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Assessment of OEO 3A black oreo for 1999–2000

I. J. Doonan, P. J. McMillan, R. P. Coburn, and A. C. Hart
NIWA
PO Box 14-901
Wellington

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This series documents the scientific basis for stock assessments and fisheries management advice in New Zealand. It addresses the issues of the day in the current legislative context and in the time frames required. The documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

ASSESSMENT OF OEO 3A BLACK OREO FOR 1999–2000

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1. EXECUTIVE SUMMARY

The biomass of black oreo in OEO 3A was estimated from deterministic stock reduction analysis using the first absolute abundance estimate from the 1997 research acoustic and trawl survey data (TAN9713), new relative abundance indices from standardised catch per unit effort analyses, and a new age selectivity ogive. Yields from the stock were low because the productivity of black oreo, based on unvalidated age estimates, is low. For the base case analysis (absolute abundance estimate plus New Zealand and Soviet standardised CPUE abundance estimates), the 95% confidence interval for B_0 was 103 000–129 000 t and the 95% confidence interval for long-term MCY was 1300–1700 t. Black oreo mean catch per year from 1988–89 to 1997–98 from OEO 3A (about 3500 t) was higher than the range of long-term MCY.

2. INTRODUCTION

2.1 Overview

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

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

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

A new stock assessment for black oreo in OEO 3A is presented based on the first estimates of absolute abundance for black oreo from research acoustic and trawl survey data plus abundance indices from a new standardised CPUE analysis. Estimates of biomass and yields were modelled using deterministic recruitment incorporating an age selectivity using the 1997 black oreo biological parameters and an updated catch history. A smooth oreo stock assessment was presented by Doonan *et al.* (1999).

2.2 Description of the fishery

Black oreo are caught by trawling at depths of 600–1200 m southern New Zealand waters (Figure 1). The OEO 3A south Chatham Rise fishery is the largest black oreo fishery in the EEZ (*see* Table 2) and is carried out between 172° and 176° E on undulating terrain (short plateaus or terraces and "drop-offs") with some fishing on seamounts. In the early years of the fishery black oreo was a target species (Soviet vessels), but in recent years it has been more likely to be a bycatch of smooth oreo target fishing.

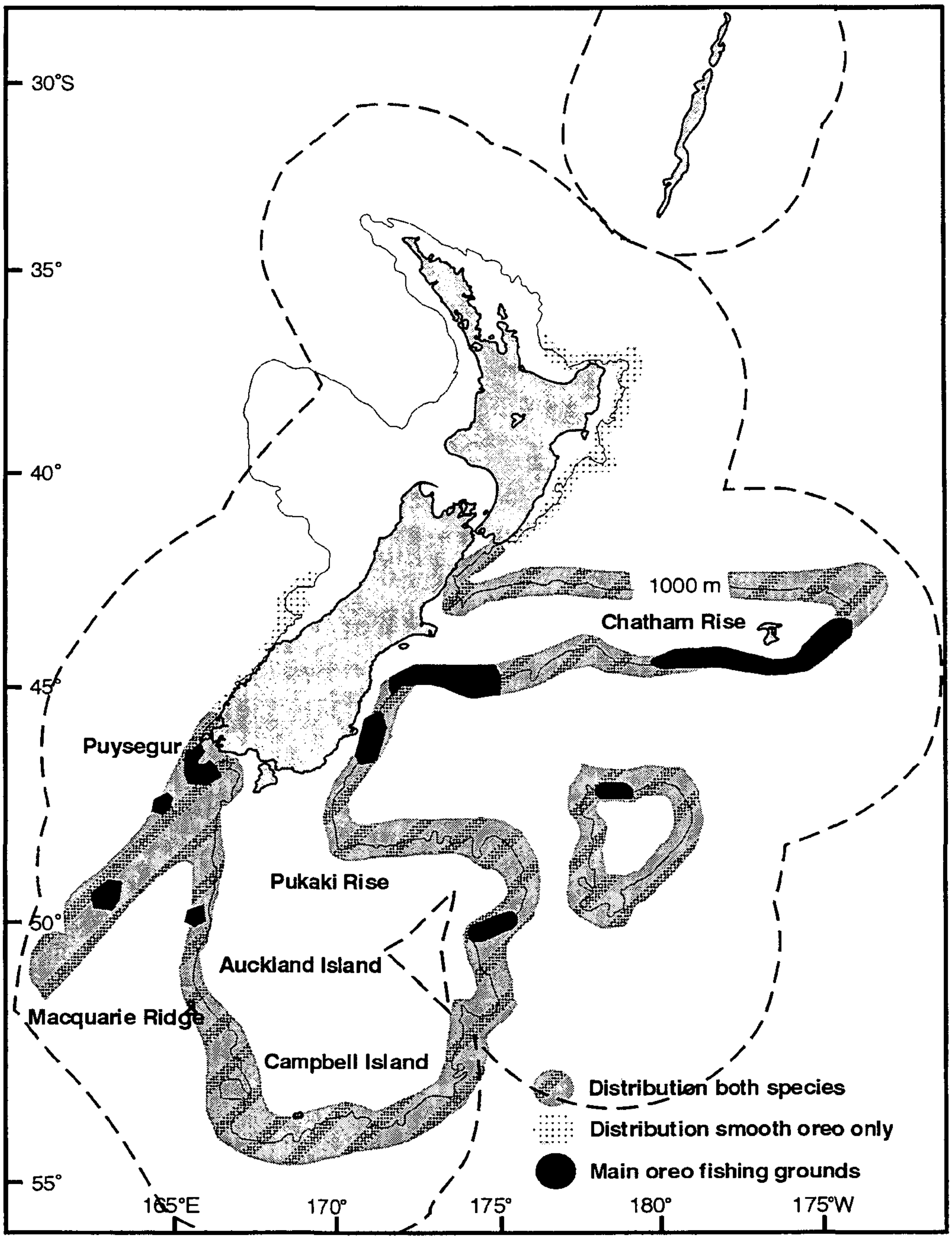


Figure 1: The main fishing grounds and distribution of black oreo and smooth oreo.

2.3 Literature review

The literature was summarised by McMillan *et al.* (1988) and McMillan & Hart (1991). The 1999 stock assessment was summarised by Annala *et al.* (1999). 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.

3. REVIEW OF THE FISHERY

3.1 TACCs, catch, landings, and effort data

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

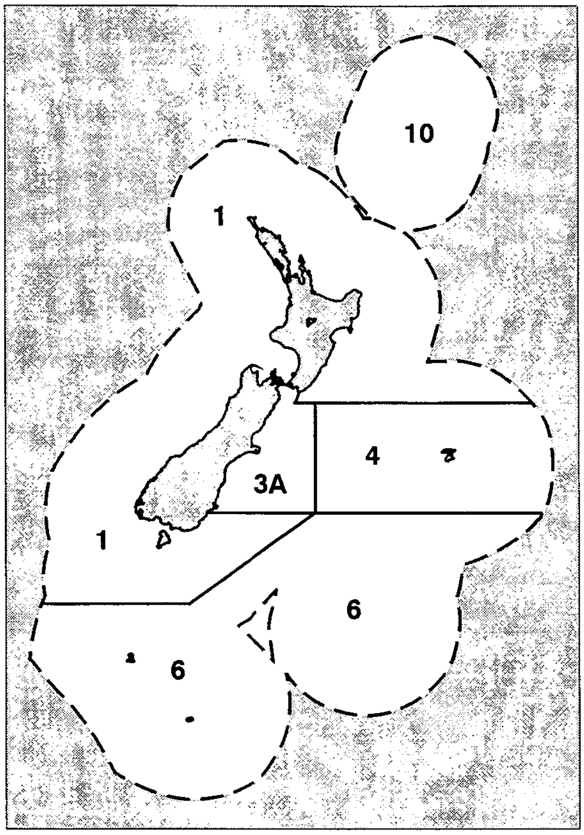


Figure 2: Oreo management areas.

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

The oreo fishery started in about 1972 when the Soviets reported 7000 t (probably black oreo and smooth oreo combined, *see* Doonan *et al.* (1995a)) from the New Zealand area (Table 1). Reported landings of oreos (combined species) and TACs from 1978–79 until 1997–98 are given in Table 2. The Chatham Rise TAC was the same from 1982–83 to 1995–96 (about

10 000 t for OEO 3A and 7000 t for OEO 4), but the TAC for OEO 3A was reduced to 6600 t for the 1996–97 fishing year. A voluntary agreement between the fishing industry and the Minister of Fisheries to limit catch of smooth oreo from OEO 3A to 1300 t (of the total oreo TAC of 6600 t) was in place for 1998–99. Reported estimated catches by species from tow by tow data recorded in catch and effort logbooks (Deepwater, TCEPR, and CELR) are given in Table 3. The values recorded as "OEO" have been scaled up to the amounts recorded for each fishstock in Table 2, i.e., SSO + BOE + OEO (Table 3) = fishstock (*see* Table 2).

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

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

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

Table 2: Total reported landings (t) for all oreo species combined by Fishstock from 1978–79 to 1997–98 and TACs (t) from 1982–83 to 1997–98

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

Source: FSU from 1978–79 to 1987–88; QMS/ITD from 1988–89 to 1997–98.
* 1 April to 31 March.
\# 1 April to 30 September. Interim TACs applied.
† 1 October to 30 September.
Note: TAC for OEO 10 (Kermadec) is 10 t but there has been no reported catch.

