OREOS – OEO 4 BLACK OREO AND SMOOTH OREO

1. FISHERY SUMMARY

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

2. BIOLOGY

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

3. STOCKS AND AREAS

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

4. STOCK ASSESMENT

4.1 Introduction

In 2018, the stock assessment was updated for smooth oreo 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 these differences, the two series present almost identical patterns of decline in relative standardised CPUEs from the time fishing 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 2001b). The west CPUE reduced to between 5% of the 1980 value and 15% of the 1981 value by 1990. The post-GPS west series is either flat or slightly increasing. The east CPUE reduced to 4% of the 1984 value and 21% of the 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 the 1993 value by 2008.

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

Fishing year	Pre-GPS east		Pre-GPS west		Fishing year	Post-GPS east		Post-GPS west	
	Index	CV	Index	CV		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 that 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

Smooth oreo was assessed in 2018 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 Oreo report), and catch history up to 2017–18. In early assessments (Doonan et al 2001, 2003, 2008), 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.

A 2014 stock assessment updated the 2012 assessment model using the same single area model structure and used an additional observation of biomass 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. The 2018 assessment updated the 2014 assessment with the inclusion of an additional acoustic survey biomass estimate in 2016 and the associated age frequency. An age frequency from a 1991 trawl survey was also included together with an age frequency from the commercial fishery in 2009. With the addition of three new age frequencies natural mortality was estimated within the model (with a Normal prior with the mean equal to 0.063 and CV=25% – see table 1 in the Biology section).

Year class strengths (YCS) were estimated for 1940–2005 (based on the range of age estimates in the age frequency data). A "near uniform" prior was used (parameterised as a lognormal distribution with a mode of 1 and sigma of 4), which places minimum constraint on the free YCS parameters (Haist parameterisation).

An informed prior was used for the acoustic survey proportionality constant q (lognormal with mean of 0.83 and CV of 0.3). The prior 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 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 acoustic biomass selectivity and the commercial fishery selectivity were assumed to be identical (logistic, estimated within the model).
(e) A separate selectivity was estimated for the age frequencies that were derived from trawl catches during the acoustic surveys (double normal, estimated within the model).

Bayesian estimation was used in the assessment to capture the uncertainties in model estimates of biomass and other parameters:

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; each marginal posterior distribution was described by its median and a 95% credibility interval (95% CI).

Bayesian estimates were based on results from three 15 million long MCMC chains. After a burn-in of 1 million, the last 14 million of the chain was sampled at each 1000th value. Posterior distributions were obtained from samples combined over the three chains (after the burn-in).

Table 4: Descriptions of the model runs of the 2018 smooth oreo assessment. LN, lognormal distribution with mean and CV given in the bracket. N, normal distribution with mean and CV in the bracket. All use Haist parameterisation for YCS.

Model run	Description
Base	Acoustic q estimated with a LN(0.83, 0.3) prior, nearly uniform prior on YCS, *M* estimated with a N(0.063, 0.25) prior, adult biomass indices (school marks)
LowM-Highq	M fixed at 0.0632 (20% less than the base estimate) and the mean of the acoustic q prior 20% higher
HighM-Lowq	M fixed at 0.0948 (20% higher than the base estimate) and the mean of the acoustic q prior 20% lower
Plus LFs	Base but with commercial length frequencies included
Fixed M	Base but with fixed M = 0.063 (as assumed in the 2014 assessment)

4.3.1 Estimates of fishery parameters and abundance

The 2018 assessment incorporated the catch history and the adult acoustic biomass indices. Five age frequencies were fitted. Commercial length frequencies (five scaled length frequencies between 1996 and 2008) were not included in the base model but were fitted in a sensitivity run (see Table 4).

Catch history

A catch history for smooth oreo in OEO 4 was developed by scaling the estimated catch to the QMS values (Table 5). A catch of 2500 t was assumed for 2017–18.

