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Age compositions of orange roughy from the Puysegur Bank region (ORH 3B) in 1992 and 2015

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EXECUTIVE SUMMARY

Doonan, I.J.; Horn, P.L.; Ó Maolagáin, C.; Datta, S. (2019). Age compositions of orange roughy from the Puysegur Bank region (ORH 3B) in 1992 and 2015.

***New Zealand Fisheries Assessment Report 2019/04*. 14 p.**

Age frequencies were estimated for orange roughy (*Hoplostethus atlanticus*) sampled in the Puysegur Bank region (ORH 3B) using otoliths sampled from both a 1992 random trawl survey and a 2015 acoustic survey. The age frequencies represent an early and a recent age composition for use in future stock assessments. Otoliths were prepared and read by one reader following the accepted ageing protocol methods. The sample size was around 400 otoliths for each survey (397 and 398 respectively) The 2015 survey had an age mode around 35 years, and fewer fish in the 55 to 70 year age range than seen in the 1992 sample. The 1992 survey had an age mode at around 45 years. The frequencies from the two surveys were similar for fish older than 80 years. 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 2 of Project DEE201620, "Routine age determination of middle depth and deepwater species from commercial fisheries and resource surveys", and was funded by the Ministry for Primary Industries (MPI). The research in 2016–17 was the preparation and ageing of otoliths of orange roughy sampled from the Puysegur Bank region (in ORH 3B), from a trawl survey carried out in 1992 and from an acoustic survey of spawning plumes that took place 23 years later in 2015. These data enable the estimation of age frequencies from early in the fishery and also from 18 years after the fishery had been closed. The revised age distributions 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 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 The Puysegur Bank fishery and relevant research

Late in 1990, substantial quantities of orange roughy, black oreo (*Allocyttus niger*), and smooth oreo (*Pseudocyttus maculatus*) were caught by several commercial vessels off southern Puysegur Bank west of Stewart Island (Clark & Tracey 1992). This led to a survey in the region carried out for the Exploratory Fishing Company (ORH 3B) Limited, comprising an exploratory fishery phase followed by a trawl survey conducted by the then MAF Fisheries (now Fisheries New Zealand) using the commercial FV *Will Watch* (Clark & Tracey 1992). A two-phase stratified random trawl survey design was applied (after Francis 1984). The survey area was divided into 14 strata on the basis of catches and bottom features found during the exploratory fishing phase carried out in the three weeks prior to the survey being started. Also used to inform the survey design was the experience and knowledge of M.R. Clark (then MAF Fisheries, now NIWA) about distribution and abundance patterns of orange roughy in other fisheries. The survey period was 2–22 July 1991.

Based on the 1991 survey results, a voluntary catch limit for the Puysegur Bank region of 5000 t was set for 1992−93, but with a requirement that another survey take place in 1992 (see below). The catch limit remained at 5000 t for 1993−94, then was reduced in subsequent years to 2000 t, 1000 t, and finally to 500 t in 1996−97. The fishery was voluntarily closed in 1997−98 to enable rebuilding of the stock. It was re-opened in 2010–11 with a catch limit of 150 t (Ministry for Primary Industries 2014).

A Puysegur Bank exploratory fishing and a two-phase random trawl survey was repeated in June–August 1992, using the FV *Giljanes* (voyage GIL9201) in a cooperative venture between the Exploratory Fishing Company (ORH 3B) Limited and MAF Fisheries (Clark & Tracey 1993). The random survey occurred from 9 to 25 July 1992, and the strata were re-designed based on the 1991 survey results. This restratification improved the precision with more tows allocated in important high orange roughy catch rate strata. Because the 1992 survey had better coverage overall of the population distribution at Puysegur Bank, it was decided that otoliths from this second research survey would be chosen to produce the early fishery age frequency for this report.

