OREOS – OEO 4 BLACK OREO AND SMOOTH OREO

1. FISHERY SUMMARY

This is presented in the Fishery Summary section at the beginning of the Oreos report.

2. BIOLOGY

This is presented in the Biology section at the beginning of the Oreos report.

3. STOCKS AND AREAS

This is presented in the Stocks and Areas section at the beginning of the Oreos report.

4. STOCK ASSESMENT

4.1 Introduction

In 2014, the stock assessment was updated for smooth oreos in OEO 4.

4.2 Black oreo

Investigations were carried out in 2009 using age-based single sex single step preliminary models in CASAL. The data used in these models were four standardised CPUE indices (pre– and post–GPS in the east and west), and observer length frequencies. Growth and maturity were also estimated in some of the runs.

4.2.1 Estimates of fishery parameters and abundance

Absolute abundance estimates from the 1998 acoustic survey

Absolute estimates of abundance were available from an acoustic survey on oreos which was carried out from 26 September to 30 October 1998 on *Tangaroa* (voyage TAN9812). Transects on flat ground were surveyed to a stratified random design and a random sample of seamounts were surveyed with either a random transect (large seamounts) or a systematic “star” transect design. For some seamounts the flat ground nearby was also surveyed to compare the abundance of fish on and near the seamount either by extending the length of the star transects or by extra parallel transects. Acoustic data were collected concurrently for flat and seamounts using both towed and hull mounted transducers. The OEO 4 survey covered 59 transects on the flat and 29 on seamounts. A total of 95 tows were carried out for target identification and to estimate target strength and species composition. In situ and swimbladder samples for target strength data were collected and these have yielded revised estimates of target strength for both black oreo and smooth oreo.

Acoustic abundance estimates for recruit black oreo from seamounts and flat for the whole of OEO 4 are in Table 1. About 59% of the black oreo abundance came from the background mark-type. This mark-type is not normally fished by the commercial fleet and this implies that the abundance estimate did not cover the fish normally taken by the fishery. In addition the scaling factor to convert the acoustic area estimate to the trawl survey area estimate was 4.3, i.e., the acoustic survey area only had about 23% of the abundance. The magnitude of this ratio suggests that the size of the area surveyed was borderline for providing a reliable abundance estimate.

Table 1: OEO 4 recruit black oreo seamount, flat, and total acoustic abundance estimates (t) and recruit CV (%) based on knife-edge recruitment (23 years).

	Abundance (t)	CV (%)
Seamount	127	91
Flat	13 800	56
Total	13 900	55

Relative abundance estimates from standardised CPUE analyses – 2009 analysis

The CPUE analysis method involved regression based methods on the positive catches only. Sensitivities were run where the positive catch tow data and the zero catch tow data were analysed separately to produce positive catch and zero catch indices. All data were included, whether they were target or bycatch fisheries, with the target offered to the model (and not accepted).

The best data-split was investigated using the Akaike Information Criteria (AIC) on a number of potential regressions. Four indices were subsequently used, pre- and post-GPS in the east and west areas respectively. These two areas are very distinct: the west consists of flat fishing and the east of hill fishing, the west area was fished 10 years prior to the east, and there has been a move by the fishery since the early 1990s from the west to the east. However, despite of all these differences, the two series present almost identical patterns of decline in relative standardised CPUEs from the time their exploitation started in earnest (1980 in the west and 1992 in the east) which would suggest that for this fishery CPUE might be a reasonable index of abundance (because less influenced by technology, fishing patterns, hills or flats etc).

The standardised CPUE series and CVs are described in Table 2. Over comparable time periods and data sets, the trends from the updated series were similar to those from the 2000 analyses (Coburn *et al.* 2001). The west CPUE reduced to between 5% of 1980 value and 15% of 1981 value by 1990. The post-GPS west series is either flat or slightly increasing. The east CPUE reduced to 4% of 1984 value and 21% of 1985 value by 1990 even though catches were low. The post-GPS east series showed a further steep initial decline with total reduction to 15% of 1993 values by 2008.

Table 2: OEO 4 black oreo standardised CPUE analyses in 2009 (expressed in t / tow).

	Pre-GPS east		Pre-GPS west			Post-GPS east		Post-GPS west	
fishing year	index	cv	index	cv	fishing year	index	cv	index	cv
1980			8.97	0.17	1993	0.71	0.15	0.73	0.41
1981			4.00	0.11	1994	0.63	0.13	0.45	0.32
1982			2.24	0.10	1995	0.31	0.15	0.41	0.31
1983			2.20	0.09	1996	0.21	0.15	0.28	0.27
1984	0.47	0.95	1.54	0.10	1997	0.24	0.12	0.61	0.27
1985	0.41	0.28	1.51	0.07	1998	0.20	0.11	0.45	0.23
1986	0.38	0.32	1.28	0.10	1999	0.16	0.12	0.46	0.23
1987	0.65	0.30	0.67	0.10	2000	0.17	0.12	0.68	0.25
1988	0.10	0.18	0.54	0.13	2001	0.14	0.08	0.62	0.24
1989	0.02	0.20	0.48	0.12	2002	0.18	0.07	0.47	0.29
					2003	0.13	0.06	0.49	0.24
					2004	0.13	0.06	0.93	0.24
					2005	0.14	0.07	0.91	0.26
					2006	0.13	0.07	0.68	0.26
					2007	0.12	0.07	1.00	0.27
					2008	0.10	0.09	0.88	0.24

Relative abundance estimates from trawl surveys

The estimates, and their CVs, from the four standard *Tangaroa* south Chatham Rise trawl surveys are treated as relative abundance indices (Table 3).

