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Revision of smooth oreo life history parameters

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1. EXECUTIVE SUMMARY

Life history parameters of smooth oreo were revised using new age estimates from samples collected from the Puysegur area in 1992.

Revised life history parameters for smooth oreo

		1995 estimates			1997 estimates		
Parameter	**Symbol (unit)**	**Female**	**Male**	**Both**	**Female**	**Male**	**Both**
Natural mortality	M (yr^{-1})	–	–	0.05	–	–	0.063
Age at 50% recruitment	A_r (yr)	20	20	–	21	21	–
Age at maturity	A_m (yr)	30	–	–	31	–	–
von Bertalanffy parameters							
	L_∞ (cm, TL)	52	41	–	50.8	43.6	–
	k (yr^{-1})	0.046	0.080	–	0.047	0.067	–
	t_0 (yr)	-2.9	-1.0	–	-2.9	-1.6	–
Length at 50% recruitment	(cm, TL)	34	–	–	34	–	–
Length at maturity	(cm, TL)	40	–	–	40	–	–

2. INTRODUCTION

This document presents estimates of natural mortality (M) for smooth oreo (*Pseudocyttus maculatus*) using new age estimates obtained from reading otolith thin sections. Previous estimates of age for New Zealand smooth oreo have been made from samples collected from random trawl surveys of oreos on the Chatham Rise (Doonan *et al.* 1995). Those estimates of age were not used to estimate M because the Chatham Rise smooth oreo population was considered to be too heavily exploited to provide unbiased estimates. An estimate of M (0.05) was made in 1995 using a rule-of-thumb method (Doonan *et al.* 1995) based on the oldest age (90 years) observed in non-random samples of otoliths collected from a lightly fished Australian stock. No level of precision could be attached to that estimate.

In this study smooth oreo samples collected in 1992 from the lightly fished Puysegur Bank area fishery were used to estimate M. A fishery for orange roughy (*Hoplostethus atlanticus*) started in the Puysegur area in 1989–90, with a bycatch of smooth oreo and black oreo (*Allocyttus niger*). It was assumed that the smooth oreo population was at equilibrium in 1992 (when the otoliths were taken), i.e., that fishing for smooth oreo had not reached a level where the age structure of the smooth oreo population had been altered substantially by fishing.

The Puysegur and 1995 Chatham Rise age data were used to revise smooth oreo growth, age at 50% recruitment, and age at onset of maturity.

2.1 Literature review

Previous estimates of age and mortality for smooth oreo were given by Doonan *et al.* (1995). Age and *M* estimates for Australian smooth oreo were made by Smith & Stewart (1994).

3. DATA

Puysegur

Smooth oreo otoliths were collected during a stratified random trawl survey, designed mainly for orange roughy on the Puysegur Bank area south of New Zealand (Figure 1), carried out between 18 August and 12 September 1992 (Clark & Tracey 1994) using the NIWA research vessel *Tangaroa* (voyage TAN9208).

Included strata
Strata from which otoliths were used to estimate age were mainly in west Puysegur (Figure 1), and included all but one (stratum 246) of the main strata for smooth oreo biomass (Table 1). The smooth oreo catch from the stations sampled for otoliths within each stratum totalled more than 70% of the catch of smooth oreo from that stratum in all but two strata (Table 2). Smooth oreo catch and length data from stations not sampled for otoliths were not used in the natural mortality estimation. To increase the sample size, two stations (37 and 48) that had large smooth oreo catches but poor performance codes were included, resulting in a total of 32 stations, of which 16 had catches less than 100 kg. There did not appear to be any major biases in the data included.

Excluded strata
Strata were excluded when otoliths were not sampled, or came from only one station (Table 2). Only one stratum was excluded which contained substantial biomass (stratum 246, 7% of the total biomass).

