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# Assessment of Chatham Rise smooth oreo (OEO 3A and OEO 4) for 1996

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## 1. EXECUTIVE SUMMARY

Biomass of smooth oreo was estimated from stock reduction analyses for OEO 3A using abundance indices from catch per unit effort (CPUE) and research trawl survey data, 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 1000 (maximum likelihood) to 1900 t (upper 95% confidence interval). Estimated long-term sustainable yield (MCY) for smooth oreo in OEO 4, based on a minimum biomass, was 1000 t. The recent catch levels of smooth oreo from OEO 3A and OEO 4 are higher than these yield estimates.

## 2. INTRODUCTION

### 2.1 Overview

This document presents an updated (from 1995, *see* Doonan *et al.* (1995a)) standardised CPUE analysis, a stock reduction analysis, and stock assessment for smooth oreo in OEO 3A. A new assessment of smooth oreo in OEO 4 is also presented, based on a stock reduction analysis using the south Chatham Rise trawl survey data. New trawl survey indices are given.

### 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 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 hill fishing: 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.

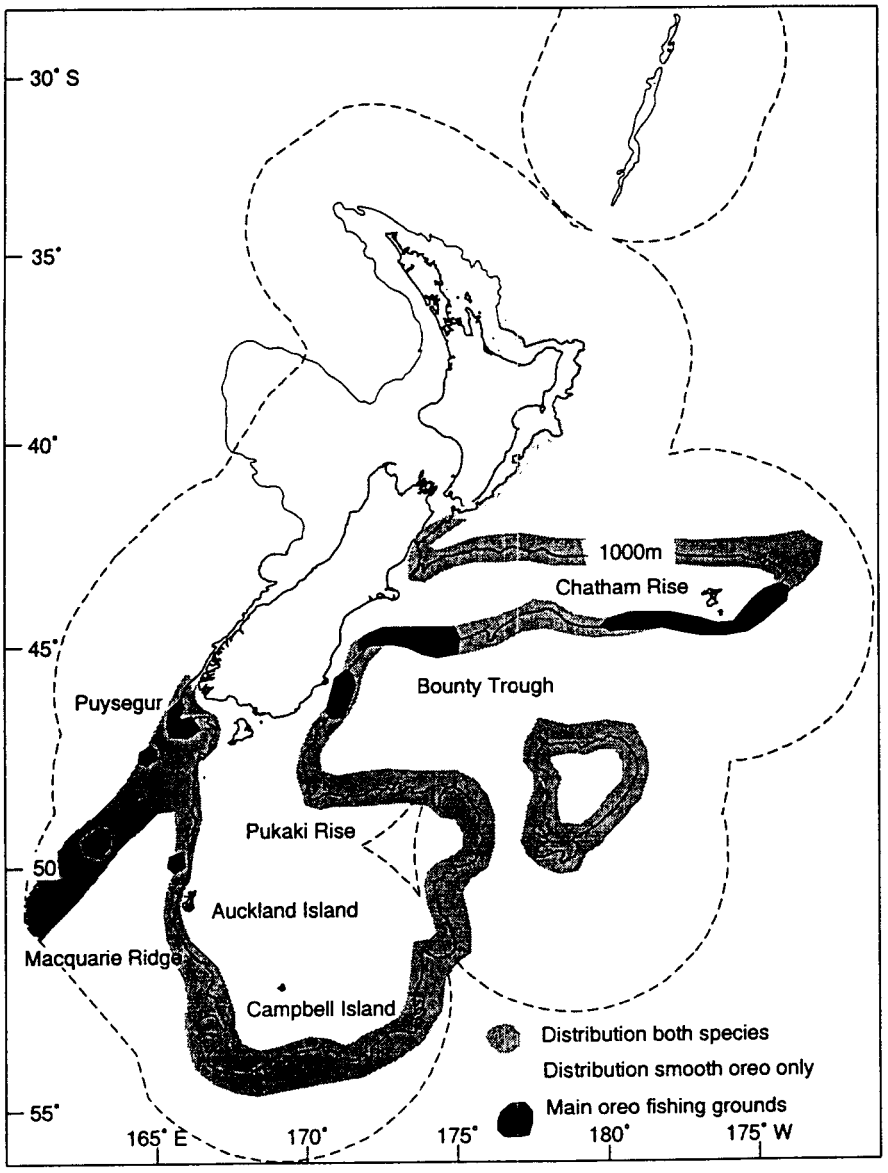


**Figure 1: The main fishing grounds and distribution of black oreo and smooth oreo.**

## 2.3 Literature review

The literature was summarised by McMillan *et al.* (1988), McMillan & Hart (1991), and Doonan *et al.* (1995a). The most recent stock assessment was given in Annala and Sullivan (1996). Age estimates for Chatham Rise oreos were given by Doonan *et al.* (1995b). Fincham *et al.* (1991) provided a summary of oreo catches from 1972 to 1988, and McMillan & Hart (1994a, 1994b, 1994c, 1995) reported on annual south Chatham Rise biomass trawl surveys from 1990 to 1993.

