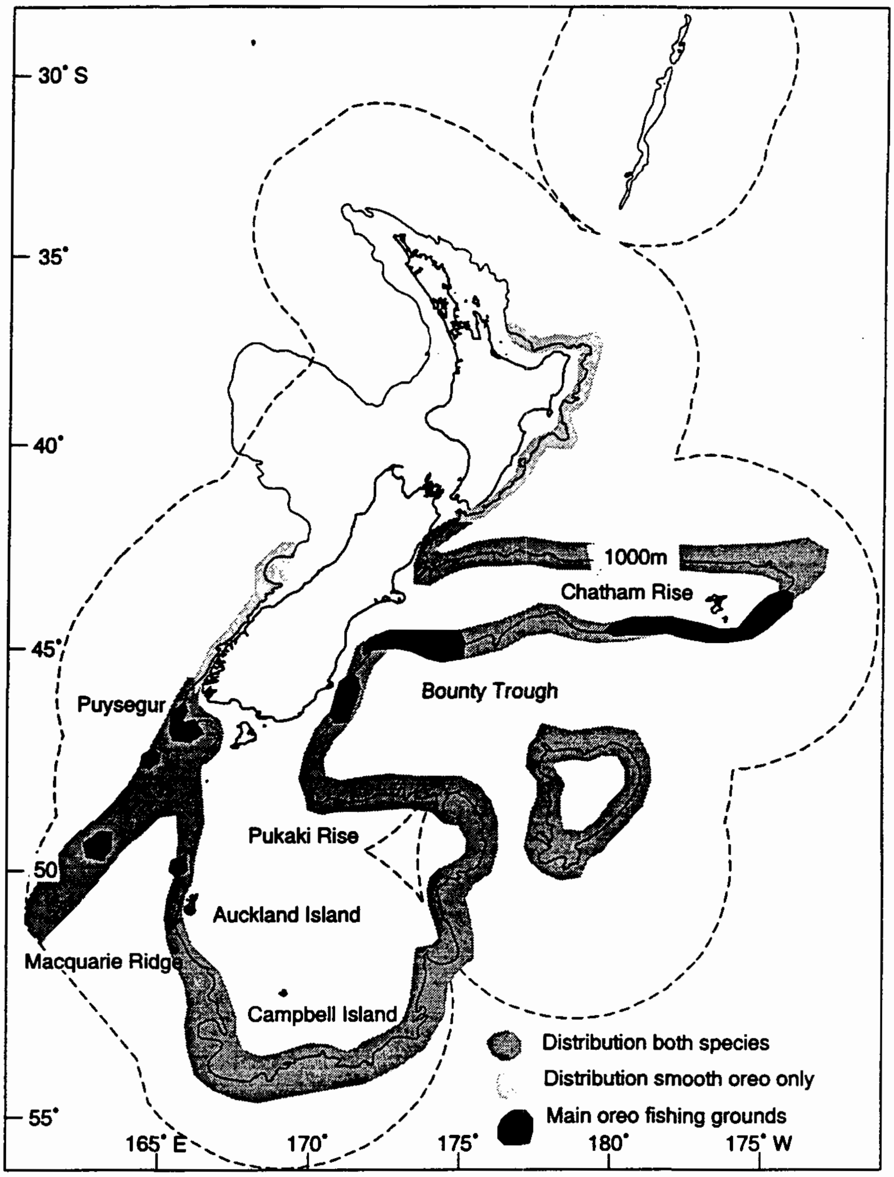

Figure 1: The main fishing grounds and distribution of black and smooth oreos.

2.3 Literature review

Literature was summarised by McMillan *et al.* (1988) and McMillan & Hart (1991). The most recent stock assessment was given in Annala (1995). Fincham *et al.* (1991) provided a summary of oreo catches from 1972 to 1988, and reports of south Chatham Rise biomass trawl surveys carried out in 1990, 1991, and 1992 were reported by McMillan & Hart (1994a, 1994b, 1994c).

3. REVIEW OF THE FISHERY

3.1 Management

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.

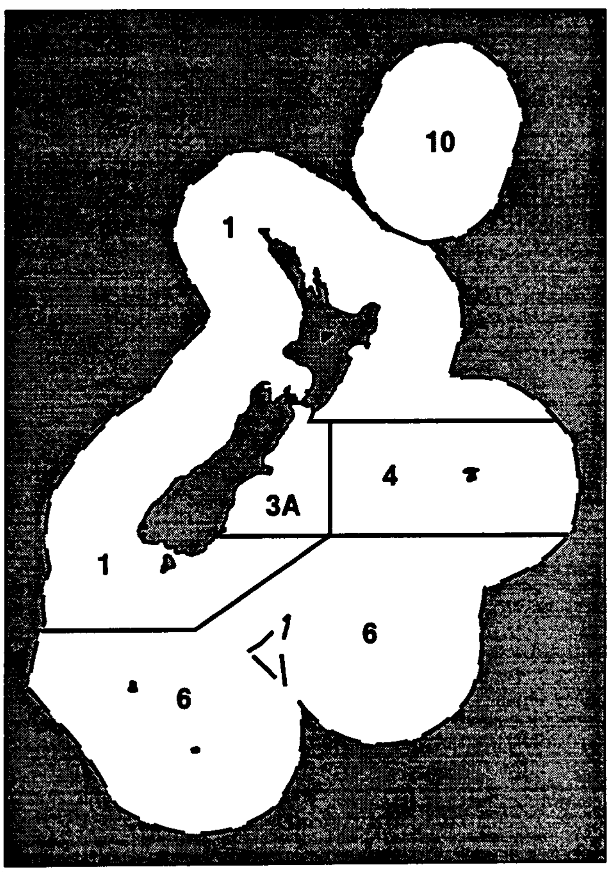

Figure 2: Oreo management areas.

3.2 TACs and catches

Separate catch statistics for each oreo species were not requested in the first version of the catch statistics logbook, used when the New Zealand EEZ was enacted in April 1978, so the catch from 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 in the logbooks. 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 Russians reported 7000 t (probably black oreo and smooth oreo combined) from the New Zealand area (Table 1). Reported landings of oreos (combined species) and TACs from 1978–79 until 1993–94 are given in Table 2 and reported estimated catches by species in Table 3.

TACs were introduced in 1986 and have not changed much since. The TAC in OEO 1 was increased by 1000 t in 1992–93.

3.3 Recreational, traditional, and Maori fisheries

There is no known non-commercial catch of oreos.

Table 1: USSR 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 1993–94 and TACs (t) from 1982–83 to 1993–94

										FISHSTOCK
	OEO 1		OEO 3A		OEO 4		OEO 6		Total	
Fishing 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

Source: FSU from 1978–79 to 1987–88; QMS/FIC from 1988–89 to 1993–94.
* 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 1993–94

	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+	1 993	4 755	4 757	808	2 615	3 974	1 547	35	302	377	2 015	140	23 318

Source: FSU from 1978–79 to 1987–88 and FIC from 1988–89 to 1993–94.
* 1 April to 31 March.
# 1 April to 30 September.
+ 1 October to 30 September.
– Less than 1 t.

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. Reported catches of all oreo (smooth, black, and unspecified oreo) from 1978–79 to 1992–93 from the south Chatham Rise (44 to 45° 30′ S and 172° E to 174° W, including "Big Chief" but not "The Andes") have been plotted by latitude in Figure 3. The figure shows that there have been only small catches made between 176° and 178° 20′ E (a distance of about 100 n. mile) and this provides support for at least two 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. Each species should be managed separately. They have different depth and geographical distributions, growth, and productivity (McMillan, 1985, Doonan *et al.*, unpubl. results).

The technique of enzyme protein differentiation using gel electrophoresis was tested on samples of Australian and New Zealand black oreo and smooth oreo. Samples from the south Chatham Rise were sent to CSIRO for genetic comparison with Australian stocks. There were no differences between 100 New Zealand and 200 southern Tasmanian black oreo at seven allozyme loci. A similar comparison with smooth oreo found no differences between samples from New Zealand (n = 109), Tasmania (n = 200), Western Australia (n = 99), and Lord Howe Rise (n = 15) at 11 allozyme loci (R.H. Ward, CSIRO, Hobart, pers. comm.). Preliminary results from DNA testing support the results of the allozyme study (R.H. Ward, CSIRO, Hobart pers. comm.). Although a broad scale stock is suggested by these results, an alternative possibility is that loci that distinguish stocks have yet to be found.