In 2015, the Deepwater Group Ltd funded Australian researchers to carry out an acoustic survey in the Puysegur Bank region using the FV *Amaltal Explorer* (voyage AEX1501) (Ryan & Tilney 2016). During the acoustic survey some trawling was carried out on spawning aggregations of orange roughy in the region. In total, 11 tows were carried out and otoliths from these trawls were chosen to produce a second age frequency from the recent period. The 2015 age distribution was then compared with that estimated from the 1992 trawl survey data.

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 there are on-going and consistent zone interpretations and no reader drift (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 Analytical methods

2.2.1 Otolith selection

The method of analysis followed that of Doonan et al. (2013) for orange roughy region ORH 7A. The number of otoliths to prepare is n_{unique}. Otoliths were selected with replacement until the specified total number of unique otoliths, $n_{\text{unique,}}$ is reached. The procedure was continued to provide a selection of additional '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 depended on the sampling design:

- stratified random trawl surveys (applicable to the 1992 random trawl survey on *Giljanes*): selection probabilities are proportional to the total numbers in each stratum and within that, the square-root of the numbers of fish caught in each tow (or to catch weight in the tow, if mean fish weights are similar across all tows) divided by the number of otoliths from the tow.
- sampling of commercial catch (applicable to the 2015 acoustic survey on *Amaltal Explorer*): selection probabilities are proportional to the numbers of fish caught in each tow (or to catch weight in the tow, if mean fish weights are similar across all tows) divided by the number of otoliths from 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}.

The proposed otolith sample size was 400 for each survey. The trawl tows sampled in the 2015 acoustic survey were not from any defined strata, hence orange roughy otolith selection from this survey was as described above for the sampling of commercial catches.

2.2.2 Analysis

The data consisted of the age estimated 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. For stratified surveys, these tows were resampled within strata.

Kernel smoothing was used to show the density of the age estimates in the resulting plots. The smoothing method 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) and *width* was set to 10.

2.3 1992 trawl survey

Age data from 1992 were estimated from samples collected during a two-phase stratified random trawl survey in the Puysegur Bank region (Figure 1) (Clark & Tracey 1993). Tow distance was 3.0 n. miles and mean tow speed was about 3 knots.

In the current age frequency analysis, strata were excluded where estimated orange roughy abundance was 1.2% or less of the total, or where there were low catches in a stratum area such as occurred in the Snares Islands strata.). This left seven of the original 15 strata available to be used in the analysis (strata 4, 10, 11, 31–33, and 51). These strata accounted for around 97% of the estimated abundance for the survey. Tows with no otoliths were also removed. The survey sampling had produced 40 tows with otolith data, with up to 20 otoliths per tow for most tows, but 40 otoliths per tow when catches were large. This resulted in a total of 788 otoliths to choose from for the 1992 analysis.

