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I. J. Doonan
P. J. McMillan
A. C. Hart

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I. J. Doonan
P. J. McMillan
A. C. Hart

NIWA
Private Bag 14901
Wellington

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EXECUTIVE SUMMARY

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Population age frequencies for smooth oreo in quota management area OEO 4 were determined by estimating ages from otoliths and data collected on two acoustic surveys carried out in 1998 and 2005. Two people with previous experience of reading smooth oreo otoliths were involved and the readings were performed using a protocol set of otolith sections with agreed zone counts. All the sampled otoliths (n = 546) from the 1998 survey and randomly selected otoliths (n = 500) from the 1800 otoliths collected during the 2005 survey were prepared and read. All the otoliths sampled from the largest catches in the 2005 survey were selected and read because the large tows had a large influence on the total age frequency. Ageing error was 8.5% including between-reader error, but not including between-lab error. Age reading temporal drift estimates for one reader (7 months) was -0.6 year which is trivial compare to other error sources. The age frequencies had a mean weighted c.v. of 36% (1998) and 45% (2005).

Simulations showed that individual spikes present in the estimated frequency distributions were due to sampling noise, but that smoothing applied to the curves reliably revealed the general profile of the age frequency. Smoothing the age frequencies showed that in 1998 there was a pulse of younger fish finishing at age 16 years, and that this pulse was absorbed into the main body of the age frequency in 2005. A mean weighted c.v. of about 30% for the age frequency should be possible if about 1000 otoliths per survey are read.

Comparison of the observed age frequencies with the predicted age frequencies from the stock assessment model showed that a block of good recruitment was required in the model to achieve a reasonable correspondence, although the length of the block appeared smaller in 1998 then in the 2005 age sample, i.e., assuming constant recruitment might lead to a biased assessment analysis. Again, predicted total mortality (Z) values from the stock assessment model were consistent with the observed values only when a block of recruitment was introduced into the model. An analysis of the influence of the mark-type (School-deep, School-shallow, Layers, Background, and Hills) on the age frequency analysis showed that there were no unexplained or unpredicted effects.

Future surveys should aim to collect at least 2000 smooth oreo otoliths, and age estimates should be a routine part of smooth oreo stock assessment work.

1. INTRODUCTION

1.1 Overview

This work addresses the following objectives in MFish project "Ageing of smooth oreo otoliths for stock assessment purposes" (OEO2006/03).

Overall objective

1. To carry out a stock assessment of black oreo (*Allocyttus niger*) and smooth oreo (*Pseudocyttus maculatus*), including estimating biomass and sustainable yields.

Specific objective

1. To estimate the population age structure of OEO 4 smooth oreo, from near the start of the fishery, and from the recent fishery, by direct age estimates of research survey otolith samples

The OEO 4 smooth oreo fishery has a recent annual catch of 5000–6000 t and is the largest oreo fishery in the EEZ. Stock assessments were completed in 2001 (Doonan et al. 2001) using an abundance estimate from the 1998 acoustic survey, and in 2003 using abundance estimates from the 1998 and 2001 acoustic surveys (Doonan et al. 2003, Sullivan et al. 2005). Another acoustic survey of OEO 4 smooth oreo was completed in November 2005 (project OEO2005/01) and abundance estimates from that survey were presented to the Deepwater Fishery Assessment Working Group in February-March 2007.

The 2001 and 2003 stock assessments of OEO 4 smooth oreo incorporated observer and research length data into the model as a proxy for population age estimates. In the 2003 assessment the observer length data and acoustic absolute abundance estimates dominated the model fits and drove the analysis. The assessment suggested that the previously observed estimates of natural mortality (M) and growth (Doonan et al. 1995, 1997) were inconsistent with the observer length data. The assessment also predicted a pronounced shift in the age frequencies over time. It was suggested that better population model results for the next stock assessment would be obtained by using direct age estimates from otolith reading of research samples collected early on and more recently from these fisheries since this gives the best contrast in any signal that is present. It was also suggested that the age estimates may provide information on relative levels of recruitment over time.

Previous smooth oreo age estimates were made by counting zones in thin sections and gave maximum unvalidated estimates of 80 years for a 51.3 cm total length fish (Doonan et al. 1995, 1997). Unpublished Australian radiometric results suggest that the species is long lived. The same thin section age technique used by Doonan et al. (1995, 1997) was proposed for the present study subject to it being consistent with the results of a project to estimate smooth oreo ages using the bomb radiocarbon technique (project DEE200501). That project was completed by NIWA during 2005–06 and the preliminary results provided support for the age estimation technique using growth zone counting, and consequently the Doonan et al. (1995, 1997) thin section techniques were employed to estimate age.

The work reported here estimated smooth oreo population age distributions using data collected from two acoustic surveys of smooth oreo in area OEO 4 carried out in 1998 (Project OEO9801, survey TAN9812) and 2005 (Project OEO200501, surveys TAN0514 and SWA0501). Estimated age distributions were analysed and compared for the two years, within- and between-reader estimates were analysed, and results were compared with previous age estimates and with predicted model results. In future (not in the current project) the two age distributions could be used in stock assessment analyses for OEO 4 smooth oreo.

2. METHODS

2.1 Sampling, otolith preparation, and reading

Otolith samples from the mark identification trawling carried out in OEO 4 during 1998 and also in 2005 (project OEO200501) were used. Samples are stored at NIWA, Greta Point, and associated biological data for each sample are stored on the *Trawl* database maintained by NIWA.

All smooth oreo otoliths sampled during the 1998 survey were used (n = 546). About 1800 smooth oreo otoliths were sampled during the 2005 survey, so otoliths were selected at random from tows by mark-type. At least one otolith was sampled from each tow, but the remainder were sampled in proportion to the abundance contribution that the mark-type made to the total and the catch size of the tow within its mark-type. A total of 500 otoliths were used for estimating age.

The otoliths were selected, located and removed from storage, and then prepared for reading. The dorso-ventral (cutting) axis was marked and the whole otolith then embedded in epoxy resin (in sets of 5 per block), thin sections cut, then the section was glued to a slide, polished, and read under a microscope using transmitted light. The otolith reading protocol was that outlined by Doonan et al. (1995 & 1997). Readability codes of 1–5 were assigned where 1 is excellent and 5 is unreadable. Final readings were entered into the *age* database maintained by NIWA, along with associated biological data.

2.2 Between- and within-reader error analysis

A random selection of 200 otoliths (100 from each year sampled), representing the range of lengths sampled, was read twice by two readers. Data with one readability code of 5 for any of the readings on each otolith were excluded.

Readings were plotted and a smooth (lowess) line fitted and this was compared to the 1:1 line for each reader. The two readings were averaged for each reader and these averages were plotted and the smooth line was fitted and compared to the 1:1 line. Deviations indicate drift or between-reader biases. Drift was investigated by estimating the median and mean difference in the two within-reader ages from the first to the second reading. Reader 1 read these otoliths a third time seven months after the end of the work on the first two readings. This tested for drift in the readings after a lengthy period of time. An extra 106 otoliths were also selected from the 2005 survey for fish with lengths between 28 and 32 cm, inclusive. These were used to check the mean age by 1 cm length bin for the 2005 sample which showed a deviation from other data sets in this length range.

A common c.v., c, was assumed across all ages for within- and between-reader error. This c.v. was estimated by $c^2 = \sum_j \left(\frac{x_{1j} - x_{2j}}{x_{1j} + x_{2j}} \right)^2 \Big/ n$ where x_1 is the age estimated by reader 1 and x_2 is that for reader 2. For between-reader error, the mean of each reader's two ages were averaged and these were compared as above. The expected c.v. with no extra variation from the between-reader source is $c/\sqrt{2}$. With between-reader variations acting as another independent multiplicative factor, the total c.v. would be approximately $\sqrt{c_{between}^2 + c^2/2}$.

2.3 Analysis of age estimates

The age data were collected from trawls on mark-types which form strata within the acoustic survey area and so each otolith must be given a weight, w_i, depending on the population size in the stratum it came from, the contribution of the tow to that population estimate, and the sampling fraction within the tow. The population age frequency is then given by $f_a = \sum_k^{otoliths} I_{a_k=a} w_k$, where $I_{a=b}$ is the indicator function that is 1 if a = b and 0 otherwise. The factor w_k is given by $\frac{N_{s_i}}{\sum_s N_s} \frac{c_{s_i j_i}}{\sum_j c_{sj}} \frac{1}{n_{sj}}$, where c_{sj} is the catch rate for the j[th] tow in the s[th] mark-type-stratum, N_s is the abundance, and n_{sj} is the sample size. The variance structure is estimated by bootstrapping the tows within mark-types (1998) and within mark-type and stratum (2005). The ageing error was estimated by comparing age estimates from two readers and also by using repeated readings from the same reader. An overall c.v. is reported based on the average c.v. over the frequency, weighted by the estimated frequency.

Age frequencies were estimated by sex and combined over sexes. A combined age frequency was also estimated for the non-fished mark-types (layers with mixed species present) and for the fished mark-types (oreo marks containing mostly oreos). Length data were available with the otolith samples and these were used to make up a length frequency that was compared to the length frequency using the larger length-only samples (typically 200 fish per tow or all fish if there were fewer than 200).

An estimate of the equivalent sample size (N_equ) for independent random samples drawn from the age frequency treated as a simple multinomial distribution was estimated by $V(a)/V_{boot}$ where V_{boot} is the bootstrap variance of the mean age from the sample and $V(a)$ is the variance for the distribution assuming the estimated frequency is the true frequency.

To investigate the information in the estimated age frequency, simple random samples of size N_equ were drawn from the distribution using a smoothed version (smooth width 5 yr, density function (R Development Core Team (2004)) of the estimated age frequency as the "true" distribution. These samples were smoothed using a width of 2.5, 5, 10, and 15, and compared to the total distribution. 500 simulated samples were taken.

2.4 Observed versus predicted age frequencies from the stock assessment model

The observed age frequencies from this study (estimated and a smoothed version) were compared with those predicted for the acoustic selected population from the stock assessment model that used constant recruitment and were also compared with results from a re-run of the stock assessment model with good recruitment from 1972 to 1985 (as 1 year olds).

2.5 Estimates of total mortality (Z)

Fishing mortality was estimated using $\log\left((1+A)/A\right)$, where A is the mean age past the age of full vulnerability, *Tc*, i.e., $\sum_{age=Tc} f_{age}(age-Tc) \Big/ \sum_{age=Tc} f_{age}$, where f_j is the frequency for age j. A range of *Tc*s were used, but the one estimated in the stock assessment was 25 for the east and 27 for the west fisheries. Z was estimated for the 1998 and 2005 surveys. A c.v. for the estimates was made from the bootstrap age frequencies generated above.

Z can also be estimated using the predicted age frequency for the acoustic selectivity in the model years 1998–99 and 2005–06. The latter assumes average recruitment, so an estimate was made using a block of good recruitment at age one in 1973 to 1984 (year class strength [YCS] = 2) with poorer recruitment outside this range (YCS 0.5). The year range is suggested from the results reported here, but the YCS values used are purely for illustrative purposes. A (potentially) different Z is used in the model each year to generate catches, but this is different from the one estimated here since the age frequency is a result of cumulative changes from different Zs in the past unless the system is in equilibrium.

2.6 Influence of mark-type on the age frequency distribution

The Deepwater Stock Assessment Working Group asked for an analysis of the effect of the abundance survey mark-type categories on the age frequency. The design of the surveys included sampling from specific mark-types (which were made into strata in the 2001 and 2005 survey analyses). These mark-types are School-deep, School-shallow, Layers, Background, and Hills (Important, Complexes, Other). Otoliths sampled from catches that made a large contribution to the abundance received more weight in the age frequency, so a sensitivity analysis was performed that examined the influence of the mark-types on the survey age frequency. This involved excluding the data from each mark-type from the analysis, one at a time, and re-estimating the age frequency.