Table 3: OEO 4 black oreo research survey abundance estimates (t). N is the number of stations. Estimates were made using knife-edge recruitment set at 33 cm TL. Previously knife-edge recruitment was set at 27 cm and estimates of abundance based on that value are also provided for comparison.

Year	Mean abundance		CV (%)	N
	27 cm	33 cm		
1991	34 407	13 065	40	105
1992	29 948	12 839	46	122
1993	20 953	6 515	30	124
1995	29 305	9 238	30	153

Observer length frequencies

Observer length frequencies were available for about 20% of the yearly catch from 1989 to 2008. Analyses conducted on these data indicated they were not representative of the spatial spread of the fishery. When stratified by depth, the length frequencies had double-modes, centred around 28 cm and 38 cm, with inconsistent trends in the modes between years. Alternative stratification by subarea, hill, etc, did not resolve the problem; some tows showed bimodality. These patterns in length frequencies were an issue because the yearly shifts in length frequencies and double mode cannot be representative of the underlying fish population since black oreo is a slow growing long-lived fish. They are more likely linked with discrete spatial sub-groups of the population.

A similar double mode was reported for some strata in the same area from the 1994 Tangaroa trawl survey (Tracey & Fenaughty 1997). It is likely that there is further spatial stock structure that is currently unaccounted for.

4.2.2 Biomass estimates

The 2009 stock assessment of OEO 4 black oreo was inconclusive as assessment models were unable to represent the observer length frequency structure, and were considered unreliable. The CPUE was fitted satisfactorily under a two-stock model but could not be fitted in a single homogeneous stock model. However, the WG agreed that:

1. The CPUE indices are consistent with a two-stock structure or at least a minimally-mixing single stock.
2. The updated CPUE estimates were probably a reasonable indicator of abundance (at the spatial scale of the east and west analyses).

4.2.3 Estimation of Maximum Constant Yield (MCY)

In 2000, MCY was estimated using the equation, MCY = $c*Y_{AV}$ (Method 4). There was no trend in the annual catches, nominal CPUE, or effort from 1982–83 to 1987–88 so that period was used to calculate the MCY estimate (1200 t). The MCY calculation was not updated in 2009.

4.2.4 Estimation of Current Annual Yield (CAY)

CAY cannot be estimated because of the lack of current biomass estimates.

4.3 Smooth oreo

Biomass and yield estimates for smooth oreo were made using a CASAL age-structured population model with Bayesian estimation, incorporating stochastic recruitment, life history parameters (Table 1 of the Biology section at the beginning of the Oreos report), and catch history up to 2012-13. In early assessments (Doonan et al. 2008, 2003, 2001), the stock area was split at 178° 20′ W into a west and an east fishery based on an analysis of commercial catch, standardised CPUE, and research trawl and acoustic result, and data fitted in the model included acoustic survey abundance estimates, standardised CPUE indices, observer length data, and the acoustic survey length data. In 2012, the Deepwater Working Group decided that using CPUE to index abundance should be discontinued, due to changes in fishing patterns over time within the stock area. With no CPUE indices, the 2012 assessment was simplified to a single area model using only the observations of vulnerable biomass from acoustic surveys carried out in 1998, 2001, 2005, and 2009.

The 2014 stock assessment updated the 2012 assessment model using the same single area model structure and used an additional observation of abundance from the research acoustic survey carried out in 2012. The assessment also revised the previous assessments by including the age frequency estimates from the 1998 and 2005 acoustic surveys and by estimating relative year class strengths.

Oreo catch data showed marked changes in fishing patterns over time. Large catches first started in the west and then progressed east over time and appeared to represent successive exploitation of new areas. Previously exploited areas in the west did not later sustain high catches. The target species and the type of fishing also changed over time with smooth oreo the target species in the west on flat, dropoff, and seamounts from the late 1970s, with a gradual change to target fishing for orange roughy on seamounts in the east from the late 1980s. Since the late 1990s, there has been an increase in target fishing for smooth oreo in the east, with more fish being caught as a target species than as bycatch. Given the above, the Deepwater Working Group decided in 2012 that using CPUE to index abundance should be discontinued.

To limit the extra uncertainty in "layer" marks which contained the pre-recruited fish, the abundance data were re-worked into vulnerable abundance of adult sized fish (school marks). Selectivities for both the commercial fishery and acoustic survey were assumed to be length-based and knife-edged at 33 cm derived from the distribution of the observer length commercial data Acoustic abundance data were fitted as relative abundances using a log-normal likelihood with no additional process error. The model assumed a fixed M (0.063).

The 2014 assessment used the same model structure as that in 2012, but it also used a separate logistic selectivity for fitting the age frequency data from the acoustic surveys and this was estimated within the model.

Year class strengths (YCS) were estimated for 1955–2000 (based on the range of age estimates in the age frequency data). YCS were assumed to be fixed at 1 in previous assessments as no age data were used. A number of prior distributions on YCS were investigated. The base case used a prior that is close to being uniform (parameterised as a lognormal distribution with a mode of 1 and sigma of 4), which places minimum constraint on the YCS (Haist parameterisation).

