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Tini a Tangaroa

Age compositions of smooth oreo samples from OEO 4, Chatham Rise: 1991 trawl survey, 2008–09 commercial catch, and 2016 acoustic survey.

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I.J. Doonan
P.J. McMillan
C. Ó Maolagáin
S. Datta

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EXECUTIVE SUMMARY

Doonan, I.J.; McMillan, P.J.; Ó Maolagáin, C.; Datta, S. (2018). Age compositions of smooth oreo samples from OEO 4, Chatham Rise: 1991 trawl survey, 2008–09 commercial catch, and 2016 acoustic survey.

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Smooth oreo (*Pseudocyttus maculatus*) otoliths sampled from a 1991 relative abundance trawl survey (TAN9104), the 2008–09 commercial fishery collected by observers, and a 2016 abundance acoustic survey were prepared and aged. About 400 otoliths from each source were read by one reader following the accepted ageing protocol. The aim was to develop age compositions for use in a stock assessment of the OEO 4 smooth oreo population. The smoothed age distribution from the 1991 survey had a mode at about 22 years, while that from the 2008–09 commercial fishery had a mode at about 24 years but had relatively few fish older than about 40 years. The 2016 acoustic survey smooth age distribution had a main mode at about 18 years, and secondary modes at around 9 and 29 years. The multi-modal structure of the 2016 sample may reflect the small number of tows available for that analysis.

1. INTRODUCTION

This report fulfils parts of the reporting requirements for Objectives 1 and 2 of Project DEE2016-20, "Routine age determination of middle depth and deepwater species from commercial fisheries and resource surveys", funded by the Ministry for Primary Industries. The objectives were:

1. To determine catch-at-age for commercial catches and resource surveys of specified middle depth and deepwater fishstocks
2. To age other species as required for targeted studies to meet specific research requirements

This work aimed to provide age estimates for smooth oreo (*Pseudocyttus maculatus*) from OEO 4 to produce numbers-at-age distributions for input into a stock assessment. The last published smooth oreo stock assessment (Fu & Doonan, 2015) used age estimates from the 1998 and 2005 acoustic surveys and abundance estimates from the 1998, 2001, 2005, 2009, and 2012 acoustic surveys. The Deepwater Fisheries Assessment Working Group decided to include an age distribution estimate from an older research survey (in 1991) to provide a comparison with age distribution estimates from the recent commercial fishery (2008–09) and 2016 research acoustic survey.

In New Zealand, smooth oreo age determination methods were developed by Doonan et al. (1995) and gave a maximum estimated age from otolith zone counts of 86 years (51.3 cm TL fish). Estimates of life history parameters were later refined by Doonan et al. (1997), but routine age estimation for smooth oreo was not carried out for this species until 2008 when Doonan et al. (2008) reported age distributions for samples collected during acoustic surveys of OEO 4 smooth oreo in 1998 and 2005. Prior to 2008 there were no population age estimates available for stock assessments. Validation of smooth oreo age estimates using otolith zone counts is difficult because techniques such as tagging, and seasonal otolith marginal increment formation are impractical. Atomic weapon testing in the Pacific Ocean in the 1950s resulted in elevated environmental levels of C^{14} levels, and this was used by Kalish (1993) to develop a method for testing the age of long-lived fishes. A preliminary study of C^{14} levels in smooth oreo otoliths provided only partial support for age estimates made using otolith zone counts (Neil et al. 2008), and the method remains un-validated.

Substantial catch of smooth oreo from OEO 4 was first reported in 1981–82, and a TAC (6750 t, for combined oreo species) was established in 1982–83 but was reduced to 3000 t in 2015–16 following a stock assessment based largely on research survey abundance estimates (Ministry for Primary Industries 2017). Smooth oreo mean annual catch from 1997–98 to 2007–08 was 5300 t (Ministry for Primary Industries 2017).

2. METHODS

A total of 400 otoliths were selected from each of the three sources.

2.1 1991 research trawl survey

The 1991 relative abundance stratified random trawl survey of black oreo and smooth oreo from the south Chatham Rise (OEO 3A and OEO 4) was carried out using *Tangaroa* (voyage TAN9104) from 11 October to 9 November (McMillan & Hart 1994). This was the first of a new time series of trawl surveys using *Tangaroa* (subsequent surveys were conducted in 1992, 1993, and 1995), but it did not include some hills which were first sampled in the 1992 survey. The survey area showing subareas 3–5 in Fishstock area OEO 4 is in Figure 1.

