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Assessment of OEO 3A smooth oreo for 1999–2000

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1. EXECUTIVE SUMMARY

The biomass of smooth oreo in OEO 3A was estimated from deterministic stock reduction analyses using an absolute abundance estimate from the 1997 research acoustic and trawl survey (TAN9713) and relative abundance indices from catch per unit effort analyses. Yields from the stock were low because the productivity of smooth oreo, based on unvalidated age estimates, is low. For the base case analysis (acoustic absolute abundance estimate plus New Zealand and Soviet standardised CPUE abundance estimates), the 95% confidence interval for B_0 was between 76 500 and 92 500 t and the 95% confidence interval for long-term MCY was 1200–1500 t. Smooth oreo mean catch per year between 1988–89 and 1997–98 from OEO 3A (about 5000 t) was higher than the range of long-term MCY.

2. INTRODUCTION

2.1 Overview

This work addresses the following objectives in MFish project "Oreo stock assessment" (OEO9802).

Overall objective:

1. To carry out a stock assessment of black oreo (*Allocyttus niger*) and smooth oreo (*Pseudocyttus maculatus*), including estimating biomass and sustainable yields.

Specific objective:

1. To update the stock assessment for black oreo and smooth oreo in OEO 3A.

A new stock assessment for smooth oreo in OEO 3A is presented based on the first estimates of absolute abundance for smooth oreo from research acoustic and trawl survey data plus abundance indices from an updated standardised CPUE analysis. The last major assessment was that of Doonan *et al.* (1997a). Estimates of biomass and yields were modelled using deterministic recruitment (knife-edge at 34 cm TL), incorporating the 1997 biological parameters and an updated catch history. A black oreo stock assessment is presented in a separate report (Doonan *et al.*, unpublished results).

2.2 Description of the fishery

Smooth oreo are caught by trawling at depths of 800–1300 m in southern New Zealand waters (Figure 1). The OEO 3A south Chatham Rise fishery is the second largest oreo fishery in the EEZ (*see* Table 2) and is carried out between 172° and 176° E on undulating terrain (short plateaus or terraces and "drop-offs") with some fishing on seamounts. Black oreo is the other main species caught and orange roughy is a small bycatch.

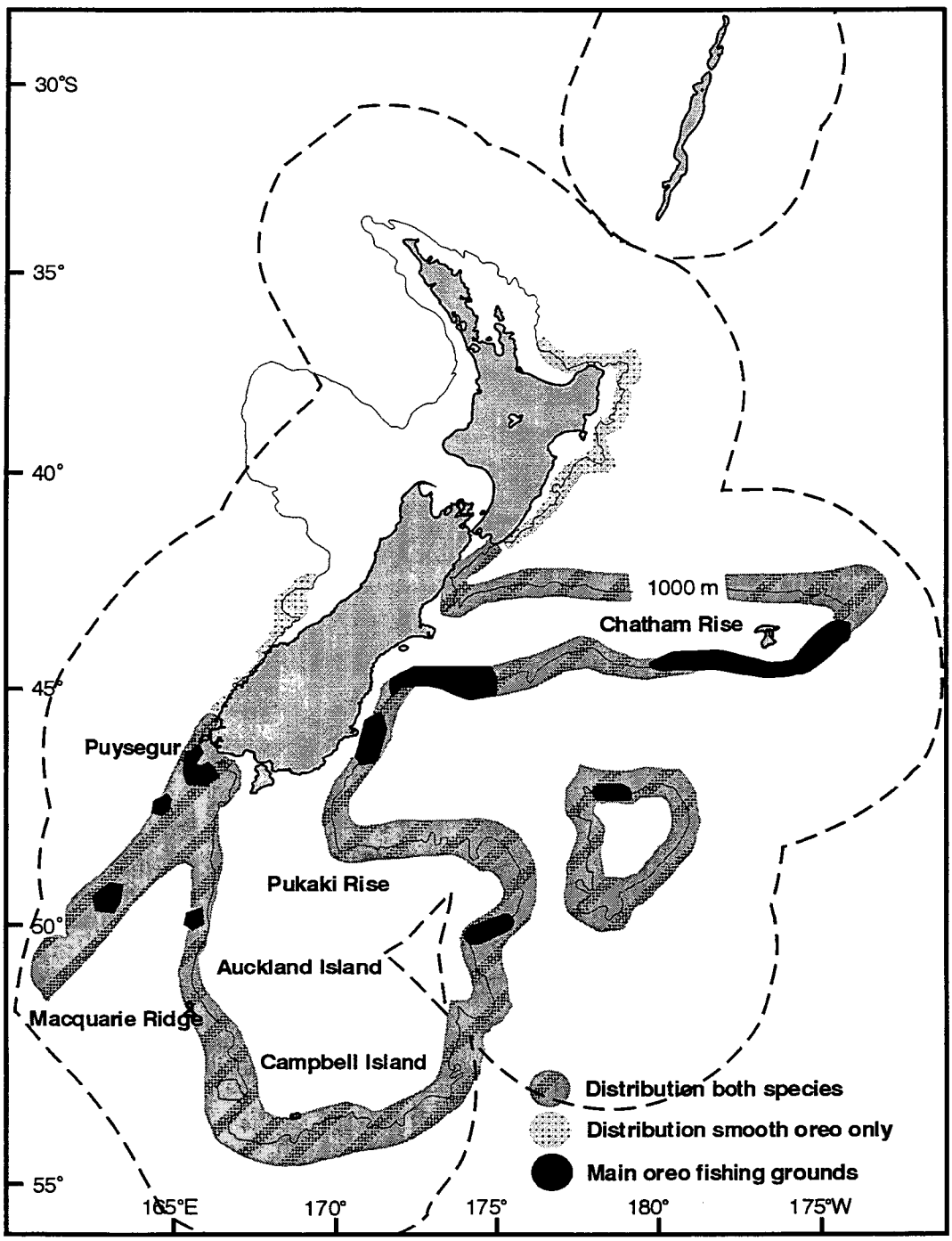

Figure 1: The main fishing grounds and distribution of black oreo and smooth oreo.

