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Update of data inputs for assessment of OEO 3A black oreo in 2012–13

New Zealand Fisheries Assessment Report 2015/41

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This report presents results of standardised catch per unit effort analyses, as well as estimates of absolute abundance for black oreo from the 1997, 2002, 2006 and 2011 research acoustic surveys, a revised catch history, and length frequency distributions derived from the acoustic survey and commercial observer programmes. Data were for the years up to the 2011–12 fishing year.

The CPUE series show that after an initial decline in abundance in the fished areas (Areas 2 & 3), the abundance stabilised and was more or less constant, and that this has continued in the more recent data added here. The new commercial length frequency distributions show no clear changes from those as far back as 2007 for Area 1 & 2, and back to 2006 for Area 3. This lack of trend suggests that the abundance is stable.

1. INTRODUCTION

This work addresses the following objectives in the Ministry for Primary Industries project "Stock assessment of Oreo" (DEE 2010/02).

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

Specific objective
To update standardised catch per unit effort analyses and stock assessments of oreo, including estimates of biomass, risk and yields for: BOE 3A in 2012–13

1.1 Overview

The stock assessment for black oreo in OEO 3A (Figure 1) is structured around a number of distinct spatial areas that cover the main fishing grounds. Previous analyses (Doonan et al. 1999b) have identified time, area, and depth effects on the structure of length data collected by observers from catches made by commercial fishing vessels, and three main fishing areas were delineated as a result. The three fishery areas can be summarised as follows: a northern area that contains small fish and is generally shallow flat ground (Area 1); a southern area that contained large fish before 1993 and which is generally deeper with many features and where short tows have historically taken place (Area 3); and a transition area (Area 2) that lies between Areas 1 and 3 (Figure 2). The boundary between Areas 1 and 2 was defined in terms of the northern edge of the area that enclosed 90% of the total catch from the fishery. Thus, Areas 2 and 3 contains most of the fishery and Area 1 consists of lightly fished and unfished ground. The boundary between Areas 2 and 3 was defined by the 32.5 cm contour in mean fish length for data before 1993 so that the fishery is split into an area containing smaller fish and another that has larger fish.

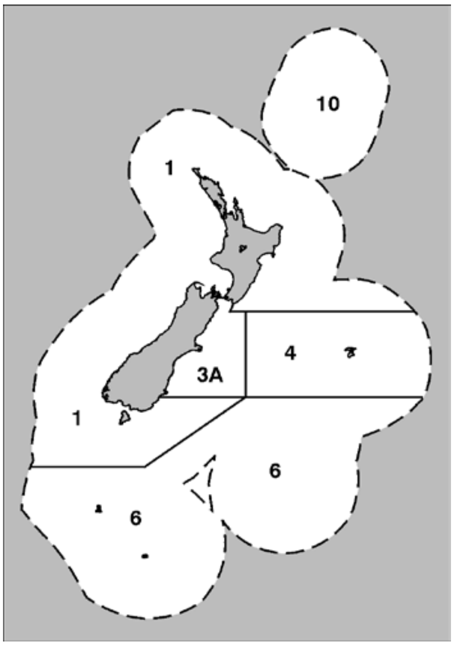

Figure 1: Oreo management areas.

The commercial abundance and length frequency data for the stock assessment were collected from within Areas 1–3, and taken to be indicative of the whole of OEO 3A, which assumes that the population outside the main fishery follows the same spatial pattern of smaller fish at shallower depths. The acoustic survey area represents an even smaller region (Figure 2). The catch is taken from the whole of OEO 3A and split between shallow and deep areas based on the relative catches recorded in commercial log-books.

A spatial stock assessment model for black oreo in OEO 3A was first implemented in 2000-01 (Hicks et al. 2002). This model was converted to the NIWA CASAL software (Bull et al. 2003) with revised Areas 1–3 in the 2002-03 stock assessment (Doonan et al. 2004). The most recent stock assessment occurred in 2006-07 (Doonan et al. 2009), and was an update of the model used for the 2002-03 analysis. Migration was allowed in the model, and area specific selectivity curves were estimated using length frequency data derived from observed tows in the commercial fishery. However, further data have been collected since 2009 which suggest that assumptions made by this model are incorrect. Specifically, differences in the size distribution between areas now seem likely to be due to differential growth rates, rather than movement (Doonan, unpublished data). The stock assessment model applied by Doonan et al. (2009) was therefore considered inadequate. As a consequence no assessment was performed in the current year (2012-13), with a view to developing a new model for subsequent assessments.

This report presents results of the standardised catch per unit effort analyses, as well as estimates of absolute abundance for black oreo from the 1997, 2002, 2006 and 2011 research acoustic surveys, a revised catch history, and length frequency distributions derived from the acoustic survey and commercial observer programmes. Data were for the years up to and including the 2011–12 fishing year.

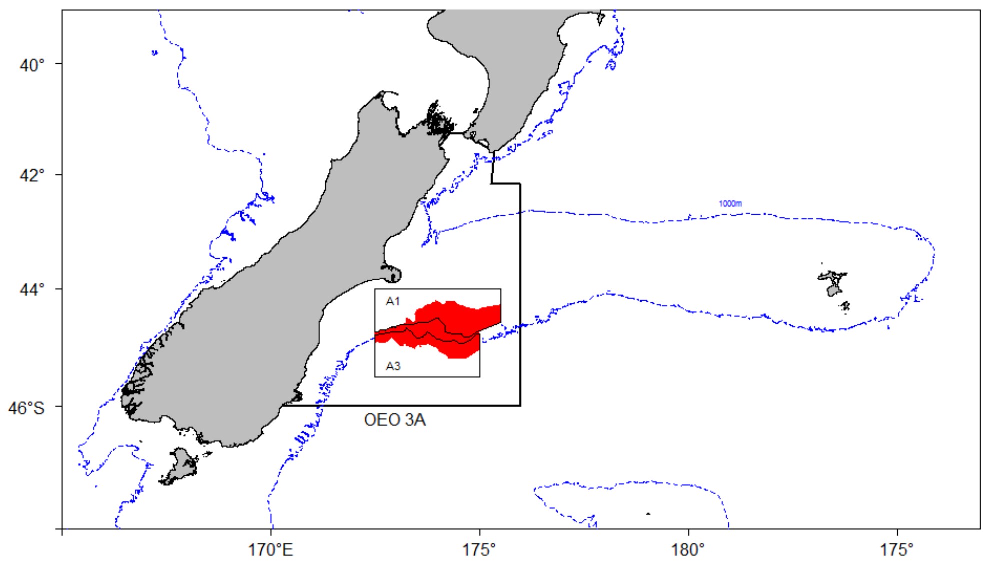

Figure 2: Spatial areas for the assessment of black oreo in OEO 3A (Doonan et al. 2009). Commercial abundance and length frequency data were collected from Area 1 (A1) and Area 3 (A3) shown, with Area 2 being the transition zone between them. The shaded red areas indicate the spatial extent assumed by the acoustic survey, and for which absolute abundance indices were constructed.

