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Assessment of OEO 4 black oreo for 2000–01

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EXECUTIVE SUMMARY

Doonan, I.J.; McMillan, P.J.; Coburn, R.P.; Hart, A.C. (2001): Assessment of OEO 4 black oreo for 2000–01.

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Preliminary estimates of black oreo biomass in OEO 4 were made with deterministic stock reduction analysis using the first absolute abundance estimate from a research acoustic and trawl survey in 1998 (TAN9812), new relative abundance indices from standardised catch per unit effort analyses, and relative abundance estimates from *Tangaroa* trawl surveys (1991–93, 1995). Biomass estimates were made for the whole of OEO 4 and also separately for the west and east parts of OEO 4 divided at 178° 20′ W. This separation was based on analysis of commercial catch, research trawl, and acoustic results which suggested distinct oreo fisheries for the west and east parts of OEO 4.

This stock assessment is unreliable because the acoustic abundance estimate is uncertain. Most of the acoustic abundance was recorded from dispersed marks (background backscatter) where the acoustic method performed poorly, rather than from black oreo schools. The acoustic survey was aimed at smooth oreo and consequently the black oreo areas in OEO 4 received only minimal coverage. The poor coverage of black oreo areas by the acoustic survey was compensated for by multiplying the acoustic survey area abundance by a scaling factor of 4.3 (based on research surveys) to make the estimate equivalent to the trawl survey area and then by a further 1.06 to estimate a total abundance for OEO 4. In addition, only small acoustic abundance estimates were made from the seamounts, which suggests that either black oreo abundance on seamounts was low or the estimate was biased low.

Yields from this stock will be low because the productivity of black oreo, based on unvalidated age estimates, is low. The base case analysis (acoustic absolute abundance plus standardised CPUE relative abundance estimates) produced a 95% confidence interval for B_0 of 30 000–40 000 t and a 95% confidence interval for long-term MCY of 400–530 t. Black oreo mean catch per year from 1989–90 to 1998–99 from OEO 4 (about 1100 t) was higher than the range of long-term MCY. The summed biomasses and yields from the separate west and east base case analyses were similar to the OEO 4 base case values but both separate analyses gave estimates of mean B_0 which were at B_{min} and are therefore considered unreliable.

1. INTRODUCTION

1.1 Overview

This work addresses the following objectives in MFish project "Oreo stock assessment" (OEO1999/02).

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 objectives

1. To analyse length frequency, sex ratio, and reproductive condition data for black oreo and smooth oreo collected by the Scientific Observer Programme and other sources and from research projects OEO9801 and ORH9801 during the 1998–99 fishing year for input into stock assessment models.
2. To conduct a stock assessment for black oreo and smooth oreo in OEO 4, including estimating biomass and sustainable yields.

A new stock assessment for black oreo in OEO 4 is presented based on the first estimates of absolute abundance for black oreo from research acoustic survey data, abundance indices from a new standardised CPUE analysis, and past relative abundance estimates from trawl surveys. Assessments reported earlier, e.g., Annala et al (2000), used only catch history for estimating biomass and maximum constant yield. Estimates of biomass and yields were modelled using deterministic recruitment (knife-edge at 33 cm TL), and incorporated the 1997 biological parameters and a new catch history.

1.2 Description of the fishery

Black oreo are caught by trawling at depths of 600–1200 m in southern New Zealand waters (Figure 1). The OEO 4 south Chatham Rise fishery is the second largest black oreo fishery in the EEZ (see Table 2) and operates between 176° E and about 172° W mostly on undulating terrain (short plateaus, terraces and "drop-offs") at the west end, and mostly on seamounts in the east. Most black oreo is caught as a bycatch to orange roughy or smooth oreo fishing.

1.3 Literature review

The literature was summarised by McMillan et al. (1988) and McMillan & Hart (1991). Age estimates for Chatham Rise black oreo were given by Doonan et al. (1995b) and McMillan et al. (1997). The 2000 stock assessment was summarised by Annala et al. (2000). Fincham et al. (1991) summarised oreo commercial catches from 1972 to 1988, and McMillan & Hart (1994a, 1994b, 1994c, 1995) and Hart & McMillan (1998) reported on annual south Chatham Rise relative abundance research trawl surveys from 1990 to 1995.

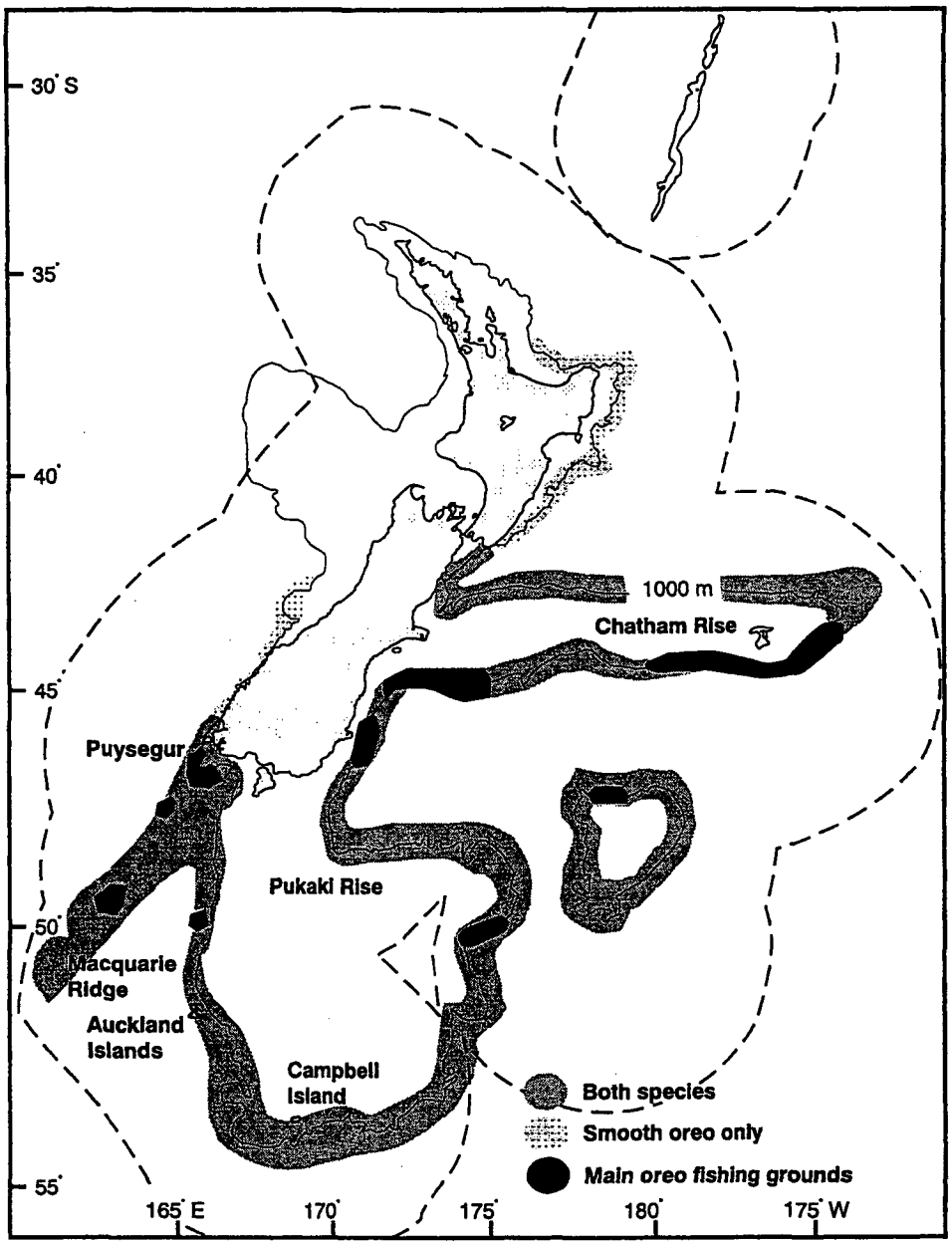

Figure 1: Approximate location of main fishing grounds and distribution of black oreo and smooth oreo. Dashed line is the EEZ boundary.

2. REVIEW OF THE FISHERY

2.1 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.

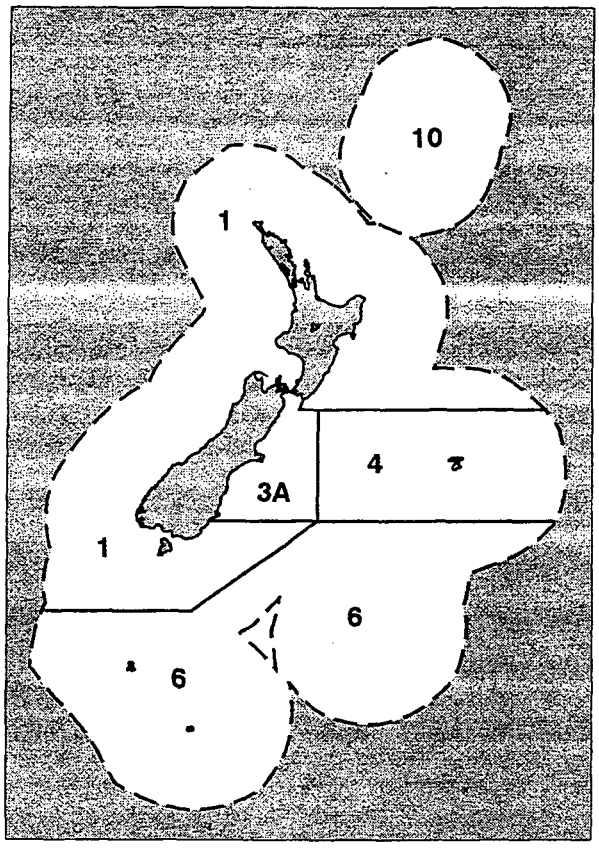

Figure 2: Oreo management areas.

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 Quota Management System 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.

Reported landings of oreos (combined species) and TACs from 1978–79 until 1998–99 are given in Table 1. The OEO 4 TAC has been about 7000 t from 1982–83 to 1999–2000. Reported estimated catches by species from tow by tow data recorded in catch and effort logbooks (Deepwater, TCEPR, and CELR) are given in Table 2. Soviet catches from the New Zealand area from 1972 to 1977 were assumed to be black oreo and smooth oreo combined and to be from area OEO 3A (Doonan et al. 1995a).

Table 1: Total reported landings (t) for all oreo species combined by Fishstock from 1978–79 to 1998–99 and TACs (t) from 1982–83 to 1998–99.

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	25 644
1997–98†	2 681	6 044	6 336	6 600	7 010	7 000	5 222	6 000	21 249	25 644
1998–99†	4 102	5 033	5 501	6 600	6 931	7 000	5 287	6 000	21 821	24 633

Source: FSU from 1978–79 to 1987–88; QMS/MFish from 1988–89 to 1998–99. *, 1 April to 31 March. #, 1 April to 30 September. Interim TACs applied. †, 1 October to 30 September.

Table 2: Reported estimated catch (t) by species (smooth oreo (SSO), black oreo (BOE), by Fishstock from 1978–79 to 1998–99 and the ratio (percentage) of the total estimated SSO plus BOE, to the total reported landings (from Table 1). –, less than 1.