2.3 Literature review

The literature was summarised by McMillan *et al.* (1988), McMillan & Hart (1991), and Doonan *et al.* (1995a, 1996, 1997a). The 1999 stock assessment was summarised by Annala *et al.* (1999). Age estimates for Chatham Rise smooth oreo were given by Doonan *et al.* (1995b,

1997b). Fincham *et al.* (1991) summarised oreo catches from 1972 to 1988, and McMillan & Hart (1994a, 1994b, 1994c, 1995) and Hart & McMillan (1998) reported on annual south Chatham Rise relative abundance 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 that 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.

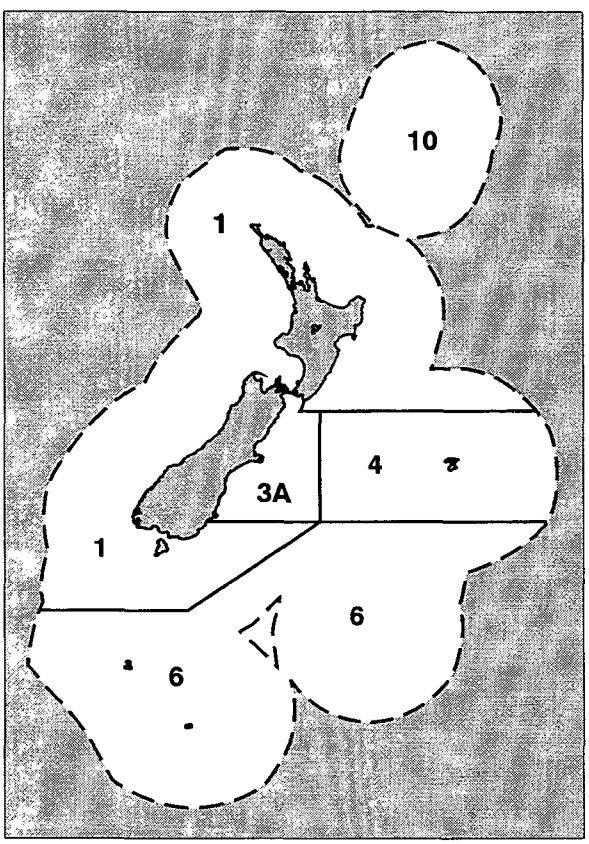

Figure 2: Oreo management areas.

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 1997–98 are given in Table 2. The Chatham Rise TAC was the same from 1982–83 to 1995–96 (about 10 000 t for OEO 3A and 7000 t for OEO 4), but the TAC for OEO 3A was reduced to 6600 t for the 1996–97 fishing year. A voluntary agreement between the fishing industry and the Minister of Fisheries to limit catch of smooth oreo from OEO 3A to 1300 t (of the total oreo TAC of 6600 t) was in place for 1998–99. 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 (*see* 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 1997–98 and TACs (t) from 1982–83 to 1997–98

	FISHSTOCK									
Fishing	OEO 1		OEO 3A		OEO 4		OEO 6		Totals	
year	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1978–79*	2 808	–	1 366	–	8 041	–	17	–	12 231	–
1979–80*	143	–	10 958	–	680	–	18	–	11 791	–
1980–81*	467	–	14 832	–	10 269	–	283	–	25 851	–
1981–82*	21	–	12 750	–	9 296	–	4 380	–	26 514	–
1982–83*	162	–	8 576	10 000	3 927	6 750	765	–	13 680	17 000
1983–83#	39	–	4 409	#	3 209	#	354	–	8 015	#
1983–84†	3 241	–	9 190	10 000	6 104	6 750	3 568	–	22 111	17 000
1984–85†	1 480	–	8 284	10 000	6 390	6 750	2 044	–	18 204	17 000
1985–86†	5 390	–	5 331	10 000	5 883	6 750	126	–	16 820	17 000
1986–87†	532	4 000	7 222	10 000	6 830	6 750	0	3 000	15 093	24 000
1987–88†	1 193	4 000	9 049	10 000	8 674	7 000	197	3 000	19 159	24 000
1988–89†	432	4 233	10 191	10 000	8 447	7 000	7	3 000	19 077	24 233
1989–90†	2 069	5 033	9 286	10 106	7 348	7 000	0	3 000	18 703	25 139
1990–91†	4 563	5 033	9 827	10 106	6 936	7 000	288	3 000	21 614	25 139
1991–92†	4 156	5 033	10 072	10 106	7 457	7 000	33	3 000	21 718	25 139
1992–93†	5 739	6 044	9 290	10 106	7 976	7 000	815	3 000	23 820	26 160
1993–94†	4 910	6 044	9 106	10 106	8 319	7 000	983	3 000	23 318	26 160
1994–95†	1 483	6 044	6 600	10 106	7 680	7 000	2 528	3 000	18 291	26 160
1995–96†	4 783	6 044	7 786	10 106	6 806	7 000	4 435	3 000	23 810	26 160
1996–97†	5 181	6 044	6 991	6 600	6 962	7 000	5 645	6 000	24 779	25 654
1997–98†	2 679	6 044	6 330	6 600	7 011	7 000	5 219	6 000	21 239	25 654

Source: FSU from 1978–79 to 1987–88; QMS/ITD from 1988–89 to 1997–98.
* 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 1997–98. OEO includes the total reported landing from Table 1 minus the BOE and SSO catch, i.e., the balance to make the total the same as that reported

	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†	2 517	3 591	5 236	2 562	1 296	3 361	364	1 166	970	834	1 206	707	23 810
1996–97†	2 203	3 063	5 390	2 492	2 578	3 549	530	1 950	479	712	1 136	1 144	24 779
1997–98†	1 385	4 565	5 814	2 477	1 167	1 494	801	1 877	127	271	396	865	21 239

Source: FSU from 1978–79 to 1987–88 and ITD from 1988–89 to 1997–98
* 1 April to 31 March.
\# 1 April to 30 September.
† 1 October to 30 September.
– Less than one tonne.

3.1.1 CPUE analysis

Data

The 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 1997–98 (*see* figure 4 in Doonan *et al.* 1995a). This area contained most of the smooth oreo reported caught in OEO 3A from 1978–79 to 1997–98, about 85%.

