Fisheries New Zealand
Tini a Tangaroa

Age composition of orange roughy from ORH 3B, Chatham Rise, 2016: Mount Muck, Old Plume, Rekohu Plume, and Morgue.

New Zealand Fisheries Assessment Report 2018/48

I.J. Doonan
P.L. Horn
C. Ó Maolagáin
S. Datta

ISSN 1179-5352 (online)
ISBN 978-1-98-857123-2 (online)

November 2018

New Zealand Government

Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries websites at:
http://www.mpi.govt.nz/news-and-resources/publications
http://fs.fish.govt.nz go to Document library/Research reports

Table of Contents

EXECUTIVE SUMMARY

Doonan, I.J.; Horn, P.L.; Ó Maolagáin, C.; Datta, S. (2017). Age composition of orange roughy from ORH 3B, Chatham Rise, 2016: Mount Muck, Old Plume, Rekohu Plume, and Morgue.

***New Zealand Fisheries Assessment Report 2018/48*. 15 p.**

Orange roughy otoliths were prepared and aged from each of three known spawning sites (Old Plume, Rekohu Plume, and Mount Muck) on the east and south Chatham Rise (ORH 3B) sampled in 2016, and also from Morgue on the northwest Chatham Rise. 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 stocks, with sample sizes for each spawning site of 150–300 otoliths. As found in previous years, age samples for the most recently exploited Rekohu Plume were dominated by younger fish (mode about 35 years), while the Old Plume and Mount Muck had similar distributions with relatively older fish (modes about 40–50 years). The Morgue sample had a mode at 30 years, even younger than that for the Rekohu Plume.

1. INTRODUCTION

This report fulfils the reporting requirements for Objective 2 of Project DEE2016-20, 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 targeted studies to meet specific research requirements. The work identified for 2016 was the otolith preparation and ageing of samples of orange roughy from both the east and south Chatham Rise (ESCR) and northwest Chatham Rise (NWCR). This follows previous work on the age composition of orange roughy on the Chatham Rise (Doonan et al. 2014a, 2014b).

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 (Horn et al. 2016). 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 (Tracey et al. 2009). 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 (Horn et al. 2016).

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.

An experimental voyage was conducted in July 2016 on the north Chatham Rise using the FV *Amaltal Explorer* at aggregations on the east and south Chatham Rise and the NWCR. We report age compositions for orange roughy from four separate areas following the methods described in Doonan et al. (2014a, 2014b).

1.1 East and south Chatham Rise spawning plumes

The first reported orange roughy fishery on the east and south 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 2015–16 was 1220 t (Ministry for Primary Industries 2017).

An acoustic survey series of the regular spawning plume (Old Plume) started in 2002 and has been conducted in several years since. A new spawning plume (named the Rekohu Plume) was observed (but not fished) in the winter of 2010 to the west of the Old Plume 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 from the new (Rekohu) plume younger (as they were 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. 2014a).

In 2013, an experimental voyage surveyed the Old and Rekohu Plumes, as well as another aggregation on a feature named Mount Muck. For 2013, sampled age frequencies varied markedly between the three east and south Chatham Rise plumes, with the most recently exploited Rekohu Plume dominated by younger fish, with a strong mode of about 38 years and very few fish older than 50 years, while the Old Plume and Mount Muck both had similar main modes but with relatively more fish older than 50 years (Doonan et al. 2014b).

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 to avoid fishing the northwest Rise in 2010–11 and 2011–12. The other main hill fished for orange roughy in the Graveyard hill complex, Morgue, has been closed to fishing (both bottom and midwater trawling) since 2001 as part of the Seamounts closures (Ministry for Primary Industries 2015).

An assessment of this stock commenced in late 2013, and required age frequency data. For the previous analysis (Doonan et al. 2014a), orange roughy otoliths were prepared and aged from a wide area research survey at Morgue, on the northwest Chatham Rise (ORH 3B) in 1994. The age composition showed that the northwest Chatham Rise was also dominated by younger fish with a mode of about 30 years.

2. METHODS

2.1 Ageing of orange roughy

Otoliths were prepared using the NIWA preparation method (Horn et al. 2016). One 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.

All otoliths were read once by one reader. Otolith interpretation and reading protocols followed those described in the Ageing Workshop Report (Horn et al. 2016). The data produced included 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 using 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 (Horn et al. 2016). 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. The number of otoliths to prepare is n_{unique}. Otoliths were selected with replacement until the specified total number of unique otoliths, $n_{unique,}$ was reached. The procedure was continued to provide a selection of spare otoliths which are often needed to replace damaged or lost samples. The spares were used in the order of their selection. The selection probabilities for individual otoliths (Appendix A) are proportional to the numbers of fish caught in each tow (or catch, if mean weights are similar across all tows) divided by the number of otoliths in the tow. This selection probability was based on all otoliths that were available and assumed that the otolith sampling was random. If the same otolith was selected more than once, its age was repeated in estimating the mean age and age frequency. Since an age estimate may be used more than once, the number of ages, n_{ages}, is likely to be greater than the number of otoliths n_{unique}.

