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EXECUTIVE SUMMARY

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New Zealand Fisheries Assessment Report 2001/40. **17 p.**

A new non-parametric age selectivity curve was developed for black oreo in OEO 3A by estimating a length selectivity ogive and converting this into age using the established growth relationship. The length ogive was constructed by dividing the length frequency of the recruited (fished) part of the stock by the length frequency for the population. The length frequency of the recruited stock came from observer length data (1979–2000) and the population length frequency came from research length data from seven trawl surveys (1986–95). The observer data generated spurious annual length frequencies, in part because areas with small fish, where the fishery operated infrequently, were over-sampled. All the observer data were therefore combined and the over-sampling of small-fish areas resolved by using spatial prediction to generate a length frequency surface over the fishery area. The overall length frequency of the recruited population was taken as the mean of the length frequency surface weighted by the accumulated catch (1979–2000).

This analysis assumed that there were no time trends for lengths in the observer data. However a generalised additive model (GAM) regression analysis showed that the mean lengths of the observer data had a declining trend over time (about 2 cm over 20 years), in addition to the stronger spatial trends. This implies that the estimated standard age selectivity ogive included some time averaging. An alternative age ogive was developed as a sensitivity test, using the observer data restricted to the period covered by the research trawl surveys, when mean length declined by about 1 cm. The alternative ogive was to the right of the standard ogive.

1. INTRODUCTION

This work contributes to the following objectives in MFish project "Oreo stock assessment" (OEO2000/02).

Overall objective

1. To carry out a stock assessment of black oreo and smooth oreo, including estimating biomass and sustainable yields.

Specific objective

1. To conduct a stock assessment for black oreo in OEO 3A, including estimating biomass and sustainable yields.

A preliminary (empirical) age selectivity age ogive was estimated in 1999 and used in the NIWA black oreo OEO 3A stock assessment (Doonan et al. 1999). That analysis identified concerns about the quality of the black oreo observer data from OEO 3A. Those data were collected in an ad hoc manner without regard to the main fishing activity and with only a few tows sampled each year. The data showed a distinct spatial separation of small and large fish with a similar number of samples from each group before 1999. The annual length frequencies were generally composed of either mostly small or mostly large fish (Figure 1) so that they flip-flopped from small to large to small again with no clear time trend, i.e., annual length frequencies were biased. These annual samples reflected more the location of the sampling in each year than the length composition of the annual commercial catch.

Seafood Industry Council (SEAFic) scientists used the observer data, without analysing the quality, to assess black oreo in OEO 3A in 1999 (Annala et al. 1999). Their model incorporated observer data from three years where the mean length was low, which resulted in a selectivity ogive that was to the left of that used by Doonan et al. (1999). The 1997 survey absolute abundance estimate used in the NIWA and SEAFic assessments had most of the biomass in the lower lengths. Consequently, the SEAFic estimate of recruited stock size for 1997 was much larger than the NIWA estimate and the SEAFic population model provided biomass estimates and yields for the black oreo OEO 3A stock that were much more optimistic than those provided by the NIWA assessment (Annala et al. 1999, Doonan et al. 1999).

The present study aimed to analyse the quality and quantity of the observer data in order to produce an unbiased estimate of the length of fish caught by the commercial oreo fishery in OEO 3A and to provide a refined age selectivity ogive for the 2001 stock assessment of black oreo.

2. METHODS

The following is a summary of the steps performed in the analysis. Details of each step are provided in the numbered sections below.

1 All research survey length data were combined after being weighted by stratum and research catch and a research length frequency produced. This length frequency was assumed to represent the population length frequency.
2 All observer length data were combined, to avoid biases in annual samples noted above. Observer length frequency data were assumed to represent the recruited part of the population.
3 An observer length frequency surface was generated using spatial prediction tools where mean length was taken as a proxy for length frequency. An overall observer length frequency was estimated from the mean of the length frequency surface weighted by the accumulated commercial catch.
4 A length selectivity ogive was constructed by dividing the overall observer (recruited) length frequency by the research (population) length frequency and adjusting the result so that the far right hand part of the curve was 1, i.e., fully recruited.

5 A new non-parametric age selectivity ogive (standard) was developed by converting length to age using established age parameter values.
6 A sensitivity analysis was carried out to see if there were any parameters other than spatial ones that were important in determining the observer length frequency distribution and an alternative age selectivity ogive was constructed to capture the main effects of other parameters.

2.1 Research trawl survey data

Research data from random stratified trawl surveys carried out in OEO 3A in 1986, 1987, 1990, 1991–93, and 1995 were used (Table 1). From each survey, a length frequency by sex was estimated for the portion of the survey that was in the area covered by the 1997 acoustic survey (Figure 2). These survey length frequencies were averaged, i.e., the sex ratio was fixed at 50:50.

2.2 Observer data

The observer data were restricted to the CPUE study area OEO 3A (Coburn et al. 1999). The study area included the area where observers sampled tows that caught oreos and where the main commercial fishery took place and was contained within the 1997 acoustic survey area (Figure 2).

Observer length data for black oreo were extracted from the MFish observer database (obs_lf) using the CPUE study area bounds: 44° 12′ to 45° 00′ S and 172° 30′ to 175° 00′ E and black oreo catches were extracted from the MFish logbook database for the same area. Data covered the period 1979–80 to 1999–2000.

For each observed trawl, a combined length frequency was calculated composed of separate male and female observer length frequencies in equal proportions. The sex ratio was fixed at 50:50 and reduced the complexity of the analysis. Some early data did not have all fish sexed, so the frequency was based on total numbers sampled. This procedure should be approximately correct as later data had 79% of tows with sex ratios between 0.4 and 0.6. Data from one tow were excluded because fewer than 30 fish were measured.

