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Comparison of age between 1993 and 2010 for mid-east coast orange roughy (ORH 2Asouth, 2B & 3A)

New Zealand Fisheries Assessment Report 2013/44

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Otoliths from orange roughy wide-area research trawl surveys on the mid-east coast (management areas ORH 2Asouth, 2B, and 3A) conducted during March–April in 1993 and 2010, were prepared and read by two readers (n=1000). The aim of the work was to test the hypothesis that population age structure had changed over the last two decades for mid-east coast (MEC) orange roughy. There was no apparent bias in otolith zone counts between readers, and the between-reader precision had a coefficient of variation (c.v.) of 7.5%. Length frequency samples from the survey were up-scaled to the whole survey area using the strata abundance (in numbers) and the relative tow catch density within a stratum, and then an age-length key applied, to get an overall age frequency for each survey.

There was a strong mode in both frequencies at age 20 in 1993, which increased to age 25 in 2010, albeit with a lower peak. Both of these modes were younger than the assumed mean age of recruitment to the fishery. However, the observed age frequencies were not the same shape as predicted in the stock assessment model, especially in 1993, with the age frequency observations having more fish in the strong pre-recruit mode, and so fewer older fish that were vulnerable to the fishery. Clearly, either the trawl biomass survey series was biased, or the model structure and assumptions were incorrect for fitting the trawl surveys in the model. If trawl surveys are to be used, then how to use them needs to be investigated.

1. INTRODUCTION

This work addresses the following objectives in Ministry for Primary Industries (MPI) project DEE2010/08, *Targeted ageing of otoliths from selected deepwater stocks.*

1.1 Overall objective

To determine the age distribution of deepwater populations of black oreo (*Allocyttus niger*) and orange roughy (*Hoplostethus atlanticus*) for use in stock assessment.

1.2 Specific objective

1. To estimate the age of orange roughy in mid-east coast (ORH MEC) by analysing research samples from the trawl surveys in 1993 and 2010.

1.3 Orange roughy — mid-east coast (ORH 2Asouth, 2B, & 3A)

This fishery started in the early 1980s with landings peaking from 1989–90 to the mid-1990s, after which landings were reduced by Total Allowable Commercial Catch (TACC) limits. The fishing-down phase for this stock occurred up until the mid-1990s, by which time the cumulative reported landings exceeded 100 000 t, which was approximately the virgin biomass estimated in subsequent stock assessments. The 2011–12 mid-east coast (MEC) TACC was 1500 t (Ministry for Primary Industries, 2012).

The stock assessments completed in 2004 and 2005 indicated that the estimated stock size would increase if the landings were kept at the TACC of 1500 t (Ministry for Primary Industries, 2012). However, Dunn (2010) showed that the assumption of constant recruitment would always predict a biomass rebuild after the mid-1990s, regardless of subsequent observational data (trawl surveys, acoustic surveys, or catch-per-unit-effort (CPUE)). Hence, data were needed to inform the assessment model of any trends in recruitment.

Because MEC stock assessment models have typically failed to fit all of the observational data well, recent research has investigated some alternative model assumptions, specifically concerned with alternative spatial structures (Dunn 2011; Dunn & Forman 2011). Revised assumptions of spatial structure alone were not sufficient to produce a good fit to all observational data, at least whilst assuming deterministic recruitment (Dunn 2011). The analyses used length frequencies to infer relative abundance of difference age classes in different areas, but because orange roughy growth slows down after maturation, length data cannot separate out ages after about 30 years of age. Hence, having age frequencies that cover all stock components will help interpretations, and also allow evaluation of stochastic recruitment hypotheses.

Trawl surveys of the MEC stock were carried out with the RV *Tangaroa* in 1992–94 (Grimes 1994, 1996a,b) and again in 2010 (Doonan & Dunn 2011). Here, we report estimated age frequencies from otolith samples collected during the 1993 and 2010 surveys.

The aim of the work was to evaluate whether population age structure had changed over the last two decades for MEC orange roughy.

2. METHOD

2.1 Trawl surveys

1993 survey

The 1993 trawl survey was the second of a series of three trawl surveys from 1992 to 1994 which covered the MEC, in March-April (Grimes 1994, 1996a&b). The general survey area was the same for all three surveys, but there were slight changes in strata, with new strata introduced in 1993 and retained in 1994 (Figure 1, Table 1). Strata outside of hill areas were delineated by depth: 600–800, 800–1000, 1000–1200, and 1200–1500 m. All surveys used a two-phase random stratified design (Francis 1984).

In 1993, the total number of strata, including hill strata, was 33. There were 220 stations in the biomass estimate, which for all orange roughy was 14 272 tonnes (c.v. 20 %). In deriving this estimate, the swept area of the trawl was assumed to be that between the trawl wingtips (not between the trawl doors).

In 2010, the trawl survey was designed for the MEC stock only, so the East Cape Management area (to the north of the region) was excluded from the 1993 data set (the area in Tolaga sub-area north of 38° 23’ S). For the 1993 survey, this reduced the area of the Tolaga sub-area from 6806 km^2 to 2186 km^2. The biomass estimate for this reduced-area 1993 survey was 13 728 t, from 201 stations (Doonan & Dunn, 2011).

The catches from each valid tow were sorted and weighed by species on motion compensating scales to the nearest 0.1 kg. Large catches of fish were sub-sampled and the total catch estimated from the proportions in the sample. For catches too large to be weighed, the catch was estimated from the weighed processed catch using a conversion factor. From each tow, a random sample of up to 200 orange roughy, and 50–200 of other species were randomly selected from the catch to be measured and sexed. A detailed biological sample of 20 orange roughy was taken from each catch, recording: standard length, total weight, sex, macroscopic gonad stage, stomach fullness and contents noted on some occasions, and otoliths extracted. All orange roughy were sampled when the catch was less than 20 fish, and multiple samples were taken from large catches (one sample for each 10 t of catch).

2010 survey

The 2010 survey was based on the design of the 1993 survey, so that it could be compared directly. The same trawling protocols and net were used in 2010 as in the 1992–94 series. The survey area was reduced to just the MEC stock area. The sub-areas are shown in Figure 2 and Table 1. In the 2010 survey, there were 171 stations in 33 strata, and the total orange roughy biomass was estimated to be 6800 t (c.v. 17%). Catch sampling followed the same protocol used in 1993.