For the southeast Chatham Rise spawning plumes, n_{unique} was 200 otoliths from the Old Plume, 250 from Rekohu, and 150 from Mount Muck, i.e. 600 in total. For the northwest Chatham Rise, 300 otoliths from Morgue were prepared.

2.2.1 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 age-otolith sample. Standard error was assessed using a bootstrap analysis where tows were resampled along with the ages within each selected tow.

Kernel smoothing was used to show the results in the 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 Core Team 2014). *Width* was set to 10, the lowest level of smoothing judged by eye to remove excessive noise.

2.3 Chatham Rise survey

An experimental voyage was conducted over the period 18 June – 15 July 2016 on the north Chatham Rise using the FV *Amaltal Explorer*, leaving from and finishing at Nelson. Acoustic surveys were completed on four spawning aggregations: Old Plume, Rekohu Plume, and Mount Muck on the east and south Chatham Rise, and Morgue on the northwest Chatham Rise (Figure 1). The Sealord Acoustic Optical System (AOS) was used, with 38 kHz and 120 kHz ES60 echo sounders, as well as camera and video capabilities. A demersal trawl was used to collect samples for catch composition, recording length, weight, sex, stage and otoliths, for orange roughy and other species.

2.3.1 East and south Chatham Rise plume surveys

For the Old Plume, 5 tows were carried out over the period 7–12 July. For Rekohu Plume, 9 tows were carried out on 20–22 and 26–28 June, and 1–6 July. For Mount Muck, 2 tows were carried out on 6–10 July. Fish were sampled from these tows and otoliths were collected. Details of the stations used in the analysis are listed in Appendix A (Table A1).

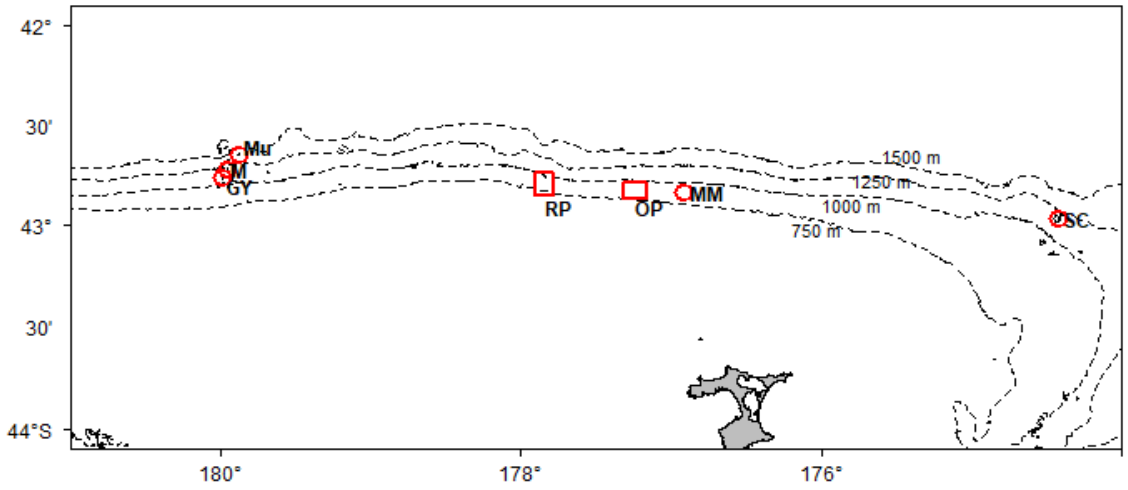

Figure 1: Locations of spawning aggregations on the north Chatham Rise. OP, Old Plume; RP, Rekohu Plume; MM, Mount Muck; M, Morgue; Mu, Mummy; GY, Graveyard; SC, Smiths City.

2.3.2 Northwest Chatham Rise survey

For Morgue, sampling periods were 19–20, 24–25, and 29–30 June, with 3 tows carried out in total. Morgue was closed to bottom trawling and the special permit for sampling specified that the trawl gear did not land on the bottom at any time. Lower effort acoustic surveys (with no trawl tows) were also carried out at the nearby spawning sites of Mummy and Graveyard.

3. RESULTS

3.1 East and south Chatham Rise spawning plumes

Details of the otolith samples from the three spawning areas are given in Table 1. Age frequencies are presented for Old Plume (Figure 2), Rekohu Plume (Figure 3) and Mount Muck (Figure 4). Age-frequency data are listed in Appendix B (Table B1).

Table 1: Details of 2016 Chatham Rise orange roughy otolith samples by location. *N*, intial number of otoliths selected; replacements, the number of otoliths replaced from the initial selected set (e.g., because they were missing or broken); rejects, number of preparations unable to be aged.

