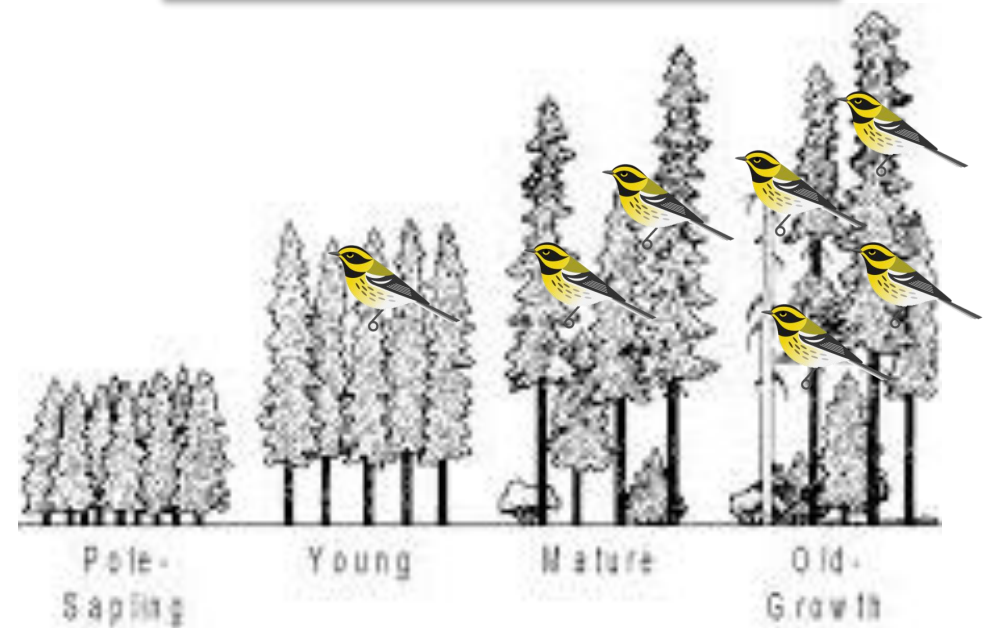
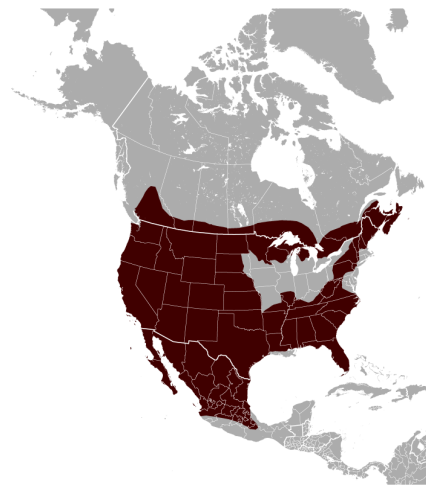


Using SEMs to model occupancy and species interactions



Two exercises today...

