Occupancy and hidden Markov models

Olivier Gimenez

Lecture 1

Hidden Markov models (HMM) and occupancy data

Occupancy to map species distribution

Occupancy: proportion of an area occupied by a species

- Species range dynamics
- Habitat preferences
- Metapopulation dynamics
- …

0	0	1	0	0
0	1	0	0	0
0	1	1	0	0
0	0	1	0	0
1	0	1	0	0
0	1	0	0	0
0	0	0	0	1
0	0	0	0	1

10/40 = 0.25

Levins 1967, McKenzie *et al*. 2003, 2006

Issue of detectability < 1

0	0	1	0	0
0	1	0	0	0
0	1	1	0	0
0	0	1	0	0
1	0	1	0	0
0	1	0	0	0
0	0	0	0	1
0	0	0	0	1

True occupancy = 25%

Issue of detectability < 1

0	0	1	0	0
0	1	0	0	0
0	1	1	0	0
0	0	1	0	0
1	0	1	0	0
0	1	0	0	0
0	0	0	0	1
0	0	0	0	1

True occupancy = 25%

0	0	1	0	0
0	1	0	0	0
0	1	1	0	0
0	0	1	0	0
1	0	1	0	0
0	1	0	0	0
0	0	0	0	1
0	0	0	0	1

Species detected in 6 occupied sites

Occupancy underestimation

0	0	1	0	0
0	1	0	0	0
