Dina research school

Likelihood-based inference for hierarchical/mixed statistical models

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Distribution of starfish on Iceland scallops ground in Breidifjordur West of Iceland : effects on scallops mortality.

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Introduction

During the last 5 years, the stock size of Iceland scallop has undergone a dramatic decline. This period has been characterized by steady increase in summer sea temperature and in 2003 the temperature had reached a historical maximum of the last century. As well, since 1998, there have been fluctuations in chl-a level, with the lowest values observed in 1999 and 2000. At the same time, muscle weight has declined and a minimum weight was attained in 2001-2002. In the following years, natural mortality of scallops in Breidifjordur increased significantly. The mortality was however quite localized within the main fishing area in the southern part of Breidifjordur. At the same time two Coccidia parasites have been described in Iceland scallop from Breidifjordur. These parasite may have influenced
the survival of the scallops. Starfishes have also been found in proportionally high numbers where scallops mortality has been high.

In this workshop the focus was on:

How much of scallop mortality can be explained by starfish ? Has starfish negative effect on scallop mortality and hence their abundance.

The data set:

The data covers 13 years and are spatial, there are 19 subareas, and 2- 20 townumbers within subareas (Fig. 1).

Natural mortality of scallops, expressed as the number of alive scallops and dead scallops still attached on their hinges on every townmuber.

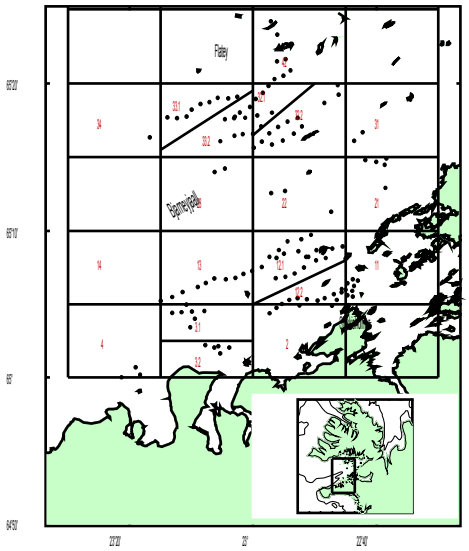


Figure 1. The survey area in Breidifjordur. Each square containing a subarea is labelled. All townumber are marked with dots.

In the surveys, the weight of other bycatch was also measured.

The model:

The model was binomial (% dead scallops, and total number of scallops as weight). The

random variables were: Subareas and townumbers. The slopes of starfish were fixed at each subarea. The f

ixed effect were the ratio of starfish compared to scallops (rstarfish) and year as factor (1993 – 2003). Starfish has significant effect on scallop mortality (Fig. 2 and 3). The effect of year 2002 and 2003 were much higher than previous years (1993 – 2001). There is a overdispersion in the model, that means we could be measuring the wrong factors, but that could also be due to spacial effects.

The fit of the model was not bad, but there were a couple of outliers, and most of them came from subareas thad had high natural mortality during 2002 and 2003 (Fig. 4 - 6) . Around 83% of the random variable lied within in subareas and 17 % within townumbers. Ratio of dead scallops was 1.3% (1.2 - 1.5), the intercept. If the starfish

were 20% of the scallop catch, the expected ratio of dead scallops would be 2.5 % (2.2 - 2.7).

$$\text{prop}_{ijk} \sim \text{Binomial}(\text{total}_{ijk}, \pi_{ijk})$$

$$\begin{aligned}\text{logit}(\pi_{ijk}) = {} & \beta_{0jk}\text{cons} + \beta_{1k}\text{rstarfish}_{ijk} + \text{-0.117(0.125)year\_1994}_{ijk} + \text{-0.289(0.131)year\_1995}_{ijk} + \\ & \text{-0.378(0.126)year\_1996}_{ijk} + \text{-0.251(0.135)year\_1997}_{ijk} + \text{-0.359(0.144)year\_1998}_{ijk} + \\ & \text{-0.241(0.132)year\_1999}_{ijk} + \text{-0.410(0.143)year\_2000}_{ijk} + \text{0.287(0.118)year\_2001}_{ijk} + \\ & \text{0.814(0.112)year\_2002}_{ijk} + \text{1.120(0.110)year\_2003}_{ijk}\end{aligned}$$

