



Monitoring wolf occupancy and reproductive groups at regional level

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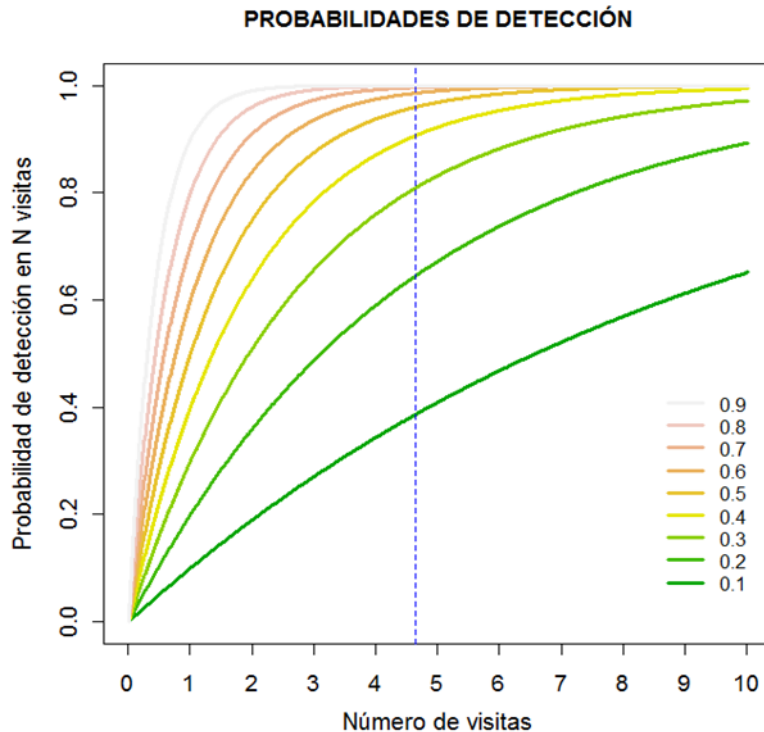
Wolf monitoring

- **Presence:** lineal transects **searching for wolf signs**
- **Reproduction:** howling points

Caveat:

Not take in account the detection probability!

Sampling and detection



How many times do I have to sample a species in a site, if its probability of detection in one visit is 30%, to be sure **I will** detect it?

Ten times is not enough!

$$p^+ = 1 - (1 - p)^n$$

Reproductive groups

Detection probability
is usually under 0.30

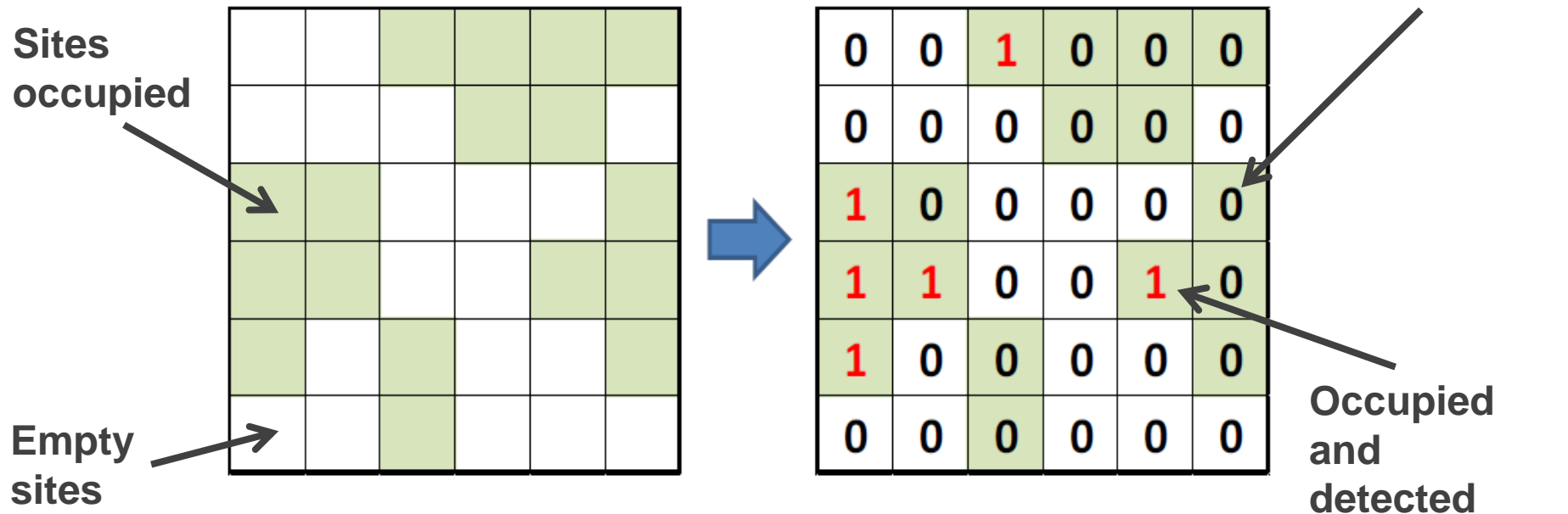
In consequence,
estimate the
reproductive packs
as the total number
with positive
detection in howling
points is wrong



