Dealing with Uncertainty in Amphibian and Reptile Population Monitoring for Conservation

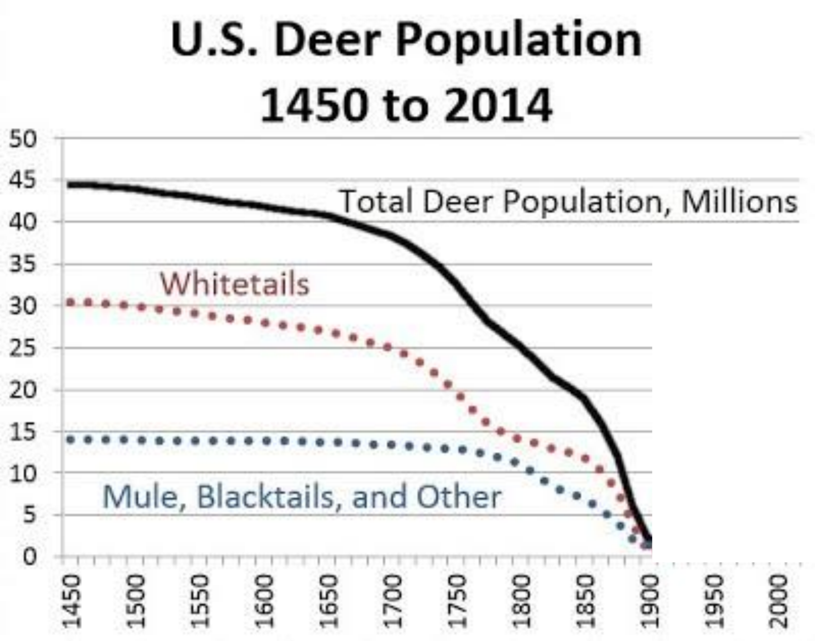
Sam Cruickshank

PhD defence



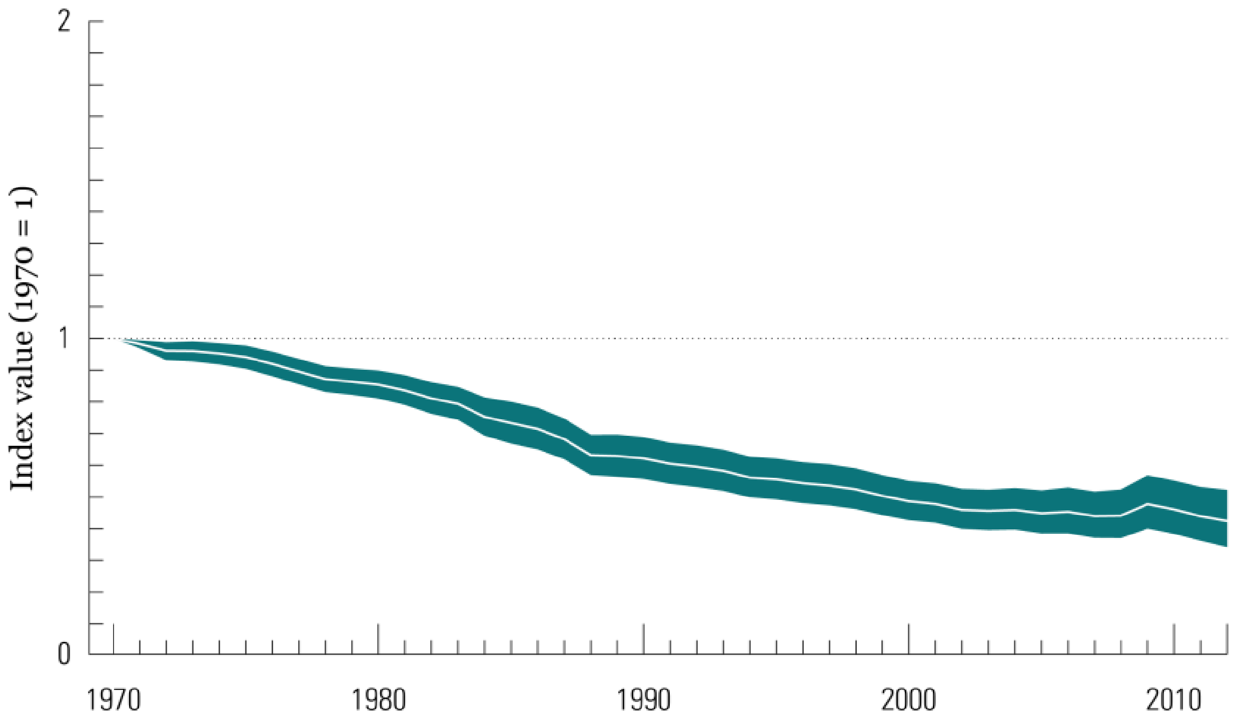


Biodiversity is under threat

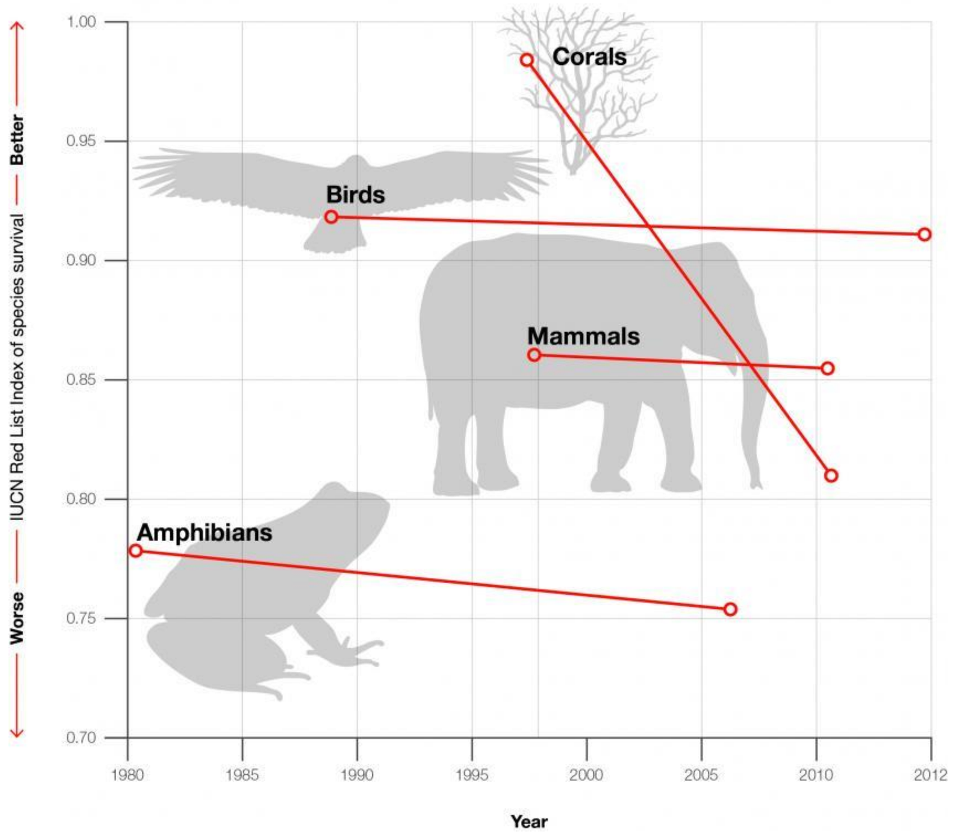


Monitoring underpins conservation

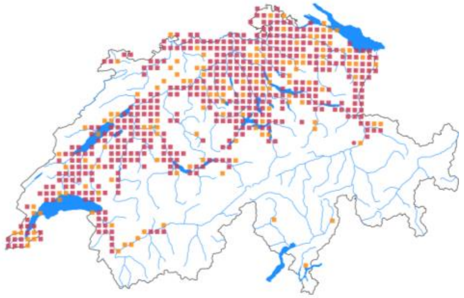
Living Planet Index



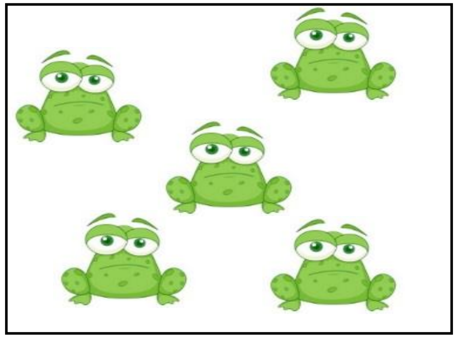
Red List Index

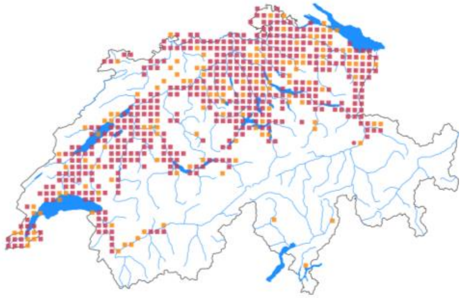


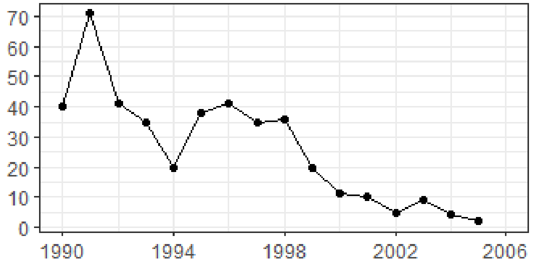

YES
NO



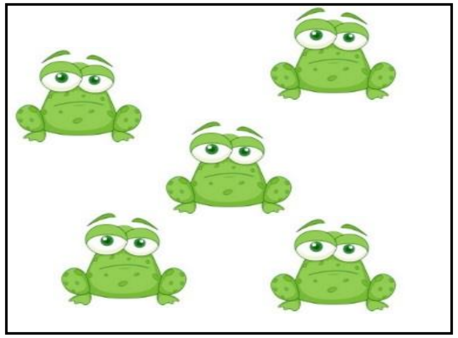

YES
NO

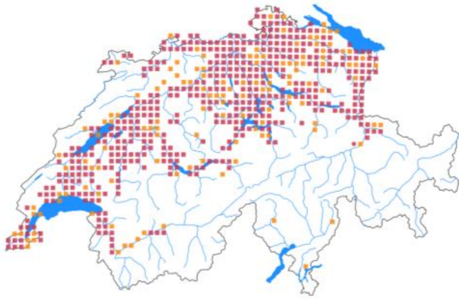


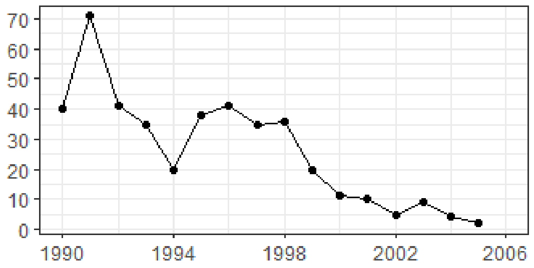


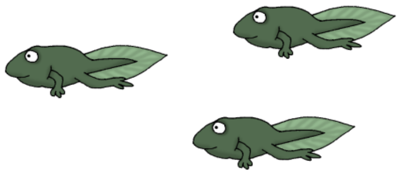

70
60
50
40
30
20
10
0
1990
1994
1998
2002
2006


YES
NO






70
60
50
40
30
20
10
0
1990
1994
1998
2002
2006



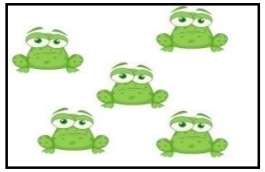
Talk outline

- Calculating status change in the face of imperfect detection

Cruickshank et al 2016 Conservation Biology

- When is a species not there?
- Volunteer data and false-positive observations
- Estimating abundance when individuals aren't available

TODAY



- Error rates in individual identification for mark-recapture


Cruickshank & Schmidt 2017 Amphibia-Reptilia

Part One

Assessing conservation status in the face of imperfect detection

Imperfect detection: what is it?

Imperfect detection

Occupancy Modelling

MacKenzie et al. 2002 Ecology
MacKenzie et al 2003 Ecology
Tyre et al. 2003 Ecological Applications

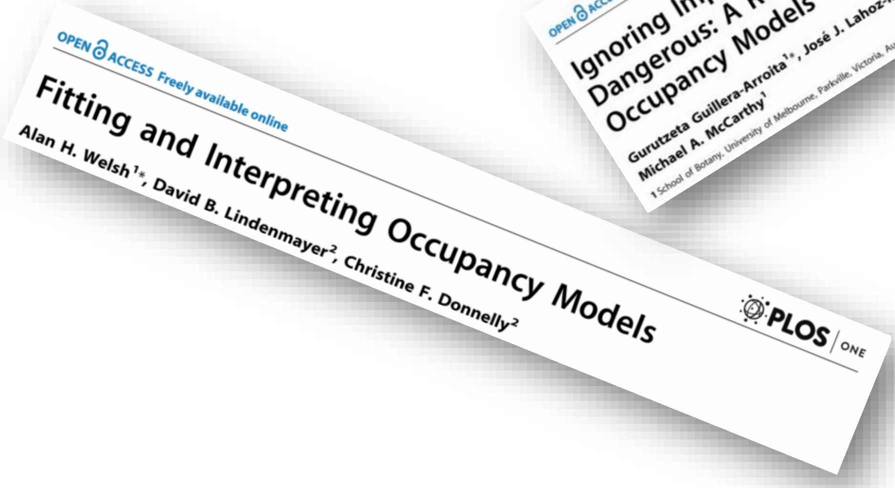
Site	Occupied?	Visit Number					
		1	2	3	4	5	6
A	Yes	0	1	1	0	0	1
B	?	0	0	0	0	0	0
C	?	0	0	0	0	0	0
D	Yes	1	0	0	0	1	1
E	Yes	1	1	1	1	0	1
F	Yes	0	1	0	0	0	0
G	?	0	0	0	0	0	0

$\frac{12}{24}$ = 50% Detection probability (p)

$P(000000 | \text{occupied}) = 0.5^6 = 0.016$

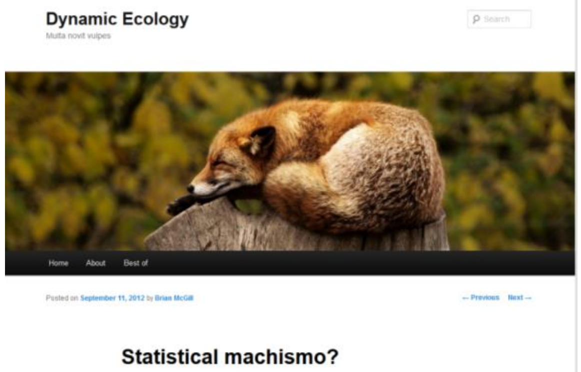
Controversy?