3. RESULTS

3.1 Sampling, otolith preparation and reading

An example of an otolith annotated with the zones counted by one reader is shown in Figure 1. This was a male of 37.7 cm total length with about 50 zones (assumed to be years). Typically for smooth oreo otoliths, the first 6–7 zones are wide and probably represent a period of faster growth before the individual settles on the bottom. The zones from about 8 to 20 can be more difficult to interpret and sometimes can appear to have an extra or split zone. But the numerous zones from about 20 to the edge are often relatively easy to count and for older/larger fish make up the most of the total zone count.

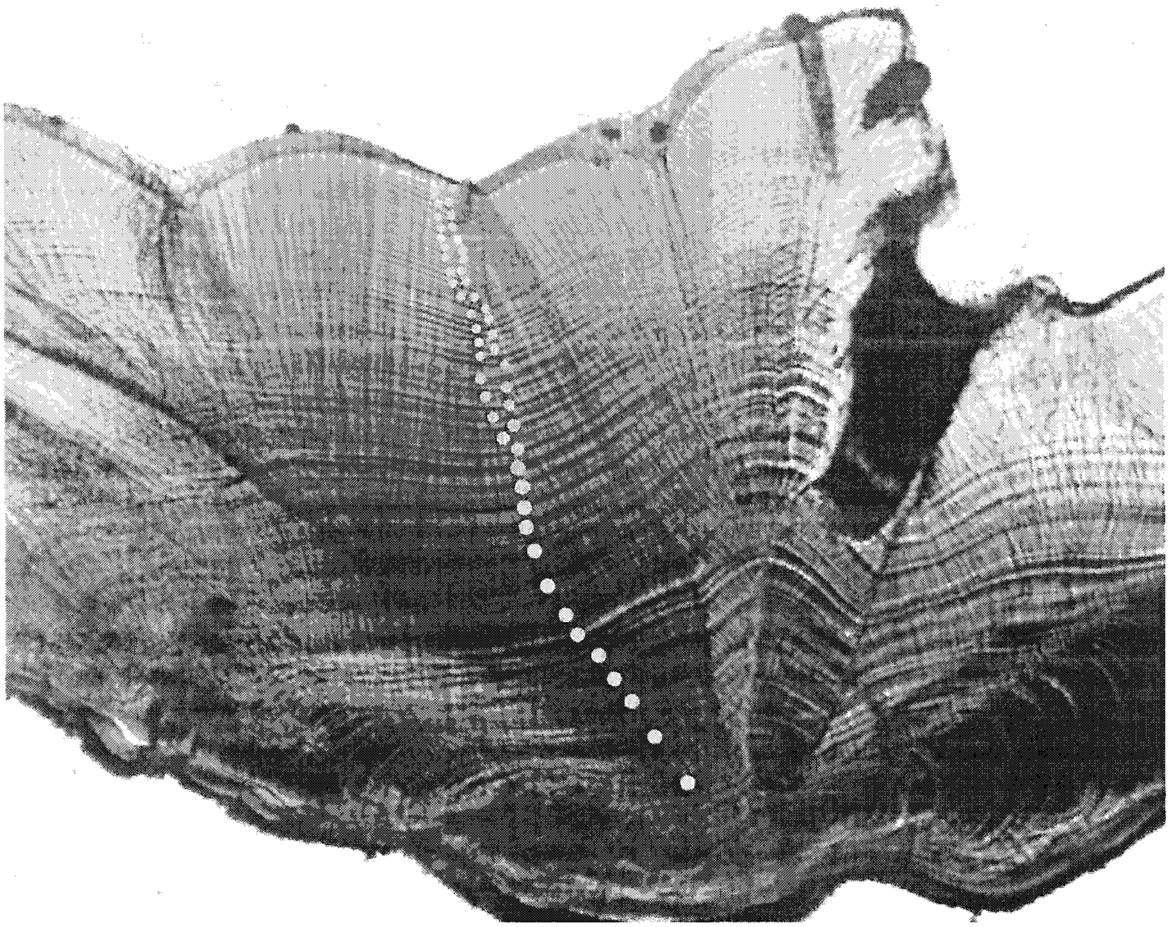


Figure 1: Example of a smooth oreo otolith section with zones counted shown (about 50) as dots, interpreted as a year of growth. Viewed at approx. 100 times with transmitted light. This was a 37.3 cm total length male (fish no. 1007, station 33, TAN9812).

3.2 Between- and within-reader error analysis

There were 206 otoliths read twice by two readers of which 18 had a readability code of 5 and were excluded from further analysis. Of the excluded otoliths, reader 2 had one code 5 in a second reading on one otolith. Reader 1 had 18 code 5 readings (including the one otolith of reader 2), 9 for the first reading and 9 for the second reading of which 6 were common to both readings.

There was a small amount of drift between the first and second readings for both readers, and this was slightly larger for reader 1 (Figure 2). The mean difference in the second age relative to the first was 1.6 years for reader 1 and 0.57 years for reader 2. In terms of ratios (2^{nd}/1st), reader 1 had a statistically significant difference at 1.07 and a 95% range of ratios from 0.80 to 1.30. Reader 2's mean ratio was not significant (1.01) and he had a 95% range of 0.71 to 1.41. For the third readings made by reader 1 there was a -0.6 yr difference compared to the second reading.

The within-reader c.v. was 7.3 and 7.6% for readers 1 and 2. The between-reader c.v. for the mean ages was 6.6% compared to about 5.3% if there were no between-reader component. This indicates that the between-reader source c.v. was 4%. The total error c.v., including the between-reader error, for any one reading is 8.5%.

The plot of mean age by readers (Figure 3) shows little differences between the readers for the most part, but perhaps a year difference for older ages.

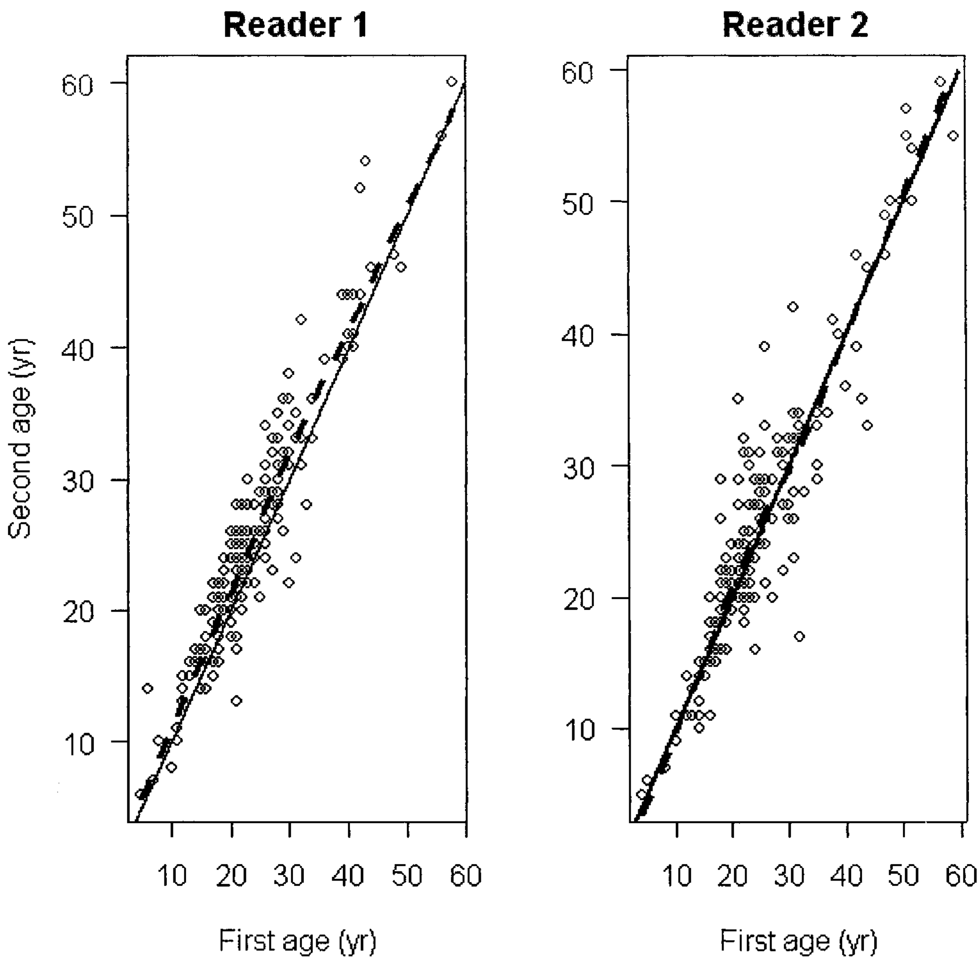


Figure 2: **Comparison of the paired readings by reader. The solid line is the 1:1 and the dotted line is a smooth curve fitted to the data.**

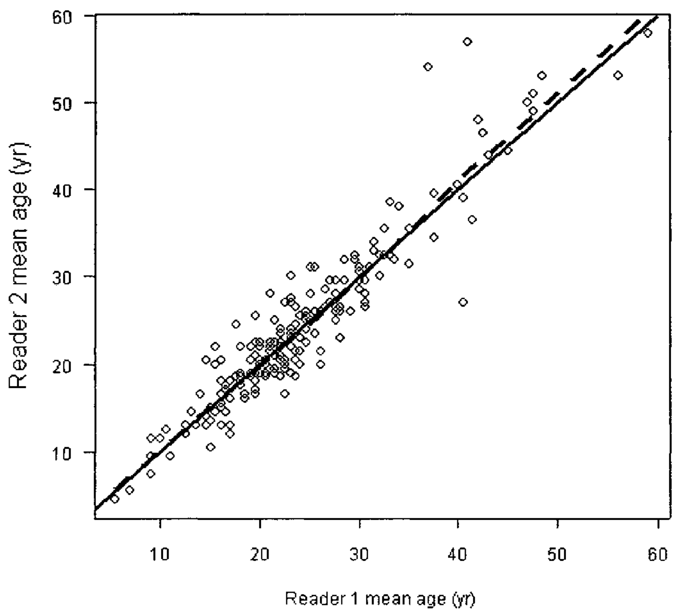


Figure 3: **Comparison of the mean ages of the paired readings for the two readers. Solid line is the 1:1 and dotted line is a smooth curve fitted to the data.**

To check consistency of ageing, the mean age for a given length was computed for the 1998 and 2005 samples. This showed some discrepancies for the 2005 fish aged about 20 (Figure 4). When data aged in 1994 and 1995 were used (M and growth project), the same result applied, but with a wide divergence for the greatest lengths (over 40 cm) which are lengths in the right hand tail of the length frequency (Figure 5). When an extra 106 otoliths from 2005 from fish with lengths between 28 and 33 cm were read, the mean ages were very similar to the previous values. Ages under 20 were mostly in the layer mark-types in 1998, but these ages were few in 2005.