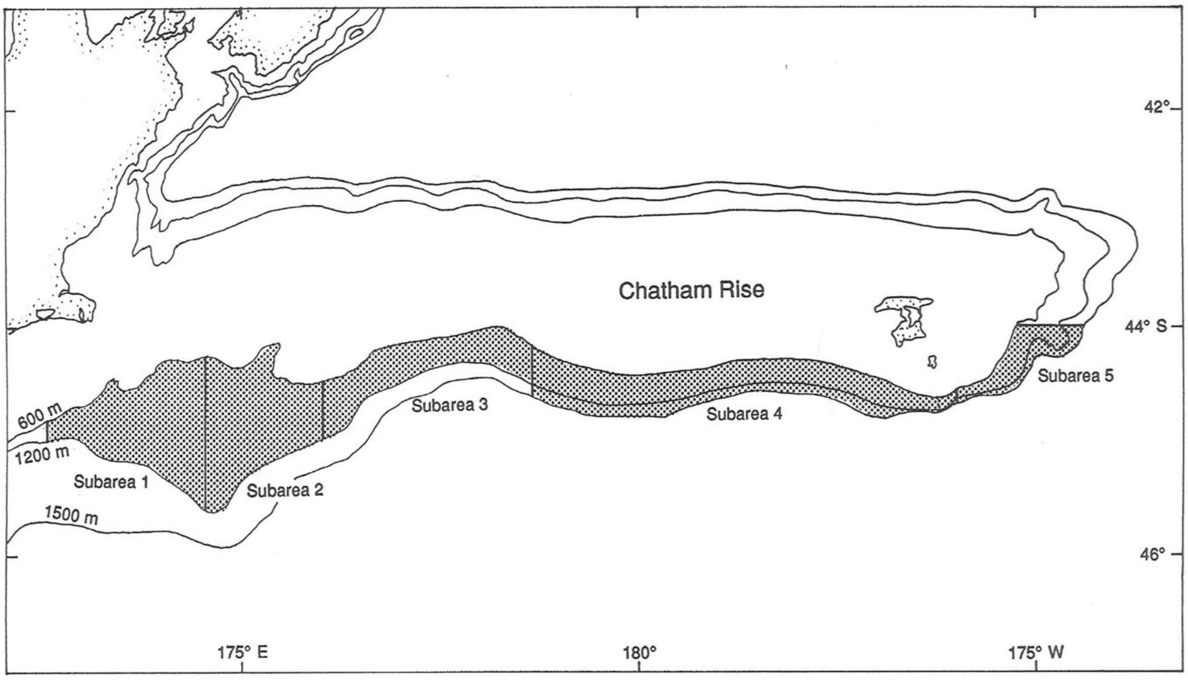

Figure 1: Survey area for the 1991 trawl survey (TAN9104). OEO 4 includes subareas 3–5.

Standard biological sampling procedure in 1991 was to take up to 20 otoliths per tow from the survey target species (which included smooth oreo) irrespective of the size of the catch. Later surveys included the sampling of more otoliths from bigger catches. Subareas 3–5 contained 16 strata but only the 10 strata that provided 99% of the smooth oreo abundance were used for otolith selection. Otolith selection was proportional to the stratum abundance and catch size from each tow within the stratum, divided by the number of otoliths sampled from that tow, i.e., relatively more otoliths were selected from large catches. The selection was repeated for each otolith until 400 were chosen. A summary of the strata and numbers of tows used for the otolith selection is in Table 1.

Table 1: Details of survey strata and tows on the south Chatham Rise OEO 4 area during the 1991 trawl survey (TAN9104) used for otolith selection in the current analysis.

Subarea	Stratum	Area (km^2)	Depth (m)	No. of tows	Mean no. otoliths/tow	SSO abundance (‘000 t)
3	12	1 571	800–900	5	11	6.4
3	13	1 677	900–1000	8	14	33.0
3	14	2 123	1000–1100	4	10	28.0
4	17	2 890	800–900	6	14	33.0
4	18	2 364	900–1000	5	8	30.0
4	19	2 454	1000–1100	7	11	15.0
4	20	2 275	1100–1200	3	16	51.0
5	24	315	900–1000	3	17	3.7
5	25	593	1000–1100	3	16	1.8
5	26	614	1100–1200	4	13	4.2

2.2 The 2008–09 commercial fishery

Data and at least 600 otoliths from smooth oreo in OEO 4 collected by Ministry observers were available from each of the fishing years 2004–05 and 2011–12. Data were selected from MPI's commercial catch and effort database (CE) if they were derived from trawls that caught or targeted smooth oreo with start positions between latitudes 42° 00' and 47° 00' S, and also between longitudes 176° 00' E to 172° 00' W. Observer data (from MPI's COD database) were selected using the same criteria, but with an additional criterion that otoliths from smooth oreo were available from each trawl. There was variation between years in the areal and temporal distribution of the sampled tows, and also the target species (although most smooth oreo otoliths were sampled from tows targeting oreos or orange roughy). The 2007–08 and 2008–09 samples comprehensively sampled the geographical and temporal distribution of the smooth oreo target fishery. The latter year was chosen for analysis because it was closer to the current (2017) year. The 2008–09 data included 1284 otoliths, taken from 122 tows over 7 trips. The median catch of smooth oreo from sampled tows was 8.5 t. A plot of OEO 4 smooth oreo catch from 2008–09 by 0.1 degree longitude bins was compared with catches for tows sampled by observers scaled-up relative to the size of all the observed tows, and shows the relative importance of a small number (i.e., 7) of observed tows (Figure 2). In the CE data, about 68% of tows in 2008–09 had smooth oreo as the target, with orange roughy as the next main target species. About 84% of the selected observed tows had smooth oreo as the target species.

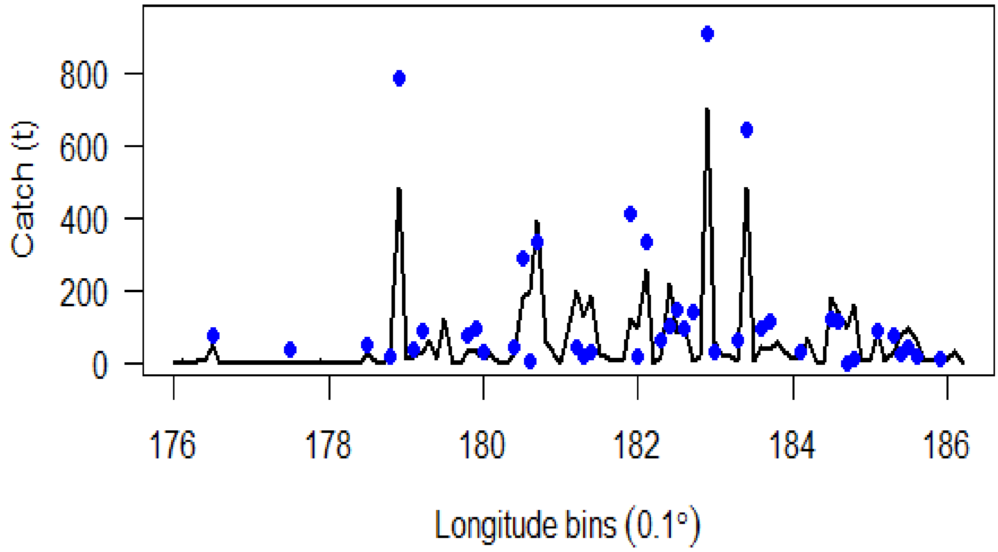

Figure 2: OEO 4 smooth oreo catch from 2008–09 by 0.1 degree longitude bins (black line) compared to relative catch for individual observed tows scaled up by the catch-per-tow and grouped in the same 0.1 degree longitude bins (blue dots).

The probability of otolith selection was proportional to the tow catch and inversely proportional to the number of otoliths in each tow, i.e., more otoliths were selected from large catches if there were sampled otoliths available. Otoliths were selected with replacement until there were 400 unique otoliths. A summary of the otoliths available for selection is in Table 2.

