Ministry for Primary Industries
Manatū Ahu Matua

Age composition of orange roughy from ORH 3B (Chatham Rise: northwest ,1994, and northeast,2013), and from ORH 7A (Challenger Plateau in 1987, 2006 and 2009)

New Zealand Fisheries Assessment Report 2014/59

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ISSN 1179-5352 (online)
ISBN 978-0-478-43768-3 (online)

October 2014

New Zealand Government

Growing and Protecting New Zealand

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EXECUTIVE SUMMARY

Doonan, I.J.; Horn, P.L.; Ó Maolagáin, C. (2014). Age composition of orange roughy from ORH 3B (Chatham Rise: northwest ,1994, and northeast,2013), and from ORH 7A (Challenger Plateau in 1987, 2006 and 2009).

***New Zealand Fisheries Assessment Report 2014/59*. 33 p.**

Orange roughy otoliths were prepared and aged from each of three spawning sites (Old Plume, Rekohu Plume, and Mount Muck) on the northeast Chatham Rise (ORH 3B) sampled in 2013, from a wide area research survey on the northwest Chatham Rise (ORH 3B) in 1994, and from three research surveys on the Challenger Plateau (ORH 7A) in 1987, 2006 and 2009. Otoliths were prepared and read by one reader following the accepted ageing protocol. The aim was to develop age compositions for use in assessments of these three stocks, with individual sample sizes of 250–300 otoliths. Sampled age frequencies varied markedly between the three northeast Chatham Rise plumes, with the most recently exploited Rekohu Plume dominated by younger fish, with a mode of about 38 years, while the Old Plume and Mount Muck had similar distributions with relatively more old fish. The 1994 sample from the northwest Chatham Rise was also dominated by younger fish with a mode of about 30 years. Comparisons between the Challenger Plateau samples from 1987, 2006 and 2009 showed a clear dominance of younger fish in later years supporting the hypothesis that the observed increase in spawning biomass in the Challenger Plateau surveys is from recent recruitment of stronger year classes.

1. INTRODUCTION

This report fulfils the reporting requirements for Objective 8 of Project MID201001D, routine age determination of hoki and middle depth species from commercial fisheries and trawl surveys, funded by the Ministry for Primary Industries. The objective was: to age other species as required for validation of the ageing technique or for targeted studies to meet specific research requirements. The work identified for 2013–14 was the otolith preparation and ageing of samples of orange roughy from spawning plumes on the northeast Chatham Rise in 2013, from a research survey on the northwest Chatham Rise in 1994, and from research surveys on the Challenger Plateau in 1987, 2006, and 2009. Smaller samples from the 1987 and 2009 Challenger Plateau surveys were aged previously (Doonan et al. 2013), but additional ageing was necessary to provide age distribution data sets of sufficient size for use in stock assessments. The Chatham Rise samples were also aged to produce input data for stock assessments.

Prior to 2007, orange roughy age estimates produced by New Zealand and Australian readers had poor comparability (Francis 2005, 2006, Hicks 2005), which led to low confidence in the age-frequency data and resulted in age data being excluded from the stock assessments carried out in 2006. Francis (2006) suggested that a significant source of between-agency bias was the method used to identify the transition zone (TZ), a feature believed to be associated with the switch from somatic growth to gamete production.

In response, an Orange Roughy Ageing Workshop was held in 2007 to improve otolith preparation and interpretation between agencies, especially in relation to the TZ. A new protocol for age interpretation was developed during the workshop (Tracey et al. 2007). In 2009, the new protocol was tested by two NIWA and two FAS (Fish Ageing Services Pty. Ltd., Victoria, Australia) readers by ageing the otolith pairs from 160 fish, i.e., potentially 8 age estimates per fish. The new protocol solved the inter-agency problems, and provided a consistent and documented method for the interpretation of growth zones in orange roughy otoliths.

Early growth of orange roughy was validated by examining the otolith marginal increment type and by length frequency analysis (Mace et al. 1990). Later, Andrews et al. (2009) applied an improved lead-radium dating technique to otolith cores, grouped by growth-zone counts from thin sections. Results showed a high degree of correlation of the growth-zone counts to the expected lead-radium growth curve, and provided support for both a centenarian life span for orange roughy and for the age estimation procedures using thin otolith sectioning.

1.1 Northeast Chatham Rise spawning plumes

The first reported orange roughy fishery on the northeast Chatham Rise was in 1978–79 when about 11 500 t was taken from the Spawning Box (which includes Old Plume and Mount Muck, see below), but it was known that the Soviet fleet had fished in the area before that date. Catches from the Spawning Box peaked at 27 900 t in 1979–80 and then declined, both because the fleet moved to fish in other areas and times, and because of catch restrictions. Reported catch in 2012–13 was 1450 t (Ministry for Primary Industries 2014).

An acoustic survey series of the regular spawning plume (Old Plume) started in 2002 and has been conducted every year since. A new spawning plume (the Rekohu Plume) was observed (but not fished) in the winter of 2010 on the northeast Chatham Rise (ORH 3B) while steaming back to port

after an acoustic survey of the Old Plume. During the 2011 acoustic survey, the Rekohu Plume was fished and spawning orange roughy were caught in quantities expected from a spawning aggregation. Consequently, the Rekohu fish were included as part of the spawning biomass in the area (Doonan et al. 2012). There was no record of the Rekohu Plume before 2010.

Otoliths collected on the 2012 survey were used to consider the following questions:

- Is the average age of fish in the new (Rekohu) plume younger (as they are 1 cm shorter on average) than the Old Plume fish?
- Are the age distributions from the two plumes different?

That analysis showed that the Rekohu fish were, on average, younger by 11 years and that the age composition difference between the two plumes was very marked and statistically significantly different (Doonan et al. 2014).

An experimental voyage in 2013 surveyed another aggregation on a feature named Mount Muck, so there are now three spawning aggregations with abundance estimates. The 2013–14 assessment of this stock planned to use the 2013 survey estimates and the 2012 age frequencies and it was therefore desirable to have another set of age frequencies from all three aggregations for comparison. These are reported below.

1.2 Northwest Chatham Rise

The first catches (840 t) were recorded from this area in 1979–80. In the early 1990s, the catch limit was 3500 t, which was reduced over time to 750 t in 1996–97 and has remained at that amount since then. From 2002–03 on, catches were split approximately 50:50 between the Graveyard Hill and the rest of the Northwest area, but because catches continued to decline quota owners agreed in 2010–11 and 2011–12 to avoid fishing the Northwest Rise.

An assessment of this stock commenced in late 2013, and required age frequency data. Fish from the wide-area trawl survey that was completed in 1994 were selected for ageing as the flat areas had been surveyed before the spawning season.

1.3 Challenger Plateau (ORH 7A)

This fishery commenced in 1981 on the southwest Challenger Plateau. The catch limit peaked at 12 000 t in 1987–88, but was reduced in 1989–90 and several times after that until the fishery closed from 1 October 2000 (with a catch limit of 1 t). As part of the research for this stock, a series of trawl surveys were carried out during the spawning season from 1987 to 1990 (Clark & Tracey 1994).

Starting in 2005, the Deepwater Group Ltd. (previously the Orange Roughy Management Company Ltd.) commissioned combined acoustic and stratified random trawl surveys to investigate the state of the orange roughy stock. These surveys were aimed at spawning fish in the south-west part of the Challenger Plateau in 2005, 2006, 2009, and 2010 (Clark et al. 2005, 2006, Doonan et al. 2009, 2010. They used the same trawl gear design, core strata, and survey protocols (but a different vessel) as the earlier (1987 to 1990) trawl survey series.

Based on the results of these surveys the fishery was re-opened in 2010–11 with a 500 t catch limit.

In 2009 and 2010, spawning plumes were found close to the area where they were last observed in 1989. There are at least two hypotheses for their reappearance in 2009:

- the new plumes are young fish, i.e., new recruits to the spawning population,
- older fish have re-colonised the area.

Length frequency distributions were not helpful for testing these hypotheses because age structure estimated from length data is poorly determined after maturation. However, these hypotheses can be tested by constructing and comparing mean age, and age frequency distributions directly estimated by reading otoliths from the two surveys in 1987 and 2009.

2. METHODS

2.1 Ageing of orange roughy

Orange roughy otoliths were prepared using the NIWA preparation method as reported by Tracey et al. (2007). Briefly, one complete otolith from each of the pairs was individually embedded in resin and cured in an oven. A thin section was cut along a line from the primordium through the most uniform posterior-dorsal axis using a sectioning saw with dual diamond-impregnated wafering blades separated by a 380 μm spacer. The section was mounted on a glass microscope slide under a glass cover slip.

To estimate age, all otoliths were read once by one reader. Otolith interpretation and reading protocols followed those described in the Ageing Workshop Report (Tracey et al. 2007). The data produced include counts of zones from the primordium to the TZ, and from the TZ to the otolith margin, and readability codes for those readings (on a 5-stage scale). Data with a readability code of 5 (i.e., unreadable) for either the pre- or post-TZ readings were excluded. The presence of a transition zone was identified, ideally, by the following three criteria: a clear reduction in zone width, a marked change in the optical density of the otolith from dark to light, and a change in curvature of the posterior arm of the otolith (Tracey et al. 2007). TZs were classified using a 4-stage scale, i.e.:

- 0, not formed (observed),
- 1, clear and unambiguous with all three criteria met,
- 2, a gradual transition with at least two criteria met,
- 3, a gradual transition with none or one of the criteria met.

For TZ classification 3, only a total age was recorded.

2.2 Analytical methods

The method of analysis followed that of Doonan et al. (2013) for ORH 7A orange roughy. We assigned a probability to each otolith collected which represented the contribution that the sampled orange roughy catch (in the tow the otolith came from) made to the total abundance (in numbers), and also the number of samples in the tow, i.e., all otoliths in the same tow had the same probability. This assumed that the otolith sampling was random. This selection probability was based on all otoliths that were available. The set of all otolith ages and their associated probabilities is an approximation to the age distribution. The probabilities collapsed all survey structure into one number and so do not have to be considered again. Otolith selection was a random sample with replacement (like bootstrapping) using the otolith probabilities.

2.2.1 Otolith selection probabilities for stratified surveys (Northwest Chatham Rise and Challenger Plateau)

The mean age for the population from a stratified random trawl survey is a weighted average of the mean ages from each tow, i.e.,

$$\frac{\sum_{s}^{strata} \frac{A_s}{m_s} \sum_{i}^{tows\ in\ stratum\ s} \left(\frac{1}{n_{is}} \sum_{j}^{otoliths\ in\ tow\ i} a_{isj} \right) N_{is}}{\sum_{is} \frac{A_s}{m_s} N_{is}}$$

where a_{isj} is the age from the j^{th} otolith in the i^{th} tow in the s^{th} stratum, n_{is} is the number of otoliths sampled in the tow, $\frac{1}{n_{is}} \sum_{j}^{otoliths\ in\ tow\ i} a_{isj}$ is the mean age in a tow, N_{is} is the fish density in the is^{th} tow, A_s is the area of stratum s, and m_s is the number of tows in stratum s. For a single otolith, the probability of selection is

$$\frac{\frac{A_s}{m_s} N_{is} \frac{1}{n_{is}}}{\sum_{is} \frac{A_s}{m_s} N_{is}}.$$

The rest of the selection probability, excluding the term $\frac{1}{n_{is}}$, is the station's contribution to the overall population size, in numbers. N_{is} is obtained from the catch density using a mean weight derived using aL^b, where L is the length, a = 9.21e-05 and b = 2.71.