# 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.

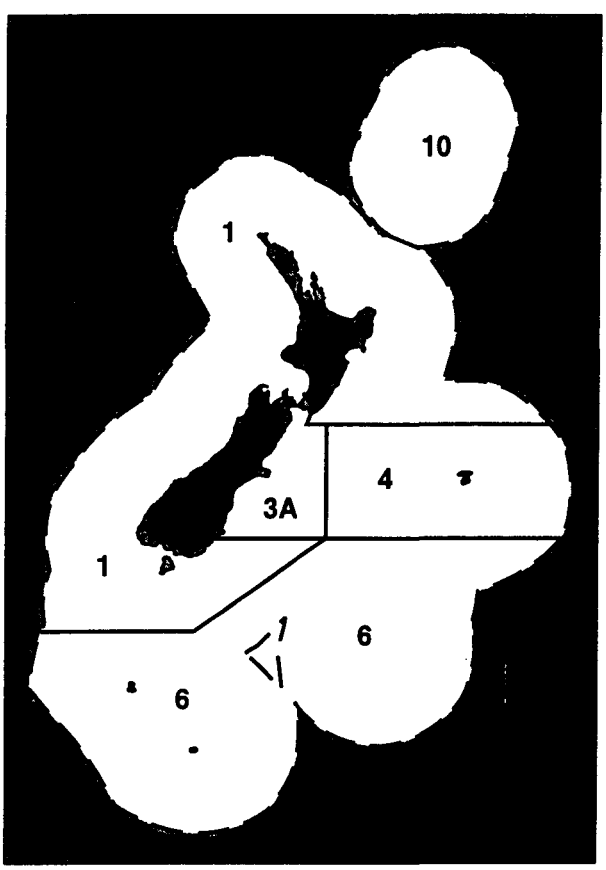


**Figure 2: Oreo management areas.**

## 3.2 TACs and catches

Separate catch statistics for each oreo species were not requested in the version of the catch statistics logbook used when the New Zealand EEZ was enacted 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) from the New Zealand area (Table 1). Reported landings of oreos (combined species) and TACs from 1978–79 until 1994–95 are given in Table 2 and reported estimated catches by species in Table 3.

## 3.3 Recreational, traditional, and Maori fisheries

There is no known non-commercial catch of oreos.

**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 1994–95 and TACs (t) from 1982–83 to 1994–95**

| | 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† | 1 676 | 6 044 | 6 600 | 10 106 | 7 879 | 7 000 | 2 528 | 3 000 | 18 683 | 26 160 |

Source: FSU from 1978–79 to 1987–88; QMS/ITD from 1988–89 to 1994–95.

* 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 1994–95**

| | 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† | 813 | 3 624 | 5 569 | 1 815 | 309 | 2 176 | 602 | 225 | 554 | 800 | 1708 | 488 | 18 683 |

Source: FSU from 1978–79 to 1987–88 and ITD from 1988–89 to 1994–95.

* 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 (*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 new genetic data to define stock structure on the Chatham Rise, see Doonan *et al.* (1995a).

## 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 were not considered to be comparable 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 dropoff 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 biomass estimates are not reported here because there are only two sets of estimates and they have high individual *c.v.*s.

**Table 4: Random stratified trawl surveys (standard) 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 |

† 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 1978–79 to 1994–95 (*see* figure 4 in Doonan *et al.* 1995a). The total estimated catch of smooth oreo from this area was 53 368 t and the smooth oreo catch from the rest of area OEO 3A was 10 522 t between 1978–79 and 1994–95. A catch of about 3800 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 when comparing catch from the two areas, i.e., smooth oreo catch totals were 50 771 t from the CPUE study area, and 7022 t from the rest of OEO 3A between 1978–79 and 1994–95 (*see* Doonan *et al.* (1995a) for further details).

### 4.3.2 Method of CPUE analysis

The CPUE analysis method was the same as that described by Doonan *et al.* (1995a), i.e., the same selected variables were used in the New Zealand and Soviet regressions, and the same method was used for the CPUE regressions. Two cases were presented by Doonan *et al.* (1995a): the first or ("base") case used all the CPUE data and the second ("two nation") case analysed the Soviet and New Zealand CPUE data separately. The Orange Roughy and Oreos Stock Assessment Working Group preferred the two nation case because the Soviet and New Zealand data sets were essentially separate data sets with only a small overlap in time and with fleets that probably had different fishing practices. This assessment presents only the two nation case.

