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Is the south Chatham Rise trawl survey series providing an index of smooth oreo abundance in OEO 4?

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Ministry of Fisheries, Wellington

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.

Correction to FARD 96/16

Is the south Chatham Rise trawl survey series providing an index of smooth oreo abundance in OEO 4? by P.J. McMillan *et al.*

Pages 17 and 18 were inadvertently omitted from this FARD and are attached.

Please accept our apologies.

50. 45 p.

McMillan, P.J. & Hart, A.C. 1994b: Trawl survey of oreos and orange roughy on the south Chatham Rise, October-November 1992 (TAN9210). *N.Z. 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). *N.Z. Fisheries Data Report No.*

60. 49 p.

Appendix 1: Comparison of catchability of smooth oreo from *Tangaroa* trawl surveys of hills and the flat (TAN9210 & TAN9309)

Catchability factors	Flat	Hills	Net effect (positive) on catchability
1. Area swept	Doors well spread (118 m)†. Headline height moderate (7 m). Long tows (1.9 n. miles). Gear stable, i.e., smooth ground.	Doors moderately spread (103 m)†. Headline height high (9 m). Short tows (0.3 n. mile). Gear unstable, i.e., sloping ground.	Flat > hills
2. Vulnerability	Relatively high, perhaps > 0.5.	Relatively high, perhaps > 0.5.	Uncertain
3. Vertical availability	Most fish within 10 m of the bottom, but schools may be up to about 100 m above the bottom. There is anecdotal evidence that fish are herded down by trawl gear	Most fish within 10 m of the bottom, but schools may be up to about 100 m above the bottom. There is anecdotal evidence that fish are herded down by trawl gear	Nil
4. Areal availability	Fish on rough ground not available, perhaps 10–20% of total area	Tops and parts of some hills too rough to trawl, perhaps less than 30% of the area of hills in the survey	Flat > hills ?

† Means of the 1992 and 1993 surveys values are in parentheses.

Vulnerability and vertical availability for smooth oreo cannot be estimated until methods for directly observing fish behaviour near the bottom and around trawl gear have been developed.

IS THE SOUTH CHATHAM RISE TRAWL SURVEY SERIES PROVIDING AN INDEX OF SMOOTH OREO ABUNDANCE IN OEO 4?

P. J. McMillan, I. J. Doonan, R. P. Coburn, and A. C. Hart
New Zealand Fisheries Assessment Research Document 96/16. 18 p.

1. EXECUTIVE SUMMARY

Research survey information and catch statistics were analysed to determine whether the standard south Chatham Rise trawl survey, which samples flat ground and not hills, indexes most of the smooth oreo population in OEO 4. Results show that habitat available to smooth oreo on hills is relatively small (240 km²) compared to flat areas where good catch rates have been achieved (11 600 km²); that research surveys indicate that only 15–25% of smooth oreo biomass is on hills; and that most of the commercial catch of smooth oreo (62%) has been on the flat in the period 1980–81 to 1994–95. We conclude that the trawl survey probably provides an abundance index for most of the OEO 4 smooth oreo population.

2. INTRODUCTION

The south Chatham Rise trawl surveys (1991–93, 1995) have covered flat/undulating/dropoff areas (called "flat" below) of the south Chatham Rise (Figure 1) in what is termed the "standard" survey, covering an area of about 39 453 km² in OEO 4 (east of 176° E, subareas 3–7, *see* McMillan & Hart 1994a, 1994b, 1995). The commercial fishery for smooth oreo on the south Chatham Rise now appears to be mainly on hills, where smooth oreo is taken as bycatch during orange roughy fishing. We surveyed six south Chatham Rise hills, chosen at random from a list of 14 (then known) fishing hills, using random trawl techniques in 1992 and 1993 (the "hill" survey, *see* McMillan & Hart 1994b, 1995), but individual hill biomass estimates had a high variance and the hill survey was dropped in 1995.

At the 1995 Deepwater project review meeting the use of the trawl surveys to index abundance of smooth oreo in area OEO 4 was questioned (Clark 1996, p. 41). The smooth oreo fishery was perceived as being a hill fishery, especially in recent years, so a survey of "flat" ground was questioned. This paper examines smooth oreo research and catch information from OEO 4 in order to clarify the use of the trawl survey biomass estimates. We considered the following questions.

- (a) What is the distribution and abundance of the smooth oreo population on the hills and flat?
- (b) How and when are the two areas fished, i.e., the distribution of oreo catches on the two areas over time?
- (c) Do the fish on the flat mix with those on the hills and vice versa?