Informed priors were assumed for the survey catchability coefficient q. For the time series based on fished marks, a lognormal prior with mean of 0.83 and CV of 0.3 was used. The choice of the priors was based on limited information on target strength, the QMA scaling-factor, and the proportion of vulnerable biomass in the vulnerable acoustic marks (Fu & Doonan 2013).

A brief description of the base case and sensitivity runs presented are summarised in Table 4. The Deepwater Working Group recommended that MCMC runs be carried out for the base case and models 5.1, 5.2 and 5.4 to address the uncertainty in survey q and acoustic abundance estimate, the following assumptions were made in the stock assessment analyses:

(a) Recruitment followed a Beverton & Holt relationship with steepness of 0.75.
(b) Catch overruns were 0% during the period of reported catch.
(c) The population of smooth oreo in OEO 4 was a discrete stock or production unit.
(d) The catch history was accurate.

Bayesian procedures were used in the assessment to estimate the uncertainties in model estimates of biomass for all model runs using the following procedure:

1. Model parameters were estimated using maximum likelihood and the prior probabilities;
2. Samples from the joint posterior distribution of parameters were generated with the Monte Carlo Markov Chain procedure (MCMC) using the Hastings-Metropolis algorithm;
3. A marginal posterior distribution was found for each quantity of interest by integrating the product of the likelihood and the priors over all model parameters; the posterior distribution was described by its median, 5th and 95th percentiles for parameters of interest.

Bayesian estimates were based on results from a 30 million long MCMC. After a burn-in of 25 million, the last 5 million of the chain was sampled at each 1000th value. Posterior distributions were obtained from samples combined over three independent chains.

Table 4: Descriptions of the model runs of the 2014 smooth oreo assessment. LN, lognormal distribution with mean and CV given in the bracket. All use Haist parameterisation for YCS.

Model run	Description
5.0 (base case)	estimated *q* with a LN (0.83, 0.3) prior, nearly uniform prior on YCS, *M* fixed at 0.063, adult abundance indices (school marks)
5.1	5.0, but estimated *q* with a LN(1, 0.3) prior, M fixed at 0.05
5.2	5.0, but estimated *q* with a LN(0.6, 0.3) prior, M fixed at 0.07
5.4	5.0, but excluded the 2012 large school mark in stratum 52 in the acoustic abundance

4.3.1 Estimates of fishery parameters and abundance

The 2014 assessment incorporated the catch history and the adult acoustic abundance indices based on either the length cut-off of 33 cm or fished marks. The updated CPUE indices, observer length data, and acoustic length data were not included in the 2014 assessment model.

Catch history

A catch history for OEO 4 was developed by scaling the estimated catch to the QMS values, Table 5.

Table 5: Catch history for OEO 4 smooth oreo (t)

Year	OEO 4	Year	OEO 4
1978–79	1 321	1996–97	6 359
1979–80	112	1997–98	6 248
1980–81	1 435	1998–99	6 030
1981–82	3 461	1999–00	6 357
1982–83	3 764	2000–01	6 491
1983–84	5 759	2001–02	4 291
1984–85	4 741	2002–03	4 462
1985–86	4 895	2003–04	5 656
1986–87	5 672	2004–05	6473
1987–88	7 764	2005–06	5955
1988–89	7 223	2006–07	6363
1989–90	6 789	2007–08	6422
1990–91	6 019	2008–09	6090
1991–92	5 508	2009–10	6118
1992–93	5 911	2010–11	6518
1933–94	6 283	2011–12	6357
1994–95	6 936	2012–13	5964
1995–96	6 378		

Absolute abundance estimates from the 1998, 2001, 2005, 2009, and 2012 acoustic surveys

Absolute estimates of abundance were available from five acoustic surveys:

(i) 26 September to 30 October 1998 on *Tangaroa* (voyage TAN9812);
(ii) 16 October to 14 November 2001 using *Tangaroa* for acoustic work (voyage TAN0117) and *Amaltal Explorer* (voyage AEX0101) for trawling;
(iii) 3–22 November 2005 using *Tangaroa* for acoustic work (voyage TAN0514) and 3–20 November 2005 using *San Waitaki* (SWA0501) for mark identification trawling;
(iv) 2–18 November 2009 using *Tangaroa* for acoustic work (voyage TAN0910) and 2–18 November 2009 using *San Waitaki* (SWA0901) for mark identification trawling.
(v) 8–26 November 2012 using *Tangaroa* for acoustic work (voyage TAN01214) and 8–26 November 2012 using *San Waitaki* (SWA1201) for mark identification trawling.

Acoustic abundance estimates were made for total smooth oreo from seamounts and flat for the whole of OEO 4. The 1998 and 2001 estimates for the mixed species mark-types were adjusted to match the larger contribution for non-smooth oreo species in these mark types from the trawl net used in 2005.