				Transition zone classification code			
	N	Replacements	Rejects	0	1	2	3
Old Plume	200	29	0	13	63	96	28
Rekohu Plume	250	34	2	10	50	159	29
Mount Muck	150	28	2	3	52	75	18

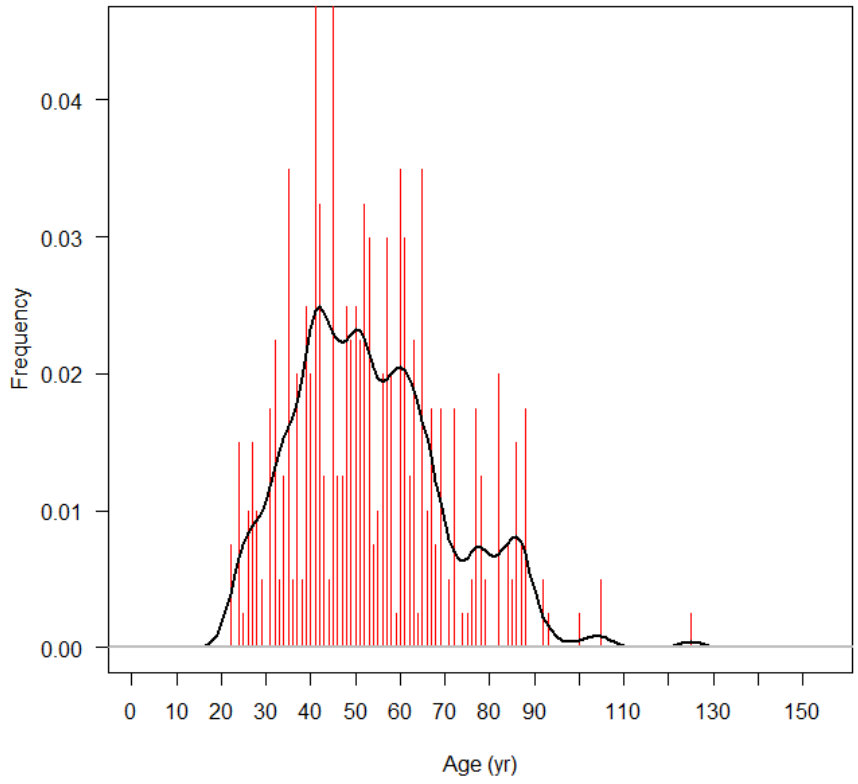

Figure 2: 2016 Old Plume estimated age frequency (red bars) with a smoothed density through the age estimates (black curve).

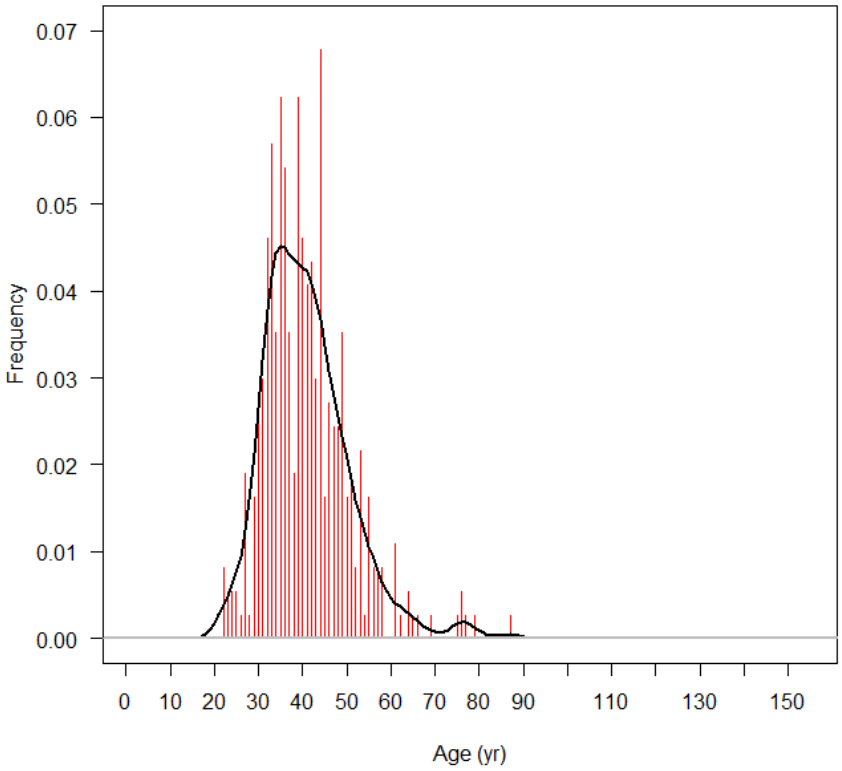

Figure 3: 2016 Rekohu Plume estimated age frequency (red bars) with a smoothed density through the age estimates (black curve).

