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Age composition of orange roughy from Cook Canyon (ORH 7B) in 2019

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A. Dutilloy,
P.L. Horn,
C. Ó Maolagáin

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EXECUTIVE SUMMARY

Dutilloy, A.; Horn, P.L.; Ó Maolagáin, C. (2020). Age composition of orange roughy from Cook Canyon (ORH 7B) in 2019.

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Age frequencies were estimated for orange roughy (*Hoplostethus atlanticus*) from Cook Canyon (ORH 7B) using otoliths sampled from a 2019 acoustic survey. Otoliths (n = 500) were prepared and read by one reader following the accepted ageing protocol methods. The Cook Canyon aggregation had an age mode around 45 years, a relatively large group of fish over 100 years, and few younger fish.

1. INTRODUCTION

This report fulfils the reporting requirements relating to orange roughy (*Hoplostethus atlanticus*) for Objective 1 of Fisheries New Zealand project MID201902, "To determine catch-at-age for commercial catches and resource surveys of specified middle depth and deepwater fishstocks". The research in 2019–20 was the preparation and ageing of otoliths of orange roughy sampled from Cook Canyon (ORH 7B), from an acoustic survey conducted in June-July 2019 aboard FV *Amaltal Mariner*. These data enabled the estimation of ORH 7B age frequency for the 2019–20 fishing year, 13 years after the fishery had been closed. The derived age distribution will be used in the next ORH 7B stock assessment.

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 revised 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 revised 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 Cook Canyon fishery and relevant research

This fishery commenced in 1983 on an area near Cook Canyon in Statistical Areas 033, 034, and 705. Up to 1996–97, about 80% of catches were taken in winter (June-July) when orange roughy aggregate for spawning. The Total Allowable Commercial Catch (TACC) peaked at 1708 t between 1988–89 and 1994–95, was reduced in 1995–96, and reduced again in 2001–02 until the fishery was effectively closed from 1 October 2007 (with a TACC of 1 t). Since 2015, a series of acoustic surveys have been conducted in Cook Canyon aimed at locating and surveying spawning plumes. In 2015, an orange roughy plume was identified. However, due to its transitory nature, the plume was not acoustically surveyed (Ryan & Tilney 2016). In 2016, another acoustic survey was attempted, and, although a plume was identified, the survey was unsuccessful due to bad weather. In 2017, a successful acoustic survey was conducted on FV *Amaltal Explorer*, when the towed acoustic optical system (AOS) captured three snapshots of a single spawning plume in Cook Canyon, giving an average biomass estimate of 824 t (Ryan & Tilney 2017). It was determined that the timing of the snapshots was late relative to the spawning cycle, because 40–50% of sampled fish had spent gonads (Ryan & Tilney 2017).

The 2019 survey (Ryan & Tilney 2019) marked the fourth acoustic biomass survey of orange roughy for Cook Canyon and was conducted from FV *Amaltal Mariner*. The average biomass estimate from the 2019 survey was 877 t. The age frequency from this survey was deemed suitable to be used in a stock assessment for the region, because it was considered to be representative of the spawning population.

2. METHODS

2.1 Ageing of orange roughy

Orange roughy otoliths were prepared using the NIWA preparation method described by Horn et al. (2016). One whole otolith from each of the selected fish was 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 experienced reader in accordance with the otolith interpretation and reading protocols described in the ageing methodology document (Horn et al. 2016). Although 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 because 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, only the total age estimates were used in the analyses.

2.2 Survey design

The voyage was conducted from 26 June to 16 July 2019 in Cook Canyon using the FV *Amaltal Mariner* (Ryan & Tinley 2019). The acoustic survey was designed to focus on the main spawning aggregation location as identified in the 2015, 2016, and 2017 surveys. Otoliths were randomly sampled by voyage scientists.

2.3 Analytical methods

2.3.1 Otolith selection

The method of analysis followed that of Dutilloy et al. (2019) for ORH 7A orange roughy. 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 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}.