What's the error size?

Effects of imperfect detection: **underestimation**

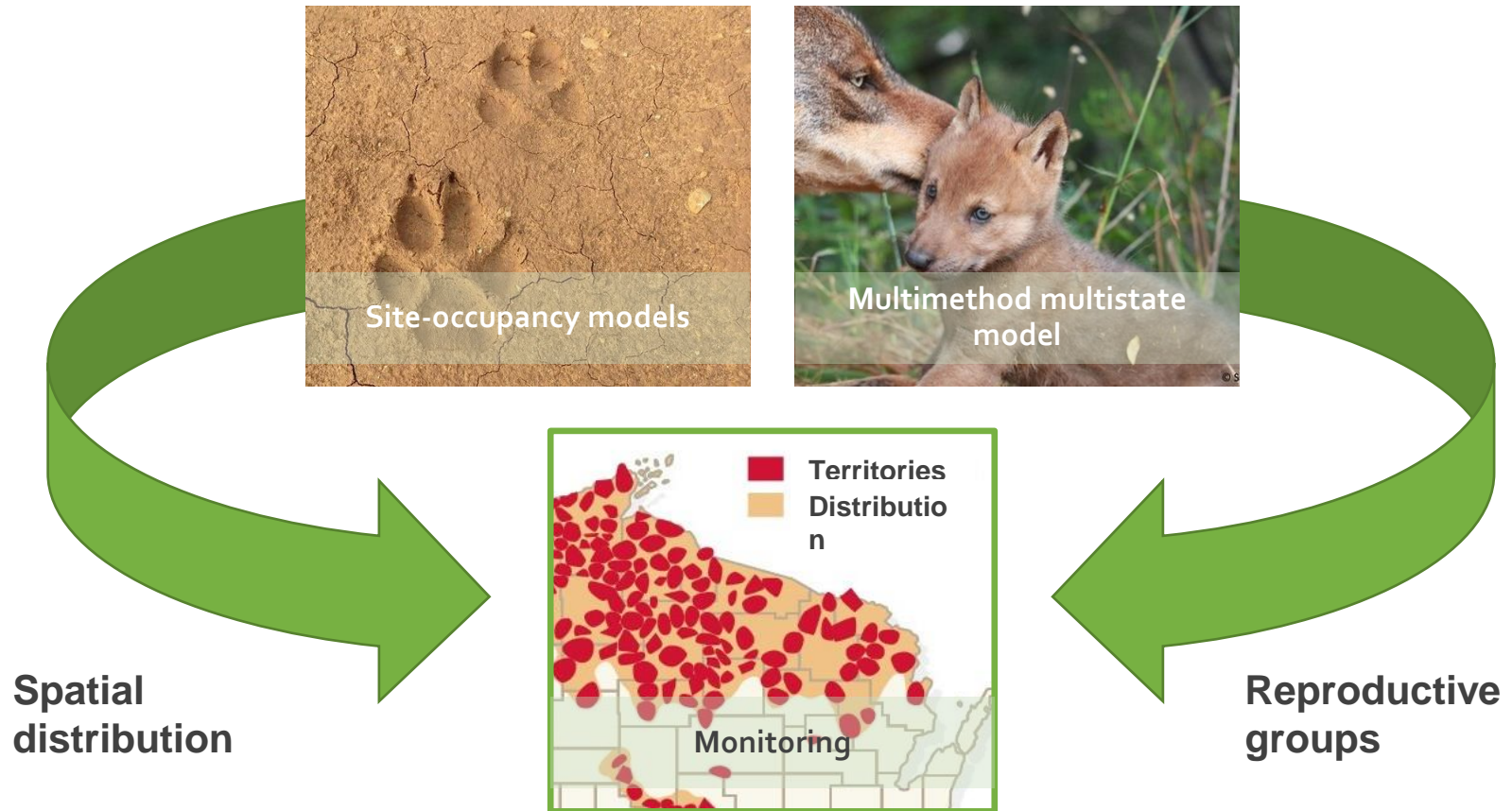
Naïve occupancy = real occupancy x detection