2.3 Spatial prediction of observer length frequency

All the observer length frequency data were used to generate a length frequency surface by predicting, using ordinary kriging (described below), the length frequency at each point of a 50 x 50 grid covering the main fishery. The total commercial catch for all years was also calculated for each cell in the grid. The overall observer length frequency of the recruited population was then the mean of the length frequency surface weighted by the accumulated catch (1979–2000) at each point in the grid.

Kriging

A length frequency distribution was predicted at the centre of each cell of the accumulated catch grid using ordinary kriging (Thompson 1992). The kriging combined data as a weighted mean, using weights calculated from a semivariogram and the distance between the predictor's position and each datum's position. Because length frequency distributions are multivariate the analysis was simplified by using one variate, mean length, as a proxy for the length frequency. Thus the weights used in the kriging were calculated from the semivariogram of the mean lengths and then applied to the length frequencies.

Ordinary kriging (Thompson 1992) was used to predict mean length at point s using $\sum_{i=1}^{n_s} a_{i,s}\mu_i$, where n_s is the number of points within a specified radius (data window) of s, the $a_{i,s}$ are constants to be estimated and depend on the spatial correlation, and the μ_i are the sample means within the window. The points (s) are at the centre of each cell in the 50 by 50 grid and the μ_i are the mean lengths of observed tows. The spatial correlation was expressed through the semivariogram, which depended on the distance between points, not location, and was estimated from the mean length data before the kriging predictions were done. Data were restricted to a maximum distance of about 28 km in the north-south direction and 42 km in the east-west direction.

The predicted length frequency at point s for length l, f_{sl}, is given by $f_{sl} = \sum_{i=1}^{n_s} a_{i,s} f_{il}$, where $a_{i,s}$ are the kriging weights as estimated from the spatial correlation of the mean length, and f_{il} is the frequency of length l in the i-th trawl. These predicted length frequencies give the same mean length as directly kriging the mean lengths.

The empirical semivariogram was estimated in bins of 0.01 degrees longitude using the robust method of Cressie & Hawkins (1980) and a two-dimensional spherical semivariogram function fitted to these points using weighted least squares (Cressie 1985). In a preliminary analysis, several semivariogram functions were fitted and the spherical function fitted best and so was used here. The spherical function is given by

$$\sigma^2,\ r > d$$

$$\sigma^2\left(a + \frac{(1-a)}{\pi}\left(\frac{r}{d}\sqrt{1-\frac{r^2}{d^2}} + \sin^{-1}\frac{r}{d}\right)\right),\ 0 < r \le d$$

$$0,\ r = 0$$

where σ^2 (sill), d (range), and a are parameters to be estimated ($a\sigma^2$ is the "nugget" effect).

Anisotropy can occur in the semivariogram and this commonly takes two basic forms: different ranges on different axes (not necessarily perpendicular) and different sills in different directions. A combination of both can also occur. In estimating the semivariogram, any sill differences were ignored, but range differences between north-south and east-west can be accommodated by scaling longitude so that the ranges are about the same. If the principal directions for the ranges were not north-south and east-west, then a rotational transformation would be needed before scaling. Anisotropy in the semivariogram of the mean lengths was observed, oriented north-south and east-west, with a shorter range and higher sill north-south than east-west. Longitude was therefore scaled by 0.5 to make the ranges about the same (this was more than was needed to scale longitude to the same distance scale as latitude).

2.4 Length selectivity ogive

The length selectivity ogive was calculated using the following assumptions.

1 The observer length frequency was an estimate of the recruited population length frequency.
2 The population length frequency is related to the research trawl survey length frequency.
3 The right hand limb of the selectivity curve was constant at 1.0, where fish were assumed to be fully recruited.

The right hand limb of the population length frequency was derived from the right hand limb of the combined research length frequency. The left hand limb of the population length frequency was taken to be constant and was set to the maximum frequency seen in the combined research length frequency.

The length selectivity ogive was estimated by first dividing the recruited length frequency by the population length frequency and then scaling so that the selectivity was 1 on the curve at and to the right of the length at full recruitment. The length at full recruitment was the length where the ratio of the population to recruited length frequencies flattens to an approximately horizontal line as length increases. The scaling factor was the inverse of the median of the initial division. The selectivity was then set to 1 for lengths over full recruitment.

2.5 Age selectivity ogive

The age selectivity ogive was estimated from the length selectivity ogive by converting the length to age using the von Bertalanffy equation in Annala et al. (2000). Running medians over three consecutive values were used to make the curve increase with age, if needed.

An alternative set of selectivity curves was estimated using only observer data from the time of the trawl surveys (1986–95). The semivariogram was the same as used above. This should give a length selectivity curve that applied at the time the population length frequency was estimated, and should match the data better.

2.6 Sensitivity of the observer length frequency data to other parameters (not spatial)

One drawback of the above analysis was that it assumed that there was no time trend for lengths in the observer data. To test for dependencies in the mean lengths on time and other variables that do not have an implicit spatial dimension, GAM (generalised additive model, Hastie & Tibshirani 1990) regressions on mean length using depth, longitude, latitude, fishing year, catch size, time of day, and month as variables were performed. The first three variables are spatially based and their effects were incorporated into the spatial prediction. Significant effects from the last four variables could introduce errors into the spatial predictions, although theoretically they could be taken into account.

3. RESULTS

3.1 Research trawl survey data

The research length frequency is shown in Figure 3. This had a modal peak at 29 cm with another possible mode at 34 cm.

3.2 Observer data

The length data included samples from 365 tows from 52 trips between 1979 and 2000. There was a gap with no data from 1981 to 1985. The median number of trips per year was 2 for years with data before 1998, but increased to 6 from 1998 to 2000. The median number of sampled tows per year was 11 for years with data before 1999, which increased to 70 for 1999 and 2000.

New data from 1999 and 2000 included 60% more tows and these were added to the data (1979 to 1997–98) used to construct the previous age selectivity ogive for the 1999 stock assessment (Doonan et al. 1999). The new data had a mean length mode at 30.5–32 cm with few tows having a mean greater than 33 cm (Figure 4a). These lengths are intermediate between two clear modes at 28–29 and 34–35 cm in the pre-1999 data (Figure 4b). The 1999–2000 data are different from the pre-1999 data and have a profound effect on the estimated selectivity ogives.