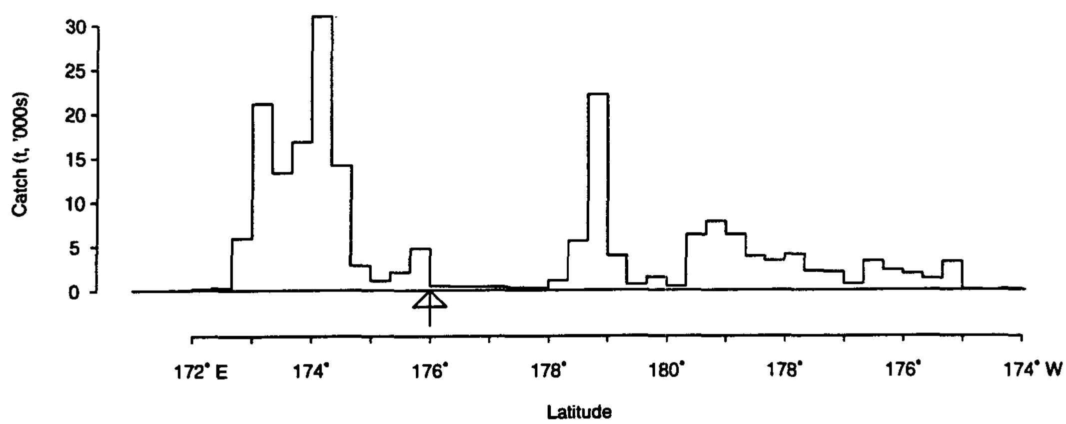

Figure 3: Separate oreo fishing grounds on the south Chatham Rise. Catch (t) of all oreo (smooth, black, and unspecified) reported caught from the south Chatham Rise (44 to 45° 30′ S and 172° E to 174° W, including "Big Chief " but not "The Andes") from 1978–79 to 1992–93. The arrow marks the boundary between OEO 3A and OEO 4.

4.2 Resource surveys

Trawl surveys have been carried out in most years since 1986 (Table 4). The biomass estimates from the surveys before 1991 are not comparable because different vessels were used. Other results from those early surveys are used, e.g., gonad staging to determine length at maturity. The 1991 to 1993 surveys are comparable, although major changes to survey design were put in place for the 1992 survey. Hills were first sampled in 1992, but biomass estimates from the hill surveys are not reported here because there are only two sets of estimates and they have high *c.v.*s.

Table 4: Random stratified trawl surveys for oreos on the south Chatham Rise

Year	Area (km^2)	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

† The survey area is for the "standard" survey and does not include specific trawling on hills, which began in 1992.

4.3 CPUE for smooth oreo from OEO 3A

4.3.1 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 1979 to 1994 (Figure 4). The total estimated catch of smooth oreo from the CPUE study area was 50 135 t and the smooth oreo catch from the rest of area OEO 3A was 10 133 t, between 1978–79 and 1993–94. For the CPUE analysis a catch of about 3500 t, reported from Waitaki in 1991–92, was not typical or sustained and was therefore excluded from the "rest of area" total. The data from 1991–92 were therefore excluded from the CPUE study area when total estimated smooth oreo catch from the two areas was calculated, i.e., smooth oreo catch totals were 47 537 t from the CPUE study area, and 6632 t from the rest of OEO 3A between 1978–79 and 1993–94.

Data for which smooth oreo was recorded as the target species were used for all nations except the domestic fleet. For the domestic fleet, data with smooth oreo and generic oreo (OEO) recorded as the target species were used. These tow data contained: start position, catch by species, the target species, depth, vessel, distance towed, time of day, and date. The vessel's nationality and tonnage were recorded separately.

We added two fields to these data: the fishing year, and one of seven subareas. The fishing year starts on 1 October, but for simplicity in the text, tables, and figures below we have labelled each year with the main calendar year involved, e.g., the year 1980 refers to the 1979–80 fishing year. Four subareas, "subA", "subB", "subC" and "Neils.p" (Figure 4) contained 60% of the total oreo catch (i.e., both black oreo and smooth oreo) from 1979 to 1994. The remaining area to the west of 175° E was divided into "shallow" and "deep" subareas by the 920 m isobath. The seventh subarea, "E175", was that area east of longitude 175° E which was fished late in the data series and had a different fishing pattern. The data from a whole year were excluded if only one vessel fished in that year or if there were less than 50 tows per year.

4.3.2 Descriptive CPUE

From 1979 to 1994 fishing was widespread in OEO 3A but was concentrated in particular areas (Figure 4). Three of these areas consistently produced most of the catch and are defined as subareas for this analysis, i.e., subA, subB, and subC. The subareas "Neils.p" and "E175" were fished later, starting in about 1989.

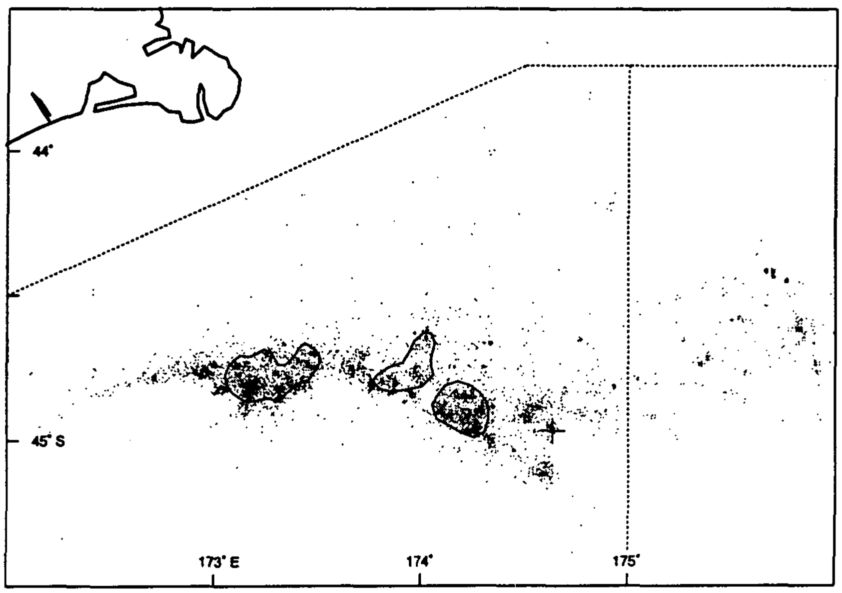

Figure 4: The CPUE study area, i.e., the area of the rectangle excluding the area north of the dashed line near the top of the figure. Dots show targeted shots which caught smooth oreo in the period 1979 to 1994. Three subareas for the CPUE analysis are enclosed by solid dark lines, i.e. from left to right: subA, subB, and subC. Neils.p is marked with a + and the subarea E175 is that area east of 175° E.

The total smooth oreo catch (to the nearest 1000 t) from 1979 to 1994 from OEO 3A for the seven subareas defined in the text was: subA, 11 000; subB, 2000; subC, 8000; Neils.p, 2000; shallow, 5000; deep, 13 000; E175, 7000. "Blind" fishing was probably done in poor weather, in the shallow subarea, and by inexperienced fishers and made up a minority of the total catch. At the start of the fishery the fleet was mainly Russian (Table 5), but switched to mainly New Zealanders (domestic) by 1988. The yearly mean of the raw catch-per-tow declined from 1980 to 1994 (Figure 5), but the medians declined even more, i.e., the distribution of catches shifted to lower values with time but some large catches were still possible late in the time period. This suggests that the stock has declined. However, the yearly mean of the catch per vessel-day is more or less constant (Figure 6), so the on-the-wharf perception is of an unchanging stock size.

Since 1988, there have been changes in fishing gear technology; e.g., Global Positioning System (GPS) has replaced satellite navigation, and there are now better echo sounders, net monitors, doors, and nets. The fleet has changed from foreign licensed, to foreign charter, to domestic. The experience and knowledge of people doing the fishing has increased. These factors are likely to have increased the efficiency of fishing for oreos. Consequently oreo catch rates should have increased if the stock size has remained constant.