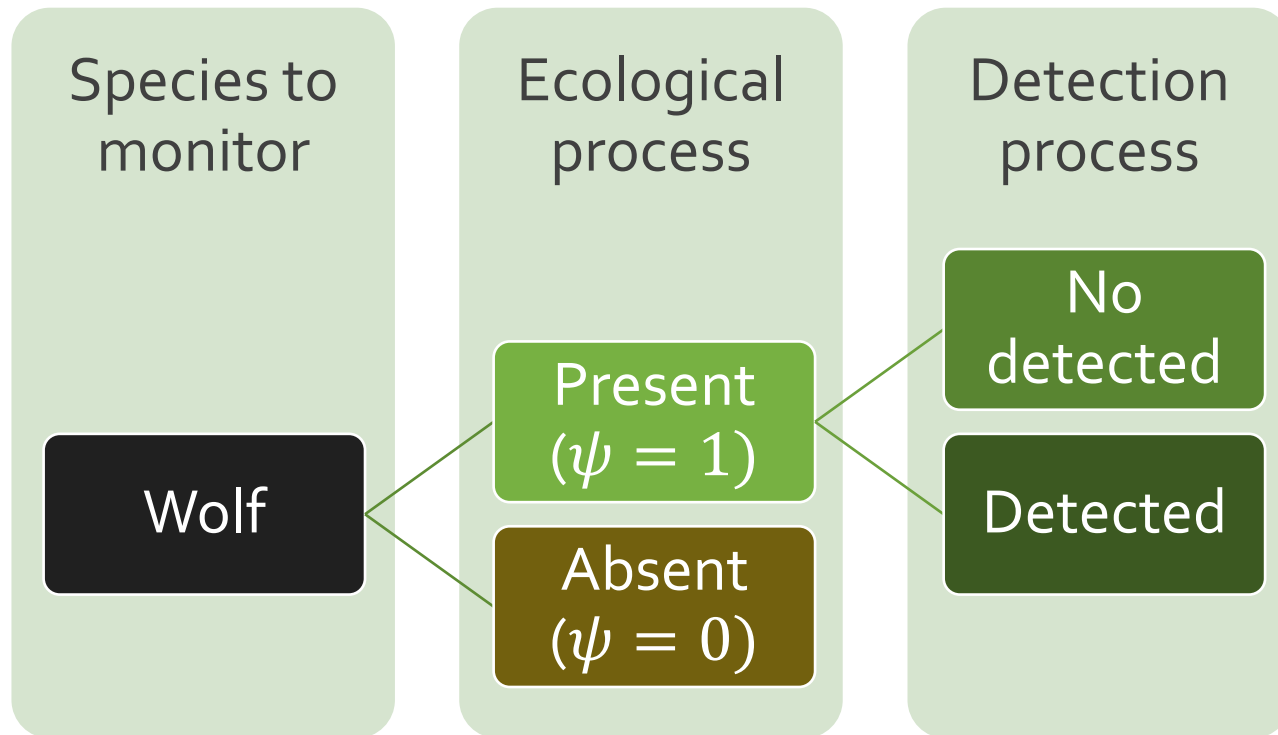
17 occupied sites from 36 sampled sites; real occupancy = $17/36 = 0.47$

Detected in 6 from 17 occupied sites ($p=0.35$); naïve estimate = $6/36 = 0.17$

How to solve it?



What's the model basis?



What's the model basis?