Table 2: Summary of the otoliths by observer trip collected from OEO 4 during 2008–09 used for otolith selection.

Trip code	2699	2714	2744	2807	2862	2864	2911
No. of tows	22	15	22	30	9	18	6
No. of otoliths	212	175	185	275	187	160	90

2.3 2016 research acoustic abundance survey

The 2016 acoustic abundance survey of black oreo and smooth oreo from the south Chatham Rise (OEO 3A and OEO 4) was carried out using *Amaltal Explorer* (voyage AEX1602, funded by MPI) from 16 October to 8 November (I. Doonan, NIWA, unpublished report). The 2016 survey area (Figure 3) was redesigned relative to earlier surveys to reduce cost, e.g., one survey vessel was used rather than an acoustic survey vessel and a catcher vessel. Separate flat and hill surveys were carried out. The survey area for the flat survey was divided into strata defined from analyses of previous research trawl survey results and historic smooth oreo commercial catch data, e.g., Doonan et al. (2000). Randomly selected north-south acoustic transects were carried out and mark identification tows were made on specific mark-types for each stratum. The list of hills to survey was defined from previous analyses of historic commercial catch and from information supplied from fishing industry sources, e.g., Doonan et al. (2000). All the important hills, a random selection of hills from a complex (Big Chief), and a random selection of named other hills were sampled. Hills were acoustically surveyed with either a star or parallel transect design, and mark identification tows were carried out on any substantial marks observed. A defined regime of catch and biological data recording, and otolith collection for smooth oreo samples was carried out for all mark identification tows.

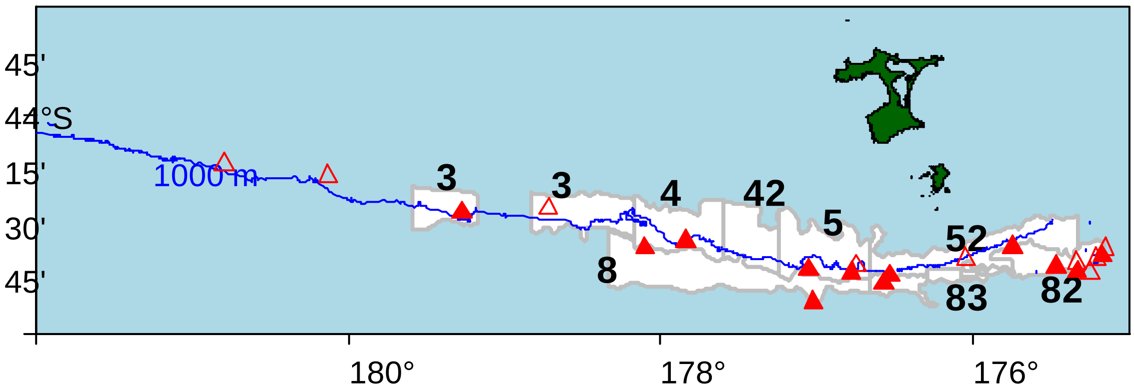

Figure 3: Survey strata and surveyed hills (filled triangles) for the 2016 smooth oreo acoustic survey of OEO 4. Bold numbers are the flat area strata. Strata 82 and 3 had two separate parts. Hills not surveyed are shown as open triangles.

The probability of otolith selection was proportional to the stratum-mark-type abundance and catch size from each tow within that stratum-mark-type, divided by the number of otoliths in the tow. Otoliths were selected with replacement until there were 400 unique otoliths. A summary of the otoliths available for selection is in Table 3.

Table 3: Summary of the sources of otoliths from OEO 4 collected during the 2016 acoustic survey (AEX1602) and used for otolith selection.

	Acoustic mark-type		
	Schools (deep)	Hills	Schools (shallow)
Number of tows	8	14	8
Mean number of otoliths per tow	36	2	36

2.4 Ageing of smooth oreo

Procedures for preparation and reading of smooth oreo otoliths in this study follow those described in Horn et al. (2018). Briefly, otoliths were marked along the dorso-ventral cutting axis, embedded in resin, three to a block, and cured in an oven. A thin section was cut and the section was mounted on a glass microscope slide under a glass cover slip. All otoliths were read once by one reader and zone counts and readability scores (5-stage scale) were produced for each otolith.

2.5 Analytical methods

2.5.1 Otolith selection

The method of analysis followed that of Doonan et al. (2013) for orange roughy in region ORH 7A. The target number of otoliths to prepare was 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 spare otoliths to replace any damaged or lost samples and 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 1991 random trawl survey on *Tangaroa*): 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 the square-root of catch weight in the tow, if mean fish weights are similar across all tows) divided by the number of otoliths from the tow,
- observer sampling of commercial catch (applicable to the 2008–09 commercial fishery sample): selection probabilities are proportional to the square-root of the numbers of fish caught in each tow (or to the square-root of catch weight in the tow, if mean fish weights are similar across all tows) divided by the number of otoliths in the tow,
- acoustic stratified surveys with mark-types (applicable to the 2016 survey on *Amaltal Explorer*): selection probabilities are proportional to the total numbers in each stratum/mark-type combination and within that, the square-root of numbers of fish caught in each tow (or to the square-root of catch weight in the tow, if mean fish weights are similar across all tows) divided by the number of otoliths in the tow.

Taking the square-root of the number of fish or the catch weight down-weights the influence of very large catches. The selection probability was based on all otoliths that were available and assumes 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 prepared otoliths n_{unique}.

2.5.2 Analysis

Otoliths with a readability score of 5 (i.e., unreadable) were excluded from the 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. For stratified surveys, these tows were resampled within strata or within stratum and mark-type combinations.

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.

2.5.3 Calculation of age frequency coefficient of variation

For the 1991 survey the coefficient of variation (CV) was calculated by using a bootstrapping procedure for tows within each stratum. The CV for the 2008–09 commercial data was also calculated using a bootstrapping procedure for tows (no strata). A slightly more complicated analysis was required for the 2016 acoustic survey CV calculation because low sample sizes for some mark-types required the use of tow data from the deficient mark-type from adjacent strata, but the CV was calculated by bootstrapping tows within their original stratum-mark-type.