0	1	1	0	0
0	0	1	0	0
1	0	1	0	0
0	1	0	0	0
0	0	0	0	1
0	0	0	0	1

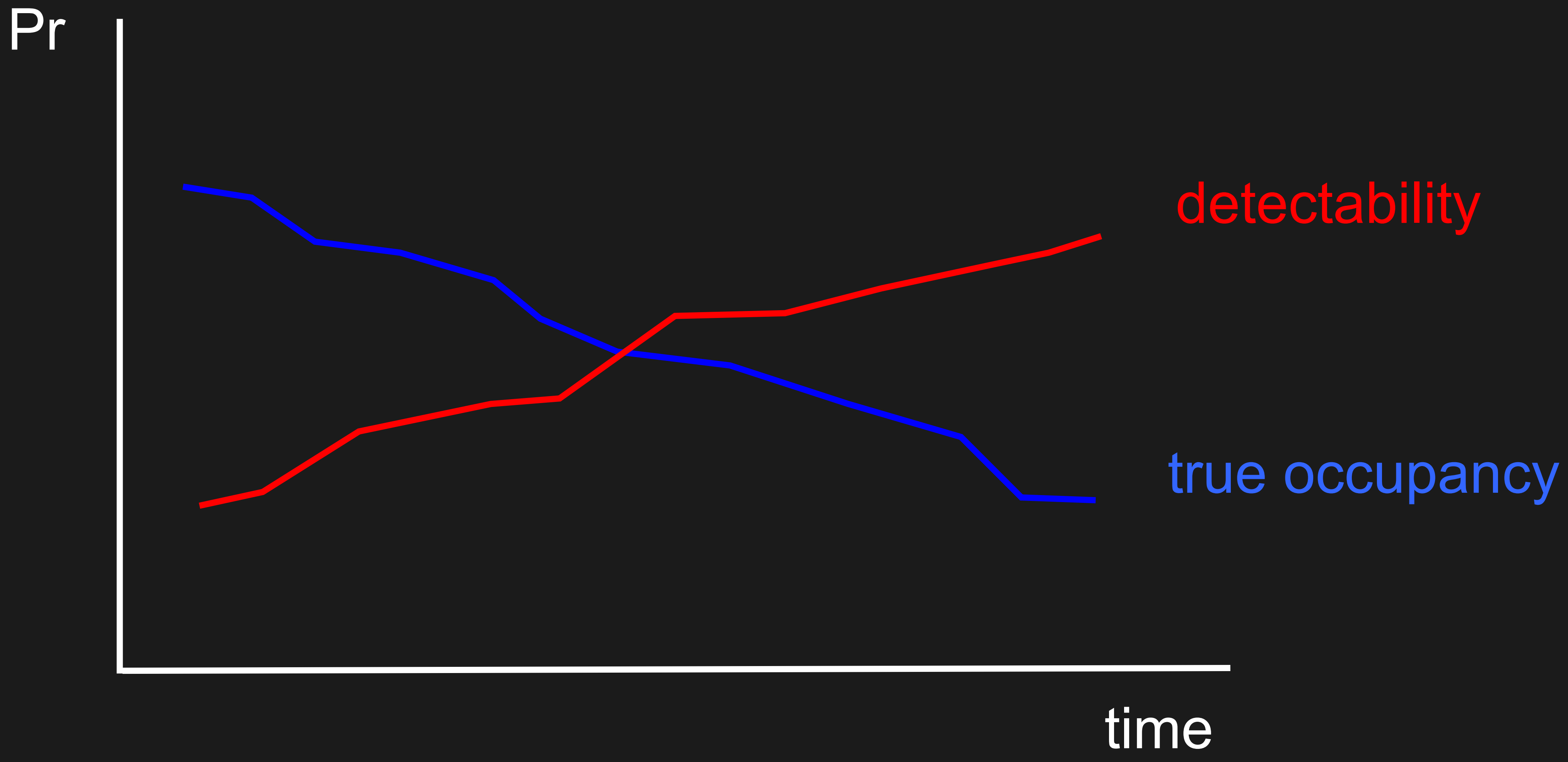
True occupancy = 25%

0	0	1	0	0
0	1	0	0	0
0	1	1	0	0
0	0	1	0	0
1	0	1	0	0
0	1	0	0	0
0	0	0	0	1
0	0	0	0	1

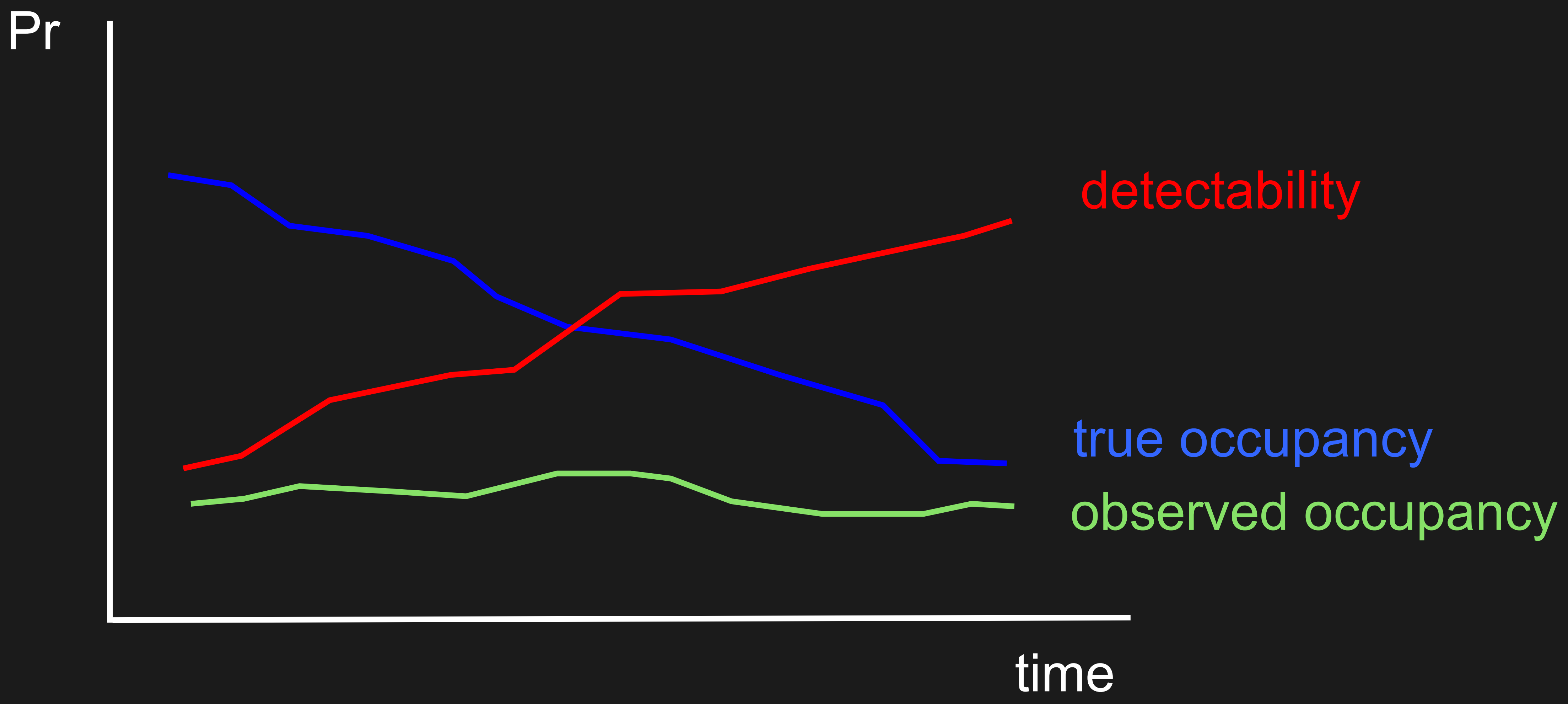
Species detected in 6 occupied sites

Naive occupancy estimate = 6/40 = 15%

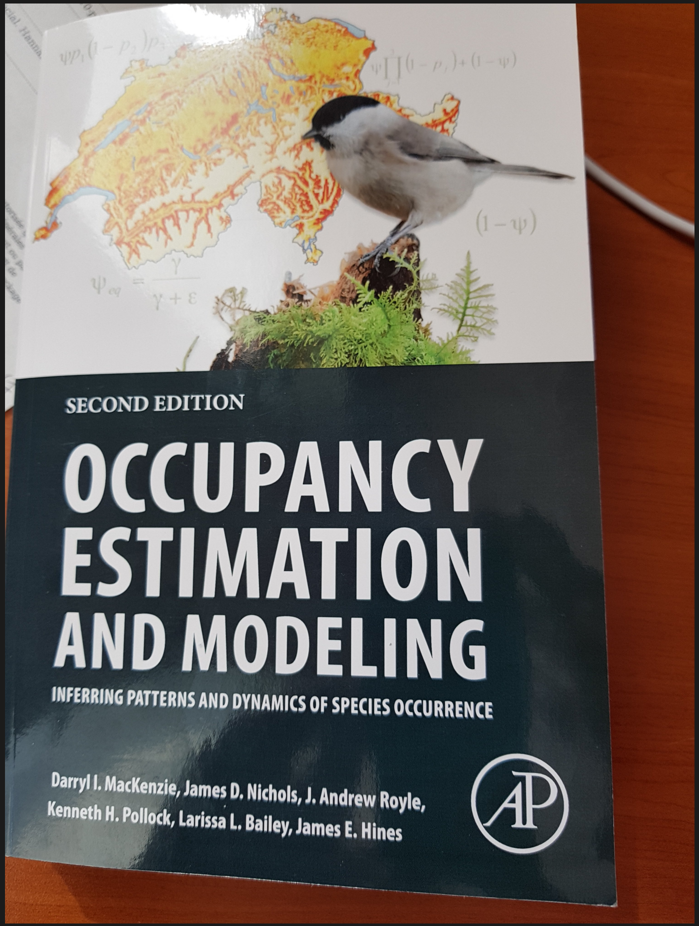
Issue of detectability < 1



Bias in occupancy trends



Occupancy models



ECOGRAPHY

A JOURNAL OF SPACE AND TIME IN ECOLOGY

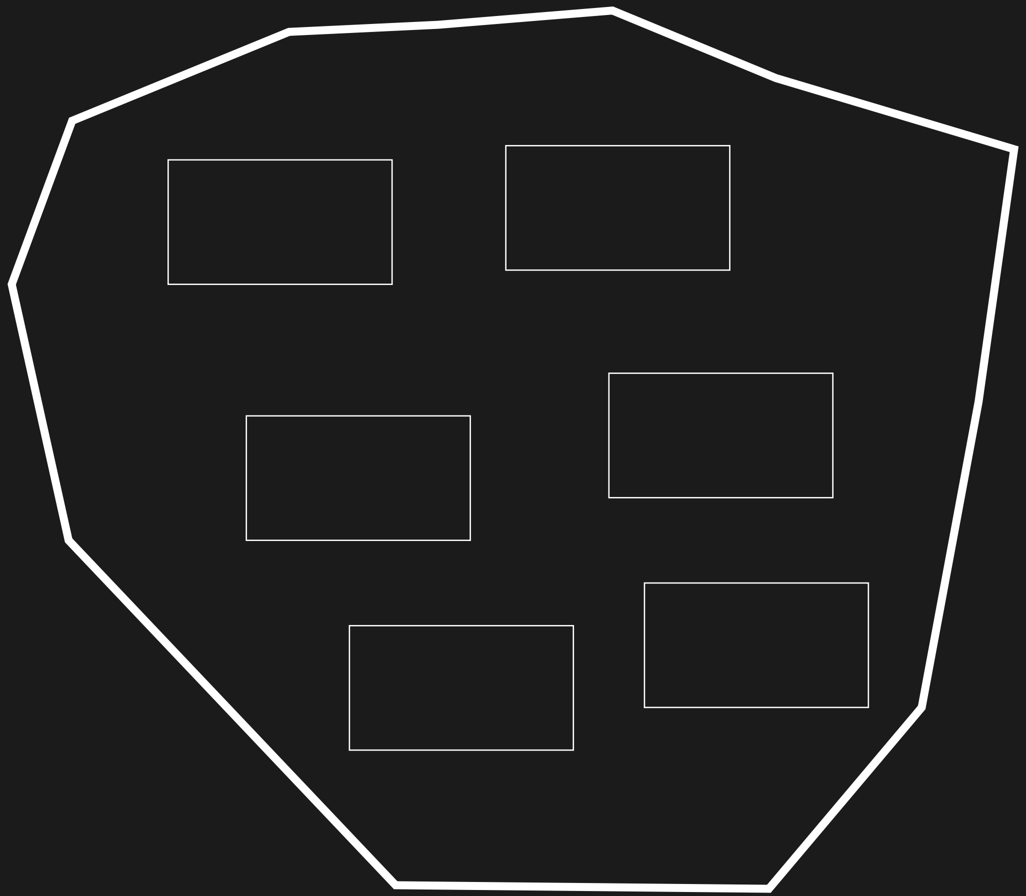
Review & synthesis | Free Access

Modelling of species distributions, range dynamics and communities under imperfect detection: advances, challenges and opportunities

Gurutzeta Guillera-Arroita

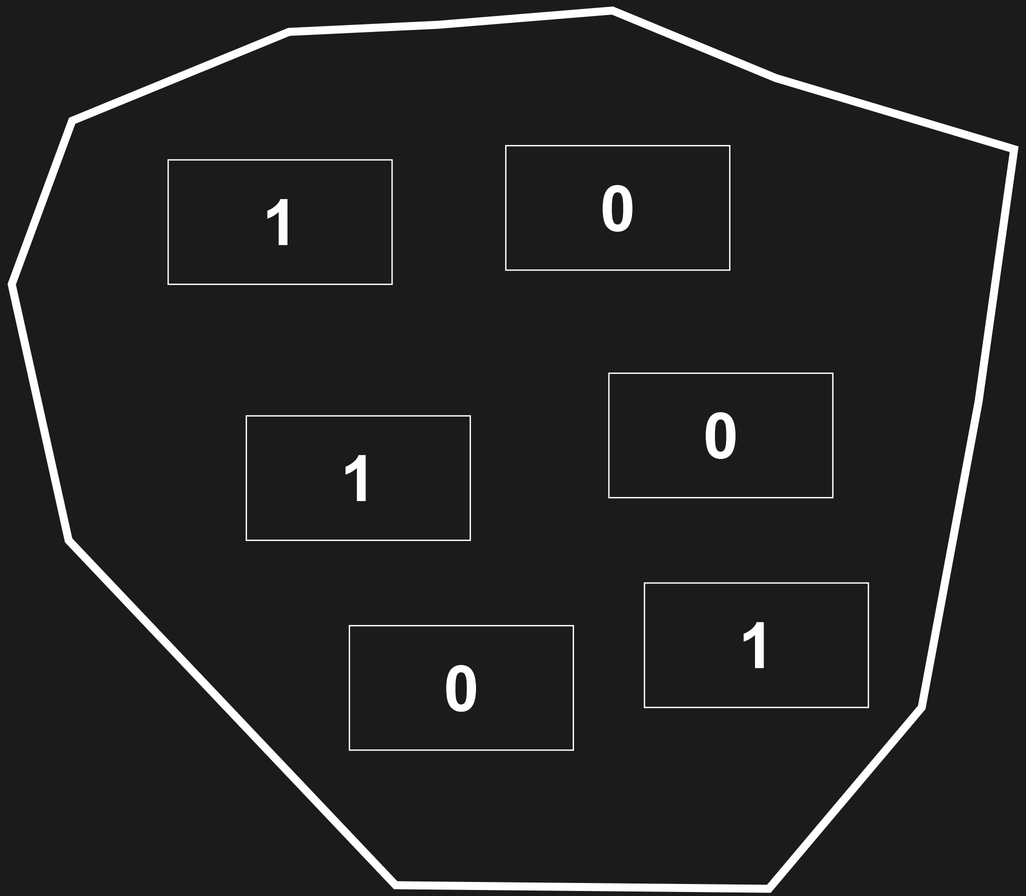
First published: 20 June 2016 | https://doi.org/10.1111/ecog.02445 | Citations: 134