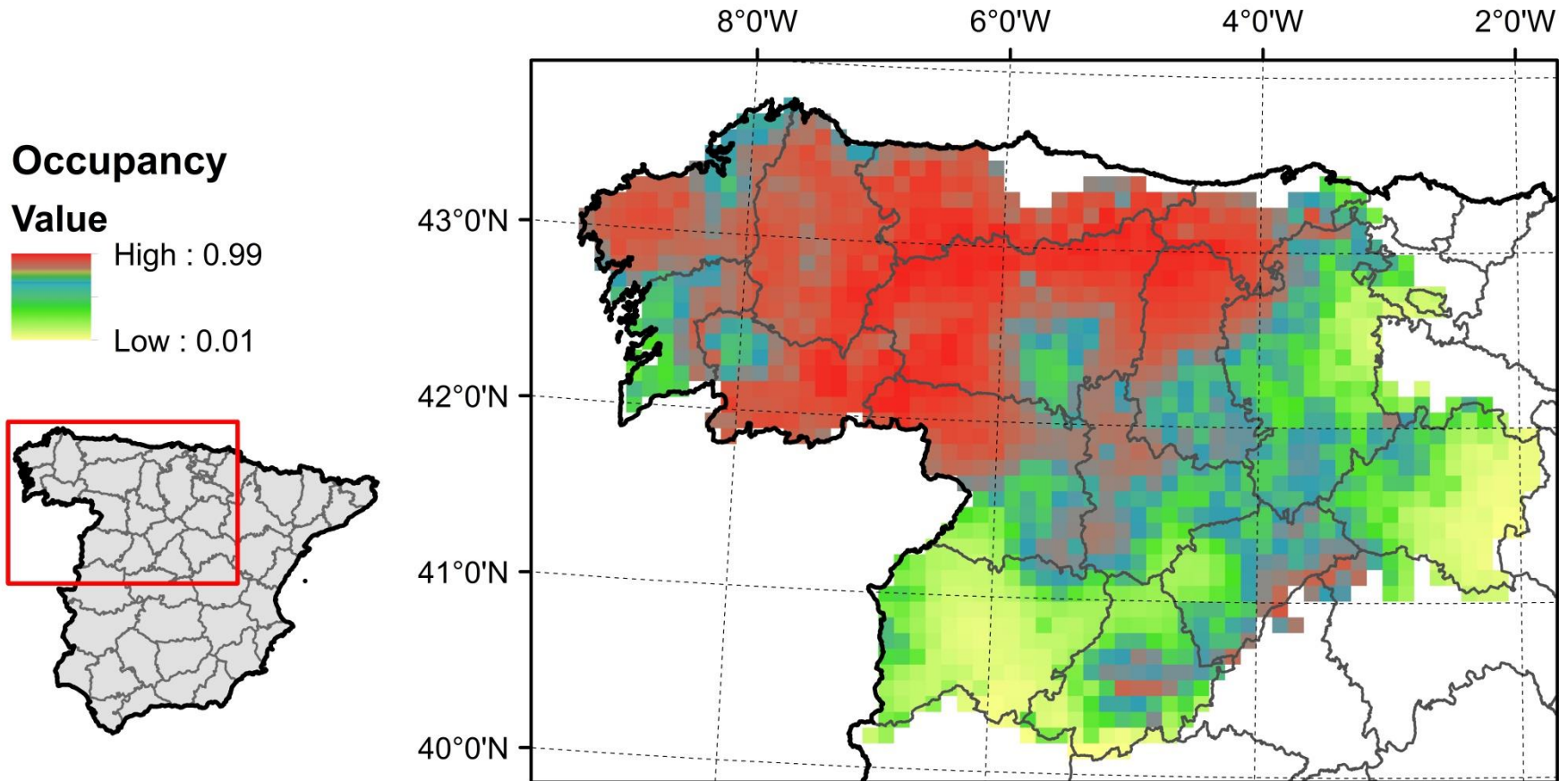
Ecological process

$$z_i \sim \textit{Bernoulli}(\psi)$$

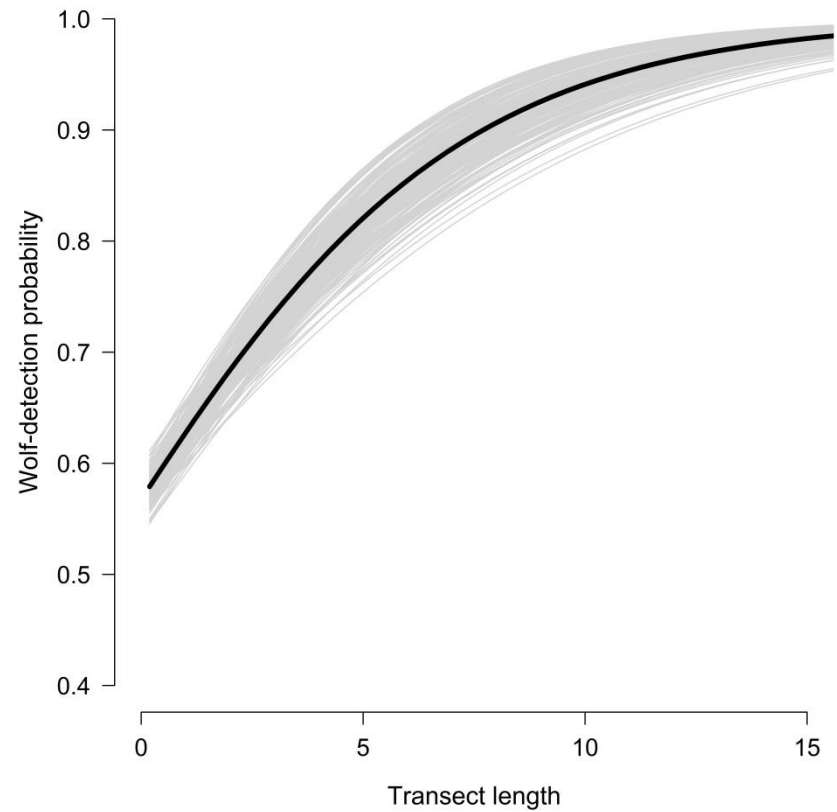
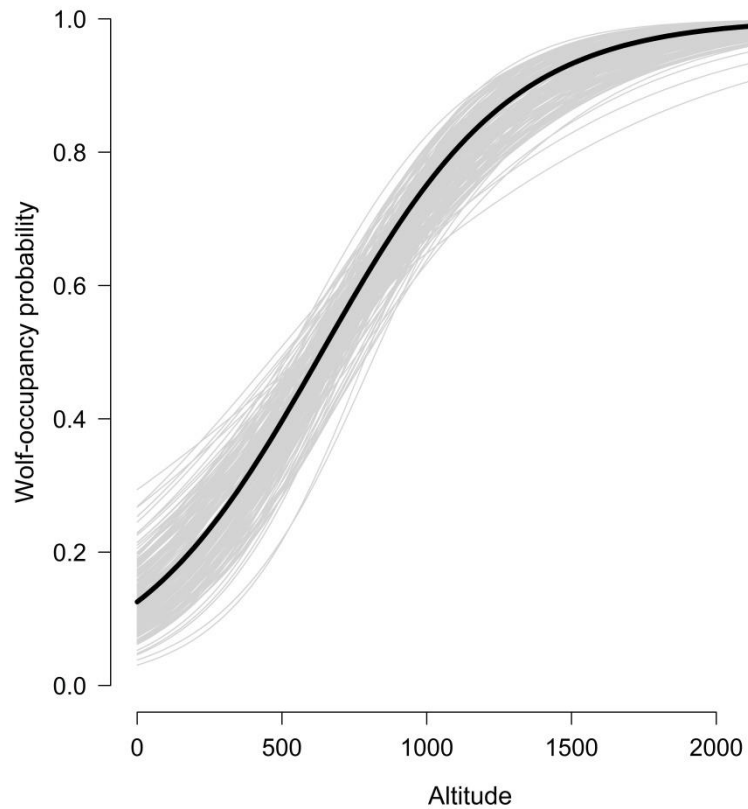
Observational process


$$[y_i | z_i] \sim \textit{Bernoulli}(z_i \times p)$$

Site-occupancy vs. ICAR models



Occupancy



A lone wolf stands in the center of a vast, snow-covered field. The landscape is dotted with small, dark, scrubby bushes. The sky is a pale, uniform blue, suggesting an overcast day. The overall scene is quiet and desolate.

