Survey design

- Introduction
- Some concepts
  - Coverage
  - Plus/minus sampling and edge effects
- Point transect designs
- Line transect designs
- Effort calculations for design
- Stratification
- Example surveys

See

- *Chapter 7 of Buckland et al. (2001) Introduction to Distance Sampling*
- *Chapter 7 of Buckland et al. (2004) Advanced Distance Sampling*
- *Chapter 2 of Buckland et al. (2015) Distance Sampling: Methods and Applications*

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Survey design

Why is design (and good field methods) so important for distance sampling surveys?

- Distance sampling uses design-based estimates
- It is extremely hard and often impossible to compensate for poor design at the analysis stage
- Good design makes analysis more straightforward

Survey design – things to consider

- What are your objectives?
- What precision do you need?
- What resources are required?
- Are sufficient resources available?
- Include training in the costings.
- Cost for statistical advice!!
- Conduct a pilot survey.

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Terminology

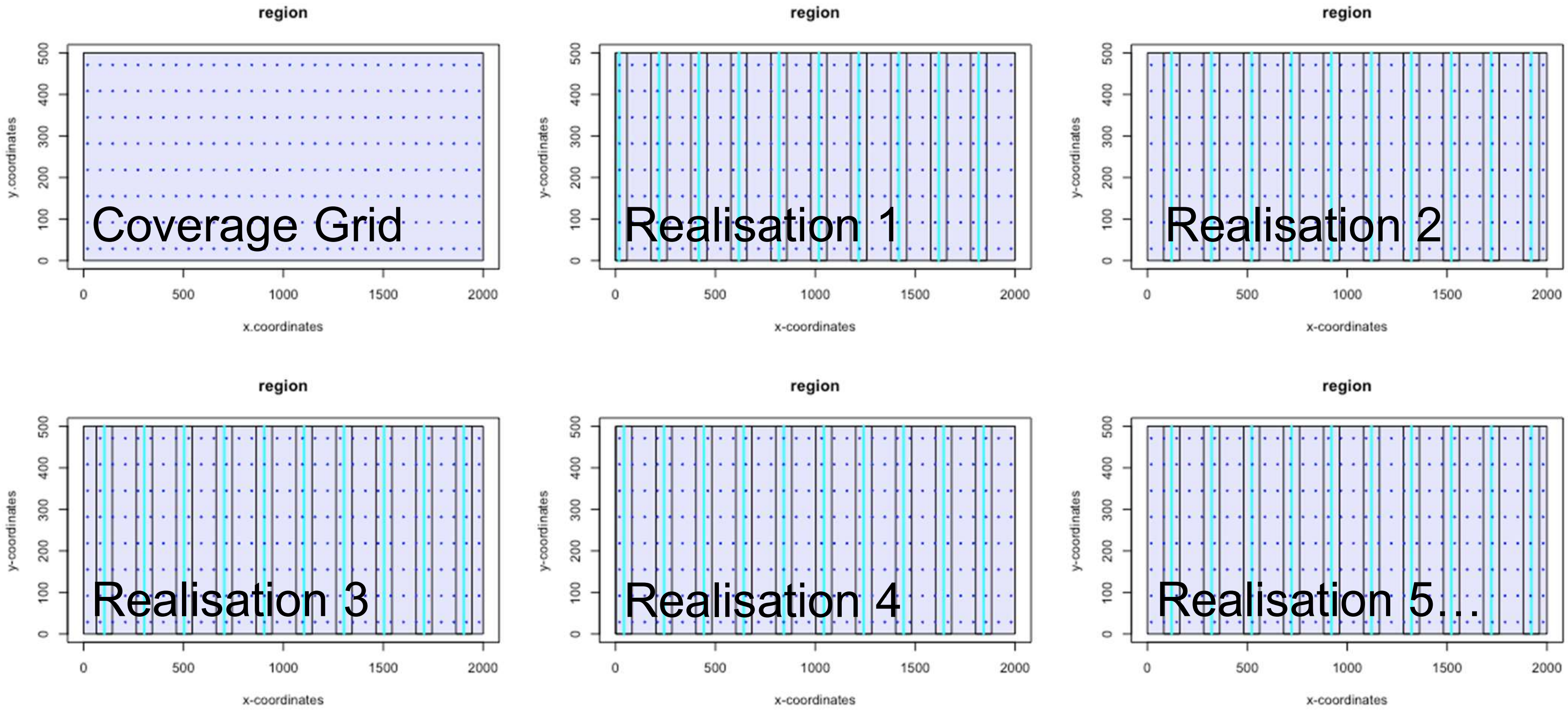
Design – a description of how the transects are laid out throughout the survey region.

Survey – a single realisation of a design

Sampler – a sample unit
- Strip (line transect)
- Circle (point transect)

Coverage score – the average number of times a particular point in the study region will be within a simulated "covered area"

Coverage



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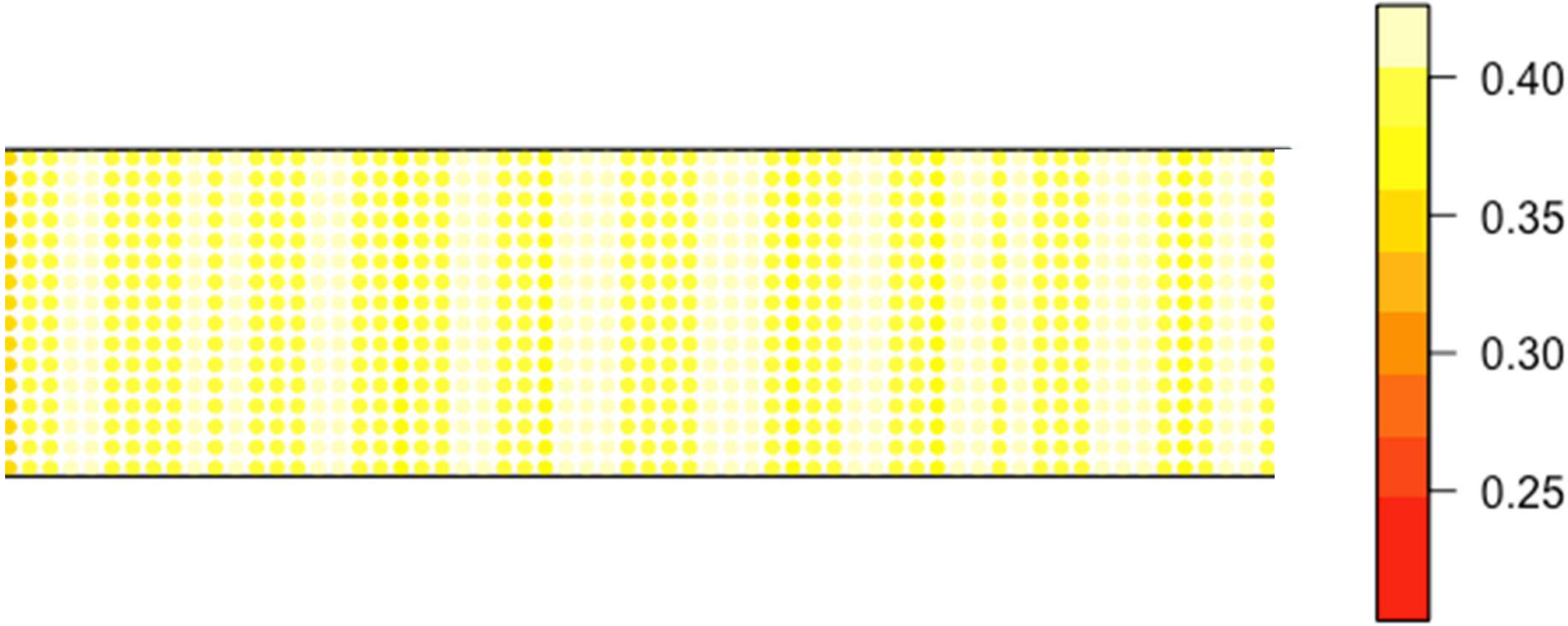
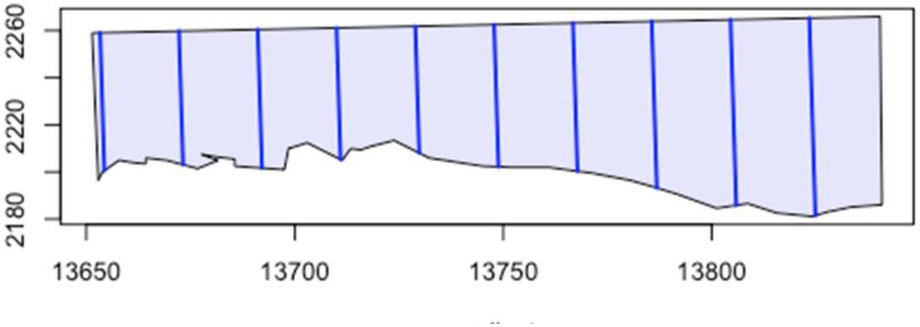
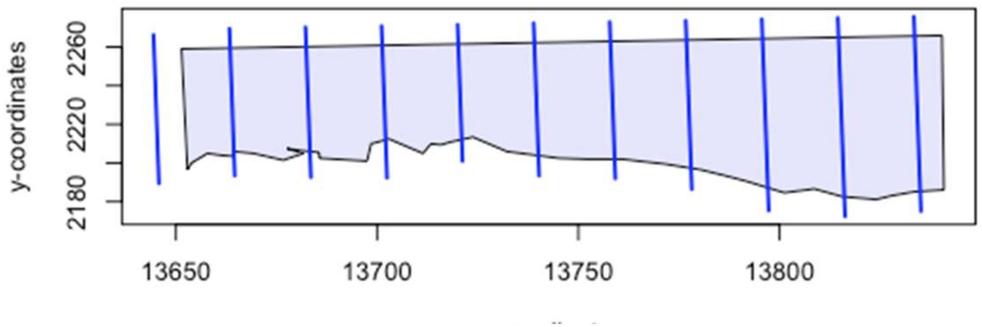
Coverage