Fish size
Only otoliths from fish 32 cm TL or more were aged because those fish were estimated to be the smallest that could be old enough to be used in the analysis. The 32 cm cutoff was determined from a scatterplot of Chatham Rise age and length data which showed that the upper range of ages for fish with lengths below 32 cm was below the age of 50% recruitment (34 cm). Only ages of fish that had fully recruited to the fishery were used in the natural mortality analysis (*see* Methods below), so 32 cm was chosen as the smallest size of fish that should be aged.

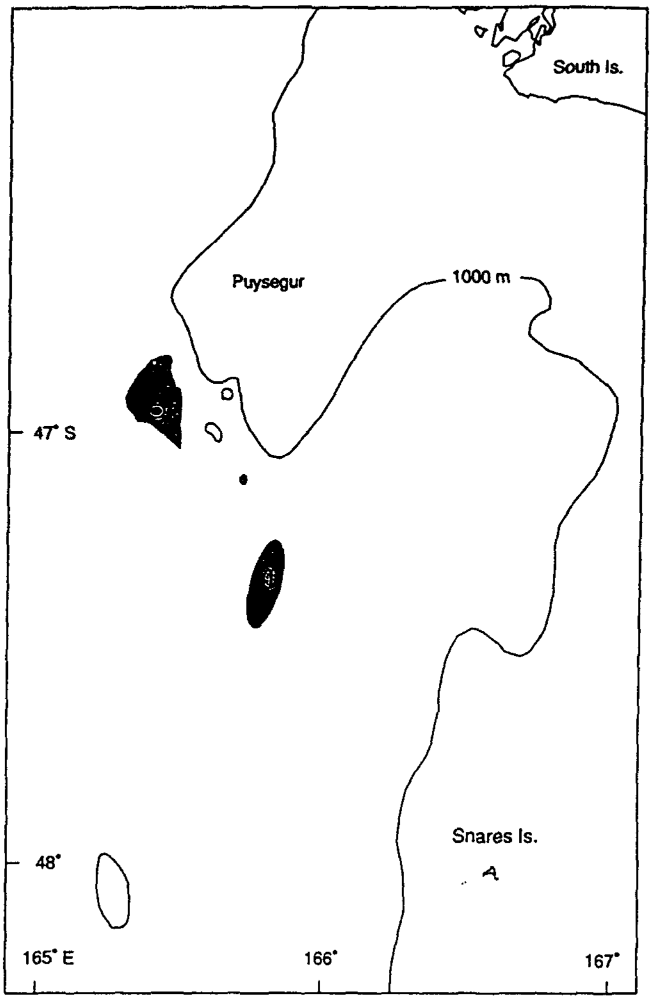


Figure 1: General survey area for voyage TAN9208 and the approximate areas (shaded) where fish used in the analysis were sampled.

Table 1: Relative biomass of smooth oreo (% of total) and area (km^2) by strata for the voyage TAN9208 divided into those strata that were included in the analysis and those that were excluded

Included			Excluded		
Stratum	Biomass	Area	Stratum	Biomass	Area
244	32	7	246	7	28
502	14	7	250	2	461
501	13	19	320	1	78
245	11	17	120	0	112
241	9	102	242	0	257
243	7	10	720	0	375
247	3	21	750	0	408
			110	0	252
			740	0	585
			210	0	180
			410	0	79
			220	0	71
			230	0	62
			140	0	64

Table 2: For included strata, the number of stations with a smooth oreo catch of 100 kg or more (catch over 100 kg), the number of those tows that also had otolith samples (otoliths), and the fraction of the total catch for stations within that stratum which were sampled for otoliths (Catch (%))

Stratum	Number of stations with		Catch (%) for stations
	catch > 100 kg	otoliths	with otoliths
247	2	2	92
502	3	2	83
501	3	2	79
245	9	5	73
243	3	2	72
244	6	2	54
241	2	1	46

South Chatham Rise

The data used were from otoliths of smooth oreo selected from several research voyages on the South Chatham Rise (Doonan *et al.* 1995).