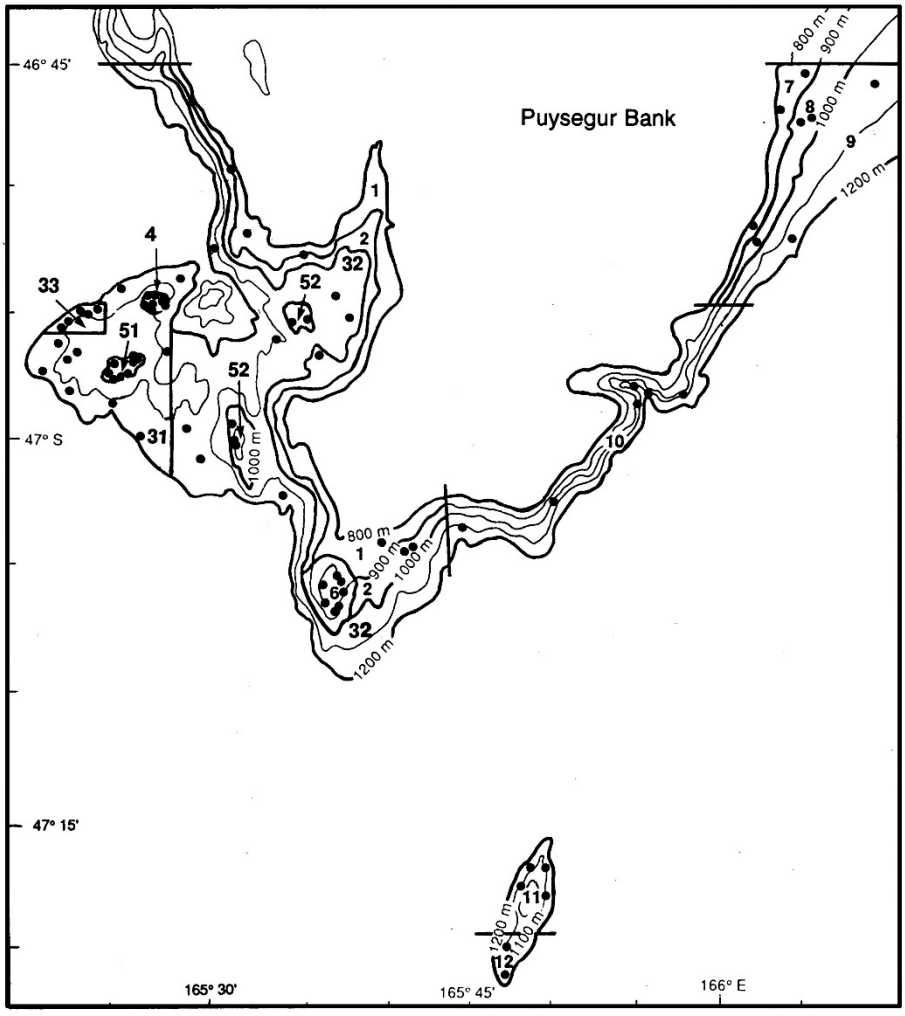

Figure 1: Stratification for the 1992 Puysegur Bank random trawl survey by FV *Giljanes*, showing strata and tow positions as black dots (from Clark & Tracey 1993).

2.4 2015 acoustic survey

In the 2015 acoustic survey at Puysegur Bank, trawls were centred primarily in two areas (Figure 2), in the region of the 1992 high density stratum 51. These areas each had 2–3 tows carried out in them producing large catches (over 4.5 t) (Figure 2). Two tows were conducted outside the main areas of high fish density. In total, 11 tows from the high catch rate areas had 830 otoliths which could be used in the age analysis.

