Survey design

- Introduction
- Some concepts
  - Coverage
  - Plus/minus sampling and edge effects
- Point transect designs
- Line transect designs
- 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*

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.

Terminology

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

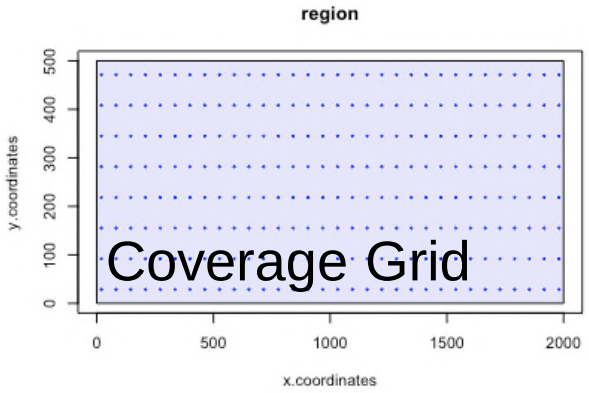
Survey – a single realisation of a design

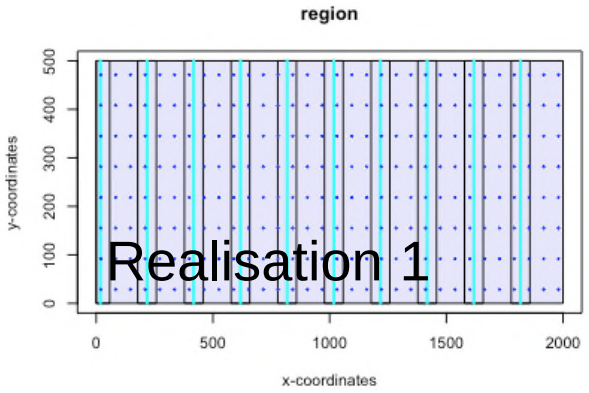
Sampler – a sample unit

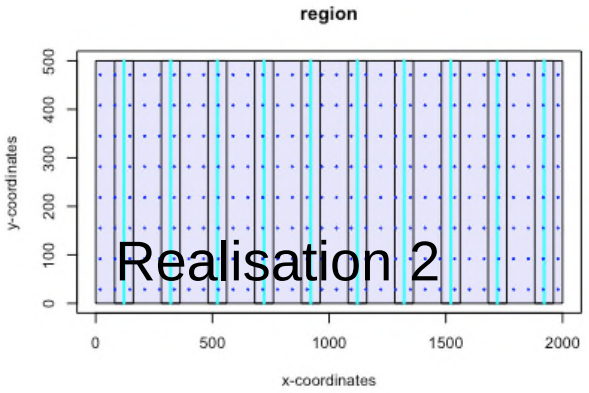
- Strip (line transect)
- Circle (point transect)

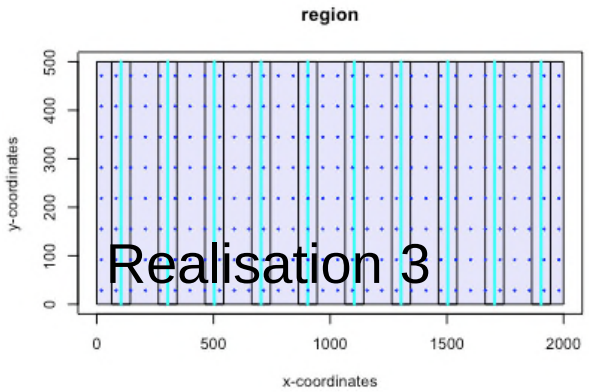
Coverage score – the average number of times a particular point in the study region will be included in a survey.

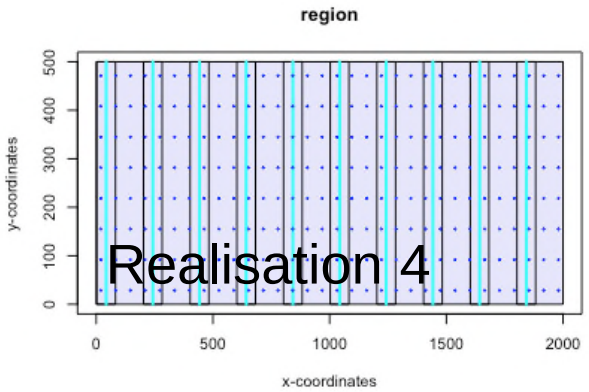
Coverage

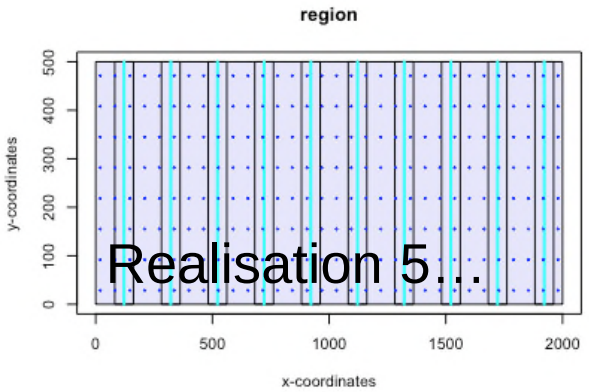












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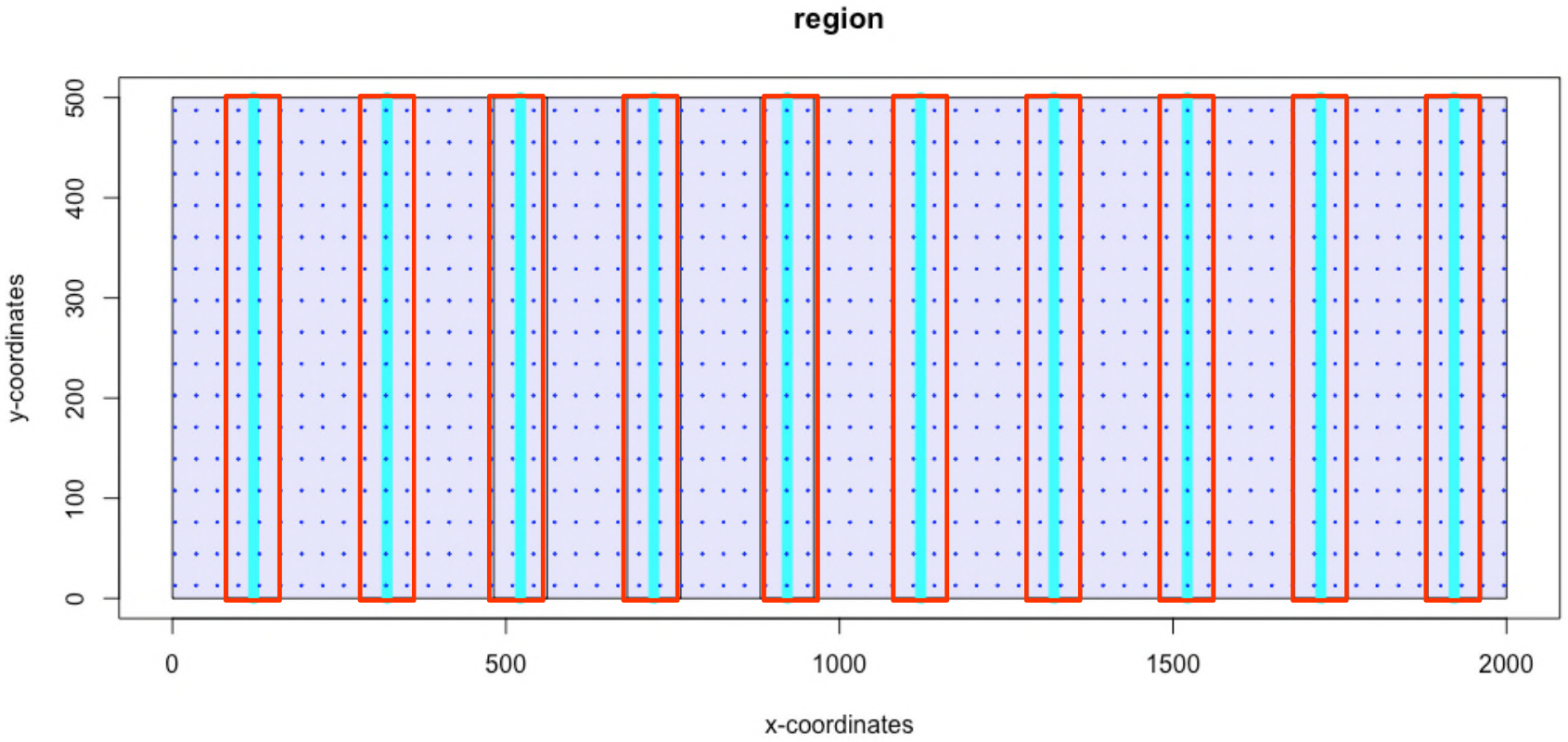
Coverage