The catch data extracted came from 19 178 tows with a median number of tows each year of 859.

3.3 Spatial prediction of observer length frequency

The final estimated spherical semivariogram of mean lengths had parameters of $\sigma = 2.86$, $d = 0.20$, and $a = 0.15$. The fit is shown in Figure 5. The predicted mean length surface showed that there was a spatial separation with two main areas of relatively constant mean lengths, one with large fish in the south (generally deeper) and the other with smaller fish in the north (generally shallower), and a transition region connecting them (Figure 6).

The accumulated catch plotted on the 50 by 50 grid is shown in Figure 7 and was unevenly distributed spatially with most taken from the south and east. A large proportion of the observer length data came from outside the heavily fished areas (Figure 8), where mean lengths tended to be under 30 cm. 29% of the tows in the observer data had mean lengths less than 30 cm. The location of observer length samples did not seem to cover the whole fishery adequately, e.g., there was a concentration of samples where mean length was less than 30 cm near 44.65° S, 173.2° E in Figure 8.

3.4 Length selectivity ogive

The length selectivity ogive is given in Figure 9 and is based on a length of full selectivity at 35 cm.

3.5 Age selectivity ogive

The age selectivity ogive is shown in Figure 10 and the selectivity values by year for the standard (all data) and for the alternative (1986–95) age ogives are given in Table 2. The shift in the current standard age ogive from that used in 1999 (Doonan et al. 1999) was caused by a combination of the new observer length data (1999 and 2000) which had means between the small and large fish modes in the pre-1999 data (boosting the contribution for these middle lengths) and the weighting of the observer data from the length frequency surface by the accumulated catch which reduced the selectivities for small fish.

3.6 Sensitivity of the observer length frequency data to other parameters (not spatial)

In the GAM regressions on mean length, the significant variables in order of importance were depth, latitude, longitude, and year (Figure 11). The fishing year effect produced a decline in mean length of about 2 cm over 20 years and meant that using all the observer data to estimate length selectivity involved some time-averaging in a weighted way because sampling was not uniform over the years. The consequence of the non-uniform sampling in time and the time trends is that some years are weighted up compared to others leading to some bias in the selectivity.

The alternative selectivity ogive (see Figure 10) is to the right of the standard ogive and is constructed using data from 139 observed tows. The alternative curve would mainly affect the recruited abundance from the acoustic results through the length selectivity. From 1986 to 1995, the decrease in mean length due to the year effect in the GAM regression was about 1 cm, instead of the 2 cm over the whole data set. Thus, any effect on the selectivity from this source was reduced. It is possible that the fishery is now targeting smaller fish which were previously not fished, i.e., that the selectivity curve has shifted to the left over time. If the latter is the case, then the change in fishing pattern cannot be wholly based on moving to areas with smaller fish because then there would not be a year effect in the GAM regressions. The latter already takes spatial variation into account through the variables longitude, latitude, and depth.

4. DISCUSSION

There is a problem with using OEO 3A black oreo observer length data as if they were sampled at random from the commercial fishery. Assuming random collection implicitly self-weights for the spatial distribution of fishing effort because locations with the largest effort will be sampled more often (this is in addition to weighting the length frequency by the size of the catch that the sample was taken from). With large numbers of samples, the distributions of the sampled locations will be similar to the actual spatial distribution in the fishery, but sampling small numbers of tows, even randomly, can give large errors if there are strong trends in fish mean length with location, as occurs in the black oreo fishery.

In general, data from tows within a trip are correlated, in part, because fishing tends to take place in localised areas. As well, individual vessels and companies have their own patterns and strategies of fishing that are different from each other, and this introduces another source of non-randomness. Observers are placed on trips and trips are usually not selected at random. This practice can exaggerate the errors caused by strong spatial trends. A solution is to make structural assumptions so that the non-random sampling is not so relevant. Here, we assumed that lengths have a spatial dependency that persisted in time so that estimating an intermediate length frequency surface from the data reduced the dependence on random sampling. Sampling still has to be adequate to estimate this surface. The disadvantages of this approach are that it was a more complex analysis and required some extra assumptions (e.g., one semivariogram captured the spatial correlation over the whole fishery area).

The black oreo fishery in OEO 3A is not the only one in which observer sample data were found to have spatial structure within stock areas. Francis & Tracey (2000) examined orange roughy observer data collected all round New Zealand and concluded that most of the data were not useful as stock assessment model inputs mainly because of inconsistent sampling, i.e., the same areas were not sampled every year and much of the sampling (choice of trips and location of fishing) was not at random. Within the Spawning Box on the north Chatham Rise, orange roughy samples from the Plume and the Crack (about 30 km apart) were shown to have different mean lengths over time (Francis & Tracey 2000). Thus, a general conclusion is that any results based on observer data, such as mean length or mean age of the catch, obtained by analysing observer-collected data should be treated with caution, perhaps even rejected, until it has been shown that assuming simple random sampling can give acceptable results.

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Table 1: Random stratified trawl surveys (standard, i.e. flat tows only) for oreos on the south Chatham Rise (OEO 3A).

Year	Area (km^2)	Vessel	No. of stations	Reference
1986	21 050	*Arrow*	82	Fincham et al. (1987)
1987	21 050	*Amaltal Explorer*	87	Fenaughty et al. (1988)
1990	19 365	*Cordella*	45	McMillan & Hart (1994a)
1991	19 365	*Tangaroa*	44	McMillan & Hart (1994b)
1992	21 050	*Tangaroa*	24	McMillan & Hart (1994c)
1993	21 050	*Tangaroa*	24	McMillan & Hart (1995)
1995	21 050	*Tangaroa*	24	Hart & McMillan (1998)

Table 2: Black oreo age selectivity ogive values per year for OEO 3A. "Std" is the standard ogive using all the observer data (1979–2000) and "Alt" is the alternative ogive based on observer data from 1986 to 1995.