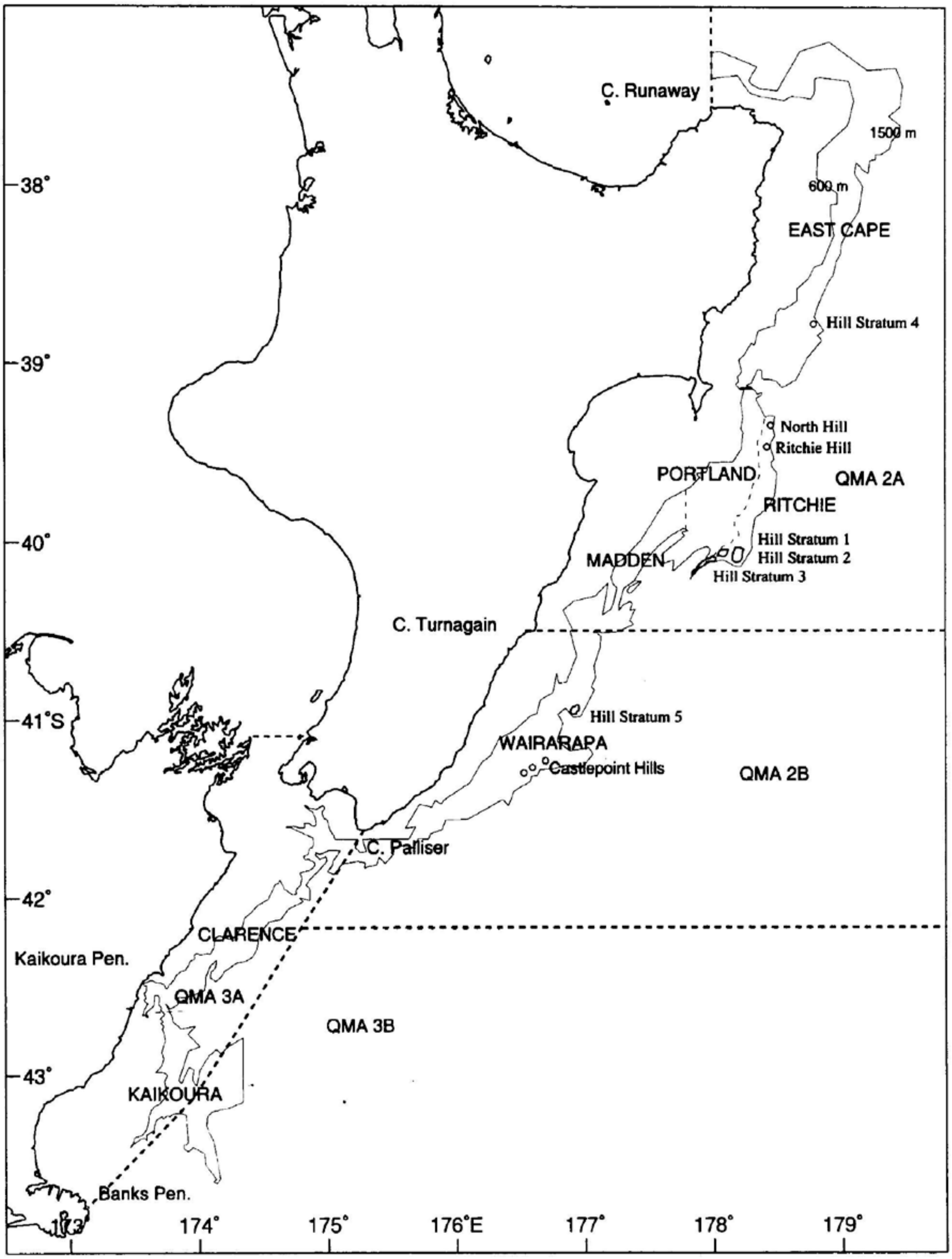

Figure 1: Survey area for the 1992–94 trawl surveys with the commercial ("Hill") strata used in 1993 and 1994 (Hill Strata 1–3 were used in 1992). In 1993 and 1994, East Cape was a combined sub-area made up of East Cape in the north and Tolaga in the southern half of the sub-area shown in the plot. In 1992, there were two sub-areas, East Cape and Tolaga.

Table 1: Sub-areas, hills, and codes used in the 1993 and 2010 surveys

Area	Area code	Area (km^2)	QMA	Boundaries
Flat ground areas				
Kaikoura	KAIK	2 681	3A, 3B	174° 20'E to 42° 40' S
Clarence	CLAR	2 689	3A	42° 40' S to Cape Palliser
Wairarapa	WAIR	4 202	2B	Cape Palliser to Cape Turnagain
Madden	MADD	2 184	2A	Cape Turnagain to 177° 50' E
Portland	PORT	2 035	2A	177° 50' E to 39° 07' S excluding the Ritchie Banks
Ritchie Banks	RICH	1 400	2A	Ritchie Banks east of the Portland 1000 m contour
Tolaga	EAST	6 806□ 2 186	2A	39° 07' S to Cape Runaway. In 1992, this sub-area was split into two: East Cape and Tolaga.
Commercial (Hill) strata				
Tim's Bank	TIMB	28	2A	
SW Ritchie	SWRI	50	2A	
Rockgarden	ROCK	100	2A	
Tolaga Hill	TOLA	30	2A	
Castlepoint	CLPT	50	3A	Small area north of the Castlepoint hills

□ area for the full 1993 survey, reduced to 2 186 in 2010.

2.2 Ageing of orange roughy

Before 2007, orange roughy age estimates from different agencies had poor comparability (Francis 2005, 2006, Hicks 2005), which led to low confidence in the age-frequency data, and resulted in age data being excluded from stock assessments in 2006. Francis (2006) suggested that a significant source of between-agency bias was the method used to identify the transition zone (TZ), a feature on the otolith believed to be associated with the switch from somatic growth to gamete production.

In response to ageing problems, an Orange Roughy Ageing Workshop was held in 2007 to improve otolith preparation and interpretation between agencies, especially in relation to the TZ. A new protocol for age interpretation was developed during the workshop. In 2008–09, the new protocol was tested by two NIWA readers and two FAS (Fish Ageing Services Pty. Ltd., Victoria, Australia) readers by ageing the otolith pairs from 160 fish, i.e., potentially 8 age estimates per fish. The new protocol removed the inter-agency biases.