Table 3: Reported estimated catch (t) by species (smooth oreo (SSO), black oreo (BOE), and unspecified species (OEO)) by Fishstock from 1978–79 to 1997–98. OEO includes the total reported landing from Table 1 minus the BOE and SSO catch, i.e., the balance to make the total the same as that reported

	SSO				BOE				OEO				
Year	OEO 1	OEO 3A	OEO 4	OEO 6	OEO 1	OEO 3A	OEO 4	OEO 6	OEO 1	OEO 3A	OEO 4	OEO 6	Total
1978–79*	0	0	0	0	9	0	0	0	2 799	1 366	8 041	0	12 231
1979–80*	16	5 075	114	0	118	5 588	566	18	0	8	0	0	11 791
1980–81*	1	1 522	849	2	66	8 758	5 224	215	400	4 424	4 142	0	25 851
1981–82*	21	1 283	3 352	2	0	11 419	5 641	4 378	0	41	9	0	26 514
1982–83*	28	2 138	2 796	60	6	6 438	1 088	705	128	0	42	0	13 680
1983–83#	9	713	1 861	0	1	3 693	1 340	354	30	3	9	0	8 015
1983–84†	1 246	3 594	4 871	1 315	1 751	5 524	1 214	2 254	243	72	18	0	22 111
1984–85†	828	4 311	4 729	472	544	3 897	1 651	1 572	103	76	10	0	18 204
1985–86†	4 257	3 135	4 921	72	1 060	2 184	961	54	0	12	0	0	16 820
1986–87†	326	3 186	5 670	0	163	4 026	1 160	0	36	7	0	0	15 093
1987–88†	1 050	5 897	7 771	197	114	3 140	903	0	65	12	0	0	19 159
1988–89†	261	5 864	6 427	–	86	2 719	1 087	0	85	1 608	933	0	19 070
1989–90†	1 141	5 355	5 320	–	872	2 344	439	–	96	1 587	1 589	0	18 744
1990–91†	1 437	4 422	5 262	81	2 314	4 177	793	222	812	1 228	881	0	21 666
1991–92†	1 008	6 096	4 797	2	2 384	3 176	1 702	15	764	800	958	16	21 718
1992–93†	1 716	3 461	3 814	529	3 768	3 957	1 326	69	360	1 871	2 837	217	23 924
1993–94†	2 000	4 767	4 805	808	2 615	4 016	1 553	35	295	323	1 961	140	23 318
1994–95†	835	3 589	5 272	1 811	385	2 052	545	230	263	959	1 863	487	18 291
1995–96†	2 517	3 591	5 236	2 562	1 296	3 361	364	1 166	970	834	1 206	707	23 810
1996–97†	2 203	3 063	5 390	2 492	2 578	3 549	530	1 950	479	712	1 136	1 144	24 779
1997–98†	1 385	4 565	5 814	2 477	1 167	1 494	801	1 877	127	271	396	865	21 239

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

3.1.1 CPUE analysis

Data

The black oreo catch and effort data were restricted to that area within OEO 3A (the "CPUE study area") where the main fishery occurred from 1979–80 to 1997–98 (*see* figures 1 and 5 in Coburn *et al.* 1999). Soviet and New Zealand data were analysed separately. The CPUE study area contained 99% of the Soviet OEO 3A target black oreo catch from 1979–80 to 1988–89 and 81% of the New Zealand OEO 3A black oreo catch for tows that targeted black oreo, smooth oreo, and unspecified oreo from 1986–87 to 1997–98.

Method of CPUE analysis

The CPUE analysis method was described by Doonan *et al.* (1995a) and Coburn *et al.* (1999) and used a two part model which separately analysed the tows that caught black oreo using a log-linear regression (positive catch regression) and a binomial part which used a Generalised Linear Model with a logit link for the proportion of successful tows (zero catch regression). The variables considered in the analyses included year, latitude, longitude, depth, season, time, target species, and vessel (Table 4). The mean *c.v.*s for the combined indices (all years) were estimated using a jackknife technique (Doonan *et al.* 1995a). The *c.v.* for the reference year was zero, so that year was excluded when the mean *c.v.* was calculated. The individual annual (including the reference year) *c.v.* estimates for the New Zealand and Soviet standardised CPUE abundance indices used in the stock reduction analysis were calculated by dividing the mean annual *c.v.*s from each standardised CPUE analysis by $\sqrt{2}$. This allowed the reference year and *c.v.* for both series to be included in the stock reduction analysis.

Table 4: Summary of non-year variables that could be selected in the regression models used in the CPUE analysis. All were categorical variables. "df" was the number of parameters to be estimated for that variable

Variable	df	Description
Latitude	8	Latitude at start of tow.
Longitude	8	Longitude at start of tow.
Depth	8	Depth at start of tow. Bins were defined to contain about the same number of tows.
Season	8	The fishing year divided into 8 periods.
Time	8	Time of day at start of tow, blocked into 8 periods.
Target	3	Target species for the tow (black, smooth, or generic oreo, OEO). NZ data only.
Vessel	–	A parameter estimated for each vessel.

Results of CPUE analysis

For the Soviet abundance series, the final model for positive catch used vessel and year (R^2 = 29%), and that for zero catch used year and vessel (R^2 = 17%). Data from 1979–80 were not used in the stock reduction analysis because that index had a high *c.v.* The mean *c.v.* of the remaining indices, 34%, was taken as the *c.v.* for the abundance index series. For the New Zealand abundance series, the final model for positive catch used vessel, depth, year, and longitude (R^2 = 23%) and that for zero catch used vessel, depth, and year (R^2 = 20%). The mean *c.v.* of the indices, 51%, was taken as the *c.v.* for the abundance index series. The time series of abundance indices for the Soviet and New Zealand data is given in Table 5. The Soviet series declines steeply at the start then flattens out in the last 5 years. The New Zealand series fluctuates with three peaks and short declines, but the indices at the end of the series are about half the value of those at the start.

Table 5: Soviet and New Zealand time series of combined abundance indices from a standardised CPUE analysis. –, no estimate

Year	Soviet	New Zealand
1979–80*	1.82	–
1980–81	1.45	–
1981–82	1.30	–
1982–83	1.00	–
1983–84	0.64	–
1984–85	0.46	–
1985–86	0.41	–
1986–87	0.44	1.37
1987–88	0.15	1.54
1988–89	0.44	0.54
1989–90	–	1.00
1990–91	–	1.10
1991–92	–	1.55
1992–93	–	1.25
1993–94	–	1.20
1994–95	–	0.65
1995–96	–	0.90
1996–97	–	1.08
1997–98	–	0.78

*Data from 1979–80 were not used in the stock reduction analysis because that index had a high *c.v.*

3.2 Other information

Mean (total) length

Mean length changes over time might indicate the status of the stock. For example, if recruitment was assumed to be relatively constant, then the standing stock of older fish should decline over time because of fishing and the proportion of older to younger fish would be expected to decline. Therefore the mean length should also decline over time.

Mean length per year was estimated for males and females from all observer length data collected from commercial vessels fishing in OEO 3A (Figure 3). Mean length per year for males and females was also estimated for data which had been separated into those from New Zealand and Soviet vessels and those from depths greater than and less than 900 m (Tables 6 and 7 and Figure 4). Data were analysed in this way to examine nationality, depth, and area sampling effects and to enable comparison with previous analyses (McMillan *et al.* 1998).

Mean length for the combined data appeared to decline from 1979 to 1998 by about 3 cm for males and about 4 cm females (*see* Figure 3), but when the data were analysed by nation and depth (*see* Tables 6 and 7 and Figure 4) they were shown to be erratically collected, with no samples from 1981–85 and 1992–93. Although total sample numbers by nation/depth are similar, the numbers by nation/depth by year varied greatly. For all series, the means at the end are less than those at the start of the series.

Table 6: Numbers of tows where black oreo length/sex samples were taken by observers in OEO 3A from 1979 to 1998. Data are divided into two depth zones and from Soviet and New Zealand vessels. Total includes tows observed on all vessels (not just NZ and Soviet vessels)

Year	New Zealand		Soviet		Total
	< 900 m	≥ 900 m	< 900 m	≥ 900 m	
1979	0	0	0	24	24
1980	0	0	0	6	6
1981	0	0	0	0	0
1982	0	0	0	0	0
1983	0	0	0	0	0
1984	0	0	0	0	0
1985	0	0	0	0	0
1986	0	0	6	2	9
1987	0	0	1	5	9
1988	1	7	32	3	43
1989	0	0	0	0	16
1990	5	12	0	0	17
1991	8	3	0	0	11
1992	0	0	0	0	0
1993	0	0	0	0	0
1994	19	8	0	0	27
1995	6	3	0	0	9
1996	1	3	1	0	5
1997	15	0	0	0	17
1998	1	0	0	0	7

Table 7: Numbers of black oreo length/sex samples taken by observers in OEO 3A from 1979 to 1998. Data are divided into two depth zones and from Soviet and New Zealand vessels. There were no data from 1981 to 1985. Total includes samples taken on all vessels (not just NZ and Soviet vessels)

Year	New Zealand		Soviet		Total
	< 900 m	≥ 900 m	< 900 m	≥ 900 m	
1979	0	0	0	2 293	2 293
1980	0	0	0	886	886
1986	0	0	707	271	1 081
1987	0	0	214	858	1 284
1988	100	694	4 178	312	5 284
1989	0	0	0	0	2 124
1990	512	1 114	0	0	1 626
1991	904	251	0	0	1 155
1992	0	0	0	0	0
1993	0	0	0	0	0
1994	1 750	835	0	0	2 585
1995	660	233	0	0	1 030
1996	114	373	54	0	541
1997	1 290	0	0	0	1 502
1998	90	0	0	0	865

3.3 Recreational and Maori customary fisheries

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

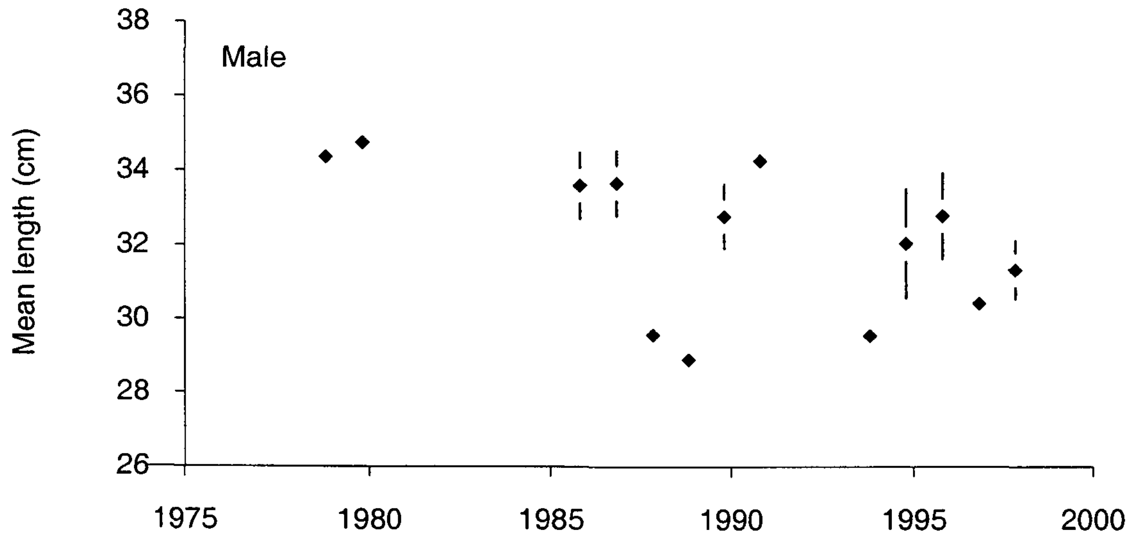
3.4 Other sources of fishing mortality

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

4. RESEARCH

4.1 Stock structure

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". There are no genetic data to define stock structure on the Chatham Rise.