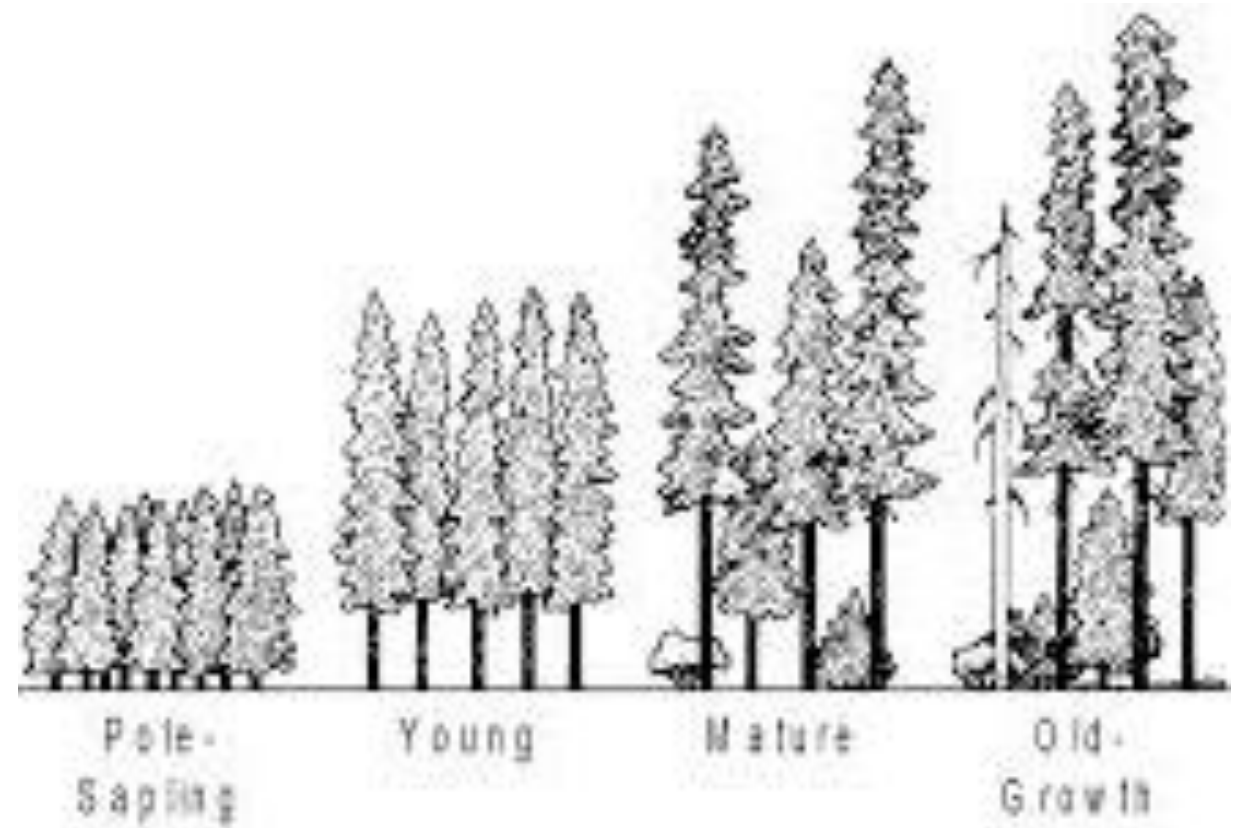
1. Townsend's warbler occupancy



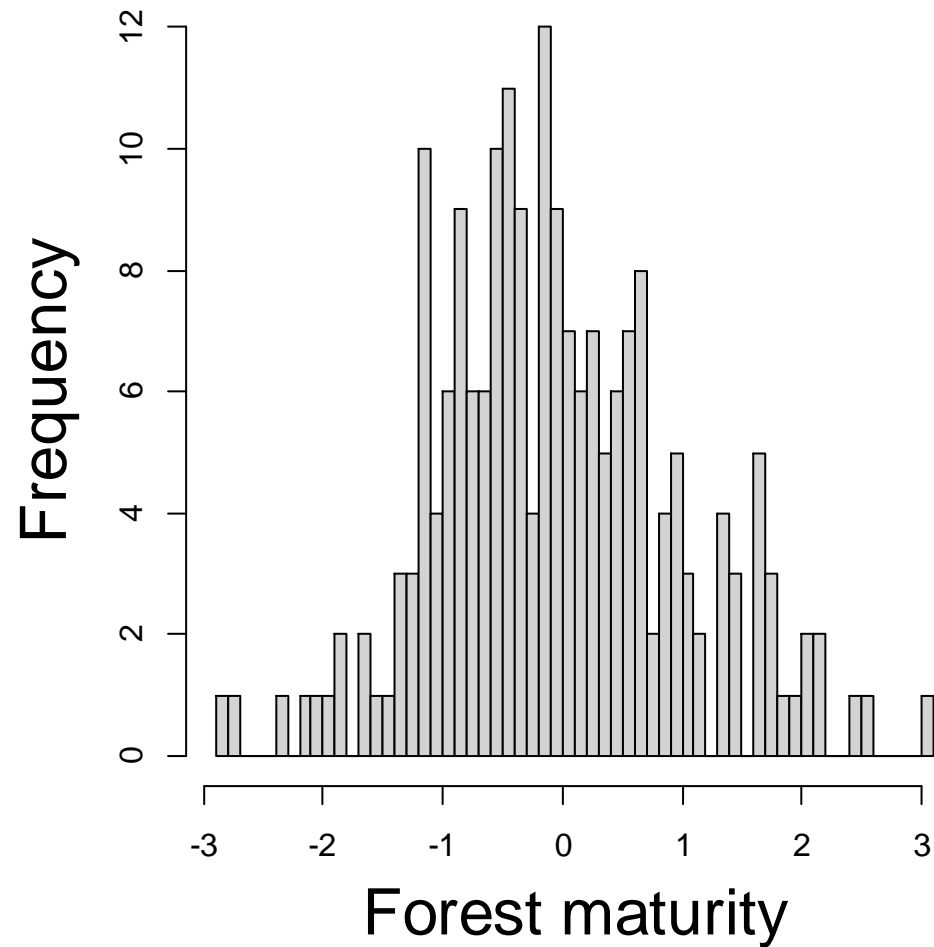
2. Felid occupancy and competition



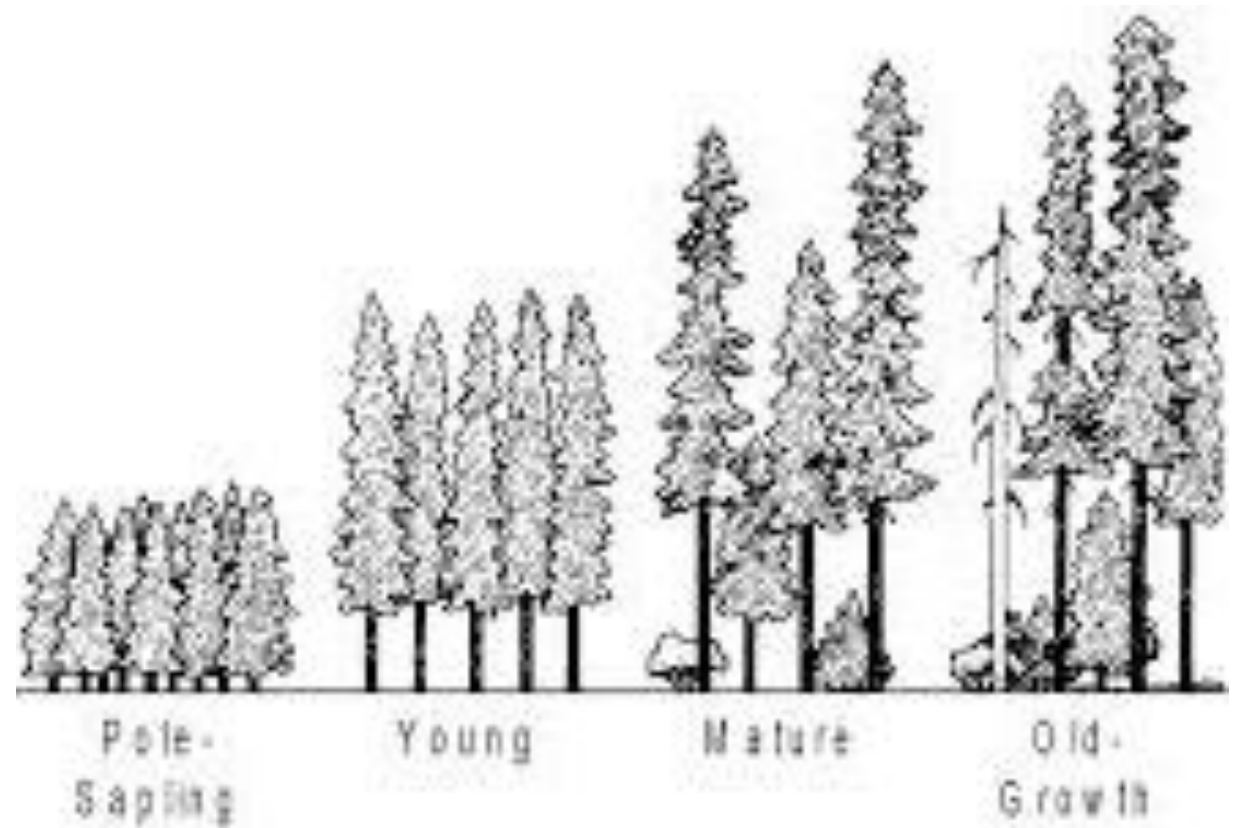
Townsend's warbler example



Step 1: simulate variation in forest maturity



$$m \sim \text{normal}(0, 1)$$



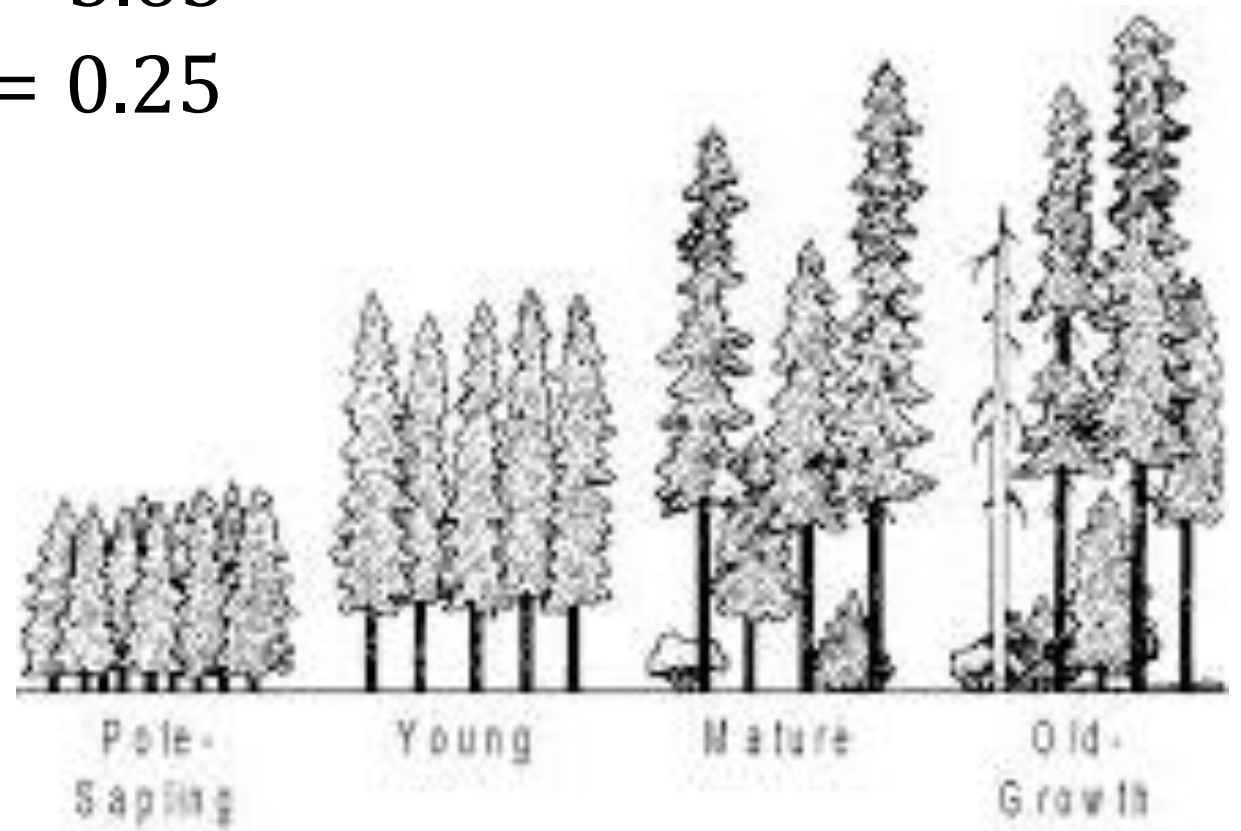
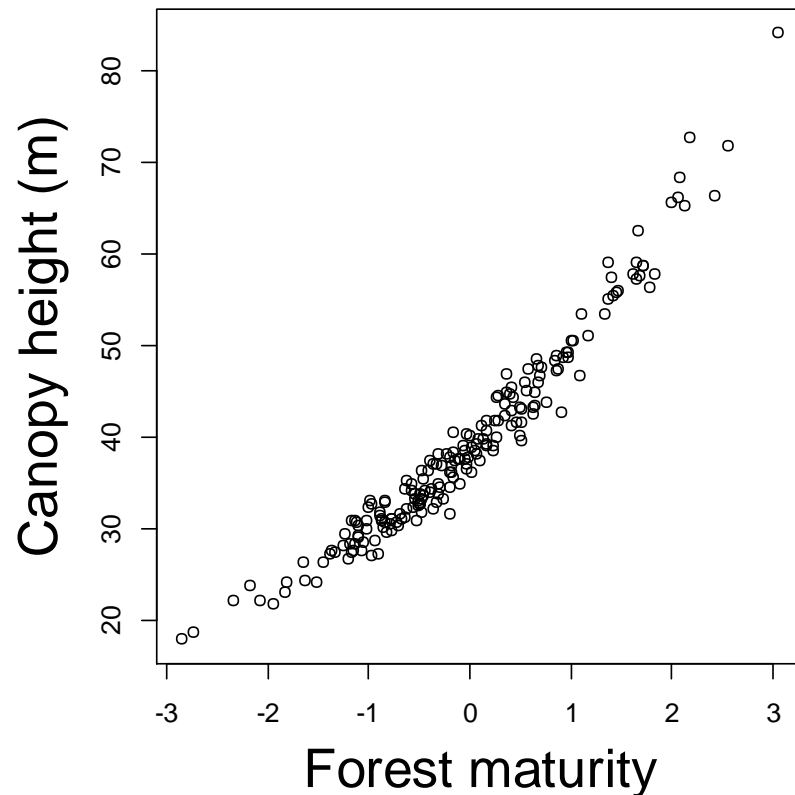
Step 2: simulate variation in canopy height (c)