### 4.3.3 Results

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 ($R^2$ = 29%), and also for the zero catch regression ($R^2$ = 14%). Data from 1980–81 to 1981–82 were dropped because there were less than 50 tows per year. The 1979–80 data were dropped because that 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 for the *c.v.* of the indices and so the mean *c.v.* (61%) was taken as the *c.v.* for the abundance index.

For the New Zealand abundance series, the data used were from 1986–87 to 1994–95. The variables year, vessel, area, depth, 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 less than 50 tows per year. The reference year chosen was 1990–91. There was no relationship amongst the *c.v.*s of the index series and so the mean, 55%, was used.

The time series of abundance indices for the Soviet and New Zealand data are given in Table 5: both series show a decline which is more marked in the Soviet data.

**Table 5: Smooth oreo, OEO 3A. Soviet and New Zealand time series of abundance indices from CPUE. –, no data**

| Year | Soviet | New Zealand |
|---|---|---|
| 1980–81 | – | – |
| 1982–83 | 6.92 | – |
| 1983–84 | 1.75 | – |
| 1984–85 | 3.41 | – |
| 1985–86 | 2.55 | – |
| 1986–87 | 1.00 | 2.28 |
| 1987–88 | 0.61 | 1.99 |
| 1988–89 | – | 1.22 |
| 1989–90 | – | 1.23 |
| 1990–91 | – | 1.00 |
| 1991–92 | – | 1.58 |
| 1992–93 | – | 1.04 |
| 1993–94 | – | 1.00 |
| 1994–95 | – | 0.83 |

## 4.4 Other studies — mean length (total length) data for smooth oreo

### OEO 3A

Research and observer mean length data from 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, and only a small amount of new research data from survey TAN9511 (*see* the 1995 biomass estimate in Table 10 below).

### OEO 4

The smooth oreo mean length data collected from the standard research trawl survey (i.e., flat tows only) and by observers on New Zealand commercial vessels fishing on the flat and on hills were analysed. The research data were scaled to represent the biomass and the commercial data were scaled by catch. They included all lengths, i.e., pre-recruit and recruited fish. These data were not presented by Doonan *et al.* (1995a).

#### Research data

The female and male mean length research data (Figure 3) 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.

Observer data

The observer 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 6. Data were divided into four areas based on closeness (discrete fishing areas) and consistent sampling. The four areas had different patterns of fishing and this may have influenced trends.

**Table 6: 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 1995. 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) | 8 (835) | 8 (952) | 3 (643) |

Mean lengths are shown in Figure 4. There was no trend in area 1. In area 2 there was a decline for both sexes in 1994 which remained at that level in 1995 with the male mean length again close to the female value after the decline. Area 3 showed no trend and area 4 showed a decline of about 1 cm from values that were initially higher than in the other areas.

## 4.5 Biomass estimates

Biomass estimates for smooth oreo in OEO 3A and OEO 4 were made using deterministic stock reduction analyses (Francis 1990). The CPUE study area in OEO 3A and the trawl survey area in OEO 4 were assumed to contain the two main biological stocks of smooth oreo on the south Chatham Rise. In OEO 3A most of the smooth oreo commercial catch taken from 1978–79 to 1994–95 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 life history parameters (Table 7), catch history (Tables 8 & 9), and the trawl survey biomass indices and their *c.v.*s (Table 10). Life history parameters are unchanged from those in Doonan *et al.* (1995b), except for the addition of recruitment variability. Note that recruitment variability is not required to estimate biomass but is needed to estimate yields. Catch overruns were assumed to be 0%. Varying the maximum fishing mortality ($F_{max}$) from 0.5 to 3.5 altered $B_0$ for smooth oreo in OEO 3A only