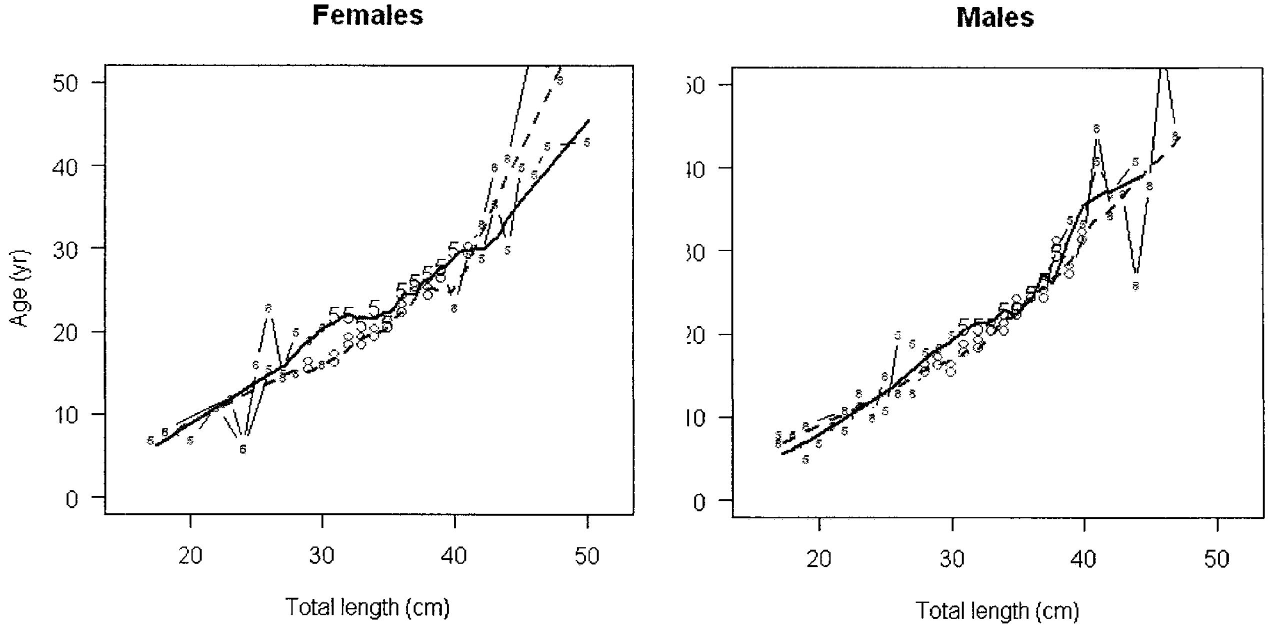


Figure 4: Comparison of the mean age by length for the 1998 ("8") and 2005 ("5") samples. Points are larger when the mean is based on 10 or more fish. A smoothed line is fitted though the individual points, dashed for 1998 and solid for 2005, a lowess function with the parameter f set to 0.2.

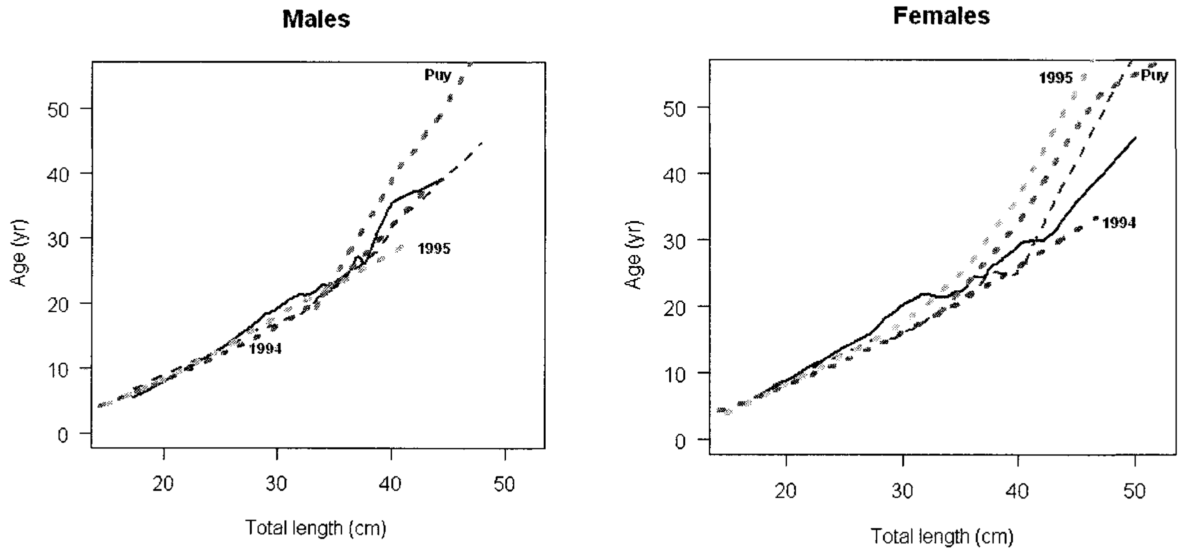


Figure 5: Comparison of the smooth line fitted to age and length for the 1998 and 2005 samples, dashed for 1998 and solid for 2005. The dotted lines are smoothed lines for the data read in 1994 ("1994"), 1995 which were OEO 4 fish from the "flats" and the hills ("1995"), and Puysegur from a 1992 survey and aged in 1995 ("Puy"). Smoothed curves were estimated using a lowess function.

3.3 Analysis of age estimates

The raw age frequencies for the 1998 and 2005 acoustic surveys are shown in Figure 6. The most notable feature is a pulse of fish centred on age 16 years in the 1998 survey that is not present in the 2005 survey.

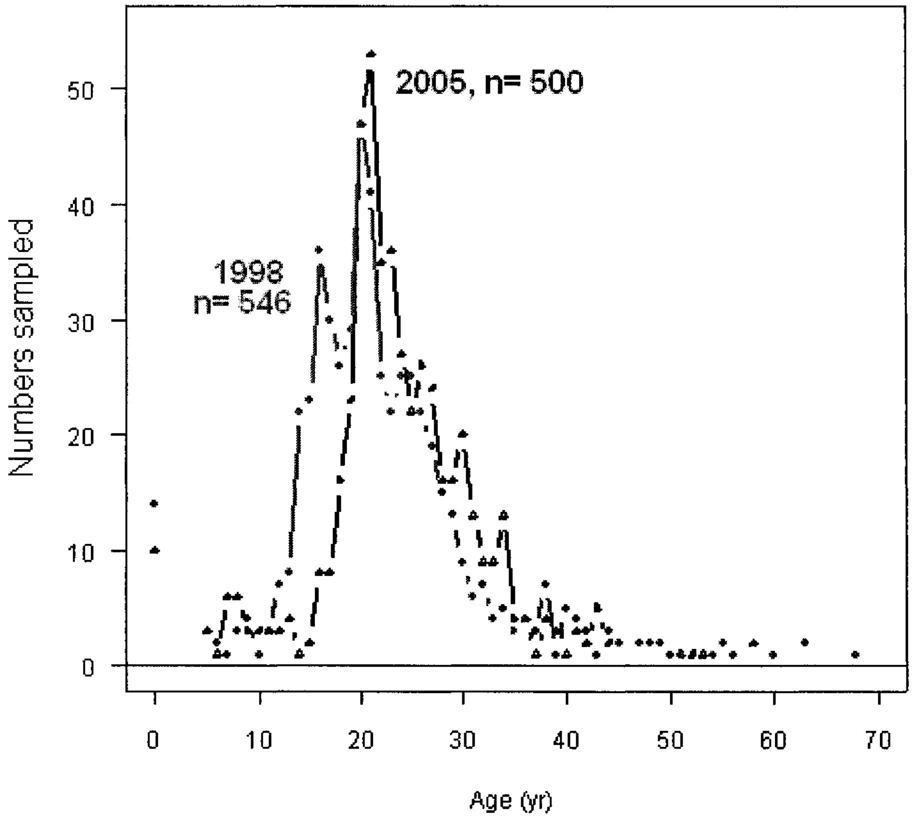


Figure 6: Raw age frequencies for the data collected in the 1998 and 2005 acoustic surveys.

3.3.1 1998 acoustic survey

The age frequency distribution by sex (Figure 7) shows broad similarities for males and females with some differences in sampling spikes (see below). The age data were combined over sex (Figure 8) and had an average c.v. of 45%.

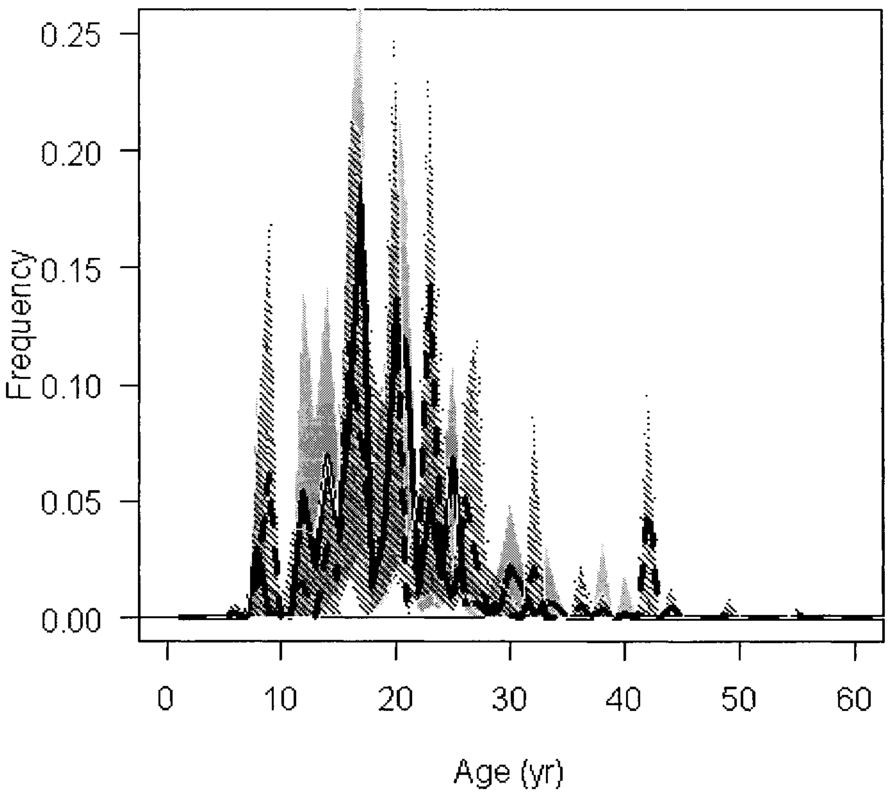


Figure 7: 1998 survey. Age frequency for males (dashed line) and females (solid line) with the 95% C.I. (male, stippled area; female, grey area).

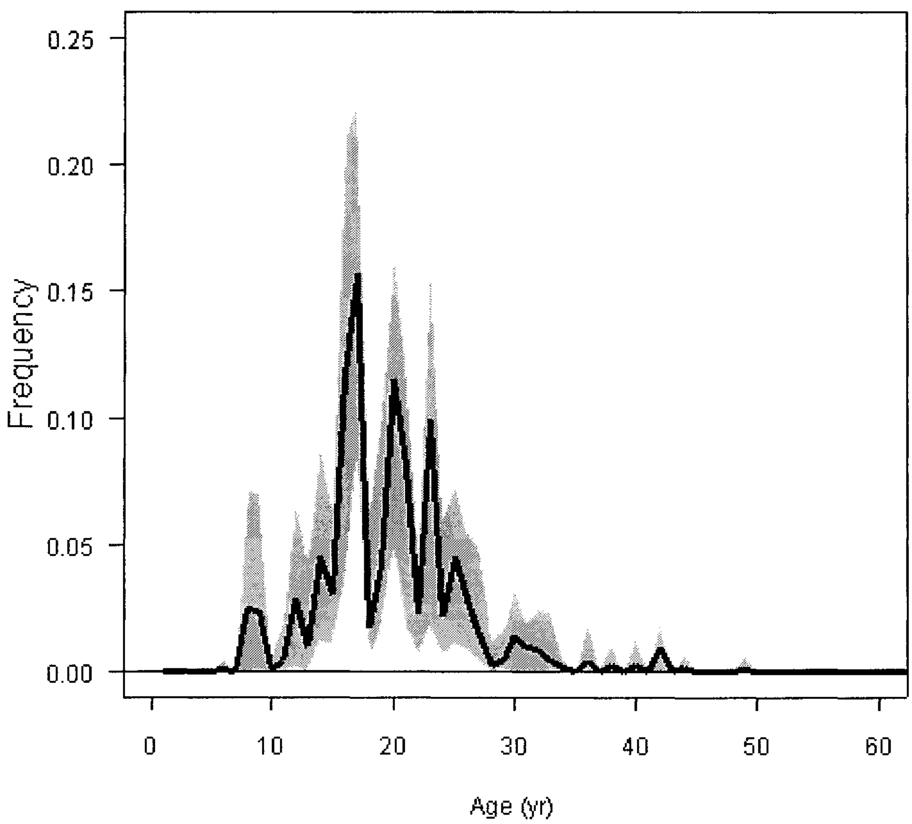


Figure 8: 1998 survey. Age frequency (solid line) for sexes combined and the 95% C.I. (shaded area).