Occupancy protocol



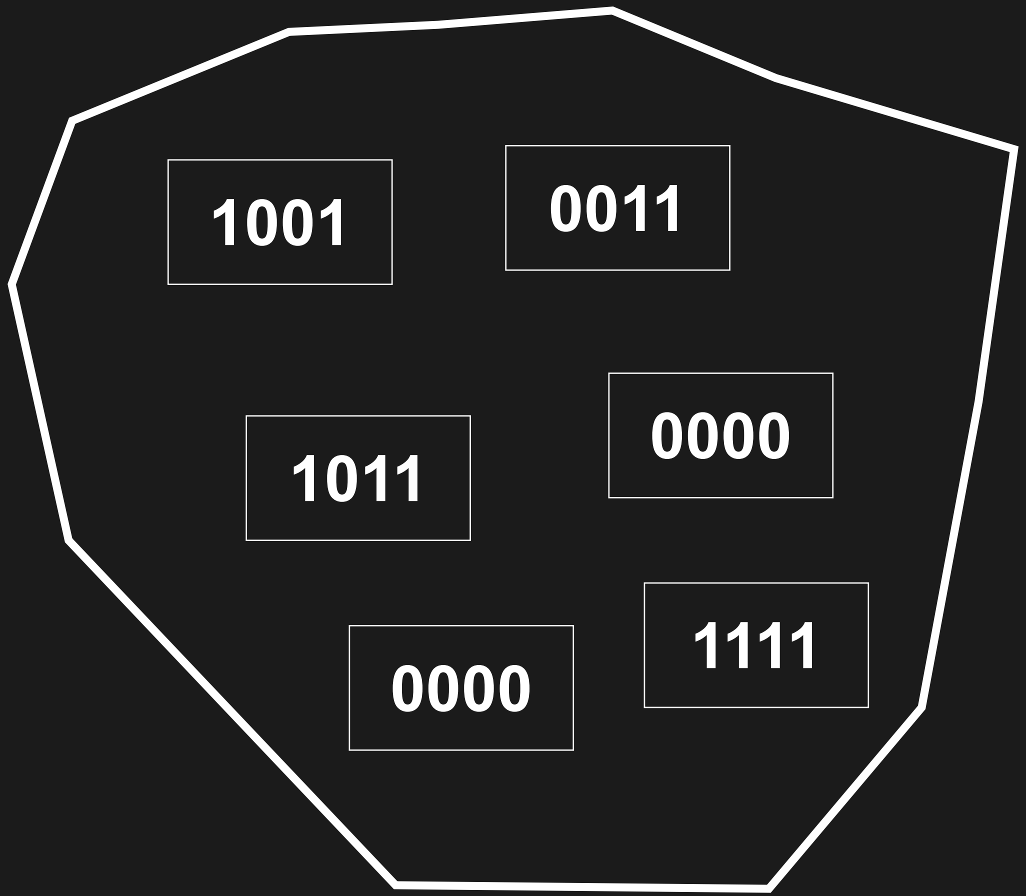
- Several sampling units surveyed

Occupancy protocol



- Several sampling units surveyed
- Collection of detection/non-detection

Occupancy protocol



- Several sampling units surveyed
- Collection of detection/non-detection
- Replicate surveys in each unit

True or false absence?

reality

True or false absence?

True or false absence?

True or false absence?

reality

observation

Single-season occupancy model likelihood

$\psi_1 =$ prob. a site is initially occupied - **occupancy**

p = prob. species is detected (given presence) – **detection**

Single-season occupancy model likelihood

$\psi_1 =$ prob. a site is initially occupied - **occupancy**

p = prob. species is detected (given presence) – **detection**

Assuming closure, and independence of surveys:

Pr(1001) = $?$

Single-season occupancy model likelihood

$\psi_1 =$ prob. a site is initially occupied - **occupancy**

p = prob. species is detected (given presence) – **detection**

Assuming closure, and independence of surveys:

Pr(1001) = $\psi_1\, p\, (1 - p)\, (1 - p)\, p$

Single-season occupancy model likelihood

$\psi_1 =$ prob. a site is initially occupied - **occupancy**

p = prob. species is detected (given presence) – **detection**

Assuming closure, and independence of surveys:

Pr(0000) = $?$

Single-season occupancy model likelihood

$\psi_1 =$ prob. a site is initially occupied - **occupancy**

p = prob. species is detected (given presence) – **detection**

Assuming closure, and independence of surveys:

Pr(0000) = ψ_1 (1 – p) (1 – p) (1 – p) (1 – p) + (1 - ψ_1)

Single-season occupancy model as a HMM

Initial states

$$\begin{array}{cc} U & O \\ \end{array}$$
$$\begin{pmatrix} 1-\psi_1 & \psi_1 \end{pmatrix}$$

O = occupied; U = unoccupied

ψ_1 = occupancy, p = detection

Single-season occupancy model as a HMM

Initial states

$$\begin{array}{cc} U & O \\ \left(1-\psi_1 \right. & \left. \psi_1 \right) \end{array}$$

State process

$$\begin{array}{ccc} & & U \quad O \quad \textbf{t+1} \\ \textbf{t} & \begin{array}{c} U \\ O \end{array} & \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \end{array}$$

Markov model

O = occupied; U = unoccupied

ψ_1 = occupancy, p = detection

Single-season occupancy model as a HMM

Initial states

$$\begin{array}{cc} U & O \\ (1-\psi_1 & \psi_1) \end{array}$$

State process

$$\begin{array}{ccc} & \begin{array}{cc} U & O \end{array} & \textbf{t+1} \\ \textbf{t} \begin{array}{c} U \\ O \end{array} & \left(\begin{array}{cc} 1 & 0 \\ 0 & 1 \end{array}\right) & \end{array}$$

Markov model

Observation process

$$\begin{array}{ccc} & \begin{array}{cc} 0 & 1 \end{array} & \textbf{t} \\ \textbf{t} \begin{array}{c} U \\ O \end{array} & \left(\begin{array}{cc} 1 & 0 \\ 1-p & p \end{array}\right) & \end{array}$$