	Selectivity	
Age	Std	Alt
1	0	0
2	0	0
3	0	0
4	0	0
5	0.09	0.10
6	0.13	0.13
7	0.17	0.16
8	0.20	0.17
9	0.22	0.18
10	0.26	0.20
11	0.31	0.23
12	0.39	0.28
13	0.47	0.33
14	0.52	0.37
15	0.57	0.41
16	0.62	0.45
17	0.68	0.51
18	0.75	0.56
19	0.78	0.58
20	0.79	0.58
21	0.81	0.58
22	0.83	0.59
23	0.84	0.61
24	0.85	0.63
25	0.86	0.66
26	0.87	0.68
27	0.88	0.71
28	0.89	0.74
29	0.90	0.77
30	0.91	0.80
31	0.92	0.83
32	0.93	0.86
33	0.94	0.88
34	0.95	0.91
35	0.95	0.94
36	0.96	0.96
37	0.97	0.99
38	0.98	1
39	0.98	1
40	0.98	1
41	0.98	1
42	0.99	1
43	0.99	1
44	0.99	1
45	1	1

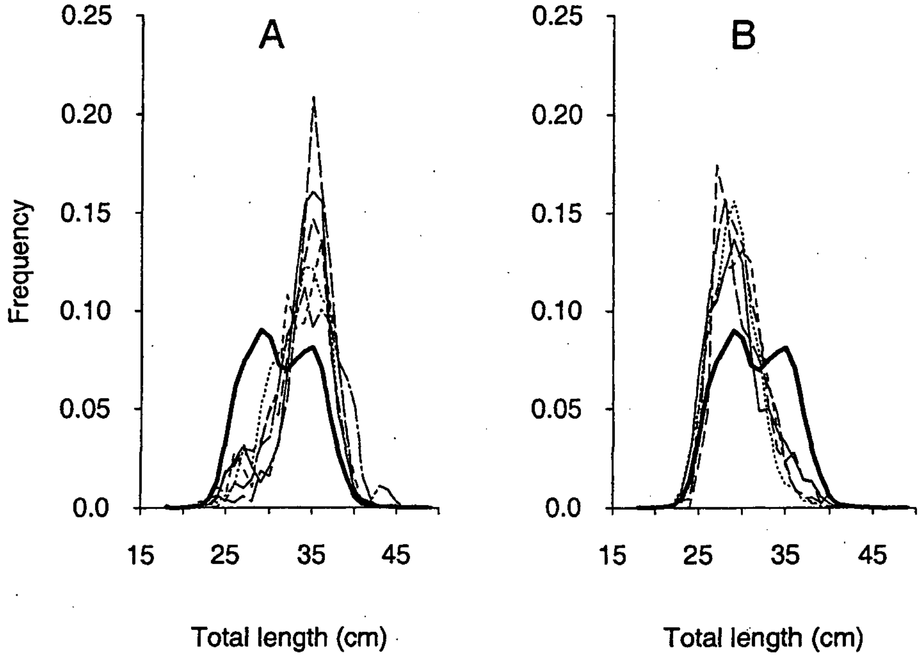

Figure 1: **Annual observer-collected length frequencies scaled up to the weight of the catch that was sampled. The thick black line shows all the scaled length frequency data collected before 1998 combined. "A" shows each annual length frequency where large fish predominated (1979, 1986, 1987, 1990, 1991, and 1994); "B" shows each annual length frequency where small fish predominated (1988, 1989, 1993, 1995, and 1997). The 1996 length frequency was similar to the combined curve and is not shown.**

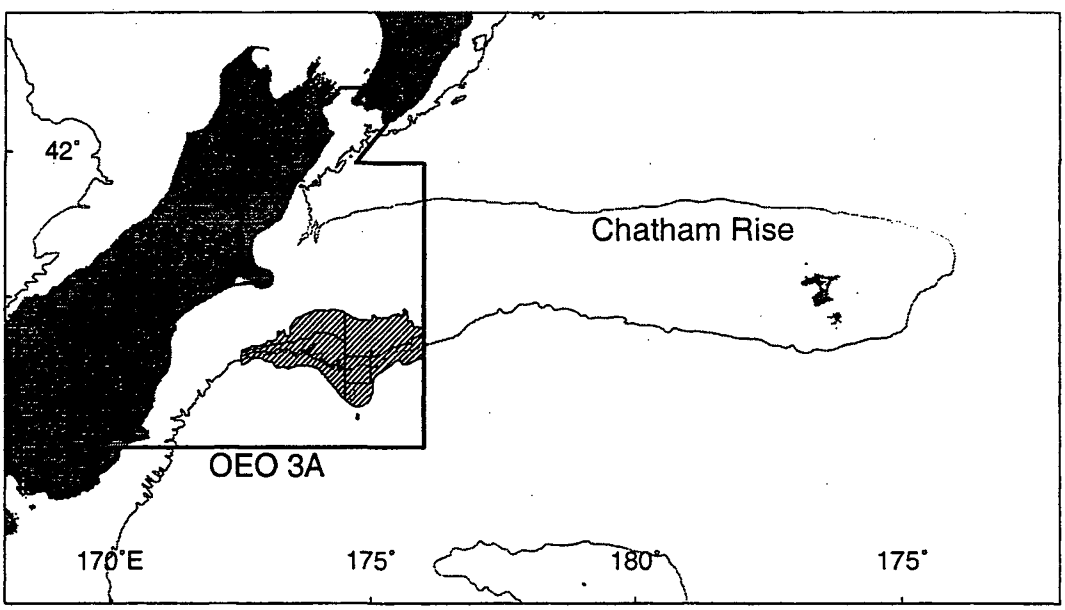

Figure 2: **OEO 3A oreo management area (thick black line) and the 1997 acoustic survey area (hatched) which covered the main black oreo fishery.**