4. METHODS

Estimating growth, age at onset of maturity, age at 50% and at full recruitment (Puysegur and Chatham Rise data)

The Puysegur otoliths were prepared and read in the way described for the south Chatham Rise otoliths by Doonan *et al.* (1995). Male and female growth were estimated from the combined Puysegur and south Chatham Rise data in the same way as previously (Doonan *et al.* 1995). The length at full recruitment, i.e., the minimum length at which all fish have recruited to the fishery, and the length at 50% recruitment, i.e., at which 50% of the fish have recruited, were estimated from unscaled length data collected from the Chatham Rise commercial fishery by observers from 1986 to 1992 between 43° 30′ S and 45° 30′ S, 172° E and 174° W. Length at 100% recruitment was calculated from the length frequency distribution at the first major mode and length at 50% recruitment was calculated from the left hand limb of the first major mode from the length frequency distribution (*see* pp. 7–8 in McMillan & Hart 1994). Length at onset of maturity was estimated from length and gonad stage data (stages 3–7 for females) collected from the Puysegur area during voyages WIL9101, GIL9201, TAN9208, and TAN9409.

Estimating natural mortality (Puysegur data only)

The method was modified from that used for orange roughy (Doonan 1994). This method required a weighted population mean age where the weighting was related to catch size and stratum area because the age data were derived from fish sampled by a stratified random trawl survey. In addition, a correction was applied to account for the fish below 32 cm which were not sampled for age. The population mean age for fish that were fully recruited (x), i.e., ages greater than or equal to T_c, the age of full recruitment, was given by

$$x = \frac{\sum_i W_i f_i \, age_i}{\sum_j W_j f_j}$$

where i and j index stations,

$$W = N * \frac{area_s}{n_s}$$

and N is the catch rate in numbers of fish with lengths of 32 cm or more, $area_s$ is the area of stratum s, n_s is the number of tows done in that stratum, f is the fraction of fish with ages over T_c for fish with lengths 32 cm or more, and *age* is the mean age for fish that were aged at T_c and over.

M was then estimated by

$$\log \frac{1 + x - T_c}{x - T_c}$$

Estimating the variance was complex because there were several sources of uncertainty, including recruitment variation, reading error, and sampling error all mixed into a random stratified design where stations were not treated equally but were weighted by their catch size and stratum area. Two steps were used in estimating variance (Doonan 1994). First the stratified random survey was reduced to an equivalent one based on simple random sampling. Second, simple random sampling was used to add in the recruitment variability and reading error for an estimate of the total variance. This approach avoided having to model spatial distribution of age classes, their distribution by catch size, and changes to distributions because of cohort size.

In greater detail, the first step, which quantified the error due to sampling, was as follows. The sampling *c.v.* of M due to the stratified survey design was estimated by bootstrap methods. Then, the sample size, n_{eq}, was found that gave the same *c.v.* (as the survey estimate) for estimating M from a simple random sample that was drawn from an age structure made up from constant recruitment and M (as estimated above).

The second step added error due to recruitment and reading otoliths, by drawing random samples of size n_{eq} from an age structure generated by log normal recruitment, constant M (as estimated above), and a linear selection ogive from T_{min} to T_c, and then added reading error to the selected ages.

