# Modelling Birds Population

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## 1 Introduction

According to (REF, Etterson) one of the basic research goals in Ecology consist on understand the distribution and abundance of the animal population. In this work, the particular goal will be to explore alternatives to model the time trends in Western Great Lakes Birds population over 1994 to 2011.

### 1.1 Data description

Next table shows total bird count on year 2007 for the most abbundant species, just to compare it with the online annual report. After the table the overall trend for the raw counts over the year are ploted.

| Specie | Chequamegon | Chippewa | Superior |
|---|---|---|---|
| OVEN | 1003 | 835 | 1168 |
| REVI | 823 | 997 | 771 |
| BTNW | 254 | 177 | 219 |
| NAWA | 240 | 348 | 867 |
| BLJA | 222 | 199 | 230 |
| CSWA | 211 | 330 | 375 |
| RBGR | 208 | 70 | 181 |
| WTSP | 180 | 387 | 940 |
| HETH | 175 | 249 | 265 |
| AMRO | 156 | 102 | 154 |
| LEFL | 155 | 368 | 120 |
| YBSA | 132 | 150 | 129 |
| COYE | 126 | 209 | 71 |
| VEER | 91 | 402 | 264 |
| WIWR | 48 | 50 | 195 |

Forest 9090 (NAMES) is consistently higer than the other two in terms of overal abundance, also it seems to be an increment of the total bird population over time regardless specie.

Figure 1: Raw trend in the data

### 1.2 Initial models

Perhaps the simplest model we could be a quadratic regression separatedly for each specie and forest.

$$
\begin{aligned}
Y_{tfs} &= \beta_{0fs} + \beta_{1fs}t + \beta_{2fs}t^2 + \epsilon_{tfs} \\
\epsilon_{tfs} &\sim N(0, \sigma^2_{fs})
\end{aligned} \tag{1}
$$

where $Y_{tfs}$ represent the average bird count on year $t$ in the forest $f$ for the specie $s$. There are 73 species and 3 forest in the data set so there are 219 models in total.

Table **??** shows the summary statistics for each coefficient and figure **??** presents histograms for each one of the model coefficients.

Figure 2: Densities for coefficients of model 1.

Figure 3: Bivarieate relation among coefficients of model 1.

| forestN | parameter | Min. | 1st Qu. | Median | Mean | 3rd Qu. | Max. |
|---|---|---|---|---|---|---|---|
| Chequamegon | b0 | -5.797 | -3.453 | -2.328 | -2.463 | -1.691 | 1.009 |
| Chequamegon | b1 | -0.143 | -0.004 | 0.030 | 0.036 | 0.072 | 0.211 |
| Chequamegon | b2 | -0.045 | -0.011 | -0.004 | -0.007 | 0.000 | 0.012 |
| Chequamegon | sigma | 0.110 | 0.250 | 0.364 | 0.443 | 0.625 | 1.099 |
| Chippewa | b0 | -5.859 | -3.474 | -2.637 | -2.658 | -1.507 | 0.741 |
| Chippewa | b1 | -0.104 | 0.012 | 0.048 | 0.044 | 0.077 | 0.245 |
| Chippewa | b2 | -0.023 | -0.010 | -0.005 | -0.006 | -0.002 | 0.010 |
| Chippewa | sigma | 0.127 | 0.294 | 0.451 | 0.482 | 0.646 | 1.057 |
| Superior | b0 | -6.177 | -4.310 | -2.846 | -3.005 | -1.567 | 0.815 |
| Superior | b1 | -0.150 | 0.000 | 0.028 | 0.028 | 0.061 | 0.248 |
| Superior | b2 | -0.022 | -0.006 | -0.003 | -0.002 | 0.000 | 0.024 |
| Superior | sigma | 0.033 | 0.270 | 0.392 | 0.458 | 0.615 | 1.199 |

A second model considered is a regression using data from all 73 species in each forest and including random terms for the species coefficients.

$$
\begin{aligned}
log(Y_{tfs}) &= \beta_{0fs} + \beta_{1fs}t + \beta_{2fs}t^2 + \epsilon_{tfs} \\
\beta_{0fs} &\sim N(\beta_{0f}, \sigma^2_{0f}) \\
\beta_{1fs} &\sim N(\beta_{1f}, \sigma^2_{1f}) \\
\beta_{2fs} &\sim N(\beta_{2f}, \sigma^2_{2f}) \\
\epsilon_{tfs} &\sim N(0, \sigma^2_{f})
\end{aligned} \tag{2}
$$

| forest | parameter | mean | variance |
|---|---|---|---|
| 9020 | b0 | -2.900 | 1.462 |
| 9020 | b1 | 0.119 | 0.126 |
| 9020 | b2 | -0.007 | 0.008 |
| 9020 | residual | 0.000 | 0.487 |
| 9030 | b0 | -3.035 | 1.523 |
| 9030 | b1 | 0.108 | 0.000 |
| 9030 | b2 | -0.005 | 0.001 |
| 9030 | residual | 0.000 | 0.526 |
| 9090 | b0 | -3.207 | 1.727 |
| 9090 | b1 | 0.056 | 0.116 |
| 9090 | b2 | -0.002 | 0.006 |
| 9090 | residual | 0.000 | 0.523 |

## 2 Statistical Model

$$\begin{aligned} log(Y_{tfs}) &= \beta_{0fs} + \beta_{1fs}t + \beta_{2fs}t^2 + \epsilon_{tfs} \\ \beta_{fs} &= \begin{pmatrix} \beta_{0fs} \\ \beta_{1fs} \\ \beta_{2fs} \end{pmatrix} \sim N(0, \Sigma_{fs}) \\ \Sigma_{fs} &\sim \text{inv-gamma, scaled inv-gamma, ...} \\ \epsilon_{tfs} &\sim N(0, \sigma_\epsilon^2) \\ \sigma_\epsilon^2 &\sim inv - gama(\alpha, \gamma) \end{aligned} \tag{3}$$