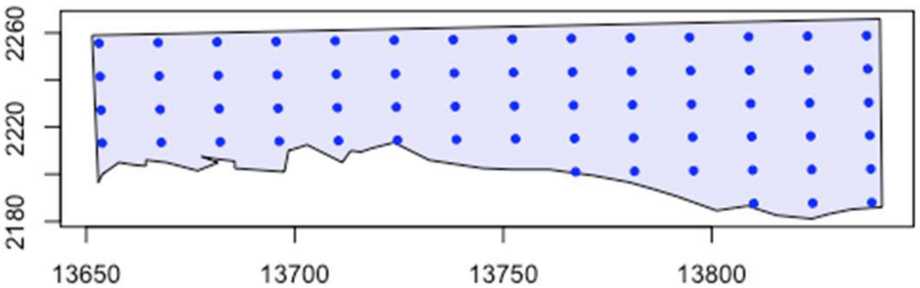
Minus v Plus Sampling

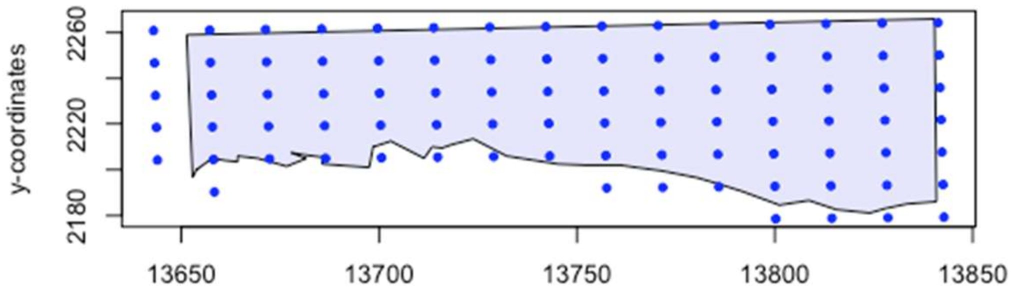




MINUS SAMPLING

PLUS SAMPLING





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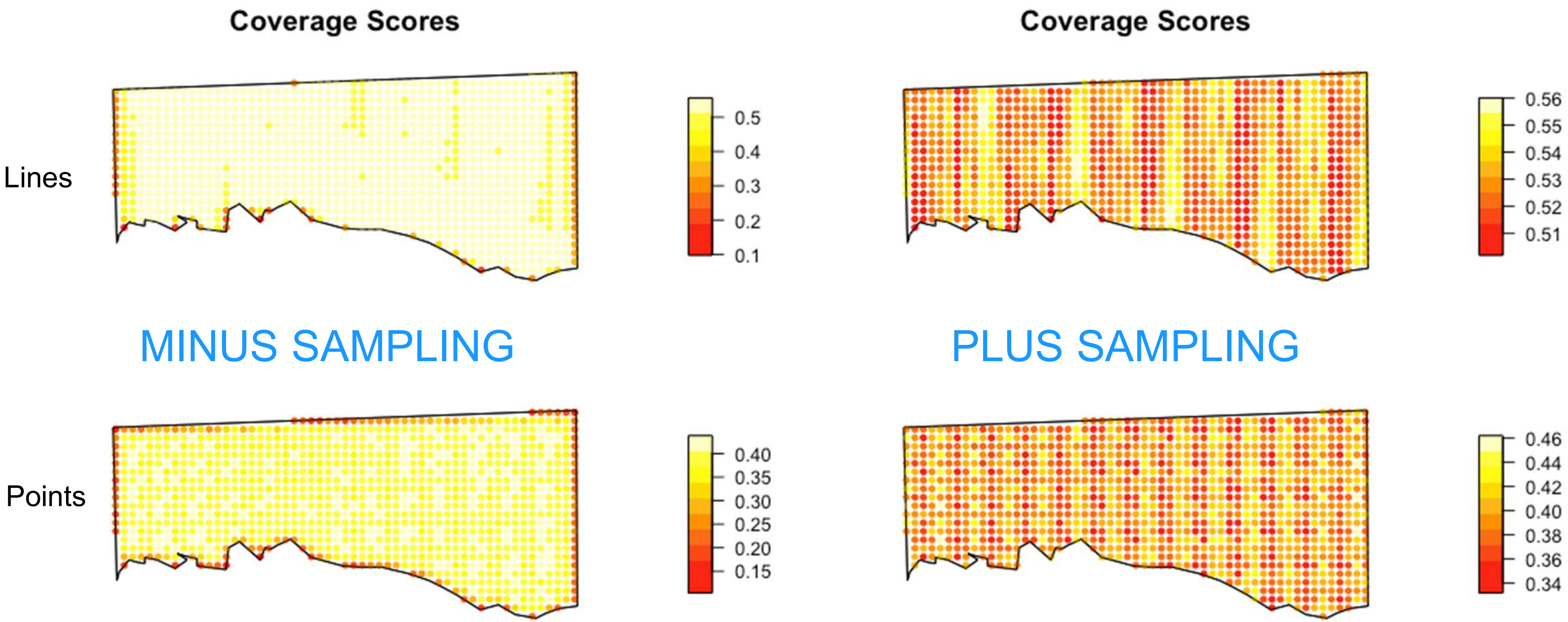
Coverage for 500 repetitions



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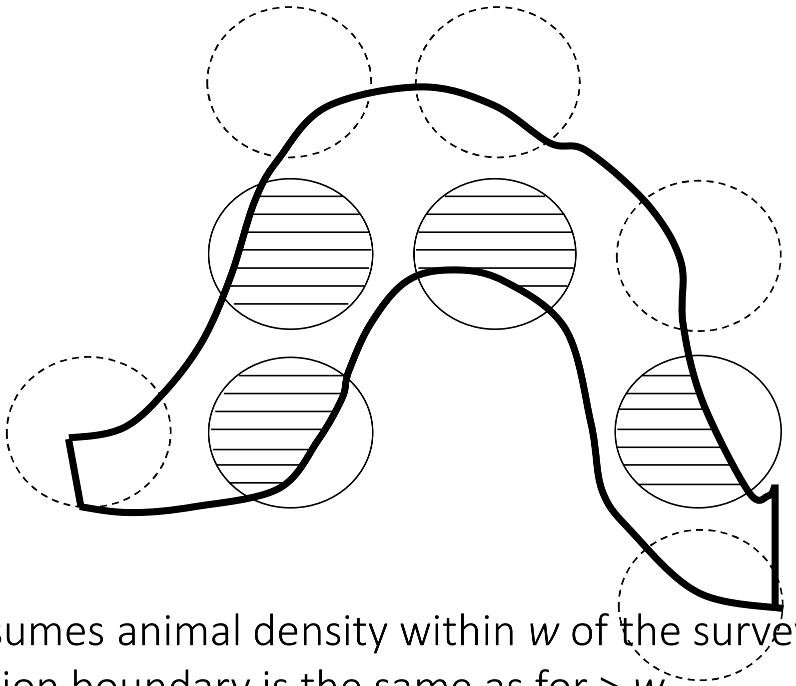
Point transect edge effects