Table 5: Catch history for OEO 4 smooth oreo

Year	Catch (t)	Year	Catch (t)
1978–79	1 321	1999–00	6 357
1979–80	112	2000–01	6 491
1980–81	1 435	2001–02	4 291
1981–82	3 461	2002–03	4 462
1982–83	3 764	2003–04	5 656
1983–84	5 759	2004–05	6 473
1984–85	4 741	2005–06	5 955
1985–86	4 895	2006–07	6 363
1986–87	5 672	2007–08	6 422
1987–88	7 764	2008–09	6 090
1988–89	7 223	2009–10	6 118
1989–90	6 789	2010–11	6 518
1990–91	6 019	2011–12	6 357
1991–92	5 508	2012–13	5 964
1992–93	5 911	2013–14	6 016
1933–94	6 283	2014–15	6 318
1994–95	6 936	2015–16	1 992
1995–96	6 378	2016–17	2 279
1996–97	6 359	2017–18	2 500
1997–98	6 248		
1998–99	6 030		

Biomass estimates from the 1998, 2001, 2005, 2009, 2012, and 2016 acoustic surveys

Estimates of biomass were available from six 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;
(vi) 16 October to 17 November 2016 on *Amaltal Explorer* (AEX1602).

The method of estimating variance and bias was the same as in previous oreo surveys (Doonan et al 1998, 2000). Variance was estimated separately for the flat and for hills and then combined. Sources of variance were:

- sampling error in the mean backscatter
- the proportion of smooth oreo and black oreo in the acoustic survey area
- sampling error in catches which affects the estimate of the proportion of smooth oreo
- error in the target strengths of other species in the mix
- variance in the estimate of smooth oreo target strength
- sampling error of fish lengths (negligible)
- variance of the mean weight, for smooth oreo

Vulnerable smooth oreo was estimated 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. 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 were not smooth oreo, reduced the total biomass for smooth oreos to 36 550 t. However, the consensus of skippers consulted about the mark is that it was likely to be smooth oreo.

Table 6: Estimated smooth oreo vulnerable biomass (t) and CV (%, after the addition of 20% process error) from acoustic surveys in 1998, 2001, 2005, and 2009, 2012, and 2016; includes school marks and hills.

Year	Biomass (t)	CV (%)
1998	65 679	33
2001	81 633	33
2005	63 237	32
2009	26 953	33
2012	58 603	36
2016	34 022	38

Age frequencies from the 1998, 2005, and 2016 acoustic surveys

Age frequency distributions were derived from trawl samples taken for smooth oreo in OEO 4 during three acoustic surveys carried out in 1998 and 2005 (Doonan et al 2008) and 2016. 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, with 398 otoliths used from the 2016 survey.

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 (e.g., Doonan et al 2008). 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% which was used in the assessment. The age frequencies (male and female combined) were included in order to estimate year class strength.

Other age frequencies

Two additional age frequencies were constructed for the 2018 assessment. The first was for the commercial catch in 2008–2009. The 1284 otoliths available from the observer programme were sampled at random (with replacement) until 400 unique otoliths were obtained. The probability of selection was proportional to the tow catch and inversely proportional to the number of otoliths sampled in the tow. The mean weighted CV was 30% (obtained by bootstrapping). The second age frequency was constructed for the 1991 trawl survey of OEO 4 (TAN9104). Otoliths collected during the trawl survey were sampled at random until 400 unique otoliths were obtained. The probability of selection was proportional to the stratum biomass estimate and by tow catch within stratum, divided by the number of otoliths available from the tow. The mean weighted CV was 35% (obtained by bootstrapping).

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.

Five scaled length frequencies from 1996 to 2008 were used in a sensitivity run but not used in the base model.

4.3.2 Biomass estimates, year class strengths, and exploitation rates

For the base model, and all of the sensitivities, B_0 was estimated at about 140 000 t with 95% CIs ranging from about 110 000 t to 210 000 t (Table 7). Current stock status is estimated to be at the target level of 40% for the base case. However, it is estimated to be just above 30% B_0 for the LowM-Highq and Fixed M runs (Table 7). For all of the runs the estimated probability of current stock status being below the soft limit of 20% B_0 is less than 5% (Table 7). The probability of current stock status being below the hard limit of 10% B_0 was estimated at 0 for all runs (Table 7).

Table 7: Bayesian estimates of M, B_0, and current stock status (B_{18}/B_0) for the base model and sensitivities (the median and 95% CIs are given). The probability of current stock status being below 10% or 20% B_0 is also given.

	M (yr^{-1})	B_0 (000 t)	ss_{18} (% B_0)	P(ss_{18} < 10%)	P(ss_{18} < 20%)
Base	0.079 (0.057–0.01)	138 (111–184)	40 ((23–59)	0.00	0.01
LowM-Highq	0.0632	138 (118–173)	31 (19–46)	0.00	0.04
HighM-Lowq	0.0948	146 (111–208)	50 (33–67)	0.00	0.00
Incl. LFs	0.085 (0.067–0.011)	133 (111–172)	42 (26–60)	0.00	0.00
Fixed M	0.063	143 (121–184)	33 (21–50)	0.00	0.02

The spawning biomass trajectory for the base model shows a decreasing trend from the start of the fishery in the 1980s with a flattening off in 2015–16 when catches were substantially reduced (Figure 1, Table 5). Current stock status is estimated to be at the target biomass although the 95% CIs are very wide (Figure 1, Table 7).