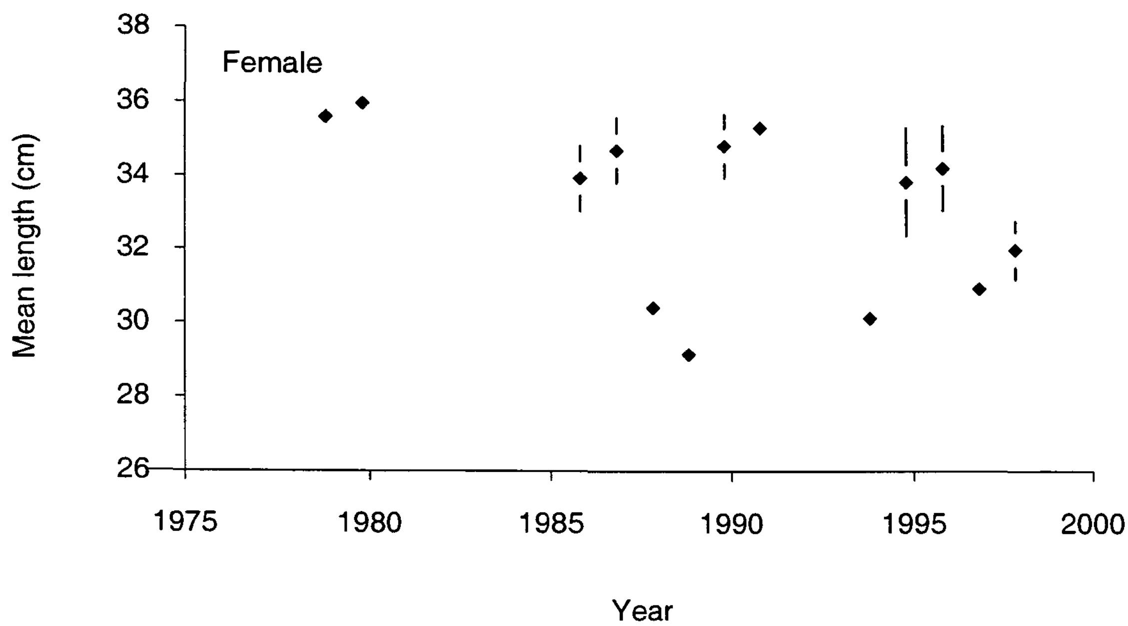


Figure 3: All observer length frequency data from 1979 to 1998 scaled to catch. Mean length (•). Vertical lines are ± 2 s.e.

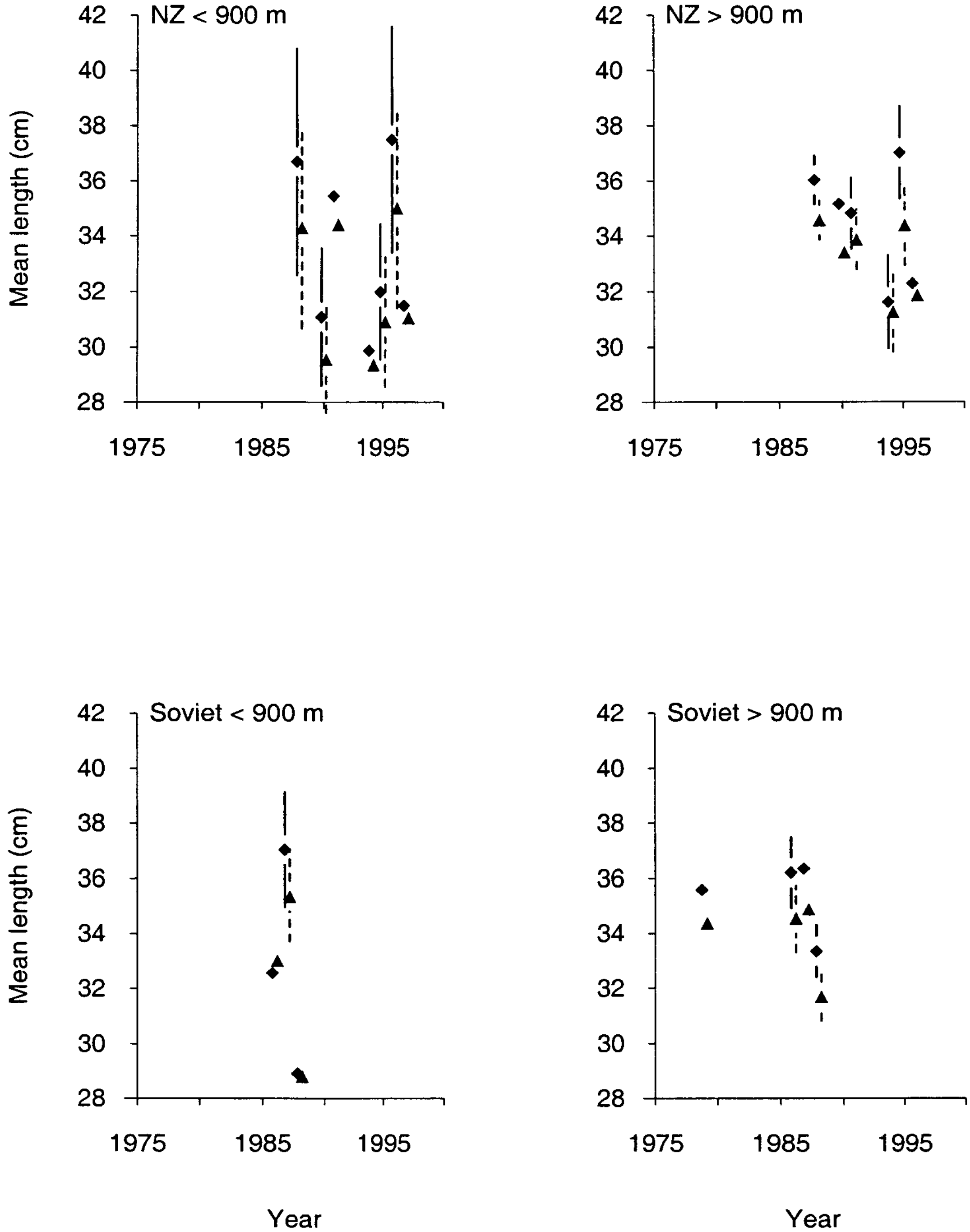


Figure 4: Observer length frequency data from 1979 to 1998 from New Zealand or Soviet vessels, and from less than or greater than 900 m, scaled to catch. Mean length (females ◆ and males ▲). Vertical lines are ± 2 s.e., solid (females), dashed (males).

4.2 Age estimates

Estimates based on counting zones observed in otolith thin sections of Chatham Rise samples were given by Doonan *et al.* (1995b) and for Puysegur samples by McMillan *et al.* (1997) and gave maximum ages of 153 years for a 45.5 cm TL fish and 142 years for a 42.3 cm TL fish respectively. Estimates for Australian fish were made by counting zones observed in otolith thin sections (Stewart & Smith 1994) and gave a maximum age of 100 years and by Fenton, University of Tasmania, unpublished results) who used "radiometric techniques" involving measurement of the ratio of the radioisotopes ^{210}Pb and ^{226}Ra in otoliths and reported the "oldest black oreo analysed about 100 years old...".

4.3 OEO 3A empirical age selectivity ogive

Initial estimates of biomass and yield presented to the Deepwater Stock Assessment Working Group were made using knife-edge recruitment set at 33 cm TL (23 years). This suggested that a large proportion of the black oreo biomass from the flat (88%) was pre-recruit fish and this was too large given that constant recruitment was assumed in the modelling. Also a large proportion of the observer data was pre-recruit fish (knife-edge recruitment set at 33 cm TL) suggesting that the fishery caught mainly small fish. A new analysis was developed which used an age selectivity ogive for the recruited population. Observer and research length data were analysed to derive a length selectivity ogive, and the length ogive was then converted into an age selectivity ogive using established growth information (Annala *et al.* 1999).

Areas within OEO 3A containing small and large sized black oreo

The observer length data in Section 3.2 varied with sampling time, area, and depth. Consequently the structure of the distribution of small and large fish within OEO 3A and the flip-flop nature of the mean length by year data were investigated by analysing commercial catch, research acoustic results, and observer length data.

(a) Commercial catch data

This analysis was based on the observation during research surveys that there were extensive juvenile fish marks on smooth and gently sloping bottom in the shallower depths of the black oreo distribution (less than about 850 m) where long commercial tows were possible. In contrast, larger fish tended to school up into more vertical marks, usually associated with hilly ground or drop-offs in deeper waters where shorter tows were carried out. Tow duration was used to divide the main fishing area in OEO 3A into a small fish area and a large fish area and initially used 100 minutes as the dividing value. This value was based on extensive plotting of commercial tow lengths on the flat and around known hills in the orange roughy and smooth oreo fisheries on the Chatham Rise.

The data used in the final analysis were restricted to commercial tows that were long (over 200 min.) or short (under 60 min.). Tows of about 100 minutes were excluded to sharpen the division between long and short tows and, it was hoped small and large sized black oreo areas. A boundary line was drawn between the short tow and long tow areas using a grid made up of 2-D smoothing of log (duration/100) values, by plotting the zero contour which was equivalent to 100 minutes (Figure 5). Most of the area divided into a northern long tow and a southern short tow area corresponding to shallow and deeper areas. There were some small areas of overlap (Figure 5).

(b) Juvenile fish marks from acoustic survey results

Juvenile fish marks observed on acoustic transects during the 1997 survey were analysed to determine where they occurred in relation to the boundary line drawn from commercial tow length data. The deep end of juvenile marks seen on transects in the 1997 acoustic survey (S) mostly occurred on the shallow side of the boundary line (*see* Figure 5). Two were on the deeper side, suggesting that there was not always a sharp dividing line between small and large fish.

(c) Observer length data

Observer data were grouped into three classes based on the mean length of the black oreo catch in each tow: small fish (mean less than 30.5 cm), large fish (mean greater than 32.6 cm), and intermediate fish. These divisions were based on the frequency of the mean lengths (Figure 6), which showed two main modes. The positions of the small fish tows were mainly on the shallow side of the boundary line (Figure 7), and only 18 (19%) out of 93 were deeper than the boundary line. The points north of latitude 44.4° S were at depths of 590 to 708 m, at the shallow end of black oreo depth distribution and outside the main distribution of oreo tows. They were atypical of the fishing effort. Another atypical grouping was the cluster near longitude 173.2° E, which contained about a third of the total small fish samples. The positions of the large fish tows were mainly on the deep side of the boundary line (Figure 8), and only 7 (7%) out of 98 were shallower than the boundary line.