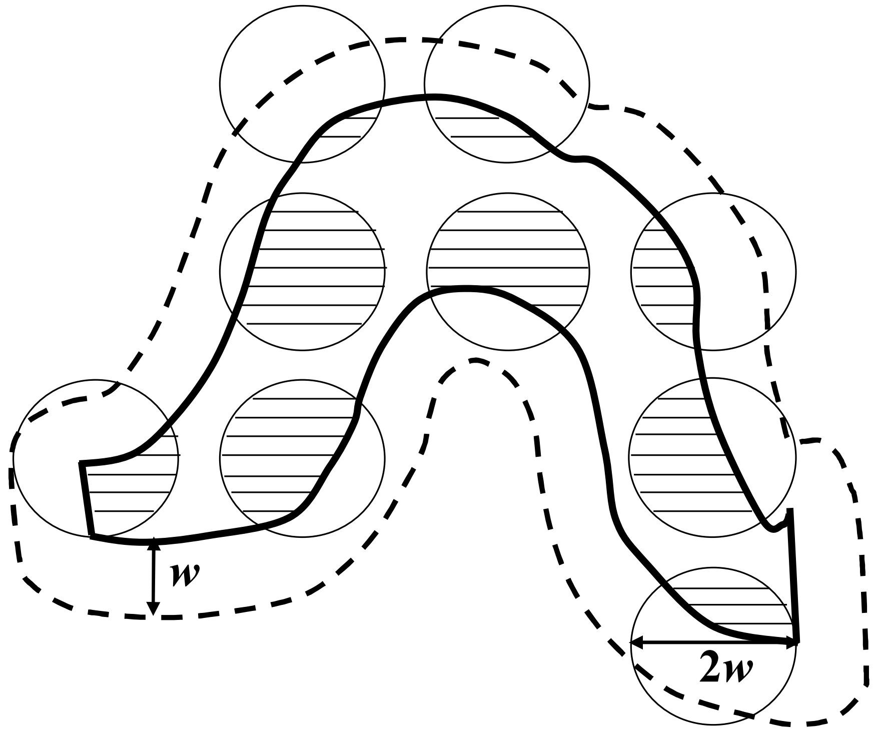
Minus sampling

•Only a problem if study area is very small or narrow relative to *w*



Assumes animal density within *w* of the survey region boundary is the same as for > *w*

Plus sampling



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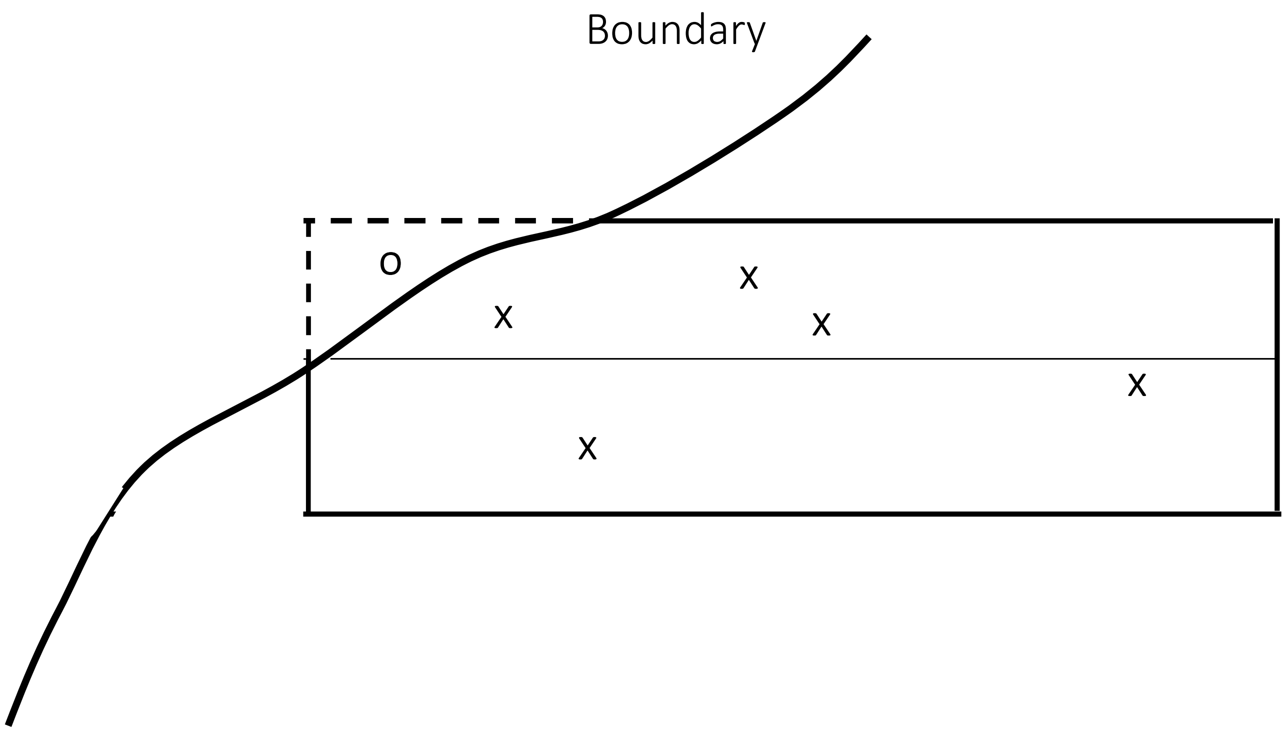
Minus Sampling – Line Transects



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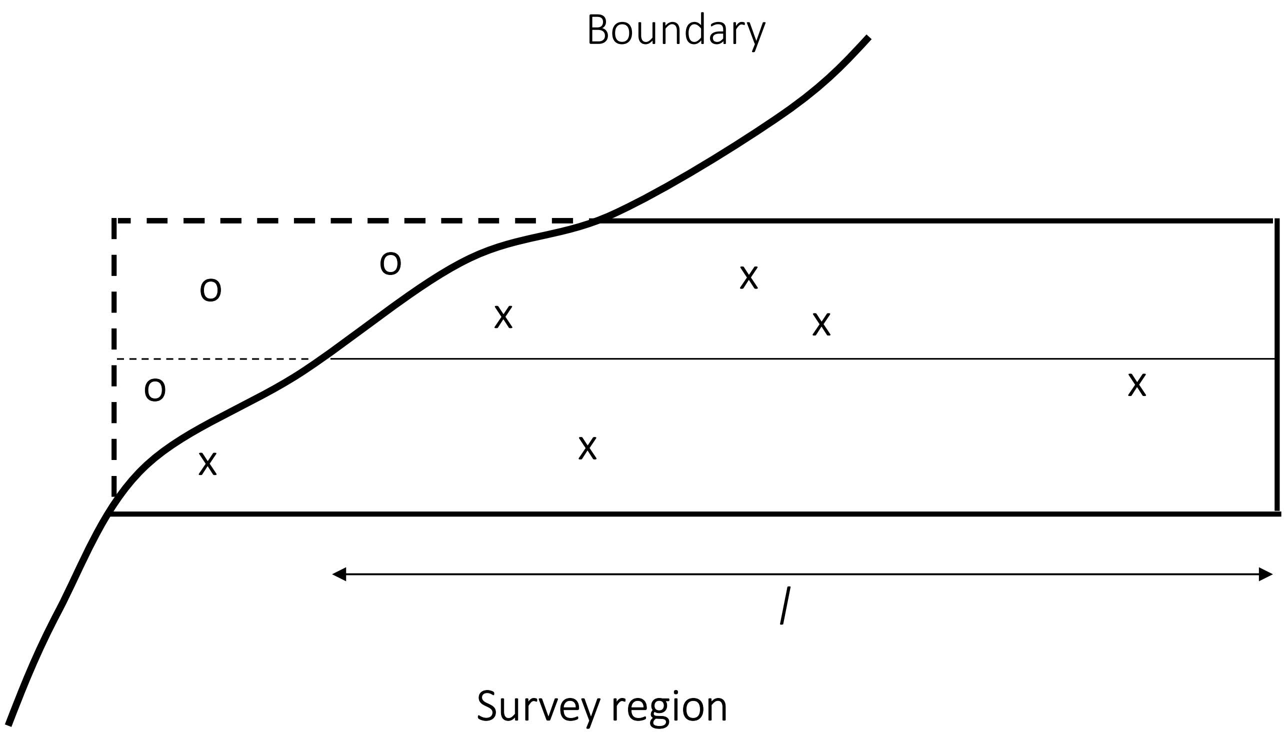
Plus Sampling – Line Transects



Extend the line beyond the boundary, but don’t include the associated effort, and don’t record animals detected outside the region (o)

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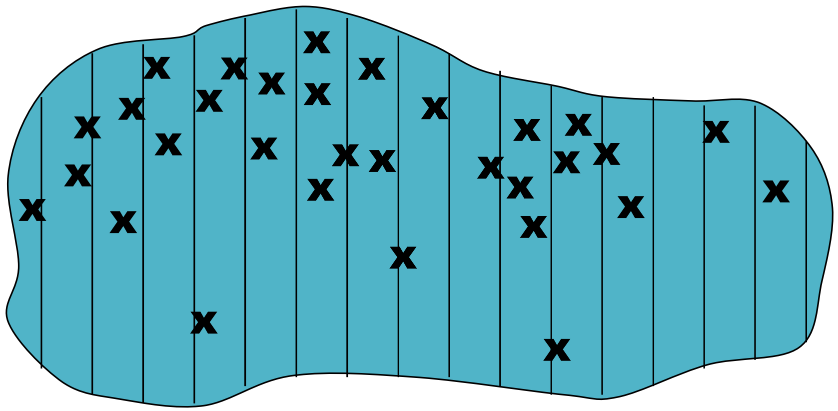
What do we need from our design?

