Electronic Supplementary Material 2

The single-season occupancy model can be naturally defined hierarchically, where there is an explicit separation of an observation model and a latent process model. This model is defined for site-level variation on detection and occupancy as written, such that we observe y_i (the number of detections per occupied site) across i sites with k replicate surveys with probability p_i:

Observation Model: $$y_i \sim \begin{cases} 0 & , z_i = 0 \\ Binom(k_i, p_i) & , z_i = 1 \end{cases}$$

Process Model: $$z_i \sim Bern(\psi_i)$$

The model parameters for detection (p_i) and occupancy (ψ_i) can be further modeled to incorporate biological hypotheses concerning covariate effects (e.g., habitat, survey effort):

Parameter Model: $probit(p_i) = \mathbf{W_i'}\boldsymbol{\alpha}$ $\quad probit(\psi_i) = \mathbf{X_i'}\boldsymbol{\beta}$

Hyper-parameter Model (priors): $\boldsymbol{\alpha} \sim Normal(\boldsymbol{\mu}_\alpha, \boldsymbol{\Sigma}_\alpha)$ $\quad \boldsymbol{\beta} \sim Normal(\boldsymbol{\mu}_\beta, \boldsymbol{\Sigma}_\beta)$

The joint posterior distribution can be written conditionally as the probability of all unknown parameters, given the data (where [] indicate a probability distribution),

$$[\boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{z}|\boldsymbol{y}] \propto \left(\prod_{i=1}^{N} [y_i|p_i][z_i|\psi_i] \right) [\boldsymbol{\alpha}][\boldsymbol{\beta}] \qquad (1)$$

The model can be fit using a Bayesian method, where inference is achieved by sampling full conditional posterior distributions of each unknown parameter ($\boldsymbol{\alpha}, \boldsymbol{\beta}, z$) separately using Markov chain Monte Carlo methods.