Single Season Study Design

Camera-trap focus

USGS science for a changing world

Proteus wildlife research consultants

Points for consideration

Don’t forget; *why*, *what* and *how*.

A well designed study will:

- highlight gaps in current knowledge.
- provide better information.
- allow more efficient use of resources.

Issues with respect to occupancy

- How to define a ‘sampling unit’?
- Selecting sampling units
- What is a ‘season’?
- Repeat surveys
- Avoiding heterogeneity
- More units vs. more surveys?

- Many of these issues are relevant even if p=1

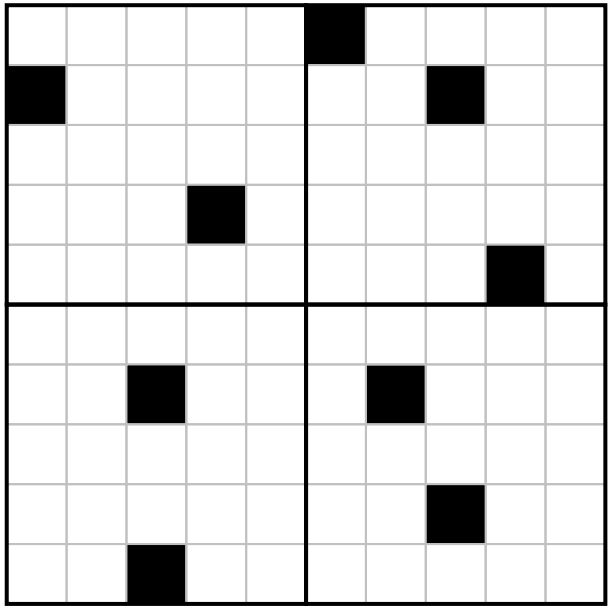
First golden rule

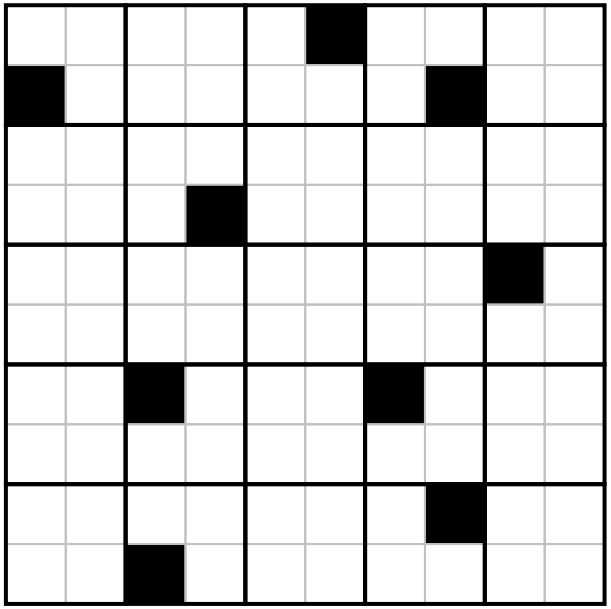
- Clearly identify your population of interest!

How to define a ‘sampling unit’?

- Should be assessed on a case-by-case basis.
- Large enough to have a reasonable probability of occupancy, but not so large that any measure may be meaningless.
- Size matters!

How to define a ‘sampling unit’?





How to define a ‘sampling unit’?

- Is there a natural definition?
- Might potential sampling units change through time?
- At what scale do you want to measure occupancy?
- Is the species territorial?
- What density does the species occur at?
- What is the size of the species home range?

How to define a ‘sampling unit’?

- Consider the likely field methods to be used and any impact on physical area being surveyed
  - Influence of lures or bait
  - Effective detection radius

Selecting sampling units

- How units are selected determines how results can be generalized.
- Each sampling unit within the population of interest should have a non-zero probability of being selected.
- If units are selected such that occupancy is different to the population of interest, estimates may be biased.
  - e.g., surveying only at historic sites.

Selecting sampling units

- Sampling units should also selected in a manner conducive to the study objective.
  - e.g., estimate occupancy across a larger area of interest vs. contrast occupancy in specific habitats within the area.

What is a ‘season’?

- A season is a period of time during which it is reasonable to assume occupancy is static or changes occur completely at random.

- Depends very much on the target species and study objective.

What is a ‘season’?

- Is there a natural definition? (e.g., a breeding season)
- How mobile is the species? (i.e., occupancy vs use)
- What is the ecology of the species?
- What, exactly, do you mean by ‘presence’?

Repeat surveys

Repeat surveys do not (necessarily) imply repeat visits.

- Discrete visits.
- Multiple surveys within single visit
  - Single observer, conducting multiple surveys
  - Multiple observers each conducting a single survey
  - Multiple survey plots within a larger sampling unit
  - Multiple survey methods
- Camera-trap studies: almost always use temporal replication

Repeat surveys

However, how the repeat surveys are conducted can influence what is a ‘season’ and what is the biological quantity your sampling is capturing.

"I only have one survey of each unit, can I shoehorn my data into these methods?"

- You could:
  - break each survey into smaller units

    e.g., a nightly survey into 2-hour periods, or a 1km transect into 200m stretches
  - overlay a grid and adjust grid size such that you have multiple surveys within each grid cell.

- Camera trap studies: can always use temporal replication

Special Notes on Spatial Replication

- ‘Closure’ is now spatial – the species is everywhere within the larger sampling unit.
- If not, then the sub-sampling of the unit must ensure that the species is present within the selected smaller unit at random.
- When there is a limited number of potential sub-units that could be sampled, and the species is not in all of them, then sub-units should be sampled with replacement.

