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Age composition of orange roughy on the south-west Challenger Plateau (ORH 7A) and Westpac Bank in 2018

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Table of Contents

EXECUTIVE SUMMARY

Dutilloy, A.; Horn, P.L.; Ó Maolagáin, C. (2019). Age composition of orange roughy on the south-west Challenger Plateau (ORH 7A) and Westpac Bank in 2018.

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Age frequencies were estimated for orange roughy (*Hoplostethus atlanticus*) sampled in the south-west Challenger Plateau region (ORH 7A) using otoliths sampled from a 2018 trawl and acoustic survey. Otoliths (n = 900) were prepared and read by one reader following the accepted ageing protocol methods. The Volcano feature on the Westpac Bank had an age mode around 50 years, and relatively abundant fish up to age 75 years. The Central Flats and Western Aggregation on the south-west Challenger Plateau held generally younger fish mainly in the age range 20 to 55 years, with age modes just over 40 years. Available age distributions from 2006 to 2018 indicate a current population on the Central Flats largely comprised of a pulse of fish spawned from around the mid 1960s to the mid 1980s. Sufficient age data are now available for this population to enable a revision of life history parameters.

1. INTRODUCTION

This report fulfils the reporting requirements relating to orange roughy (*Hoplostethus atlanticus*) for Objective 1 of Project MID201803, "Routine age determination of middle depth and deepwater species from commercial fisheries and resource surveys", and was funded by Fisheries New Zealand. The research in 2018–19 was the preparation and ageing of otoliths of orange roughy sampled from the south-west Challenger Plateau (ORH 7A), and the Westpac Bank (on the Challenger Plateau just outside the New Zealand Exclusive Economic Zone (EEZ)), from an acoustic survey conducted in June–July 2018. These data enable the estimation of an age frequency from 18 years after the fishery had been closed. The age distribution will be used in a stock assessment for the region.

Recognising that orange roughy age estimates produced by New Zealand and Australian readers had poor comparability (Francis 2005, 2006, Hicks 2005), an Orange Roughy Ageing Workshop was held in 2007 to improve otolith preparation and zone interpretation between agencies. A new protocol for ageing orange roughy was developed during the workshop (Tracey et al. 2007) and later this protocol was tested by two scientists from National Institute of Water and Atmospheric Research Ltd (NIWA) and two scientists from Fish Ageing Services Pty. Ltd. (FAS, Victoria, Australia). The new ageing protocol solved the inter-agency between-reader problems and provided a consistent and documented method for the interpretation of growth zones in orange roughy otoliths for the region (Tracey et al. 2009, Horn et al. 2016).

The growth of juvenile 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 orange roughy otolith cores, grouped by growth-zone counts from thin sections to validate age data. Results showed a high degree of correlation between the growth-zone counts and 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 The Challenger Plateau fishery and relevant research

This fishery commenced in 1981 on the southwest Challenger Plateau. Catches increased rapidly with the discovery of spawning aggregations, mainly on the Challenger Flats to the north-west of the Pinnacles, and outside the EEZ on the Westpac Bank. The TACC peaked at 12 000 t in 1987–88, and was reduced in 1989–90 and several times after that until the fishery was effectively closed from 1 October 2000 (with a TACC of 1 t). As part of the research for this stock, a series of trawl surveys were carried out during the spawning season between 1987 and 1990 (Clark & Tracey 1994). Starting in 2005, the Orange Roughy Management Company Ltd and Deepwater Group Ltd commissioned combined acoustic and stratified random trawl surveys for orange roughy to investigate the current state of the stock. These surveys were on spawning fish in the south-western part of the Challenger Plateau in 2005 (Clark et al. 2005), 2006 (Clark et al. 2006), 2009 (Doonan et al. 2009), 2010 (Doonan et al. 2010), 2011 (Hampton et al. 2013), 2012 (Hampton et al. 2014), and 2013 (Hampton et al. unpublished data). These surveys used the same trawl gear design, core strata, and survey protocols (but a different vessel) as the earlier (1987 to 1990) trawl survey series. The survey area was expanded to the east of the Pinnacles in 2006 and further east in 2009 to include an area where concentrations of orange roughy had been found in the 2006 survey. The surveys included Westpac Bank in all years except 2012 when there was insufficient vessel time to survey there. An acoustic survey in 2014 covered the Volcano feature on the Westpac Bank only (Ryan et al. 2015)