$$c \sim \text{lognormal}(\alpha_1 + \beta_1 \mathbf{m}, \sigma_c = 0.05)$$

$$\alpha_1 = 3.65$$

$$\beta_1 = 0.25$$



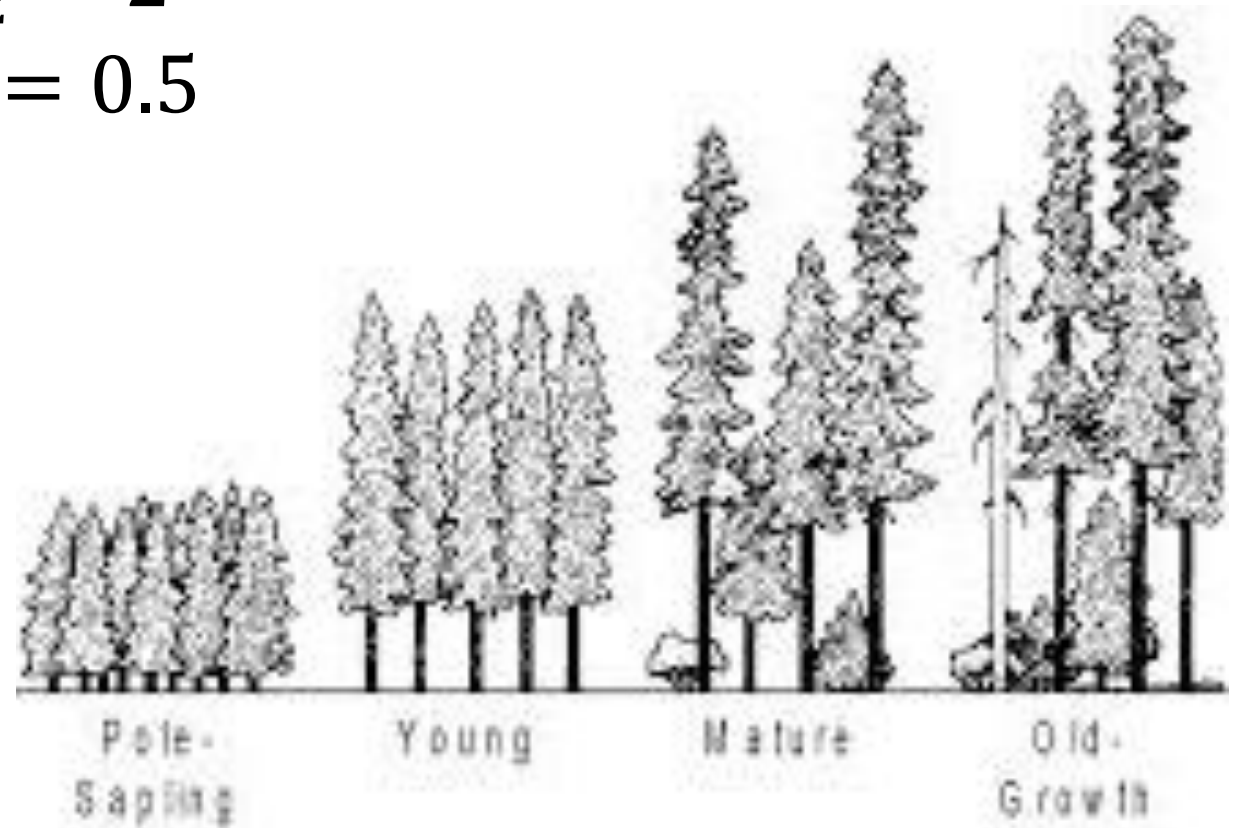
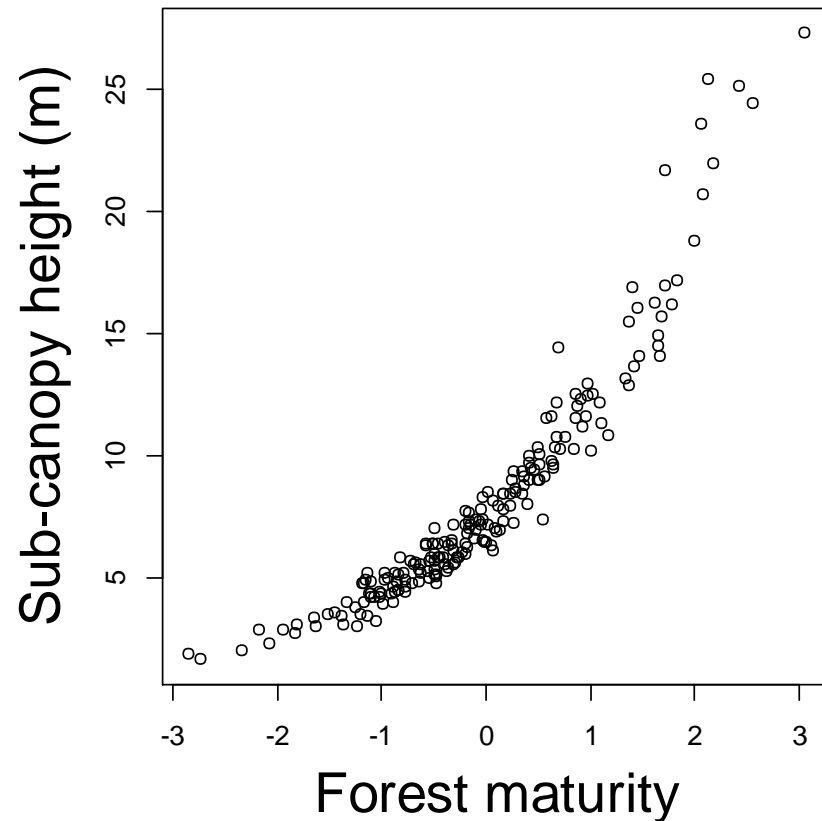
Step 3: simulate variation in sub-canopy height (s)



$$\mathbf{s} \sim \text{lognormal}(\alpha_2 + \beta_2 \mathbf{m}, \sigma_s = 0.05)$$