	SSO				BOE					
Year	OEO 1	OEO 3A	OEO 4	OEO 6	OEO 1	OEO 3A	OEO 4	OEO 6	Total estimated	Estimated:landings (%)
1978–79*	0	0	0	0	9	0	0	0	9	–
1979–80*	16	5 075	114	0	118	5 588	566	18	11 495	98
1980–81*	1	1 522	849	2	66	8 758	5 224	215	16 637	64
1981–82*	21	1 283	3 352	2	0	11 419	5 641	4 378	26 096	98
1982–83*	28	2 138	2 796	60	6	6 438	1 088	705	13 259	97
1983–83#	9	713	1 861	0	1	3 693	1 340	354	7 971	100
1983–84†	1 246	3 594	4 871	1 315	1 751	5 524	1 214	2 254	21 769	99
1984–85†	828	4 311	4 729	472	544	3 897	1 651	1 572	18 004	99
1985–86†	4 257	3 135	4 921	72	1 060	2 184	961	54	16 644	99
1986–87†	326	3 186	5 670	0	163	4 026	1 160	0	14 531	96
1987–88†	1 050	5 897	7 771	197	114	3 140	903	0	19 072	100
1988–89†	261	5 864	6 427	–	86	2 719	1 087	0	16 444	86
1989–90†	1 141	5 355	5 320	–	872	2 344	439	–	15 471	83
1990–91†	1 437	4 422	5 262	81	2 314	4 177	793	222	18 708	87
1991–92†	1 008	6 096	4 797	2	2 384	3 176	1 702	15	19 180	88
1992–93†	1 716	3 461	3 814	529	3 768	3 957	1 326	69	18 640	78
1993–94†	2 000	4 767	4 805	808	2 615	4 016	1 553	35	20 599	88
1994–95†	835	3 589	5 272	1 811	385	2 052	545	230	14 719	81
1995–96†	2 517	3 591	5 236	2 562	1 296	3 361	364	1 166	20 093	84
1996–97†	2 203	3 063	5 390	2 492	2 578	3 549	530	1 950	21 755	88
1997–98†	1 510	4 790	5 868	2 531	1 027	1 623	811	1 982	20 142	95
1998–99†	2 904	2 363	5 638	3 344	782	2 716	840	1 211	19 798	91

Source: FSU from 1978–79 to 1987–88 and MFish from 1988–89 to 1998–99
*, 1 April to 31 March..#,1 April to 30 September. †,1 October to 30 September.

2.1.1 CPUE analysis

Data

The catch and effort data were restricted to that area within OEO 4 (the "study area") where the main black oreo fishery occurred from 1978–79 to 1998–99. Data from OEO 4 were divided into those from: target fishing for black oreo and bycatch black oreo (target orange roughy); pre- and post-global positioning system (GPS).

East and west analyses

Initial analysis of OEO 4 oreo catch data showed marked changes in fishing patterns over time. This involved a progression of high catches over time starting in the west and moving east and appeared to represent successive exploitation of new areas (Figure 3). Areas in the west previously exploited did not later return to sustained high catches. The target species and the type of fishing changed over time with black oreo and smooth oreo the target species in the west on flat, dropoff, and seamounts from the late 1970s, with a gradual change to target fishing for orange roughy on seamounts in the east in the late 1980s (Figure 4). The catch data were therefore split at 178° 12.6′ W into a west series from 1979–80 to 1988–89 and an east series from 1992–93 to 1998–99. The intermediate years (1989–90 to 1991–92) represented a period of rapid improvement of fishing ability due largely to the introduction of GPS which gave a continuous update of vessel position and allowed seamounts to be fished at any time of the day. Previous positioning systems gave only irregular single estimates of position (fixes) and position estimates were calculated by dead reckoning (based on vessel speed, direction, etc.) in the interval between fixes.

Method of CPUE analysis

The CPUE analysis method was described by Doonan et al. (1995a, 1996, 1997) and involved regression based methods where the zero catch tow and the positive catch tow data were analysed separately to produce positive catch and zero catch indices. For target fishing, a combined index (positive catch and zero catch indices) was calculated. The predictor variables considered in the analysis included axis-position (position along a line drawn west to east through the fished band along the continental slope of the south Chatham Rise), depth, season, time, seamount (indicates if a tow starts within 5 km of a known seamount), and vessel. The reference year can be any year but was arbitrarily assigned to a year near the middle of the time series. Annual c.v.s for the combined indices were estimated using a jackknife technique (Doonan et al. 1995a). The overall mean c.v. for the series was then calculated by dividing the square root of the mean of the squared annual c.v.s. (excluding the reference year c.v. = 0) by the square root of 2. This approximately estimates the c.v. for the variability within the target year alone.

For the black oreo (BOE) target fishery combined indices were used in the stock reduction, but for the bycatch fishery (target orange roughy) only the positive catch indices were used in the stock reduction analyses.

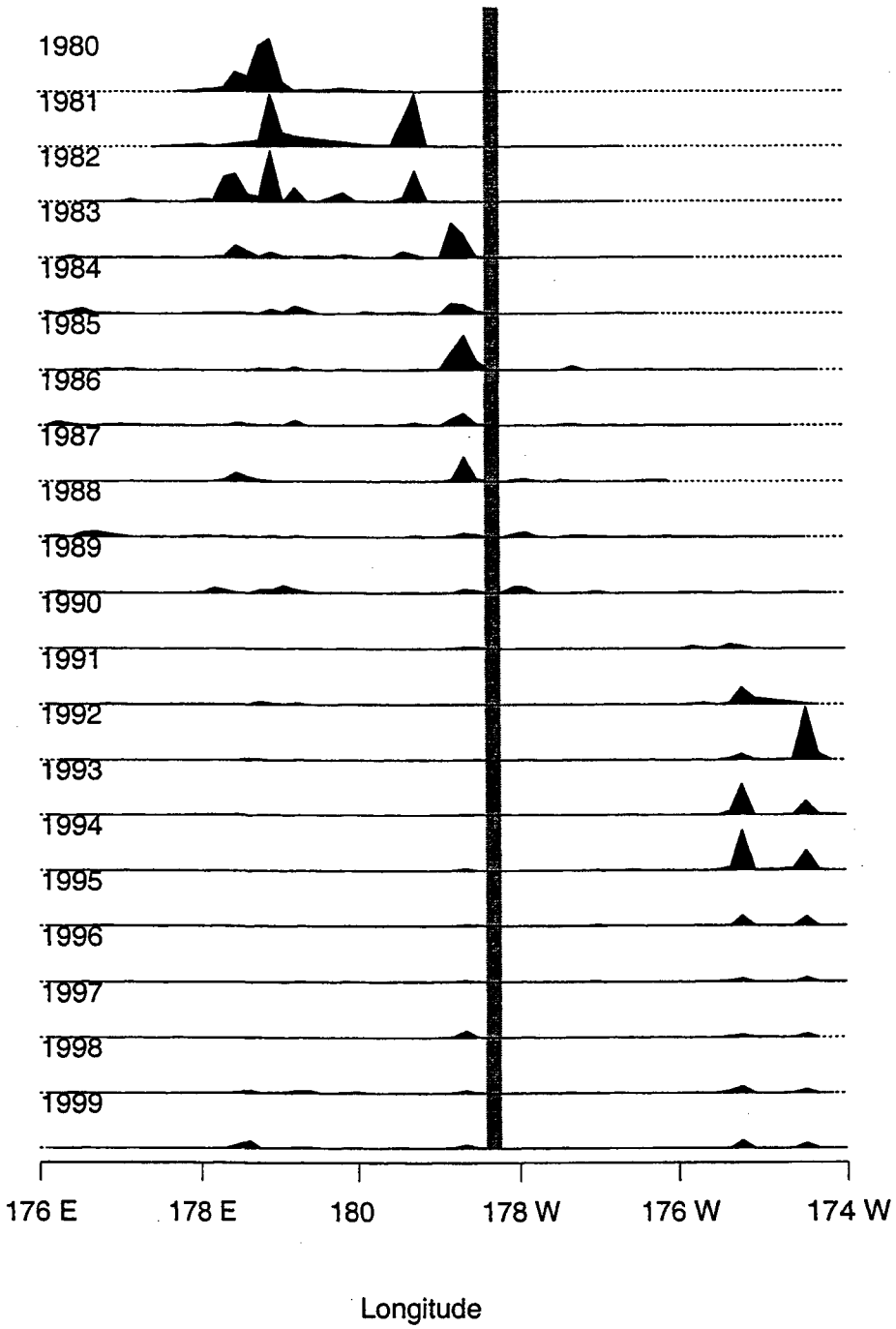

Figure 3: **All estimated reported catches of black oreo (black shading, t) by longitude over time from OEO 4 on the south Chatham Rise between 176° E and 174° W, south of 44° S. Years are fishing years, e.g., 1982 is 1981–82. There were no reported catches of black oreo before 1979–80. Vertical scale is 1000 t between years (horizontal lines). The vertical line at 178° 20' W marks the split between west and east parts of OEO 4.**

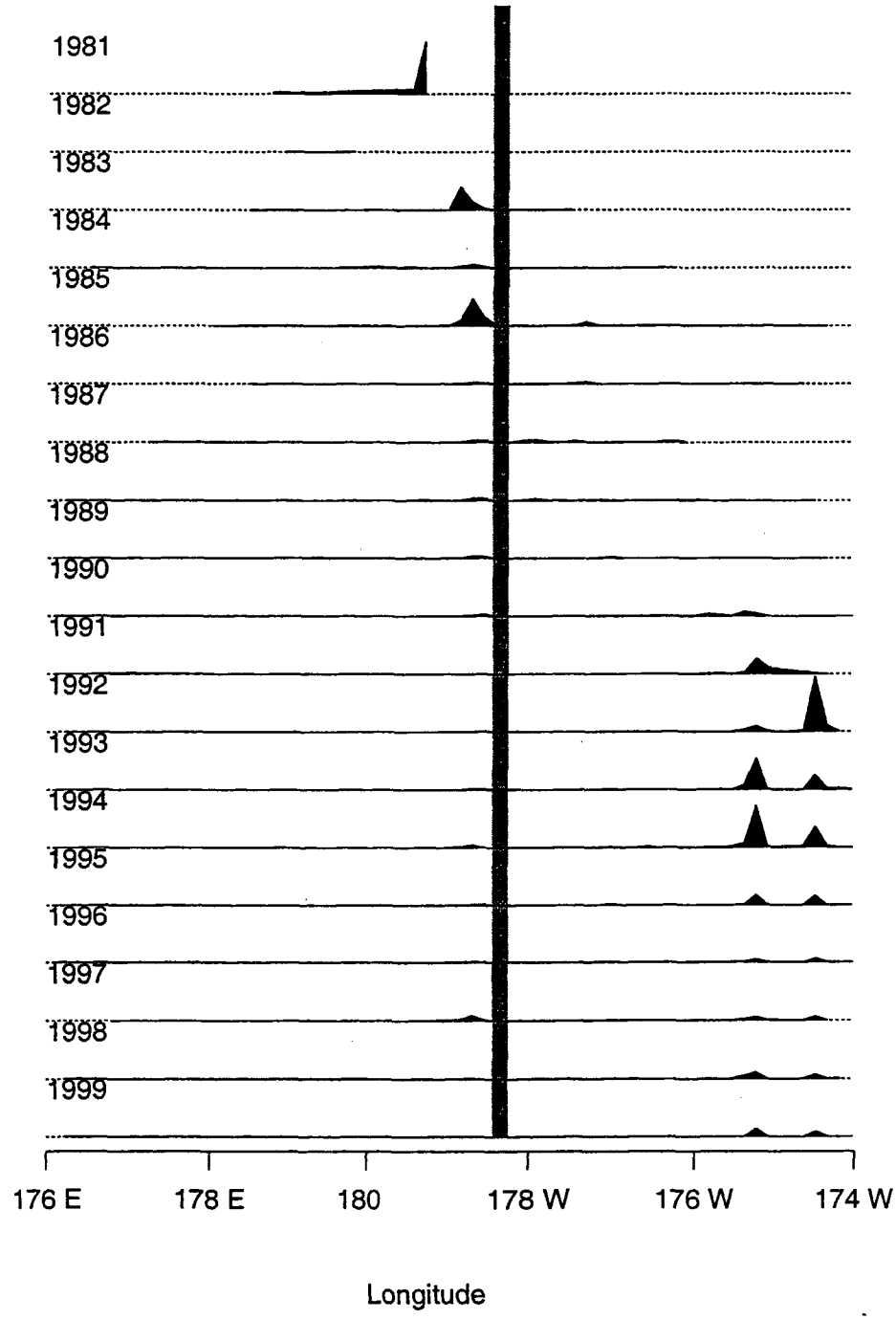

Figure 4: **Estimated reported catches of black oreo (black shading, t) where target species was orange roughy, by longitude over time from OEO 4 on the south Chatham Rise between 176° E and 174° W, south of 44° S. Years are fishing years, e.g., 1982 is 1981–82. There were few reported catches of black oreo before 1980–81 so 1980–81 includes that year plus prior catches. Vertical scale is 1000 t between years (horizontal lines). The vertical line at 178° 20' W marks the split between west and east parts of OEO 4.**