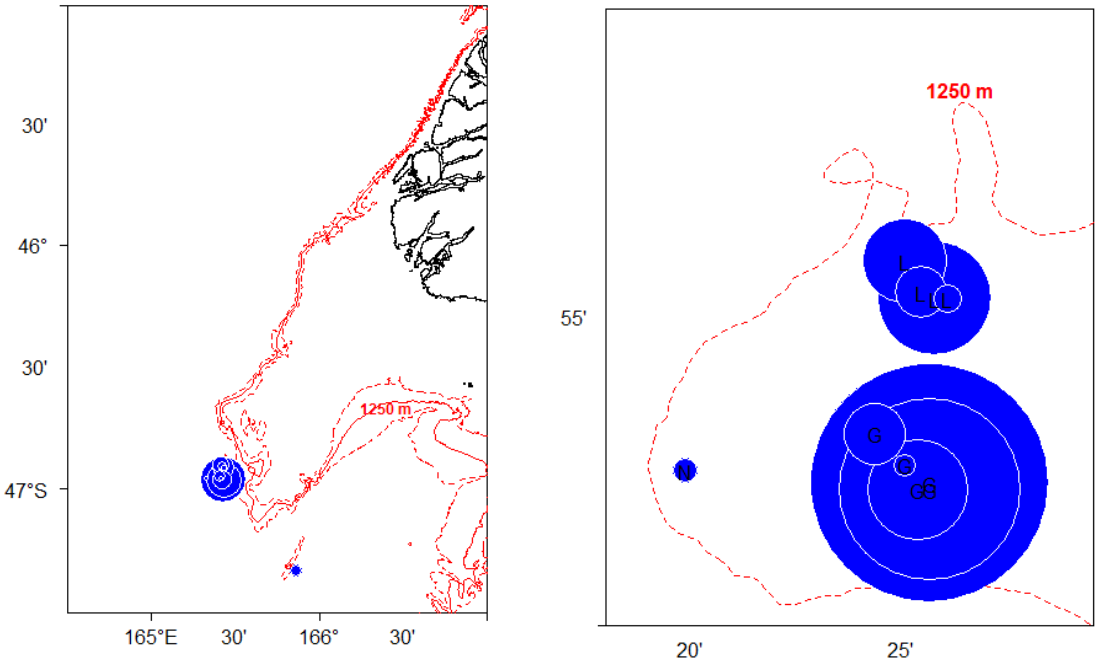

Figure 2: Survey area for the 2015 acoustic survey by FV *Amaltal Explorer*, showing the location of the trawl catches from which otoliths were available (blue circles). Circle size is proportional to the catch of orange roughy.

3. RESULTS

3.1 1992 trawl survey

The number of otoliths prepared and read from the 1992 survey was 399, but two otoliths were excluded because of readability problems (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 1992 age frequency distribution, with a smoothed density through the age estimates, is shown in Figure 3 with data listed in Appendix B (Table B1). The distribution is dominated by orange roughy with a broad mode from about 35 to 70 years, but there is also a significant number of younger fish centred at around 25 years. There is a reasonable number of fish aged older than 70 years (19% of the sample), and some fish older than 100 years. The mean weighted coefficient of variation (MWCV) was 52%.