3. RESULTS

3.1 Otolith samples selected and read

Details of the stations used in the analysis are listed in Appendix A (Table A1). Details of the otolith samples used in the age estimation analyses from the three sources are given in Table 4. Age frequency distributions are presented for the 1991 trawl survey (Figure 4), the 2008–09 commercial fishery (Figure 5) and the 2016 acoustic survey (Figure 6). Age-frequency data for all samples are listed in Appendix B.

Table 4: Details of the smooth oreo otolith samples from the 1991 trawl survey, the 2008–09 commercial fishery, and the 2016 acoustic survey of OEO 4 on Chatham Rise. *N*, initial number of otoliths selected; replacements, the number of otoliths replaced from the initial selected set (e.g., because the selected otoliths were missing or broken); rejects, the number of preparations unable to be aged (readability code = 5).

Survey	*N*	Replacements	Rejects
1991 trawl survey	400	9	4
2008–09 commercial fishery	400	0	10
2016 acoustic survey	400	0	2

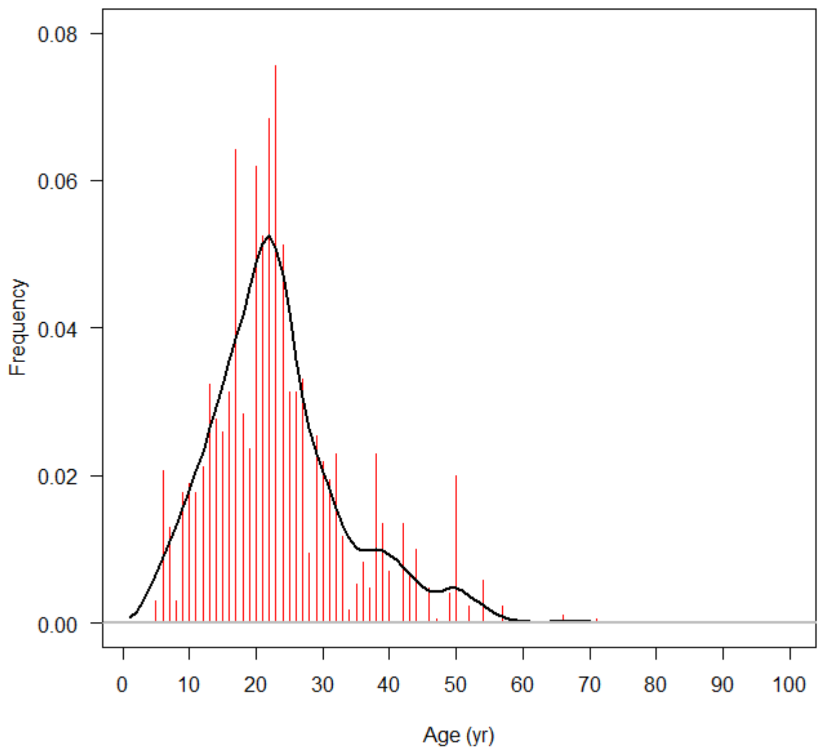

Figure 4: Estimated age frequency distribution (red bars) for the 1991 trawl survey smooth oreo otolith sample (*n* = 396) with a smoothed density through the age estimates (black curve).

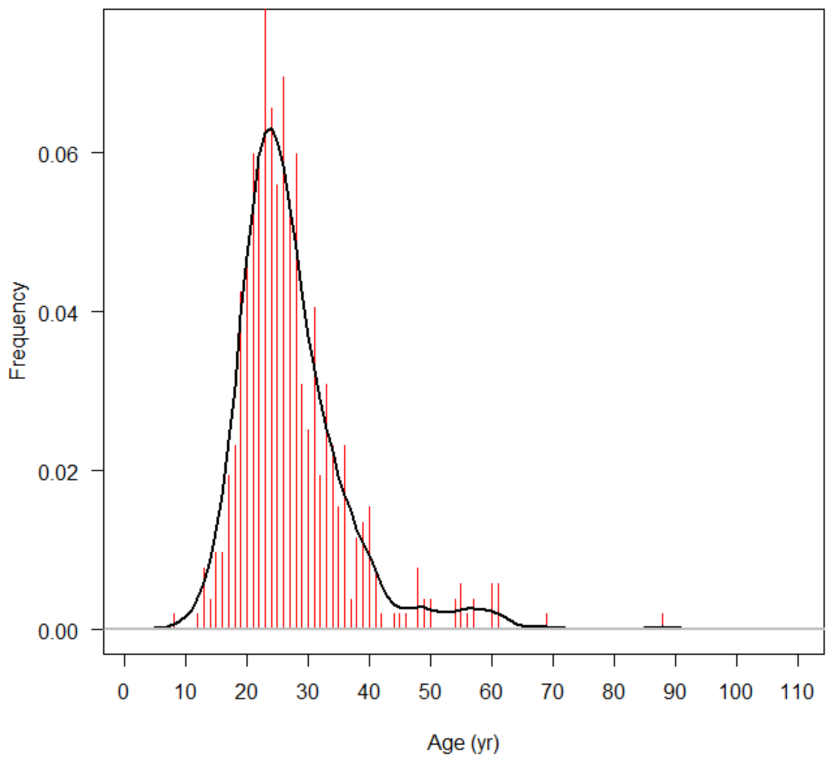

Figure 5: Estimated age frequency distribution (red bars) for the 2008–09 commercial fishery smooth oreo otolith sample (*n* = 390) with a smoothed density through the age estimates (black curve).