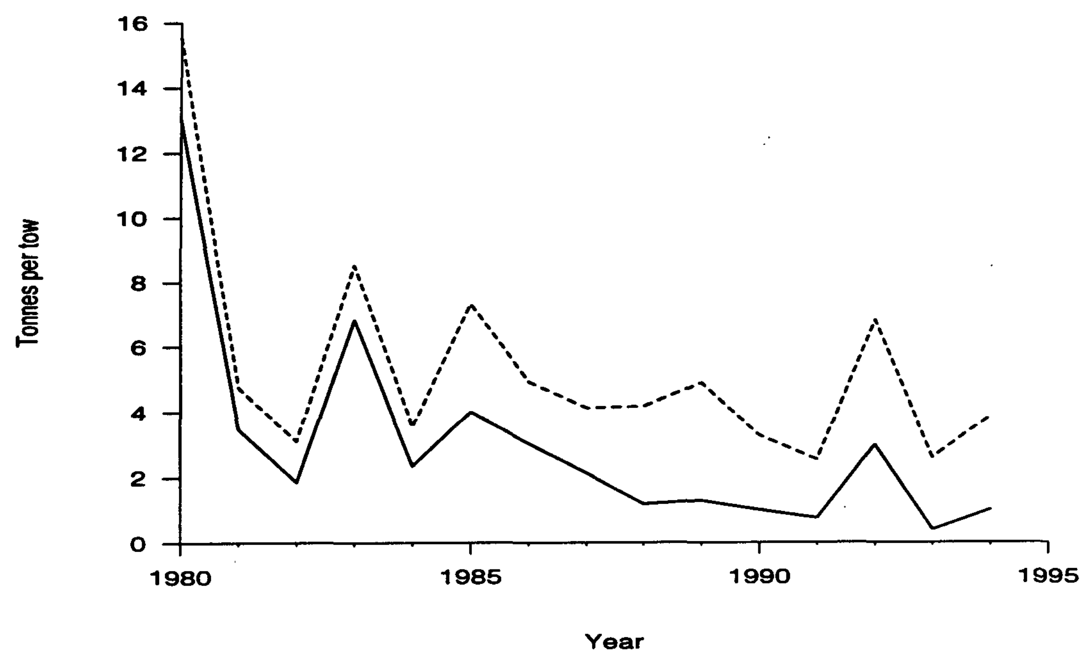

Figure 5: Yearly mean (dashed line) and median (solid line) raw smooth oreo catch per tow from 1980 to 1994 from the CPUE study area in OEO 3A.

Table 5: Number of tows by nation by year from OEO 3A. –, no data

Year	Number of tows		
	USSR	New Zealand	Others
1980	166	–	–
1981	36	–	37
1982	37	–	–
1983	137	3	–
1984	366	4	50
1985	227	36	70
1986	194	18	128
1987	267	197	14
1988	212	501	18
1989	6	675	1
1990	–	1 111	–
1991	50	1 470	45
1992	–	305	–
1993	–	895	–
1994	–	945	–

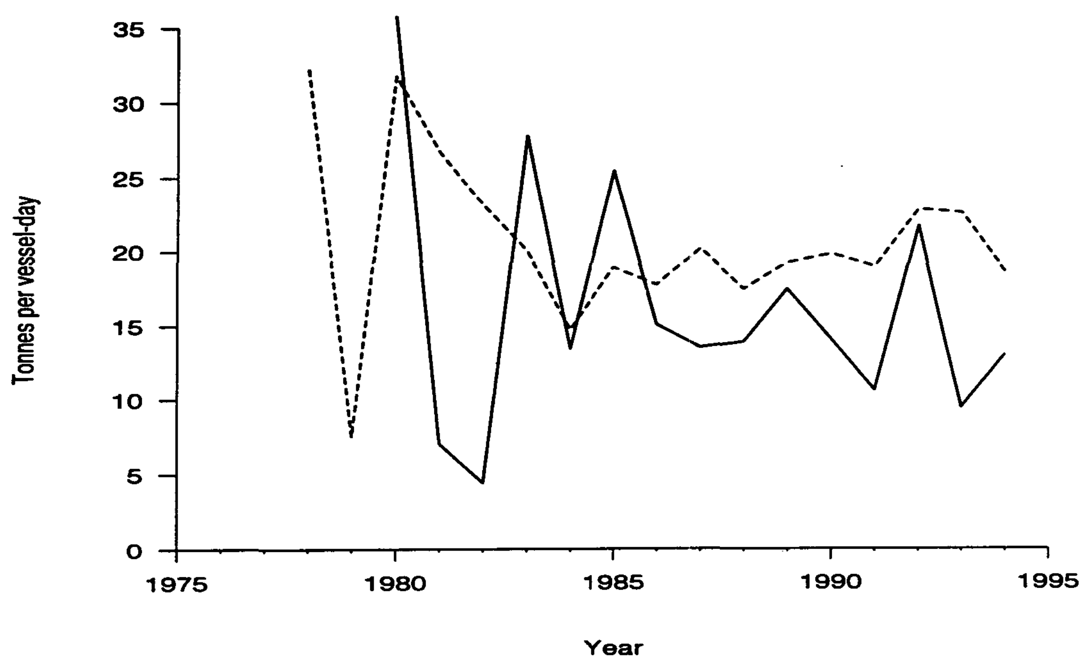

Figure 6: The mean smooth oreo catch per vessel day (solid line) from tows that targeted smooth oreo (or targeted "oreo" in the case of domestic data). The mean total oreo catch per vessel day (dashed line) from tows that caught or targeted oreos.

4.3.3 Choice of CPUE measure

Catch per tow (t per tow) instead of catch per kilometre (t per km) was chosen as the measure of CPUE, after discussion by the Orange roughy/Oreos Fishery Assessment Working Group. The length of tow was not considered to reflect effort in the oreo fishery because of the mix of flat, dropoff, and hill fishing, and because most of the fishing targeted fish marks. The fishing practice, for all subareas except "shallow", was to search for marks (fish schools) on the echo-sounder, turn, and try to fish through the mark. Technology improvements (GPS and net monitors) now allow fishers to do this in a shorter distance, making tow length irrelevant.

Data combinations – "base" and "two nation" cases

Two analyses were performed on the data:

1. the base case used all the CPUE data described above in section 4.3.1;

2. the two nation case treated the USSR CPUE data as one series and the domestic CPUE data as a separate series.

4.3.4 Method of CPUE analysis

Abundance indices can be obtained from a log regression of catch rate on year and other variables (Doonan 1991). Zero catches are usually handled in one of two ways; excluded or a constant added to all catch rates. If the proportion of zero catches is small then the results of the analysis are not affected much. If zero catches are more than 10% of the data, then a simple simulation[1] shows that the indices become distorted after the abundance has dropped to some level, even if the proportion of zeros is constant. The higher the proportion of zero catches the more pronounced the distortion.

The proportion of zero catches each year varied from 3% to 41%, with a median of 19% (Table 6). These levels of zero catch will cause problems in the abundance index if a log regression analysis is employed. To resolve this, the analysis was initially separated into two regressions; one for the proportions of zero catches and another for the positive catches. The year effects estimated from the two regressions were then transformed and combined to form an abundance index for each year. Details were given by Vignaux (1994).

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[1] For each year, the mean catch and proportion of zero catches were specified so that there was a decline of 90% over the series, i.e., year was the sole variable in the decline. Zero catches were binomially distributed, positive catches had a lognormal distribution. Simulated catches were analysed by regressing log(catch + constant) on year.

Table 6: Percentage of tows with zero catch by year

Year	Percentage	Year	Percentage
1980	13	1987	22
1981	3	1988	29
1982	14	1989	18
1983	19	1990	27
1984	25	1991	31
1985	14	1992	14
1986	10	1993	41
		1994	21

Regression for positive catches

The regression for positive catches was based on:

$$\log(X_{ij}) = \mu + Y_i + \sum_k F_k(i\,j) + \mathrm{error}(i\,j)$$

where X_{ij} is the catch for tow j in year i, μ is the grand mean in the log scale, Y_i is the year effect for year i, and $F_k\,(ij)$ is factor k evaluated for the (ij)-th tow.

The variables considered for the regression are listed in Table 7, and were included only if they lowered R^2 by more than 0.005 in a stepwise selection procedure, except for year which was always included.

The contribution to the abundance index for year i relative to year r was

$$e^{Y_i - Y_r}$$

Table 7: Summary of non-year variables that could be selected in the regression models. Types are "Num" for numeric, and "Cat" for categorical. "df" is the number of parameters to be estimated for that variable

Variable	Type	df	Description
Tonnage	Num	1	Tonnage of a vessel
Area	Cat	7	Subareas within area OEO 3A
Nation	Cat	5	Nationality of the officers and crew. They are New Zealand, Japan, Korea, USSR, and other.
Depth	Cat	10	Depth at start of a tow. Bins are defined to contain about the same number of tows
Season	Cat	10	The fishing year is divided into 10 periods
Time	Cat	10	Time of day when a tow started, blocked into 10 periods.
Target	Cat	2	Target species for the tow (smooth or generic oreo, OEO). Applies only to domestic data
Vessel	Cat	–	A parameter is estimated for each vessel. Tonnage and nation cannot be used.

Regression for zero catches

We used the Generalised Linear Model (GLM) with a binomial distribution and a logit link for the proportions, i.e.,

$$\log \frac{p_{ij}}{1 - p_{ij}} = \mu^1 + Y_i^1 + \sum_k F_k^1(i\,j)$$

where p_{ij} is the expected proportion of zero catches for tow j in year i, and the other terms correspond to those in the positive catch regression. Note that only the expected proportion of zero catches is transformed, not the data. In the positive catch regression, the data are transformed.