Early attempts to age orange roughy were equivocal about whether the species was short (less than 30 years) or long (over 50 years) lived. A review by Merrett & Haedrich (1997) concluded that the debate whether orange roughy were short or long lived ‘was not settled’, but a subsequent review by Tracey & Horn (1999) concluded that the weight of evidence supported a high longevity. All New Zealand stock assessment research after 1999 assumed orange roughy had a high longevity. Most recently, Andrews et al. (2009) applied an improved lead-radium dating technique to otolith cores, grouped by growth-zone counts from thin sections. Results showed a high degree of correlation of the growth-zone counts to the expected lead-radium growth curve, and provided convincing support for both a centenarian life span for orange roughy, and the age estimation procedures using thin otolith sectioning.

Preparation and reading of otoliths

NIWA’s preparation method was used because the CAF (Central Ageing Facility, Victoria, Australia) prepared otoliths have produced a higher proportion of unreadable otolith sections (Tracey et al. 2007). Briefly, the left otoliths were individually embedded in resin and cured in an oven. Thin sections were then cut along a line from the primordium through the most uniform postereo-dorsal axis. The section was then mounted on a glass microscope slide under a glass cover slip.

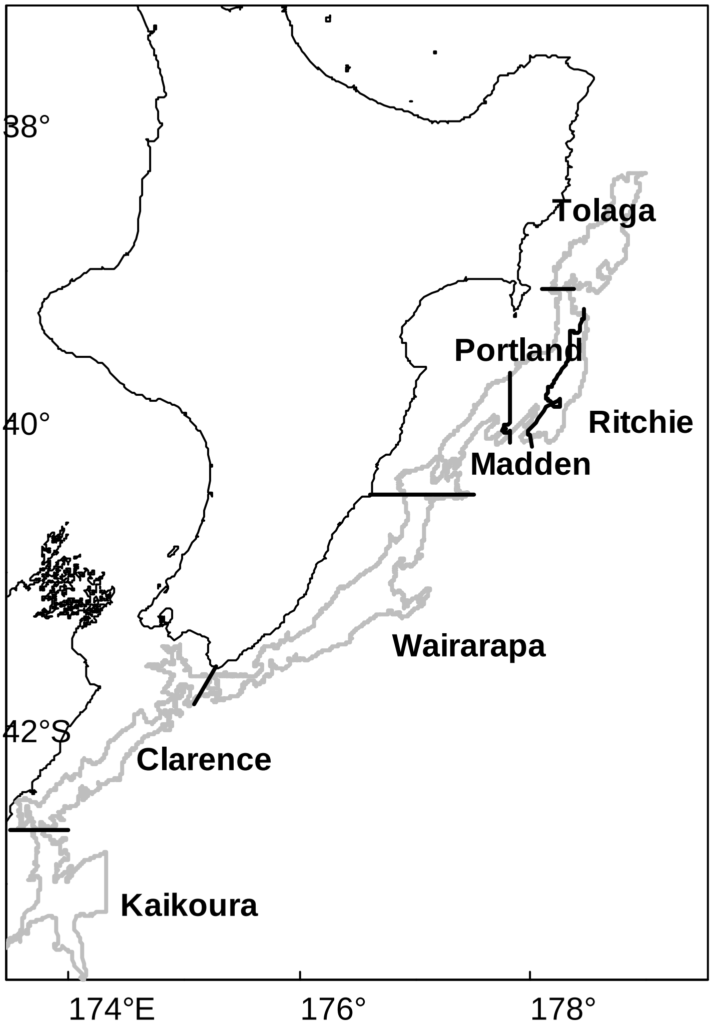

Figure 2: Survey sub-areas for the 2010 MEC trawl survey. Grey lines are the survey area and these are based on the 600 and 1500 m isobaths.

To estimate ages of orange roughy, otoliths were read once by two different readers and these estimated ages were averaged. Otolith interpretation and reading protocols followed those described in the Ageing Workshop Report (Tracey et al. 2007).

Reader error analysis

Data with a readability code of 5 (i.e., unreadable) for either of the readings were excluded.

Only inter-reader variability (consistency) between otolith readings was considered. First, the readings by each reader were plotted against each, and summarised by fitting a lowess smoothing line (R Development Core Team (2010), parameter “f” set to 0.1). A 1:1 line was added to the plot, and a lowess line that consistently deviated from the 1:1 line would indicate bias between the two readers.

Precision was quantified using the c.v. of between reader error from the two readings for each otolith. Precision was related to the index of average percentage error (IAPE) (Campana et al. 1995, 2001) by:

$$\text{c.v.} = 1.4 * \text{IAPE}.$$

2.3 Analytic method

Age frequencies were estimated using an age-length key (ALK) approach, with the survey area split into two regions, north and south at the boundary between Clarence and Wairarapa sub-areas. There was a separate ALK for each region and survey (i.e., four ALK in total). The southern region contained the sub-areas Kaikoura and Clarence, which had length frequencies that contained relatively more small fish than the north. A total of 1000 otoliths were processed, split into 500 for each survey, and then further split into 300 for the north and 200 for the south. Because most fish in the orange roughy surveys were pre-recruits to fishery, and so relatively young, the ALK approach should be sufficiently informative.

Estimated scaled numbers-at-age were calculated using the "R" software (R Development Core Team 2010) "Catch-at-age", developed by NIWA (Bull & Dunn 2002). "Catch-at-age" computes biomass estimates and scaled length-frequency distributions by stratum for trawl survey catch and length frequency data, using the calculations in Bull & Gilbert (2001) and Francis (1989). "Catch-at-age" computes the coefficient of variation (c.v.) for each length and age class and overall mean-weighted c.v. for each distribution using a bootstrapping routine: fish length records are resampled within each catch, catches are resampled within each stratum, and the age-length data are resampled, all with replacement. The bootstrap length and age-frequency distributions are computed for each resample, and the c.v.s and mean-weighted c.v.s computed from the bootstrap distributions.

Kernel smoothing was used on the length frequencies to give more stable results. This was because the estimated frequency for any one age was a weighted average of surrounding cohorts, for example the analyses found that the ageing error had a c.v. of 12%, or ±6 years at age 30 years (at the younger end of the age distribution). Random spikes in frequencies from sample variation could also be observed, an effect which was exacerbated by the low ratio of otoliths aged to the age range that needed to be covered. Kernel smoothing is controlled by a parameter, *width*, which is approximately the moving window width over which averaging is done. The function used was density from the R statistical package (R Development Core Team, 2010). In this analysis, *width* was set to 10.