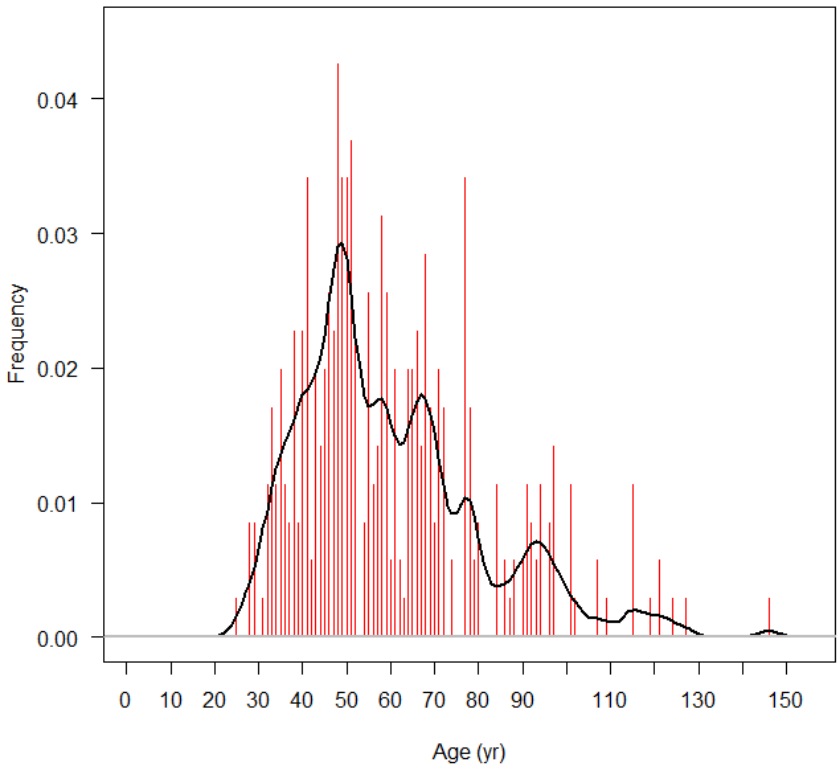

Figure 4: 2016 Mount Muck estimated age frequency (red bars) with a smoothed density through the age estimates (black curve).

A comparison of the age frequencies from the three east and south Chatham Rise areas is shown in Figure 5. It shows that the Old Plume and Mount Muck had quite similar age distributions, although the Mount Muck distribution was displaced slightly to the right (i.e., it had slightly older fish). The Rekohu Plume age distribution had a strong mode of younger fish with few older specimens.

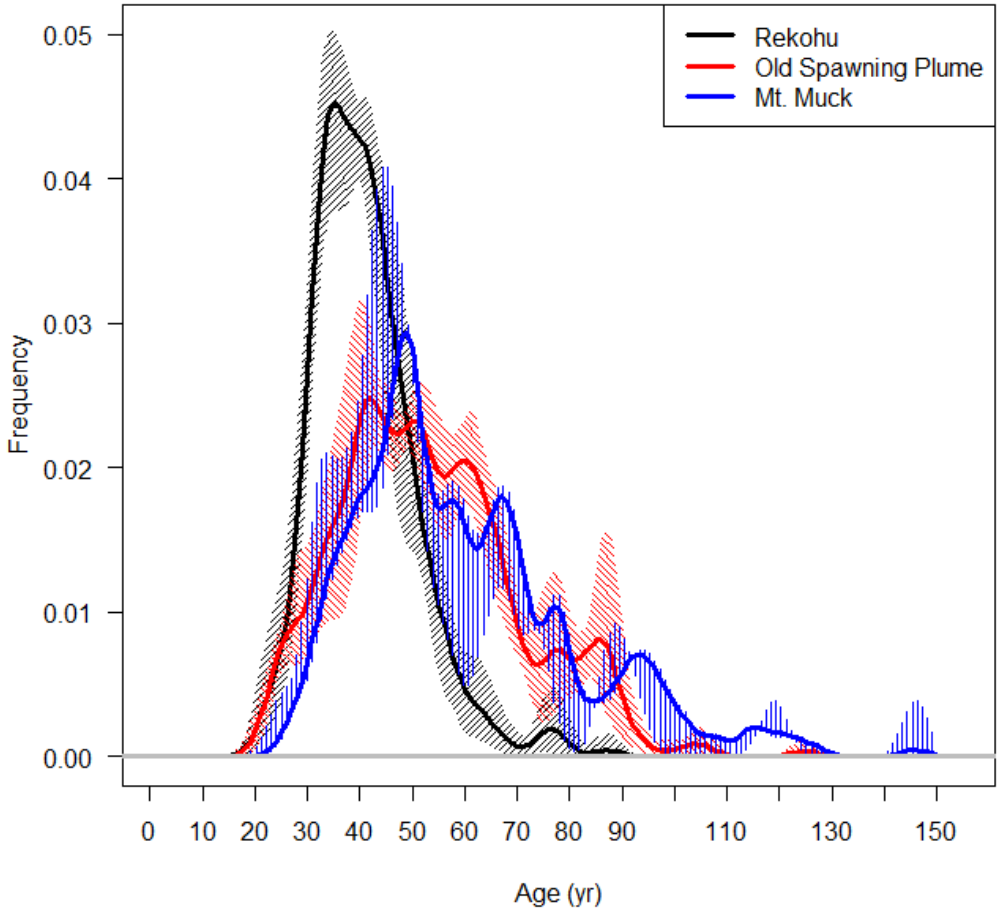

Figure 5: 2016 smoothed age frequencies and pairwise 95% CI for Rekohu Plume (black), Old Plume (red), and Mount Muck (blue).