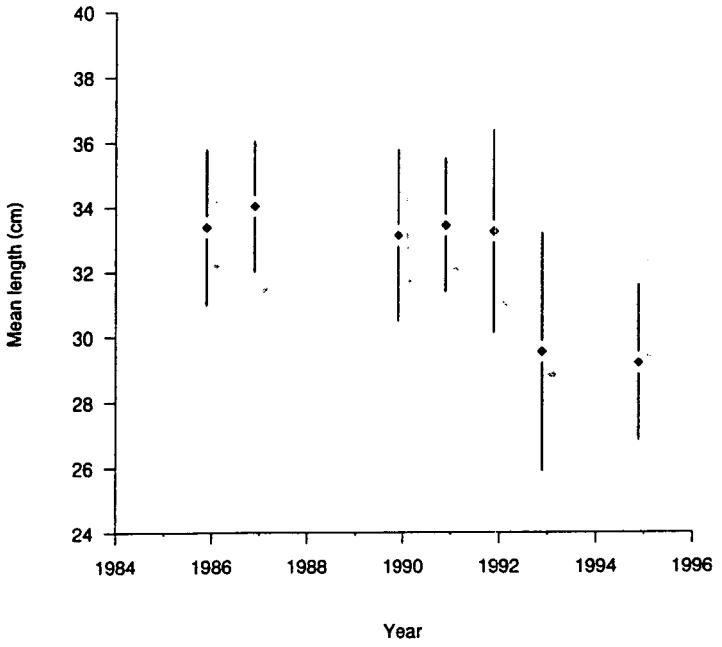


Figure 3: Smooth oreo, OEO 4. Research length frequency data scaled to biomass. Mean length (◆). Vertical lines are ± 2 s.e., dark (females), pale (males).

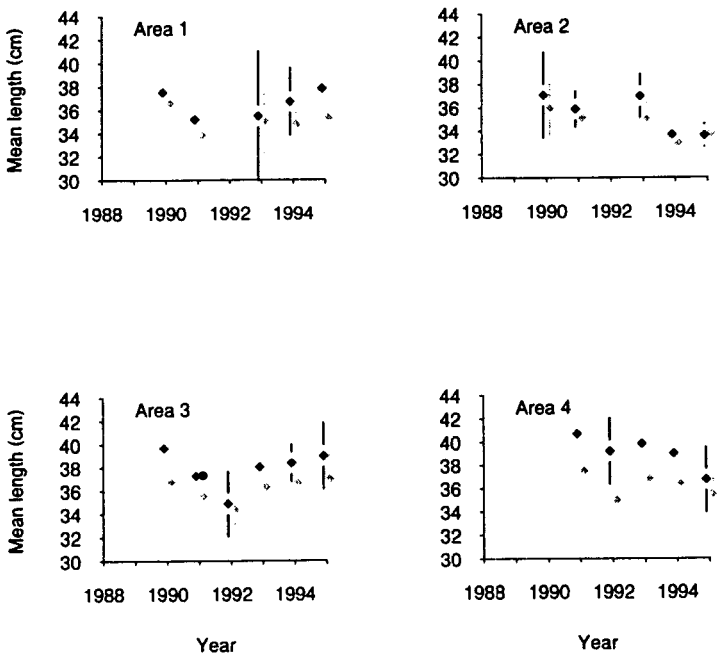


Figure 4: Smooth oreo, OEO 4. Observer length frequency data scaled to catch. Mean length (◆). Vertical lines are ± 2 s.e., dark (females), pale (males). Areas are: 1, 178° 20′ to 177° 15′ W; 2, 177° 08′ to 176° 16′ W; 3, 176° 04′ to 175° 00′ W; 4, 175° 00′ to 174° 00′ W.

by about 6%, so an assumed value of 0.9 was used in all the analyses below. The trawl surveys occurred in the first few months of the fishing year and so were assumed to index beginning-of-year biomass.

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 to provide advice for the appropriate management areas. The calculations used for each area are given below.

### 4.5.1 Smooth oreo, OEO 3A

Biomass estimates were made for the CPUE study area (as opposed to the whole of area OEO 3A) based on the CPUE time series of abundance indices (*see* Table 5), and the mean *c.v.* for that series. Fishing mortality was assumed to occur throughout the fishing year, so the CPUE index was for the middle of the year. The analysis used the Soviet and New Zealand CPUE time series of abundance indices. The catch history for the CPUE study area only (*see* Table 8) has been updated from that presented by Doonan *et al.* (1995a). The biomass results of the four standard *Tangaroa* surveys from 1991–93 and 1995 provide the only comparable research biomass estimates. The *c.v.* for the 1995 survey was set at 0.73, the median for the first three surveys (1991–93) because the actual 1995 estimate (0.3) was considered to be an underestimate. The earlier trawl surveys all had one or more large catches (and therefore large *c.v.*s), but the 1995 survey did not include any large catches.

**Table 7: Life history parameters for smooth oreo. –, not estimated**

| 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 | $L_\infty$ (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 variability | | 0.65 | 0.65 |
| Recruitment steepness | | 0.75 | 0.75 |
| Length at recruitment | (cm, TL) | 34 | – |
| Length at maturity | (cm, TL) | 40 | – |

**Table 8: 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 | 4 244 | 3 737 |
| 1994-95 | 3 656 | 2 148 |
| 1995–96‡ | 5 000 | 5 000 |