One of the major uncertainties in the assessment is from the large contribution to the total acoustic abundance estimate from smooth oreo estimated to be in the LAYER mark-type (72% of the total abundance for the 1998 survey, 47% for the 2001 survey, 45% for the 2005 survey, 61% for the 2009 survey, 49% for the 2012 survey). The contribution of large (greater than 31 cm) smooth oreo to the total backscatter in these LAYER marks was typically less than 10% of the total LAYER abundance, with the remainder composed of a number of associated bycatch species and smaller smooth oreo in 1998 and 2001. The layer acoustic abundance may be biased due to misspecification of the contribution made by other fish species present in the layers, thus adding to the overall uncertainty in the biomass estimates from the assessment. The contribution of large smooth oreo to the total backscatter in the SCHOOL mark-types was typically greater than 75% in 1998 and 2001. Therefore, the acoustic smooth oreo abundance estimates from the schools were considered to be better estimated than the equivalent acoustic estimates from the layers.

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Abundance of vulnerable smooth oreo was estimated using two different methods. The first method was based on the acoustic mark types, where vulnerable biomass was the sum over two flat mark types: DEEP SCHOOLS and SHALLOW SCHOOLS, with the hill biomass added on. The second method was based on the length cut-offs on the total biomass, where the ratio of vulnerable to total biomass was calculated from the length data collected from the surveys using a vulnerable cut-off length determined from a mid-point on the left hand limb of the commercial length distribution. Estimates were therefore produced for a length cut-off of 33 cm (the 2012 assessment also considered a length cut-off of 34 cm as a sensitivity analysis). These estimates were made for smooth oreo in the whole of OEO 4 (Table 6).

One major source of uncertainty in the 2012 survey estimates was that about 25% of the total estimate came from one school mark on the flat. The species composition of this mark was not able to be verified by trawling. Excluding this mark, i.e., assuming they are not smooth oreo, reduced the total abundance for smooth oreos to 64 860 t with a reduced CV of 31%.

Table 6: Estimated smooth oreo abundance (t) and CV (in brackets, %) from acoustic surveys in 1998, 2001, 2005, and 2009, and 2012, including estimates for total abundance and vulnerable abundance. The vulnerable abundance estimates were based either on vulnerable acoustic marks (shallow and deep schools, plus hills), or a length cut-off of 33 cm.

	Total		Adult (school mark)		Adult (>33cm)	
Year	Abundance (t)	CV (%)	Abundance (t) *	CV (%)	Abundance (t)	CV (%)
1998	146 000	33	65 679	26	99 619	33
2001	218 200	22	81 633	26	142 348	19
2005	115 500	28	63 237	25	90 316	22
2009	66 500	36	26 953	26	63 471	30
2012	88 558	42	58 603	30	69 925	42

* When the single large mark was removed from the adult (school mark) estimate for 2012, the abundance was reduced to 36,550 t, with an assumed CV of 30%.

Age frequencies from the 1998 and 2005 acoustic surveys

Population age frequency distributions for smooth oreo in OEO 4 were determined by estimating ages from otoliths and data collected on two acoustic surveys carried out in 1998 and 2005 (Doonan 2008b). All of the sampled otoliths (n = 546) from the 1998 survey and randomly selected otoliths (n = 500) from the 1800 otoliths collected during the 2005 survey were read.

The age frequency distribution was estimated using the aged otoliths from tows in each mark-type weighted by the catch rates and the proportion of abundance in the mark-type. Age frequencies were estimated by sex and combined over sexes. The variance was estimated by bootstrapping the tows within mark-types for the 1998 survey and within mark-type and stratum for the 2005 survey (Doonan 2008b). The ageing error was estimated by comparing age estimates from two readers and also by using repeated readings from the same reader. The age frequencies had a mean weighted CV of 36% (1998) and 45% (2005). The ageing error was estimated to be about 8.5%. The age frequencies data (male and female combined) were included in order to estimate year class strength.

Observer length frequencies
Observer length data were extracted from the observer database. These data were stratified by season (October-March and April-September) and into west and east parts. The length frequencies were combined over strata by the proportion of catch in each stratum.

The scaled length were used to determine the length cut-offs for estimating the adult abundance, but were not otherwise included in the assessment model

Relative abundance estimates from standardised CPUE analyses
The CPUE analysis was not updated for the 2014 assessment.

4.3.2 Biomass estimates
When carrying out MCMC simulations to obtain posterior samples, the survey *q* was estimated as a free parameter (it was estimated as a nuisance parameter in the MPD). This allowed the uncertainly associated with *q* to be incorporated into model results because estimates of stock sizes were integrated over possible values of *q*.

The estimates of biomass for base case and sensitivity models are summarised in **Error! Reference source not found.**. For the base case (model 5.0), the median of B_0 was estimated to be 131 000 t, with a 90% credible interval between 115 000 and 156 000 t. The estimate of 2013 stock status was 27% B_0, with a 90% confidence interval between 16 and 41%. The biomass trend showed a steeper decline after the mid-2000s (Figure 1). Estimated probability of B_{2013} being above the target biomass (40% B_0) was 0.067, and being below the soft (20% B_0) and hard (10% B_0) limit was 0.167 and 0.003, respectively (Table 8).

Biomass estimates were sensitive to the assumed *q* and *M*. If the assumed prior mean of *q* was 20% higher, and *M* was 20% lower (model 5.1) than in the base case, B_{2013} was estimated to be 18% B_0, with a 90% confidence interval between 11 and 29%; if the prior mean of *q* was 20% lower, and *M* was 20% higher than the base case (model 5.2), B_{2013} was estimated to be 36% B_0, with a 90% confidence interval between 21 and 56%. The location and shape of the posterior distribution of survey *q* appeared to be strongly driven by the assumed prior, suggesting that the signal in the acoustic estimates is not strong enough to determine *q* (Figure 2).