3.2 Northwest Chatham Rise

The number of otoliths prepared and read from Morgue on the northwest Chatham Rise was 300. No age readings were excluded because of readability problems. The number of replacement otoliths used was 47.

The age frequency distribution is shown in Figure 6 and the data are listed in Appendix B (Table B2). The distribution for Morgue was dominated by younger fish with a mode centred near 30 years, with few older specimens.

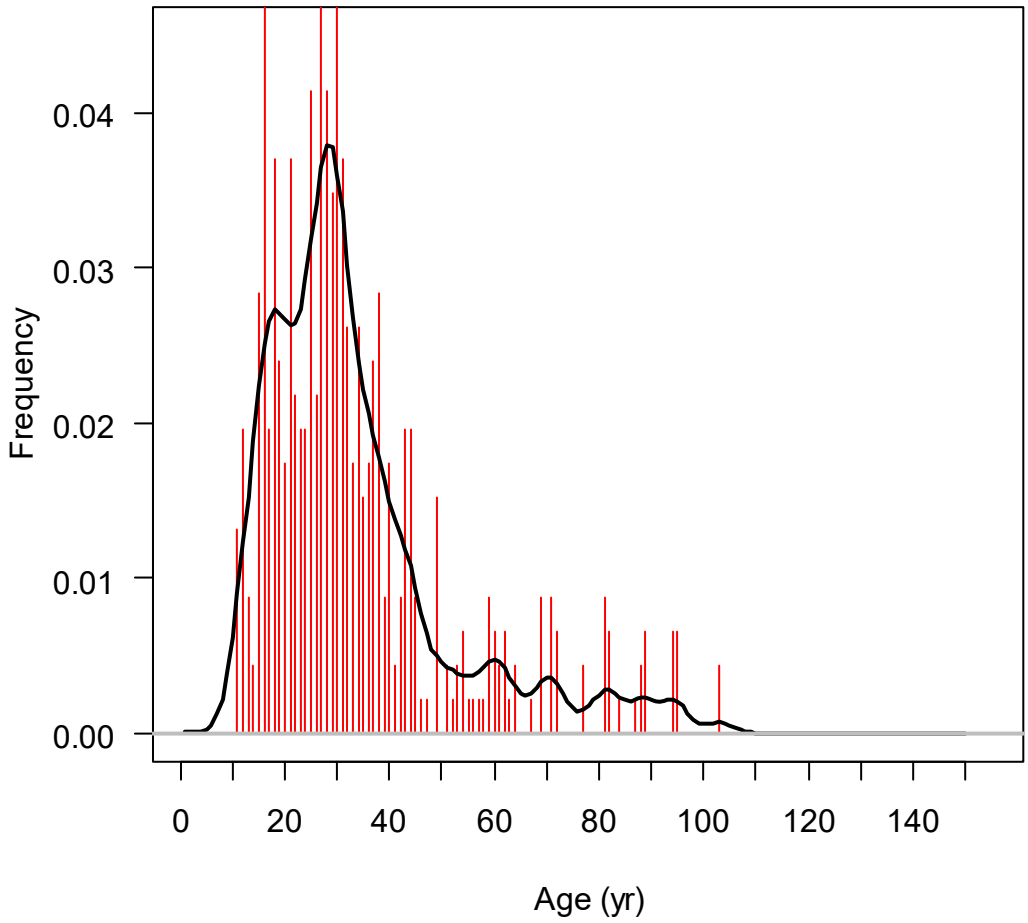

Figure 6: 2016 estimated age frequency (red bars) for northwest Chatham Rise with a smoothed density through the age estimates (black curve).

4. CONCLUSIONS

On the east and south 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 from the two other plumes. Growth rates were similar for fish from the Old and Rekohu Plumes (Doonan et al. 2014b). All three spawning plumes were assumed to be part of the same population. It is not known if the Rekohu Plume existed before 2010.

On the northwest Chatham Rise, Morgue had an age frequency comprised mainly of younger fish aged 10 to 45 years, with a mode around 30 years. The mean fish age was clearly much younger than on the east and south Chatham Rise grounds analysed above. The dominant mode on Morgue was at a younger age than in the Rekohu Plume distribution where the young fish mode was centred near 35 years. There was no new age frequency available for Graveyard, the main fishing hill on the northwest Chatham Rise.

5. ACKNOWLEDGMENTS

This work was funded by the New Zealand Ministry for Primary Industries under Project DEE201620. Thanks to Peter McMillan and Richard O'Driscoll for useful reviews of the document.

