Not to be cited without permission of the authors

New Zealand Fisheries Assessment Research Document 97/8

Revision of black oreo life history parameters

P. J. McMillan, I. J. Doonan, and A. C. Hart
NIWA
PO Box 14–901
Wellington

May 1997

Ministry of Fisheries, Wellington

This series documents the scientific basis for stock assessments and fisheries management advice in New Zealand. It addresses the issues of the day in the current legislative context and in the time frames required. The documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Revision of black oreo life history parameters

P. J. McMillan, I. J. Doonan, and A. C. Hart

New Zealand Fisheries Assessment Research Document 97/8. 13 p.

1. EXECUTIVE SUMMARY

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

Revised life history parameters for black oreo

		1995 estimates			1997 estimates		
Parameter	**Symbol (unit)**	**Female**	**Male**	**Both**	**Female**	**Male**	**Both**
Natural mortality	M (yr^{-1})	–	–	–	–	–	0.044
Age at 50% recruitment	A_r (yr)	–	–	–	23	–	–
Age at maturity	A_m (yr)	42	–	–	27	–	–
von Bertalanffy parameters							
	L_∞ (cm, TL)	44.4	43.0	–	39.9	37.2	–
	k (yr^{-1})	0.019	0.017	–	0.043	0.056	–
	t_0 (yr)	-35.1	-42.5	–	-17.6	-16.4	–
Length at 50% recruitment	(cm, TL)	27	–	–	32.9	–	–
Length at maturity	(cm, TL)	34	–	–	34	–	–

2. INTRODUCTION

This document presents estimates of natural mortality (M) for black oreo (*Allocyttus niger*) using new age estimates obtained from reading otolith thin sections. Previous estimates of age for New Zealand black oreo were 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 they were considered to be uncertain and the Chatham Rise black oreo population was also considered to be too heavily exploited to provide unbiased estimates. Crude estimates can be made using $M = \log(100)/(\text{maximum age})$, where the maximum observed age for New Zealand data was 153 years (Doonan *et al.* 1995), i.e., 0.030 yr^{-1}, and for Australian data where the maximum age was 100 years (Smith & Stewart 1994), i.e., 0.046 yr^{-1}. No level of precision can be attached to these estimates.

In this study black 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 (*Pseudocyttus maculatus*) and black oreo. It was assumed that the black oreo population was at equilibrium in 1992 (when the otoliths were taken), i.e., that fishing for black oreo had not reached a level where the age structure of the black oreo population had been altered substantially by fishing.

The Puysegur age data were used to estimate black oreo growth, age at 50% recruitment, age at onset of maturity, and natural mortality. Chatham Rise age data (Doonan *et al.* 1995) were included for comparison.

2.1 Literature review

Previous estimates of age for New Zealand black oreo were given by Doonan *et al.* (1995) and for Australian black oreo by Smith & Stewart (1994).

3. DATA

Puysegur

Black 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). This was the third survey of the Puysegur area, but the first using *Tangaroa*.

Included strata
Otoliths used to estimate age came from strata in west Puysegur, the south Puysegur hills (Mt. Duncan and Porirua), and the west Snares hills (Figure 1). Most of the black oreo biomass came from these strata (Table 1). The black oreo catch from the stations sampled for otoliths within each stratum totalled 57% or more of the catch of black oreo from that stratum in all but stratum 244 (Table 2). Black oreo catch and length data from stations not sampled for otoliths were not used in the natural mortality estimation. To increase the sample size, one station (48) that had a large black oreo catch but poor performance code was included, resulting in a total of 22 stations, of which four had catches less than 100 kg. Another station with a large catch but poor performance code (37, stratum 244) was excluded because about half the otoliths, including many of the large fish, were lost. 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 (*see* Table 1). No strata were excluded which contained substantial biomass (the largest was stratum 250 with 1% of the total biomass).

Fish size
All available otoliths were read.