In 2009 and 2010, spawning plumes were found close to the area where they were last observed in 1989. There were at least two hypotheses for their reappearance in 2009: that the new plumes are young fish, i.e., new recruits to the spawning population; or that older fish have re-colonised the area. Doonan et al. (2013) tested these hypotheses by constructing and comparing mean age and age frequencies from two surveys separately widely in time (i.e., 1987 and 2009). They found that the 2009 fish were twenty years younger, on average, than those in 1987 (33 years compared with 53). The age composition difference between the two years was so marked that only 3% of the 2009 fish were older than the mean age in 1987. In addition, 24% of the 2009 fish had no identifiable transition zone (which is believed to be linked to the onset of maturity) compared to just 0.8% with no zone in 1987. Consequently, it was concluded that 2009 fish were mainly a pulse of recently matured fish and not the result of migration from some other lightly fished stock.

The 2018 survey (Ryan 2018) marked the eighth combined trawl and acoustic biomass survey of orange roughy on the south-west Challenger Plateau (including Westpac Bank) conducted from FV *Thomas Harrison*. The age-frequency from this survey can be used in a stock assessment for the region.

2. METHODS

2.1 Ageing of orange roughy

Orange roughy otoliths were prepared using the NIWA preparation method described in Horn et al. (2016). One whole otolith from each of the selected fish was individually embedded in resin and cured in an oven. A thin section was cut along a line from the primordium (otolith nucleus region) 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 using the otolith interpretation and reading protocols described in the ageing methodology document (Horn et al. 2016). While the ageing protocols suggest that two readers are the ideal, inter-agency calibrations continue at regular intervals between the NIWA and FAS scientists to ensure that there are on-going and consistent zone interpretations and no reader drift, so these single reader age readings were considered acceptable (P.L. Horn, NIWA, pers. comm.). The data produced include counts of zones from the primordium to the transition zone (TZ, the zone that marks the onset of orange roughy maturity (Francis & Horn 1997)), and from the TZ to the otolith margin, and readability codes for those readings provided on a 5-stage readability scale. Otolith data with a readability code of 5 (i.e., unreadable) for either the pre- or post-TZ readings were excluded. The presence of a TZ 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 (Horn et al. 2016). TZs were classified using a 4-stage scale, i.e.:

- 0, not yet formed (or 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 by the reader as the likely location of the TZ was undefined. Although pre- and post-TZ zone counts were recorded in the age determination of most otoliths examined here, only the total age estimates were used in the analyses.

2.2 Survey design

The voyage was conducted from 27 June to 7 July 2018 on the Challenger Plateau using the FV *Thomas Harrison* (Ryan 2018). The acoustic survey was designed to focus on aggregations on the Central Flats in ORH 7A and on an aggregation on Volcano outside the EEZ on Westpac Bank. The trawl survey occurred in the 'Central Flats' area in ORH 7A and Volcano, as has been the practice since 2006. The survey strata were slightly modified over previous surveys here and comprised two core strata encapsulating areas where previous surveys and commercial tows had produced high catch rates, and four bounding guard strata (Figure 1). The revised strata incorporated an area where over 95% of the biomass was encountered during previous trawl surveys in ORH 7A (Figure 2).

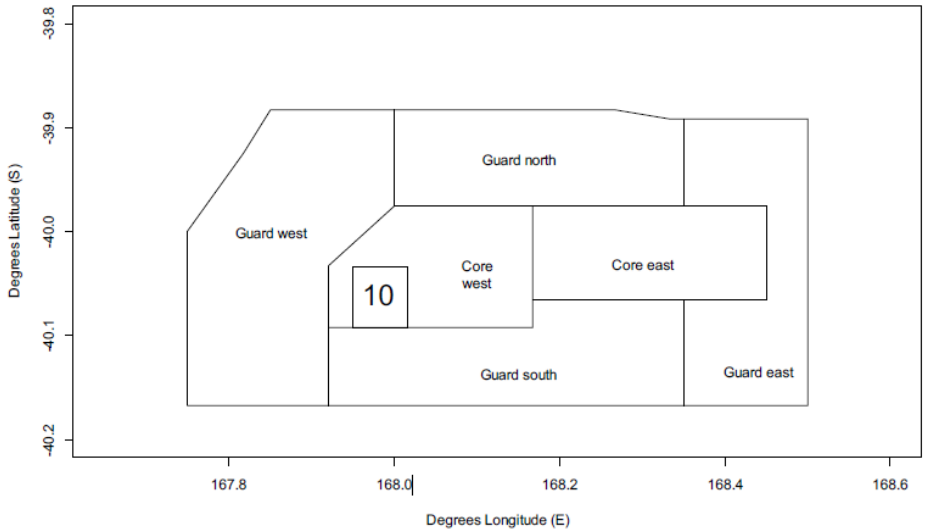

Figure 1: The 2018 trawl survey strata on the south-west Challenger Plateau in ORH 7A (from Ryan 2018). The hill stratum (10) was excluded from the trawl survey.