$$\beta_{0jk} = \text{-4.324(0.138)} + v_{0k} + u_{0jk}$$

$$\beta_{1k} = \text{3.356(0.464)} + v_{1k}$$

$$\begin{bmatrix} v_{0k} \\ v_{1k} \end{bmatrix} \sim \text{N}(0,\ \Omega_v) \ :\ \Omega_v = \begin{bmatrix} \text{0.150(0.071)} & \\ \text{-0.156(0.221)} & \text{0.725(0.821)} \end{bmatrix}$$

$$\begin{bmatrix} u_{0jk} \end{bmatrix} \sim \text{N}(0,\ \Omega_u) \ :\ \Omega_u = \begin{bmatrix} \text{0.165(0.036)} \end{bmatrix}$$

$$\text{var}(\text{prop}_{ijk}|\pi_{ijk}) = \text{2.636(0.111)}\pi_{ijk}(1 - \pi_{ijk})/\text{total}_{ijk}$$

Figure 2. The outcome of the best model using MlwiN IGLS (2nd order PQL).

$$\text{prop}_{ijk} \sim \text{Binomial}(\text{total}_{ijk}, \pi_{ijk})$$

$$\begin{aligned}\text{logit}(\pi_{ijk}) = {} & \beta_{0jk}\text{cons} + \beta_{1k}\text{rstarfish}_{ijk} + \text{-0.117(0.075)year\_1994}_{ijk} + \text{-0.276(0.080)year\_1995}_{ijk} + \\ & \text{-0.350(0.076)year\_1996}_{ijk} + \text{-0.224(0.082)year\_1997}_{ijk} + \text{-0.332(0.087)year\_1998}_{ijk} + \\ & \text{-0.219(0.081)year\_1999}_{ijk} + \text{-0.385(0.088)year\_2000}_{ijk} + \text{0.309(0.072)year\_2001}_{ijk} + \\ & \text{0.833(0.069)year\_2002}_{ijk} + \text{1.152(0.068)year\_2003}_{ijk}\end{aligned}$$

$$\beta_{0jk} = \text{-4.344(0.136)} + v_{0k} + u_{0jk}$$

$$\beta_{1k} = \text{3.136(0.499)} + v_{1k}$$

$$\begin{bmatrix} v_{0k} \\ v_{1k} \end{bmatrix} \sim \text{N}(0,\ \Omega_v)\ :\ \Omega_v = \begin{bmatrix} \text{0.201(0.098)} & \\ \text{-0.211(0.242)} & \text{1.664(1.329)} \end{bmatrix}$$

$$\begin{bmatrix} u_{0jk} \end{bmatrix} \sim \text{N}(0,\ \Omega_u)\ :\ \Omega_u = \begin{bmatrix} \text{0.248(0.042)} \end{bmatrix}$$

$$\text{var}(\text{prop}_{ijk}|\pi_{ijk}) = \text{2.636(0.000)}\pi_{ijk}(1 - \pi_{ijk})/\text{total}_{ijk}$$