The estimated year class strengths show a pattern (in the medians) from 1972 to 1987 of above average cohort strength with below average cohort strength from 1990 to 2005 (Figure 2), consistent with the age composition data.

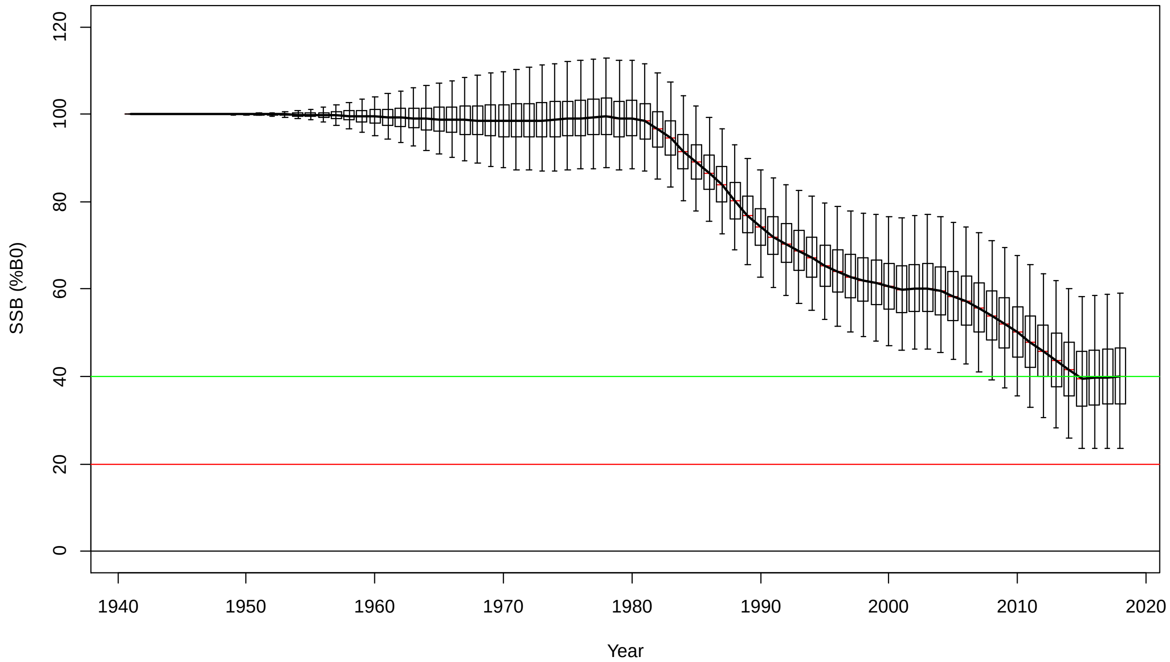


Figure 1: Base, MCMC estimated spawning-stock biomass trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The soft limit (red) and target biomass (green) are marked by horizontal lines.