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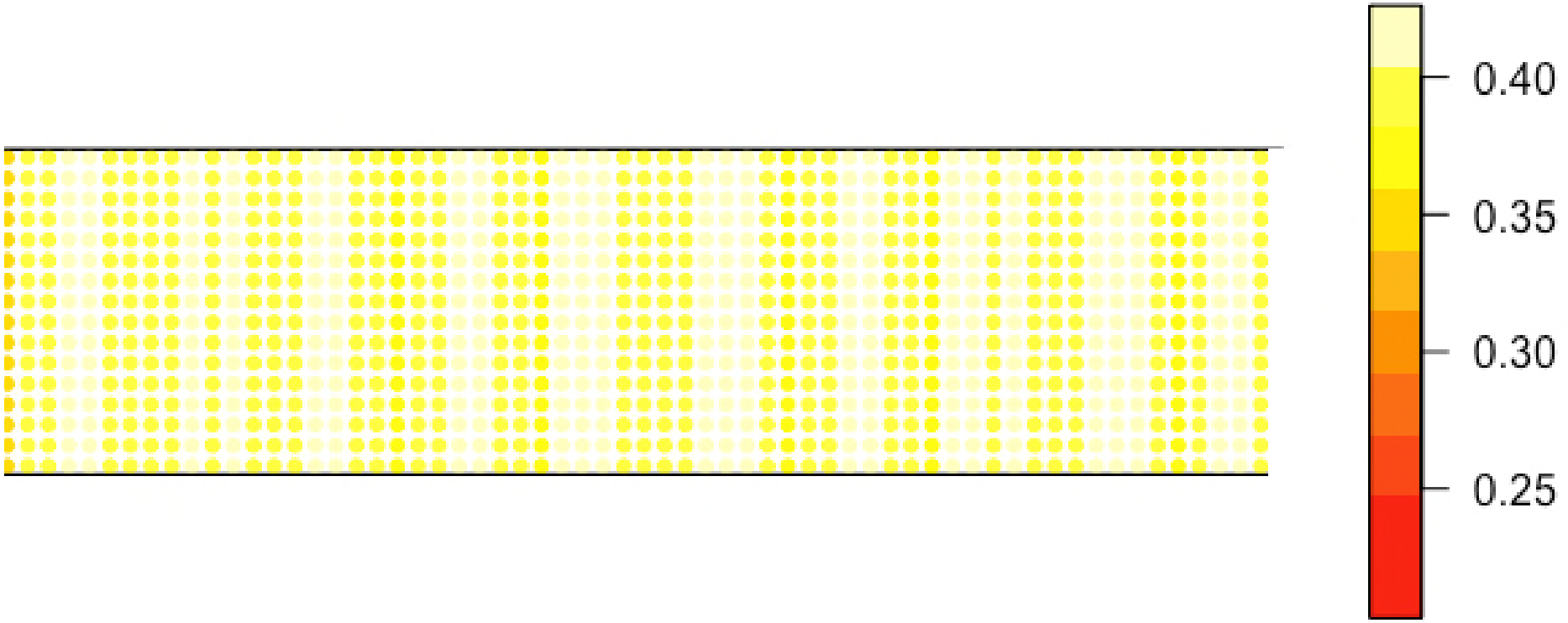
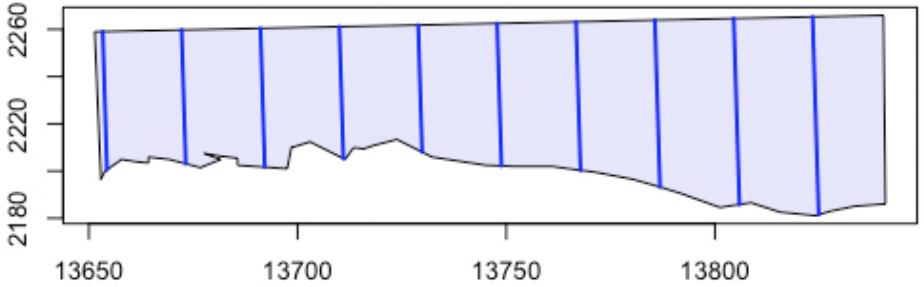
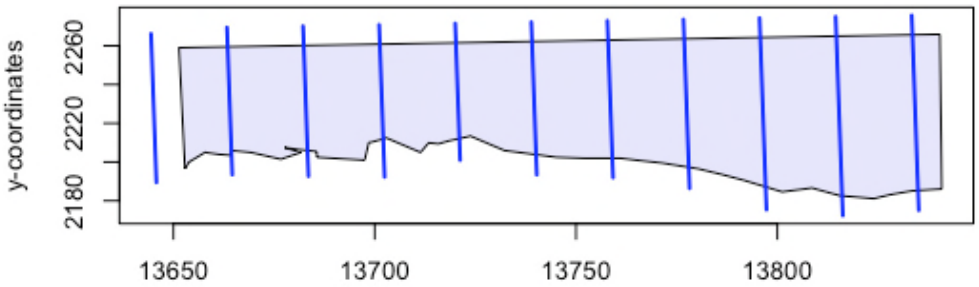
Coverage



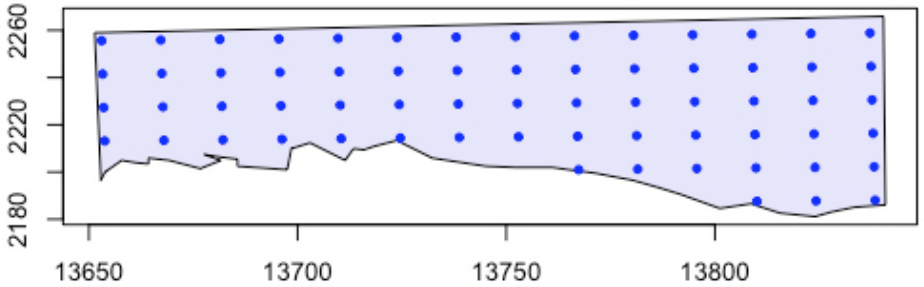
Minus v Plus Sampling

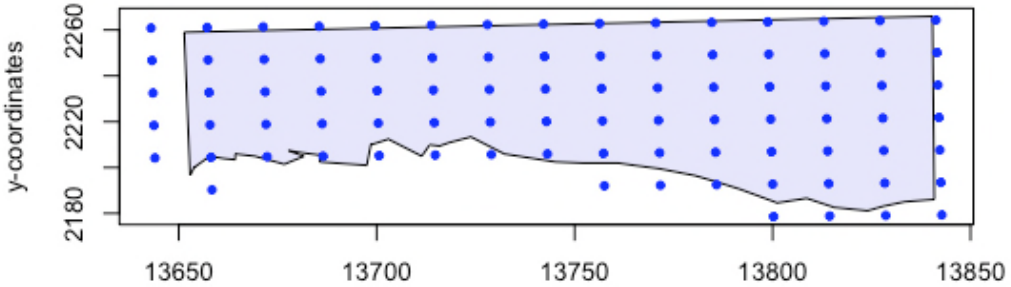




MINUS SAMPLING

PLUS SAMPLING





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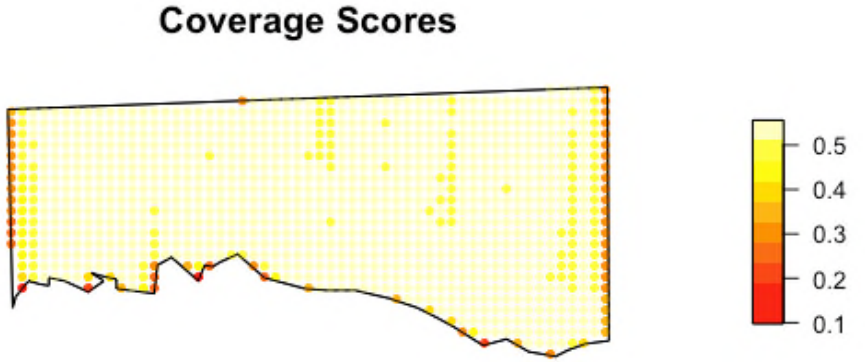
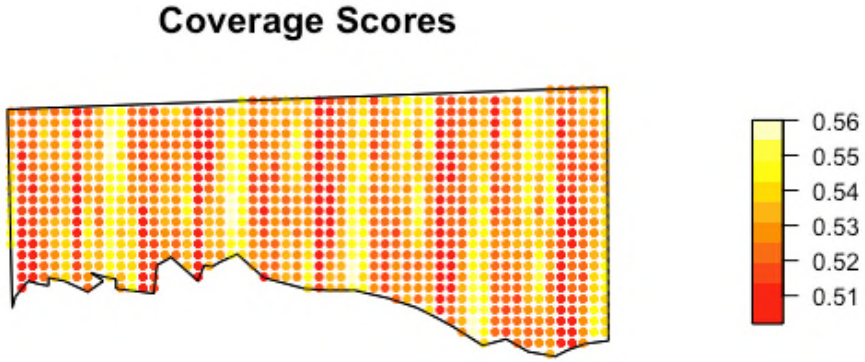
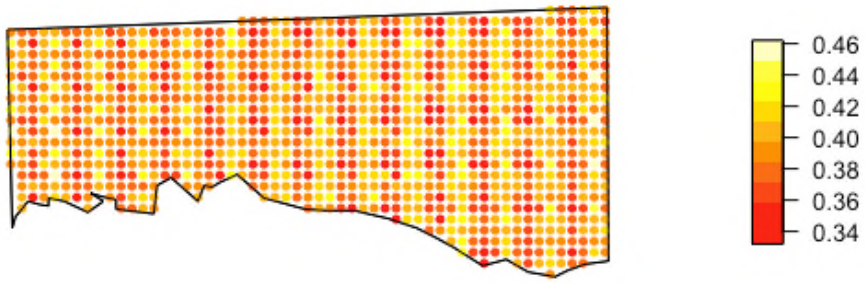
Coverage for 500 repetitions





MINUS SAMPLING

PLUS SAMPLING



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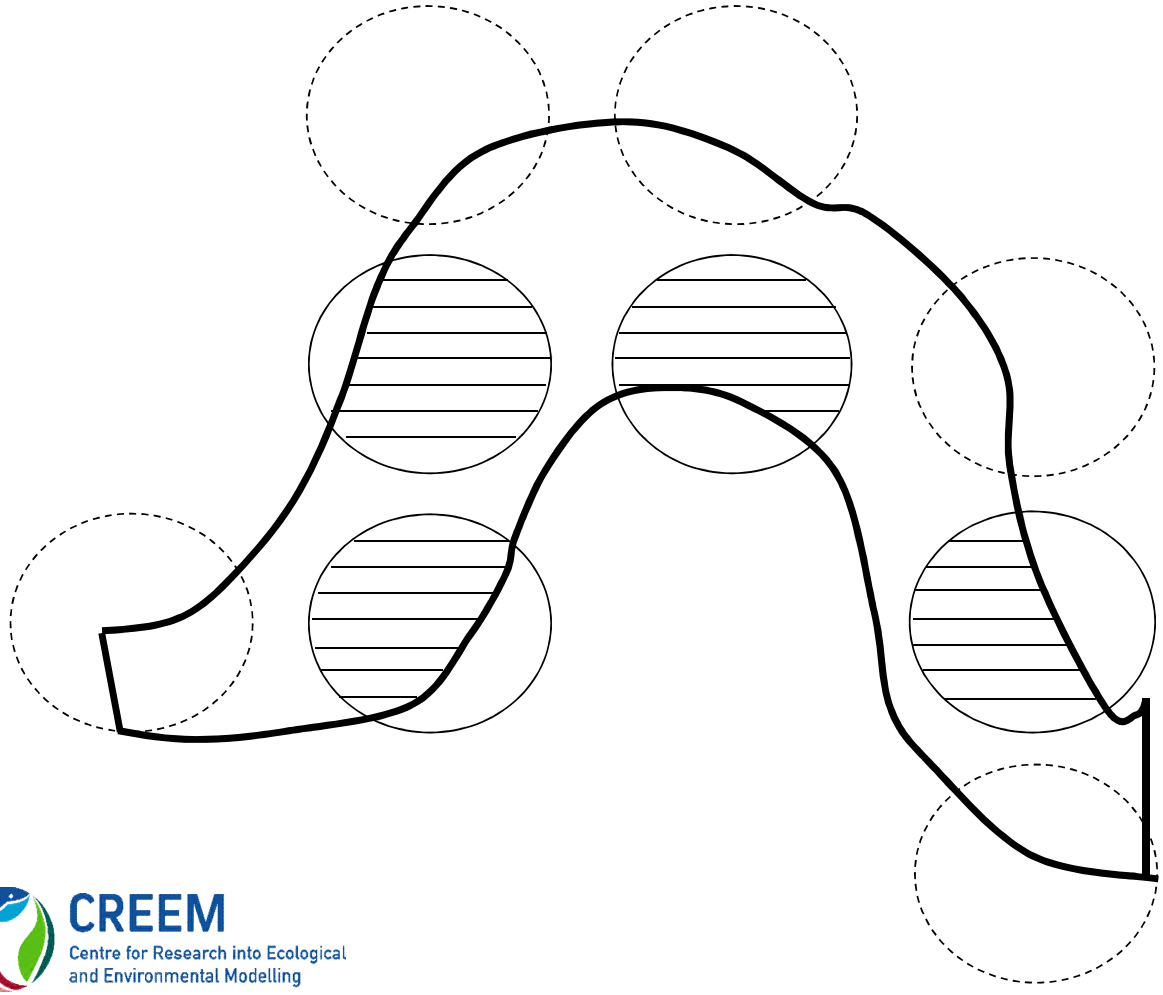
Minus Sampling – Point Transects



