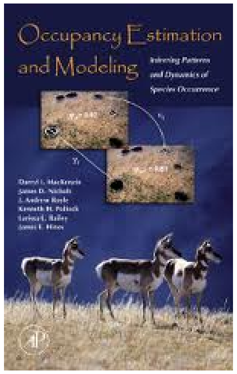
Occupancy Estimation and Modeling



Motivation

Occupancy models were developed to estimate metapopulation parameters when detection probability (p) is < 1.

Parameters of interest:

- ψ – Probability that a site is occupied
- γ – Probability that an unoccupied site becomes colonized
- ε – Probability that an occupied site goes extinct
- p – Probability of detecting at least one individual at a site that is occupied (on a single sampling occasion)

Detection probability

If $p < 1$, we might incorrectly conclude that a site is unoccupied if we don't detect any individuals

Consequences

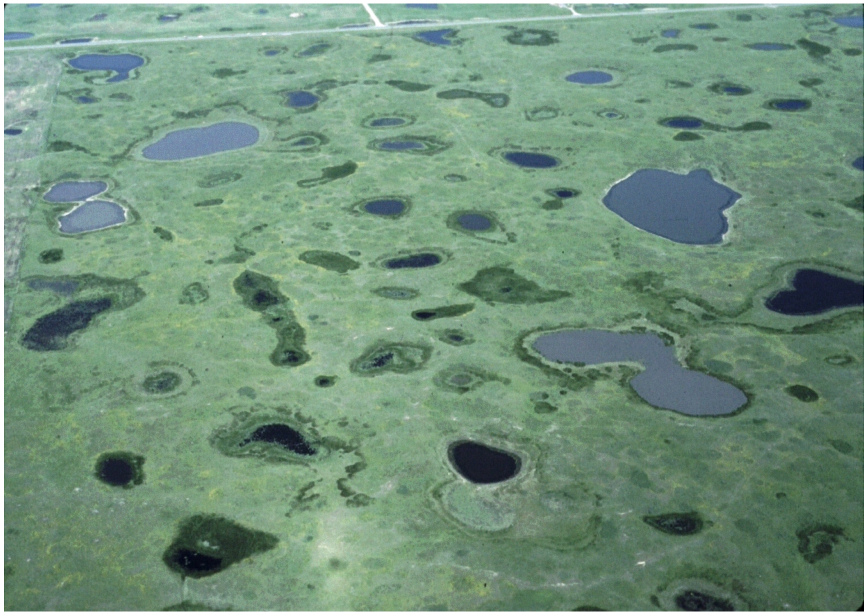
- We will underestimate the state variable: The proportion of sites occupied
- We might make incorrect conclusions about habitat relationships

Single-season models

Scenario

- No interest in colonization or extinction events
- Instead, we directly estimate ψ during one season
- Useful for assessing snapshot of habitat relationships or for modeling a species' distribution
- We assume population closure: A site's occupancy state does not change during the survey period (season)
- Definitions of site and season are very important

How many potholes are occupied by mallards?



Single-season model

Model for the occurrence state

$$O_i \sim \text{Bernoulli}(\psi)$$

Model for the data

$$y_{ij} \sim \text{Bernoulli}(O_i \times p)$$

We need to estimate ψ (occurrence probability) and p (detection probability)

Design

To estimate ψ and p, we should use a good study design:

- We need multiple sites
- Sites should be randomly selected
- We must have multiple sampling occasions at (a subset of) the sites

Data y_{ij} – low detection probability

10 sites and 3 sampling occasions

	Occasion 1	Occasion 2	Occasion 3
Site 1	0	0	1
Site 2	0	0	0
Site 3	0	0	0
Site 4	1	0	0
Site 5	0	0	0
Site 6	1	0	1
Site 7	1	0	0
Site 8	0	0	0
Site 9	0	1	0
Site 10	0	0	0

Data y_{ij} – high detection probability

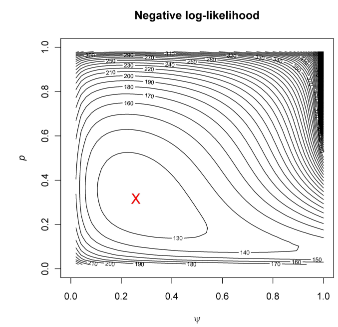
10 sites and 3 sampling occasions

	Occasion 1	Occasion 2	Occasion 3
Site 1	1	1	1
Site 2	0	0	0
Site 3	0	0	0
Site 4	1	1	1
Site 5	0	0	0
Site 6	1	0	1
Site 7	1	1	1
Site 8	0	0	0
Site 9	0	1	1
Site 10	0	0	0

How do we estimate ψ and p?