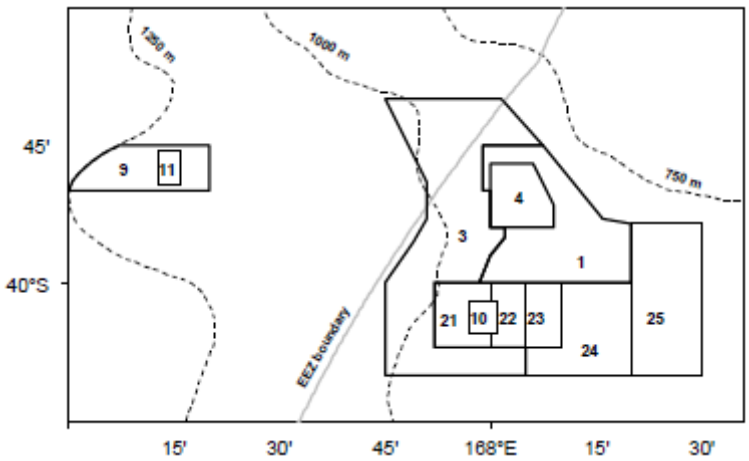

Figure 2: Trawl survey strata used in the 2009–2013 surveys (from Doonan et al. 2009). Stratum 11 incorporates Volcano on the Westpac Bank.

2.3 Analytical methods

2.3.1 Otolith selection

The method of analysis followed that of Doonan et al. (2013) for ORH 7A orange roughy. The number of otoliths to prepare was n_{unique}. Otoliths were selected with replacement until a specified total number of unique otoliths, $n_{\text{unique,}}$ was reached. The procedure was continued to provide a selection of spare otoliths which were used to replace damaged or lost samples. The spares were used in the order of their selection. The selection probabilities for individual otoliths are proportional to the numbers of fish caught in each tow (or total orange roughy catch from the tow, if mean fish 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 prepared, n_{unique}.

2.3.2 Allocation of the number of otoliths to process from each spawning aggregation

Otoliths were sampled from three areas: Random trawl survey area (Trawl); Volcano; and Western Aggregation. The three sampled areas were analysed separately, so the target of 900 otoliths to prepare and read was split between the aggregations (Appendix A). Due to low numbers of otoliths collected on Volcano and Western Aggregation (149 and 301, respectively), all otoliths were selected from these areas with no spares. The remaining 450 otoliths were allocated to the trawl survey area with a further 25 otoliths selected as spares. Preliminary orange roughy abundance estimates were derived by Ryan (2018).

Stations 37 and 38 were foul tows that came fast on Volcano and were thus excluded from the analysis. Stations 41, 45 and 50 were also excluded as these tows on the central flats were hauled early owing to the net fullness alarm being triggered.

2.3.3 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 Development Core Team 2014). *Width* was set to 10.

3. RESULTS

The number of otoliths prepared and read from the 2018 survey samples was 900, but nine otoliths were excluded because of a readability code of 5. The station weights (i.e., relative population by station used to randomly sample otoliths) and otolith selection probabilities are listed in Appendix A (Tables A1, A2 and A3).

3.1 Central Flats (Trawl)

The 2018 age frequency distribution is shown in Figure 3 with data listed in Appendix B (Table B1). The distribution is dominated by younger to middle-aged fish with ages ranging mainly from 25 to 55 years and a mode centred near 40 years. The distribution does not extend beyond 100 years. The mean weighted CV (MWCV) across all age classes was 44%.