- Only a problem if study area is very small or narrow relative to *w*
- Minus sampling assumption
  - Animal density within *w* of the survey region boundary is the same as for > *w*

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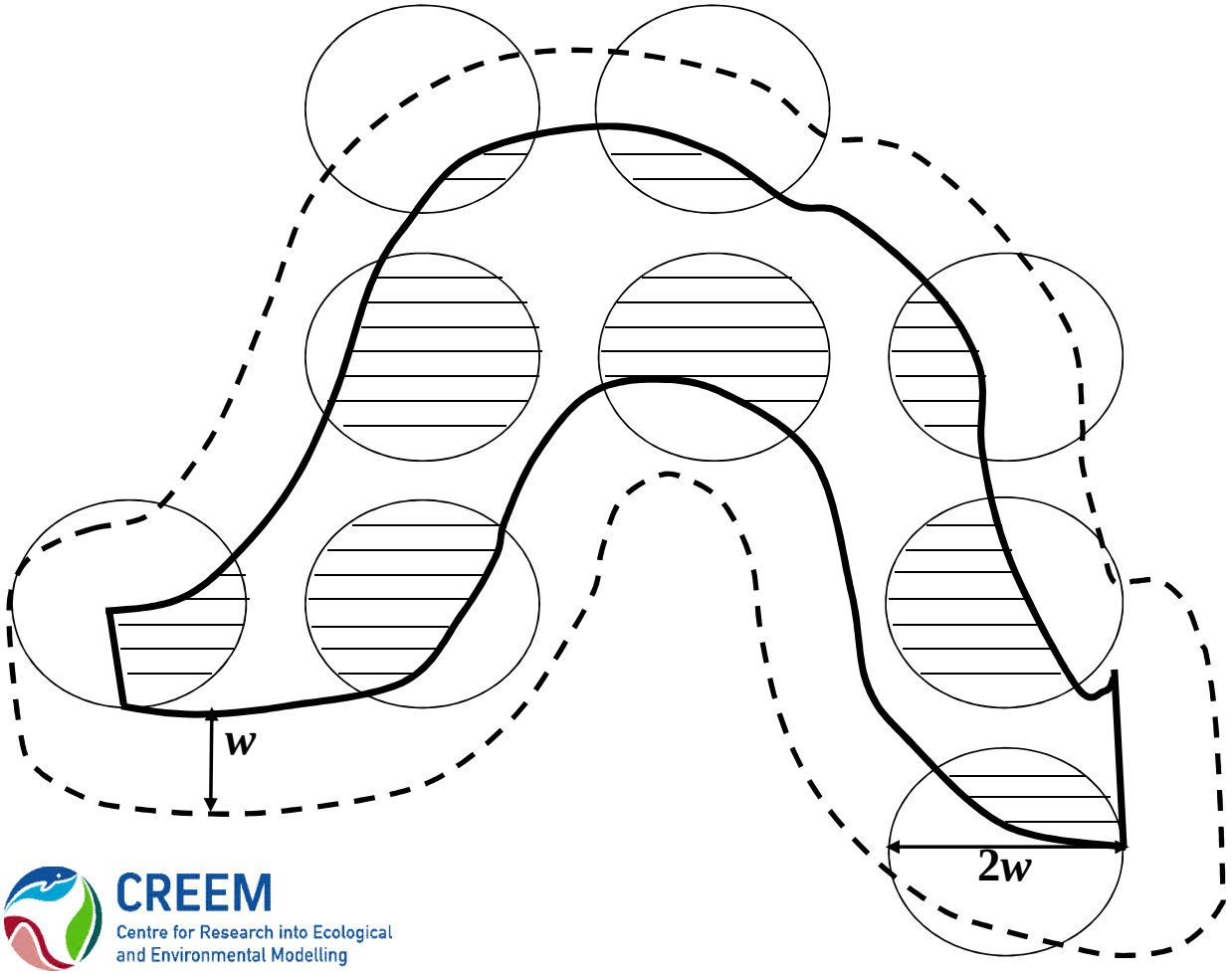
Plus Sampling – Point Transects



- Sample all points within a buffer **w** around the survey region
- Record only animals within the survey region
- Analysis:
  - 0's and 1's
  - Proportions (GIS)

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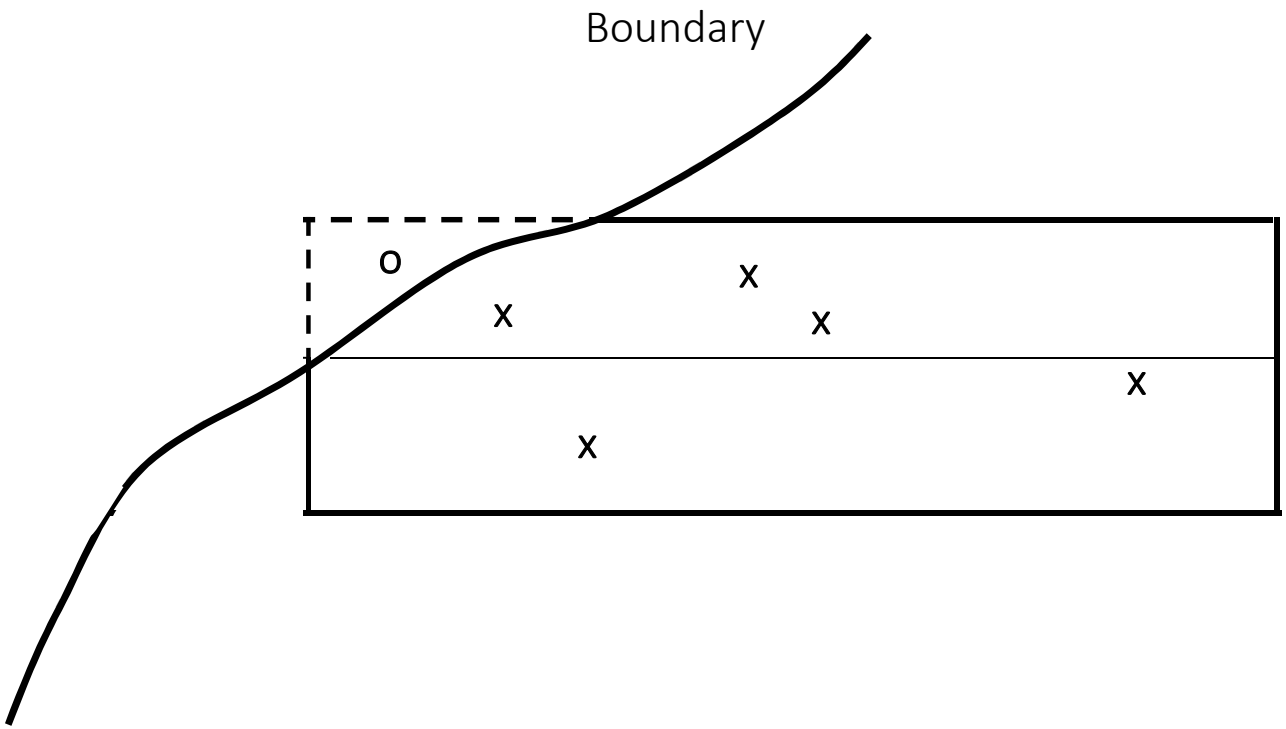
Minus Sampling – Line Transects



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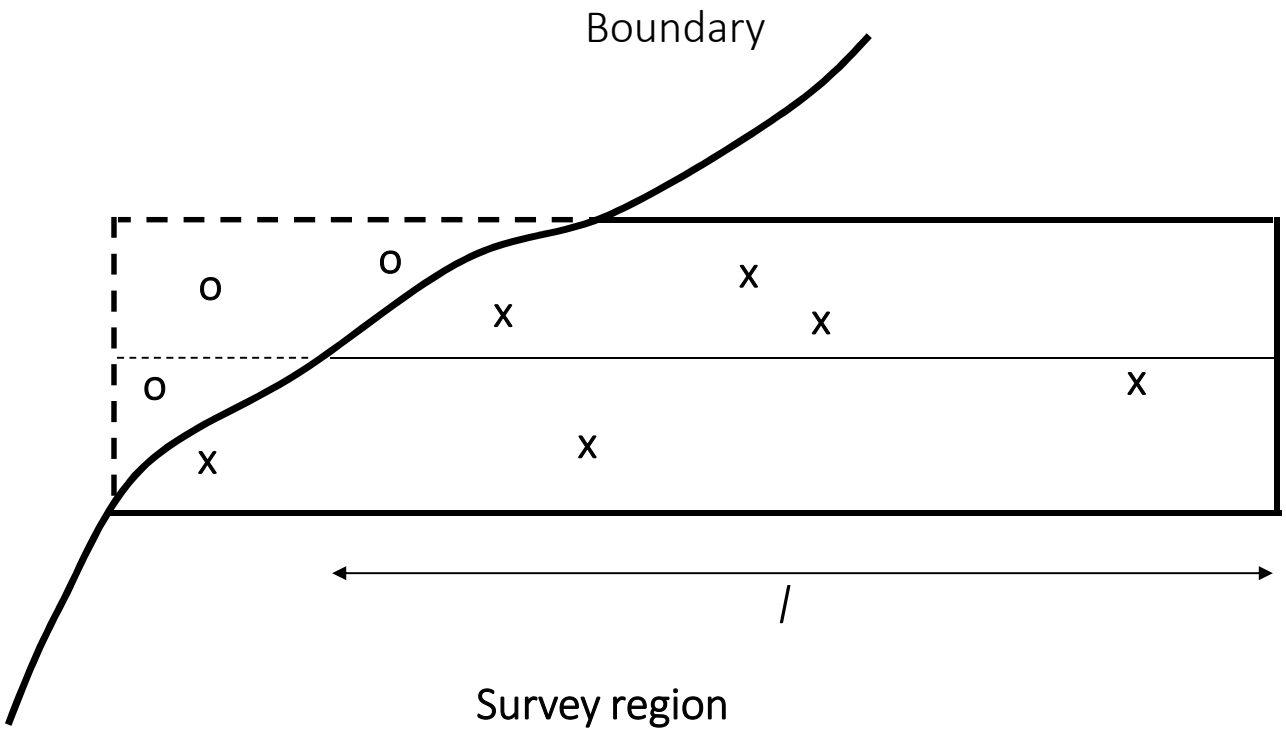
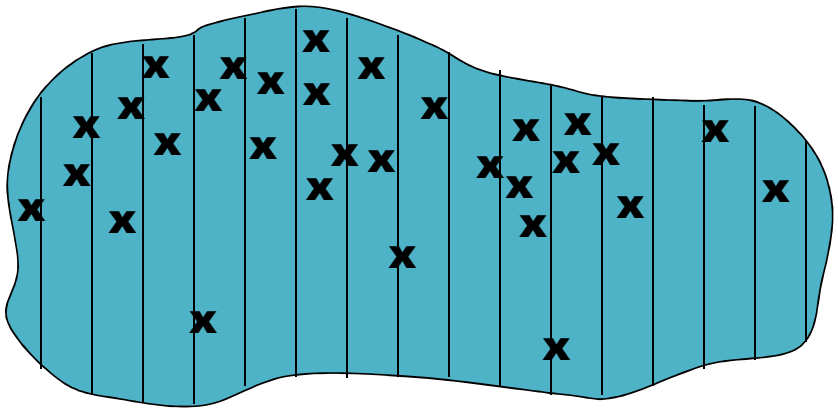
Plus Sampling – Line Transects