Results of CPUE analysis

There were four standardised CPUE analyses considered: target black oreo pre-GPS, target black oreo post-GPS, bycatch black oreo (target orange roughy) pre-GPS, bycatch black oreo (target orange roughy) post-GPS. Analyses were carried out if there were 50 or more tows carried out per year and provided that one vessel did not dominate (greater than 80%) the number of tows in any year. Applying these criteria resulted in analyses of target black oreo pre-GPS, bycatch black oreo (target orange roughy) pre-GPS, and bycatch black oreo (target orange roughy) post-GPS. Only one series was used in the stock reduction model analyses for each time period. There were two series available for the pre-GPS time period, but the target black oreo pre-GPS series was preferred to the bycatch black oreo (target orange roughy) pre-GPS series because the former used data where black oreo was the target species.

a) Target black oreo, pre-GPS series. Data used were from 1980–81 to 1986–87 and were mainly from the west. The final model for positive catch used vessel, year, season, and depth and that for zero catch used vessel, season, year, depth and axis-position. The combined index from the final year was approximately a fifth that of the first year with most of the decline occurring in the first three years (Table 3a). The overall mean c.v. (applied across the series including the reference year) was 66%.

b) Bycatch black oreo (target orange roughy), post-GPS series. Data used were from 1992–93 to 1998–99 and were mainly from the east. The final model for positive catch used axis-position, vessel, year, depth, and season. The positive catch index fell to about a third over the period (Table 3b). The overall mean c.v. (applied across the series including the reference year) was 104%.

Table 3: Black oreo standardised CPUE analyses. The overall mean c.v.s for the two series were 66% for the target and 104% for the bycatch series respectively.

	Index	c.v.
(a) Target pre-GPS combined index and jacknife c.v.		
1980–81	2.80	122.0
1981–82	2.72	94.8
1982–83	1.02	68.1
1983–84	1.00	0.0
1984–85	0.64	60.8
1985–86	0.46	127.0
1986–87	0.41	63.4
(b) Bycatch post-GPS positive index and jacknife c.v.		
1992–93	1.32	39.2
1993–94	1.31	75.4
1994–95	1.00	0.0
1995–96	0.63	88.1
1996–97	0.95	45.9
1997–98	0.63	39.2
1998–99	0.37	332.0

2.2 Other information

Descriptive length distribution and mean length

Data collected from the commercial fishery by observers are described. A separate analysis of the potential use of length data (observer and research survey) for stock assessment modelling was carried out. Mean total length (TL) per year was estimated for males and females from all observer length data collected from commercial vessels fishing in OEO 4. Data from the observer database (Obs_lf) from the

south Chatham Rise between 176° E and 174° W south of 44° S from 1979 to 1999 (calendar years) were extracted for tows where target species was smooth oreo, black oreo, unspecified oreo, or orange roughy only (oreo samples from tows where the target was hoki were excluded as they do not represent the fish at depths exploited in the target oreo or orange roughy fisheries). Mean lengths for the data from OEO 4 (as defined above) are shown in Table 4, numbers of tows sampled are given in Table 5, and numbers of fish measured are shown in Table 6. Annual length distributions scaled by catch size for OEO 4 data are shown in Appendix 1. For the years where at least 1000 fish were measured (1990–95) there appears to be no trend in mean length for the total, males, and females, except that the 1995 values are much lower than those for the other years (Table 4).

Table 4: **Black oreo mean length (cm) for males, females, and both sexes combined (Total) from samples taken by observers in OEO 4 from 1979 to 1999 from all vessels, scaled to catch. See Table 5 for numbers of tows, and Table 6 for numbers of fish sampled ('Total'). –, no data.**

Year	Total	Males	Females
1988	33.9	31.7	34.8
1989	–	–	–
1990	36.7	35.7	37.5
1991	36.0	35.4	37.2
1992	36.5	36.0	36.9
1993	37.3	36.8	37.9
1994	36.4	35.4	37.1
1995	30.5	30.2	30.8
1996	33.9	33.3	34.6
1997	34.6	35.2	34.5
1998	–	–	–
1999	32.9	32.5	33.2

Data were also split into five major fishing areas plus the remaining area within OEO 4 because of known spatial and temporal fishing patterns for oreos in OEO 4 (Coburn et al. *2001*):

Area 1 178° E to 177° 08' W. Flat ground and dropoffs excluding seamounts (includes Bobbin Tow and Urk).
Area 2 177° 08' W to 176° 16' W. Includes seamounts such as Hegerville and Paranoia.
Area 3 176° 16' W to 175° W. Includes seamounts such as Condoms and Big Chief.
Area 4 175° to 174° W. Includes the Andes.
Area 5 178° E to 177° 08' W. Seamounts only including Trev's Pin and Mt. Kiso.
Rest The remainder of OEO 4 south of 44° S.

The length distributions scaled to catch for these areas by year are plotted in Appendices 2–6. The estimated mean lengths for males and females by area by year scaled to catch show no strong trends in mean length by area (Tables 7 and 8) although sample sizes were small with only at least 1000 fish per year measured in two years for Area 3 and in four years in Area 4 (Table 6).

Table 5: **Numbers of tows where black oreo length/sex samples were taken by observers in OEO 4 from 1979 to 1999 from all vessels. Area 1 - 178° E to 177° 08' W, flat ground and dropoffs excluding seamounts. Area 2 - 177° 08' W to 176° 16' W. Area 3 - 176° 16' W to 175° W. Area 4 - 175° to 174° W. Area 5 - 178° E to 177° 08' W, seamounts only. Rest - the remainder of OEO 4 south of 44° S.**

Year	Area 1	Area 2	Area 3	Area 4	Area 5	Rest of OEO 4	Total
1988	2	0	0	0	0	2	4
1989	0	0	0	0	0	0	0
1990	0	0	21	0	0	0	21
1991	2	1	1	45	1	0	50
1992	0	0	0	10	0	0	10
1993	0	0	30	28	1	0	59
1994	1	9	10	32	0	0	52
1995	0	2	2	7	2	1	14
1996	0	1	0	0	0	0	1
1997	0	0	1	2	1	1	5
1998	0	0	0	0	0	0	0
1999	1	0	0	0	0	1	2

Table 6: **Numbers of fish measured for black oreo length/sex samples taken by observers in OEO 4 from 1979 to 1999 from all vessels. See Table 5 for explanation of areas.**

Year	Area 1	Area 2	Area 3	Area 4	Area 5	Rest of OEO 4	Total
1988	238	0	0	0	0	211	449
1989	0	0	0	0	0	0	0
1990	0	0	2 454	0	0	0	2 454
1991	134	57	100	4 325	93	0	4 709
1992	0	0	0	1 065	0	0	1 065
1993	0	0	2 959	2 880	102	0	5 941
1994	91	686	800	3 591	0	0	5 168
1995	0	159	207	737	202	117	1 422
1996	0	138	0	0	0	0	138
1997	0	0	85	195	101	99	480
1998	0	0	0	0	0	0	0
1999	206	0	0	0	0	267	473

Table 7: **Mean length (cm TL) of male black oreo from samples taken by observers in OEO 4 scaled to catch from 1979 to 1999 from all vessels. See Table 5 for explanation of areas. –, no data.**

Year	Area 1	Area 2	Area 3	Area 4	Area 5	Rest of OEO 4
1988	28.7	–	–	–	–	33.3
1989	–	–	–	–	–	–
1990	–	–	35.7	–	–	–
1991	35.0	32.9	36.6	35.4	–	–
1992	–	–	–	36.0	–	–
1993	–	–	37.0	36.1	30.3	–
1994	30.4	26.9	36.5	35.0	–	–
1995	–	32.4	35.6	28.9	31.8	33.1
1996	–	33.3	–	–	–	–
1997	–	–	37.8	35.9	33.2	33.5
1998	–	–	–	–	–	–
1999	32.0	–	–	–	–	32.8

Table 8: **Mean length (cm TL) of female black oreo from samples taken by observers in OEO 4 scaled to catch from 1979 to 1999 from all vessels. See Table 5 for explanation of areas. –, no data.**

Year	Area 1	Area 2	Area 3	Area 4	Area 5	Rest of OEO 4
1988	29.3	–	–	–	–	35.8
1989	–	–	–	–	–	–
1990	–	–	37.5	–	–	–
1991	36.0	36.8	38.1	37.2	–	–
1992	–	–	–	36.9	–	–
1993	–	–	38.0	37.8	30.0	–
1994	33.7	27.2	38.1	36.6	–	–
1995	–	34.2	36.3	29.3	32.3	35.7
1996	–	34.6	–	–	–	–
1997	–	–	37.3	35.7	33.1	31.8
1998	–	–	–	–	–	–
1999	32.8	–	–	–	–	33.4

Descriptive female gonad stage data

Gonad stage data from females sampled by observers on commercial vessels fishing in OEO 4 were selected from the observer database (Obs_lf) from the south Chatham Rise between 176° E and 174° W south of 44° S from 1979 to 1999 from all tows where black oreo gonad stage data were collected (Table 9). The staging definitions used for these data are uncertain and may be a mixture of the four stage oreo scale and the five stage orange roughy scale provided in the observer manual. In the five stage scale, stages 3 and 4 are equivalent to stage 3 in the four stage scale. The data suggest that black oreo spawn from October to January and this is consistent with research results (Annala et al. 2000).

Table 9: **Percentage female gonad stages by month for black oreo from observed trawls in OEO 4, from 1990–91 to 1999–00, all years combined. n, number of fish sampled. –, less than 1 %.**

	Gonad stage					
Month	1	2	3	4	5	n
Jan	59	37	3	1	0	137
Feb	–	–	–	–	–	–
Mar	39	61	0	0	0	93
Apr	11	76	13	0	0	63
May	48	51	–	0	0	426
Jun	–	–	–	–	–	–
Jul	44	56	0	0	0	41
Aug	0	99	1	0	0	70
Sep	72	23	5	0	0	1 001
Oct	42	44	13	2	–	1 270
Nov	41	31	27	1	0	925
Dec	69	27	4	1	0	143

2.3 Recreational and Maori customary fisheries

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

2.4 Other sources of fishing mortality

Dumping of unwanted or small fish and accidental loss of fish (lost or ripped codends) were features of oreo fisheries in the early years. These sources of mortality were probably substantial but are now thought

to be relatively small. No estimate of mortality from these sources has been made because of lack of data and because they now appear to be small. Estimates of discards of oreos were made for 1994–95 and 1995–96 from MFish observer data. This involved calculating the ratio of discarded oreo catch to retained oreo catch and then multiplying the annual total oreo catch from the New Zealand EEZ by this ratio. Estimates were 207 and 270 t for 1994–95 and 1995–96 respectively (Clark et al. 2000).