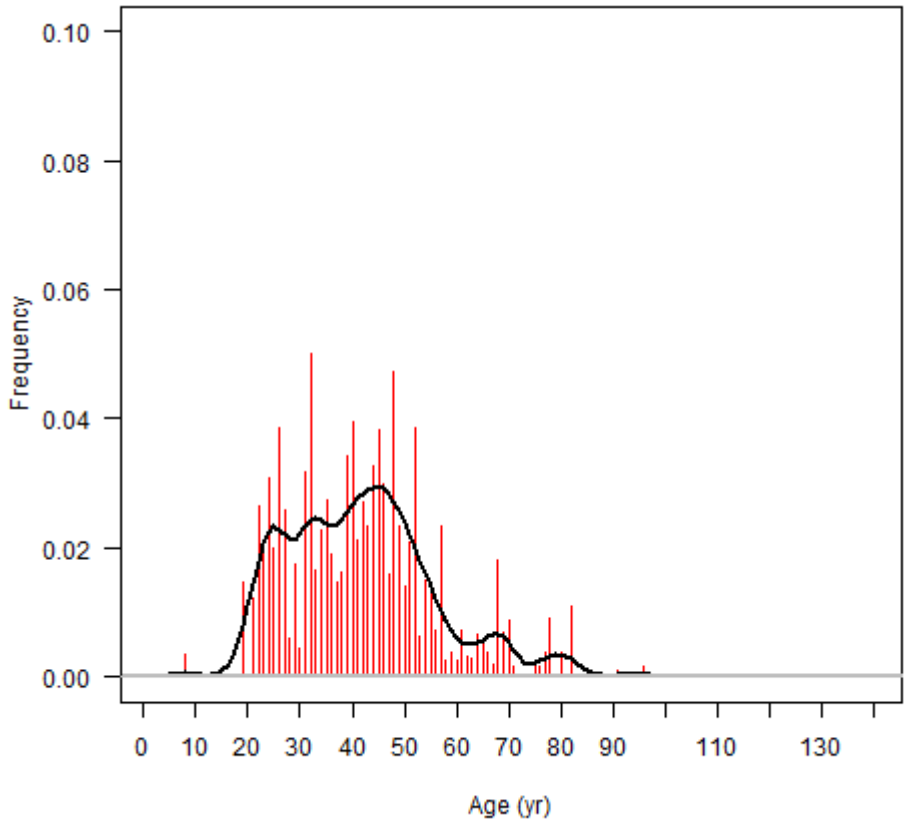

Figure 3: 2018 trawl and acoustic survey: Estimated age frequency (red bars) for Central Flats with a smoothed density through the age estimates (black curve).

3.2 Volcano

The 2018 age frequency distribution is shown in Figure 4 with data listed in Appendix B (Table B2). The distribution is dominated by younger to middle-aged fish with ages ranging mainly from 30 to 75 years and a mode centred near 50 years. The MWCV was 74%. There was only one successful tow conducted on Volcano.