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

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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Point Transect Designs

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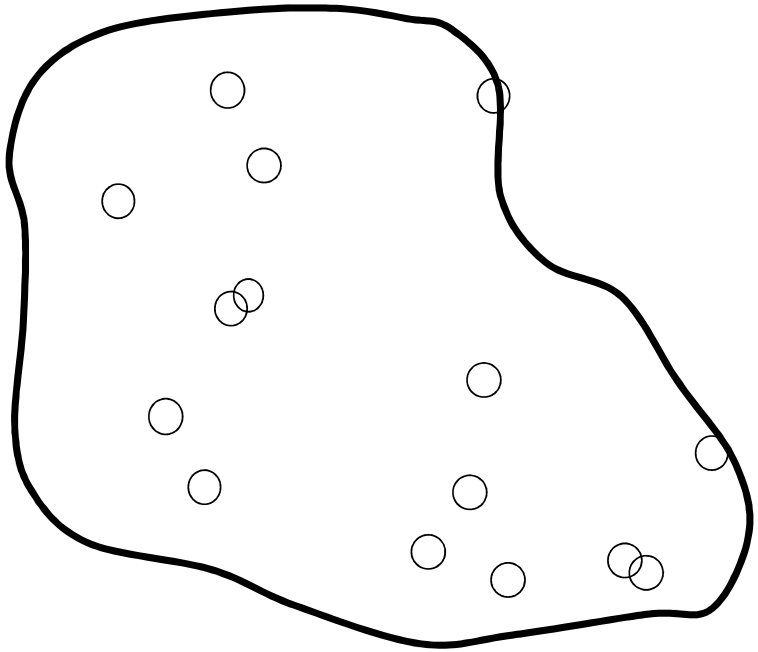
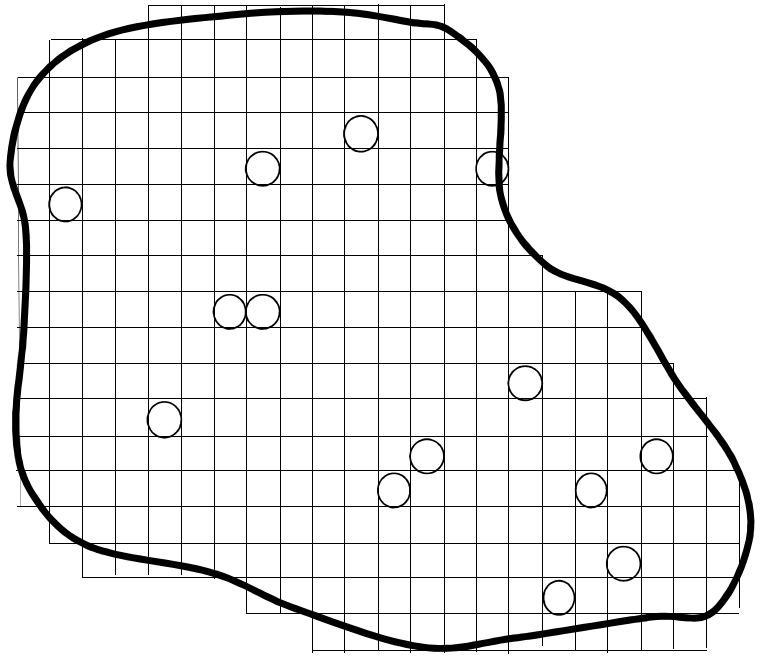
Simple Random Sampling





Non-overlapping simple random sampling. The grid will be laid out at random each time a new survey is generated

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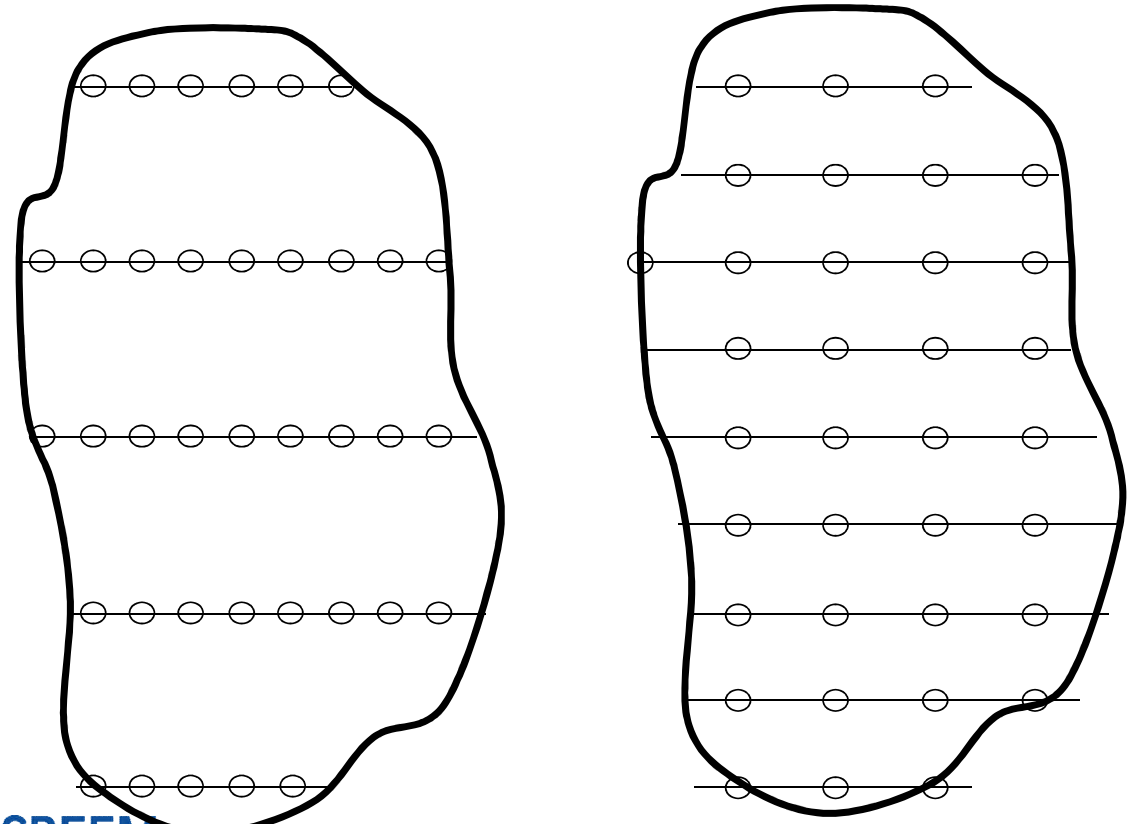
Systematic Sampling



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** – all have uniform coverage (excluding edge effects)
- Systematic has more **even coverage** for any given realisation
- Can have **overlap** of samplers in the pure simple random sampling design
- Out of the 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

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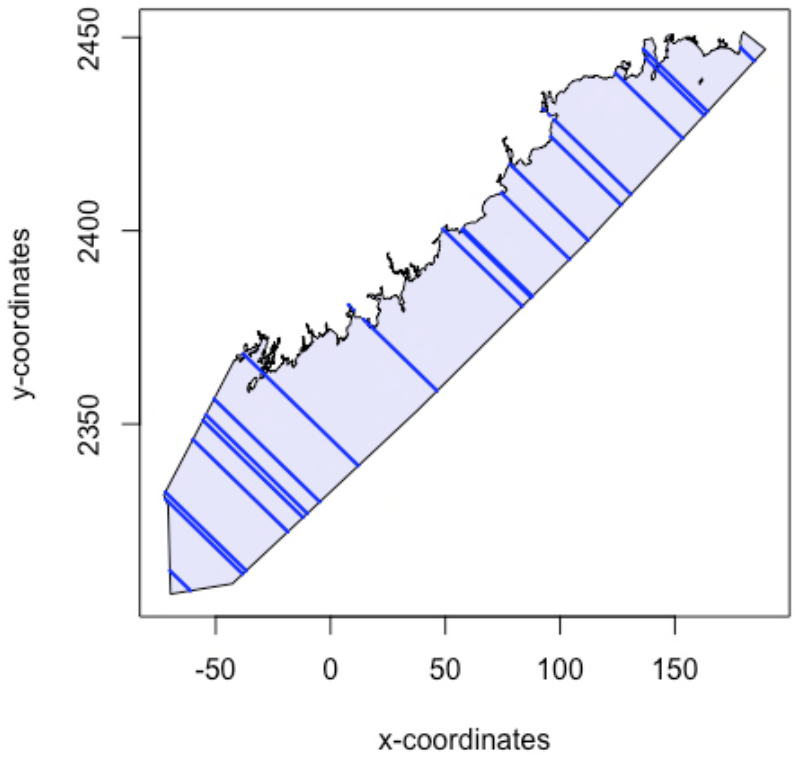
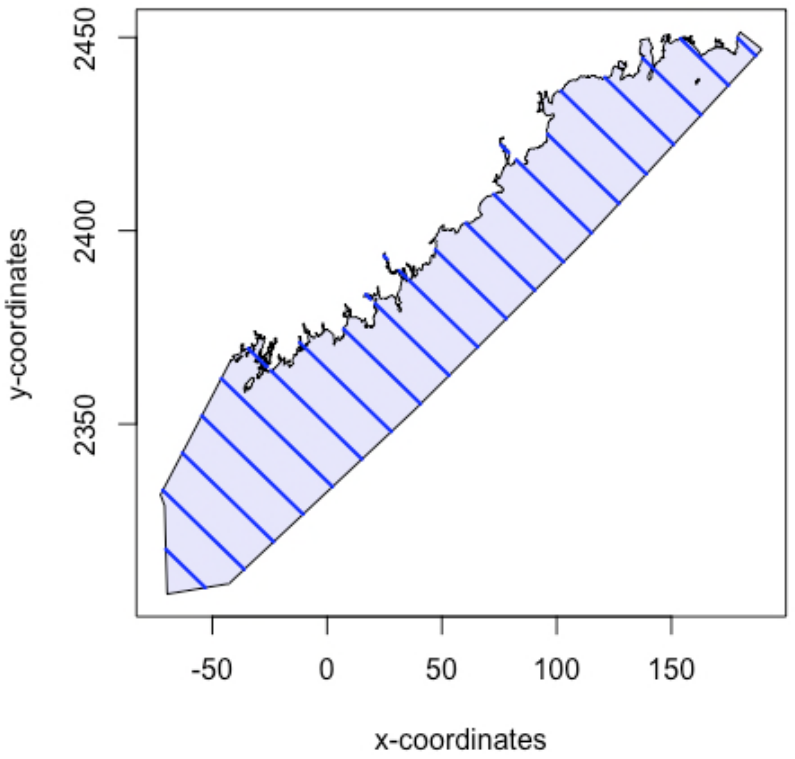
Parallel Line Transect Designs

