

Counting Animals Part II: Sample Counts

EFB 390: Wildlife Ecology and Management

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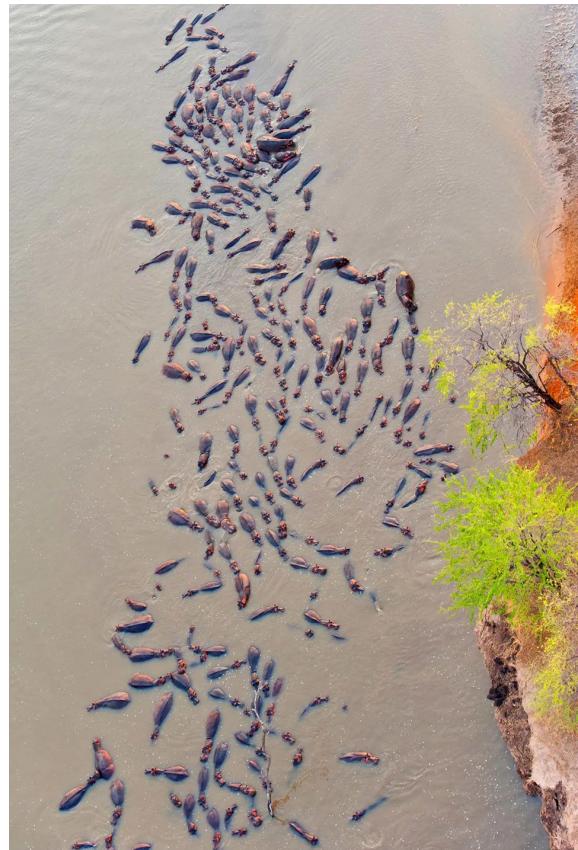
Drawbacks of total counts / censusing

Expensive & labor-time intensive

Impractical for MOST species / systems

- need to ALL be **visible**
- the **ENTIRE** study area needs to be survey-able

Hard to assess precision



Hippos

Is the great Elephant Census a Census?



Sample counts

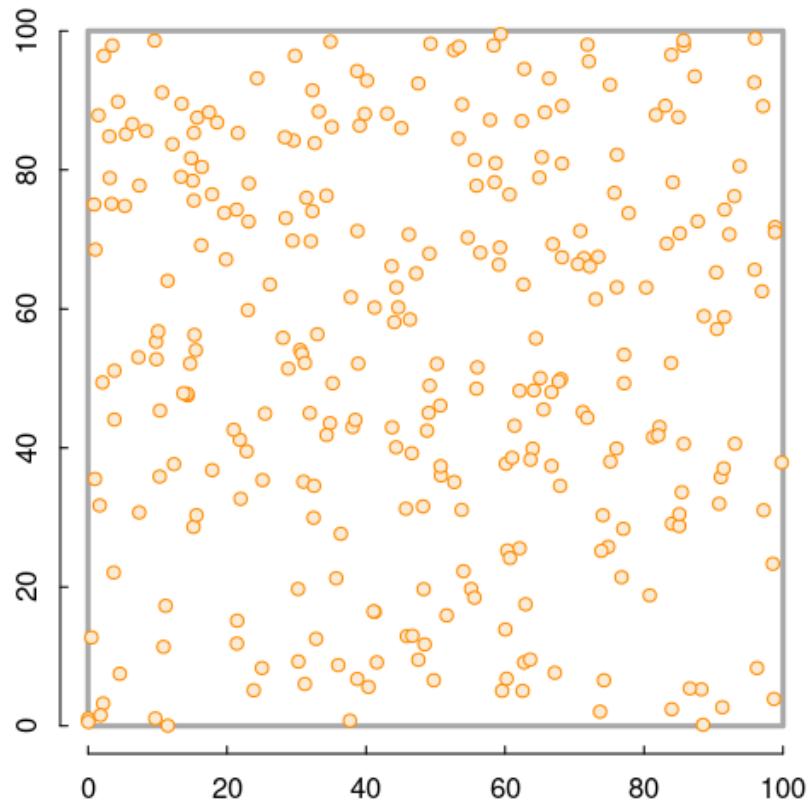
Simple idea:

- count *some* of the individuals
- extrapolate!

In practice:

- Involves some tricky statistics and modeling!
- Necessarily - less *precise* due to *sampling error*.
- BUT ... if properly done ... more *accurate* and **much less effort**.

A random population

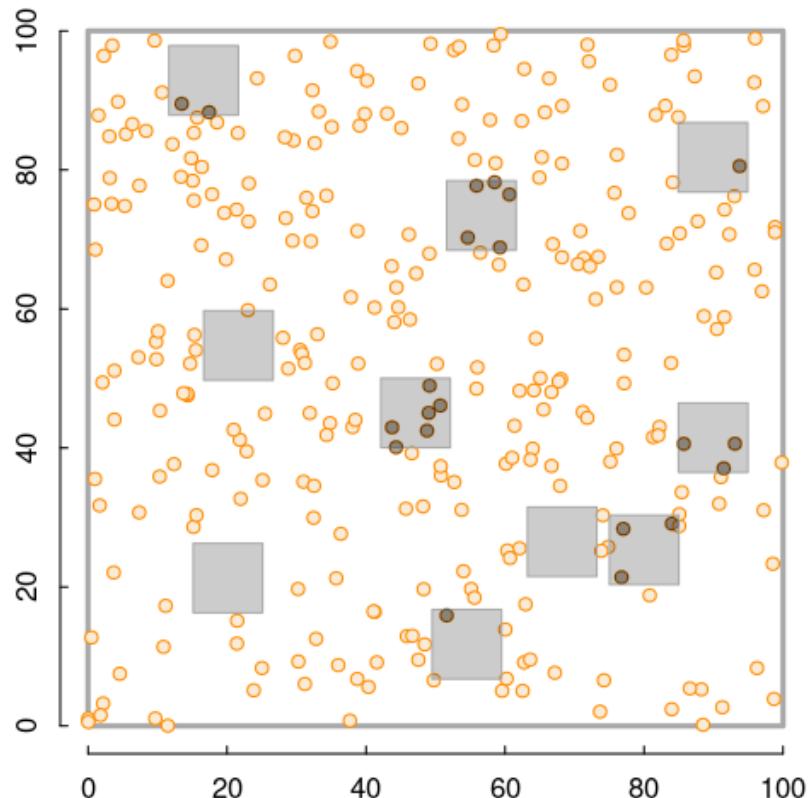


Population density

$$N = A \times D$$

- N - total count
- A - total area
- D - overall density

Sampling from the population



Squares, aka, quadrats

Sample density:

$$n_{sample} = \sum_{i=1}^k n_i$$

$$a_{sample} = \sum_{i=1}^k a_i$$

$$d_{sample} = \frac{n_{sample}}{a_{sample}}$$

Sample vs. Population

	Population	Sample
size	N	n_s
area	A	a_s
density	D	d_s

Note: sample density is an *estimate* of total density. So $\widehat{D} = d_s$.