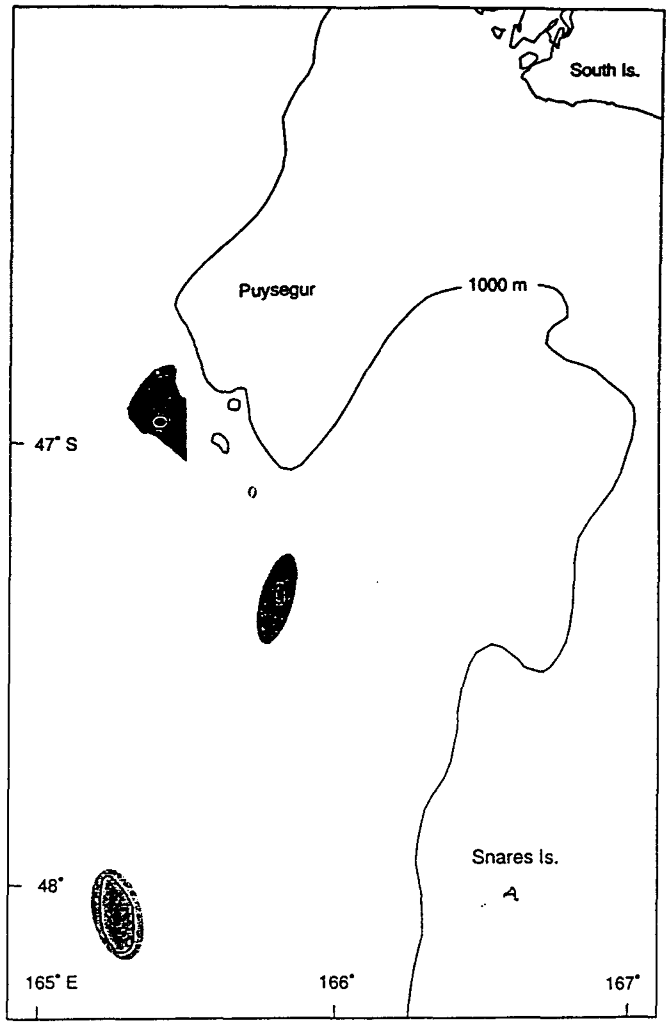


Figure 1: General survey area for voyage TAN9208 and the approximate areas (shaded) where fish used in the analysis were sampled.

Table 1: Relative biomass of black oreo (% of total) and area (km^2) by strata for 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
802	38	14	250	1	461
502	17	7	242	0	257
245	16	17	210	0	180
244	8	7	320	0	78
243	6	10	900	0	250
801	6	8	246	0	28
501	4	19	247	0	21
241	3	102	230	0	62
			440	0	187

Table 2: **For included strata, the number of stations with a black oreo catch of 100 kg or more (catch > 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
502	2	1	57
245	8	3	58
244	6	3	44
243	4	3	87
501	2	2	94
241	3	1	60
801	5	3	92
802	2	2	100

South Chatham Rise

The data used were from otoliths of black oreo selected from several research surveys 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 data)

All of the Puysegur otolith samples from voyage TAN9208 were used and these were prepared and read in the way described for the south Chatham Rise otoliths by Doonan *et al.* (1995). Male and female growth for post-settlement fish, i.e., 25 cm TL or more (23 cm was used for Chatham Rise growth) was estimated from the Puysegur data only in the same way as previously (Doonan *et al.* 1995). The length at full recruitment (minimum length at which all fish have recruited to the fishery) and length at 50% recruitment (length at which 50% of the fish have recruited), and the length at onset of maturity (female gonad stages 3–7) were estimated from research length data collected from the four Puysegur area voyages (WIL9101, GIL9201, TAN9208, and TAN9409), weighted by catch and area and then combined. 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.

Estimating natural mortality (Puysegur data)

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

For the Puysegur samples, 266 otoliths were readable and 50 were not readable. The maximum age was 142 years for a 42.3 cm female. Age estimates for male and female Puysegur black oreo samples are given in Figure 2. The data were scaled to stratum area and catch size (upper) and unscaled (lower) and a smoothed curve was fitted to both plots. In theory, the age distribution should have high frequencies around the age of full recruitment (T_c), with a subsequent exponential decline with increasing age. This was seen in the scaled plot, which was used to estimate M.

The von Bertalanffy growth curves for Puysegur and Chatham Rise females and males (Figure 3) showed a substantial difference between the two areas between 15 and 50 years. Consequently there were substantial differences between the new growth parameter values calculated using the Puysegur data only and those estimated in 1995 from the Chatham Rise data (Doonan *et al.* 1995), (Table 3).