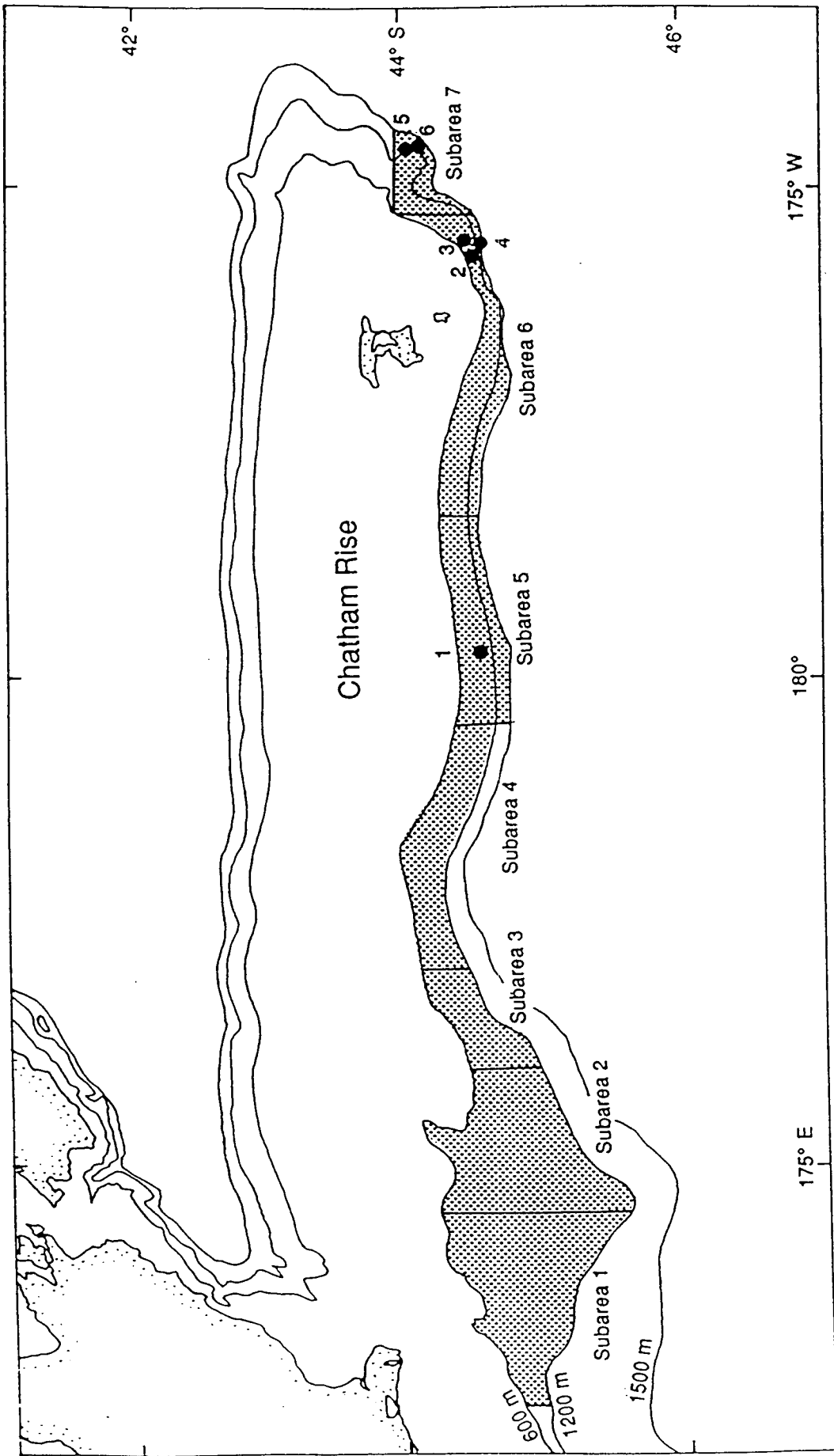


Figure 1: Trawl survey area showing subareas and location of hills sampled in 1992 and 1993. The boundary of area OEO 3A and OEO 4 is at 176 ° E, shown on the figure as the line between subareas 2 and 3. Hills are: 1, Trev's Pinni; 2, Condom's; 3, Mangrove; 4, Charlie's; 5, Possum; 6, Cotopaxi.

3. HABITAT AVAILABLE FOR SMOOTH OREO IN OEO 4

The 1995 Deepwater Review meeting (*see* Clark 1996) asked what area of habitat was available on hills and on the flat in order to model the potential biomass from the two areas? Area estimates are made below and biomass is considered in the following section.

3.1 Hill area

The 36 hills that are or have been fished in OEO 4 (Table 1) are all assumed to support smooth oreo aggregations or schools. The list has a northern limit of 44° S, east of Chatham Island because that is the limit of the survey area, and was compiled from plots of smooth oreo catch along the south and east Chatham Rise, the list of features examined during survey TAN9406, and from information provided by individual fishers.

Table 1: Hills fished from 176° E to 44 ° S on the south Chatham Rise (OEO 4), arranged west to east

Hill name	Latitude (° ' S)	Longitude (° ' E or W)
Fletcher's Pin	44 13.72	179 12.26 E
Mt Nelson	44 16.91	179 52.26 E
Trev's Pinni	44 27.03	179 16.32 W
Mt Kiso	44 25.91	178 43.21 W
Dory Pimple	44 36.78	178 06.09 W
Amaltal Pimple	44 34.82	177 50.41 W
Hegerville	44 42.55	177 03.50 W
Chucky's	44 51.40	177 01.59 W
Nielson's	44 43.50	176 47.02 W
Der Spriggs	44 41.64	176 45.02 W
Dolly Parton	44 46.38	176 34.61 W
Paranoia	44 44.26	176 32.37 W
Unnamed	44 40.03	176 18.45 W
Featherlite	44 39.71	176 03.12 W
Condom's	44 36.36	175 45.28 W
PIN	44 43.27	175 35.70 W
Hill 94	44 32.18	175 30.22 W
Mangrove	44 41.83	175 28.25 W
Charlie's	44 40.65	175 20.45 W
Cook's	44 43.22	175 20.36 W
Flintstone	44 37.20	175 15.70 W
Big Chief	44 39.73	175 12.87 W
Lucky	44 38.40	175 12.20 W
F.B.I./Little Chief	44 39.69	175 12.85 W
Teepee	44 36.94	175 09.84 W
Litehouse	44 28.39	175 06.39 W
Jimmy	44 13.13	174 35.20 W
Dickies	44 12.29	174 33.60 W
Andes=Rachael	44 09.00	174 33.00 W
Iceberg	44 07.50	174 31.20 W
Cathy	44 10.20	174 30.40 W
Possum	44 13.00	174 28.92 W
Cotopaxi	44 09.90	174 26.70 W
Patsy	44 09.00	174 26.60 W
Sir Michael	44 11.08	174 24.14 W
Chillybin	44 10.00	174 23.00 W

Most of these hills are conical and relatively regular, i.e., nearly symmetrical in some vertical planes, except the hill complexes, which include the group of hills around "Big Chief" and the "Andes". Estimates of the surface area of nine of the hills (surveyed during south Chatham Rise trawl surveys) are given in Table 2. Most of these are surrounded by mainly flat ground, but where one side was deeper than the others a cutoff of 1200 m depth was applied, i.e., the approximate depth limit for large concentrations of smooth oreo and orange roughly.