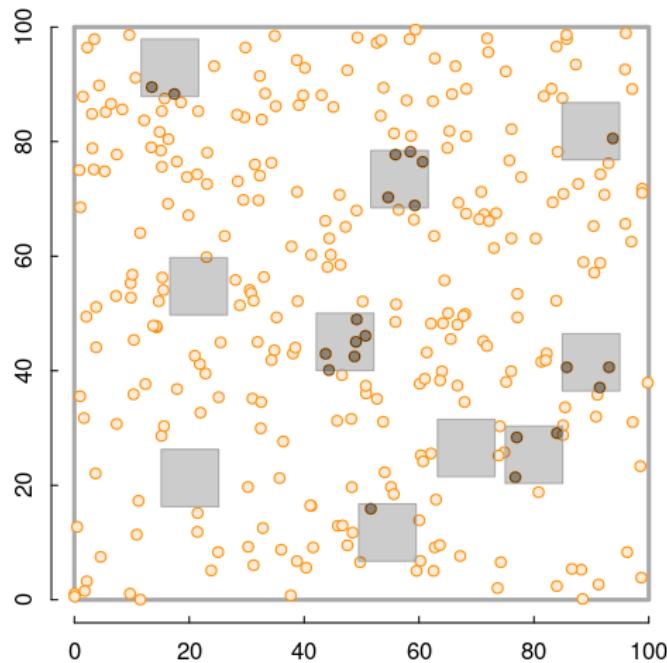
True population:

$$N = A \times D$$

Population **estimate** (best guess for N): just replace true (unknown) density D with *sampling estimate* of density d_s :

$$\widehat{N} = A \times \widehat{D} = A \times \frac{n_s}{a_s}$$

Example



Data

10 quadrats; 10x10 km each

$n = \{0, 0, 5, 0, 3, 1, 2, 3, 6, 1\}$

note: variability / randomness!

Analysis

$$n_s = \sum n_i = 21$$

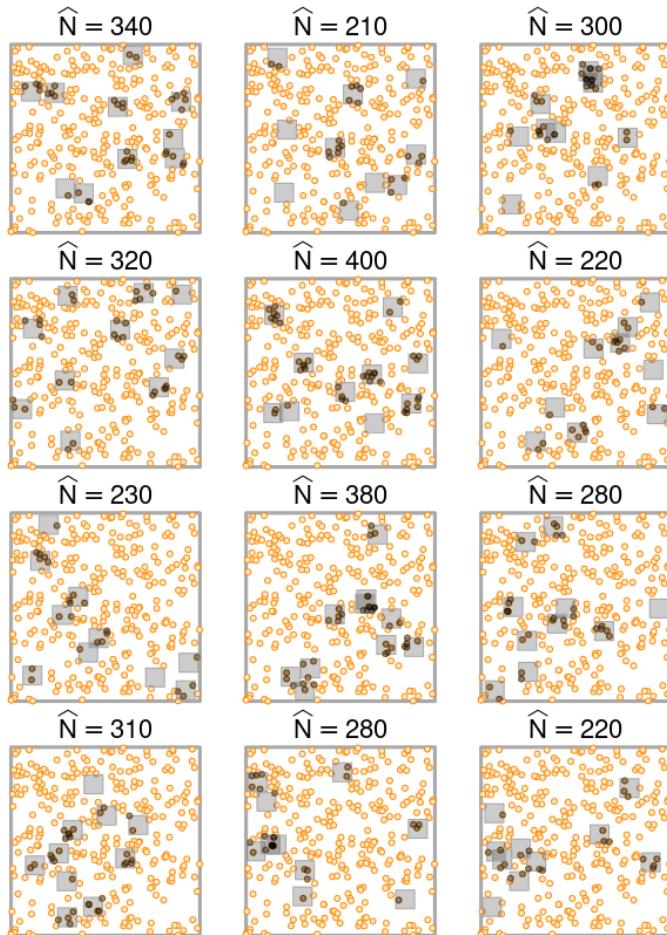
$$d_s = \widehat{D} = \frac{35}{10 \times 10 \times 10} = 0.021$$

$$A = 100 \times 100$$

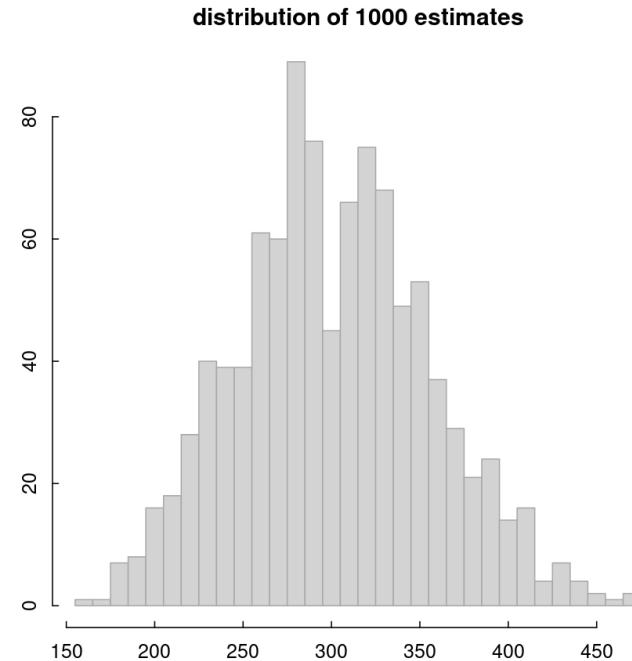
final estimate:

$$\widehat{N} = \widehat{D} \times A = 100 \times 100 \times 0.021 = 210$$

What happens when we do this many times?



Every time you do this, you get a different value for \hat{N} .



Statistics

Mean of estimates:

$$\widehat{N} = 301.5$$

S.D. of estimate:

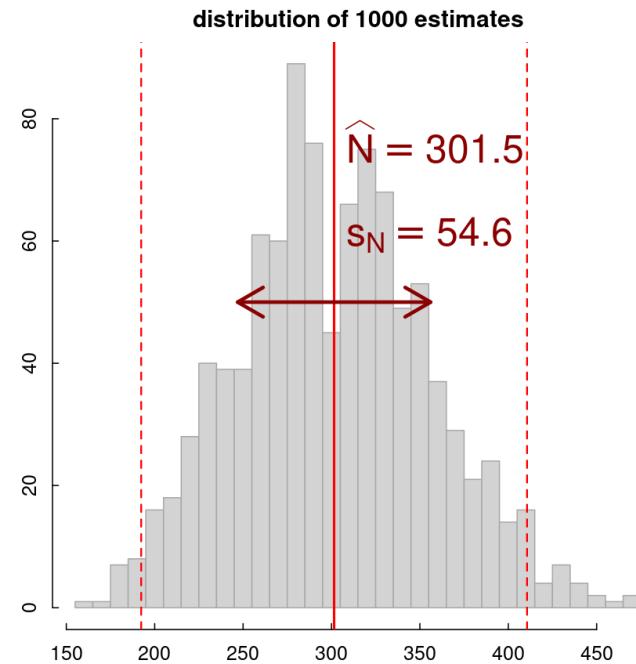
$$s_{\widehat{N}} = 54.6$$

important: the *standard deviation of an estimate* = **standard error, SE**

95% Confidence Interval:

$$\widehat{N} \pm 1.96 \times SE = \{195 - 408\}$$

note: the 1.96 is the number of standard deviations that captures 95% of a Normal distribution.