The length frequency data from all the voyages combined (WIL9101, GIL9201, TAN9208 and TAN949) had two modes, at 28 and 35 cm, so potentially the length at 50% recruitment had two values, 27.5 and 31.6 cm. The 28 cm length frequency mode was found to be due to one station in each of three of the surveys, but was not present in the TAN9208 data. When the length frequency data were re-analysed excluding the stations contributing the small fish (WIL9101, 81; GIL9201, 79; and TAN9409, 99) the calculated length at 50% recruitment was 32.9 cm. This procedure produced a more robust result and assumed that the dip in the length frequency was due to reduced availability of fish between 28 and 35 cm. Length at 50% recruitment for Chatham Rise fish (27 cm) was calculated from observer data (*see* Doonan *et al.* 1995) and was based on a similar first mode in a bimodal length distribution. An age of 23 years corresponded to the female length at 50% recruitment of 32.9 cm for the Puysegur samples.

The length at full recruitment (LCR) was estimated to be 35 cm for female fish, but 36.5 cm was used to estimate the age at full recruitment (T_c), of 40 years, from the age-length curve. There was a chance that the true LCR was greater than 35 cm, so 1.5 cm was added arbitrarily to ensure that full recruitment was achieved. This resulted in the loss of some data, but will not bias the estimate of M. An age of 27 years corresponded to the length at onset of maturity for females, of 34 cm. The age at maturity decreased substantially from the Chatham Rise estimate of 42 years (Doonan *et al.* 1995) because of the new growth curve (*see* Figure 3).