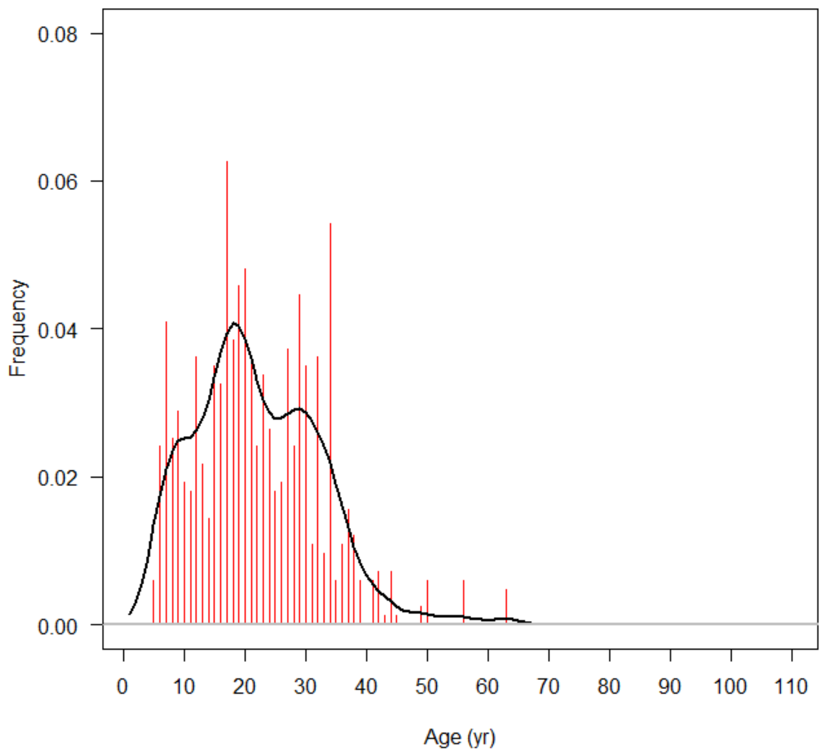

Figure 6: Estimated age frequency distribution (red bars) for the 2016 acoustic survey smooth oreo otolith sample (*n* = 398) with a smoothed density through the age estimates (black curve).

3.2 Comparison of the three age frequencies

The age frequency distributions from the three sources are compared in Figure 7. The right-hand limbs of the 2008–09 commercial fishery and 2016 acoustic survey are similar for ages of about 33 years or more, but the 1991 survey limb is to the left and that sample contains a greater proportion of younger fish. This could be because the random trawl survey would be expected to sample a wide size range of fish sizes, compared to the commercial fishery and the 2016 acoustic survey both of which mainly target fish on observed marks (i.e., not random trawling). The commercial fishery data had a single strong mode at about 23 years probably because marks (schools) of smooth oreo tend to be made up of larger and middle to older aged fish, which also live deeper than smaller and younger fish. In contrast, the 2016 acoustic survey had a secondary mode at about nine years suggesting that smaller fish were more likely to be sampled, possibly from shallower depths.

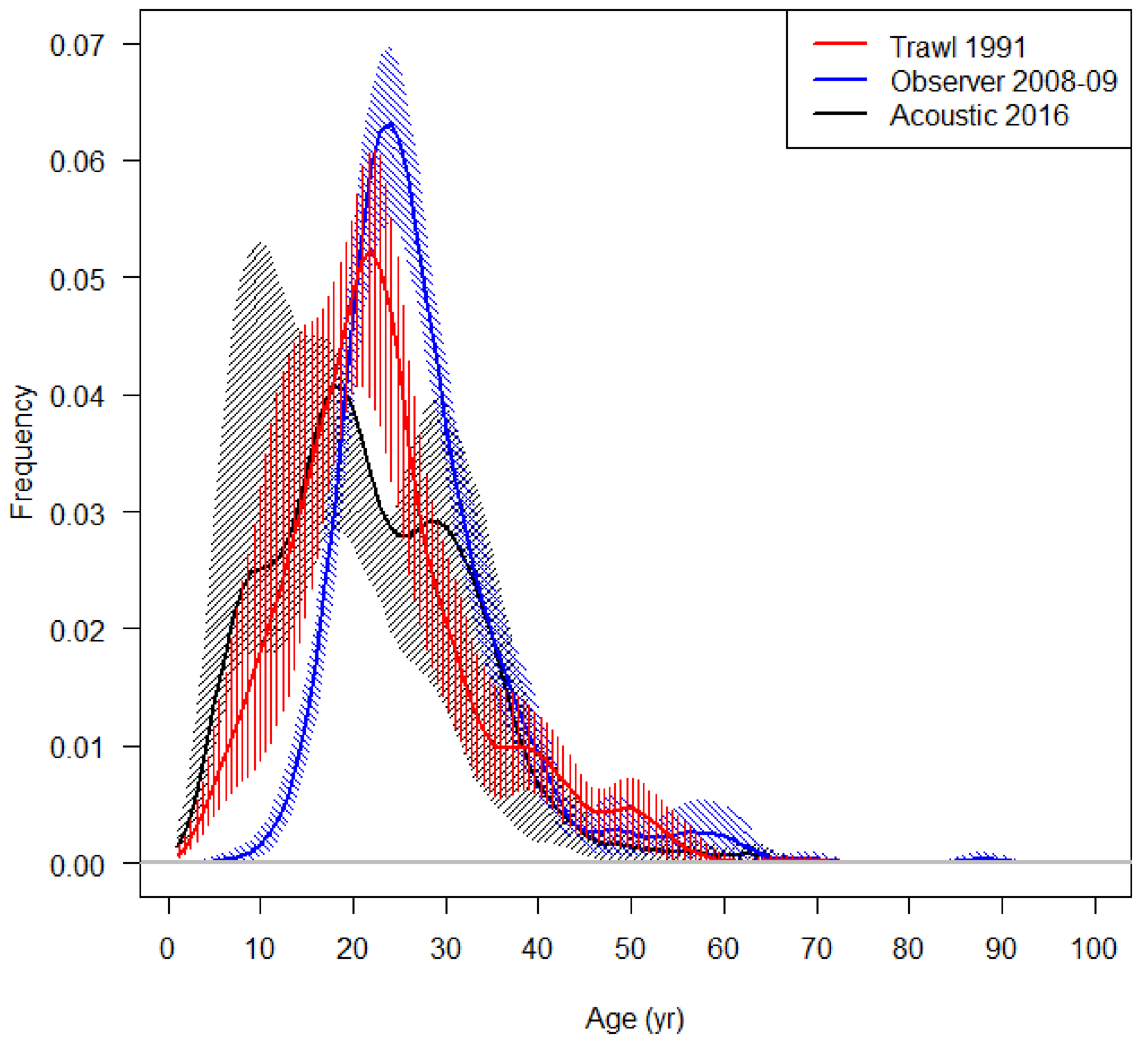

Figure 7: Comparison of the estimated smooth oreo age frequency distributions for the 1991 trawl survey (red), 2008–09 commercial fishery (blue), and 2016 acoustic survey (black), with pairwise 95% CIs (shaded areas).

