Time-to-detection occupancy models

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SEEC - Statistics in Ecology, Environment and Conservation

ENDANGERED WILDLIFE TRUST

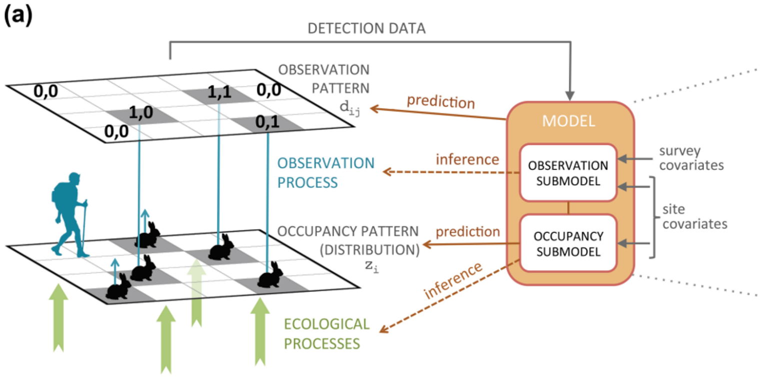
Occupancy models - previous toolboxes

Species	Temporal	Spatial AC	Data	Framework	URL
Single	Static	No	Detection/non-detection	ML	Talk 1
Single	Static	No	Detection/non-detection	Bayesian	Talk 2
Single	Dynamic	No	Detection/non-detection	ML	Talk 3
Single	Static	Yes	Detection/non-detection	Bayesian	Talk 4
Multi	**Static**	**No**	**Continuous time**	**Bayesian**	**Talk 5**

Outline of toolbox

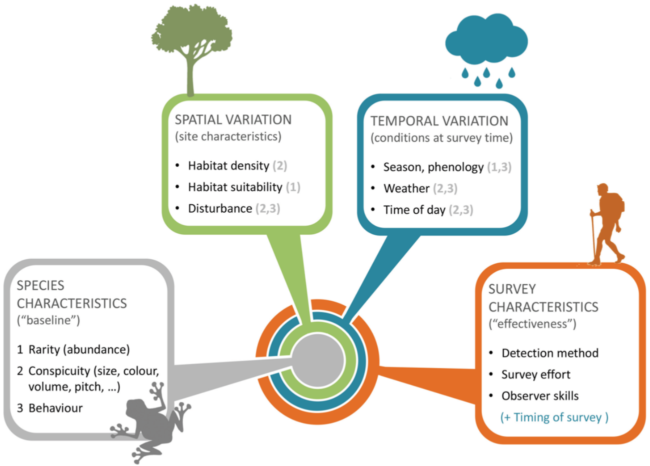
- Background of TTD models
- Single species TTD model (simulated data)
- Data processing (field data)
- Multi-species TTD model
- Plotting parameters and predictions

Occupancy models



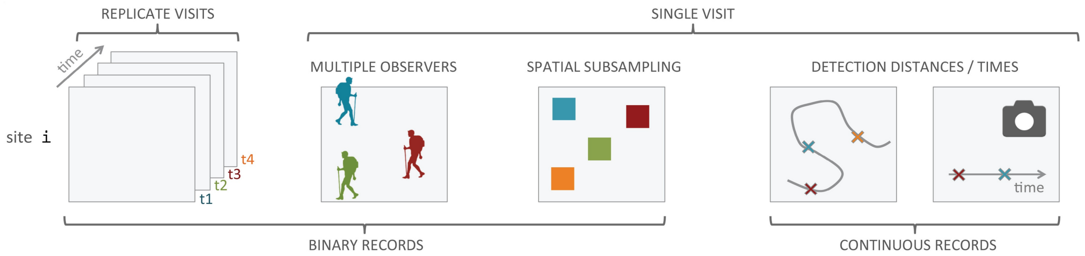
Guillera-Arriota, G. 2016. *Ecography* 39: 1-15