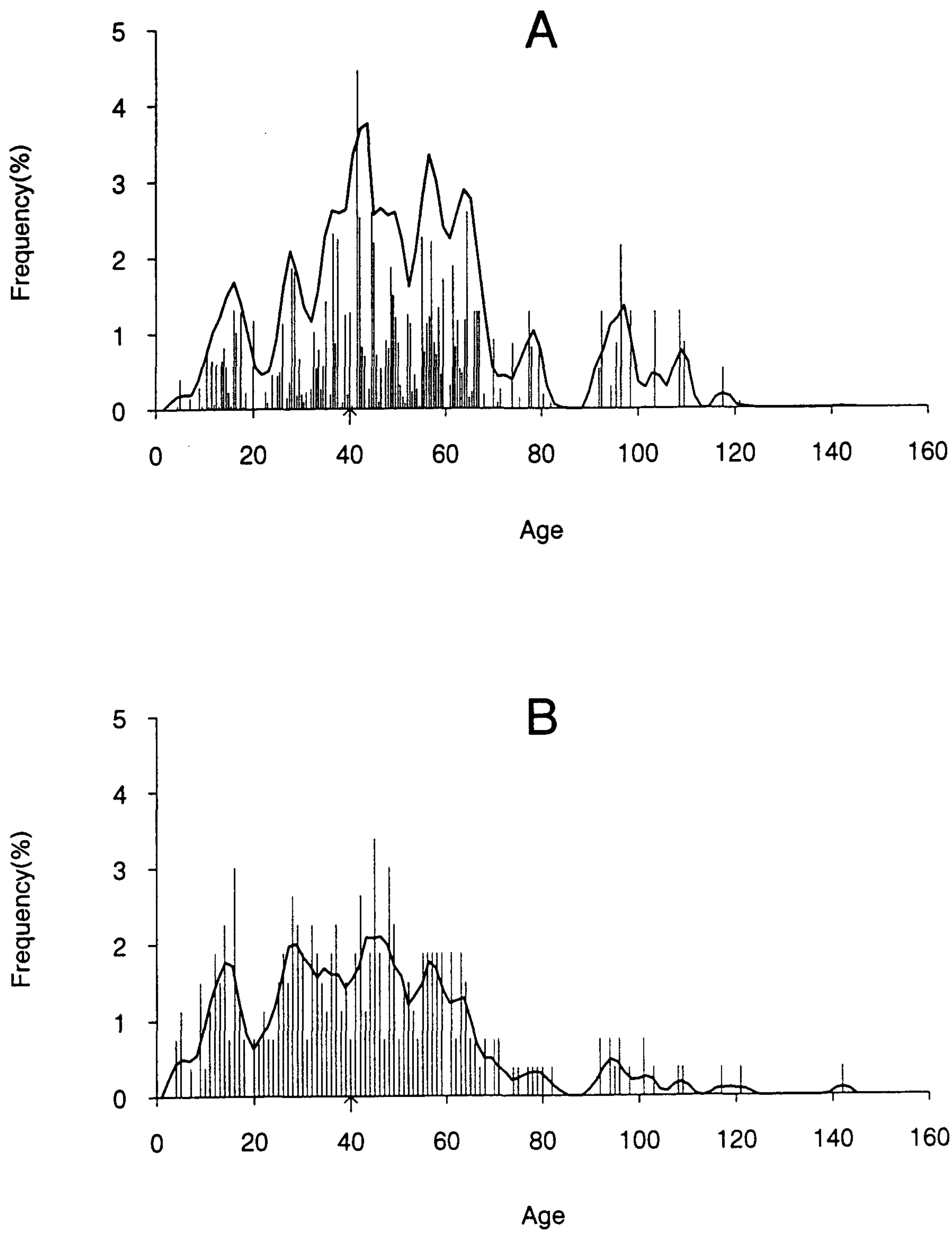
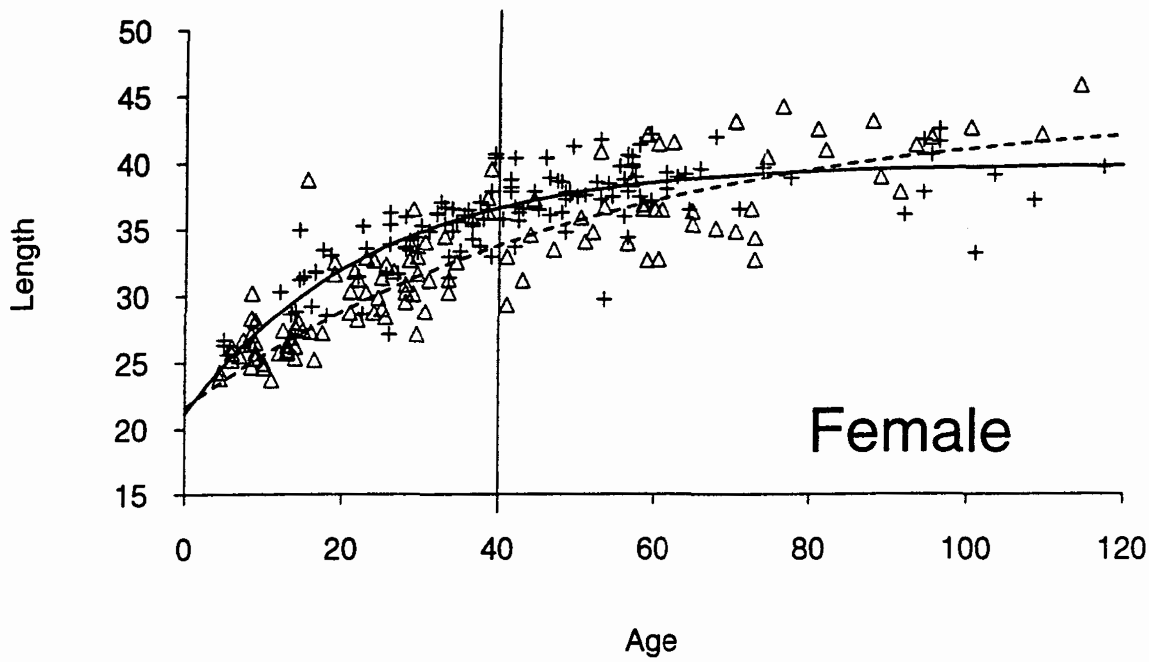


Figure 2: **Puysegur black oreo population age (years) distribution (vertical lines) for males and females combined, weighted by stratum area and catch size (A), and without weighting (B). The curved lines are smoothed versions of the age frequency. The arrows mark the age of full recruitment, T_c.**