OPEN ACCESS Freely available online
PLOS ONE
Ignoring Imperfect Detection in Biological Surveys Is Dangerous: A Response to 'Fitting and Interpreting Occupancy Models'
Gurutzeta Guillera-Arroita[1]*, José J. Lahoz-Monfort[1], Darryl I. MacKenzie[2], Brendan A. Wintle[1], Michael A. McCarthy[1]
1 School of Botany, University of Melbourne, Parkville, Victoria, Australia, 2 Proteus Wildlife Research Consultants, Outram, New Zealand


OPEN ACCESS Freely available online
PLOS ONE
Fitting and Interpreting Occupancy Models
Alan H. Welsh[1]*, David B. Lindenmayer[2], Christine F. Donnelly[2]


50 YEARS WITH IMPACT
Journal of Applied Ecology
Journal of Applied Ecology 2014, 51, 849–859
doi: 10.1111/1365-2664.12272
REVIEW
Assessing the utility of statistical adjustments for imperfect detection in tropical conservation science
Cristina Banks-Leite[1,2]*, Renata Pardini[3], Danilo Boscolo[4], Camila Righetto Cassano[2,5], Thomas Püttker[3], Camila Santos Barros[2] and Jos Barlow[6,7]


FORMAL COMMENT
Adjusting for One Issue while Ignoring Others Can Make Things Worse
Alan H. Welsh*, David B. Lindenmayer, Christine F. Donnelly

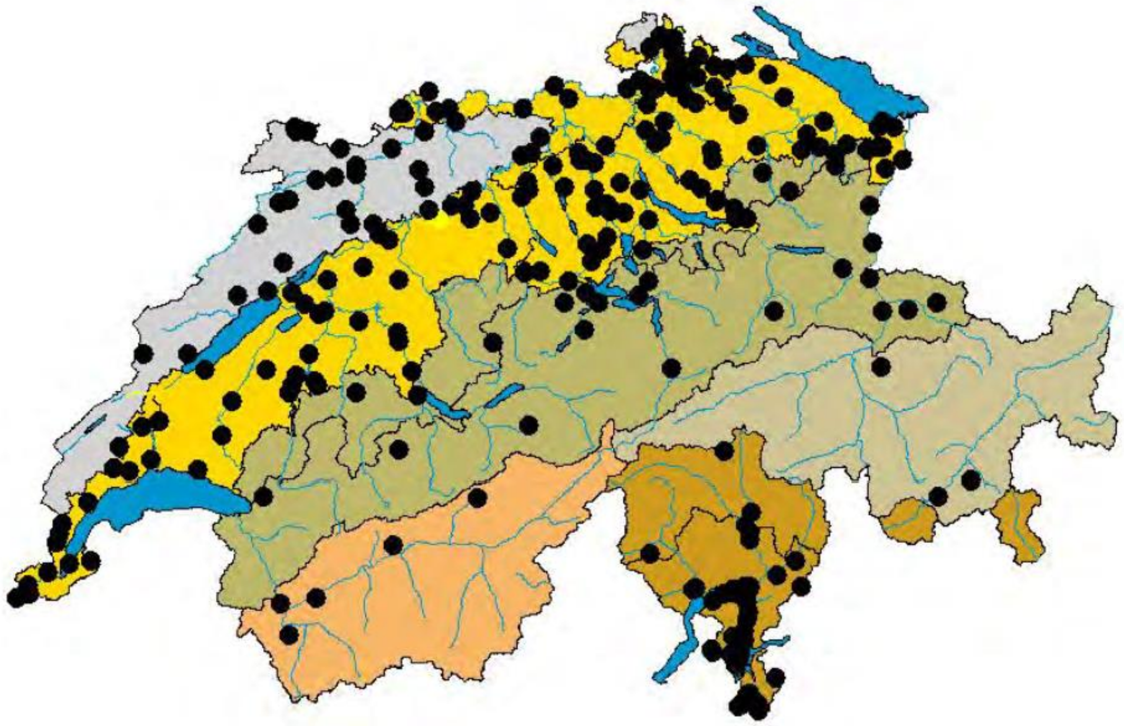


Concern: Repeat visits mean we can survey less places …is this actually worth the extra cost?

Question: Can we afford to ignore detectability?

Dataset

- Revisitation study
- 300 sites
- 12 species
- Repeat surveys at each pond



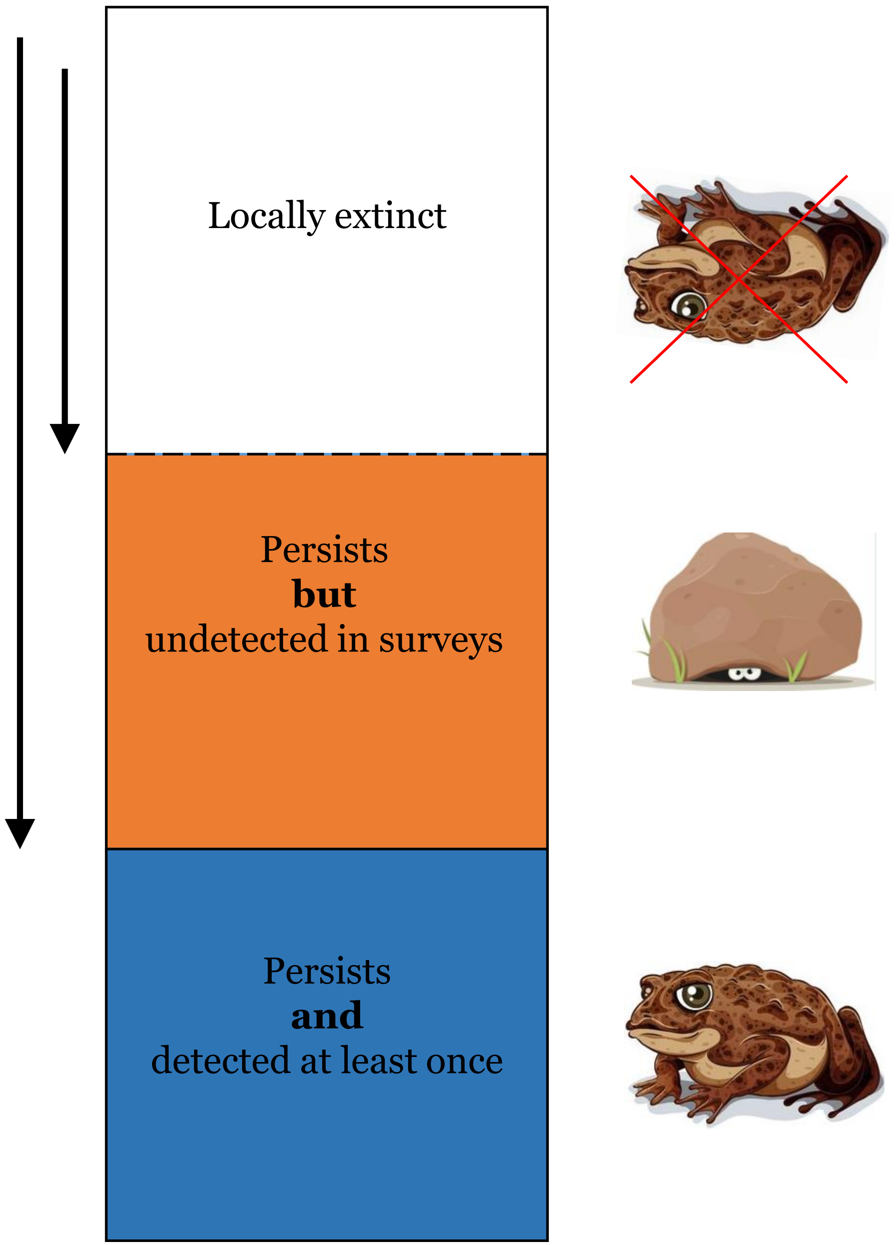
Calculating status change

Calculate declines:

