Stock assessment of the Cascade Plateau orange roughy 2006

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1. SUMMARY

This paper updates the quantitative assessment of the Cascade Plateau orange roughy population first performed in 2004. An integrated assessment model, with age- and sex-structured population dynamics was used. All available data have been included – catch records, length-frequency data from 1998-2004, age-frequency samples from 1999 and 2004, and the 2005 absolute acoustic biomass estimate. The changes from last year's assessment are: addition of catch data for 2005; use of the 2005 absolute acoustic biomass estimate instead of 2003 and 2004 estimates; and the software for conducting the assessment has been updated to Stock Synthesis 2 (SS2).

The 2005 acoustic biomass estimate is approximately three times higher than the 2003 and 2004 estimates, so clearly does not form a consistent series with the previous estimates. The difference between these biomass estimates is in keeping with qualitative observations from earlier surveys that have observed a substantial variability between seasons (Prince 2004). This means that we cannot use the acoustic estimates as a relative index (as is the case for the Eastern Zone), but include the largest observed biomass as an absolute biomass estimate. This requires making assumptions about target strength, absolute levels of retention time and proportion spawning, which are essentially assumed invariant and are therefore excluded from relative estimates., The large year-to-year variability observed in biomass estimates does raise questions about the ability of acoustic estimates to distinguish, in the short term, fishery induced changes from natural variability (Ryan 2006).

Three biomass estimates are used in the assessment – all other data remain constant.. The base case assumes that any overestimates in acoustic biomass (eg. due to incorrect target strength) are balanced by assuming the largest observed bomass on one night represents the entire mature population. Alternative biomass estimates assume that acoustic biomass estimates are high by a factor of two, or that only 50% of the mature population is present on any one night. For the base case, current female spawning biomass is estimated to be 73 % of average unfished biomass, for the lowest biomass index this proportion is 62 %, and for the largest biomass index it is 82 %.

The recommended biological catches under three versions of the Tier 2 rule of the SESSF harvest strategy framework are calculated.The recommended biological catch for 2007 ranges from 283 t to 1,307 t for the three scenarios, and the three versions of the Tier 2 harvest control rule. We note that under the base case fishing at 50:50:20 results in 60% of spawning biomass being reached in 18 years, suggesting that a phased approach to the 60:60:20 rule may be possible for this fishery.

A comparison of the 2006 assessment results using the old software and using SS2 was performed. This comparison is reported in detail in Appendix A. The two assessments are extremely similar.

2. INTRODUCTION

2.1 The Fishery

Orange roughy inhabit deep, cold waters over steep continental slopes and oceanic ridges. In Australia, they occur in depths of 700 m to 1400 m, on the continental slope between Port Stephens in NSW and Cape Naturaliste in WA, and on the South Tasman Rise, the Cascade Plateau and the Lord Howe Rise (Kailola et al., 1993). Adult fish form dense winter spawning aggregations, commonly associated with submerged hills or pinnacles. They also form non-spawning aggregations. Orange roughy are slow-growing, long-lived and have low fecundity.

Orange roughy fisheries are generally high-value, targeted fisheries. Most of the Australian catches of orange roughy have occurred off southern and eastern Tasmania, at reliable spawning locations. Each spawning stock fishery appears to be based on a separate stock, and is thus managed separately.

The Cascade Plateau is a rocky seamount approximately 125 nautical miles ESE of Hobart, Tasmania. With a current total allowable catch (TAC) of 700 t, it is Australia's largest domestic orange roughy fishery. Initial fishing on the Plateau was in 1990 by foreign vessels that caught approximately 2,000 t of roughy. Substantial fishing did not occur again until 1996, when almost 1,000 t of orange roughy were caught. Since then, the Plateau has been fished consistently, subject to a TAC.

The Cascade Plateau fishery has been monitored since 1998 using funding from a voluntary industry levy – initially when a competitive TAC operated through a levy/kilo; subsequent to ITQs being introduced through 100 t of the TAC being set aside for research surveys. Biospherics Pty. Ltd. collected and analysed data on catches, length, weight, gonad staging, acoustic observations and environmental variables on industry-led surveys from 1999-2004. In 2003, Biospherics Pty. Ltd. and industry members conducted the first quantitative survey of the Cascade Plateau, using acoustic equipment on industry vessels that could be directly compared to standardised scientific equipment using standard CSIRO school identification and biomass estimation approaches. This survey was repeated in 2004, 2005, and 2006. From 2006, biomass estimates will only be worked up as they are informative to the assessment – ie. they are thought to either provide a larger absolute biomass estimate or start to show a consistent trend.

2.2 Previous Assessments

An analysis of catch per shot data from 1997 to April 2001 showed no trend, due in part to high intervessel variability and variability for individual vessels between years (Wayte, 2001). Catch per shot data for the remainder of 2001 are not directly comparable with earlier years' data as fishing practices changed following the loss of quarterly TACs.

Industry-led surveys in 1999, 2000, 2001 and 2002 described the dynamics of the spawning aggregation and the fishery (e.g. Prince, 2002). Preliminary acoustic biomass estimates for 2000 suggested a spawning biomass in the range of 5,000 – 15,000 t. The volume of the 2001 spawning biomass was more than double that recorded in 2000 and 5 times that recorded in 1999. While there is no direct link between volume and biomass (packing density has been shown to be variable), these results suggest that the biomass of fish spawning on the Plateau is variable and may have increased in recent years.