Otolith selection

Otoliths were selected separately for the north and south regions. Survey strata were ignored. Otoliths were selected randomly within length bins, which included two combined classes (plus groups) for each end of the length distribution, with 1 cm bins in between. There were 20 bins: under 20 cm, 20 to 37 cm, and 38 cm and over. The sample size for each length bin was given by:

$$\text{minimum sample size} + A * B * \text{proportion of otoliths in a bin}$$

where *B* is a factor to emphasize lengths 32 cm or larger, and *A* is a factor to make the sum over bins match the total number of otoliths required. Otoliths were selected for the 2010 survey first, and the resulting age frequency used to inform selections for 1993.

For the 2010 survey, the minimum bin sample size was 10 for north and 7 for south. The factor *B* was set to 1, but later 30 more otoliths were added that came from fish with lengths 32 cm or more (this was done because reading time was quicker than originally planned, since most ages were below 40 years). The sample final size by bin is shown in Table 2. Not enough otoliths were available for the planned sample sizes for two length bins for south, so all were selected. The total sample size was 202 for south, and 298 for north.

Table 2: 2010 survey, sample sizes by length bin for the first set of 500 otoliths. "(20,21]" have lengths from 20.00 cm to 20.99 cm.

	Number of otoliths selected			Number of otoliths selected	
Length bin	South	North	Length bin	South	North
(0,20]	15	14	(29,30]	12	17
(20,21]	8	10	(30,31]	12	18
(21,22]	9	11	(31,32]	14	18
(22,23]	9	12	(32,33]	12	18
(23,24]	10	12	(33,34]	13	18
(24,25]	11	13	(34,35]	10	18
(25,26]	10	14	(35,36]	9	16
(26,27]	10	15	(36,37]	8	15
(27,28]	11	15	(37,38]	4	13
(28,29]	10	18	(38,100]	5	13

For the 1993 survey selections, *B* was set to 2, and the minimum bin sample size was 10 for north and 7 for south. The sample size by bin is shown in Table 3. The total sample size was 202 for south and 302 for north.

Table 3: 1993 survey, sample sizes by length bin. "(20,21]" have lengths from 20.00 cm to 20.99 cm.

	Number of otoliths selected			Number of otoliths selected	
Length bin	South	North	Length bin	South	North
(0,20]	15	13	(29,30]	10	15
(20,21]	10	10	(30,31]	10	15
(21,22]	12	11	(31,32]	9	16
(22,23]	13	12	(32,33]	10	21
(23,24]	12	12	(33,34]	8	22
(24,25]	12	12	(34,35]	7	22
(25,26]	13	13	(35,36]	7	19
(26,27]	11	14	(36,37]	7	17
(27,28]	11	14	(37,38]	7	14
(28,29]	11	15	(38,100]	8	15

2.4 Comparisons of age frequencies

Sample lengths were plotted against age, and compared to the growth curve used in the stock assessment. This was important because the length distribution is converted into age in the model, and if the growth patterns were not similar then comparisons of predicted age frequencies to observed will be flawed.

The observed age frequencies were compared with those predicted from versions of the most recent stock assessment. Two models were reported in the MPI Plenary document (Ministry for Primary Industries 2012); nominally referred to as RunP and RunQ (Anderson & Dunn 2011. These runs were bounding cases, with one giving a low $B_{current}$ as a percentage of B_o (RunP), and the other a high value. RunP used a natural mortality of 0.25, and in RunQ it was estimated at 0.055. We re-ran RunP without the south catches, since using them created a "hole" in the age frequencies. This was because catches in the south use a domed selectivity so that only a limited range of ages are caught. In the early fishery, catches were large enough in the south to remove almost all fish in the selected age range resulting in a "hole" in the age frequency. Our ageing study (see results) suggested that this hole in the age distribution was not observed, and therefore RunP as it was originally specified was not plausible. Our revised version of RunP simply represents age structure as it would be expected with a low natural mortality.

3 RESULTS

3.1 Otoliths and precision

The number of otoliths processed from each survey was 501 for 1993, and 520 for 2010. The number of otoliths removed because they were unreadable was 48 (Table 4). Where one reader found an otolith unreadable, 36% of the time the other reader estimated it to be aged 40 or more. Ages over 40 made up just 2.5% of the age frequency in 1993, and 5% in 2010.

Table 4: Unreadable otoliths by reader and year.

Survey	Reader 1 only	Reader 2 only	Both readers	Total
1993	1	14	4	19
2010	2	14	13	29
Total	3	28	17	48

Table 5 shows the number of otoliths that did not have a TZ, by reader. Most otoliths did not have a TZ, which was expected since most were smaller than the size at maturity, but there appeared to be a slight difference in detection of TZ between the readers. There was a 90% agreement between readers for the absence of a TZ.

Table 5: Absence of transition zone by reader.

Year	Reader1 only	Reader2 only	Both readers	Total	Proportion %
1993	7	25	312	344	71.4
2010	8	36	365	409	83.3
Total	15	61	677	753	77.4

The number of otoliths used in subsequent analyses was 482 for 1993 and 491 for 2010.

Readers' estimated ages show mostly no bias, except for in 1993, where there was a 1 year difference at age 50, increasing to 5 years at age 100 (Figure 3). Between-reader c.v. was 7.5%, which compares favourably to about 15% which was obtained in the protocol testing study for orange roughy (Tracey et al. 2007). The mean difference between readers, over all otoliths, was zero and the mean of the absolute differences was 1.4 years. The range of absolute differences between readers was from 0 to 6 years.