Table 2: Estimates of the surface area of hills in OEO 4 from 176° E to 44 °S. Estimates were made using the formula for the surface area of a cone, i.e., $\pi r l$, where r is the radius of the base and l is the length of the side (from the side at the base to the tip of the cone). Data are from Simrad echosounder traces and Seaplot collected during *Tangaroa* surveys. The dimensions "r", "l", and "h" height are in kilometres. h is the distance from the top to the base, usually at about 1200 m. Surface area (SA) in km²

Hill name	r	h	l	SA
Fletcher's Pin	0.52	0.08	0.53	0.8
Mt Nelson	0.70	0.11	0.72	1.6
Trev's Pinni	0.56	0.13	0.57	1.0
Hegerville	1.85	0.45	1.90	11.0
Neilson's	2.70	0.42	2.75	23.3
Condom's	0.83	0.30	0.89	2.3
Mangrove	0.76	0.33	0.83	2.0
Possum	1.43	0.43	1.50	6.7
Cotopaxi	0.97	0.37	1.04	3.2
Total				51.9 (mean = 5.8)

A total hill area of about 240 km² was estimated, assuming a total of 40 hills for the area (allowing four extra to those listed in Table 1), and a mean surface area of 6 km² per hill (Table 2, but note that the median is 2 km²). The estimates in Table 2 are fairly crude and are intended only to show that most of the hills are relatively small and therefore provide only a small area of habitat. The total area of hills is also small.

3.2 Area of flat habitat

Most of the area in OEO 4 between 600 and 1500 m is trawlable and therefore available to the standard trawl survey, but the hills listed above were not sampled in that survey because they did not conform to stratum depth bounds, i.e., they generally covered depth intervals greater than 100 m. In addition they were so small relative to the flat area that they were unlikely to be at a randomly chosen position. Some random trawl survey stations were carried out very close to hills.

The area of the seven main biomass producing strata from the standard trawl survey area (strata 10, 11, 18–22) totals about 11 600 km² (McMillan & Hart 1994a, 1994b, 1995), almost 50 times that of the hill habitat estimate of 240 km².

4 RELATIVE BIOMASS OF SMOOTH OREO ON HILLS AND FLAT FROM RESEARCH TRAWL SURVEYS

The *Tangaroa* trawl surveys estimated relative biomass on the flat from standard surveys in 1991–93 and 1995, and estimated relative biomass from six hills during the hill surveys in 1992 and 1993 (McMillan & Hart 1994b, 1995). Biomass from the flat can be compared with that from the hills by assuming that catchability of smooth oreo is the same on both. The validity of this assumption can be assessed by considering the elements that contribute to estimating catchability, (Hurst 1988) Appendix 1. It is difficult to be conclusive because of lack of hard data, but it seems unlikely that there is much difference in the catchability of smooth oreo between hills and the flat given that the surveys of both areas were carried out at the same time of year with the same vessel and gear.

4.1 Biomass on hills

The 1992 and 1993 hill trawl surveys estimated relative biomass on six hills selected at random from the list of 14 main hills (Table 3).

Table 3: Recruited smooth oreo relative biomass (t, wing spread estimates) from six Chatham Rise hills sampled in 1992 (TAN9210) and 1993 (TAN9309)

	1992			1993		
	t	c.v.(%)	N	t	c.v.(%)	N
Trev's Pinni	278	57	3	23	98	4
Condom's	1 410	40	3	464	51	4
Mangrove	1 336	82	3	472	38	4
Charlie's	272	36	3	688	24	3
Possum	417	71	3	46	84	4
Cotopaxi	99	56	3	11	11	3
Total	3 812	34	18	1 705	20	22
Mean biomass	635			284		

Multiplying the mean hill biomass from Table 3 by the total number of fishing hills (40) gives the relative biomass of smooth oreo on OEO 4 fishing hills (Table 4), assuming that the six hills surveyed are representative of the south Chatham Rise hills listed in Table 1. This is probably a generous assumption because some of the hills are not populated by smooth oreo in any abundance, e.g., Possum and Cotopaxi are known as orange roughy hills with little smooth oreo catch.

Table 4: Scaling relative biomass (t) from six randomly selected south Chatham Rise hills up to the OEO 4 fishing hills

	1992	1993
Mean biomass	635	284
Scaled to 40 hills	25 400	11 400
c.v. (%)	34	20

4.2 Biomass on the flat

Relative biomass estimates from the standard survey are given in Table 5.

Table 5: Recruited mean biomass and 95% confidence interval (lower and upper bound) estimates (t, wing spread) from research surveys for smooth oreo from the south Chatham Rise, OEO 4 only. N, number of stations

	Mean biomass	Lower bound	Upper bound	c.v.(%)	N
1991	133 492	52 951	214 034	30	110
1992	83 550	27 619	139 481	33	122
1993	71 982	38 673	105 290	23	124
1995	27 187	7 029	47 346	37	149

Estimated total hill biomass was 23% of the 1992 total biomass (hill plus flat), and 14% of the 1993 total biomass.

4.3 Biomass on the flat as an index of the biomass of smooth oreo from OEO 4

To use the flat biomass estimates as an index of the biomass of smooth oreo in the whole of OEO 4 requires the assumption that the flat biomass was a constant proportion of the total (flat plus hills) OEO 4 biomass during the flat surveys (1991–95). This implies that smooth oreo did not strongly favour hills over flat habitat (or vice versa) and that interchange or mixing of fish took place between hills and flat in 1991–95. That good research catches were made on the flat in the same parts of the survey area in 1991–95 suggests that the flat habitat was not being abandoned by smooth oreo (McMillan & Hart 1994a, 1994b, 1995). At the same time large commercial catches were taken from hills (Table 6) suggesting that both hills and flat were favourable for smooth oreo. Mixing of fish is suggested by the close proximity of commercially fished hills to flat areas providing good commercial and research catches (see section 5.1 below).

5 CATCHES IN THE SURVEY AREA, OEO 4

Research and commercial catches and catch rates of smooth oreo in OEO 4 were analysed to determine the distribution of catches in the survey area, the proportion of catch from hills versus flat, the catch rates on hill versus flat, and changes in fishing pattern and catch rates over time. The commercial data were from the catch and effort database, i.e., mostly from Trawl Catch Effort and Processing Returns (TCEPR) from 1989 onwards plus Fisheries Statistics Unit deepwater logbook data before 1989. The hills are those listed in Table 1 and the catch from each hill is from a 5 km radius around the hill centre. This assumes an area at the hill base of about 31 km² for each hill (in contrast to the 6 km² cone area estimated from research data above). A larger area was used to ensure that all or most of the hill catch was included. Earlier records on the commercial catch database gave only the start position, which was likely to be a few kilometres from the hill top. Positions reported using transit satellite navigation systems (before the introduction of the 24 hour Global Positioning System in about 1990) may have been in error by up to a few kilometres.