hidden

O = occupied; U = unoccupied

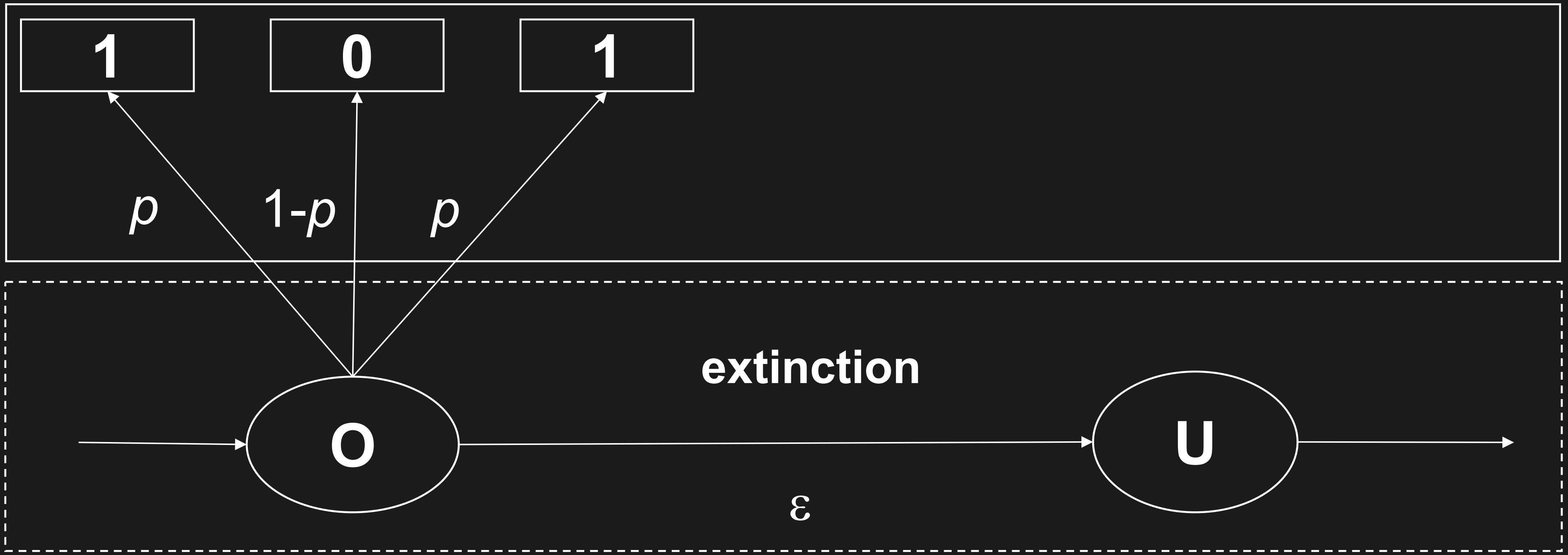
ψ_1 = occupancy, p = detection

Dynamic (multi-season) occupancy models

O = occupied; U = unoccupied

Dynamic (multi-season) occupancy models

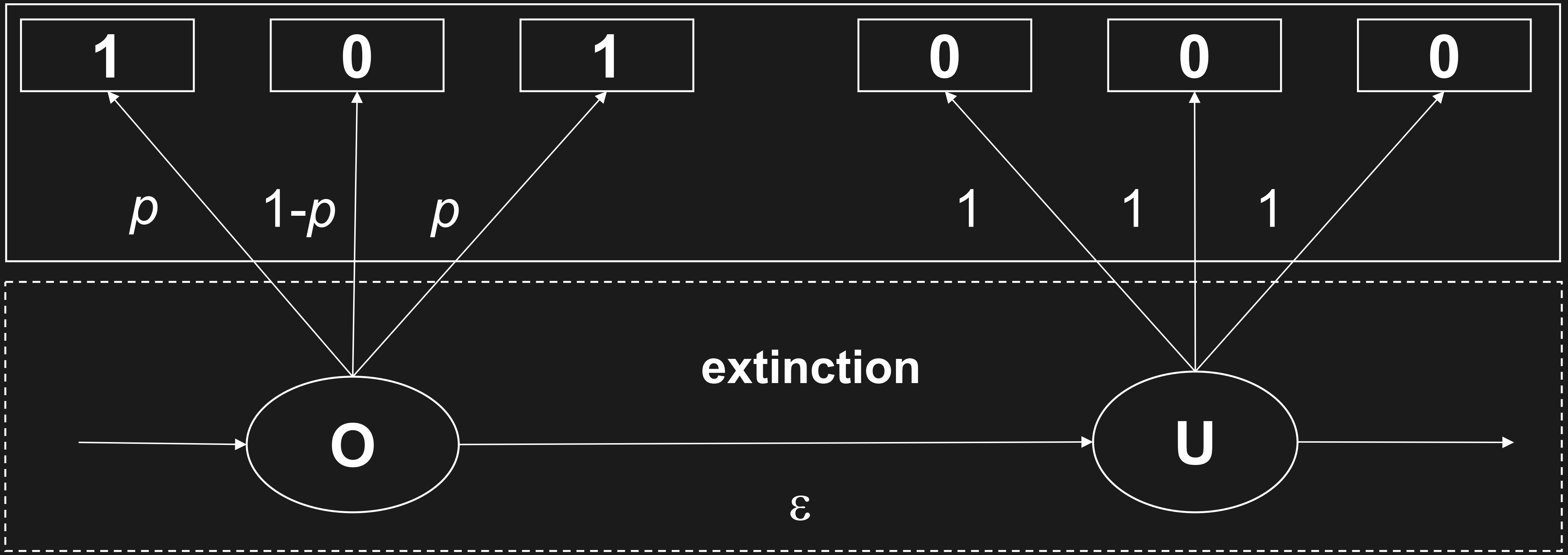
1 = species detected; 0 = species undetected



O = occupied; U = unoccupied

Dynamic (multi-season) occupancy models

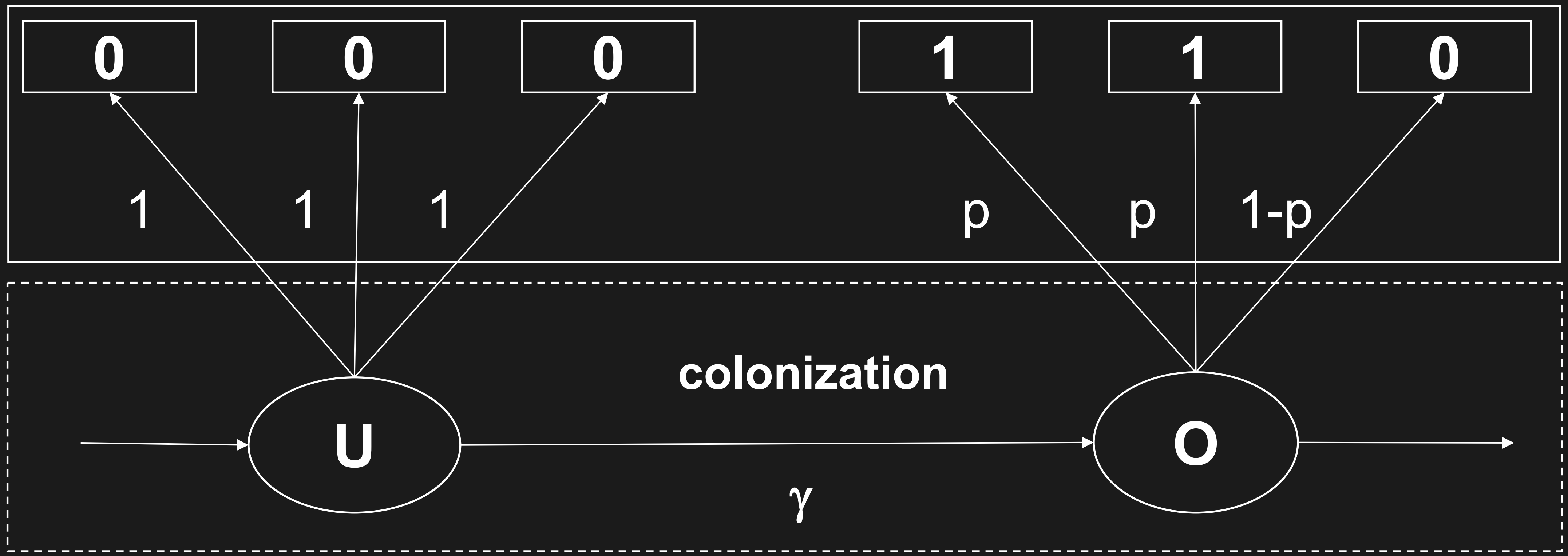
1 = species detected; 0 = species undetected



O = occupied; U = unoccupied

Dynamic (multi-season) occupancy models

1 = species detected; 0 = species undetected



O = occupied; U = unoccupied

Dynamic (multi-season) occupancy models

ψ_1 = prob. a site is occupied - **occupancy**

p = prob. species is detected (given presence) – **detection**

γ = prob. unoccupied site becomes occupied – **colonisation**

ε = prob. occupied site becomes unoccupied – **extinction**

Dynamic occupancy model likelihood

ψ_1 = **occupancy**

p = **detection**

γ = **colonisation**

ε = **extinction**

Pr(110 000) = ?

Dynamic occupancy model likelihood

ψ_1 = **occupancy**

p = **detection**

γ = **colonisation**

ε = **extinction**

Pr(110 000) =

Three replicated surveys or secondary occasions
Closure assumption

Dynamic occupancy model likelihood

ψ_1 = **occupancy**

p = **detection**

γ = **colonisation**

ε = **extinction**

Pr(110 000) = $\psi_1\ p\ p\ (1 - p)$

Three replicated surveys or secondary occasions
Closure assumption

Dynamic occupancy model likelihood

ψ_1 = **occupancy**

p = **detection**

γ = **colonisation**

ε = **extinction**

$$\Pr(110\ 000) = \psi_1\, p\, p\, (1 - p)\, [\, \varepsilon + (1 - \varepsilon) \ldots \,]$$

Dynamic occupancy model likelihood

ψ_1 = **occupancy**

p = **detection**

γ = **colonisation**

ε = **extinction**

$$\Pr(110\ 000) = \psi_1\, p\, p\, (1 - p)\, [\, \varepsilon + (1 - \varepsilon)\, (1 - p)\, (1 - p)\, (1 - p)\,]$$

Dynamic occupancy model likelihood

ψ_1 = **occupancy**

p = **detection**

γ = **colonisation**

ε = **extinction**

Pr(000 010) = ?