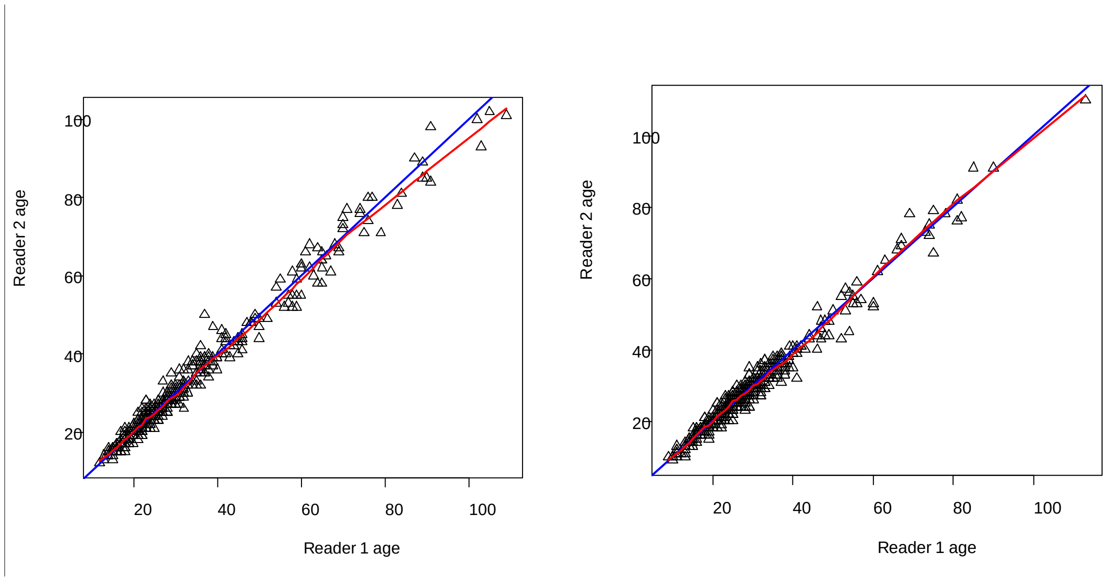

Figure 3: Comparison of ages from two readers for the same otolith. Left panel, 1993; right panel, 2010. Also shown are the 1:1 line (red) and a smoothed curve (blue).

3.2 Growth comparison

Figure 4 shows the growth curves (lowess curves) estimated from the data created under the current study, and the von Bertalanffy growth model used previously in stock assessments. Both growth models were similar for fish over age 30, but the von Bertalanffy curve implied a relatively faster growth for fish under age 30.

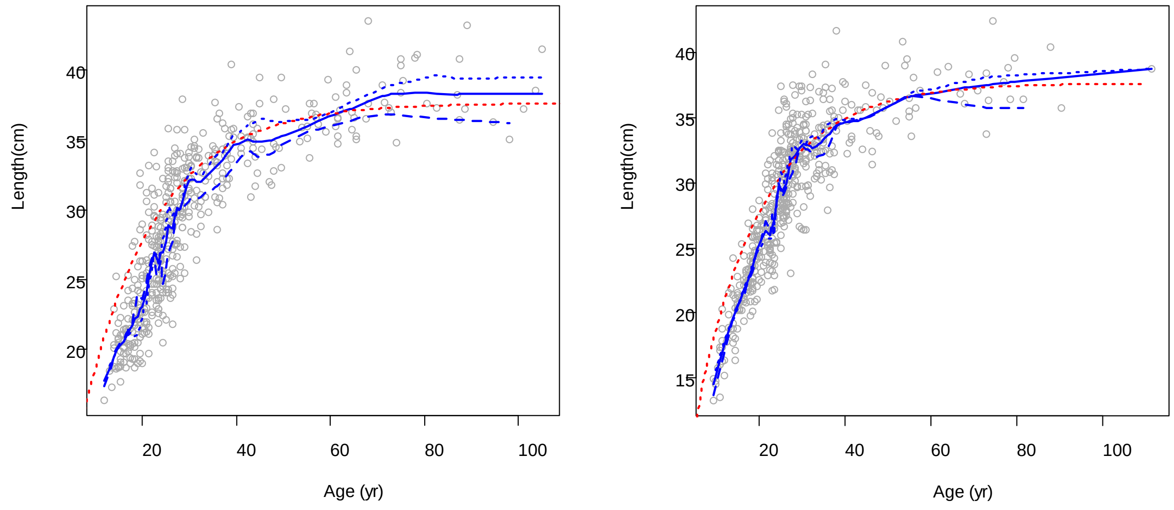

Figure 4: Growth in 1993 (left panel) and 2010 (right panel) compared to the von Bertalanffy curves used in the assessment model (red dashed line). Lowess smoothers have been used for males (blue dashed line) and females (blue dotted line), and for all fish (solid line).

3.2 Age frequencies

Figure 5 shows the estimated age frequencies for the two surveys. The age range was 12 to 105 in 1993, and 10 to 111 in 2010. Appendix A has details of the raw and smoothed age frequencies for both years.

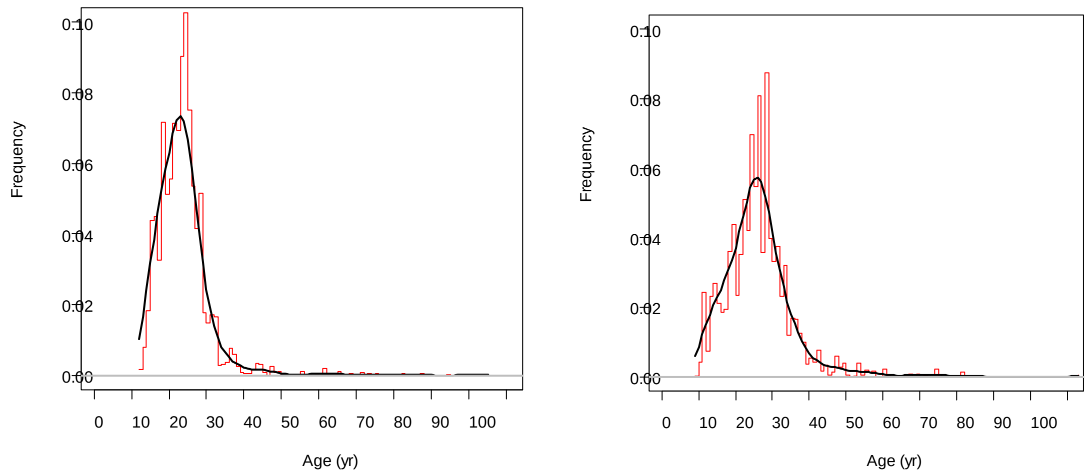

Figure 5: Smoothed age frequencies (curve) and the raw frequencies (histogram) for the 1993 survey (left panel) and the 2010 survey (right panel).

A comparison of age frequencies is shown in Figure 6. There was a strong mode in both samples, with the mode in 1993 at age 22 for the smoothed distribution and age 24 for the estimated length frequency, increasing slightly in 2010 to age 25 (smooth) and age 28 (estimated). The 95% pointwise confidence intervals (CI) did not overlap in two places (i.e., ages about 20–24 and about 33–36) suggesting that the shift in mode was statistically significant. The mode was lower in 2010 than in 1993, which suggests a greater proportion of older fish in 2010. However, there is an overlap in the CI for the mode heights, so that the lower peak in 2010 may not be a real difference. The mean age was 23.4 in 1993, and 26.0 in 2010.