4. DISCUSSION

The three sources of smooth oreo otoliths probably sampled different parts of the population in OEO 4 Chatham Rise. The 1991 trawl survey was more likely to be representative of the demersal part of the population for smaller and medium sized fish; it may not have sampled deeper schools of larger, older fish, which tend to have localised distributions and were infrequently encountered using random trawl methods, and it also did not sample fish on hills. The 2008–09 commercial fishery samples were most likely representative of medium to large fish of middle to older ages. Such fish tend to form larger schools and were more easily observed using echosounders prior to fishing. The 2016 acoustic survey sampled larger fish and produced a secondary mode at about 29 years, but with the strongest mode made up of fish around 18 years old. The 2016 acoustic survey sample came from relatively few tows (i.e., 30) from three main flat strata and eight hills.

In conclusion, the three age frequency distributions presented here were likely to have been derived using sampling methods with three different selectivities. This will need to be taken into account when applying the data in a stock assessment model.

5. ACKNOWLEDGMENTS

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APPENDIX A: STATION WEIGHT AND OTOLITH SELECTION PROBABILITIES

Table A1: 1991 trawl 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 population	Number of otoliths	Probability to select one otolith
13	31	1.1	0.001016	4	2.54E-04
14	32	5.8	0.004037	9	4.49E-04
14	33	7.8	0.003759	8	4.70E-04
14	34	1.0	0.001875	1	1.87E-03
12	35	5.3	0.001996	10	2.00E-04
12	38	1.2	0.001106	3	3.69E-04
13	39	2 461.7	0.024136	20	1.21E-03
12	40	7.6	0.002440	16	1.53E-04
13	41	5 341.0	0.035025	20	1.75E-03
14	42	4 397.8	0.082929	20	4.15E-03
13	43	4 792.9	0.037077	20	1.85E-03
12	44	8.9	0.001928	7	2.75E-04
13	45	21.6	0.004359	20	2.18E-04
12	46	2 087.2	0.036940	20	1.85E-03
13	49	4 503.5	0.036888	20	1.84E-03
19	51	3.4	0.007176	6	1.20E-03
18	52	6.4	0.003021	8	3.78E-04
17	53	2.5	0.003233	9	3.59E-04
19	54	1.0	0.002613	1	2.61E-03
18	56	2.9	0.002569	5	5.14E-04
17	57	4.9	0.005661	16	3.54E-04
17	58	59.5	0.011531	20	5.77E-04
17	59	0.2	0.000875	1	8.75E-04
18	61	1.4	0.001748	2	8.74E-04
19	62	156.7	0.034852	20	1.74E-03
19	64	5.9	0.006609	7	9.44E-04
18	65	1.7	0.001769	3	5.90E-04
19	67	93.6	0.032947	20	1.65E-03
19	68	3.0	0.005630	5	1.13E-03
19	69	12.2	0.011113	19	5.85E-04
20	70	8.5	0.005048	13	3.88E-04
20	71	11.0	0.006244	15	4.16E-04
18	72	6 065.3	0.134351	20	6.72E-03
17	73	2 621.9	0.081518	20	4.08E-03
17	75	6 398.2	0.085740	20	4.29E-03
20	76	24 790.5	0.211750	20	1.06E-02
26	77	5.3	0.000794	6	1.32E-04
25	80	2.6	0.001552	19	8.17E-05
24	82	1.9	0.002669	14	1.91E-04
25	84	2.3	0.001053	9	1.17E-04
24	86	8.4	0.002579	16	1.61E-04
26	90	1.8	0.001104	6	1.84E-04

Stratum	Station	Catch (kg)	Relative population	Number of otoliths	Probability to select one otolith
26	91	58.1	0.005004	20	2.50E-04
26	92	2 435.9	0.018275	20	9.14E-04
25	93	312.7	0.008822	20	4.41E-04
24	94	1 480.9	0.024380	20	1.22E-03
13	139	0.4	0.000950	3	3.17E-04
13	140	1.4	0.001313	6	2.19E-04

Table A2: 2008–09 commercial fishery — trip and sample numbers, catch, relative population by sample used to randomly sample otoliths, number of otoliths collected, and probability to select one otolith (i.e., relative population divided by the number of otoliths sampled).

Trip	Sample number	Catch (kg)	Relative population	Number of otoliths	Probability to select one otolith
2699	11	27 969	0.01963	12	0.00164
2699	12	27 819	0.01952	10	0.00195
2699	16	45 000	0.03158	12	0.00263
2699	24	1 000	0.00070	5	0.00014
2699	48	2 000	0.00140	5	0.00028
2699	72	34 899	0.02449	10	0.00245
2699	74	14 950	0.01049	12	0.00087
2699	85	2 400	0.00168	12	0.00014
2699	113	1 800	0.00126	12	0.00011
2699	123	2 500	0.00175	3	0.00058
2699	133	5 375	0.00377	12	0.00031
2699	134	14 854	0.01042	11	0.00095
2699	136	20 000	0.01404	10	0.00140
2699	138	15 000	0.01053	10	0.00105
2699	139	25 000	0.01755	20	0.00088
2699	145	3 000	0.00211	5	0.00042
2699	155	1 000	0.00070	5	0.00014
2699	166	250	0.00018	5	0.00004
2699	169	10 000	0.00702	10	0.00070
2699	170	35 000	0.02456	10	0.00246
2699	172	17 542	0.01231	11	0.00112
2699	173	26 730	0.01876	10	0.00188
2714	2	1 000	0.00070	5	0.00014
2714	10	16 500	0.01158	20	0.00058
2714	14	8 000	0.00561	10	0.00056
2714	25	50	0.00004	5	0.00001
2714	33	8 369	0.00587	10	0.00059
2714	40	7 000	0.00491	10	0.00049
2714	47	6 418	0.00450	10	0.00045
2714	53	27 410	0.01924	20	0.00096
2714	65	10 382	0.00729	5	0.00146
2714	69	23 339	0.01638	20	0.00082
2714	121	10 500	0.00737	10	0.00074