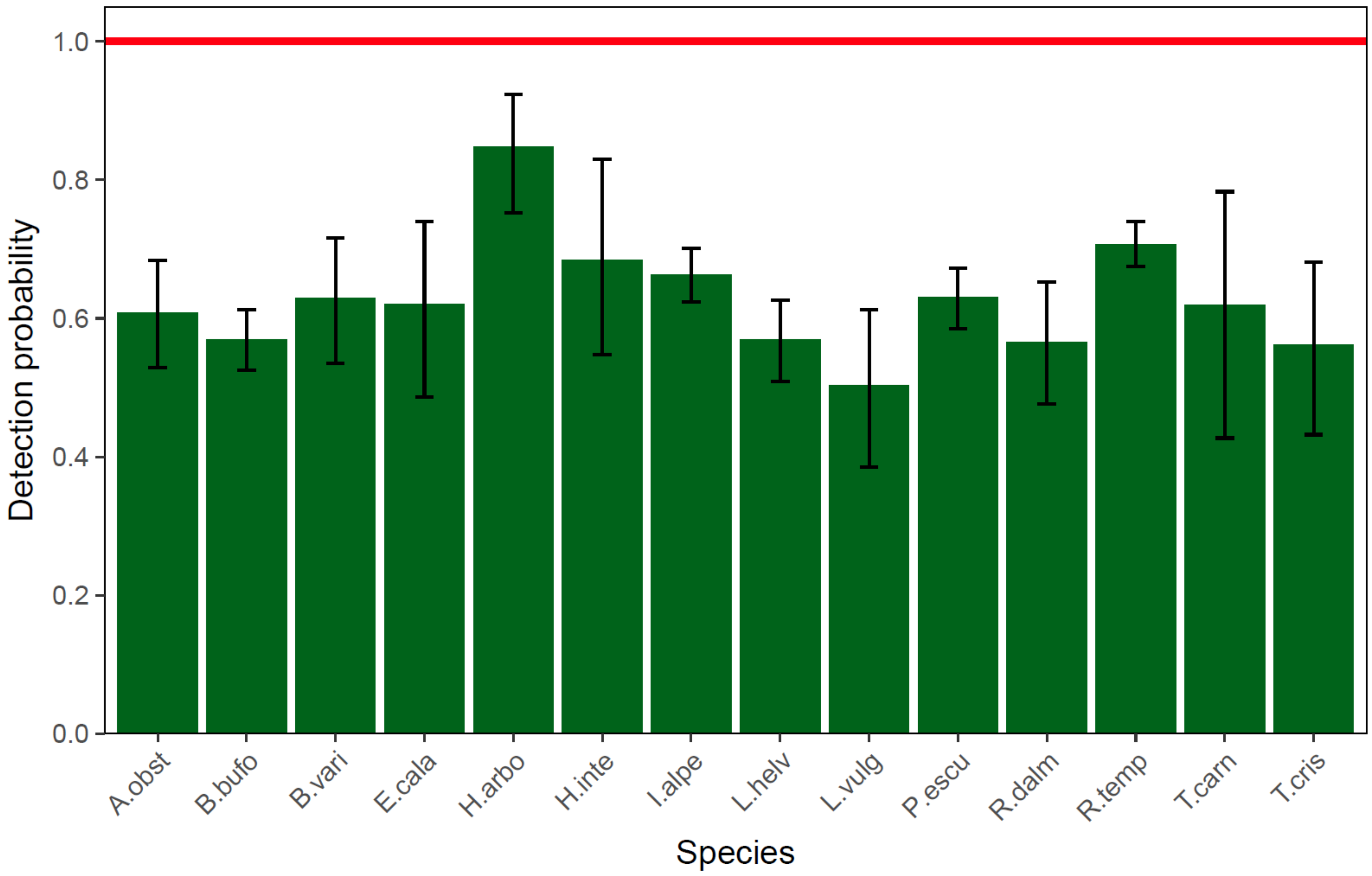
1. Ignoring p
2. Accounting for p

Calculate Red List threat status

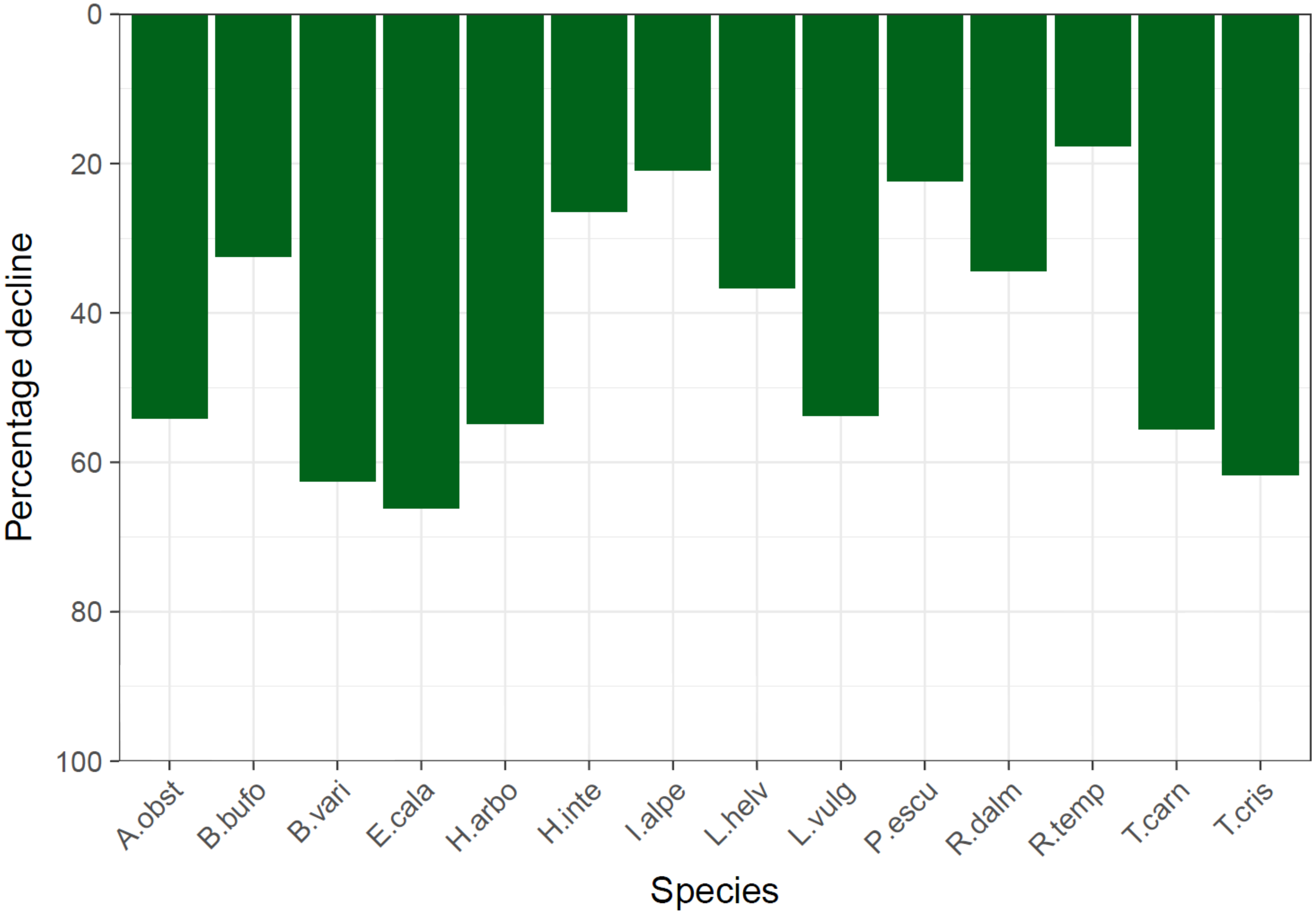
➢Direct consequences for management



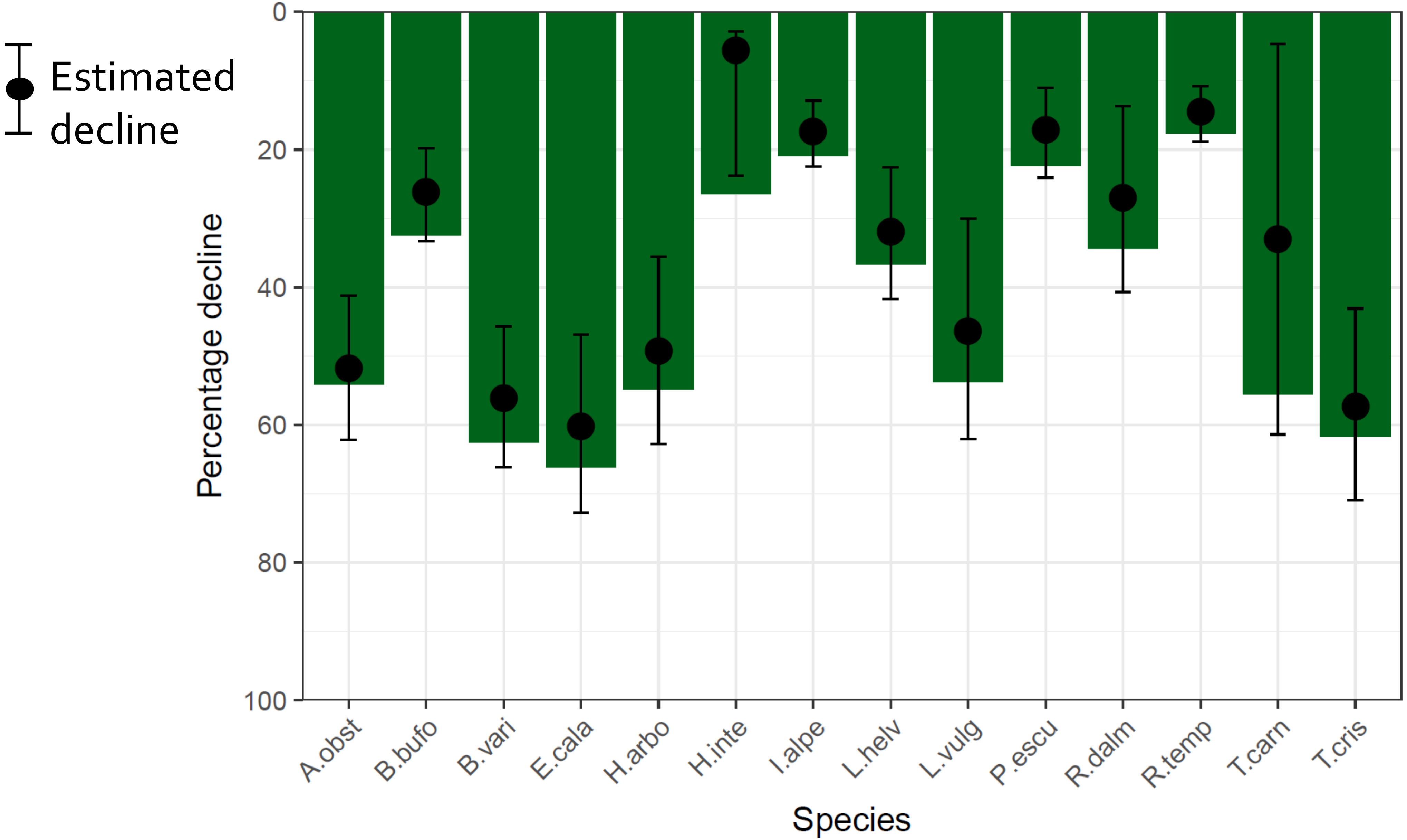
Imperfect detection is the rule



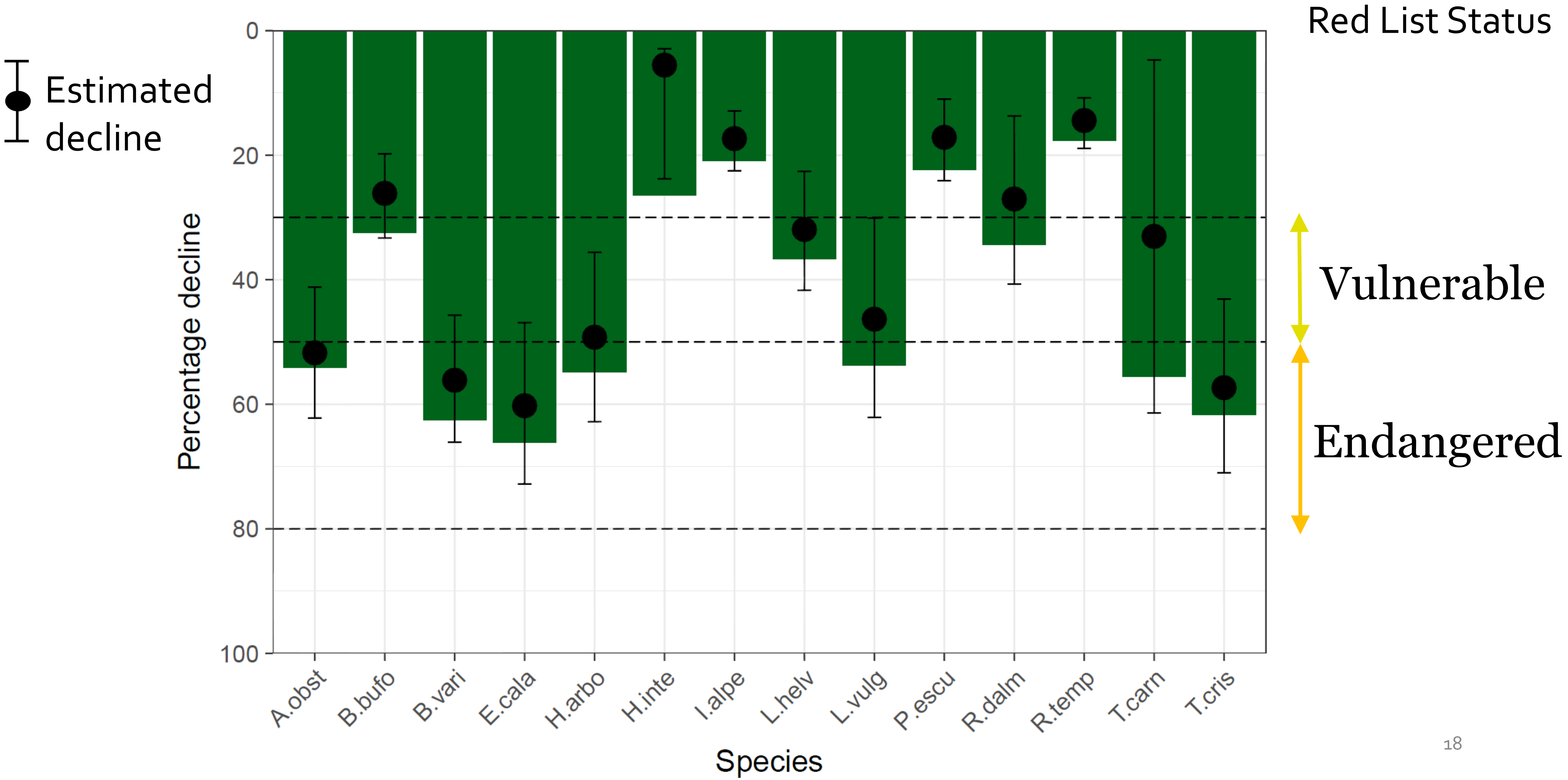
Observed decline



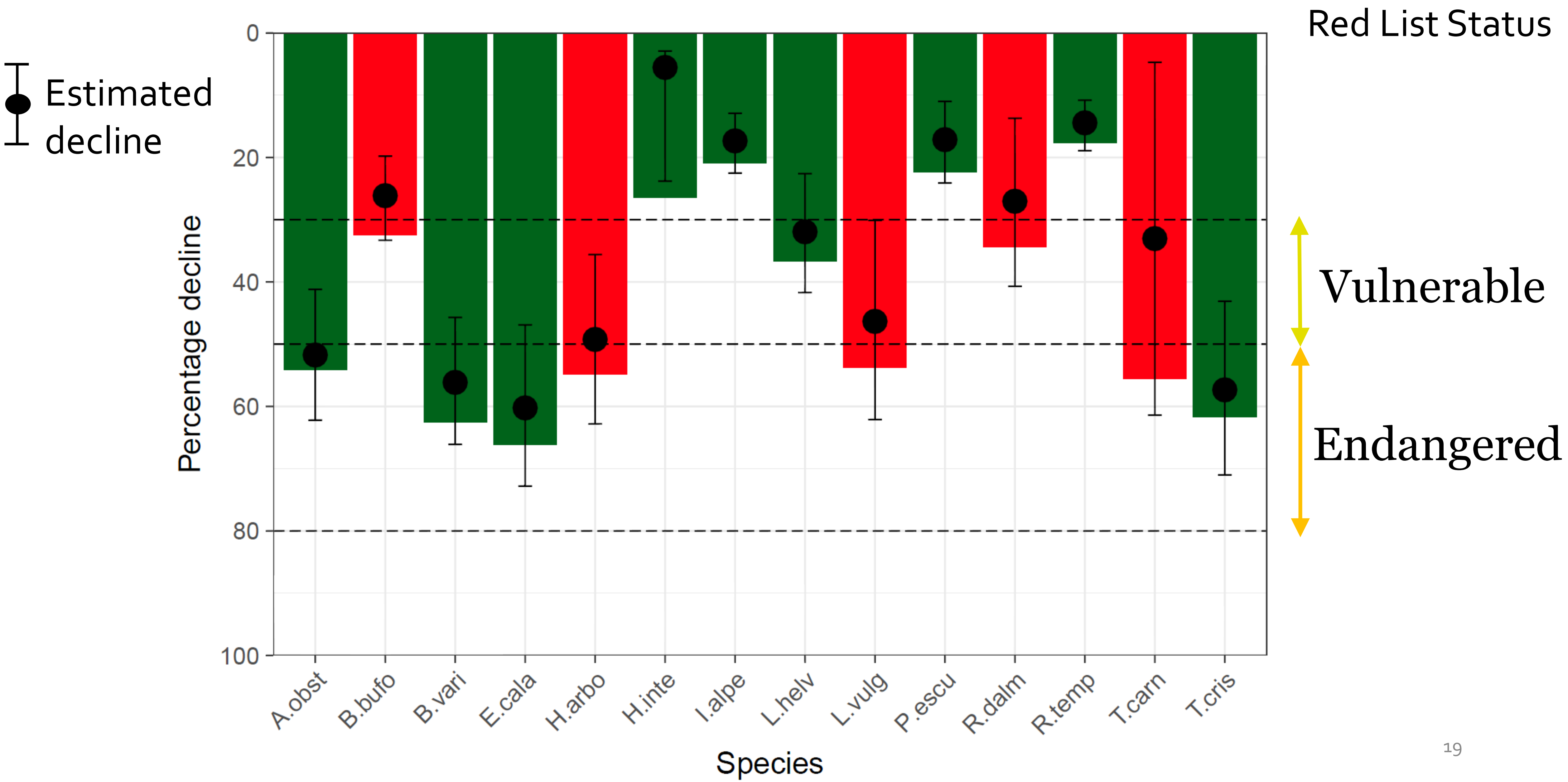
Observed and estimated decline



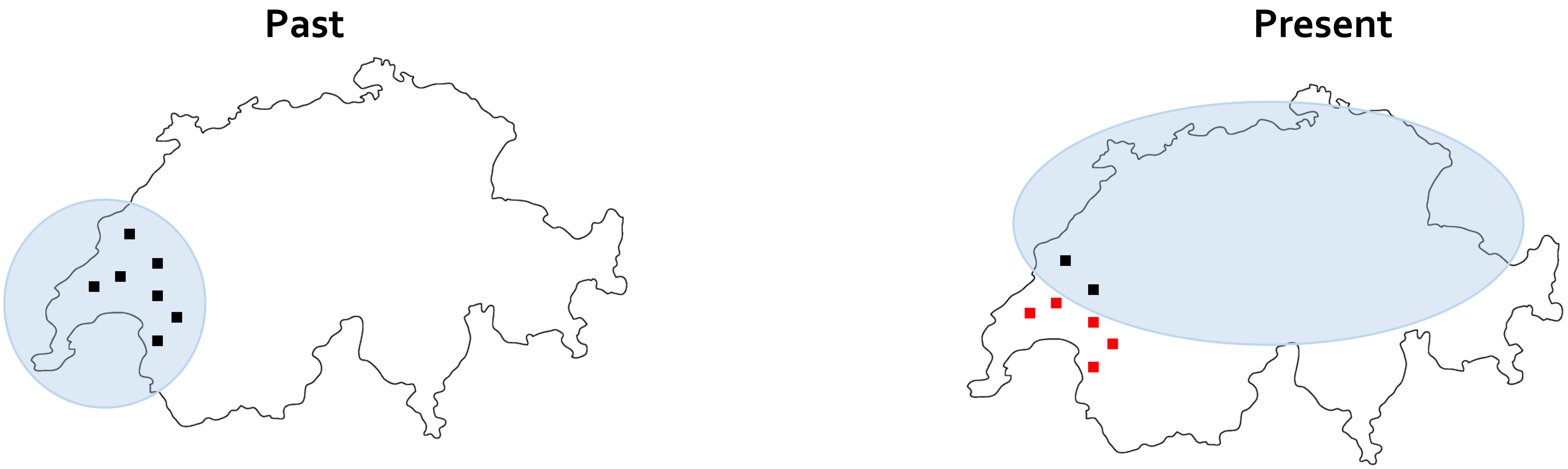
Observed and estimated decline



Red List Status



Baselines needed to incorporate turnover



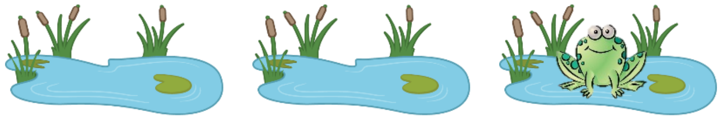
- Revisitation studies can't allow for colonisation
  - Problem: this is how things are normally done!
- Ignoring detection easily leads to negative conservation impacts
- Recording survey effort to infer absence is essential

Cruickshank *et al.* (2016) Conservation Biology

Part Two

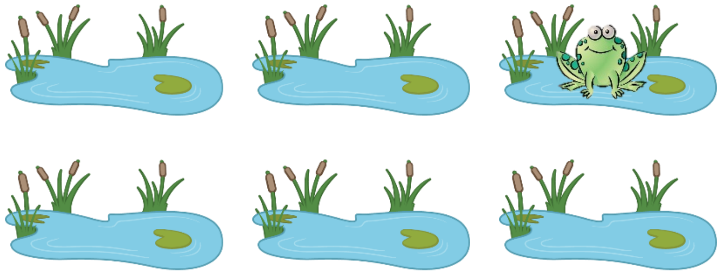
How can we tell if a species isn't there?

The problem….



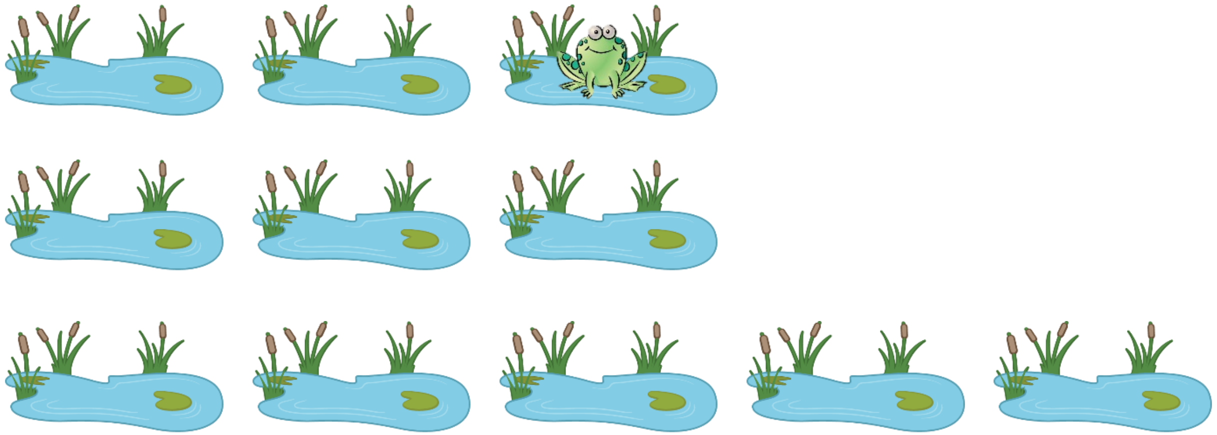
Observation History	Occupied?
001	✓

The problem….



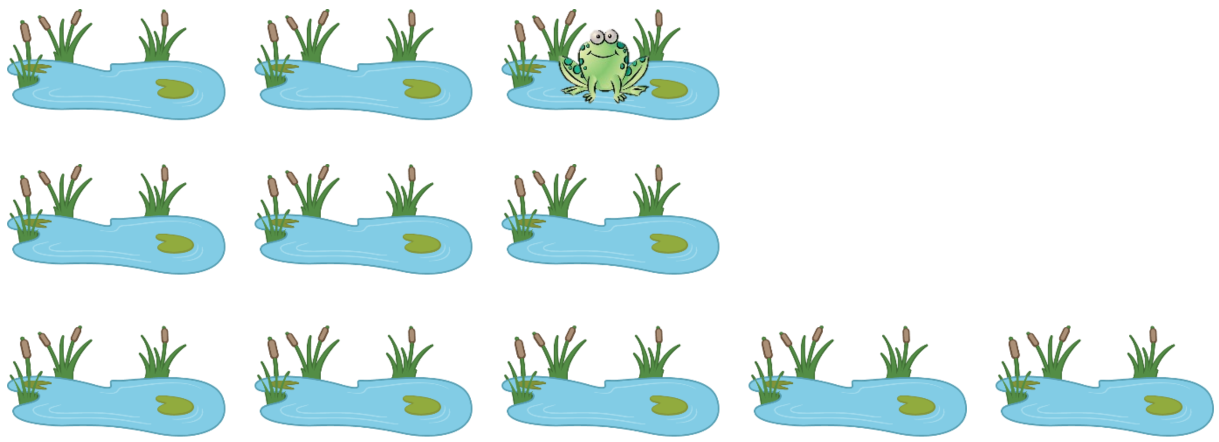
Observation History	Occupied?
001	✓
000	?

The problem….



Observation History	Occupied?
001	✓
000	?
00000	?

The problem….