Method of CPUE analysis

The CPUE analysis method was described by Doonan *et al.* (1995a, 1996, 1997a). The same selected variables as used in the 1997 analysis including target species were used in the New Zealand regressions. The Soviet analysis was unchanged from 1997 (no new data). The mean *c.v.*s for the combined indices (all years) were estimated using a jackknife technique (Doonan *et al.* 1995a). The *c.v.* for the reference year was zero so that year was excluded when the mean *c.v.* was calculated. The individual annual (including the reference year) *c.v.* estimates for the New Zealand and Soviet standardised CPUE abundance indices used in the stock reduction analysis were calculated by dividing the mean annual *c.v.*s from each standardised CPUE analysis by $\sqrt{2}$. This allowed the reference year and *c.v.* for both series to be included in the stock reduction analysis.

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 1997–98. The variables year, vessel, area, depth, target species, and season were used for the positive catch regression (R^2 = 29%), but only year, vessel, and season were used for the zero catch regression (R^2 = 11%). 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.*, 51%, 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: Soviet and New Zealand time series of combined abundance indices from a standardised CPUE analysis. –, no estimate

Year	Soviet	New Zealand
1982–83	6.92	–
1983–84	1.75	–
1984–85	3.41	–
1985–86	2.55	–
1986–87	1.00	2.33
1987–88	0.61	2.04
1988–89	–	1.32
1989–90	–	1.32
1990–91	–	1.00
1991–92	–	1.77
1992–93	–	1.29
1993–94	–	1.32
1994–95	–	1.16
1995–96	–	0.69
1996–97	–	0.75
1997–98	–	0.79

3.2 Other information

Mean (total) length

Mean length changes over time might indicate the status of the stock. For example, if recruitment was assumed to be relatively constant then the standing stock of older fish should

decline over time because of fishing and the proportion of older to younger fish would be expected to decline. Therefore the mean length should also decline over time.

Mean length per year was estimated for males and females from all observer length data collected from commercial vessels fishing in OEO 3A (Figure 3). Mean length per year for males and females was also estimated for data which had been separated into that from New Zealand and Soviet vessels and that from depths greater than and less than 900 m (Tables 5 and 6 and Figure 4). Data were analysed in this way to examine sampling effects, including nationality, depth, and area effects and to enable comparison with previous analyses (McMillan *et al.* 1998).

Mean length for the combined data appeared to decline from 1979 to 1998 by about 2 cm for both males and females (*see* Figure 3). But when the data were analysed by nation and depth (*see* Tables 5 & 6, Figure 4) the data were shown to be sparse and erratically collected, with only "NZ > 900m" having more than 3 years of useful data (200 or more fish measured per year). Data were collected from Soviet vessels from 1979 to 1988 and from New Zealand vessels from 1987 to 1998. The two New Zealand data sets show no trend in mean length, while the two short Soviet sets suggest a decline.

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

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.

Table 5: **Numbers of tows where smooth oreo length/sex samples were taken by observers in OEO 3A from 1979 to 1998 from all vessels (Total). Data from tows made by Soviet and New Zealand vessels from two depth zones were also analysed**

Year	New Zealand		Soviet		Total
	< 900 m	≥ 900 m	< 900 m	≥ 900 m	
1979	0	0	0	22	22
1980	0	0	0	2	2
1981	0	0	0	0	0
1982	0	0	0	0	0
1983	0	0	0	0	0
1984	0	0	0	0	0
1985	0	0	0	0	0
1986	0	0	0	1	2
1987	0	6	1	4	13
1988	0	11	3	1	15
1989	0	0	0	0	0
1990	4	23	0	0	27
1991	6	3	0	0	9
1992	0	0	0	0	0
1993	0	1	0	0	1
1994	15	14	0	0	29
1995	1	6	0	0	7
1996	0	1	0	0	1
1997	1	2	0	0	6
1998	0	0	0	0	11

Table 6: **Numbers of smooth oreo length/sex samples taken by observers in OEO 3A from 1979 to 1998 from all vessels (Total). Data from tows made by Soviet and New Zealand vessels from two depth zones were also analysed. There were no data from 1981–1985**

Year	New Zealand		Soviet		Total
	< 900 m	≥ 900 m	< 900 m	≥ 900 m	
1979	0	0	0	2 195	2 195
1980	0	0	0	150	150
1986	0	0	0	134	240
1987	0	544	171	713	1 553
1988	0	1 132	276	132	1 540
1989	0	0	0	0	0
1990	268	2 656	0	0	2 924
1991	633	286	0	0	919
1992	0	0	0	0	0
1993	0	64	0	0	64
1994	780	771	0	0	1 858
1995	59	619	0	0	678
1996	0	107	0	0	107
1997	122	243	0	0	696
1998	0	0	0	0	1 489