3. RESEARCH

3.1 Stock structure

Ward et al. (1996) compared black oreo samples from New Zealand with material from south of Tasmania, the south Tasman Rise, and Western Australia and concluded that the New Zealand samples of black oreo constituted a stock distinct from the Australian samples based on "small but significant difference in mtDNA haplotype frequencies (with no detected allozyme differences), supported by differences in pyloric caeca and lateral line counts". A New Zealand pilot study examined black oreo stock relationships using samples from four management areas (OEO 1, OEO 3A, OEO 4, and OEO 6) of the New Zealand EEZ. Techniques used included genetic (nuclear and mitochondrial DNA), lateral line scale counts, settlement zone counts, parasites, otolith microchemistry, and otolith shape. Lateral line scale and pyloric caeca counts were different between samples from OEO 6 and the other three areas. The relative abundance of three parasites differed significantly between all areas. Otolith shape from OEO 3A samples was different to that from OEO 1 and OEO 4, but OEO 1, OEO 4, and OEO 6 otolith samples were not morphologically different. Genetic, otolith microchemistry, and settlement zone analyses showed no regional differences (Smith et al. 2000).

3.2 Resource surveys

Trawl surveys

Trawl surveys of oreos on the south Chatham Rise were carried out in seven years between 1986 and 1995 (Table 10). The abundance estimates from the surveys before 1991 were not considered to be comparable with the *Tangaroa* series because different vessels were used. Other results from those early surveys were used, e.g., gonad staging to determine length at maturity. The 1991–93 and 1995 "standard" (flat, undulating, and drop-off ground) surveys are comparable.

Table 10: 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	Reference
1986	47 137	*Arrow*	South	186	Fincham et al. (1987)
1987	47 496	*Amaltal Explorer*	South	191	Fenaughty et al. (1988)
1990	56 841	*Cordella*	South, southeast	189	McMillan & Hart (1994a)
1991	56 841	*Tangaroa*	South, southeast	154	McMillan & Hart (1994b)
1992	60 503	*Tangaroa*	South, southeast	146	McMillan & Hart (1994c)
1993	60 503	*Tangaroa*	South, southeast	148	McMillan & Hart (1995)
1995	60 503	*Tangaroa*	South, southeast	172	Hart & McMillan (1998)

Relative abundance estimates from trawl surveys

Estimates using knife-edge recruitment at 33 cm TL were made for the whole of the trawl survey area ("OEO 4") and split into the west and east parts of OEO 4 to correspond to the standardised CPUE abundance estimates (Section 2.1.1), Table 11.

Table 11: Research survey recruit black oreo abundance estimates (t) from the south Chatham Rise, OEO 4. N is the number of stations. Estimates were made based on a recruited length of 33 cm TL using the distance between the wings of the net.

	Mean abundance	c.v. (%)	N
OEO 4			
1991	13 065	51	105
1992	12 839	46	122
1993	6 515	30	124
1995	9 238	30	153
West			
1991	10 125	45	59
1992	11 918	49	38
1993	6 002	33	54
1995	8 803	31	45
East			
1991	2 571	83	46
1992	920	42	84
1993	513	50	70
1995	435	47	108

Acoustic survey

Absolute estimates of abundance are available from the acoustic survey on oreos that was carried out from 26 September to 30 October 1998 on *Tangaroa* (voyage TAN9812). Doonan et al. (2000) described details of the survey including the methods of estimating abundance so only a brief summary of the survey is given here. Transects on flat ground were surveyed to a stratified random design and a random sample of seamounts was surveyed with either a random transect (large seamounts) or a systematic "star" transect design (Figure 5). For some seamounts the flat ground nearby was also surveyed to compare the abundance of fish on and near the seamount either by extending the length of the star transects or by extra parallel transects. Acoustic data were collected concurrently for flat and seamounts on both towed and hull mounted transducers. The 1998 OEO 4 survey covered 59 transects on the flat and 29 on seamounts. A total of 95 tows was carried out for target identification and to estimate target strength and species composition (Tables 12 and 13). In situ and swimbladder samples for target strength data were collected and these have yielded revised estimates of target strength for both black and smooth oreos. Stratum seven, the area of past substantial commercial catch of black oreo was not surveyed because of time constraints caused by bad weather. A preliminary survey of the seamount called Flintstone was carried out but no survey transects were made because no fish marks were observed. Flintstone was assigned an abundance of zero.

Table 12: Numbers of flat transects and tows completed, and the number of strata for smooth oreo (SSO) and black (BOE) oreo. Tows were counted only if their performance was acceptable (code 1 or 2).

	SSO strata						BOE stratum
Stratum	2	22	3	4	42	5	7
Transects completed	17	8	6	10	10	8	0
Tows completed	8	6	10	8	11	14	0

Table 13: List of seamounts surveyed, number of tows, and number of transects carried out. Categories A to C rank seamounts in the order of descending importance based on oreo catch history.

Seamount	Category	Number of transects	Number of tows
Hegerville	A	5	3
Paranoia	A	4	3
Flintstone	B	0	0
Teepee	B	4	3
Chuckys	C	4	3
Featherlite	C	4	2
Fletchers	C	4	3
Mt. Nelson	C	4	4

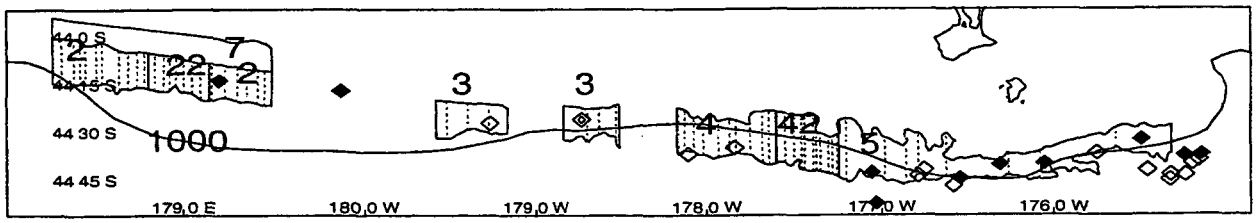

Figure 5: OEO 4 survey area showing smooth oreo (2–5, 22, & 42) and black oreo (7) flat strata (dark lines) and transects (dashed lines). Seamounts selected for sampling (♦) plus seamounts listed but not selected for sampling(◇).

Acoustic absolute abundance estimates

Estimates were made for recruit fish using the following parameter values. The mean absorption coefficient of sound in seawater used was 8.9 $dB.km^{-1}$. Shadow zone corrections were made (R. Barr. NIWA, unpublished results). Approximate corrections for loss of acoustic signal strength due to towbody motion were based on the method of Stanton (1982).

The equation for the tilt averaged target strength, <TS>, versus the logarithm of fish total length (L, cm) for smooth oreo was

$<TS> = -89.16 + 30.42 * \log_{10}(L)$.

The mean TS for a 35 cm fish is -42.5 dB which is an increase of about 7.5 dB from the value derived from the relationship used in the 1999 stock assessment (Doonan et al. 1999a). The equation for black oreo was

$<TS> = -62.94 + 15.76 * \log_{10}(L)$, where L is total length (cm).

The mean TS for a 35 cm fish is -38.7 dB which is a decrease of about 1.1 dB from 1999 (Doonan et al. 1999b).

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.

Mark categorisation methods to assign acoustic backscatter to marks recorded on transects were developed and involved using supervised statistical classification techniques (Doonan & McMillan 2000). About 59% of the black oreo abundance came from the background mark-type (Table 14). This

mark-type was not thought to be important and would not be expected to contribute much to the abundance for a survey where black oreo schools were encountered. Background marks are not normally fished by commercial vessels. Trawls on these marks during the survey had very low catch rates and produced mixed catches.

Table 14: Recruit black oreo (BOE) percentage abundance for each flat stratum and mark-type.

	Stratum						Mark-type		
	2	22	3	4	42	5	High/Medium	Low	Background
BOE	11	4	23	11	12	38	18	24	59

Scaling estimates to OEO 4

Estimates from the acoustic flat survey area were scaled up to the trawl survey area and then to the OEO 4 area. Abundance was estimated by:

$$B_{Total} = f_{T2All}\left(f_{A2T}B_{Flat} + B_{Hills}\right),$$

where B_{Flat} is the estimated abundance for the flat ground in the acoustic survey, B_{Hills} is the estimated abundance for all seamounts in the trawl survey area, f_{A2T} converts the flat abundance from the acoustic survey area to the trawl survey area, and f_{T2All} converts the abundance from the trawl survey area up to the OEO 4 area.

The scaling factor f_{A2T} was calculated using data from three trawl surveys (TAN9210, TAN9309, and TAN9511) to estimate the fraction of recruit black oreo in the acoustic survey area compared to the trawl survey area. A mean black oreo density was estimated for each trawl stratum and this density was applied to the sub-areas in the stratum resulting from splitting off the part, where applicable, in the acoustic survey area. For recruit black oreo this factor was 4.3 for the whole of OEO 4, i.e., the acoustic area had about 23% of the abundance. This factor was 5.2 for the west and 1.2 for the east parts of OEO 4. The magnitude of these ratios suggests that the size of the area surveyed was borderline for providing a reliable abundance estimate.

For the scaling factor f_{T2All}, the ratio of catches in the total OEO 4 area to that in the trawl survey area was used to adjust the abundance (seamount plus flat ground) up to the total OEO 4 area from the trawl survey area. Data from the fishing years 1986–87 to 1998–99 were analysed with 1986–87 chosen as the start because the Quota Management System was introduced in that year (Working Group decision first recorded by Annala & Sullivan (1997)). For recruit black oreo it was 1.06 (10 900/10 300). All estimates presented below are scaled up to the total OEO 4 area including the estimates from the west and east parts of OEO 4.

Acoustic abundance estimates for recruit black oreo from seamounts and flat for the whole of OEO 4 are given in Table 15 and split into the west and east parts of OEO 4 to correspond to the standardised CPUE abundance estimates (Section 2.1.1) in Table 16.

Table 15: OEO 4 and west and east (split at 178° 20′ W) recruit black oreo for seamount, flat, and total acoustic abundance estimates (t) and recruit c.v. (%) based on knife-edge recruitment (23 years).

	OEO 4		West		East	
	Abundance	c.v.	Abundance	c.v.	Abundance	c.v.
Seamount	127	91	36	96	96	109
Flat	13 800	56	6 500	64	2 350	57
Total	13 900	55	6 540	63	2 450	55

3.3 Other studies

Catchability (q) of black oreo from the trawl surveys of OEO 4

Doonan et al. (1997) 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 recruit smooth oreo very well. This also seems likely to be true for black oreo. The OEO 4 trawl survey abundance estimates used in the stock reduction analysis had associated unknown q values and were therefore not included in the "base case" analysis.

3.4 Biomass estimates

Stock reduction analysis

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

(a) The black oreo acoustic abundance estimate was an unbiased absolute value.
(b) The CPUE analysis indexed the abundance of black oreo in the whole of OEO 4. Most of the black oreo commercial catch taken from 1978–79 to 1998–99 came from the CPUE study area and research trawl surveys indicated that there was little habitat for, and biomass of, black 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.
(g) The population of black oreo in OEO 4 was a discrete stock or production unit.
(h) The catch histories were accurate.

Input data

Input data included the recruit absolute acoustic abundance estimates and c.v.s (see Table 15), the time series of combined abundance indices from standardised CPUE analyses and c.v.s (see Table 3), the relative abundance estimates from the trawl surveys (1991–93, 1995, see Table 11), the life history parameters from McMillan et al. (1997) (Table 16), and the catch history (Table 17).

Table 16: Life history parameters for black oreo. –, not estimated.

Parameter	Symbol (unit)	Female	Male
Natural mortality	M (yr^{-1})	0.044	0.044
Age at recruitment	A_r (yr)	–	–
Age at maturity	A_m (yr)	27	–
von Bertalanffy parameters	L_∞(cm, TL)	39.9	37.2
	k (yr^{-1})	0.043	0.056
	t_0 (yr)	-17.6	-16.4
Length–weight parameters	a	0.008	0.016
	b	3.28	3.06
Length at recruitment	(cm, TL)	–	–
Length at maturity	(cm, TL)	34	–

Catch history (Table 18)

This was derived from Tables 1 and 2 and included the yearly total catch for OEO 4 and catches from west and east (split at 178° 20′ W) to correspond to the standardised CPUE abundance estimates (section 2.1.1).