1.2 TACCs, catch, and landings data

Black oreo are caught by trawling at depths of 600–1200 m in southern New Zealand waters. The OEO 3A south Chatham Rise fishery was until recently the largest black oreo fishery in the EEZ (from 2005–06 onwards the Pukaki Rise fishery has been larger) and operates between about 172 and 176° E, mostly on undulating terrain (short plateaus, terraces, and drop-offs) in the west and central parts, and mostly on hills in the east. At times, black oreo is caught as a bycatch of smooth oreo target fishing.

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 1.

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.

The oreo fishery started in about 1972 when the Soviets reported 7000 t (assumed to be black oreo and smooth oreo combined, see Doonan et al. (1995)) from the New Zealand area. Reported landings of oreos (combined species) and TACs from 1978–79 until 2011–12 are given in Table 1. The OEO 3A TAC was reduced from 10 106 to 6600 t in 1996–97. A voluntary agreement between the fishing industry and the Minister of Fisheries to limit catch of smooth oreo from OEO 3A to 1400 t of the total oreo TAC of 6600 t was implemented in 1998–99, with the balance of the TAC being black oreo by default. Subsequently, the total OEO 3A TAC was reduced to 5900 t in 1999–2000, 4400 in 2000–01, 4095 in 2001–02, and 3100 t in 2002–03. In 2009-10 it went up to 3350 tonnes. Reported estimated catches by species from tow by tow data from the MPI "*Warehou*" database are given in Table 1.

Table 1: Total reported landings and TACs (tonnes) for all oreo species combined and total estimated catch (tonnes) for smooth oreo (SSO) and black oreo (BOE) for OEO 3A from 1972–73 to 2011–12. Fishing year prior to 1984 refers to 1 April in the previous year to 31 March. The fishing year in 1984 refers to 1 April 1983 to 30 September 1984. Fishing year from 1985 onwards refers to the period from 1 October of the previous year to 30 September. Catches before 1979 were assumed to be equally divided between BOE and SSO.

Fishing Year	Landings	TAC	Estimated Landings BOE	Estimated Landings SSO
1973	6 880	-	3 440	3 440
1974	7 600	-	3 800	3 800
1975	10 200	-	5 100	5 100
1976	2 520	-	1 260	1 260
1977	7 760	-	3 880	3 880
1978	11 500	-	5 750	5 750
1979	1 366	-	806	560
1980	10 958	-	6 990	3 968
1981	14 832	-	12 696	2 136
1982	12 750	-	11 479	1 271
1983	8 576	10 000	6 018	2 558
1984	13 599	10 000	9 800	3 799
1985	8 284	10 000	3 844	4 440
1986	5 331	10 000	1 938	3 393
1987	7 222	10 000	3 805	3 417
1988	9 049	10 000	3 888	5 161
1989	10 191	10 000	4 588	5 603
1990	9 286	10 106	3 148	6 138
1991	9 827	10 106	4 030	5 797
1992	10 072	10 106	3 355	6 717
1993	9 290	10 106	4 117	5 173
1994	9 106	10 106	4 200	4 906
1995	6 600	10 106	2 878	3 722
1996	7 786	10 106	4 074	3 712
1997	6 991	6 600	3 548	3 443
1998	6 336	6 600	2 397	3 939
1999	5 763	6 600	2 756	3 007
2000	5 859	5 900	3 285	2 574
2001	4 577	4 400	2 653	1 924
2002	3 923	4 095	2 126	1 797
2003	3 070	3 100	1 314	1 756
2004	2 856	3 100	1 471	1 385
2005	3 061	3 100	1 187	1 874
2006	3 333	3 100	1 682	1 651
2007	3 073	3 100	1 659	1 414
2008	3 092	3 100	1 607	1 485
2009	2 848	3 100	1 649	1 199
2010	3 550	3 350	1 973	1 577
2011	3 370	3 350	1 659	1 711
2012	3 324	3 350	1 475	1 849

2. ASSESSMENT MODEL

The most recent assessment model was applied by Doonan et al. (2009). This used a spatial population partition to accommodate the structure of the catch and length data, with age-dependent migration between areas. However, further data have now been collected which suggest that assumptions made in this model are incorrect. Specifically, differences in the size distribution between areas now seem likely to be due to differential growth rates, rather than movement. The model applied by Doonan et al. (2009) was therefore considered inadequate and as a result no stock assessment was performed for the current year (2012-13), with a view to developing a new model for subsequent assessments. This model will allow differential growth in each area, as well as area specific recruitment. Progress with development will be reported in an accompanying document.

3. OBSERVATIONAL DATA

Despite an assessment model not being reported here, we nevertheless provide an update concerning the basic empirical data collected for the fishery.

3.1 Spatial areas

In the 2006-07 assessment (Doonan et al. 2009), the study area was subdivided into three so that the observer length data could be more easily modelled. The subdivision was based on both absolute catch biomass and mean fish length in order to separate the main fishing grounds from lightly fished areas and to capture an increase in mean length with depth. The northern area contained small fish in generally shallow depths which was also not greatly fished (Area 1). The fished areas were divided into a southern area that contained large fish and was generally deeper (Area 3), and a transition area (Area 2) that lay between Areas 1 and 3. In the 2006 acoustic survey (used in the 2006-07 assessment), the internal boundaries of the subareas were adjusted slightly to make the survey more practical. Areas are shown in Figure 2.

3.2 Catch history

Catches of black oreo were estimated from the total oreo catch in OEO 3A using the proportion of black oreo recorded per year in commercial logbooks from vessels fishing within Areas 1–3 (Figure 2). These estimated catches are shown in Table 1. They were further subdivided by area, again using the logbook data, and are listed in Table 2. All catches were assumed to be from the fishing year (1 October to 30 September).

Table 2: Black oreo catch (tonnes) for each fishing year in the three spatial areas of OEO 3A.