Dynamic occupancy model likelihood

ψ_1 = **occupancy**

p = **detection**

γ = **colonisation**

ε = **extinction**

$$\Pr(000\ 010) = [\ \psi_1\ (1 - p)\ (1 - p)\ (1 - p)\ (1 - \varepsilon) + (1 - \psi_1)\ \gamma\ ]$$

Dynamic occupancy model likelihood

ψ_1 = **occupancy**

p = **detection**

γ = **colonisation**

ε = **extinction**

$$\Pr(000\ 010) = [\ \psi_1\ (1 - p)\ (1 - p)\ (1 - p)\ (1 - \varepsilon) + (1 - \psi_1)\ \gamma\ ] \\ \times\ (1 - p)\ p\ (1 - p)$$

Derived parameters

ψ_1 = **occupancy**

p = **detection**

γ = **colonisation**

ε = **extinction**

- Season-specific occupancy:

$$\psi_{t+1} = \psi_t (1 - \varepsilon_t) + (1 - \psi_t) \gamma_t$$

- Rate of change in occupancy:

$$\lambda_t = \psi_{t+1} / \psi_t$$

Dynamic occupancy model as a HMM

Initial states

$$\begin{array}{cc} U & O \\ \end{array}$$
$$\begin{pmatrix} 1-\psi_1 & \psi_1 \end{pmatrix}$$

State process

$$\begin{array}{c|cc} & U & O \\ \hline U & 1-\gamma & \gamma \\ O & \epsilon & 1-\epsilon \end{array}$$

Markov model

Observation process

$$\begin{array}{c|cc} & 0 & 1 \\ \hline U & 1 & 0 \\ O & 1-p & p \end{array}$$

hidden

Single-season is a particular case of multi-season

No colonization ($\gamma = 0$) and no extinction ($\varepsilon = 0$)

Initial states

$$\begin{array}{cc} U & O \\ \left(1-\psi_1 \right. & \left. \psi_1 \right) \end{array}$$

State process

$$\begin{array}{c|cc} & U & O \\ U & 1 & 0 \\ O & 0 & 1 \end{array}$$

$$\begin{array}{cc} & \begin{array}{cc} U & O \end{array} \\ \begin{array}{c} U \\ O \end{array} & \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \end{array}$$

Observation process

$$\begin{array}{cc} & \begin{array}{cc} 0 & 1 \end{array} \\ \begin{array}{c} U \\ O \end{array} & \begin{pmatrix} 1 & 0 \\ 1-p & p \end{pmatrix} \end{array}$$

ECOGRAPHY

A JOURNAL OF SPACE AND TIME IN ECOLOGY

Research | Free Access

Mapping and explaining wolf recolonization in France using dynamic occupancy models and opportunistic data

Julie Louvrier, Christophe Duchamp, Valentin Lauret, Eric Marboutin, Sarah Cubaynes, Rémi Choquet, Christian Miquel, Olivier Gimenez

Determinants and patterns of habitat use by the brown bear *Ursus arctos* in the French Pyrenees revealed by occupancy modelling

Published online by Cambridge University Press: **10 July 2017**

Blaise Piédallu, Pierre-Yves Quenette, Nicolas Bombillon, Adrienne Gastineau, Christian Miquel and Olivier Gimenez

Show author details

Lecture 2

Heterogeneity

Key occupancy model assumptions

- Independent detections
- No unmodelled heterogeneity
- No false positives

Key occupancy model assumptions

- Independent detections
- **No unmodelled heterogeneity**
- No false positives

How to deal with heterogeneity?

- Lynx in the Jura mountains
- Signs of presence between 2002 and 2006
- 197 sites, 5 1-y periods
- Static model

Detection heterogeneity

Random effect

$$logit(p_i) = \mu + \eta_i$$

$$\eta_i \sim N(0, \sigma^2)$$

Royle (2006), Gimenez & Choquet (2010)

Detection heterogeneity

Random effect

$$logit(p_i) = \mu + \eta_i$$

$$\eta_i \sim N(0, \sigma^2)$$

Royle (2006), Gimenez & Choquet (2010)

Finite mixture

$$\begin{array}{cc} & \begin{array}{cc} 0 & 1 \end{array} \\ \begin{array}{c} U1 \\ U2 \\ O1 \\ O2 \end{array} & \begin{pmatrix} 1 & 0 \\ 1 & 0 \\ 1 - p^1 & p^1 \\ 1 - p^2 & p^2 \end{pmatrix} \end{array}$$

Gimenez et al. (2014), Louvrier et al. (2018)

Model selection

	Model	AIC
M_0	$[\psi(forest), p]$	1000.1
M_{ran}	$[\psi(forest), p(random)]$	978.6
M_{mix}	$[\psi(forest), p(mixture)]$	980.2

Results

Random effect

$$\hat{\mu} = .10 \text{ (SE=0.20)}$$
$$\hat{\sigma} = 1.25 \text{ (SE=0.22)}$$

Finite mixture

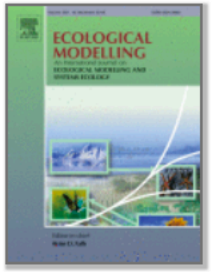
$$\hat{p}^1 = .25 \text{ (SE=0.05)}$$
$$\hat{p}^2 = .74 \text{ (SE=0.08)}$$
$$\hat{\pi} = 0.54 \text{ (SE=0.1)}$$

- Occupancy is higher in heterogeneity models
- Relationship between occupancy and forest cover is stronger

ELSEVIER

Ecological Modelling

Volume 387, 10 November 2018, Pages 61-69



Accounting for misidentification and heterogeneity in occupancy studies using hidden Markov models

Julie Louvrier [a, b], Thierry Chambert [a], Eric Marboutin [c], Olivier Gimenez [a]

Lecture 3

Multistate occupancy models incorporating uncertainty

Multistate occupancy model

Conservation Biology

Spatial Patterns of Breeding Success of Grizzly Bears Derived from Hierarchical Multistate Models

JASON T. FISHER,* MATTHEW WHEATLEY,† AND DARRYL MACKENZIE‡

2014

- Spatial patterns of grizzly bears *breeding success* (Rocky mountains)
- Breeding success = bear with at least one cub
- Relationship between breeding success and type of land cover

Define the states and observations

Breeding states

- U = not occupied
- ONB = non-breeders only
- OB = at least some breeders

- **Observations**
  - Species undetected = 0
  - Species detected without young = 1
  - Species detected with young = 2

HMM formulation of multistate occupancy model

Initial states

$$\begin{array}{ccc} U & ONB & OB \\ (\,1-\psi_1-\psi_2 & \psi_1 & \psi_2\,) \end{array}$$

State process

$$\begin{array}{c|ccc} & U & ONB & OB \\ \hline U & 1 & 0 & 0 \\ ONB & 0 & 1 & 0 \\ OB & 0 & 0 & 1 \end{array}$$

ψ^1 (resp. ψ^2) probability the site is occupied by non-breeders (resp. by breeders)

HMM formulation of multistate occupancy model

Observation process

$$
\begin{array}{l}
 \\
U \\
ONB \\
OB
\end{array}
\begin{array}{c}
\begin{array}{ccc} \quad 0 \quad & \quad 1 \quad & \quad 2 \quad \end{array} \\
\begin{pmatrix}
1 & 0 & 0 \\
1 - p^1 & p^1 & 0 \\
1 - p^2 & p^2(1-\delta) & p^2\delta
\end{pmatrix}
\end{array}
$$

p^1 (resp. p^2) detection probability of non-breeders (resp. of breeders)