1 Catches from 1978–79 to 1982–83 (1 April to 31 March) were assumed to be for fishing years (1 October to 30 September).
2 The 1978–79 catch of unspecified oreo (8041 t, Table 1) was assumed to be the same proportion of black oreo to smooth oreo catch reported in 1979–80 (566/(566 +114) = 0.832) (See Table 2). The estimate of the 1978–79 black oreo catch was 8041 t x 0.832 = 6690 t.
3 The 6 month catch of black oreo reported as 1983–83 (1340 t, Table 2) was split and half each (670 t) added to the preceding and subsequent years (1982–83 and 1983–84). There was only an 8 t difference between estimated and reported catch in 1983–83 (See Tables 1 & 2), so no adjustment to the reported smooth oreo catch was made.
4 From 1979–80 to 1998–99 the catch was calculated by multiplying the value reported in Table 1 by the proportion of black oreo to smooth oreo in Table 2.
5 The last two years of the catch history are assumed projected catch.

Table 17: Reconstructed catch history (t) of black oreo from OEO 4 used in the 2000 stock reduction analysis. OEO 4 is the catch from the whole area, and "West" is the proportion of the total taken west and "East" is the catch taken east of 178° 20′ W. ‡ indicates assumed catch.

Year	OEO 4	West	East
1978–79	6 690	6 690	0
1979–80	566	566	0
1980–81	8 833	8 833	0
1981–82	5 831	5 831	0
1982–83	1 770	1 770	0
1983–84	1 888	1 850	38
1984–85	1 654	1 555	99
1985–86	961	894	67
1986–87	1 160	951	209
1987–88	903	587	316
1988–89	1 221	818	403
1989–90	560	224	336
1990–91	908	272	636
1991–92	1 953	137	1 816
1992–93	2 058	226	1 832
1993–94	2 032	183	1 849
1994–95	720	151	569
1995–96	442	177	265
1996–97	623	368	255
1997–98	851	0	851
1998–99	899	0	899
1999–00	‡850	‡0	‡850
2000–01	‡850	‡0	‡850

Results of several different stock reduction model runs (referred to as "cases") with different abundance inputs are presented below. The "base" case for the whole of OEO 4 used the acoustic abundance estimate, the target pre-GPS combined standardised CPUE index and the bycatch post-GPS standardised positive catch CPUE index (Figure 6). The trawl survey indices were not used in the base case because they had a poor fit to the trajectory, and had wide 95% confidence intervals (C.I.). The means for the two early years of the target pre-GPS standardised CPUE abundance indices were well above, although still within, one standard error of the trajectory line. The two later years were not within one standard error of the trajectory line.

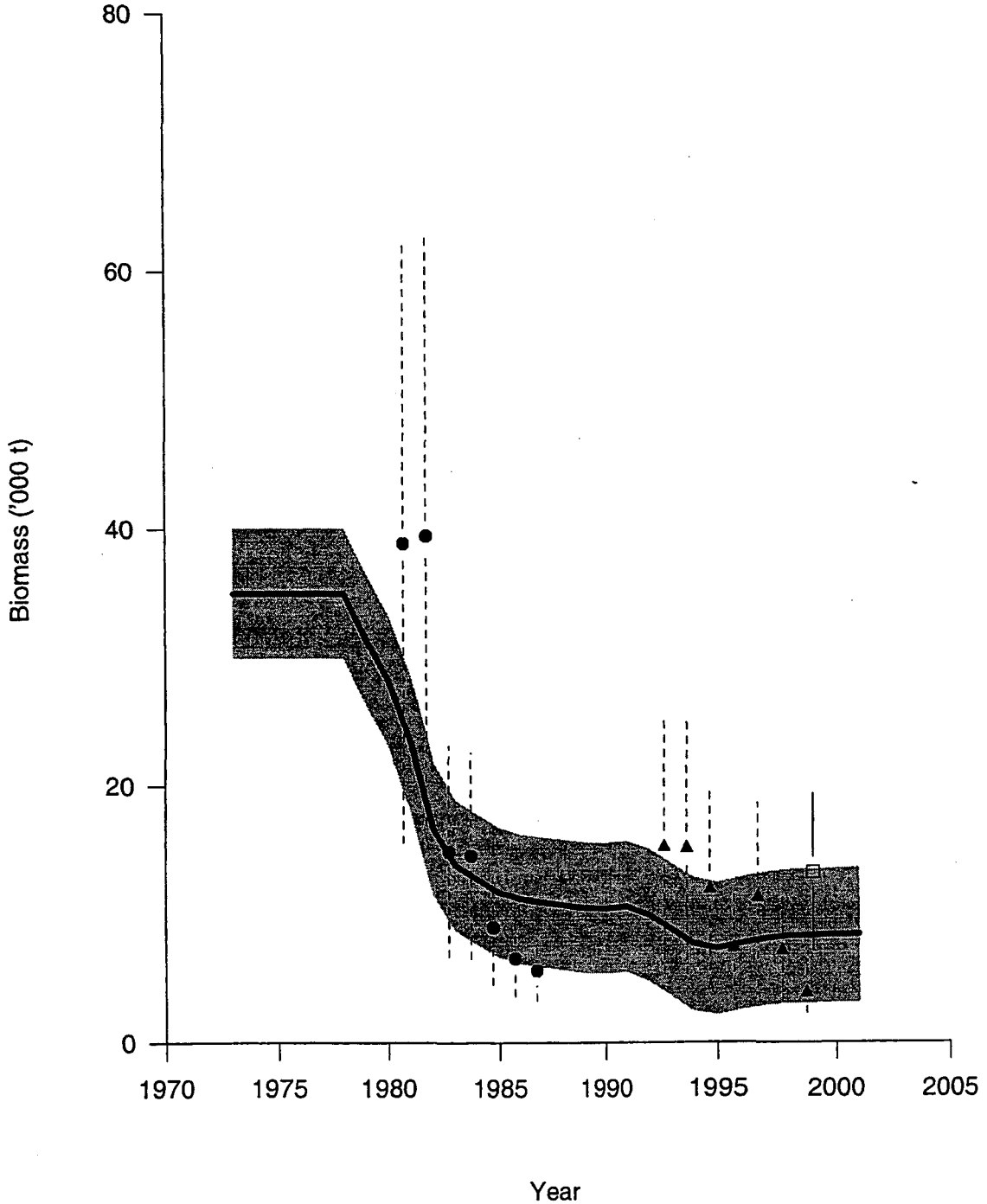

Figure 6: **Biomass trajectory for OEO 4 from stock reduction analysis for the base case (acoustic absolute abundance, plus the target pre-GPS combined and bycatch post-GPS positive standardised CPUE indices). ● target pre-GPS CPUE, ▲ bycatch post-GPS CPUE, □ acoustic absolute abundance estimate. Dashed vertical lines are one standard deviation. The grey area is bounded by the trajectories from B_0 that make up the 95% C.I. for B_0.**

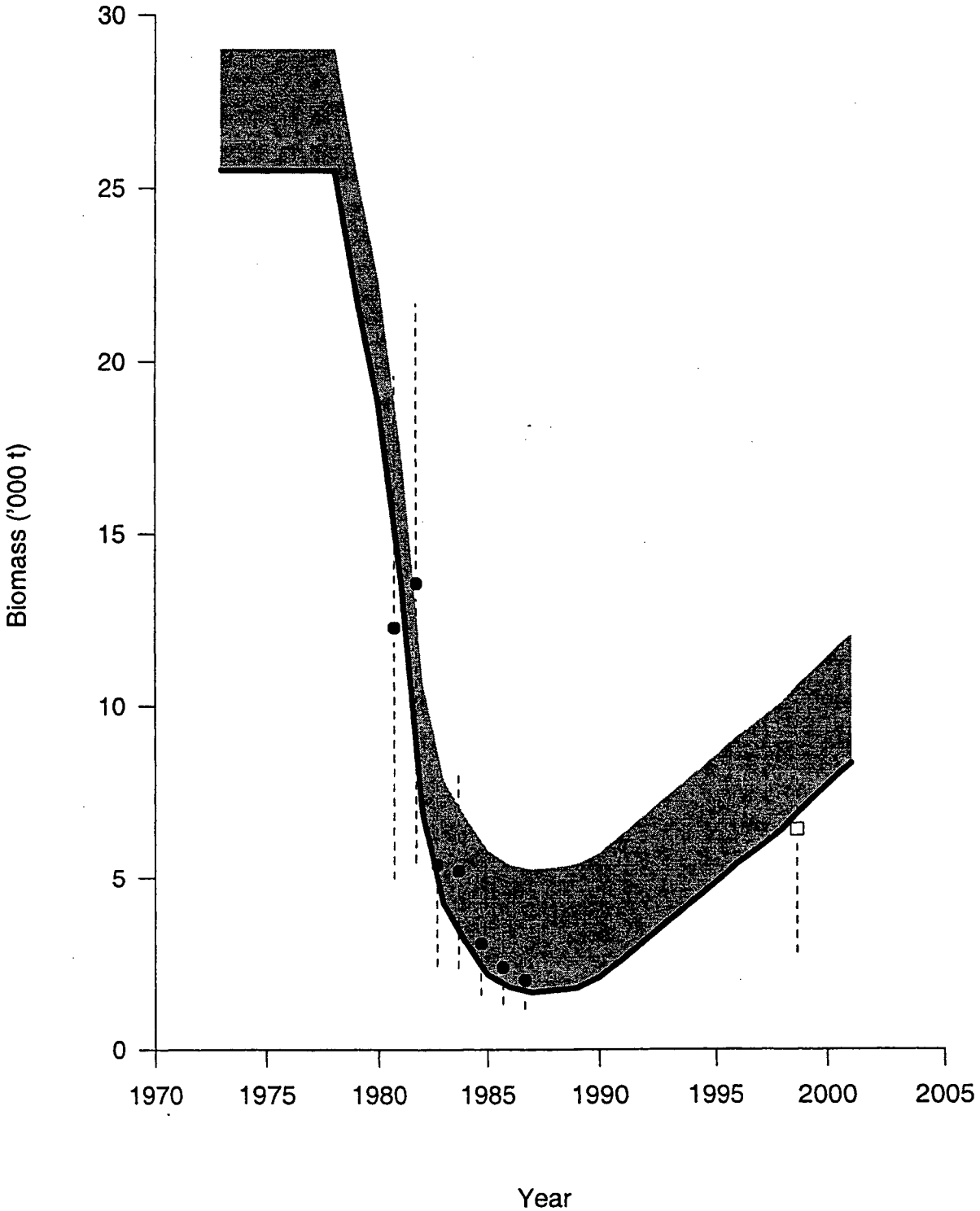

Figure 7: Biomass trajectory for west (OEO 4 west of 178° 20′ W) from stock reduction analysis for the base case (west acoustic absolute abundance, plus the target pre-GPS standardised combined CPUE index). ● target pre-GPS CPUE, □ acoustic absolute abundance estimate. Dashed vertical lines are one standard deviation. The grey area is bounded by the trajectories from B_0 that make up the 95% C.I. for B_0. The lower 95% C.I. is on the trajectory line because the biomass estimates are at B_{min}.

