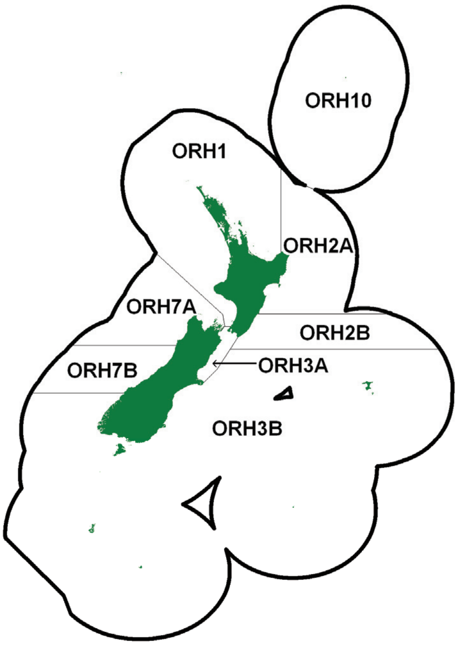
ORANGE ROUGHY (ORH)

(*Hoplostethus atlanticus*)



1. INTRODUCTION

The main orange roughy fisheries have been treated separately for assessment and management purposes, and individual reports produced for each of five different areas consisting of one or more stocks as follows:

1. Northern North Island (ORH 1)
    - Mercury-Colville stock
    - Other stocks
2. Cape Runaway to Banks Peninsula (ORH 2A, 2B, & 3A)
    - East Cape stock
    - Mid-East Coast stock
3. Chatham Rise and Puysegur (ORH 3B)
    - Northwest Chatham Rise stock
    - East Chatham Rise stock
    - South Chatham Rise stock
    - Puysegur stock
    - Other minor stocks or subareas
4. Challenger Plateau (ORH 7A)
5. West coast South Island (ORH 7B)
6. Outside the EEZ
    - Lord Howe
    - Northwest Challenger
    - Louisville
    - West Norfolk
    - South Tasman

Note that since 2006, the area that was formerly referred to as the Northeast Chatham Rise is now called the East Chatham Rise to be consistent with the names of management areas used within ORH 3B.

2. BIOLOGY

Orange roughy inhabit depths between 700 m and at least 1500 m within the New Zealand EEZ. Their maximum depth range is unknown.

Orange roughy are very slow-growing, long-lived fish. On the basis of otolith ring counts and radiometric isotope studies, orange roughy may live up to 120–130 years. Age determination from otolith rings has been validated by length-mode analysis for juveniles up to four years of age, and adult ages have been validated from a preliminary study by Andrews and Tracey (2003).

Orange roughy otoliths have a marked transition zone in banding which is believed to be associated with first spawning (Francis & Horn 1997). This has been used to estimate mean age at the onset of maturity, which ranges from 23 to 31.5 years for fish from various New Zealand fishing grounds (Horn *et al*. 1998, Seafood Industry Council/NIWA unpublished data). Orange roughy in New Zealand waters reach a maximum size of about 50 cm standard length (SL), and 3.6 kg in weight. Their average size is around 35 cm SL, although there is some variation between areas.

Spawning occurs once each year between June and early August in several areas within the New Zealand EEZ, from the Bay of Plenty in the north, to the Auckland Islands in the south. Spawning occurs in dense aggregations at depths of 700–1000 m and is often associated with bottom features such as pinnacles and canyons. Spawning fish are also found outside the EEZ on the Challenger Plateau, Lord Howe Rise, and Norfolk Ridge to the west, and the Louisville Ridge to the east. It is likely that individual orange roughy do not spawn every year.

Fecundity is relatively low, with females carrying on average about 40,000–60,000 eggs. The eggs are large (2–3 mm in diameter), are fertilised in the water column, and then drift upwards towards the surface and remain planktonic until they hatch close to the bottom after about 10 days. Details of larval biology are poorly known.

Orange roughy juveniles are first available to bottom trawls at age about 6 months, when they exhibit a mean length of about 2 cm. Juveniles have been found in large numbers in only one area, at a depth of 800–900 m about 150 km east of the main spawning ground on the north Chatham Rise.

Orange roughy also form aggregations outside the spawning period, presumably for feeding. Their main prey species include mesopelagic and benthopelagic prawns, fish and squid, with other organisms such as mysids, amphipods and euphausiids occasionally being important.

Natural mortality (M) is estimated at 0.045 yr^{-1}. This was based on otolith age data from a 1984 research survey of the Chatham Rise that used an estimation technique based on mean age. A similar estimate was obtained in 1998 from a lightly fished population in the Bay of Plenty.