Year	Area 1	Area 2	Area 3	Total
1972–73	110	2 010	1 320	†3 440
1973–74	130	2 214	1 456	†3 800
1974–75	170	2 970	1 960	†5 100
1975–76	40	736	484	†1 260
1976–77	130	2 260	1 490	†3 880
1977–78	190	3 350	2 210	†5 750
1978–79	27	750	30	806
1979–80	39	2 189	4 762	6 990
1980–81	793	7 813	4 090	12 696
1981–82	12	7 616	3 851	11 479
1982–83	57	3 384	2 577	6 018
1983–84	682	5 925	3 192	9 800
1984–85	148	1 478	2 218	3 844
1985–86	13	814	1 112	1 938
1986–87	33	1 863	1 908	3 805
1987–88	49	2 399	1 439	3 888
1988–89	244	3 532	811	4 588
1989–90	696	1 164	1 288	3 148
1990–91	753	1 947	1 330	4 030
1991–92	289	1 250	1 816	3 355
1992–93	180	2 221	1 717	4 117
1993–94	339	2 509	1 353	4 200
1994–95	139	1 894	845	2 878
1995–96	231	2 744	1 099	4 074
1996–97	418	2 095	1 035	3 548
1997–98	257	874	1 267	2 397
1998–99	138	2 047	572	2 756
1999–00	133	2 246	906	3 285
2000–01	89	1 804	761	2 653
2001–02	58	1 447	620	2 126
2002–03	82	997	236	1 314
2003–04	233	775	464	1 471
2004–05	61	766	360	1 187
2005–06	55	1 315	312	1 682
2006–07	48	914	698	1 659
2007–08	53	926	629	1 607
2008–09	59	920	671	1 649
2009–10	115	973	885	1 973
2010–11	38	859	762	1 659
2011–12	31	534	910	1 475

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

3.3 Relative abundance estimates from standardised CPUE analyses

Standardised CPUE indices for OEO 3A black oreo were developed and used as indices of abundance for the first spatial stock assessment (Hicks et al. 2002). In 2002, these indices were revised to account for the revised spatial areas and also to introduce new predictors (Doonan et al. 2004). For each area, there are two series, based on the introduction of GPS between 1989 and 1992. The pre-GPS series from 1979–80 to 1988–89 have not been updated since 2004 since there have been no new data or analyses.

During the post-GPS period, there was a period (1998–99 to 2001–02) when a number of reductions were made to the TAC and an industry (voluntary) cap was introduced on the amount of smooth oreo caught. This is likely to have changed the practices of the fishery so the post-GPS series was split into two. Initially, the split was in 2002–03, but the Deepwater Working Group considered that the whole period from 1998–99 to 2001–02 should be dropped, resulting in an early series from 1992–93 to 1997–98, and a late series from 2002–03 onwards. Since there are no new data for the post-GPS early series, this is also left unchanged from previous standardisation results. Only the post-GPS late series is updated here, using data that now extends from 2002–03 to 2011–12.

3.3.1 Catch per Unit Effort (CPUE) Data

Only data within a pre-defined spatial area were considered useful for assessing abundance (Figure 2). This area corresponds to the main fishing area and overlaps with the acoustic survey areas. Tows were initially selected for inclusion in the CPUE standardisation if they targeted or caught black oreo within this area, up to and including the 2011–12 fishing year. The tow data included start position, black oreo catch, target species, depth, vessel, distance towed, time of day, and date. Nationality and tonnage were recorded for each vessel. Catch-per-tow (tonnes-per-tow) was chosen as the index of abundance rather than catch-per-kilometre and follows the Deepwater Working Group's preference in previous smooth oreo and black oreo standardised CPUE analyses (Doonan et al. 1995, Coburn et al. 1999). The length of tow was not considered to reflect effort because of the mix of flat, drop-off, and hill fishing that was carried out and because most vessels targeted marks. Technology changes, most importantly the adoption of GPS, allowed vessels to more accurately target marks and reduce tow length. Different fishing patterns and therefore tow length were observed in the three areas (e.g., more long tows in the shallows) and for the two time periods (pre- and post-GPS), suggesting that tow length was not a good measure of effective effort across the fishery.

Of the 6895 tows recorded in the database, 2483 were excluded because they did not target or catch BOE, 1626 fell outside of the areas shown in Figure 2, and two had no depth record and were therefore excluded. Only a small percentage of these tows reported a zero catch (on average less than 1% per year). To simplify the statistical modelling, these tows (26 in total) were also excluded. Finally, core vessels were selected which had operated in the fishery for more than two years and had at least 10 records per year. In an attempt to control for the fluctuating dynamics of the fishing fleet, only tows from these vessels were retained for the standardisation. These vessels represented approximately 80% of the catch per year and about 60% of the tows.

3.3.2 Method of CPUE analysis

Standardisation of the CPUE series followed the procedure used by Doonan et al. (2009). It implemented a log-linear regression (with Gaussian error) and involved a step-wise model selection procedure, in which explanatory factors were selected according to changes in the residual error, measured using the R^2 statistic. Specifically, factors that lead to the greatest increase in R^2 were selected first, proceeding in a stepwise manner until the change in R^2 fell below a threshold of 2% (Doonan et al. 2009), at which point the process was terminated. All continuous variables were binned to account for non-linear effects. Eight bins were used, ensuring an approximately equal number of data points per bin. The simplest model considered included fishing year, area and an interaction between the two. This allowed estimation of an annual index for each area. Additional factors considered were the vessel, target species, binned time of day, binned day during the year, the binned depth nested within area, and binned latitude/longitude.

3.3.3 Results of the CPUE analyses

For the post-GPS late series, Table 3 shows the distribution of data amongst the areas and as a percentage of all data in the study area that was retained in the analysis. The step-wise selection of explanatory factors is shown in Table 4. The final model retained, in addition to year and area (and their interaction), depth, vessel, target species and longitude. This model was used to produce a unique index for each year and area by taking a weighted mean of the model predicted values across other factor levels included in the final model.

Table 3: Number of tows, catch, and number of vessels in the post-GPS late CPUE series.

Year	Number of tows				Catch		Number of vessels	
	Area 1	Area 2	Area 3	% of total	Tonnes	% of total	Number	% of total
2003	36	96	63	50	894	0.78	8	35
2004	153	89	91	68	935	0.83	10	42
2005	18	119	101	71	1038	0.89	8	42
2006	24	88	41	48	1166	0.87	6	38
2007	27	68	93	50	1050	0.85	9	50
2008	20	148	139	62	1270	0.86	8	50
2009	6	91	105	41	946	0.68	6	40
2010	99	77	109	54	1404	0.79	7	47
2011	33	105	167	57	1369	0.88	6	50
2012	35	52	184	60	1372	0.85	7	54
2013	5	35	94	65	768	0.88	4	67

Table 4: R^2 for selection of explanatory variables in the post-GPS late CPUE series.