Random Parallel Design



Systematic Parallel Design



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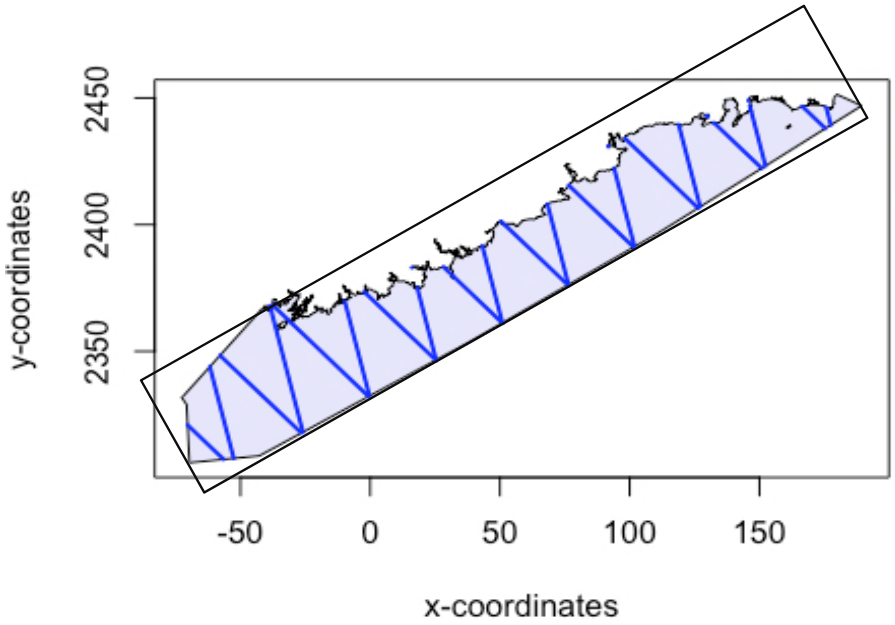
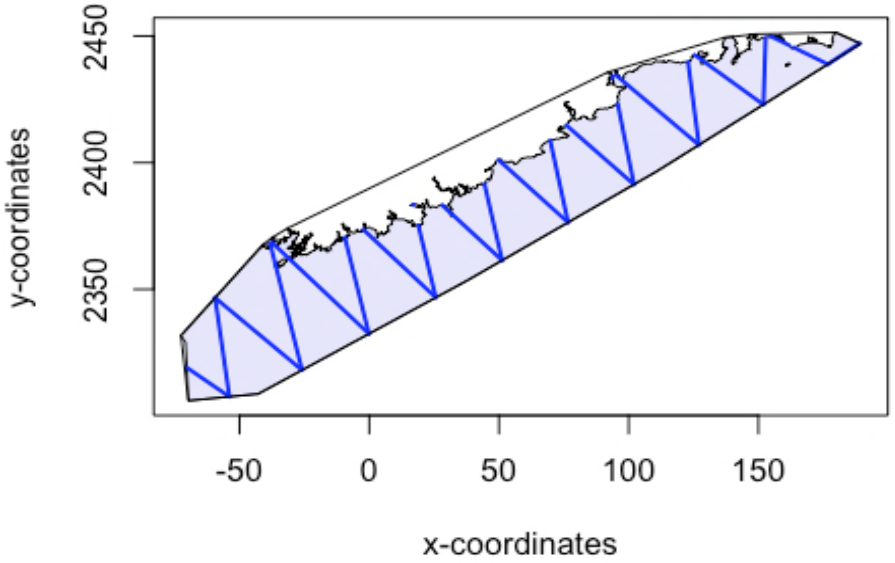
Equal Spaced Zigzag Designs

Generated inside a minimum bounding rectangle



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



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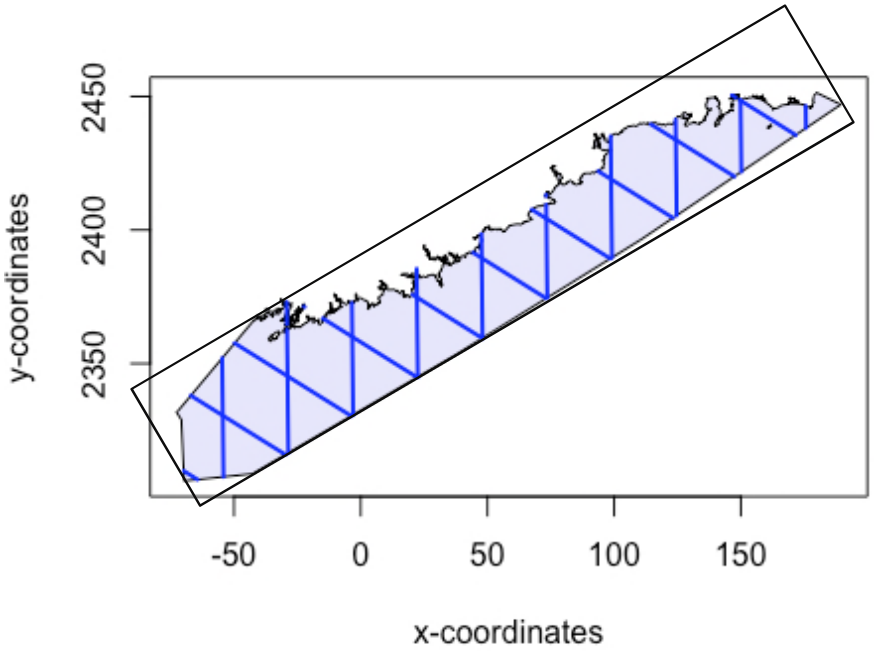
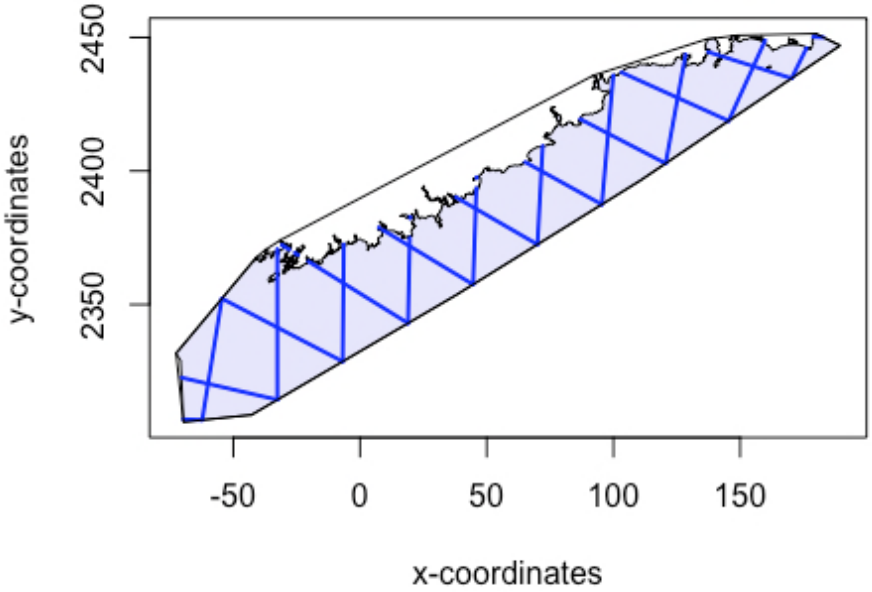
Complementary Equal Spaced Zigzags