Biological parameters used in the following assessments (Tables 1 and 2) were estimated by Doonan (1994) with modifications of A_r, A_m, S_r, and S_m for the 1998 stock assessment meetings by Francis and Horn (1997), Horn *et al*. (1998), and Doonan *et al.* (1998), and further modifications for the 2006 assessment by Hicks (2006).

Possible biases in reading ages from otoliths were recently identified and it was recommended by the reviewers of orange roughy workshops in October 2005 and February 2006 that no age data should be input into the assessments until the biases can be quantified and corrected for. They suggested, however, that the age data could be used post-estimation to check for severe inconsistencies in a model or run.

It is believed that ages from otoliths collected during the 1984 and 1990 trawl surveys of the East Chatham Rise and aged by NIWA personnel do not contain serious biases, thus these were used to estimate a single-sex growth curve, length-weight parameters, and a maturity ogive based on transition zones. The estimates are shown in Table 1 and were used for both the East Chatham Rise and the Northwest Chatham Rise, although the otoliths used were collected from only the East Chatham Rise (of which most were from the Spawning Box).

The growth and length-weight parameters were estimated in a slightly different way than in the past. The models used for orange roughy assessments bin the lengths by 1cm and use the midpoint of each bin. For example, a length of 32.3 cm is in the length class between 32 and 33 cm, and is treated as 32.5 when calculating age or weight. Therefore, the lengths in the external estimation of the growth and length-weight parameters were treated the same.

The maturity estimates were only used in initial runs. In final runs the maturity ogive was assumed equal to estimated selectivity, where appropriate. See Section 3(c) below for a more in-depth explanation.

Table 1: Biological parameters as used for orange roughy assessments. –, not estimated.

Parameter	Symbol	Male	Female	Both sexes
Natural mortality	M	–	–	0.045 yr^{-1}
Age of recruitment	A_r (a_{50})	–	–	$=A_m$
Gradual recruitment	S_r (a_{to95})	–	–	$=S_m$
Age at maturity	A_m (a_{50})	–	–	Table 2
Gradual maturity	S_m (a_{to95})	–	–	Table 2
von Bertalanffy parameters				
– Chatham Rise (default)	L_∞	36.4 cm	38.0 cm	–
– Northwest Chatham Rise[†]	L_∞	–	–	37.78 cm
– East Chatham Rise[*]	L_∞	–	–	37.78 cm
– Ritchie Bank	L_∞	–	–	37.2 cm
– Challenger Plateau	L_∞	33.4 cm	35.0 cm	–
– All areas (default)	k	0.070 yr^{-1}	0.061 yr^{-1}	–
– Northwest Chatham Rise[†]	k	–	–	0.059 yr^{-1}
– East Chatham Rise[*]	k	–	–	0.059 yr^{-1}
– Ritchie Bank	k	–	–	0.065 yr^{-1}
– All areas (default)	t_0	-0.4 yr	-0.6 yr	–
– East Chatham Rise[*]	t_0	–	–	-0.491
– Northwest Chatham Rise[†]	t_0	–	–	-0.491
– Ritchie Bank	t_0	–	–	-0.5
Length-weight parameters				
– default	a	–	–	0.0921
– East & Northwest Chatham Rise[*]	a			0.0800
– default	b	–	–	2.71
– East & Northwest Chatham Rise[*]	b			2.75
Recruitment variability	s_R	–	–	1.1
Recruitment steepness		–	–	0.75

[*] New estimates used in 2006 assessments, estimated using floored+0.5 lengths

[†] New estimates used in 2006 assessment estimated from East Chatham Rise data

Table 2: Estimates of A_m and S_m by area for New Zealand orange roughy from transition zone observations.

	A_m			S_m		
Area	M	F	Both sexes	M	F	Both sexes
Chatham Rise (default)	–	–	29	–	–	3
Northwest Chatham Rise[*]	–	–	28.51	–	–	4.56
East Chatham Rise[*]	–	–	28.51	–	–	4.56
Ritchie Bank	–	–	31.5	–	–	6.5
Challenger Plateau	–	–	23	–	–	3
Puysegur Bank	–	–	27	–	–	3
Bay of Plenty	26	27	–	4	5	–

[*] New estimates used in 2006 assessments from East Chatham Rise only data

The differing parameter values in Tables 1 and 2 by area mean that yield estimates also differ by fishing ground (Table 3).

Table 3: Estimates of MCY, E_{CAY} and MAY for New Zealand orange roughy.