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

**Table 9: Smooth oreo catch (t) from flat and hills in OEO 4. Only the data from the trawl survey area were used in the stock reduction analysis. All data are for the 1 October to 30 September fishing year**

| Year | Trawl survey area | Rest of OEO 4 |
|---|---|---|
| 1977–78 | 4 020 | 1 |
| 1978–79 | 100 | 10 |
| 1979–80 | 1 829 | 2 |
| 1980–81 | 1 334 | 78 |
| 1981–82 | 1 928 | 43 |
| 1982–83 | 1 997 | 75 |
| 1983–84 | 4 764 | 118 |
| 1984–85 | 4 689 | 52 |
| 1985–86 | 4 711 | 184 |
| 1986–87 | 5 562 | 111 |
| 1987–88 | 7 569 | 196 |
| 1988–89 | 6 987 | 232 |
| 1990–90 | 6 648 | 142 |
| 1990–91 | 4 929 | 1090 |
| 1991–92 | 5 165 | 343 |
| 1992–93 | 5 552 | 380 |
| 1993–94 | 5 566 | 722 |
| 1994–95 | 6 568 | 546 |

**Table 10: The 95% confidence interval (lower and upper bounds) for smooth oreo research survey recruited biomass estimates (t) from the south Chatham Rise. N, number of stations**

OEO 3A

| | 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 |
| 1995 | 316 | 124 | 507 | 30 | 23 |

OEO 4

| | Mean biomass | 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 |

The fit of the data to the stock reduction model is shown in Figure 5. Biomass estimates are given in Table 11. The 95% confidence interval estimates of $B_0$ for the CPUE study area from this analysis are 68 000–124 000 t, but the maximum likelihood estimate of $B_0$ (68 000 t, on the lower 95% limit) lies on the constraint $B_{min}$, i.e., the minimum biomass that is consistent with both the catch history and $F_{max}$. Biomass estimates are also uncertain because the variability of the CPUE data resulted in a 61% *c.v.* for the Soviet index series and a 55% *c.v.* for the New Zealand index. This variability translates into highly uncertain estimates for biomass, e.g., mid-year $B_{1994–95}$ could be between 13% and 100% of $B_0$, but there is an estimated probability of 79% that estimates of $B_{1994–95}$ are less than 20% $B_0$ (Figure 6).

Under an MCY policy, $B_{MSY}$ is 44% of $B_0$. The estimated mid-year $B_{1994–95}$ is 29% of $B_{MSY}$ and there is an estimated probability of 94% that the mid-year $B_{1994–95}$ is less than $B_{MSY}$.

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 (7022 t) to the estimated catch from the CPUE study area (50 771 t) from 1978–79 to 1994–95, i.e., 1.14. This scaling assumes that the exploitation rate in the CPUE study area was the same as that in the rest of area OEO 3A. Because the catch from outside the CPUE study area is low relative to that from the CPUE study area, deviation from this assumption will not greatly influence biomass and yield results from this assessment.

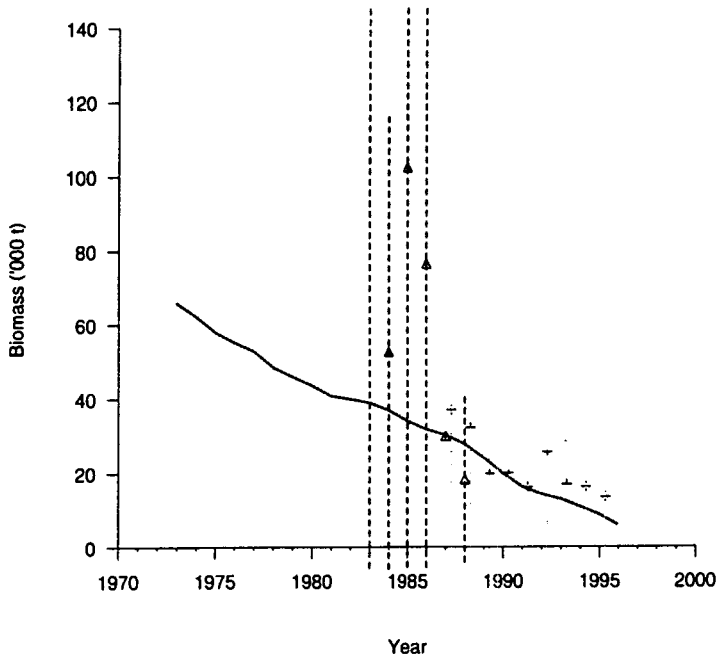


Figure 5: Smooth oreo, OEO 3A. Estimated mid-year biomass (t) from the stock reduction analysis (dotted line) for the CPUE study area. The vertical lines are two standard errors on the CPUE biomass indices for Soviet (triangles, dark dashed line) and New Zealand (pluses, faint dashed line) data.