2.2.2 Otolith selection probabilities for aggregations (East Chatham Rise)

A previous analysis (Doonan et al. 2012) used data from a stratified trawl survey, but for the three Chatham Rise samples analysed here, there were no strata so the method was adjusted to accommodate this. The mean age for the population was a weighted average of the mean estimated ages from each tow, i.e.,

$$\frac{\sum_{i}^{tows} \left(\frac{1}{n_i} \sum_{j}^{otoliths\ in\ tow\ i} a_{ij} \right) N_i}{\sum_{i} N_i}$$

where a_{ij} is the age from the j^{th} otolith in the i^{th} tow, n_i is the number of otoliths sampled in the tow, $\frac{1}{n_i} \sum_{j}^{otolith\sin towi} a_{ij}$ is the mean age in a tow, and N_i is the fish density (in numbers) in the i^{th} tow. For a single otolith, the probability of selection is

$$\frac{N_i \frac{1}{n_i}}{\sum_{i} N_i}.$$

The rest of the selection probability, excluding the term $\frac{1}{n_i}$, is the contribution of the tow to the overall population size, in numbers. N_i is obtained from the catch density using a mean weight derived using aL^b, where L is the length, a = 9.21e-05 and b = 2.71.

2.2.3 Otolith selection

The number of otoliths prepared was n_{unique}. Ages associated with each otolith were selected with replacement using the otolith selection probabilities described above. In selecting the ages, we implicitly selected the otoliths. Ages were not known at selection time but this procedure determined the data to use in the mean age or age frequency when the ages from otoliths were estimated. Since an age estimate may be used more than once, the number of ages, n_{ages}, is likely to be greater than n_{unique}.

Random sampling ofotoliths was carried out one at a time until the number of unique otoliths equalled n_{unique}. The procedure was continued to provide a selection of spare otoliths which were needed to replace damaged or lost samples. The spares were used in the order of their selection.

2.2.4 Analysis

The data consisted of the age estimate from each otolith replicated by any repeat count. The mean age estimate was the sample mean. The age frequency was the fraction of data at each age over this sample. Standard error was assessed using a bootstrap analysis where tows were resampled along with the ages within each selected tow. Where there was little within-tow correlation, the analytical standard deviation was given by $\sqrt{\sum_i^{otolith} n_i s^2 / {n_{\text{ages}}}^2}$, where n_i is the number of repeat counts for an otolith and s^2 is the sample standard variance.

Kernel smoothing was used to show results in plots. It used one parameter, *width*, which is approximately the moving window width over which the average age was calculated. This procedure used the 'density' function from the R statistical package (R Development Core Team 2010). *Width* was set to 10.

2.2.5 Sample sizes

For the Chatham Rise spawning plumes, the aim was to prepare 250 otoliths per aggregation, i.e., 750 in total. For the Northwest Chatham Rise, the aim was to prepare 300 otoliths. For the Challenger Plateau surveys, the aim was for a total of 300 prepared otoliths per survey. Since there were already 130 prepared and read for each of the 1987 and 2009 surveys, we required 170 more otoliths to prepare for those surveys, and 300 for the 2006 survey, i.e., a total of 640 new otolith preparations.

2.3 East Chatham Rise plume surveys

An experimental voyage was conducted 1–13 July 2013 on the north Chatham Rise using the FV *Amaltal Explorer*. Surveys were completed on three spawning aggregations: Mount Muck, Old Plume, and Rekohu Plume (Figure 1).

For Mount Muck, two star surveys were completed on 16 and 20 July using a net-attached Acoustic Optical System. Five tows were completed on the aggregation, and fish were sampled from these tows (including otolith collection). Estimated total abundance (including a dead zone factor) was 5900–8300 t (two frequencies over two surveys) (Tim Ryan and Rudy Kloser, CSIRO, unpublished data). Details of trawl stations used in the analysis are listed in Appendix A (Table A1).

For the Old and Rekohu Plumes, parallel transect surveys were completed using a net-attached Acoustic Optical System and also the hull transducer. Fish were sampled from tows on the aggregations, including otolith collection. Estimated abundance for the Old Plume was 4000–20 000 t. Estimated abundance for the Rekohu Plume was 20 000–46 000 t.

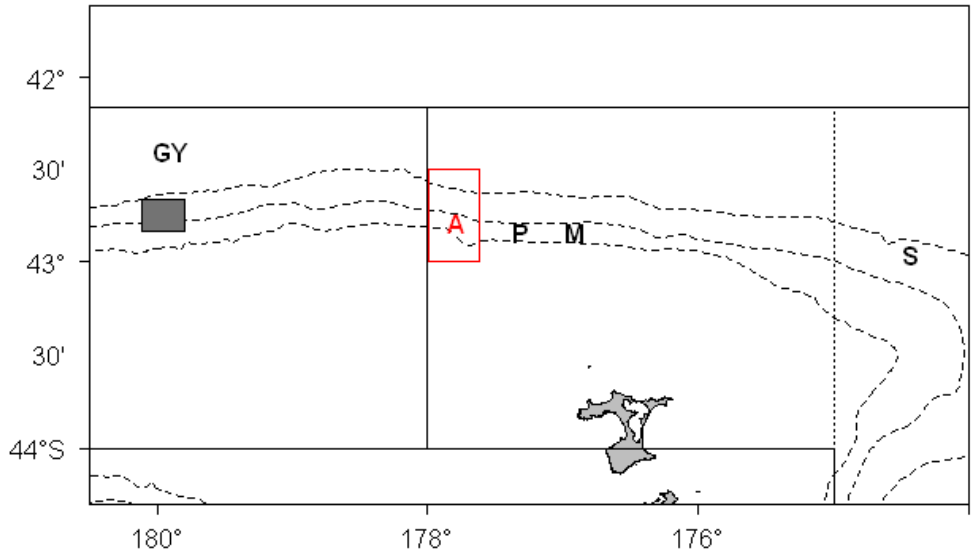

Figure 1: Locations of spawning aggregations on the north Chatham Rise. P, Old Plume; A, Rekohu Plume; M, Mount Muck; GY, Graveyard; S, Smiths City (from M. Dunn, VUW, pers. comm.).

2.4 Northwest Chatham Rise survey

The tows on the Graveyard Hill complex and from the northwest Chatham Rise part (Northwest Flat) of a three month, wide-area, 1994 *Tangaroa* survey were used (Tracey & Fenaughty 1997). The flat strata were surveyed from 21–29 May and 2–6 June, and the hills on 23–26 May, 6 June, and 3–4 July. The 1994 survey area is shown in Figure 2. Details of the strata used are listed in Table 1. Stratum 1E was excluded since it caught no orange roughy. Details of trawl stations used in the analysis are listed in Appendix A (Table A2).

The survey was a single-phase stratified random design and station positions and sequence occupied were about the same as used in the 1992 survey (except for strata 1A to 1D which were new). Tow distance was 3.0 n. miles and mean tow speed was about 3 knots.

Detailed biological sampling was carried out on 20 orange roughy from each tow, with length, weight, sex, and gonad stage recorded, and otoliths were extracted. Multiple samples were taken from large catches (i.e., greater than 10 t).

Abundance estimates used 26 m as the effective trawl width and a vulnerability of 0.23 (ratio of distance between the wings and between the doors). Vertical and areal vulnerabilities were set to 1.0. For the Northwest Flat strata, there were 31 tows and the estimated recruited (fish length greater than or equal to 32 cm) abundance was 7450 t (CV 18%).

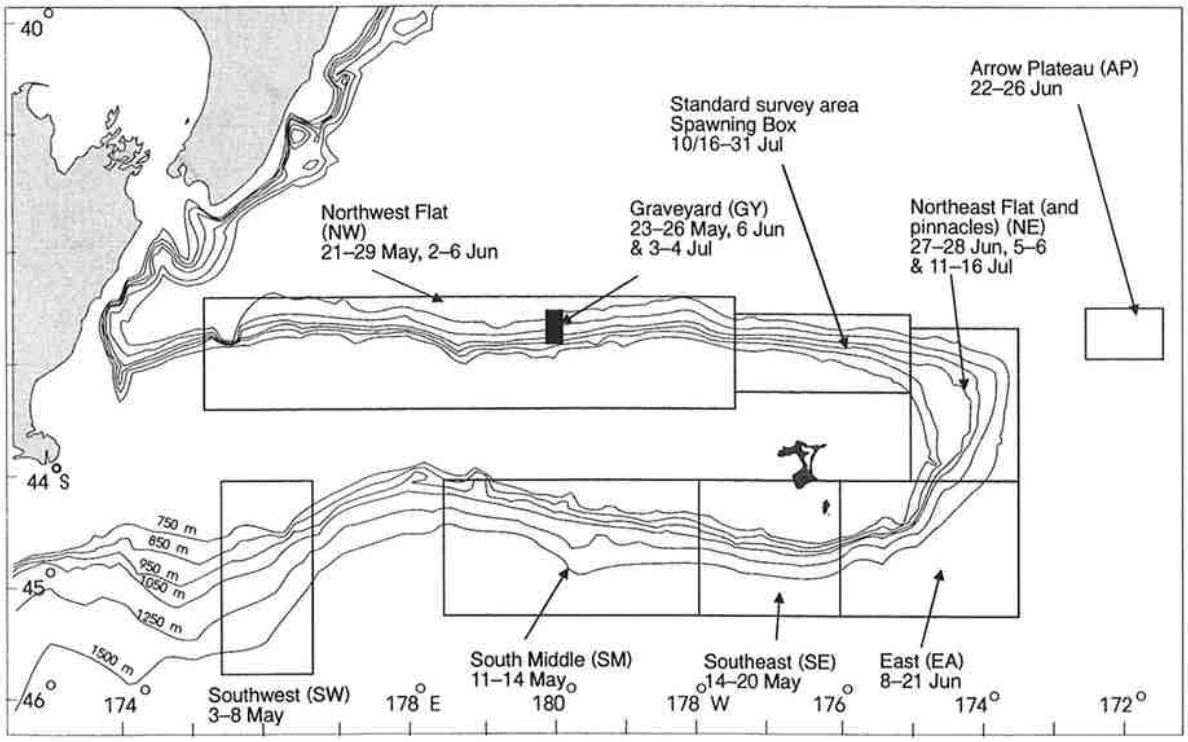

Figure 2: Survey areas for the 1994 *Tangaroa* trawl survey, reproduced with permission from Tracey & Fenaughty (1997).

Table 1: Details for the northwest Chatham Rise strata for the 1994 *Tangaroa* survey.