Area	MCY (%B_0)	E_{CAY}	MAY (%B_0)
Bay of Plenty (ORH 1)	1.47	0.063	1.94
Ritchie Bank (ORH 2A)	1.46	0.062	1.92
Chatham Rise (ORH 3B)	1.51	0.064	1.99
Puysegur Bank (ORH 3B)	1.47	0.062	1.94
Challenger Plateau (ORH 7A)	1.40	0.060	1.84

For all these stocks, the mean biomass when fishing using an MCY policy is estimated to be 51% of B_0, and for a CAY policy it is 30% of B_0 (these values varied by less than 1% between the various stocks.)

3. ENVIRONMENTAL EFFECTS OF FISHING

This section is new for the May 2010 Plenary and has been considered by the Aquatic Environment Working Group (AEWG). It includes only a summary of the incidental bycatch of marine mammals and seabirds in this fishery and does not consider other potential environmental effects. A more detailed assessment of environmental effects across all fisheries will be available in the Ministry's Aquatic Environment Plenary that is under development.

3.1 Role in the ecosystem

Not discussed by the AEWG.

3.2 Incidental catch (fish and invertebrates)

Not discussed by the AEWG.

3.3 Incidental catch (seabirds and mammals)

This section provides an overview of the incidental captures of seabirds and marine mammals in deepwater fisheries; this grouping of fisheries covers orange roughy, oreo species and cardinal fish. Capture estimates include only those animals landed (alive, injured or dead) on fishing vessels but may not include all sources of cryptic mortality e.g. seabirds struck by the warp but not landed onboard the vessel. Various projects have estimated the total incidental captures in this fishery. This section refers to ratio estimates of incidental captures for all years and model based estimates where available (for methods see MacKenzie and Fletcher 2006, Abraham et al. 2010, Thompson et al. in press).

Annual observed seabird capture rates ranged from 0.07 to 3.47 per hundred tows in deepwater fisheries during the period from 1998-99 to 2007-08. Estimated means of total annual captures ranged from 10 to 74 seabirds (ratio estimated) and 38 to 91 (model estimated) (Table 4). Note that the confidence intervals have reduced as observer coverage rates have increased throughout the period.

Seabird species that were observed caught in the hoki fishery from 1998-99 to 2007-08 are (with total numbers of each species observed caught during this period); white-chinned petrel (24), cape petrels (16), black-browed albatross (unidentified) (12), albatrosses (unidentified) (5), grey petrel (3), Salvin's albatross (3), white-capped albatross (3), seabird – large (2), common diving petrel (2), Chatham Island albatross (2), Buller's albatross (2), Gibson's albatross (1), petrel (unidentified) (1), giant petrels (unidentified) (1), Pacific albatross (1), white-faced storm petrel (1), seabird – small (1), sooty shearwater (1), storm petrels (1), shy albatross (1), and other species (2) (Abraham et al. 2010). Note that identification to species or group level is done by observers onboard and some birds are not readily identifiable.

Annual observed fur seal capture rates ranged from 0.00 to 0.30 per hundred tows in deepwater fisheries during the period from 1998-99 to 2007-08. Estimates of total annual captures ranged from 0 to 13 fur seals (Table 5).

3.4 Benthic interactions

These deepwater fishes are taken almost entirely using bottom trawls but a summary has not been discussed by the AEWG

5.5 Other considerations

Not discussed by the AEWG.

Table 4: Summary of all bird captures in the deepwater trawl fishery, for 10 fishing years, with the number of tows, number of tows observed, percentage of tows observed, number of observed captures, capture rate per hundred tows, total estimated captures with 95% confidence intervals, percentage of tows included in the estimate (from Abraham et al. 2010) and model based estimates of captures with 95% confidence intervals for ORH target trawling by vessels over 28 m (from MacKenzie & Fletcher 2006).

	Observed					Ratio estimated			Model based estimate	
	Tows	No. obs	% obs	Captures	Rate	Captures	(95% c.i.)	% effort in est.	Captures	(95% c.i.)
1998–99	13 714	1 010	7.4	35	3.47	74	(44 - 124)	99.4	91	(66 - 130)
1999–00	12 505	1 934	15.5	5	0.26	53	(20 - 102)	99.3	38	(22 - 61)
2000–01	8 925	1 187	13.3	4	0.34	30	(13 - 52)	99.2	71	(44 - 112)
2001–02	8 220	1 377	16.8	6	0.44	34	(17 - 54)	99.2	50	(29 - 86)
2002–03	8 867	1 380	15.6	1	0.07	13	(6 - 21)	99.6	47	(27 - 81)
2003–04	8 006	1 261	15.8	3	0.24	29	(12 - 52)	99.8	60	(37 - 94)
2004–05	8 406	1 618	19.2	19	1.17	86	(39 - 157)	99.7		
2005–06	8 291	1 292	15.6	5	0.39	33	(13 - 57)	99.2		
2006–07	7 477	2 320	31	1	0.04	10	(2 - 23)	99.7		
2007–08	6 743	2 810	41.7	6	0.21	16	(11 - 23)	99.4		