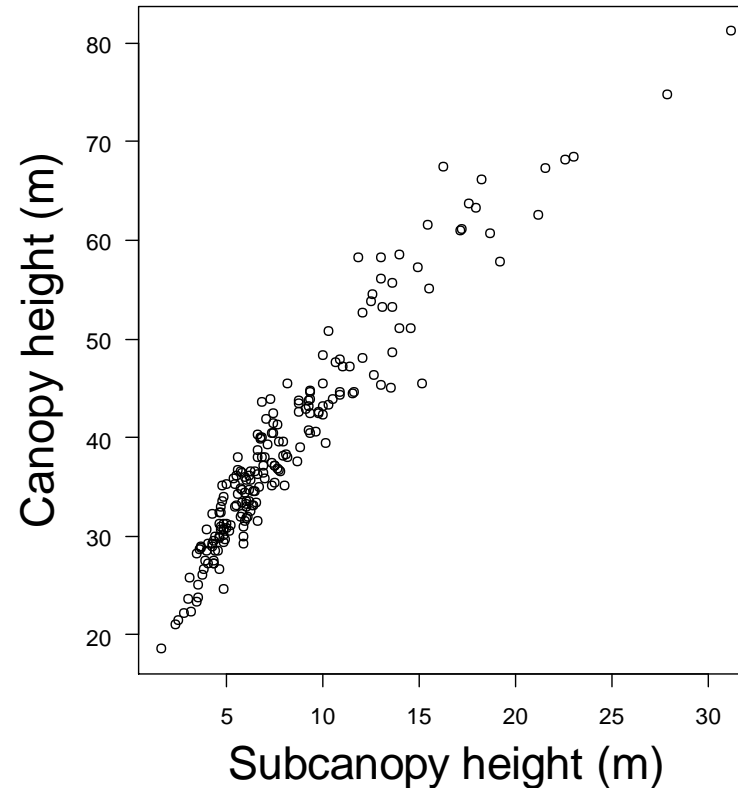
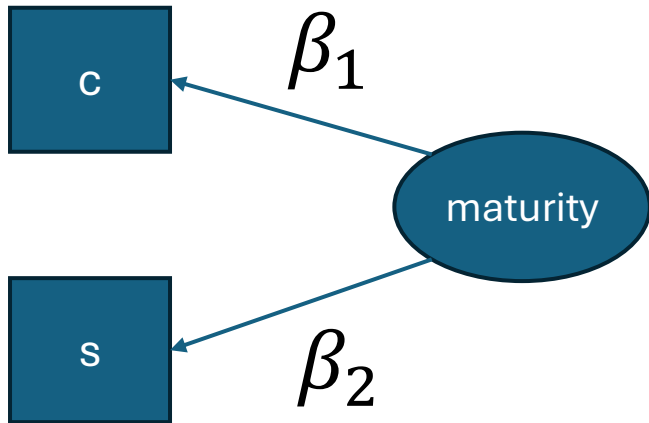
$$\alpha_2 = 2$$

$$\beta_2 = 0.5$$



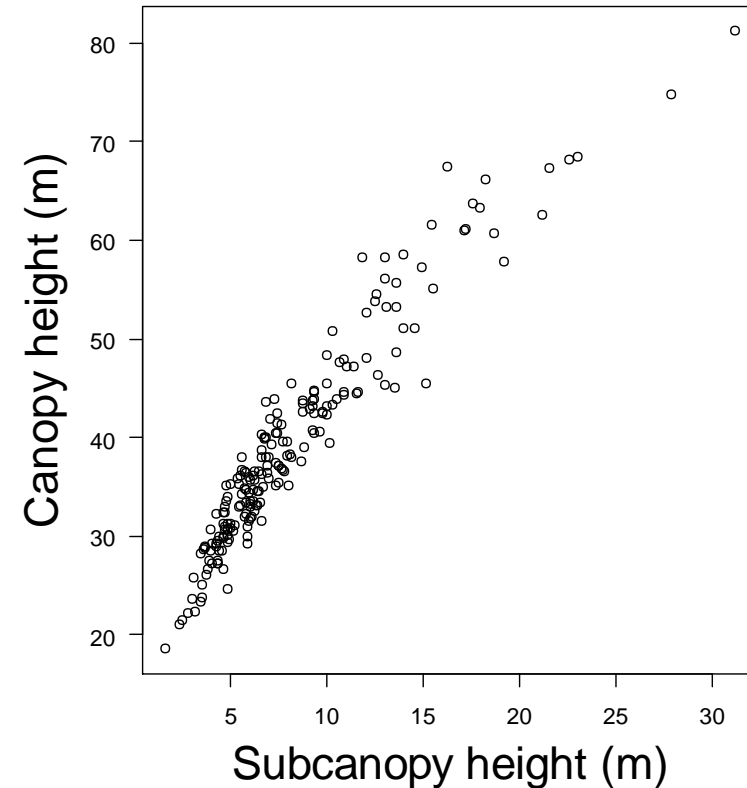
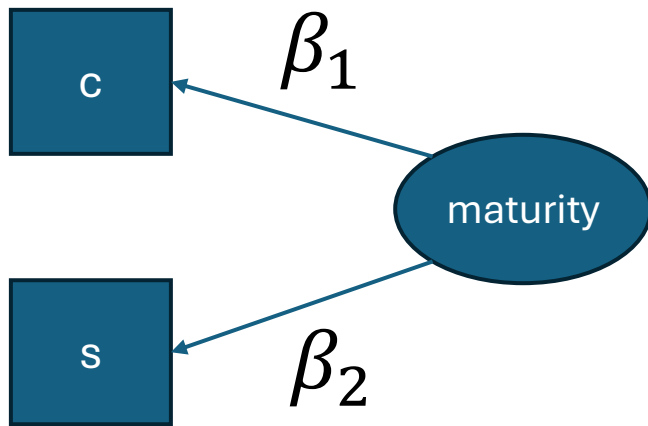


The hypothesis: older forests will have greater canopy heights and greater sub-canopy heights





The most important caveat: if things aren't collinear, then you can't assign them to a latent variable