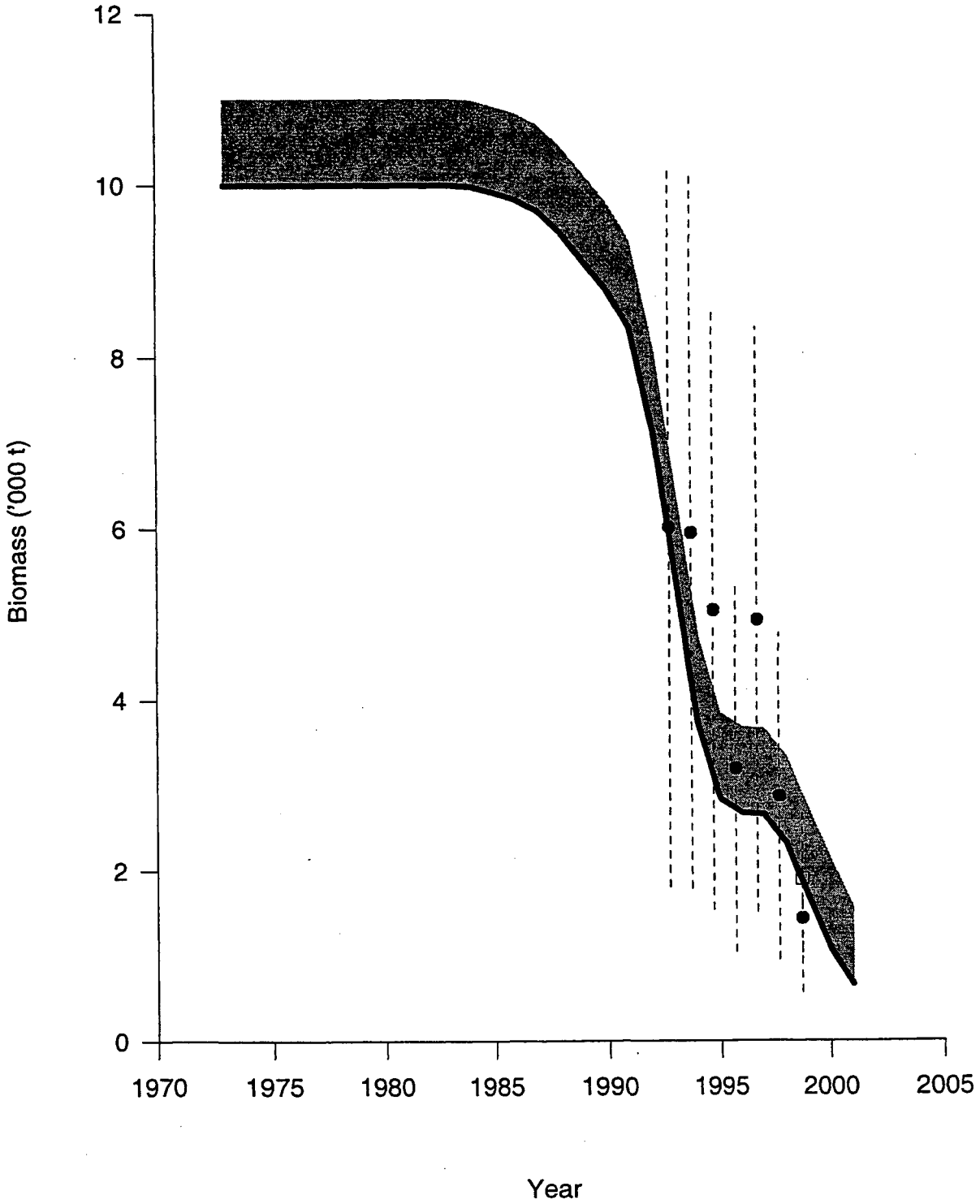

Figure 8: **Biomass trajectory for east (OEO 4 east of 178° 20′ W) from stock reduction analysis for the base case (east acoustic absolute abundance, plus the bycatch post-GPS standardised positive CPUE index). ● bycatch post-GPS CPUE, □ acoustic absolute abundance estimate. Dashed vertical lines are one standard deviation. The grey area is bounded by the trajectories from B_0 that make up the 95% C.I. for B_0. The lower 95% C.I. is on the trajectory line because the biomass estimates are at B_{min}.**

All but the last year of the bycatch post-GPS CPUE abundance indices were within one standard error of the trajectory line. The absolute acoustic abundance (adjusted to a mid-year value) fell above the line. The base case for west of 178° 20′ W used the west acoustic abundance estimate and the target pre-GPS standardised CPUE abundance indices (Figure 7). The estimate of B_0 was at B_{min} indicating that the trajectory line was a poor fit to the data. The base case for east of 178° 20′ W used the east acoustic abundance estimate and the bycatch post-GPS standardised CPUE abundance indices (Figure 8). This estimate of B_0 was also at B_{min} indicating that the trajectory line was a poor fit to the data.

Biomass estimates by case, including the maximum likelihood value and the 95% confidence intervals (in parentheses), are given in Table 18. The 95% confidence interval estimates of B_0 for the OEO 4 base case from this analysis were 30 000–38 500 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. For OEO 4 combined the estimates of B_0 from the CPUE-only and trawl-only cases sit on B_{min} and have very high upper 95% confidence intervals. Cases that include the acoustic abundance estimate had smaller 95% confidence intervals for B_0 illustrating the importance of the acoustic estimate.

Table 18: Recruit biomass estimates (t) from the stock reduction model. The 95% confidence intervals are in parentheses. Base cases marked in bold. "East" is to the east of 178° 20′ W. "West" is west of 178° 20′ W.

	B_0 (t)		Mid-year $B_{1999-00}$ (t)			($\%B_0$)
OEO 4						
Abs.+ Tar. pre-& bycatch post-GPS CPUE	**35 000**	**(30 000-40 000)**	**8 360**	**(3 120-13 500)**	**24**	**(10-34)**
Abs.+ Tar. pre-& bycatch post-GPS CPUE + Tr.	35 000	(30 000-40 500)	8 360	(3 120-14 000)	24	(10-35)
Absolute (Abs.)	37 000	(30 000-43 000)	10 400	(3 120-16 500)	28	(10-38)
Target (Tar.) pre- & bycatch post-GPS CPUE	30 000	(30 000–1 000 000)	3 120	(3 120–974 000)	10	(10–97)
Trawl (Tr.)	30 000	30 000–1 000 000)	3 120	(3 120–974 000)	10	(10–97)
West						
Abs.+ Tar. pre-GPS CPUE	**25 500**	**(25 500–29 000)**	**7 040**	**(7 040–10 700)**	**28**	**(28–37)**
Abs.+ Tar. pre-GPS CPUE + Tr.	25 500	(25 500–30 000)	7 040	(7 040–11 800)	28	(28–39)
Absolute (Abs.)	25 500	(25 500–29 500)	7 040	(7 040–11 200)	28	(28–38)
Target (Tar.) pre-GPS CPUE	25 500	(25 500–34 000)	7 040	(7 040–15 800)	28	(28–47)
Trawl (Tr.)	33 000	(25 500–1 000 000)	15 000	(7 040–982 000)	45	(28–98)
East						
Abs.+ Bc. post-GPS CPUE	**10 000**	**(10 000–11 000)**	**1 690**	**(1 690–2 710)**	**17**	**(17–25)**
Abs.+ Bc. post-GPS CPUE + Tr.	10 000	(10 000–11 500)	1 690	(1 690–3 220)	17	(17–28)
Absolute (Abs.)	10 000	(10 000–11 000)	1 690	(1 690–2 710)	17	(17–25)
Bycatch (Bc.) post-GPS CPUE	10 000	(10 000–1 000 000)	1 690	(1 690–992 000)	17	(17–99)
Trawl (Tr.)	10 000	(10 000–1 000 000)	1 690	(1 690–992 000)	17	(17–99)

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

1. Age estimates. Black oreo age estimates are not validated, although Australian workers using the same method achieved similar results. Small black oreo are not available to known sampling methods and other ageing methods are needed to validate age estimates from otolith sections.
2. Stock discreteness for black 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.
3. The east-west split assumes that these areas have discrete stocks or that fish stay at or near the same place once they reach maturity. The latter also assumes that the recruitment split between areas is proportional to the east-west virgin biomasses.

Sensitivity analyses of biomass and yield estimates of smooth oreo and black oreo for OEO 3A (Doonan et al. 1999a, 1999b) suggest that the following uncertainties are likely to be important.

1. Target strength of black oreo. Virgin and current biomass estimates are sensitive to the value of black oreo target strength.

2. Recruitment steepness. Yields are sensitive to the uncertainties in the estimate of the value of recruitment steepness but there are no data available to check the assumed value of recruitment steepness.
3. Natural mortality estimate. Increasing M will increase and decreasing M will decrease the estimates of base case long-term MCY.

3.4.1 Sensitivity of biomass estimates, OEO 4 base case

Because of the uncertainty involved with the biomass estimates (see Management Implications below) sensitivity was not considered for this assessment.

3.5 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 16 was 1.3% B_0. Under continued fishing at this level the mean biomass was 43% B_0 (B_{MCY}).

Yield estimates for black oreo from OEO 4 (Table 19) were calculated from the results of the stock reduction analyses reported above, using the methods of Francis (1992). Where stocks are depressed (below 20% B_0), the MCY for 2000–01 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 16 was 0.0469. The mean catch when fishing at F = 0.0469 was 1.54% B_0, and the mean biomass (B_{MAY}) is 24% B_0. Yield estimates are shown in Table 19.

Table 19: Yield estimates (t). The 95% confidence limits are in parentheses. Base cases marked in bold. "East" is to the east of 178° 20′ W. "West" is west of 178° 20′ W.

	$MCY_{2000-01}$		$MCY_{long-term}$		$CAY_{2000-01}$	
OEO 4						
Abs.+ Tar. pre-& bycatch post-GPS CPUE	**460**	**(210-530)**	**460**	**(400-530)**	**370**	**(150-590)**
Abs.+ Tar. pre-& bycatch post-GPS CPUE + Tr.	460	(210-530)	460	(400-530)	370	(150-610)
Absolute (Abs.)	490	(210-570)	490	(400-570)	460	(150-720)
Target (Tar.) pre- & bycatch post-GPS CPUE	210	(210–13 000)	400	(400–13 000)	150	(150–41 000)
Trawl (Tr.)	210	(210–13 000)	400	(400–13 000)	150	(150–41 000)
West						
Abs.+ Tar. pre-GPS CPUE	**340**	**(340–380)**	**340**	**(340–380)**	**350**	**(350–500)**
Abs.+ Tar. pre-GPS CPUE + Tr.	340	(340–400)	340	(340–400)	350	(350–550)
Absolute (Abs.)	340	(340–390)	340	(340–390)	350	(350–530)
Target (Tar.) pre-GPS CPUE	340	(340–450)	340	(340–450)	350	(350–720)
Trawl (Tr.)	440	(340–13 000)	440	(340–13 000)	680	(350–41 000)
East						
Abs.+ Bc. post-GPS CPUE	**110**	**(110–150)**	**130**	**(130–150)**	**43**	**(43–86)**
Abs.+ Bc. post-GPS CPUE + Tr.	110	(110–150)	130	(130–150)	43	(43–110)
Absolute (Abs.)	110	(110–150)	130	(130–150)	43	(43–86)
Bycatch (Bc.) post-GPS CPUE	110	(110–13 000)	130	(130–13 000)	43	(43–42 000)
Trawl (Tr.)	110	(110–13 000)	130	(130–13 000)	43	(43–42 000)

3.5.1 Sensitivity of MCY to M and steepness

Because of the uncertainty involved with the estimates (see Management Implications below) the sensitivity of MCY estimates was not considered for this assessment.

4. MANAGEMENT IMPLICATIONS

This stock assessment of OEO 4 black oreo is unreliable for the following reasons:

1. The acoustic abundance estimate is uncertain. The acoustic survey was aimed at smooth oreo and consequently the black oreo areas in OEO 4 received only minimal coverage. The estimate of recruit abundance is low and is largely based on background abundance, where the acoustic method performed poorly, rather than from black oreo schools. The poor coverage of black oreo areas by the acoustic survey was compensated for by multiplying the acoustic survey area abundance by a scaling factor of 4.3 (based on research surveys) to make the estimate equivalent to the trawl survey area and then by a further 1.06 to estimate a total abundance for OEO 4. In addition, only small acoustic abundance estimates were made from the seamounts which suggests that either black oreo abundance on seamounts was low or the estimate was biased low.