Stratum	Area (km^2)		Description
1A	404.2	175–176E	750–849 m
1B	405.9	175–176E	850–949 m
1C	561.2	175–176E	950–1049 m
1D	1 000.0	175–176E	1050–1249 m
2A	778.3	176–178E	750–849 m
2B	609.1	176–178E	850–949 m
2C	1 177.2	176–178E	950–1049 m
2D	707.6	176–178E	1050–1249 m
2E	707.6	176–178E	1250–1500 m
3A	667.8	178E–180	750–849 m
3B	667.2	178E–180	850–949 m
3C	656.8	178E–180	950–1049 m
3D	1 084.9	178E–180	1050–1249 m
3E	1 084.9	178E–180	1250–1500 m
4A	885.7	180–177 30W	750–849 m
4B	764.2	180–177 30W	850–949 m
4C	692.8	180–177 30W	950–1049 m
4D	1 545.7	180–177 30W	1050–1249 m
4E	1 545.7	180–177 30W	1250–1500 m
GY01	0.01	Deadringer	
GY03	0.01	Morgue	
GY04	0.01	Graveyard	
GY05	0.01	Zombie	
GY06	0.01	Mummy	

2.5 Challenger Plateau trawl surveys

The trawl surveys used to provide age data were conducted in 1987 (Clark & Tracey 1994), 2006 (Clark et al. 2006), and 2009 (Doonan et al. 2009). The 2006 and 2009 surveys were part of the same series and used the same vessel. The 1987 survey used a different vessel and was part of a series that ended in 1990. The later trawl survey series had core strata based on those used in 1987 to 1990, and also used a similar net, i.e., the Arrow style net. Survey protocols were similar between the two series.

1987 survey

The 1987 survey was selected as the early survey to be analysed because it was the only one in the series (1987 to 1990) that sampled two spawning plumes. It was conducted in June-July 1987 by FV *Amaltal Explorer* and had three parts (Clark & Tracey 1988). The data used came from the second part which covered the core survey area (similar to, but not quite the same as, the 2006 and 2009 surveys), from 25 June to 1 July (similar to the first half of the 2009 survey). There were 54 tows, and otoliths were collected from each tow from up to 20 individuals (or 60 for the largest catches — sampling from the start, middle and end of the catch bag). The strata used were 1, 2, and 3 (see strata A1, A2, and A3 in Figure 3, Table 2). Tows were 1.5 n. miles long. Details of trawl stations used in the analysis are listed in Appendix A (Table A3).

The largest catch of orange roughy was 35 t and five catches were 19 t or more. The smallest catch was 4.4 kg. The abundance was estimated as 60 000 t using a distance between the wings (swept area) of 22.8 m.

Table 2: Stratum detail and results from Part 2 of the 1987 survey. Abundance estimates are wingspread values.

Stratum	Area (km^2)	Number of tows	Abundance (t)	Description
0001	727	30	48 800	Stratum A1, 800–900 m
0002	382	12	2 200	Stratum A2, 900–1000 m
0003	228	12	9 000	Stratum A3, around the Pinnacles

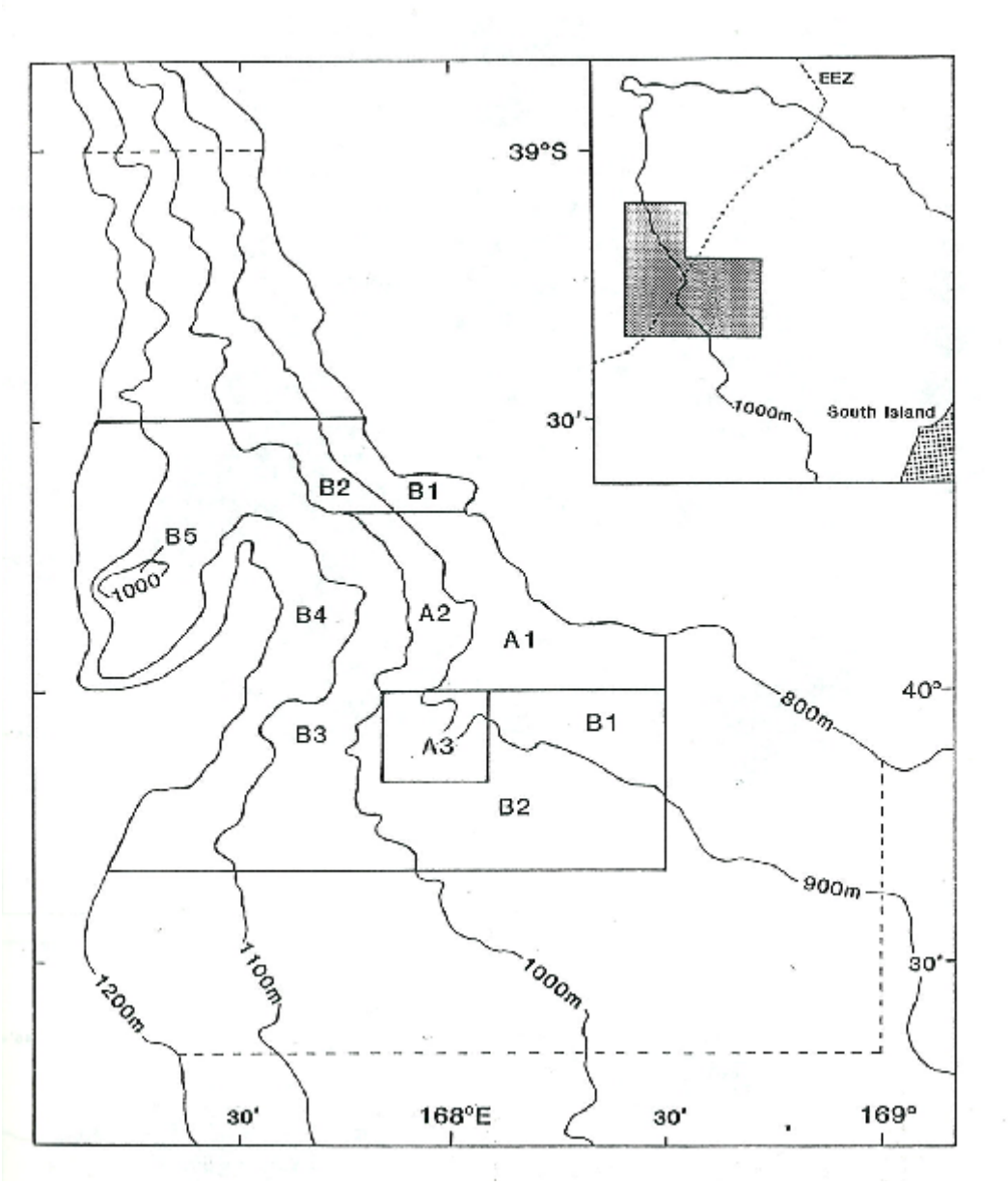

Figure 3: Survey strata for the 1987 Challenger Plateau survey. Part 2 surveyed A1, A2, and A3. (Reproduced with permission from Clark & Tracey (1988).)

2006 and 2009 surveys

These surveys were part of a revamped series starting in 2005, with the second survey in 2006 and the third in 2009. Strata are shown in Figure 4 and the design was a random stratified survey using two phases (after Francis 1984). Tow length was 1.5 n. miles. We excluded otolith samples from the Westpac Bank since these fish spawn later and may be a different stock.

The bottom trawl used for the survey was a four-panel net (Arrow trawl) with cutaway lower wings, a single lengthener, and two codends. The gear was configured similarly to that used in trawl surveys in the 1980s, with a rubber and steel bobbin rig, 24 headline floats (1500 m rated), 0.5 m layback, 50 m bridles, and 70 m sweeps. Doors were High-aspect Super-Vees (2300 kg, 7 m^2). Doorspread was recorded at 120–147 m (mean 137 m). The mean headline height was 5.5 m and the mean trawling speed was 3.1 knots.

Detailed biological sampling was carried out on 20 orange roughy from each tow, with length, weight sex, and gonad stage recorded, and otoliths were extracted. Multiple samples were taken from large catches (one sample per 10 t of catch).

The 2006 trawl survey was conducted from 22 June to 5 July using the FV *Thomas Harrison* (Clark et al. 2006). Doorspread was recorded at 120–147 m (mean 137 m). The mean headline height was 5.5 m and the mean trawling speed was 3.2 knots. The total number of valid abundance tows was 56, of which 54 were in the EEZ zone part of the survey. The orange roughy total mature abundance index was 17 000 t (CV 25%). Details of trawl stations used in the analysis are listed in Appendix A (Table A4).

The 2009 trawl survey was conducted from 26 June to 6 July using the FV *Thomas Harrison* (Doonan et al. 2009). Doorspread was recorded at 120–147 m (mean 137 m). The mean headline height was 5.5 m and the mean trawling speed was 3.1 knots. The total number of valid abundance tows was 64, of which 59 were in the EEZ zone part of the survey. The orange roughy total mature abundance index was 48 749 t (CV 26%). The 2009 survey had an extra stratum (25), but this contributed only 0.8% to the overall abundance estimate. Details of trawl stations used in the analysis are listed in Appendix A (Table A5).

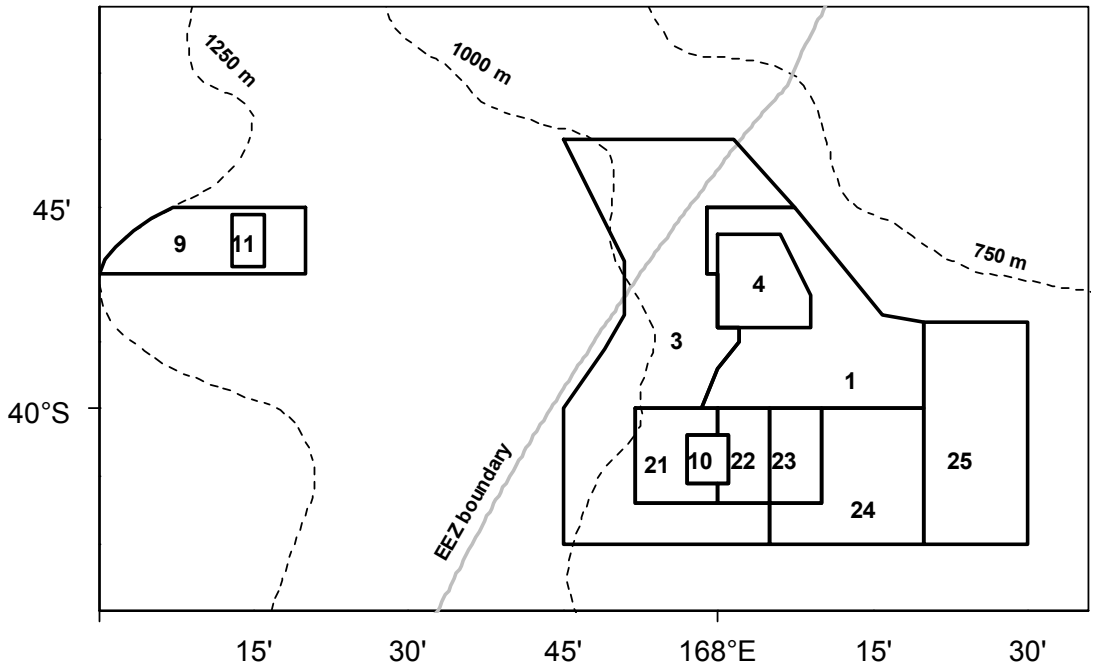

Figure 4: The 2006 and 2009 survey area, showing the trawl survey strata (from Doonan et al. 2009). Strata 9 and 11 (Westpac Bank) were excluded from the analysis. Stratum 25 was used only in the 2009 survey.