General principle: The bigger the sample, the smaller the error.

1. If $a_s \ll A$ (i.e. low sampling intensity)

$$SE(\widehat{N}) = \frac{A}{a} \sqrt{\sum n_i}$$

remember: $n_s = \sum n_i$ is the total sample count

in our example: $SE = 100^2/(10 \times 10^2)\sqrt{30} = 54.8$

2. If you are NOT resampling previously sampled locations:

$$SE(\widehat{N}) = \frac{A}{a} \sqrt{\sum n_i(1 - a_s/A)}$$

This is the **Finite Area Correction**. If $a = A$ - you sampled everything - SE goes to 0 as expected.

in our example: $SE = 54.5 \dots$ Almost no difference (because $a \ll A$).

Some more complex formulae

from Fryxell book Chapter 12:

Table 12.3 Estimates and their standard errors for animals counted on transects, quadrants, or sections. The models are described in the text.

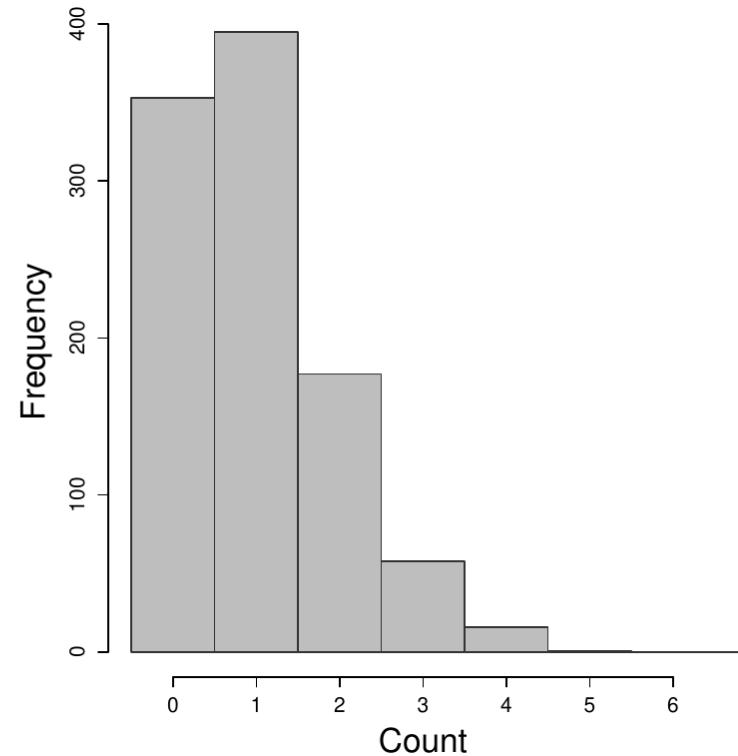
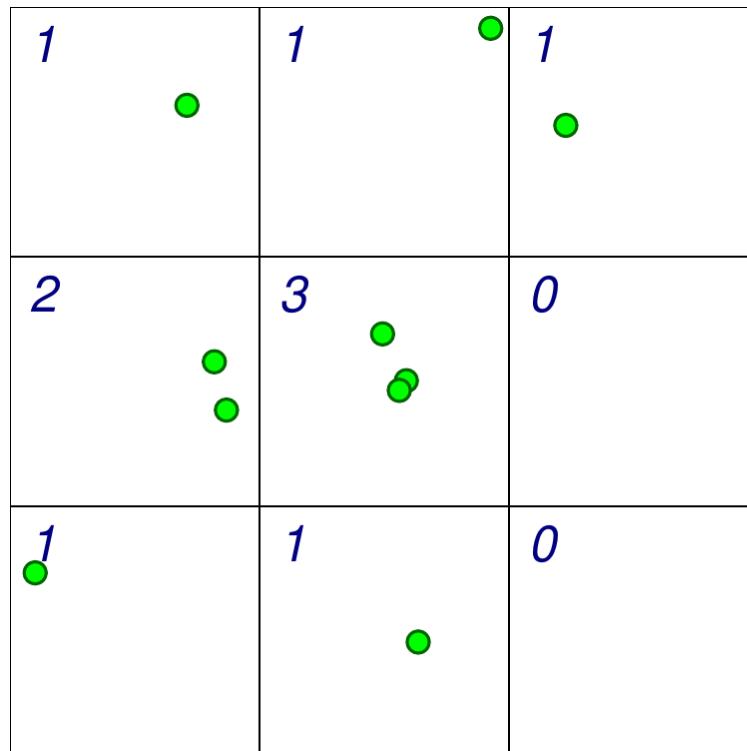
Model	Density	Numbers
Simple Estimate	$D = \Sigma y / \Sigma a$	$Y = A \times D$
Standard error of estimate (SWR)	$SE(D)_1 = 1/a \times \sqrt{(\Sigma y^2 - (\Sigma y)^2/n)/n(n-1)}$	$SE(Y) = A \times SE(D)_1$
Standard error of estimate (SWOR)	$SE(D)_2 = SE(D)_1 \times \sqrt{1 - (\Sigma a)/A}$	$SE(Y) = A \times SE(D)_2$
Ratio Estimate	$D = \Sigma y / \Sigma a$	$Y = A \times D$
Standard error of estimate (SWR)	$SE(D)_3 = n/\Sigma a \times \sqrt{(1/n(n-1))(\Sigma y^2 + D^2 \Sigma a^2 - 2D\Sigma ya)}$	$SE(Y) = A \times SE(D)_3$
Standard error of estimate (SWOR)	$SE(D)_4 = SE(D)_3 \times \sqrt{1 - (\Sigma a)/A}$	$SE(Y) = A \times SE(D)_4$
PPS Estimate	$d = 1/n \times \Sigma(y/a)$	$Y = A \times d$
Standard error of estimate (SWR)	$SE(D) = \sqrt{(\Sigma y/a)^2 - (\Sigma(y/a))^2/n}/n(n-1)$	$SE(Y) = A \times SE(d)$

SWR, sampling with replacement; SWOR, sampling without replacement. Notation is given at the beginning of Section 12.5.1.

These are used when **sampling areas** are unequal, and account for differences when sampling **with replacement** or **without replacement**.