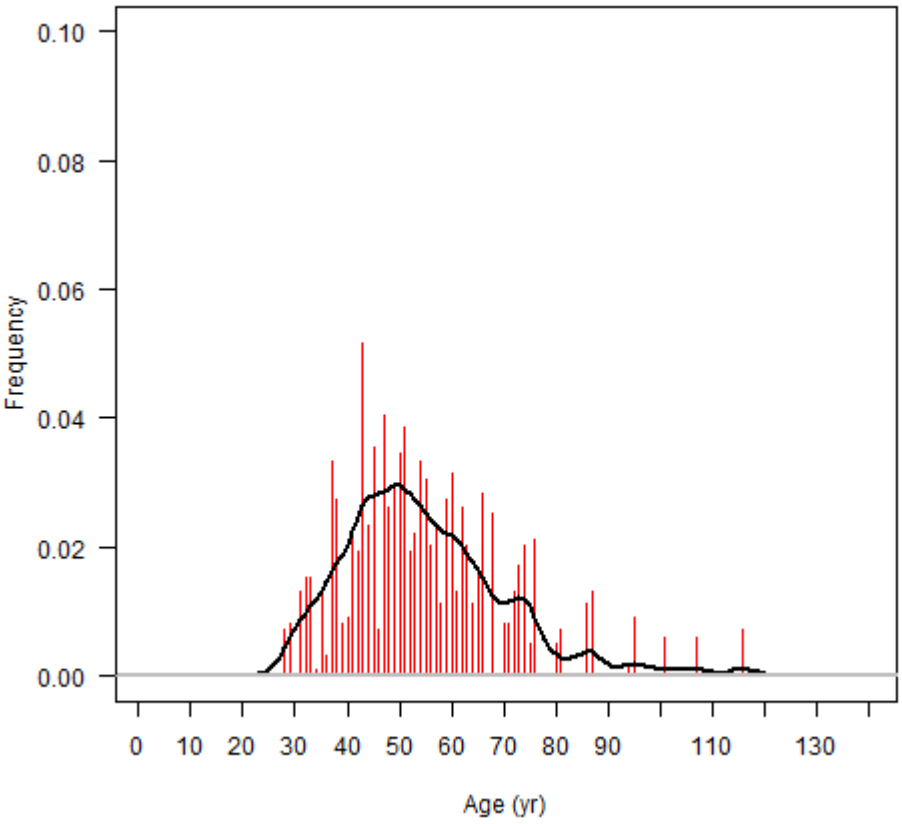

Figure 4: 2018 trawl and acoustic survey: Estimated age frequency (red bars) for Volcano with a smoothed density through the age estimates (black curve).

3.3 Western Aggregation

The western aggregation occurred in the core strata adjacent to the northern part of the boundary between core west and core east (see Figure 1). Three tows from this aggregation were sampled and analysed (Table A3). The 2018 age frequency distribution is shown in Figure 5 with data listed in Appendix B (Table B3). The distribution is dominated by younger to middle-aged fish with ages ranging mainly from 25 to 55 years and a mode centred near 40 years. The MWCV was 27%.

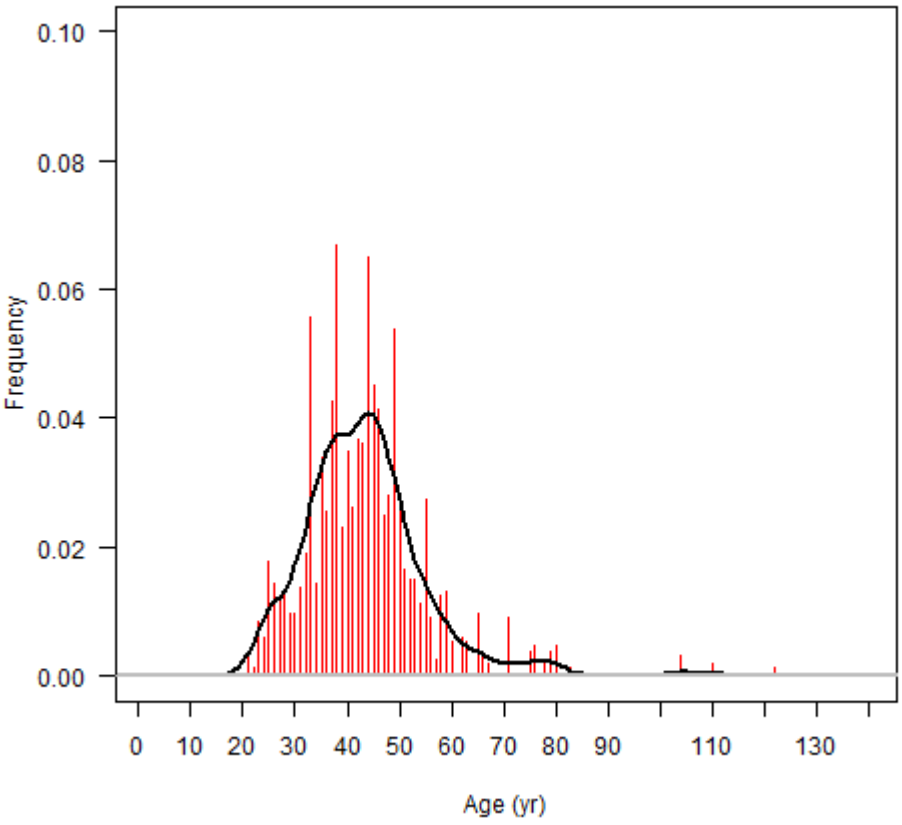

Figure 5: 2018 trawl and acoustic survey: Estimated age frequency (red bars) for Western Aggregation with a smoothed density through the age estimates (black curve).

4. DISCUSSION

The smoothed age distributions from the three areas are compared in Figure 6. Volcano has a greater abundance of older individuals, with an age mode around 50 years, and more fish in the 55 to 100+ year age range. The Central Flats has a mode at around 40 years, and relatively more fish in the 15 to 30 year age range than the other areas. Western Aggregation and Central Flats have similar frequencies of fish older than 60.