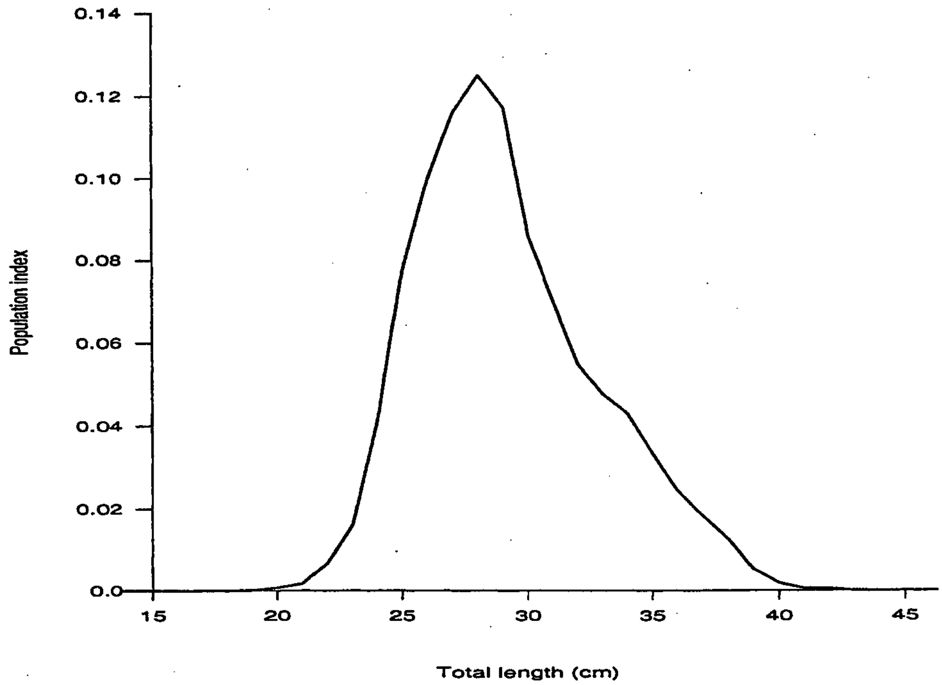

Figure 3: Black oreo length frequency distribution from data collected on annual research surveys (1986–87, 1990, 1991–93, 1995) carried out in OEO 3A, scaled to strata and research catch.

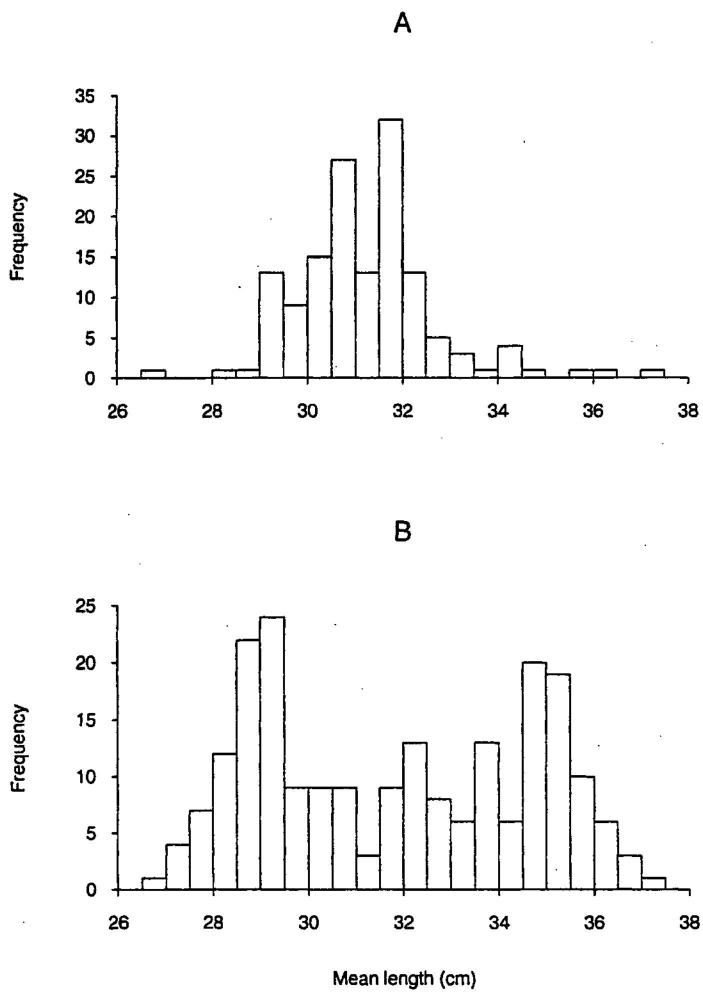

Figure 4: Mean length frequency (%) of the observer data. A) 1999 and 2000 data; B) pre-1999 data.