<u>Conclusion</u>

The spatial structure of the small and large sized fish in the observer data was largely captured by the boundary line. Clearly, the flip-flop nature of the yearly length distributions from observer data is the result of a small number of observed tows which can occur entirely in the small fish area or the large fish area.

Length selectivity ogive (Figure 9)

Research survey length frequency data from 1986, 1987, 1990, 1991–93, and 1995, scaled by abundance, and all available observer length frequency data from 1979–80 to 1997–98 weighted by catch were used to derive the ogive.

The following assumptions were made.

1. The observer length frequency was an estimate of the recruited population length frequency.
2. The population length frequency was derived from the right hand limb of the combined research length frequency. The left hand limb of the population length frequency was approximated from the maximum frequency seen in the research length frequency.
3. Fish were fully recruited at about 37 cm TL.

The length frequency curves were converted into the relative frequency of the population at length. The observer length frequency curve was scaled so that the right hand limb of the curve coincided with the right hand limb of the population (research) length selectivity curve based on the assumption that fish of about 37 cm or greater were fully recruited (3 above). The length selectivity ogive was calculated by dividing the population relative frequency by the observer relative frequency at each length.

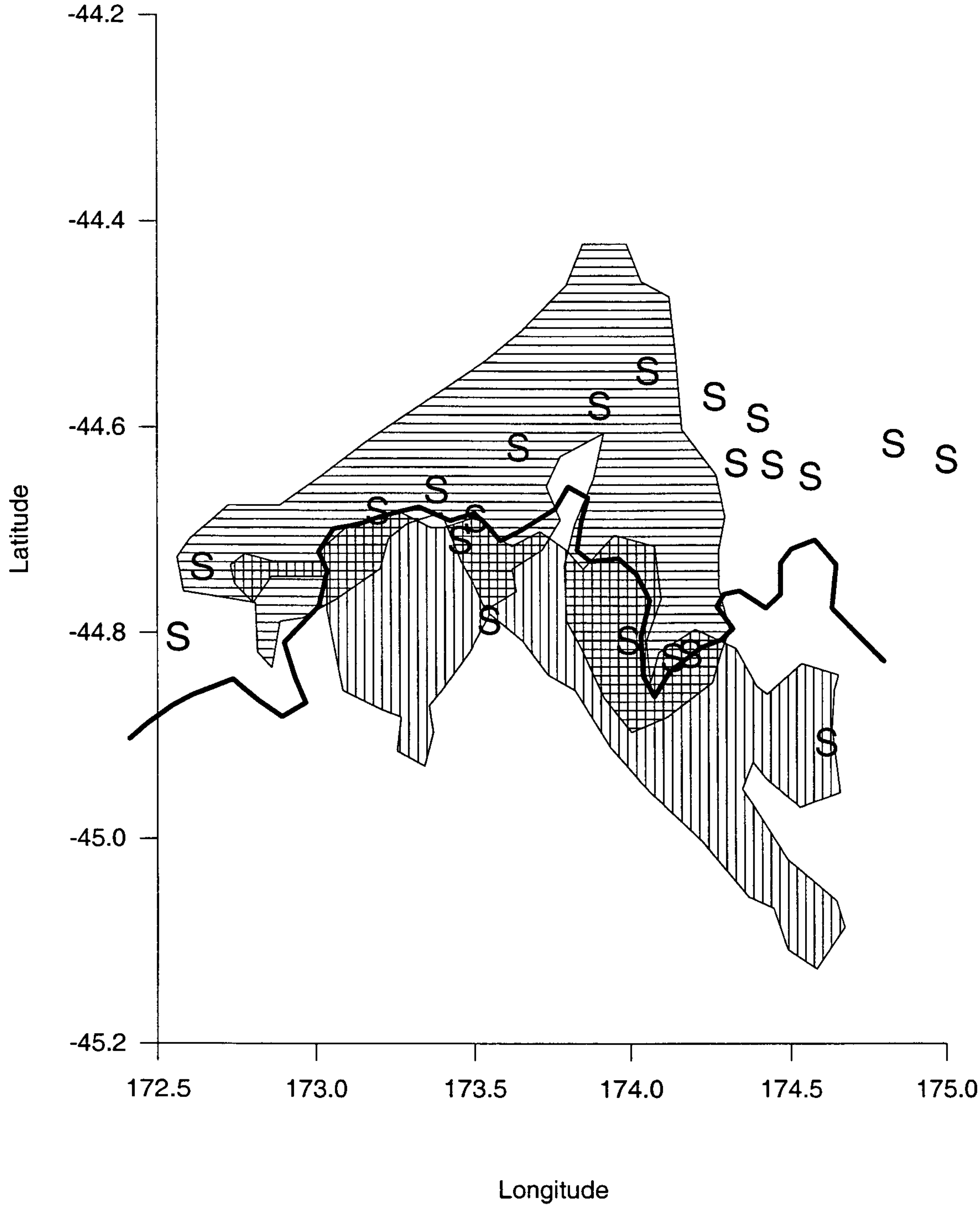


Figure 5: **Estimated boundary line between small and large black oreo distribution (thick black line). The southern area (vertical lines) contains 90% of the short tows (under 60 min). The northern area (horizontal lines) contains 90% of the long tows (over 200 min). Overlap areas are cross-hatched. "S" marks the position of the deep end of small black oreo marks on transects in the 1997 acoustic survey.**

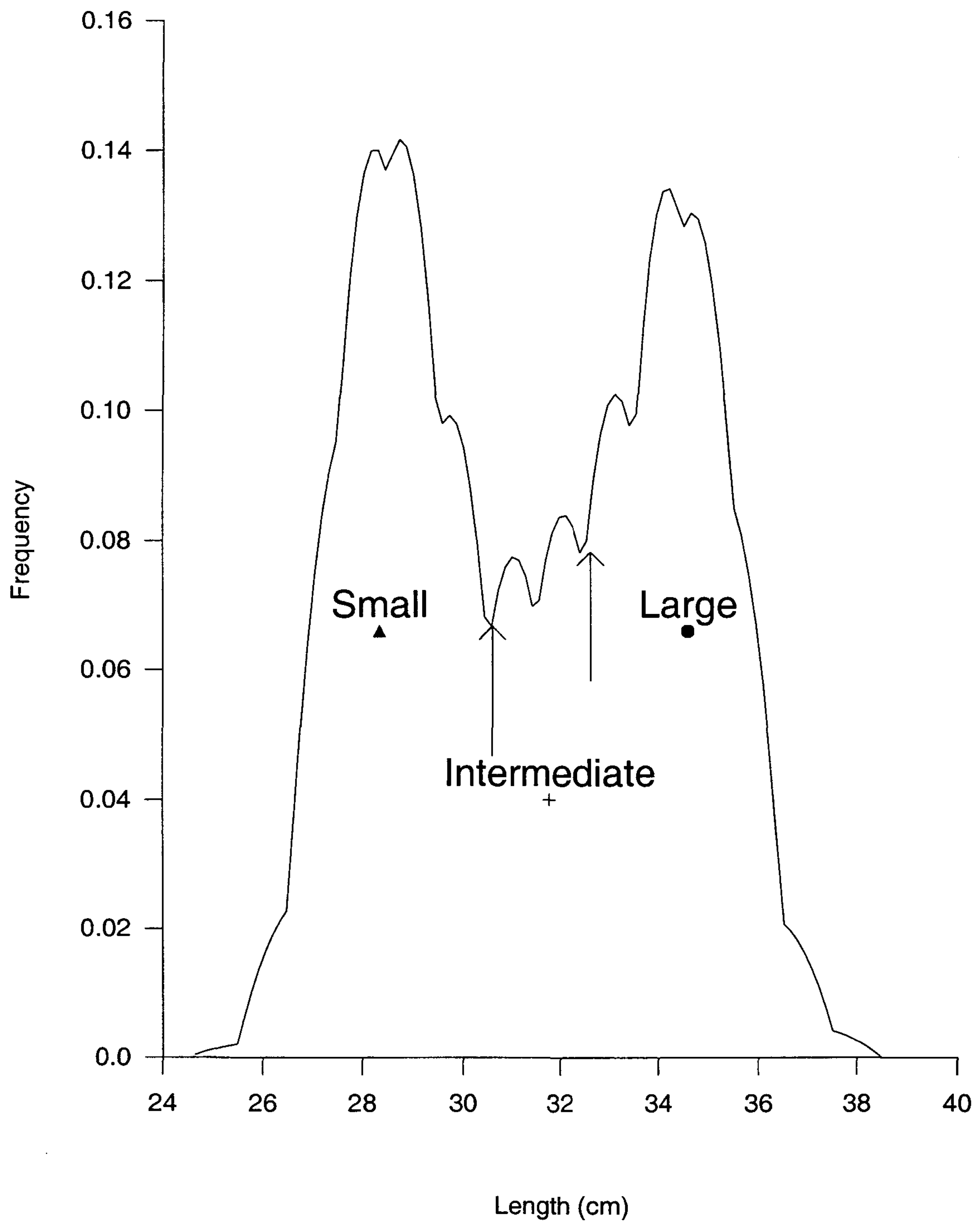


Figure 6: Distribution of black oreo mean length by tow for the observer data collected in OEO 3A, from 1979 to 1997–98 fishing years. Arrows divide the mean lengths into small fish (mean length less than 30.5 cm), intermediate, and large (mean lengths greater than 31.6 cm). The plotting symbols for each size class used in Figures 7 & 8 are shown.