PRIOR SPECIFICATIONS

$p(\beta_0) \propto 1$

$p(\beta_1) \propto 1$

$p(\beta_2) \propto 1$

$p(\beta_3) \propto 1$

$p(\beta_4) \propto 1$

$p(\beta_5) \propto 1$

$p(\beta_6) \propto 1$

$p(\beta_7) \propto 1$

$p(\beta_8) \propto 1$

$p(\beta_9) \propto 1$

$p(\beta_{10}) \propto 1$

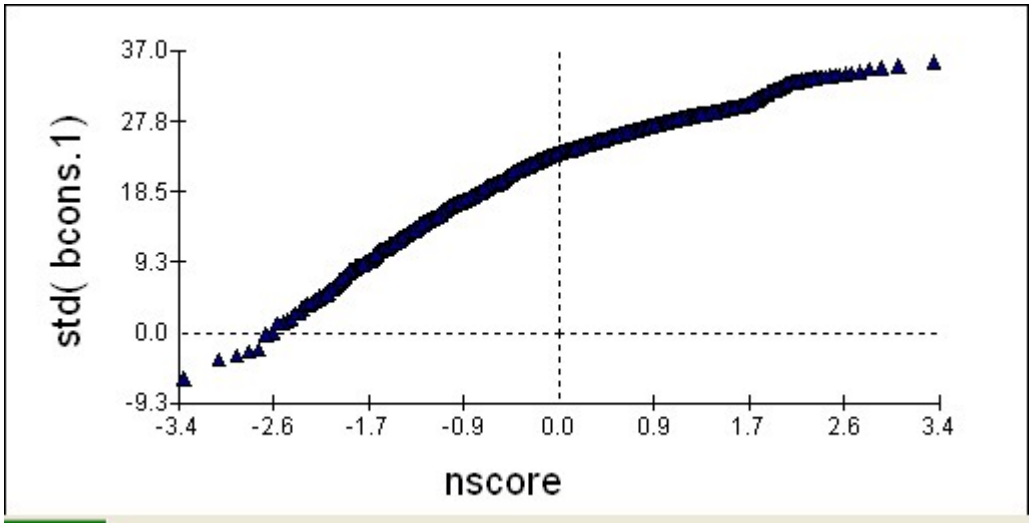
$p(\beta_{11}) \propto 1$

$$p(\Omega_v) \sim \text{inverse Wishart}_2[\ 2*\text{S}_v,\ 2],\ \ \text{S}_v = \begin{bmatrix} 0.150 & \\ -0.156 & 0.725 \end{bmatrix}$$

$$p(1/\sigma^2_{u0}) \sim \text{Gamma}(0.001, 0.001)$$

Deviance(MCMC) = 9448.595(1252 of 1252 cases in use)

Figure 3. The outcome of the best model using MCMC methods, 50000 iterations (every 10 stored)



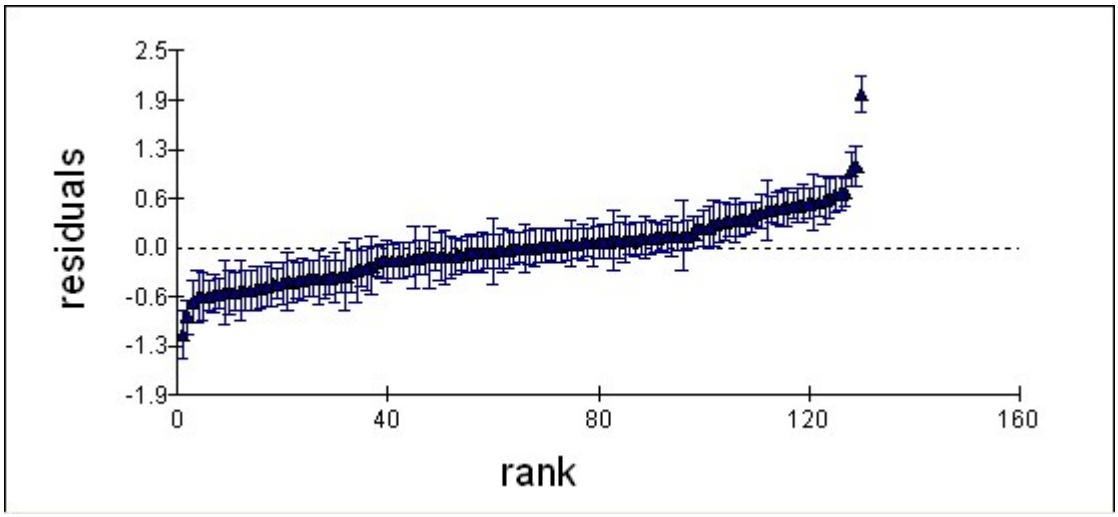


Figure 4. Residuals from the MCMC model on 1.st level.