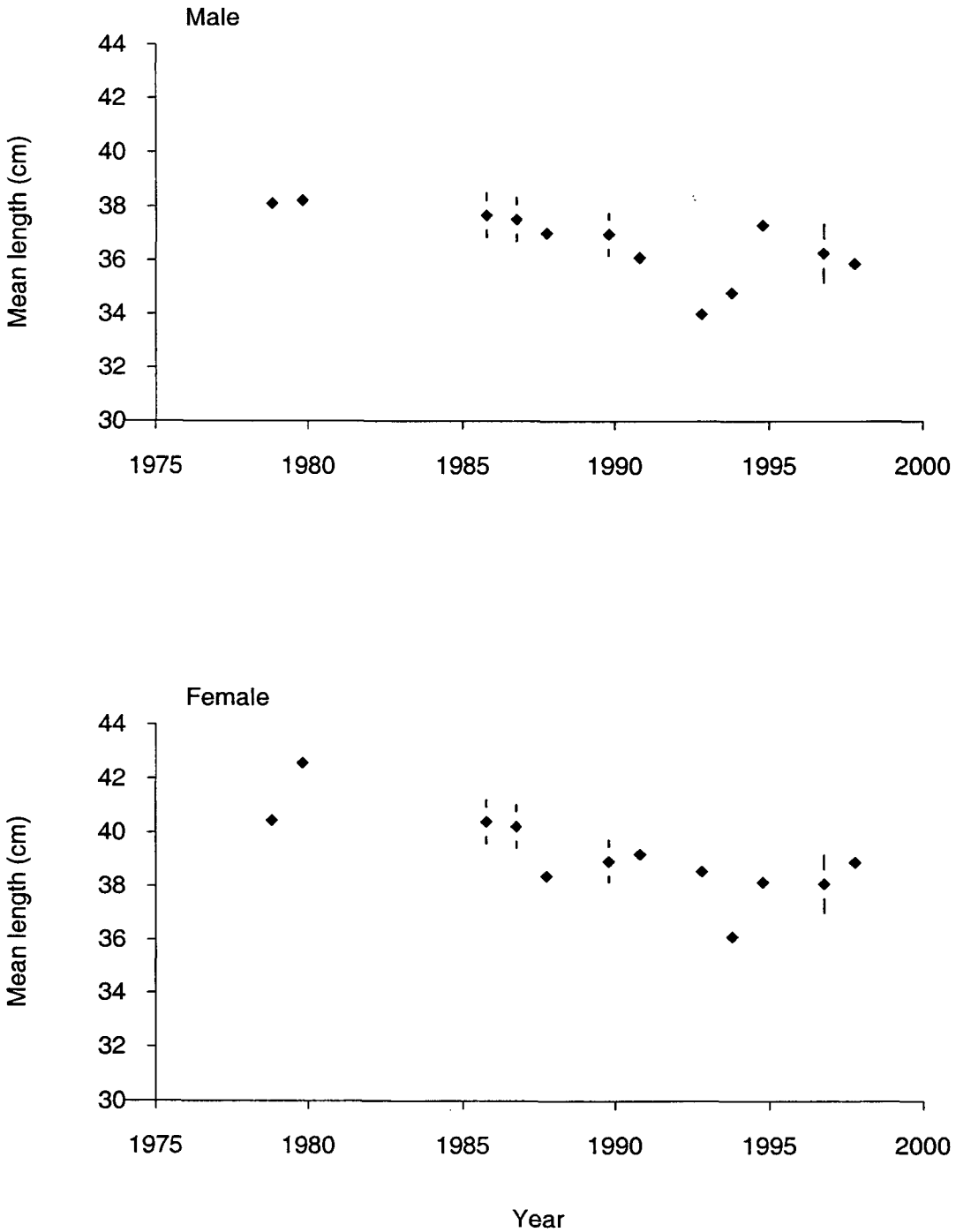

Figure 3: **All observer length frequency data from 1979 to 1998 scaled to catch. Mean length (♦). Vertical lines are ± 2 s.e..**

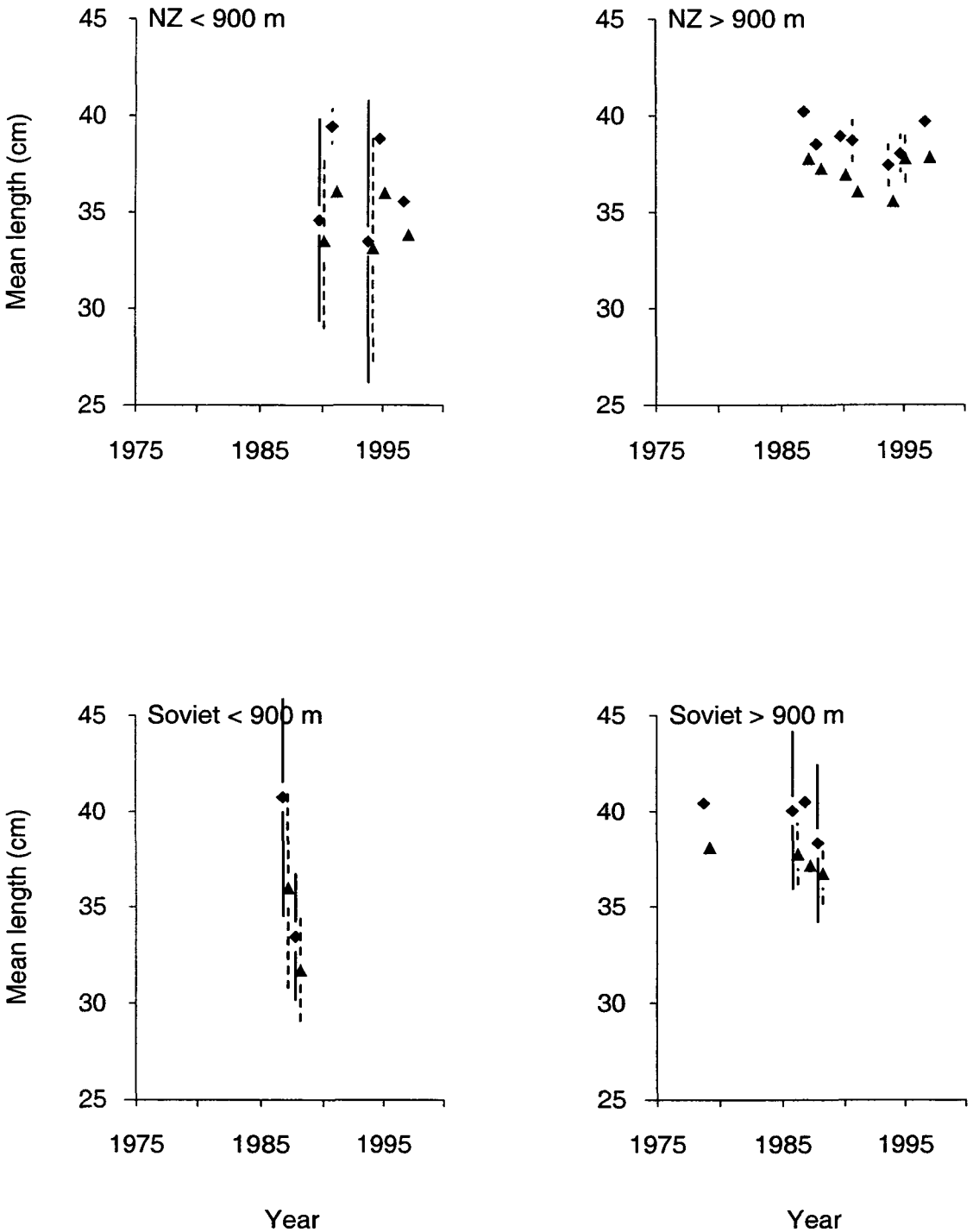

Figure 4: **Observer length frequency data from 1979 to 1998 from New Zealand or Soviet vessels, and from above or below 900 m, scaled to catch. Mean length (females ♦ and males ▲). Vertical lines are ± 2 s.e., solid (females), dashes (males).**

4.2 Resource surveys

Trawl surveys

Trawl surveys of oreos on the south Chatham Rise were carried out in most years since 1986 (Table 7). The abundance estimates from the surveys before 1991 were not considered to be comparable with the *Tangaroa* series because different vessels were used. Other data 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.