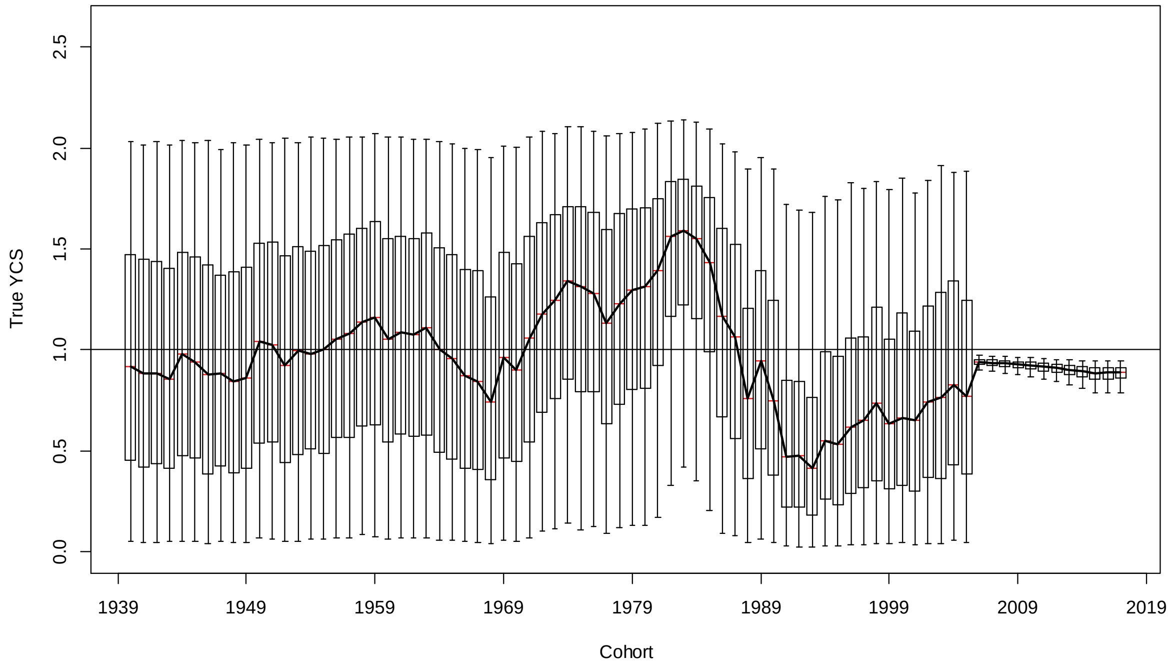


Figure 2: Base, MCMC estimated "true" YCS (R_y/R_0). The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution.

Exploitation rates in the fishery were estimated to be generally increasing from the start of the fishery up until 2014–15 (Figure 3). Catches in the years immediately prior to the TACC reduction in 2015–16 were at a level increasingly above the exploitation rate corresponding to the target biomass, $U_{40\%B0}$. With the substantial catch reduction in 2015–16 the estimated exploitation rate (median) dropped to below 5% where it has remained (Figure 3).

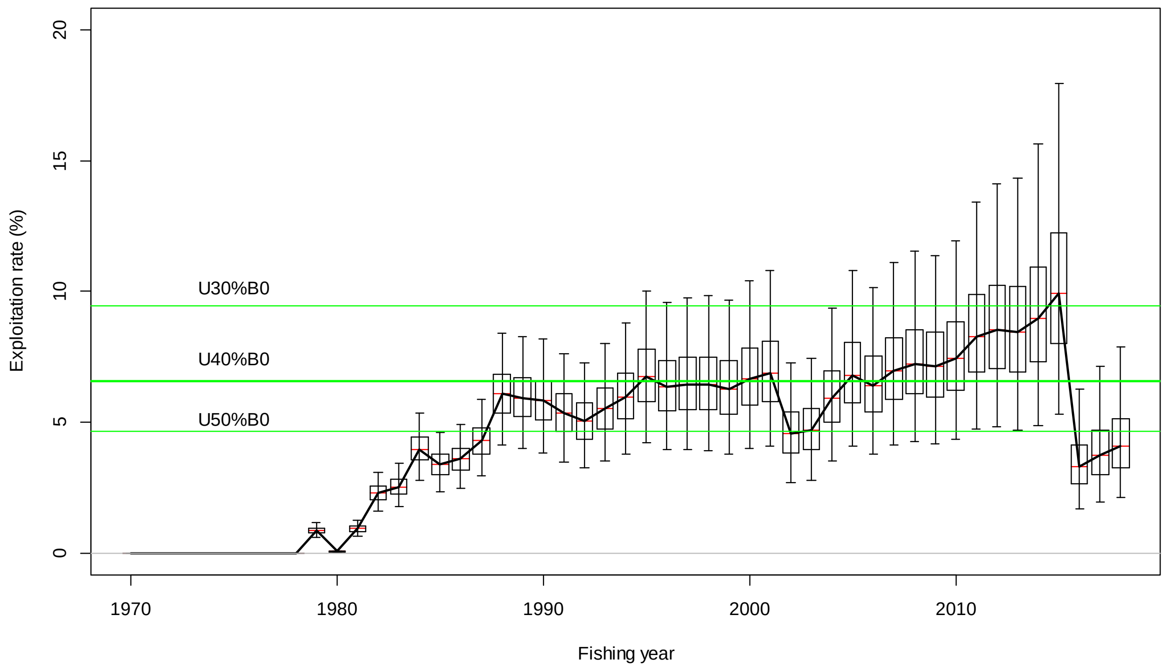


Figure 3: Base, MCMC estimated exploitation rate trajectory. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The exploitation rate, $U_{40\%B0}$, corresponding to the biomass target of 40% B_0 is marked by the middle horizontal line ($U_{x\%B0}$ is the exploitation rate that will drive deterministic spawning biomass to x% B_0). $U_{30\%B0}$ and $U_{50\%B0}$ are also marked by horizontal lines.