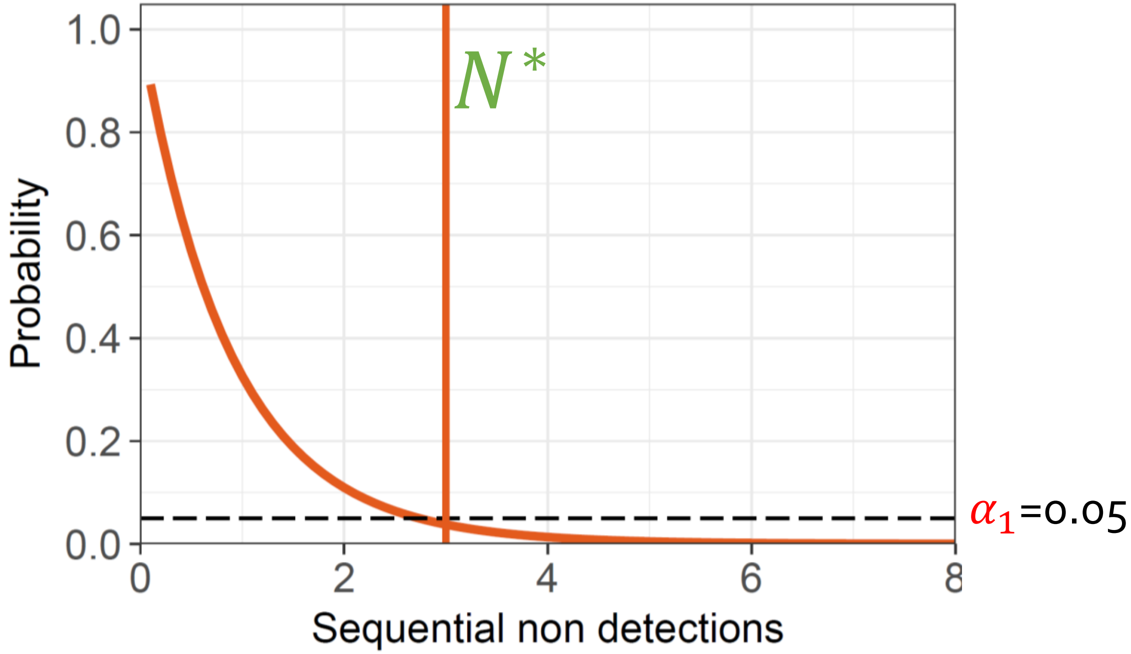
Observation History	Occupied?
001	✓
000	?
00000	?

Question:

How many non-detections is enough to be sure?

McArdle 1990 Oikos

Simple guidance: 1-parameter



$$P(undetected|occupied) = 1-(1-p)^N$$

$$N^* = \frac{log(1-\alpha)}{log(1-p)}$$

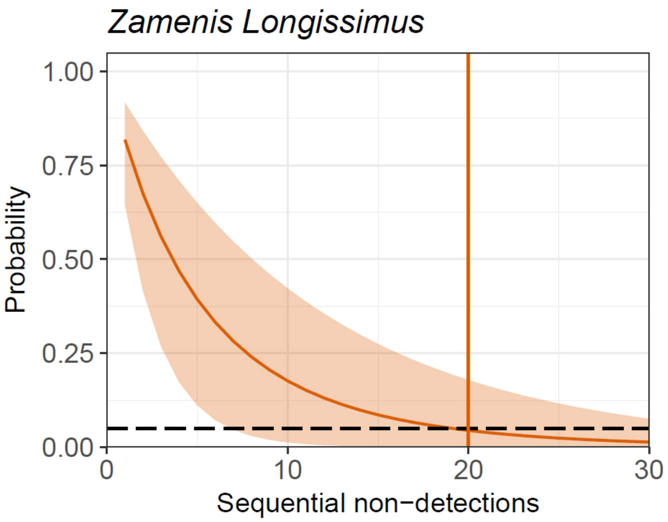
Data collection

- 12 reptile species
- 294 1km² quadrats
- 1-3 visits

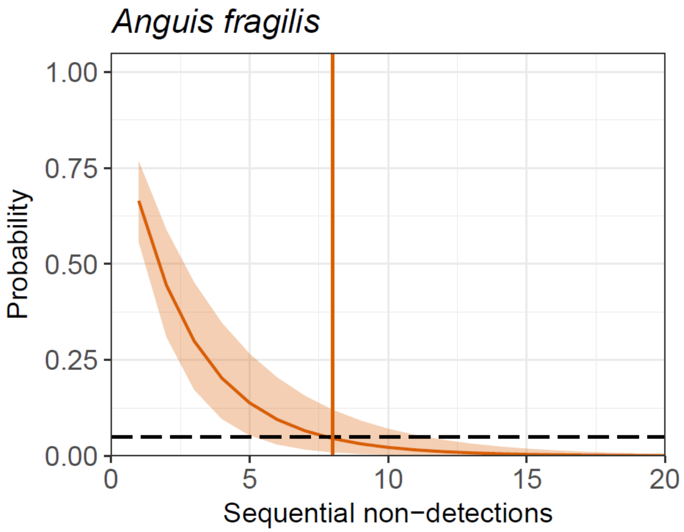
Occupancy models → Detection probability

Examples: Reptile species

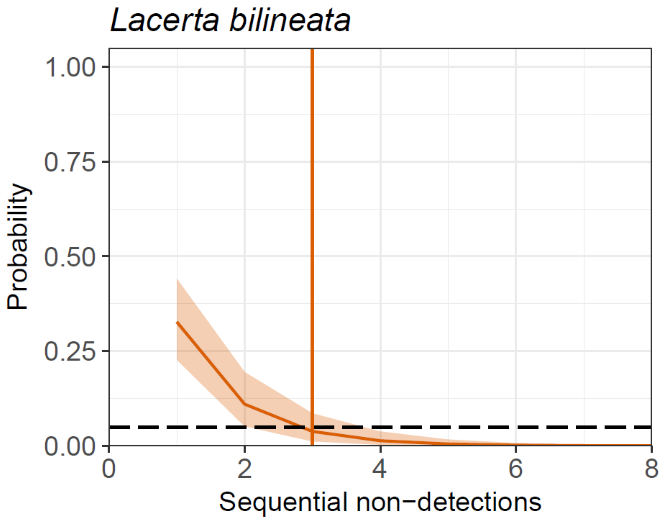
Detection: 0.184

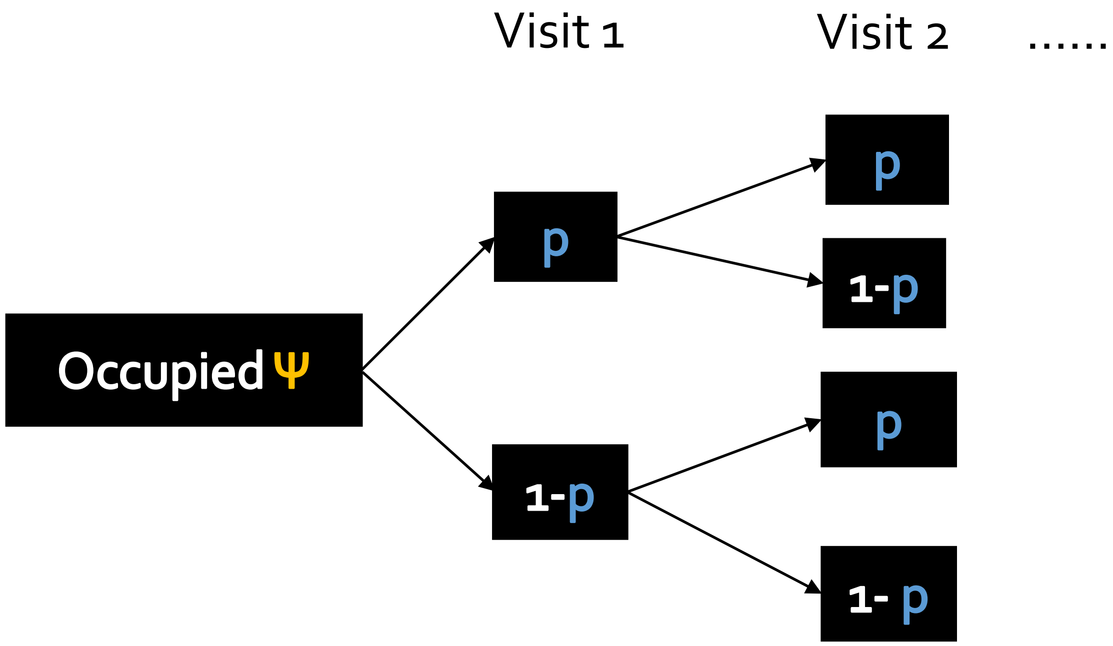


Detection: 0.336



Detection: 0.675





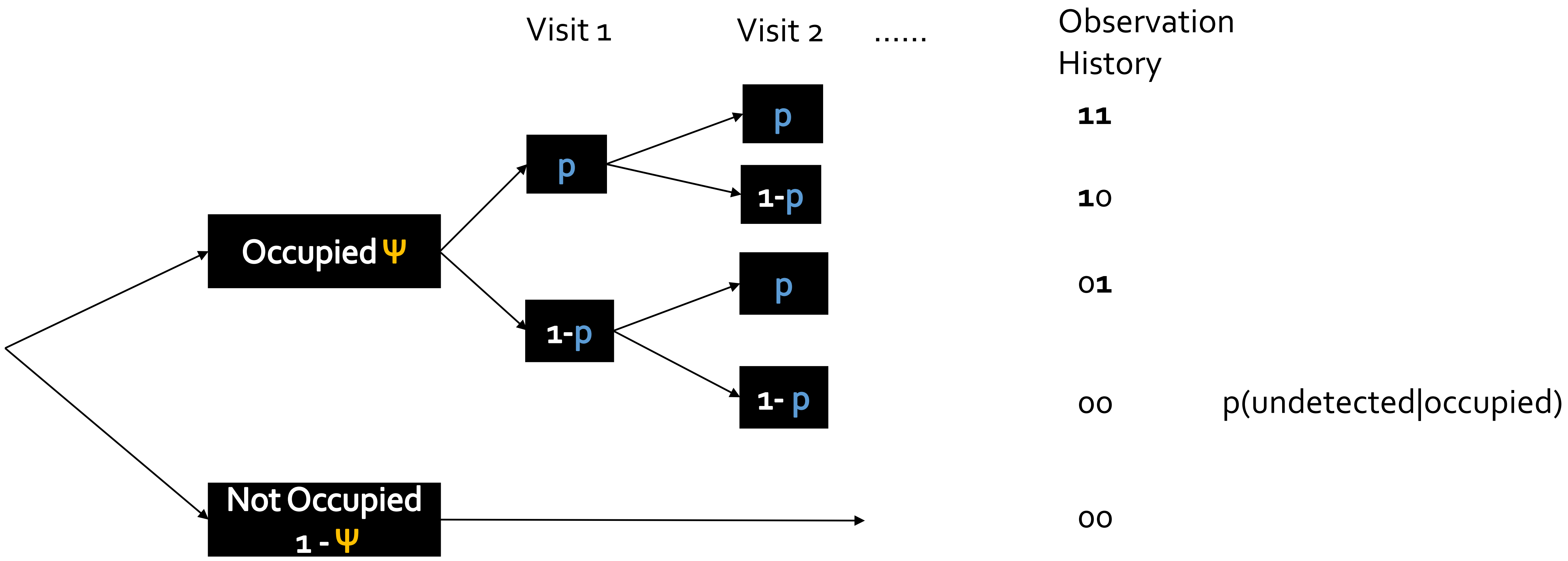
Observation History

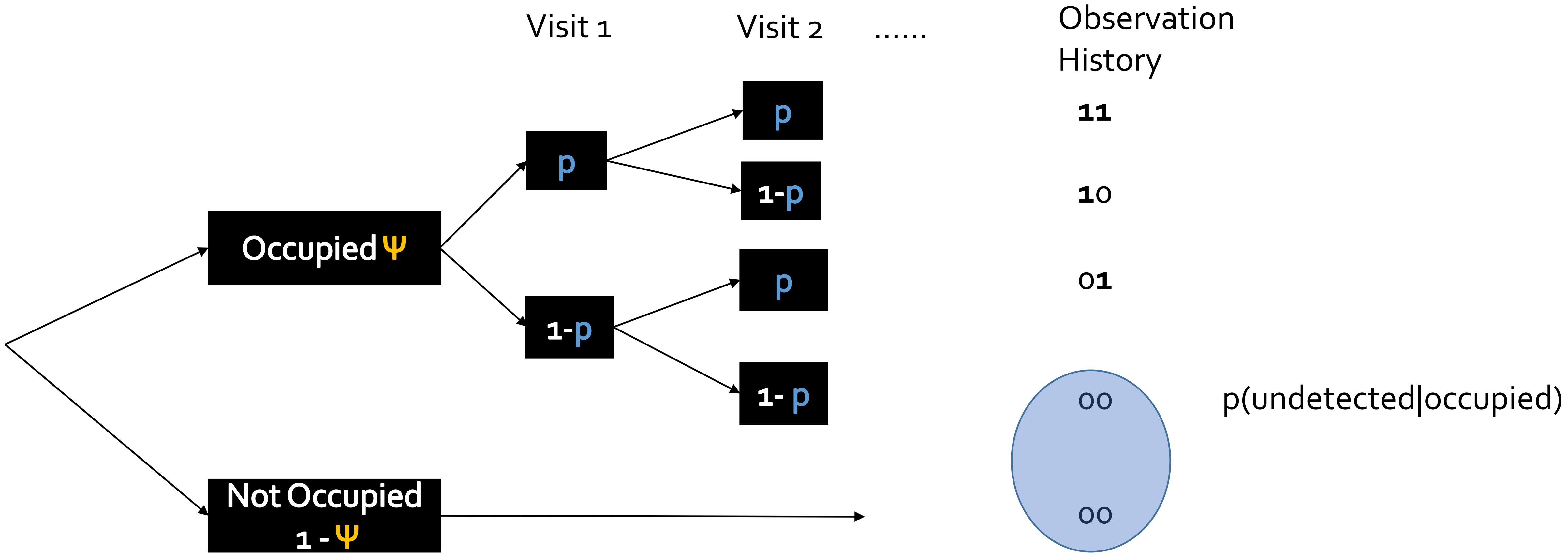
11

10

01

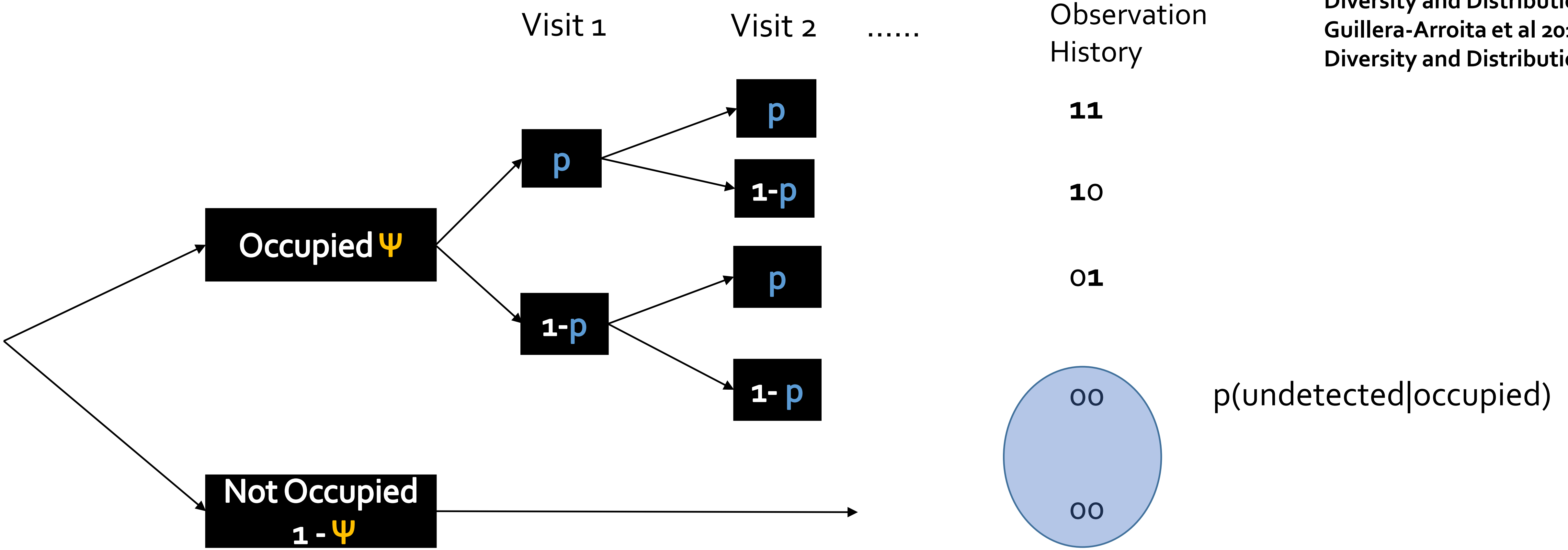
00 p(undetected|occupied)


Visit 1
Visit 2
......
Observation History
Occupied Ψ
p
1-p
p
1-p
p
1- p
Not Occupied 1 - Ψ
11
10
01
00
p(undetected|occupied)
00



Visit 1
Visit 2
……
Observation History
Occupied Ψ
Not Occupied 1 - Ψ
p
1-p
p
1-p
p
1- p
11
10
01
00
00
p(undetected|occupied)

Wintle et al 2012
Diversity and Distributions
Guillera-Arroita et al 2015
Diversity and Distributions