5. RESULTS

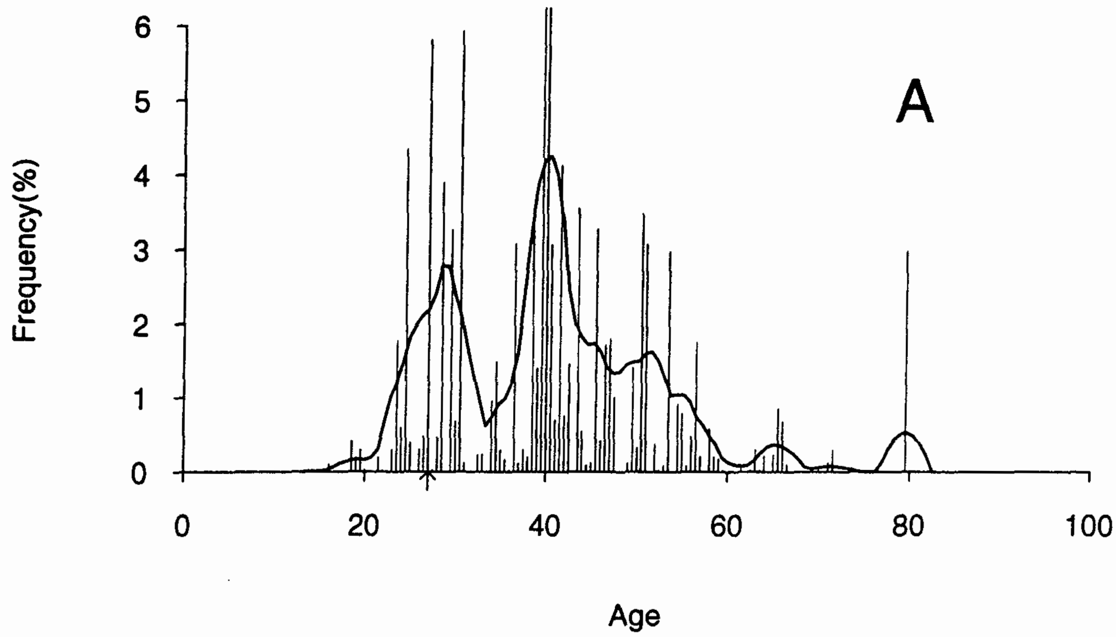
Growth, age of onset of maturity, age at 50% and at full recruitment (Puysegur and Chatham Rise data)

There were 243 otoliths prepared and examined, but 53 of those were unreadable. The maximum age recorded from the Puysegur otoliths was 79.5 years for a female of 51.3 cm TL. Age estimates for male and female Puysegur smooth oreo samples are in Figure 2. The data are scaled to stratum area and catch size (upper) and unscaled (lower) and a smoothed curve has been fitted to both plots. The distribution of age estimates would be expected to have high frequencies around T_c, with a subsequent exponential decline with increasing age. This was seen in the unscaled plot, but the scaled plot, which was used to estimate M, showed the influence of small samples of otoliths, taken from large catches, causing the distribution to be very spiky.

Female growth
The main difference between the new growth parameter values and those estimated in 1995 from the Chatham Rise data (Doonan *et al.* 1995) was in L_∞ but the values are within one standard deviation of each other (Table 3). Puysegur smooth oreo growth does not appear to be different to that from the Chatham Rise (Figure 3), but the Puysegur data had more large and old fish and lacked fish less than 32 cm. Mean length-at-age from Lowess fits (a method for smoothing data) for fish 32 cm or more showed similar values for the two data sources (Chatham Rise and Puysegur) where age was less than 30 and more than 60 years. The Chatham Rise data had lower length-at-age from ages of 35 to 60 years, but the data are sparse for ages over 35 years and so comparisons are limited. However, it seems reasonable to conclude that growth is the same for both areas and therefore a combined curve was produced using Chatham Rise and Puysegur data. There may be some minor differences in growth between the two regions which were not detected in this analysis.

Male growth
There appeared to be a difference in growth, but this was probably because there were fewer large old males on the Chatham Rise (*see* Figure 3). The Chatham Rise data therefore appeared cropped at about 40 cm with few ages over about 45, which is where good data were required to define L_∞. Why the lack of large/old fish should be more marked in males than females is unknown. Lowess curves for mean length-at-age from the two areas matched only below age 25, but that part of the curve had sparse data for Puysegur fish because only fish 32 cm or more were sampled.

An age of 21 years (20.9 for females, 21.6 for males) corresponded to the length at 50% recruitment, 34 cm (Doonan *et al.* 1995). An age of 31 years corresponded to the length at onset of maturity for females, 40 cm. These both increased by one year from the 1995 estimates (*see* Table 3). The length at full recruitment was estimated to be 37 cm TL and the age at full recruitment, T_c, estimated from the age-length curve, was 27 years (the larger of the male and female age values).