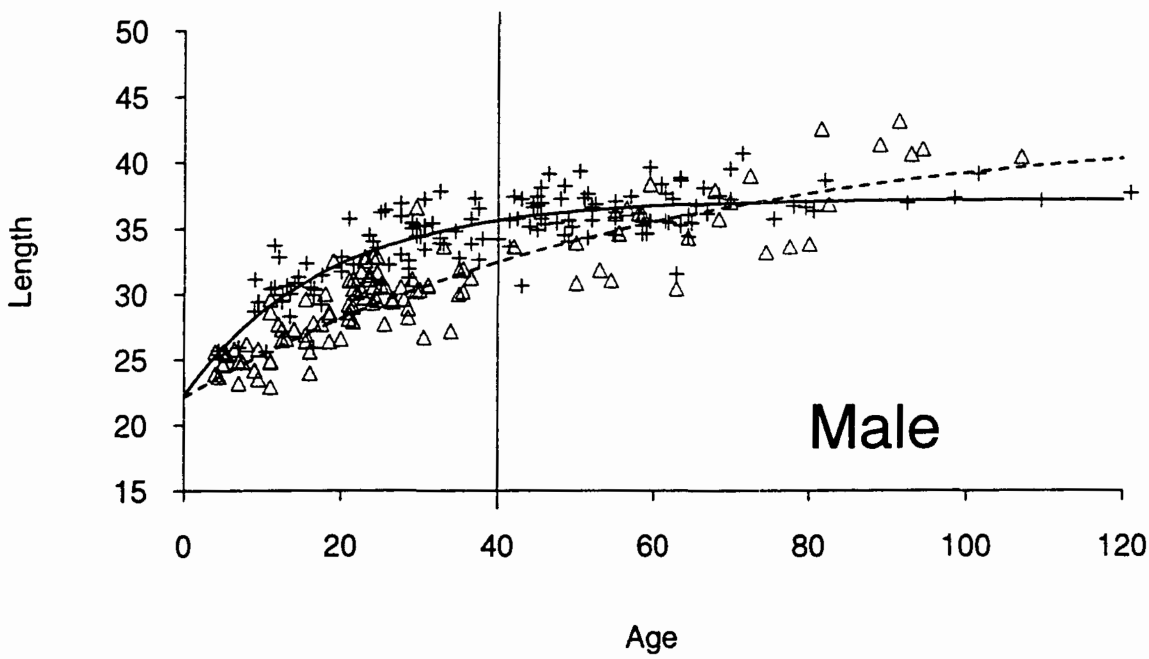


Figure 3: Black oreo growth data (age in years) from the South Chatham Rise (triangles) and Puysegur (crosses). The solid lines are the von Bertalanffy growth curves estimated from Puysegur data and the dashed lines are the von Bertalanffy growth curves estimated from Chatham Rise data only. To estimate M only Puysegur data for fish 40 years or more (vertical line) were used.

Life history parameters

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

Table 3: Revised life history parameters for black oreo

Parameter	Symbol (unit)	1995 estimates Female	Male	Both	1997 estimates Female	Male	Both
Natural mortality	M (yr^{-1})	–	–	–	–	–	0.044
Age at 50% recruitment	A_r (yr)	–	–	–	23	–	–
Age at maturity	A_m (yr)	42	–	–	27	–	–
von Bertalanffy parameters							
	L_∞ (cm, TL)	44.4	43.0	–	39.9	37.2	–
	k (yr^{-1})	0.019	0.017	–	0.043	0.056	–
	t_0 (yr)	-35.1	-42.5	–	-17.6	-16.4	–
Length at 50% recruitment	(cm, TL)	27	–	–	32.9	–	–
Length at maturity	(cm, TL)	34	–	–	34	–	–

Natural mortality, *M* (Puysegur data)

Estimates of mortality parameter values are given in Table 4.