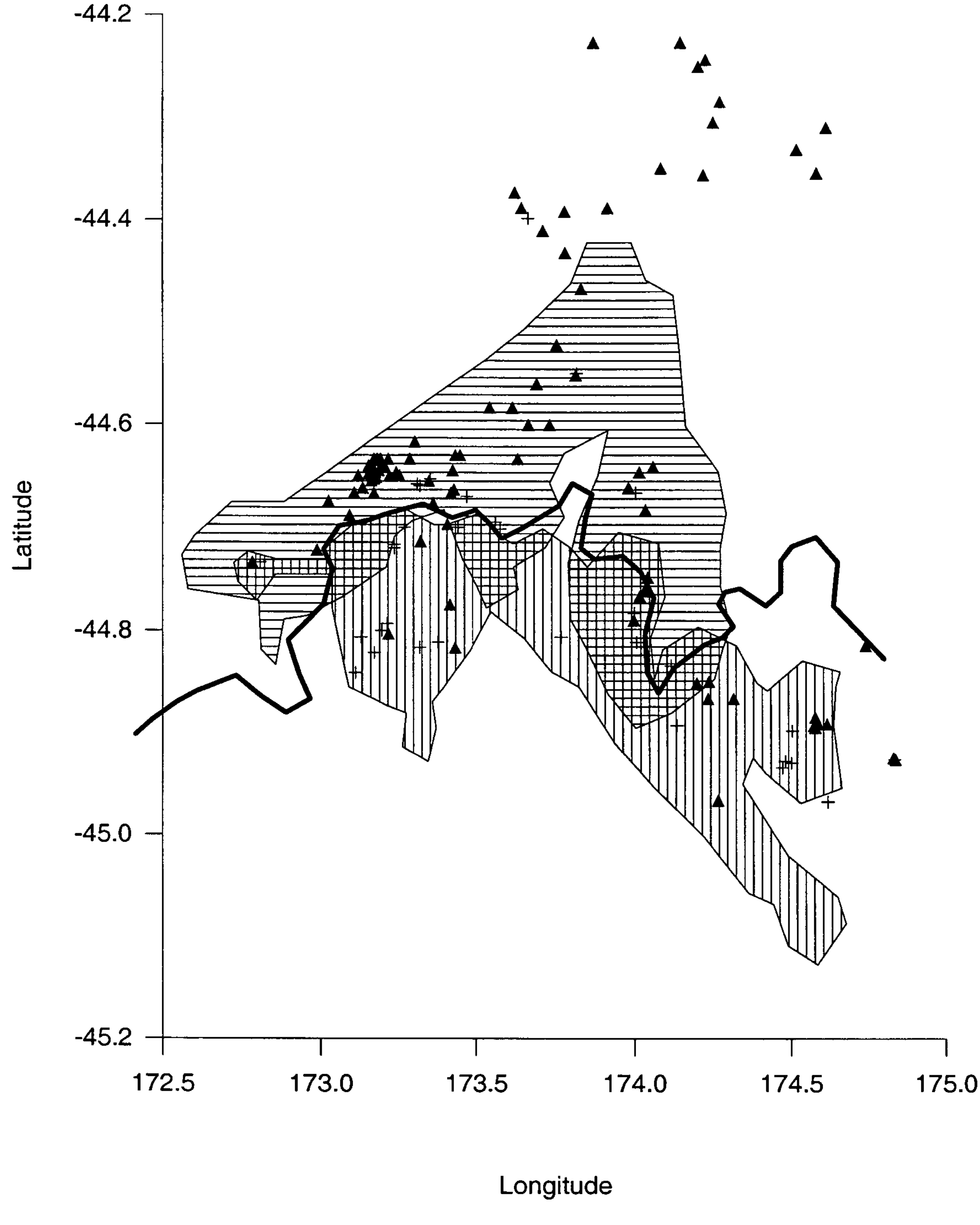


Figure 7: Positions of tows with small (▲) and intermediate (✚) black oreo mean lengths in the OEO 3A observer data compared to the small-large boundary line (thick black line). ***See*** **Figures 5 and 6 for explanations of areas and the definition of small and intermediate.**

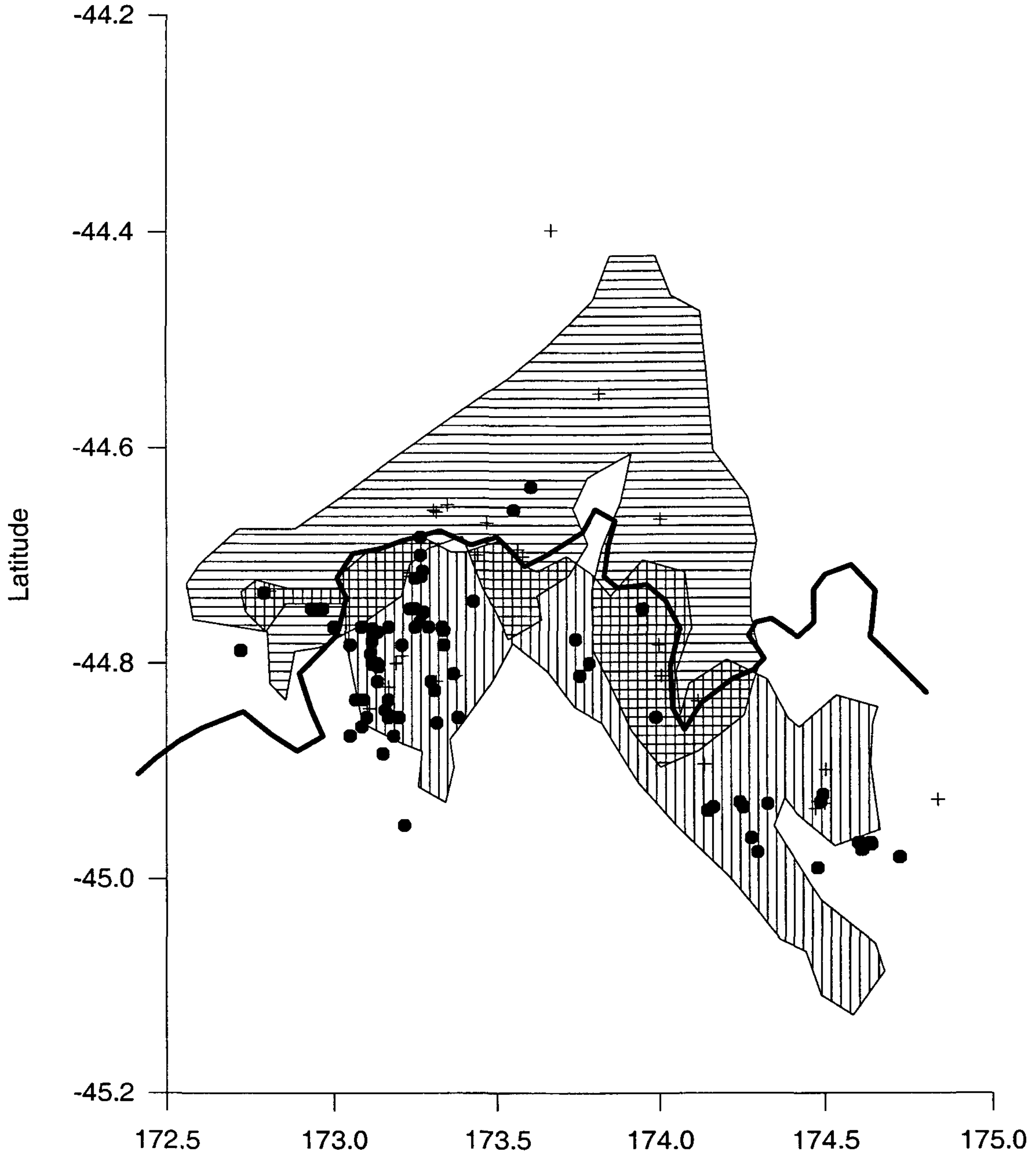


Figure 8: Positions of tows with large (●) and intermediate (✚) black oreo mean lengths in the OEO 3A observer data compared to the small-large boundary line (thick black line). *See* Figures 5 and 6 for explanations of areas and the definition of large and intermediate.

Age selectivity ogive (Figure 10)

The length selectivity ogive was converted to an age selectivity ogive (dots and crosses in Figure 10) by converting the length to age using the von Bertalanffy equation in the 1999 plenary report (Annala *et al.* 1999).

4.3 Resource surveys

Trawl surveys

Trawl surveys of oreos on the south Chatham Rise were carried out in most years between 1986 and 1995 (Table 8). 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 8: Random stratified trawl surveys (standard, i.e. flat tows only) for oreos on the south Chatham Rise (OEO 3A & OEO 4)

Year	Area (km^2)	Vessel	Survey area	No. of stations
1986	47 137	*Arrow*	South	186
1987	47 496	*Amaltal Explorer*	South	191
1990	56 841	*Cordella*	South, southeast	189
1991	56 841	*Tangaroa*	South, southeast	154
1992	60 503	*Tangaroa*	South, southeast	146
1993	60 503	*Tangaroa*	South, southeast	148
1995	60 503	*Tangaroa*	South, southeast	172

Acoustic surveys

Absolute estimates of abundance for OEO 3A black oreo are available from the first acoustic survey of the area which was carried out from 10 November to 19 December 1997 (TAN9713) Doonan (*et al.* 1998). The survey covered the “flat” with a series of random north-south transects over six strata at depths of 600–1200 m (Figure 11). Seamounts were also sampled using parallel and “starburst” transects. Targeted and some random (background) trawling (n = 51) was carried out to identify targets and to determine species composition. The numbers of acoustic transects on the flat and seamounts are given in Table 9. In situ target strength measurements were carried out on 10 marks, including 2 smooth oreo, 2 black oreo, and 6 mixed oreo marks. Preliminary black oreo target strength estimates from the OEO 4 acoustic survey carried out from 26 September to 30 October 1998 (TAN9812) were also used in the analysis.