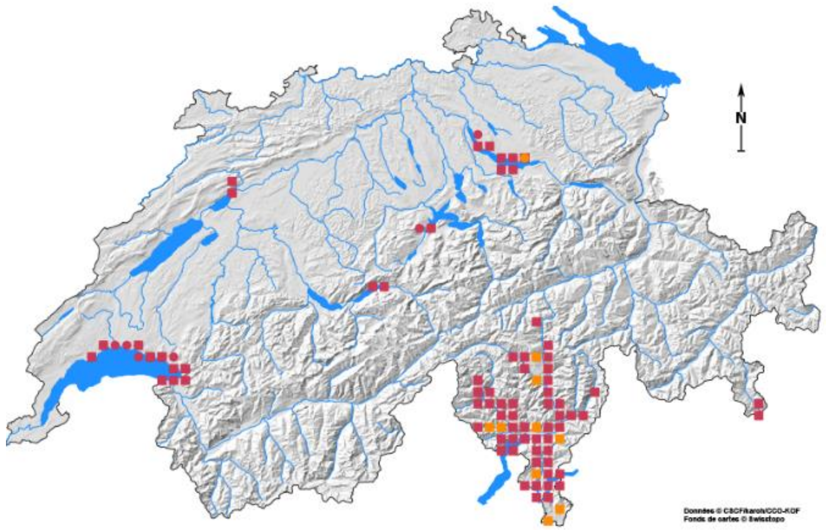
$$P(occupied|undetected) = \frac{\psi(1-p)^N}{\psi(1-p)^N + (1-\psi)}$$

$$N^* = \frac{log\left(\frac{1-\psi}{\psi} \cdot \frac{\alpha}{1-\alpha}\right)}{log(1-p)}$$

Prevalence estimates

- 12 reptile species

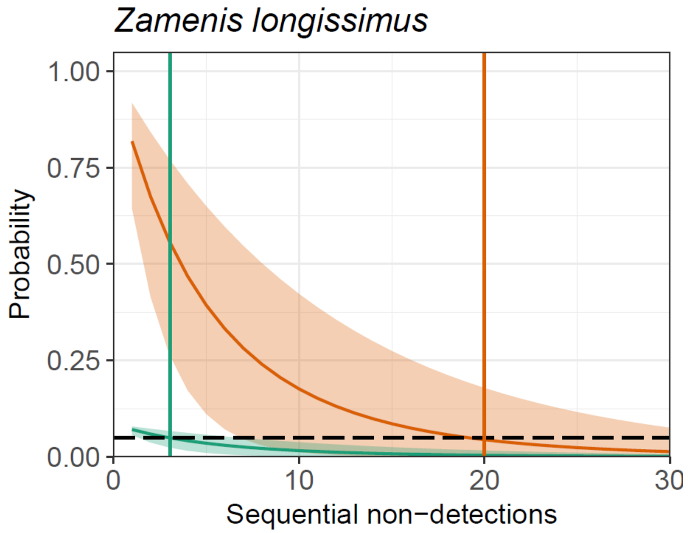
1. Amount of suitable habitat
2. Look at KARCH observation records
3. Calculate proportion of 5x5 km grid squares



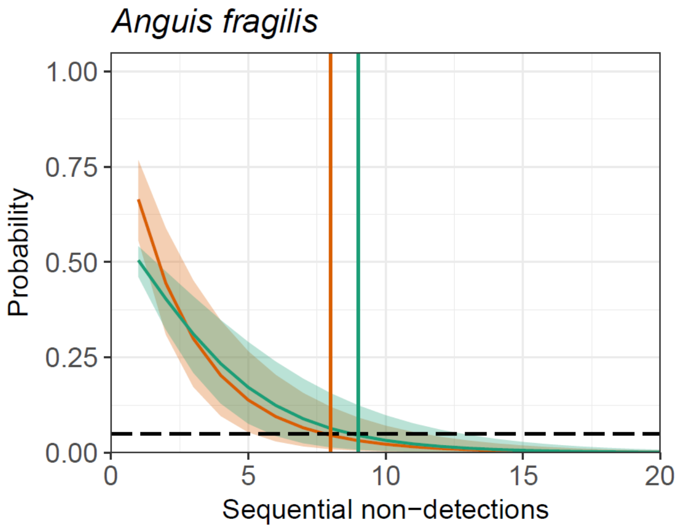
Recommendations

Framework
1-parameter
2-parameter

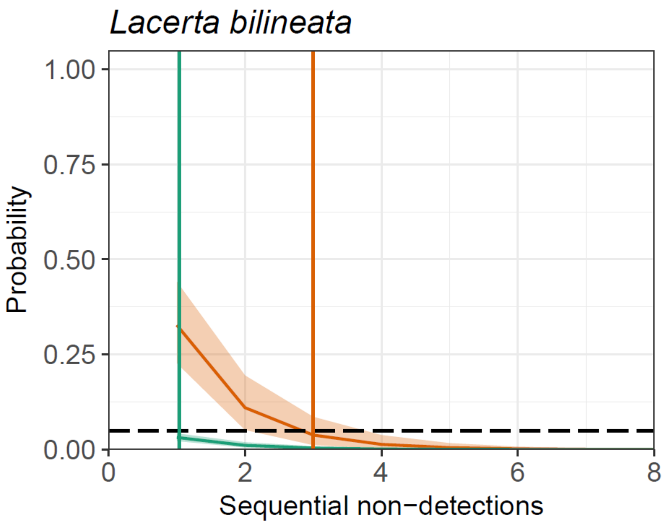
Detection: 0.184
Prevalence: 8.5%



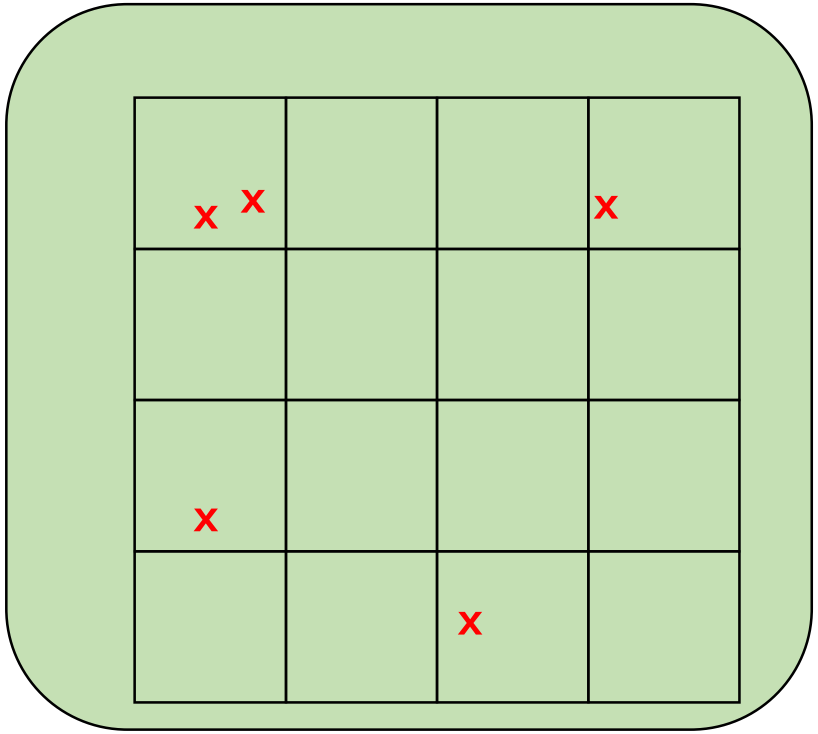
Detection: 0.336
Prevalence: 60.6%



Detection: 0.675
Prevalence: 62.1%

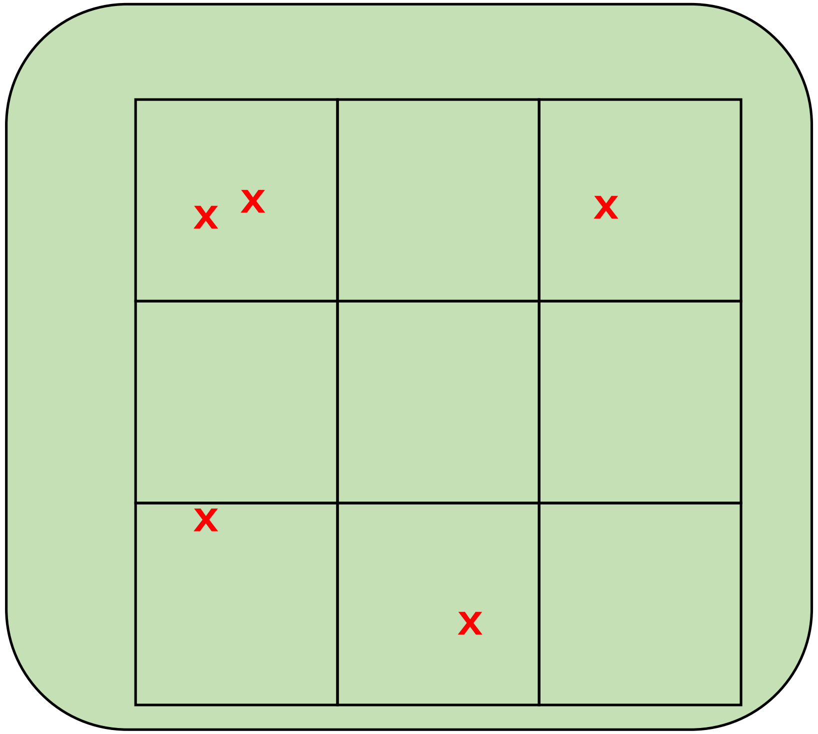


Estimating prevalence



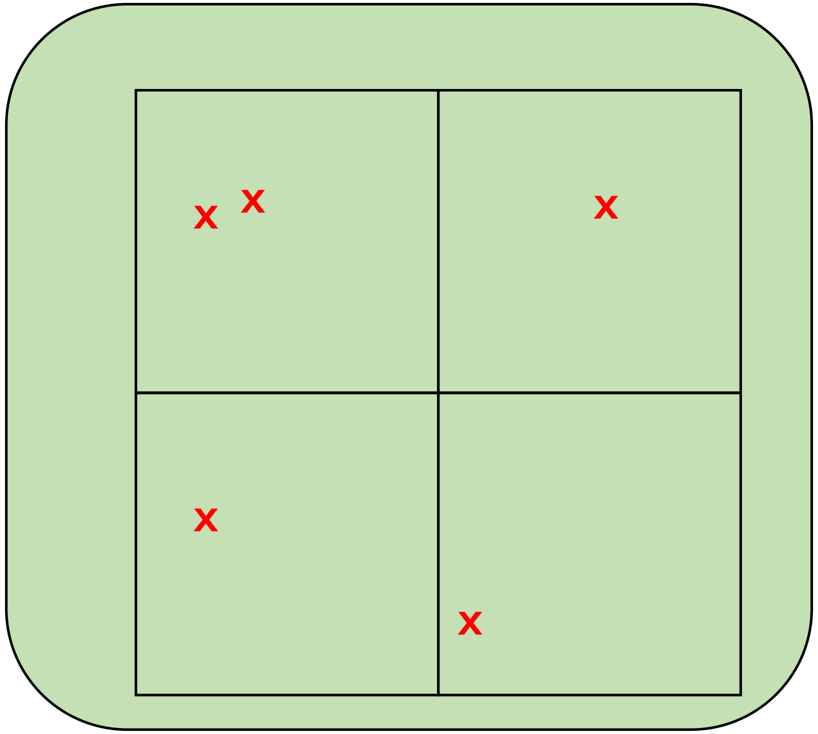
$$\frac{4}{16} = 25\%$$

Estimating prevalence

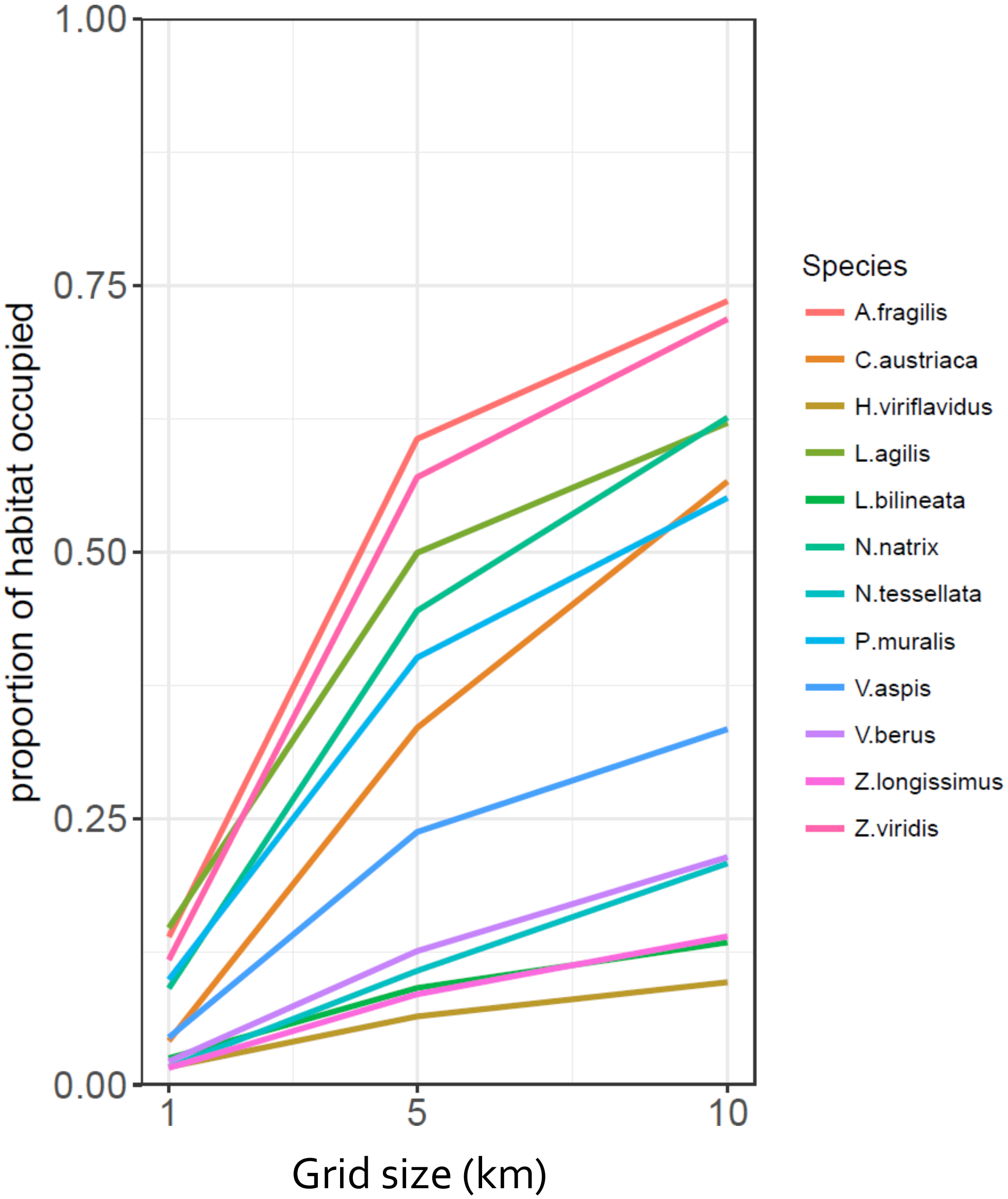


$$\frac{4}{9} = 44\%$$

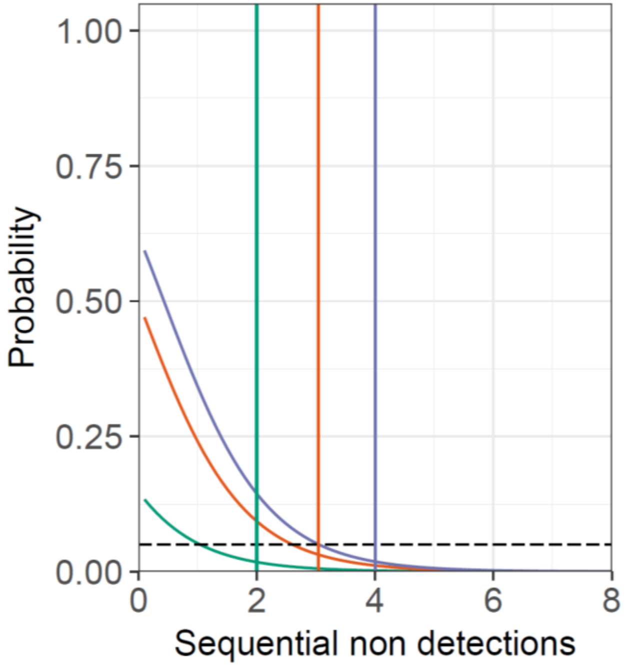
Estimating prevalence

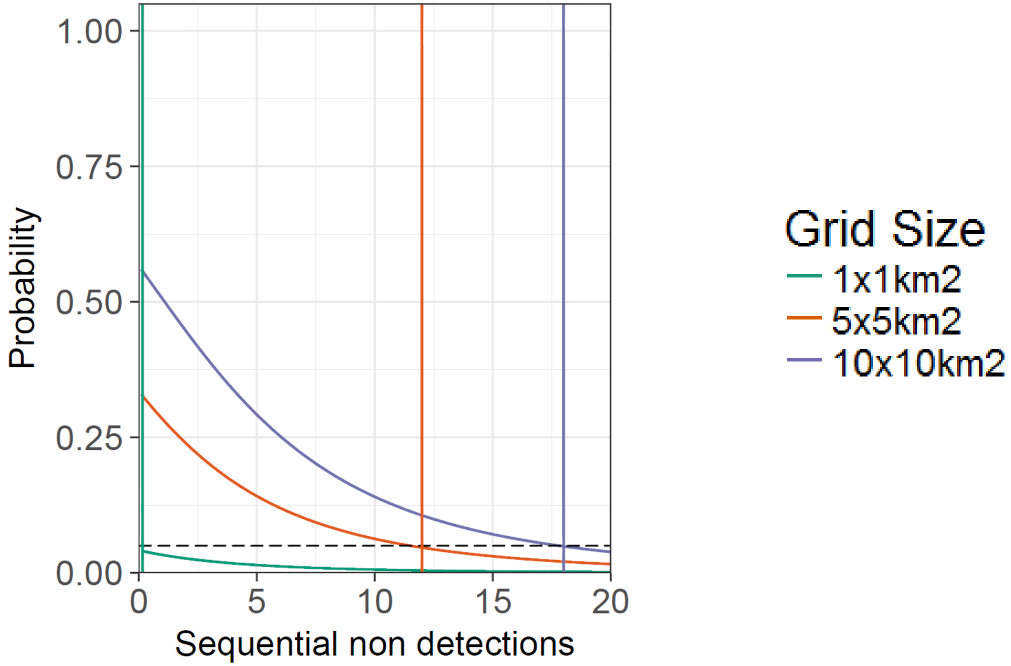


$$\frac{4}{4} = 100\%$$



What if we don’t use an appropriate scale?