Simple deterministic population modeling indicated that the prefishery biomass would have to have been about 30,000 t or larger and the biomass in 2002 about 20,000 t or larger for the current catch of 1,600 t to be within the preliminary management target for this fishery (ie. B2010 > 0.30 B1988) (Wayte, 2003). Note that the biological parameters and management target used for this analysis were different from those used in the current analysis, so these analyses are not comparable.

There has been no indication of a declining trend in catch or catch rate in this fishery, but any decline would be disguised by the high variability in catch rate data. Given the lack of a clear signal in the data, and the changed fishing practices, the Orange Roughy Assessment Group (ORAG) recommended that annual acoustic and biological surveys of the spawning aggregation continue until such a time that current biomass estimates are refined and a formal stock assessment is completed. Industry members indicated their support for continuing surveys and continuing support for a voluntary closure of the spawning area during spawning in 2003, 2004 and 2005 to facilitate these surveys.

Biospherics Pty. Ltd. and industry members conducted the first quantitative survey of the Cascade Plateau in 2003, using acoustic equipment on industry vessels that could be directly compared to standardized scientific equipment (Honkalehto and Ryan, 2003). The survey was supported by industry through the 100 t research quota. ORAG provided funds for the acoustic biomass estimate.

The first formal quantitative assessment of the Cascade Plateau population of orange roughy was performed in 2004 (Wayte, 2004). An integrated assessment model, with an age- and sex-structured population dynamics model was applied. This assessment concluded that it is likely that a sustainable long-term annual catch level for the Cascade Plateau could be between 200 and 400 t. The pre-fishery population size was estimated to be much less than half those estimated in the Eastern or Southern zones, and the stock productivity was estimated to be half that of other stocks.

In 2005 the assessment was updated with the 2004 acoustic biomass estimate, which was slightly lower than the 2003 estimate (Wayte, 2005). Assessment results were similar to the previous year. The recommended biological catch was estimated to be less than 500 t for all scenarios considered. However the 2005 survey estimated a larger absolute biomass present than in previous years, leading DeepRAG to send a letter out of session to AFMA updating the 2005 assessment. This 2006 assessment is the first formal assessment to use the higher 2005 survey estimate.

3. METHODS

3.1 The Data and Model Inputs

3.1.1 Catches

The Cascade Plateau was first fished in 1989/90 when 2,000 t of roughy were caught by mostly foreign vessels. Smaller catches were reported by domestic vessels from the Cascade Plateau between 1991 and 1994, but these data are believed to be misreported. Substantial fishing did not occur again until 1996, when 863 t were caught. In April 1997 a precautionary trigger limit of 1,000 t set by the South East Trawl Management Advisory Committee (SETMAC) was reached. An ORAG proposal to increase fishing to a 1,600 t competitive TAC (400 t per quarter with no carryover of uncaught quota between quarters or years) based on a strategic fishing and research program, was accepted by SETMAC for 1998 and subsequently approved by the Australian Fisheries Management Authority (AFMA). Individual Transferable Quotas (ITQs) replaced the competitive TAC from 1 April 2001, and the quarterly distribution of quota was lost, increasing effective fishing effort in the fishery.

Information on catches reported here (Table 1) has been obtained from the AFMA catch landings database (SEF2). These figures include the 100 t research quota. Total reported catches to the end of 2005 are 16,647 t.

Table 1 Cascade Plateau catches and quota (the catches include the 100 t research quota)

Year	Agreed TAC (t) (before adjustment)	Research quota	Management method	landed catch (t)
1989	None		none	260
1990	None		none	1,858
1991	None		none	0
1992	None		none	0
1993	None		none	0
1994	1,000		trigger limit	0
1995	1,000		trigger limit	0
1996	1,000		trigger limit	972
1997	1,000		trigger limit	1,178
1998	1,600		4 openings	1,560
1999	1,600		4 openings	1,689
2000	1,600		4 openings	1,639
2001 (first quarter)	400		1 opening	310
2001 (after April 1)	1,165		ITQs	1,156
2002	1,500	100	ITQs	1,592
2003	1,500	100	ITQs	1,638
2004	1,500	100	ITQs	1,520
2005	1,200	100	ITQs	1,275
2006	700	100	ITQs	?
			Total catch	16,647

3.1.2 Length frequencies

Length frequency data (Figure 1) have been collected from the industry surveys run by Biospherics Pty. Ltd. from 1998-2004 (eg. Prince, 2002). Sub-samples of 100-200 fish were taken from large catches; all fish were measured in smaller samples. The data from each shot are considered to be uniform and representative of the population, thus no weighting by proportion of catch sampled has been performed (J.Prince, pers.comm.).

In stock assessments of orange roughy in New Zealand (Smith et al, 2002), effective sample sizes calculated from bootstrap resampling of the length frequency samples were used in place of the actual sample sizes in the likelihood. This was done in an attempt to take sampling error into account. Due to time constraints the bootstrap re-sampling procedure has not yet been done for the Cascade Plateau dataset. Instead, the effective sample sizes are approximated by multiplying the actual sample sizes by 0.01 (the average of the ratios of effective to actual sample sizes calculated in New Zealand orange roughy length-frequency samples). Sensitivity to this weighting was investigated in the 2004 assessment.