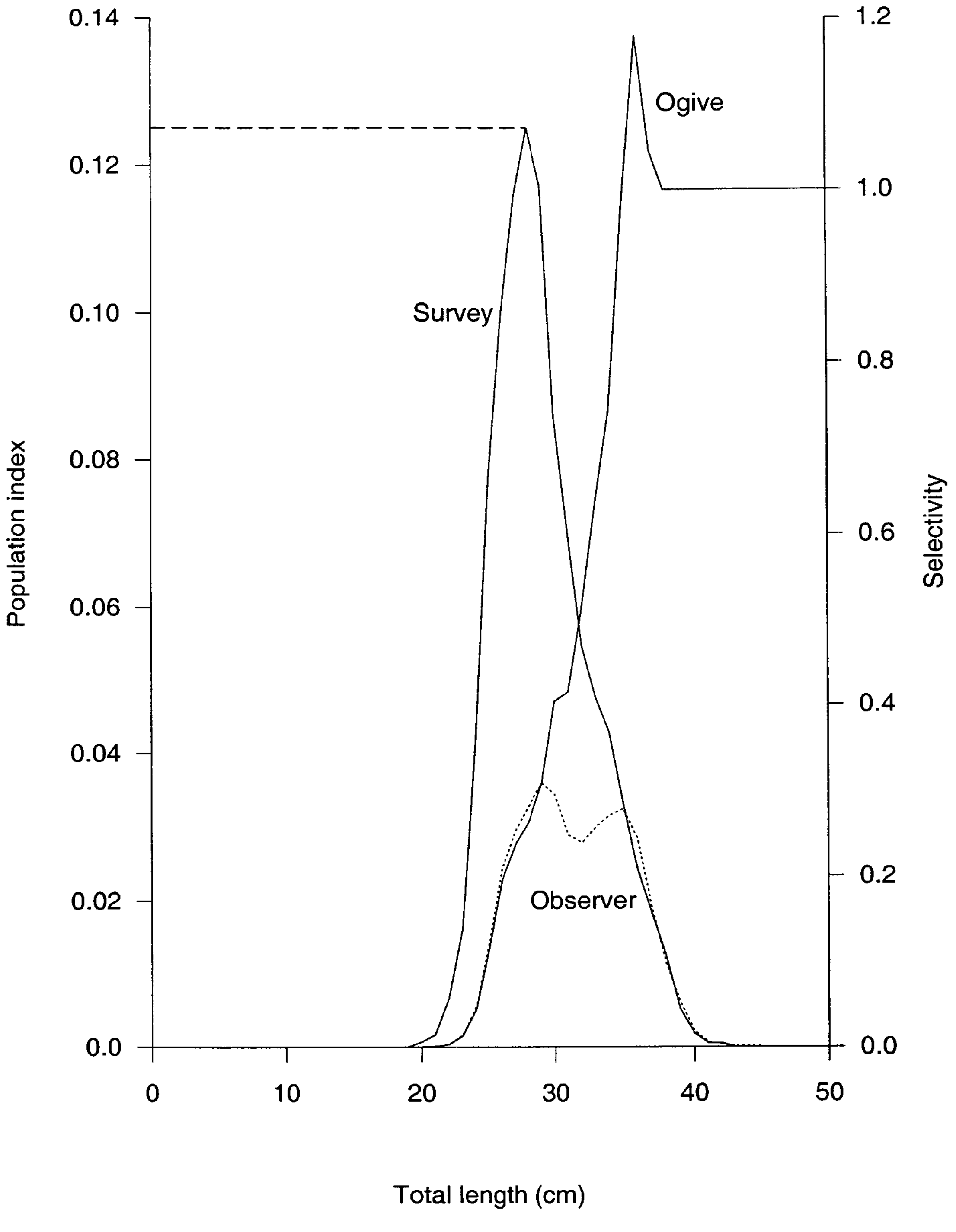


Figure 9: Selectivity ogive by length using combined research (Survey, solid line) data (1986, 1987, 1990, 1991–1993, 1995) scaled by abundance, and observer (dotted line) data (1979 to 1997–98) scaled by catch and also scaled to fit the far right hand side limb of the research curve. The population length frequency is the right hand side limb of the research (Survey) length frequency plus the horizontal dashed line on the left hand side of the research mode.

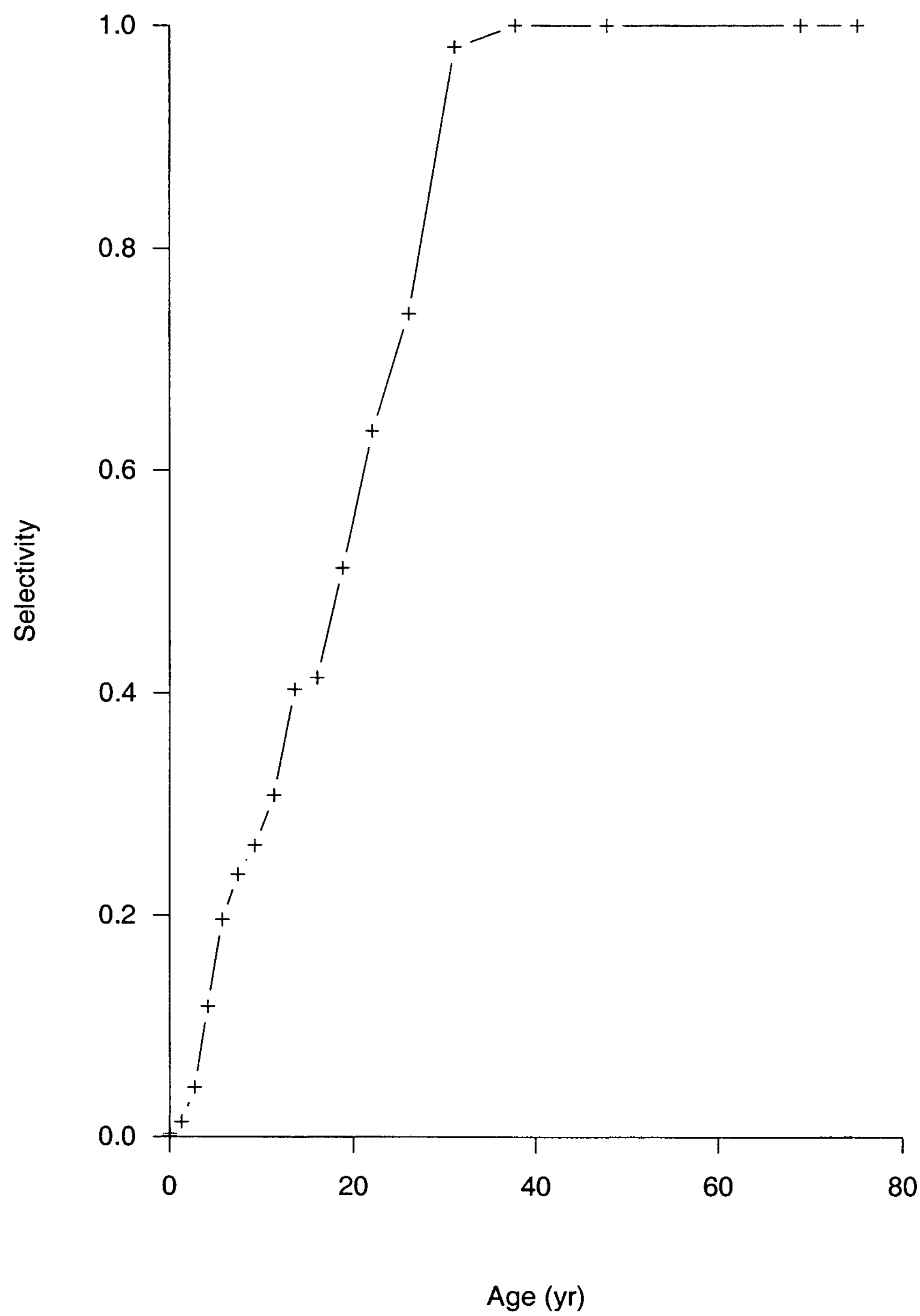


Figure 10: Selectivity ogive by age.

Table 9: Summary of acoustic transects surveyed in area OEO 3A by stratum. For the seamounts, NC is Neil's Condom, NP Neil's Pinny and HA Hill A

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

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

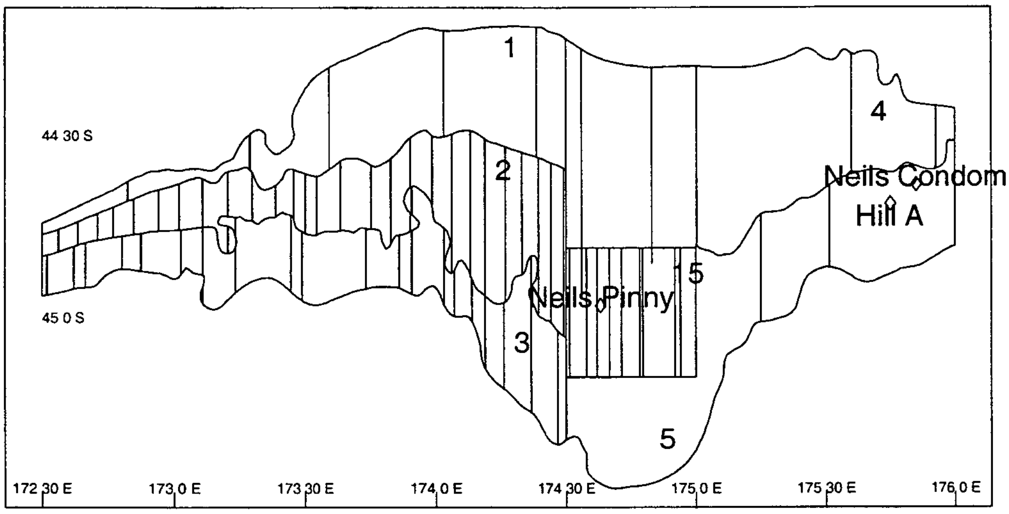


Figure 11: Survey areas for the 1997 Chatham Rise acoustic survey showing strata and transects on the flat and the positions of the hills surveyed in area OEO 3A.

Acoustic absolute abundance estimates

Previous estimates of abundance were made using knife-edge recruitment. A new analysis is presented which incorporates a length (and age) selectivity ogive for the recruited population. Recruited abundance from the acoustic data was estimated by:
1. estimating the absolute abundance for each length centimetre class
2. multiplying each absolute abundance by the length selectivity for it's length class to give a recruited abundance
3. summing the recruited abundance values over all length classes

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

The target strength-length (L) relationship used for species other than black oreo 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 using the TS-length relationship given by Foote (1987) and that for deepwater species used the swimbladder model data from the rattails *Caelorinchus innotabilis* and *Coryphaenoides subserrulatus*, and smooth oreo to set the general level, but used the scatter of data from Foote (1987) to estimate target strength using bootstrap techniques.

Absolute abundance estimates from the survey area were scaled up to the OEO 3A area by multiplying the survey estimates by 1.06, the ratio of catches (1979–80 to 1996–97) from the total area to those from the survey area (Table 10).

Table 10: OEO 3A pre-recruit, recruit, and total acoustic abundance estimates (t) and recruit *c.v.* (%) for black oreo based on the empirical age selectivity ogive from the 1997 survey (TAN9713) for flat plus seamounts for the survey area and scaled up to the OEO 3A area

Survey area				OEO 3A			
Pre-recruit	Recruit	*c.v.*	Total	Pre-recruit	Recruit	*c.v.*	Total
79 200	48 500	36	127 600	84 000	51 400	36	135 000

Mean (total) length

Mean length data from research surveys were analysed for the same reasons as the observer data (See Section 3.2). Data from the south Chatham Rise surveys carried out between 1986 and 1995 are in Figure 12. Mean lengths for males declined by 0.5 and for females by 0.9 cm over the series. It is likely that the trawl survey catchability problem noted for smooth oreo in OEO 3A (Doonan *et al.* 1997) also applies to black oreo from this area.