Table 4: Estimates of black oreo natural mortality parameter values from Puysegur data

Parameter	Symbol (unit)	Value
Minimum age sampled	T_{min}(years)	15
Age at full recruitment	T_c (years)	40
Length-weight parameters	a	0.0078
	b	3.26
Stratified sampling variance for M	*c.v.* (%)	22
Equivalent sample size for simple random sampling	n_{eq}	28
Recruitment variability	σ_r (log)	1
Variance for reading error	*c.v.* (%)	8.3
Total variance of M	*c.v.* (%)	25
Natural mortality	M (yr^{-1})	0.044
95% confidence limit for M	(yr^{-1})	0.028–0.075

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, 11.7%, divided by $\sqrt{2}$, i.e., 8.3% (the age estimate was the average from two readers). M was estimated to be 0.044 with a total *c.v.* of 25% and 95% confidence limits of 0.028 to 0.075. By stratum, M ranged from 0.031 (stratum 802) to 0.086 (stratum 245). The bootstrap estimate of the sampling *c.v.* for M may be relatively uncertain because of the small number of stations in the analysis. The equivalent sample size for simple random sampling is a measure of the number of fish, picked at random, that would be required to achieve the same level of precision of M as the stratified random survey estimate. Simple random sampling is an idealised way to sample fish and would be very difficult to achieve in practice.

M sensitivity analysis

Increasing or decreasing the length of full recruitment by 1 cm changed T_c to 48 and 34 years and resulted in a 9% increase or an 11% decrease respectively in M (Table 5). A 10% reading bias in the estimated ages would change the estimate of M by 10%. Doubling the reading error increased the *c.v.* of the M estimate by 17%. Halving the recruitment variability decreased the *c.v.* of the M estimate by 25%.

Table 5: Black oreo M sensitivity analysis. "Puysegur only" included data from west and south Puysegur (strata 241, 243–245, 501–502). "Snares only" included data from the west Snares hills (strata 801 & 802). – not estimated

Case	M	*c.v.* (%)
T_c = 48	0.048	–
T_c = 34	0.039	–
Puysegur only	0.067	–
Snares only	0.033	–
Reading bias: - 10%	0.040	–
Reading bias: + 10%	0.049	–
Double the reading error	0.044	33
Half the recruitment variance	0.044	21

Sensitivity of M to area

The biggest change in the estimate of M came from analysing the data from the west and south Puysegur area ("Puysegur only", strata 241, 243–245, 501 and 502) separately from the data from the west Snares hills ("Snares only", strata 801 and 802), although the two resulting M estimates (*see* Table 5) are within the 95% confidence limits for the point estimate from the combined value (*see* Table 4). The bootstrap sample distribution of M for the Snares data had a mode at 0.033, the same as the M estimate. But the Puysegur M estimate is biased because the bootstrap sample distribution for that data gave an 80% chance that the true Puysegur M estimate is less than 0.067.

This analysis was carried out as a test to investigate the assumptions of (a) even fishing over the survey area and (b) a relatively unexploited stock. The trawl survey area was divided into west Puysegur (strata 241, 243–245), south Puysegur (strata 501 and 502), and west Snares (strata 801 and 802). The total black oreo catches for the years 1990–91 to 1994–95 (1 October to 30 September) for each area were extracted from the catch effort database (Table 6). The Snares had the largest catch, 6616 t compared to 3174 t from south Puysegur and 3114 t from west Puysegur. The years when the highest catch of black oreo was taken from each area were also determined and were 1990–91 for south Puysegur, 1991–92 for west Puysegur, and 1992–93 for Snares. The survey (TAN9208) was in October 1992, so for black oreo the Snares was lightly fished up to that time, while catch from south Puysegur had declined and west Puysegur catch had peaked. The difference between the estimates of M from the Snares and the west plus south Puysegur suggested an uneven change in age structure due to fishing, i.e., fishing preferentially takes older fish. The data therefore may contain a mixture of pristine age structures (needed for estimating M) and a fished age structure where the relative proportion of older fish was lower than in pristine stocks.

This is a tentative conclusion because few tows were carried out, especially in the Snares area, and not all tows were sampled for otoliths.

Table 6: Total reported catch (t) of black oreo, smooth oreo, and orange roughy from west Puysegur (strata 241, 243–245), south Puysegur (strata 501 and 502), and west Snares (strata 801 and 802) from 1990–91 to 1994–95 (1 October to 30 September)

	West Puysegur	South Puysegur	West Snares	Total
Orange roughy	15 338	619	844	16 801
Smooth oreo	1 815	1 098	2 307	5 220
Black oreo	3 114	3 174	6 616	12 904

Table 7: Year of reported highest catches (close second in parentheses) for black oreo, smooth oreo, and orange roughy from west Puysegur (strata 241, 243–245), south Puysegur (strata 501 and 502), and west Snares (strata 801 and 802) from 1990–91 to 1994–95 (1 October to 30 September)