4.3.3 Yield estimates and projections

Five year projections were made from the base model at a constant catch of 2300 t which is the approximate level of the last reported annual catch (2279 t in 2016–17) and also at 3000 t (the TACC for OEO 4). Year class strengths from 2006 onwards were sampled at random from the last 10 estimated year class strengths (1996–2005). Based on the projections, stock status is expected to stay fairly constant over the next five years for annual catches in the range 2300–3000 t (Figures 4 and 5, Table 8). There is a small upward trend in median stock status at annual catches of 2300 t (Figure 4, Table 8).

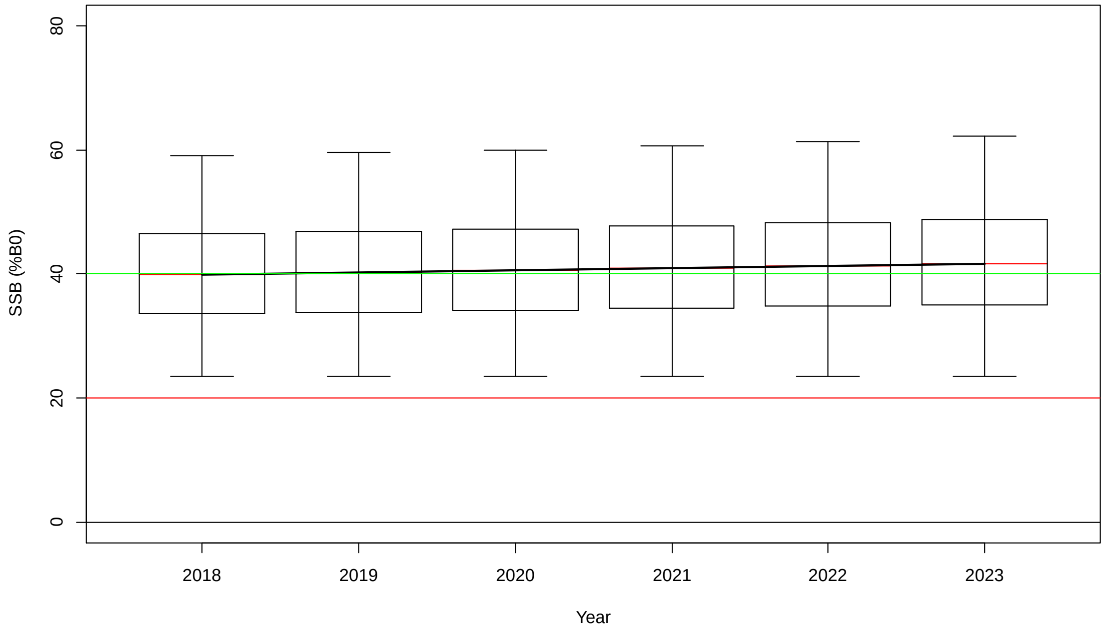


Figure 4: Base, MCMC projections at a constant annual catch of 2300 t. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The target biomass (40% B_0) is marked by the horizontal green line and the soft limit (20% B_0) by the horizontal red line.