2. The CPUE abundance estimates are uncertain. There is only a small fishery for black oreo in OEO 4 (about 1100 t per year from 1989–90 to 1998–99) with target fishing largely confined to the west end during the late 1980s and early 1990s. Both CPUE indices suggest steep declines in abundance. The target CPUE indices used in the assessment of biomass for the west end of OEO 4 and the bycatch CPUE indices used in the assessment of biomass for the east end of OEO 4 both force the estimate of B_0 to lie on B_{min}. This suggests that estimates of abundance in this assessment are too low.

The following preliminary conclusions could be drawn from this assessment.

Base case, whole of OEO 4

1. The biomass at the start of 1999–2000 (7330 t) was likely to be close to 22% of B_0 and also close to B_{MCY} (24% B_0).

2. Yields from this stock will be low because the productivity of black oreo is low, based on unvalidated age estimates. The long-term MCY estimates from a stock of between 30 000 and 40 000 t are 400–530 t, 36–48% of the mean annual reported (partly reconstructed) black oreo catch in OEO 4 from the last 10 years (about 1100 t per year, 1989–90 to 1998–99, from Table 17). Therefore, it seems likely that the recent catch levels of black oreo from OEO 4 are higher than the long-term sustainable yield and will not allow the stock to remain near B_{MCY}.

Base cases, west and east OEO 4

Both analyses cause the virgin biomass estimates to lie at B_{min} (the minimum biomass consistent with the catch history and with the life history parameters) and consequently the analyses appear too uncertain to allow conclusions to be drawn.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Annala, J.H.; Sullivan, K.J. (Comps.) (1997). Report from the Fishery Assessment Plenary, May 1997: stock assessments and yield estimates. 381 p. (Unpublished report held in NIWA library, Wellington.)

Annala, J.H.; Sullivan, K.J.; O'Brien, C.J. (Comps.) (2000). Report from the Fishery Assessment Plenary, May 2000: stock assessments and yield estimates. 495 p. (Unpublished report held in NIWA library, Wellington.)

Clark, M.R.; Anderson. O.F.; Gilbert, D.J. (2000). Discards in trawl fisheries for southern blue whiting, orange roughy, hoki, and oreos in waters around New Zealand. *NIWA Technical Report 71*. 73 p.

Doonan, I.J.; McMillan, P.J. (2000). Objective classification of acoustic fish marks for the 1998 south Chatham Rise (OEO 4) oreo survey (TAN9812). *In* Coombs, R.F. Final Research Report for Ministry of Fisheries Project OEO9801. (Unpublished report held by Ministry of Fisheries, Wellington.)

Doonan, I.J.; Hart, A.C.; McMillan, P.J.; Coombs, R.F. (2000). Oreo abundance estimates from the October 1998 survey of the south Chatham Rise (OEO 4). *New Zealand Fisheries Assessment Report 2000/52*. 26 p.

Doonan, I.J.; McMillan, P.J.; Coburn, R.P.; Hart, A.C. (1996). Assessment of Chatham Rise smooth oreo (OEO 3A and OEO 4) for 1996. New Zealand Fisheries Assessment Research Document 96/17. 21 p. (Unpublished report held in NIWA library, Wellington.)

Doonan, I.J.; McMillan, P.J.; Coburn, R.P.; Hart, A.C.; Cordue, P.L. (1995a). Assessment of smooth oreo for 1995. New Zealand Fisheries Assessment Research Document 95/12. 31 p. (Unpublished report held in NIWA library, Wellington.)

Doonan, I.J.; McMillan, P.J.; Kalish, J.M.; Hart, A.C. (1995b). Age estimates for black oreo and smooth oreo. New Zealand Fisheries Assessment Research Document 95/14. 26 p. (Unpublished report held in NIWA library, Wellington.)

Doonan, I.J.; McMillan, P.J.; Coburn, R.P.; Hart, A.C. (1997). Assessment of Chatham Rise smooth oreo (OEO 3A and OEO 4) for 1997. New Zealand Fisheries Assessment Research Document 97/21. 26 p. (Unpublished report held in NIWA library, Wellington.)

Doonan, I.J.; McMillan, P.J.; Coburn, R.P.; Hart, A.C. (1999a). Assessment of OEO 3A smooth oreo for 1999–2000. New Zealand Fisheries Assessment Research Document 99/45. 21 p. (Unpublished report held in NIWA library, Wellington.)

Doonan, I.J.; McMillan, P.J.; Coburn, R.P.; Hart, A.C. (1999b). Assessment of OEO 3A black oreo for 1999–2000. New Zealand Fisheries Assessment Research Document 99/52. 30 p. (Unpublished report held in NIWA library, Wellington.)

Fenaughty, J.M.; Banks, D.A.; Hart, A.C.; McMillan, P.J. (1988). Cruise report: the second stratified random bottom trawl survey of the south Chatham Rise, November 1987. Fisheries Research Centre Internal Report No. 99. 73 p. (Unpublished report held in NIWA library, Wellington.)

Fincham, D.J.; Banks, D.A.; McMillan, P.J. (1987). Cruise report – stratified random bottom trawl survey of the southern Chatham Rise, 600 1200 m, 31 October-7 December 1986. Fisheries Research Division Internal Report No. 74. 63 p. (Unpublished report held in NIWA library, Wellington.)

Fincham, D.J.; McMillan, P.J.; Hart, A.C. (1991). Catches of oreos (Family Oreosomatidae) in New Zealand waters, 1972–88. *New Zealand Fisheries Data Report No. 38.* 58 p.

Foote, K.G. (1987). Fish target strengths for use in echo integrator surveys. *Journal of Acoustic Society of America 82:* 981–987.

Francis, R.I.C.C. (1990). A maximum likelihood stock reduction method. New Zealand Fisheries Assessment Research Document 90/4. 11 p. (Unpublished report held in NIWA library, Wellington.)

Francis, R.I.C.C. (1992). Recommendations concerning the calculation of maximum constant yield (MCY) and current annual yield (CAY). New Zealand Fisheries Assessment Research Document 92/8. 27 p. (Unpublished report held in NIWA library, Wellington.)

Hart, A.C.; McMillan, P.J. (1998). Trawl survey of oreos and orange roughy on the south Chatham Rise, October–November 1995 (TAN9511). *NIWA Technical Report 27.* 48 p.

McMillan, P.J.; Doonan, I.J.; Hart, A.C. (1997). Revision of black oreo life history parameters. New Zealand Fisheries Assessment Research Document 97/8. 13 p. (Unpublished report held in NIWA library, Wellington.)

McMillan, P.J.; Hart, A.C. (1991). Assessment of black and smooth oreos for the 1991–92 fishing year. New Zealand Fisheries Assessment Research Document 91/10. 29 p. (Unpublished report held in NIWA library, Wellington.)

McMillan, P.J.; Hart, A.C. (1994a). Trawl survey of oreos and orange roughy on the south Chatham Rise, October–November 1990 (COR9004). *New Zealand Fisheries Data Report No. 49.* 46 p.

McMillan, P.J.; Hart, A.C. (1994b). Trawl survey of oreos and orange roughy on the south Chatham Rise, October–November 1991 (TAN9104). *New Zealand Fisheries Data Report No. 50.* 45 p.

McMillan, P.J.; Hart, A.C. (1994c). Trawl survey of oreos and orange roughy on the south Chatham Rise, October–November 1992 (TAN9210). *New Zealand Fisheries Data Report No. 51.* 45 p.

McMillan, P.J.; Hart, A.C. (1995). Trawl survey of oreos and orange roughy on the south Chatham Rise, October–November 1993 (TAN9309). *New Zealand Fisheries Data Report No. 60.* 49 p.

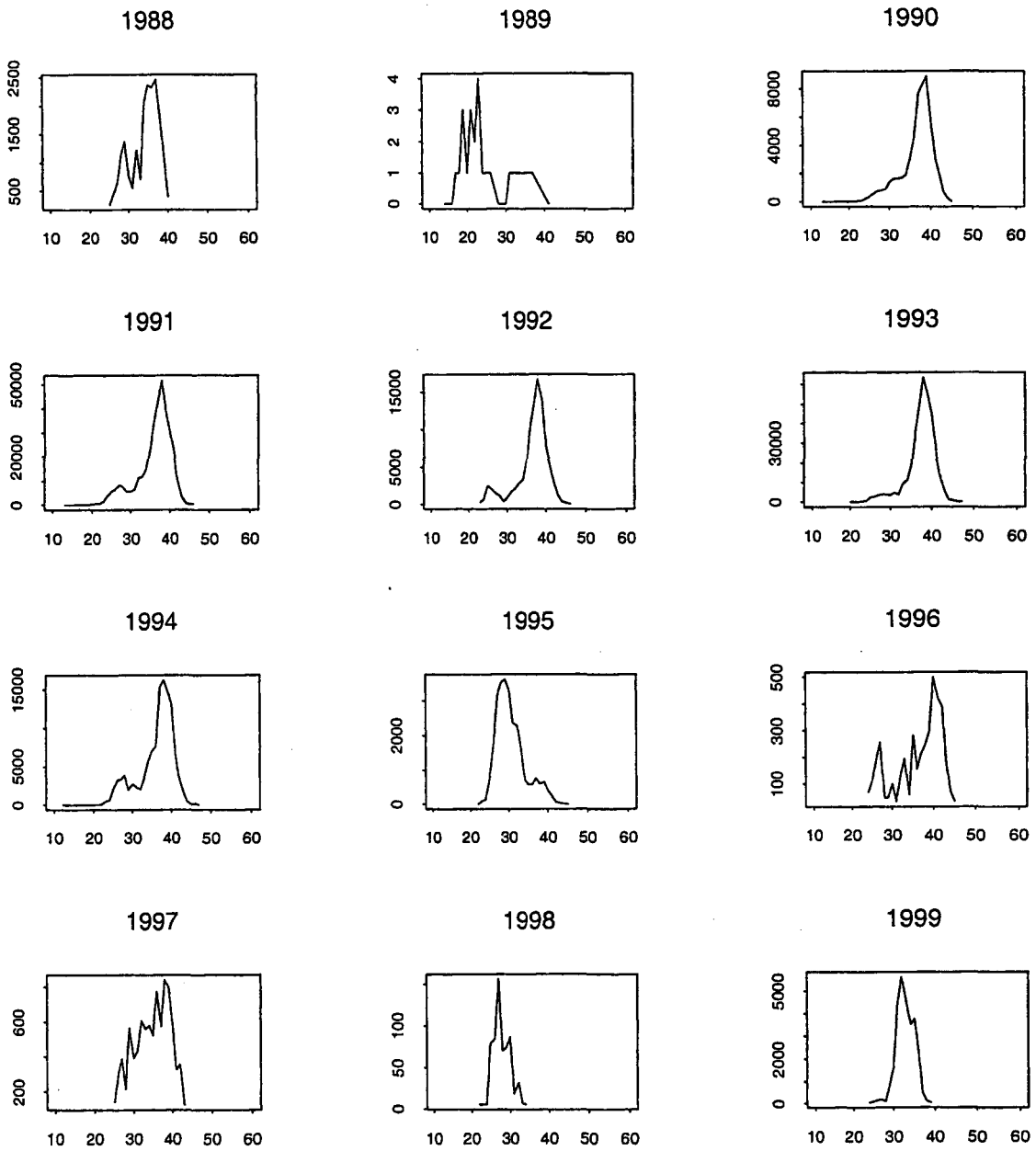
McMillan, P.J.; Hart, A.C.; Banks, D.A. (1988). Black and smooth oreos. New Zealand Fisheries Assessment Research Document 88/35. 18 p. (Unpublished report held in NIWA library, Wellington.)