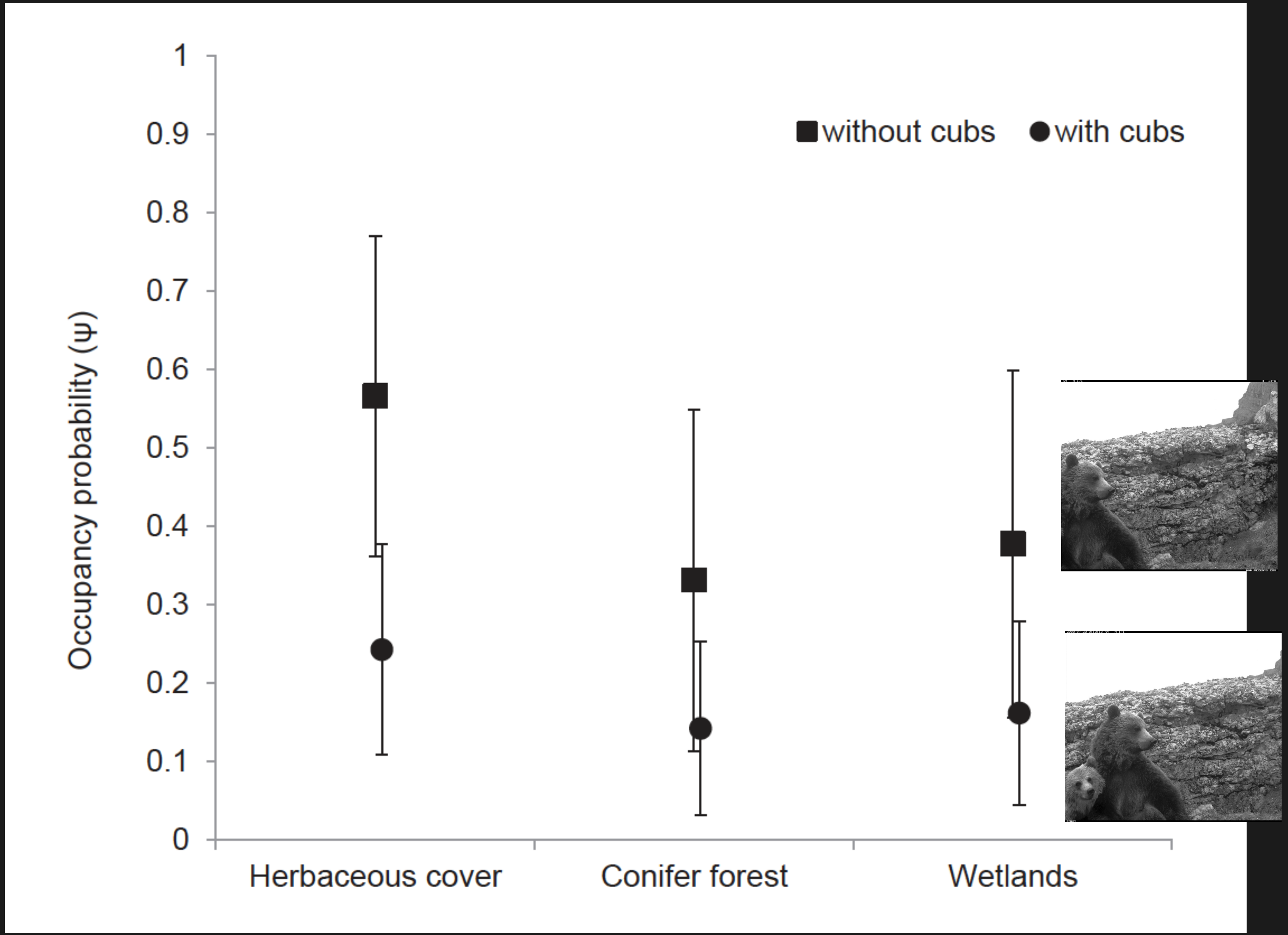
HMM formulation of multistate occupancy model

Observation process

$$
\begin{array}{l}
 \\ U \\ ONB \\ OB
\end{array}
\begin{array}{c}
\begin{array}{ccc} 0 & 1 & 2 \end{array} \\
\begin{pmatrix}
1 & 0 & 0 \\
1 - p^1 & p^1 & 0 \\
1 - p^2 & p^2(1 - \delta) & p^2\delta
\end{pmatrix}
\end{array}
$$

State uncertainty; reproduction may occur on a site, but the young may not be detected. δ probability of detecting evidence of reproduction, given the site is occupied with young

Results



without cubs
with cubs
Occupancy probability (ψ)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Herbaceous cover
Conifer forest
Wetlands

Alternative parameterization

We had:

ψ_1 = prob. a site is occupied by species **non-breeding**

ψ_2 = prob. a site is occupied by species **breeding**

Now let's define:

$\psi = \psi_1 + \psi_2$ = prob. of occupancy

$R = \psi_2 / \psi$ = prob. a being in state 2, given site occupied
= conditional prob. of successful reproduction

Hidden Markov model – part 1 modified

Initial states

$$\begin{array}{ccc} \text{U} & \text{ONB} & \text{OB} \\ \end{array}$$
$$\begin{bmatrix} 1-\psi & \psi(1-R) & \psi R \end{bmatrix}$$

Lecture 4

Occupancy models with species misidentification

Species misidentification

OPEN ACCESS Freely available online 2013

PLOS | ONE

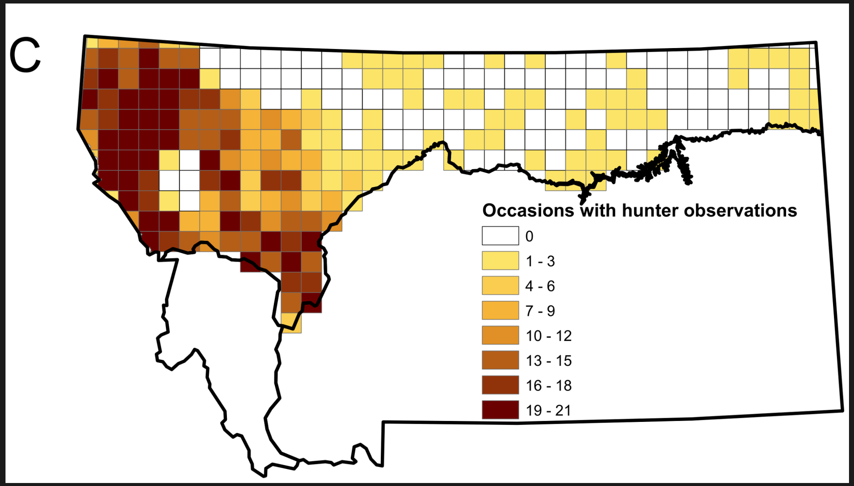
Determining Occurrence Dynamics when False Positives Occur: Estimating the Range Dynamics of Wolves from Public Survey Data

David A. W. Miller[1,2]*, James D. Nichols[1], Justin A. Gude[3], Lindsey N. Rich[4], Kevin M. Podruzny[3], James E. Hines[1], Michael S. Mitchell[4]

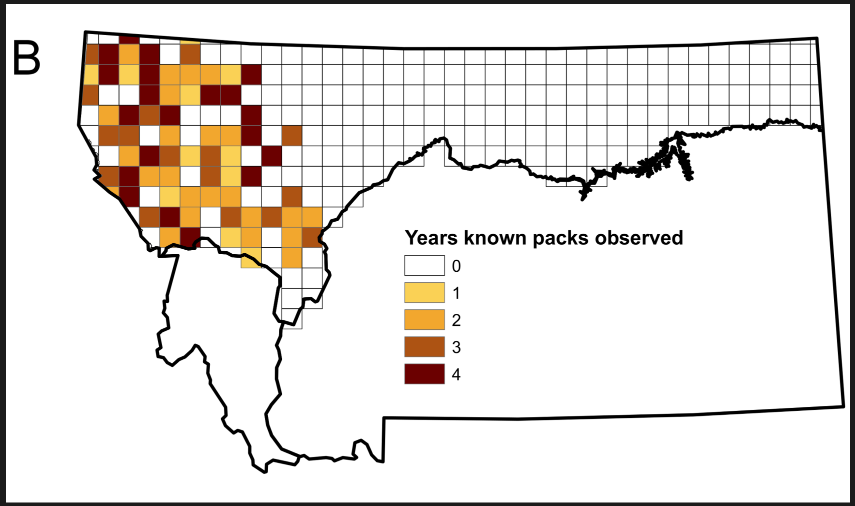
- How to account for false positives due to species misidentification?