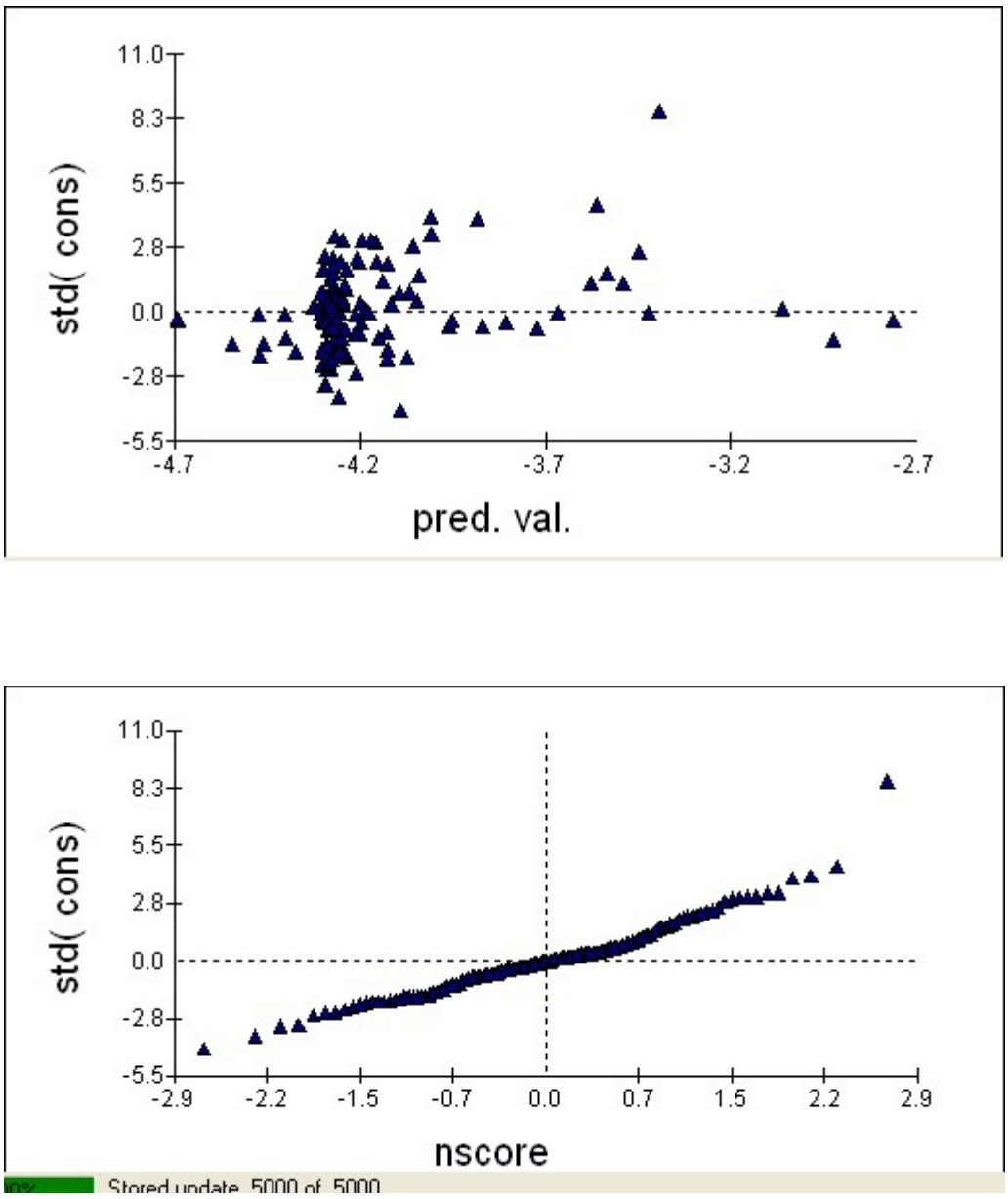


Figure 5. Residuals from the MCMC on townumber level.