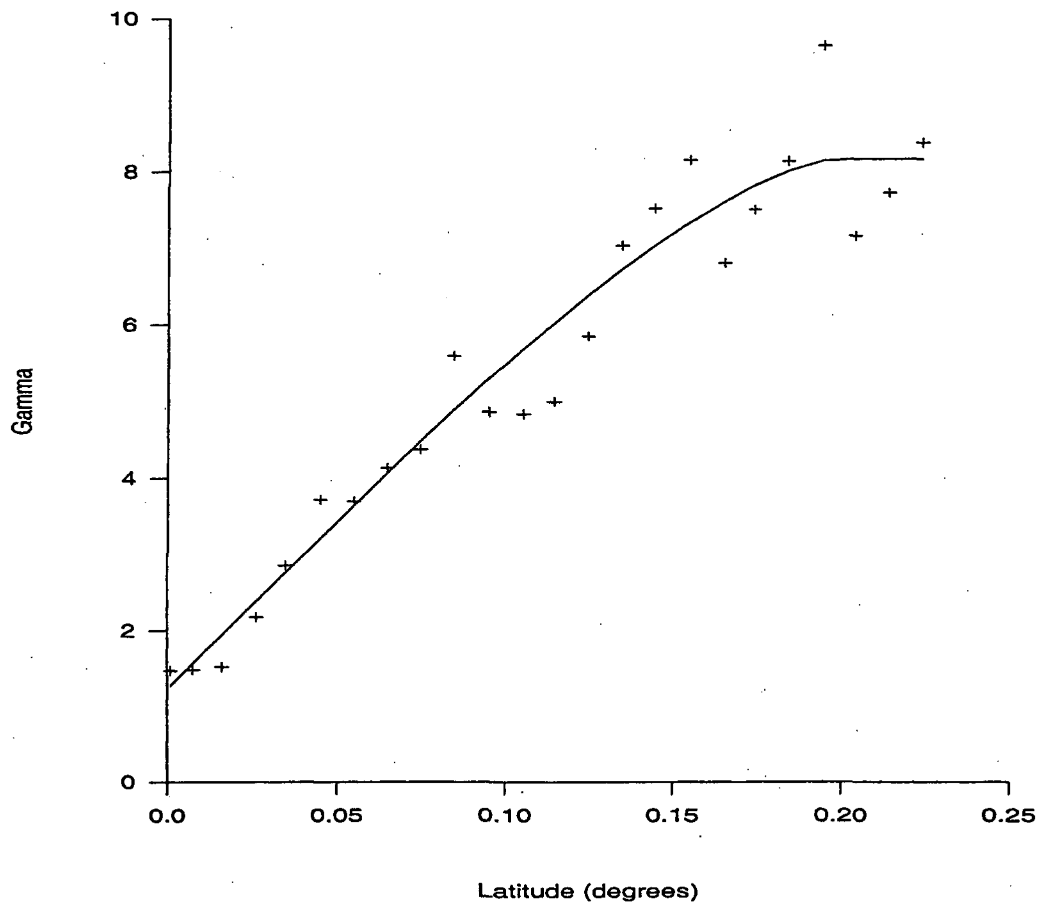

Figure 5: Semivariogram (gamma) of the mean lengths. "+", the mean point estimate for 0.01 length bins. The line is the fitted curve (spherical semivariogram) through the points. Longitude was divided by 2 so that the correlation range in the longitude direction approximately matched that for the latitude.

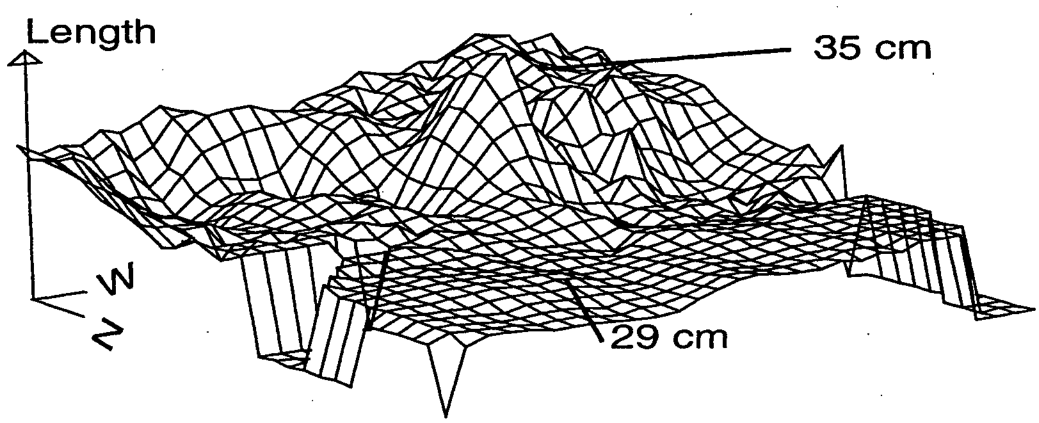

Figure 6: Predicted mean length surface over the main area of the black oreo fishery in OEO 3A. View looking to the southwest. Surface using a window radius of 12 minutes latitude and 24 minutes longitude to include data.

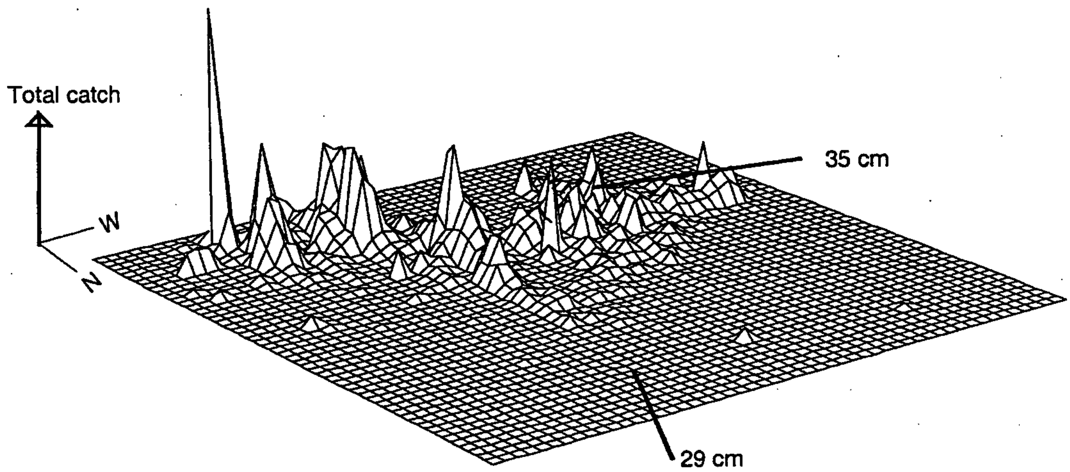

Figure 7: Accumulated black oreo catch from 1989 to 2000 over a 50 x 50 km grid in OEO 3A. View looking to the southwest. The maximum value is 2062 t. The predicted mean lengths (29 and 35 cm) are marked at the same positions in Figure 6.