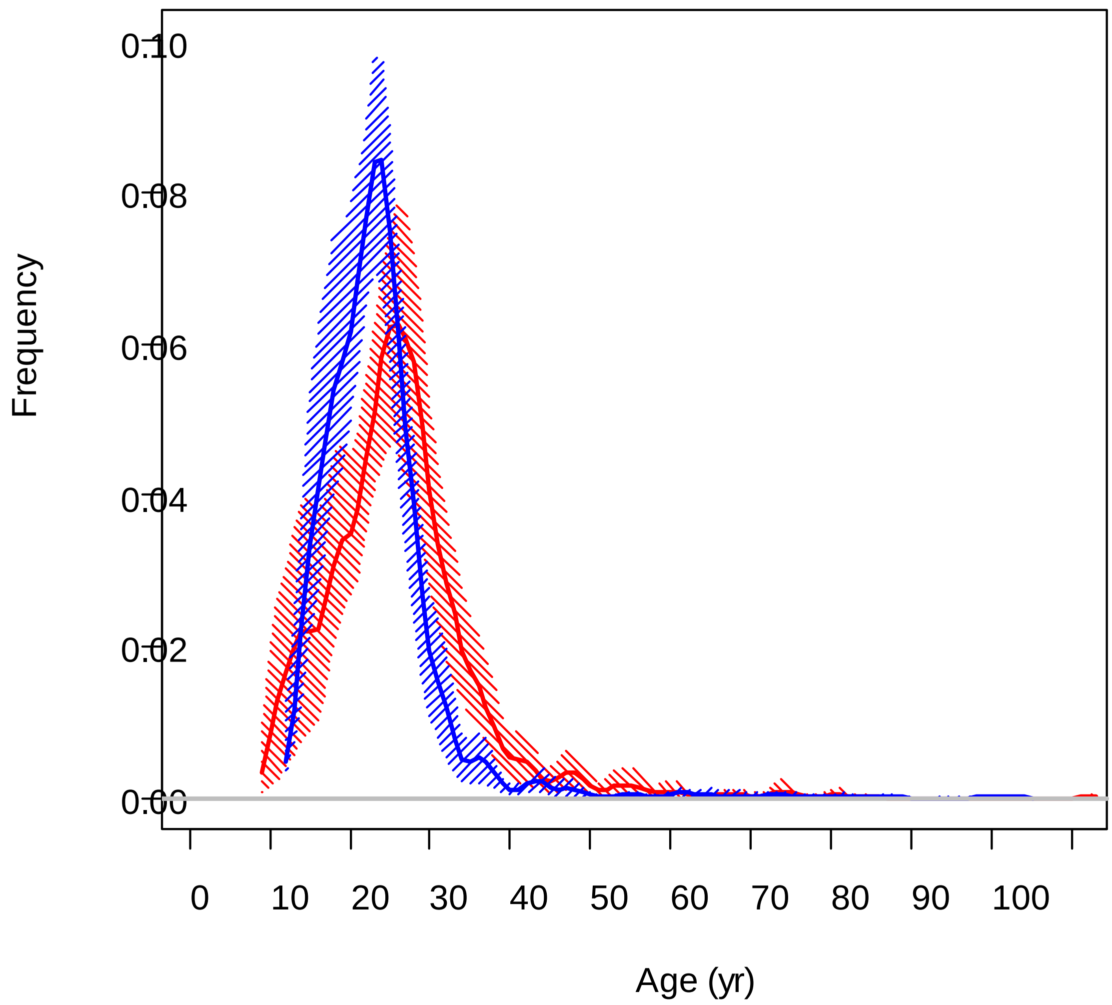

Figure 6: Comparison of age frequencies (curve lines) with their pointwise 95% confidence interval (slanted lines)for 1993 (blue, slanting upwards) and 2010 (red, slanting downwards).

3.3 Comparison with predicted age frequencies from stock assessments

Figure 7 shows the comparison of model predicted and observed age frequencies. It is clear that the observed frequencies do not fit well with the predicted ones, especially in 1993 and when using a low natural mortality.

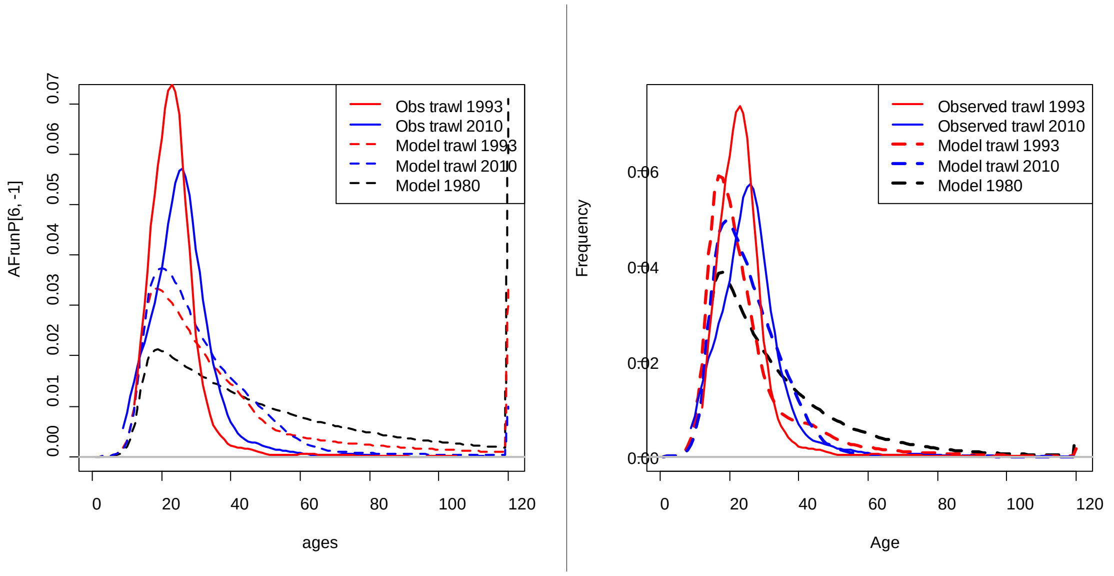

Figure 7: Comparison of observed and model predicted age frequencies from the two model runs reported in the Plenary report, RunP (left panel) and RunQ (right panel) (see text for details).