	West Puysegur	South Puysegur	West Snares
Orange roughy	1991–92 (92–93)	1990–91	1992–93
Smooth oreo	1993–94	1993–94	1992–93 (93–94)
Black oreo	1991–92	1990–91	1992–93 (93–94)
Year fishery started	1990–91	1989–90	1990–91†

† 4 t of smooth oreo in 1983–84

6. DISCUSSION

Age and growth

Black 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. Results of reading black 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 observed in black oreo appear very similar to those in warty oreo, and therefore it seems likely that black oreo is also a slow growing, long lived species.

Growth of black oreo from the Puysegur area differs from that in Chatham Rise fish (Doonan *et al.* 1995) and consequently growth estimates have been revised using only the Puysegur data. It is difficult to determine the reasons for this result, but it could be due to real differences in the growth of Chatham Rise fish, i.e., that fish grow slower than Puysegur fish. There could be sampling effects because the Chatham Rise trawl surveys probably over-sampled dispersed (non-schooling) smaller fish. Another possible explanation for differences in growth could be altered otolith reading by the two readers. The same two people were involved so some "learning" may have occurred. A set of otoliths with agreed interpretations was used to "introduce" the reader for each period of otolith reading so drastic changes in interpretation were unlikely. The good between-reader variability (8.3% *c.v.* for reading error) also suggests that if there was a systematic change in otolith interpretation, it must have occurred for both readers simultaneously. It could be possible to determine if interpretation had changed by re-reading a sub-sample of the Chatham Rise otoliths. It would be useful to carry out a comparison of age interpretation for black oreo with our Australian colleagues to determine between-institution variability for age estimates.

Growth estimates from the Puysegur data appear more reasonable than the Chatham Rise estimates because the Puysegur data produce a more plausible value of age at onset of maturity (27 years, compared to 42 years for Chatham Rise data). The Puysegur growth curve also appears more plausible because it tends towards the origin at low ages and flattens out more at high ages. More importantly, the age estimates are from a randomly sampled population (some bigger fish were selected for the Chatham Rise data) and the black oreo population is more likely to have had a pristine age structure than that from the Chatham Rise which was heavily fished since the 1980s.

Natural mortality

The main problems with the Puysegur samples were that only small samples were taken from large catches and that the estimates of M are sensitive to area. Otolith sample size for individual tows should be increased in proportion to the size of the catch in future surveys where possible.

M estimates were relatively insensitive to small changes in the values of the parameters used in the calculations. The greatest change resulted from treating the data from different areas within the survey area separately. This effect could be due to real differences in the age distributions of the populations from the different areas, probably as a result of fishing, because only small distances separate each area (less than about 50 n. miles), or it could be due to sampling problems, e.g., small sample sizes. The assumption that the black oreo fishery was not developed in 1992 seems reasonable for the southern part of the trawl survey area (west Snares) but not for the northern area (west and south Puysegur). Analysis suggests that even by 1992 catches of black oreo from the northern area had reached a peak.

Estimates of black 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

This research was carried out for the Ministry of Fisheries under Project DEOE02. Peter Horn (NIWA, Nelson) provided constructive comments on the manuscript.

7. REFERENCES

Clark, M. R. & Tracey, D. M. 1994: Trawl survey of orange roughy, black oreo, and smooth oreo in southern New Zealand waters, August-September, 1992 (TAN9208). *N.Z. Fisheries Data Report No. 40.* 37 p.

Doonan, I. J., McMillan, P. J., Kalish, J. M., & Hart, A. C. 1995: Age estimates for black oreo and smooth oreo. N.Z. Fisheries Assessment Research Document 95/14. 26 p.

Smith, D. C. & Stewart, B. D. 1994: Development of methods to age commercially important dories and oreos. Final report to the Fisheries Research & Development Corporation. Department of Conservation and Natural Resources, Victorian Fisheries Research Institute. 120 p.

Stewart, B. D., Fenton, G. E., Smith, D. C., & Short, S. A. 1995: Validation of otolith-increment age estimates for a deepwater fish species, the warty oreo, *Allocyttus verrucosus*, by radiometric analysis. *Marine Biology 123*: 29–38.