4.3 Other studies

Catchability (q) of black oreo from the trawl surveys of OEO 3A

It was assumed that black oreo abundance estimates from the OEO 3A trawl surveys would have inconsistent estimates of q, similar to those reported for smooth oreo (Doonan *et al.* 1999) and consequently the OEO 3A trawl survey abundance estimates were not used in the following biomass analysis.

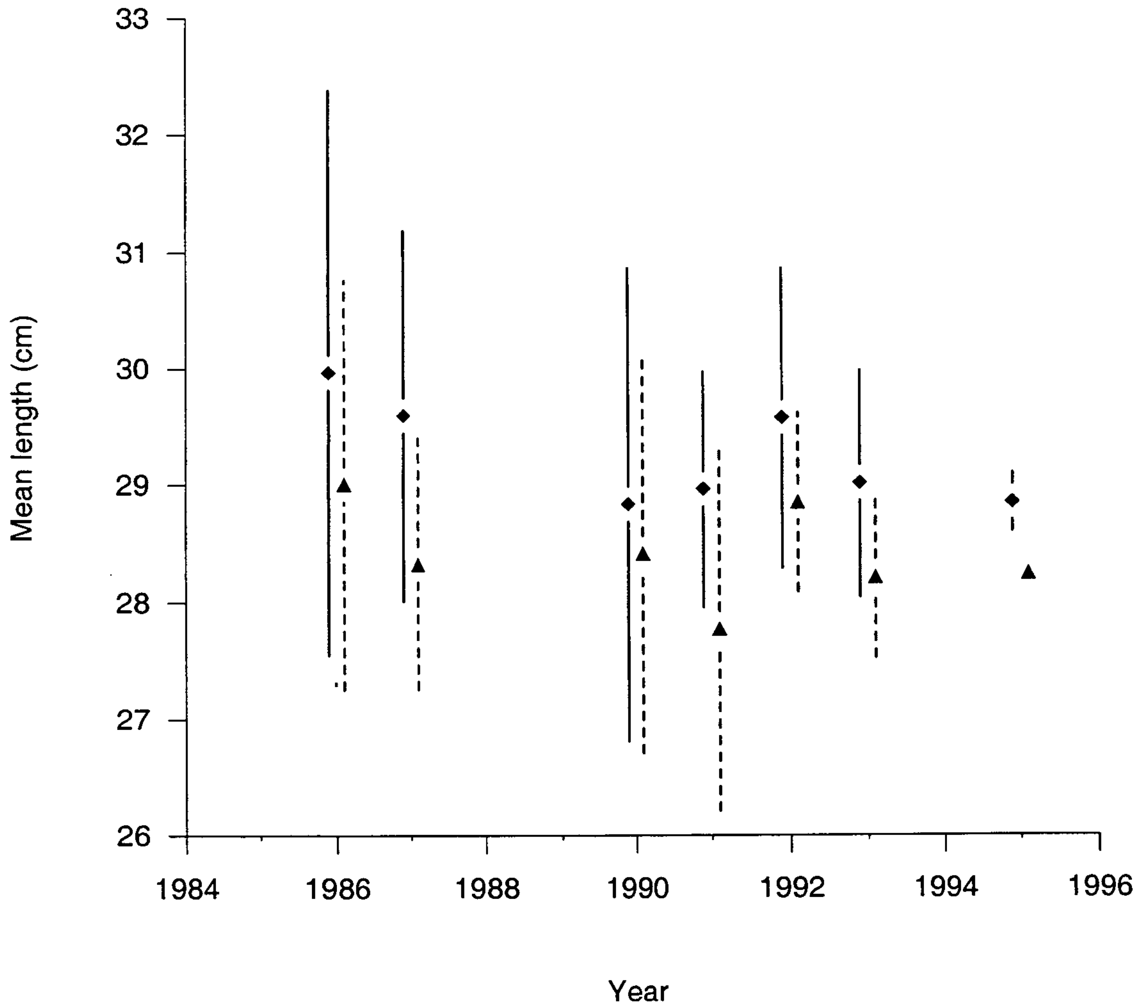


Figure 12: Research length frequency data scaled to biomass. Mean length (females • and males ▲). Vertical lines are ± 2 s.e., solid (females), dashed (males).

4.4 Biomass estimates

Stock reduction analysis

Biomass estimates were made using deterministic stock reduction analyses (*after* Francis 1990).

The estimated selectivity values (dots/crosses in Figure 10) for each year were used except that selectivities for ages below 5 years were set to zero and selectivities for ages greater than 31 years were set to 1.

The following important 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 3A. Most of the black oreo commercial catch taken from 1978–79 to 1997–98 came from the

CPUE study area and research trawl surveys indicated that there was little habitat for, and biomass of, black oreo outside that area.

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

(d) The value of the maximum fishing mortality (F_{max}) used in all the analyses below was 0.9.

(e) Recruitment was deterministic and followed a Beverton & Holt relationship with steepness of 0.75.

(f) Catch overruns were 0% during the period of reported catch.

Other minor assumptions were as follows.

(a) The population of black oreo in OEO 3A (in the main fishing ground at least) was a discrete stock or production unit.

(b) The catch histories were accurate.

Input data

Input data included the recruited absolute acoustic abundance estimates and *c.v.*s (*see* Table 10), the Soviet and New Zealand time series of combined abundance indices from standardised CPUE analyses and *c.v.*s (*see* Table 4), the life history parameters from McMillan *et al.* 1997 (Table 11), and the catch history (Table 12).

Table 11: 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 12)

This was derived from Tables 1–3 as follows.

1. Soviet catch of unspecified oreo from FAO area 81.5 from 1972 to 1977 (Table 1) was assumed to be all from OEO 3A, to be 50:50 black to smooth oreo, and to be for fishing rather than calendar years.
2. Catches from 1978–79 to 1982–83 (1 April to 31 March) were assumed to be for fishing years (1 October to 30 September).
3. The 1978–79 catch of unspecified oreo (1366 t, Table 2) was assumed to be the same proportion of black to smooth oreo catch reported in 1979–80 (5588/(5588 + 5075) = 0.524), Table 3. The estimate of the 1978–79 black oreo catch was 1366 x 0.524 = 716.
4. The 6 month OEO 3A black oreo catch reported as 1983–83 (3693 t, Table 3) was split and half each (1846.5) added to the preceding and subsequent years (1982–83 and 1983–84). Only 3 t of unspecified oreo was reported from OEO 3A in 1983–83 (Table 3), so no adjustment to the reported black oreo catch was required.

5. From 1979–80 to 1997–98 the catch was calculated by multiplying the value reported in Table 2 by the proportion of black to smooth oreo in Table 3.
6. The last two years of the catch history were assumed projected catch based on previous annual catch.

Data used in the initial analysis and presented to the Deepwater Working Group (Table 12, "OEO 3A") had minor errors: the corrected values ("Amended") are given. The total catch for the amended series was about the same as the total used in the analysis, so using the amended catch history in the stock reduction analysis resulted in trivial changes to biomass and yield results.

Table 12: Reconstructed catch history (t) of black oreo from OEO 3A used in the 1999 stock reduction analysis ("OEO 3A"). Amended data are also shown

Year	OEO 3A	Amended
1972–73	†3 440	†3 440
1973–74	†3 800	†3 800
1974–75	†5 100	†5 100
1975–76	†1 300	†1 260
1976–77	†4 000	†3 880
1977–78	†5 750	†5 750
1978–79	683	716
1979–80	5 743	5 743
1980–81	12 636	12 636
1981–82	11 462	11 462
1982–83	6 438	8 285
1983–84	5 568	7 414
1984–85	3 933	3 933
1985–86	2 189	2 189
1986–87	4 032	4 032
1987–88	3 144	3 144
1988–89	3 228	3 228
1989–90	2 827	2 827
1990–91	4 774	4 774
1991–92	3 450	3 450
1992–93	4 956	4 956
1993–94	4 164	4 164
1994–95	2 401	2 401
1995–96	3 764	3 764
1996–97	3 752	3 752
1997–98	1 560	1 561
1998–99	‡3 300	‡3 300
1990–00	‡3 300	‡3 300

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

Results of several different stock reduction model runs (referred to as "cases") with different abundance inputs are presented below (Table 13). The "base" case used all the abundance sources including the Soviet and New Zealand CPUE plus the acoustic abundance estimate (Figure 13). The "MW layer removed" case used the base case data minus the absolute abundance from the shallow midwater layers. The "Mature fish only" case used knife-edge selectivity (greater than 26 years old), included midwater layers, and excluded all CPUE indices. The mature fish catch was estimated by multiplying the annual total catch by the fraction of mature fish in the observer length frequency (0.41).

The Soviet CPUE abundance indices have a poor fit to the trajectory, have wide 95% confidence intervals (CI), and show a very steep declining trend with time. The New Zealand CPUE abundance indices are scattered around the trajectory.

Biomass estimates for each case, including the 95% confidence intervals and the maximum likelihood ("best") value (in parentheses), are given in Table 13. The 95% confidence interval estimates of B_0 for the base case from this analysis were 103 000–129 000 t, based on bootstrap simulation that used the *c.v.* from the CPUE indices, the *c.v.* from the absolute abundance estimates, and assumed deterministic recruitment.

Table 13: Recruited biomass estimates (t) from the stock reduction model. The 95% confidence intervals are in parentheses. Base case marked in bold

	B_0 (t)		Mid-year $B_{1998-99}$ (t)		($\%B_0$)	
NZ CPUE only	114 000	(93 000–1 000 000)	33 900	(11 800–922 000)	30	(13–92)
Soviet CPUE only	86 000	(86 500–110 000)	4 010	(4 590–29 200)	5	(5–27)
NZ & Soviet CPUE only	94 000	(88 000–110 000)	12 900	(6 280–29 200)	14	(7–27)
Absolute only	126 000	(103 000–143 000)	46 200	(22 400–63 500)	37	(22–44)
Absolute & NZ CPUE	125 000	(106 000–142 000)	45 200	(25 100–62 000)	36	(24–44)
Absolute & Soviet CPUE	117 000	(101 000–131 000)	37 000	(20 300–50 800)	32	(20–39)
Absolute & NZ & Sov CPUE	**117 000**	**(103 000–129 000)**	**37 000**	**(21 900–49 300)**	**32**	**(21–38)**
MW layer removed	106 000	(96 500–115 000)	25 600	(15 500–34 400)	24	(16–30)
Mature fish only	36 000	(31 500–39 500)	9 220	(4 630–12 800)	26	(15–32)

4.4.3 Sensitivity of biomass estimates

The "Soviet CPUE only" and"NZ & Soviet CPUE only" cases gave estimates that were markedly different to those from the other cases (*see* Table 13). Virgin biomass estimates were sensitive to changes in M because increasing M by 2 standard errors resulted in a 16% reduction in B_0, but reducing M by 2 standard errors resulted in an 11% increase (Table 14). Catch history was also important and increased or decreased B_0 by 7% when it was 10% higher or lower respectively. Increasing black oreo target strength by 2 dB decreased B_0 by 10% and decreasing target strength by 2 dB increased B_0 by 15%. The ratio of $B_{1998-99}$ to B_0 was not very sensitive to M or catch history but was moderately sensitive to black oreo target strength.