Age data are now available from five surveys conducted on the Challenger Plateau: 1987, 2006, 2009, 2014, and 2018 (Doonan et al. 2013, 2014, 2015, and the current work). The distributions from each survey are, however, not strictly comparable as the aged otoliths were not derived from the same areas in each survey. Nevertheless, some comparisons can be made. The otoliths analysed from 2014 were from five tows (468 otoliths) on the Volcano feature only. Most fish were aged 30–56 years, with a mode around 40 years, and a tail of older fish extending to the high 70s (Doonan et al. 2015). The

distribution for the single Volcano tow in 2018 (149 otoliths) had generally older fish (i.e., most aged between 32 and 75 years, with a tail of fish to more than 100 years). The difference between surveys in the modal age was not explained by the 4-year gap between them, but the low sampling intensity in 2018 may have resulted in a poor representation of the true population on that feature.

Age samples from the central flats area are available from the 1987, 2006, 2009 and 2018 surveys, although there are between-survey differences in the actual area surveyed (Doonan et al. 2014; current work). The 1987 distribution had a mode at 46 years and many fish older than 60 years. The 2006 and 2009 distributions comprised generally younger fish with modes at 28 and 32 years, respectively, and few fish older than 60 years. In 2018 the mode (central flats and western aggregation combined) was about 43 years, with some fish older than 60 but very few older than 80. The distributions with modes at 28, 32 and 43 years in 2006, 2009 and 2018 respectively indicate a current population largely comprised of a pulse of fish spawned from around the mid 1960s to the mid 1980s. New recruits (i.e., fish aged 20–25 years old) were apparent in all distributions, but most particularly in 2018.

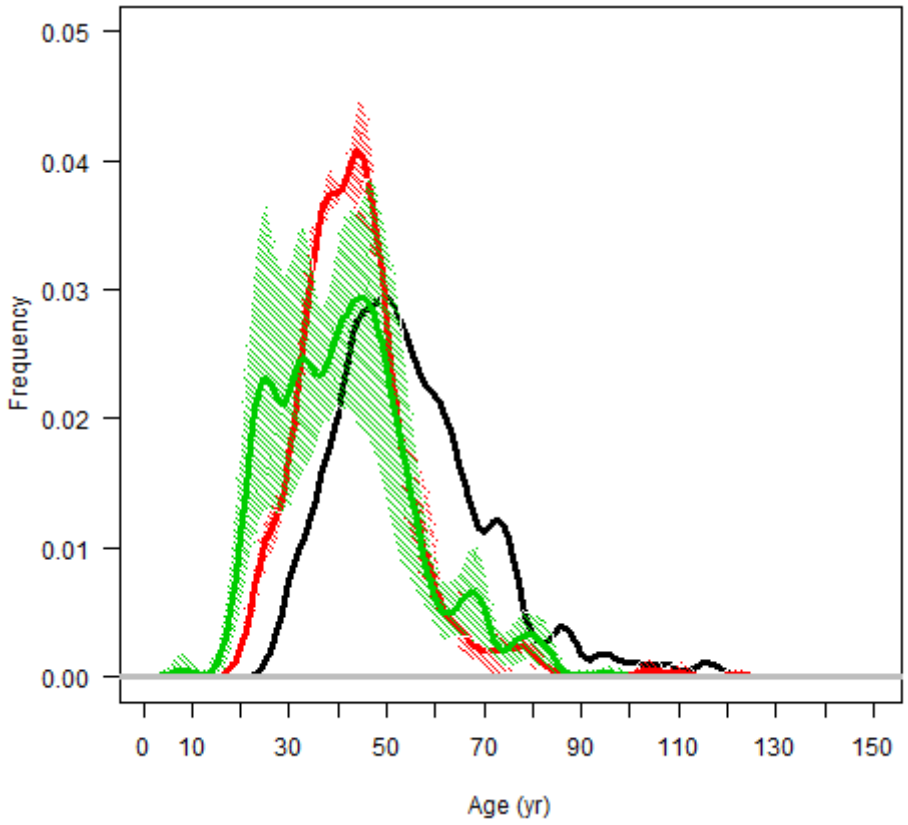

Figure 6: Comparisons of the age frequency distributions of Challenger Plateau orange roughy from Volcano (black), Western Aggregation (red) and Central Flats (green). The pairwise 95% confidence limits are indicated by the shaded areas. Confidence limits for the Volcano distribution cannot be estimated because only one catch was sampled from this area.

The data produced in this work and from previous surveys in the same area could be used to provide revised estimates of productivity parameters for the Challenger Plateau orange roughy population. It would be desirable to use growth parameters specifically applicable to these fish in stock assessments. The available data on age at the formation of the otolith transition zone would also enable age at maturity to be re-estimated using data produced following the revised age determination protocol.