Excluding the uncertain large mark in stratum 52 from the 2012 survey led to much more pessimistic estimates of stock status (Model 5.4), with B_{2013} estimated to be 20% B_0 (90% CI of 12–36%).

For the base case, estimated YCS appeared noisy with associated large variability (Figure 3–left). Overall they suggested that there was a period of relatively low recruitment before 1970, relatively high recruitment between 1970 and 1985, and the recruitment in more recent years was below the long term average. Estimated exploitation rates appear to have steadily increased over time, especially after 2000 (Figure 3, right). The current median exploitation rate was estimated to be 0.16, which is significantly higher than $U_{40\%B0}$ (estimated to be 0.057).

4.3.3 Yield estimates and projections
The five year projection for the base case, with future annual catch assumed to be 6000 t for 2014–2018 suggested that the biomass is likely to decrease, and the median of spawning biomass in 2018 (B_{2018}) was estimated to be 22 400 t, or 18% B_0. The estimated probability of B_{2018} being above 40% B_0 was 0.003, and being below the soft (20% B_0) and hard (10% B_0) limit was 0.616 and 0.16, respectively (Table 8).

Table 7: Estimates of mature biomass for OEO 4 smooth oreo for MCMC models 5.0 (base case), 5.1, 5.2, and 5.4. AcAq, catchability coefficient for relative indices of vulnerable biomass; U2013, current exploitation rate.

			MCMC 5.0			MCMC 5.1
	5%	Median	95%	5%	Median	95%
B_0	115 000	131 000	156 000	126 000	138 000	159 000
B_{2013}	18 000	35 000	62 000	13 000	25 000	45 000
B_{2013} ($\%B_0$)	0.16	0.27	0.41	0.11	0.18	0.29
ACAq	0.65	0.94	1.36	0.79	1.11	1.55
U_{2013}	0.09	0.16	0.29	0.12	0.21	0.38
			MCMC 5.2			MCMC 5.4
	5%	Median	95%	5%	Median	95%
B_0	112 000	132 000	185 000	113 950	127 000	152 000
B_{2013}	23 000	43 000	99 050	13 000	27 000	53 000
B_{2013} ($\%B_0$)	0.21	0.34	0.56	0.12	0.22	0.36
ACAq	0.44	0.75	1.10	0.64	0.95	1.33
U_{2013}	0.06	0.13	0.24	0.10	0.20	0.39

Table 8: Summary of current and projected biomass indicators for the base case (5.0), with future annual catch assumed to be 6000 t for 2014–2018: spawning biomass as a percentage of B_0, the probability of spawning being above the target biomass (40% B_0), below the soft limit (20% B_0), and below the hard limit (10% B_0), and the probability of exploitation rate (U_t) being above $U_{40\%B0}$.

	B_t $\%B_0$ (90% CI)	Pr($B_t > 40\%B_0$)	Pr($B_t < 20\%B_0$)	Pr($B_t < 10\%B_0$)	Pr ($U_t > U_{40\%B0}$)
2013	27 (16–41)	0.067	0.167	0.003	1.000
2018	18 (6–32)	0.003	0.616	0.160	1.000