Repeat surveys

Main thing to consider is how proposed design relates to model assumptions.

- Closure / randomness.
- Independence.
- Heterogeneity.

Of utmost importance to keep in mind how the design may impact upon the biological interpretation of the ‘occupancy’ parameter.

Avoiding heterogeneity

- Important to consider potential sources of detection heterogeneity.
  - Abundance
  - Habitat
  - Observers
  - Relative timing of surveys at different sites

Avoiding heterogeneity

- Design study to control heterogeneity or allow it to be estimated.
  - define units at a scale where abundance will be relatively constant
  - collect habitat information and include as a covariate

Repeat Surveys

Design A

	Day								
Site	1			2			3		
1	X	X	X						
2							X	X	X
3				X	X	X			
4				X	X	X			
5							X	X	X
6	X	X	X						
7				X	X	X			
8							X	X	X
9	X	X	X						
p	0.5			0.3			0.8		

Design B

	Day								
Site	1			2			3		
1	X				X				X
2			X	X			X		
3		X				X		X	
4		X		X					X
5			X			X	X		
6	X				X				X
7		X		X				X	
8			X		X		X		
9	X					X		X	
p	0.5			0.3			0.8		

Allocation of effort

- How many camera traps to allocate per sample unit?
  - One trap per unit is most common
- More traps per unit translates to higher detection probability and precision
- But for fixed number of traps, more traps per sample unit means fewer units surveyed
  - Explore trade-offs with GENPRES

Allocation of effort

- For a ‘standard design’ there is an optimal number of repeat surveys per unit.
- The optimal number depends upon values for ψ and p.
- Does not depend upon number of units or total number of surveys.
- Reasonably robust to effect of cost.

Number of surveys

	ψ								
p	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
0.1	14	15	16	17	18	20	23	26	34
0.2	7	7	8	8	9	10	11	13	16
0.3	5	5	5	5	6	6	7	8	10
0.4	3	4	4	4	4	5	5	6	7
0.5	3	3	3	3	3	3	4	4	5
0.6	2	2	2	2	3	3	3	3	4
0.7	2	2	2	2	2	2	2	3	3
0.8	2	2	2	2	2	2	2	2	2
0.9	2	2	2	2	2	2	2	2	2

How many units?

- Once the number of repeat surveys has been determined, how many units to survey can be determined from the variance equation

$$Var\left(\hat{\psi}\right) = \frac{\psi}{s}\left[\left(1-\psi\right) + \frac{\left(1-p^{*}\right)}{p^{*} - Kp\left(1-p\right)^{K-1}}\right]$$

$$p^{*} = 1-\left(1-p\right)^{K}$$

How many units?

- Example, if $\psi \approx 0.7$ and $p \approx 0.4$, should use 5 surveys per unit; $p^* = 0.92$
- To achieve a SE of 0.04

$$0.04^2 = \frac{0.7}{s}\left[(1-0.7) + \frac{(1-0.92)}{0.92 - 5\times 0.4(1-0.4)^{5-1}}\right]$$

$$s = \frac{0.7}{0.04^2}\left[0.3 + \frac{0.08}{0.92-0.26}\right]$$

$$= 437.5\left[0.3 + 0.12\right]$$

$$\approx 183$$

How many units?

- Important to realise we can never do better than if $p = 1$.
  - required $s = 132$
- What if different field methods could be used such that $p = 0.6$?
  - $K = 3$; required $s = 175$
  - total survey effort is reduced by 43%

Non-standard designs?

- Repeatedly surveying a subset of units and elsewhere only once *does not* generally provide a more efficient design.

- Surveying a unit repeatedly until first detection (up to a maximum) may provide a more efficient design, but may be less robust.
  (Note the 'optimal' maximum number is higher than values given in the previous table)

Other considerations

- Alternative definitions of ‘optimal’ result in tables of different magic numbers, but similar patterns remain.
- Some results break down in small samples, hence simulation should be used to verify asymptotic results (e.g., via GENPRES).
- Guillera-Arroita et. al., 2010, *Methods in Ecology and Evolution*

General recommendations on allocating effort

- When detection probability is >0.5, at least 3 surveys per unit.
- More surveys will be required when p is lower.
- For rare species, survey more units less intensively.
- Increasing spatial replication with insufficient repeat surveys may not be worthwhile.

General recommendations on allocating effort

Example: if $\psi \approx 0.4$ and $p \approx 0.3$

Surveying 200 units twice gives $SE(\hat{\psi}) = 0.11$

Surveying 80 units 5 times gives $SE(\hat{\psi}) = 0.07$

- a decrease of 36%

With only 2 surveys per unit, would require 500 units to achieve same level of precision, or increase total effort 250%!

General recommendations on allocating effort

Expected $SE(\hat{\psi})$ when $\psi = 0.4,\ p = 0.3$

Total Surveys	Surveys							
	2	3	4	5	6	7	8	9
100	0.220	0.162	0.144	0.138	0.139	0.142	0.147	0.153
200	0.155	0.115	0.102	0.098	0.098	0.101	0.104	0.108
500	0.098	0.072	0.064	0.062	0.062	0.064	0.066	0.068
800	0.078	0.057	0.051	0.049	0.049	0.050	0.052	0.054
1100	0.066	0.049	0.043	0.042	0.042	0.043	0.044	0.046
1400	0.059	0.043	0.038	0.037	0.037	0.038	0.039	0.041
1700	0.053	0.039	0.035	0.034	0.034	0.035	0.036	0.037
2000	0.049	0.036	0.032	0.031	0.031	0.032	0.033	0.034