Table 7: Random stratified trawl surveys (standard, i.e. flat tows only) for oreos on the south Chatham Rise (OEO 3A & OEO 4)

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
1995	60 503	*Tangaroa*	South, southeast	172

Acoustic surveys

Absolute estimates of abundance are available from the first acoustic survey on oreos which was carried out from 10 November to 19 December 1997 (TAN9713), Doonan (*et al.* 1998). The survey covered the "flat" with a series of random north-south transects over 6 strata at depths of 600–1200 m (Figure 5). Three seamounts were also sampled using parallel and "starburst" transects. Targeted and some random (background) trawling (n = 51) was carried out to identify targets and to determine species composition. The number of acoustic transects on the flat and seamounts are in Table 8. In situ target strength measurements were carried out on 10 marks: 2 smooth oreo, 2 black oreo and 6 mixed oreo marks. Preliminary smooth oreo target strength estimates from the OEO 4 acoustic survey carried out from 26 September to 30 October 1998 (TAN9812) were also used to estimate absolute abundance.

Table 8: Summary of acoustic transects surveyed in area OEO 3A by stratum. For the seamounts, NC is Neil's Condom, NP Neil's Pinny and HA Hill A

Stratum Flat	Number of transects Hull	Tow body
1	5	5
2	29	27
3	24	19
4	5	5
5	3	3
15	9	5

Stratum Seamounts	Number of transects Hull	Tow body
NC	16	16
NP	14	14
HA	4	4

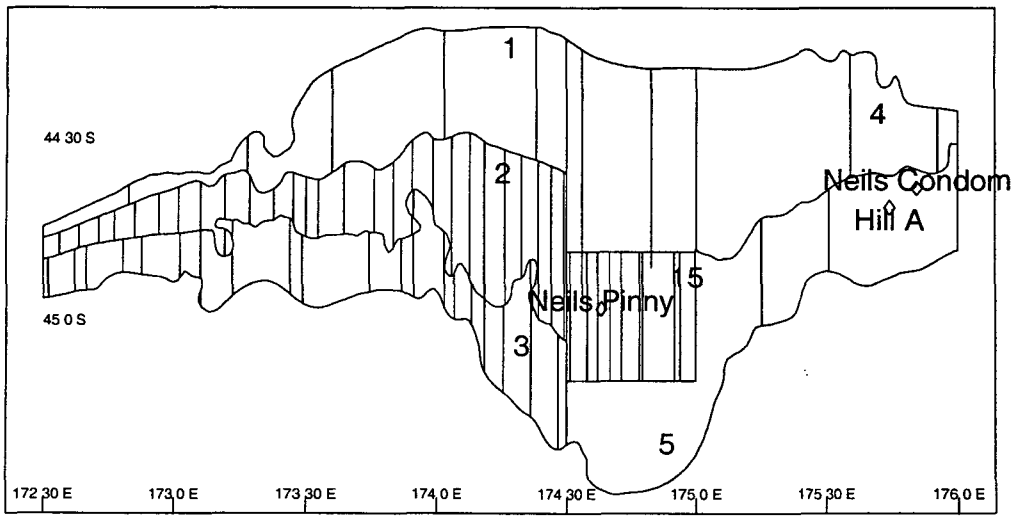

Figure 5: Survey areas for the 1997 Chatham Rise acoustic survey showing strata and transects on the flat and the positions of the hills surveyed in area OEO 3A.

Acoustic absolute abundance estimates

Estimates were made for pre-recruit and recruit fish using the values of parameters as follows where they differ from those given by Doonan *et al.* (1998). The mean absorption coefficient of sound in seawater used was 8.9 $dB.km^{-1}$ (Doonan 1999). Shadow zone corrections were made using the results of Barr (1998). Revised target strength (TS) relationships:
Black oreo TS = -74.2 + 23.7 * log10(L).
Smooth oreo TS = - 124.9 + 48.5 * log10(L) where L is fish length in cm (total length).
The target strength estimate for black oreo is the largest potential source of bias for the acoustic survey abundance estimates for smooth oreo.

The target strength-length (L) relationship used for species other than black and smooth oreo was divided into three target strength categories: non-swimbladder (-77 + $20\log_{10}$ L), cod-like (-67.5 + $20\log_{10}$ L), and deepwater-like (-79.4 + $20\log_{10}$ L). Target strength for cod-like species was estimated from the TS-length relationship given by Foote (1987) and that for deepwater species used the swimbladder model data from the rattails *Caelorinchus innotabilis* and *Coryphaenoides subserrulatus*, and smooth oreo to set the general level, but used the scatter of data from Foote (1987) to estimate target strength using bootstrap techniques.

Absolute abundance estimates from the survey area were scaled up to the OEO 3A area by multiplying the survey estimates by 1.22, the ratio of catches (1979–80 to 1996–97) from the total area to those from the survey area (Table 9).

Table 9: OEO 3A pre-recruit, recruit, and total acoustic abundance estimates (t) and recruit *c.v.* (%) for smooth oreo based on knife-edge recruitment (21 years) for flat plus seamounts for the survey area and scaled up to the OEO 3A area

Survey area				OEO 3A			
Pre-recruit	Recruit	*c.v.*	Total	Pre-recruit	Recruit	*c.v.*	Total
9 100	19 700	27	28 800	11 100	24 000	27	35 100

Mean (total) length

Research collected mean length data were analysed for the same reasons as the observer data (*see* Section 3.2). Previous analyses of the data from OEO 3A by Doonan *et al.* (1995a) are reproduced here (Figure 6). There are too few data from voyage TAN9511 to include in a new analysis. Mean lengths for males and females show a steep decline over time, but recent small mean length estimates are probably due to survey sampling problems. Section 4.3 below discusses the problem of inconsistent catchability which was noted for smooth oreo for the *Tangaroa* OEO 3A trawl surveys.