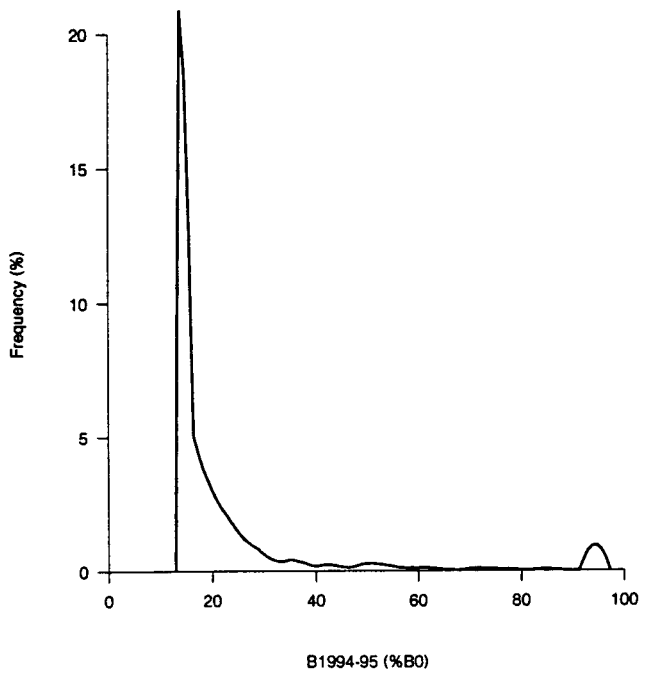


Figure 6: Smooth oreo, OEO 3A. The bootstrap distribution of estimates of mid-year $B_{1994-95}$ for the CPUE study area, expressed as a percent of $B_0$ ("B1994–95(%B0)" on the × axis).

**Table 11: Stock reduction biomass estimates (t) for smooth oreo for the OEO 3A CPUE study area only and adjusted to total area, and for the OEO 4 trawl survey area only and adjusted for the total area. The ranges for OEO 3A are the 95% confidence limits (lower limit is the maximum likelihood value) but only the minimum estimates are given for OEO 4**

| | | $B_0$ | mid-year $B_{1994-95}$ | $\%B_0$ |
|---|---|---|---|---|
| OEO 3A | CPUE study area | 68 000–124 000 | 8 700–66 000 | 13–53 |
| | Total area | 77 000–141 000 | 9 900–75 000 | 13–53 |
| OEO 4 | Trawl survey area | 72 000 | 9 600 | 13 |
| | Total area | 77 000 | 10 300 | 13 |

### 4.5.2 Smooth oreo OEO 4

Estimates of biomass were made using the results from the four standard *Tangaroa* south Chatham Rise trawl surveys as a relative abundance index. The trawl survey abundance estimates show a declining trend (*see* Table 10). However the estimated catchability (q) from the stock reduction analysis was high (4.0) and not consistent with the values (0.03–0.3) from the stock reduction analysis of *Tangaroa* data from the surveys of OEO 3A carried out in 1991–95, or with values estimated for orange roughy from deepwater surveys on the north Chatham Rise, Puysegur Bank, and Challenger Plateau (0.6–1.7), or with values for the 1986, 1987, and 1990 oreo surveys of OEO 3A (0.4–2, implied q values calculated from the stock reduction biomass trajectory).

This assessment is therefore uncertain and preliminary, and only minimum biomass estimates are presented.

Smooth oreo catch data used in the analysis are from the trawl survey area (*see* figure 1 in McMillan *et al.* 1996) only (*see* Table 9), but catches from the rest of OEO 4 are also shown in the table and include catches from the hills as well as from the flat. The estimated catches from catch-effort returns were scaled to the QMR reported catch of oreo from the trawl survey area. Also, 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.

The fit of the data to the stock reduction model is shown in Figure 7. Biomass estimates based only on minimum estimates of $B_0$ are shown in Table 11. The maximum likelihood estimate of $B_0$ (72 000 t) lies on the constraint $B_{min}$, i.e., the minimum biomass that is consistent with both the catch history and $F_{max}$.

Under an MCY policy, $B_{MSY}$ is 44% of $B_0$. For the minimum estimate of $B_0$ the mid-year $B_{1994-95}$ is 30% of $B_{MSY}$.

