Overview

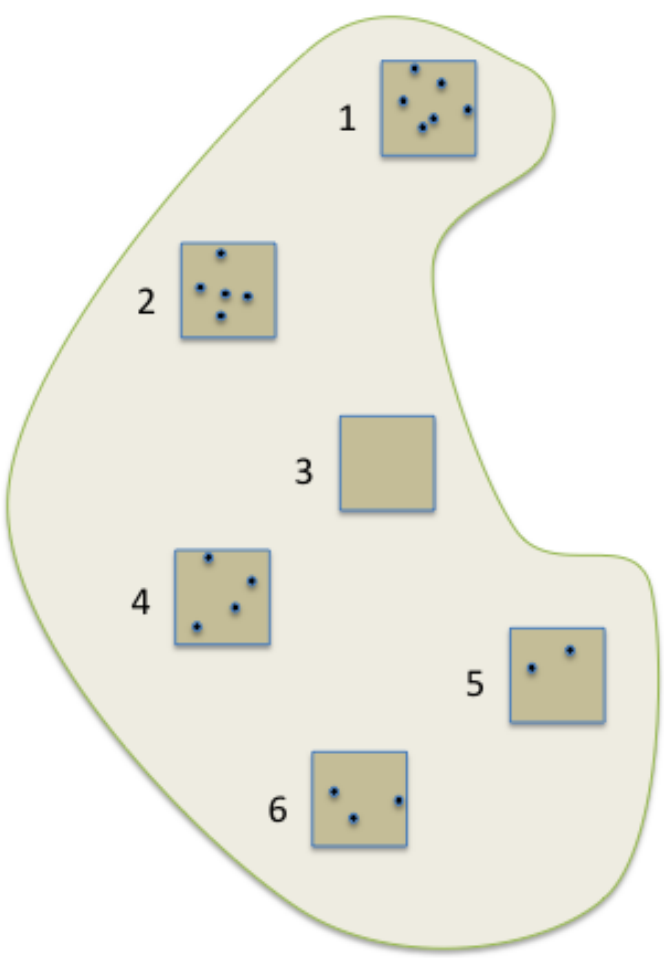
Occupancy

- Binary data indexed by site and visit;
- Accounts for imperfect detection (false-negative);
- Assumes population closure;
- The "mixture" component accounts for sampling process mechanistically.

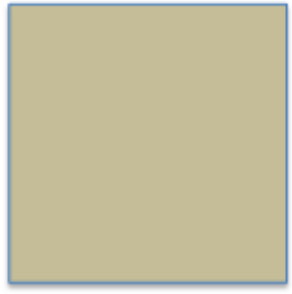
Capture-Recapture

- Binary data indexed by individual and capture history;
- Accounts for imperfect detection;
- Assumes population closure;
- The "mixture" component (data augmentation) allows inference on abundance.

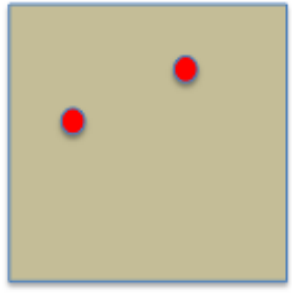
Occupancy Data



$y_1 = 1$



$y_3 = 0$



$y_5 = 0$

Occupancy Data

$$y_{i,j} \in \{0, 1\}$$

Site $i = 1, \ldots, n$
Visit $j = 1, \ldots, J_i$

$$y_i = \sum_{j=1}^{J_i} y_{i,j}$$

i	$y_{i,1}$	$y_{i,2}$	$y_{i,3}$	y_i
1	0	1	0	1
2	1	1	0	2
3	0	0	1	1
4	0	0	0	0
5	0	0	0	0

Occupancy Model

Suppose there are J_i visits for each site ($i = 1, \ldots, n$):

$$y_i \sim \begin{cases} 0 & , z_i = 0 \\ \text{Binom}(J_i, p) & , z_i = 1 \end{cases}$$

$$z_i \sim \text{Bern}(\psi_i)$$
$$\text{logit}(\psi_i) = \mathbf{x}_i' \boldsymbol{\beta}$$
$$p \sim \text{beta}(a, b)$$
$$\boldsymbol{\beta} \sim \text{N}(\boldsymbol{\mu}_\beta, \boldsymbol{\Sigma}_\beta)$$

Draw The DAG

JAGS Implementation

Extensions

- Detection probability (p) varies by site;
- Detection probability varies by site and visit;
- Spatial/temporally correlated occupancy probability (ψ);
- ...

Capture-Recapture Data & Model

$$y_i \sim \begin{cases} 0 & , z_i = 0 \\ \text{Binom}(J, p) & , z_i = 1 \end{cases}$$

Individual $i = 1, \ldots, M$

$z_i \sim \text{Bern}(\psi)$

$\psi \sim \text{Beta}(a_\psi, b_\psi)$

$p \sim \text{beta}(a_p, b_p)$

i	$y_{i,1}$	$y_{i,2}$	$y_{i,3}$	y_i
1	0	1	0	1
2	1	1	0	2
3	0	0	1	1
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
M	0	0	0	0

Data Augmentation

Specifying super-population size, M, and prior on membership probability, ψ, implies a prior on abundance, N.

$$N = \sum_{i=1}^{M} z_i, \;\; z_i \sim \text{Bern}(\psi) \Rightarrow N \sim \text{Binom}(M, \psi)$$

For example,

$$\psi \sim \text{Unif}(0, 1) \Rightarrow N \sim \text{DiscUnif}(0, M)$$

$$\psi \sim \text{Beta}(a_\psi \to 0, b_\psi = 1) \Rightarrow [N] \propto 1/N$$

Draw The DAG

JAGS Implementation

Extensions

- Detection probability (p) varies by capture occasion;
- Detection probability varies by individual, need to augment individual covariates for super-population;
- Temporal dependence in capture history;
- ...

References

Hobbs, N.T. and M.B. Hooten. (2015). Bayesian Models: A Statistical Primer for Ecologists. Princeton University Press.

Hooten, M.B. and T.J. Hefley. (2019). Bringing Bayesian Models to Life. CRC Press.