4.3 Other studies

Catchability (q) of smooth oreo from the trawl surveys

Inconsistent estimates of catchability (q), resulting from stock reduction analyses of the abundance estimates from the *Tangaroa* trawl surveys carried out in OEO 3A were identified at the 1996 stock assessment plenary meeting. Doonan *et al.* (1997a) reported on analysis of smooth oreo trawl survey catchability for OEO 3A and concluded that the *Tangaroa* surveys in OEO 3A probably did not sample recruited smooth oreo very well. The surveys produced q values that were inconsistent with the estimated q values from other non-*Tangaroa* surveys in OEO 3A (and with those from OEO 4). They also concluded that the abundance estimates of smooth oreo for OEO 3A from the *Tangaroa* surveys should be removed from the stock reduction analysis because the q value estimates from the series were too low. The OEO 3A trawl survey abundance estimates have therefore not been used in the following biomass analysis.

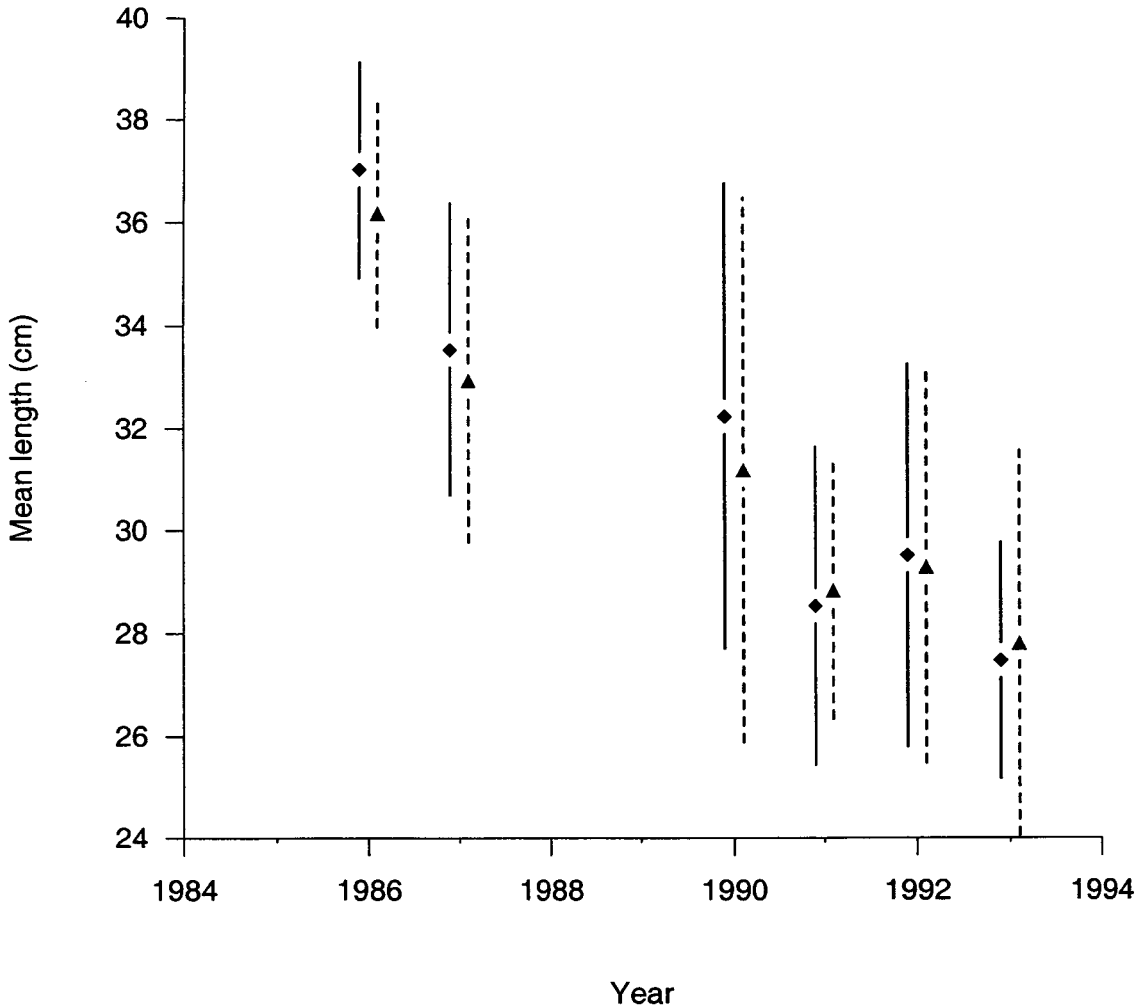

Figure 6: Research length frequency data scaled to biomass. Mean length (females ♦ and males ▲). Vertical lines are ± 2 s.e., solid (females), dashes (males) (from Doonan *et al.* 1995a).

4.4 Biomass estimates

Stock reduction analysis

Biomass estimates were made using deterministic stock reduction analyses (*after* Francis 1990). The following important assumptions were made in these analyses.

(a) The smooth oreo acoustic abundance estimate was an unbiased absolute value.

(b) The CPUE analysis indexed the abundance of smooth oreo in the whole of OEO 3A. Most of the smooth oreo commercial catch taken from 1978–79 to 1997–98 came from the CPUE study area and research trawl surveys indicated that there was little habitat for, and biomass of, smooth oreo outside that area.

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

(d) Varying the maximum fishing mortality (F_{max}) from 0.5 to 3.5 altered B_0 for smooth oreo in OEO 3A by only about 6% in the 1996 assessment, so only one assumed value (0.9) was used in all the analyses below.

(e) Recruitment was deterministic and followed a Beverton & Holt relationship with steepness of 0.75.
(f) Catch overruns were 0% during the period of reported catch.

Other minor assumptions were as follows.
(a) The population of smooth oreo in OEO 3A (in the main fishing ground at least) was a discrete stock or production unit.
(b) The catch histories were accurate.

Input data

Input data included the recruited absolute acoustic abundance estimates and *c.v.*s (*see* Table 9), the Soviet and New Zealand time series of combined abundance indices from standardised CPUE analyses and *c.v.*s (*see* Table 4), the life history parameters from Doonan *et al.* 1997b (Table 10), and the catch history (Table 11).