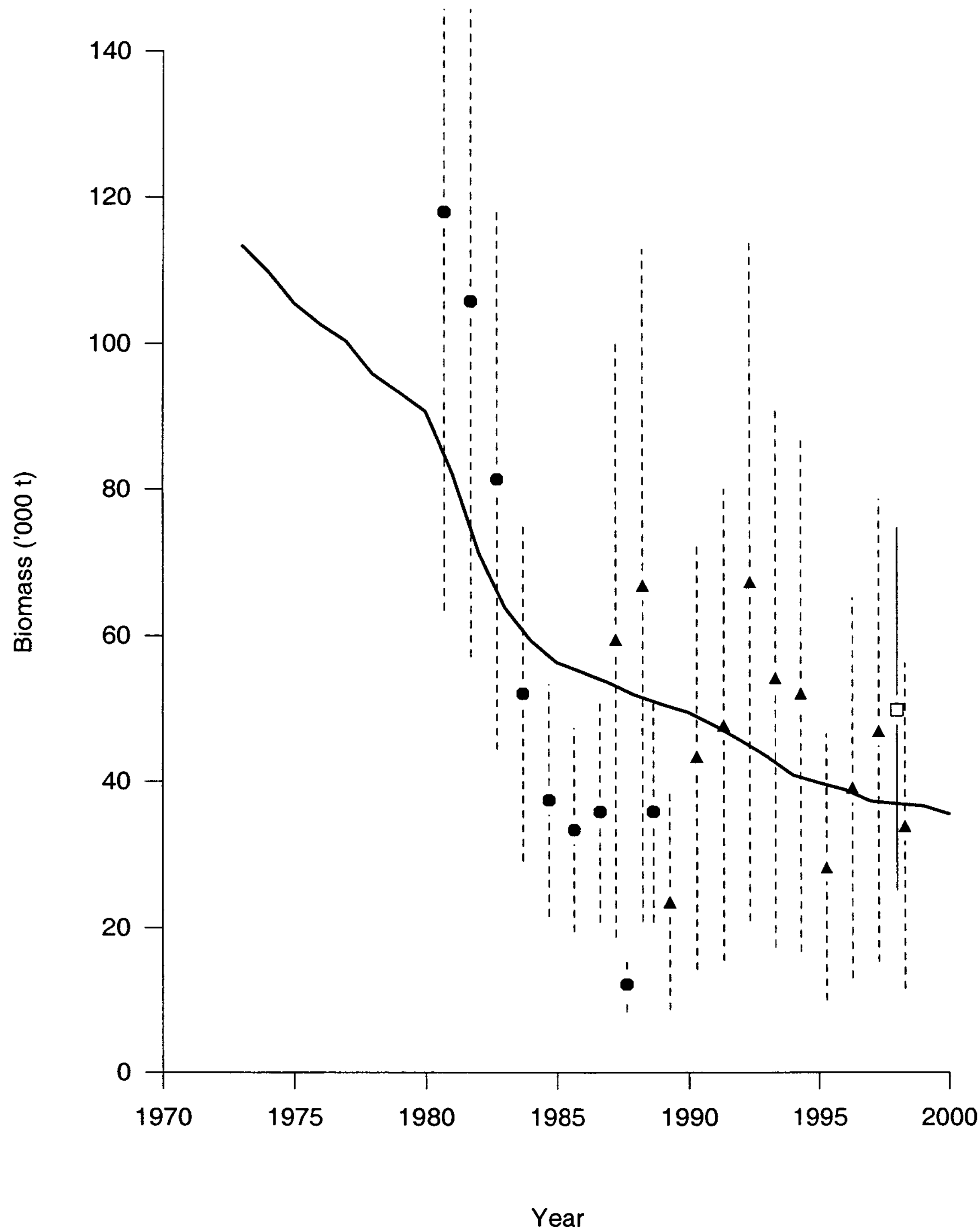


Figure 13: Biomass trajectory for OEO 3A black oreo from stock reduction analysis for the base case (absolute abundance, plus New Zealand and Soviet abundance indices from standardised CPUE analyses). ● Soviet CPUE, ▲ New Zealand CPUE, □ acoustic absolute abundance estimates. Dashed lines are the 95% CI. The CI for the first two Soviet estimates exceed the upper range of the figure.

Table 14: Sensitivity of OEO 3A black oreo virgin (B_0) and mid–year ($B_{1998-99}$) biomass estimates (t) to changes in the CPUE index, natural mortality (M), black oreo target strength estimate (TS_BOE) and catch history for the base case. se is standard error

Change in parameters	B_0 (t)	$B_{1998-99}$ (t)	$B_{1998-99}$ (% B_0)
Base case	117 000	37 000	32
M + 2 se (0.075)	98 000	35 300	36
M – 2 se (0.028)	130 000	38 400	30
Catch + 10%	125 000	36 900	29
Catch - 10%	109 000	37 100	34
TS_BOE + 2dB	105 000	24 500	23
TS_BOE - 2dB	135 000	55 400	41

4.5 Yield estimates

Estimation of Maximum Constant Yield (MCY)

Using the method of Francis (1992), the maximum constant catch that can be taken indefinitely (without reducing the population below 20% B_0 more than 10% of the time) from a population with life history parameters as in Table 11 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 3A (Table 15) were calculated from the results of the stock reduction analyses reported above, using the "Depressed stocks" methods of Francis (1992). Where stocks are depressed (below 20% B_0), the MCY for 1999–2000 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 11 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 given in Table 15.

Table 15: Yield estimates (t). The 95% confidence limits are in parentheses. Base case marked in bold

	$MCY_{1999-00}$		$MCY_{long-term}$		$CAY_{1999-00}$	
NZ CPUE only	1 500	(770–13 000)	1 500	(1 200–13 000)	1 600	(540–42 000)
Soviet CPUE only	260	(300–1 400)	1 100	(1 100–1 400)	180	(200–1 400)
NZ & Soviet CPUE only	840	(410–1 400)	1 200	(1 100–1 400)	590	(280–1 400)
Absolute only	1 600	(1 300–1 900)	1 600	(1 300–1 900)	2 100	(1 000–2 900)
Absolute & NZ CPUE	1 600	(1 400–1 800)	1 600	(1 400–1 800)	2 100	(1 200–2 900)
Absolute & Soviet CPUE	1 500	(1 300–1 700)	1 500	(1 300–1 700)	1 700	(940–2 400)
Absolute & NZ & Sov CPUE	**1 500**	**(1 300–1 700)**	**1 500**	**(1 300–1 700)**	**1 700**	**(1 000–2 300)**
MW layers removed	1 400	(1 000–1 500)	1 400	(1 300–1 500)	1 200	(720–1 600)
Mature fish only	610	(390–670)	610	(530–670)	720	(370–990)

4.5.2 Sensitivity of MCY to M and steepness

M was varied by plus or minus 2 standard errors, and steepness values were changed to 0.5 and 0.95 from the 0.75 used in the yield estimates above. Long term MCY, as a percentage of virgin biomass, varied widely with changes in M and steepness (Table 16). For the base case, for OEO 3A this resulted in a range of long term MCY estimates from 1100 to 2000 t (Table 17).

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

			Steepness
M	0.50	0.75	0.95
0.028	–	0.87	–
0.044	0.89	1.31	1.62
0.075	–	2.01	–

Table 17: Sensitivity of long term MCY (t) to M and "steepness" for the base case. –, not estimated

			Steepness
M	0.50	0.75	0.95
0.028	–	1 100	–
0.044	1 100	1 500	1 900
0.075	–	2 000	–

5. MANAGEMENT IMPLICATIONS

This stock assessment of OEO 3A black oreo is based on stock reduction analyses incorporating deterministic recruitment from a new age selectivity ogive and included the first absolute (acoustic) abundance estimate plus relative abundance estimates from a new standardised CPUE analysis.

The following conclusions can be drawn from this assessment.

Base case

1. The 95% confidence interval for current biomass (21–38%B_0) is between B_{MAY} (24%B_0) and B_{MCY} (43%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 103 000 and 129 000 t are 1300–1700 t, 37–49% less than the mean annual reported (partly reconstructed) black oreo catch in OEO 3A from the last 10 years (about 3500 t, 1988–89 to 1997–98, from Table 11). Therefore, it seems likely that the recent catch levels of black oreo from OEO 3A are higher than the long-term sustainable yield and will not allow the stock to move towards B_{MCY}. If the stock is above B_{MAY}, then this catch level will decrease stock size towards B_{MAY}.

3. The selectivity ogive used in this assessment implies that a large proportion of the current catch is made up of fish that have not reached sexual maturity (about 27 years for females).

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

1. NIWA age estimates of black oreo are not validated but the long-lived, slow-growing hypothesis is supported by two Australian age studies which used zone counts in otolith thin sections and radiometric techniques to conclude that the species reaches about 100 years.
2. Recruitment steepness. There are no data available to check the assumed value.
3. Recruitment was assumed to be deterministic, but initial stock reduction model runs using knife-edge recruitment (at 33 cm TL) produced ratios of pre-recruit to recruit fish biomass that were one-seventh that observed in the acoustic abundance estimate for the base case and one-quarter that observed for the "MW layer removed" case. This suggested that either past recruitment was a lot lower than average; or that the current biomass of pre-recruits was a lot greater than average, or that natural mortality of pre-recruits was a lot higher than the recruit natural mortality; or perhaps identification of pre-recruit acoustic marks is incorrect. Other interpretations are possible. Stochastic recruitment could be considered in future assessments.
4. 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.

In spite of these uncertainties, the estimates of current biomass ($B_{1998\text{–}99}$) from the sensitivity analysis only once exceeded the 95% CI for the base case of 21 900–49 300 t when black oreo target strength was decreased by 2 dB (55 400 t). In addition, the range of long-term yield estimates from the sensitivity analysis varied from the 95% CI estimates for the base case of 1300–1700 t by only 200–300 t. This suggests that the true range of long-term yields are unlikely to be substantially different from those presented here.

6. ACKNOWLEDGMENTS

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