- Surveyed area needs to be a representative sample of the study area
  - Uniform coverage
  - Use random allocation of transect locations
  - Do not use roads, tracks etc.
- Maximise the number of transects
  - Many short lines are better than a few long lines
- Minimise variability between transects
  - Try to orientate lines perpendicular to density contours or to linear features (e.g. woodland edge or coastline)
- Lines are generally preferable to points



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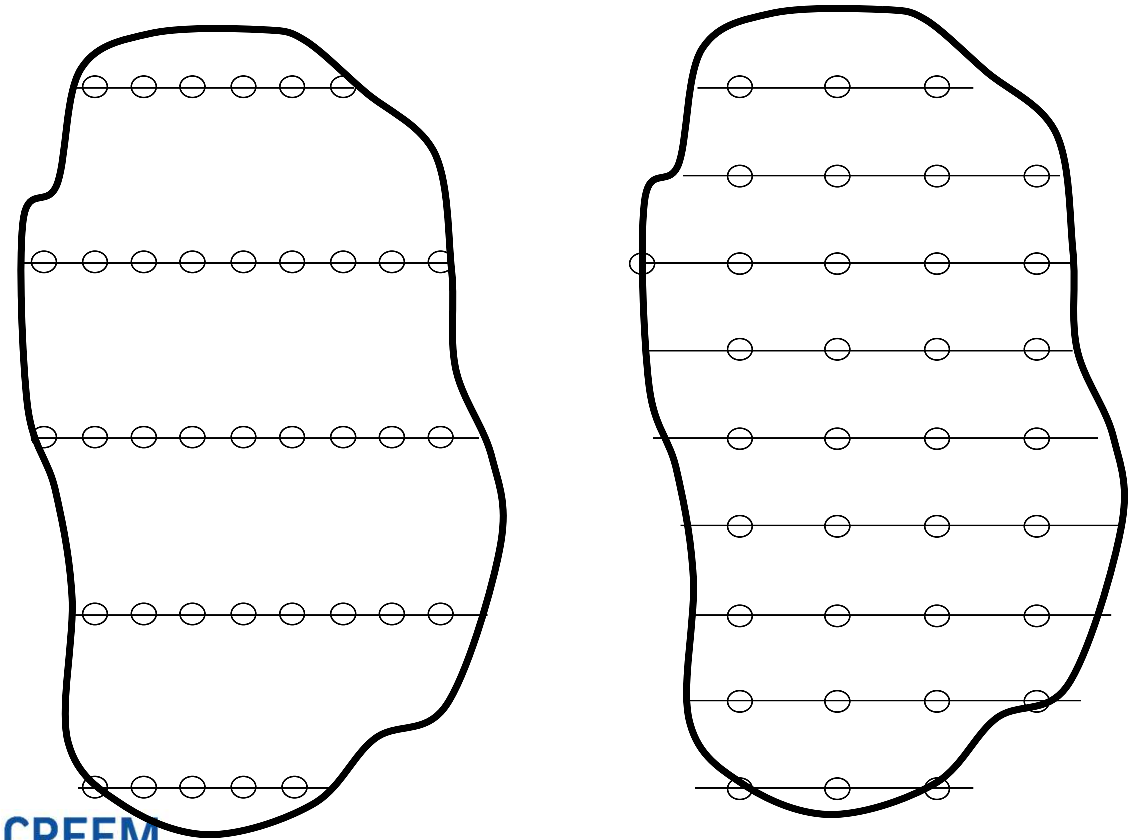
Systematic Sampling



Systematic designs with random start points.

Left-hand design: the lines should be taken as the sampling units,

Right-hand design: the individual points can be taken as the sampling units

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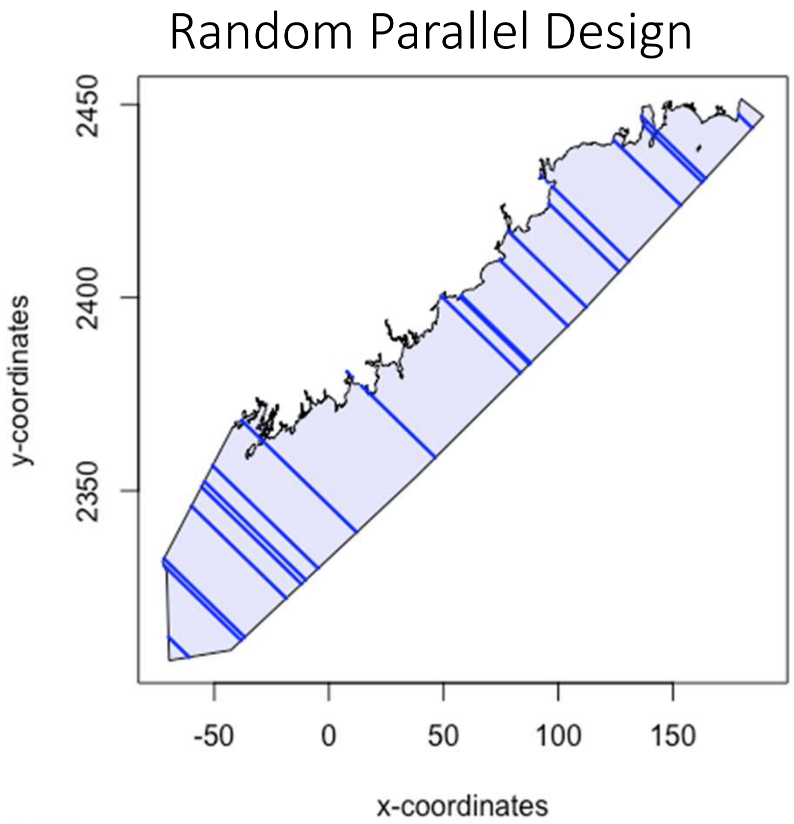
Comparison of Point Transect Designs

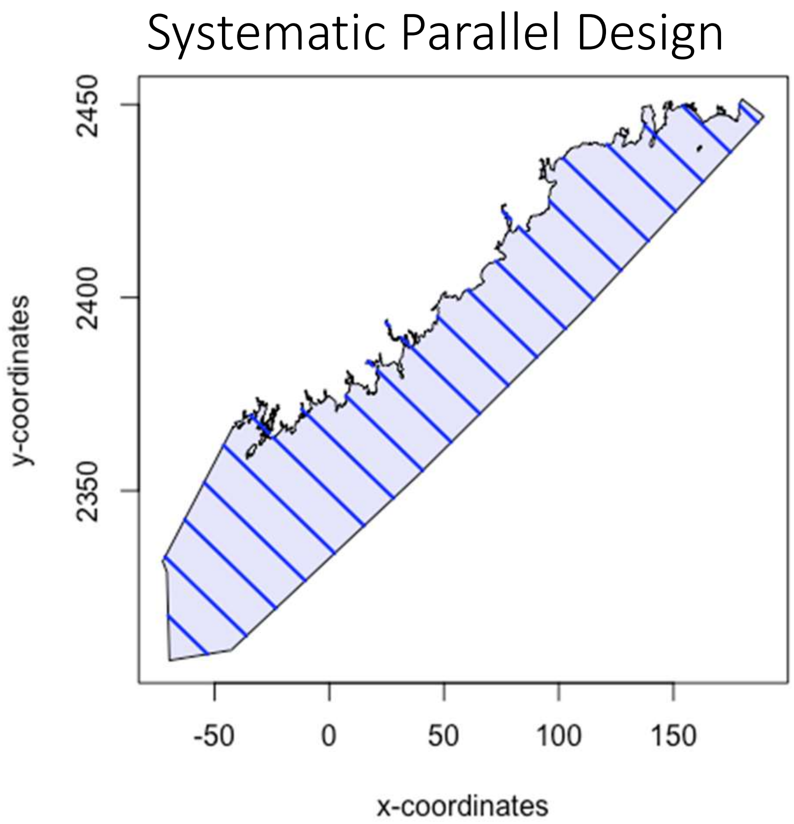
- **Uniform coverage** – random and systematic designs have uniform coverage
- *With exception of edge effects*
- Systematic has more **even coverage** for any given realisation
- For systematic designs
- *equal spacing in the x and y directions have* ***more sampling units***
- *better for variance estimation*
- Cost of travel is similar
    - If this is important a cluster sampling design can be used