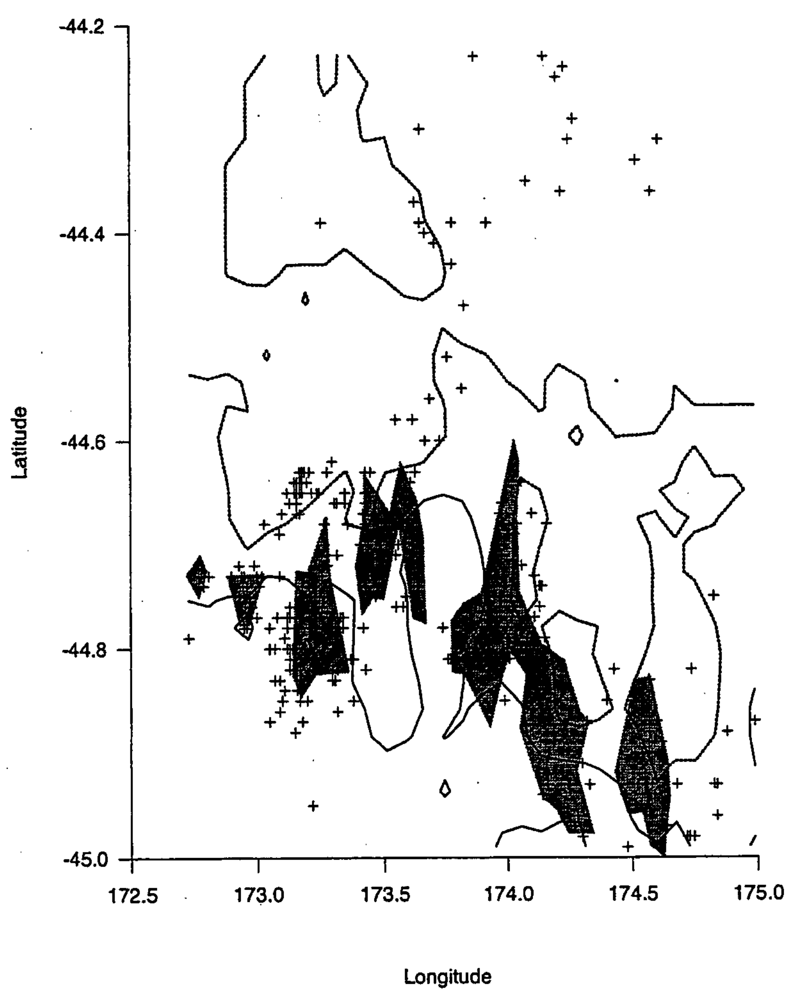

Figure 8: Observer mean length contours at 30 cm (dotted lines) and at 33 cm (lines) from the predicted mean length surface. The sample positions of the observer data are marked with crosses, and the area where 75% of the accumulated commercial catch from 1980 to 2000 was caught is shaded.

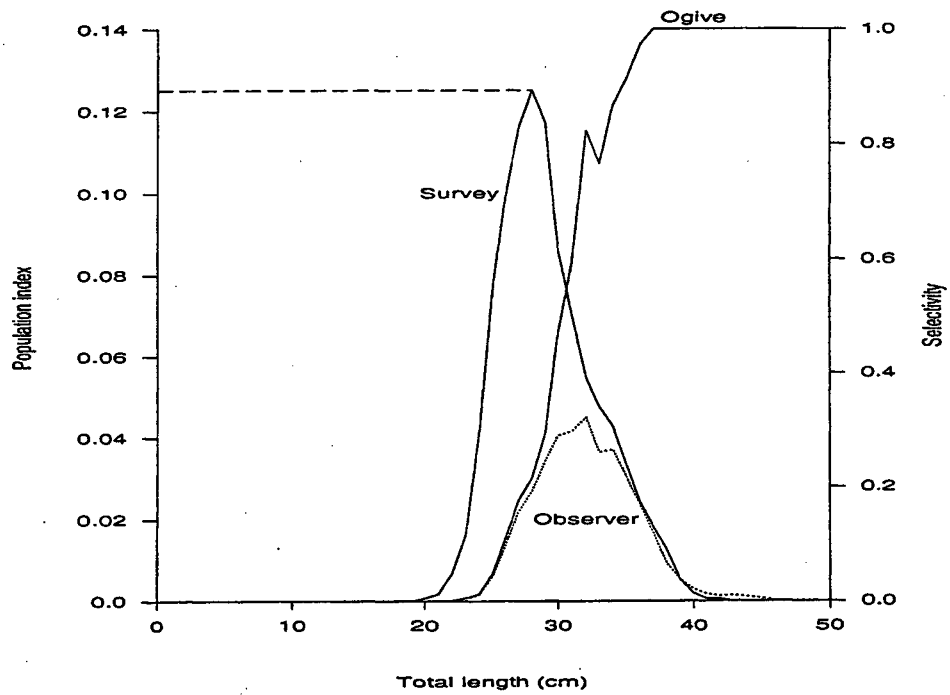

Figure 9: Selectivity ogive ('Ogive') estimated by length using the combined research survey data (1986, 1987, 1990, 1991–1993, 1995) scaled by abundance, and observer data (1979 to 2000) scaled by accumulated catch and also scaled to fit the far right hand limb of the research curve ('Survey'). The population length frequency is the horizontal dashed line on the left hand side of the research survey mode plus the right hand limb of the research length frequency.