There may be several reasons for the misfit, but it is clear that something in the fitting of trawl surveys within the model is in error. It is possible that trawlable ground in the trawl survey area does not index vulnerable fish to the fishery in the same proportion as pre-vulnerable fish, or that there is a higher natural morality on pre-vulnerable fish, or a combination of both. Using a pulse of recruitment to reproduce this pattern would require a complex series of year class strengths, because the mode in 1993 was at age 22 and if the extra height of this mode was due to a pulse of recruitment, then there should have been a mode, or shoulder in the frequency distribution, at age 39 in 2010, but this was not observed.

4 SUMMARY

The aim of this study was to evaluate whether population age structure had changed over the last two decades for MEC orange roughy. Whilst there appear to have been some changes, such as the shift in the dominant mode from age 22 years in 1993 to age 25 years in 2010, the overall pattern of the age frequencies did not agree with that predicted from the accepted stock assessment models. Consequently, interpretation of the observed age frequencies is currently unclear, and these data imply that there needs to be a re-evaluation of the assumptions and structure of the stock assessment models. For example, currently accepted growth for roughy has a negative bias for ages up to 20 or so, and using a low natural mortality of 0.025 with a domed selectivity for the southern fishery is not supported by the observed age frequencies (Figure 8).

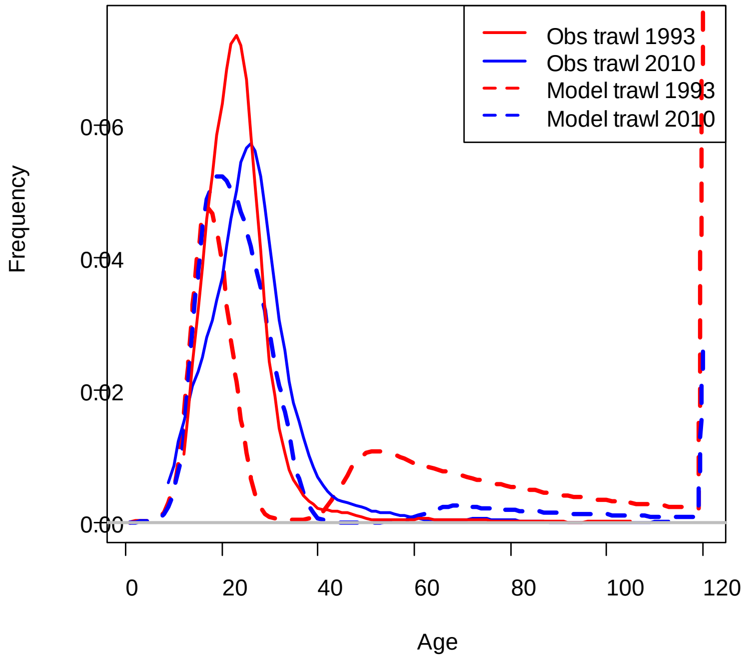

Figure 8: Comparison of observed and RunP model predicted age frequencies reported in the Plenary report. RunP has a fixed natural mortality of 0.025.

ACKNOWLEDGMENTS

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APPENDIX A: AGE FREQUENCIES FOR THE TRAWL SURVEYS IN 1993 AND 2010

Table A.1 Age frequencies in 1993.

Age	Male	Female	Unsexed	Total	c.v. total
12	0.00330	0	0	0.00163	1.364
13	0.00859	0.00750	0	0.00804	0.645
14	0.01949	0.01719	0	0.01833	0.500
15	0.05627	0.03156	0	0.04376	0.307
16	0.06598	0.02465	0	0.04505	0.356
17	0.01587	0.04868	0	0.03249	0.426
18	0.08997	0.05374	0	0.07162	0.341
19	0.05605	0.04644	0	0.05118	0.349
20	0.04406	0.06681	0	0.05558	0.412
21	0.05058	0.09168	0	0.07139	0.373
22	0.07267	0.06627	0	0.06942	0.491
23	0.09462	0.08610	0	0.09030	0.428
24	0.09023	0.11449	0	0.10252	0.461
25	0.07124	0.07881	0	0.07508	0.458
26	0.05108	0.05595	0	0.05355	0.504
27	0.03712	0.04551	0	0.04137	0.562
28	0.04218	0.06043	0	0.05142	0.510
29	0.01201	0.02306	0	0.01761	0.652
30	0.01574	0.0138	0	0.01476	0.657
31	0.02442	0.00972	0	0.01697	0.800
32	0.01970	0.01357	0	0.01660	0.856
33	0.00392	0.00188	0	0.00288	0.829
34	0.00354	0.00279	0	0.00316	0.947
35	0.00499	0.00247	0	0.00372	0.993
36	0.00715	0.00793	0	0.00754	0.815
37	0.00803	0.00397	0	0.00597	0.809
38	0.00195	0.00271	0	0.00234	0.775
39	0	0.00172	0	0.00087	0.738
40	0	0.00094	0	0.00047	1.354
41	0.00106	0.00016	0	0.00061	0.884
42	0.00283	0.00016	0	0.00148	0.779
43	0.00522	0.00165	0	0.00341	0.740
44	0.00595	0.00016	0	0.00302	1.163
45	0	0.00124	0	0.00063	0.798
46	0	0	0	0	NA
47	0.00513	0	0	0.00253	1.349
48	0.00126	0.00051	0	0.00088	0.896
49	0.00171	0.00031	0	0.001	1.049
50	0.00016	0	0	8e-05	1.517
51	0	0	0	0	NA
52	0	0	0	0	NA
53	0	0.00051	0	0.00026	1.335
54	0	0.00016	0	8e-05	1.083
55	0.00082	0.00107	0	0.00095	1.014
56	0.00011	0.00042	0	0.00027	1.172
57	0.00033	0	0	0.00016	0.849
58	0	0	0	0	NA
59	0	0.00047	0	0.00024	1.011
60	0	0	0	0	NA
61	0.00053	0.00318	0	0.00187	0.650
62	0	0.00042	0	0.00021	1.244
63	0.00044	0.00038	0	0.00041	0.922
64	0	0.00071	0	0.00036	1.101
65	0.00067	0.00116	0	0.00092	0.869

