Example 3: Birds on the alpine landscapes of Switzerland

We are interested in how landscape characteristics influence habitat use by a rare bird, the willow tit. There are N sites and we search each site n_i times looking and listening for the bird. Thus, we take observations for each site for each time period recording 0 if the the bird was not observed and 1 if it was observed.

Our hypothesis was that the probability that the ith site was occupied was related to its elevation and forest cover, both being quantitative variables.

We must account for the fact that a string of 0's for all visits to a site could mean two things: the bird was absent from the site, or the bird was present and unobserved. If we fail to account for these differences, we will underestimate occupancy.

Data:

y_i = the number of times that a bird was detected at site i given n_i attempts to find the bird

Royle, J. A., and R. M. Dorazio. 2008. Hierarchical Modeling and Inference in Ecology: The Analysis of Data from Populations, Metapopulations, and Communities. Academic Press, London, UK.

Accounting for detectability

Define the state variable z_i as describing the *true* state of a site:

$z_i = 0$ if the site is unoccupied

$z_i = 1$ if the site is occupied

Note that each site can take on only 1 of the two states and it is presumed to be in that state throughout the sampling period.

Thus, we can model z_i as:

$$z_i \sim \text{Bernouli}\left(\text{invlogit}\left(\beta_0 + \beta_1 elev_i + \beta_2 elev^2{}_i + \beta_3 forest_i\right)\right)$$

Accounting for detectability

Let p = the probability that we would detect a bird if it is present on a site.

Thus, the probability of detcting a bird on a given vist to a site is

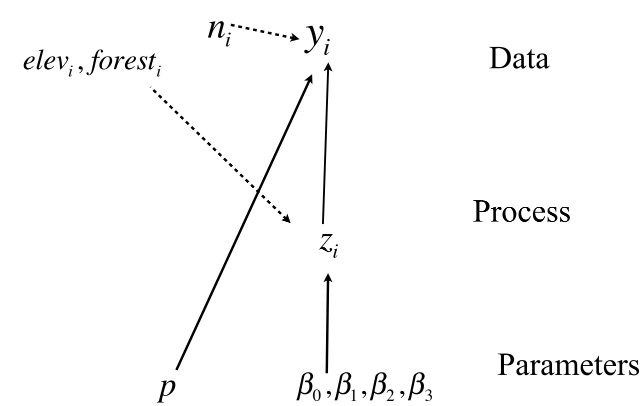
$z_i \cdot p = 0$ if the site is not occupied

$z_i \cdot p = p$ if the site is occupied

$[y_i \mid, n_i, z_i \cdot p]$

$[z_i \mid \beta_0, \beta_1, \beta_2, \beta_3]$

$[\beta_0],[\beta_1][\beta_2][\beta_3][p]$

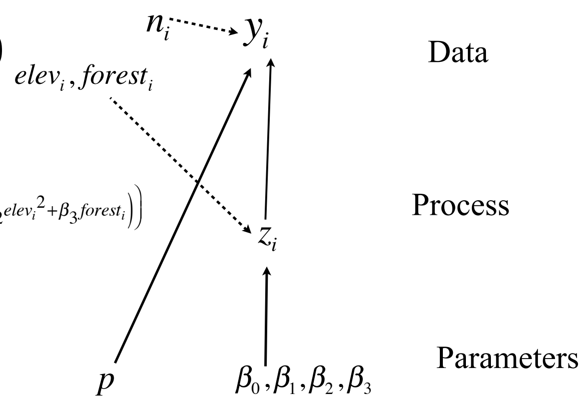


So, the the number of times we observe a the bird on a site is determined by its true state (occupied or not) and the probability that we are able to detect the bird. The true state, in turn is influenced by the attributes of the landscape and the birds' response to them.

$y_i \sim \text{binomial}\left(z_i \cdot p, n_i\right)$

$z_i \sim \text{Bernouli}\left(\text{invlogit}\left(\beta_0+\beta_1 elev_i+\beta_2 elev_i{}^2+\beta_3 forest_i\right)\right)$

$[\beta_0],[\beta_1][\beta_2][\beta_3][p]$



$$
\begin{aligned}
[\boldsymbol{\beta}, \mathbf{z}, p|\mathbf{y}] \quad \propto \\
& \prod_{i=1}^{N} \text{binomial}\left(y_i|p \cdot z_i, n_i\right) \times \\
& \text{Bernoulli}(z_i|\text{invlogit}(\beta_0 + \beta_1 elev_i + \beta_2 elev_i{}^2 + \beta_3 forest_i)) \times \\
& \text{normal}\left(\beta_0|0, 2.25\right) \text{normal}\left(\beta_1|0, 2.25\right) \times \\
& \text{normal}\left(\beta_2|0, 2.25\right) \text{normal}(\beta_3|0, 2.25) \text{beta}\left(p|1, 1\right)
\end{aligned}
$$

Notice how the true state variable modifies the detection probability--if there are no birds present, that probability should be 0. This general framework can be applied to any occupancy problem.