Smith, P.; Proctor, C.; Robertson, S.; McMillan, P.; Bull, B.; Diggles, B. (2000). Stock relationships of black oreo in New Zealand waters. Final Research Report for Ministry of Fisheries Research Project DEE9801 objective 1 (part two). 79 p. (Unpublished report held by Ministry of Fisheries, Wellington.)

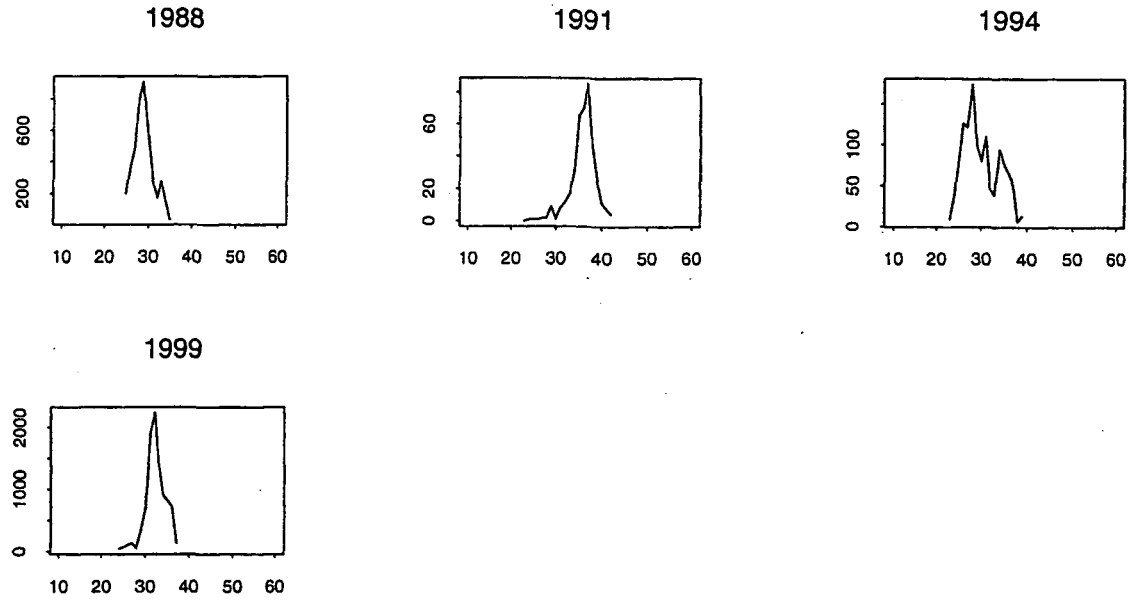
Stanton, T.K. (1982). Effects of transducer motion on echo-integration techniques. *Journal of the Acoustical Society of America 72(3):* 947–949.

Ward, R.D.; Elliot, N.G.; Yearsley, G.K.; Last P.R. (1996). Species and stock delineation in Australasian oreos (Oreosomatidae). Final Report to Fisheries Research and Development Corporation. CSIRO, Hobart. 144 p. (Unpublished report held in CSIRO library, Hobart.)

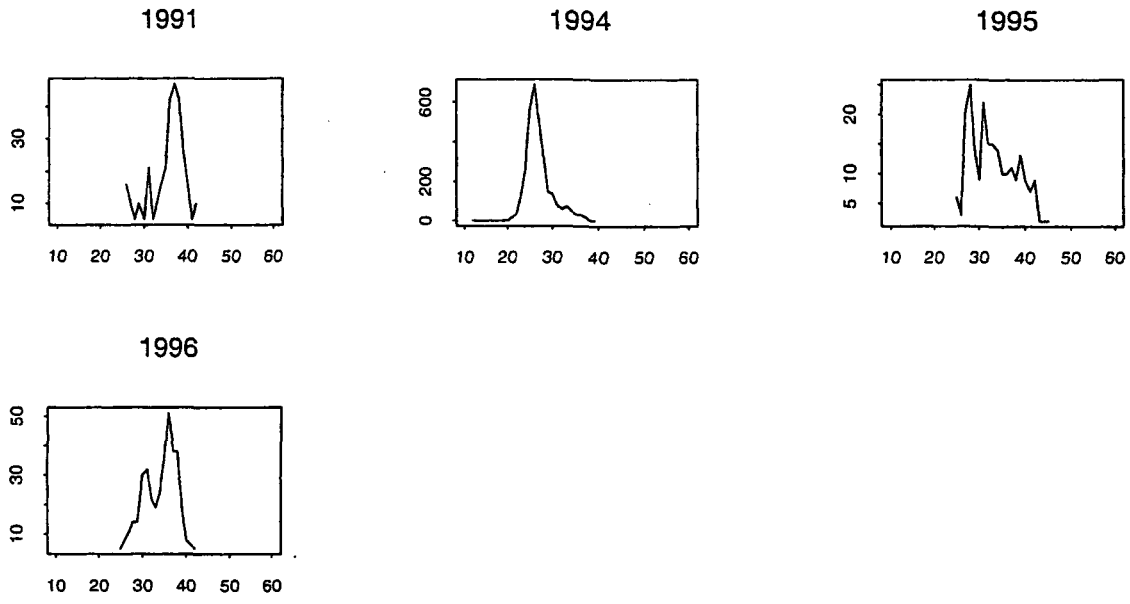
Appendix 1: Black oreo observer-collected length distributions by calendar year from the whole of OEO 4 (176° E to 174° W, south of 44° S). Data from all nations scaled by catch weight. Horizontal (x) axis is total length (cm) and vertical (y) axis is numbers of fish. See Table 5 for numbers of tows sampled and Table 6 for numbers of fish measured.



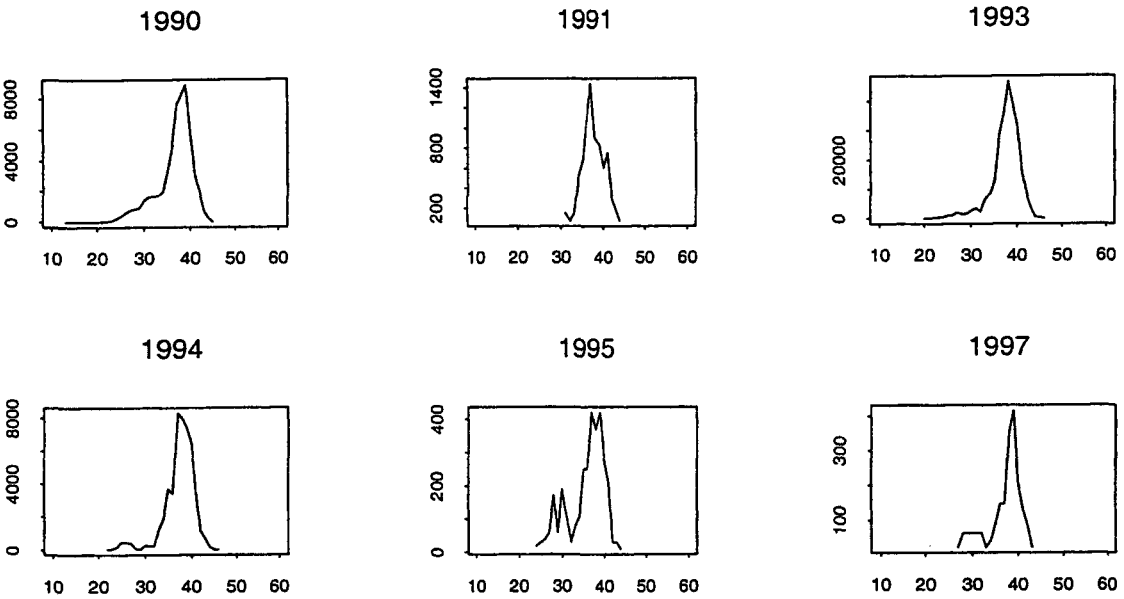
Appendix 2: Black oreo observer-collected length distributions by calendar year from area 1 (178° E to 177° 08'W, south of 44° S, excludes hills). Data from all nations scaled by catch weight. Horizontal (x) axis is total length (cm) and vertical (y) axis is numbers of fish. See Table 5 for numbers of tows sampled and Table 6 for numbers of fish measured.



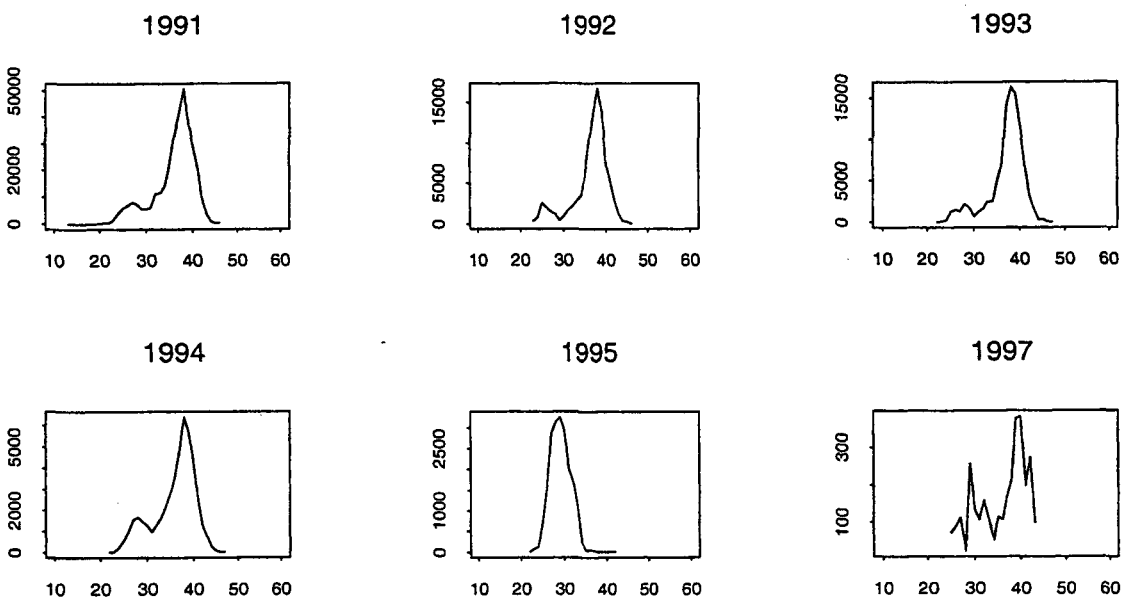
Appendix 3: Black oreo observer-collected length distributions by calendar year from area 2 (177° 08' W to 176° 16' W, south of 44° S, includes hills). Data from all nations scaled by catch weight. Horizontal (x) axis is total length (cm) and vertical (y) axis is numbers of fish. See Table 5 for numbers of tows sampled and Table 6 for numbers of fish measured.



Appendix 4: Black oreo observer-collected length distributions by calendar year from area 3 (176° 16' W to 175° W, south of 44° S, includes hills). Data from all nations scaled by catch weight. Horizontal (x) axis is total length (cm) and vertical (y) axis is numbers of fish. See Table 5 for number of tows sampled and Table 6 for number of fish measured.



Appendix 5: Black oreo observer-collected length distributions by calendar year from area 4 (175° W to 174° W, south of 44° S, includes hills). Data from all nations scaled by catch weight. Horizontal (x) axis is total length (cm) and vertical (y) axis is numbers of fish. See Table 5 for number of tows sampled and Table 6 for number of fish measured.



Appendix 6: Black oreo observer-collected length distributions by calendar year from area 5 (178° E to 177° 08' W, south of 44° S, hills only). Data from all nations scaled by catch weight. Horizontal (x) axis is total length (cm) and vertical (y) axis is numbers of fish. See Table 5 for number of tows sampled and Table 6 for number of fish measured.