A total of 700 otoliths were sampled from the Cook Canyon spawning aggregation in 2019, of which a target of n_{unique} 500 otoliths were to be prepared and read, with a further 50 otoliths selected as spares. Preliminary orange roughy abundance estimates were derived by Ryan & Tilney (2019).

2.3.2 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 the entire age-otolith sample and was also estimated for each sex separately. Standard error was assessed using a bootstrap analysis where tows were resampled 500 times 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 2019 survey samples was 500, but six 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 (Table A1).

The sex-specific age frequency distributions are shown in Figure 1, based on data listed in Appendix B (Table B1, Table B2), and have different trends in age distribution. The male distribution is dominated by fish with ages ranging mainly from 20 to 65 years with a mean age of 51.5 years (19–138 years). The female age distribution is dominated by fish aged at between 30 and 65 with a mean age of 62.5 years (21–147 years).

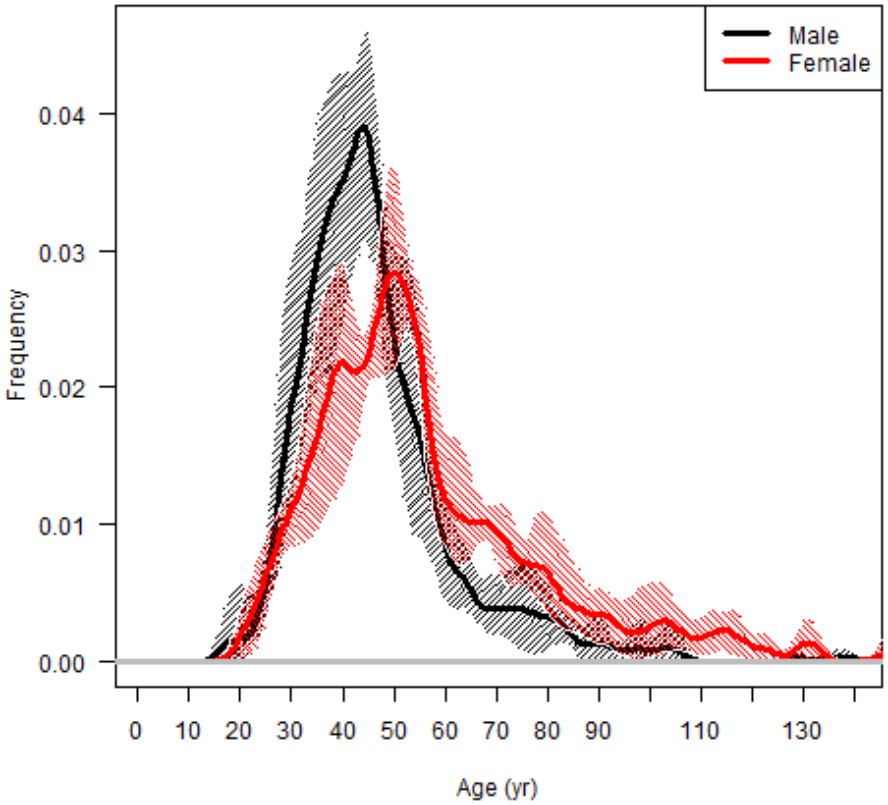

Figure 1: Comparisons of the age frequency distributions by sex (females – red; males – black). The pairwise 95% confidence limits are indicated by the shaded areas.

The overall, combined sexes age frequency distribution is shown in Figure 2, with data listed in Appendix B (Table B3). The distribution is dominated by middle-aged fish with ages ranging mainly from 30 to 65 years and a mode centred near 45 years. However, there was a relatively large number of fish aged over 100 years. The mean weighted CV was 15.4 %.