- For many species…resolution makes **large** differences
- Unless meaningful scale is obvious, may be better to ignore prevalence
- If prevalence is very low, don’t bother surveying…..

Implications for monitoring

- Wide-scale surveys of rare species won’t work
- Non-detections for hard-to-detect species don’t provide much information
- Expectation of species prevalence is important, but may muddy the waters

Part Three

Quantifying data quality in volunteer-collected monitoring

Are volunteer data *really* low quality?

Assessing data quality

1. Imperfect detection

2. False-positive errors

Incorporating false positives?

Site	Occupied?	Visit Number					
		1	2	3	4	5	6
A	Yes	0	1	1	0	0	1
B	?	0	0	0	0	0	0
C	?	0	0	0	0	0	0
D	Yes	1	0	0	0	1	1
E	Yes	1	1	1	1	0	1
F	Yes	0	1	0	0	0	0
G	?	0	0	0	0	0	0

Incorporating false positives?

Site	Occupied?	Visit Number					
		1	2	3	4	5	6
A	?	0	1	1	0	0	1
B	?	0	0	0	0	0	0
C	?	0	0	0	0	0	0
D	?	1	0	0	0	1	1
E	?	1	1	1	1	0	1
F	?	0	1	0	0	0	0
G	?	0	0	0	0	0	0

Possible Solutions:	**Option 1**	**Option 2**
Occupancy	57%	0%
Detection probability	50%	0%
False positive rate	0%	29%

Incorporating false positives?

Site	Occupied?	Visit Number					
		1	2	3	4	5	6
A	?	0	1	1	0	0	1
B	?	0	0	0	0	0	0
C	?	0	0	0	0	0	0
D	?	1	0	0	0	1	1
E	?	1	1	1	1	0	1
F	?	0	1	0	0	0	0
G	?	0	0	0	0	0	0

Possible Solutions:	**Option 1**	**Option 2**
Occupancy	57%	0%
Detection probability	50%	0%
False positive rate	0%	29%

Solutions (single season):

1. Constrain pF (false-positive rate) **Royle & Link 2006 Ecology**
2. Use ‘confirmed’ detections **Miller et al. 2011 Ecology**
Chambert et al. 2015 Ecology

Dynamic models pose greater issues:

e.g. :

Year 1	Year 2
1	1

- pT, persist, pT
- pT, extinction, pF
- pF, colonisation, pT
- pF, no colonisation, pF
- …
- …
- …
- …

Solutions and simulations

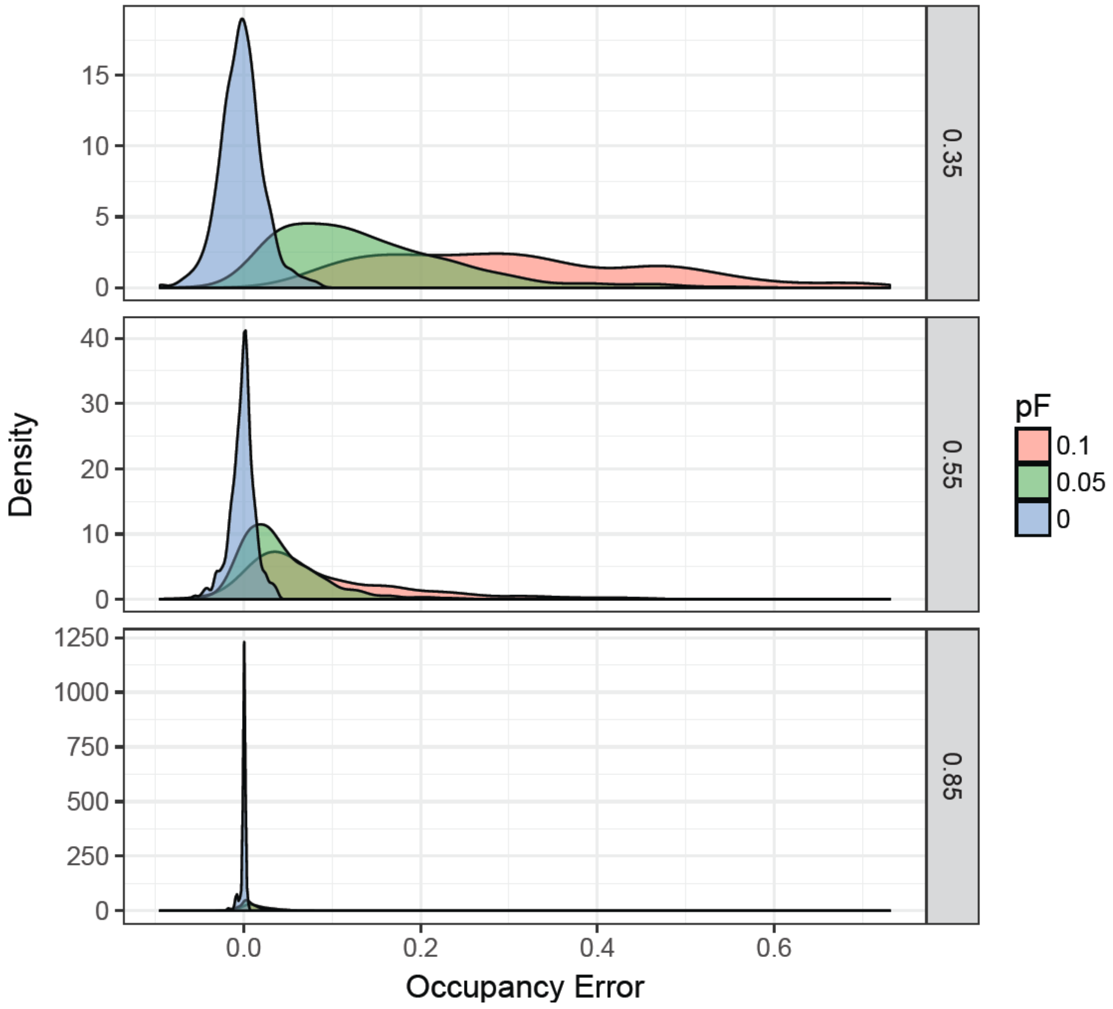
Combination of:

- Confirmed detections
- Informative priors

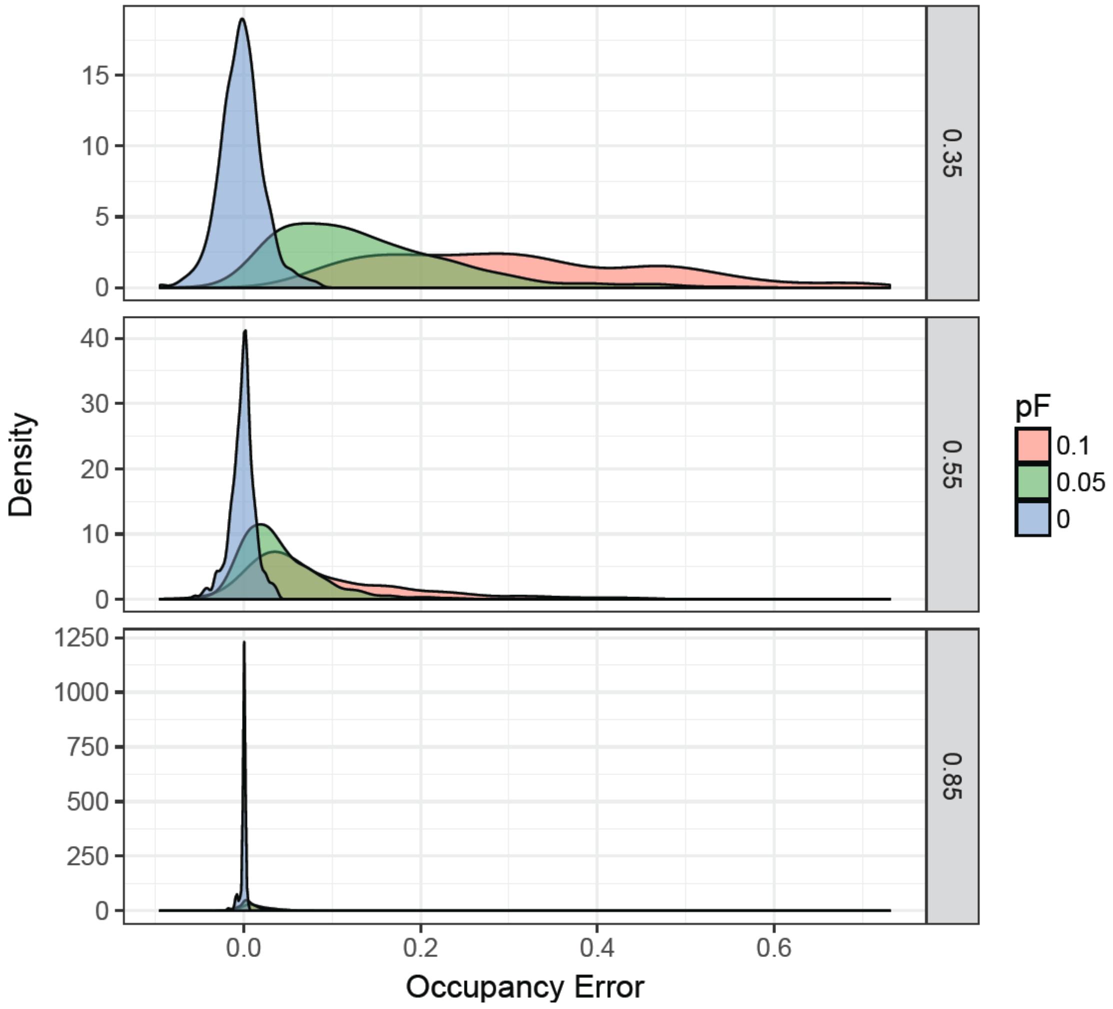
Testing needed:

- Simulated many datasets
  - Different detection rates
  - Different dynamic rates
- How well does the model perform?

Simulation study



Simulation study



- Occupancy well estimated unless:
  - Detection is low (<50%) **AND**
  - False-positive rates are high (>5%)

