Lecture 11

Estimating abundance: Occupancy modeling

WILD6900 (Spring 2020)

Readings

> Kéry & Schaub 383-409

Estimating abundance?

For the past few weeks, we've been modeling abundance:

$$N_t \sim Poisson(\lambda)$$

Occupancy is the probability a site is occupied

- reduced-information form of abundance
  - If $N_i > 0, z_i = 1$
  - If $N_i = 0, z_i = 0$

So even when occupancy is the state-variable, we are still modeling something related to abundance

Estimating abundance?

Typical state model for occupancy

$$z_i \sim Bernoulli(\psi)$$

If the expected abundance is λ, what is the probability $N = 0$?

$$Pr(N = 0|\lambda) = \frac{\lambda^0 e^- \lambda}{0!} = e^{-\lambda}$$

If the expected abundance is λ, what is the probability $N > 0$?

$$1 - Pr(N = 0|\lambda) = 1 - e^{-\lambda}$$

So (if our assumptions are valid):

$$\psi = 1 - e^{-\lambda}$$

Why estimate occupancy?

Less effort

Historical data sets

More reliable when N very small

Occupancy = abundance (e.g., breeding territory)

Metapopulation dynamics

Distribution/range size

Disease dynamics

Why not just use observed presence/absence?

As in all ecological studies, we rarely (if ever) observe the state process perfectly

In the case of occupancy, some sites will be occupied but we will fail to detect the species

- i.e., $p < 1$

Also possible (though generally more rare) that we record the species when it's not present (false positive)

- see Royle & Link 2006

Similar to N-mixture models, estimating p requires temporal replication

Estimating p

Imagine a single site surveyed 3 times:

- Assume site is closed across samples
- Assume constant p

$$y_i = [111]$$

What is the likelihood of this observation?

$$\psi p^3$$

Estimating p

What about?

$$y_i = [011]$$

$$\psi(1-p)p^2$$

Estimating p

What about?

$$y_i = [000]$$

$$(1-\psi) + \psi(1-p)^3$$

Single-season (static) occupancy model

State-space formulation

- State-model

$$z_i \sim Bernoulli(\psi_i)$$

$$logit(\psi_i) = \alpha_0 + \alpha_1 x_i$$

- Observation-model

$$y_{i,k} \sim Bernoulli(z_i p_{i,k})$$

$$logit(p_{ik}) = \beta_0 + \beta_1 x_{i,k}$$

Single-season (static) occupancy model

```
model{
  # Priors
  psi ~ dbeta(1, 1)
  p ~ dbeta(1, 1)

  # Likelihood
  for(i in 1:M){
    # State model
    z[i] ~ dbern(psi)

    # Observation model
    for(k in 1:K){
      y[i, k] ~ dbern(p * z[i])
    }
  }
}
```

Single-season (static) occupancy model

```
model{
  alpha0 ~ dnorm(0, 0.1)
  alpha1 ~ dnorm(0, 0.1)
  mu.lp ~ dnorm(0, 0.1)
  tau.p ~ dunif(0, 10)

  for(i in 1:M){
    z[i] ~ dbern(psi[i])
    logit(psi[i]) <- alpha0 + alpha1 * x1[i]
    for(k in 1:K){
      y[i, k] ~ dbern(p[i,k] * z[i])
      logit(p[i,k]) <- lp[i,k]
      lp[i,k] ~ dnorm(mu.lp, tau)
    }
  }

  N.occ <- sum(z[1:M])
}
```

Multi-season (dynamic) occupancy model

What if occupancy can change over time?

- Data collection using the *robust design*
  - Population open between primary periods (e.g., years)
  - Population closed within secondary periods (e.g., occasions)

$$y_i = [\underbrace{101}_{Year\ 1} \quad \underbrace{000}_{Year\ 2} \quad \underbrace{110}_{Year\ 3} \quad \underbrace{100}_{Year\ 4}]$$

- In year 1:

$$z_{i,1} \sim Bernoulli(\psi)$$

- In years 2+:

$$z_{i,t} \sim Bernoulli(z_{i,t-1}(1-\epsilon) + (1 - z_{i,t-1}\gamma))$$