5. ACKNOWLEDGMENTS

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APPENDIX A: STATION WEIGHT AND OTOLITH SELECTION PROBABILITIES

Table A1: Central Flats: 2018 trawl and acoustic survey — station and stratum numbers, catch, number of otoliths collected, and probability to select one otolith.

Stratum	Station	Catch (kg)	Number of otoliths	Probability to select one otolith
GW	4	8.9	13	0.00031
GW	5	4.4	6	0.00047
GW	6	2.9	6	0.00038
CW	7	263.3	20	0.00004
GN	8	2.7	5	0.00020
GN	9	36.8	20	0.00018
GN	10	7.4	9	0.00018
GE	11	11.1	10	0.00022
GE	12	1.4	2	0.00039
GE	13	107.5	20	0.00034
CW	14	74.5	20	2.4E-05
CW	15	3.4	2	5.1E-05
CW	16	16.0	15	1.5E-05
CW	17	369.0	20	5.3E-05
CW	18	3 162.7	20	0.00015
CW	19	128.4	20	3.1E-05
CW	21	525.7	20	6.3E-05
CW	22	59.3	20	2.1E-05
CW	25	1 846.8	19	0.00012
CW	26	49.8	20	1.9E-05
CW	27	2 077.7	20	0.00013
CW	28	5.5	3	4.3E-05
CW	30	141.8	20	3.3E-05
CW	31	113.5	20	2.9E-05
CW	33	7.8	10	1.5E-05
CW	34	131.1	20	3.1E-05
CW	35	1 311.2	20	9.9E-05
CE	40	2 911.8	20	0.00056
CE	42	77.8	20	9.1E-05
CE	43	77.6	20	9.1E-05
CE	44	45.4	20	6.9E-05

Table A2: Volcano: 2018 trawl and acoustic survey — station and stratum numbers, 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).

Stratum	Station	Catch (kg)	Relative station population	Number of otoliths	Probability to select one otolith
11	39	1 375	1	149	0.00671

Table A3: Western Aggregation: 2018 trawl and acoustic survey — station and stratum numbers, 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).

Stratum	Station	Catch (kg)	Relative station population	Number of otoliths	Probability to select one otolith
CW	20	1 155	0.27932	100	0.00279
CW	29	1 565	0.37848	100	0.00378
CW	36	1 415	0.34220	101	0.00339

APPENDIX B: ESTIMATED AGE FREQUENCIES

Table B1: Central Flats — estimated age frequencies for Challenger Plateau orange roughy from the 2018 trawl and acoustic survey (THH1801).

Age	Frequency	CV	Age	Frequency	CV
22	0.080247	0.689524	76	0	0
23	0	0	77	0.005271	0.983799
24	0	0	78	0.022590	0.692089
25	0	0	79	0	0
26	0	0	80	0	0
27	0	0	81	0	0
28	0	0	82	0	0
29	0.013703	0.834338	83	0	0
30	0	0	84	0.002259	1.195189
31	0	0	85	0	0
32	0.008283	1.107205	86	0	0
33	0.006173	1.205524	87	0	0
34	0.002259	1.195189	88	0	0
35	0.077839	0.657395	89	0	0
36	0	0	90	0	0
37	0	0	91	0	0
38	0.003012	1.107205	92	0	0
39	0.025602	0.540520	93	0	0
40	0.031775	0.609116	94	0	0
41	0.005271	0.914158	95	0	0
42	0.004518	1.152649	96	0.003012	1.195189
43	0	0			
44	0.032380	0.320962			
45	0.058131	0.428560			
46	0.027861	0.370788			
47	0.080247	0.326780			
48	0.136565	0.533711			
49	0.035234	0.914973			
50	0.023641	0.729446			
51	0.033133	0.365797			
52	0.099379	0.502180			
53	0.003012	1.195189			
54	0.041862	0.658285			

Table B2: Volcano— estimated age frequencies for Challenger Plateau orange roughy from the 2018 trawl and acoustic survey (THH1801).