3. RESULTS

3.1 Northeast Chatham Rise spawning plumes

Details of the otolith samples from the three spawning areas are given in Table 3. Age frequencies are presented for the Old Plume (Figure 5), Rekohu Plume (Figure 6) and Mount Muck (Figure 7). Age-frequency data are listed in Appendix B (Table B1).

Table 3: Details of otolith samples by location. *N*, number prepared and read; Replacements, number of otoliths replaced from the initial selected set; Rejects, number of preparations unable to be aged.

				Transition zone classification code			
	N	Replacements	Rejects	0	1	2	3
Old Plume	250	38	0	32	97	97	24
Rekohu Plume	250	38	0	65	26	107	52
Mount Muck	250	49	0	34	77	114	25

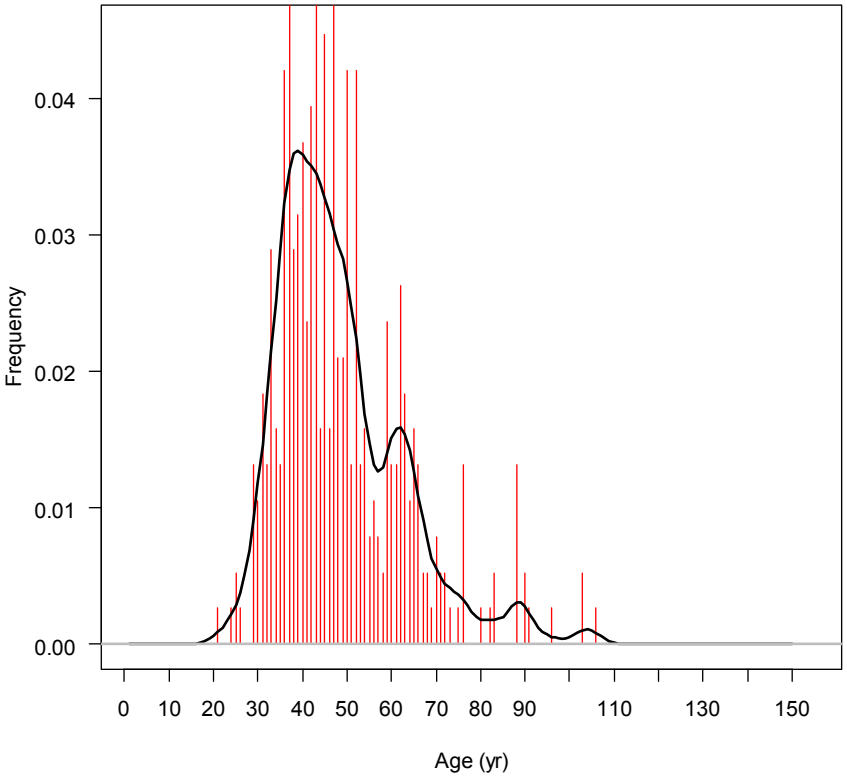

Figure 5: 2013 Old Plume estimated age frequency (red bars) with a smoothed density through the age estimates (black curve).

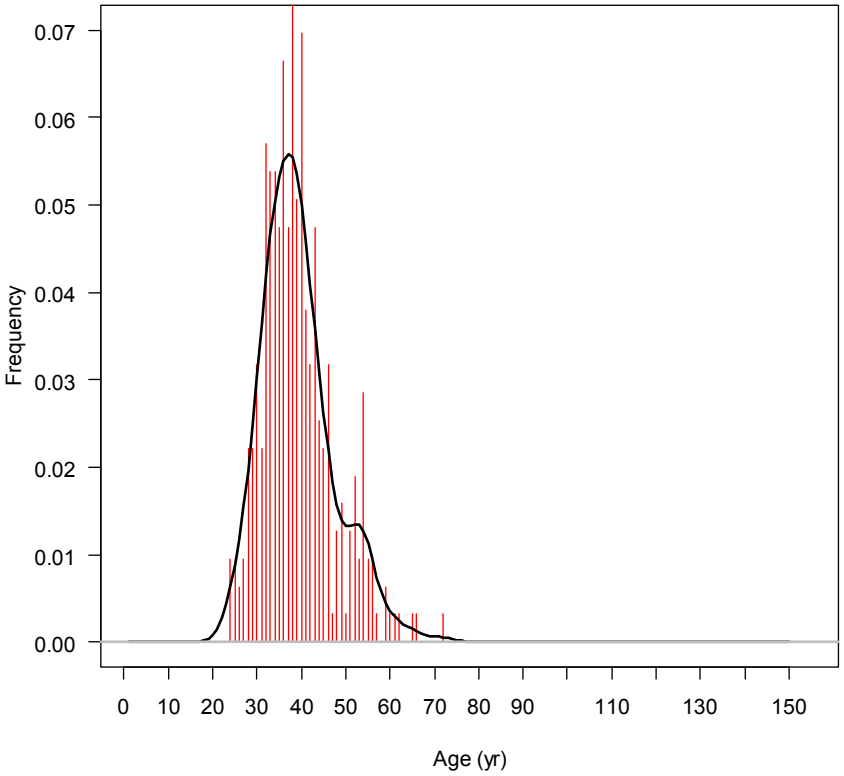

Figure 6: 2013 Rekohu Plume estimated age frequency (red bars) with a smoothed density through the age estimates (black curve).

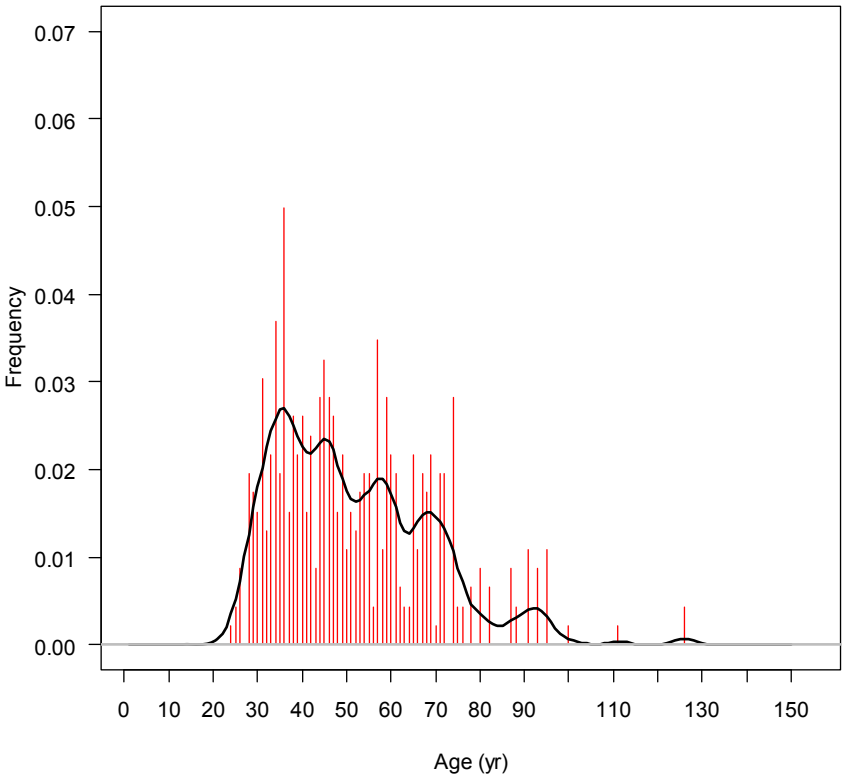

Figure 7: 2013 Mount Muck estimated age frequency (red bars) with a smoothed density through the age estimates (black curve).

A comparison of the age frequencies from the three northeast Chatham Rise areas is shown in Figure 8. It shows that Old Plume and Mount Muck have similar age distribution, except that Mount Muck has relatively more old fish. The Rekohu Plume age distribution has a strong mode of younger fish with few older specimens.

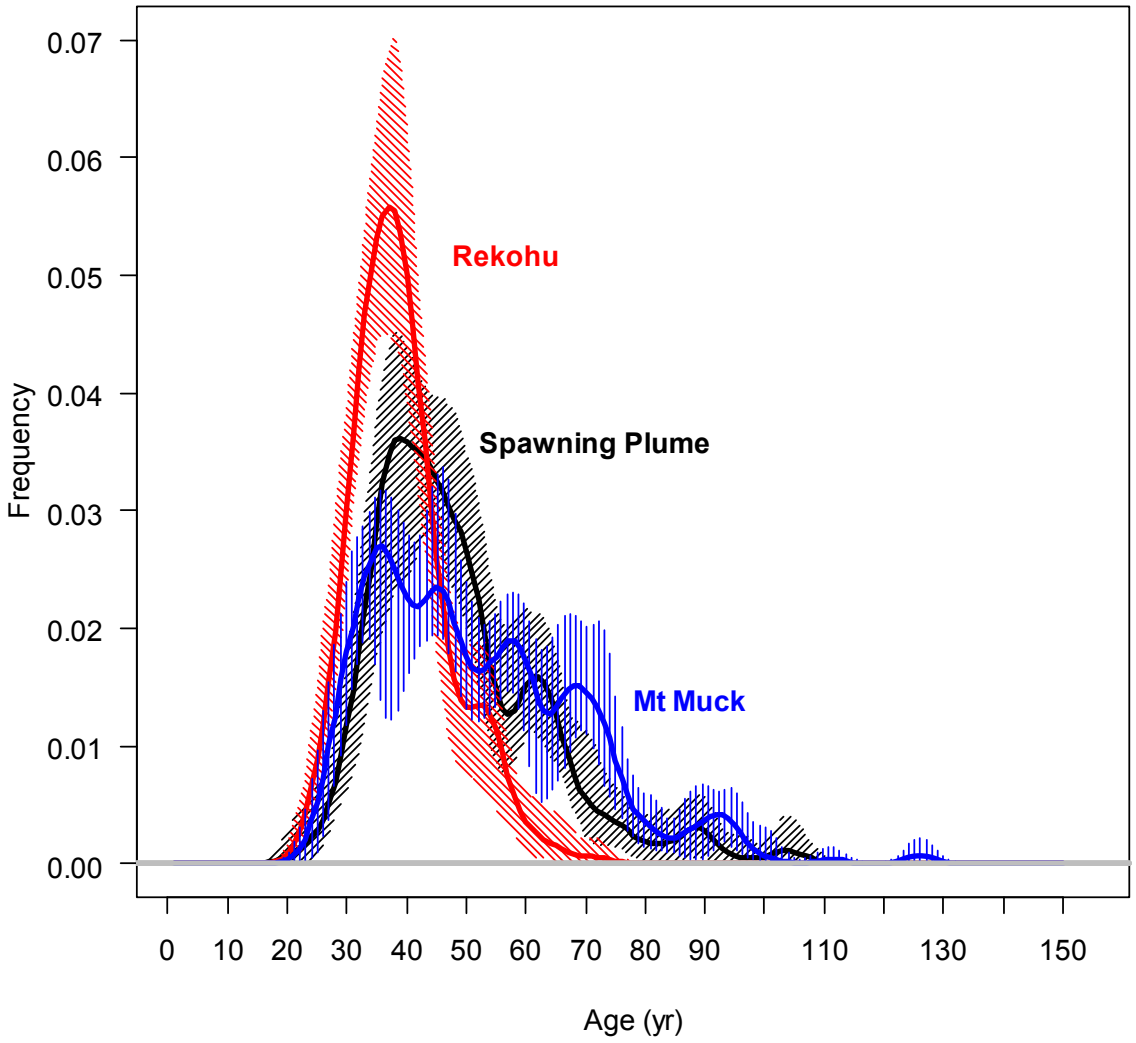

Figure 8: Smoothed age frequencies and pairwise 95% CI for Old Plume (Spawning Plume, black), Rekohu Plume (red), and Mount Muck (blue).