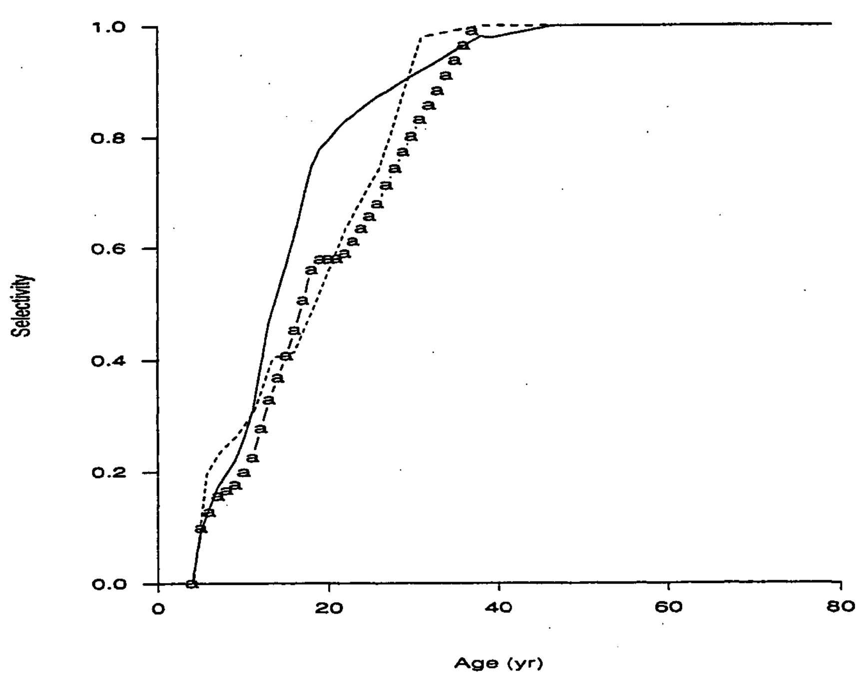

Figure 10: Selectivity ogive by age (years). The solid line is the standard ogive based on all the catch and observer data, i.e., from 1979 to 2000. The alternative ogive (a) based on the catch and observer data from 1986 to 1995 is also shown. The dashed line is the ogive used in the 1999 assessment.

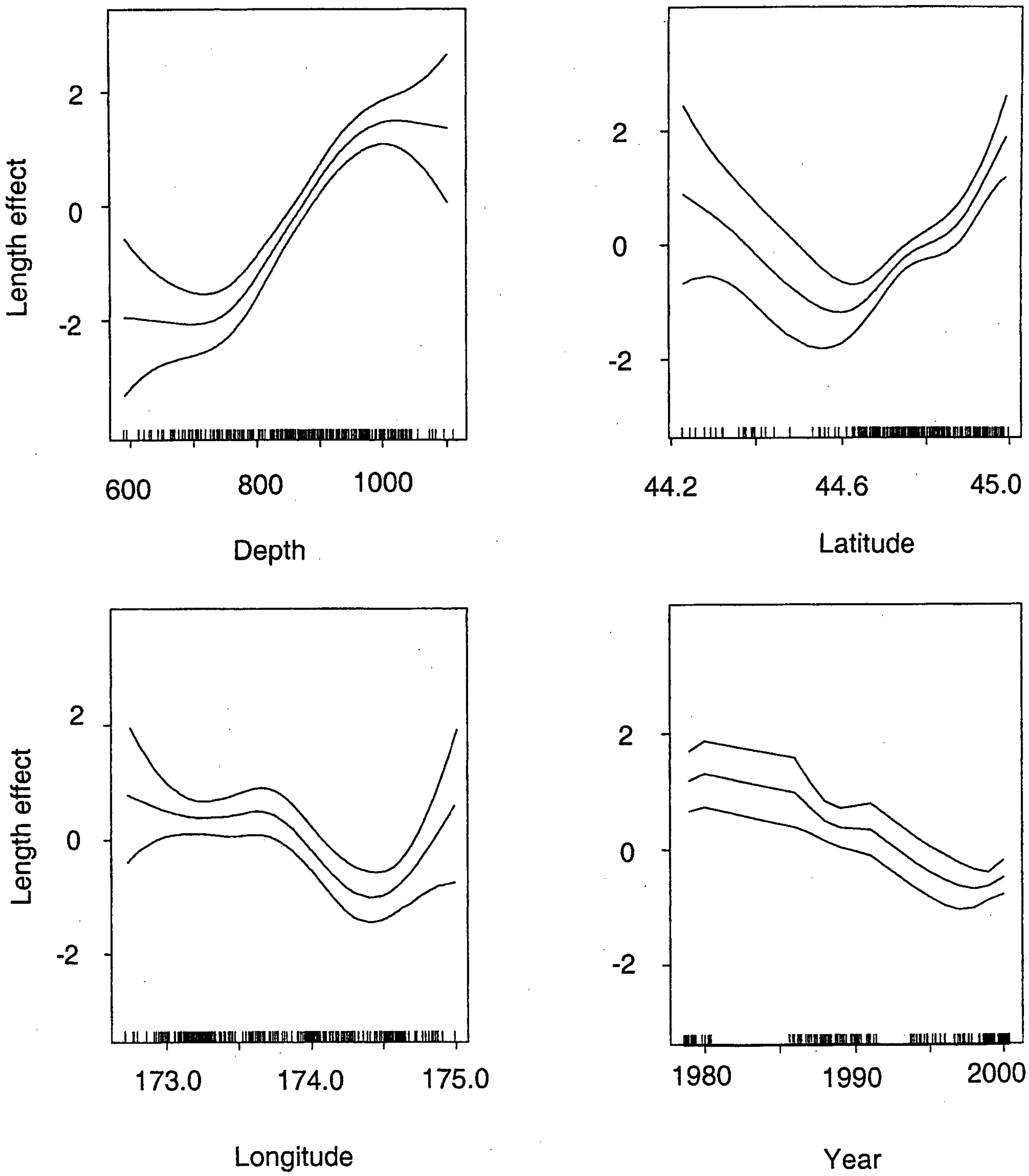

Figure 11: Observer mean length (cm) dependence on depth (m), latitude (lat), longitude (long), and calendar year. The solid lines are smoothed and the dotted lines are the upper and lower pointwise twice-standard-error curves. On the bottom axis, short marks represent the location of each sample. On the y-axis, each effect has been standardised to the mean value (zero).