Non-year variables were included only if they lowered the deviance so that the GLM equivalent of R^2 increased by more than 0.005 in a stepwise selection procedure.

The contribution to the abundance index for year i relative to year r was

$$\frac{1}{1 - \pi_r(1 - e^{Y_i^1 - Y_r^1})}$$

where π_r is some reference proportion of zeros from year r.

Combined abundance index

The combined abundance index was a product of the two parts

$$\left[\frac{1}{1 - \pi_r(1 - e^{Y_i^1 - Y_r^1})}\right]\left[e^{Y_i - Y_r}\right]$$

The logit transformation does not back-transform the year effects into a variable for year that depends only on the year. It depends on the level of other (non-year) variables as well. In practice, varying the levels of the non-year variables caused trivial shifts in the index so the raw proportion of zero catches in the reference year r was taken as the value for π_r. This gave an abundance index for each year in our dataset, i.e., resulting in one time series of abundance indices. Then r was varied to make each year, in turn, the reference year, resulting in several time series of abundance indices (one for each reference year). These different time series of abundance indices were compared and if they were all similar one was chosen for the stock reduction analysis. If they were different, then separate analyses would need to be done for each.

Estimate of the *c.v.* for the abundance index

The *c.v.* of the abundance index was calculated by a modified jackknife method, using vessel data as the subset, rather than carrying through the variances of the year effects from the regressions. This was done because, for a few years, removing the data belonging to the vessel with the most tows in that year strongly shifted that year's index, more than would be expected from the regression variances of the year effects.

For year i, pseudo-abundance indices (suppressing the index i) were generated by

$$y_j^* = k * y_{all} - (k-1)\, y_j$$

where y_j is the abundance index when the data for vessel j are left out, y_{all} is the abundance index with all data included, and k is the number of vessels in year i. Usually the number of data points left out is the same for all j, but in our application the size of the data subsets varied so much that we needed to weight each y^*_j in calculating the variance. The weights for y^*_j were the number of tows vessel j did in year i. Thus the variance of the index for year i is s^2/k, where

$$s^2 = \sum_j \frac{n_j}{N}(y_j^* - y_{all})^2$$

n_j is the number of tows in year i for vessel j and $N = \sum_j n_j$.

This ignored the contributions from vessels that did not fish in year i, but which had an influence on the estimated effects of variables, e.g., nation, and through them an influence on the index for year i. Similarly, the effects of vessels that mainly fished in the reference year were not included as that year always had an index of 1, by definition.

The *c.v.*s from the jackknife method were not used directly, but were regressed against the number of vessels in each year that had more then 20 tows (n_v). The limit of 20 tows for n_v was chosen as a compromise between excluding too many vessels and their associated data versus giving excessive weighting to small amounts of data. The predicted *c.v.* from this fit was used in the stock reduction analysis.

4.3.5 Results

Base case

The data from 1981 and 1983–94 were analysed. Data from 1982 were omitted because there were less than 50 tows, and 1980 data were omitted because that data caused the regressions to fail when individual vessel parameters were included. Individual vessel parameters were almost always the most important variable in the regression, i.e., they explained most of the variability in the data.

The variables year, vessel, area, depth, and season were selected for the positive catch regression, (Table 8), giving an overall R^2 of 31%. For the zero catch GLM, year, vessel, and season were selected. The percentage of the deviance "explained" was 11%.

The 13 different time series of combined abundance indices derived by using each year as the reference year (Figure 7) were similar. 1987 was chosen as the reference year because that time series was in the middle of the set. The time series of abundance indices using 1987 as the reference year (Table 9) showed a decline of about 80%. Both parts of the series showed a decline, i.e., that due to zero catches (less pronounced decline), and that due to positive catches alone. There was no relationship with n_v amongst the *c.v.*s so the mean *c.v.* was used, i.e., 43%.

Table 8: Base case stepwise selection of variables for the positive-catch regression (A) and the zero-catch GLM (B). New variables are added, one at a time, until R^2, or its equivalent, fails to increase by more than 0.005. At each iteration, the variable that increases R^2 the most is added. The variables are in the order selected are above the dotted line

A. R^2

Variable	Iteration						
	1	2	3	4	5	6	7
Vessel	0.265						
Year	0.064	0.290					
Area	0.058	0.272	0.297				
Depth	0.018	0.272	0.295	0.304			
Season	0.030	0.278	0.297	0.304	0.312		
———							
Target	0.017	0.267	0.291	0.298	0.305	0.312	
Tonnage	0.134						
Nation	0.041						
Increase	0.265	0.025	0.007	0.007	0.007	0.000	

B. R^2 (GLM equivalent)

	Iteration				
	1	2	3	4	5
Vessel	0.083				
Year	0.032	0.102			
Season	0.006	0.094	0.112		
———					
Depth	0.005	0.087	0.105	0.114	
Area	0.003	0.086	0.104	0.113	
Target	0.000	0.083	0.102	0.112	
Tonnage	0.001				
Nation	0.017				
Increase	0.083	0.019	0.010	0.002	

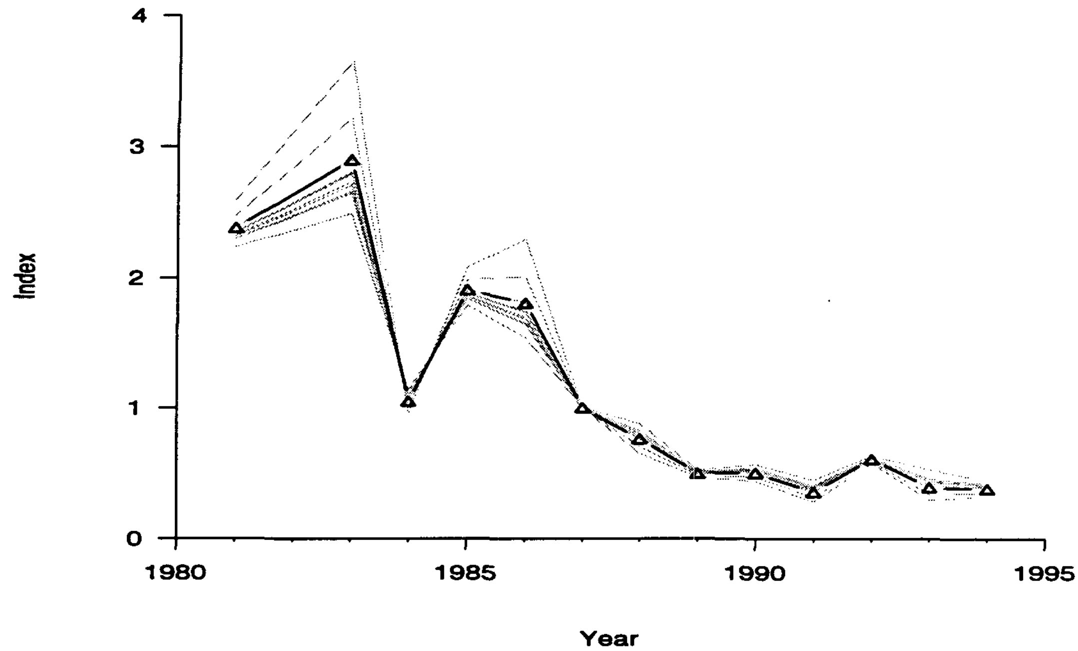

Figure 7: Time series of combined abundance indices for each of 13 different reference years (1981, 1983–94) for the base case. The solid line (Δ) is the time series chosen for the stock reduction analysis.

Table 9: Base case time series of combined abundance indices from CPUE, plus the equivalent indices due solely to the zero catches and positive catches, using 1987 as the reference year

Year	Combined index	Zero-catch index	Positive-catch index
1981	2.38	1.08	2.21
1983	2.90	1.20	2.41
1984	1.05	0.91	1.16
1985	1.91	1.08	1.76
1986	1.80	1.21	1.49
1987	1.00	1.00	1.00
1988	0.76	0.84	0.91
1989	0.50	0.94	0.53
1990	0.51	0.86	0.59
1991	0.36	0.75	0.48
1992	0.61	0.95	0.64
1993	0.39	0.69	0.57
1994	0.38	0.83	0.47

Two nation case

For the USSR abundance series, the data used were from 1983–88. The variables year, vessel, area, depth, and season were selected for the positive catch regression (R^2 = 29%). The same variables were selected for the zero catch regression (R^2 = 14%) (Table 10). Data from

1981–82 were dropped because there were less than 50 tows per year. The 1980 data were dropped because that data caused the regression to fail (vessel was a variable in the regression). The data from 1990 were dropped because there was only one vessel in that year. No relationship was seen for the *c.v.* of the indices and so the mean *c.v.* was taken as the *c.v.* for the abundance index, i.e., 61%.