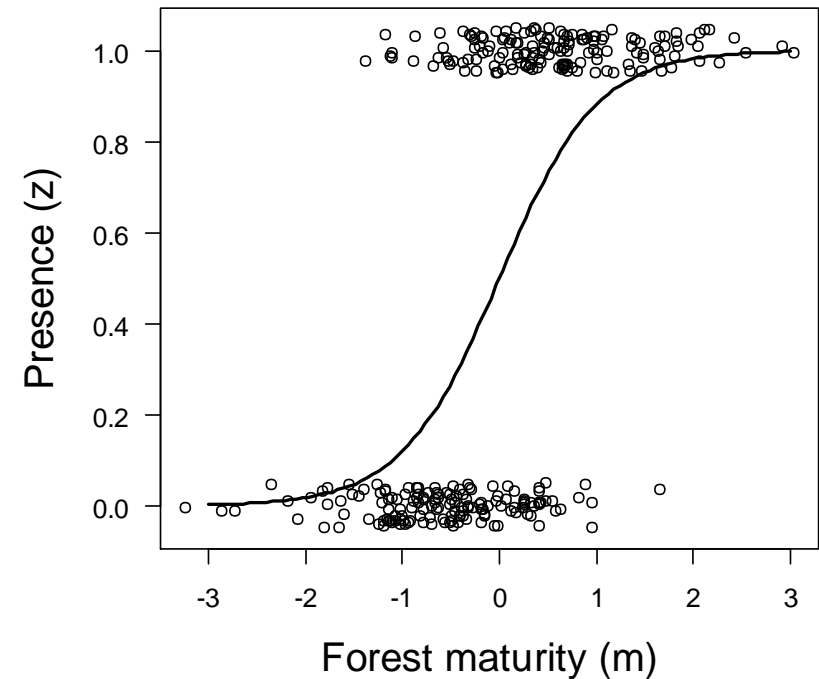
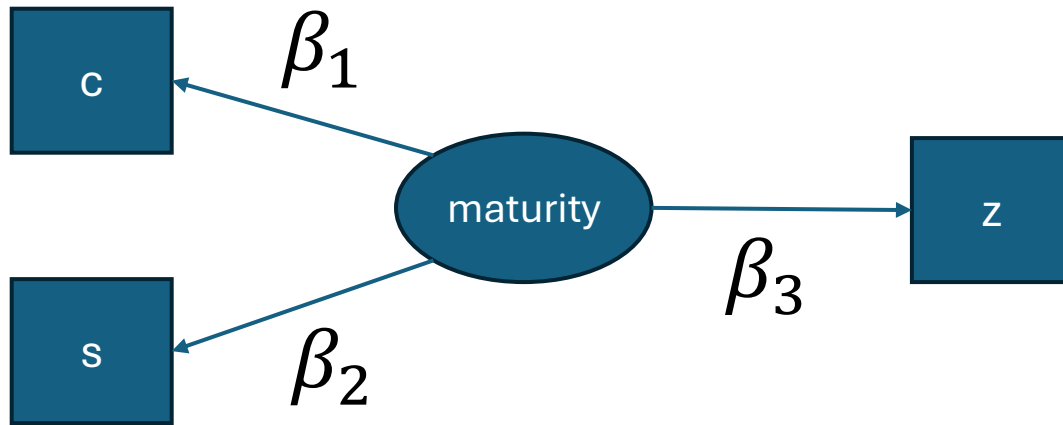
Step 4: simulate variation in warbler occupancy (z)



$$z \sim \text{Bernoulli}(\text{logit}^{-1}(\alpha_3 + \beta_3 m))$$

$$\alpha_3 = 0$$

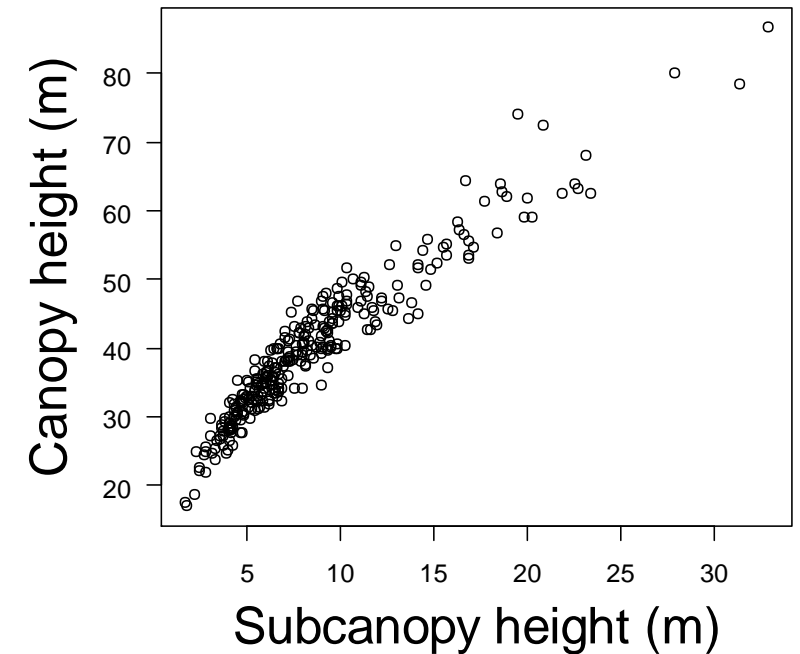
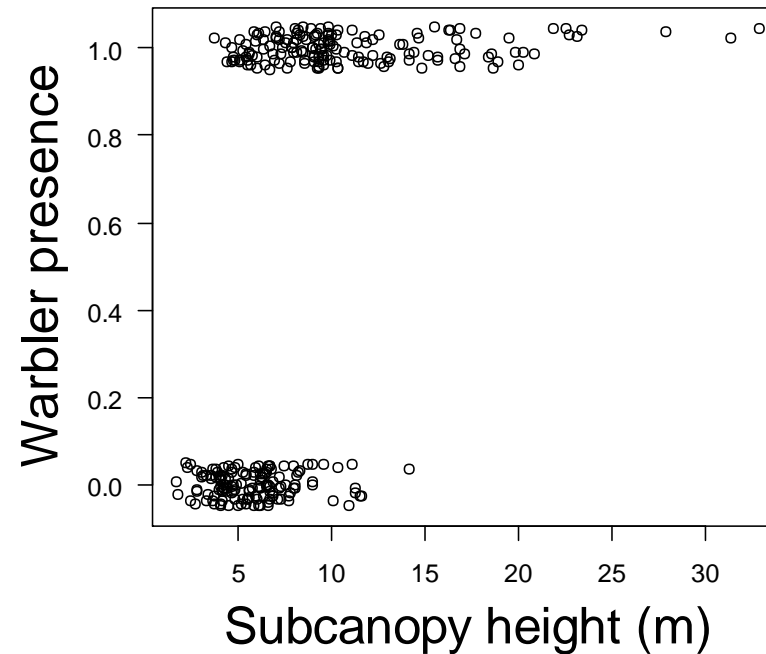
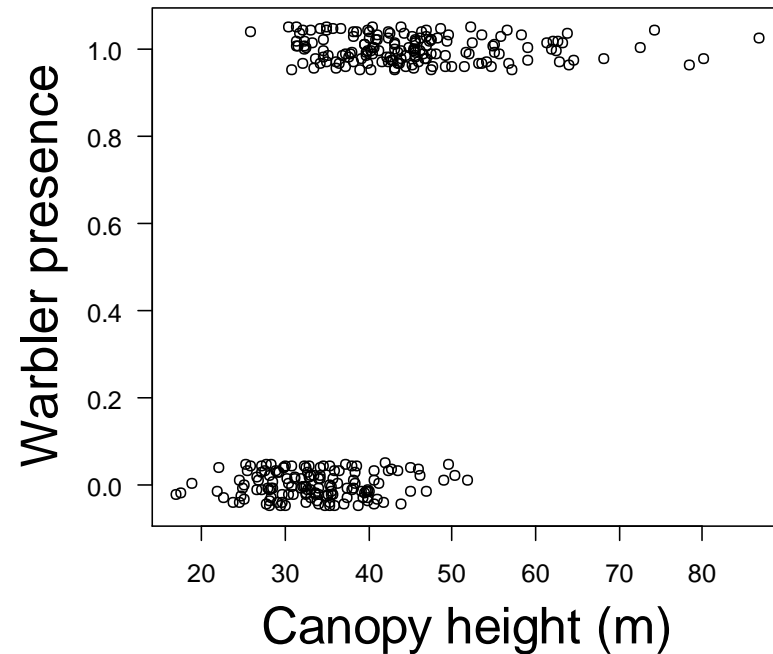
$$\beta_3 = 2$$