3.2 Northwest Chatham Rise

The number of otoliths prepared and read was 300. No age readings were excluded because of readability problems. The number of replacement otoliths used was 17. Numbers of otoliths by classification code for the TZ were:

TZ code	0	1	2	3
Number of otoliths	169	60	58	13

The age frequency distribution is shown in Figure 9 and the data are listed in Appendix B (Table B2). The distribution is dominated by younger fish with a mode centred near 30 years, with few older specimens. The dominance is more marked than the Rekohu Plume distribution where the mode of younger fish is centred near 38 years.

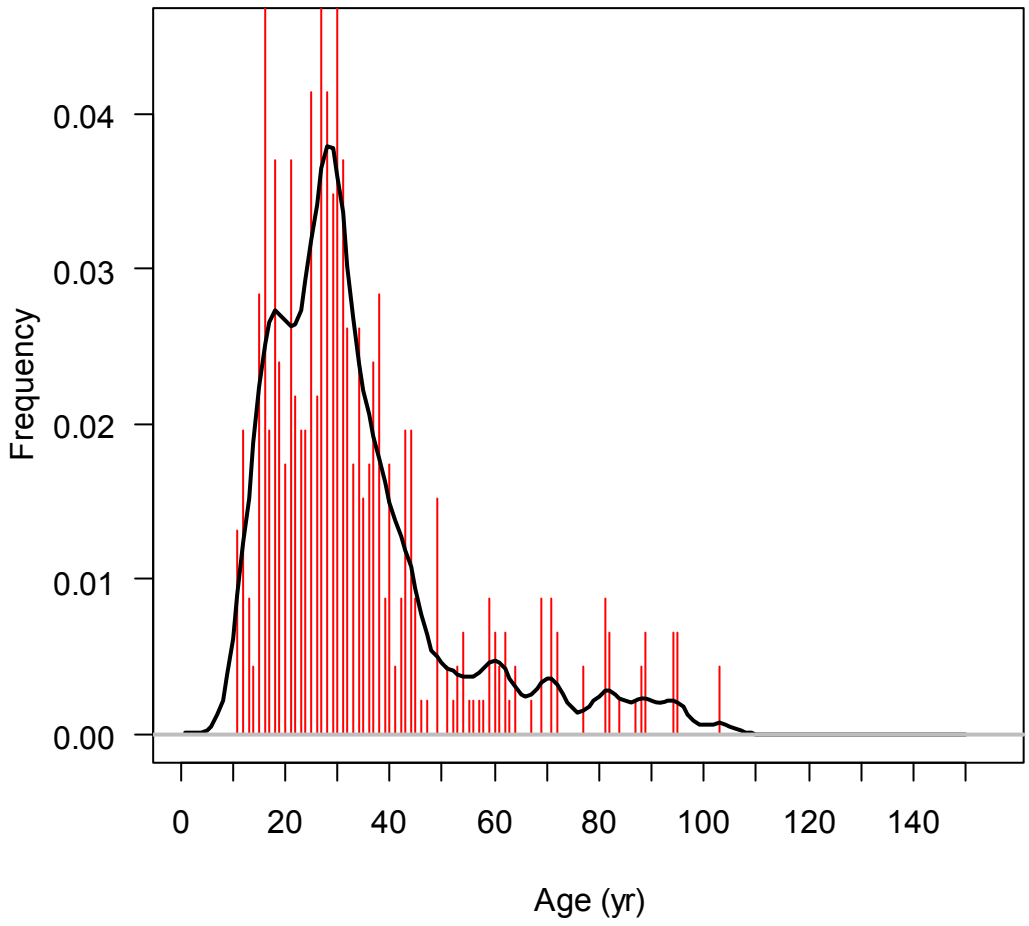

Figure 9: Estimated age frequency (red bars) for northwest Chatham Rise with a smoothed density through the age estimates (black curve).

3.3 Challenger Plateau (ORH 7A)

For the 2006 survey, the number of otoliths prepared and read was 301. No age readings were excluded because of readability. The number of replacement otoliths used was 38. Numbers of otoliths by readability code for the TZ were:

TZ code	0	1	2	3
Number of otoliths	98	56	122	25

The age frequency distribution is shown in Figure 10 and the data are listed in Appendix B (Table B3).

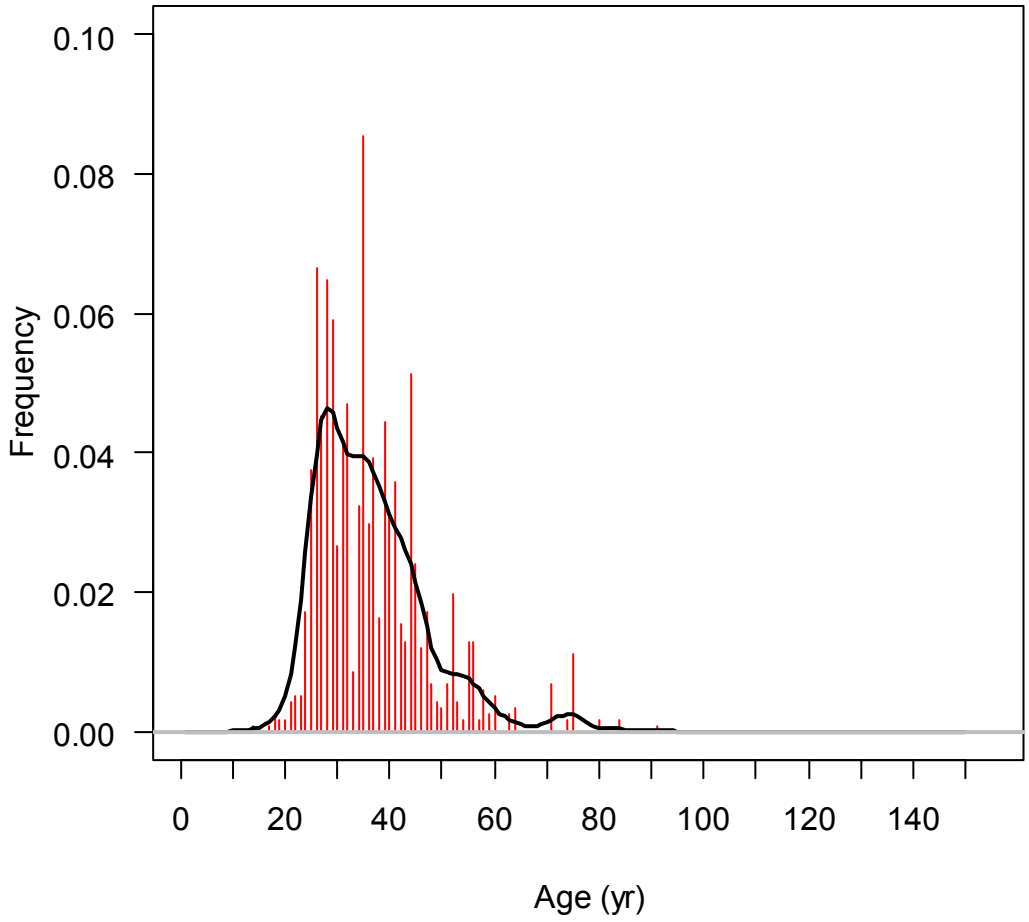

Figure 10: 2006 Challenger Plateau estimated age frequency (red bars) with a smoothed density through the age estimates (black curve).

For the 1987 survey, 170 new otoliths were prepared and one new reading was rejected since it had a reading code of 5. The number of replacement otoliths used was 20. The total number of otoliths in the analysis was 301.

For the 2009 survey, 170 new otoliths were prepared and none was rejected. The number of replacement otoliths used was 22. The total number of otoliths in the analysis was 301.

The age frequency distributions are shown in Figure 11 and the data are listed in Appendix B (Table B3).

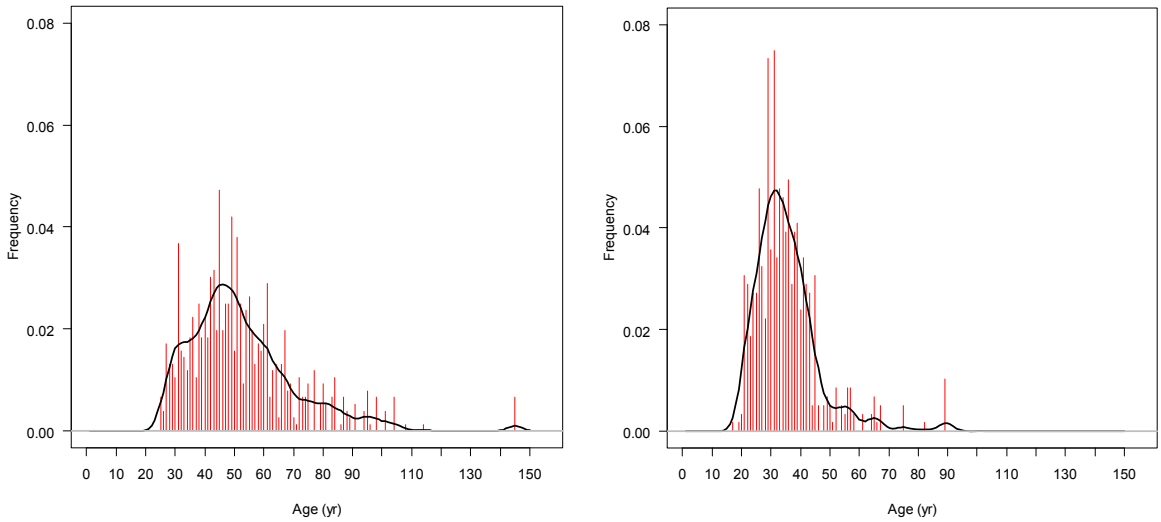

Figure 11: Age frequencies (red bars) with a smoothed density through the age estimates (black curve) for the 1987 (left panel) and 2009 surveys (right panel), both using 301 otoliths.

Comparisons of the first (older) age data with the second (newer) readings for both 1987 and 2009 are shown in Figure 12. The 1987 distributions are similar, but the 2009 distribution has the mode of the newer readings just outside the 95% CI of the older age frequency, a shift of 8 years. This difference indicates that with a sample size of 130, the bootstrap CI may not have captured all the variability in the data.