For the domestic abundance series, the data used were from 1987–94. The variables year, vessel, area, depth, and season were selected for the positive catch regression ($R^2 = 29\%$). But only year, vessel, and season were selected for the zero catch regression ($R^2 = 9\%$) (Table 11). Data from 1983–86 were dropped because they had less than 50 tows per year. The reference year chosen was 1991. There was no relationship amongst the *c.v.*s of the index series and so the mean, 49%, was used.

The time series of combined abundance indices for the USSR and domestic data is given in Table 12. Both time series show a decline but there is a more marked decline in the USSR time series of abundance indices.

Table 10: USSR case stepwise selection of variables for the positive-catch regression (A) and the zero-catch GLM (B). New variables are added, one at a time, until R^2, or its equivalent, fails to increase by more than 0.005. At each iteration, the variable that increases R^2 the most is added. The variables selected are above the dotted line

A. R^2

	Iteration						
Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Year	0.157						
Season	0.083	0.220					
Vessel	0.096	0.215	0.274				
Area	0.008	0.175	0.231	0.288			
Depth	0.020	0.175	0.229	0.283	0.294		
———							
Tonnage	0.001	0.164	0.231				
Increase	0.157	0.063	0.054	0.014	0.006		

B. R^2 (GLM equivalent)

	Iteration						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Vessel	0.063						
Year	0.039	0.115					
Season	0.035	0.090	0.129				
Depth	0.018	0.073	0.123	0.136			
Area	0.011	0.071	0.119	0.135	0.143		
———							
Tonnage	0.005						
Increase	0.063	0.052	0.014	0.007	0.007		

Table 11: Domestic case stepwise selection of variables for the positive-catch regression (A) and the zero-catch GLM (B). New variables are added, one at a time, until R^2, or its equivalent, fails to increase by more than 0.005. At each iteration, the variable that increases R^2 the most is added. The variables selected are above the dotted line

A. R^2

Variable	Iteration 1	2	3	4	5	6	7
Vessel	0.252						
Year	0.020	0.264					
Depth	0.038	0.262	0.274				
Area	0.083	0.260	0.272	0.284			
Season	0.019	0.261	0.272	0.282	0.292		
———							
Target	0.008	0.255	0.265	0.275	0.284	0.293	
Tonnage	0.122						
Increase	0.252	0.012	0.010	0.010	0.008	0.001	

B. R^2 (GLM equivalent)

	Iteration 1	2	3	4	5	6	7
Vessel	0.068						
Year	0.027	0.084					
Season	0.017	0.083	0.092				
———							
Area	0.003	0.070	0.085	0.093			
Depth	0.008	0.073	0.088	0.096			
Target	0.002	0.068	0.084	0.092			
Tonnage	0.004						
Increase	0.068	0.016	0.008	0.004			

Table 12: Two nation case. USSR and domestic cases time series of combined abundance indices from CPUE. –, no data

Year	USSR	Domestic
1981	–	–
1983	6.92	–
1984	1.75	–
1985	3.41	–
1986	2.55	–
1987	1.00	2.24
1988	0.61	2.03
1989	–	1.24
1990	–	1.25
1991	–	1.00
1992	–	1.55
1993	–	1.07
1994	–	0.94

4.4 Other studies

Smooth oreo mean lengths (total length) were calculated from data collected during research trawl surveys in OEO 3A. These data were scaled, to represent the biomass, and included all lengths, i.e., pre-recruit and recruited fish (Figure 8). Mean length of both sexes declined from 1986 to 1993.

The mean length of smooth oreo calculated from OEO 3A data collected by observers are given in Figures 9 (males) and 10 (females). Length data were separated by sex and were weighted (scaled) by the catch. Data collected from domestic or "other nationality" vessels were analysed separately because of possible differences in fishing patterns between fleets. Preliminary analyses determined if there were differences between lengths from samples caught at depths shallower or deeper than 900 m, or from east or west ends of OEO 3A. There were few samples from less than 900 m, so those data were excluded from the analysis. No area differences were seen. The mean length of males and females has declined about 1 cm between 1979 and 1991.

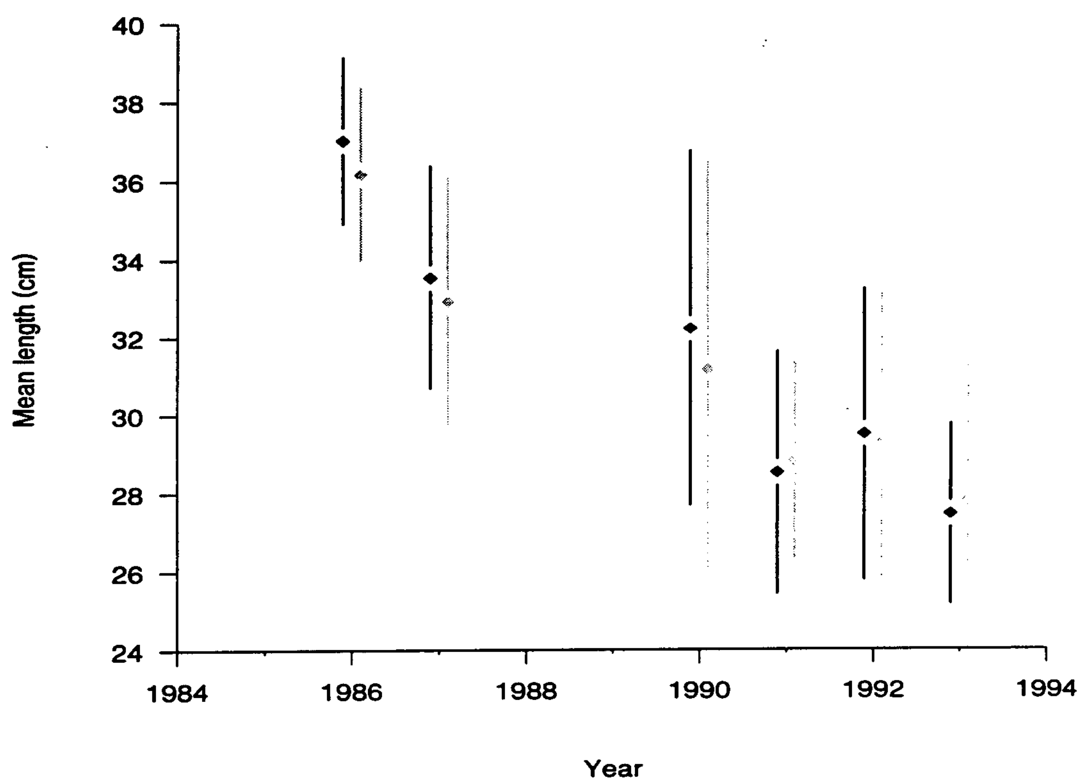

Figure 8: Scaled length frequency of smooth oreo from research data, OEO 3A. Mean length (◆). Vertical lines are ± 2 s.e., dark (females), pale (males).

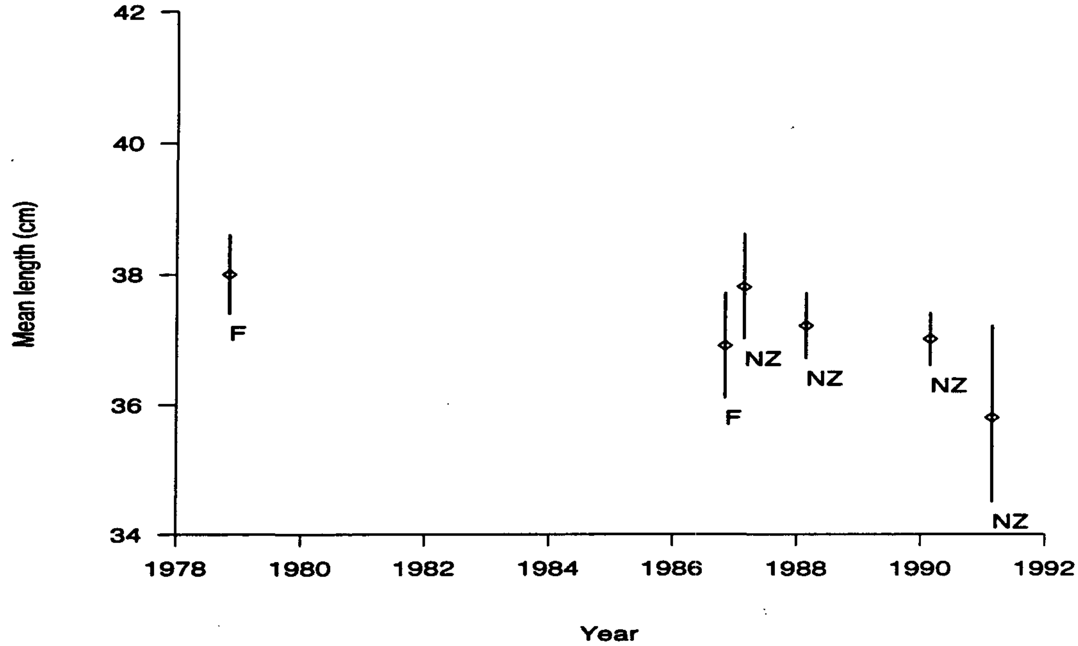

Figure 9: **Male smooth oreo length frequency data collected by observers from OEO 3A, and scaled to catch. Mean length ± 2 s.e. NZ = data from New Zealand vessels, F = other nationalities.**