5.1 Distribution of catches

Figure 2 shows all commercial catches of smooth oreo, i.e., target and non-target catch, from OEO 4 between 1978–79 and 1994–95. The upper figure shows all catches over 1 t and the lower catches over 10 t. A 5 km radius circle is plotted for each of the hills listed in Table 1. The figure shows that there has been extensive fishing on the flat, close to, and also at some distance from hills. Substantial catches (over 10 t) have also been taken on the flat. East of the Big Chief complex there appears to be very little smooth oreo caught on the flat. Figure 3 is a plot of smooth oreo research catches from the standard (flat only) trawl surveys (1986, 1987, 1990–93, and 1995) and shows a similar pattern to the commercial catch data with good catches from the same general areas. Some good commercial and research catches were made on the flat close to hills which suggests the possibility of interchange of fish between flat and hills.

5.2 Catches and catch rates

Reported catches of smooth oreo from the hills and the flat from 1980–81 to 1994–95 are given in Table 6 and the total hill and total flat catch plus the proportion of tows on hills are plotted in Figure 4. The catch from the flat was greater than the hill catch before 1991–92. Fish have been caught on the flat in every year, the lowest catch being 893 t in 1993–94. Over the entire time period, 62% of the smooth oreo caught came from the flat. The proportion of tows on hills increased from 11% in 1986–87 to 66% in 1991–92. In the last 4 years, 75–83% of all tows have been on hills.

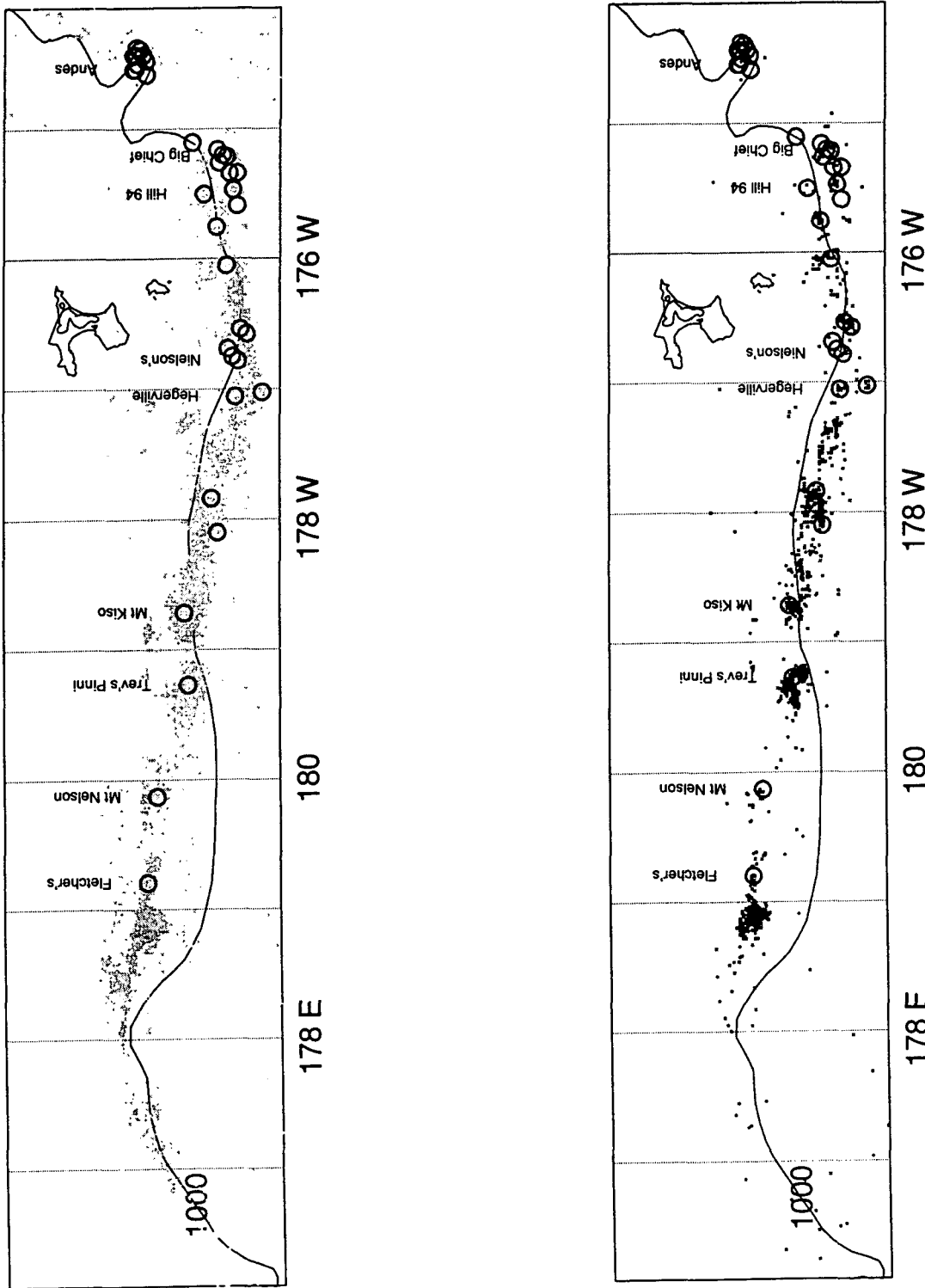


Figure 2: Commercial catches of smooth oreo from OEO 4 only, greater than 1 t (pale dots in upper figure), and greater than 10 t (dark dots in lower figure), including hill and flat catch, from 1978-79 to 1994-95. Circles are at a radius of 5 km around a hill.