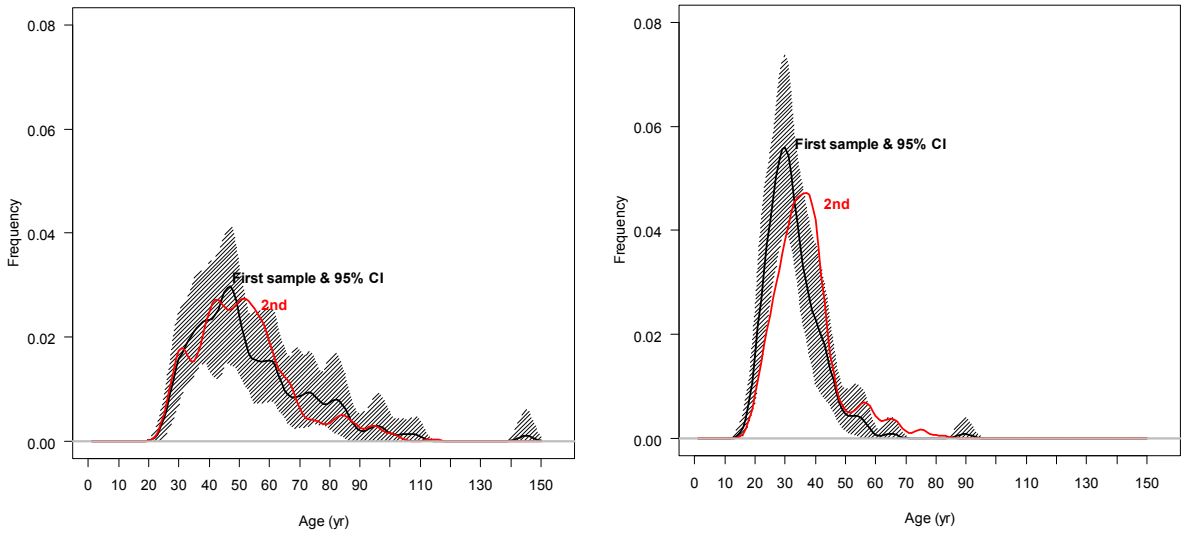

Figure 12: Comparison of the smoothed age frequency from the first sample of 130 otoliths (black line) with the smoothed frequency from the second sample of 170 otoliths (red line) and the pairwise 95% CI (slanted lines). Left panel, 1987 survey; right panel, 2009 survey.

4. CONCLUSIONS

On the northeast Chatham Rise (ORH 3B), the Old Plume and Mount Muck had age frequencies that were significantly different to the Rekohu Plume. Rekohu fish were 12 years younger on average than those in the two other plumes. Growth rates were similar for fish from the Old and Rekohu Plumes (Doonan et al. 2014). All three spawning plumes were assumed to be part of the same population. It is not known if the Rekohu Plume existed before 2010.

The age frequencies for orange roughy sampled in 1987 and 2009 from the Challenger Plateau showed marked differences. The 1987 survey distribution had a mode at 46 years, with many fish aged over 60 years while the 2006 and 2009 survey distributions had modes at 28 and 32 years, respectively, and both had few fish older than 60 years. For one year (2009), the distribution mode of the new sample of 170 otoliths was outside the CI for the first sample of 130 otoliths which indicates that a sample size of 130 otoliths was probably inadequate to capture all the variability in the data. Final sample sizes for all age distributions produced in this work were 250–300 otoliths per area or year.

The ageing protocol for orange roughy developed by Tracey et al. (2007) can make a difference in the interpretation of age frequencies used in stock assessments. The age readings determined originally by CAF (Central Ageing Facility, Victoria, Australia) for the 1989–91 Mid East Coast (MEC) samples produced a double mode in the age frequencies, which was interpreted as two good periods of recruitment in the stock assessment (Patrick Cordue, ISL, pers. comm.). When the same otoliths were aged using the 2007 protocol (as reported here) the resulting age frequencies are unimodal and the stock assessment changed as a result (Patrick Cordue, ISL, pers. comm.). The main change between the two age readings resulted from a tighter definition for determining the presence or absence of a TZ, which affected the original age estimates, predominately in the 20 to 40 year age range. Previous studies found that recognition of a TZ in an otolith section produced an age estimate about 30% higher than from the same section when no TZ is recognised (Tracey et al. 2009). The earlier CAF readings of the MEC otoliths frequently did not recognise the TZ, so when they were re-evaluated, many otoliths in the younger mode (centred on 30–35 years) were recognised to have a TZ, and their ages increased by about 10 years. This reduced the size of the younger mode and produced a unimodal distribution centred on the, older, second mode.

The new readings reported here for Chatham Rise and Challenger Plateau samples were produced using the accepted protocol developed in 2007, so these data must take precedence over any previously produced CAF age data for those areas.

5. ACKNOWLEDGMENTS

This work was funded by the New Zealand Ministry for Primary Industries under Project MID201001D. Thanks to Peter McMillan for a useful review of the document.

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APPENDIX A: STATIONS USED IN THE CHATHAM RISE ANALYSIS

Table A1: Northeast Chatham Rise spawning aggregations: stations, catch, relative population by station used to randomly sample otoliths, number of otoliths collected, and probability to select one otolith (i.e., relative station population divided by the number of otoliths sampled at the station).

Station	Catch (kg)	Relative station population	Number of otoliths	Probability to select one otolith
Rekohu Plume				
36	47 100	0.3593	180	0.0020
40	32 650	0.2490	120	0.0021
45	12 000	0.0915	100	0.0009
48	4 350	0.0332	60	0.0006
49	9 000	0.0686	60	0.0011
51	26 000	0.1983	120	0.0017
Old Plume				
62	8 400	0.0909	100	0.0009
63	8 100	0.0876	100	0.0009
70	34 300	0.3710	150	0.0025
82	15 900	0.1720	75	0.0023
83	25 750	0.2785	150	0.0019
Mount Muck				
60	25 650	0.4540	150	0.0030
74	5 100	0.0903	100	0.0009
75	25 750	0.4558	200	0.0023

Table A2: Northwest Chatham Rise trawl survey: stations, catch, relative population by station used to randomly sample otoliths, number of otoliths collected, and probability to select one otolith (i.e., relative station population divided by the number of otoliths sampled at the station).

Station	Stratum	Stratum area (km^2)	Number of otoliths	Relative station population	Catch (kg)	Probability to select one otolith
82	4C	693	20	2 310	51	2.19E-04
83	4B	764	20	1 475	34	1.40E-04
84	4B	764	3	121	2	7.63E-05
86	4C	693	18	862	15	9.09E-05
87	4D	1546	8	747	9	1.77E-04
88	4D	1546	20	5 085	66	4.83E-04
89	4C	693	20	1 199	32	1.14E-04
90	4D	1546	20	6 671	84	6.33E-04
91	4C	693	20	2 854	80	2.71E-04
92	4C	693	20	1 692	45	1.61E-04
94	4D	1546	20	6 268	73	5.95E-04
95	4B	764	20	16 594	369	1.58E-03
96	4B	764	20	10 381	156	9.85E-04
97	4A	886	4	333	3	1.58E-04
98	4E	1546	16	1 876	17	2.23E-04
99	4D	1546	20	4 813	52	4.57E-04
100	GY01	0.01	20	4	1010	3.76E-07
101	GY04	0.01	20	2	696	2.09E-07
103	GY03	0.01	20	9	2892	8.68E-07
104	GY01	0.01	20	45	12702	4.23E-06
105	4A	886	20	6 659	34	6.32E-04
106	4B	764	20	15 390	306	1.46E-03
107	4E	1546	4	711	4	3.37E-04
108	4E	1546	20	5 899	30	5.60E-04
109	GY01	0.01	20	6	1106	6.11E-07
110	GY06	0.01	20	2	118	1.99E-07
111	GY03	0.01	20	12	1389	1.17E-06
112	3C	657	20	4 593	44	4.36E-04
113	3B	667	20	19 531	430	1.85E-03
114	3B	667	20	9 892	255	9.39E-04
115	3A	668	3	221	2	1.40E-04
116	3B	667	20	14 672	385	1.39E-03
119	GY04	0.01	20	12	2559	1.11E-06
120	GY01	0.01	20	1	351	1.20E-07
122	GY03	0.01	20	337	58420	3.20E-05
123	3D	1085	4	349	3	1.66E-04
124	3D	1085	20	2 762	38	2.62E-04
125	3B	667	20	36 465	1039	3.46E-03
126	3D	1085	20	17 815	244	1.69E-03
127	3E	1085	9	1 565	8	3.30E-04
128	4E	1546	20	3 041	29	2.89E-04
129	2E	708	4	307	4	1.46E-04

130	2D	708	20	1 304	33	1.24E-04
131	2D	708	6	239	7	7.56E-05
132	2E	708	11	837	15	1.44E-04
133	1C	561	6	239	6	7.58E-05
134	1C	561	4	294	3	1.39E-04
135	1C	561	8	381	7	9.04E-05
136	1D	1000	11	1 208	13	2.08E-04
137	1B	406	7	470	4	1.28E-04
138	1C	561	20	1 405	28	1.33E-04
139	1B	406	5	326	3	1.24E-04
140	1D	1000	20	2 139	25	2.03E-04
141	1D	1000	8	2 160	11	5.13E-04
142	2A	778	20	1 774	14	1.68E-04
143	2B	609	17	512	18	5.72E-05
144	2C	1177	20	3 809	61	3.62E-04
145	2C	1177	20	6 737	103	6.39E-04
146	2D	708	19	879	22	8.78E-05
147	2E	708	9	687	10	1.45E-04
148	2D	708	20	6 450	164	6.12E-04
149	2B	609	20	5 856	107	5.56E-04
150	2B	609	20	1 439	40	1.37E-04
151	2C	1177	20	4 690	70	4.45E-04
152	2D	708	19	1 815	45	1.81E-04
153	2B	609	20	20 901	388	1.98E-03
154	2B	609	20	11 828	274	1.12E-03
155	2C	1177	20	3 397	56	3.22E-04
156	2C	1177	20	6 325	100	6.00E-04
157	2A	778	20	23 012	105	2.18E-03
158	2B	609	20	9 859	116	9.36E-04
159	2A	778	20	29 290	113	2.78E-03
160	3A	668	20	74 175	581	7.04E-03
161	3B	667	20	9 514	254	9.03E-04
162	3B	667	20	9 118	301	8.66E-04
163	3A	668	19	2 967	12	2.96E-04
164	3D	1085	17	1 506	18	1.68E-04
165	3C	657	20	23 084	465	2.19E-03
166	3E	1085	7	1 233	8	3.34E-04
167	3C	657	20	28 484	557	2.70E-03
168	4B	764	20	22 666	317	2.15E-03
172	GY04	0.01	20	20	1584	1.87E-06
246	GY05	0.01	20	2	118	2.23E-07
250	GY05	0.01	20	104	5802	9.85E-06
253	GY06	0.01	20	3	109	2.41E-07

Table A3: Challenger Plateau trawl survey, 1987: stations, catch, relative population by station used to randomly sample otoliths, number of otoliths collected, and probability to select one otolith (i.e., relative station population divided by the number of otoliths sampled at the station).