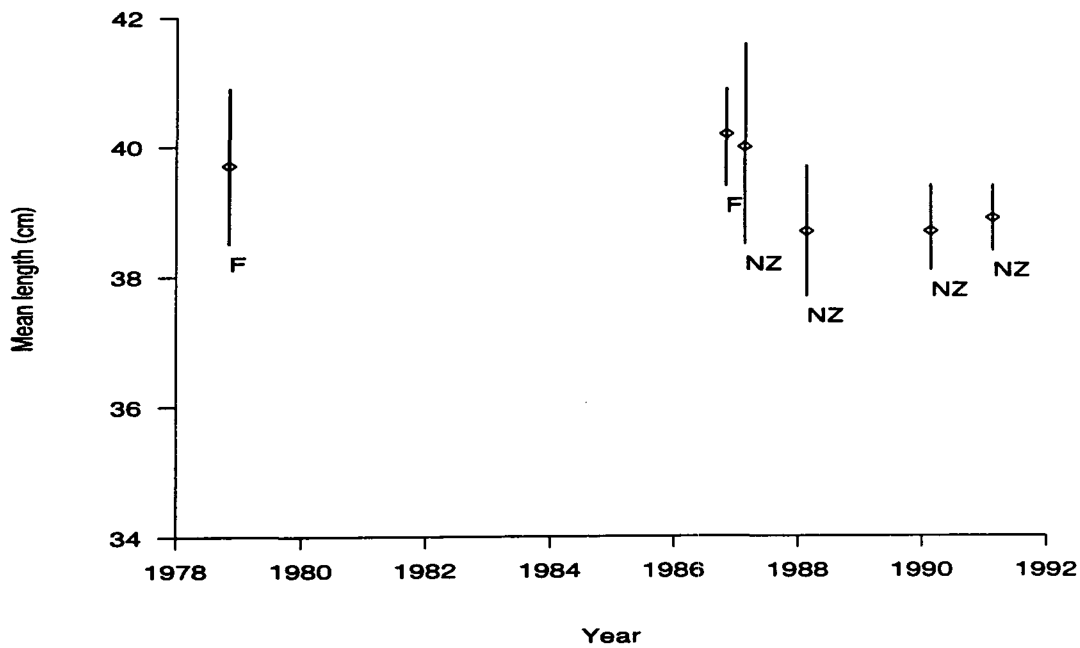

Figure 10: **Female smooth oreo length frequency data collected by observers from OEO 3A, and scaled to catch. Mean length ± 2 s.e. NZ = data from New Zealand vessels, F = other nationalities.**

4.5 Biomass estimates for smooth oreo in OEO 3A

A deterministic stock reduction model (Francis 1990) was used to estimate biomass. Biomass was estimated only for smooth oreo because the CPUE analysis was restricted to that species and was also restricted to the CPUE study area (as opposed to the whole of area OEO 3A).

Fishing mortality was assumed to occur throughout the fishing year, so the CPUE index was for the middle of the year. The maximum possible fishing mortality was assumed to be 0.9. The trawl surveys occurred in the first few months of the fishing year and so were assumed to index beginning-of-year biomass. Recruitment was assumed to be deterministic. Catch overruns were assumed to be 0%. The base and two-nation cases both used the same life history, catch history and trawl survey biomass indices. The two cases differed only by the use of the different CPUE abundance indices:

1. the base case analysis used the base case CPUE time series of abundance indices (1981, 1983–94).;
2. the two-nation case used the USSR CPUE time series of abundance indices and domestic CPUE time series of abundance indices separately. USSR biomass indices were estimated only for 1983–88 because the CPUE data from the other years were excluded. Domestic biomass indices were estimated only for 1987–94 because CPUE data for earlier years were excluded.

Table 13: Life history parameters for smooth oreo

		Smooth oreo	
Parameter	**Symbol (unit)**	**Female**	**Male**
Natural mortality	M (yr^{-1})	0.05	0.05
Age at recruitment	A_r (yr)	20	20
Age at maturity	A_m (yr)	30	30
von Bertalanffy parameters	L_∞ (cm, TL)	52	41
	k (yr^{-1})	0.046	0.080
	t_0 (yr)	-2.9	-1.0
Length–weight parameters	a	0.029	0.032
	b	2.90	2.87
Recruitment steepness		0.75	0.75
Length at recruitment	(cm, TL)	34	–
Length at maturity	(cm, TL)	40	–

Table 14: Reconstructed catch history (t) from the CPUE study area in OEO 3A

Year	Smooth oreo	Black oreo
1972–73†	3 440	3 440
1973–74†	3 800	3 800
1974–75†	5 100	5 100
1975–76†	1 300	1 300
1976–77†	4 000	4 000
1977–78†	5 750	5 750
1978–79	650	716
1979–80	5 215	5 743
1980–81	2 196	12 636
1981–82	1 288	11 462
1982–83	2 495	8 286
1993-84	3 395	5 505
1984-85	4 301	3 213
1995-86	2 529	1 931
1986-87	3 011	3 931
1987-88	4 394	3 037
1988-89	5 597	3 163
1989-90	5 643	2 708
1990-91	4 743	4 692
1991-92	2 804	2 292
1992-93	3 174	4 544
1993-94	4 266	3 728
1994-95‡	5 000	5 000

† USSR catch assumed to be mostly from OEO 3A and to be 50:50 black oreo:smooth oreo.
‡ Assumed catch for the current year.

Table 15: Research survey recruited biomass indices (t). Smooth oreo, SSO; black oreo, BOE; N is the number of stations

Management area OEO 3A

SSO	Mean biomass	Lower bound	Upper bound	*c.v.*(%)	N
1991	1 849	0	4 549	73	44
1992	3 476	0	8 535	73	24
1993	4 162	0	11 867	93	24

BOE	Mean biomass	Lower bound	Upper bound	*c.v.*(%)	N
1991	36 299	3 138	69 458	43	44
1992	19 848	6 529	33 168	34	24
1993	16 800	6 249	27 351	31	24

Management area OEO 4

SSO	Mean biomass	Lower bound	Upper bound	*c.v.*(%)	N
1991	133 492	52 950	214 034	30	110
1992	83 550	27 619	139 481	33	122
1993	71 982	38 673	105 290	23	124

BOE	Mean biomass	Lower bound	Upper bound	*c.v.*(%)	N
1991	34 407	7 697	61 118	39	110
1992	29 948	13 032	46 865	28	122
1993	20 953	12 428	29 478	20	124

4.5.1 Input data

The data required were the life history parameters (Table 13), catch history for the CPUE study area only (Table 14), the trawl survey biomass indices and their *c.v.*s (Table 15), the CPUE time series of abundance indices (Tables 9 and 12), and the mean *c.v.* for each of the CPUE time series of abundance indices.

Life history

New data on estimated age were used to estimate life history parameters (Table 13), Doonan *et al.* (unpubl. results).

Catch history

The reconstructed catch history for the CPUE study area (*see* Table 14) needs some explanation and we consider that it is probably conservative.

USSR catches from 1972 to 1977 were reported by calendar year mostly from waters east of New Zealand. The figures are probably only estimates, i.e., some are to the nearest 1000 t. We have assumed that these catches came from the Chatham Rise. The concentration of oreo fishing on the Chatham Rise by the USSR licensed and charter fleet (*see* Table 2 and Fincham *et al.* (1991)) in the late 1970s and early 1980s indicates that this is the most likely explanation. We have assumed that these catches came from OEO 3A (although this is not consistent with the high catch from OEO 4 in 1978–79) and that it was within the CPUE study area. These assumptions are based on discussions by Peter McMillan with USSR skippers/mates during seatrips on USSR vessels in 1981 and 1982 which indicated that the grounds in OEO 3A were well known while those in OEO 4 were only relatively recently fished at the time. The 1972–77 USSR catch figures are likely to be low because of conservative reporting. For example, the USSR fleet used a very low conversion factor of 1.62 (i.e., 62% recovery of headed and gutted from green weight) in the early years of the MAF "Deepwater logbook" scheme. A more realistic figure is 2.15 (47% recovery).

