Appendix 4

INVESTIGATION AND IMPLICATIONS OF SPATIAL AND TEMPORAL PATTERNS IN SEX RATIO DATA FROM WEST GREENLAND MINKE WHALE CATCHES

Geof H. Givens, Kristin Laidre, Lars Witting, Doug Butterworth, and Mads-Peter Heide-Jørgensen

The sub-group based its deliberations on the computations set out below, which were carried out by Givens following input from sub-group members.

Data were available on 614 M and 1891 F minke whales caught between 1987 and 2006. The response variable was 1 if the whale was F and 0 if it was M. Predictor variables were Year (treated as a continuous variable and expressed as years since 1986), Month (treated as a factor variable with sum contrasts with April as the reference group), and Region (three regions northwest (NW), central west (CW) and southwest (SW) treated as a factor with CW as the reference group). Observations from January, February, and March (n=27) were deleted from the dataset.

We fit a standard logistic regression using the glm() function in R. Month and Year were allowed to interact with Region. Model comparisons were made using the likelihood ratio test. For simplicity, we did not fit an overdispersion parameter, but this should probably be investigated later. There was no significant Region:Month interaction however Region:Year interaction was statistically significant, as summarised below:

Model 1: Sex ~ Region + Year + Month
Model 2: Sex ~ Region + Year + Month + Region:Year

	Resid. Df	Resid. Dev	Df	Deviance	P(>|Chi|)
1	2,466	2,726.69			
2	2,464	2,717.38	2	9.30	0.01

The best model has main effects for Year, Month, and Region, and a Region:Year interaction. Here are the estimated model coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	1.052229	0.389733	2.700	0.00694	**
RegionNW	-0.082884	0.306125	-0.271	0.78658	
RegionSW	1.022538	0.321533	3.180	0.00147	**
Year	0.007525	0.014989	0.502	0.61563	
Month5	0.813130	0.407717	1.994	0.04611	
Month6	0.034720	0.360550	0.096	0.92329	
Month7	-0.137181	0.344401	-0.398	0.69040	
Month8	-0.233195	0.343092	-0.680	0.49670	
Month9	-0.262841	0.344426	-0.763	0.44539	
Month10	-0.023286	0.354193	-0.066	0.94758	
Month11	0.107542	0.420588	0.256	0.79819	
Month12	-0.598873	0.463619	-1.292	0.19645	
RegionNW:Year	0.005175	0.023299	0.222	0.82423	
RegionSW:Year	-0.061949	0.023333	-2.655	0.00793	**

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(Dispersion parameter for binomial family taken to be 1)
Null deviance: 2763.6 on 2477 degrees of freedom
Residual deviance: 2717.4 on 2464 degrees of freedom

These results show that the proportion of females in the SW region (in the observed dataset) has declined as years progress.

We also need to know whether the proportion of sampled animals (in the dataset) has shifted between regions over time. To address this question, we fit another logistic regression. In this model, the response variable was 1 if the animal is from SW and 0 otherwise. The predictor is Year. The results are:

Model 1: SW ~ 1
Model 2: SW ~ Year

	Resid. Df	Resid. Dev	Df	Deviance	P(>|Chi|)
1	2,477	3169.6			
2	2,476	3161.7	1	7.9	0.004924

with coefficients

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.379654	0.112044	-3.388	0.000703	***
Year	-0.023976	0.008531	-2.811	0.004945	**

This second analysis shows that sampling effort (for sexed whales in the dataset) has shifted northward as years progress. The analysis results presented above demonstrate that the female ratio in the SW region has declined over time while – simultaneously – sampling has shifted away from SW. These two trends could offset each other, thereby yielding an apparently flat time series of sex ratios that does not fully reflect underlying demography.

Given these results, a small working group considered the options for modifying the modelling and assessment approach to accommodate spatially dependent interannual trends in sex ratios. First, stratification by area was recommended, except that the NW and CW areas should be combined since they show no significant sex ratio differences. Second, the proportion of the catch in each of the three regions was examined with respect to month and year (see Fig. 1). This analysis showed that the monthly distribution of in the two strata (CW+NW and SW) did not vary substantially between the first and second decades represented in this dataset. This supports a decision not to stratify assessment modelling/analyses by month.

However, the analyses conducted here used only the most recent dataset from Greenland (1987-2006). Therefore, the working group made two suggestions about the remaining catch data. First, Cherry Allison should investigate the Norwegian catches to determine if the data suggest a similar spatial division i.e., one area north of, and one other area south of, 63.0 degrees north; if they exhibit a similar Year:Region interaction; and if they exhibit a lack of Month:Region interaction in the catch proportion data (as seen in Fig. 1). Second, the Greenlandic scientists should examine the dataset from the first Greenland fishery period to: (a) determine if the data are of sufficient quality to investigate spatial division, and (b) if they are, examine the same questions recommended for investigation with the Norwegian data. It was noted that population modelling would be simplified if the same spatial division for the later Greenland period could be used for the two earlier periods as well

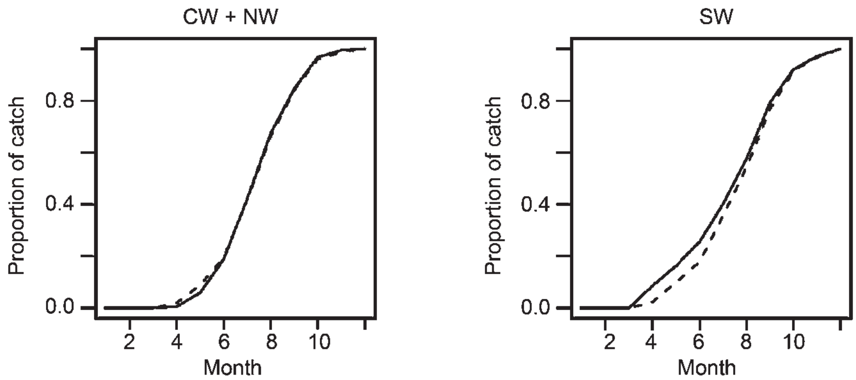

Fig. 1. Proportion of catch by month in NW and CW regions (pooled) and SW separately. Solid lines are catches in 1987-96 and dotted lines are 1997-2006.