Quality

Sampling appears to have resulted in spikes that are artefacts. Therefore, only the broad features have meaning in these data. The length frequency distribution from the otolith data show spikes that are absent in the frequency from the larger length data samples (Figure 9). The length data are mostly inside the bootstrap confidence interval (C.I.) for the otolith length frequency. This comparison indicates how much more variable the smaller otolith sampling is compared to the length samples.

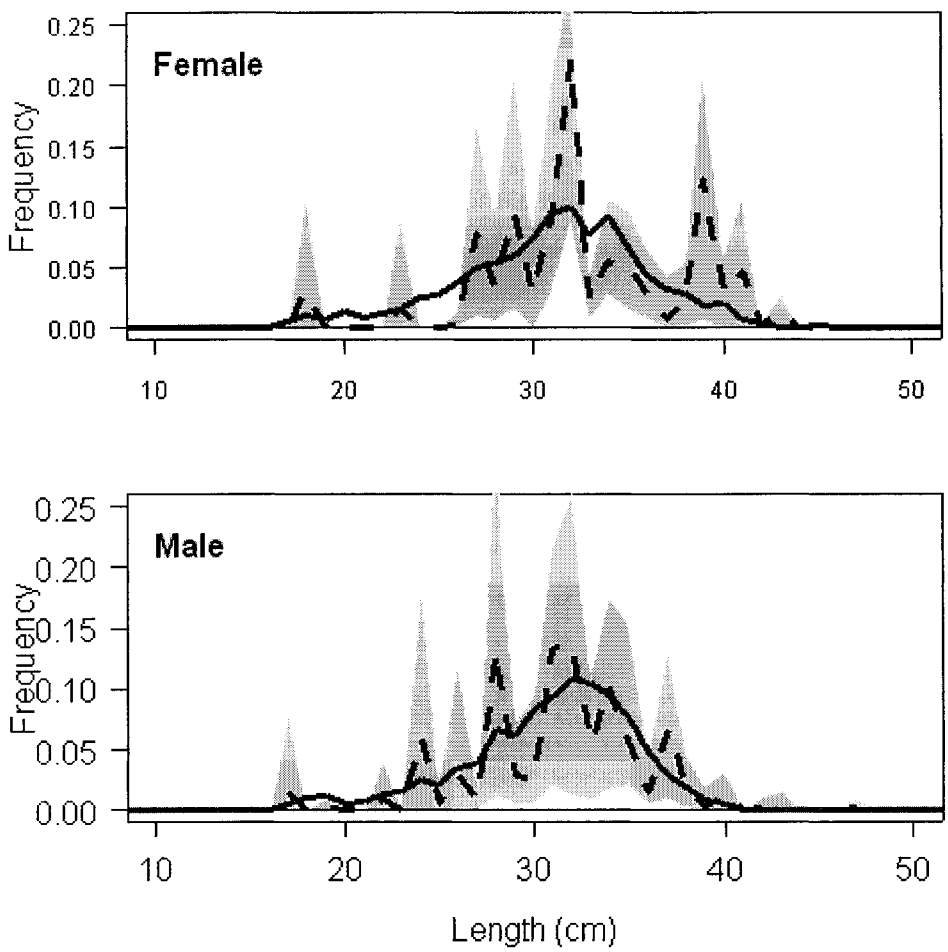


Figure 9: 1998 survey: Total length frequency from the otolith data (dashed line, 90%C.I. grey shading) with the length frequency from the full length data (solid line).

For the age frequency for the mixed species mark-types and the oreo school marks, peaks do not coincide where the frequencies overlap (Figure 10). This would indicate sampling variations for peaks. To remove these spikes, the frequencies were smoothed (Figure 11).

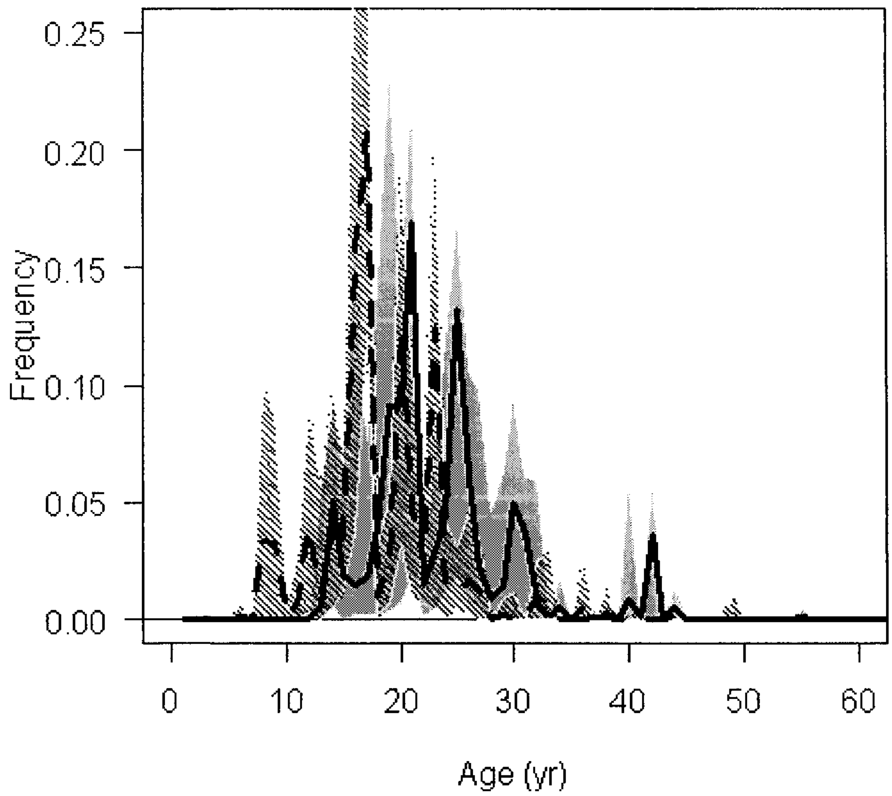


Figure 10: 1998 survey: Age frequency and 95%C.I. for mixed species mark-types (dotted line & stippled area) and oreo school marks (solid line and grey area).

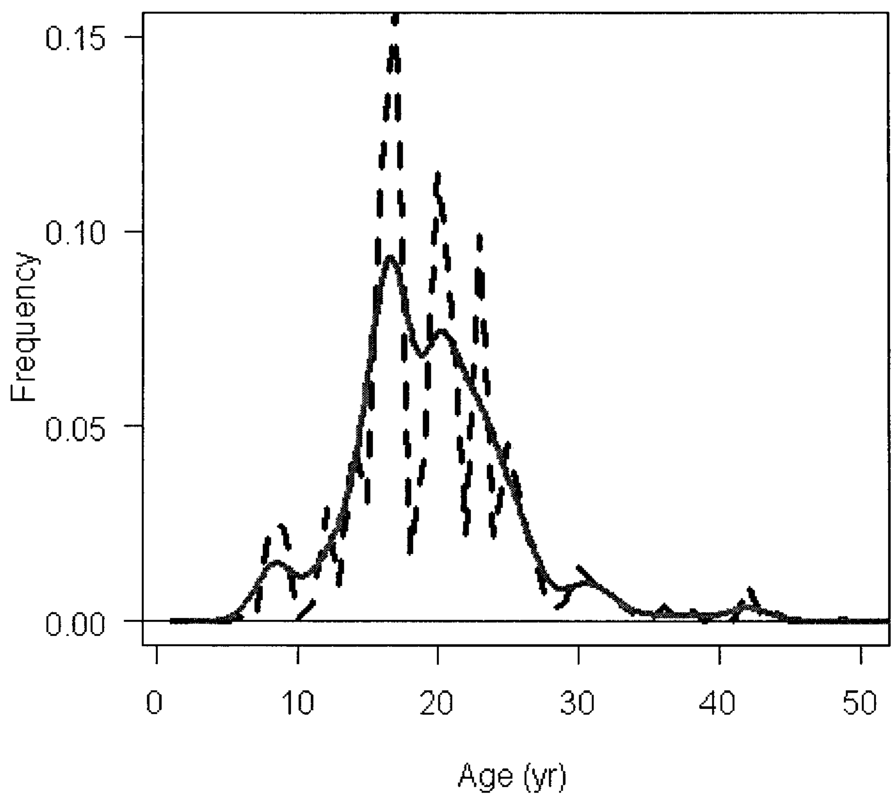


Figure 11: 1998 survey. Combined age frequency (dashed line) and a smoothed curve (solid line, smoothing width of 5 cm).

The effective sample size for a completely random sample is 55 (otoliths). Three examples of age frequencies using 55 random samples are shown in Figure 12. Note the spiky nature of the individual sample distribution despite the fact that they were sampled from the smoothed "true" distribution, and how the smoothed versions are more like the "true" age frequency.

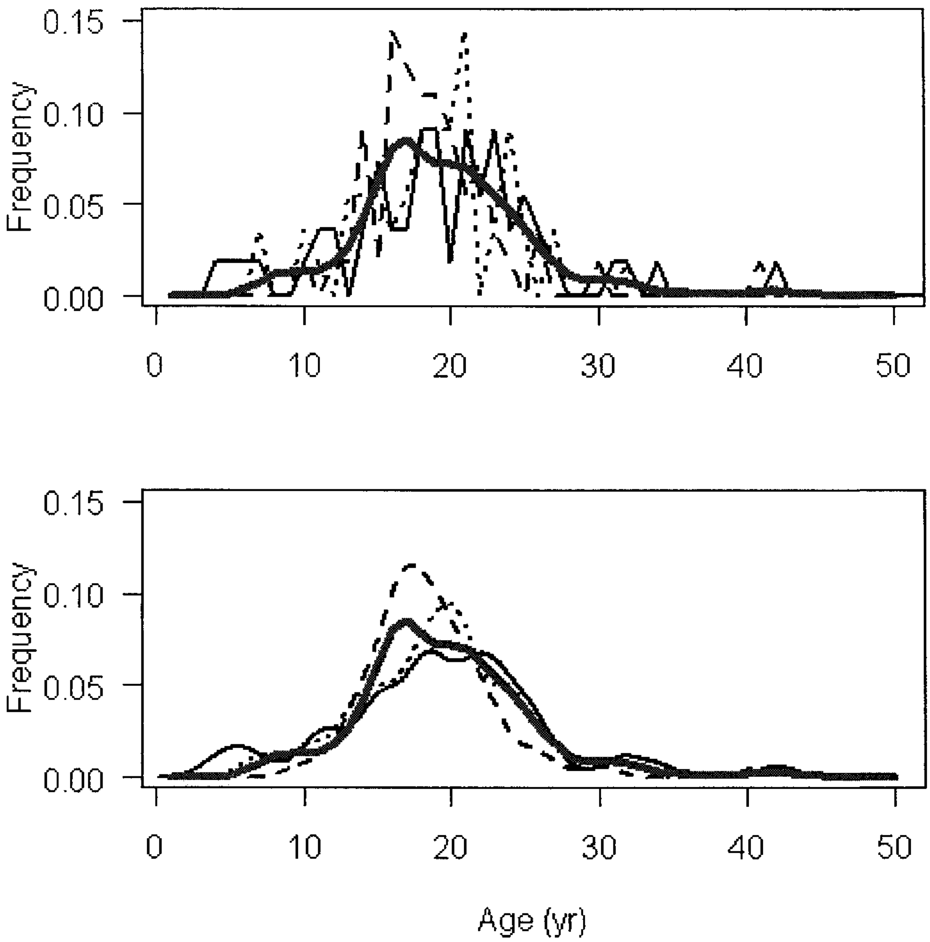


Figure 12. 1998 survey. Three simulated examples of age frequencies using a random sample of size 55 otoliths (top panel) and their smoothed curves (width 5 cm, bottom panel). The thick solid line is the "true" age frequency used to simulate random samples and is based on the 1998 survey smoothed age frequency with a width of 6 cm.