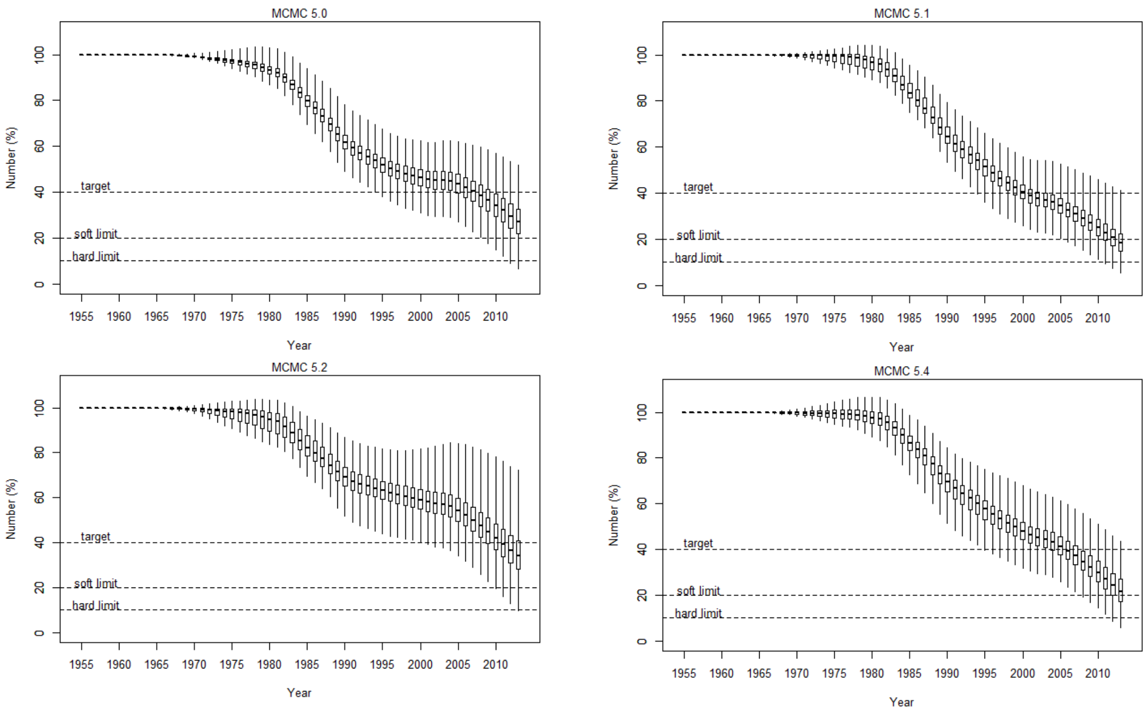


Figure 1: Bayesian posterior distribution of mature biomass mature biomass as a percentage of B_0 (right) for models 5.0, 5.1, 5.2, and 5.4. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution.

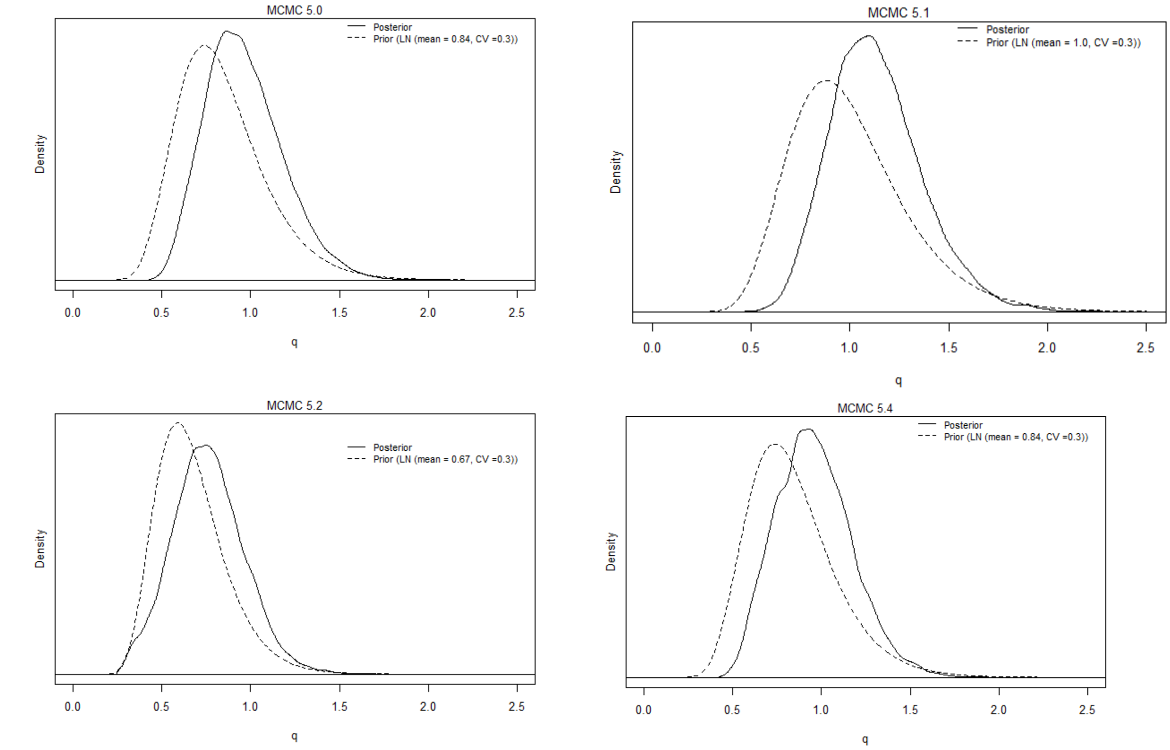


Figure 1: Estimated Bayesian posterior distribution and the assumed prior distribution for survey *q* for models 5.0, 5.1, 5.2, and 5.4.

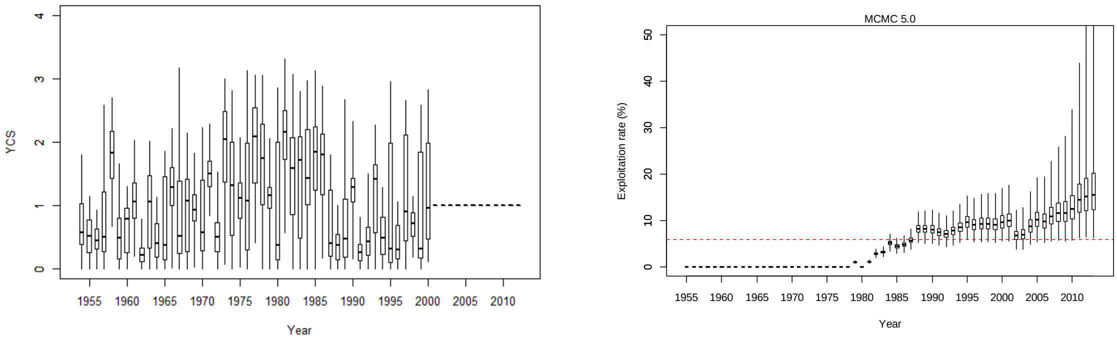


Figure 2: Estimated Bayesian posterior distributions of year class strength (left) and exploitation rates (right) for the base case. The box shows the median of the posterior distribution (horizontal bar), the 25th and 75th percentiles (box), with the whiskers representing the full range of the distribution. YCS were estimated for 1955–2000, and fixed at 1 for other years.