Factors that influence detection



Guillera-Arriota, G. 2016. *Ecography* 39: 1-15

Data requirements



site 1	1	0	0	...	1
site 2	0	–	1	...	–
site 3	0	0	0	...	0
site 4	1	0	1	...	–
...	...	...	...	...	...
site S	0	0	1		1

site 1	23, 59, 101
site 2	44
site 3	no detection
site 4	18, 51, 66
...	...
site S	55, 123

Guillera-Arriota, G. 2016. *Ecography* 39: 1-15

Origins of TTD

Austral Ecology A Journal of ecology in the Southern Hemisphere

Austral Ecology (2008) **33**, 986–998

When have we looked hard enough? A novel method for setting minimum survey effort protocols for flora surveys

GEORGIA E. GARRARD,[1]* SARAH A. BEKESSY,[1] MICHAEL A. McCARTHY[2] AND BRENDAN A. WINTLE[2]

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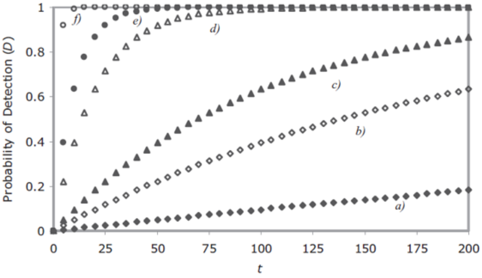


Fig. 5. Detectability curves for species with single time step detection probabilities (λ) of: (a) 0.001, (b) 0.005, (c) 0.01, (d) 0.05, (e) 0.1 and (f) 0.5. Curves like these can be used to determine the length of time an observer would need to spend looking for a species to achieve a specified level of certainty of detecting it if it is present at a site. For example, for a species which has an average detection time $\bar{t} = 100$ ($\lambda = 0.01$, curve c), an observer would need to spend around 165 time steps to achieve a probability of detection of 0.80.

Detection curves

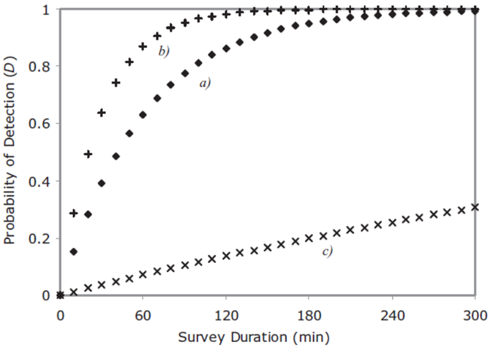


Fig. 6. Detectability curves for *Calocephalus citreus*, a plant found in Melbourne's Western (Basalt) Plains Grassland, under (a) average conditions; (b) best-case conditions; and (c) worst-case conditions.

Time-to-detection models

State process

$$z_{ik} \sim Bernoulli(\psi_{ik}) \tag{1}$$

Observation process

$$y_{ijk}|z_{ik} \sim Exponential(\lambda_{ijk})C(Tmax_{ij}) \tag{2}$$

Detection probability after survey duration d

$$p = 1 - e^{-\lambda_k * d} \tag{3}$$

Notation: site i, survey j, species k

Garrard, G.E., et al. 2008. *Austral Ecology* 33: 986-998

Censoring of data

Model for occurrence

$$z_{ik} \sim Bernoulli(\psi_{ik})$$

Model for censoring of data

$$d(Tmax_{ij}) = z_{ik} * I(y_{ijk} > Tmax_{ij}) + (1 - z_{ik})$$

Model for observed data of data

$$\begin{array}{ll} y_{ijk}|z_{ik} \sim Exponential(\lambda_{ijk}) & \text{if } d_{ijk} = 0 \\ y_{ijk} = NA & \text{if } d_{ijk} = 1 \end{array}$$

Weibull distribution

Generalisation of the exponential distribution

Detection rate can vary over time (e.g., decrease as surveys progress)

Shape parameter (k) governs the change in rate

- $k = 1$ exponential with constant rate
- $0 < k < 1$ detection rate decreases over time
- $k > 1$ detection rate increases over time

Read: Medina-Romero, et al. 2019. Ecography 42(9): 1514-1522.