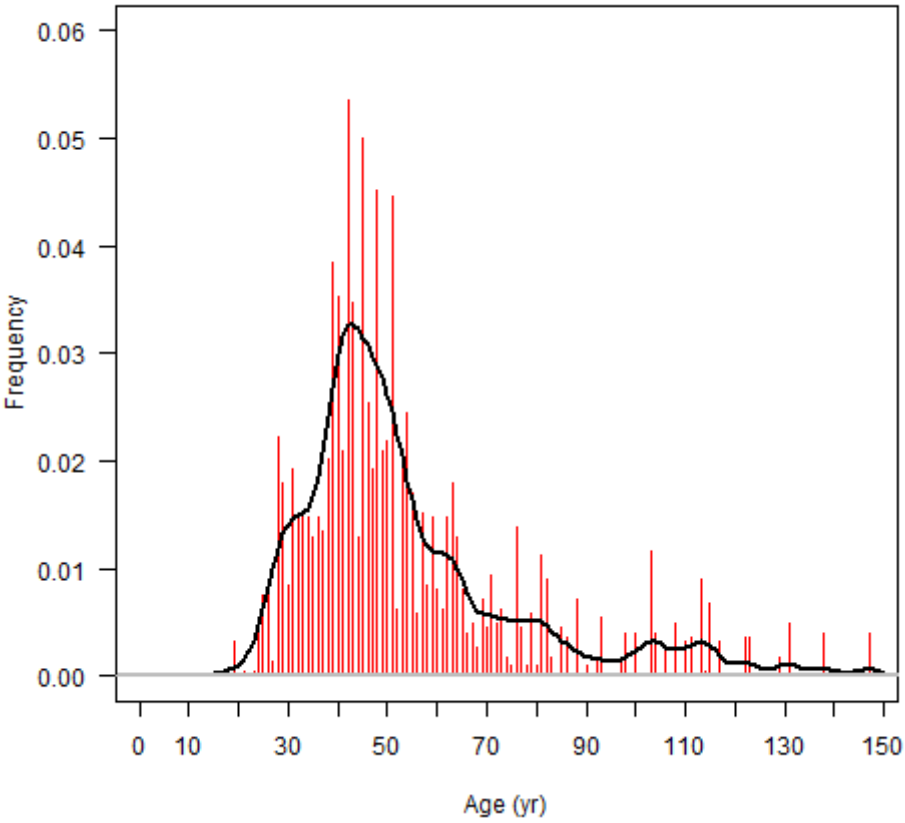

Figure 2: Estimated age frequency distribution (red bars) for Cook Canyon with a smoothed density through the age estimates (black curve).

4. DISCUSSION

Although otoliths have been routinely collected during research surveys of Cook Canyon, only those collected as part of the 2019 acoustic survey have been aged. This is due to otoliths collected in previous surveys being considered unrepresentative of the spawning population, either because they were sampled from a single tow in the spawning plume, or because sampling took place late in the spawning season. The 500 otoliths sampled in 2019 were taken from 6 tows targeting the spawning plume, with males and females being almost equally represented in each tow. However, the age distributions by sex were different, which may indicate: 1) different levels of exploitation, with males being more heavily exploited, 2) the area is considered transitory and the sexes do not arrive simultaneously, or 3) the fish were predominantly aggregating by sex and size, and the small number of tows did not comprehensively sample the population (Figure 2). Although the mode of the overall age frequency was around 45 years, there was a relatively large group that were aged at over 100 years (predominantly female), and few younger fish.

The data produced in this work could be used to provide estimates of productivity parameters for the Cook Canyon 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: 2019 acoustic survey — station and stratum numbers, catch, number of otoliths collected, and probability to select one otolith. CC – Cook Canyon.

Stratum	Station	Catch (kg)	Number of otoliths	Probability to select one otolith
CC	1	2 080	200	0.001024
CC	2	1 790	99	0.00178
CC	8	1 690	100	0.001663
CC	13	1 240	100	0.00122
CC	14	1 850	100	0.001821
CC	19	1 510	100	0.001486

APPENDIX B: ESTIMATED AGE FREQUENCIES

Table B1: Estimated age frequencies for Cook Canyon female orange roughy from the 2019 acoustic survey.