Factor	R^2	Improvement	Selected?
Year/Area	0.23	-	Yes
+ Depth	0.31	0.08	Yes
+ Vessel	0.36	0.05	Yes
+ Target Sp.	0.39	0.02	Yes
+ Longitude	0.41	0.02	Yes
+ Time of day	0.41	0.00	No
+ Time of year	0.41	0.00	No

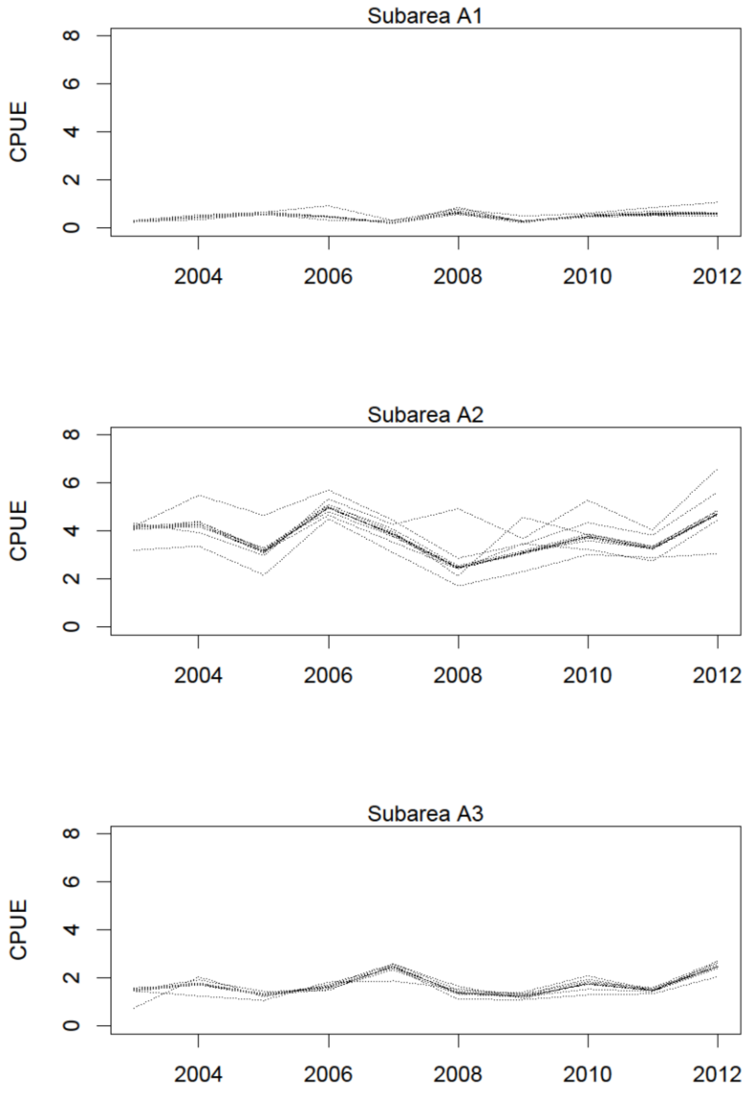

Figure 3: Jackknife of standardised CPUE with each core vessel removed.

The influence of Vessel on the standardised CPUE index was assessed using a Jackknife procedure in which each core vessel was dropped and the statistical model re-fitted using the same explanatory variables. The results of this process are illustrated in Figure 3, and indicated that the results (specifically the time trend) are not biased by the inclusion of any particular vessel. Uncertainty in the Year coefficient was assessed by bootstrapping the data, re-estimating the indices for each iteration, and estimating the coefficient of variation (CV) for each year/area from this distribution. Finally each CPUE series for each Year/Area combination was re-scaled to a geometric mean of one. The results of this standardisation process, along with estimated CVs, are shown in Table 5 and Figure 4.

Table 5. Standardised CPUE series, including results from new analysis of the post-GPS late series. Each series has been standardised to have a geometric mean of one. The pre-GPS series and post-GPS early series are from Doonan et al. (2009).

Fishing Year	Pre-GPS						Post-GPS					
	Area 1		Area 2		Area 3		Area 1		Area 2		Area 3	
	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
1979–80	-	-	1.45	39	1.52	125	-	-	-	-	-	-
1980–81	-	-	1.84	17	2.55	15	-	-	-	-	-	-
1981–82	-	-	1.71	22	2.15	9	-	-	-	-	-	-
1982–83	-	-	1.41	8	1.80	14	-	-	-	-	-	-
1983–84	-	-	0.99	8	1.04	19	-	-	-	-	-	-
1984–85	-	-	0.95	27	0.99	12	-	-	-	-	-	-
1985–86	-	-	0.63	31	0.66	33	-	-	-	-	-	-
1986–87	-	-	0.81	22	0.88	36	-	-	-	-	-	-
1987–88	-	-	0.45	20	0.49	23	-	-	-	-	-	-
1988–89	-	-	0.72	21	0.23	44	-	-	-	-	-	-
1989–90	-	-	-	-	-	-	-	-	-	-	-	-
1990–91	-	-	-	-	-	-	-	-	-	-	-	-
1991–92	-	-	-	-	-	-	-	-	Early series			
1992–93	-	-	-	-	-	-	-	-	1.62	14	2.46	20
1993–94	-	-	-	-	-	-	-	-	1.17	17	1.20	15
1994–95	-	-	-	-	-	-	-	-	0.96	13	0.82	17
1995–96	-	-	-	-	-	-	-	-	0.89	15	0.68	22
1996–97	-	-	-	-	-	-	-	-	1.06	18	0.96	17
1997–98	-	-	-	-	-	-	-	-	0.58	47	0.64	63
1998–99	-	-	-	-	-	-	-	-	-	-	-	-
1999–00	-	-	-	-	-	-	-	-	-	-	-	-
2000–01	-	-	-	-	-	-	-	-	-	-	-	-
2001–02	-	-	-	-	-	-	Late series					
2002–03	-	-	-	-	-	-	0.62	90	1.11	24	0.9	38
2003–04	-	-	-	-	-	-	0.99	45	1.15	27	1.05	37
2004–05	-	-	-	-	-	-	1.33	63	0.85	32	0.8	56
2005–06	-	-	-	-	-	-	1.1	63	1.34	23	0.99	31
2006–07	-	-	-	-	-	-	0.51	78	1.05	27	1.49	24
2007–08	-	-	-	-	-	-	1.52	44	0.67	66	0.84	33
2008–09	-	-	-	-	-	-	0.65	73	0.84	44	0.75	30
2009–10	-	-	-	-	-	-	1.17	29	1.02	26	1.06	30
2010–11	-	-	-	-	-	-	1.38	52	0.89	30	0.9	22
2011–12	-	-	-	-	-	-	1.37	44	1.28	24	1.49	18