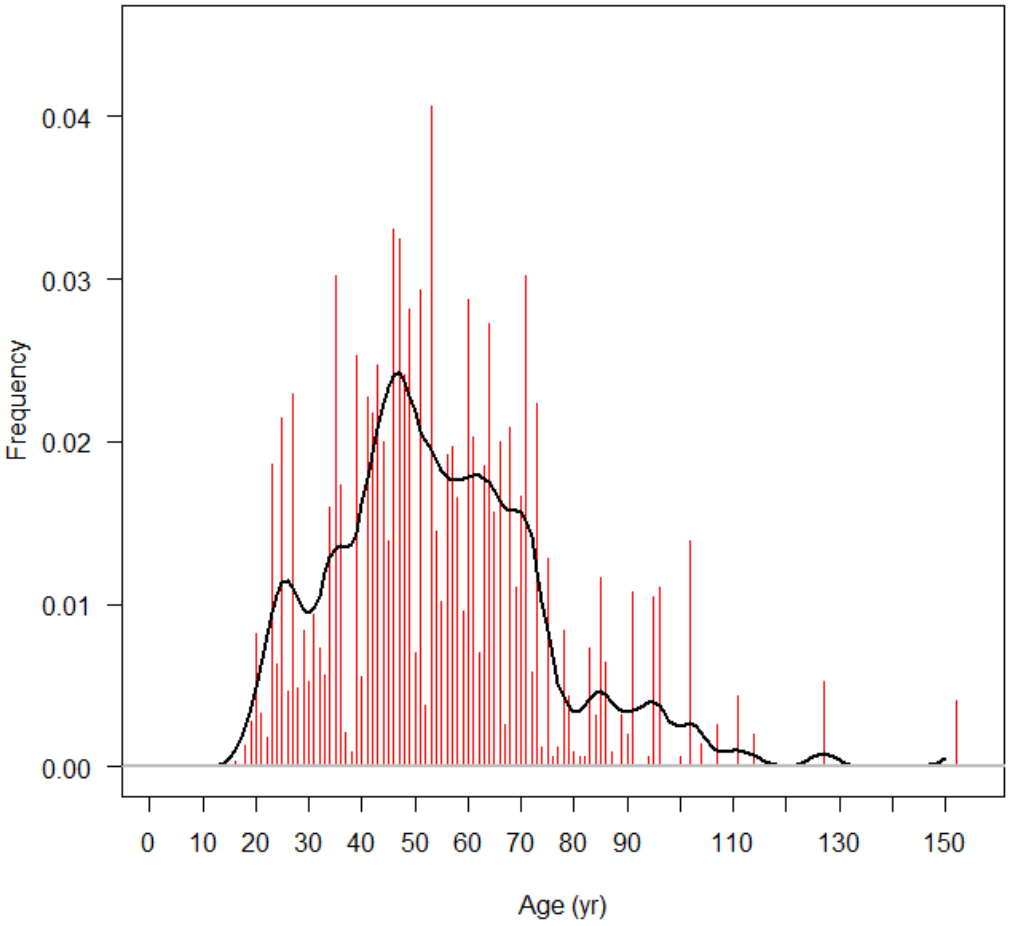

Figure 3: 1992 trawl survey: Estimated age frequency (red bars) for Puysegur Bank with a smoothed density through the age estimates (black curve).

3.2 2015 acoustic survey

The number of otoliths prepared and read from the 2015 survey samples was 400, but two 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 A2).

The 2015 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 an age range of about 25 to 50 years and a mode centred near 35 years. Fish up to about 75 years are reasonably well represented (only 11% of fish were older), but the distribution does extend beyond 100 years. The MWCV was 42%.

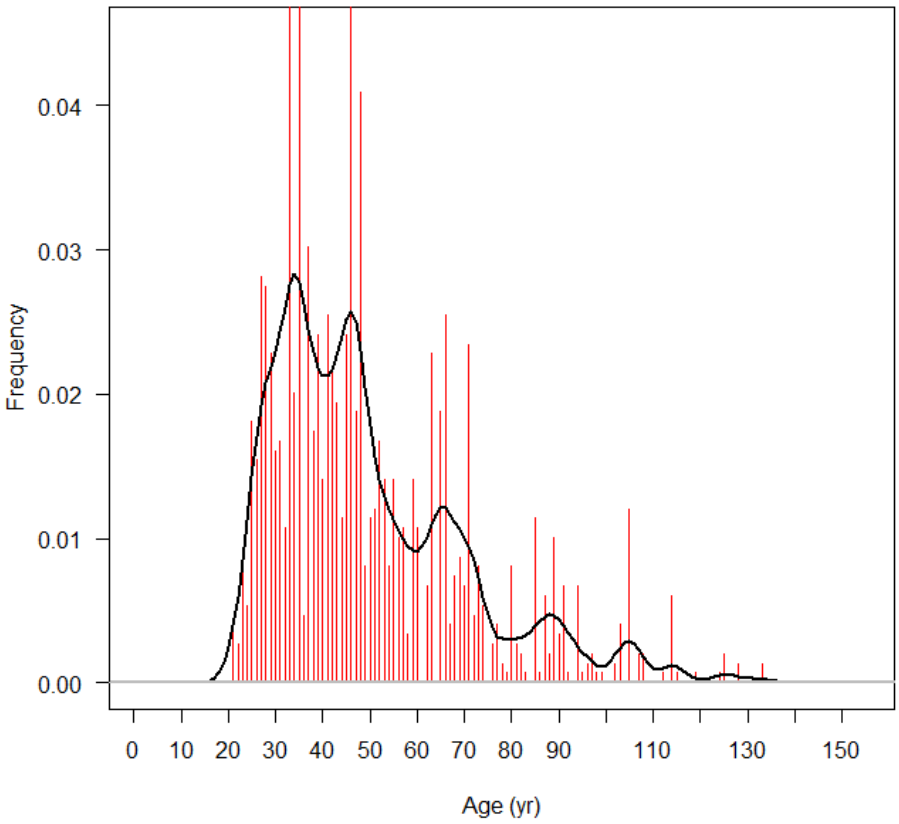

Figure 4: 2015 acoustic survey: Estimated age frequency (red bars) for Puysegur Bank with a smoothed density through the age estimates (black curve).