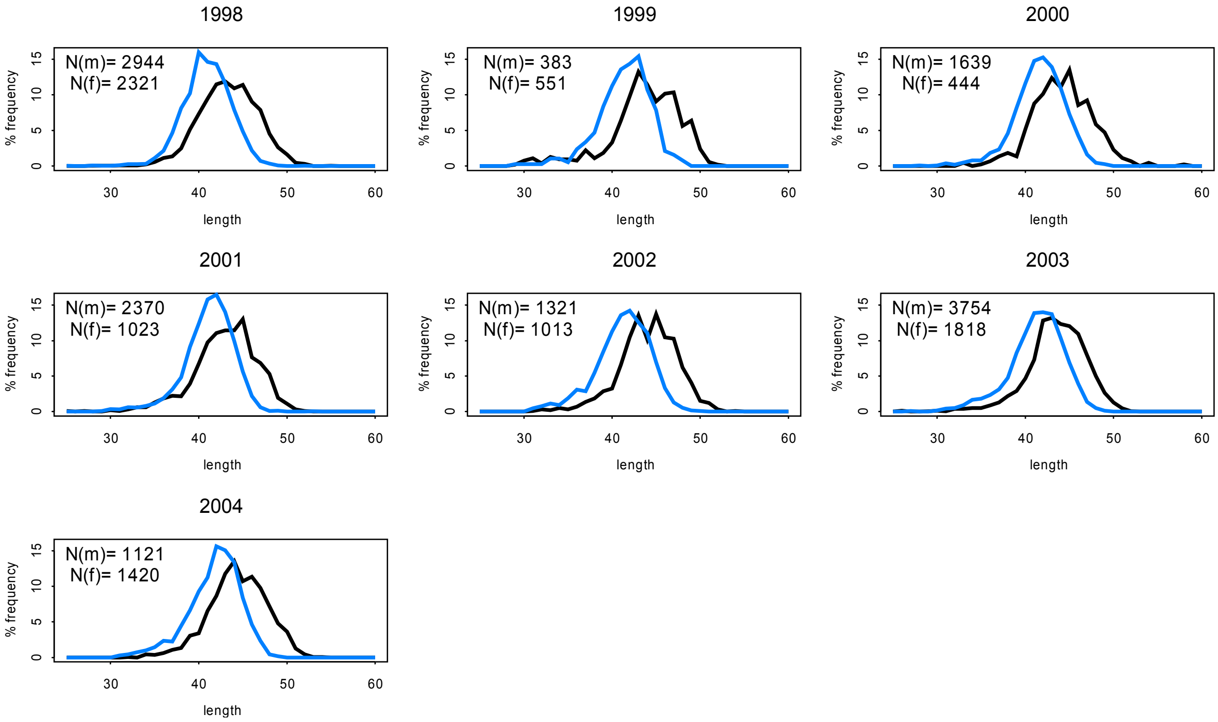

Figure 1 Female (black) and male (grey) length frequencies, with sample sizes.

3.1.3 Age frequency

Two age frequency samples from the Cascade Plateau have been aged by the Central Ageing Facility in Queenscliff. 816 otoliths (529 female and 287 male) were taken in 1999, and 540 otoliths (383 female and 157 male) in 2004 (). The sexes have been combined when input to the model, as there are too few observations for the sexes separately to produce a sensible age-frequency distribution (too many ages have no observations).

If a sample of otoliths has been re-aged it is possible to estimate imprecision in ageing using an ageing error matrix. However, only 250 of the 1999 otoliths have been re-aged. This is not enough to estimate a useful ageing error matrix for such a long-lived species.

Actual sample sizes are multiplied by 0.1 to approximate effective sample sizes, based on the same reasoning described for the adjustment of length frequency sample size, but retaining greater emphasis on the age data, as the age data are considered to contain more information than the length frequency data. Sensitivity to this weighting was investigated in the 2004 assessment.

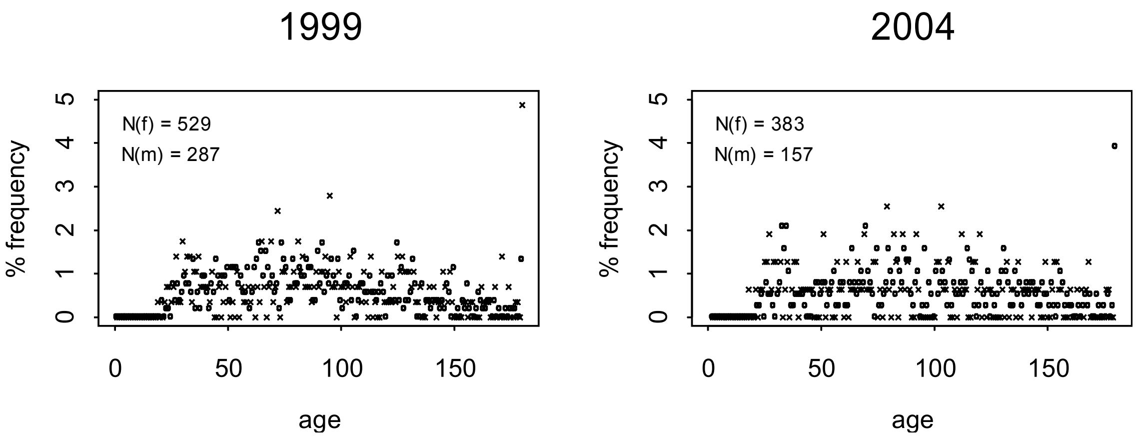

Figure 2 1999 and 2004 female (dots) and male (crosses) age frequencies, with sample sizes.