Table 10: Life history parameters for smooth oreo. –, not estimated

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

Catch history (Table 11)

This was derived from Tables 1–3 as follows.

1 Soviet catch of unspecified oreo from FAO area 81.5 from 1972 to 1977 (Table 1) was assumed to be all from OEO 3A, to be 50:50 smooth to black oreo, and to be for fishing rather than calendar years.
2 Catches from 1978–79 to 1982–83 (1 April to 31 March) were assumed to be for fishing years (1 October to 30 September).
3 The 1978–79 catch of unspecified oreo (1366 t, Table 2) was assumed to be the same proportion of smooth to black oreo catch reported in 1979–80 (5075/(5075+5588) = 0.476), Table 3. The estimate of the 1978–79 smooth oreo catch was 1366 x 0.476 = 650.
4 The 6 month catch reported as 1983–83 (713 t, Table 3) was split and half each (356.5) added to the preceding and subsequent years (1982–83 and 1983–84). Only 3 t of unspecified oreo was reported in 1983–83 (Table 3) so no adjustment to the reported smooth oreo catch was required.
5 From 1979–80 to 1997–98 the catch was calculated by multiplying the value reported in Table 2 by the proportion of smooth to black oreo in Table 3.
6 The last two years of the catch history are assumed projected catch.

The initial data used in the analysis and presented to the Deepwater Working Group (*see* Table 11, "OEO 3A") had minor errors and corrected ("amended") values are also given. The total catch for the amended series was about the same as the total used in the analysis, so using the amended catch history in the stock reduction analysis resulted in trivial changes to biomass and yield results.

Table 11: Reconstructed catch history (t) of smooth oreo from OEO 3A used in the 1999 stock reduction analysis ("OEO 3A"). Amended data are also shown

Year	OEO 3A	Amended
1972–73	†3 440	†3 440
1973–74	†3 800	†3 800
1974–75	†5 100	†5 100
1975–76	†1 300	†1 260
1976–77	†4 000	†3 880
1977–78	†5 750	†5 750
1978–79	650	650
1979–80	5 215	5 215
1980–81	2 196	2 196
1981–82	1 288	1 288
1982–83	2 495	2 495
1983–84	3 600	3 979
1984–85	4 720	4 351
1985–86	2 980	3 142
1986–87	3 160	3 190
1987–88	5 970	5 905
1988–89	6 970	6 963
1989–90	6 480	6 459
1990–91	5 140	5 053
1991–92	6 640	6 622
1992–93	4 470	4 334
1993–94	4 970	4 942
1994–95	4 080	4 199
1995–96	3 990	4 022
1996–97	3 230	3 239
1997–98	4 700	4 769
1998–99	‡3 300	‡3 300
1990–00	‡3 300	‡3 300

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

Results of several different stock reduction model runs (referred to as "cases") with different abundance inputs are presented below. The "base" case used all the abundance sources: the Soviet and New Zealand CPUE plus the acoustic abundance estimate (Figure 7). The Soviet CPUE abundance indices have a poor fit to the trajectory, have wide 95% confidence intervals (CI), and show a very steep declining trend with time. The New Zealand CPUE abundance indices mostly fall around the trajectory line and the absolute acoustic abundance (adjusted to a mid-year value) falls close to the line.

Biomass estimates for each case, including the maximum likelihood value and the 95% confidence intervals (in parentheses), are given in Table 12. The 95% confidence interval estimates of B_0 for the base case from this analysis were 76 500–92 500 t, based on bootstrap simulation that used the *c.v.* from the CPUE indices, the *c.v.* from the acoustic abundance estimates, and assumed deterministic recruitment.

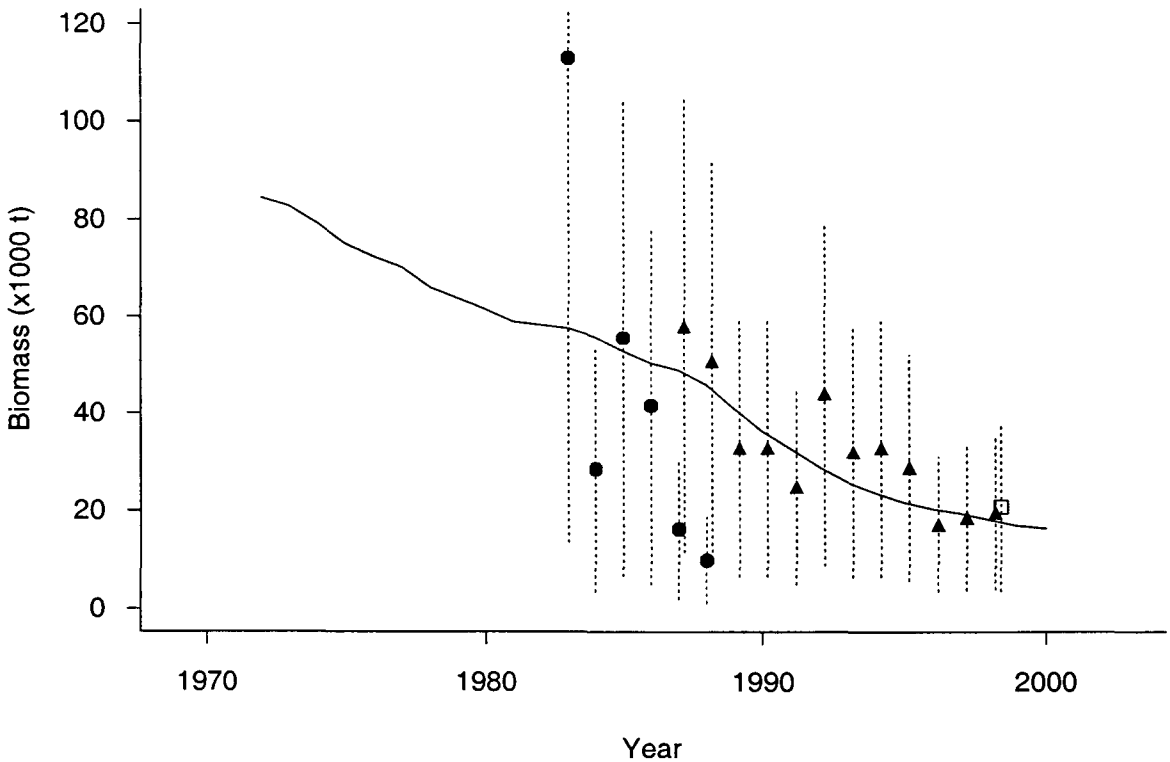

Figure 7: Biomass trajectory from stock reduction analysis for the base case (acoustic absolute abundance, plus New Zealand and Soviet abundance indices from standardised CPUE analyses). ● Soviet CPUE, ▲ New Zealand CPUE, □ acoustic absolute abundance estimates. Dashed lines are the 95% CI. The CI for the first Soviet estimate exceeds the upper range of the figure.