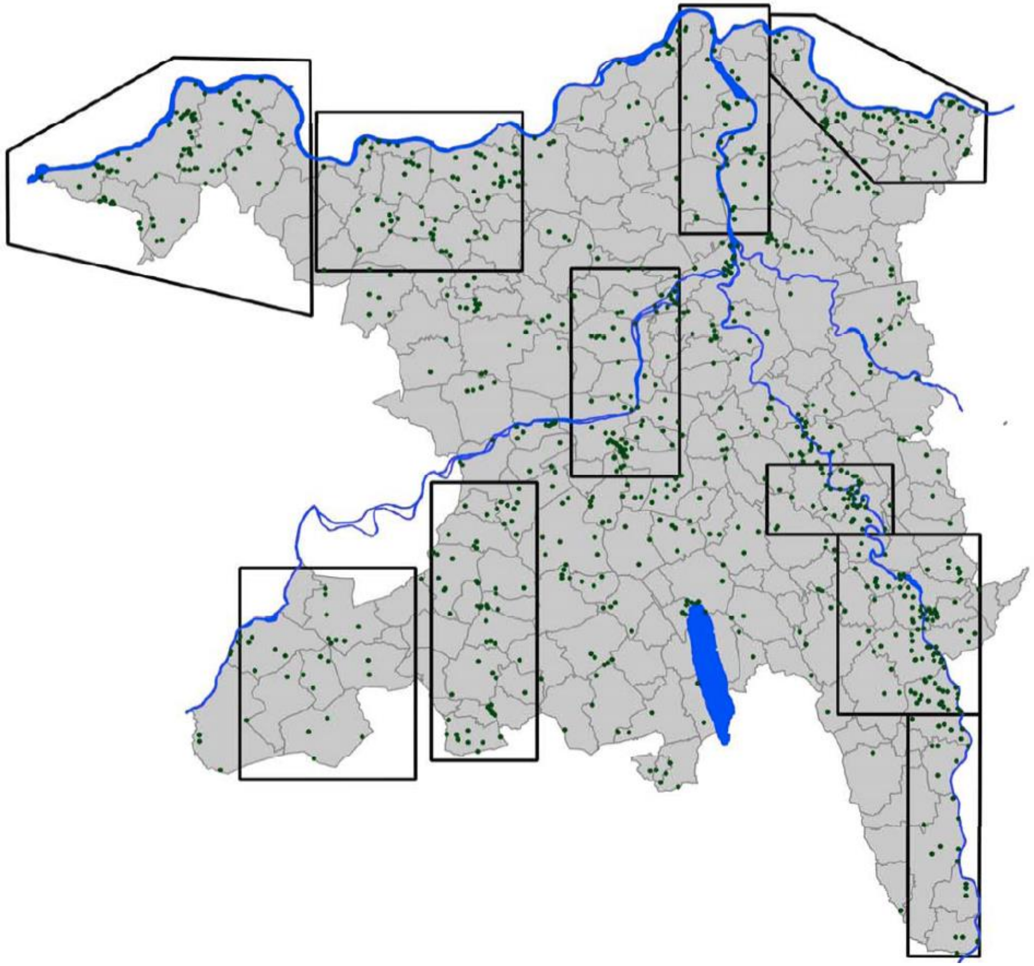
- Few ‘confirmed’ observations needed

Aargau dataset

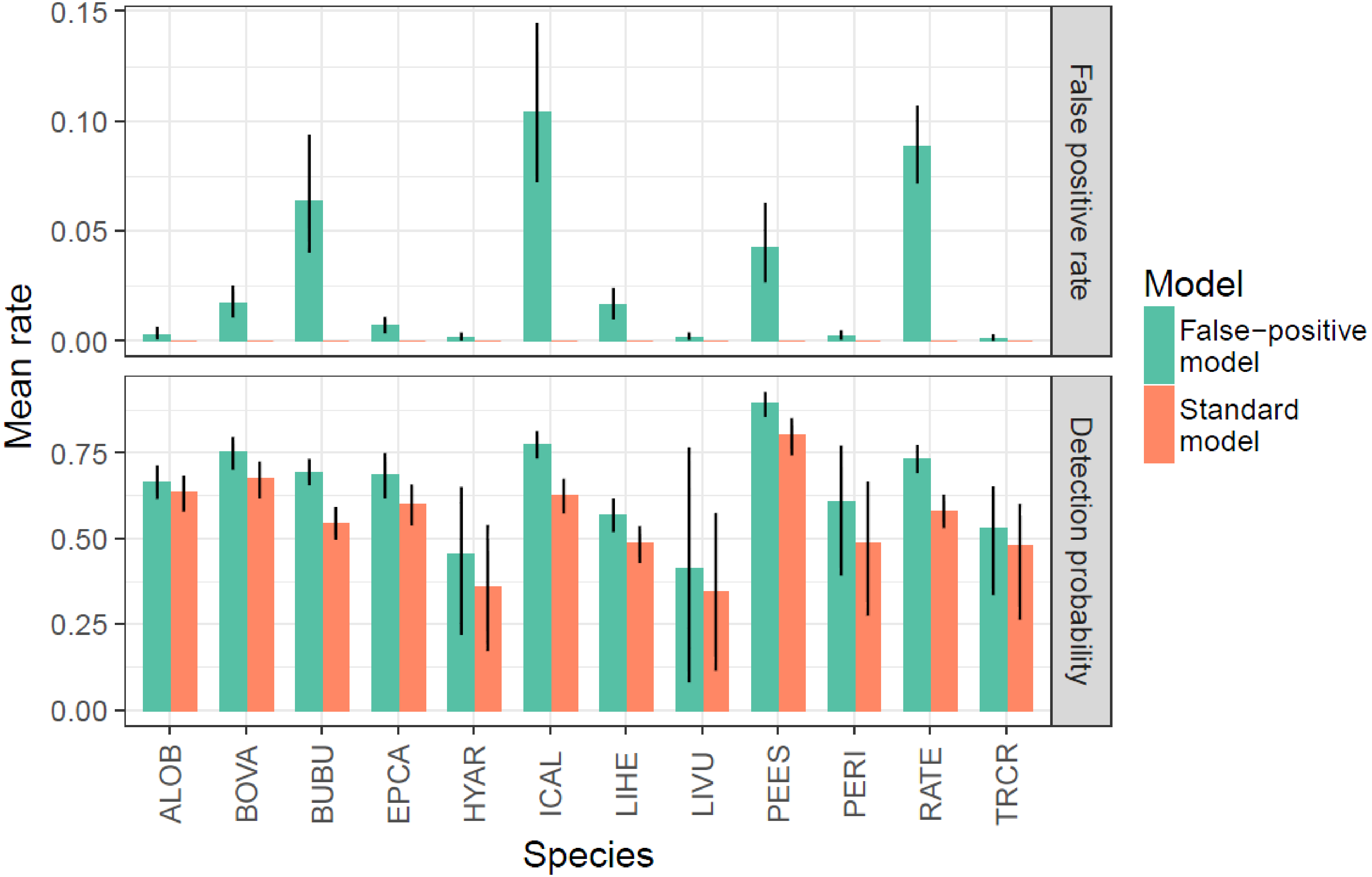
- Volunteer data
- 10 areas/ 650 sites
- 15 years
- 3 observations/year
- 12 Species

Applied:

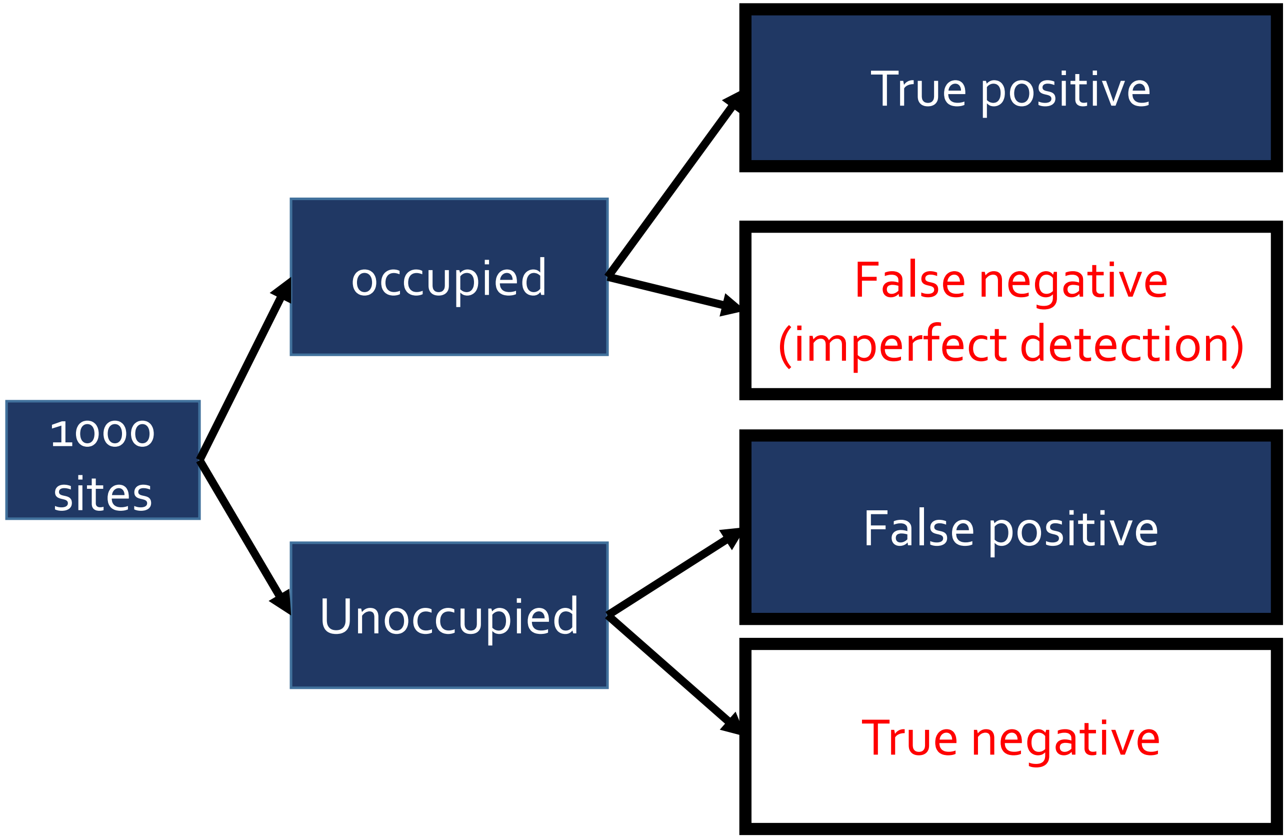
1. False-positive occupancy model
2. Standard occupancy model
   - ➢ Compare results



Detection rates

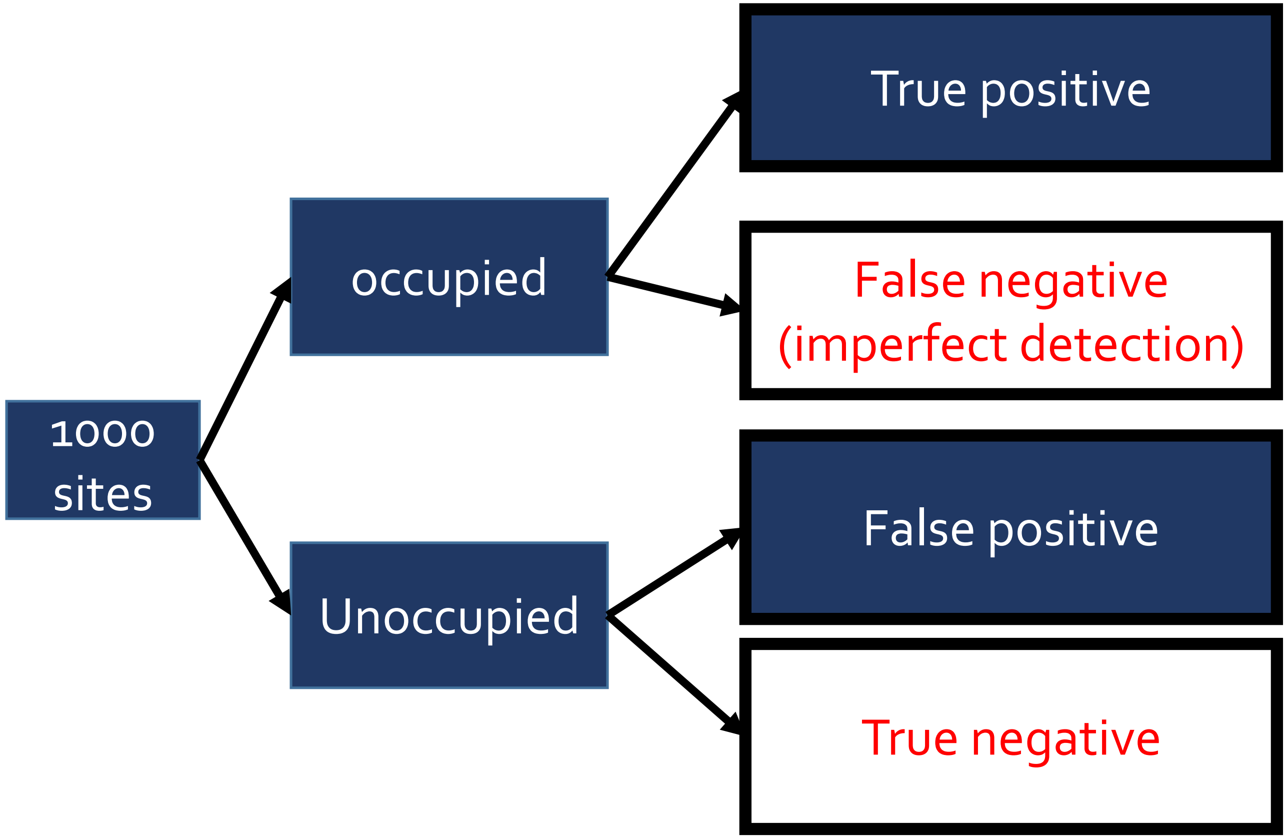


Consequences of false positives



Consequences of false positives

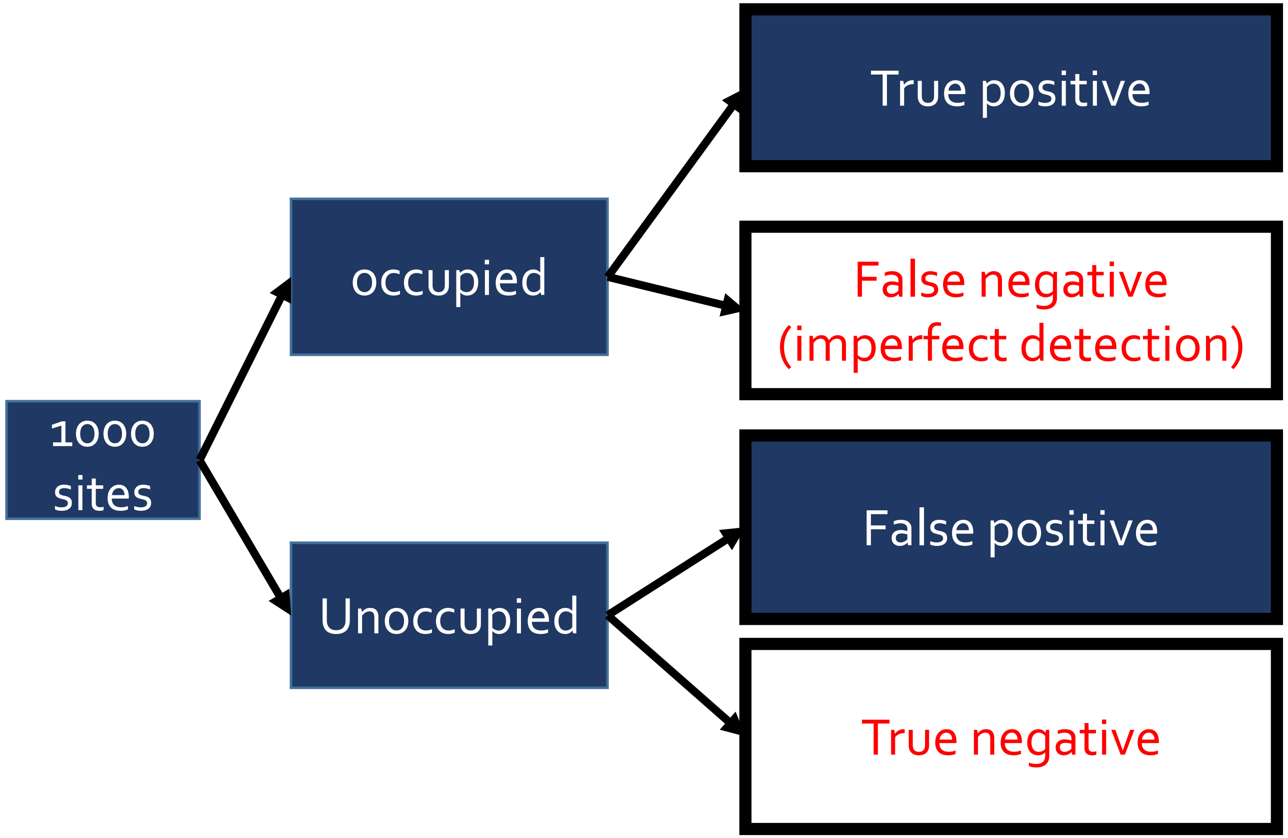
Detection probability: 75%
False-positive rate: 10 %



Consequences of false positives

Detection probability: 75%
False-positive rate: 10 %

Common (Ψ=90%)