3.1.4 Acoustic biomass estimate

Biospherics Pty. Ltd. and industry members conducted the first quantitative survey of the Cascade Plateau in 2003, using acoustic equipment on industry vessels that could be directly compared to standardized scientific equipment (Honkalehto and Ryan, 2003). This survey was repeated in 2004 (Honkalehto and Ryan, 2005) and 2005 (Ryan, 2006). A number of absolute biomass estimates were obtained, depending on the value of target strength (TS) used, and the method used to classify orange roughy schools.

Orange roughy target strength (TS) is not well understood especially for the larger fish found on the Cascade Plateau, and thus two alternative published values were used in the acoustic biomass estimation calculations: "Hampton" and "Doonan". Acoustic data were echo integrated for biomass estimation using a classification scheme based on a 3-tiered ranking of confidence of orange roughy echosign. The estimates from scheme OR1, obvious roughy schools, are used in the stock assessment, as these are the most defendable biomass estimates. An acoustic deadzone correction was applied to the data.

The 2005 acoustic biomass estimate is approximately a factor of three higher than the 2003 and 2004 estimates, so clearly does not form a consistent series with the previous estimates. It had been hoped that a third biomass estimate would allow the series to be used as a relative index, but this is not possible. In this assessment the 2005 estimate has been used on its own as an absolute biomass estimate. The difference between the three biomass estimates is in keeping with qualitative observations from earlier surveys that have observed a substantial variability between seasons (Prince 2004). However, the large variability observed does raise questions about the ability of acoustic estimates to distinguish, in the short term, fishery induced changes from natural variability (Ryan 2006).

The acoustic biomass estimate of orange roughy in schools at the time of the survey is a snapshot biomass estimate. To convert the snapshot acoustic biomass estimates into a Cascade population estimate requires accounting for the proportion of adult fish that do not come to spawn and the turnover of adult fish in the schools. Quantitative measures of the proportion of fish that do not spawn each year are not available for the Cascade fishery but it is estimated to be between 0 to 30%. The Eastern Zone assessment assumed 20-30% of fish do not spawn each year. The turnover of fish on the spawning grounds based on limited information from the Eastern Zone and New Zealand fisheries is estimated to be in the range of 0 to 50%. In this assessment the snapshot acoustic surveys are doubled (100%) to provide an upper bound taking into account the proportion of adult fish that do not come to the spawning grounds and the turnover of fish in the schools. Future surveys should look at testable hypotheses to quantify and narrow the bound of this range.

3.1.5 Biological parameters

Orange roughy from the Cascade Plateau are noticeably larger than those from the Eastern Zone so it was necessary to calculate values for biological parameters from fish collected from the Plateau, rather than use values used in the Eastern Zone stock assessments.

Natural mortality

In previous Cascade stock assessments natural mortality has been estimated to be 0.02. This is used in this assessment.

Length-weight relationship

The length-weight relationship was calculated by Honkalehto and Ryan (2003) from length-weight data from 1,003 female roughy collected during the 2000 spawning survey of the Cascade Plateau:

$$\text{weight(g)} = 0.382*\text{length(cm)}^{2.3409}$$

Growth

The Von Bertalanffy growth curve was fitted separately for males and females using the age and length data from the 2004 age composition sample (Figure 3). Due to the lack of data for younger ages it was not possible to estimate a sensible value for t_0 which was therefore fixed at 0. Sensitivity to fixing t_0 at –10 (and altering the other growth parameters accordingly) was investigated in the previous assessment.

Males: $l_t = 42.98(1 - e^{-0.062t})$ 157 observations

Females: $l_t = 45.98(1 - e^{-0.059t})$ 383 observations

The 2004 stock assessment used Von Bertalanffy parameters estimated from the 1999 age composition sample. However, in 1999 the fish aged were larger than those in the length frequency sample, leading to doubts over whether the aged sample was representative of the population. In 2004 the length frequency distribution of the aged fish was the same as the fish measured for length only.