We have also assumed that the catch in 1978–79, which was not reported by species, has the same species proportions as the 1979–80 catch. USSR vessels fished without logbooks in April 1978 so data for about 5000 t of fish were not recorded (King *et al.* 1985). Most of this was probably oreo and some of it was probably from OEO 3A.

Fishing years changed from 1 April to 31 March to 1 October to 30 September in 1983. We allocated the catch of the 6 month intervening period equally between the previous and succeeding years. Ideally the early years should be changed to the October-September year. The oreo catch that is reported in catch effort data as unspecified oreo (OEO) has been allocated to species using the proportions of each oreo species reported for that year.

From 1983–84 onwards the catch of oreo was calculated by the following method: the ratio of estimated oreo (OEO) from the CPUE study area to the rest of OEO 3A was used to allocate OEO reported landings (*see* Table 2) between the two areas; the catch of each oreo species was then calculated from the ratio of smooth to black oreo estimated catch from the CPUE study area.

In the early years of the fishery, discarding of oreos, mainly black oreo but also small fish of both species, was reported by observers and fishers. This applied particularly in area OEO 4. There is also the probability that oreo caught in area OEO 4 has been reported from OEO 3A because of the large bycatch of oreo while target fishing for orange roughy in OEO 4.

Trawl survey biomass indices

The biomass results of the three *Tangaroa* surveys from 1991 to 1993 (*see* Table 15) provide the only comparable estimates.

4.5.2 Biomass estimates for smooth oreo from the CPUE study area

Base case

Estimated virgin biomass, B_0 was 66 000 t and beginning of year biomass, $B_{1995-96}$ was 6100 t (9% of B_0).

Two-nation case

Biomass estimates were B_0 = 66 000 t, and beginning of year $B_{1995-96}$ = 6100 t (9% B_0).

Biomass estimates are uncertain for two reasons. First, the variability of the CPUE data resulted in a 61% *c.v.* for the USSR index series and a 49% *c.v.* for the domestic index. This variability translates into highly uncertain estimates for B_0 and $B_{1995-96}$. $B_{1995-96}$ could be between 9 and 100% of B_0 (Figure 11), but 73% of the estimates of $B_{1995-96}$ are less than 20% B_0. Second, the maximum likelihood estimate of B_0 (66 000 t) lies on the constraint B_{min}, i.e., the minimum biomass that is consistent with the catch history. Left unconstrained by B_{min}, the maximum likelihood estimate of B_0 is below B_{min} when it should be above B_{min}. Either B_{min} was chosen too high or one or more assumptions in the analysis may not hold.

This analysis suggests that B_0 for smooth oreo in the main fishing area of OEO 3A is not large. Results of a simulation show that 95% of the B_0 estimates were less than 139 000 t.

The data fit the stock reduction model because the CPUE indices (converted to biomass with the estimate of catchability from the stock reduction analysis) are within two standard errors of the yearly biomass (Figure 12). The USSR CPUE indices are mostly above the stock reduction biomass estimates, but because these CPUE indices have large *c.v.*s they contribute little to the virgin biomass estimate.

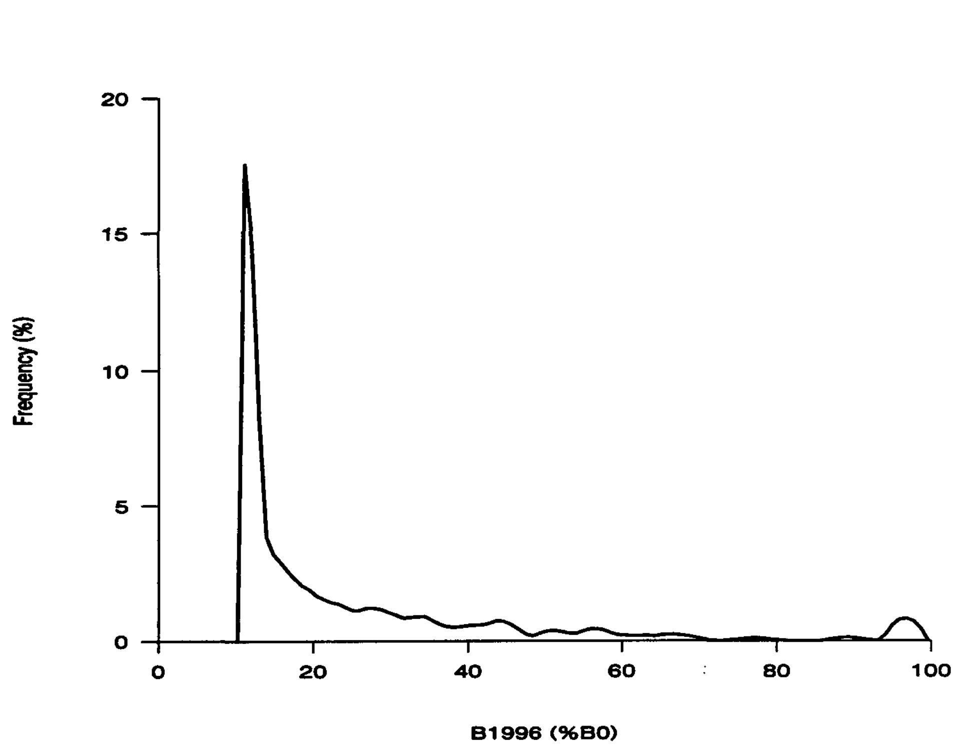

Figure 11: The distribution of the estimates of $B_{1995-96}$, for the CPUE study area, expressed as a percent of B_0 ("B1996(%B0)" on the x axis). Results from simulation model runs for the two-nation case.

4.5.3 Sensitivity of biomass estimates

M, catch history

For the two-nation case, doubling M results in a 17% reduction in B_0 but halving M results in a 35% increase in B_0 (Table 16). M values are important for this analysis and a better estimate is needed. Catch history is also important with a reduced catch history causing about a 20% reduction of B_0 for the two-nation case.

Estimation of $B_{1995-96}$ is not sensitive to M and catch history ranging from 4600 to 7500 t.

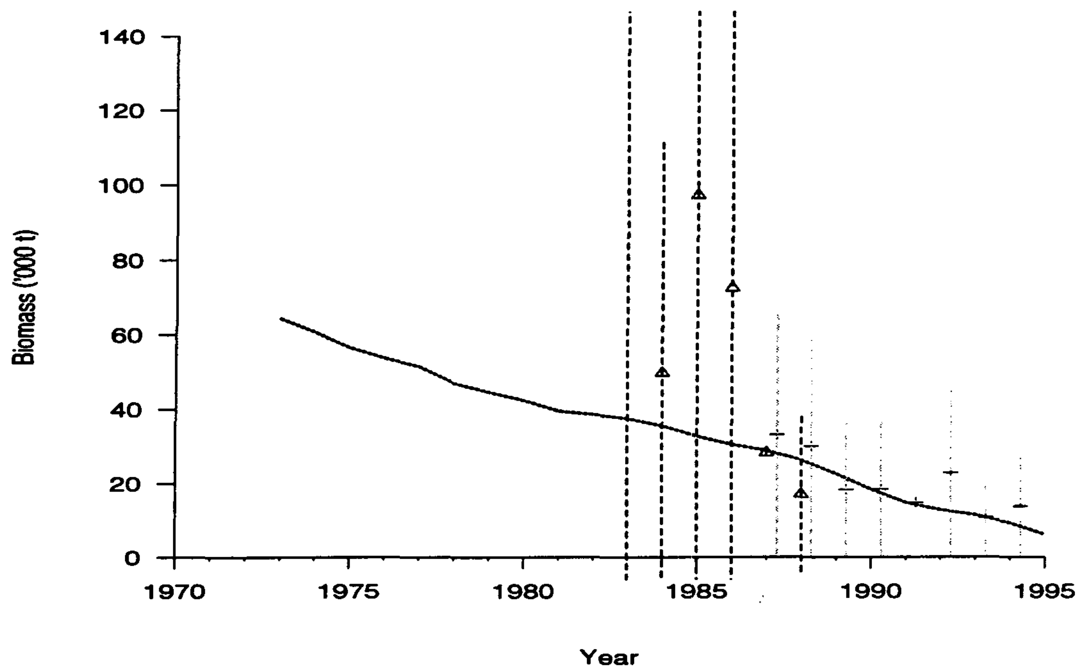

Figure 12: Estimated midyear biomass (t) for the two-nation case, by year from the stock reduction analysis (dotted line) for the CPUE study area. The corresponding biomass calculated from the CPUE indices using the estimated catchability (USSR, triangles; domestic, crosses), and two standard errors on the CPUE biomass (vertical lines).