Table 5: Summary of New Zealand fur seal captures in the deepwater trawl fishery, for 10 fishing years, with the number of tows, number of tows observed, percentage of tows observed, number of observed captures, capture rate per hundred tows, total estimated captures with 95% confidence intervals, percentage of tows included in the estimate (from Abraham et al. 2010) and model based estimates of captures with 95% confidence intervals (from Thompson et al. in press).

	Observed					Ratio estimated			Model based estimate	
	Tows	No. obs	% obs	Captures	Rate	Captures	(95% c.i.)	% effort in est.	Captures	(95% c.i.)
1998–99	13 714	1 010	7.4	3	0.3	4	(3 - 5)	92.9		
1999–00	12 505	1 934	15.5	0	0	0	(0 - 1)	99.3		
2000–01	8 925	1 187	13.3	1	0.08	1	(1 - 2)	89		
2001–02	8 220	1 377	16.8	0	0	0	(0 - 1)	91.1		
2002–03	8 867	1 380	15.6	0	0	0	(0 - 1)	99.6	5	(0 -16)
2003–04	8 006	1 261	15.8	2	0.16	11	(2 - 25)	99.8	10	(3 - 28)
2004–05	8 406	1 618	19.2	4	0.25	13	(6 - 23)	99.7	17	(6 - 41)
2005–06	8 291	1 292	15.6	2	0.15	11	(2 - 23)	99.2	11	(3 - 29)
2006–07	7 477	2 320	31	2	0.09	3	(2 - 5)	99.7	4	(2 - 8)
2007–08	6 743	2 810	41.7	4	0.14	7	(4 - 11)	99.4	7	(4 - 15)

4. STOCK ASSESSMENT ISSUES

In recent assessments of individual stocks and areas, some issues arose which affect all orange roughy stocks. These concern the use of CPUE (catch per unit effort) as an index of abundance, the use of research surveys as indices of abundance, and the relationship between maturity and vulnerability to commercial fishing.

4.1 CPUE and abundance

Some previous orange roughy assessments in both NZ and Australia have shown inconsistencies between CPUE and survey indices, with models based on CPUE biomass indices estimating lower relative stock sizes than models based solely on survey biomass indices (for example, this behaviour has been observed in the ORH 2AS/2B/3A and ORH 3B NW assessments [Annala *et al*. 2002]). One possible way of reconciling the difference between these data sources is achieved by allowing a non-linear relationship between CPUE and vulnerable biomass (V) as in Equation 1 (Hilborn & Walters 1992).

$$CPUE = qV^{\beta} \qquad (1)$$

A meta-analysis was undertaken on orange roughy assessments where there were comparable estimates of stock abundance based on CPUE data and fishery independent surveys to determine the relationship between CPUE and abundance. Of the four stocks analysed, three showed significant hyperdepletion, where CPUE declines faster than abundance (Hicks 2004a). The fourth stock, ORH 3B NE, did not show a significant departure from a linear proportional relationship. Using these meta-analysis results, a prior for the parameter β (Eq. 1) was determined to allow this parameter to be estimated within a stock assessment model. The prior for β is log-normal with the mean of ln(β) equal to 0.7075 and the standard deviation of ln(β) equal to 1.0446 (Hicks 2004b).

While working on assessments in 2004 and 2005 there was some debate about the utility of estimating β. For the 2004 assessments, it was agreed that at least two alternative runs would be carried out for each stock: one in which β was estimated using the prior from the meta-analysis (‘EstBeta’), and another in which it was not estimated but was set equal to 1 (‘Beta1’). For stocks with fishery-independent data, a third run was made in which the CPUE data were excluded (NoCPUE). For both stocks where all three runs were made, the results from the EstBeta and NoCPUE runs were similar and quite different from those for Beta1. This emphasis on CPUE reflects differing signals received from fishery-independent vs. fishery-dependent data for orange roughy.