Station	Stratum	Stratum area (km^2)	Number of otoliths	Relative station population	Catch (kg)	Probability to select one otolith
76	1	727	30	0.00456	668	1.52E-04
77	1	727	27	0.00736	1 128	2.73E-04
78	1	727	32	0.01119	1 901	3.50E-04
79	1	727	29	0.00176	258	6.07E-05
80	1	727	12	0.00010	14	8.07E-06
81	1	727	20	0.05218	3 231	2.61E-03
82	1	727	40	0.12301	19 575	3.08E-03
83	1	727	20	0.00430	688	2.15E-04
84	1	727	20	0.00464	736	2.32E-04
85	1	727	28	0.00462	690	1.65E-04
86	1	727	27	0.00891	1 375	3.30E-04
87	1	727	20	0.01020	1 730	5.10E-04
88	1	727	40	0.11581	19 247	2.90E-03
89	1	727	20	0.04279	7 201	2.14E-03
90	1	727	60	0.16448	25 932	2.74E-03
91	2	382	20	0.00725	845	3.62E-04
92	2	382	28	0.00245	306	8.76E-05
93	1	727	60	0.20760	34 987	3.46E-03
94	2	382	20	0.01149	1 469	5.74E-04
95	1	727	20	0.00040	64	1.98E-05
96	1	727	28	0.00430	739	1.54E-04
97	1	727	25	0.00098	146	3.90E-05
98	1	727	30	0.02012	3 262	6.71E-04
99	1	727	30	0.00210	324	6.99E-05
100	2	382	25	0.00605	738	2.42E-04
101	1	727	20	0.00298	478	1.49E-04
102	1	727	23	0.00017	28	7.55E-06
103	1	727	10	0.00007	12	7.47E-06
104	1	727	20	0.00207	296	1.03E-04
105	1	727	20	0.00193	318	9.64E-05
106	3	228	20	0.00234	465	1.17E-04
107	3	228	50	0.14935	27 247	2.99E-03
108	3	228	21	0.00124	226	5.90E-05
109	3	228	30	0.00079	142	2.63E-05
110	3	228	30	0.00144	239	4.81E-05
111	3	228	32	0.00058	98	1.82E-05
112	3	228	29	0.00035	60	1.22E-05
113	3	228	20	0.00057	98	2.86E-05
114	3	228	29	0.00238	440	8.20E-05
115	3	228	20	0.00094	176	4.68E-05
116	3	228	30	0.00089	153	2.96E-05
117	3	228	28	0.00419	743	1.49E-04
118	2	382	29	0.00101	113	3.48E-05

Station	Stratum	Stratum area (km^2)	Number of otoliths	Relative station population	Catch (kg)	Probability to select one otolith
119	2	382	30	0.00040	45	1.35E-05
120	2	382	35	0.00035	35	9.87E-06
121	2	382	27	0.00059	77	2.18E-05
122	2	382	30	0.00090	93	3.00E-05
123	2	382	40	0.00045	45	1.12E-05
124	2	382	20	0.00092	111	4.58E-05
125	2	382	20	0.00360	475	1.80E-04
126	1	727	23	0.00019	30	8.11E-06
127	1	727	15	0.00012	17	8.08E-06
128	1	727	4	0.00004	4	1.00E-05
129	1	727	20	0.00051	76	2.54E-05

Table A4: Challenger Plateau trawl survey, 2006: stations, catch, relative population by station used to randomly sample otoliths, number of otoliths collected, and probability to select one otolith (i.e., relative station population divided by the number of otoliths sampled at the station).

Station	Stratum	Stratum area (km^2)	Number of otoliths	Relative station population	Catch (kg)	Probability to select one otolith
16	3	688	20	0.0035	23	1.76E-04
17	1	429	20	0.0026	28	1.32E-04
18	4	166	20	0.0016	27	7.91E-05
19	4	166	20	0.0013	24	6.45E-05
20	4	166	20	0.0020	49	9.99E-05
21	1	429	2	0.0002	1	1.05E-04
22	1	429	6	0.0007	4	1.09E-04
23	4	166	29	0.0012	20	4.20E-05
24	4	166	3	0.0011	21	3.71E-04
25	4	166	20	0.0017	33	8.41E-05
27	3	688	19	0.0034	12	1.76E-04
28	21	121	15	0.0009	11	5.98E-05
29	21	121	15	0.0009	12	5.68E-05
30	22	83	20	0.0005	42	2.44E-05
31	22	83	20	0.0108	1 008	5.38E-04
32	22	83	20	0.0016	144	8.11E-05
33	23	93	20	0.0207	1 322	1.04E-03
34	23	93	20	0.1495	10 378	7.47E-03
35	23	93	20	0.0020	141	9.93E-05
40	22	83	20	0.0494	4 296	2.47E-03
41	22	83	20	0.0007	50	3.56E-05
42	23	93	20	0.2333	12 278	1.17E-02
43	24	304	20	0.0601	766	3.00E-03
44	24	304	20	0.0090	104	4.49E-04
45	23	93	20	0.0023	147	1.13E-04
54	3	688	20	0.0031	20	1.53E-04
55	3	688	14	0.0023	10	1.66E-04

Station	Stratum	Stratum area (km^2)	Number of otoliths	Relative station population	Catch (kg)	Probability to select one otolith
56	3	688	17	0.0027	14	1.57E-04
57	21	121	16	0.0009	14	5.34E-05
59	22	83	20	0.0037	321	1.87E-04
60	3	688	20	0.0098	56	4.89E-04
61	22	83	15	0.0034	266	2.26E-04
63	10	8	19	0.0003	95	1.56E-05
64	22	83	20	0.0010	86	5.17E-05
65	1	429	20	0.0297	303	1.48E-03
66	23	93	20	0.0480	3 359	2.40E-03
67	22	83	20	0.0388	3 009	1.94E-03
70	10	8	20	0.0002	26	8.87E-06
71	22	83	20	0.0031	260	1.54E-04
72	1	429	20	0.0037	29	1.84E-04
73	1	429	19	0.0338	328	1.78E-03
74	24	304	19	0.0100	111	5.25E-04
75	24	304	20	0.0021	22	1.05E-04
76	24	304	20	0.1164	1 260	5.82E-03
79	23	93	20	0.0032	203	1.60E-04
80	23	93	20	0.0706	4 715	3.53E-03
81	23	93	20	0.0526	3 707	2.63E-03

Table A5: Challenger Plateau trawl survey, 2009: stations, catch, relative population by station used to randomly sample otoliths, number of otoliths collected, and probability to select one otolith (i.e., relative station population divided by the number of otoliths sampled at the station).

Station	Stratum	Stratum area (km^2)	Number of otoliths	Relative station population	Catch (kg)	Probability to select one otolith
1	1	478	3	0.0002	2	5.09E-05
2	1	478	19	0.0012	18	6.25E-05
3	1	478	20	0.0014	20	6.77E-05
4	4	149	20	0.0035	186	1.74E-04
6	3	945	20	0.0073	44	3.64E-04
7	3	945	7	0.0013	7	1.79E-04
8	4	149	20	0.0006	22	2.77E-05
9	4	149	20	0.0005	24	2.29E-05
10	1	478	20	0.0020	29	1.01E-04
11	23	93	20	0.0029	852	1.44E-04
12	23	93	20	0.0255	7 587	1.27E-03
14	22	83	20	0.0003	78	1.52E-05
15	22	83	20	0.0001	33	5.19E-06
16	22	83	20	0.0005	137	2.45E-05
17	22	83	20	0.0094	2 738	4.72E-04
18	22	83	40	0.1076	16 087	2.69E-03
19	10	8	18	0.0075	3 105	4.18E-04
20	10	8	20	0.0011	824	5.60E-05
21	10	8	20	0.0005	577	2.73E-05
22	22	83	20	0.0436	11 777	2.18E-03
23	22	83	21	0.0228	6 332	1.09E-03
24	23	93	60	0.1400	38 175	2.33E-03
32	21	121	20	0.0077	451	3.86E-04
33	21	121	20	0.0113	710	5.65E-04
34	21	121	20	0.0005	28	2.35E-05
36	10	8	20	0.0200	5 101	1.00E-03
37	23	93	20	0.0093	3 026	4.64E-04
38	23	93	40	0.1145	16 023	2.86E-03
39	25	437	4	0.0001	3	2.85E-05
40	25	437	9	0.0002	7	2.50E-05
41	22	83	20	0.0066	1 765	3.28E-04
42	22	83	20	0.0003	97	1.74E-05
43	23	93	20	0.0067	1 984	3.34E-04
44	23	93	20	0.0007	239	3.70E-05
45	24	304	20	0.0026	245	1.31E-04
46	24	304	40	0.1130	10 000	2.82E-03
47	25	437	10	0.0002	9	2.32E-05
48	25	437	20	0.0032	150	1.58E-04
49	24	304	20	0.0205	1 689	1.02E-03
50	23	93	20	0.0012	320	5.76E-05
51	23	93	20	0.0025	705	1.25E-04
52	23	93	20	0.0024	705	1.22E-04
53	24	304	20	0.0010	91	5.17E-05

Station	Stratum	Stratum area (km^2)	Number of otoliths	Relative station population	Catch (kg)	Probability to select one otolith
54	23	93	20	0.0010	303	5.08E-05
55	22	83	21	0.0311	7 649	1.48E-03
56	24	304	20	0.0006	54	2.83E-05
57	24	304	18	0.0002	18	1.19E-05
58	25	437	20	0.0011	47	5.35E-05
59	25	437	20	0.0017	69	8.51E-05
60	25	437	20	0.0008	35	4.02E-05
61	25	437	20	0.0010	44	4.91E-05
62	24	304	20	0.0010	91	5.14E-05
63	24	304	20	0.0027	244	1.37E-04
64	24	304	20	0.0029	262	1.44E-04
65	24	304	20	0.0484	4 428	2.42E-03
66	24	304	20	0.1821	7 675	9.10E-03
67	24	304	20	0.0007	68	3.60E-05
68	23	93	20	0.0206	5 806	1.03E-03

APPENDIX B: ESTIMATED AGE FREQUENCIES

Table B1: Estimated age frequencies for Northeast Chatham Rise orange roughy in the Old Plume, Rekohu Plume, and Mount Muck, in 2013.