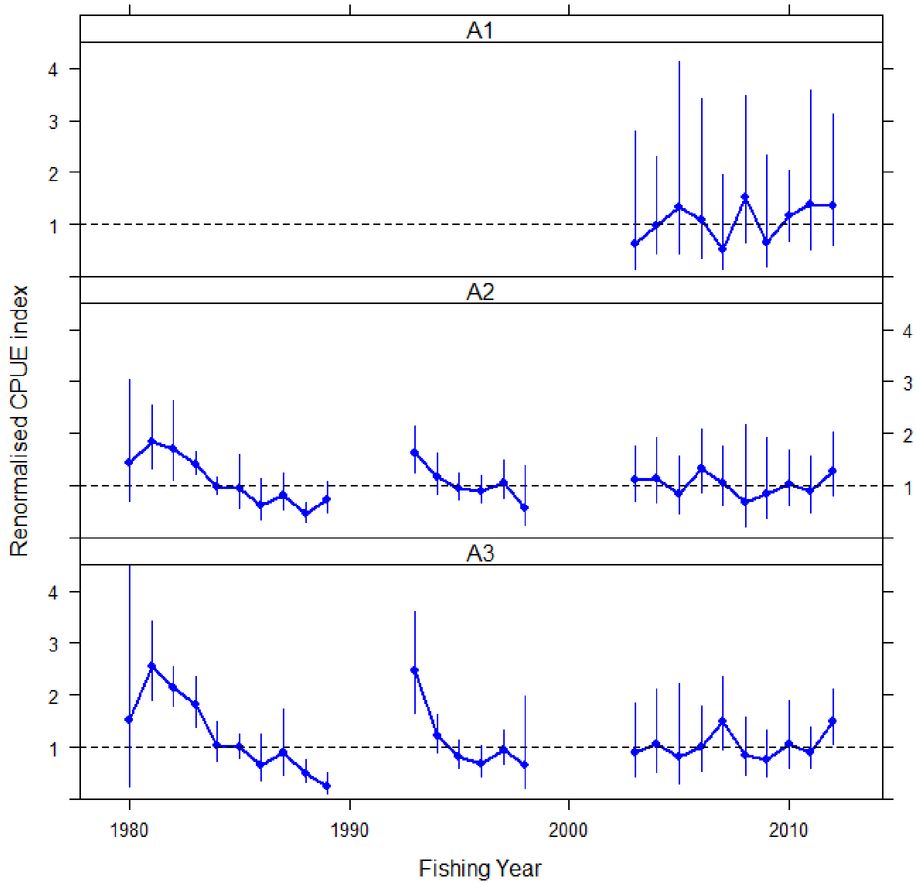

Figure 4: Standardised CPUE series, including results from new analysis of the post-GPS late series. Each series has been standardised to have a geometric mean of one. Error bars show the 95% confidence interval, assuming a log-normal error with CV estimated from the bootstrapped distribution of Year/Area effects.

3.4 Relative abundance estimates from trawl surveys

Trawl surveys of oreos on the south Chatham Rise were carried out in seven years between 1986 and 1995, but the abundance estimates from the surveys before 1991 were not considered to be comparable because different vessels were used. Four comparable surveys were carried out using *Tangaroa* from 1991 on, and relative abundance estimates from those surveys are given in Table 6, but these estimates were not used in the biomass analyses for the same reasons as given in Doonan et al. (1999a) for smooth oreo. They considered that catchability could be inconsistent between surveys for smooth oreo from OEO 3A, as the *Tangaroa* trawl surveys did not sample recruited smooth oreo well. The schools of recruited smooth oreo were so small and scattered that they were very unlikely to be encountered by the trawl given the number of tows allocated. If a school was encountered, the resulting survey abundance estimate had a high CV because most of the trawls sampled background (low density) recruited smooth oreo. The *Tangaroa* series also spanned only five years so the index had a low weight compared to a longer time series.

Table 6: OEO 3A black oreo research survey abundance estimates (tonnes) from *Tangaroa* surveys. N is the number of stations. Estimates were made using knife-edge recruitment set at 27 and 33 cm TL.

Year	Mean abundance		CV (%)	N
	27 cm	33 cm		
1991	36 299	8 999	42	44
1992	19 848	6 427	39	24
1993	16 800	4 888	40	24
1995	22 148	3 778	21	24

3.5 Absolute abundance estimates from acoustic surveys

Absolute estimates of abundance for black oreo are available from four acoustic surveys of oreos carried out from 10 November to 19 December 1997 (voyage TAN9713) (Doonan et al. 1998, 1999b), 25 September to 7 October 2002 (TAN0213) (Smith at al. 2006), 17 to 30 October 2006 (TAN0615) (Doonan et al. 2008), and 17 November and 1 December 2011 using *San Waitaki* (SWA1102) (Doonan et al. 2013). The 1997 survey covered the flat with a series of random north-south transects over six strata at depths of 600–1200 m. Hills were also sampled using parallel and starburst transects. Targeted and some random (background) trawling was carried out to identify targets and to determine species composition. In situ target strength measurements were made on 10 marks including 2 smooth oreo, 2 black oreo, and 6 mixed oreo marks. In 2002, the survey was limited to flat ground with 77 acoustic transects and 21 mark identification trawls completed (the smooth oreo part was dropped). The 2006 survey was a repeat of the 2002 survey design and completed 78 transects and 22 trawls. The 2011 survey was again a repeat of the 2002 design and used 78 transects and completed 24 mark-identification trawls.

Absolute total (immature plus mature) acoustic abundance at the start of the fishing year was estimated for each of the three new areas. These estimates have been scaled up to include the proportion of catch caught outside the study area, but within the OEO 3A management area. The 1997 acoustic abundance for black oreo in OEO 3A was re-estimated in 2002 using the revised estimates of target strength for smooth oreo, black oreo, and a number of bycatch species. Absolute total acoustic abundance estimates for all surveys are in Table 7.

Table 7: Total black oreo abundance estimates for the 1997, 2002, 2006 and 2011 acoustic surveys for the three model areas in OEO 3A (Figure 2) with CVs given as a percentage in brackets.

Survey	Area 1	Area 2	Area 3	Total
1997	148 000 (29)	10 000 (26)	5 240 (25)	163 000 (26)
2002	43 300 (31)	15 400 (27)	4 710 (38)	63 400 (26)
2006	56 400 (37)	16 400 (30)	5 880 (34)	78 700 (30)
2011	138 087 (27)	36 826 (28)	7 415 (35)	182 328 (21)

3.6 Length data analyses

3.6.1 Observer length frequency distributions

Catch at length data collected by observers in Areas 1, 2, and 3 were extracted from the COD database maintained by NIWA for MPI. The data consisted of numbers of fish by sex, length and location, along with the total catch weight for that particular tow. Proportions were obtained by first using a weight-at-length relationship to scale up the number observed to an estimate of the numbers caught, and then combining this information across tows. Bootstrapping was used to generate CVs by resampling tows and fish within each tow to give a CV for each length. A regression fit to the CV as a function of the proportion in each length bin, as carried out by Doonan et al. (2009), was not attempted. The number of observed commercial tows is shown in Table 8. A total of 60 tows were excluded because they had fewer than 30 fish measured, extreme mean lengths (under 20 cm or more than 40 cm) or missing catch information. The length frequency data are shown in Figure 5.

Table 8: Number of observed commercial tows where black oreo was measured for length frequency.