**How many
wolf packs
do we have?**

Model in R+BUGS

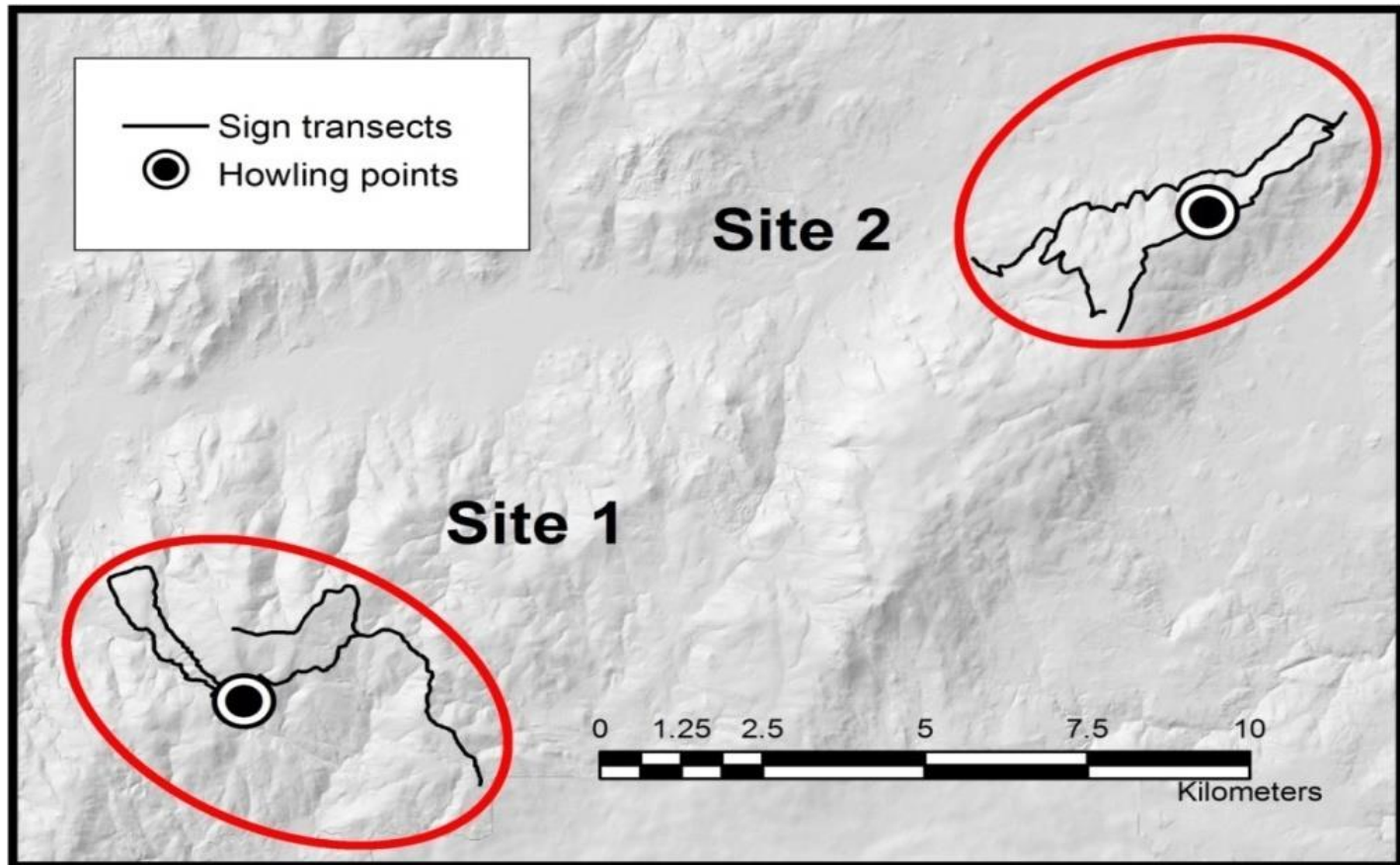
- Using transect we can estimate occupancy with high probability (ψ) but not the reproductive status (absent/adults without reproduction/reproduction)
- Using howling points we can estimate the reproductive status but with very low probabilities



Integrate both methodologies at the same code in BUGS

Jiménez, J., García, E. J., Llaneza, L., Palacios, V., González, L. M., García Domínguez, F., Muñoz, J. and López-Bao, J. V. (2016). Multimethod, multistate Bayesian hierarchical modeling approach for use in regional monitoring of wolves. *Conservation Biology*, 1–23. <http://doi.org/10.1111/cobi.12685>

Site selection



Data simulation

- 50 sites, and 3 transects replica
- 50 sites with 12 replica in howling points
- Probabilities
 - $\psi = 0.8$ (occupancy)
 - $r = 0.7$ (reproductive groups)
 - $\psi_{\text{sign}} = 0.6$ (detection in transects)
 - $p_2 = 0.3$ (adults detection in howling points)
 - $p_3 = 0.2$ (pups detection in howling points)