4. DISCUSSION

The smoothed age distributions from the 1992 and 2015 surveys are compared in Figure 5. In contrast to the 1992 distribution, the 2015 survey has a greater abundance of younger individuals, with an age mode around 35 years, and fewer fish in the 55 to 70 year age range. The 1992 survey has a mode at around 45 years, and relatively more fish in the 45 to 75 year age range than in 2015. For older fish, those aged to over 80 years, the frequencies from the two surveys are similar.

There is a marked difference in the shapes of these age distributions from data sets collected 23 years apart. While the frequencies of fish older than 80 years do not appear to differ between samples, there is clearly a greater proportion of younger fish in the later sample. This could be encouraging from the point of view of a stock rebuild, but could also be explained by heavy exploitation of middle-aged fish when the fishery was initially active. It could also be postulated that the mode of fish around 40–50 years old in 1992 has progressed through to produce the mode around 60–70 years old in 2015.

The data produced in this work could be used to provide revised estimates of productivity parameters for the Puysegur Bank 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 otolith transition zone would also enable age at maturity to be estimated.

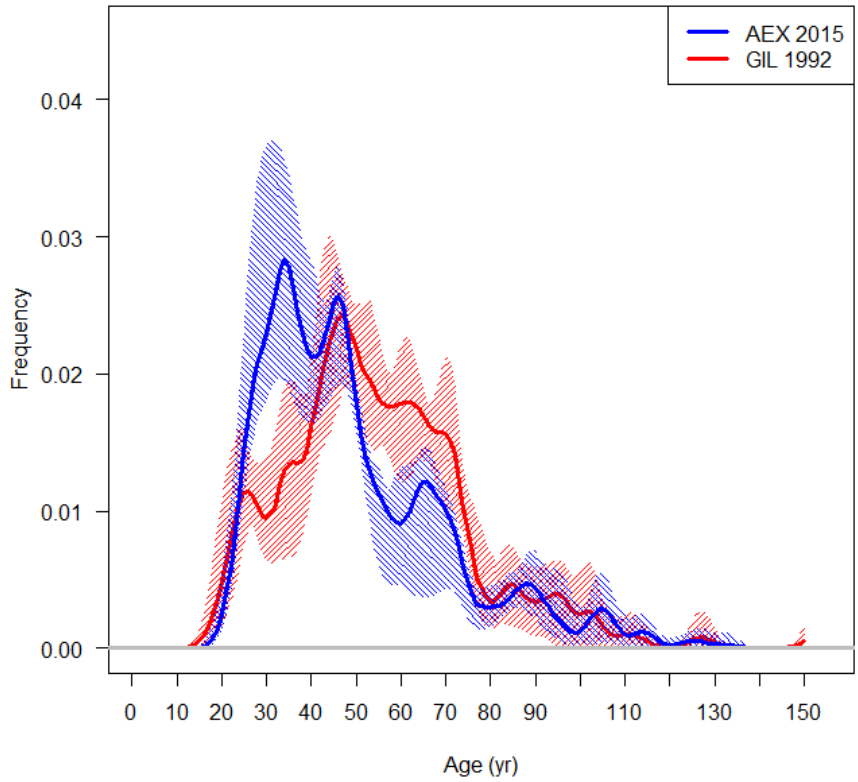

Figure 5: Comparisons of the age frequency distributions of Puysegur Bank orange roughy from the 1992 (red) and 2015 (blue) surveys. The pairwise 95% confidence limits are indicated by the shaded areas.