Line Transect Designs

Full width line transect designs

Parallel Line Transect Designs





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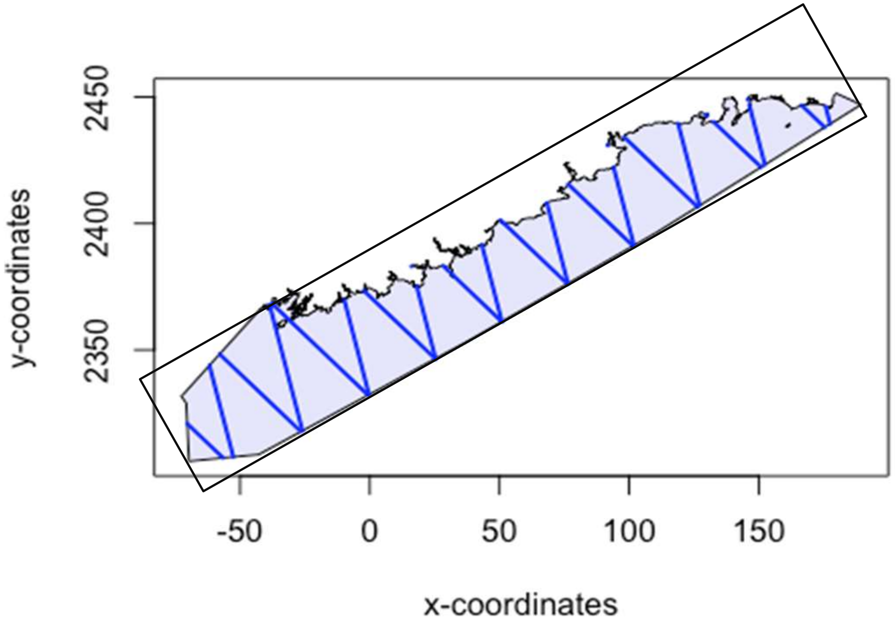
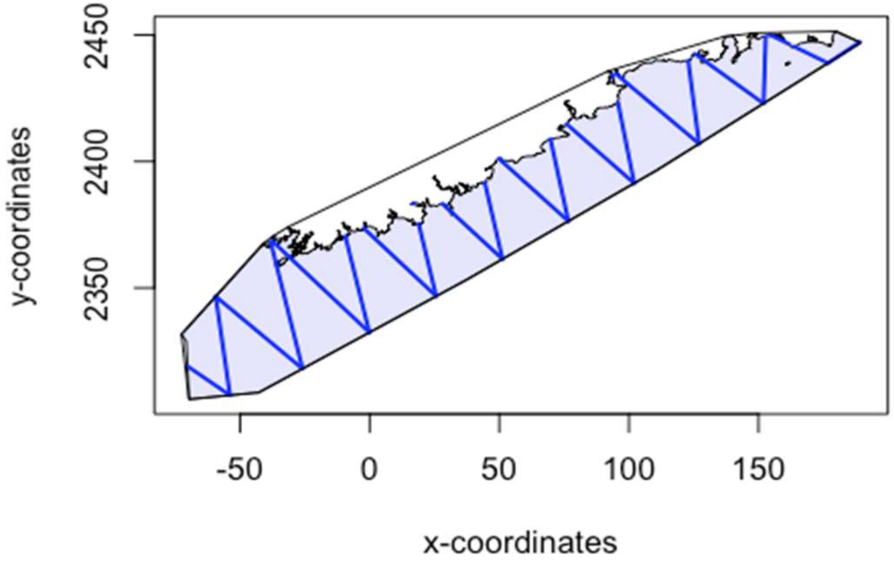
Equal Spaced Zigzag Designs

Generated inside a minimum bounding rectangle



Generated inside a convex hull – like stretching an elastic band around the study region



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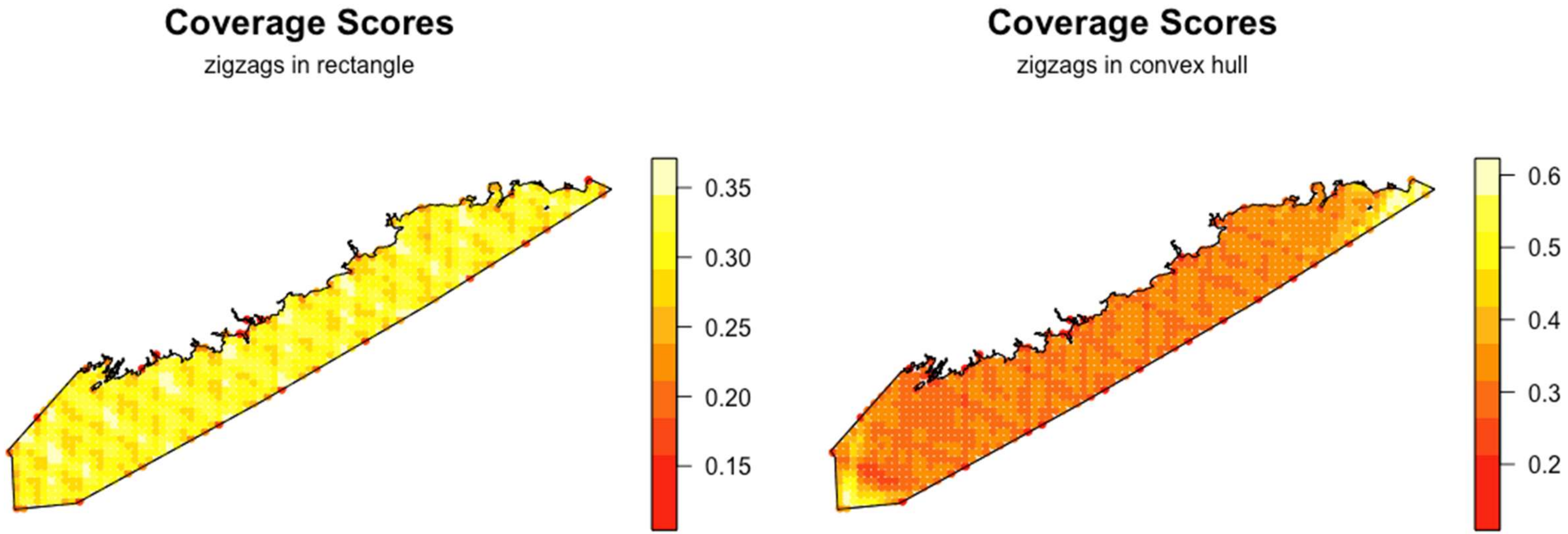
Complementary Equal Spaced Zigzags



Simulation based on generating 1000 surveys

Comparison of Line Transect Designs

- Uniform coverage – parallel line designs and zigzags generated inside a rectangle have uniform coverage (excluding edge effects)
  - Zigzags inside a convex hull can have non-uniform coverage
- Systematic designs (systematic parallel and zigzag) have more even coverage for any given realisation
- Zigzags generated inside a convex hull are usually more efficient (less off-effort transit between transects) and complementary zigzags can further improve efficiency
- Can have overlap of samplers in the parallel random design. Also some overlap in zigzag designs.