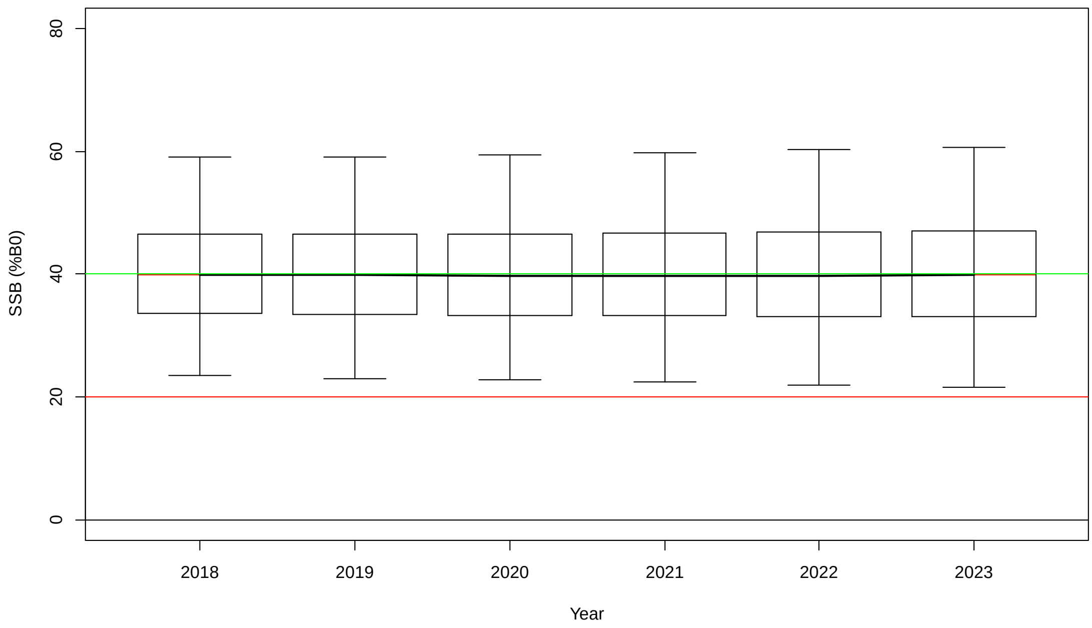


Figure 5: Base, MCMC projections at a constant annual catch of 3000 t. The box in each year covers 50% of the distribution and the whiskers extend to 95% of the distribution. The target biomass (40% B_0) is marked by the horizontal green line and the soft limit (20% B_0) by the horizontal red line.

Table 8: The expected value of stock status in 2023 ($E(ss_{23})$) and the probabilities of being above the target biomass (40% B_0) or below the soft limit (20% B_0) or below the hard limit (10% B_0) under projected annual catches of 2300 t or 3000 t.

Annual catch (t)	$E(ss_{23})$ (% B_0)	$P(ss_{23} > 40\%)$	$P(ss_{23} < 20\%)$	$P(ss_{23} < 10\%)$
2300	42	0.57	0.01	0.00
3000	40	0.49	0.02	0.00

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. These include:

- uncertainty in the estimates of species composition of catch histories,
- confounding of estimates of M with others parameters in the model, and
- the assumption that acoustic selectivity is the same as the commercial selectivity.

4.3.5 Future research considerations

- Regular acoustic surveys are required to monitor the trend in adult biomass.
- Improved estimates of smooth oreo target strength would reduce the uncertainty in the assessment as would additional age frequency data.
- A continued emphasis on mark identification of large schools during the surveys is important.
- Sensitivities to assumptions about the species composition in deriving catch histories could be insightful.
- It would also be useful to investigate correlations between model parameters.
- A more generic research consideration, possibly to be undertaken by the Stock Assessment Methods Working Group, is to develop guidelines for when M should be estimated in models, and when (and how) it should be independently estimated.

5. STATUS OF THE STOCKS

There is an updated stock assessment in 2018 for the smooth oreo stock in OEO 4.

Stock Structure Assumptions

Black and smooth oreo in OEO 4 are assessed separately but managed as a single stock (although catches are often estimated separately). 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 in OEO 4 are assumed to be distinct from OEO 1 and 6 stocks but may mix with the 3A stock.

- **OEO 4 (Black Oreos)**

Stock Status	
Year of Most Recent Assessment	2009
Assessment Runs Presented	No quantitative stock assessment model
Reference Points	Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Not defined
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	-

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 Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown

Assessment Methodology and Evaluation		
Assessment Type	Level 2 – Partial Quantitative Stock Assessment	
Assessment Method	Age-based model in CASAL	
Period of Assessment	Latest assessment: 2009	Next assessment: Unknown
Overall assessment quality rank	-	
Main data inputs (rank)	- 4 standardised CPUE indices (pre/post GPS and east/west) - Observer length frequencies	- -
Data not used (rank)	N/A	
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.	