Step 4: simulate variation in warbler occupancy (z)



$$z \sim \text{Bernoulli}(\text{logit}^{-1}(\alpha_3 + \beta_3 m))$$



Step 5: simulate detection* data (y)



$$\mathbf{y} \sim \text{binomial}(\mathbf{z} \times v, p)$$

$$p = 0.35$$

$$v = 5$$

So... if warblers aren't there ($z = 0$), we won't see them

$$\mathbf{y} \sim \text{binomial}(\mathbf{0} \times v, p)$$

$$v = 5$$

$$p = 0.35$$

$$\mathbf{y} \sim \text{binomial}(\mathbf{z} \times v, p)$$

If they are there ($z = 1$), we'll see them 0 to 5 times

$$\mathbf{y} \sim \text{binomial}(\mathbf{1} \times v, p)$$

$$v = 5$$

$$p = 0.35$$

$$\mathbf{y} \sim \text{binomial}(\mathbf{z} \times v, p)$$

A quick primer on occupancy models

$$y_1 = [1, 0, 0, 0, 0, 0, 0, 1, 0, 0]$$

$$y_2 = [0]$$

$$z_1 = 1$$

$$z_2 = ?$$

Survey data for the same species at two sites, is it present at site 2?

A quick primer on occupancy models

$$y_1 = [1, 1, 1, 1, 1, 1, 1, 1, 1, 1]$$

$$y_2 = [0]$$

$$z_1 = 1$$

$$z_2 = ?$$

Survey data for the same species at two sites, is it present at site 2?

A quick primer on occupancy models

$$y_1 = [1, 0, 0, 0, 0, 0, 0, 1, 0, 0]$$

$$y_2 = [0]$$



$$z_1 = 1$$

$$z_2 = ?$$

Survey data for the same species at two sites, is it present at site 2?

A quick primer on occupancy models

$$y_1 = [1, 1, 1, 1, 1, 1, 1, 1, 1, 1]$$

$$y_2 = [0]$$

$$z_1 = 1$$

$$z_2 = ?$$



Survey data for the same species at two sites, is it present at site 2?

A quick primer on occupancy models

Ecological process

$$\mathbf{z} \sim \text{Bernoulli}(\text{logit}^{-1}(\alpha_3 + \beta_3 \mathbf{m}))$$

Is this species even present?

Observation process

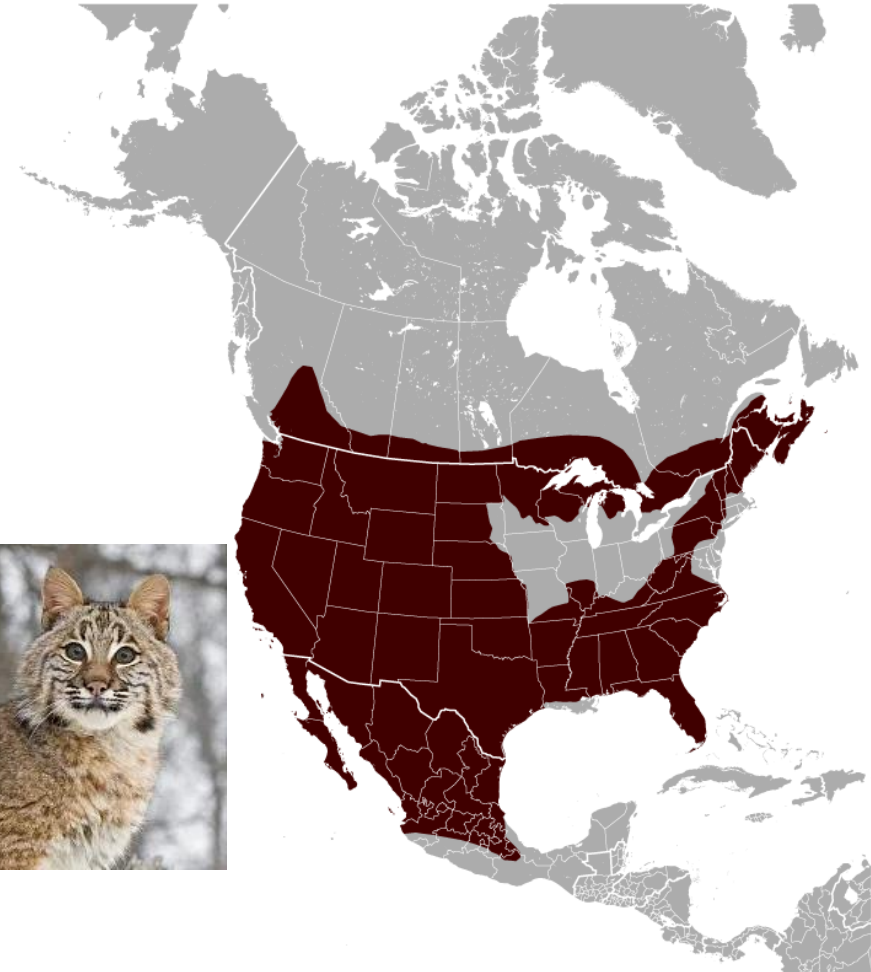
$$\mathbf{y} \sim \text{binomial}(\mathbf{z} \times v, p)$$

Did we detect it?



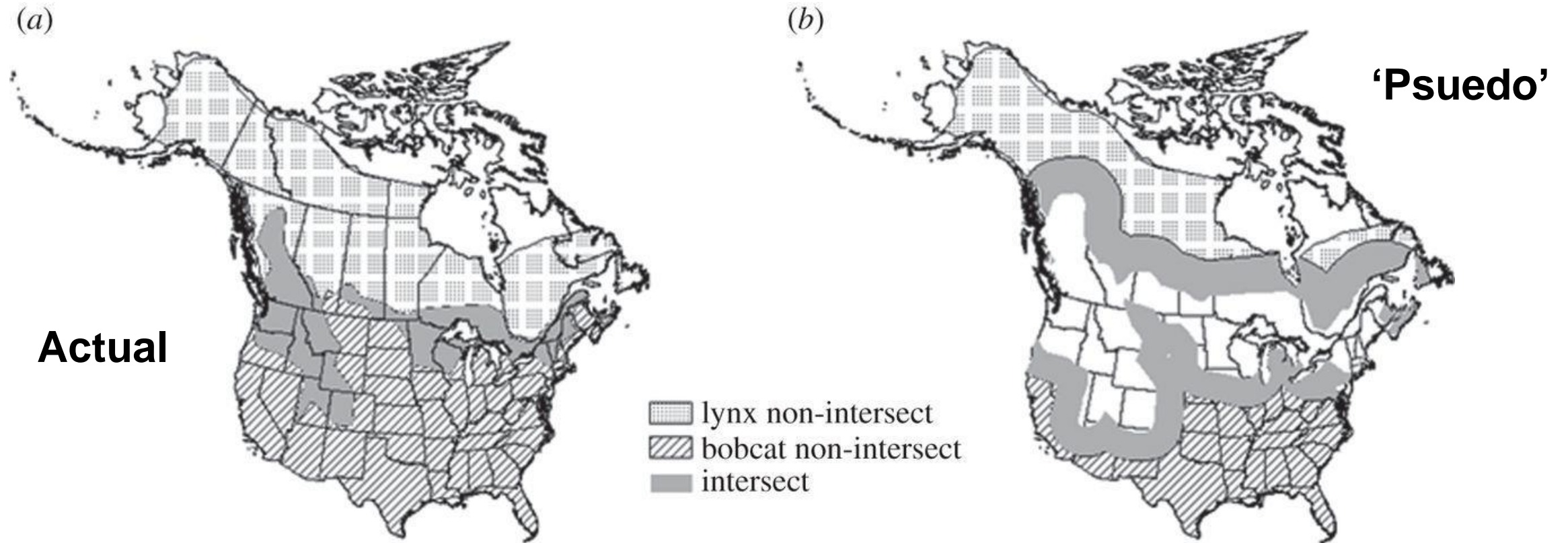
Let's go to the code, but first cats!