Segmented Line Designs

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Fixed length transects

Systematic segmented trackline

Systematic segmented grid

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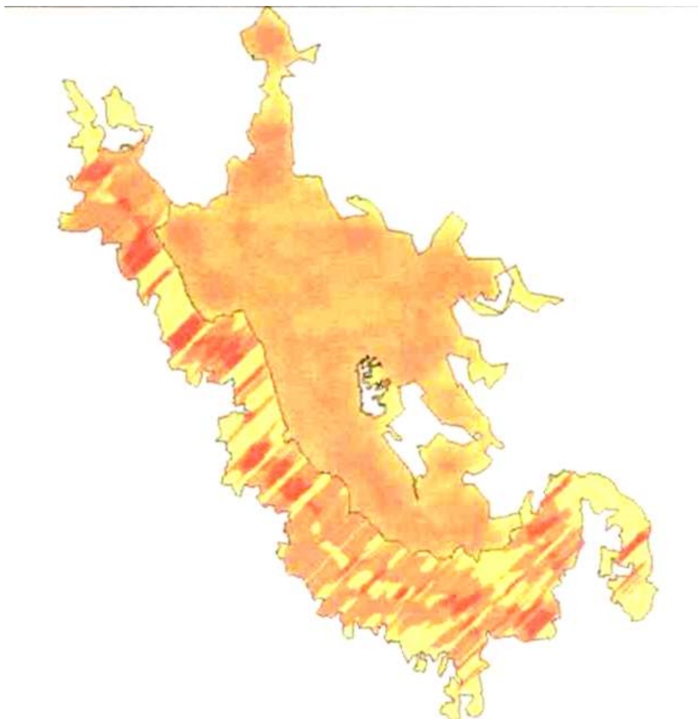
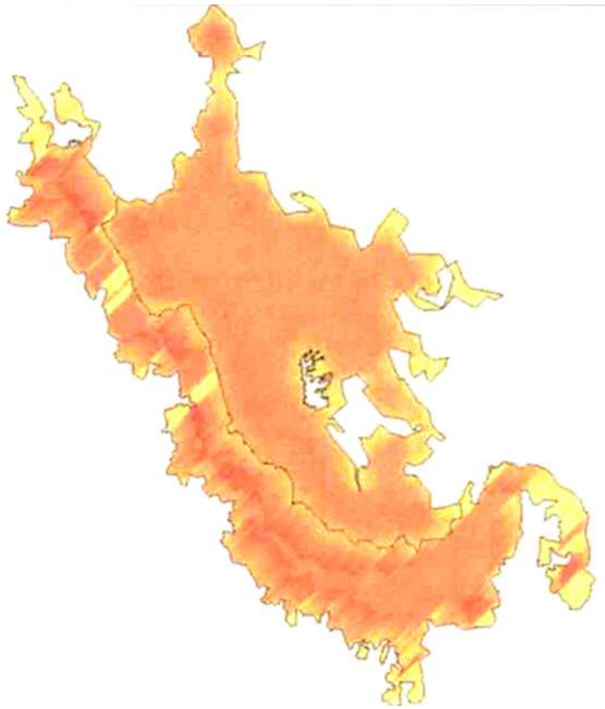
Edge Effects - push segments more than half in all the way in and discard others

Systematic segmented trackline



Systematic segmented grid



N.B. Both use random orientation of transects in the northern stratum

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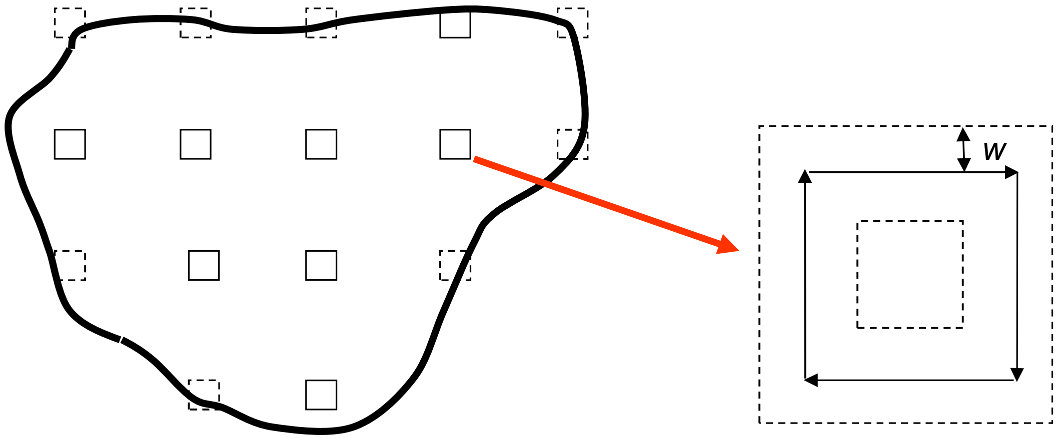
Comparison of Segmented Designs

- Systematic segmented grid seems to give more even coverage
- The between segment spacing should be the same in the x and y directions to maximise the number of sampling units
- Consider random orientation of lines, may give more uniform coverage
- Other designs (such as circuit samplers or segmented zigzags) might be worth considering



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Sample size

Estimating the required sample size when designing a distance sampling survey.

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Sample size

- Aim for at least 60-80 sightings for fitting the detection function
- and at least 20 lines or points for estimating encounter rate *n/L* or *n/k*
- Whether reliable estimates can be obtained from smaller samples is a matter of luck
  - depends on the data
  - do not employ a design that relies upon luck

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Sample size – continued

More observations are required:

- if detection function is spiked
- if population is highly aggregated
- for point transect sampling

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Increasing sample size using repeat counts

If a line is sampled three times,

- pool the distance data from the three visits
- enter survey effort as three times the line length.

If a point is sampled three times,

- enter survey effort as 3.

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Determining total line length

Pilot study: n_0 animals (or clusters) counted from lines totalling L_0 in length.

Total line length required in main survey is

$$L = \left(\frac{b}{\left[cv_t(\hat{D})\right]^2} \right) \times \frac{L_0}{n_0}$$

Where $cv_t(\hat{D})$ is the target cv (e.g. 10% is 0.1) and...

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Determining line length (cont)

b is approximately $$\frac{Var(n)}{n} + \frac{n \cdot Var[\hat{f}(0)]}{[\hat{f}(0)]^2}$$

Pilot studies are typically too small to estimate *b*. If past similar data sets are not available, assume *b* = 3.

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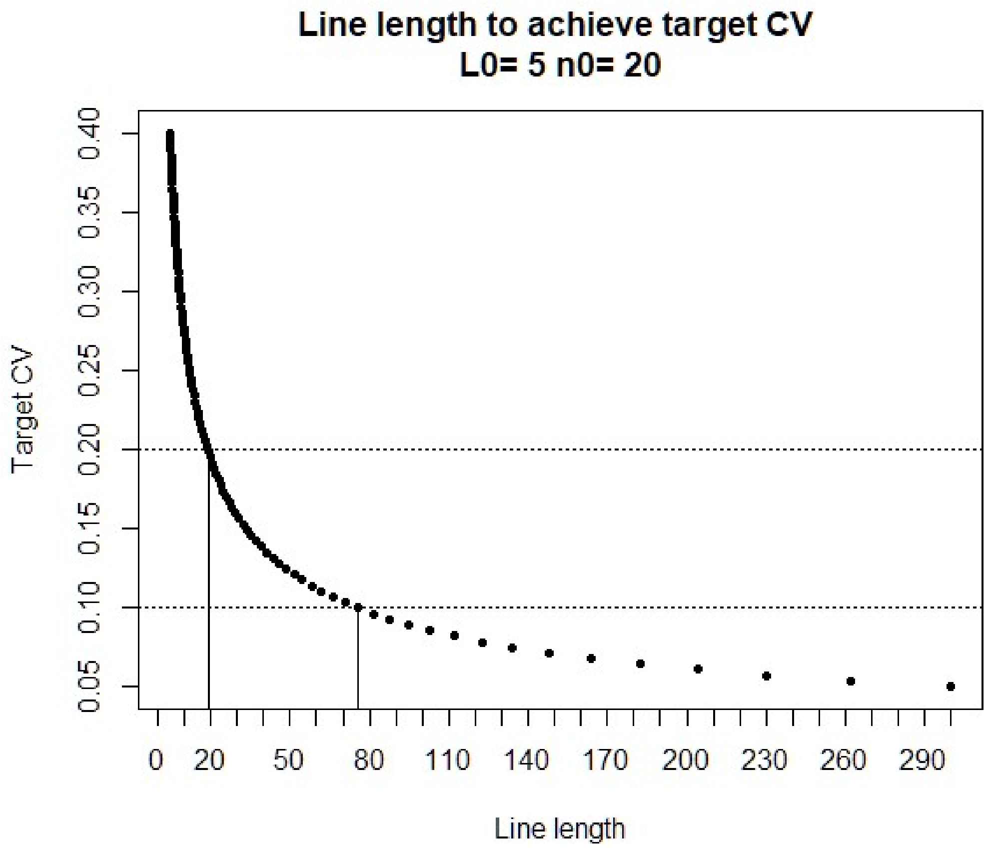
Line length example

A pilot study yields n_0 = 20 observations from lines of total length 5km. We require a CV of 10% and assume b = 3.

$$L = \frac{3}{0.1^2} \times \frac{5}{20} = 75\text{km}$$

Estimated sample size is

$$n = L \times \frac{n_0}{L_0} = 75 \times \frac{20}{5} = 300$$



Determining line length (cont)

If pilot survey is sufficiently large, calculate line length for main survey as

$$L = \frac{L_0[cv(\widehat{D}_0)]^2}{[cv_t(\widehat{D})]^2}$$

where

$cv(\hat{D}_0)$ is the cv of estimated density obtained from the pilot survey, and L is total line length in the main survey

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Point transects: number of points

or

$$k = \left(\frac{b}{[cv_t(\widehat{D})]^2}\right) \times \frac{k_0}{n_0}$$

$$k = \frac{k_0[cv(\widehat{D}_0)]^2}{[cv_t(\widehat{D})]^2}$$

where k_0 points in the pilot survey yielded n_0 detections, or estimated density of $\hat{D}_0$

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Stratification

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Stratification (Geographic)

Why stratify?