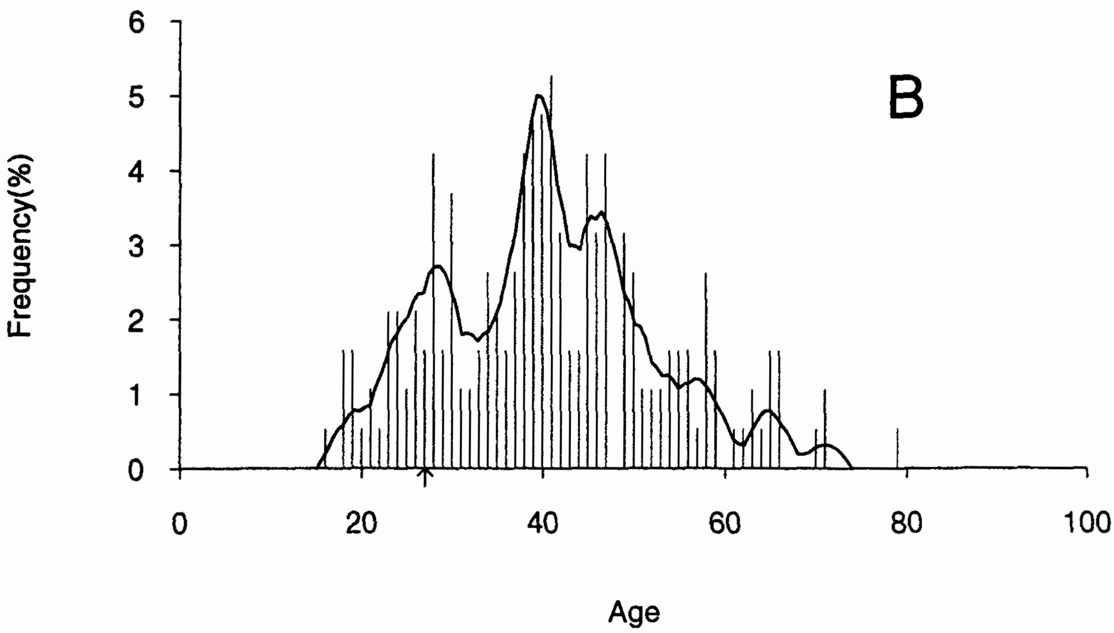


Figure 2: **Smooth oreo population age (years) distribution (vertical lines) for males and females combined from the Puysegur area, weighted by stratum area and catch size (A), and without weighting (B). The curved lines are smoothed versions of the age frequency. The arrows mark the age of full recruitment, T_c.**