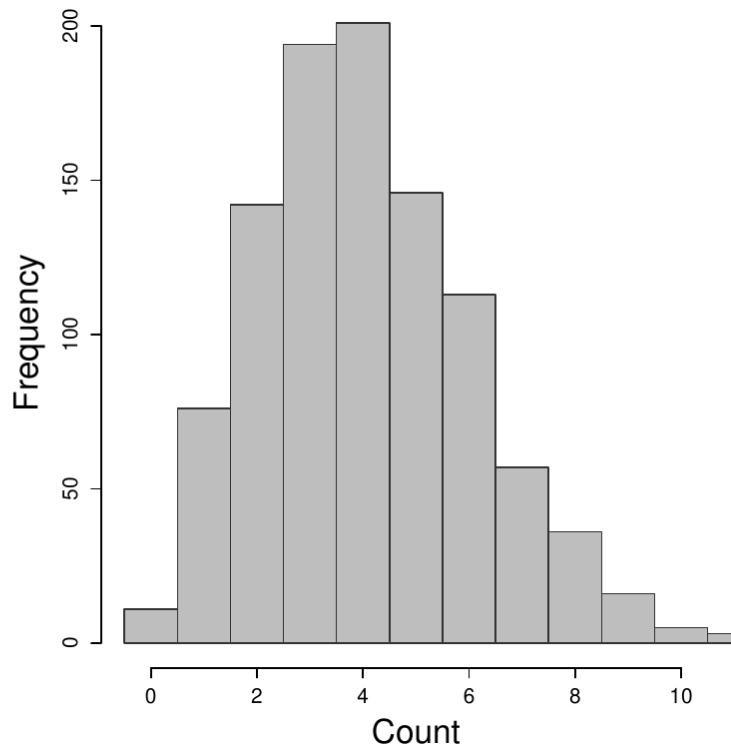
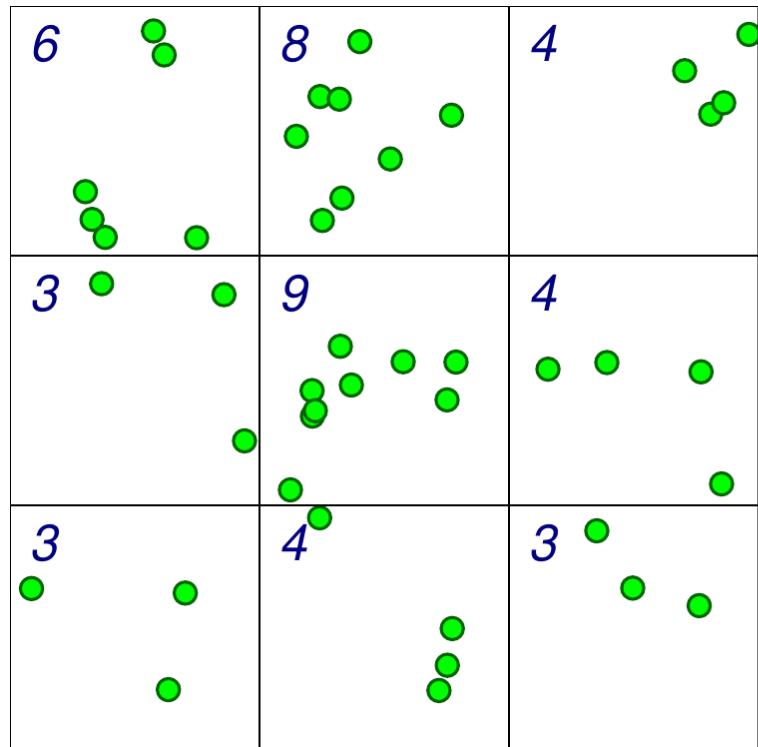
Poisson process

Models *counts*. If you have a perfectly random process with mean *density* (aka *intensity*) 1, you might have some 0 counts, you might have some higher counts. The *average* will be 1:



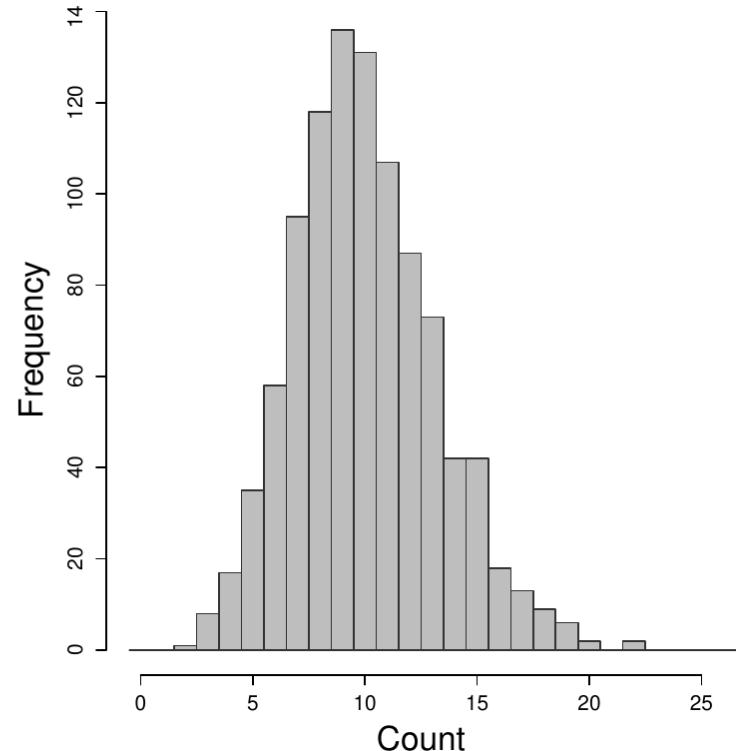
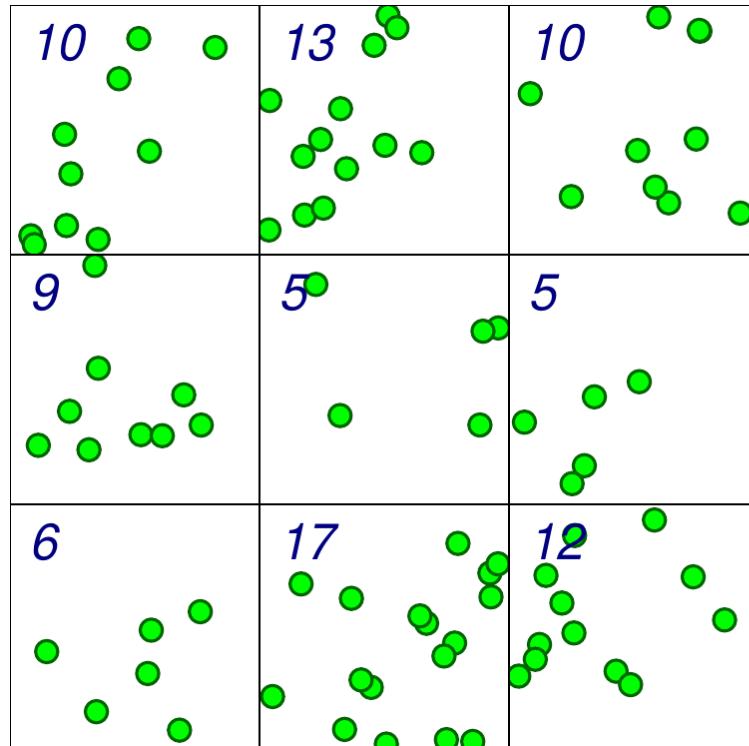
Poisson process

Here, the intensity is 4 ...