Data simulation

Truth: 50 sites, 42 occupied, 31 reproduction

	[,1]	[,2]	[,3]
[1,]	1	1	0
[2,]	0	0	0
[3,]	1	1	1
[4,]	0	1	1
[5,]	1	1	1
[6,]	1	1	0
[7,]	0	0	1
[8,]	0	1	1
[9,]	1	0	0
[10,]	0	0	1
[11,]	0	0	1
[12,]	0	0	0
[13,]	0	1	1
[14,]	0	1	1
[15,]	1	1	0
[16,]	0	0	0
[17,]	1	1	1
[18,]	0	1	1
[19,]	0	0	0
[20,]	1	0	1
[21,]	1	1	1

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	[,1]	[,2]	[,3]	[,4]	[,5]	[,6]	[,7]	[,8]	[,9]	[,10]	[,11]	[,12]
[1,]	1	1	1	1	1	1	1	1	1	1	2	1
[2,]	1	1	1	1	1	1	1	1	1	1	1	1
[3,]	2	1	1	2	1	1	1	1	1	1	1	1
[4,]	1	1	1	1	1	1	3	1	1	1	1	1
[5,]	1	1	1	1	1	1	1	1	1	1	1	1
[6,]	1	1	2	1	1	1	1	1	1	1	2	1
[7,]	1	1	1	2	1	1	1	1	1	3	1	1
[8,]	1	1	1	3	1	1	1	1	1	3	1	2
[9,]	1	1	1	2	1	1	1	1	1	2	1	1
[10,]	1	2	1	1	1	1	1	1	1	2	1	1
[11,]	1	1	2	2	2	1	1	1	1	2	2	2
[12,]	1	1	1	1	1	1	1	1	1	1	1	1
[13,]	1	1	1	2	1	1	1	1	1	2	1	1
[14,]	1	2	1	2	1	2	1	2	2	1	2	2
[15,]	1	1	1	1	1	1	1	1	1	1	1	1
[16,]	1	1	1	1	1	1	1	1	1	1	1	1
[17,]	1	1	1	1	1	1	1	1	1	1	1	3
[18,]	1	1	1	1	1	1	2	1	1	1	3	1
[19,]	1	1	1	1	1	1	1	1	1	1	1	1
[20,]	1	3	1	1	2	1	3	1	1	3	1	1
[21,]	1	1	1	1	1	2	1	1	1	1	3	1

17

Observed

Truth, naïve estimate and model

Inference for Bugs model fit using WinBUGS,
3 chains, each with 2500 iterations (first 500 discarded)
n.sims = 6000 iterations saved

	mean	sd	2.5%	25%	50%	75%	97.5%	Rhat	n.eff
psi	0.813	0.056	0.698	0.777	0.817	0.854	0.908	1.001	6000
r	0.743	0.116	0.506	0.660	0.752	0.835	0.931	1.001	6000
psign	0.620	0.043	0.533	0.590	0.621	0.650	0.700	1.001	6000
p2	0.325	0.088	0.200	0.261	0.307	0.374	0.533	1.001	6000
p3[1]	0.851	0.019	0.811	0.839	0.852	0.864	0.886	1.001	6000
p3[2]	0.076	0.018	0.043	0.064	0.075	0.088	0.113	1.001	6000
p3[3]	0.073	0.017	0.044	0.060	0.071	0.083	0.110	1.001	6000
p3sim	0.149	0.019	0.114	0.136	0.148	0.161	0.189	1.001	6000
theta	0.488	0.098	0.314	0.419	0.483	0.556	0.689	1.001	6000
n.occ[1]	8.706	0.544	7.000	8.000	9.000	9.000	9.000	1.001	6000
n.occ[2]	10.108	4.178	4.000	7.000	10.000	13.000	18.000	1.001	6000
n.occ[3]	31.186	4.232	23.000	28.000	31.000	35.000	38.000	1.001	6000
deviance	696.685	9.485	679.400	690.175	696.100	702.300	718.000	1.001	6000

For each parameter, n.eff is a crude measure of effective sample size,
and Rhat is the potential scale reduction factor (at convergence, Rhat=1).

DIC info (using the rule, $pD = \text{var}(\text{deviance})/2$)

$pD = 45.0$ and $DIC = 741.7$

DIC is an estimate of expected predictive error (lower deviance is better).

- Truth:
31
- Naive estimate:
17
- Model estimate:
 31.18 ± 4.23

RMSE