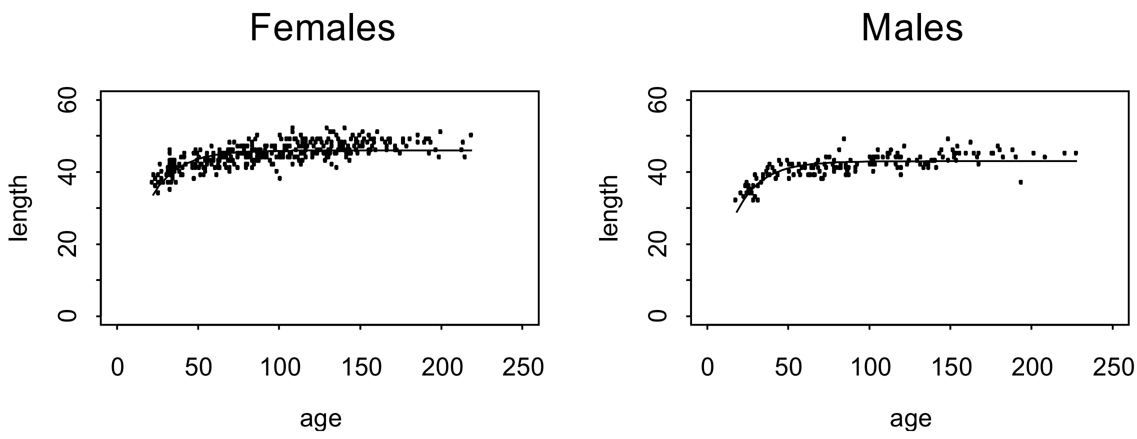

Figure 3 Female and male growth curves

Other biological parameters

The fixed biological parameters used in the stock assessment are summarised in Table 2. Values for stock-recruit steepness and recruitment variability parameters are the same as those used in other Australian orange roughy assessments. Selectivity was modelled using a logistic ogive, and the maturity ogive was set to be equal to this. σ_R is set to the empirical variability of estimated recruitments.

Table 2 Fixed biological parameters used in the assessmnent

Parameter	**symbol**	**male**	**female**	**both sexes**
natural mortality	M			0.02
von Bertalanffy growth	L_∞	42.98 cm	45.98 cm	-
	k	0.062 yr^{-1}	0.059 yr^{-1}	-
	t_0	0 yr	0 yr	-
length -weight	a			0.382 g/cm^3
	b			2.3409
stock-recruit steepness	d			0.75
recruitment variability	σ_R			0.25
length-at-age cv	σ_l			0.05
plus-group age	z			180

3.2 The Assessment Model

3.2.1 Model Structure

The 2006 assessment is based on the Stock Synthesis model of Methot (2005). The software used to estimate the parameters of the model, SS2, is a generalised assessment package based on the integrated analysis paradigm. This means that all relevant processes are built into the model, and goodness-of-fit is estimated in terms of the original data. This model differs from that used previously for stock assessment of Cascade orange roughy in only a few technical details. Appendix A compares SS2 and the previous assessment method.

3.2.2 Parameter estimation

The base case analysis estimates 182 parameters (R_0, 2 selectivity parameters and 179 recruitment deviations). Selectivity is based on length rather than age, and is modeled using a logistic curve.

Due to time constraints a smaller set of sensitivity tests were performed in this assessment than in the 2004 assessment. The sensitivity tests performed in the 2004 assessment did not produce any surprises or anomalous results, and are not all worth repeating. The only sensitivity tests performed this year were using different biomass estimates.

4. RESULTS

4.1 Base case analysis

The base case analysis includes all the data, and estimates all 182 free parameters. It uses the acoustic estimate calculated using the Hampton TS estimate. Length where 50% of the population is selected is estimated to be 41.5 cm, with the width for 95% selection estimated to be 8.42 cm.

The fit to the acoustic estimate and the estimated recruitment multipliers are shown in Figure 4.

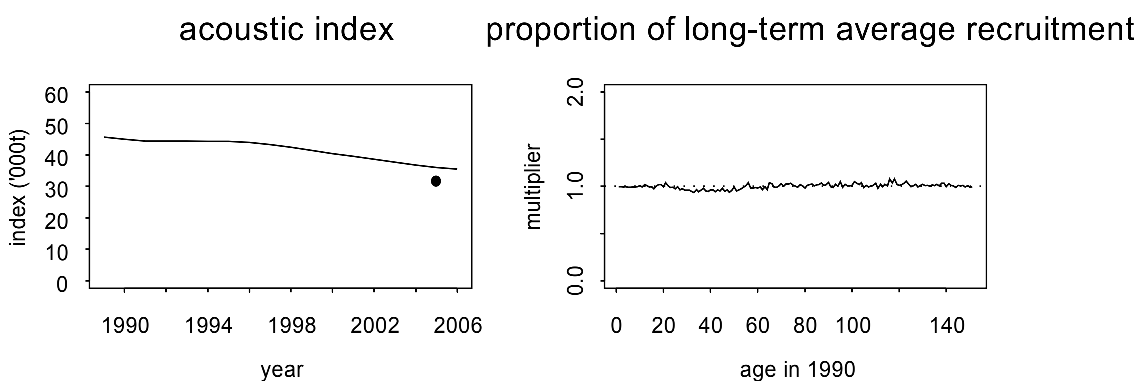

Figure 4 MPD fits for the base case

The base case MPD fits to the age frequency data are shown in Figure 5. The fits to the age data appear reasonable given the large amount of variability in the data. The variability in the data occurs partly because there are relatively few observations (885 in 1999 and 540 in 2004) compared to the number of age classes (180), which leads to few (and occasionally no) observations in each age class. The sexes have been combined when input to the model, as there are too few observations for the sexes separately to produce a sensible age-frequency distribution (too many ages have no observations). The standard deviation of the recruitment deviations has been set to 0.25, based on the empirical variability of estimated recruitments. If this value is set too high, the biomass will be estimated to decline even without fishing, due to bias arising from the log-normal distribution of the recruitment deviations (Punt, 2006).