Poisson process

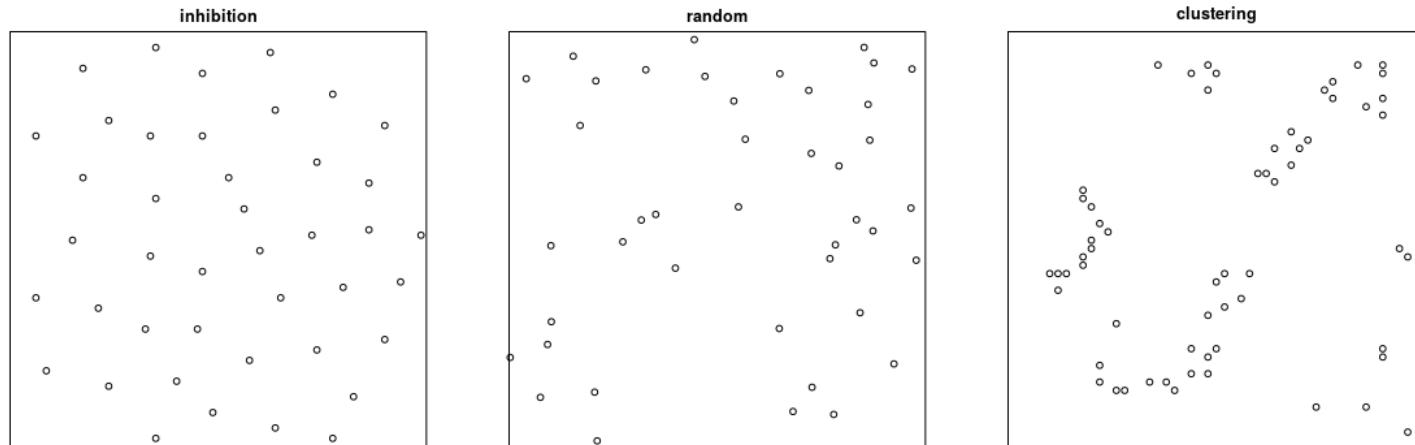
... and 10. Note, the bigger the intensity, the more "bell-shaped" the curve.



Here's the formula of the Poisson Distribution: $f(k; \lambda) = \Pr(X=k) = \frac{\lambda^k e^{-\lambda}}{k!}$

Poisson distribution holds if process is truly random

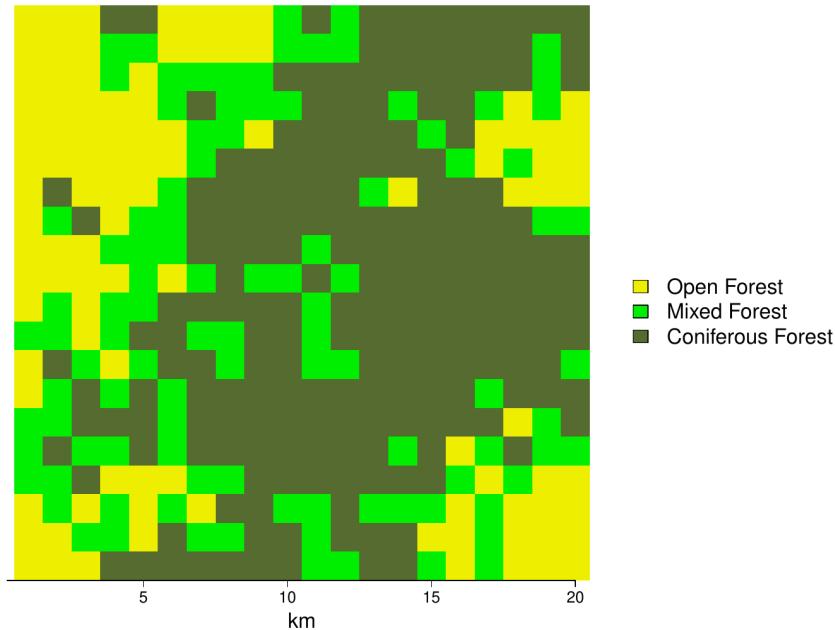
... not **clustered** or **inhibited**



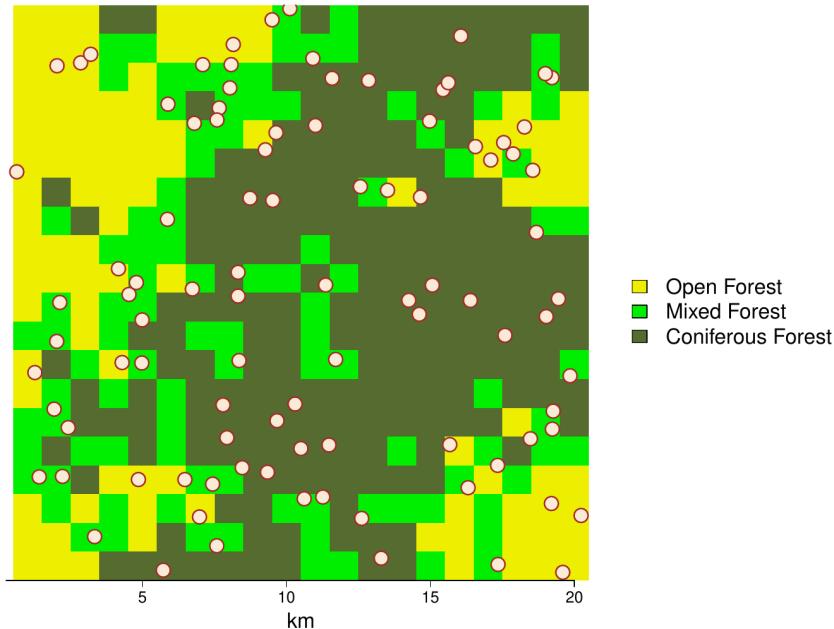
If you **sample** from these kinds of spatial distributions, your standard error might be smaller (*inhibited*) or larger (*clustering*). This is called *dispersion*.

Also ... densities of animals can depend on habitat

Imagine a section of forest ...



... with observations of moose

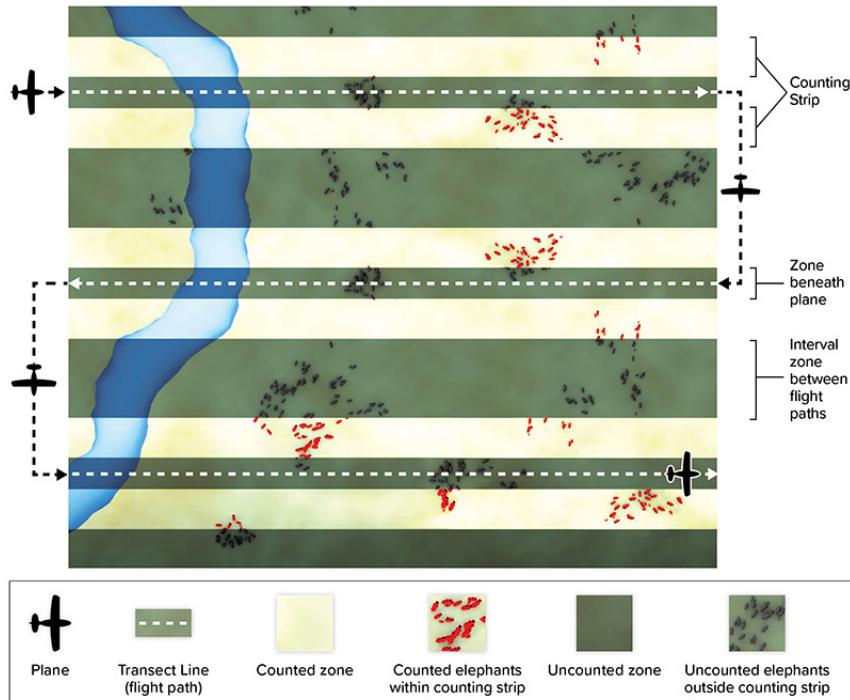


How can we tell what the moose prefers?