Year	Area 1	Area 2	Area 3	Other
1979–80	0	9	35	0
1980–81	0	0	0	0
1981–82	0	0	0	0
1982–83	0	0	0	0
1983–84	0	0	0	0
1984–85	0	0	0	0
1985–86	0	1	0	0
1986–87	0	2	6	0
1987–88	0	6	3	0
1988–89	30	8	4	2
1989–90	12	6	1	0
1990–91	2	5	7	1
1991–92	0	10	1	0
1992–93	0	0	0	0
1993–94	8	16	2	5
1994–95	0	4	2	2
1995–96	2	3	2	6
1996–97	0	1	1	2
1997–98	13	2	5	0
1998–99	2	1	0	3
1999–00	7	94	11	6
2000–01	3	110	22	2
2001–02	8	23	8	5
2002–03	3	17	4	4
2003–04	9	1	2	3
2004–05	3	5	3	1
2005–06	0	38	7	7
2006–07	6	1	2	5
2007–08	0	9	5	7
2008–09	4	16	9	3
2009–10	4	14	4	2
2010–11	1	15	7	2
2011–12	3	6	1	0

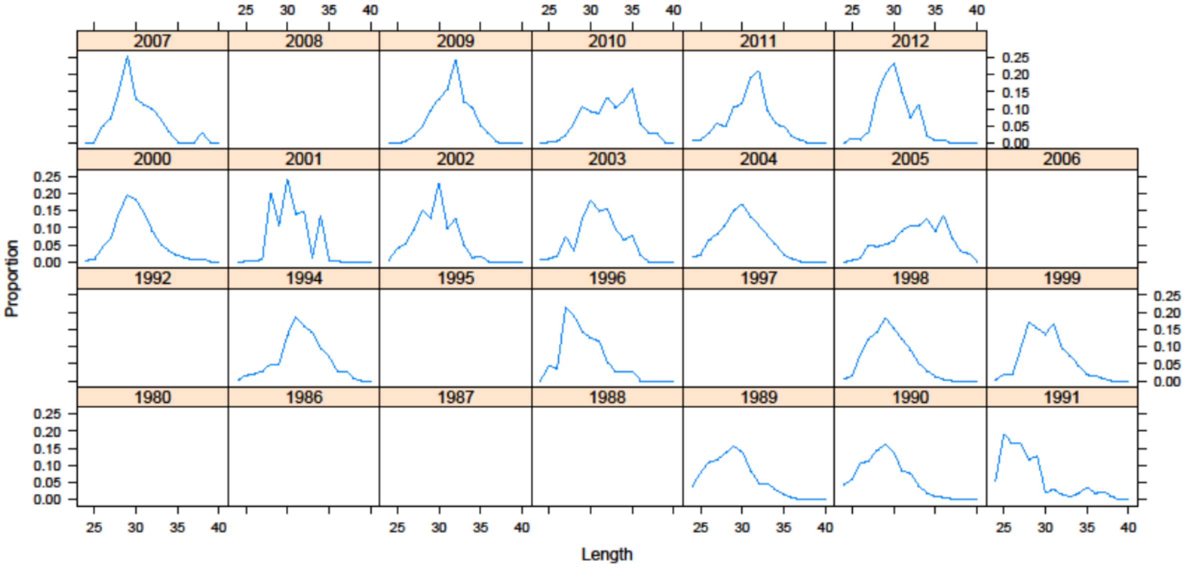

Figure 5a: Length frequency data for Area 1.

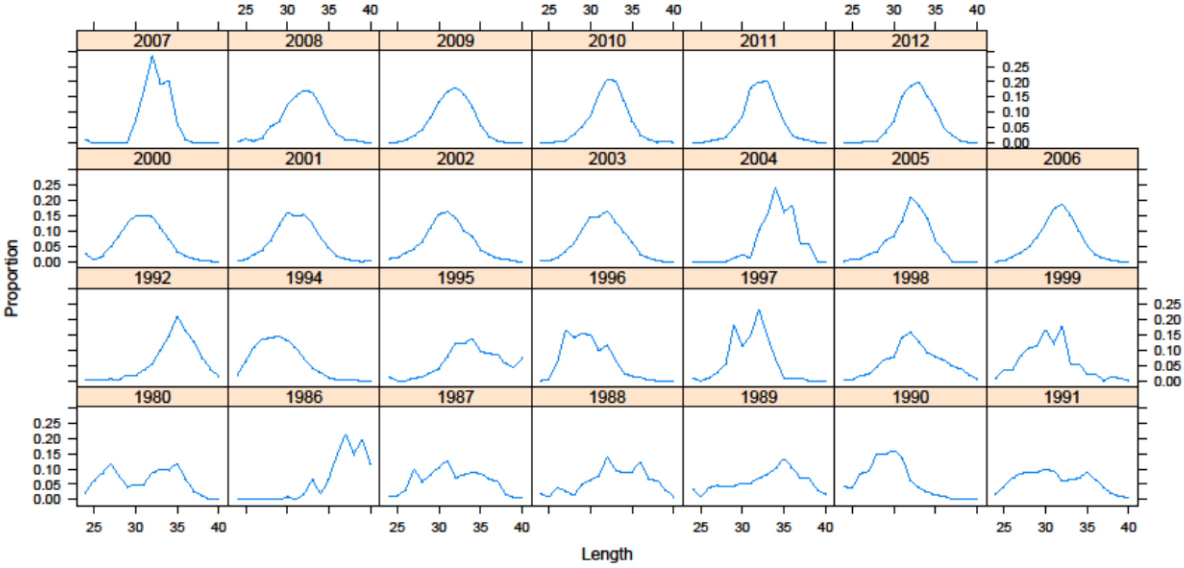

Figure 5b: Length frequency data for Area 2.

