Occupancy Estimation and Modeling
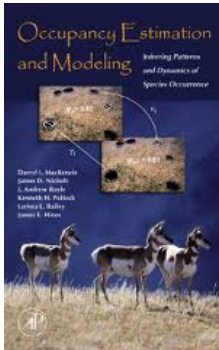
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- ψ – Probability that a site is occupied
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- ε – Probability that an occupied site goes extinct
- p – Probability of detecting at least one individual at a site that is occupied (on a single sampling occasion)

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- We might make incorrect conclusions about habitat relationships

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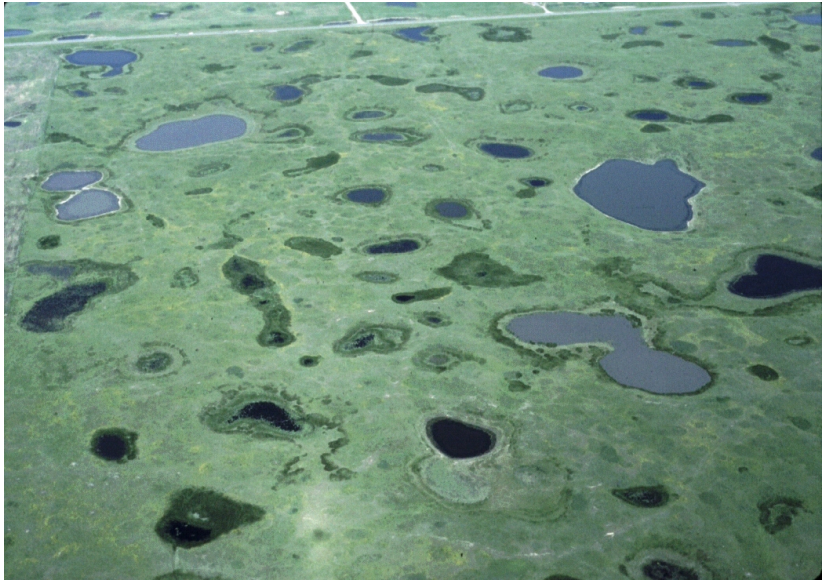
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- Instead, we directly estimate ψ during one season
- Useful for assessing snapshot of habitat relationships or for modeling a species' distribution
- We assume population closure: A site's occupancy state does not change during the survey period (season)
- Definitions of site and season are very important

Model for the occurrence state

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

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

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

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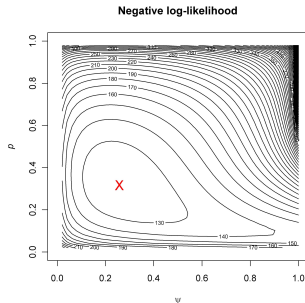|	Occasion 1	Occasion 2	Occasion 3
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Maximum likelihood

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- It can also be used to estimate standard errors (SEs) and confidence intervals (CIs)

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Negative log-likelihood

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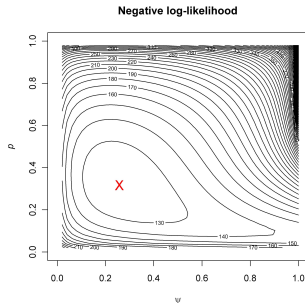
Software
Program PRESENCE, Program MARK, R package unmarked

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Naive occupancy $= 5/10 = 0.50$

Estimated occupancy $= \hat{\psi} = 0.61 \pm 0.22$

Estimated detection $= \hat{p} = 0.44 \pm 0.16$

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)

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(4) Statistical independence

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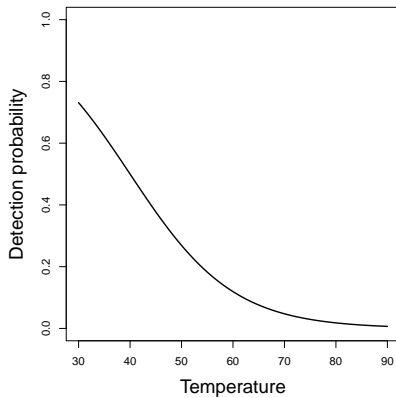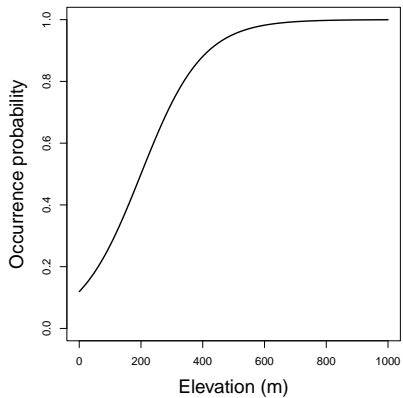
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How do we accommodate covariates?

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

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

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

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

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

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
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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.