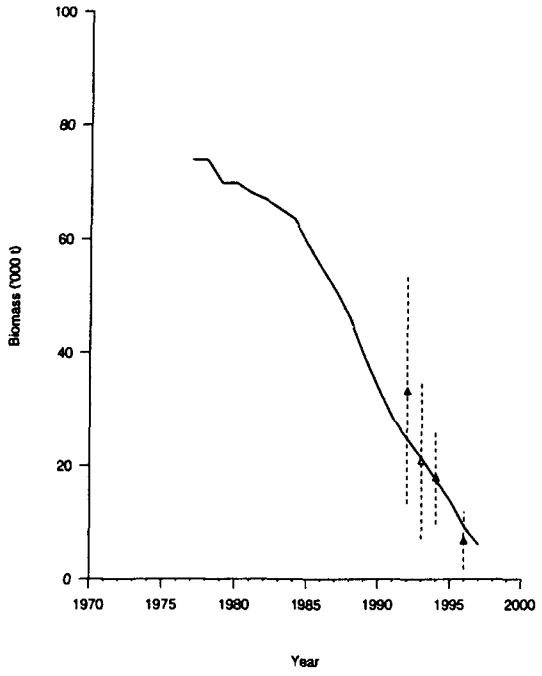


**Figure 7: Smooth oreo OEO 4. Estimated beginning-of-year biomass (t) from the trawl survey indices by year from the stock reduction analysis (solid line) for the trawl survey area. Vertical lines are two standard errors on the estimates.**

Biomass estimates (and yield estimates) 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 (3762 t) to the catch from the trawl survey area (54 546 t) from the fishing years 1986–87 to 1994–95 (Table 9), i.e., a ratio of 1.07. The 1986–87 season was chosen as the start of the adjusted catch data series because an Individual Transferable Quota management system was introduced in that year. This scaling assumes that the exploitation rate in the trawl survey area was the same as that in the rest of OEO 4. Because the catch from outside the trawl survey area (mainly north Chatham Rise catch) is low relative to that from the trawl survey area, deviation from this assumption will not greatly influence biomass and yield estimates from this assessment.

### 4.5.3 Sensitivity of biomass estimates

Catches are likely to be underestimated because of codend bursts, discarding, etc, and therefore $B_0$ estimates are likely to be low. There were insufficient data to quantify catch not reported for this assessment.

#### Smooth oreo, CPUE study area in OEO 3A

Doubling M resulted in a 17% reduction in $B_0$, but halving M resulted in a 35% increase (Table 12). M values are important for this analysis and a better estimate is needed. Catch history is also important, e.g., $B_0$ was reduced by 20% when catch history was about 27% lower (Table 12).

The ratio of $B_{1994-95}$ to $B_0$ is not sensitive to M or catch history.

**Table 12: Sensitivity of mid-year biomass estimates for smooth oreo to changes in natural mortality (M) and catch history for the CPUE study area. (A) no change to catch history, and (B) setting all catches to zero before the 1979–80 fishing year. $B_0$ is virgin biomass**

| M | Catch history | $B_0$ (t) | $B_{1994-95}$ (t) | $B_{1994-95}$ (% $B_0$) |
|---|---|---|---|---|
| 0.025 | A | 79 000 | 9 300 | 12 |
| 0.05 | A | 67 000 | 8 700 | 13 |
| 0.1 | A | 49 000 | 7 200 | 15 |
| 0.025 | B | 62 000 | 9 800 | 16 |
| 0.1 | B | 44 000 | 7 800 | 18 |

### Smooth oreo, trawl survey area in OEO 4

Doubling the value of M results in a 21% reduction in $B_0$, but halving the value results in an 11% increase (Table 13). Changing the catch history by 10% results in a change of 8–9% in $B_0$. Setting the catch history equal to catches from the flat only (exclude hill catch) results in a 38% reduction in $B_0$, but some trawl indices are more than two standard errors from the estimated trajectory of biomass. The ratio of $B_{1994-95}$ to $B_0$ is not sensitive to M or catch history.

**Table 13: Sensitivity of $B_0$ and mid-year $B_{1994-95}$ to changes in M and catch history for the trawl survey area in OEO 4**

| Change in parameters | $B_0$ (t) | $B_{1994-95}$ (t) | $B_{1994-95}$ (%$B_0$) |
|---|---|---|---|
| Base case | 72 000 | 9 618 | 13 |
| M = 0.1 | 57 000 | 7 800 | 14 |
| M = 0.025 | 80 500 | 11 000 | 13 |
| Catches +10% | 78 000 | 9 300 | 12 |
| Catches -10% | 65 500 | 9 400 | 14 |
| "Flat" catch only | 45 000 | 8 700 | 19 |

## 4.6 Yield estimates

### 4.6.1 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 7 is 1.33% $B_0$. Under continued fishing at this level the mean biomass is 44% $B_0$. Thus the long-term MCY = 1.33% $B_0$.

Yield estimates for smooth oreo from OEO 3A and OEO 4 (Table 14) were calculated from

the results of the stock reduction analyses reported above, using the "depressed stocks" methods from Francis (1992). Where stocks are depressed (below 20% $B_0$), the MCY for 1996–97 was scaled down. The long-term MCY (the MCY when the current biomass is over 20% $B_0$) and CAY were 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) for a population with the life history parameters as in Table 7 is 0.0438. The mean catch when fishing at F = 0.0438 is 1.58% $B_0$, and the mean biomass is 24% $B_0$.