Age	Frequency	CV	Age	Frequency	CV	Age	Frequency	CV
28	0.007962	0.670280	61	0.012559	0.730577	94	0.009554	0.670280
29	0.010204	0.730577	62	0.021978	0.730577	95	0.001592	0.670280
30	0	0	63	0.022920	0.497086	96	0	0
31	0.017516	0.670280	64	0.023773	0.509666	97	0	0
32	0.022158	0.494917	65	0.009419	0.730577	98	0	0
33	0.014241	0.494161	66	0.026038	0.523832	99	0	0
34	0.005495	0.730577	67	0	0	100	0	0
35	0.011057	0.505995	68	0.016551	0.554552	101	0.005495	0.730577
36	0.004710	0.730577	69	0	0	102	0	0
37	0.036354	0.497610	70	0.007064	0.730577	103	0	0
38	0.018838	0.730577	71	0.011146	0.670280	104	0	0
39	0.010204	0.730577	72	0.007962	0.670280	105	0	0
40	0.013344	0.730577	73	0.021328	0.502804	106	0	0
41	0.035659	0.509666	74	0.030950	0.543501	107	0.001592	0.670280
42	0.010989	0.730577	75	0.020701	0.670280	108	0	0
43	0.045931	0.500401	76	0.020701	0.670280	109	0	0
44	0.027608	0.531082	77	0	0	110	0	0
45	0.033237	0.494917	78	0	0	111	0	0
46	0.009554	0.670280	79	0	0	112	0	0
47	0.035659	0.509666	80	0.001592	0.670280	113	0	0
48	0.032475	0.502707	81	0.004777	0.670280	114	0	0
49	0.026890	0.494002	82	0	0	115	0	0
50	0.017381	0.501022	83	0	0	116	0.007962	0.670280
51	0.046761	0.512531	84	0	0			
52	0.010989	0.730577	85	0	0			
53	0.014286	0.547063	86	0.007849	0.730577			
54	0.039404	0.557168	87	0.017516	0.670280			
55	0.021978	0.730577	88	0	0			
56	0.010989	0.730577	89	0	0			
57	0.019623	0.730577	90	0	0			
58	0.013434	0.498595	91	0	0			
59	0.030165	0.552107	92	0	0			
60	0.033887	0.557598	93	0	0			

Table B3: Western Aggregation — estimated age frequencies for Challenger Plateau orange roughy from the 2018 trawl and acoustic survey (THH1801).

Age	Frequency	CV	Age	Frequency	CV	Age	Frequency	CV
21	0.002860	0.805425	56	0.013933	0.406677	91	0	0
22	0.001907	0.805425	57	0.008580	1.173670	92	0	0
23	0.012393	0.763189	58	0.015950	0.367616	93	0	0
24	0.002860	0.805425	59	0.009110	0.417557	94	0	0
25	0.010486	0.444324	60	0.006140	0.567398	95	0	0
26	0.017832	0.588799	61	0	0	96	0	0
27	0.012923	0.594674	62	0.010849	0.551465	97	0	0
28	0.010906	0.303406	63	0.002860	0.805425	98	0	0
29	0.005985	0.680874	64	0	0	99	0	0
30	0.015335	0.482649	65	0.008103	0.701657	100	0	0
31	0.013078	0.402235	66	0.009533	0.746749	101	0	0
32	0.022791	0.328576	67	0.002453	0.790810	102	0	0
33	0.053631	0.243151	68	0	0	103	0	0
34	0.016092	0.322741	69	0	0	104	0.007008	0.841622
35	0.023832	0.211859	70	0	0	105	0	0
36	0.019400	0.426310	71	0.011143	0.683675	106	0	0
37	0.038084	0.276966	72	0	0	107	0	0
38	0.071914	0.239732	73	0	0	108	0	0
39	0.024514	0.189898	74	0	0	109	0	0
40	0.037115	0.197566	75	0.004205	0.841622	110	0.000701	0.790810
41	0.032744	0.229732	76	0.000953	0.805425	111	0	0
42	0.036263	0.256833	77	0	0	112	0	0
43	0.037845	0.226322	78	0.001907	0.701657	113	0	0
44	0.053615	0.275363	79	0.008409	0.616717	114	0	0
45	0.055480	0.210493	80	0.006307	0.858144	115	0	0
46	0.035925	0.237494	81	0	0	116	0	0
47	0.028747	0.376777	82	0	0	117	0	0
48	0.033529	0.439121	83	0.003153	0.790810	118	0	0
49	0.031566	0.148186	84	0	0	119	0	0
50	0.029675	0.360467	85	0	0	120	0	0
51	0.020240	0.267628	86	0	0	121	0	0
52	0.009419	0.524065	87	0	0	122	0.003153	0.790810
53	0.015559	0.535391	88	0	0			
54	0.009811	0.544038	89	0	0			
55	0.021193	0.230115	90	0	0			