Table 12: Recruited biomass estimates (t) from the stock reduction model. The 95% confidence intervals are in parentheses. Base case marked in bold

	B_0		Mid-year $B_{1998-99}$			
			(t)		(%B_0)	
NZ CPUE only	86 500	(76 000–130 500)	20 000	(9 100–65 000)	23	(12–50)
Soviet CPUE only	72 500	(72 500–1 000 000)	5 200	(5 200–940 000)	7	(7–94)
NZ & Soviet CPUE only	84 500	(75 000–121 500)	18 000	(8 000–56 000)	21	(11–46)
Absolute only	84 500	(72 500–93 500)	18 000	(5 200–27 000)	21	(7–29)
Absolute & NZ CPUE	85 000	(77 000–94 000)	19 000	(10 000–28 000)	22	(13–30)
Absolute & Soviet CPUE	84 000	(72 500–93 000)	18 000	(5 200–27 000)	21	(7–29)
Absolute & NZ & Sov CPUE	**84 500**	**(76 500–92 500)**	**18 000**	**(9 700–26 000)**	**21**	**(13–29)**

4.4.3 Sensitivity of biomass estimates

The "Soviet CPUE only" case gave estimates that were markedly different to those from all the other cases (*see* Table 12). Virgin biomass estimates were sensitive to changes in the M values because increasing M by 2 standard errors resulted in an 18% reduction in B_0, but reducing M by 2 standard errors resulted in a 15% increase (Table 13). Catch history was also important and increased B_0 by 9% when it was 10% higher and reduced B_0 by 8% when it was 10% lower. The ratio of $B_{1998–99}$ to B_0 was not sensitive to M or catch history.

Table 13: Sensitivity of virgin (B_0) and mid-year ($B_{1998–99}$) biomass estimates (t) to changes in the CPUE index, natural mortality (M), and catch history for the base case. s.e. is standard error. Only relatively large sensitivity effects are presented

Change in parameters	B_0 (t)	$B_{1998–99}$ (t)	$B_{1998–99}$ (% B_0)
Base case	84 500	18 000	21
M + 2 s.e. (0.099)	69 000	17 000	25
M - 2 s.e. (0.042)	97 000	19 000	20
Catch + 10%	92 000	19 000	21
Catch - 10%	78 000	18 000	23

4.5 Yield estimates

Estimation of Maximum Constant Yield (MCY)

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 10 was 1.6% B_0. Under continued fishing at this level the mean biomass was 44% B_0 (B_{MCY}).

Yield estimates (Table 14) were calculated from the results of the stock reduction analyses reported above, using the "Depressed stocks" methods of Francis (1992). Where stocks are depressed (below 20% B_0), the MCY for 1999–00 was scaled down.

The level of risk to the stocks by harvesting the populations at the estimated MCY values cannot be determined.

Estimation of Current Annual Yield (CAY)

CAY was estimated using the methods given by Francis (1992). 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 10 is 0.0497. The mean catch when fishing at F = 0.0497 is 1.93% B_0, and the mean biomass (B_{MAY}) is 25% B_0. Yield estimates are in Table 14.

Table 14: Yield estimates (t). The 95% confidence limits are in parentheses. Base case marked in bold

	$MCY_{1999-00}$		$MCY_{long-term}$		$CAY_{1999-00}$	
NZ CPUE only	1 400	(730–2 100)	1 400	(1 200–2 100)	980	(440–3 200)
Soviet CPUE only	420	(420–16 000)	1 200	(1 200–16 000)	260	(260–45 000)
NZ & Soviet CPUE only	1 400	(640–1 900)	1 400	(1 200–1 900)	880	(390–2 700)
Absolute only	1 400	(420–1 500)	1 400	(1 200–1 500)	880	(260–1 300)
Absolute & NZ CPUE	1 400	(810–1 500)	1 400	(1 200–1 500)	900	(490–1 400)
Absolute & Soviet CPUE	1 300	(420–1 500)	1 300	(1 200–1 500)	850	(260–1 300)
Absolute & NZ & Sov CPUE	**1 400**	**(770–1 500)**	**1 400**	**(1 200–1 500)**	**880**	**(470–1 300)**

Sensitivity of MCY to M and steepness

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 15). For the base case, this resulted in a range of long term MCY estimates from 950 to 1600 t (Table 16).

Table 15: Sensitivity of long term MCY (% virgin biomass) to M and "steepness". –, 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 16: Sensitivity of long term MCY (t) to M and "steepness" for the base case. –, not estimated

	Steepness		
M	0.50	0.75	0.95
0.042	–	1 100	–
0.063	950	1 400	1 600
0.099	–	1 600	–

5. MANAGEMENT IMPLICATIONS

This stock assessment of OEO 3A smooth oreo is based on deterministic stock reduction analyses using the first absolute acoustic abundance estimate and relative abundance indices from an updated standardised CPUE analysis.

The following conclusions can be drawn from this assessment.

Base case

1. The biomass at the start of 1998–99 is likely to be close to 20% of B_0 and also less than B_{MCY} (44% B_0).

2. 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 76 500 and 92 500 t are 1200–1500 t, 24–30% of the mean annual reported (partly

reconstructed) smooth oreo catch in OEO 3A from the last 10 years (about 5000 t, 1988–89 to 1997–98, from Table 11). 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}.

The main sources of uncertainty for this assessment are as follows.

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.
2. 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.

Biomass estimates are uncertain because of a number of factors, including sensitivity to the target strength of black oreo, the use of deterministic recruitment, and uncertainty in the estimates of M.

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