Work examining various aspects of the utility of estimating β was done intersessionally in late 2005 and early 2006, and it was found that the decision to estimate β involved a trade-off between bias and variance. In other words, if in truth, β was not equal to one, not estimating β in an assessment with CPUE data would result in a biased estimate of population size. Estimating β, however, would result in higher variance in the estimate of population size, but less bias. In an effort to reduce possible bias without estimating β in 2006 assessments, the first three values were omitted from CPUE series covering the start of a hill fishery or CPUE series that have historically shown hyperdepletion. CPUE series from the Spawning Box, for example, were left complete, as the pre-closure series showed no significant hyperdepletion in the meta-analysis done by Hicks (2004a) and the post-closure series occurs late in the fishery.

4.2 Survey abundance indices

Three types of survey indices have been used in orange roughy assessments in New Zealand: trawl surveys, acoustic surveys, and egg surveys. Assessments in 2006 viewed trawl surveys and acoustics surveys differently than in past assessments, while egg surveys remained unchanged as absolute surveys. If a trawl survey series was composed of different vessels, a separate catchability was estimated for each vessel with informed priors relating the catchabilities to each other. For example, the Spawning Box trawl survey series is made up of three vessels and thus estimated three separate catchabilities. Acoustic surveys were treated as relative indices of abundance instead of absolute indices, and informed priors were assigned to the estimated catchability. The methods for developing the informed priors are explained in Cordue (2006).

4.3 Maturity and vulnerability

Until recently it was assumed in New Zealand orange roughy stock assessments that all mature fish were vulnerable to commercial fishing but that no immature fish were. This section describes the basis of that assumption, the new data that challenge it, and the decisions that were made in response to these data.

The original assumption was based on the fact that, in the early years, most orange roughy fishing took place on spawning aggregations. There was no evidence that immature fish were present in any numbers in these spawning aggregations, nor that fishers were avoiding smaller (or younger) mature fish. Because there were no data available on the age at which fish entered the fishery it seemed reasonable to assume, as an approximation, that this was the same as the age at which they reached maturity. As fisheries developed, more fishing took place outside the spawning season when, on average, slightly smaller fish were caught. Thus, there were grounds for assuming that the age of vulnerability was slightly less than the age at maturity. However, as vulnerability data were still lacking the original assumption persisted.

Initial model runs for two stocks in 2004 suggested that this assumption was wrong. The age of vulnerability was estimated to be 7 to 20 years greater than the age at maturity and current mature biomass to be substantially larger than the vulnerable biomass (Table 6). In these runs, the age of vulnerability was estimated either from length-frequency samples or from otolith readings. The age of maturity was estimated from the "transition zone" in the otoliths, a zone that has previously been interpreted as representing the onset of maturity.

Table 6: Examples of estimates from initial model runs done in 2004 for the Mid-East Coast and Northwest Chatham Rise stocks in which the maturity and vulnerability were allowed to differ. The vulnerable biomass is that which is available to the commercial fishery. a_{50} (maturity) is the age at which 50% of fish are mature, a_{50} (commercial) is the age at which 50% of fish are available to the commercial fishery. Values are given from a range of runs, using both the NIWA and the UW/SeaFIC model and with a range of alternative assumptions.

	Current biomass		*a*50 (y)	
Stock	Mature	Vulnerable	maturity	Commercial
Northwest Chatham Rise	37 400	6 200	27.9	39.4
	37 200	5 500	27.9	39.0
	40 200	9 900	27.9	43.1
	44 200	8 000	27.9	47.1
Mid-East Coast	38 300	12 600	31.3	40.3
	47 000	23 600	31.3	38.3
	53 800	30 300	31.3	37.8

The Working Group rejected these model runs on the grounds that it did not seem plausible that the current vulnerable biomass was so much less than the mature biomass. It was agreed that, for the 2004 and subsequent assessments, the Working Group would revert to the original assumption that the ages of maturity and vulnerability were the same. Further work on interpretation of transition zones is needed.

This assumption was implemented in different ways for different stocks. Where both maturity and vulnerability data were available the former were rejected. This was because the maturity data were deemed to be indirect because they are based on the assumption that the transition zone in the otolith marks the onset of maturity (Francis & Horn, 1997). In contrast, the age- and length-frequency data used for estimating vulnerability were direct observations on the commercial fishery. Thus, for the MEC and Northwest Chatham Rise stocks the age at maturity was assumed to be the same as the age of vulnerability (technically, the maturity ogive was set equal to the estimated selectivity ogive). For stocks without vulnerability data (ORH 7B and South Chatham Rise) the age at vulnerability was assumed equal to the age at maturity (i.e., the selectivity ogive was set equal to the maturity ogive).

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