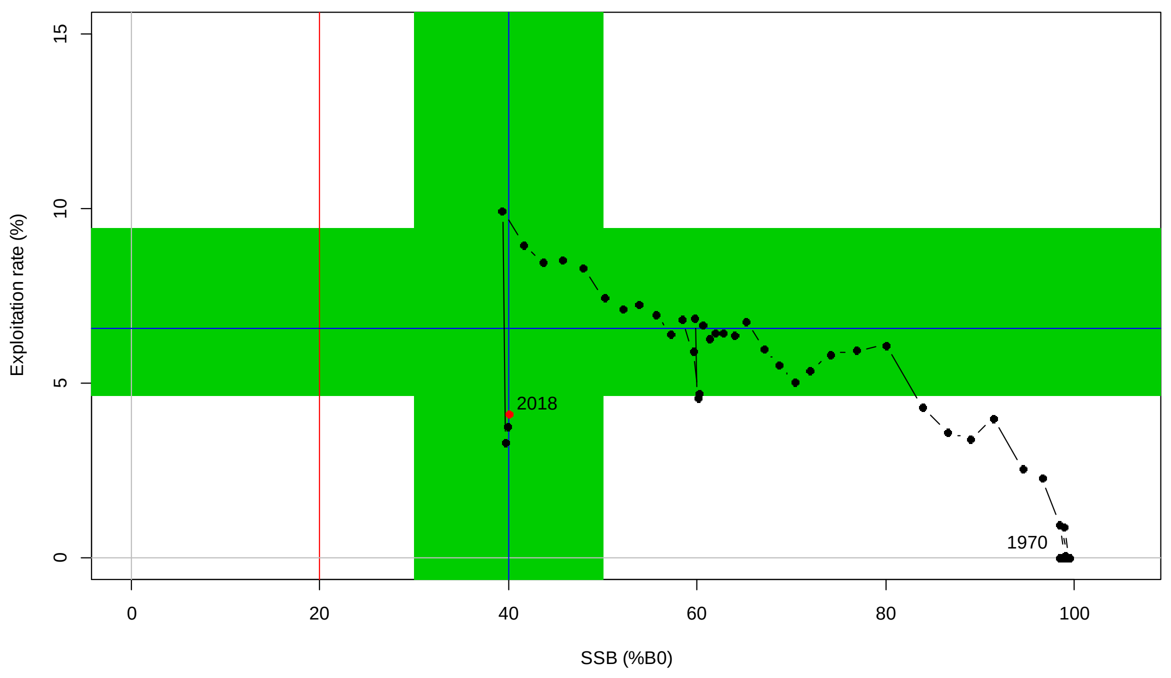
Qualifying Comments
The Working Group agreed that the stock might be split into east and west areas that were independent or at least minimally mixing for future assessments.

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 recorded include deepwater sharks and rays, seabirds and deepwater corals.

- **OEO 4 (Smooth Oreos)**

Stock Status	
Year of Most Recent Assessment	2018
Assessment Runs Presented	Base model fitted to vulnerable acoustic biomass estimates, based on school marks, and age frequencies
Reference Points	Target: 40% B_0 Soft limit: 20% B_0 Hard limit: 10% B_0 Overfishing threshold: $U_{40\%B0}$
Status in relation to Target	B_{2018} was estimated at 40% B_0 for the base model. B_{2018} is About as Likely as Not (40-60%) to be at or above the target.
Status in relation to Limits	B_{2018} is Very Unlikely (< 10%) to be below the Soft limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit.
Status in relation to Overfishing	Overfishing is Unlikely (< 40%) to be occurring.

Historical Stock Status and Exploitation Rate Trajectory



Historical trajectory of spawning biomass (%*B₀*) and exploitation rate (%) (base model, medians of the marginal posteriors). A reference range of 30-50% B_0 and the corresponding exploitation rate range are coloured in green. The soft limit (20% B_0) is marked by a red line and the target biomass (40% B_0) and corresponding exploitation rate are marked by blue lines.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	There has been little change in estimated biomass in the last 4 years.
Recent Trend in Fishing Intensity or Proxy	Following the large reduction in TACC and catch in 2015–16, estimated exploitation rates declined.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Below average cohort strength was estimated from 1990 to 2005.

Projections and Prognosis	
Stock Projections or Prognosis	Little change in projected biomass over the next five years at annual catches of 2300–3000 t
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Very Unlikely (< 10%) Hard Limit: Exceptionally Unlikely (< 1%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unlikely (< 40%) for the current catch or TACC

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 : 2018	Next assessment: 2022
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Six acoustic biomass indices (1998, 2001, 2005, 2009, 2012, 2016) - Age frequencies from acoustic surveys (1998, 2005, 2016) - Trawl survey age frequency (1991) - Commercial age frequency (2009) - Observer length data (used in a sensitivity)	1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
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 (trawl survey and commercial) and estimated M in the model	
Major Sources of Uncertainty	- Uncertainties in the prior for the survey catchability (q) o estimated target strength o scaling factor from the trawl survey area to acoustic area o scaling factor from acoustic area to the QMA area o proportion of vulnerable biomass in the surveyed marks o acoustic mark identification - Single commercial age frequency - Confounding of estimates of M with other parameters in the model - Assumption that acoustic selectivity is the same as the commercial selectivity	

Qualifying Comments
-

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. Low productivity species taken in oreo fisheries include orange roughy, rattails, and deepwater sharks and rays. Incidental captures have also been recorded for seabirds and deepwater corals.