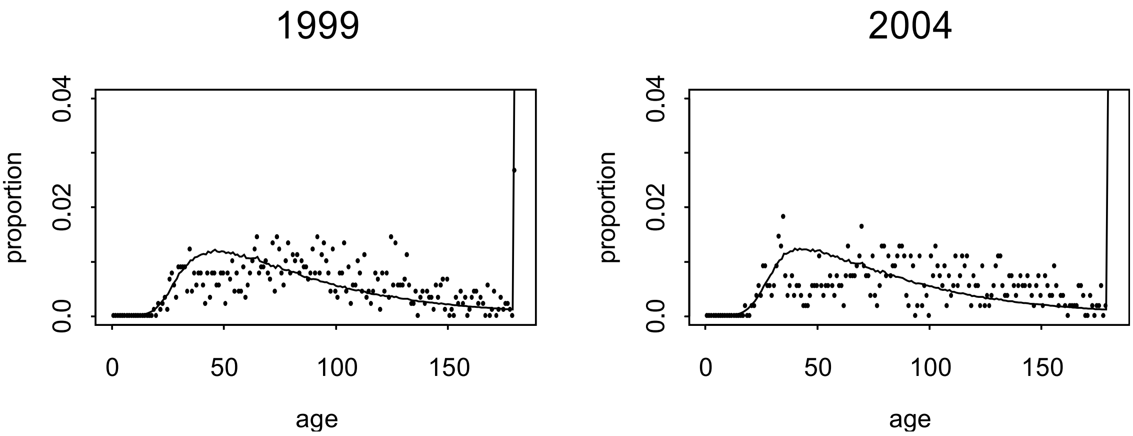

Figure 5 MPD fits (solid lines) to the age frequency data (dots) for the base-case analysis.

The fits to the length frequency compositions are generally good (Figure 6). The contradiction between the fits to the age and length frequency data observed in the 2004 assessment is no longer evident. This is because the lengths of the fish in the 2004 age frequency sample are consistent with those in the length frequency sample (and therefore hopefully representative of the population).

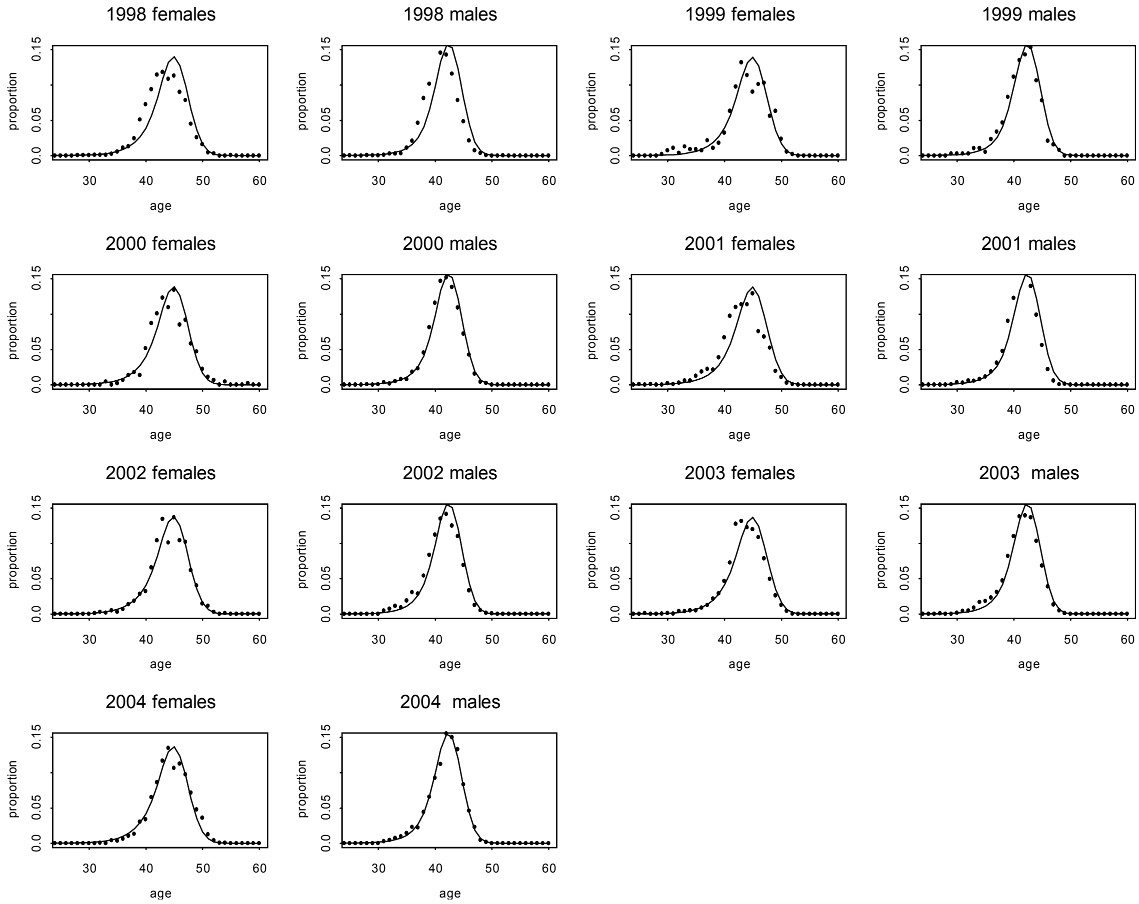

Figure 6 MPD fits (solid lines) to the length frequency data (dots) for the base-case analysis.