Age	Frequency	CV	Age	Frequency	CV	Age	Frequency	CV
19	0.003124	0.917818	56	0.005801	0.418476	98	0.004016	0.680466
21	0.000446	0.94006	57	0.015172	0.46641	100	0.004016	0.917818
23	0.000446	0.917108	58	0.008478	0.429889	103	0.011602	0.540712
24	0.004462	0.713766	59	0.014726	0.525366	104	0.004016	0.855357
25	0.007586	0.522602	60	0.008032	0.575905	106	0.002677	0.917818
26	0.008032	0.502779	61	0.006247	0.417037	108	0.004909	0.94006
27	0.001339	1.030507	62	0.014726	0.490008	110	0.003124	0.917818
28	0.022311	0.287837	63	0.017849	0.453148	111	0.00357	0.891252
29	0.017849	0.281268	64	0.012941	0.540795	113	0.008925	0.567608
30	0.008478	0.45052	65	0.008032	0.490292	114	0.000446	0.891252
31	0.019188	0.4294	66	0.004016	0.891252	115	0.006693	0.94006
32	0.014726	0.512733	67	0.004909	0.590483	117	0.003124	0.94006
33	0.015172	0.480111	68	0.002677	0.37775	122	0.00357	0.917108
34	0.014726	0.271914	69	0.00714	0.438433	123	0.00357	0.917818
35	0.012941	0.364759	70	0.004462	0.813889	129	0.001785	0.917108
36	0.014726	0.350352	71	0.009371	0.40174	131	0.004909	0.710815
37	0.013387	0.505783	72	0.004909	0.70259	138	0.004016	0.917108
38	0.02008	0.206305	73	0.006247	0.643613	147	0.004016	0.917818
39	0.038376	0.283365	74	0.001785	0.657256			
40	0.035252	0.400749	75	0.000892	0.962685			
41	0.020973	0.256026	76	0.013833	0.453921			
42	0.053548	0.099357	77	0.004462	0.917818			
43	0.034806	0.276003	78	0.000892	0.962685			
44	0.012941	0.215921	79	0.005801	0.464667			
45	0.049978	0.206938	80	0.000892	0.962685			
46	0.025435	0.415554	81	0.011156	0.349385			
47	0.019188	0.28598	82	0.008925	0.557972			
48	0.045069	0.314197	83	0.001785	0.609743			
49	0.020973	0.282038	85	0.004462	1.030507			
50	0.021865	0.293191	86	0.00357	0.78473			
51	0.044623	0.30283	88	0.00714	0.552563			
52	0.006247	0.496471	90	0.000892	0.962685			
53	0.020973	0.452249	92	0.001339	0.337799			
54	0.024543	0.326981	93	0.005355	0.605698			
55	0.016957	0.390807	97	0.001339	0.917818			

Table B2: Estimated age frequencies for Cook Canyon male orange roughy from the 2019 acoustic survey.

Age	Frequency	CV	Age	Frequency	CV
19	0.00253	1.003596	60	0.004428	0.908708
24	0.00506	1.003596	61	0.00506	0.914562
25	0.009488	0.536461	63	0.019608	0.352096
26	0.00253	1.003596	64	0.008855	1.003596
28	0.033523	0.390558	65	0.005693	0.894264
29	0.018343	0.51217	69	0.019608	0.354473
30	0.005693	0.613659	72	0.005693	0.889441
31	0.034788	0.23789	73	0.01012	0.565502
32	0.01012	0.614139	76	0.01265	0.541453
33	0.024035	0.41958	79	0.003795	0.908708
34	0.037951	0.340283	80	0.004428	0.908708
35	0.031626	0.317955	81	0.005693	0.889441
36	0.02783	0.240016	82	0.004428	0.914562
37	0.02783	0.461051	83	0.00506	0.908708
38	0.032891	0.36689	85	0.010753	0.891402
39	0.031626	0.271919	90	0.004428	0.908708
40	0.033523	0.564733	93	0.001265	0.914562
41	0.019608	0.479648	98	0.00506	0.891402
42	0.053131	0.289017	104	0.006958	0.908708
43	0.024035	0.517661	129	0.006958	0.914562
44	0.033523	0.29783	138	0.00506	0.914562
45	0.060089	0.22865			
46	0.037318	0.323001			
47	0.013283	0.406372			
48	0.037951	0.33503			
49	0.02277	0.316904			
50	0.026565	0.169602			
51	0.018343	0.195676			
52	0.011385	0.50512			
53	0.029728	0.675565			
54	0.018343	0.377511			
55	0.024035	0.370138			
57	0.031626	0.232083			
58	0.003163	0.914562			
59	0.01012	0.70876			

Table B3: Estimated age frequencies for Cook Canyon orange roughy from the 2019 acoustic survey.