6. FOR FURTHER INFORMATION

Bull, B; Francis, R I C C; Dunn, A; Gilbert, D J (2002) CASAL (C++ algorithmic stock assessment laboratory): CASAL User Manual v1.02.2002/10/21. *NIWA Technical Report 117*. 199 p.

Coburn, R P; Doonan, I J; McMillan, P J (2001a) Smooth oreo abundance indices from standardised catch per unit of effort data for OEO 4. *New Zealand Fisheries Assessment Report 2001/11*. 39 p.

Coburn, R P; Doonan, I J; McMillan, P J (2001b) Black oreo abundance indices from standardised catch per unit of effort data for OEO 4. *New Zealand Fisheries Assessment Report 2001/39*. 24 p.

Doonan, I J; Coombs, R F; McMillan, P J; Dunn, A (1998) Estimate of the absolute abundance of black and smooth oreo in OEO 3A and 4 on the Chatham Rise. Final Research Report for Ministry of Fisheries Research Project OEO9701. 47 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Doonan, I.J.; Hart, A.C.; Ladroit, Y.; McMillan, P.J. (2018). Smooth oreo abundance estimates from the October-November 2016 acoustic survey of the south Chatham Rise (OEO 4). New Zealand Fisheries Assessment Report 2018/XX. XX p.

Doonan, I J; McMillan, P J (2011) Final Research Report for Ministry of Fisheries Research Project OEO2009-01. 10 p. (Unpublished report held by Fisheries New ZealandWellington.)

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

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

Doonan, I J; McMillan, P J; Coburn, R P; Hart, A C (2001) Assessment of OEO 4 black oreo for 2000–01. *New Zealand Fisheries Assessment Report 2001/30*. 32p.

Doonan, I J; McMillan, P J; Coburn, R P; Hart, A C (2001) Assessment of OEO 4 smooth oreo for 2000–01. *New Zealand Fisheries Assessment Report 2001/21*. 37 p.

Doonan, I J; McMillan, P J; Coburn, R P; Hart, A C (2003) Assessment of OEO 4 smooth oreo for 2002–03. *New Zealand Fisheries Assessment Report 2003/50*. 55 p.

Doonan, I J; McMillan, P J; Coburn, R P; Hart, A C (2008) Assessment of OEO 4 smooth oreo for 2006–07. *New Zealand Fisheries Assessment Report 2008/40*. 45 p.

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 1995/12. 31p. (Unpublished document held by NIWA library.)

Doonan, I J; McMillan, P J; Hart, A C (2001) The use of mean length data for stock assessments of black oreo and smooth oreo in OEO 4. *New Zealand Fisheries Assessment Report 2001/34*. 16 p.

Doonan, I J; McMillan, P J; Hart, A C (2008) Ageing of smooth oreo otoliths for stock assessment. *New Zealand Fisheries Assessment Report 2008/8*. 29 p.

Francis, R I C C (1999) The impact of correlations in standardised CPUE indices. New Zealand Fisheries Assessment Research Document 1999/42. 30p. (Unpublished document held by NIWA library.)

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

Fu, D; Doonan, I J (2013) Assessment of OEO 4 smooth oreo for 2009–10. *New Zealand Fisheries Assessment Report 2013/22*. 35 p.

Fu, D.; Doonan, I J (2015). Assessment of OEO 4 smooth oreo for 2012–13. *New Zealand Fisheries Assessment Report 2015/7*. 41 p.

McMillan, P J; Doonan, I J; Coburn, R P; Hart, A C (1996) Is the south Chatham Rise trawl survey providing an index of smooth oreo abundance in OEO 4?. New Zealand Fisheries Assessment Research Document 1996/16. 18p. (Unpublished document held by NIWA library.)

McMillan, P J; Doonan, I J; Hart, A C; Coburn, R P (1998) Oreo stock assessment. Final Research Report for Ministry of Fisheries Research Project OEO9702. 16p. (Unpublished document held by Fisheries New Zealand Wellington.)

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

Tracey, D M; Fenaughty, J M (1997). Distribution and relative abundance of orange roughy on the Chatham Rise, May-July 1994. *N.Z. Fisheries Technical Report No. 44.* 43 p.