Statistics 520, Fall 2025

Assignment 9

The glaucous gull (*Larus hyperboreus*) is a top predator of the Arctic ecosystem with a diet consisting of marine invertebrates, other seabirds, and the eggs of other seabirds. The number of nesting pairs of glaucous gulls in a particular study plot at Bjornoya (Bear Island) in the Norwegian Arctic has decreased from around $150-160$ in 1987 to $20-30$ in 2010 with a similar decrease in total nesting pairs in the larger population. Concern has focused on the presence of organochlorine pollutants, and in particular organochlorine pesticides. Organochlorines are known to affect reproductive success in birds (recall American Eagles and DDT) by thinning eggshells, and may affect survival of adult glaucous gulls because they eat the eggs of other species, thus resulting in the potential to accumulate dangerous levels of these pollutants.

In a study of pollutants in this species of gull (Erikstad, *et al.* 2013) glaucous gulls were captured in traps at Bjornoya (Bear Island) in the Barnets Sea (Norwegian Arctic). A number of quantities were measured, including blood concentrations of p,p'-dichlorodiphenyldichloroethylene (DDE) and oxychlordane (OXY), both measured as nanograms per gram wet weight. Oxychlordane is believed to be the most toxic of the organochlorines measured in the study and has been reported as related to both mortality and reproductive failure in glaucous gulls. On the other hand, DDE is believed to be readily bioaccumulated and may be present in greater concentrations than other organochorine pesticides. Also recorded was body mass (weight) which might serve as a proxy for age or roughly exposure. Although this may be a rather indirect indicator, the idea is that older gulls or gulls that are heavier have not been deprived of food and thus may have eaten more contaminated food (other

birds or the eggs of other birds). Since depuration of both DDE and OXY (elimination from the body) are much slower than accumulation, heavier gulls may have higher body burdens of these compounds than lighter gulls.

In this assignment we will be interested in developing a regression model to relate OXY (as response variables) to body mass (as a covariate). The data are available on the course web page in the Data module in a file named `gullsdata.txt`. The columns in of this file are "ring", which is an individual identifier for a sampled gull (they put numbered bands or rings on the legs of gulls that have been captured and that have provided data), "bm" which is body mass (g), "hcb" which is hexachlorobenzene (ng/g wet wt.), "oxy" which is oxychlordane (ng/g wet wt.), and "dde" (ng/g/ wet weight). As already noted we will deal with the variables oxy and bm.

1. (5 pts.)

   Define random variables and covariates appropriate to develop a regression model to relate OXY to bm. Examine the scatterplot of OXY on bm. Comment on features of these data based on visual examination of the scatterplot. In particular, identify any characteristics that should be accommodated by a random component for this problem.

2. (10 pts.)

   Examine the issue of random model component choice more closely, using approaches we discussed in class. NOTE: It may very well be the case that there are two potential random components that are difficult to distinguish between at this point.

3. (10 pts.)

   Suggest what you believe is a good link function for the problem. Present supporting evidence for your choice. Again, it may be difficult to make a clear

choice between possibilities.

4. (20 pts.)

   Fit models with up to two different random components, but using a log link function for both. Estimate regression parameters using maximum likelihood, combined with the usual moment-based estimate of *phi*. Compute Wald theory intervals for the elements of $\boldsymbol{\beta}$, unscaled and scaled deviances, and maximized log likelihoods.

5. (10 pts.)

   The estimates of ϕ will be quite different between your two models but this is to be expected because of the different distributional forms involved. To see how the models are reflecting variances, compute the variance for a response distribution at several values of the covariate.

6. (10 pts.)

   Produce studentized deviance residual plots (residuals versus fitted values) for the two random components you are investigating. Do these assist you in distinguishing between the two possible models?

7. (10 pts.)

   Pick one of your two models, compute Wald theory intervals for the regression parameters and produce a pointwise 90% confidence band for the regression function.

The paper on which this assignment is based is available on the course web page in the Handouts and Additional Material module.

Erikstad, E.E., Sandvik, T.K.R., Bustnes, J.O. and Strom, H. (2013), Persistent organic pollution in a high-arctic top predator: sex-dependent thresholds in adult survival. *Proceedings of the Royal Society B (Biological Sciences)* **280**: 20131483.