Habitat	Area	n	Density
open	100	21	0.21
mixed	100	43	0.43
dense	200	31	0.17
total	400	95	0.24

Knowing how densities differ as a function of **covariates** can be very important for generating estimates of abundances, increasing both **accuracy** and **precision**, and informing **survey design**.

Sample frames need not be squares



Transects

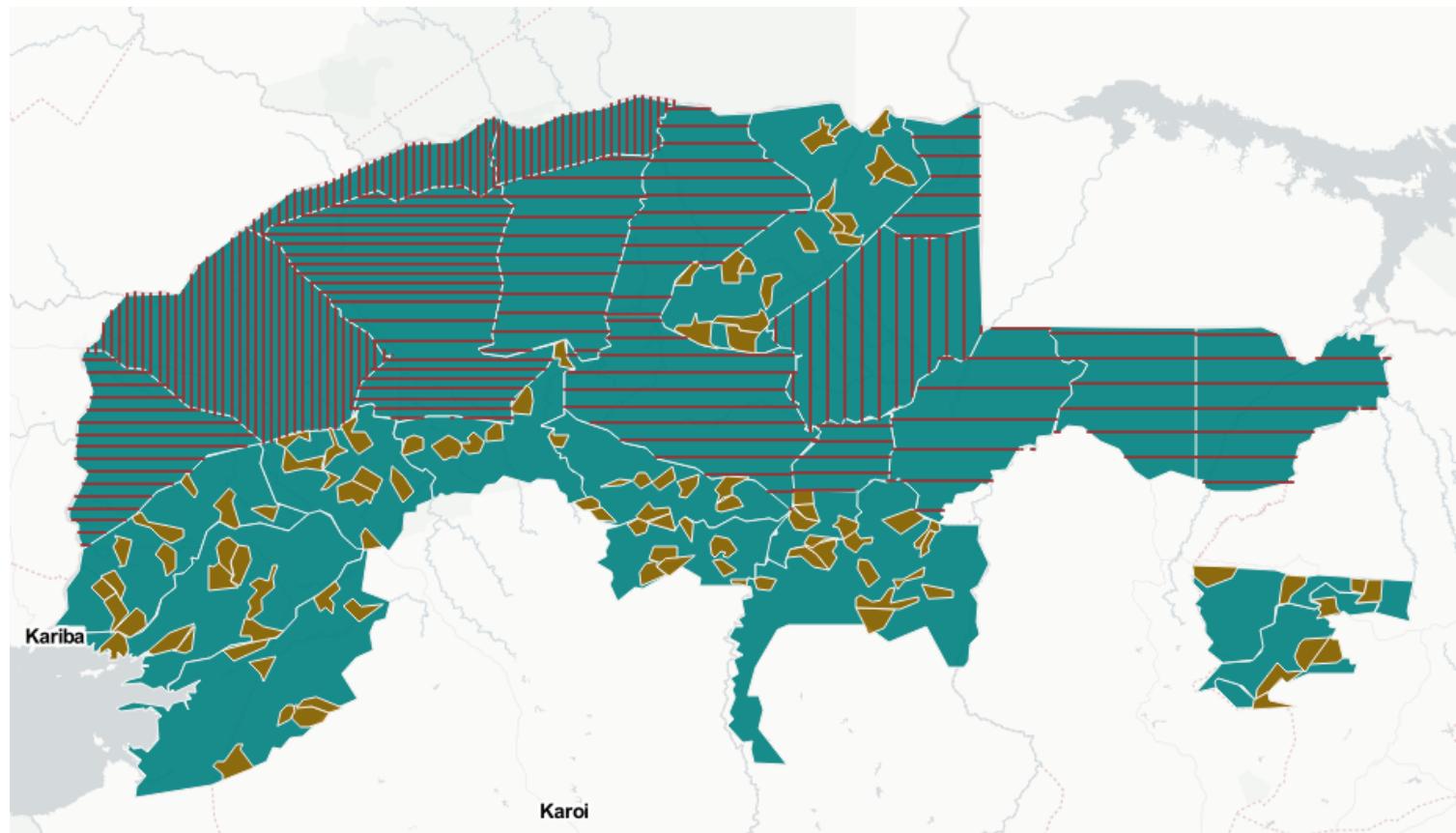
Linear strip, usually from an aerial survey.

Efficient way to sample a lot of territory.

If "perfect detection", referred to as a **strip transect**.

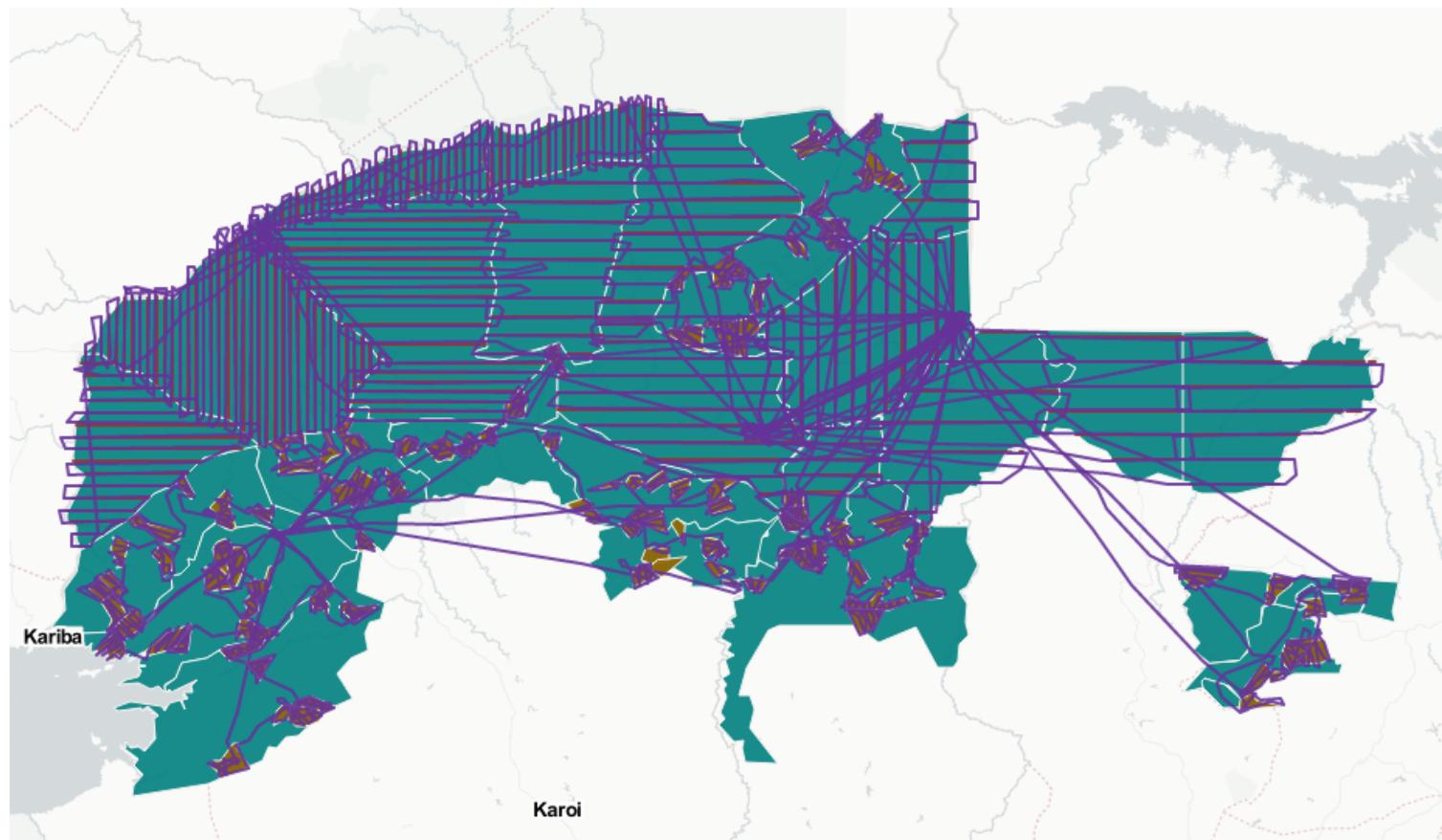
Statistics - essentially - identical to quadrat sampling.