Maximum likelihood

- This method tries to find the most "likely" values of ψ and p, given the data
- It can also be used to estimate standard errors (SEs) and confidence intervals (CIs)



Software

Program `PRESENCE`, Program `MARK`, **R** package `unmarked`

Estimates

10 sites and 3 sampling occasions

	Occasion 1	Occasion 2	Occasion 3
Site 1	0	0	1
Site 2	0	0	0
Site 3	0	0	0
Site 4	1	1	0
Site 5	0	0	0
Site 6	1	1	1
Site 7	1	0	0
Site 8	0	0	0
Site 9	0	1	0
Site 10	0	0	0

Naive occupancy $= 5/10 = 0.50$
Estimated occupancy $= \hat{\psi} = 0.61 \pm 0.22$
Estimated detection $= \hat{p} = 0.44 \pm 0.16$

Overall detection probability

If you sample a site K times, the overall detection probability ($\bar{p}$) is:

$$\bar{p} = 1 - (1 - p)^K$$

$\bar{p}$ is detection probability after K sampling occasions
p is detection probability on a single occasion
K is the number of sampling occasions (e.g., visits to a site)

Assumptions

(1) Population closure: Occurrence state does not change during sampling

(2) Occurrence probability is the same for all sites, unless we account for covariates

(3) Detection probability is the same for all sites and sampling occasions, unless we account for covariates

(4) Statistical independence

Covariates

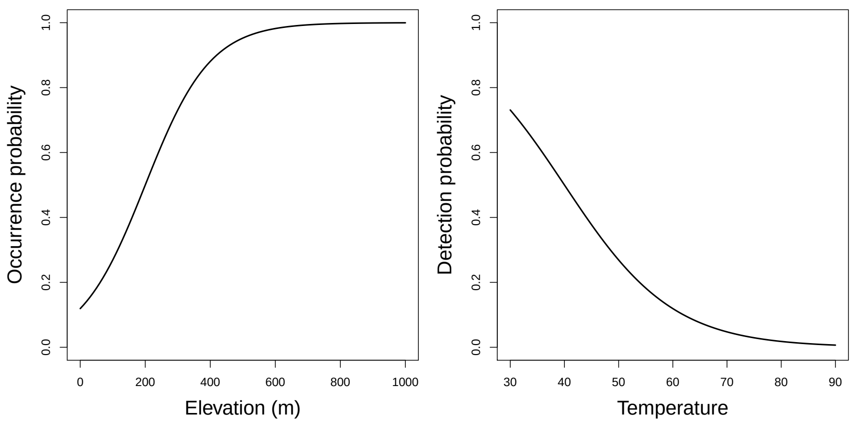
The value of ψ or p may depend on other variables, e.g. habitat, weather, observer abilities

How do we accommodate covariates?

The key is to think of detection probability as a function. A common choice is the logit-linear model:

$$\text{logit}(\psi_i) = \beta_0 + \beta_1 \text{ELEV}_i$$

Covariates



Multi-season models

With more than 1 season, we can estimate all the parameters of our metapopulation model, plus detection probability p

$$\psi_{i,t+1} = O_{i,t}(1-\varepsilon) + (1-O_{i,t})\gamma$$

$$O_{i,t+1} \sim \text{Bernoulli}(\psi_{i,t+1})$$

$$y_{i,j,t} \sim \text{Bernoulli}(O_{i,t} \times p)$$

Data format

5 sites, 2 seasons, and 3 sampling occasions

	Season 1			Season 2		
	Occasion 1	Occasion 2	Occasion 3	Occasion 1	Occasion 2	Occasion 3
Site 1	0	0	1	1	0	0
Site 2	0	0	0	0	0	0
Site 3	0	0	0	1	0	0
Site 4	1	1	1	0	0	0
Site 5	0	0	0	1	1	0

Summary

Occupancy models let us estimate metapopulation parameters when detection is imperfect

There are no individual-level data or parameters

These methods are often easy to implement over large areas and so are used in monitoring programs

Definition of site and season are very important considerations

Models can be used in other contexts, such as when a site is a human, and we are interested in proportion of people with some disease