Can we reduce sampling effort?

Methods in Ecology and Evolution

British Ecological Society

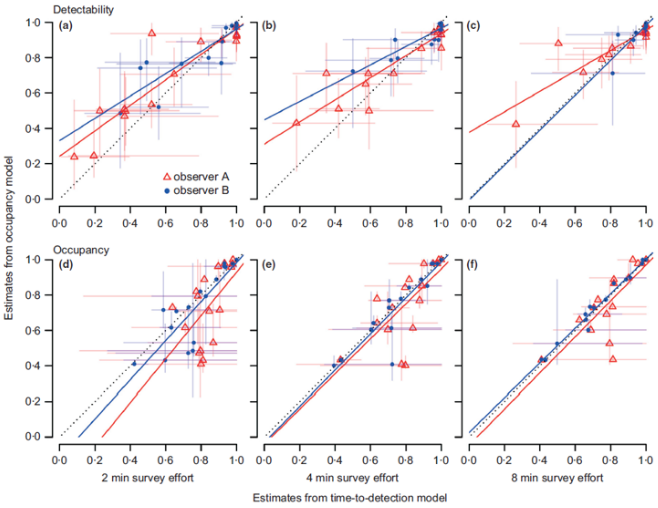
Methods in Ecology and Evolution 2014, **5**, 433–442 doi: 10.1111/2041-210X.12171

Hide-and-seek in vegetation: time-to-detection is an efficient design for estimating detectability and occurrence

Christophe N. Bornand[1]*, Marc Kéry[2], Lena Bueche[1] and Markus Fischer[1]

[1] *Institute of Plant Sciences, University of Bern, Altenbergrain 21, 3013 Bem, Switzerland; and* [2] *Swiss Omithological Institute, Seerose 1, 6204 Sempach, Switzerland*

Can we reduce sampling effort?



How well do these models perform?

Received: 4 October 2019 | Accepted: 7 February 2020

DOI: 10.1111/2041-210X.13379

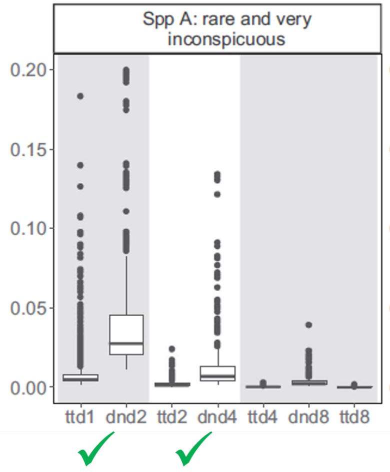
RESEARCH ARTICLE

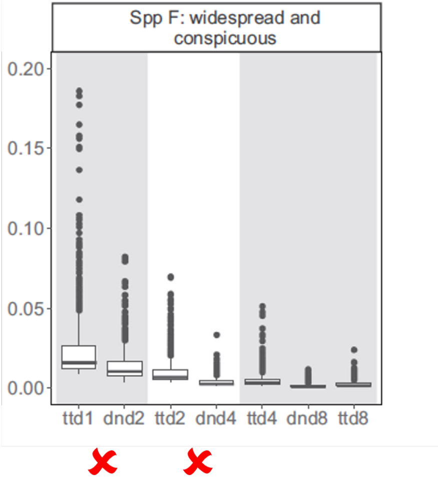
Methods in Ecology and Evolution BRITISH ECOLOGICAL SOCIETY

Can time-to-detection models with fewer survey replicates provide a robust alternative to traditional site-occupancy models?