Smoothing has a bias-variance trade-off and this can be seen here where estimated frequencies have a high variance but low bias for small smoothing widths (Figure 13) and smaller variance and increased bias for larger smoothing widths. In this example, 5 cm seems a good compromise.

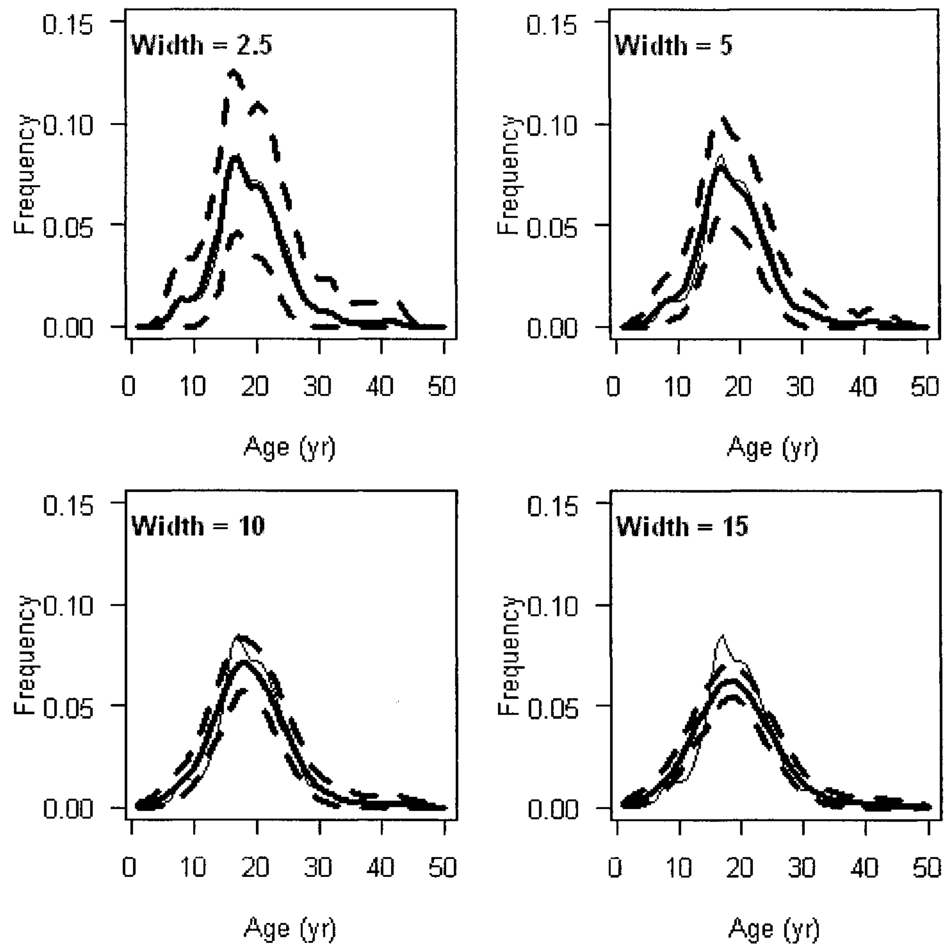


Figure 13: 1998 survey. Mean and 90% C.I. for smoothed age frequencies from 500 samples each composed of 55 otoliths for 4 smoothing widths (thick black line and dashed lines). Thin solid line is the smoothed age frequency with a width of 6 cm.

3.3.2 2005 acoustic survey

The age frequency distribution by sex (Figure 14) shows broad similarities for males and females with some differences in sampling spikes (see Quality below). The age data were combined for both sexes and had an average c.v. of 36% (Figure 15).

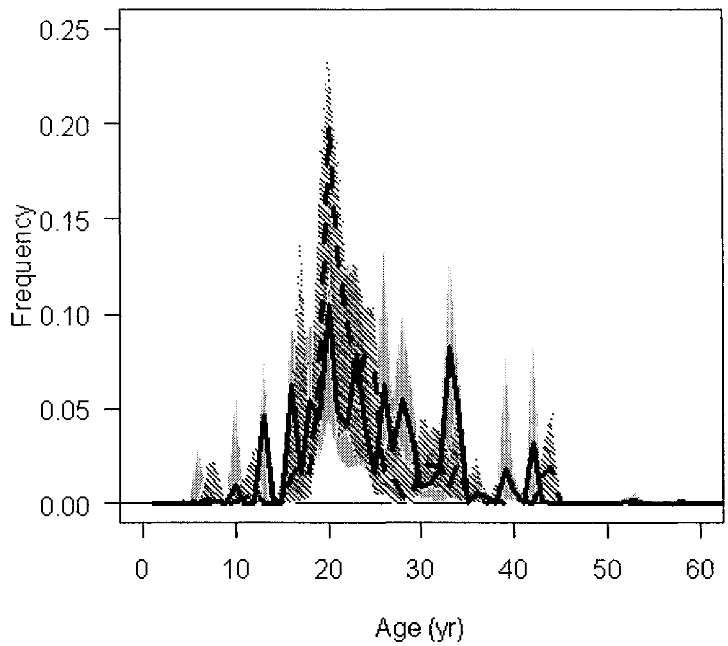


Figure 14: 2005 survey. Age frequency for males (dashed line) and females (solid lined) with the 95%C.I. (male, stippled area; female grey area).

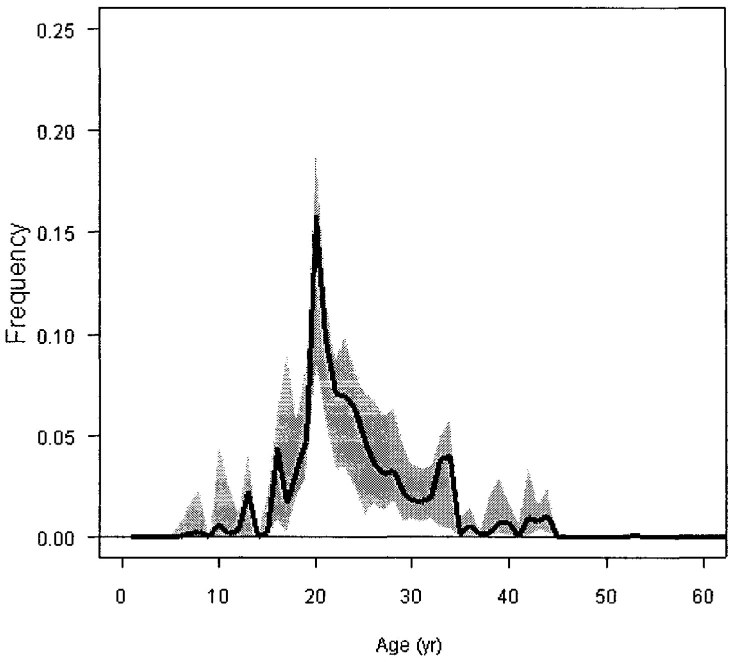


Figure 15: 2005 survey. Age frequency (line) for sexes combined and 95% C.I. (shaded area).

Quality

Sampling in 2005 also appears to have resulted in spikes that are artefacts, and therefore only the broad features have meaning in these data. The length frequency distribution from the otolith data shows spikes that are absent in the frequency from the larger length data (Figure 16). The length data are mostly inside the bootstrap CI for the otolith length frequency, but peaks do not coincide where the frequencies overlap for the age frequency for the Layer mark-types and the oreo school marks (Figure 17). This would indicate that there is sampling variation for peaks.

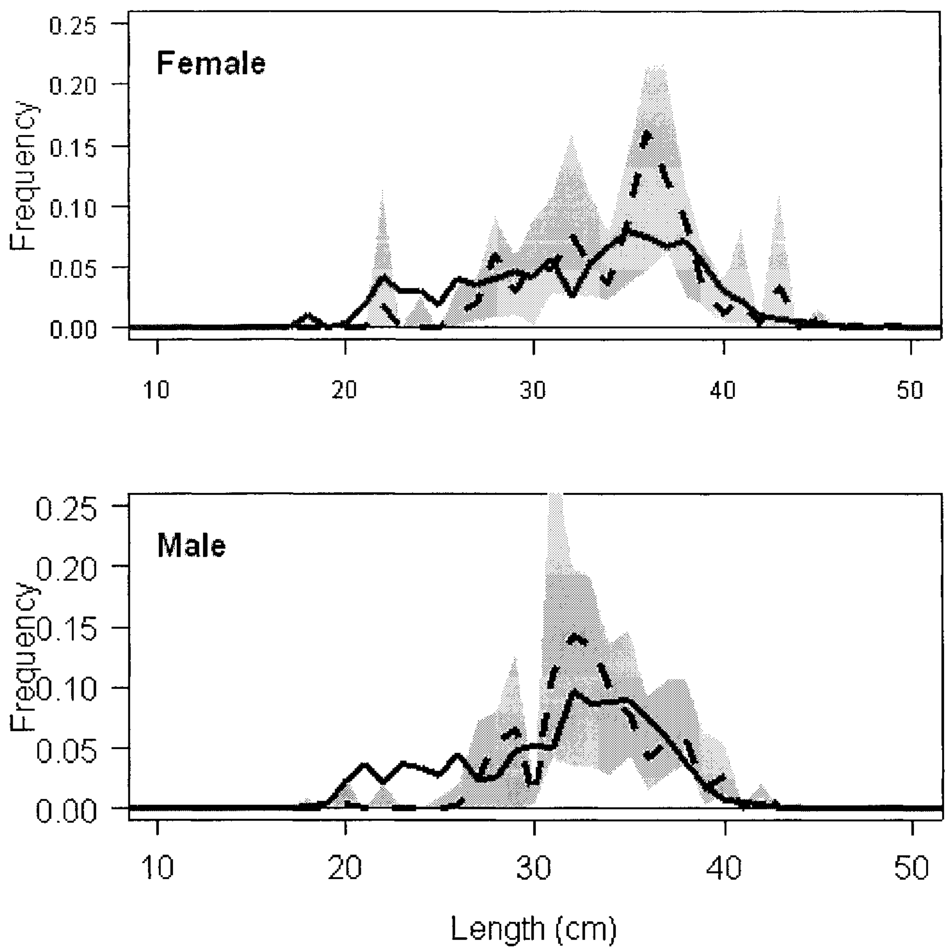


Figure 16: 2005 survey. Total length frequency from the otolith data (dashed line, 90%C.I. grey shading) with the length frequency from the full length data (solid line).

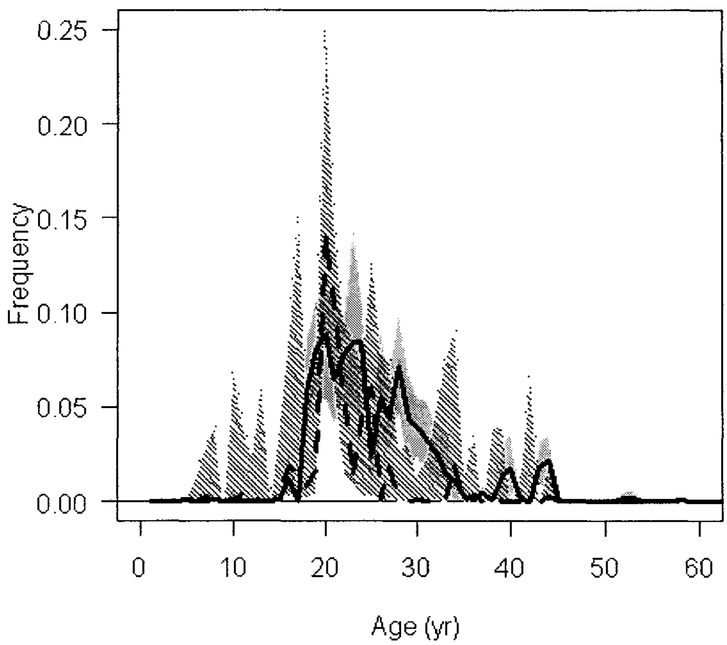


Figure 17: 2005 survey. Age frequency and 95%C.I. for Layer mark-types (dashed line & stippled area) and oreo school marks (solid line & grey area).