- We might want estimates by sub-region/stratum
- To improve precision.
  - *Estimate inter-stratum differences rather than have them contribute to variance.*
  - *Reduce overall variance by increasing effort in strata which contribute most to variance.*
- For logistic reasons

Stratification (Geographic)

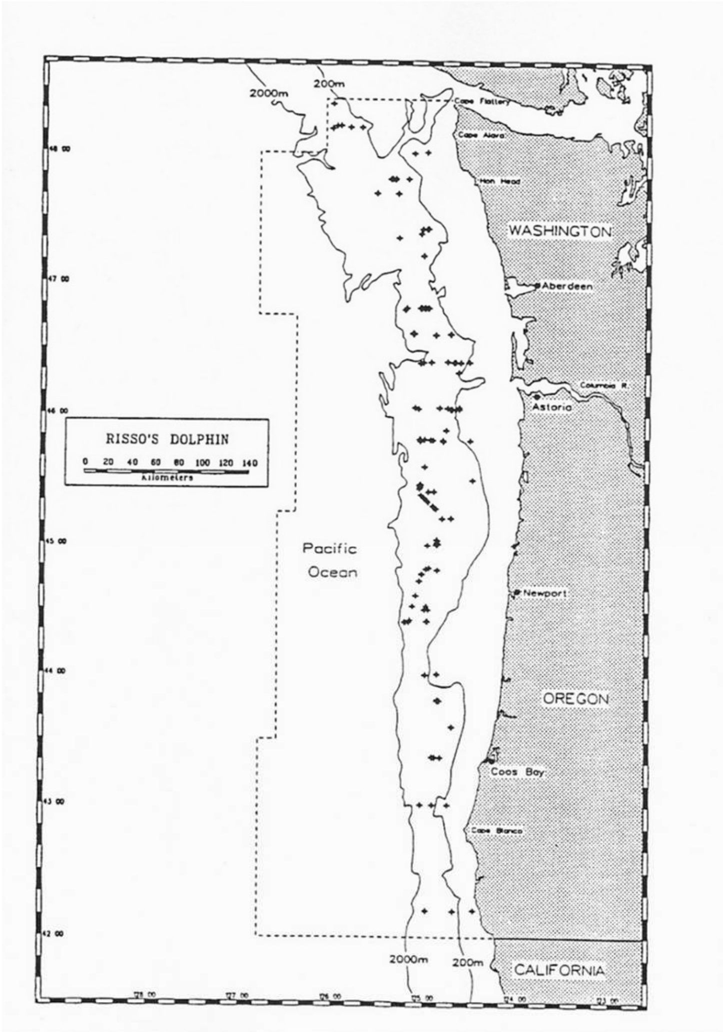
What to stratify?

- Encounter rate: Density often varies spatially.
- Detection function: May vary spatially. There are often sample size limitations on stratified estimation (too few detections in some strata).

Caution:

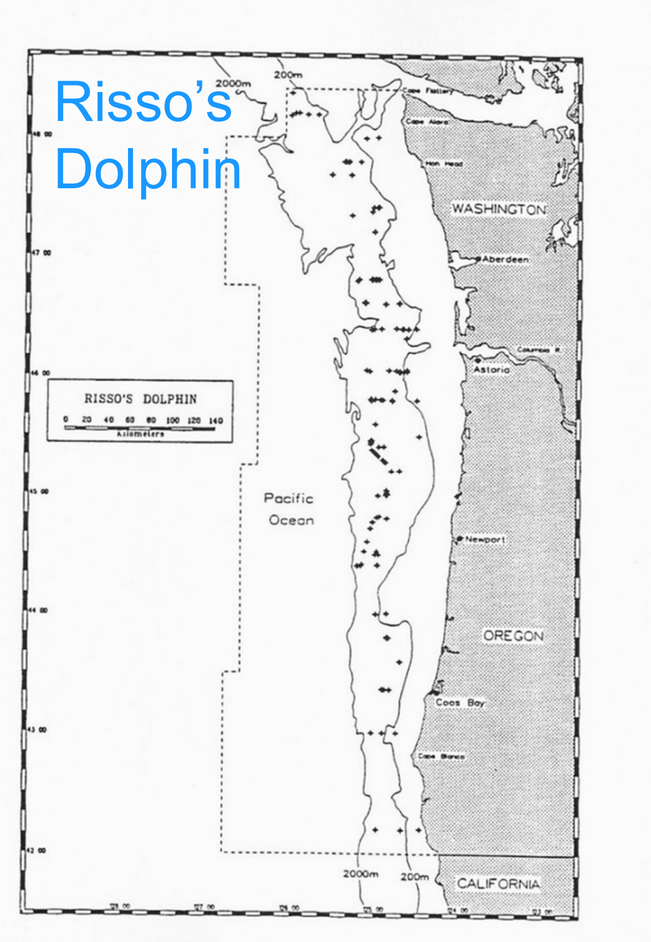
- If either of the above are estimated by pooling across strata
- when in reality they differ between strata
- within-stratum estimates are biased
- magnitude of this bias shown in demonstration found in Practical 7
    - `stratumspecific-bias.html`

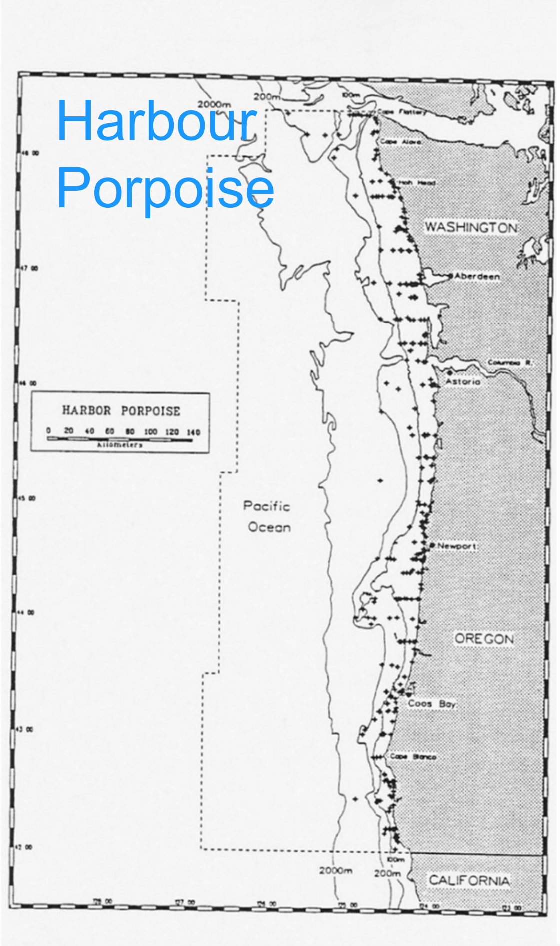
Stratification (Spatial) – Risks!



- Most animals between 200m and 2000m contours, so put more effort into a shelf-edge stratum?
- What if our sample size too low in some strata?
    - With unequal coverage between strata pooling robustness is lost!
    - Our overall sample is no longer representative of the study area as a whole.
- Other species?

Stratification (Spatial) – Risks!





Optimal effort location for one species may be poor for another species!

Uniform effort across strata is often the best design for multi-species surveys.

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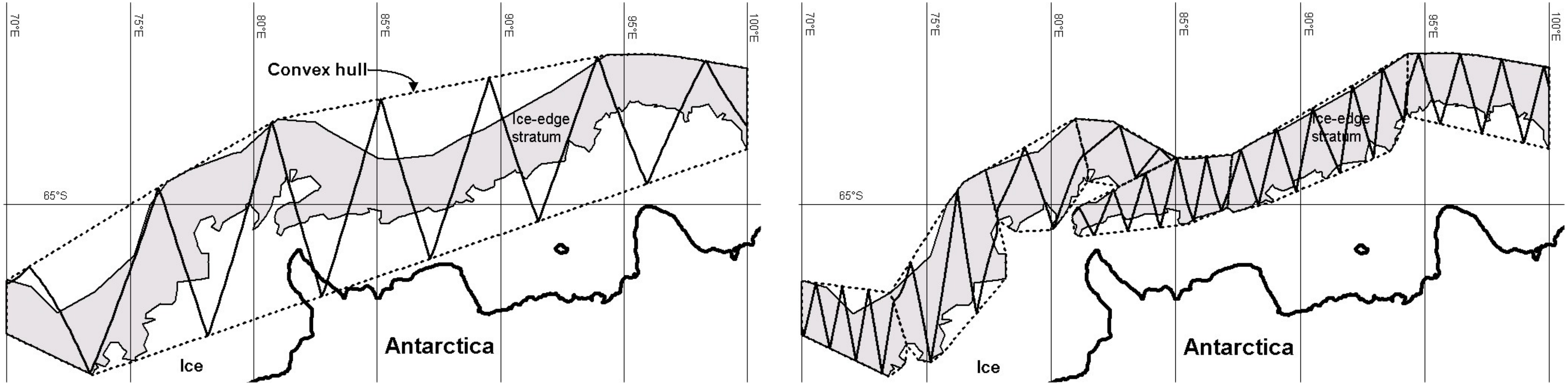
Example Surveys