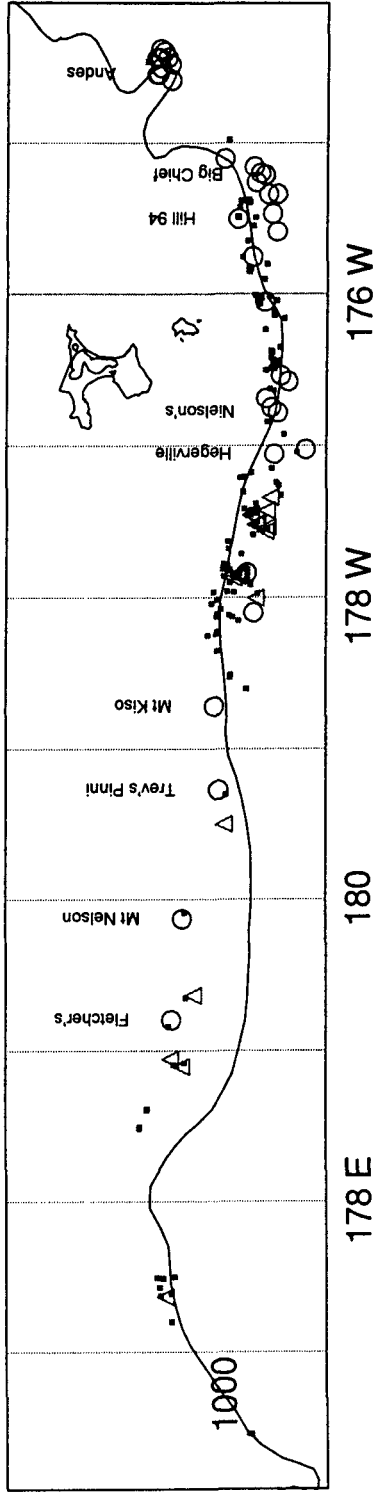


Figure 3: Research catches of smooth oreo from OEO 4 only (176° E to 44° S, 174° W) from the standard survey (1986, 1987, 1990-93, 1995). Dots represent catches of 1-5 t and triangles catches greater than 5 t. Circles are at a radius of 5 km around a hill.

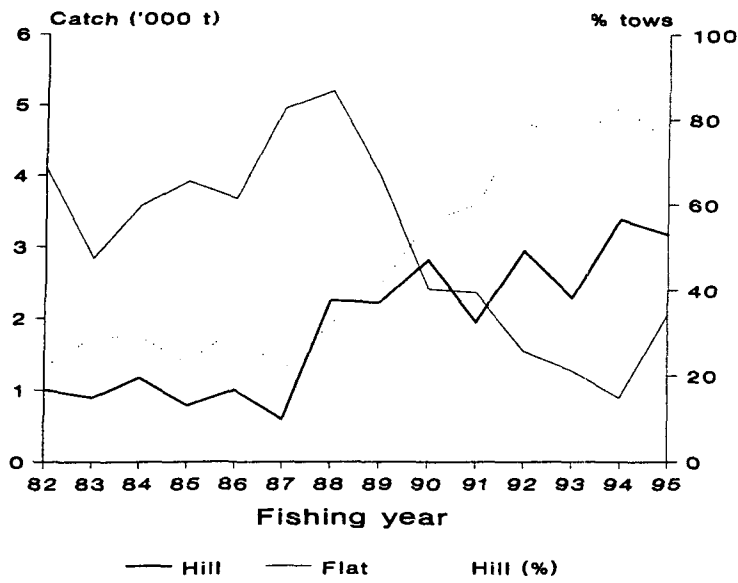


Figure 4: Total catches (target and non-target, t) of smooth oreo from OEO 4 from 1980–82 to 1994–95 (left hand axis) and the percentage of tows on hills (right hand axis).

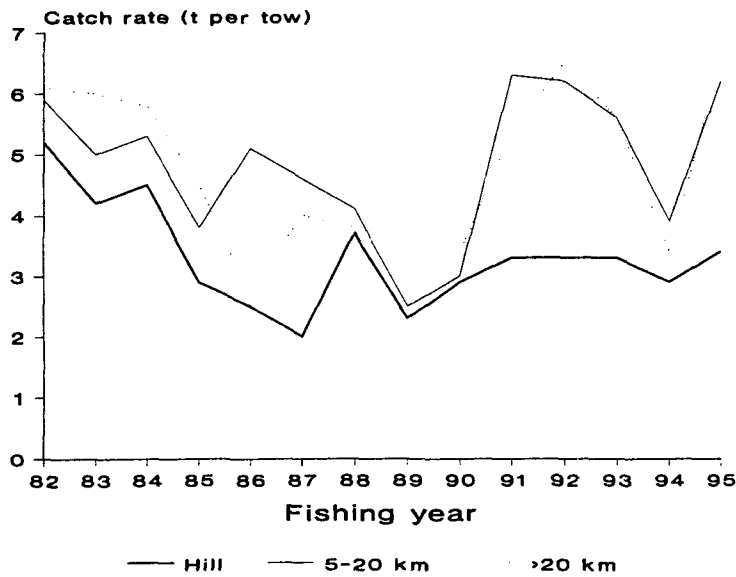


Figure 5: Total (target and non-target) catch rate (t per tow) of smooth oreo from OEO 4 from 1980–82 to 1994–95 from the flat (5–20 and > 20 km from any hill) and from hills.

Catch rates for all smooth oreo caught, i.e., target and non-target, on hills and on the flat (5–20 and over 20 km from hills) are given in Table 6 and are plotted in Figure 5. Overall catch rates from the flat and from hills were similar, although rates on the flat were consistently better. Orange roughy was the target species for much of this fishing, especially on hills, so lower rates on hills is not surprising. Catch rates from the flat and from hills declined from 1980–82 to 1988–89, but while hill catch rates have been relatively steady since that time flat catch rates have fluctuated. Note that the fishing effort on the flat was much reduced in recent years, and consequently recent flat catch rates are based on few data. This is examined below in more detail.