6. REFERENCES

Andrews, A.H.; Tracey, D.M.; Dunn, M.R. (2009). Lead-radium dating of orange roughy (*Hoplostethus atlanticus*): validation of a centenarian life span. *Canadian Journal of Fisheries and Aquatic Sciences 66*: 1130–1140.

Doonan, I.J.; Hart A.C.; Bagley, N.; Dunford, A. (2012). Orange roughy abundance estimates of the north Chatham Rise Spawning Plumes (ORH3B), *San Waitaki* acoustic survey, June-July 2011. *New Zealand Fisheries Assessment Report 2012/28*. 35 p.

Doonan, I.J.; Horn, P.L.; Krusic-Golub, K. (2013). Comparison of Challenger Plateau (ORH 7A) orange roughy age estimates between 1987 and 2009. *New Zealand Fisheries Assessment Report 2013/2*. 19 p.

Doonan, I.J.; Horn, P.L.; Ó Maolagáin, C. (2014a). Orange roughy age estimates: Chatham Rise (ORH 3B) spawning plumes in 2012, and mid-east coast North Island (ORH 2A) fishery from 1989–91 and 2010. *New Zealand Fisheries Assessment Report 2014/24*. 19 p.

Doonan, I.J.; Horn, P.L.; Ó Maolagáin, C. (2014b). 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*. 37 p.

Francis, R.I.C.C. (2005). Some orange roughy ageing problems. Presentation to the Deepwater Fisheries Assessment Working Group, November 2005. (Unpublished report held by Fisheries New Zealand, Wellington.)

Francis, R.I.C.C. (2006). Some recent problems in New Zealand orange roughy assessments. *New Zealand Fisheries Assessment Report 2006/43*. 65 p.

Hicks, A. (2005). Between-reader and between-lab ageing errors for orange roughy otoliths aged at NIWA and CAF. Document WG-DW-05/23(revised). 18 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Horn, P.L.; Tracey, D.M.; Doonan, I.J.; Krusic-Golub, K. (2016). Age determination protocol for orange roughy (*Hoplostethus atlanticus*). *New Zealand Fisheries Assessment Report 2016/3*. 30 p.

Mace, P.M.; Fenaughty, J.M.; Coburn, R.P.; Doonan, I.J. (1990). Growth and productivity of orange roughy (*Hoplostethus atlanticus*) on the north Chatham Rise. *New Zealand Journal of Marine and Freshwater Research 24*: 105–119.

Ministry for Primary Industries, Fisheries Science Group (comp.) (2017). Fisheries Assessment Plenary May 2017: Stock Assessments and Stock Status. (Unpublished report held by Fisheries New Zealand, Wellington). https://fs.fish.govt.nz/Page.aspx?pk=61&tk=212

Ministry for Primary Industries (2015). Compliance fact sheet 7. https://www.mpi.govt.nz/document-vault/7242

R Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/

Tracey, D.M.; Horn, P.L.; Doonan, I.J.; Krusic-Golub, K.; Robertson, S. (2009). Orange roughy ageing study: application of otolith reading protocol and analysis of between-agency age data. Final Research Report for Ministry of Fisheries Research Project SAP200716, Objective 1. 18 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

APPENDIX A: STATIONS USED IN THE 2016 CHATHAM RISE ORANGE ROUGHY AGE ANALYSIS

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

Station	Catch (kg)	Relative station population	Number of otoliths	Probability of selecting one otolith
Rekohu Plume				
20	18 070	0.066284	99	6.70E-04
22	37 735	0.138419	150	9.23E-04
55	68 755	0.252205	80	3.15E-03
56	27 270	0.100031	59	1.70E-03
58	6 677	0.024492	50	4.90E-04
60	25 450	0.093355	100	9.34E-04
63	36 280	0.133081	80	1.66E-03
67	16 458	0.060371	39	1.55E-03
69	35 920	0.131761	40	3.29E-03
Old Plume				
73	17 309	0.245668	100	2.46E-03
76	12 302	0.174603	50	3.49E-03
81	11 067	0.157075	50	3.14E-03
86	18 572	0.263593	50	5.27E-03
88	11 207	0.159062	50	3.18E-03
Mount Muck				
79	2 727	0.109479	100	1.09E-03
84	22 182	0.890522	150	5.94E-03
Morgue				
25	10 117	0.256036	100	2.56E-03
47	25 222	0.638305	199	3.21E-03
54	4 175	0.105659	51	2.07E-03

APPENDIX B: ESTIMATED 2016 CHATHAM RISE ORANGE ROUGHY AGE FREQUENCIES

Table B1: Estimated age frequencies for the east and south Chatham Rise orange roughy from the Old Plume, Rekohu Plume, and Mount Muck, in 2016. – no data.