4.2 RBC calculation

Tier 2 of the SESSF harvest strategy framework (Smith and Smith (2005), Smith (2006)) is recommended for Cascade orange roughy. This rule has been modified from last year, and three versions of it are applied this year. The SESSF harvest strategy framework is still under development, and will be tested via a management strategy evaluation (MSE) project due to start later this year.

The general formula for calculating the fishing mortality F_{ADJ} is :

$$F_{ADJ} = F_{TARG} \qquad \text{where } B_{CUR} > B_{break}$$

$$F_{ADJ} = F_{TARG}\left(\frac{B_{CURR} - B_{20}}{B_{break} - B_{20}}\right) \qquad \text{where } B_{break} > B_{CUR} > B_{20}$$

$$F_{ADJ} = 0 \qquad \text{where } B_{CUR} < B_{20}$$

The three versions of the harvest control rule (HCR) used this year are :

F_{TARG}=F_{50} and B_{break} =B_{50} (50:50:20)

F_{TARG}=F_{60} and B_{break} =B_{50} (60:50:20)

F_{TARG}=F_{60} and B_{break} =B_{60} (60:60:20)

The recommended biological catch (RBC) is calculated by applying F_{ADJ} to the current biomass as estimated by the agreed base case assessment model.

F_X represents the fishing mortality rate that would cause the spawning biomass to decline to X % of its unfished levels.

B_X represents the biomass at X% of unfished levels.

B_{CUR} is the current estimated biomass from the base case assessment model.

The tier 2 rules are shown graphically in Figure 7, and the projected catches under each rule are shown in Figure 8.

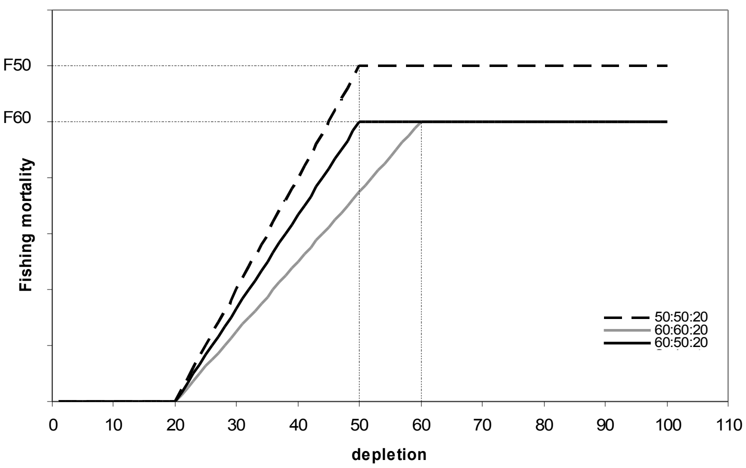

Figure 7 Tier 2 harvest control rules

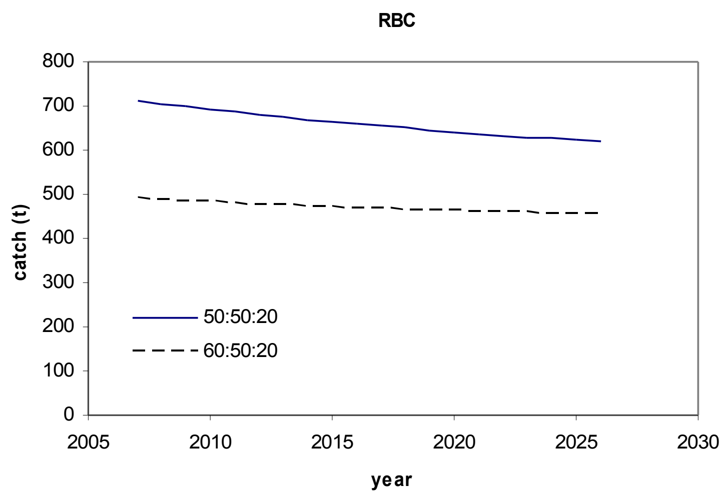

Figure 8 Projected RBCs under three versions of the Tier 2 rule for the base case analysis (the 60:50:20 and the 60:60:20 rules are the same in this case)

4.3 Projections shows fishing mortality vs depletion over time for the base case. The first graph projects into the future using a fixed catch of 800 t (the current TAC). The second graph projects 50 years into the future using the tier 2 harvest control rule 50:50:20. The straight line on the plots shows the 50:50:20 HCR.This shows that under the base case scenario with a continuing catch of 800 t, the proportion of unfished biomass remaining will continue to decline as fishing mortality increases. Using the 50:50:20 HCR, biomass will eventually stabilise at 50 % of unfished biomass, and F_{50} immediately brings down fishing effort so that 60% of unfished biomass is not reached for 18 years.