To remove these spikes, the frequencies were smoothed (Figure 18).

The effective sample size for a completely random sample is 42. Three simulated examples of estimated age frequencies using 42 random samples are shown in Figure 19. Smoothing makes the simulated samples more like the "true" frequency.

Again, smoothing these samples shows a bias-variance trade-off (Figure 20). In this case 5 cm seems a good compromise. The smoothing can give the broad features of the distribution, but spikes tend to be sampling artefacts.

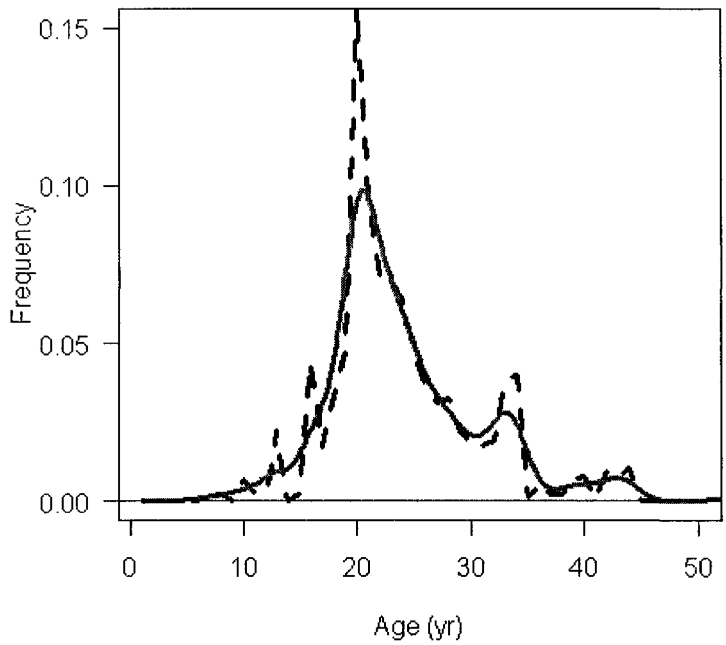


Figure 18: 2005 survey. Combined age frequency (dashed line) and a smoothed version (solid line, smoothing width of 5 cm).

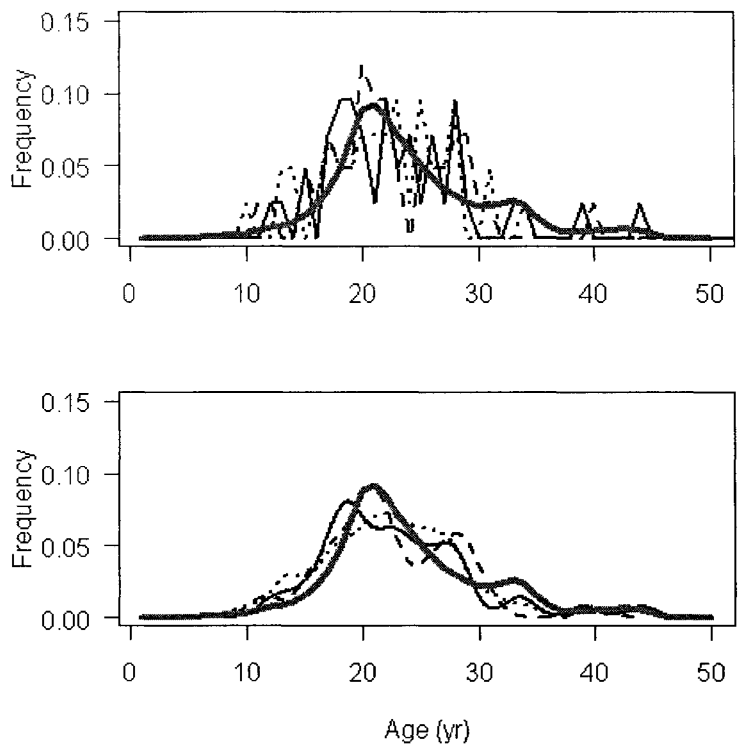


Figure 19: 2005 survey. Three simulated examples of age frequencies using a random sample of 42 otoliths (top panel) and their smoothed curves (width 5 cm, bottom panel). The thick solid line is the "true" age frequency used to simulate random samples from and it is based on the 2005 survey smoothed age frequency with a width of 6 cm.

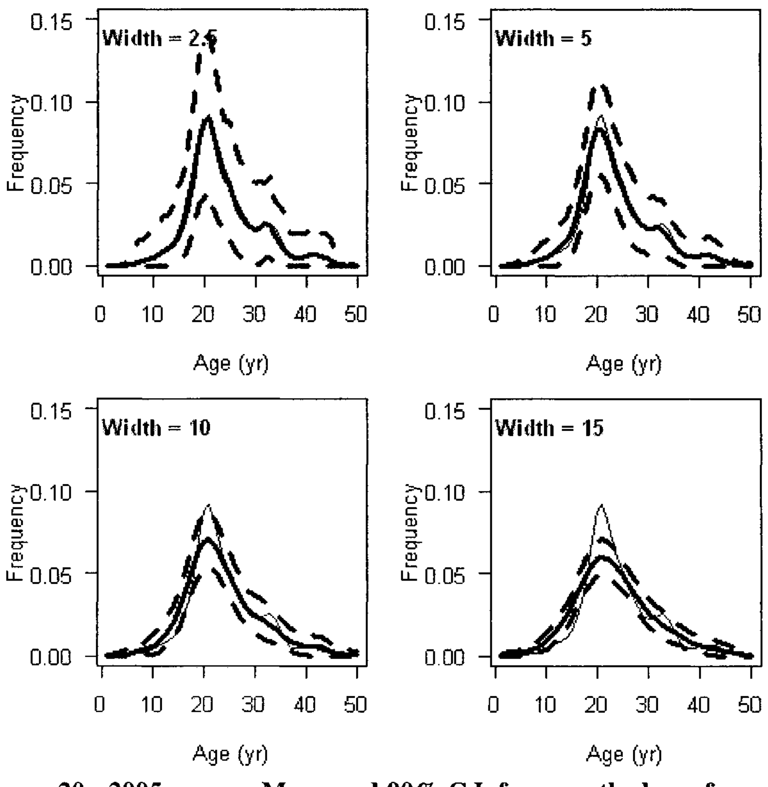


Figure 20: 2005 survey. Mean and 90% C.I. for smoothed age frequencies from 500 samples each composed of 42 otoliths for 4 smoothing widths (black line and dashed lines). The thin solid line is the smoothed age frequency with a width of 6 cm.

3.3.3 Comparison of the 1998 and 2005 age frequencies

Samples of 55 otoliths for 1998 and 42 for 2005 were simulated as before (500 times). These were smoothed using a smoothing width of 2.5, 5, 10, and 15, and the differences between them plotted (Figure 21). The results show that a width of 10 seems adequate to detect the pulse of younger fish in the 1998 sample, even if the expected size of the first peak is underestimated. When sample sizes were halved (Figure 22), the smoothing width of 10 still detected the pulse of younger fish in 1998, but the peak size is almost certainly (95%) underestimated. No within tow variability was used here. When an 8.5% aging error is also applied, the difference profiles are very similar (Figure 23).

The age frequency difference is shown in Figure 24 using a smoothing width of 10. Given the above, it seems that this feature is real, i.e., a pulse of younger fish entered the fishery in the late 1990s.

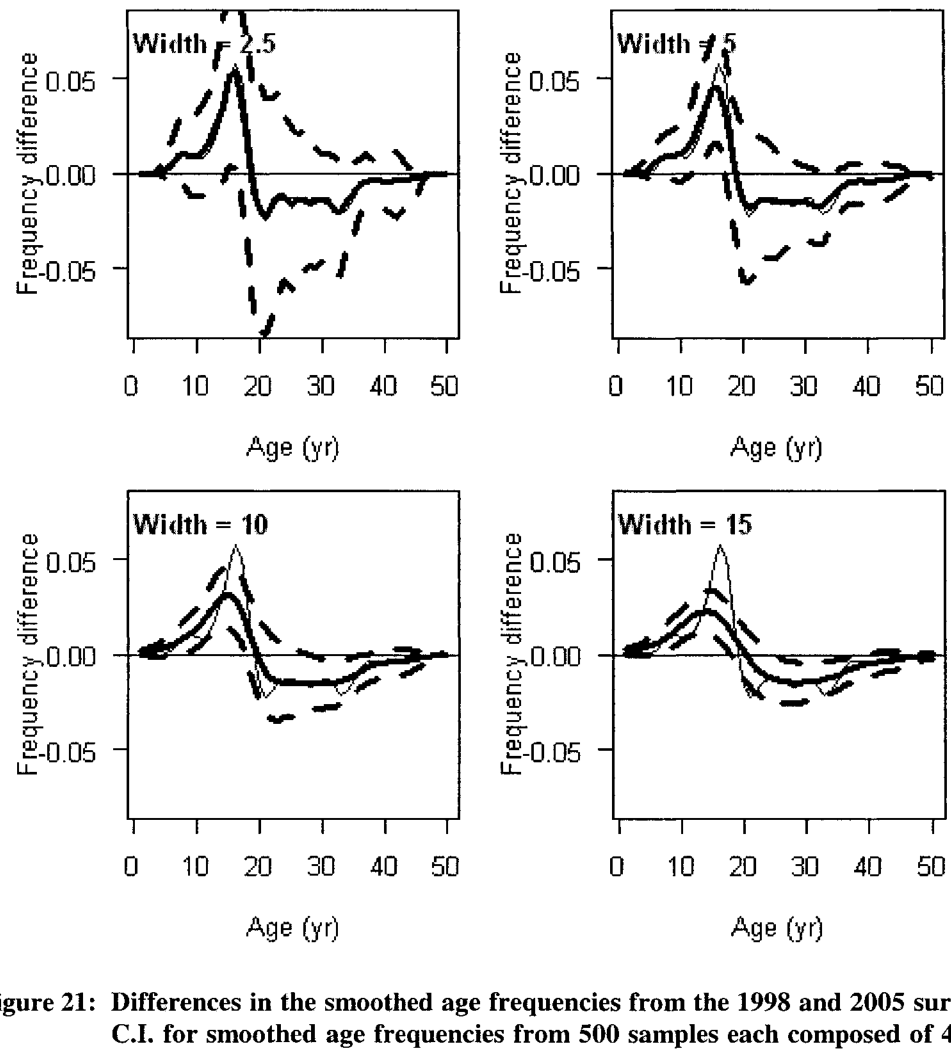


Figure 21: Differences in the smoothed age frequencies from the 1998 and 2005 surveys. Mean and 90% C.I. for smoothed age frequencies from 500 samples each composed of 42 otoliths (1998) and 55 otoliths (2005) for 4 smoothing widths (black line and dashed lines). The thin solid line is the "true" age frequency difference.