Table 6: Commercial catches of smooth oreo from hill and flat areas of the south Chatham Rise survey area in OEO 4 (176° E to 44° S, 174° W). Hills are those listed in Table 1 and all catch from within a 5 km radius of each hill are assigned to the hill. Catches between 5 and 20 km (5–20 km) and more than 20 km (>20 km) from a hill are also given

Year	Catch (t)				Tows		Catch rate (t per tow)		
	Hill	Flat	5–20 km	>20 km	Hill (%)	Hill (%)	Hill	5–20 km	>20 km
1980–82	1 010	4 102	1 087	3 015	20	22	5.2	5.9	6.1
1982–83	896	2 837	1 842	994	24	29	4.2	5.0	6.0
1983–84	1 173	3 579	1 236	2 343	25	29	4.5	5.3	5.8
1984–85	788	3 921	2 012	1 909	17	23	2.9	3.8	4.5
1985–86	1 004	3 672	2 648	1 024	21	31	2.5	5.1	2.7
1986–87	598	4 955	2 492	2 463	11	21	2.0	4.6	4.0
1987–88	2 253	5 198	3 346	1 852	30	32	3.7	4.1	3.8
1988–89	2 219	4 006	2 076	1 930	36	41	2.3	2.5	3.5
1989–90	2 816	2 413	1 618	795	54	56	2.9	3.0	3.4
1990–91	1 942	2 361	1 653	708	45	60	3.3	6.3	5.4
1991–92	2 947	1 547	1 027	521	66	79	3.3	6.2	6.5
1992–93	2 286	1 274	881	393	64	76	3.3	5.6	5.6
1993–94	3 391	893	410	483	79	83	2.9	3.9	3.4
1994–95	3 180	2 053	1 085	967	61	75	3.4	6.2	6.6
Total	26 503	42 811	23 413	19 397					

Figure 5 shows that recent catch rates on the flat were good, which conflicts with the smooth oreo abundance decline suggested by the trawl biomass estimates from OEO 4 (*see Doonan et al. 1996*). However the data presented in Table 7 and Figure 6 show that effort on the flat has been low since 1991–92, i.e., mostly fewer than 40 tows a year in each of the three areas defined above, and therefore little can be concluded about flat catch rates after 1991–92. We chose 40 tows as the cut-off in effort because at low levels of effort median catch rate estimates can be distorted by such factors as target fishing, season, or lack of representative coverage of the fleet (few vessels). Catches from within a 10 km radius of hills were defined as hill catch (and therefore excluded from the analysis) to be certain that only catch from the flat was analysed.

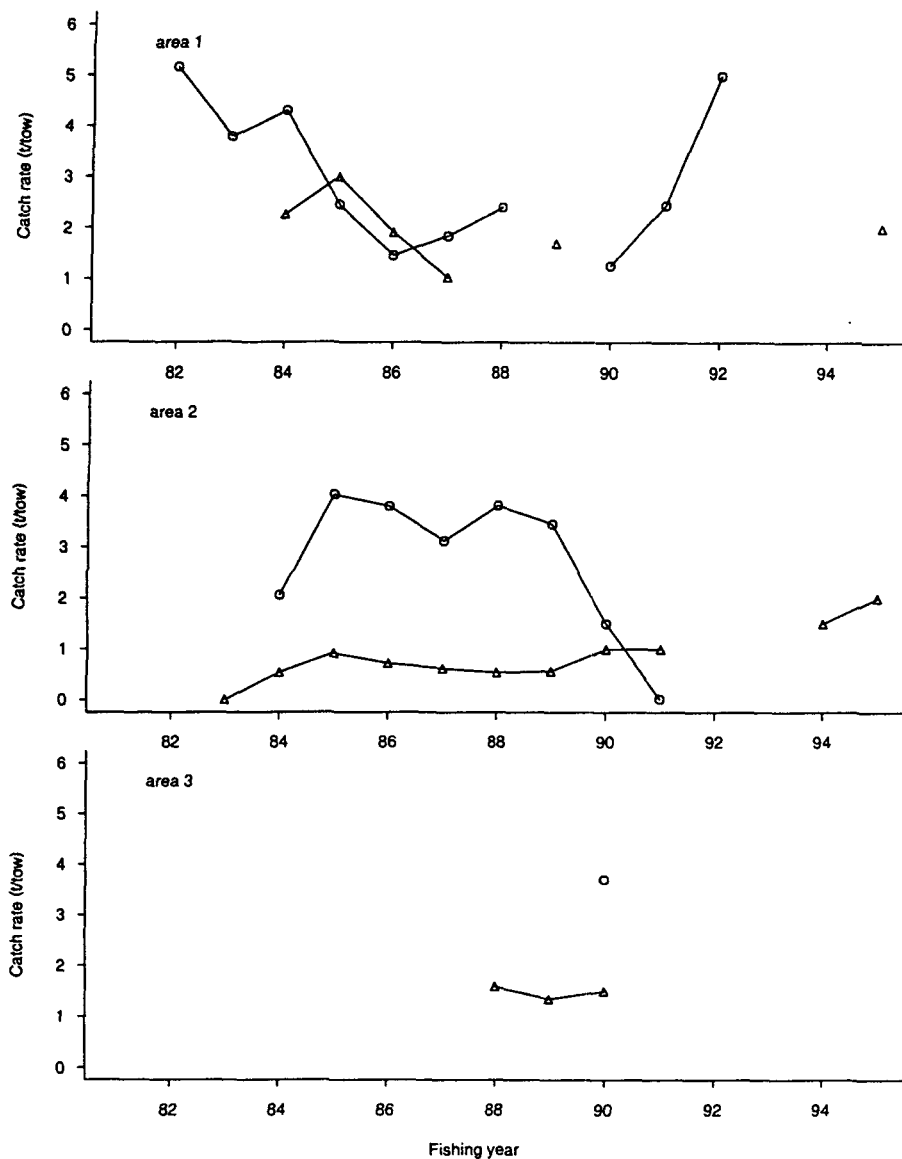


Figure 6: Smooth oreo median catch rates (t per tow) from three of the flat fishing grounds in OEO 4 where smooth oreo (circles) or orange roughly (triangles) were the target catch. Catches within a 10 km radius of any hill were excluded and catch rates are not plotted where there were less than 40 tows from that area in any year. Areas are: 1, 178° to 179° 30' E; 2, 179° to 177° 12' W; 3, 176° 54' to 175° 31' W.