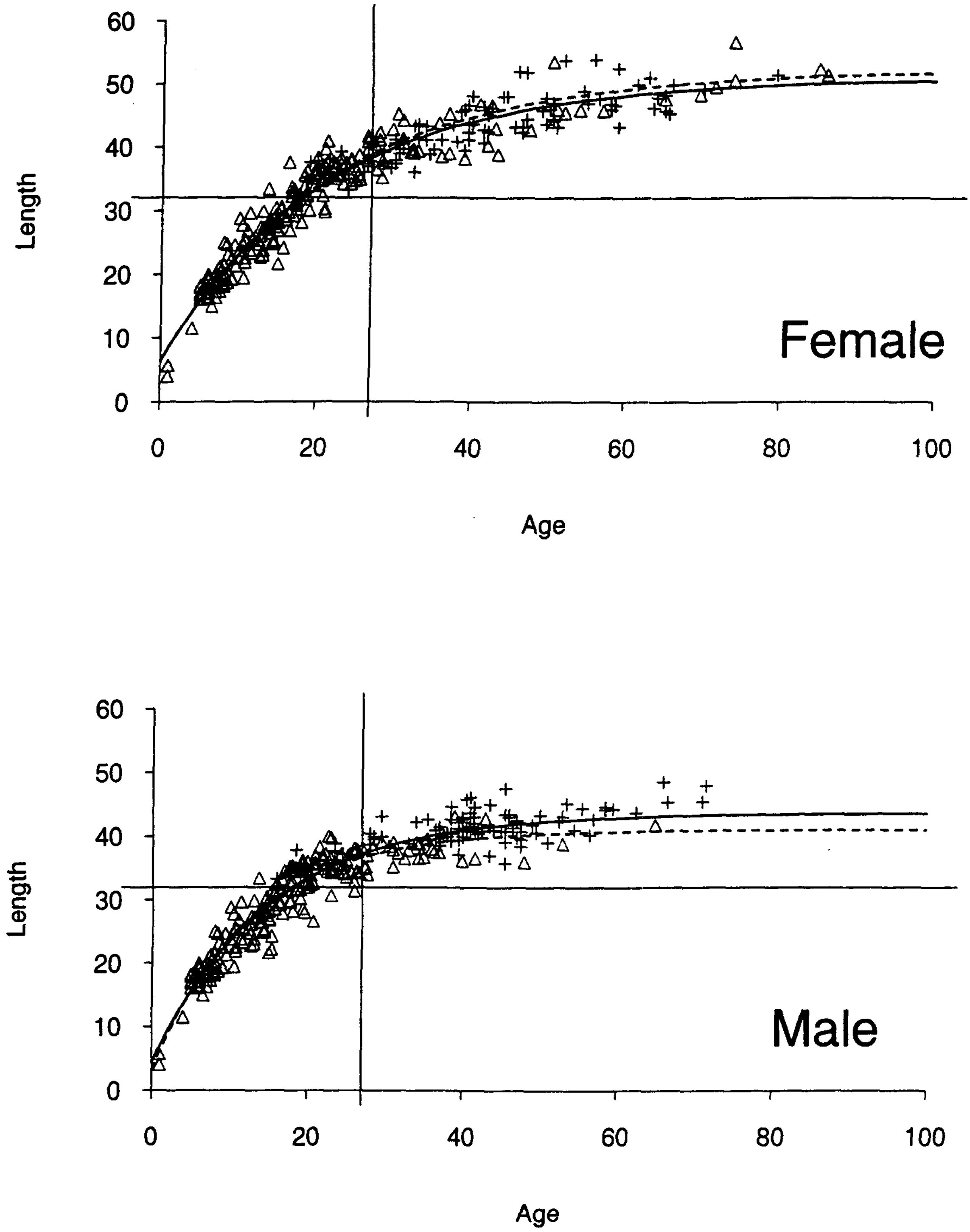


Figure 3: **Smooth oreo growth data (age in years) from the South Chatham Rise (triangles) and Puysegur (crosses). The solid lines are the von Bertalanffy growth curves estimated from all data and the dashed lines are the von Bertalanffy growth curves estimated from Chatham Rise data only. For Puysegur data, only fish 32 cm or more were aged (horizontal line) and only ages 27 years and over (vertical line) were used to estimate *M*.**

Life history parameters

Revised estimates of life history parameters for smooth oreo are given in Table 3.

Table 3: Revised life history parameters for smooth oreo

		1995 estimates			1997 estimates		
Parameter	**Symbol (unit)**	**Female**	**Male**	**Both**	**Female**	**Male**	**Both**
Natural mortality	M (yr^{-1})	–	–	0.05	–	–	0.063
Age at 50% recruitment	A_r (yr)	20	20	–	21	21	–
Age at maturity	A_m (yr)	30	–	–	31	–	–
von Bertalanffy parameters							
	L_∞ (cm, TL)	52	41	–	50.8	43.6	–
	k (yr^{-1})	0.046	0.080	–	0.047	0.067	–
	t_0 (yr)	-2.9	-1.0	–	-2.9	-1.6	–
Length at 50% recruitment	(cm, TL)	34	–	–	34	–	–
Length at maturity	(cm, TL)	40	–	–	40	–	–

Natural mortality (Puysegur data only)

Estimates of mortality parameter values are given in Table 4.