Generated inside a minimum bounding rectangle



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



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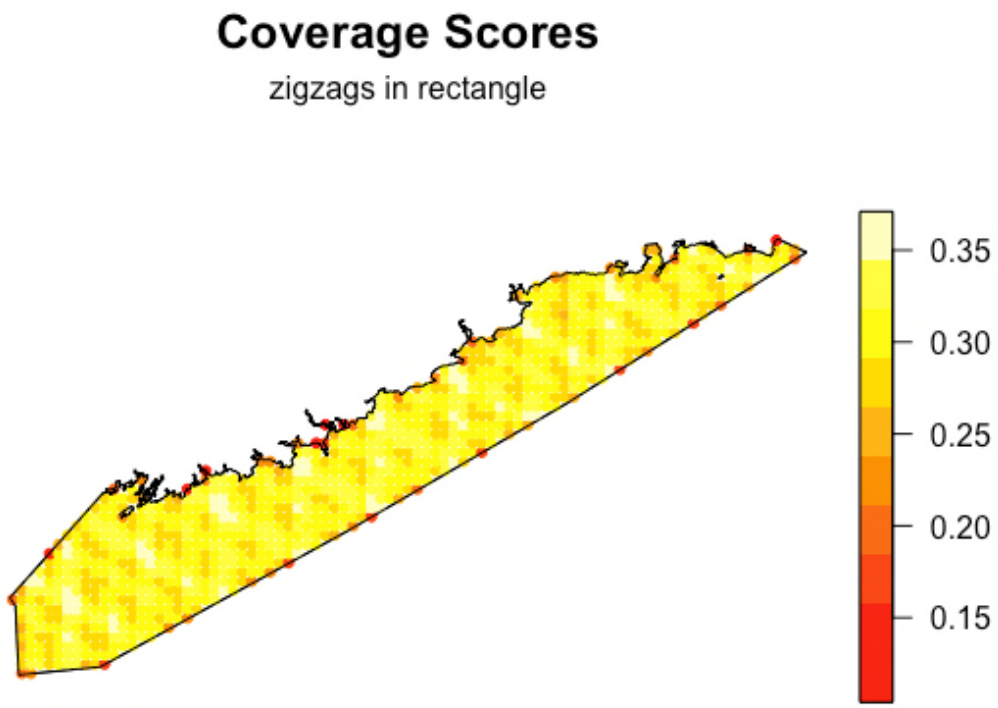
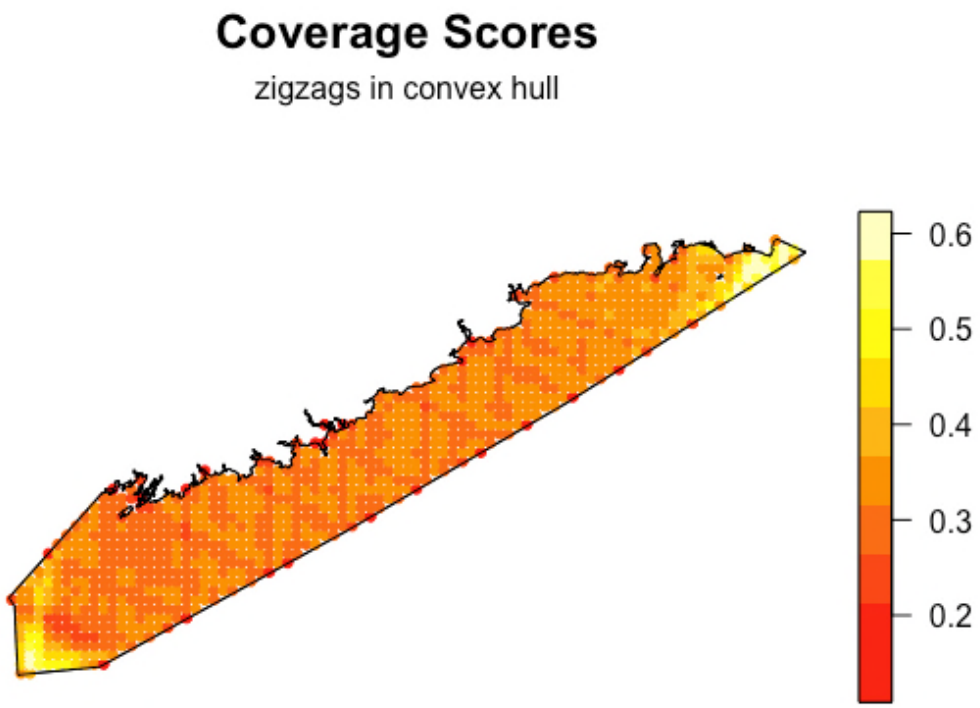
Complementary Equal Spaced Zigzags





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Simulation based on generating 1000 surveys

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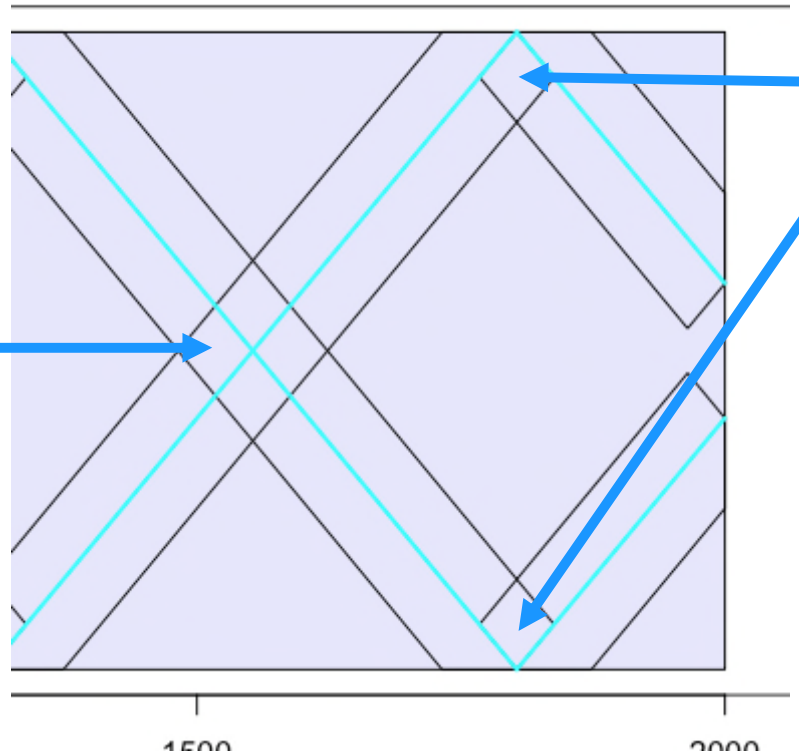
Comparison of Line Transect Designs

- **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 improve efficiency further.
- Can have **overlap** of samplers in the parallel random design. Also some overlap in zigzag designs.

Overlap in zigzag designs

Ok to survey here twice as long as detections on the second pass will be independent of detections made on the first pass.



Detections here should usually only be recorded once

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Segmented Line Designs

(Available in Distance for Windows)

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Fixed length transects

Systematic segmented trackline

Systematic segmented grid

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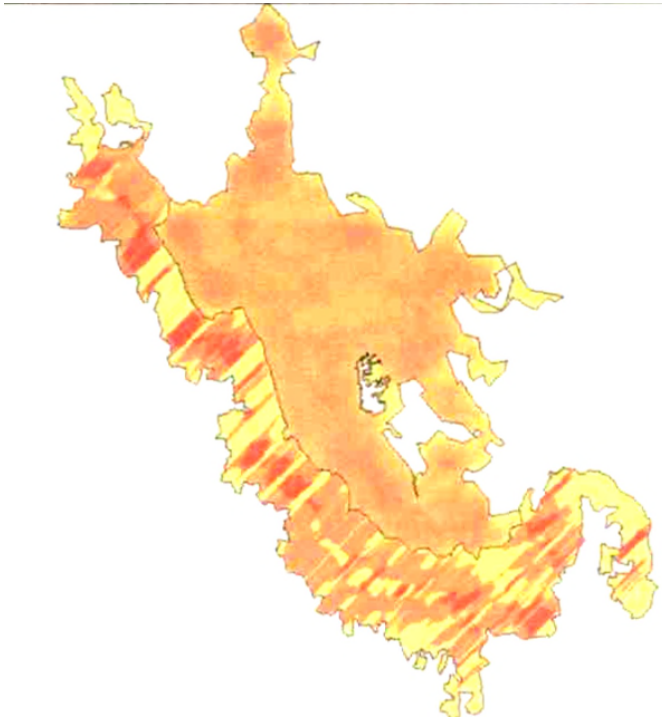
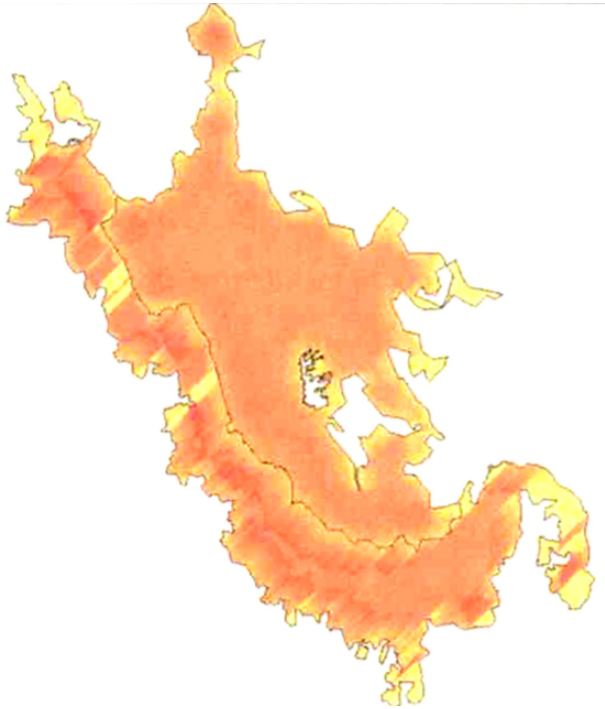
Edge Effects - push segments more than half in all the way in and discard others

Systematic segmented trackline



Systematic segmented grid



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

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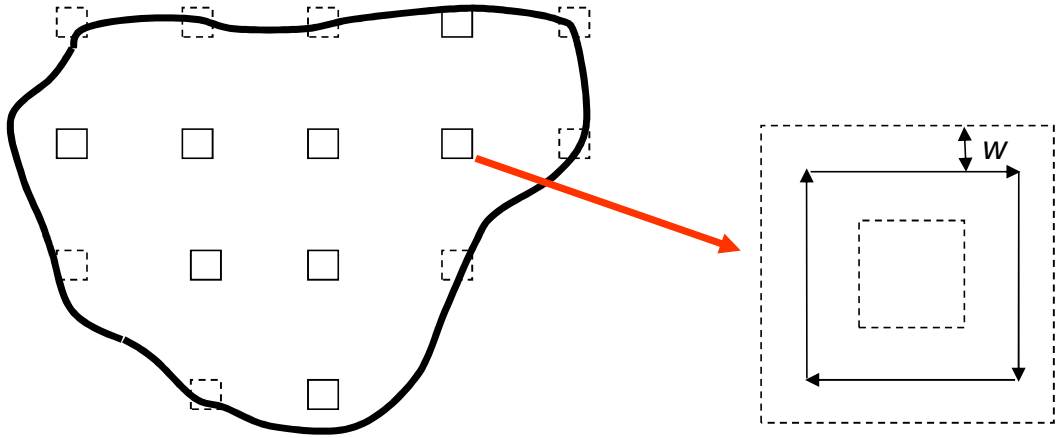
Comparison of Segmented Designs

- 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, seems to give more uniform coverage
- Other designs (such as circuit samplers or segmented zigzags) might be worth considering.