5. ACKNOWLEDGMENTS

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APPENDIX A: STATION WEIGHT AND OTOLITH SELECTION PROBABILITIES

Table A1: 1992 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
51	57	667	0.000814	20	0.0000407
51	58	18 228	0.022242	40	0.0005560
4	61	4 459	0.002936	20	0.0001468
32	62	91	0.003789	20	0.0001895
32	63	8	0.000343	15	0.0000229
32	65	5	0.000226	6	0.0000376
4	67	120	0.000079	20	0.0000040
10	70	15	0.001024	20	0.0000512
51	72	2 851	0.003479	20	0.0001739
31	73	19	0.000223	15	0.0000148
51	74	27 555	0.033623	40	0.0008406
11	78	78	0.001956	20	0.0000978
11	79	2 191	0.054955	20	0.0027478
31	82	16	0.000195	24	0.0000081
51	83	5 702	0.006958	20	0.0003479
4	84	1 531	0.001008	20	0.0000504
33	86	12 830	0.108848	40	0.0027212
51	87	1 663	0.002029	20	0.0001015
4	91	950	0.000625	20	0.0000313
4	92	330	0.000217	20	0.0000109
51	94	132	0.000161	20	0.0000080
51	95	715	0.000872	20	0.0000436
11	99	136	0.003404	20	0.0001702
32	103	8	0.000322	18	0.0000179
51	107	1 214	0.001481	20	0.0000741
31	108	1 458	0.017355	20	0.0008678
31	109	4	0.000051	4	0.0000128
31	111	150	0.001786	20	0.0000893
4	112	12 852	0.008461	20	0.0004231
11	116	53	0.001324	8	0.0001655
33	121	3 142	0.026656	20	0.0013328
32	122	660	0.027604	20	0.0013802
31	125	607	0.007225	20	0.0003613
33	126	4	0.000032	3	0.0000107
4	128	16	0.000011	12	0.0000009
4	129	11 959	0.007873	20	0.0003937
10	132	15	0.001038	13	0.0000799
33	135	2 323	0.019708	20	0.0009854
33	137	16 447	0.139535	20	0.0069767
10	138	1 980	0.137974	20	0.0068987

Table A2: 2015 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
–	21	8 464	0.098384	100	0.00098
–	27	1 804	0.020968	100	0.00021
–	30	416	0.004839	100	0.00005
–	31	21 250	0.247012	100	0.00247
–	41	2 618	0.030432	100	0.00030
–	46	509	0.005914	41	0.00014
–	48	37 000	0.430091	100	0.00430
–	52	6 568	0.076341	60	0.00127
–	55	4 579	0.053224	50	0.00106
–	58	2 498	0.029031	60	0.00048
–	60	324	0.003764	29	0.00013

APPENDIX B: ESTIMATED AGE FREQUENCIES

Table B1: Estimated age frequencies for Puysegur Bank orange roughy from the 1992 trawl survey (GIL9201).

Age	Frequency	CV	Age	Frequency	CV	Age	Frequency	CV
11	2.44E-05	0.962487	48	0.024087	0.362415	81	0.000580	0.994397
15	7.32E-05	1.024146	49	0.028149	0.382431	82	0.000580	1.000929
16	0.000317	1.013887	50	0.006965	0.596692	83	0.007255	0.697847
18	0.001291	0.751065	51	0.029310	0.328435	84	0.003192	0.878777
19	0.002807	0.819224	52	0.003773	0.796425	85	0.011608	0.695515
20	0.008201	0.912512	53	0.040628	0.322238	86	0.006384	0.558657
21	0.003244	0.722916	54	0.014510	0.479233	87	0.000871	1.063630
22	0.001766	0.698879	55	0.010157	0.523274	89	0.003192	0.926409
23	0.018649	0.576263	56	0.019153	0.445660	90	0.002031	0.994397
24	0.006363	0.569398	57	0.019734	0.533828	91	0.010737	0.690334
25	0.021480	0.465389	58	0.016541	0.569622	94	0.000580	0.975131
26	0.004643	0.650934	59	0.009577	0.507843	95	0.010447	0.769945
27	0.022956	0.429270	60	0.028730	0.607729	96	0.011028	0.849745
28	0.004893	0.560003	61	0.020314	0.455779	100	0.000580	1.063630
29	0.008394	0.527863	62	0.006965	0.627588	102	0.013930	0.849745
30	0.005224	0.599791	63	0.018470	0.456783	104	0.001451	0.994397
31	0.009360	0.500950	64	0.027257	0.345828	107	0.002612	0.994397
32	0.007255	0.544106	65	0.015671	0.697775	111	0.004353	0.878777
33	0.005633	0.641425	66	0.020024	0.417805	114	0.002031	1.043707
34	0.015961	0.487691	67	0.002612	0.842276	127	0.005224	0.878777
35	0.030205	0.347455	68	0.020894	0.486017	152	0.004063	0.878777
36	0.017360	0.422448	69	0.011028	0.833036			
37	0.002056	1.033128	70	0.016615	0.755102			
38	0.000871	1.013884	71	0.030181	0.604411			
39	0.025247	0.393355	72	0.005804	0.535933			
40	0.005514	0.583594	73	0.022345	0.453999			
41	0.022714	0.480413	74	0.001161	0.824148			
42	0.021765	0.367825	75	0.012769	0.539792			
43	0.024667	0.609765	76	0.000580	0.730127			
44	0.020024	0.671347	77	0.001161	0.827572			
45	0.013930	0.439744	78	0.008416	0.783226			
46	0.033083	0.567538	79	0.004353	0.727978			
47	0.032502	0.289877	80	0.000871	1.043707			