	Old Plume		Rekohu Plume		Mount Muck	
Age	Frequency	CV	Frequency	CV	Frequency	CV
21	0.003	0.02	0.000	–	0.000	–
22	0.000	–	0.000	–	0.000	–
23	0.000	–	0.000	–	0.000	–
24	0.003	0.02	0.009	0.09	0.002	0.02
25	0.005	0.04	0.009	0.09	0.004	0.03
26	0.003	0.02	0.006	0.06	0.009	0.07
27	0.000	–	0.009	0.09	0.000	–
28	0.000	–	0.022	0.20	0.020	0.15
29	0.013	0.10	0.022	0.21	0.017	0.14
30	0.010	0.08	0.032	0.29	0.015	0.13
31	0.018	0.14	0.022	0.20	0.030	0.25
32	0.013	0.10	0.057	0.52	0.013	0.11
33	0.029	0.23	0.054	0.50	0.022	0.19
34	0.016	0.13	0.054	0.50	0.037	0.30
35	0.013	0.10	0.047	0.43	0.020	0.16
36	0.042	0.33	0.066	0.63	0.050	0.39
37	0.068	0.52	0.047	0.45	0.015	0.13
38	0.029	0.23	0.073	0.69	0.026	0.21
39	0.031	0.25	0.051	0.47	0.022	0.19
40	0.037	0.29	0.070	0.66	0.026	0.21
41	0.024	0.19	0.038	0.36	0.015	0.12
42	0.039	0.31	0.032	0.30	0.024	0.20
43	0.055	0.43	0.047	0.44	0.009	0.07
44	0.016	0.13	0.025	0.24	0.028	0.25
45	0.045	0.35	0.022	0.21	0.033	0.26
46	0.016	0.12	0.032	0.29	0.028	0.24
47	0.047	0.37	0.003	0.03	0.026	0.22
48	0.021	0.16	0.013	0.12	0.015	0.13
49	0.021	0.16	0.016	0.14	0.022	0.18
50	0.042	0.33	0.003	0.03	0.011	0.10
51	0.013	0.10	0.013	0.11	0.015	0.13
52	0.042	0.33	0.019	0.18	0.013	0.11
53	0.013	0.10	0.009	0.09	0.017	0.14
54	0.016	0.13	0.028	0.25	0.020	0.16
55	0.008	0.06	0.009	0.09	0.020	0.16
56	0.010	0.08	0.009	0.09	0.004	0.04
57	0.008	0.06	0.003	0.03	0.035	0.29
58	0.005	0.04	0.000	–	0.011	0.09
59	0.024	0.19	0.006	0.06	0.028	0.23
60	0.013	0.10	0.003	0.03	0.022	0.17
61	0.013	0.10	0.003	0.03	0.020	0.15
62	0.026	0.21	0.003	0.03	0.007	0.05

	Old Plume		Rekohu Plume		Mount Muck	
Age	Frequency	CV	Frequency	CV	Frequency	CV
63	0.018	0.14	0.000	–	0.004	0.03
64	0.010	0.08	0.000	–	0.004	0.04
65	0.016	0.12	0.003	0.03	0.022	0.18
66	0.013	0.10	0.003	0.03	0.011	0.08
67	0.005	0.04	0.000	–	0.020	0.17
68	0.005	0.04	0.000	–	0.017	0.15
69	0.003	0.02	0.000	–	0.022	0.18
70	0.008	0.06	0.000	–	0.002	0.02
71	0.005	0.04	0.000	–	0.020	0.16
72	0.005	0.04	0.003	0.03	0.020	0.18
73	0.003	0.02	0.000	–	0.000	–
74	0.000	–	0.000	–	0.028	0.22
75	0.003	0.02	0.000	–	0.004	0.04
76	0.013	0.10	0.000	–	0.004	0.04
77	0.000	–	0.000	–	0.000	–
78	0.000	–	0.000	–	0.007	0.05
79	0.000	–	0.000	–	0.000	–
80	0.003	0.02	0.000	–	0.009	0.07
81	0.000	–	0.000	–	0.000	–
82	0.003	0.02	0.000	–	0.007	0.06
83	0.005	0.04	0.000	–	0.000	–
84	0.000	–	0.000	–	0.000	–
85	0.000	–	0.000	–	0.000	–
86	0.000	–	0.000	–	0.000	–
87	0.000	–	0.000	–	0.009	0.07
88	0.013	0.11	0.000	–	0.004	0.04
89	0.000		0.000	–	0.000	–
90	0.005	0.04	0.000	–	0.000	–
91	0.003	0.02	0.000	–	0.011	0.09
92	0.000	–	0.000	–	0.000	–
93	0.000	–	0.000	–	0.009	0.07
94	0.000	–	0.000	–	0.000	–
95	0.000	–	0.000	–	0.011	0.09
96	0.003	0.02	0.000	–	0.000	–
97	0.000	–	0.000	–	0.000	–
98	0.000	–	0.000	–	0.000	–
99	0.000	–	0.000	–	0.000	–
100	0.000	–	0.000	–	0.002	0.02
103	0.005	0.04	0.000	–	0.000	–
106	0.003	0.02	0.000	–	0.000	–
111	0.000	–	0.000	–	0.002	0.02
126	0.000	–	0.000	–	0.004	0.03

Table B2: Estimated age frequencies for Northwest Chatham Rise orange roughy from the wide area survey in 1994 (TAN9406).

Age	Frequency	CV	Age	Frequency	CV
11	0.013	0.12	44	0.020	0.17
12	0.020	0.17	45	0.009	0.08
13	0.009	0.08	46	0.002	0.02
14	0.004	0.04	47	0.002	0.02
15	0.028	0.25	49	0.015	0.14
16	0.048	0.44	51	0.004	0.03
17	0.020	0.17	52	0.002	0.02
18	0.037	0.33	53	0.004	0.04
19	0.024	0.22	54	0.007	0.05
20	0.017	0.15	55	0.002	0.02
21	0.037	0.32	56	0.002	0.02
22	0.022	0.19	57	0.002	0.02
23	0.020	0.17	58	0.002	0.02
24	0.020	0.17	59	0.009	0.07
25	0.041	0.36	60	0.007	0.06
26	0.022	0.19	61	0.004	0.03
27	0.055	0.47	62	0.007	0.06
28	0.041	0.35	63	0.002	0.02
29	0.035	0.31	64	0.004	0.04
30	0.052	0.45	67	0.002	0.02
31	0.037	0.32	69	0.009	0.08
32	0.026	0.22	71	0.009	0.08
33	0.017	0.15	72	0.007	0.06
34	0.026	0.23	77	0.004	0.04
35	0.015	0.13	81	0.009	0.07
36	0.017	0.15	82	0.007	0.05
37	0.024	0.21	84	0.002	0.02
38	0.028	0.25	87	0.002	0.02
39	0.009	0.08	88	0.004	0.04
40	0.017	0.14	89	0.007	0.06
41	0.004	0.04	94	0.007	0.05
42	0.009	0.07	95	0.007	0.05
43	0.020	0.16	103	0.004	0.04

Table B3: Estimated age frequencies for Challenger Plateau orange roughy from research surveys in 1987, 2006, and 2009.

	1987 (AEX8701)		2006 (THH0601)		2009 (THH0901)	
Age	Frequency	CV	Frequency	CV	Frequency	CV
14	0.000	–	0.001	0.02	0.000	–
15	0.000	–	0.000	–	0.000	–
16	0.000	–	0.000	–	0.000	–
17	0.000	–	0.001	0.02	0.002	0.02
18	0.000	–	0.003	0.06	0.000	–
19	0.000	–	0.002	0.04	0.002	0.03
20	0.000	–	0.002	0.04	0.003	0.05
21	0.000	–	0.004	0.11	0.031	0.46
22	0.000	–	0.005	0.13	0.029	0.43
23	0.000	–	0.005	0.13	0.019	0.28
24	0.000	–	0.017	0.45	0.027	0.42
25	0.007	0.08	0.038	0.97	0.027	0.42
26	0.004	0.05	0.067	1.74	0.048	0.73
27	0.017	0.20	0.045	1.17	0.032	0.50
28	0.013	0.16	0.065	1.65	0.022	0.33
29	0.013	0.17	0.059	1.48	0.073	1.09
30	0.010	0.13	0.026	0.69	0.036	0.52
31	0.037	0.43	0.041	1.06	0.075	1.11
32	0.016	0.19	0.047	1.23	0.034	0.50
33	0.014	0.16	0.009	0.22	0.048	0.73
34	0.012	0.15	0.032	0.81	0.046	0.67
35	0.018	0.23	0.085	2.22	0.039	0.57
36	0.022	0.27	0.030	0.76	0.049	0.74
37	0.010	0.13	0.039	0.99	0.029	0.44
38	0.025	0.30	0.016	0.40	0.039	0.58
39	0.018	0.23	0.044	1.13	0.041	0.62
40	0.022	0.27	0.032	0.82	0.024	0.35
41	0.018	0.22	0.036	0.93	0.034	0.51
42	0.030	0.37	0.015	0.38	0.029	0.44
43	0.031	0.38	0.013	0.33	0.027	0.40
44	0.020	0.24	0.051	1.38	0.005	0.07
45	0.047	0.57	0.024	0.63	0.031	0.47
46	0.020	0.23	0.012	0.31	0.005	0.07
47	0.025	0.29	0.017	0.44	0.000	–
48	0.025	0.30	0.007	0.18	0.005	0.07
49	0.042	0.51	0.004	0.11	0.007	0.10
50	0.016	0.19	0.003	0.09	0.005	0.08
51	0.038	0.48	0.007	0.18	0.002	0.02
52	0.025	0.29	0.020	0.50	0.009	0.13
53	0.009	0.12	0.004	0.11	0.000	–
54	0.024	0.29	0.002	0.05	0.005	0.08
55	0.026	0.31	0.013	0.34	0.003	0.04
56	0.020	0.23	0.013	0.33	0.009	0.12
57	0.013	0.17	0.002	0.04	0.009	0.13
58	0.017	0.21	0.006	0.15	0.003	0.05

	1987 (AEX8701)		2006 (THH0601)		2009 (THH0901)	
Age	Frequency	CV	Frequency	CV	Frequency	CV
59	0.016	0.19	0.003	0.07	0.000	–
60	0.021	0.25	0.005	0.13	0.000	–
61	0.029	0.35	0.000	–	0.003	0.05
62	0.007	0.08	0.000	–	0.000	–
63	0.012	0.14	0.003	0.07	0.000	–
64	0.013	0.16	0.003	0.08	0.003	0.05
65	0.003	0.03	0.000	–	0.007	0.10
66	0.013	0.16	0.000	–	0.002	0.02
67	0.020	0.24	0.000	–	0.005	0.07
68	0.008	0.09	0.000	–	0.000	–
69	0.009	0.11	0.000	–	0.000	–
70	0.003	0.03	0.000	–	0.000	–
71	0.001	0.02	0.007	0.17	0.000	–
72	0.010	0.12	0.000	–	0.000	–
73	0.007	0.08	0.000	–	0.000	–
74	0.007	0.08	0.002	0.04	0.000	–
75	0.009	0.11	0.011	0.30	0.005	0.08
76	0.000	–	0.000	–	0.000	–
77	0.012	0.14	0.000	–	0.000	–
78	0.000	–	0.000	–	0.000	–
79	0.005	0.06	0.000	–	0.000	–
80	0.009	0.11	0.002	0.04	0.000	–
81	0.005	0.07	0.000	–	0.000	–
82	0.000	–	0.000	–	0.002	0.03
83	0.007	0.08	0.000	–	0.000	–
84	0.010	0.13	0.002	0.04	0.000	–
85	0.000	–	0.000	–	0.000	–
86	0.001	0.02	0.000	–	0.000	–
87	0.007	0.08	0.000	–	0.000	–
88	0.004	0.04	0.000	–	0.000	–
89	0.003	0.03	0.000	–	0.010	0.17
90	0.000	–	0.000	–	0.000	–
91	0.005	0.06	0.001	0.02	0.000	–
92	0.000	–	0.000	–	0.000	–
93	0.000	–	0.000	–	0.000	–
94	0.004	0.05	0.000	–	0.000	–
95	0.008	0.09	0.000	–	0.000	–
96	0.001	0.02	0.000	–	0.000	–
97	0.000	–	0.000	–	0.000	–
98	0.007	0.08	0.000	–	0.000	–
99	0.000	–	0.000	–	0.000	–
100	0.000	–	0.000	–	0.000	–
101	0.004	0.05	0.000	–	0.000	–
104	0.007	0.08	0.000	–	0.000	–
108	0.001	0.02	0.000	–	0.000	–
114	0.001	0.01	0.000	–	0.000	–
145	0.007	0.08	0.000	–	0.000	–