	Old Plume		Rekohu Plume		Mount Muck	
Age (yr)	Frequency	CV	Frequency	CV	Frequency	CV
22	0.007481	0.946855	0.00813	0.717369	0.000	–
23	0.000	–	0.00542	1.031783	0.000	–
24	0.014963	0.489722	0.00542	0.705577	0.000	–
25	0.002494	0.930509	0.00542	0.756773	0.002841	1.359319
26	0.009975	0.67988	0.00271	0.986104	0.000	–
27	0.014963	0.40389	0.01897	0.512267	0.000	–
28	0.009975	0.717952	0.00271	1.031783	0.008523	0.547403
29	0.004988	0.918525	0.01626	0.502103	0.008523	0.547403
30	0.000	–	0.0271	0.508939	0.000	–
31	0.017456	0.555438	0.02981	0.28178	0.002841	1.359319
32	0.022444	0.402452	0.04607	0.281192	0.011364	0.898879
33	0.004988	0.930509	0.056911	0.204956	0.017045	0.188271
34	0.012469	0.918525	0.03523	0.312313	0.011364	0.427861
35	0.034913	0.358712	0.062331	0.294505	0.019886	0.547403
36	0.004988	0.872626	0.054201	0.428988	0.011364	0.547403
37	0.01995	0.489722	0.03523	0.361701	0.008523	1.097485
38	0.004988	0.551604	0.01897	0.484988	0.022727	0.043183
39	0.024938	0.395609	0.062331	0.171982	0.008523	0.617561
40	0.01995	0.309573	0.04607	0.348813	0.022727	0.547403
41	0.047382	0.309986	0.04065	0.279365	0.034091	0.547403
42	0.032419	0.364285	0.04336	0.321339	0.005682	1.359319
43	0.012469	0.418776	0.02981	0.391568	0.019886	0.791135
44	0.004988	0.930509	0.067751	0.195772	0.014205	0.743067
45	0.052369	0.378578	0.01626	0.426948	0.019886	0.514304
46	0.012469	0.454681	0.0271	0.45762	0.025568	0.547403
47	0.012469	0.61067	0.02439	0.466273	0.022727	0.427861
48	0.024938	0.422035	0.02439	0.432058	0.042614	0.29129
49	0.022444	0.458448	0.03523	0.349814	0.034091	0.547403
50	0.024938	0.244725	0.01626	0.743134	0.034091	0.188271
51	0.022444	0.507334	0.01897	0.46568	0.036932	0.547403
52	0.032419	0.448904	0.00813	0.529029	0.022727	0.043183
53	0.029925	0.584094	0.02168	0.410114	0.000	–
54	0.007481	0.62842	0.00271	0.986104	0.008523	0.547403
55	0.009975	0.594975	0.01626	0.529896	0.025568	0.009827
56	0.01995	0.581435	0.00813	1.025579	0.011364	0.547403
57	0.029925	0.148012	0.00813	0.461278	0.014205	0.29129
58	0.01995	0.375513	0.00813	0.799914	0.03125	0.547403
59	0.002494	0.918525	0.000	–	0.025568	0.547403
60	0.034913	0.430978	0.000	–	0.005682	0.547403
61	0.029925	0.308372	0.01084	0.785384	0.019886	0.547403
62	0.012469	0.604981	0.00271	1.012853	0.005682	0.547403

	Old Plume		Rekohu Plume		Mount Muck	
Age (yr)	Frequency	CV	Frequency	CV	Frequency	CV
63	0.022444	0.334021	0.000	–	0.002841	1.359319
64	0.002494	0.872626	0.00542	0.727331	0.019886	0.547403
65	0.034913	0.218863	0.00271	1.054274	0.019886	0.547403
66	0.009975	0.92008	0.00271	0.986104	0.022727	0.043183
67	0.017456	0.713578	0.000	–	0.014205	0.29129
68	0.007481	0.930509	0.000	–	0.028409	0.547403
69	0.017456	0.563543	0.00271	1.025579	0.017045	0.188271
70	0.000	–	0.000	–	0.008523	0.547403
71	0.004988	0.946855	0.000	–	0.019886	0.547403
72	0.017456	0.383056	0.000	–	0.017045	0.547403
73	0.000	–	0.000	–	0.000	–
74	0.002494	0.92008	0.000	–	0.005682	1.359319
75	0.002494	0.930509	0.00271	0.799914	0.000	–
76	0.004988	0.589095	0.00542	1.054274	0.000	–
77	0.017456	0.51361	0.00271	1.066675	0.034091	0.547403
78	0.012469	0.733141	0.000	–	0.017045	0.547403
79	0.004988	0.92008	0.00271	1.066675	0.005682	0.547403
80	0.000	–	0.000	–	0.008523	0.547403
81	0.000	–	0.000	–	0.000	–
82	0.01995	0.474191	0.000	–	0.000	–
83	0.000	–	0.000	–	0.000	–
84	0.007481	0.624647	0.000	–	0.011364	0.547403
85	0.004988	0.872626	0.000	–	0.000	–
86	0.014963	0.645203	0.000	–	0.005682	0.547403
87	0.007481	0.92008	0.00271	1.025579	0.002841	0.547403
88	0.017456	0.92008	0.000	–	0.005682	1.359319
89	0.000	–	0.000	–	0.000	–
90	0.000	–	0.000	–	0.005682	0.547403
91	0.000	–	0.000	–	0.011364	0.547403
92	0.004988	0.918525	0.000	–	0.008523	0.617561
93	0.002494	0.930509	0.000	–	0.005682	0.547403
94	0.000	–	0.000	–	0.011364	0.547403
95	0.000	–	0.000	–	0.000	–
96	0.000	–	0.000	–	0.008523	0.547403
97	0.000	–	0.000	–	0.014205	0.547403
98	0.000	–	0.000	–	0.000	–
99	0.000	–	0.000	–	0.000	–
100	0.002494	0.930509	0.000	–	0.000	–
101	0.000	–	0.000	–	0.011364	0.547403
102	0.000	–	0.000	–	0.002841	0.547403
103	0.000	–	0.000	–	0.000	–
104	0.000	–	0.000	–	0.000	–
105	0.004988	0.872626	0.000	–	0.000	–
106	0.000	–	0.000	–	0.000	–
107	0.000	–	0.000	–	0.005682	0.547403
108	0.000	–	0.000	–	0.000	–
109	0.000	–	0.000	–	0.002841	0.547403