Stratification

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

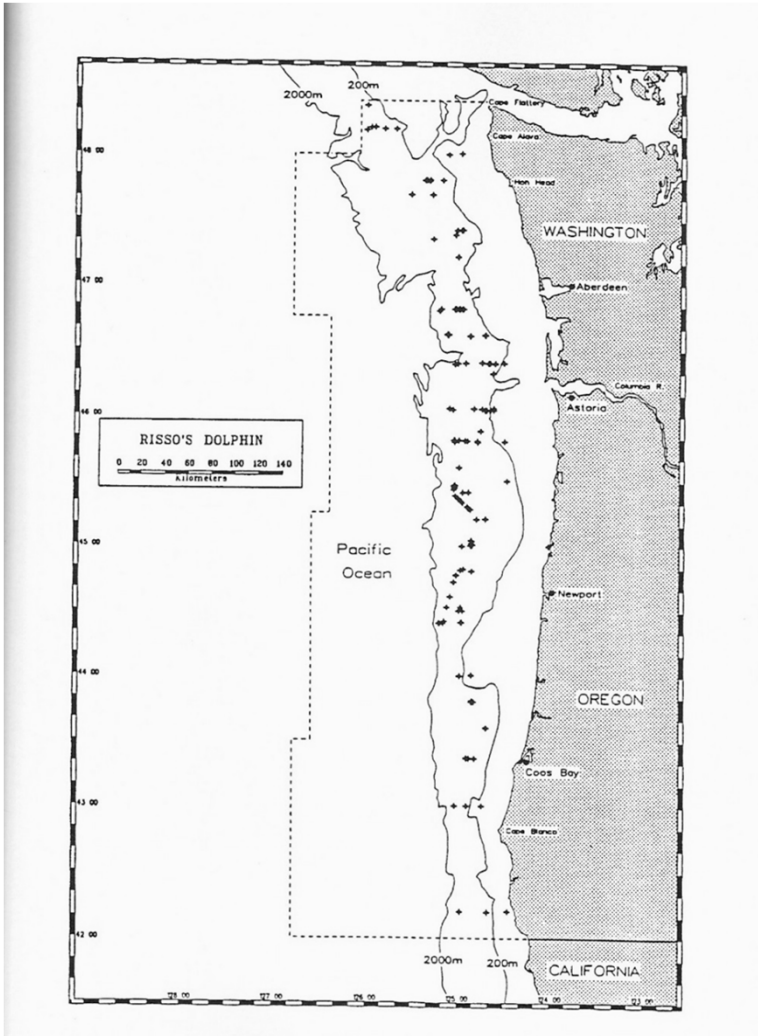
Stratification (Geographic)

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).
- Mean cluster size: May vary spatially. There may be sample size limitations on stratified estimation.

NB: If any of the above are estimated by pooling across strata, when in reality they differ between strata, within-stratum estimates are biased.

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?

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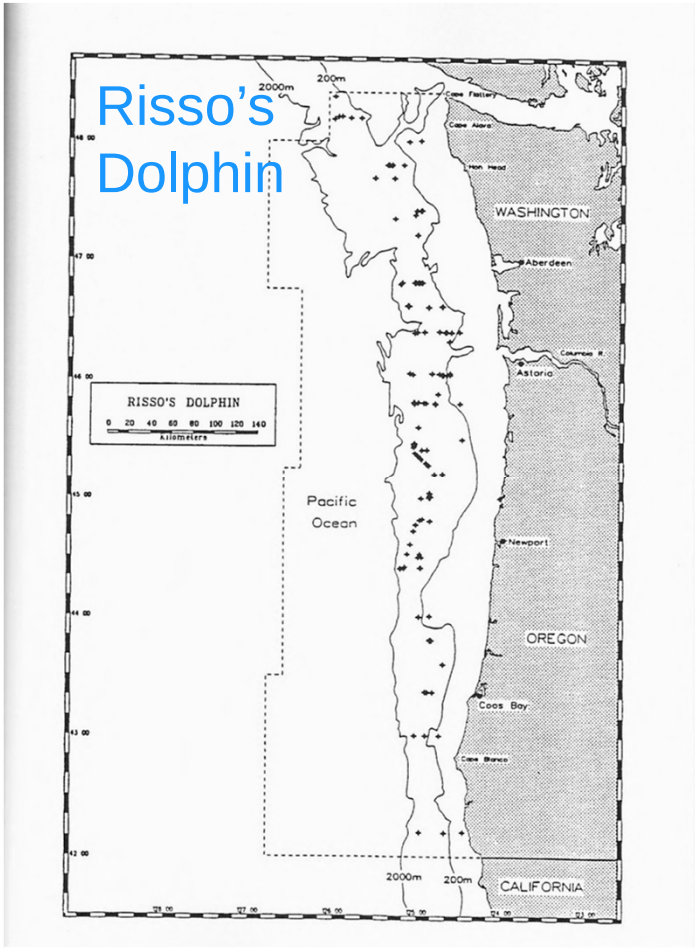
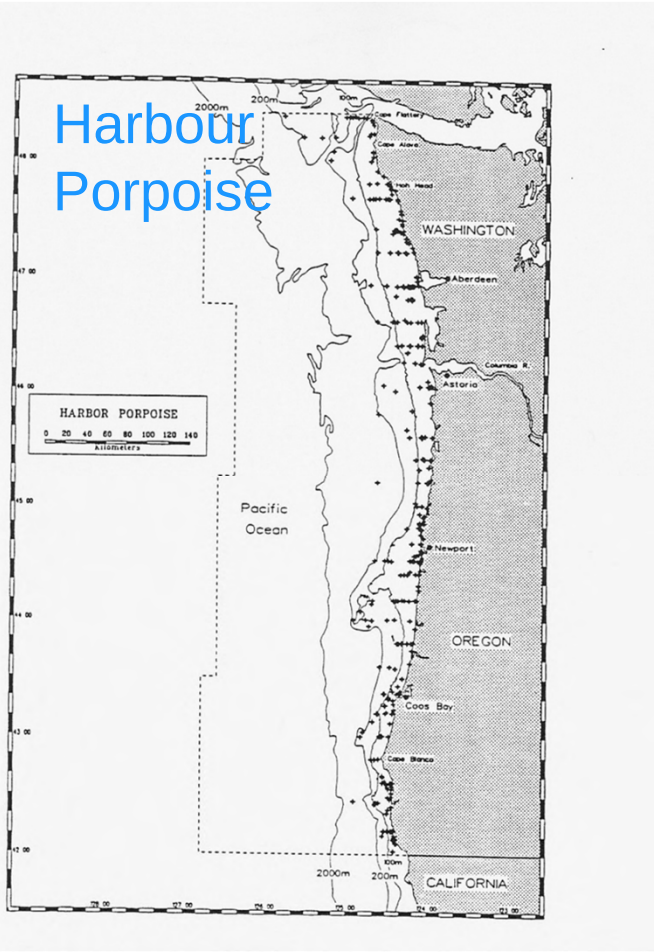
Stratification (Spatial) – Risks!





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

Uniform effort across strata is often a good design for multi-species surveys.

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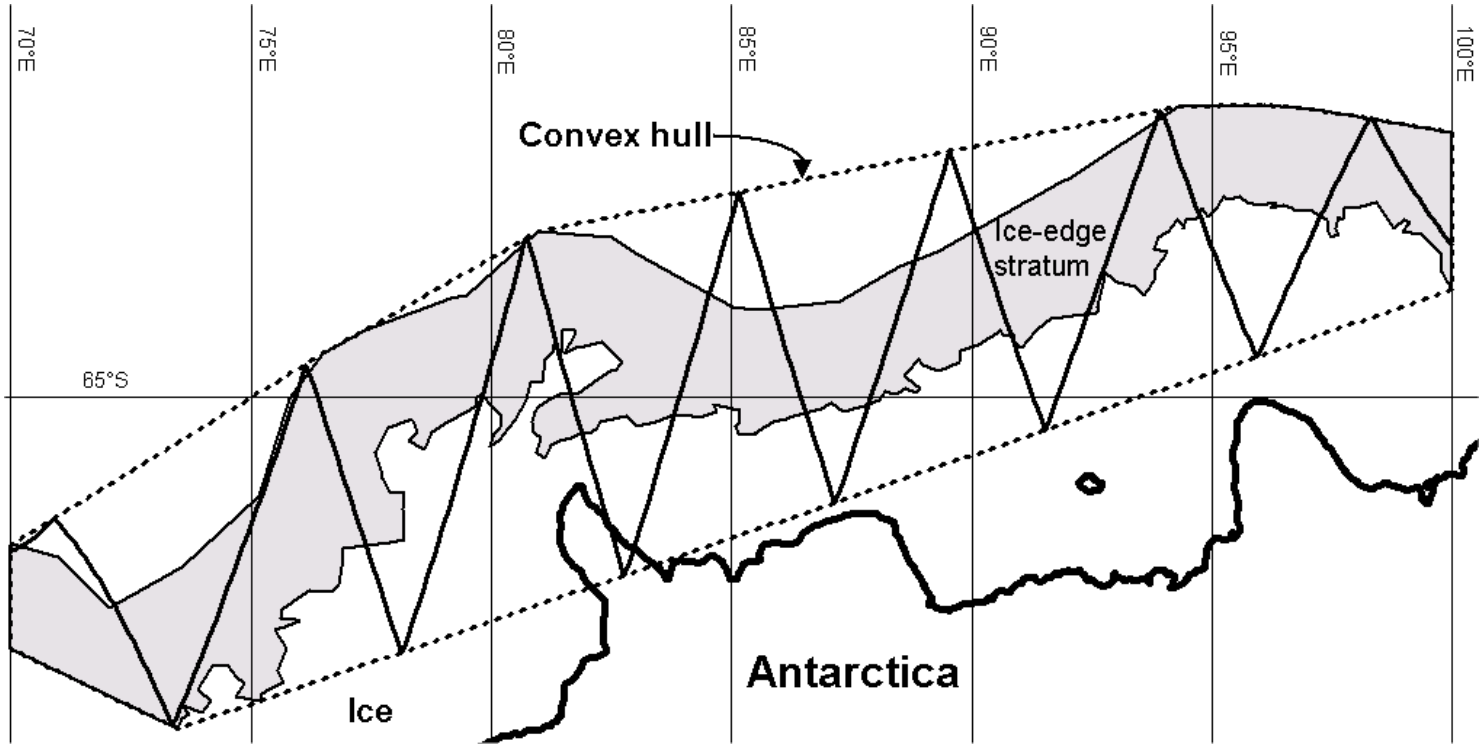
Example Surveys