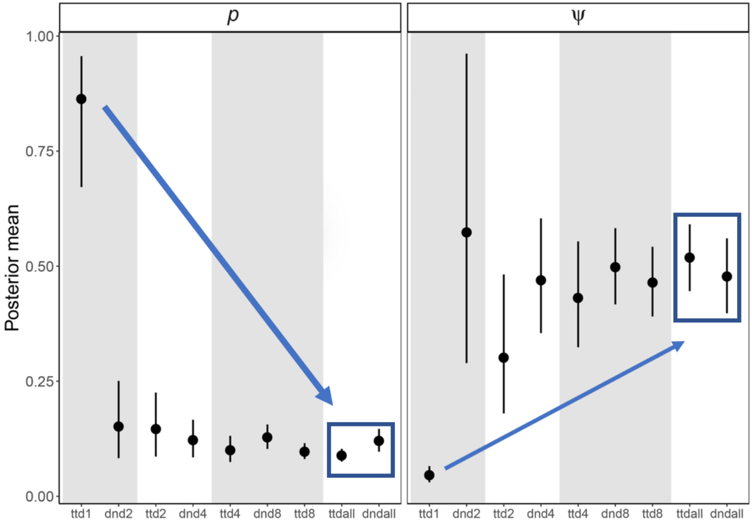
Dominic A. W. Henry[1,2] | Alan T. K. Lee[3,4] | Res Altwegg[1,5]

How well do these models perform?





How well do these models perform?



What are our options for TTD modelling?

Maximum likelihood

- unmarked::occuTTD
- Pros: Built-in functions, fast, easy to use, single & multi-season
- Cons: Single species, not customisable

What are our options for TTD modelling?

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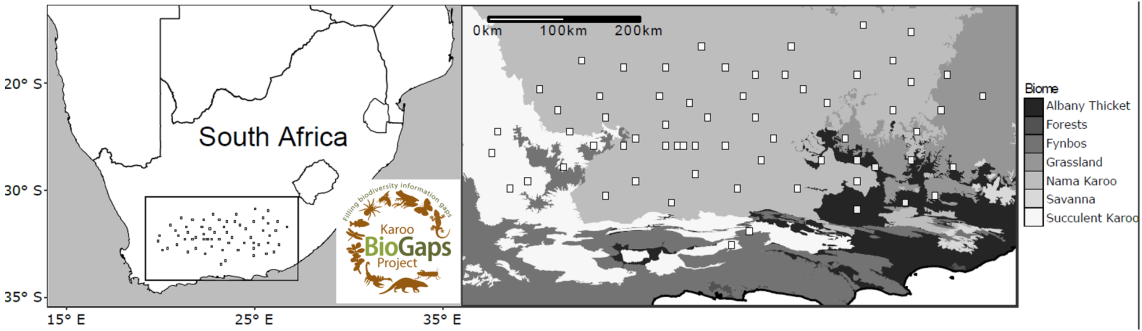
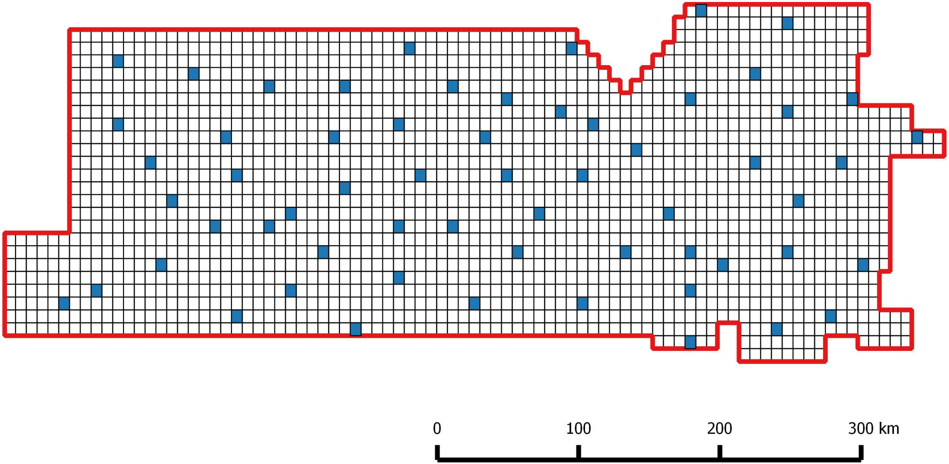
Bayesian

- WinBUGS, JAGS, NIMBLE, STAN, Greta
- Pros: Multi-species, random effects, custom distributions, sky is the limit
- Cons: manual model formulations, runtime, unhelpful error messages, computationally intensive