675

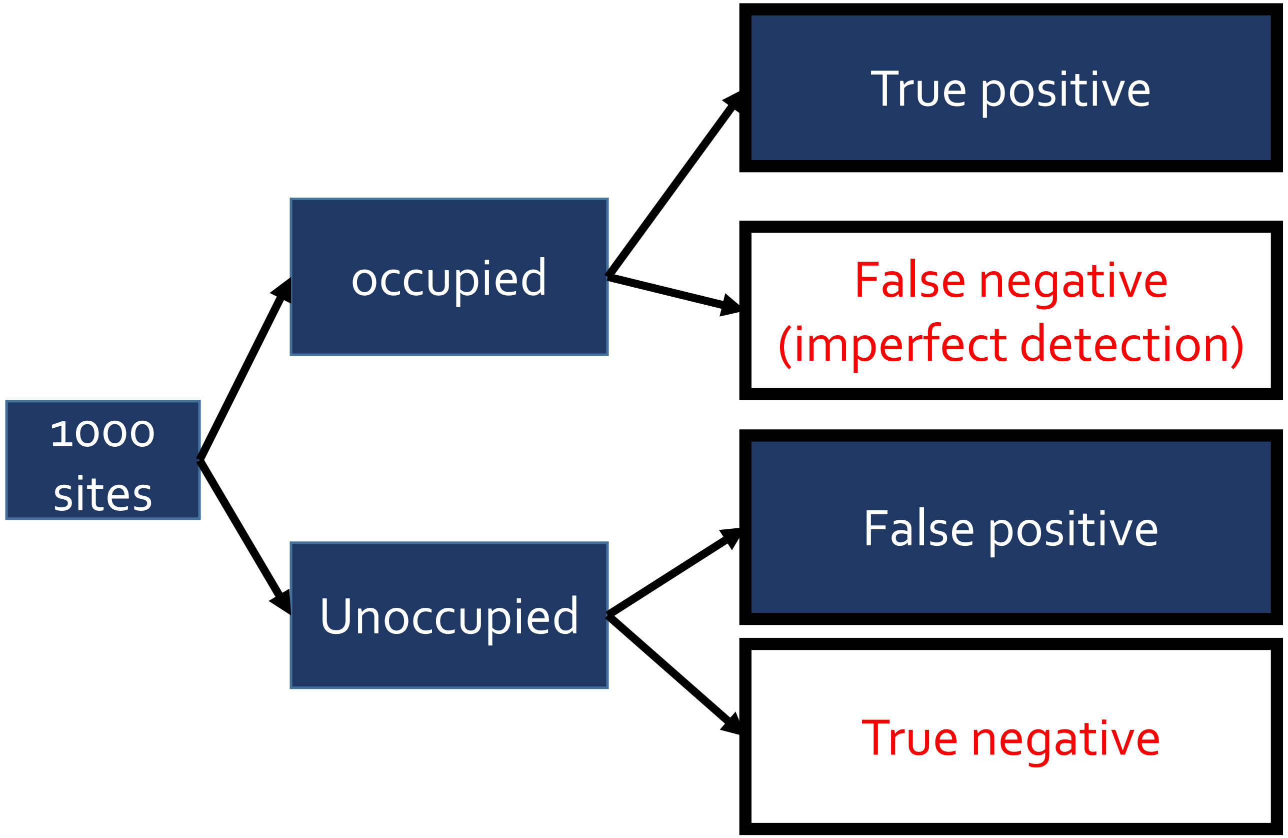
10

$\frac{10}{685}$ = 1.4%

of detections are incorrect

Consequences of false positives

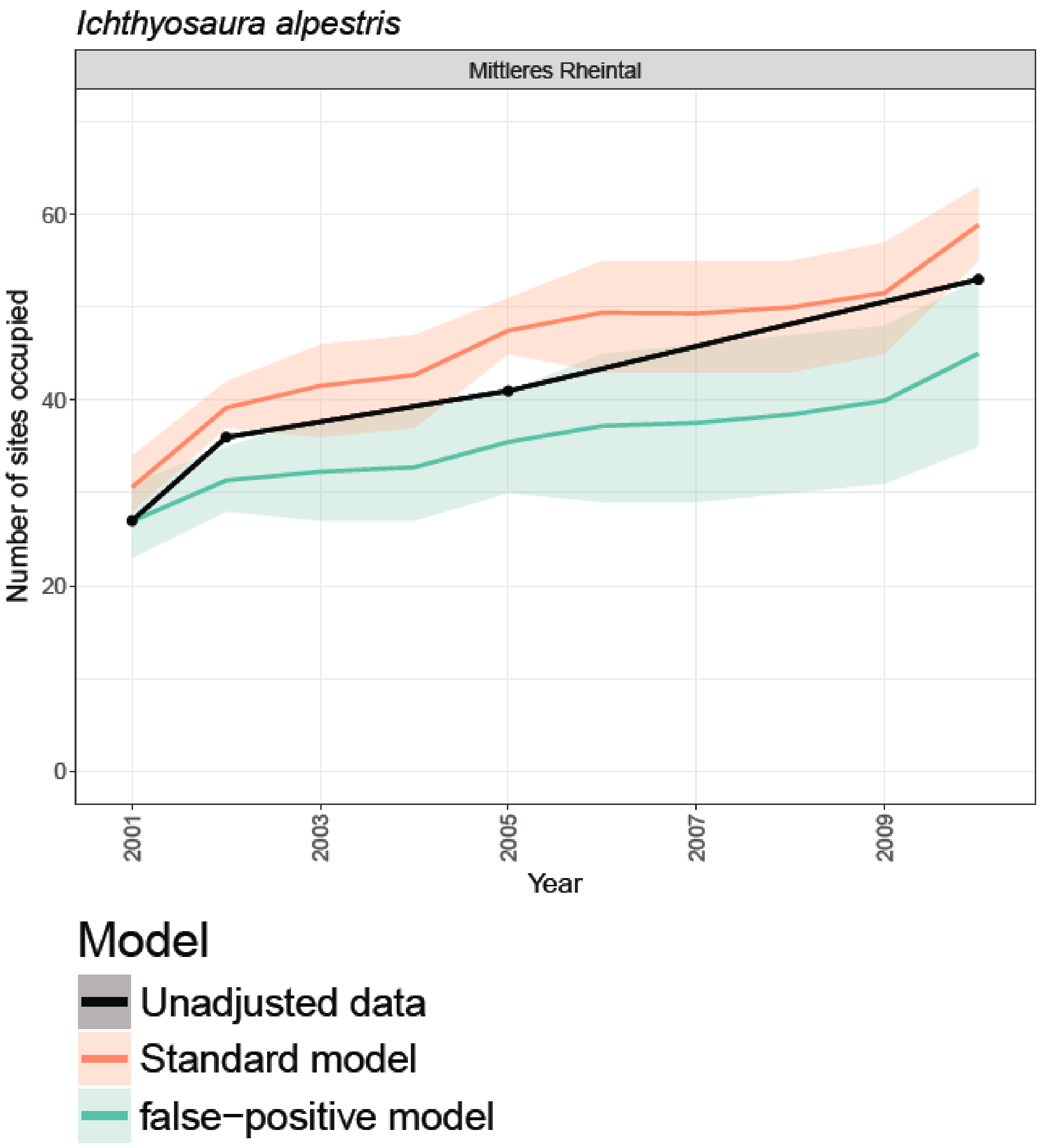
Detection probability: 75%
False-positive rate: 10 %



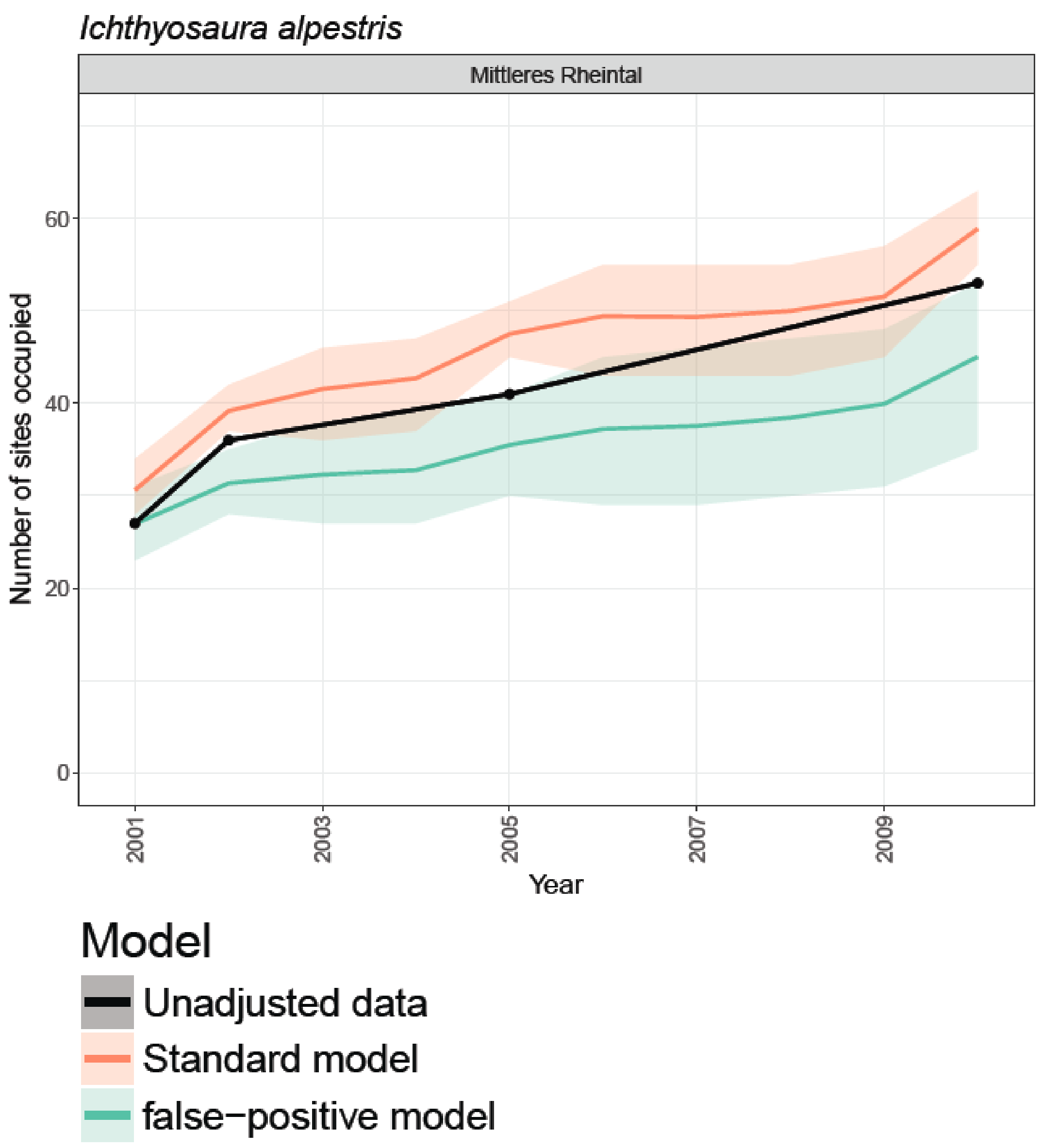
	Common (Ψ=90%)	Rare (Ψ=10%)
True positive	675	75
False positive	10	90
	$\frac{10}{685}$ = 1.4%	$\frac{90}{165}$ = 54.5%

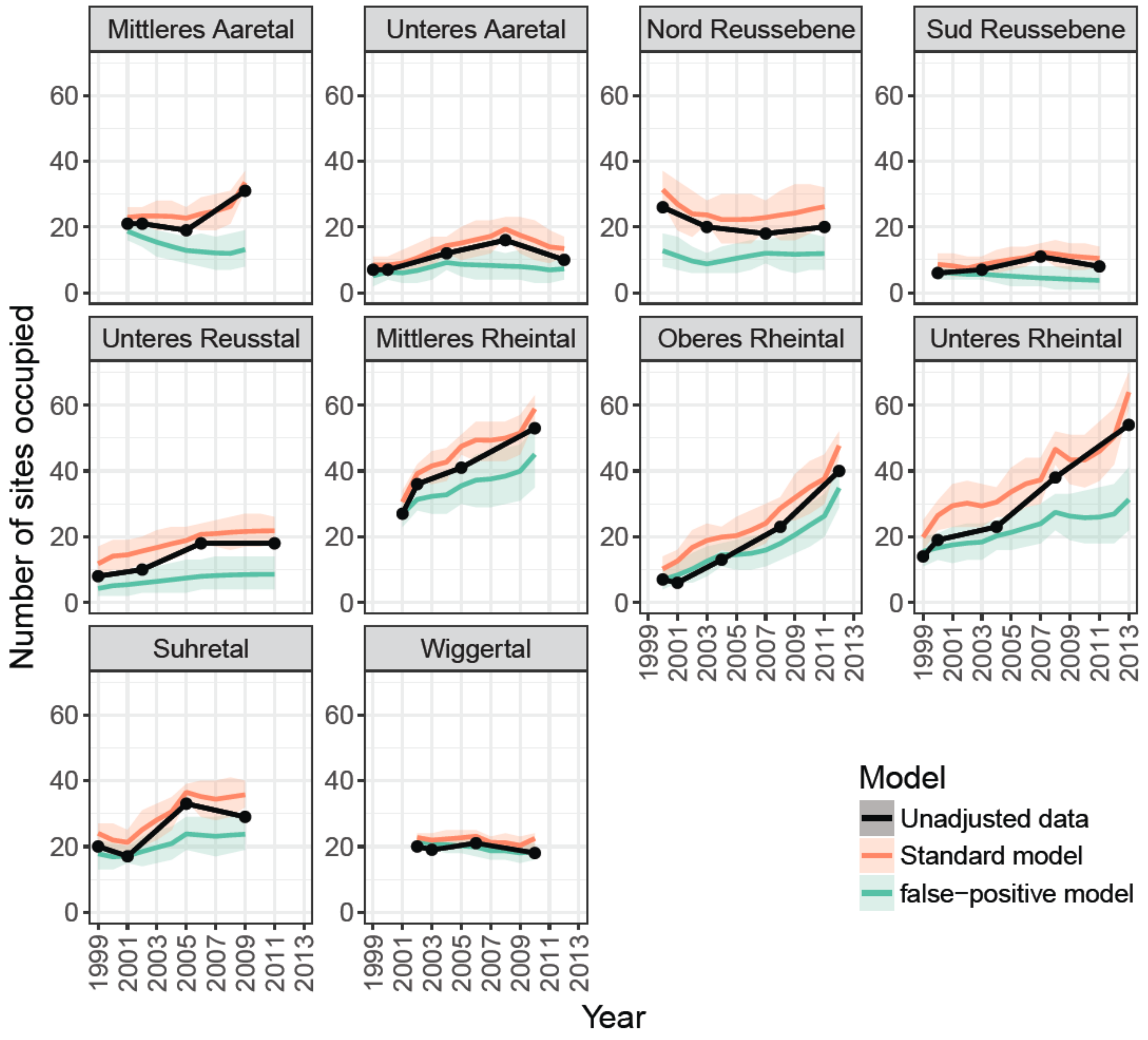
of detections are incorrect

Occupancy and trends



Occupancy and trends





Conclusions

- False-positives do exist in data
  - Don’t necessarily create issues
- False-positive errors can be accounted for
- Some differences in occupancy rates
- No significant differences in trends
- How do expert data perform….?

General summary

Part 1

Imperfect detection: important and un-ignorable!

Part 2

Identifying where species aren't is important

Part 3

Volunteers are a great resource for monitoring

Outlook

- Citizen science likely to play an increasingly important role
  - Apps make it easier (e.g. eBird, iNaturalist)
  - Spatial biases

- Environmental DNA increasingly being used
  - Comes with its own errors

- Statistical fixes are possible
  ....but always better to think carefully and minimise errors in the first place

Acknowledgements

Supervision:





Fieldwork:

+ Volunteers!

Genetics:

Advice:

Data:

info fauna karch

info fauna CSCF

Funding:

Bundesamt für Umwelt BAFU

Stiftung Artenschutz

Stiftung Claraz

Admin:


P O P E C O L

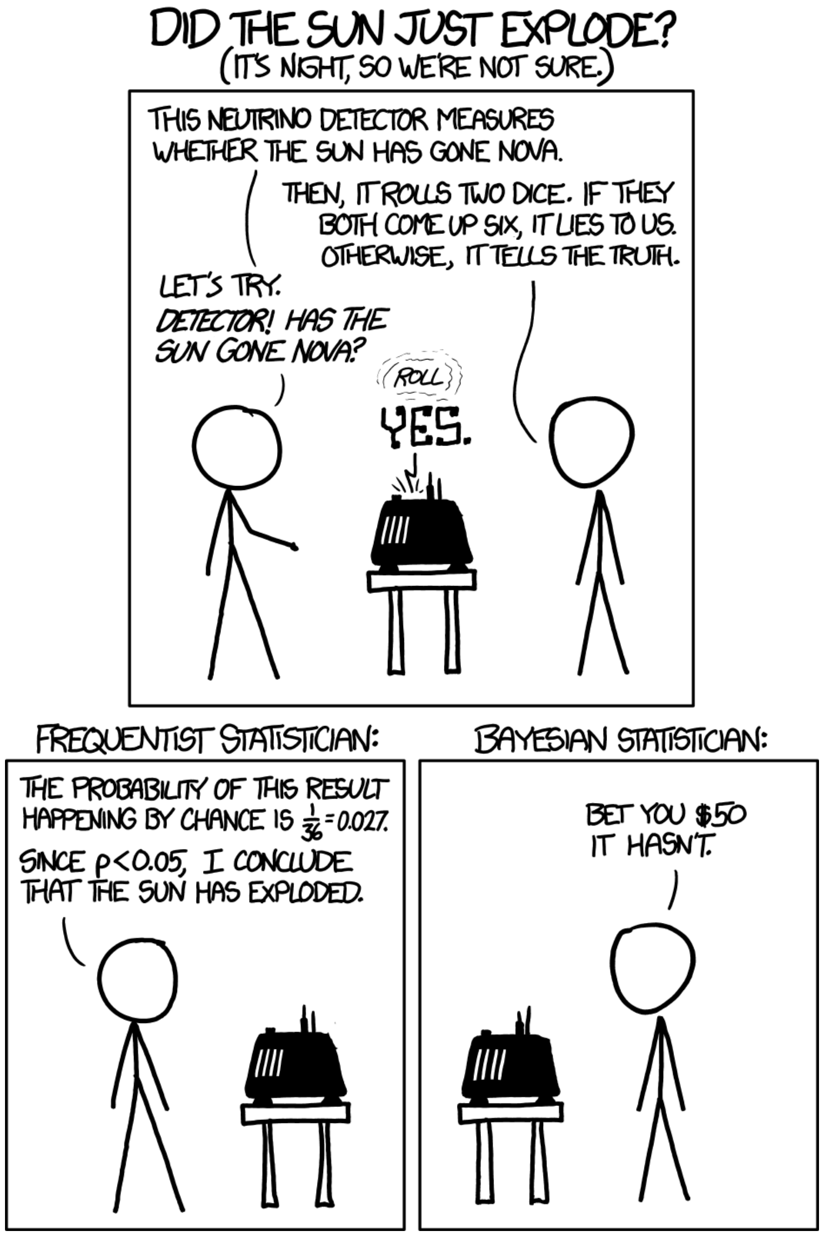

Inter Discount

Questions?

Apéro: 5:30 Orange Pony

Photo credits: Andreas Meyer





DID THE SUN JUST EXPLODE?
(IT'S NIGHT, SO WE'RE NOT SURE.)
THIS NEUTRINO DETECTOR MEASURES WHETHER THE SUN HAS GONE NOVA.
THEN, IT ROLLS TWO DICE. IF THEY BOTH COME UP SIX, IT LIES TO US. OTHERWISE, IT TELLS THE TRUTH.
LET'S TRY.
DETECTOR! HAS THE SUN GONE NOVA?
ROLL
YES.
FREQUENTIST STATISTICIAN:
THE PROBABILITY OF THIS RESULT HAPPENING BY CHANCE IS 1/36 = 0.027.
SINCE p < 0.05, I CONCLUDE THAT THE SUN HAS EXPLODED.
BAYESIAN STATISTICIAN:
BET YOU $50 IT HASN'T.