Models for spatial replication

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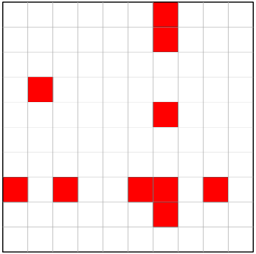
Alternatives include:

- surveys by different individuals during a single visit
- independent surveys by different methods during a single visit
- continuous monitoring (e.g. camera traps)
- spatial replication

Random sampling of locations within a site

Sample sites at random



Detection probability now depends on:

- whether species is present at location
- whether detected if present

Should random sampling be with or without replacement?

Kendall & White (2009) *J Appl Ecol*

To avoid bias, sample with replacement assuming species present at a fixed proportion of locations

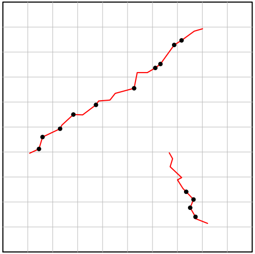
Guillera-Arroita (2011) *MEE*

To avoid bias, sample without replacement assuming species has a fixed probability of being present at each location

(Prob random sample of 10 from 100 all different = 0.6282)

Sampling along trails

Record locations of animal signs along trails



May be efficient logistically

Typically increases detection probability

Can no longer assume replicates are independent

Need to model spatial dependence

Two approaches to analysis

Hines *et al* (2010) *Ecol Appl*

Break trails into segments to create (correlated) spatial replicates

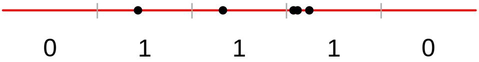
Guillera-Arroita *et al* (2011) *JABES*

Treat as continuous process, avoiding segmentation

Both approaches treat trail as one-dimensional

Hines et al approach

Break trail into segments



Modelled as a first-order Markov model.

Parameters:

$\psi =$ probability that the site is occupied

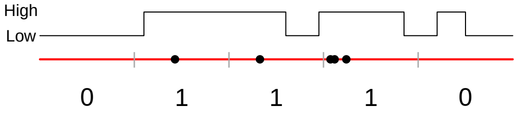
$\theta =$ probability species present on segment given present on previous segment

$\theta' =$ probability species present on segment given not present on previous segment (but site occupied)

$p =$ probability of detection in a segment, given species present

Guillera-Arroita et al approach

No segments



Modelled as a two-state Markov-modulated Poisson process

Parameters:

ψ = probability that the site is occupied

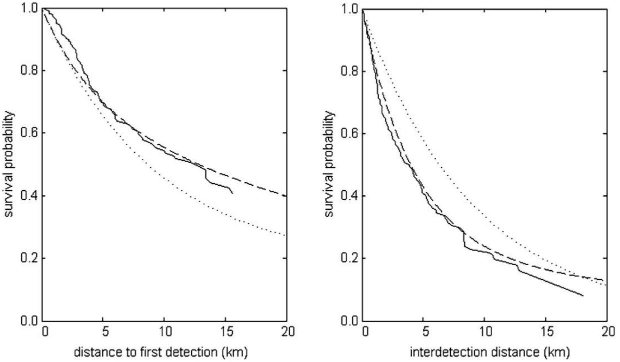
λ_1, λ_2 = rates at which detectable signs occur

μ_{12} = rate of switching from low to high rate ($\lambda_1 \to \lambda_2$)

μ_{21} = rate of switching from high to low rate ($\lambda_2 \to \lambda_1$)

Model fit for Sumatran tiger data

Two-state Markov-modulated Poisson process fits better than simple Poisson process (detections occurring at random)



Summary of the two approaches

Both approaches allow for positive correlation along the trail

Simulations show that occupancy is underestimated if this spatial dependence is ignored, but that this bias is largely corrected by using these approaches.

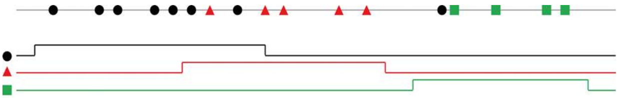
Most practical applications use Hines *et al* method (implemented in PRESENCE)

Scope for comparisons with real data

One step further - bringing in abundance

Guillera-Arroita *et al* (2012) MEE

Assume a two-state Markov-modulated Poisson process for each individual.



Assume some distribution (e.g. Poisson) for number of individuals across sites, as in Royle-Nichols model.

Aim to estimate parameters of that distribution (as well as parameters of MMPP).

Application to Sumatran tiger data

89 sites surveyed

Sites 17km $\times$ 17km (related to home range)

15–45km of trails surveyed per site

Model that incorporated both clustering of detections (MMPP) and abundance gave best AIC.

Final conclusions:

- Most sites occupied ($\hat{\psi} = 0.98$)
- Roughly 2/3 sites occupied by one tiger
- Roughly 1/3 sites occupied by two tigers

Other studies

Thorn *et al* (2011) *Biol Cons*

Use of Hines model for brown hyaenas in South Africa

Charbonnel *et al* (2014) *J Appl Ecol*

Comparison of temporal and spatial replication for Pyrenean desman, semi-aquatic mammal that lives along streams. Hines model gave good results.

Whittington *et al* (2014) *Anim Cons*

Combination of temporal and spatial replication for wolverine and Canadian lynx using snow surveys.

Hines *et al* (2014) *MEE*

Multiseason version of the Hines model