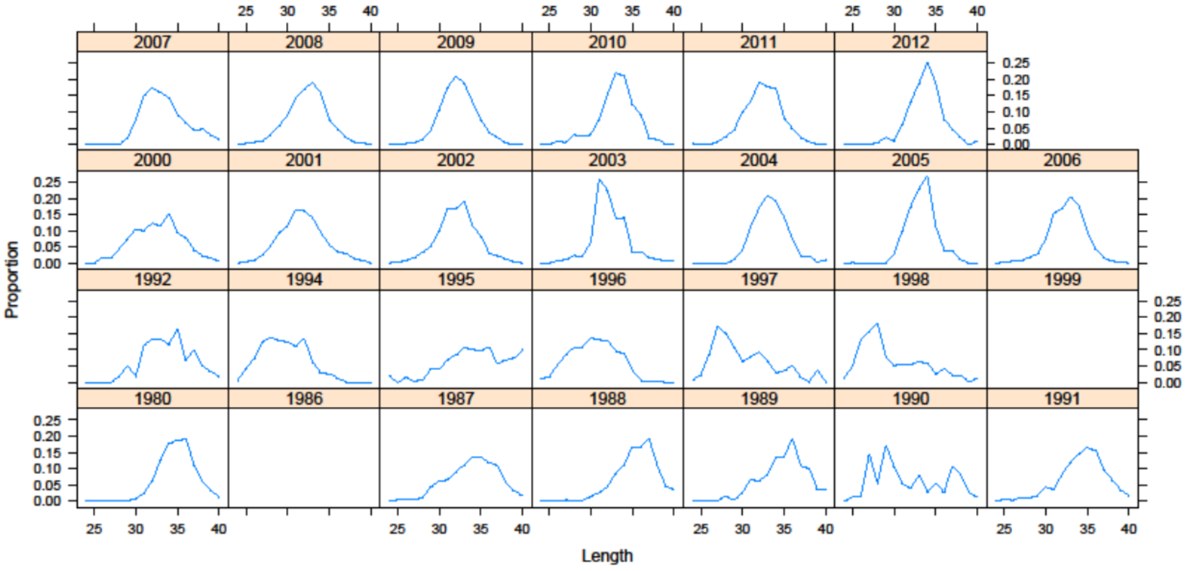

Figure 5c: Length frequency data for Area 3.

3.6.2 Acoustic research survey length data

The 1997, 2002, 2006 and 2011 acoustic survey abundance-at-length data were converted to numbers-at-length using a fixed length-weight relationship (see biological parameters in Table 10) and are listed in Table 9. For the 1997 and 2002 length frequency data, the relationship between proportion-at-length and CV established from bootstrap re-sampling of the grouped observer length frequency data were corrected for sample size and used to provide an estimate of the CV to apply to the acoustic survey length frequency proportions-at-length. For the 2006 and 2011 samples, bootstrapping both length data within mark-type and biomass by stratum and mark-type were used to estimate the CVs.

Table 9: Acoustic survey proportions at length for each area.

Length	1997			2002			2006			2011		
(cm)	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3
25	0.015	0.013	0.009	0.022	0.016	0.008	0.009	0.017	0.015	0.061	0.057	0.019
26	0.035	0.027	0.019	0.039	0.030	0.013	0.026	0.035	0.032	0.027	0.027	0.019
27	0.113	0.061	0.029	0.051	0.038	0.018	0.066	0.073	0.055	0.044	0.047	0.032
28	0.165	0.090	0.038	0.085	0.062	0.029	0.118	0.105	0.077	0.083	0.086	0.055
29	0.153	0.104	0.064	0.117	0.091	0.044	0.152	0.143	0.113	0.112	0.114	0.072
30	0.143	0.105	0.065	0.139	0.119	0.060	0.175	0.153	0.132	0.153	0.154	0.107
31	0.131	0.119	0.089	0.123	0.122	0.086	0.156	0.157	0.154	0.159	0.157	0.125
32	0.102	0.121	0.105	0.137	0.133	0.127	0.117	0.136	0.169	0.120	0.119	0.153
33	0.046	0.094	0.098	0.112	0.123	0.141	0.073	0.089	0.119	0.120	0.118	0.175
34	0.041	0.086	0.097	0.065	0.084	0.138	0.059	0.056	0.076	0.069	0.067	0.126
35	0.029	0.058	0.083	0.054	0.064	0.100	0.032	0.026	0.037	0.026	0.029	0.057
36	0.015	0.043	0.091	0.021	0.052	0.104	0.014	0.009	0.014	0.017	0.018	0.034
37	0.006	0.037	0.080	0.015	0.025	0.049	0.001	0.001	0.004	0.005	0.005	0.018
38	0.006	0.042	0.131	0.020	0.041	0.083	0.003	0.001	0.003	0.004	0.003	0.007

3.7 Biological data

This model was not sex-specific so combined sex parameters were developed (Table 10).

Table 10: Life history parameters for black oreo. The combined parameter values were used in this model. The sex-specific parameters are included in the table for comparative purposes only. Parameters *a* and *b* refer to the power function $f(x) = a.x^b$.

Parameter		Female	Male	Combined
Natural mortality (per year)	*M*	0.044	0.044	0.044
Length-weight	*a*	0.008	0.016	0.0078
	b	3.28	3.06	3.27
Age-length (Area 1)	*a*	-	-	18.85
	b	-	-	0.13
Age-length (Areas 2 and 3)	*a*	-	-	20.81
	b	-	-	0.13

Combined length-weight parameters were calculated from TAN9208 survey data, which surveyed the Puysegur area. Otoliths collected in the TAN9208 survey were aged and these data used by McMillan et al. (1997) to estimate natural mortality. Natural mortality estimates were not available from OEO 3A because there were no otolith samples for age estimation available from early in the fishery.

3.7.1 Growth

Growth was defined by a mean length at each age class in the model (1 to 70 years). Hicks et al. (2002) used von Bertalanffy growth parameters, but extension of the model to include fish from age 1 year onwards made this growth form inappropriate. In the previous assessment growth data for black oreo could be split into two groups – older and younger than age 5 – corresponding to the pre- and post-settlement life stages, and the von Bertalanffy parameters did not adequately fit the two different growth phases. Therefore mean length-at-age was calculated separately for pre-and post-settlement fish and linear interpolation was used to join the curves (Doonan et al. 2009).

For the current analysis, we re-estimated the growth curves for Area 1 and Areas 2 & 3 separately, using otolith data from the OEO 3A fishery. The Gompertz model was examined as an alternative to the von Bertalanffy growth curve but rejected in favour of a simple power function, which was tailored to approach the origin by including an intercept of one at age zero. Although data from small fish were limited, this allowed more consistency with the growth functions used in the previous assessment. Revised growth parameters are listed in Table 10 and shown in Figure 6.