	Old Plume		Rekohu Plume		Mount Muck	
Age (yr)	Frequency	CV	Frequency	CV	Frequency	CV
110	0.000	–	0.000	–	0.000	–
111	0.000	–	0.000	–	0.000	–
112	0.000	–	0.000	–	0.000	–
113	0.000	–	0.000	–	0.000	–
114	0.000	–	0.000	–	0.000	–
115	0.000	–	0.000	–	0.011364	0.547403
116	0.000	–	0.000	–	0.000	–
117	0.000	–	0.000	–	0.000	–
118	0.000	–	0.000	–	0.000	–
119	0.000	–	0.000	–	0.002841	1.359319
120	0.000	–	0.000	–	0.000	–
121	0.000	–	0.000	–	0.005682	0.547403
122	0.000	–	0.000	–	0.000	–
123	0.000	–	0.000	–	0.000	–
124	0.000	–	0.000	–	0.002841	0.547403
125	0.002494	0.92008	0.000	–	0.000	–
126	0.000	–	0.000	–	0.000	–
127	0.000	–	0.000	–	0.002841	0.547403
146	0.000	–	0.000	–	0.002841	1.359319

Table B2: Estimated age frequencies for northwest Chatham Rise orange roughy from the Morgue in 2016.

Age (yr)	Frequency	CV	Age	Frequency	CV
24	0.005612	0.676394	63	0.007856	0.435492
25	0.003367	0.676394	64	0.015339	0.277189
26	0.00636	0.676394	65	0.012346	0.600691
27	0.003367	0.676394	66	0.003367	0.676394
29	0.002993	1.365083	67	0.008979	0.370301
30	0.004863	0.676394	68	0.007108	0.676394
31	0.011972	0.24909	69	0.013094	0.238433
32	0.016461	0.499973	70	0.004863	0.290358
33	0.012346	0.676394	71	0.010475	0.676394
34	0.00636	0.940682	72	0.017957	0.476866
35	0.012346	0.334284	73	0.00636	0.789967
36	0.023943	0.259857	74	0.005612	0.751888
37	0.02544	0.207047	75	0.011972	0.991651
38	0.031425	0.094226	76	0.002993	0.676394
39	0.026188	0.456553	78	0.004489	0.560098
40	0.013094	0.341107	80	0.00636	0.940682
41	0.053124	0.405493	81	0.002619	0.676394
42	0.043771	0.18496	82	0.002993	0.940682
43	0.020202	0.676394	83	0.005612	0.676394
44	0.022447	0.531548	84	0.005238	1.365083
45	0.035915	0.533814	87	0.001871	0.940682
46	0.026936	0.102257	88	0.004863	0.676394
47	0.036663	0.497455	90	0.002993	0.940682
48	0.021324	0.395011	95	0.004863	0.940682
49	0.033296	0.136209	96	0.003367	0.676394
50	0.038159	0.139841	98	0.002993	1.365083
51	0.025065	0.315413	99	0.005238	0.36458
52	0.01459	0.292937	101	0.002619	0.940682
53	0.016835	0.300889	102	0.008605	0.676394
54	0.035915	0.264705	104	0.013094	0.676394
55	0.014216	0.164704	105	0.004489	0.676394
56	0.032548	0.570412	110	0.002245	0.676394
57	0.018706	0.253224	113	0.002245	1.365083
58	0.020576	0.676394	114	0.003367	0.940682
59	0.013468	0.260335	117	0.004489	0.676394
60	0.010475	0.338996	122	0.004489	0.676394
61	0.021324	0.152428	180	0.003367	0.676394
62	0.007482	0.987014			