Trip	Sample number	Catch (kg)	Relative population	Number of otoliths	Probability to select one otolith
2714	144	1 200	0.00084	10	0.00008
2714	148	3 826	0.00269	10	0.00027
2714	152	21 000	0.01474	20	0.00074
2714	159	7 500	0.00526	10	0.00053
2744	11	5 250	0.00368	10	0.00037
2744	14	9 812	0.00689	10	0.00069
2744	19	2 000	0.00140	10	0.00014
2744	20	44 150	0.03098	10	0.00310
2744	24	14 657	0.01029	10	0.00103
2744	25	3 500	0.00246	10	0.00025
2744	33	1 500	0.00105	5	0.00021
2744	46	103	0.00007	5	0.00001
2744	65	500	0.00035	5	0.00007
2744	69	200	0.00014	5	0.00003
2744	120	200	0.00014	5	0.00003
2744	132	4 000	0.00281	5	0.00056
2744	137	2 800	0.00197	10	0.00020
2744	142	3 000	0.00211	10	0.00021
2744	189	1 300	0.00091	5	0.00018
2744	207	1 455	0.00102	10	0.00010
2744	215	7 000	0.00491	10	0.00049
2744	221	14 770	0.01037	10	0.00104
2744	223	15 000	0.01053	10	0.00105
2744	226	6 900	0.00484	10	0.00048
2744	228	12 104	0.00849	10	0.00085
2744	232	12 000	0.00842	10	0.00084
2807	1	4 700	0.00330	10	0.00033
2807	2	9 980	0.00700	5	0.00140
2807	3	6 080	0.00427	5	0.00085
2807	4	19 002	0.01334	5	0.00267
2807	6	11 750	0.00825	5	0.00165
2807	7	14 567	0.01022	20	0.00051
2807	8	7 027	0.00493	10	0.00049
2807	88	353	0.00025	5	0.00005
2807	100	5 334	0.00374	10	0.00037
2807	114	3 056	0.00214	5	0.00043
2807	115	10 482	0.00736	20	0.00037
2807	121	16 860	0.01183	5	0.00237
2807	131	44 320	0.03110	25	0.00124
2807	132	41 350	0.02902	20	0.00145
2807	133	14 757	0.01036	5	0.00207
2807	135	24 975	0.01753	20	0.00088
2807	147	3 882	0.00272	5	0.00054
2807	154	3 592	0.00252	5	0.00050
2807	160	15 570	0.01093	5	0.00219
2807	217	2 337	0.00164	5	0.00033

Trip	Sample number	Catch (kg)	Relative population	Number of otoliths	Probability to select one otolith
2807	232	2 706	0.00190	5	0.00038
2807	239	7 953	0.00558	5	0.00112
2807	255	6 605	0.00464	10	0.00046
2807	258	4 942	0.00347	5	0.00069
2807	260	11 830	0.00830	5	0.00166
2807	264	11 880	0.00834	20	0.00042
2807	265	37 342	0.02621	10	0.00262
2807	266	7 396	0.00519	10	0.00052
2807	268	8 363	0.00587	5	0.00117
2807	271	22 465	0.01577	5	0.00315
2862	9	12 863	0.00903	18	0.00050
2862	10	35 319	0.02479	26	0.00095
2862	14	12 125	0.00851	14	0.00061
2862	15	9 805	0.00688	13	0.00053
2862	16	8 149	0.00572	31	0.00018
2862	18	21 382	0.01501	12	0.00125
2862	19	17 293	0.01214	14	0.00087
2862	21	20 891	0.01466	30	0.00049
2862	23	8 564	0.00601	29	0.00021
2864	2	695	0.00049	4	0.00012
2864	17	237	0.00017	5	0.00003
2864	23	700	0.00049	3	0.00016
2864	25	3	0.00000	1	0.00000
2864	28	14 498	0.01017	14	0.00073
2864	30	15 422	0.01082	12	0.00090
2864	34	8 140	0.00571	10	0.00057
2864	36	11 532	0.00809	10	0.00081
2864	39	17 010	0.01194	10	0.00119
2864	52	2 668	0.00187	10	0.00019
2864	55	16 894	0.01186	10	0.00119
2864	62	1 000	0.00070	10	0.00007
2864	65	3 975	0.00279	10	0.00028
2864	68	17 802	0.01249	10	0.00125
2864	69	2 870	0.00201	10	0.00020
2864	71	15 511	0.01089	11	0.00099
2864	85	1 640	0.00115	10	0.00012
2864	87	734	0.00052	10	0.00005
2911	1	624	0.00044	10	0.00004
2911	17	28 109	0.01973	10	0.00197
2911	84	29 700	0.02084	20	0.00104
2911	85	9 000	0.00632	10	0.00063
2911	86	30 990	0.02175	20	0.00109
2911	88	18 503	0.01299	20	0.00065

Table A3: 2016 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). Flat stratum are a combination of mark-type and spatial stratum, e.g., *high42* is mark-type School-deep(*high*) in stratum 42, and *mid42* is mark-type School-shallow (*mid)* in stratum 42.

Station	Stratum	Catch (kg)	Relative population	Number of otoliths	Probability to select one otolith
1	Tomahawk	37.0	0.015929	32	0.000529
2	Tomahawk	9 836.2	0.247217	40	0.006566
3	Mangrove	967.5	0.153688	40	0.004082
4	Condoms	15.0	0.007441	26	0.000304
5	Condoms	7.5	0.017193	17	0.001074
8	Dolly Parton	940.6	0.015023	40	0.000399
9	Paranoia	18.8	0.017407	20	0.000925
10	Paranoia	1 881.2	0.088189	40	0.002342
16	high42	1 101.1	0.011783	40	0.000313
17	mid42	2 848.6	0.034886	40	0.000927
18	mid42	510.5	0.006597	40	0.000175
19	high42	2 848.6	0.015846	40	0.000421
20	mid4	1 278.2	0.014697	40	0.000390
22	high4	3 816.5	0.027595	40	0.000733
23	high4	3 197.4	0.019218	40	0.000510
25	mid4	3 977.3	0.020999	40	0.000558
26	mid4	3 628.1	0.023472	40	0.000623
27	high4	10 347.1	0.031456	80	0.000418
28	Hegerville	940.7	0.006862	20	0.000364
29	Hegerville	2 902.5	0.034349	40	0.000912
30	Chucky	1 048.1	0.009182	10	0.000975
31	Nielson	50.1	0.021570	20	0.001146
32	Nelson	49.8	0.017214	19	0.000963
33	high42	2 445.6	0.013668	20	0.000726
34	high42	4 192.5	0.016276	20	0.000865
35	mid42	1 881.4	0.011556	20	0.000614
36	mid42	3 708.8	0.012337	20	0.000655
47	Hegerville	2 176.7	0.005750	20	0.000305
52	high3	296.6	0.003722	10	0.000395
53	mid3	6 933.8	0.020186	17	0.001261

APPENDIX B: ESTIMATED AGE FREQUENCIES

Table B1: Estimated age frequencies for OEO 4 Chatham Rise smooth oreo from the 1991 trawl survey, the 2008–09 commercial fishery, and the 2016 acoustic survey. – no data.