Table 4: Estimates of smooth oreo natural mortality parameters from Puysegur data

Parameter	**Symbol (unit)**	**Value**
Minimum age sampled	T_{min}(years)	18
Age at full recruitment	T_c (years)	27
Length-weight parameters	a	0.0132
	b	3.12
Stratified sampling variance for M	*c.v.* (%)	16.5
Equivalent sample size for simple random sampling	n_{eq}	38
Recruitment variability	σ_r (log)	1
Variance for reading error	*c.v.* (%)	4.7
Total variance of M	*c.v.* (%)	25
Natural mortality	M (yr^{-1})	0.063
95% confidence limit for M	(yr^{-1})	0.042–0.099

The variability of recruitment was assumed to be 1 in the log scale (1.1 was used for orange roughy) and reading error was estimated from the between-reader variability, 6.6%, divided by $\sqrt{2}$, i.e., 4.7% (the age estimate was the average from two readers). M was estimated to be 0.063 yr^{-1} with a total *c.v.* of 25% and 95% confidence limits of 0.042 to 0.099. By stratum, M ranged from 0.046 (strata 502, 243) to 0.084 (stratum 501).

M sensitivity analysis

Analyses showed that a 10% reading bias would change the estimate of M by 6–14%; an 11% increase in T_c (i.e., to 30 years) gave a 2% increase in M; and the *c.v.* of M was more affected by recruitment variability than reading error (Table 5).

Table 5: Smooth oreo *M* sensitivity analysis

Case	M	*c.v.* (%)
T_c = 30 (years)	0.064	25
Reading bias: - 10%	0.054	22
Reading bias: + 10%	0.068	26
Double the reading error	0.063	27
Half the recruitment variance	0.063	18

6. DISCUSSION

Age and growth

Smooth oreo age estimates were unvalidated, but it is highly likely that the clear zones visible in otolith sections (*see* Doonan *et al.* 1995) represent some constant time interval. The results of reading smooth oreo otoliths by Australian workers (Smith & Stewart 1994) were very similar to ours. Results of comparing otolith thin section readings with radiometric analyses for warty oreo (*Allocyttus verrucosus*) reported by Stewart *et al.* (1995) support the conclusion that warty oreo is a long lived and slow growing species. The otolith zones in smooth oreo appear very similar to those seen in warty oreo, and therefore it seems likely that smooth oreo is also a slow growing, long lived species.

Growth rates of smooth oreo from the Puysegur area and from the Chatham Rise were very similar, so the data from the two areas were combined to estimate growth parameters and mortality. Consequently the values of growth parameters for Chatham Rise smooth oreo have been revised and will be used for future assessment of Chatham Rise stocks. The 1995 Chatham Rise data contained only small numbers of large and old fish so the Puysegur and Chatham Rise data combined provided better estimates of L_∞.

Natural mortality

The Puysegur samples produced a number of problems, the main one being that only small samples were taken from large catches. When the age reading results were scaled to represent the stratum area and catch size, any fluctuations due to sampling error were exaggerated. Fortunately, the fluctuations seem to have had little effect on the estimate of M. Otolith sample size for individual tows should be increased in proportion to the size of the catch in future surveys where possible.

The assumption that the Puysegur smooth oreo fishery was not developed in 1992 seems reasonable because before 1992–93 (1 October 1992 to 30 September 1993) catches were less than

1000 t per year, i.e., 437 t in 1990–91 and 583 t in 1991–92 (Annala & Sullivan 1996). However it is possible that even that amount of catch may have altered the age structure of the population, particularly for the northern parts of the survey area which were the focus of the orange roughy fishery. Estimates of smooth oreo natural mortality should be made using samples taken from a fishery before it develops and it appears that the best opportunity to obtain such samples are from unfished areas in the subantarctic area of the New Zealand EEZ (OEO 6).

Acknowledgments

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