Age	Frequency	CV	Age	Frequency	CV	Age	Frequency	CV	Age	Frequency	CV
19	0.004799	0.995671	54	0.02601	0.345177	89	0	0	124	0	0
20	0	0	55	0.031157	0.258777	90	0.003299	0.892825	125	0	0
21	0.003007	0.795013	56	0.005584	0.279812	91	0	0	126	0	0
22	0	0	57	0.019033	0.247872	92	0.007732	0.392534	127	0	0
23	0.002577	0.972301	58	0.012538	0.390247	93	0.002059	0.650602	128	0	0
24	0.004895	0.708182	59	0.007717	0.426158	94	0	0	129	0.0009	0.908989
25	0.005058	0.468459	60	0.007813	0.380234	95	0	0	130	0	0
26	0.006565	0.52891	61	0.005795	0.402756	96	0	0	131	0.004296	0.634124
27	0.002577	0.922492	62	0.006873	0.40635	97	0.002577	0.905326	132	0	0
28	0.020459	0.294216	63	0.01733	0.292157	98	0.003988	0.703136	133	0	0
29	0.015564	0.466341	64	0.008324	0.522587	99	0	0	134	0	0
30	0.011461	0.367884	65	0.004418	0.607671	100	0.002577	0.905326	135	0	0
31	0.017056	0.224858	66	0.001718	0.972688	101	0	0	136	0	0
32	0.01429	0.359765	67	0.009021	0.3886	102	0	0	137	0	0
33	0.016893	0.31795	68	0.010739	0.275459	103	0.004725	0.481617	138	0.0012	0.908989
34	0.030113	0.262465	69	0.008098	0.391216	104	0.005147	0.659864	139	0	0
35	0.020411	0.378814	70	0.003436	0.571432	105	0	0	140	0	0
36	0.02337	0.237342	71	0.006443	0.377917	106	0.001718	0.905326	141	0	0
37	0.022518	0.355067	72	0.006525	0.486298	107	0	0	142	0	0
38	0.027309	0.325467	73	0.008235	0.529531	108	0.001289	0.795013	143	0	0
39	0.038785	0.242763	74	0.006014	0.487082	109	0	0	144	0	0
40	0.035478	0.327059	75	0.000859	0.992598	110	0.001289	0.905326	145	0	0
41	0.012905	0.460628	76	0.011194	0.38509	111	0.000859	0.972688	146	0	0
42	0.029117	0.195652	77	0.002577	0.905326	112	0	0	147	0.002148	0.905326
43	0.034231	0.21836	78	0.000859	0.992598	113	0.003007	0.641195			
44	0.023151	0.223144	79	0.011809	0.351889	114	0.000859	0.972688			
45	0.048531	0.221465	80	0.0018	0.892825	115	0.000859	0.795013			
46	0.027147	0.279193	81	0.006865	0.445124	116	0	0			
47	0.021374	0.231655	82	0.004807	0.660751	117	0.003866	0.795013			
48	0.037885	0.315755	83	0.004077	0.697102	118	0	0			
49	0.018148	0.300646	84	0	0	119	0	0			
50	0.027543	0.229675	85	0.002529	0.799688	120	0	0			
51	0.031294	0.257908	86	0.005584	0.527978	121	0	0			
52	0.01639	0.383395	87	0	0	122	0.001718	0.972301			
53	0.022048	0.414788	88	0.004296	0.631853	123	0.000859	0.905326			