Table B2: Estimated age frequencies for Puysegur Bank orange roughy from the acoustic survey in 2015 (AEX1501).

Age	Frequency	CV	Age	Frequency	CV
21	0.004021	1.097364	67	0.004021	0.600964
22	0.002681	0.677483	68	0.007373	0.540093
23	0.009383	0.566030	69	0.008713	0.418841
24	0.005362	0.765149	70	0.006702	0.690635
25	0.018097	0.370631	71	0.023458	0.278977
26	0.015416	0.663656	72	0.004692	0.868870
27	0.028150	0.532817	73	0.008043	0.407242
28	0.027480	0.215728	74	0.005362	0.747378
29	0.022788	0.270013	76	0.002681	0.677200
30	0.016086	0.284180	77	0.004021	0.836965
31	0.016756	0.605246	78	0.001340	1.331529
32	0.010724	0.491047	79	0.000670	1.230398
33	0.058981	0.171080	80	0.008043	0.359672
34	0.020107	0.259354	81	0.002681	0.888072
35	0.053619	0.327175	82	0.002011	0.992489
36	0.004692	0.751938	83	0.000670	1.230398
37	0.030161	0.094011	85	0.011394	0.388436
38	0.017426	0.391695	86	0.000670	1.230398
39	0.024129	0.319558	87	0.006032	0.888072
40	0.014075	0.666277	88	0.002011	1.097364
41	0.025469	0.370921	89	0.010054	0.403588
42	0.021448	0.260772	90	0.003351	0.688172
43	0.019437	0.289784	91	0.006702	0.696148
44	0.011394	0.200443	92	0.000670	1.439535
45	0.024129	0.458605	94	0.006702	0.695458
46	0.052949	0.133904	95	0.000670	1.230398
47	0.018767	0.188945	96	0.001340	1.331529
48	0.040885	0.142334	97	0.002011	1.230398
49	0.008043	0.210954	98	0.000670	1.230398
50	0.011394	0.507031	99	0.000670	1.230398
51	0.012064	0.406446	102	0.001340	1.088034
52	0.016756	0.651524	103	0.004021	0.888072
53	0.014075	0.216396	105	0.012064	0.497028
54	0.008043	0.611593	107	0.002011	0.888072
55	0.014075	0.693460	108	0.002011	1.230398
56	0.010054	0.548927	112	0.000670	1.230398
57	0.010724	0.836965	114	0.006032	0.888072
58	0.003351	0.688172	115	0.000670	1.097364
59	0.014075	0.618497	119	0.000670	1.230398
60	0.010724	0.719025	124	0.000670	1.230398
62	0.006702	0.599418	125	0.002011	0.888072
63	0.022788	0.370555	128	0.001340	1.230398
65	0.018767	0.382174	133	0.001340	1.097364
66	0.025469	0.323628			