Data

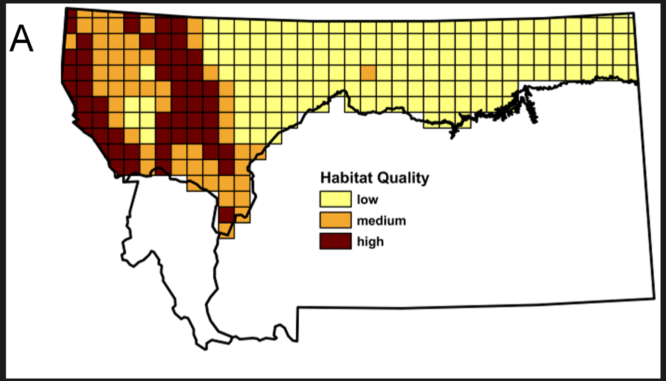
Observations by hunters (phone interviews);
uncertainty in species identification



Telemetry;
no doubt about species



Habitat quality



Reminder: static occupancy model

Initial states

$$\begin{array}{cc} U & O \\ \left(1-\psi_1\right. & \left.\psi_1\right) \end{array}$$

State process

$$\begin{array}{c|cc} & U & O \\ \hline U & 1 & 0 \\ O & 0 & 1 \end{array}$$

Observation process

$$\begin{array}{c|cc} & 0 & 1 \\ \hline U & 1 & 0 \\ O & 1-p & p \end{array}$$

Model allowing for false positives

Observation process

0

1

2

Uncertain detection

Detection with no doubt about the species

Model allowing for false positives

Observation process

$$\begin{array}{cccc} & 0 & 1 & 2 \\ U & \multicolumn{3}{c}{\left(\begin{array}{ccc} 1 - p_{10} & p_{10} & 0 \end{array} \right)} \end{array}$$

p_{10} = probability of false positive detection

Model allowing for false positives

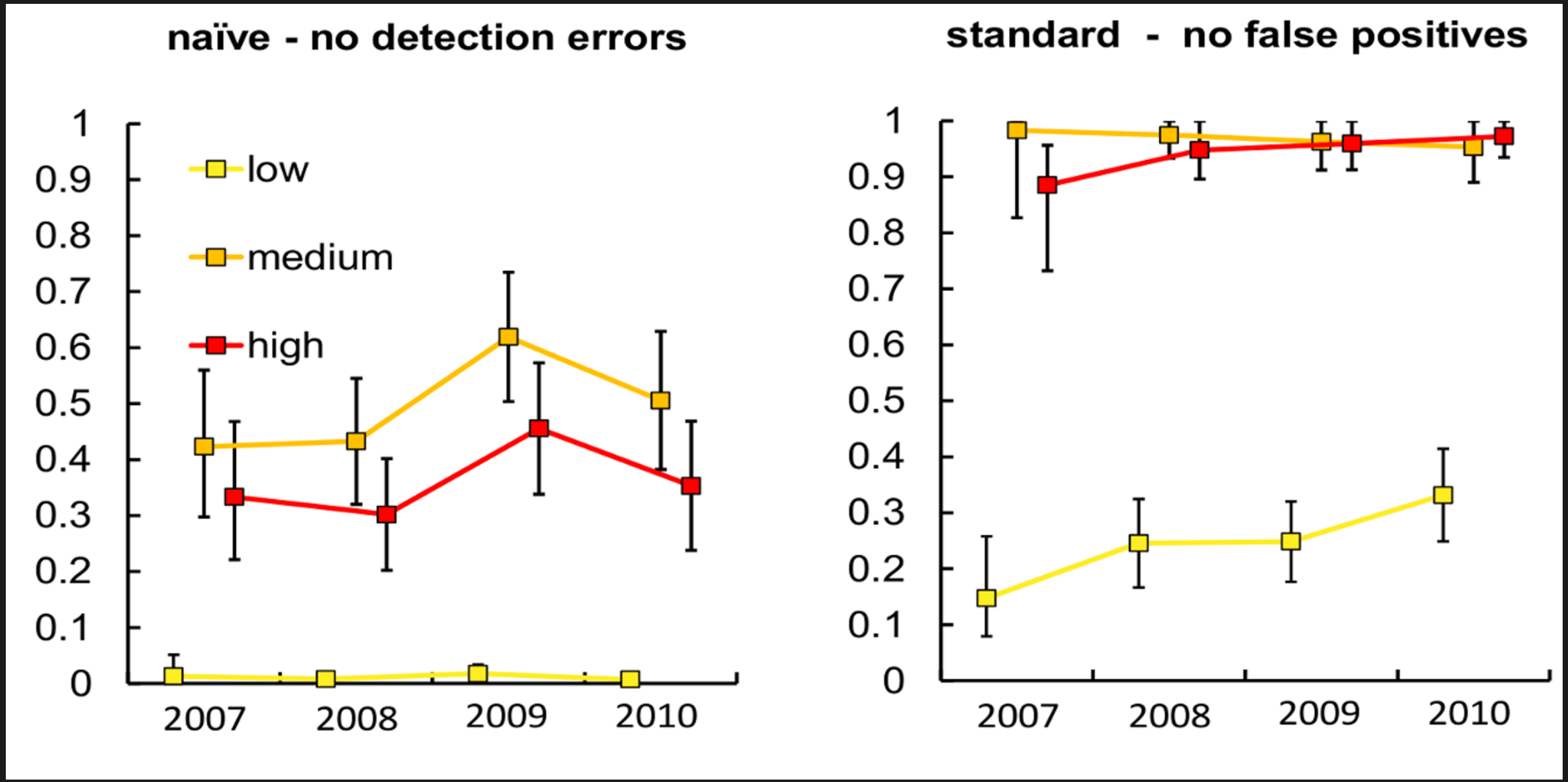
Observation process

$$\begin{array}{cc} & \begin{array}{ccc} 0 & 1 & 2 \end{array} \\ \begin{array}{c} U \\ O \end{array} & \begin{pmatrix} 1-p_{10} & p_{10} & 0 \\ 1-p_{11} & (1-b)p_{11} & bp_{11} \end{pmatrix} \end{array}$$

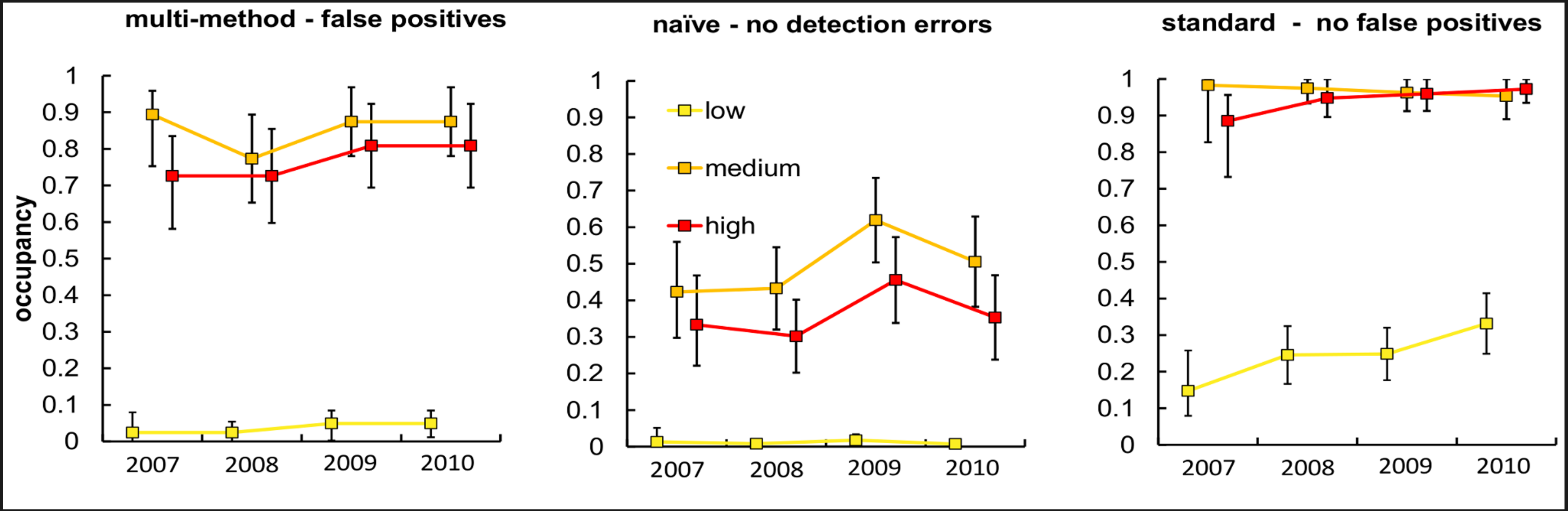
p_{11} = probability of detection

b = probability that a detection is classified as unambiguous

Estimates of occupancy for gray wolves in northern Montana from 2007–2010



Estimates of occupancy for gray wolves in northern Montana from 2007–2010



Conservation Biology

Conservation Methods

Use of ambiguous detections to improve estimates from species distribution models

Julie Louvrier, Anja Molinari-Jobin, Marc Kéry, Thierry Chambert, David Miller, Fridolin Zimmermann, Eric Marboutin, Paolo Molinari, Oliver Müeller, Rok Černe, Olivier Gimenez

First published: 16 July 2018 | https://doi.org/10.1111/cobi.13191

ÉCOLE
NORMALE
SUPÉRIEURE
DE LYON

15 parvis René-Descartes
BP 7000, 69342 Lyon cedex 07
Tél. +33 (0)4 37 37 60 00
www.ens-lyon.fr

Biologie
Master
BioSciences

LAURET Valentin

Dealing with species misidentification to make the best of citizen science data: a case study with wolf distribution in France

M2 Internship report

Internship dates : 04/01/2017 – 24/05/2017
Laboratory : CEFE, Montpellier
Supervisor : Olivier Gimenez & Julie Louvrier
Nb of words : 4139

Lecture 5

Estimating co-occurrence of interacting species

Rationale

- Several (say 2) different species on a site
- Interactions affect occupancy probabilities
- Detection of a species affected by presence of another one: blurred interactions
- Examples: predation, mutualism, competition, …
- Occupancy of a species when other species is present?