Smooth oreo catch rates, with smooth oreo the target species

Figure 6 shows that catch rates in area 1 declined between 1981–82 and 1985–86, with an increase from 1989–90 to 1991–92. In area 2, catch rates were relatively high from 1984–85 to 1988–89, but then declined (along with effort). Area 3 has had little effort on the flat and there are not enough data to show trends.

Smooth oreo catch rates, with orange roughy the target species

In all three areas catch rates have been mostly moderate to low. In area 2 there has been substantial effort (to catch orange roughy on the flat), but catch rates of smooth oreo have been relatively low and have not changed much between 1984–85 and 1990–91.

Table 7: Smooth oreo median commercial catch rates (t per tow) from three flat fishing areas on the Chatham Rise in OEO 4 where either smooth oreo (SSO) or orange roughy (ORH) was the target. No catch rate is given (–) where there are less than 40 tows. Data from within a 10 km radius of known fishing hills are excluded. Areas are: 1, 178° to 179° 30' E; 2, 179° to 177° 12' W; 3, 176° 54' to 175° 31' W. n, number of tows

Year	Area 1				Area 2				Area 3			
	ORH		SSO		ORH		SSO		ORH		SSO	
	t per tow	n	t per tow	n	t per tow	n	t per tow	n	t per tow	n	t per tow	n
1978–79	–	0	–	0	–	1	–	0	–	0	–	0
1979–80	–	4	13.3	41	–	1	–	1	–	0	–	0
1980–81	–	7	–	0	–	0	–	0	–	1	–	0
1981–82	–	4	5.2	227	–	0	–	0	–	0	–	0
1982–83	–	12	3.8	93	0	82	–	7	–	0	–	0
1983–84	2.3	49	4.3	255	0.5	141	2.1	74	–	4	–	0
1984–85	3.0	141	2.5	130	0.9	349	4.0	49	–	1	–	0
1985–86	1.9	80	1.5	115	0.7	246	3.8	69	–	0	–	0
1986–87	1.0	69	1.8	309	0.6	378	3.1	98	–	14	–	17
1987–88	–	32	2.4	109	0.5	618	3.8	305	1.6	118	–	12
1988–89	1.7	216	–	30	0.6	568	3.5	99	1.3	69	–	3
1989–90	–	29	1.3	72	1.0	180	1.5	83	1.5	68	3.7	64
1990–91	–	11	2.5	79	1.0	47	0	42	–	40	–	9
1991–92	–	22	5.0	45	–	18	–	11	–	29	–	0
1992–93	–	11	–	39	–	33	–	3	–	16	–	3
1993–94	–	38	–	0	1.5	86	–	0	–	33	–	1
1994–95	2.0	49	–	14	2.0	109	–	19	–	10	–	0

5.3 Fishing patterns

The major change in fishing pattern on the south Chatham Rise has been the shift from a mixed species (smooth oreo/black oreo/orange roughy) fishery in the late 1970s and early 1980s to a target fishery for orange roughy where smooth oreo is a bycatch (Figure 7). The orange roughy fishery is now confined almost entirely to hills. Associated changes have been a shift from extensive fishing on the flat in early years to almost entirely fishing on hills in recent years (Figure 8), and there has been a shift of smooth oreo catches from west to east along the south Chatham Rise with a slight movement back to the west in 1994–95 (Figure 9).

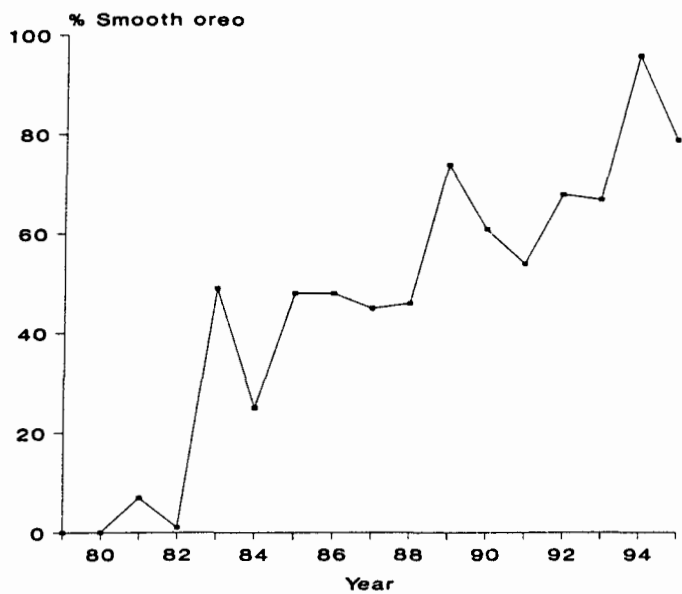


Figure 7: The catch of smooth oreo taken when orange roughy was the target species, expressed as a percentage of all smooth oreo caught each year.

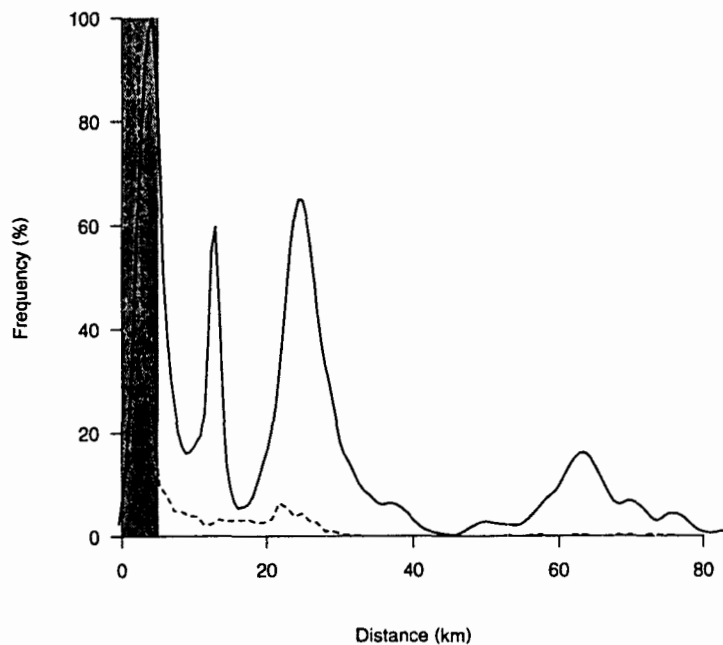


Figure 8: The frequency of all commercial tows which caught smooth oreo on the south Chatham Rise, OEO 4, plotted against distance (km) from the nearest hill for 1981-82 (solid line) and 1994-95 (dashed line) fishing years. The shaded area is within 5 km of any hill.