1991 trawl survey			2008–09 commercial fishery			2016 acoustic survey		
Age (yr)	Frequency	CV	Age (yr)	Frequency	CV	Age (yr)	Frequency	CV
5	0.002948	0.495178				5	0.006024	0.612312
6	0.020637	0.321584				6	0.024096	0.391035
7	0.012972	0.424921				7	0.040964	0.269115
8	0.002948	0.458038	8	0.001931	1.070436	8	0.025301	0.354596
9	0.017689	0.476388	9	0	–	9	0.028916	0.369941
10	0.018868	0.370913	10	0	–	10	0.019277	0.474818
11	0.017689	0.416692	11	0	–	11	0.018072	0.359228
12	0.021226	0.453505	12	0.001931	0.945738	12	0.036145	0.333273
13	0.032429	0.575605	13	0.007722	0.556839	13	0.021687	0.375442
14	0.027712	0.394432	14	0.003861	0.684716	14	0.014458	0.463376
15	0.025943	0.369748	15	0.009653	0.475960	15	0.034940	0.349094
16	0.031250	0.260266	16	0.009653	0.514016	16	0.032530	0.213911
17	0.064269	0.212433	17	0.019305	0.414290	17	0.062651	0.178032
18	0.028302	0.364485	18	0.023166	0.406415	18	0.038554	0.280092
19	0.023585	0.361983	19	0.042471	0.311176	19	0.045783	0.141895
20	0.061910	0.169553	20	0.048263	0.221072	20	0.048193	0.180979
21	0.052476	0.166707	21	0.059846	0.225428	21	0.036145	0.410527
22	0.068396	0.198407	22	0.059846	0.213810	22	0.024096	0.213317
23	0.075472	0.229973	23	0.092664	0.158564	23	0.033735	0.592707
24	0.051297	0.224404	24	0.065637	0.202857	24	0.026506	0.278462
25	0.031250	0.263863	25	0.055985	0.197502	25	0.018072	0.247434
26	0.031250	0.325780	26	0.069498	0.202177	26	0.019277	0.401147
27	0.033019	0.347825	27	0.054054	0.216176	27	0.037349	0.504866
28	0.009434	0.818842	28	0.059846	0.180415	28	0.024096	0.265661
29	0.025354	0.305861	29	0.030888	0.280262	29	0.044578	0.263880
30	0.021816	0.381289	30	0.025097	0.331252	30	0.034940	0.522156
31	0.019458	0.462019	31	0.040541	0.260440	31	0.010843	0.540718
32	0.022995	0.454864	32	0.019305	0.342925	32	0.036145	0.578536
33	0.011792	0.523359	33	0.030888	0.306267	33	0.009639	0.572605
34	0.001769	0.739494	34	0.023166	0.351752	34	0.054217	0.530014
35	0.005307	0.726498	35	0.015444	0.539061	35	0.006024	0.466203
36	0.008255	0.697631	36	0.023166	0.420519	36	0.010843	0.643315
37	0.004717	0.648046	37	0.003861	0.705198	37	0.015663	0.319026
38	0.022995	0.388748	38	0.011583	0.376846	38	0.012048	0.453447
39	0.013561	0.509845	39	0.013514	0.510881	39	0.006024	0.915528
40	0.007075	0.561653	40	0.015444	0.402108	40	0	–
41	0	–	41	0.007722	0.581166	41	0.006024	0.485450
42	0.013561	0.501688	42	0.001931	1.029933	42	0.007229	0.643064
43	0.006486	0.752811	43	0	–	43	0.001205	0.886625
44	0.010024	0.613742	44	0.001931	0.945132	44	0.007229	0.457339
45	0	–	45	0.001931	1.004683	45	0.001205	31.606960
46	0.004717	0.876148	46	0.001931	0.938465	46	0	–

1991 trawl survey		
47	0.000590	0.914619
48	0	–
49	0.004127	0.933911
50	0.020047	0.442583
51	0	–
52	0.002358	0.788488
53	0	–
54	0.005896	0.876148
55	0	–
56	0	–
57	0.002358	0.876148
58	0	–
59	0	–
60	0	–
61	0	–
62	0	–
63	0	–
64	0	–
65	0	–
66	0.001179	1.006917
67	0	–
68	0	–
69	0	–
70	0	–
71	0.000590	0.978006

2008–09 commercial fishery		
47	0	–
48	0.007722	0.964205
49	0.003861	0.634214
50	0.003861	1.029933
51	0	–
52	0	–
53	0	–
54	0.003861	0.640569
55	0.005792	0.717973
56	0.001931	0.971862
57	0.003861	0.971862
58	0	–
59	0	–
60	0.005792	0.730827
61	0.005792	0.964205
62	0	–
63	0	–
64	0	–
65	0	–
66	0	–
67	0	–
68	0	–
69	0.001931	1.000337
70	0	–
71	0	–
72	0	–
73	0	–
74	0	–
75	0	–
76	0	–
77	0	–
78	0	–
79	0	–
80	0	–
81	0	–
82	0	–
83	0	–
84	0	–
85	0	–
86	0	–
87	0	–
88	0.001931	0.980878

2016 acoustic survey		
47	0	–
48	0	–
49	0.002410	31.606960
50	0.006024	0.643064
51	0	–
52	0	–
53	0	–
54	0	–
55	0	–
56	0.006024	0.643064
57	0	–
58	0	–
59	0	–
60	0	–
61	0	–
62	0	–
63	0.004819	0.643064