States

U = site unoccupied
A = site occupied by species A only
B = site occupied by species B only
AB = site occupied by both species

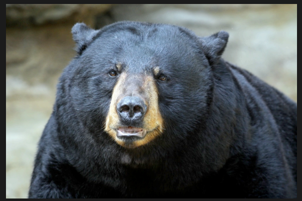
State process

ψ^{A} = prob. a site is occupied by species A

ψ^{B} = prob. a site is occupied by species B

ψ^{AB} = prob. a site is occupied by species A and B

Venn diagram



Occupied by species A only

$\psi^{A} - \psi^{AB}$

Occupied by both species

ψ^{AB}

Occupied by species B only

$\psi^{B} - \psi^{AB}$

Site unoccupied with prob.: $1 - \psi^{A} - \psi^{B} + \psi^{AB}$

Events

0 = species undetected
1 = A detected
2 = B detected
3 = both species detected

Observation process

p^A = prob. detecting species A given only species A is present

p^B = prob. detecting species B given only species B is present

r^{AB} = prob. detecting both species A and B when both present

r^{Ab} = prob. detecting species A but not B when both present

r^{aB} = prob. detecting species B but not A when both present

r^{ab} = prob. detecting neither species when both present

Hidden Markov model – part 1

Initial states

$$\begin{array}{cccc} \text{U} & \text{A} & \text{B} & \text{AB} \end{array}$$

$$\begin{bmatrix} 1-\Sigma & \psi^{A}-\psi^{AB} & \psi^{B}-\psi^{AB} & \psi^{AB} \end{bmatrix}$$

Hidden Markov model – part 2

State process

$$\begin{array}{c c} & \begin{array}{cccc} U & A & B & AB \end{array} \\ \begin{array}{c} U \\ A \\ B \\ AB \end{array} & \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \end{array}$$

Hidden Markov model – part 3

Observation process

$$
\begin{array}{c|cccc|}
 & 0 & 1 & 2 & 3 \\
\hline
U & 1 & 0 & 0 & 0 \\
A & 1-p^{A} & p^{A} & 0 & 0 \\
B & 1-p^{B} & 0 & p^{B} & 0 \\
AB & 1-\Sigma & r^{Ab} & r^{aB} & r^{AB}
\end{array}
$$

Quantifying interactions

Interaction estimated by: $\eta = \psi^{AB} / (\psi^{A} \psi^{B})$

$\eta < 1$ – avoidance (less frequent than expected)

$\eta > 1$ – convergence (more frequent than expected)

$\eta = 1$ – independence ($\psi^{AB} = \psi^{A} \psi^{B}$)

Alternative parameterization

- Introduce conditional probabilities

$$\psi^{A|B} = \text{prob. a site is occupied by A given presence of B}$$

$$\psi^{A|\overline{B}} = \text{prob. a site is occupied by A given absence of B}$$

$$\psi^{B} = \text{prob. a site is occupied by B}$$

Hidden Markov model – part 1 modified

Initial states, in 2 steps

$$\begin{array}{cc} \text{no-B} & \text{B} \\ \left[\begin{array}{cc} 1-\psi^{B} & \psi^{B} \end{array}\right] \end{array}$$

$$\begin{array}{cccc} \text{U} & \text{A} & \text{B} & \text{AB} \\ \left[\begin{array}{cccc} 1-\psi^{A|\overline{B}} & \psi^{A|\overline{B}} & 0 & 0 \\ 0 & 0 & 1-\psi^{A|B} & \psi^{A|B} \end{array}\right] \end{array}$$

Testing interactions

- A and B independent?

Compare:

model in which $\psi^{A|B} \neq \psi^{A|\overline{B}}$ vs.

model in which $\psi^{A|B} = \psi^{A|\overline{B}}$

Université de Montpellier et Montpellier SupAgro
Master Mention " Biodiversité, Écologie, Évolution, B2E "
Parcours «ÉcoSystèmeS »

Projet de recherche :

Quantifier les interactions prédateur-proies grâce au piégeage photographique et à la modélisation d’occupation multi-espèce

Le cas du système lynx-chevreuil-chamois dans le Jura français

Par
KERVELLEC Maëlis
Stage de M1

Réalisé sous la direction de
GIMENEZ Olivier, Directeur de Recherche
Centre d’Écologie Fonctionnelle et Évolutive, UMR 5175, Équipe HAIR
Sous tutelles du CNRS, l’Université de Montpellier, l’Université Paul-Valéry Montpellier, l’IRD, l’EPHE

DUCHAMP Christophe, Chargé de recherche
Office Français de la Biodiversité, Unité PAD, Équipe Loup-Lynx
Sous tutelles du ministère de la Transition écologique et solidaire et du ministère de l’Agriculture et de l’Alimentation.

ECOGRAPHY
A JOURNAL OF SPACE AND TIME IN ECOLOGY

Research | Open Access

Inferring wildlife poaching in southeast Asia with multispecies dynamic occupancy models

Lucile Marescot, Arnaud Lyet, Rohit Singh, Neil Carter, Olivier Gimenez

First published: 25 October 2019 | https://doi.org/10.1111/ecog.04536 |

A dynamic and hierarchical spatial occupancy model for interacting species

Eivind Flittie Kleiven, Frederic Barraquand, Olivier Gimenez, John-André Henden, Rolf Anker Ims,
Eeva M. Soininen, Nigel Gilles Yoccoz

doi: https://doi.org/10.1101/2020.12.16.423067

1 Abstract

Occupancy models are currently being developed in two major directions: to account for spatial structure and species interactions. As interacting species (e.g., predators and prey) often operate at different spatial scales, including nested spatial structure might be especially relevant in models for interacting species. Here we bridge these two model frameworks by developing a spatially hierarchical two-species occupancy model. The model is dynamic, i.e. it estimates initial occupancy, colonization and extinction probabilities - including probabilities conditional to the other species' presence. With a simulation study, we demonstrate that the model is able to estimate parameters without bias under low, medium and high average occupancy probabilities, as well as low, medium and high detection probabilities. We further show the model's ability to deal with sparse field data by applying it to a spatially hierarchical camera trapping dataset on a mustelid-rodent predator-prey system. The field study illustrates that the model allows estimation of species interaction effects on colonization and extinction probabilities at two spatial scales. This creates opportunities to explicitly account for the spatial structure found in many spatially nested study designs, and to study interacting species that have contrasted movement ranges with camera traps.

Lecture 6

Conclusions

Conclusions

1. (Almost?) all occupancy models in a unified HMM framework
   - Single-season, dynamic models
   - Mixture/random effects and multistate models to account for heterogeneity
   - False-positives
   - Species interactions

Conclusions

2. HMM: link occupancy and capture-recapture communities

- Goodness-of-fit
- Accounting for lack of dependence

Conclusions

3. There is a learning curve to understand HMM, is it worth it?

- HMM is a general framework
- All models can be obtained as particular cases (?)

What we did not cover

- How to choose sites? Occasions?
  - site selection
  - allocation of effort
  - design comparisons
  - survey timing
- Goodness-of-fit testing
- A few other models…
  - habitat and species occurrence dynamics, cluster sampling, …

Journal of Applied Ecology 2005
42, 1105–1114

METHODOLOGICAL INSIGHTS

Designing occupancy studies: general advice and allocating survey effort

DARRYL I. MACKENZIE* and J. ANDREW ROYLE†
**Proteus Wildlife Research Consultants, PO Box 5193, Dunedin, New Zealand; †US Geological Survey, Patuxent Wildlife Research Center, 12100 Beech Forest Road, Laurel, MD 20708–4017, USA*

Assessing the Fit of Site-Occupancy Models

Darryl I. MACKENZIE and Larissa L. BAILEY

Journal of Agricultural, Biological, and Environmental Statistics, Volume 9, Number 3, Pages 300–318
DOI: 10.1198/108571104X3361