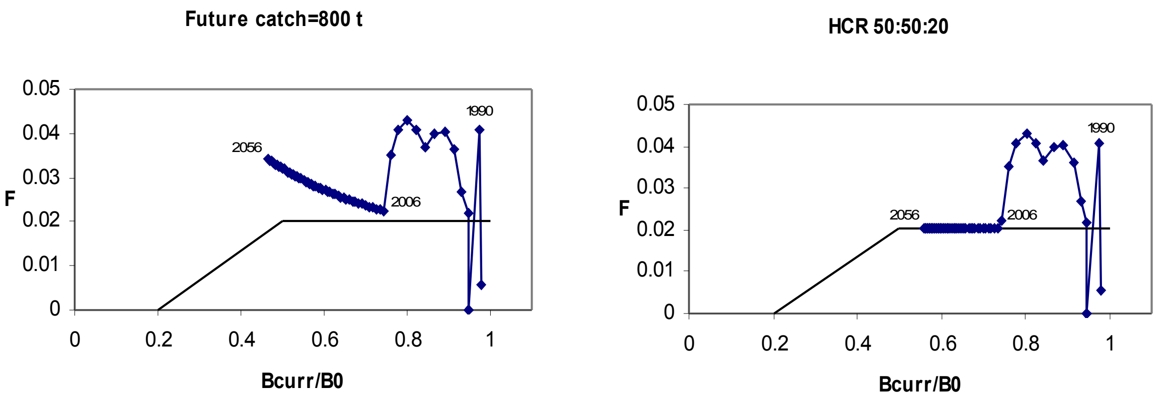

Figure 9 Projections for the base case using 800 t (left) and harvest control rule 50:50:20 (right)

4.2 Sensitivity tests

Other than the base case, the only models run were that using half the estimated acoustic biomass estimate (to take into account a different target strength value), and that using double the estimated biomass estimate (to take into account proportion spawning and turnover). Thus it can be seen that the base case effectively assumes that any overestimates caused by inaccuracy in the absolute acoustic biomass estimate are balanced by underestimates from assuming that a snapshot biomass estimate (the largest observed school in one night) represents all mature fish in the population. Table 3 summarises the results of the sensitivity tests. The results reported for each analysis are the estimates of average unfished female spawning biomass (SB_0), current (2007) female spawning biomass, and the ratio of the 2007 biomass to SB_0.

All of these results are based on the MPD (mode of the posterior distribution) estimates rather than the more accurate MCMC (Markov chain Monte Carlo) estimates, and should be interpreted with caution. There was not enough time available for calculation of the MCMC estimates.

Table 3 Results for the sensitivity tests (MPD)

	Female spawning biomass			RBCs using the 3 harvest control rules		
Acoustic estimate	Female SB_0	Female SB_{2007}	SB_{2007}/SB_0	50:50:20	60:50:20	60:60:20
31,600	28,581	20,986	0.73	711	490	490
63,200	47,206	39,092	0.82	1,307	902	902
15,800	19,247	11,915	0.62	411	283	283

5. DISCUSSION AND CONCLUSIONS

Different absolute acoustic biomass indices have virtually no effect on the fit to the age or length composition data, but do give rise to different biomass estimates and levels of depletion. For the base case, current female spawning biomass is estimated to be 73 % of average unfished biomass, for the lowest biomass index this proportion is 62 %, and for the largest biomass index it is 82 %.

The recommended biological catch for 2007 ranges from 283 t to 1,307 t for the three scenarios, and the three versions of the harvest control rule.

The Cascade biomass estimate is based on the maximum observed biomass on the spawning ground. On the one hand this could be an overestimate (target strength too low) , on the other it could be an underestimate (maximum biomasss was only a fraction of the total spawning biomass). Variability between years in size of the spawning aggregation complicates intepretation – when smaller biomasses are estimated in future years it will be difficult to distinguish an overall reduction from natural variability. It is recommended that this fishery continues to be monitored annually, through the industry program and data stored so that they can analysed in the future if needed. An MSE for management of this fishery (where biomass is based on the single largest biomass estimate) is recommended. Continued industry support for annual monitoring should be taken into account when determining the level of risk for this fishery.

6. ACKNOWLEDGEMENTS

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APPENDIX A : COMPARISON OF PREVIOUS MODEL WITH SS2

The previous assessments of Cascade orange roughy were based on an age- and sex-structured model with gradual recruitment according to age. It was fitted to data on catches, age compositions, length compositions and an acoustic abundance index. The 2006 assessment uses the stock assessment package Stock Synthesis 2 (SS2), developed by Rick Methot of NOAA Fisheries (Methot, 2005). The reasons for changing to SS2 are :

1. Well-tested and flexible software
2. Excellent output software allows rapid model testing and development
3. Calculation of RBCs is incorporated into the software
4. Provides a uniform approach to stock assessment for all SEF species
5. Allows stock assessment scientists to more easily understand (and therefore assist with) other assessments
6. Standard outputs will allow RAG members to more easily understand assessments

The model in SS2 is philosophically the same as that used in 2002, however there are some technical differences. The most important of these is that SS2 uses length- rather than age-based selectivity.

The two versions of the assessment are almost identical, so it has been concluded that the change to SS2 will produce results consistent with previous analyses.