Stratified sampling for more efficient estimation



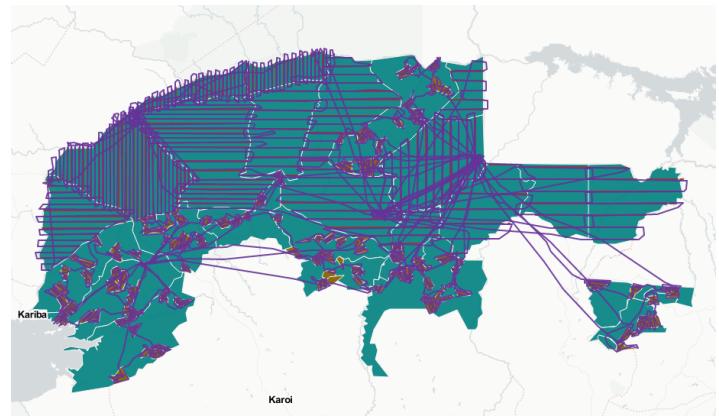
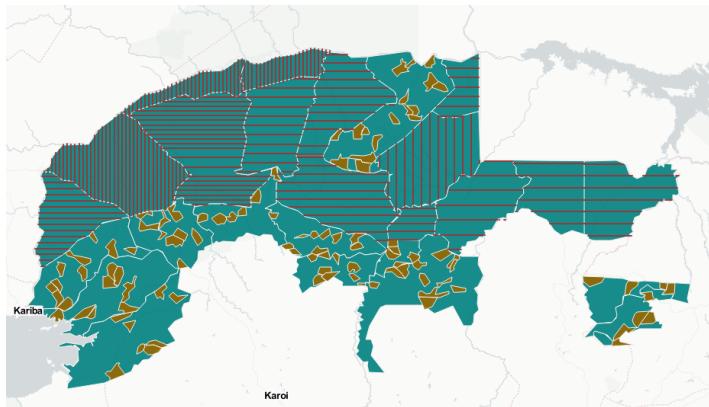
Sample more intensely in those habitats where animals are more likely to be found. Intensely survey **blocks** where detection is more difficult.

Stratified sampling for more efficient estimation



Actual elephant flight paths,

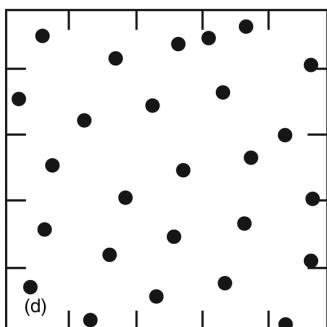
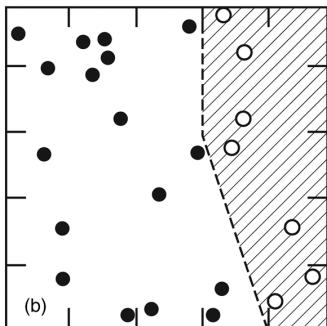
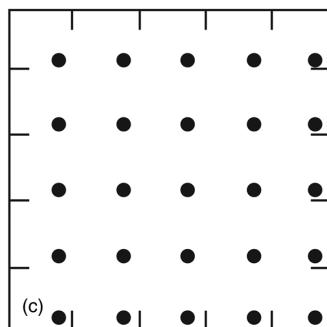
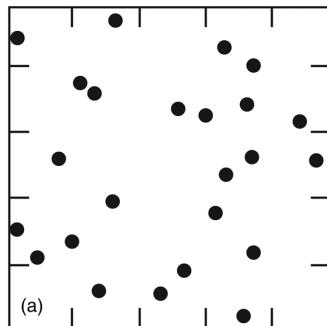
Stratified sampling



Stratification is used to optimize **effort** and **precision**. Aircraft cost thousands of dollars per hour!

(In all of these comprehensive surveys - *design* takes care of **accuracy**).

Sampling strategies



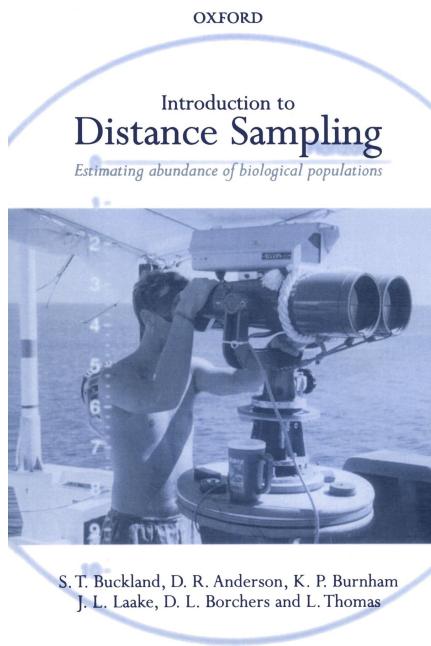
- (a) simple random,
- (b) stratified random,
- (c) systematic,
- (d) pseudo-random (systematic unaligned).

Each has advantages and disadvantages.

See also: *Adaptive Sampling*

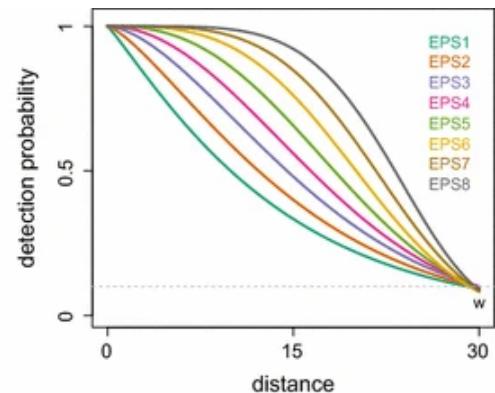
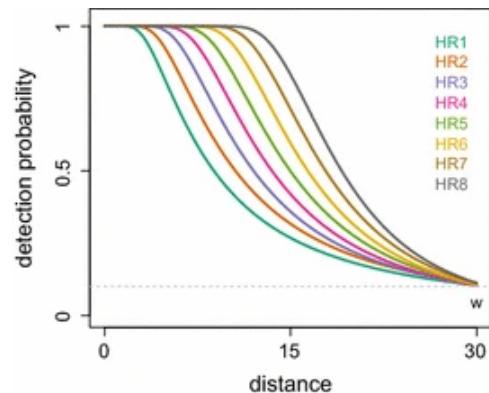
Detections usually get *worse* with distance!