4.3.4 Other factors

The Working Group considered that there were a number of other factors that should be considered in relation to the stock assessment results presented here:

- There are also a number of factors that are outside the model and the analyses that add uncertainty to the model estimates of biomass. These include the sensitivity of the acoustic biomass estimate to the low value of the target strength of smooth oreo, and uncertainty in the estimates of *M* and growth rates.

- Age frequencies estimated from the 1998 and 2005 acoustic surveys suggest the possibility of poor recruitment to 1 year olds from 1986 up to 1995, the youngest cohort that would be seen in the 2005 acoustic data (Doonan & McMillan 2011). These cohorts would enter the fishery (at about age 23 years) from 2009 to 2018. However, age data from the 1993 and 1994 trawl surveys on the eastern end of the south Chatham Rise were ambiguous (Doonan & McMillan 2011).

- Another major source of uncertainty was in the 2012 survey estimates in which a significant proportion of the biomass was from a mark which was identified as smooth oreo. The species composition of this mark was not able to be verified by trawling. Excluding this mark would reduce the 2012 adult school abundance estimate by 38%, and as a result, reduce the estimate of current spawning stock biomass to 22% B_0.

4.3.5 Future research needs

- Only two years of age composition data are included in the smooth oreo assessment. More otoliths from previous surveys should be read to improve the estimation of year class strengths.
- As the acoustic survey time series lengthens, and the number of species identification trawls increases, the uncertainty in the assessment is likely to be reduced.
- Better mark identification, particularly for very large schools, is needed to improve the survey biomass estimates. The strategy used in the acoustic surveys should be modified to maintain contact with any very large school until it can be trawled. It may also be useful to sub-stratify the area ("hotspot") that tends to have very large schools.

5. STATUS OF THE STOCKS

There is an updated stock assessment in 2014 for the smooth oreo stock.

Stock Structure Assumptions
The two oreo stocks on the Chatham Rise are assessed separately but managed as a single stock. For black oreos the population has been found to be genetically similar to other oreo stocks and it is likely that some mixing occurs. Smooth oreos are assumed to be distinct from OEO1+6 stocks but may mix with the 3A stock.

- **OEO4 (Black Oreos)**

Stock Status	
Year of Most Recent Assessment	2009
Assessment Runs Presented	No quantitative stock assessment model
Reference Points	Target(s): 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Historical Stock Status Trajectory and Current Status <No plot available>	

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has been stable for the last 5 years, after initial substantial decline during the 1980s and 1990s.
Recent Trend in Fishing Mortality or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown

Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

Assessment Methodology		
Assessment Type	Level 2 – Partial quantitative stock assessment	
Assessment Method	Age-based model in CASAL	
Main data inputs	- 4 standardised CPUE indices (pre/post GPS and east/west) - Observer length frequencies	
Period of Assessment	Latest assessment: 2009	Next assessment: Unknown
Changes to Model Structure and Assumptions	None	
Major Sources of Uncertainty	- Assessments unable to represent observer length frequency data. - CPUE could be fitted to a two-stock model but not a homogenous model. - A portion of the abundance estimates were based on data from areas not normally covered by the trawl fishery, and the surveyed area was scaled by a factor of 4.3 – the area surveyed was borderline for providing a reliable abundance estimate.	

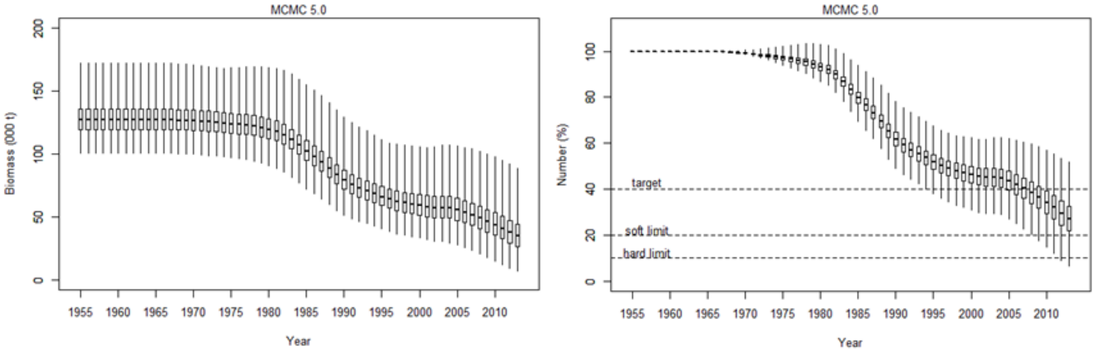
Qualifying Comments
The WG agreed that the stock might be split into east and west areas that were independent or at least minimally mixing for future assessments.

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries and in smaller numbers in hoki target fisheries. Target fisheries for oreos do exist, with main bycatch being orange roughy, rattails and deepwater sharks. Bycatch species of concern include deepwater sharks and rays, seabirds and deepwater corals.