Table 16: Sensitivity of midyear biomass estimates for smooth oreo to changes in M and catch history for the CPUE study area. All other parameter values and data as for the two nation case. (A) no change, and (B) *setting all catches to zero before the 1979–80 fishing year.* B_0 *is virgin biomass,* B_{1996} is biomass for the 1995–96 fishing year

M	Catch history	B_0 (t)	B_{1996} (t)	B_{1996} (% B_0)
0.025	A	77 000	5 200	7
0.5	A	66 000	6 100	9
0.1	A	49 000	7 500	15
0.025	B	59 000	4 600	8
0.1	B	43 000	7 000	16

Virgin biomass estimates using the MIAEL method

As a sensitivity test for the estimation of B_0, the stock reduction approach of the Hoki Working Group was applied to the smooth oreo OEO 3A assessment. This approach used a slightly different biological model (the main difference: maturity and recruitment coinciding at 25 years, rather than recruitment at 20 and maturity at 30), different *c.v.*s for the abundance indices, and a MIAEL (Minimum Integrated Average Expected Loss) estimator.

The abundance time series were assigned subjective *c.v.s* to reflect the type and quality of the data source. The cpue time series were assigned *c.v.s* of 0.35 (as in the hoki stock assessment) and the trawl time series was assigned 0.65 (as the estimated *c.v.s* attest, this is a poor quality time series).

For the MIAEL method we chose a *BestP* estimator with proportional mean squared error (*see* Cordue 1994). MIAEL estimation also provides an information index which measures how well the data determines the true value within the range of possible values, $[B_{min}, B_{max}]$, with 0% meaning no information and 100% complete information.

MIAEL estimates of B_0 were obtained for three ranges (Table 17). The lower point of the range, B_{min}, is determined by the biological model and catch history (note this model gives a slightly lower B_{min} than the two-nation case above), but the upper point, B_{max}, is subjective. The variation in the estimates is a reflection of the low level of information in the time series. The variation in the information indices shows that the relative biomass indices have little information content if B_0 is "large" (i.e., relative to the historical catches).

As part of the MIAEL estimation procedure a least squares estimate of B_0 and associated confidence intervals (C.I.) are available. This is analogous to the two-nation case and is directly comparable to it. Estimated B_0 = 68 600 t, 95% two-sided C.I. = [59 000, 450 000] t, 90% two-sided C.I. = [60 000, 125 000] t, and a 95% one-sided C.I. = [57 600, 125 000] t.

Table 17: MIAEL estimates of B_0 for smooth oreo for OEO 3A using three values for B_{max}

Range (' 000 t)	MIAEL estimate (' 000 t)	Information index (%)
57.6–250	96.7	25
57.6–500	125.5	17
57.6–1 000	159.6	12

4.5.4 Biomass estimates for smooth oreo from OEO 3A

The maximum likelihood and upper 95% estimates of current and virgin biomass, 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 (6632 t) to the estimated catch from the CPUE study area (47 537 t) from 1978–79 to 1993–94, i.e., a ratio of 1.14.

For the maximum likelihood estimate of B_0 = 66 000 t, the adjusted B_0 = 75 000 t, and beginning of year $B_{1995-96}$ = 6900 (9% B_0). For the upper 95% estimate of B_0 = 139 000 t, the adjusted B_0 = 158 000 t and $B_{1995-96}$ = 93 600 t (59% B_0).

4.6 Yield estimates for smooth oreo from OEO 3A

4.6.1 Estimation of Maximum Constant Yield (MCY)

The two-nation case was preferred over the base case analysis because there are clear differences in the USSR and domestic sets of CPUE data, and they overlap by only two years. Consequently the Orange Roughy/Oreos Working Group decided that the two sets of data should be treated as separate combined abundance indices in the stock reduction analysis for estimating yields.

MCY estimates were calculated using the "Depressed stocks" methods from Francis (1992). The long-term MCY ($MCY_{long\ term}$), i.e., the MCY when the current biomass is greater than 20% B_0, was also estimated (Table 18).

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 the values of life history parameters as in Table 13 is 1.33% B_0. Under continued fishing at this level the mean biomass is 44% B_0.

The level of risk to the stock by harvesting the population at the estimated MCY value cannot be determined.

Table 18: Estimates (t) of B_0, beginning of year biomass, MCY and CAY (t) for 1995–96

	B_0	$B_{1995-96}$	$MCY_{1995-96}$	$MCY_{long\ term}$	$CAY_{1995-96}$
Maximum likelihood	75 000	6 900	450	1 000	290
Upper 95% limit	158 000	93 600	2 100	2 100	3 900

4.6.2 Sensitivity of MCY to M and steepness

M was varied by a factor of 2 from 0.05, the value used in the main calculations above, and steepness values were changed to 0.5 and 0.95 from the value 0.75 used in the main calculations above. Long term MCY, as a percentage of virgin biomass, varied widely with changes in M and steepness (Table 19). This resulted in a range of estimates from 650 to 1300 t. (Note that each cell in Table 19 had a different virgin biomass so that the ratio of the highest and lowest values of MCY was not the same as the apparent ratio from Table 19).

Table 19: Sensitivity of long term MCY (% virgin biomass) to M and 'steepness' for the two-nation case, CPUE study area only. –, not estimated

	steepness		
M	0.50	0.75	0.95
0.025	-	0.75	-
0.05	0.87	1.33	1.61
0.10	-	2.23	-

4.6.3 Estimation of Current Annual Yield (CAY)

CAY values were estimated using the method listed in Francis (1992) which requires a value for F_{CAY}, the maximum constant fishing mortality (F) that can be applied (without reducing the population below 20% B_0 more than 10% of the time) to a population with the life history parameters as in Table 13. Our estimate of F_{CAY} is 0.0438 which when applied to $B_{1995-96}$ gives a $CAY_{1995-96}$ of 290 t (Table 18). If fishing is always done at a F of 0.0438 then in the long term the mean catch is 1.58% B_0, and the mean biomass is 24% B_0.

5. MANAGEMENT IMPLICATIONS

This stock assessment is limited to smooth oreo in area OEO 3A. It is based on a stock reduction analysis using CPUE and research trawl survey data as relative abundance indices. The following assumptions are made:

(a) the population of smooth oreo in OEO 3A (in the main fishing ground at least) is a discrete stock or production unit;

(b) the results of CPUE analysis (the two-nation case) is an index of smooth oreo abundance in the CPUE study area in OEO 3A;

(c) the ranges used for the biological values cover their true values.

The following conclusions can be drawn from this assessment

1. The virgin biomass (B_0) of smooth oreo in the main fishing ground of OEO 3A was small and was likely to be less than 158 000 t.

2. The biomass at the start of 1995–96 is likely to be less than 20% of B_0 and certainly less than B_{MCY} (44% B_0).

3. Yields from the fishery will probably be low because the productivity of smooth oreo is likely to be low, based on unvalidated age estimates. The maximum likelihood estimate of long-term yield for smooth oreo in OEO 3A from this analysis is 1000 t. The long-term yield from a stock of about 158 000 t is 2100 t.

4. The recent catch levels of smooth oreo from OEO 3A (about 4000 t per year) are higher than the long term sustainable yield.

The main sources of uncertainty for this assessment are:

1. The high variability of the USSR CPUE index series (61% *c.v.*) and of the domestic CPUE index series (49% *c.v.*) means that estimates for B_0 and $B_{1995-96}$ are highly uncertain, i.e., $B_{1995-96}$ could be between 9 and 100% of B_0 (*see* Figure 11). Note, however, that there is a 73% chance that $B_{1995-96}$ is less than 20% B_0.

2. The best estimate of B_0 lies on the constraint B_{min}, i.e., the minimum biomass that is consistent with the catch history. This may imply that one or more assumptions in the CPUE analysis may not hold.

3. Life history parameters. The main uncertainties are for age estimates and for recruitment steepness. Smooth oreo age estimates are not validated, although Australian workers using the same method achieved similar results. Small smooth oreo are not available to known sampling methods and other ageing methods will need to be employed to validate otolith section age estimates. There are no data available to check the assumed value of recruitment steepness.

4. Stock definition. Stock discreteness for smooth oreo in area OEO 3A was assumed based on the separate fishery which is carried out in OEO 3A. The fishery is separated by about 100 nautical miles from another substantial oreo fishing area to the east, on the south Chatham Rise. There are no other data to help define stocks.

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