Detection function	Form
Uniform	$1/w$
Half-normal	$\exp(-y^2/2\sigma^2)$
Hazard-rate	$1 - \exp(-(y/\sigma)^{-b})$
Negative exponential	$\exp(-ay)$

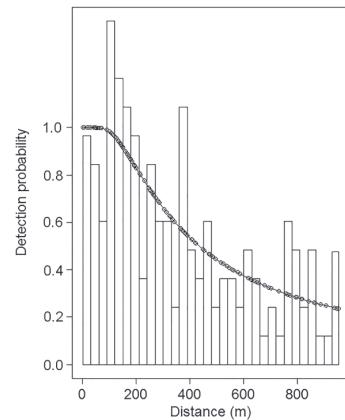
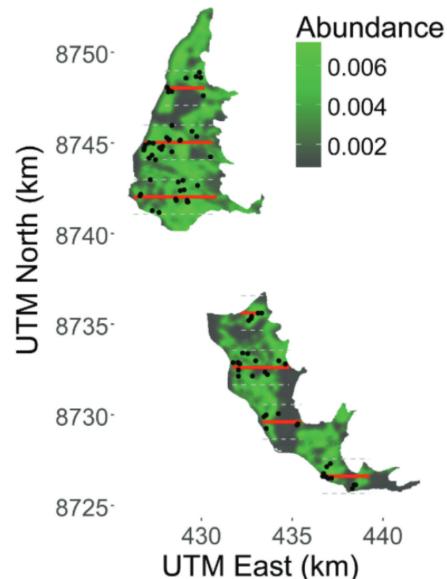
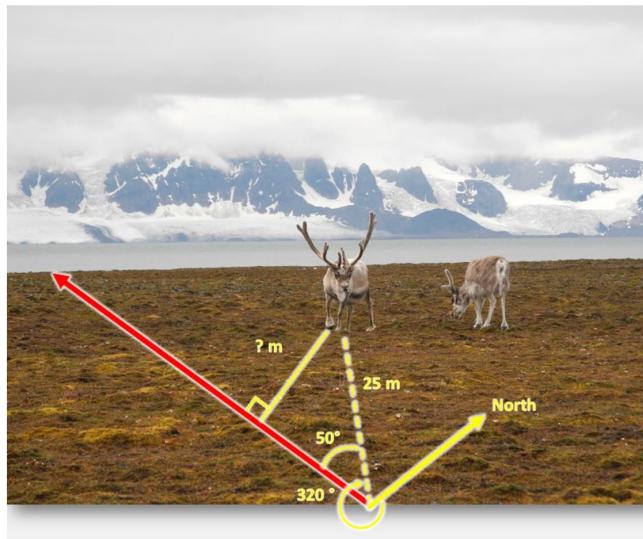


Distance Sampling

The statistics of accounting for visibility decreasing with distance



Example reindeer in Svalbard



Ungulate population monitoring in an open tundra landscape:
distance sampling versus total counts

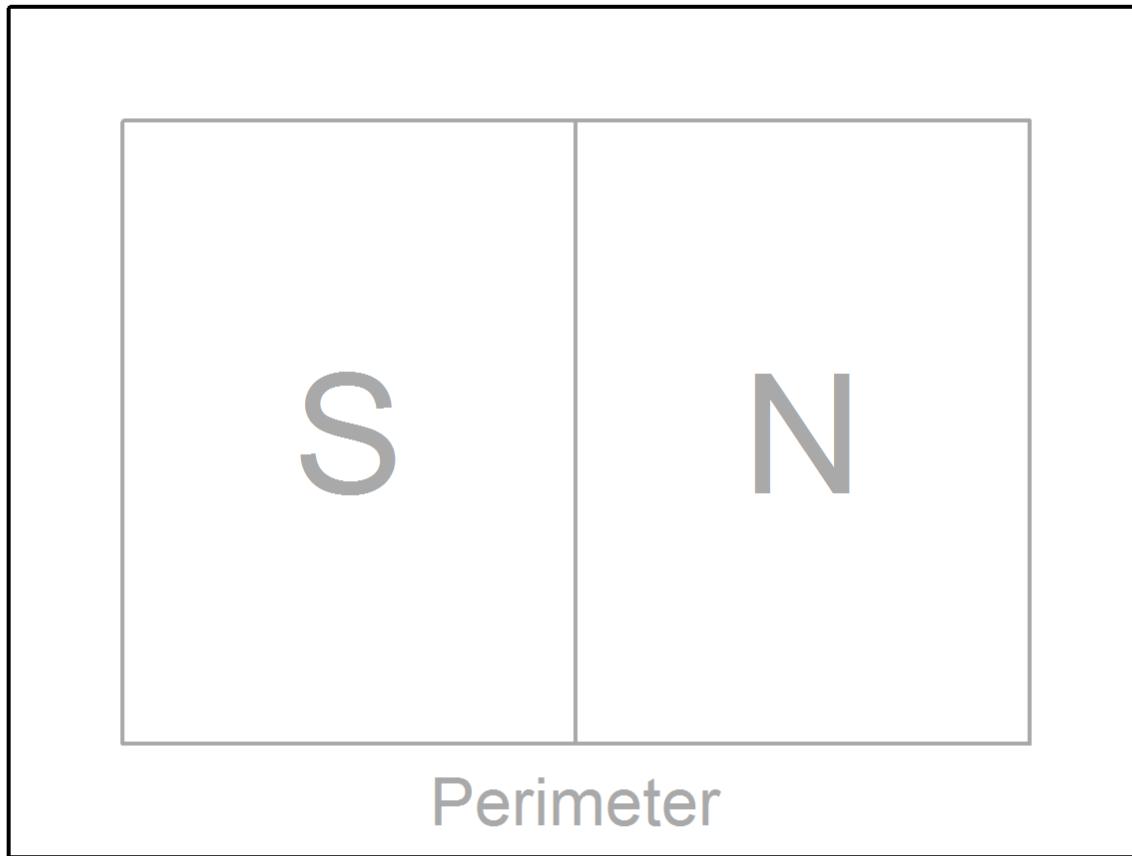
Wildlife Biology 2017: wlb.00299
doi: 10.2981/wlb.00299

Mathilde Le Moullec, Åshild Ønvik Pedersen, Nigel Gilles Yoccoz, Ronny Aanes, Jarle Tufto
and Brage Bremset Hansen

**Estimated detection distance, compared to total count,
incorporated vegetation modeling, computed standard errors,
concluded that you can get a 15% C.V. for 1/2 the cost.**

Example Ice-Seals

Example: Flag Counting at Baker



Nice video on counting caribou

<https://vimeo.com/471257951>