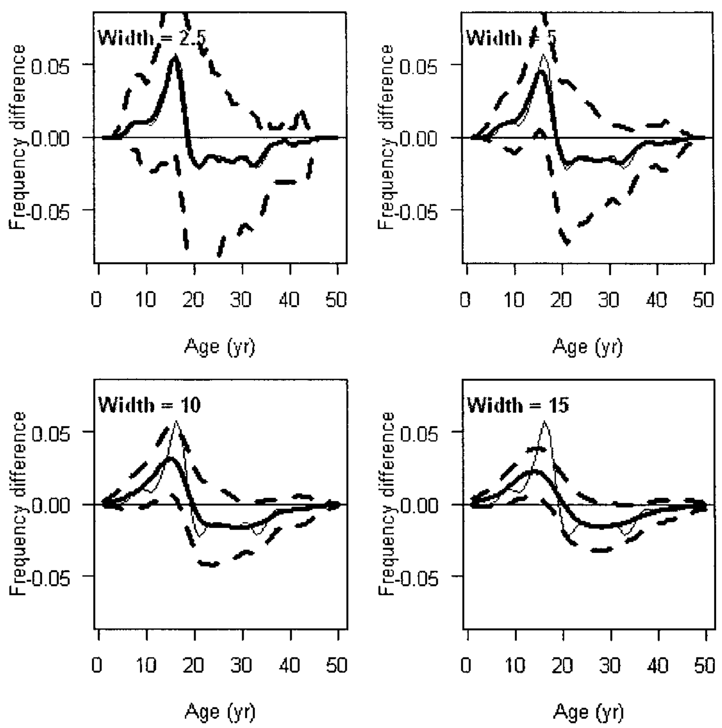


Figure 22: **Differences in the smoothed age frequencies from the 1998 and 2005 surveys. Mean and 90% C.I. for smoothed age frequencies from 500 samples each composed of 21 otoliths (1998) and 27 otoliths (2005) for 4 smoothing widths (black line and dashed lines). The thin solid line is the "true" age frequency difference.**

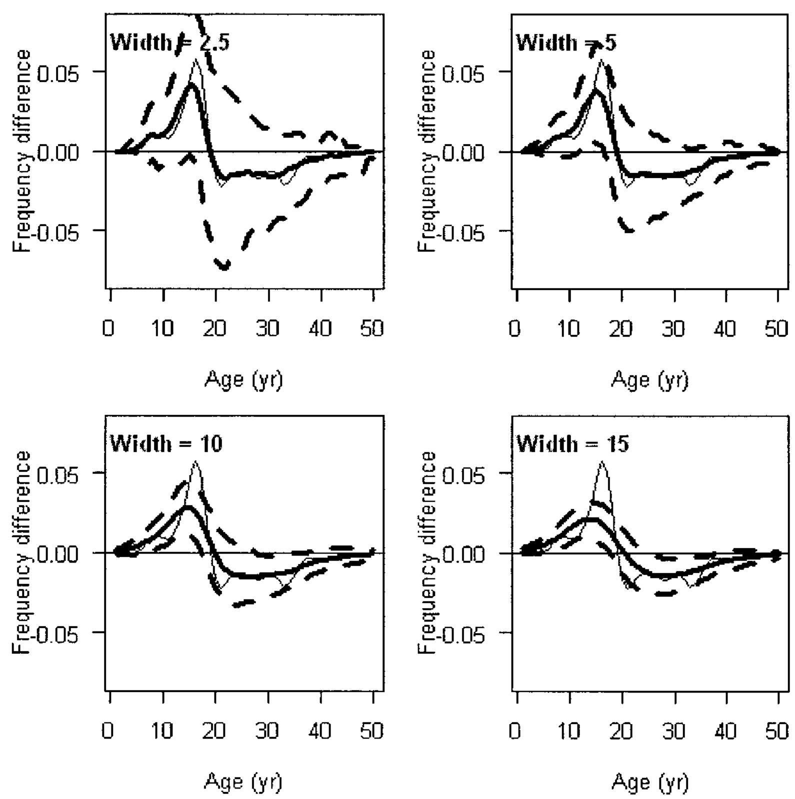


Figure 23: **Differences in the smoothed age frequencies from the 1998 and 2005 surveys with 8.5% ageing error applied. Mean and 90% C.I. for smoothed age frequencies from 500 samples each composed of 42 otoliths (1998) and 55 otoliths (2005) for 4 smoothing widths (black line and dashed lines). The thin solid line is the "true" age frequency difference.**

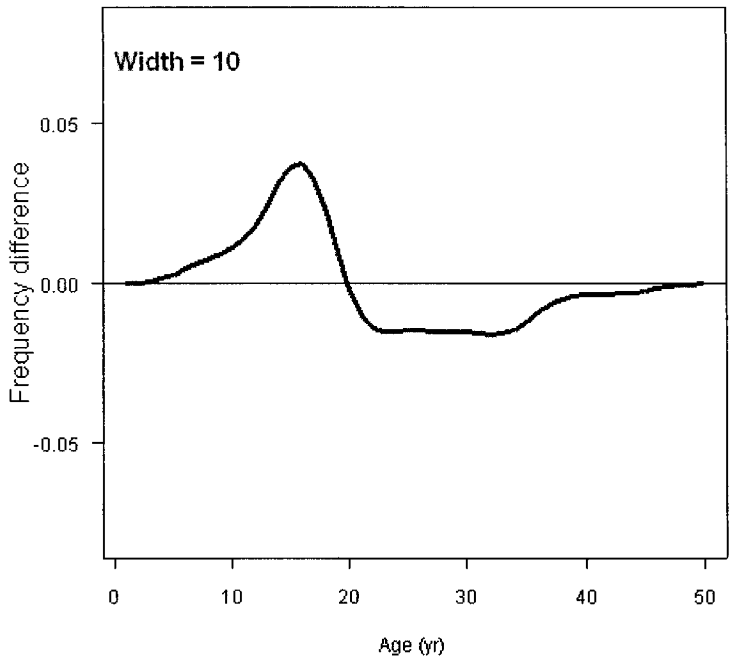


Figure 24: Differences in the smoothed age frequencies from the 1998 and 2005 surveys using a smoothing width of 1.

3.4 Observed versus predicted age frequencies from the stock assessment model

The differences between observed and predicted age frequencies are shown in Figures 25 and 26. The jagged appearance of the predicted frequencies (at about age 20 years) comes from adding the west and east parts together. These are separate stocks in the model and they have independent recruitment levels. Using constant recruitment to predict the age frequency does not fit the observed age frequency very well. Using a block of good recruitment does better in general terms although the length of the block appears smaller in 1998 then in the 2005 age sample.

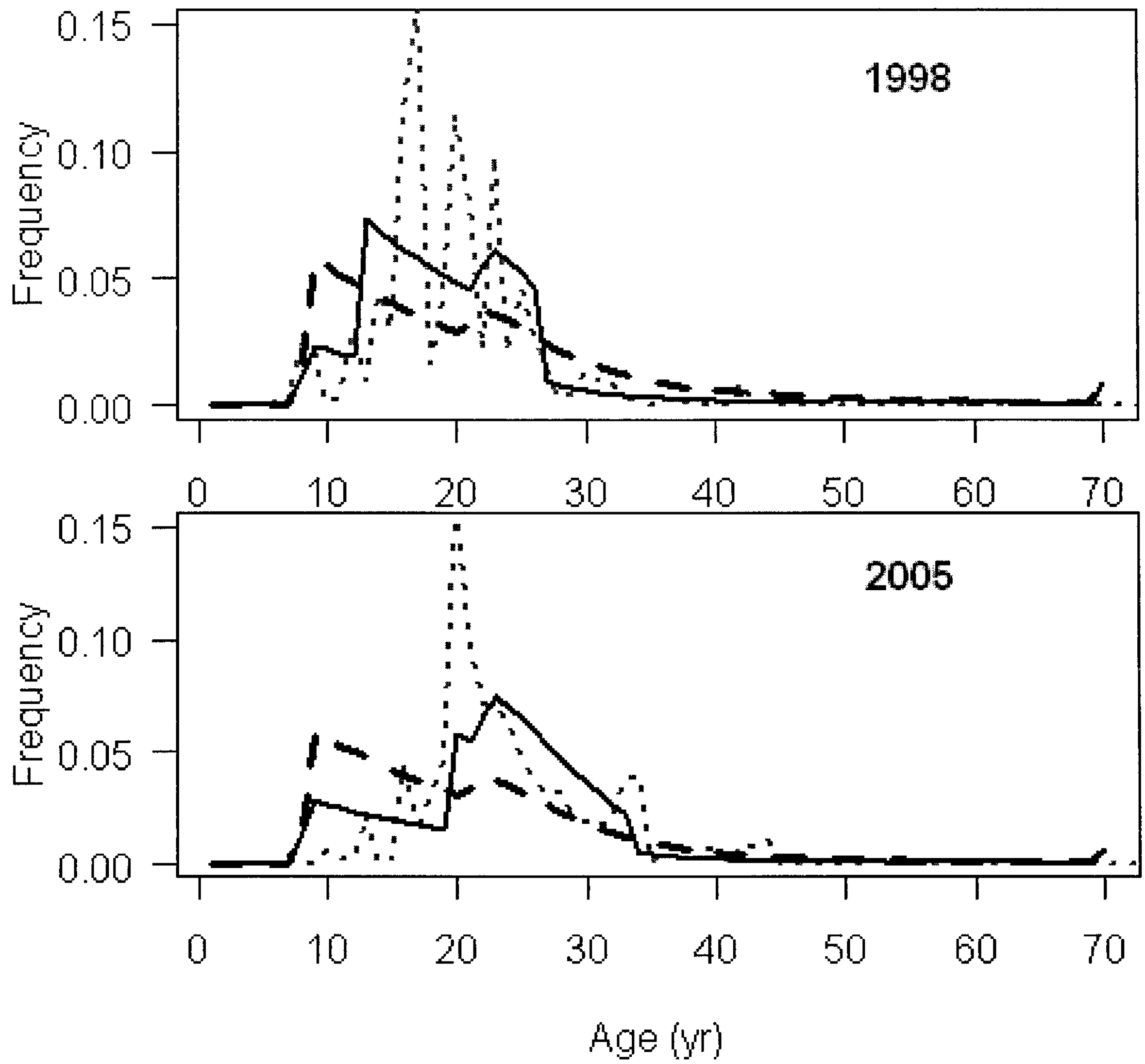


Figure 25: Age frequencies from the stock assessment model (black lines, constant recruitment; dotted lines, a block of good recruitment between 1972 and 1985) compared to that from the 1998 or 2005 survey data (not smoothed) (dotted lines).

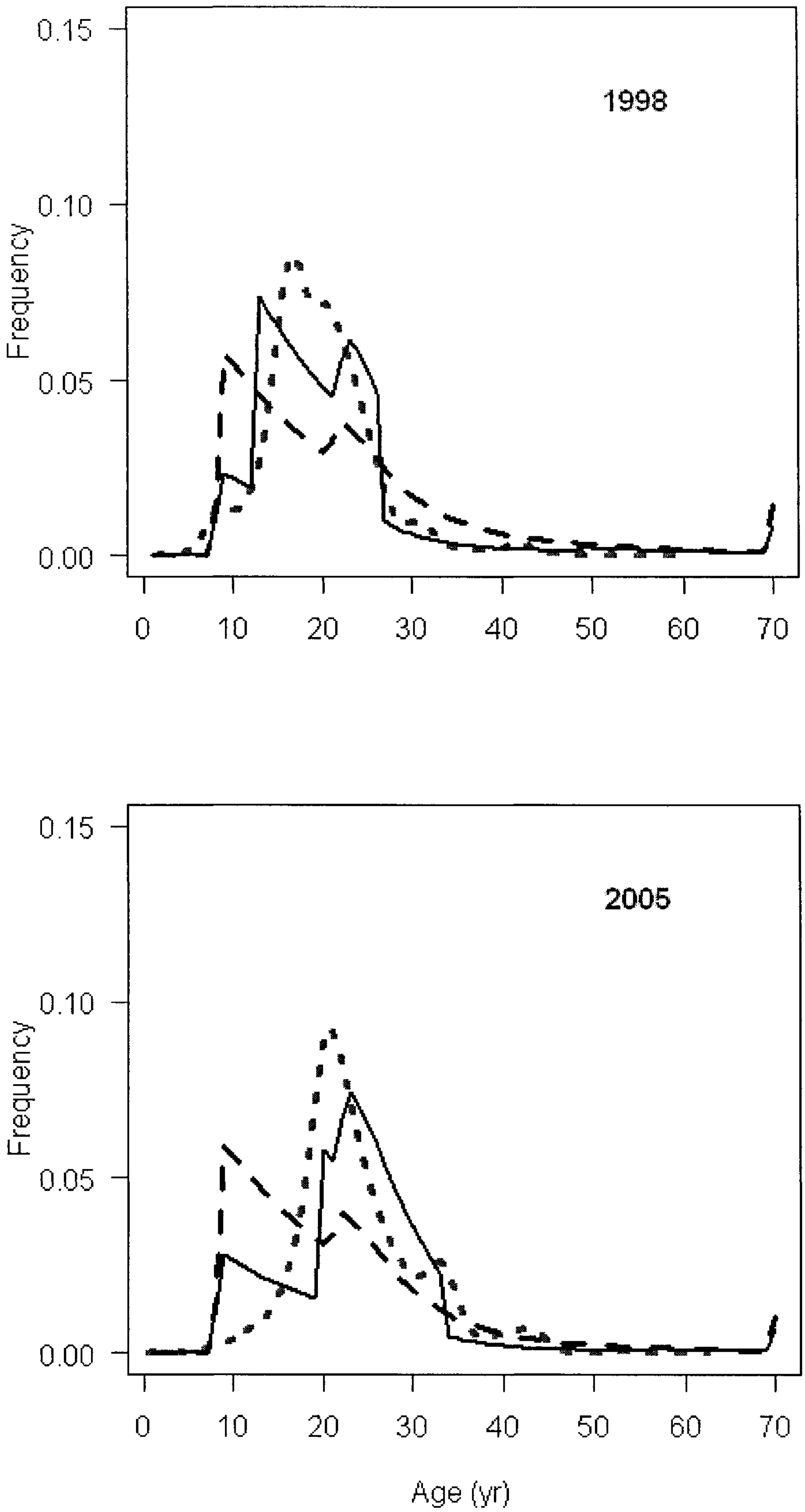


Figure 26: Age frequencies from the stock assessment model (black lines, constant recruitment; dotted lines, a block of good recruitment between 1972 and 1985) compared to a smoothed version from the 1998 and 2005 survey data (dotted line).