Yield estimates (*see* Table 14) are presented for the maximum likelihood and upper 95% estimates from the CPUE study area and trawl survey area and are also adjusted to the total area for OEO 3A. Only minimum estimates from the trawl survey area, adjusted to the total area, are presented for OEO 4.

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

**Table 14: Yield estimates (t) for smooth oreo for the OEO 3A CPUE study area only and adjusted to the total area, and for the OEO 4 trawl survey area only and adjusted for the total area. The ranges for OEO 3A are the 95% confidence limits (lower limit is the maximum likelihood value) but only the minimum estimates are given for OEO 4**

| | | $MCY_{1996-97}$ | $MCY_{long\ term}$ | $CAY_{1996-97}$ |
|---|---|---|---|---|
| OEO 3A | CPUE study area | 570–1 600 | 900–1 600 | 240–2 700 |
| | Total area | 650–1 900 | 1 000–1 900 | 270–3 100 |
| OEO 4 | Trawl survey area | 640 | 960 | 260 |
| | Total area | 680 | 1 000 | 280 |

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

M was varied by a factor of 2 from 0.05, the value used in the yield estimates above, and steepness values were changed to 0.5 and 0.95 from the value 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 OEO 3A this resulted in a range of estimates from 590 to 1800 t (Table 16). For OEO 4, long term MCY varies by 660 t to 1400 (Table 17).

**Table 15: 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 |
| 0.025 | – | 0.75 | – |
| 0.05 | 0.87 | 1.33 | 1.61 |
| 0.10 | – | 2.23 | – |

**Table 16: Sensitivity of long term MCY (t) to M and "steepness" for OEO 3A. –, not estimated**

| | steepness | | |
|---|---|---|---|
| **M** | **0.50** | **0.75** | **0.95** |
| 0.025 | – | 590 | – |
| 0.05 | 590 | 900 | 1 100 |
| 0.10 | – | 1 800 | – |

**Table 17: Sensitivity of long term MCY (t) to M and "steepness" for OEO 4. –, not estimated**

| | steepness | | |
|---|---|---|---|
| **M** | **0.50** | **0.75** | **0.95** |
| 0.025 | – | 660 | – |
| 0.050 | 680 | 1 000 | 1 300 |
| 0.100 | – | 1 400 | – |

## 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 CPUE and research trawl survey abundance indices for OEO 3A and research trawl survey abundance indices for OEO 4. The following assumptions are made:

(a) the populations of smooth oreo in OEO 3A (in the main fishing ground at least) and OEO 4 are discrete stocks or production units;

(b) the CPUE analysis indexes the abundance of smooth oreo in the CPUE study area in OEO 3A and the trawl survey biomass estimates indexes the abundance of most of the smooth oreo in OEO 4;

(c) the exploitation rates for smooth oreo in OEO 3A are the same in the CPUE study area and in the rest of OEO 3A and the exploitation rates for smooth oreo in OEO 4 are the same in the trawl survey area and in the rest of OEO 4;

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

The following conclusions can be drawn from this assessment.

Smooth oreo, OEO 3A

1. According to this analysis a 95% confidence interval for estimates of $B_0$ is 77 000 and 141 000 t.

2. The biomass at the start of 1996–97 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 77 000 and 141 000 t are 1000–1900 t, substantially less (27–51%) 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

Smooth oreo, OEO 4

1. The estimate of $B_0$ is at $B_{min}$ (the minimum biomass consistent with both the catch history and $F_{max}$). The estimate of catchability in this assessment is unrealistic and therefore the $B_0$ estimate presented is only an estimate of the minimum biomass.

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 estimate from a stock at the minimum $B_0$ of 77 000 is 1000 t, substantially less than the mean catch of smooth oreo in OEO 4 (about 4200 t per year). If $B_0$ is at, or near $B_{min}$, then the stock is currently below $B_{MSY}$.

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

Smooth oreo, OEO 3A and OEO 4

1. The main uncertainties are for age estimates and for 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 otolith section age estimates. There are no data available to check the assumed value of recruitment steepness.

Smooth oreo, OEO 3A

1. The high variability of the Soviet (61%) and the New Zealand (55% *c.v.*) CPUE index series means that estimates for $B_0$ and mid-year $B_{1994–95}$ are uncertain, i.e., $B_{1994–95}$ could be between 13 and 100% of $B_0$ (*see* Figure 6), but there is an estimated 79% chance that mid-year $B_{1994–95}$ is less than 20% $B_0$.

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.

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 dropoffs) 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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