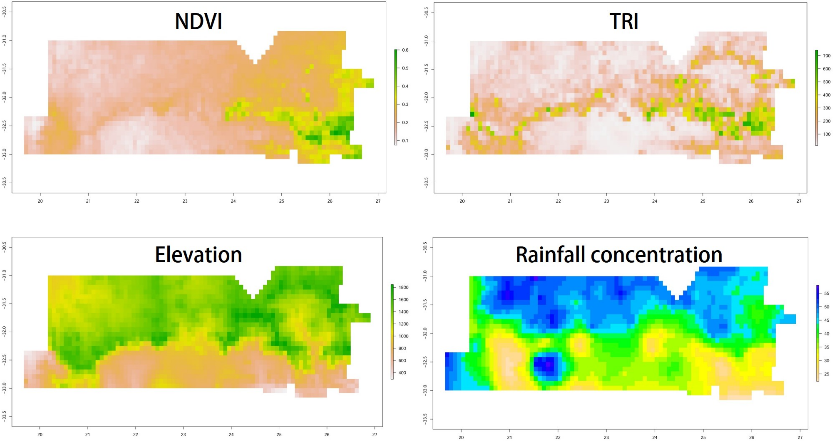
Multi-species TTD models of Karoo avifauna



Survey layout



Covariates



Detection covariates: Wind, cloud, temperature, Julian day, time of day

TTD model formulation

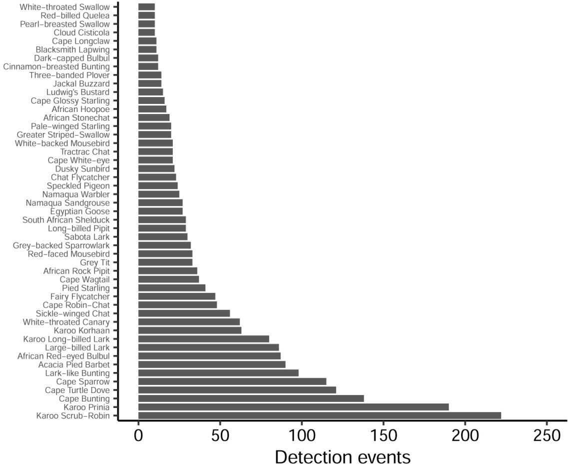
Occurrence

$$logit(\Psi_{ik}) = \beta_{0k} + \beta_{1k} \times NDVI_i + \beta_{2k} \times PCI_i + \beta_{3k} \times elev_i + \beta_{4k} \times TRI \tag{4}$$

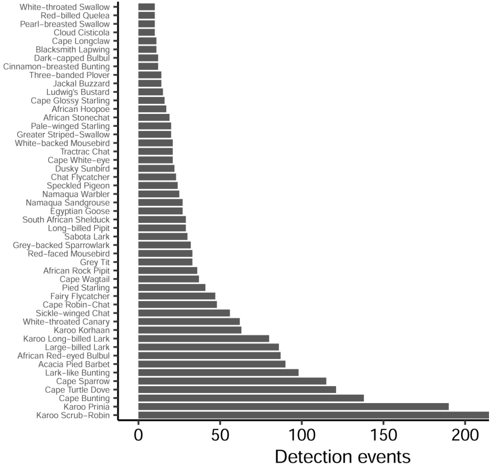
Detection

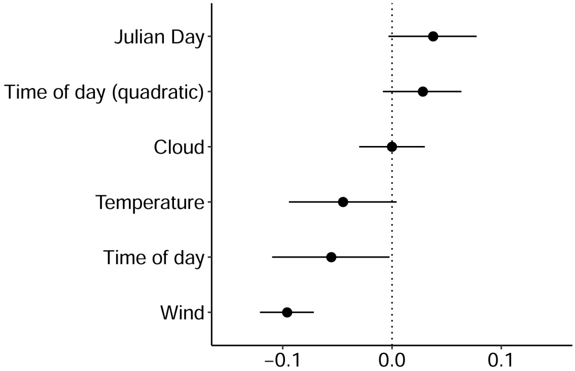
$$\begin{aligned} log(\lambda_{ijk}) =& \alpha_{0k} + \alpha_1 \times JulianDay_{ij} + \alpha_2 \times TOD_{ij} + \alpha_3 \times TOD_{ij}^2 + \\ & \alpha_4 \times temp_{ij} + \alpha_5 \times wind_{ij} + \alpha_6 \times cloud_{ij} \end{aligned} \tag{5}$$