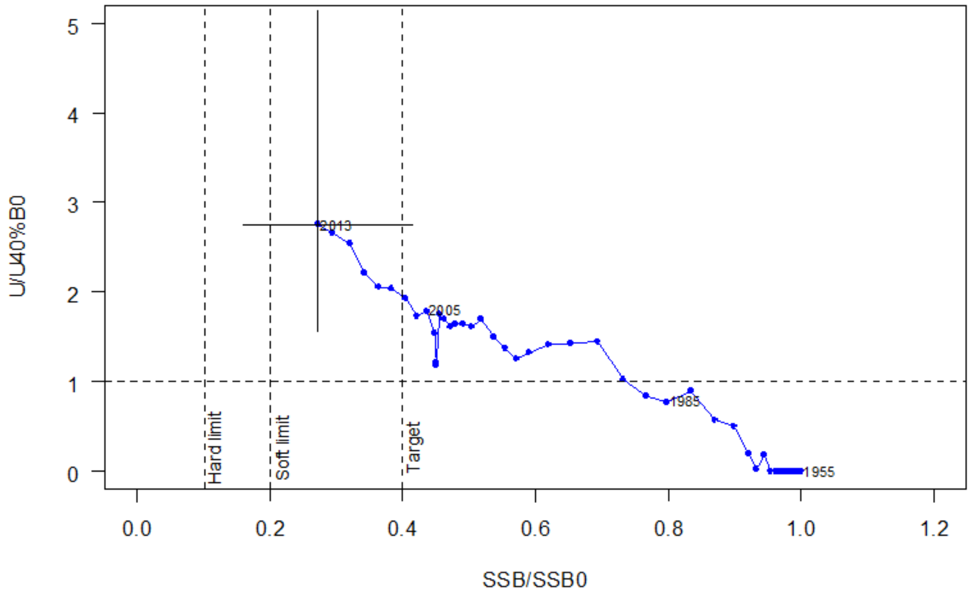
- **OEO4 (Smooth Oreos)**

Stock Status	
Year of Most Recent Assessment	2014
Assessment Runs Presented	Base case model fitted to vulnerable acoustic abundance estimates based on school marks, and age frequencies from acoustic surveys
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $F_{40\%}$
Status in relation to Target	B_{2013} was estimated at 27% B_0 for the base case model. B_{2013} is Very Unlikely (< 10%) to be at or above the target
Status in relation to Limits	B_{2013} is Unlikely (< 40%) to be below the Soft limit and Very Unlikely (< 10%) to be below Hard Limits.
Status in relation to Overfishing	Overfishing is Very Likely (> 90%) to be occurring.

Historical Stock Status Trajectory and Current Status



Spawning stock biomass trajectory for model 5.0 in number (left) and in percentage (right).



Trajectory of exploitation rate as a ratio $U_{\%40B0}$ and spawning stock biomass as a ratio of B_0 from the start of assessment period 1955 to 2013 for MCMC 5.0 (base case). The vertical lines at 10%, 20%, and 40% B_0 represent the hard limit, the soft limit, and the target respectively. $U_{\%40B0}$ is the exploitation rate at which the spawning stock biomass would stabilise at 40% B_0 over the long term. Each point on trajectory represents the estimated annual stock status: the value on x axis is the mid-season spawning stock biomass (as a ratio of B_0) and the value on the y axis is the corresponding exploitation rate (as a ratio $U_{\%40B0}$) for that year. The estimates are based on MCMC medians and the 2013 90% CI is shown by the cross line.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass appears to be steadily decreasing,
Recent Trend in Fishing Intensity or Proxy	Estimated exploitation rates have steadily increased over recent years
Other Abundance Indices	
Trends in Other Relevant Indicators or Variables	Relatively low recruitment before 1970, relatively high recruitment between 1970 and 1985, and below the long term average in more recent years

Projections and Prognosis	
Stock Projections or Prognosis	Assuming a future catch of 6000 t results in a reduction in the median estimate of spawning stock biomass to 22 400 t, or 17.6% B_0 in 2018.

Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Likely (> 60%) Hard Limit: Unlikely (<`40%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Likely (> 90%)

Assessment Methodology and Evaluation		
Assessment Type	Type 1 – Full Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment : 2014	Next assessment: 2018
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Five acoustic abundance data (1998, 2001, 2005, 2009, 2012) - Age frequencies from acoustic surveys (1998, 2005) - Acoustic length data - Observer length data (not used, except to provide a length cut-off for vulnerable fish)	1 – High Quality 1 – High Quality 1 – High Quality 2 – Medium or Mixed Quality: conflicts with M and growth information in the model
Data not used (rank)	- Commercial CPUE	3 – Low Quality: substantial changes in fishing patterns over time
Changes to Model Structure and Assumptions	- added age data and used stochastic recruitment rather than deterministic	
Major sources of Uncertainty	- uncertainties in the prior for the survey catchability (q): • estimated target strength • scaling factor from the trawl survey area to acoustic area • scaling factor from acoustic area to the QMA area • proportion of vulnerable biomass in the fished marks - mark identification of very large schools - lack of age composition data	

Qualifying Comments
The estimates derived from the model are determined largely by the prior for the survey catchability due to the limited observations.

Fishery Interactions
Both species of oreo are sometimes taken as bycatch in orange roughy target fisheries and in smaller numbers in hoki target fisheries. Target fisheries for oreos do exist, with main bycatch being orange roughy, rattails and deepwater sharks. Bycatch species of concern include deepwater sharks and rays, seabirds and deepwater corals.

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