Dealing with Complex Regions

Antarctic Minke whale shipboard survey

Study region divided into suitable strata to increase efficiency



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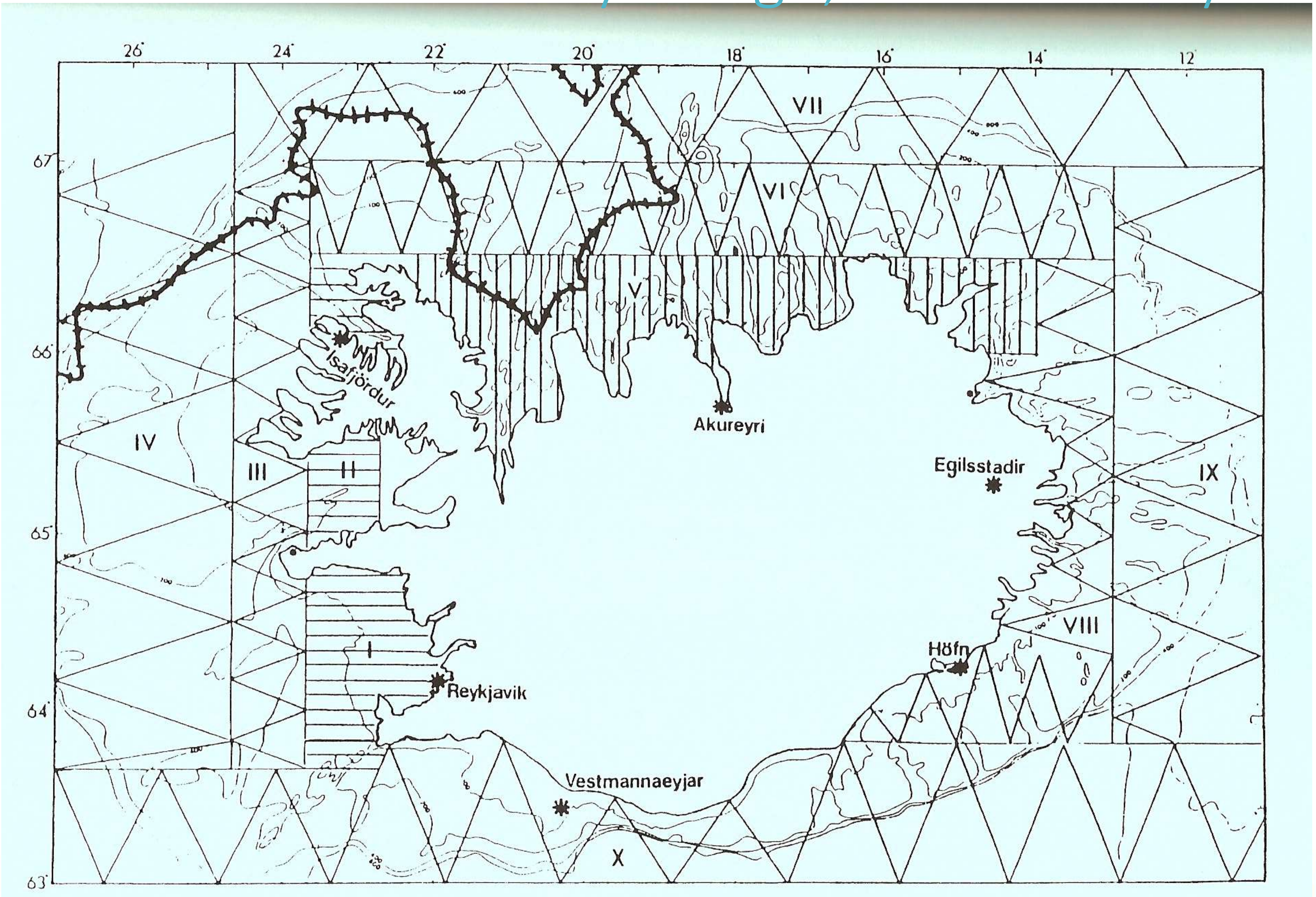
Iceland – aerial survey design, whale survey



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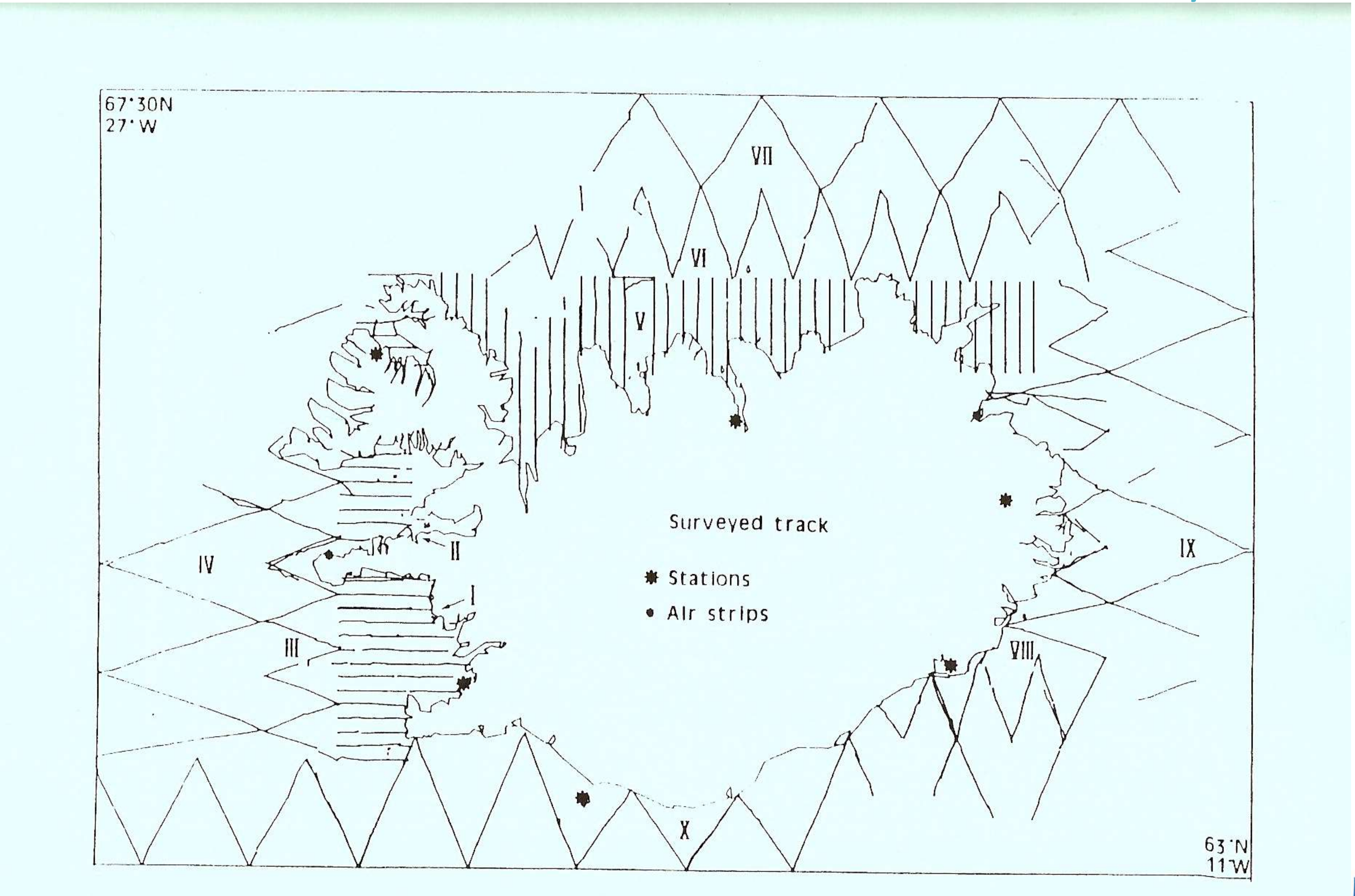
Actual effort, Icelandic whale survey



Main Points

- Line transects are generally preferable to points
- Try to achieve uniform coverage
- Systematic designs give more even coverage for any one survey
- Zig-zag designs often more efficient
- Lines should be placed parallel to density gradient (perpendicular to density contours) or to maximise the number of samplers
- Choose spacing values for points and segments which maximise sampling units
- Take care with unequal coverage stratified designs!
  - If coverage cannot be assumed equal, then it must be measured
  - Plus, abundance estimation must take into account the computed coverage
    - *Much more complex analysis*