Results - detection

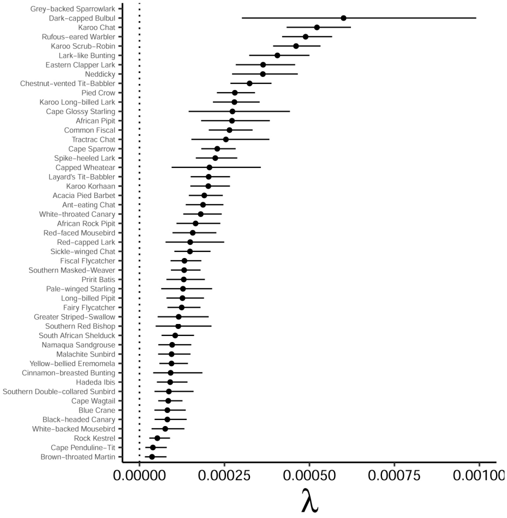


Results - detection

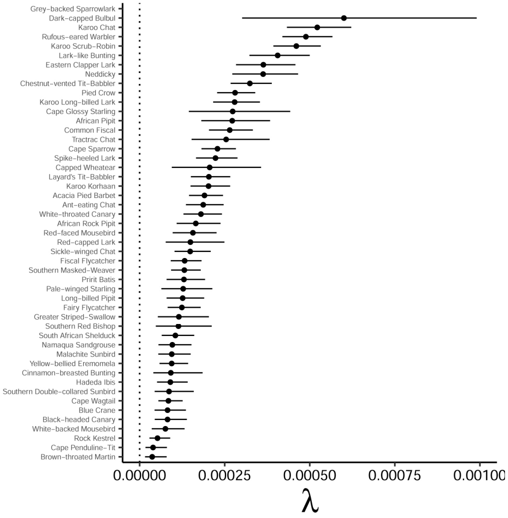


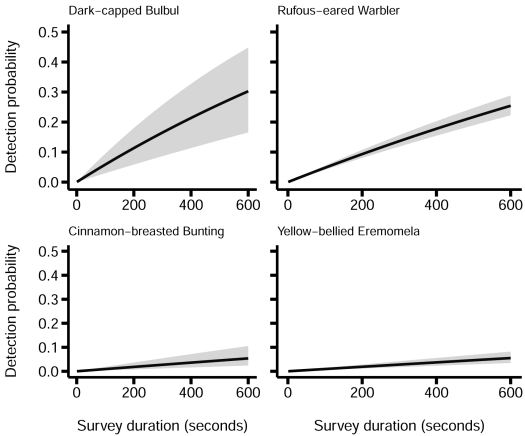


Results - detection

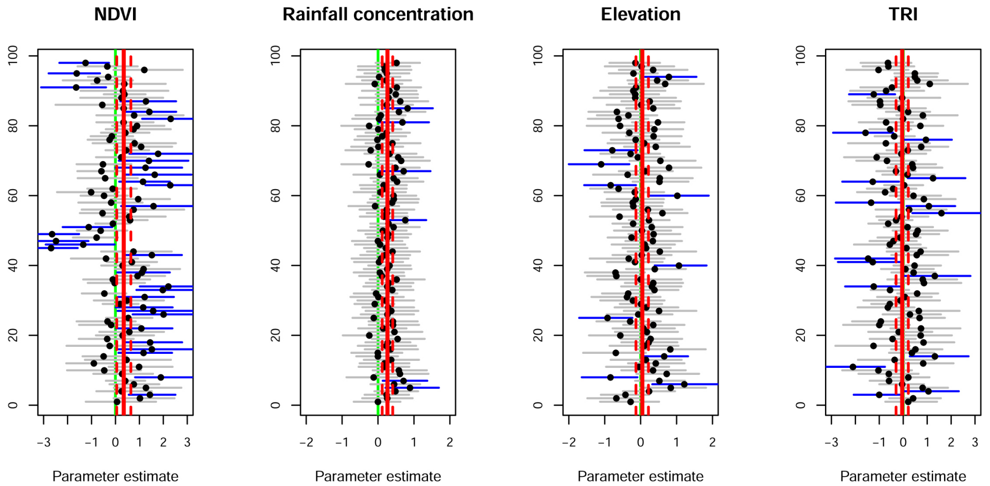


Results - detection





Results - occupancy



Occurrence maps

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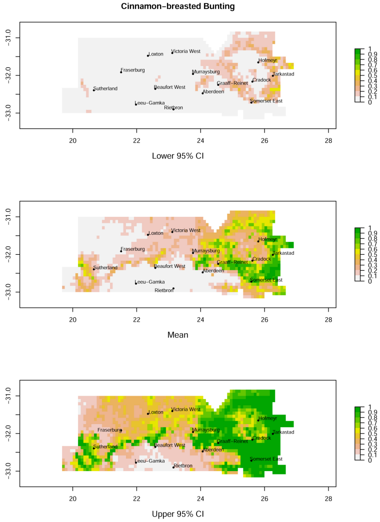
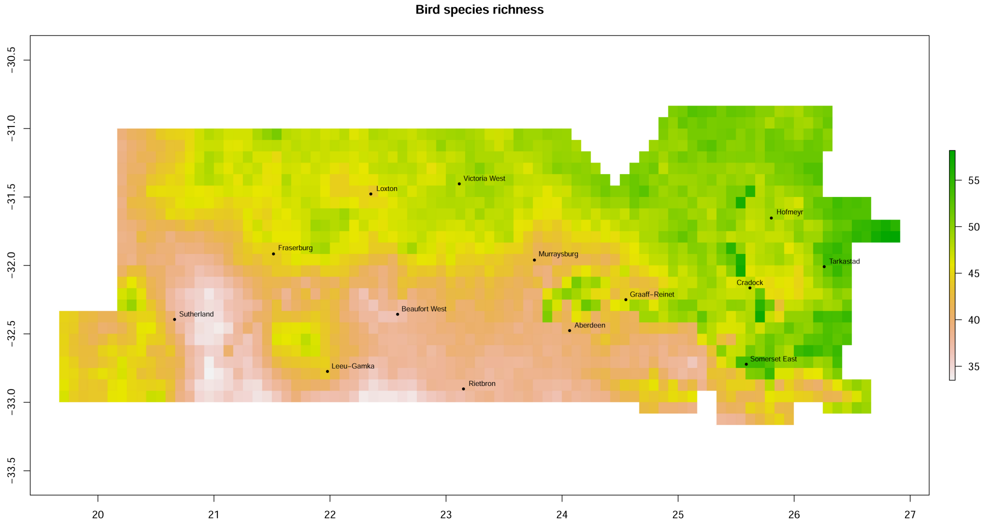


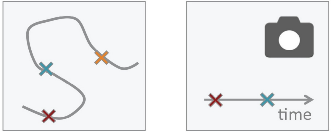
Species richness map



Recap

- Time-to-detection can provide a robust and cost effective alternative
- Detection curves as a useful by-product
- Survey replicates are still important
- Think carefully about nested set of factors that influence detection in focal species/community
- Consider whether changes in detection rate are important (Weibull)

DETECTION DISTANCES / TIMES



CONTINUOUS RECORDS

site 1	23, 59, 101
site 2	44
site 3	no detection
site 4	18, 51, 66
...	...
site S	55, 123

Key references

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- GitHub page with toolbox materials: https://github.com/DomHenry/SEEC-ttd-Toolbox