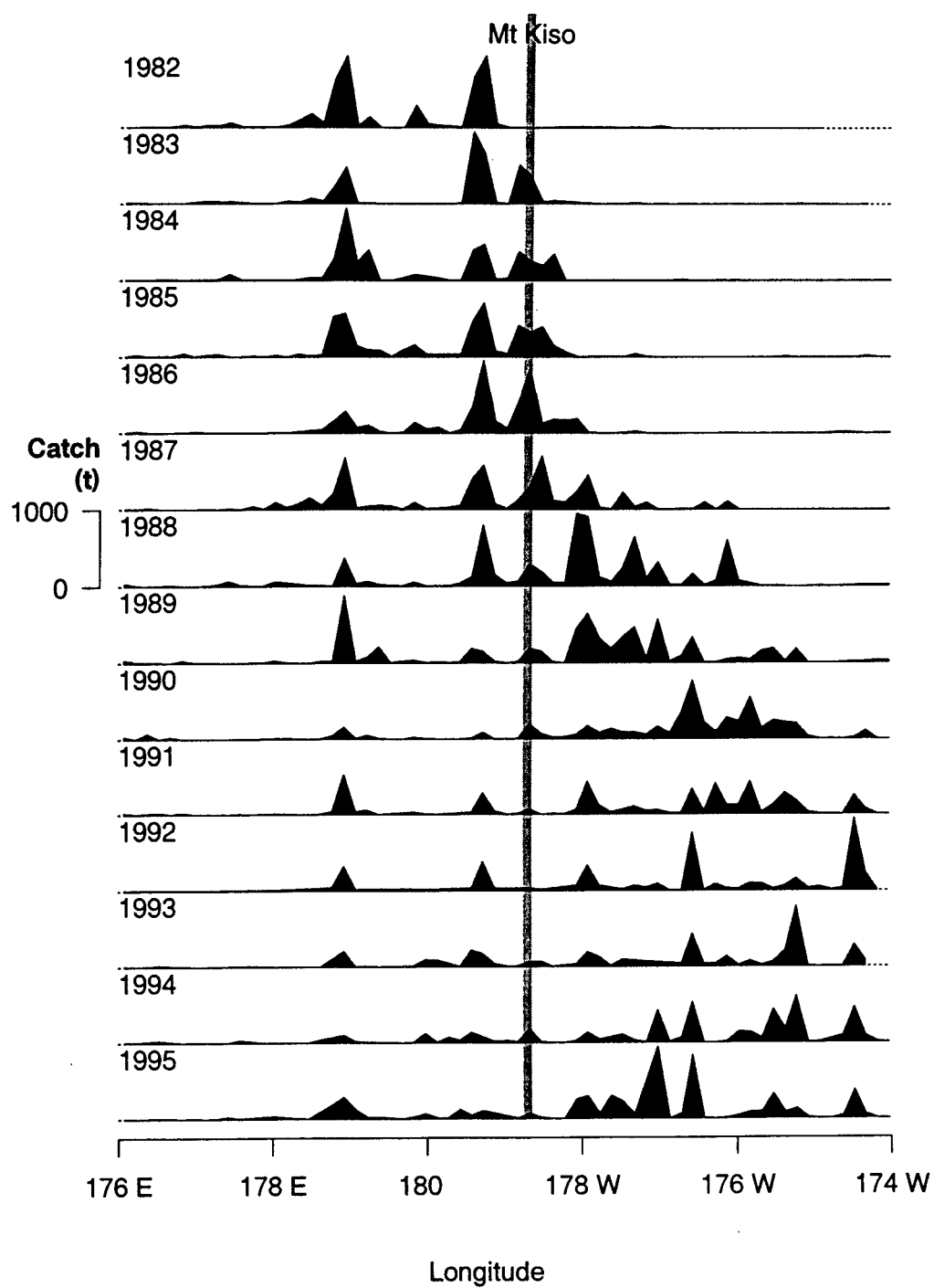


Figure 9: Total (target and non-target) catch (t) of smooth oreo from the trawl survey area, south Chatham Rise, OEO 4, by longitude, by fishing year. "1995" is the fishing year 1994–95.

6. CONCLUSIONS

1. Research survey data suggest that there is more smooth oreo on the flat than on hills. Hill biomass may have been 15–25% of the total biomass in 1992–93. This assumes that the catchability of smooth oreo from hills and the flat on *Tangaroa* trawl surveys is equal.
2. Commercial catches from the flat were 62% of the total catch between 1980–81 and 1994–95. Up to 89% (1986–87) of the total smooth oreo caught each year has been taken from the flat. Catches from the flat decreased in recent years and fishing on hills has increased. From 1991–92 to 1994–95, 67% of the total catch and 78% of the tows have been on hills.
3. The relationship of the fish on the hills to that on the flat is uncertain, but it seems likely that there is mixing of fish from the two areas because of the concentrations of smooth oreo on flat areas near the hills. Good catches have been made close to hills by random trawl and by commercial fishing. It is assumed that smooth oreo do not strongly prefer hill habitat to flat habitat or vice versa. Evidence that smooth oreo have not abandoned flat habitat is shown by consistently good research catches from the same parts of the survey area from 1991 to 1995. Large commercial catches have been taken from hills in that time.
4. We conclude that the standard trawl survey probably provides an index of the total population in OEO 4. This assumes that smooth oreo catchability is equal for hills and flat for the research surveys, that there is mixing of smooth oreo between hills and flat, and that smooth oreo do not strongly favour one area as a habitat over the other.

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