Occupancy of competing felids (bobcat [*Lynx rufus*] and lynx [*Lynx lynx*])

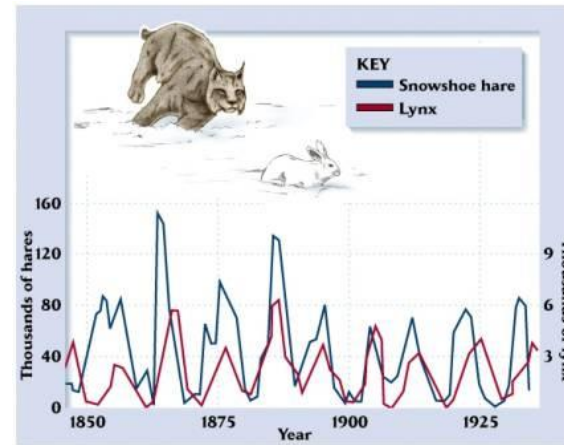
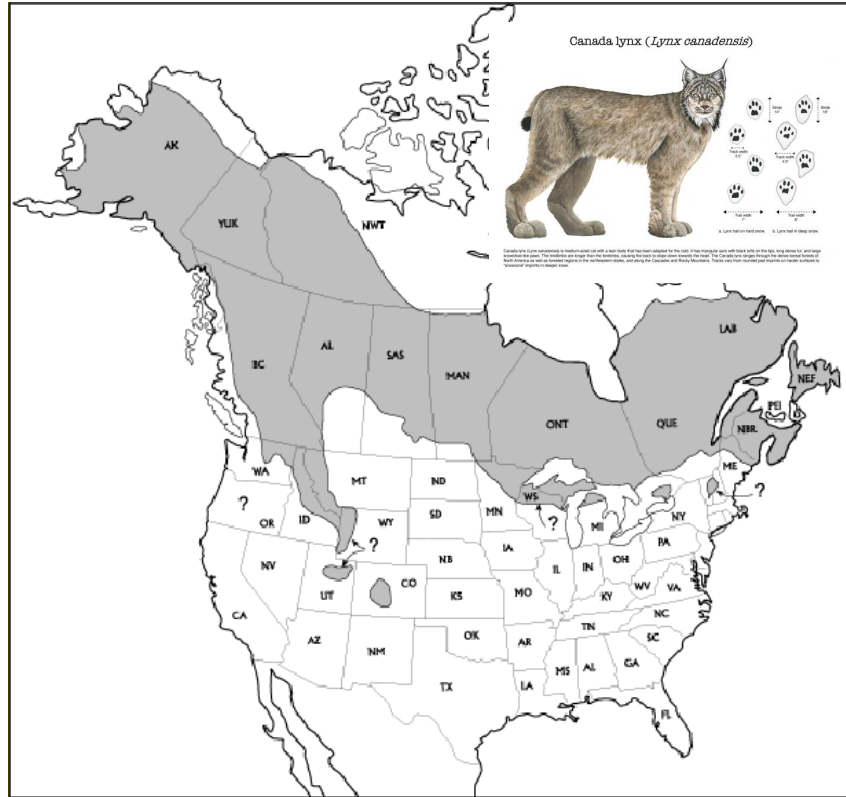


Peers, Thornton, and Murray (2013) *Proceedings B*

Occupancy of competing felids (bobcat [*Lynx rufus*] and lynx [*Lynx lynx*])

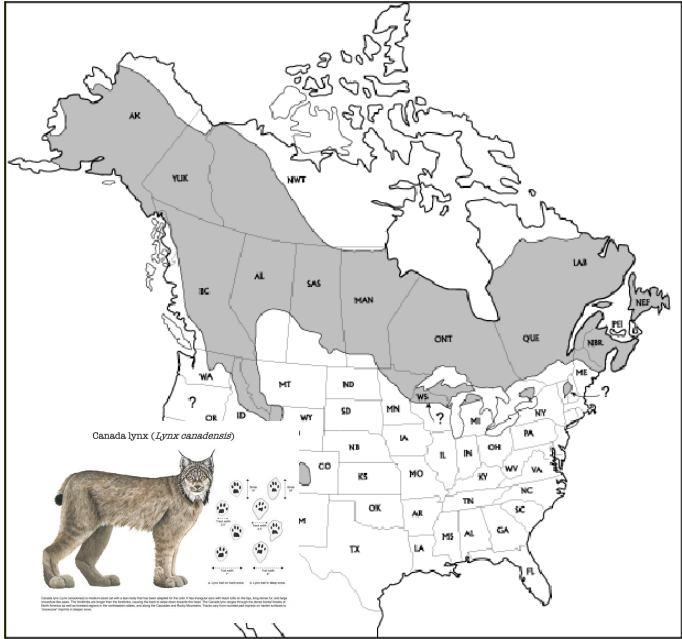


Mechanisms: Prey availability (snowshoe hare; *Lepus americanus*)



Peers, Thornton, and Murray (2013) *Proceedings B*

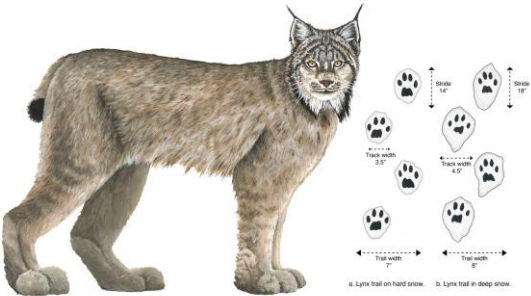
Mechanisms: Boreal (and montane) forest



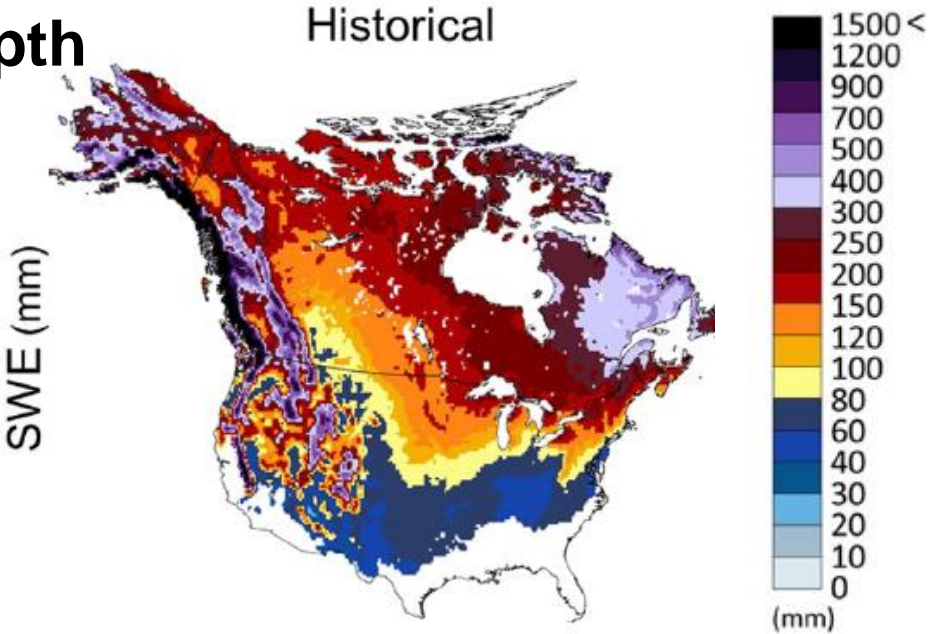
Mechanisms: Snow depth



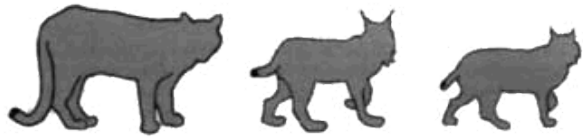
Canada lynx (*Lynx canadensis*)