3.5 Estimates of total mortality (Z)

For the observed age frequencies, the estimate of Z varied little over a wide range of age at full recruitment (Tc) values (Tables 1 and 2).

Table 1: Estimates of Z (yr^{-1}) and its precision using a range of age at full recruitment (Tc, years) values from the 1998 smooth oreo age frequency.

Tc	Mean age	Z	c.v.	95% confidence limit	
21	4.2	0.212	0.150	0.124	0.272
22	4.4	0.206	0.202	0.109	0.308
23	3.7	0.238	0.261	0.109	0.378
24	4.8	0.190	0.168	0.083	0.247
25	4.4	0.203	0.178	0.079	0.251
26	5.2	0.175	0.220	0.062	0.258
27	6.0	0.154	0.215	0.054	0.221
28	6.3	0.148	0.209	0.050	0.196
29	5.5	0.168	0.227	0.051	0.228
30	4.9	0.185	0.242	0.051	0.250
31	5.4	0.171	0.217	0.052	0.212
32	5.8	0.160	0.297	0.044	0.252
33	6.6	0.142	0.323	0.038	0.239
34	6.7	0.139	0.246	0.035	0.203
35	6.2	0.151	0.289	0.035	0.229
36	5.2	0.177	0.357	0.036	0.297

Table 2: Estimates of Z (yr^{-1}) and its precision using a range of age at full recruitment (Tc, years) values from the 2005 smooth oreo age frequency.

Tc)	Mean age	Z	c.v.	95% confidence limit	
21	6.1	0.152	0.099	0.119	0.176
22	6.1	0.151	0.089	0.120	0.171
23	6.0	0.154	0.087	0.123	0.174
24	6.0	0.154	0.077	0.129	0.172
25	6.1	0.152	0.069	0.133	0.174
26	6.0	0.154	0.065	0.135	0.179
27	5.8	0.159	0.077	0.142	0.185
28	5.6	0.165	0.096	0.139	0.199
29	5.4	0.170	0.082	0.143	0.196
30	5.0	0.181	0.094	0.152	0.211
31	4.6	0.197	0.122	0.152	0.240
32	4.1	0.218	0.156	0.151	0.277
33	3.7	0.240	0.228	0.136	0.338
34	4.2	0.215	0.196	0.134	0.302
35	6.2	0.151	0.119	0.125	0.202
36	5.3	0.173	0.152	0.139	0.250

Two sets of values are reported in Table 3, one using a Tc of 21 and another of 26 years. The stock assessment model estimates of the age at full recruitment were 24 for the east and 26 for the west part. The 95% confidence interval estimates for Z using Tc=26 was 0.06–0.26 for the 1998 survey, and 0.14–0.18 for the 2005 survey.

The Z estimates from the predicted age frequencies were 0.08–0.09 (per year) using constant recruitment, but they were higher when the block of good recruitment was used in the model, i.e., 0.09–0.17. Constant recruitment results are very low, although the 1998 values are within the 1998 confidence limits of the observed frequency of Z values. Using a block of good recruitment gave better correspondence between the model and the observed data (Table 3).

Table 3: Comparison of the estimates of Z from the observed age frequencies in the 1998 and 2005 surveys with that from the predicted age frequencies from stock assessment model runs using two recruitment alternatives, constant recruitment and a block of good recruitment from 1972 to 1985 (age 1 year). Tc is the age at full recruitment (years).

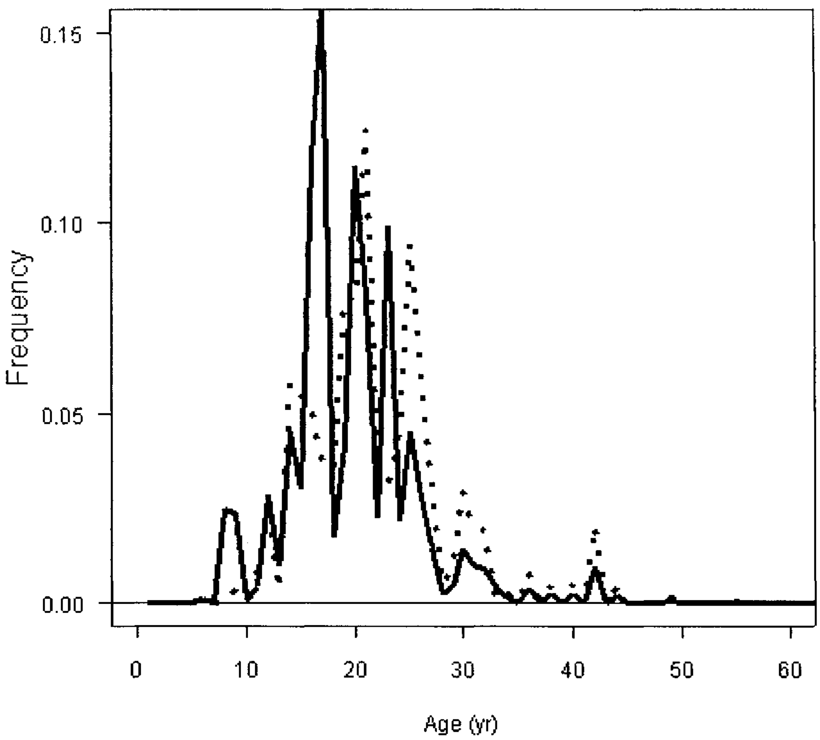
		Z estimate	
Source	Tc	1998	2005
Observed age frequency	21	0.21	0.15
Observed age frequency	26	0.18	0.15
Model			
Constant recruitment	21	0.08	0.09
Constant recruitment	26	0.08	0.09
Block recruitment	21	0.13	0.14
Block recruitment	26	0.09	0.17

There are other explanations for the discrepancy in the constant recruitment results such as M being higher, a sampling artefact for the older fish, or that the oldest fish are not fully selected (seems unlikely).

3.6 Influence of mark-type on the age frequency distribution

In the 1998 survey the most important mark-type was Layer in stratum 5. Stratum 5 was split in 2001 into two strata, 5 and 52, and these two strata were also sampled in 2005. In the 2005 survey the most important mark-type was also Layer in stratum 52 (Figure 27). Apart from the Layer mark-type in strata 5 or 52, data from each mark-type did not take stratum into account. The Layer mark-type in stratum 5 (1998) or 52 (2005) contains non-commercial sized fish and so it covers a large length range and areas within these strata are known to contain much higher densities of smaller fish. The strata also contain a substantial proportion of the total abundance so it is not surprising that they are influential.

When the other mark-types were excluded, the age frequency distributions calculated using the Layer mark-type in stratum 5 in 1998 and stratum 52 in 2005 were similar to those calculated using all the data (not shown).



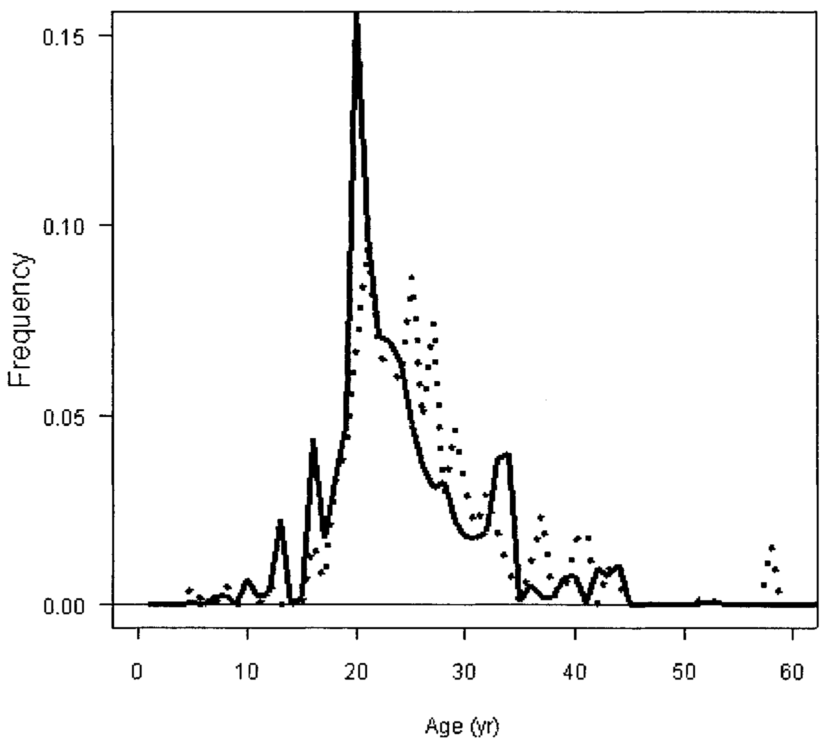


Figure 27: Age frequencies from the 1998 (top) and 2005 (bottom) acoustic surveys with (solid line) and without (dotted lines) the data from Layer mark-type in stratum 5 (1998) or 52 (2005).

4. DISCUSSION AND CONCLUSIONS

This is a first attempt to provide population age estimates for a New Zealand stock of smooth oreo (OEO 4) sampled in two different years. Previous age estimates of New Zealand smooth oreo were carried out to estimate basic population parameters including growth and natural mortality (Doonan et al. 1995, 1997). Those age estimates were unvalidated and consequently no routine age estimates of New Zealand smooth oreo have been made until now. During 2005–06 a project that used the bomb radiocarbon technique (project DEE200501) to estimate smooth oreo age provided support for the previous age estimates of smooth oreo using otolith zone counts and this allowed the present study to proceed.

This study concluded that

- It is possible to detect blocks of poor or good recruitment of young fish into the OEO 4 smooth oreo fishery, but it is not possible to detect individual year class strength because of the variability associated with age estimates made from otolith sections.
- It is possible to get an age frequency distribution for OEO 4 smooth oreo with an acceptable c.v. (less than 30%), but this can only be achieved with a planned otolith sampling scheme during the survey. About 1000 otoliths will have to be read from each survey.
- Intervals of 3–5 years between surveys of OEO 4 smooth oreo are therefore appropriate and would give a better chance of detecting blocks of recruitment.
- Total mortality estimates predicted by the current (2007) stock assessment model analysis are consistent with the observed age estimates only if a block of above average recruitment is incorporated into the stock assessment model. This suggests that the assumption of constant recruitment used in previous stock assessments of OEO 4 smooth oreo is not valid.
- Routine age estimates for OEO 4 smooth oreo are potentially valuable for stock assessment and should be part of future surveys.

5. ACKNOWLEDGMENTS

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