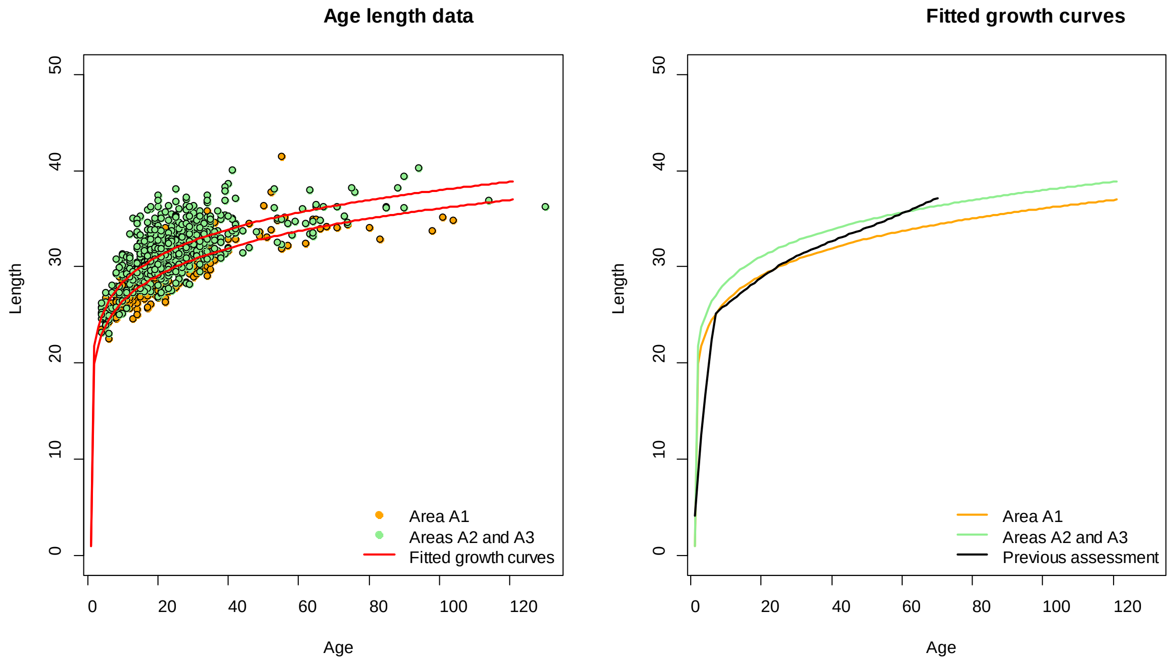

Figure 6. Growth curves fitted to black oreo otolith data from Area 1 and Areas 2 & 3 in OEO 3A. The growth curve used by Doonan et al. (2009) in the previous assessment is also shown for comparison.

3.7.2 Maturity

Doonan et al. (2009) used OEO 3A spawning season research trawl survey data from 1986 and 1987 to estimate the maturity rates by age by fitting the length ogive and length frequency data of mature and non-mature fish to that predicted by a simple population model (growth, constant recruitment, fixed M, and F). Maturity rates were represented by a capped logistic with parameters A_m (rates cap), a50L (age at 50% of A_m), and A50.95 (ages from 50% to 95% level). Errors were estimated by bootstrapping the trawl survey data within strata. Simulations were used to evaluate the estimation procedure when assumptions were violated. The estimated parameters were (F=0): A_m = 1, A50 = 37.7 yr, and A50.96 = 0.5 yr. The age ogive was almost knife-edge at 38 yr.

4. DISCUSSION

A number of problems with the assessment were noted by Doonan et al. (2009). This assessment had a high mature biomass in Area 1 (which is outside the main fished area), which could keep the total mature biomass of the stock at about 25% of virgin levels if left unfished, even if the other areas were fished to exhaustion. The fraction of biomass that is mature was based on the length frequency data, not age data, and so could introduce a bias. This led to ageing work to determine the age frequency distributions in Area 1 and in Areas 2 & 3 combined to check that the relatively high mature biomass in Area 1 in the assessment was correct.

The ageing data showed that there were different growth rates in each area (faster growth in Areas 2 & 3) and that maturity is length based. Migration was used to move fish from Area 1 (the assumed settlement area) into Area 2 and then into Area 3, based on differences in length frequency data. These problems could not be solved for the current assessment (2012-13) and an assessment was not completed.

The CPUE series show that after an initial decline in abundance in the fished areas (Areas 2 & 3), the abundance stabilised and was more or less constant, and that this has continued in the more recent data (Figure 4). The most recent acoustic abundance estimates increased over the previous three estimates (Doonan et al. 2013), but the interpretation of this increase is unclear. The new commercial length frequency distributions show no clear changes from those as far back as 2007 for Areas 1 & 2, and back to 2006 for Area 3.

5. MANAGEMENT IMPLICATIONS

The current stock status is unknown. Although recent trends in abundance and length frequency distributions suggest that the stock is stable in each of the areas, we do not know how depleted the stock is.

A new assessment model is currently being developed in ADMB that will allow different growth rates in each area, which should resolve some of the conflicts highlighted above. Furthermore, recruitment to each area will be allowed, circumventing the need for migration from shallow to deeper waters. This model is currently under development and will be presented in a separate document.

6. ACKNOWLEDGMENTS

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7. REFERENCES

Bull, B.; Francis, R.I.C.C.; Dunn, A.; McKenzie, A.; Gilbert, D.J.; Smith, M.H. (2003). CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v2.01-2003/08/01. *NIWA Technical Report 124*. 223 p.

Coburn, R.P.; Doonan, I.J.; McMillan, P.J. (1999). Black oreo abundance indices from standardised catch per unit of effort data for OEO 3A. New Zealand Fisheries Assessment Research Document 99/32. 18 p. (Unpublished report held in NIWA library, Wellington.)

Doonan, I.J.; Coburn, R.P.; McMillan, P.J. (2009). Assessment of OEO 3A black oreo for 2006–07. *New Zealand Fisheries Assessment Report* 2009/12. 46 p.

Doonan, I.J.; Coburn, R.P.; McMillan, P.J.; A.C. Hart (2004). Assessment of OEO 3A black oreo for 2002–3. *New Zealand Fisheries Assessment Report 2004/52*. 54 p.

Doonan, I.J.; Coombs, R.F.; McMillan, P.J.; Dunn, A. (1998). Estimate of the absolute abundance of black oreo and smooth oreo in OEO 3A and 4 on the Chatham Rise. Final Research Report for Ministry of Fisheries Research Project OEO9702. 47 p. (Unpublished report held by Ministry for Primary Industries, 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.)

Doonan, I.J.; McMillan, P.J.; Coburn, R.P.; Hart, A.C.; Cordue, P.L. (1995). 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.; Hart, A.C.; Dunford, A. (2014). Black oreo abundance estimates from the November-December 2011 acoustic survey of the south Chatham Rise (OEO 3A). *New Zealand Fisheries Assessment Report 2014/01*. 26 p.

Doonan, I.J.; Smith, M.H.; McMillan, P.J.; Hart, A.C.; Dunford, A. (2008). Black oreo abundance estimates from the October 2006 acoustic survey of the south Chatham Rise (OEO 3A). *New Zealand Fisheries Assessment Report 2008/41*. 21 p.

Hicks, A.C.; Doonan, I.J.; McMillan, P.J.; Coburn, R.P.; Hart, A.C. (2002). Assessment of OEO 3A black oreo for 2002–03. *New Zealand Fisheries Assessment Report 2002/63*. 58 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.)

Smith, M.H.; Doonan, I.J.; McMillan, P.J.; Hart, A.C. (2006). Black oreo abundance estimates from the September-October 2002 acoustic survey of the south Chatham Rise (OEO 3A). *New Zealand Fisheries Assessment Report 2006/33*. 20 p.