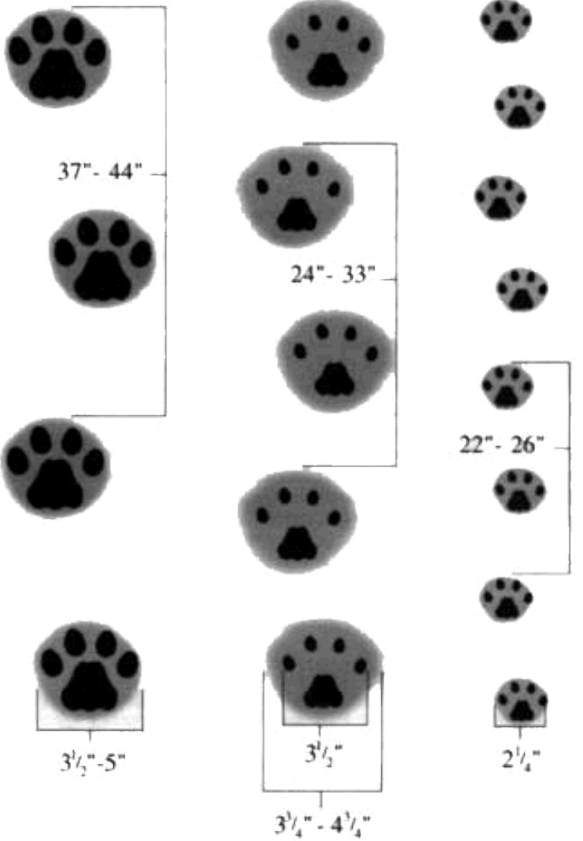
Canada lynx (*Lynx canadensis*) is medium-sized cat with a lean body that has been adapted for the cold. It has triangular ears with black tufts on the tips, long dense fur, and large snowshoe-like paws. The hindfeet are longer than the forefeet, causing the back to slope down towards the head. The Canada lynx ranges through the dense forest of North America as well as forested regions in the northeastern states, and along the Cascades and Rocky Mountains. Tracks vary from rounded paw prints on harder surfaces to "snowcone" imprints in deeper snow.



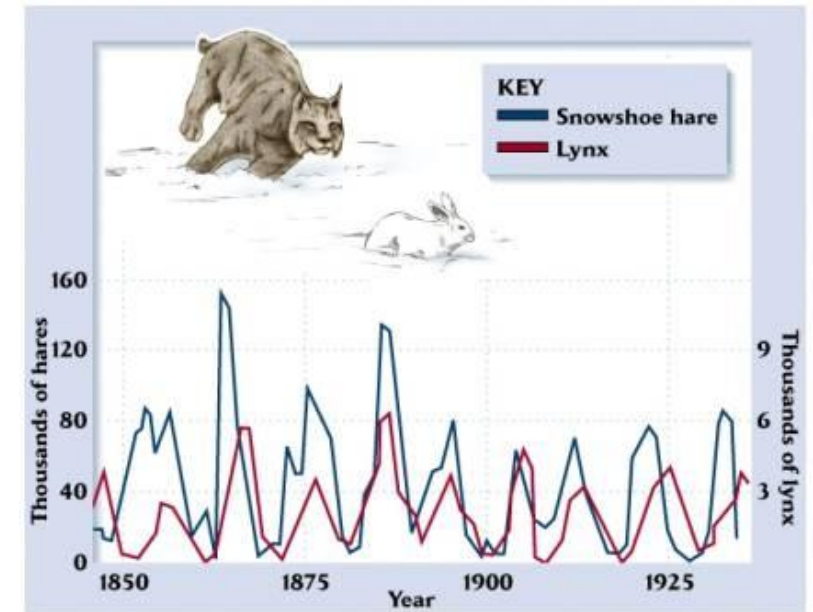
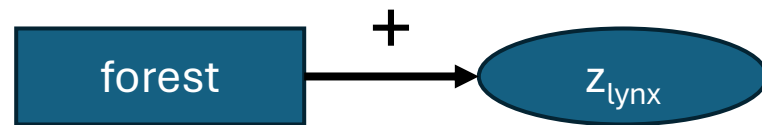
30-100kg 8-14 kg 6-15 kg



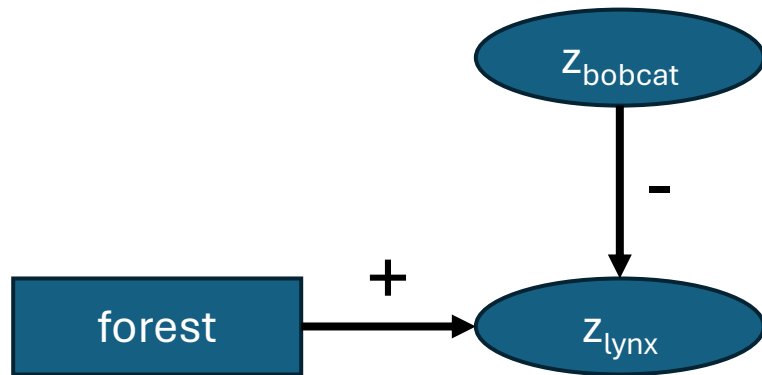
Mountain Lion Lynx Bobcat



Hypothesis 1: Forests are good for lynx



Hypothesis 2: Bobcats compete with lynx



Evidence for large-scale effects of competition: niche displacement in Canada lynx and bobcat

Michael J. L. Peers¹, Daniel H. Thornton^{1,2,3} and Dennis L. Murray¹

¹Department of Biology, Trent University, Peterborough, Ontario, Canada



²School of Environment, Washington State University, Pullman, WA, USA

³Panthera, 8 West 40th Street, New York, NY, USA

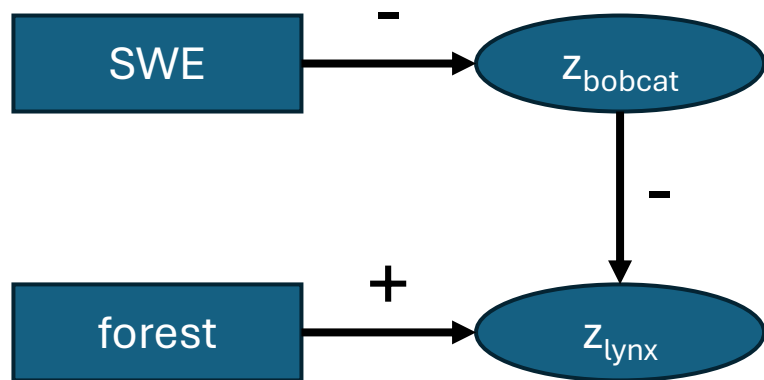
ORIGINAL RESEARCH

Ecology and Evolution  WILEY

Fine-scale habitat selection by sympatric Canada lynx and bobcat

Samantha J. Morin¹  | Jeff Bowman^{1,2} | Robby R. Marrotte¹  | Marie-Josée Fortin³

Hypothesis 3: Deep snow is bad for bobcats, but not for lynx



Criticize this model! (in small groups)