Age	Male	Female	Unsexed	Total	c.v. total
66	0	0	0	0	NA
67	0.00011	0	0	5e-05	1.3
68	0.00021	0.00073	0	0.00047	0.890
69	0	0	0	0	NA
70	0	0	0	0	NA
71	0	0.00132	0	0.00067	1.060
72	0.00016	0	0	8e-05	1.491
73	0.00119	0	0	0.00059	1
74	0	0.00051	0	0.00026	1.386
75	0.00044	0.00064	0	0.00054	0.817
76	0	0	0	0	NA
77	0	0	0	0	NA
78	0	0.00057	0	0.00029	1.151
79	0.00021	0	0	1e-04	0.999
80	0	0.00042	0	0.00021	1.271
81	0	0	0	0	NA
82	0	0.00094	0	0.00047	1.405
83	0	0	0	0	NA
84	0	0	0	0	NA
85	0	0	0	0	NA
86	0	0	0	0	NA
87	0.00011	0.00082	0	0.00047	0.885
88	0.00016	0	0	8e-05	1.429
89	0	1e-04	0	5e-05	2.184
90	0	0	0	0	NA
91	0	0	0	0	NA
92	0	0	0	0	NA
93	0	0	0	0	NA
94	0.00011	0	0	5e-05	1.229
95	0	0	0	0	NA
96	0	0	0	0	NA
97	0	0	0	0	NA
98	0.00034	0	0	0.00017	1.360
99	0	0	0	0	NA
100	0	0	0	0	NA
101	0	0.00042	0	0.00021	1.232
102	0	0	0	0	NA
103	0	0.00038	0	0.00019	1.198
104	0	0	0	0	NA
105	0	0.00014	0	7e-05	1.405

Table A.2 Age frequencies in 2010.

Age	Male	Female	Unsexed	Total	c.v. total
9	7e-04	0	0	0.00032	2.150
10	0.00498	0.00338	0	0.00412	0.966
11	0.02571	0.02305	0	0.02428	0.564
12	0.01300	0.00260	0	0.00740	0.837
13	0.01461	0.03030	0	0.02305	0.559
14	0.03913	0.01645	0	0.02692	0.572
15	0.01561	0.02593	0	0.02117	0.444
16	0.02371	0.01415	0	0.01857	0.448
17	0.01629	0.02233	0	0.01954	0.493
18	0.03053	0.04053	0	0.03591	0.364
19	0.05822	0.03119	0	0.04367	0.320
20	0.02875	0.01863	0	0.02330	0.416
21	0.05613	0.01749	0	0.03533	0.362
22	0.05545	0.04701	0	0.05091	0.298
23	0.06411	0.02328	0	0.04214	0.346
24	0.09517	0.04795	0	0.06975	0.310
25	0.04805	0.06053	0	0.05477	0.336
26	0.05616	0.10187	0	0.08077	0.329
27	0.03719	0.03461	0	0.03580	0.363
28	0.07120	0.10135	0	0.08743	0.312
29	0.04246	0.03728	0	0.03967	0.330
30	0.01737	0.04691	0	0.03327	0.367
31	0.02232	0.05074	0	0.03762	0.429
32	0.01847	0.02703	0	0.02308	0.458
33	0.03384	0.03075	0	0.03218	0.365
34	0.01313	0.01075	0	0.01185	0.566
35	0.01567	0.01797	0	0.01690	0.449
36	0.01322	0.01950	0	0.01660	0.481
37	0.01952	0.00639	0	0.01245	0.517
38	0.01094	0.00916	0	0.00998	0.581
39	0.00290	0.00421	0	0.00360	0.576
40	0.00415	0.00646	0	0.00540	0.617
41	0.00667	0.00227	0	0.00430	0.757
42	0.00910	0.00654	0	0.00772	0.653
43	0	0.00316	0	0.00170	1.069
44	0	0.00628	0	0.00338	0.857
45	0.00105	0	0	0.00048	1.138
46	0	0.00251	0	0.00135	0.849
47	0	0.01115	0	0.00600	0.621
48	0.00231	0.00316	0	0.00277	0.808
49	0	0.00728	0	0.00392	1.094
50	0	0.00092	0	0.00049	1.078
51	0	0	0	0	NA
52	0	0.00045	0	0.00024	1.571
53	0.00290	0.00502	0	0.00404	0.713
54	0	0.00067	0	0.00036	1.091
55	0.00115	0.00257	0	0.00192	0.794
56	0	0.00229	0	0.00123	0.891
57	0	0.00316	0	0.00170	1.024
58	0	0	0	0	NA
59	0	0	0	0	NA
60	0	0.00420	0	0.00226	1.064
61	0	0.00056	0	3e-04	1.164
62	0	0	0	0	NA
63	0	0.00056	0	3e-04	1.226
64	0	0	0	0	NA
65	0	0	0	0	NA
66	0	0.00092	0	0.00049	1.141

Age	Male	Female	Unsexed	Total	c.v. total
67	0	0.00160	0	0.00086	0.888
68	0	0	0	0	NA
69	0.00185	0	0	0.00085	1.171
70	0	0	0	0	NA
71	0	0.00056	0	3e-04	1.27
72	0	0	0	0	NA
73	0	0.00077	0	0.00042	1.059
74	0.00445	0	0	0.00205	1.01
75	0	0.00083	0	0.00044	0.885
76	0	0	0	0	NA
77	0	0	0	0	NA
78	0	0.00056	0	3e-04	1.246
79	0	0	0	0	NA
80	0	0	0	0	NA
81	0.00185	0.00067	0	0.00121	0.961
82	0	0.00021	0	0.00011	1.666
83	0	0	0	0	NA
84	0	0	0	0	NA
85	0	0.00045	0	0.00024	1.663
86	0	0	0	0	NA
87	0	0	0	0	NA
88	0	0	0	0	NA
89	0	0	0	0	NA
90	0	0	0	0	NA
91	0	0	0	0	NA
92	0	0	0	0	NA
93	0	0	0	0	NA
94	0	0	0	0	NA
95	0	0	0	0	NA
96	0	0	0	0	NA
97	0	0	0	0	NA
98	0	0	0	0	NA
99	0	0	0	0	NA
100	0	0	0	0	NA
101	0	0	0	0	NA
102	0	0	0	0	NA
103	0	0	0	0	NA
104	0	0	0	0	NA
105	0	0	0	0	NA
106	0	0	0	0	NA
107	0	0	0	0	NA
108	0	0	0	0	NA
109	0	0	0	0	NA
110	0	0	0	0	NA
111	0	0	0	0	NA
112	0	0	0	0	NA
113	0	0.00093	0	5e-04	1.183