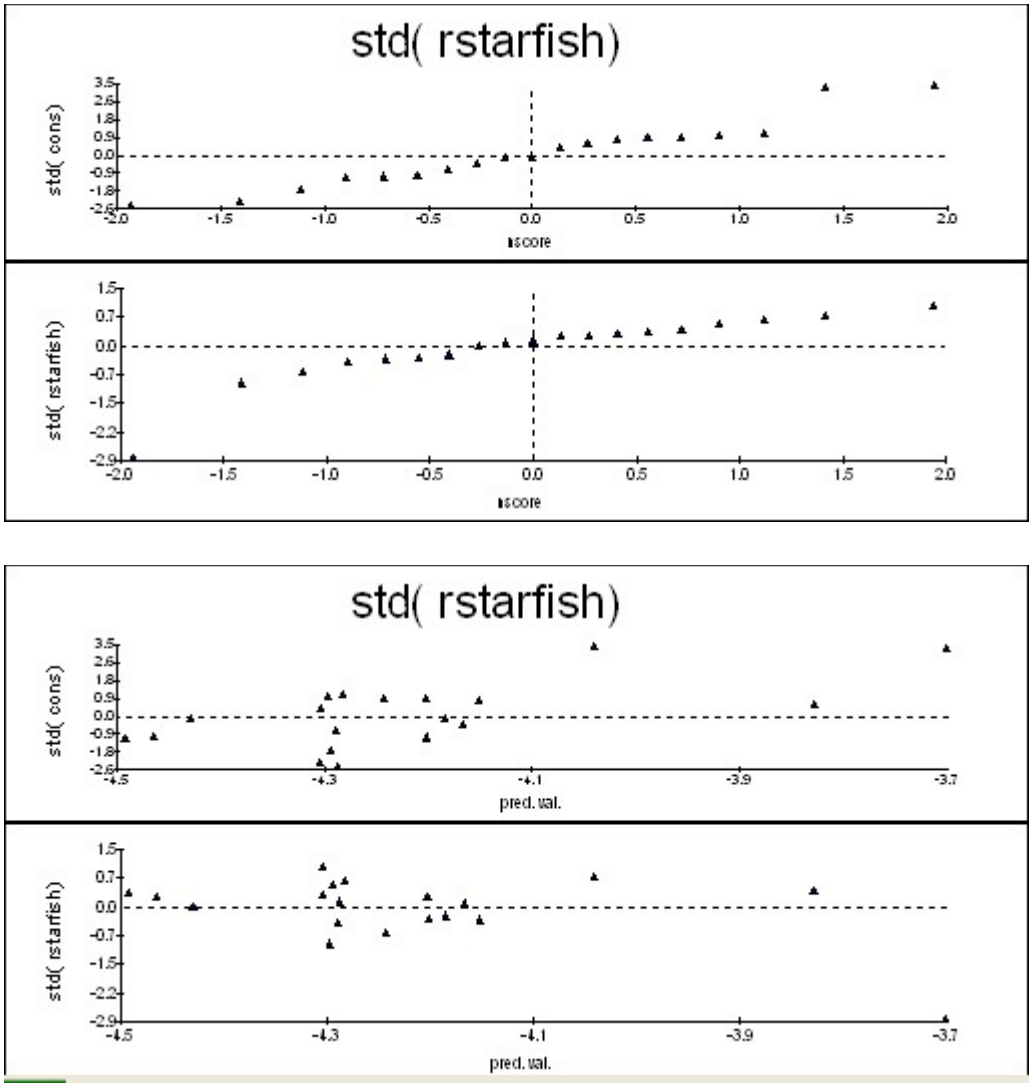


Figure 6. Residuals from the MCMC model on subarea level.

Discussion:

Although there were a negative relationship between the abundance of starfish and the mortality of scallops, there are more factors to take into account. Fisheries play for example major role, as starfishes seek in newly fished scallop beds, preying on damaged and shocked scallops.
What happened after 2002 ? At that time two Coccidia parasites have been described in Iceland scallop from Breidifjordur. These parasite may have influenced the survival of the scallops.

Starfishes have showned to cause mass mortality on scallops and are one of their major predators. The distribution of starfish on scallops ground in Breidifjordur follows areas with higher natural mortality and their precence has marked influence on scallops mortality.

Further development of the model were tried in WinBUGS using GeoBUGS. The aim of that was to incorporate spatial correlation at the random effects level but with no luck so far.