Dealing with Complex Regions

Antarctic Minke whale shipboard survey



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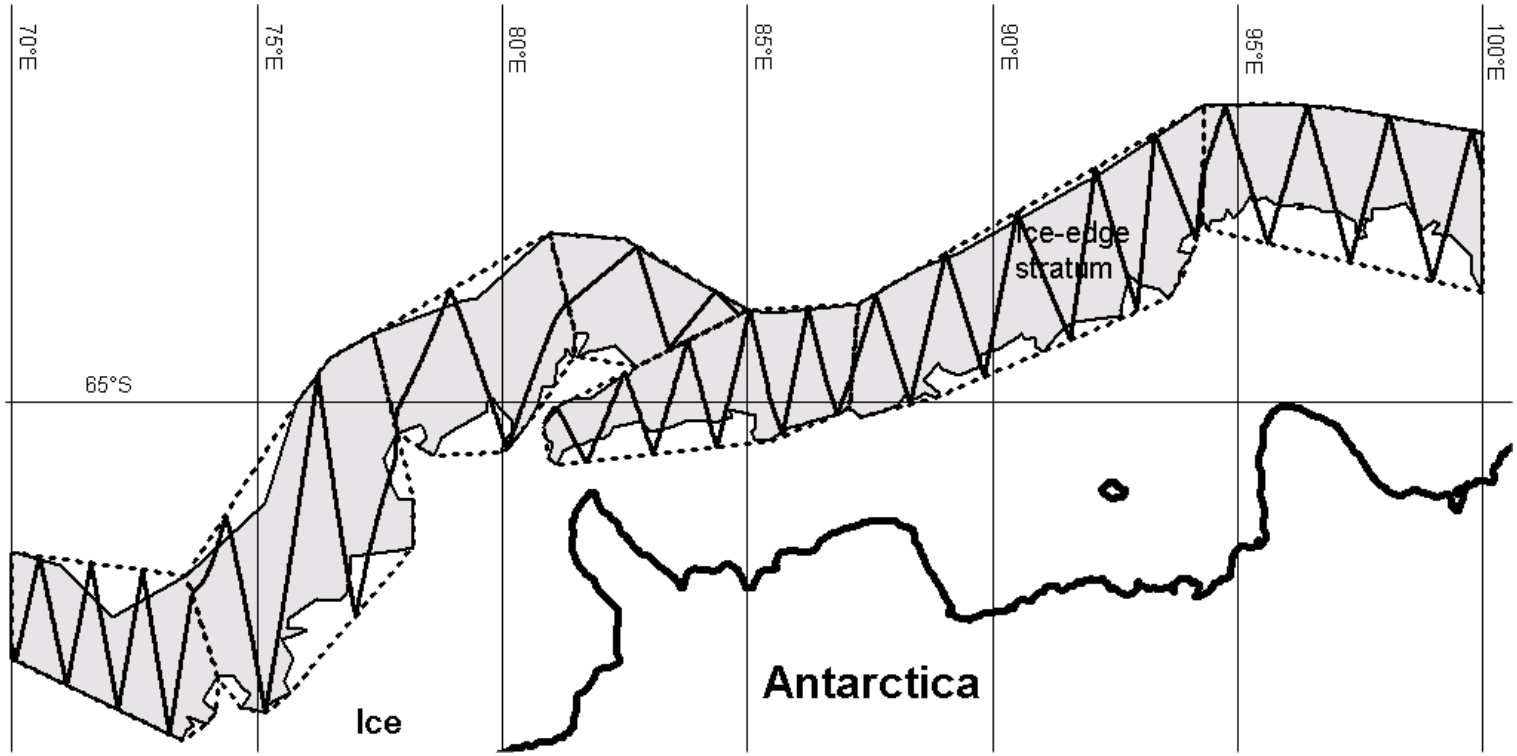
Dealing with Complex Regions

Study region divided into suitable strata to increase efficiency



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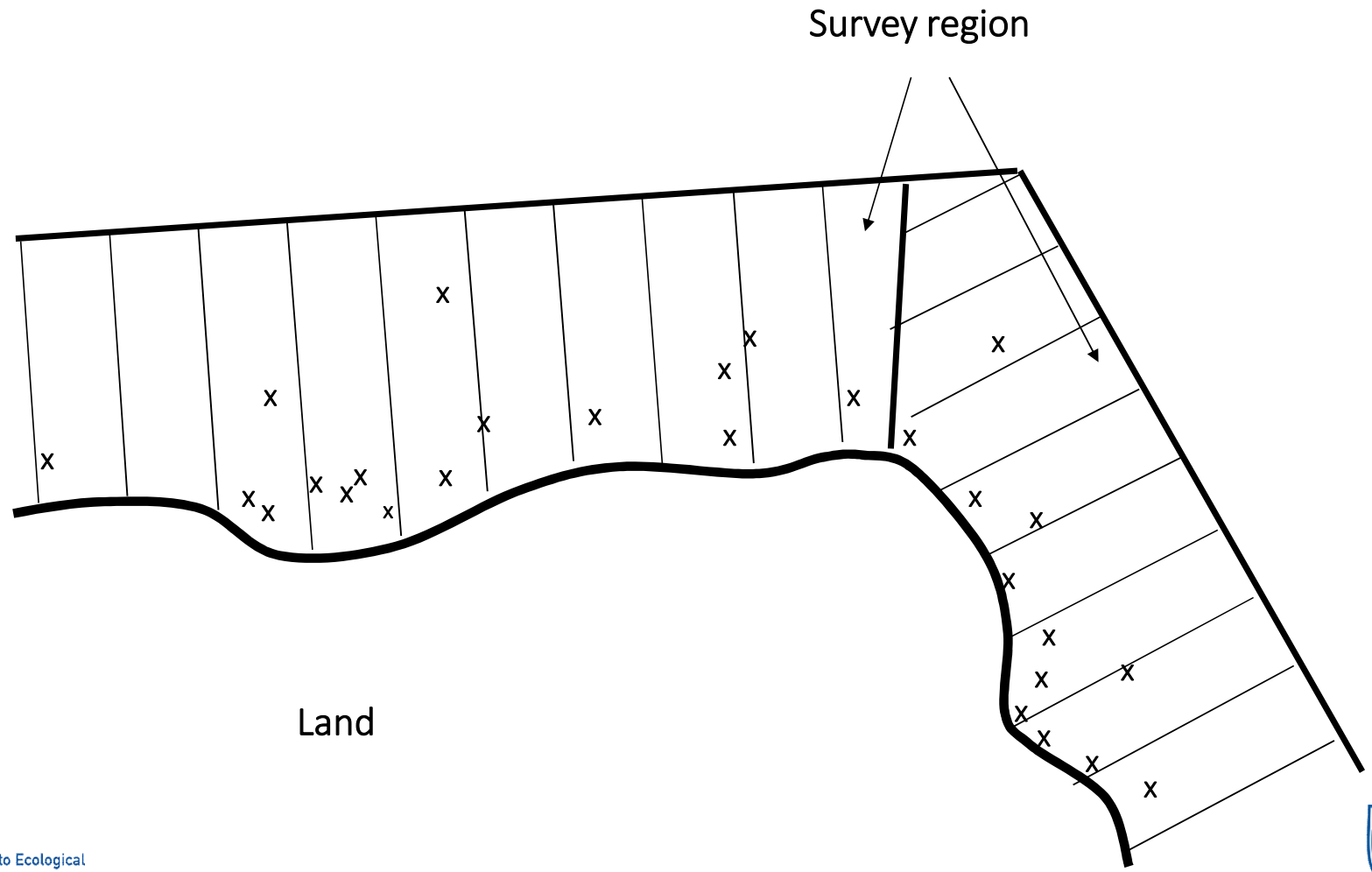
Designing an inshore survey



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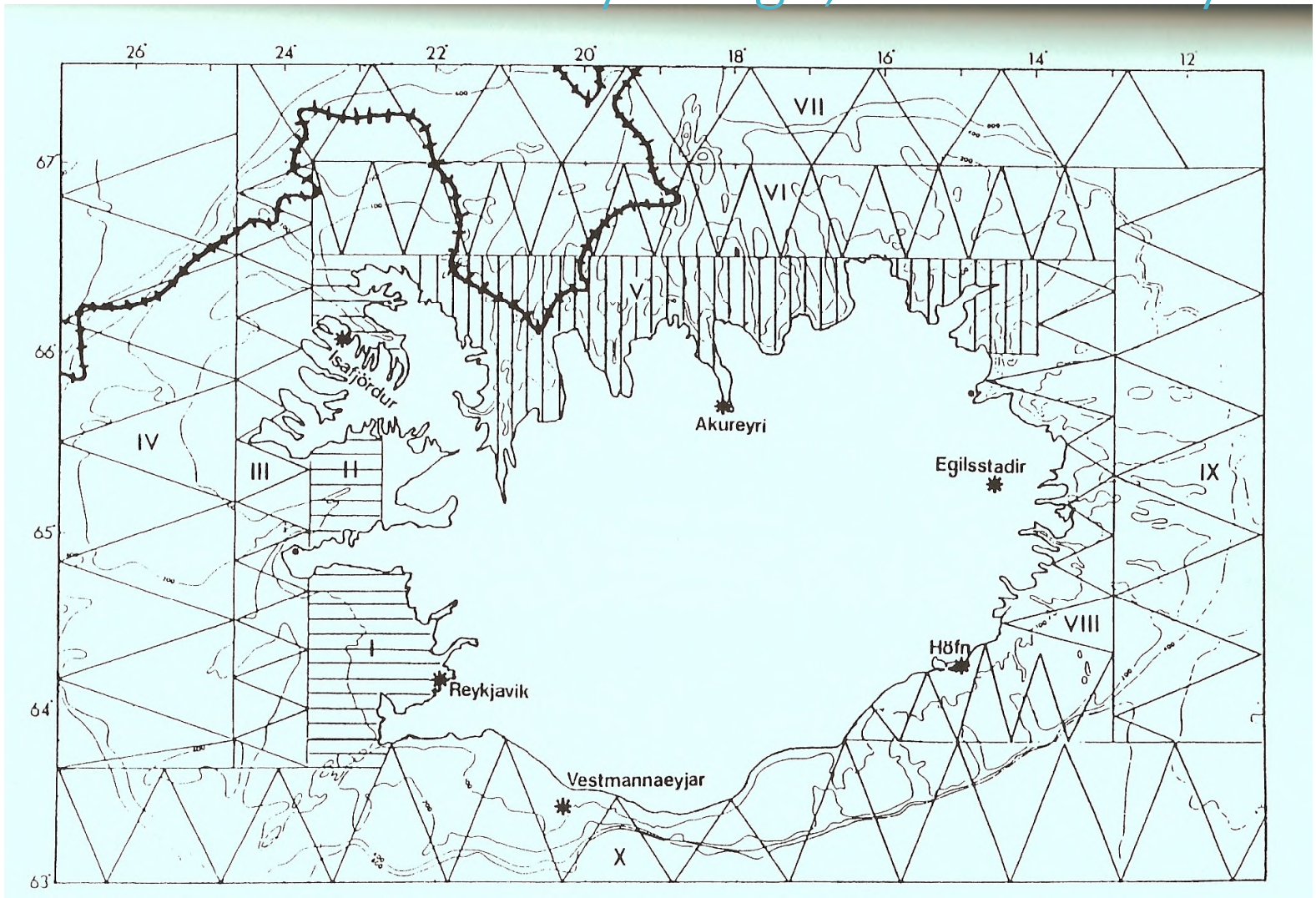
Iceland – aerial survey design, whale survey



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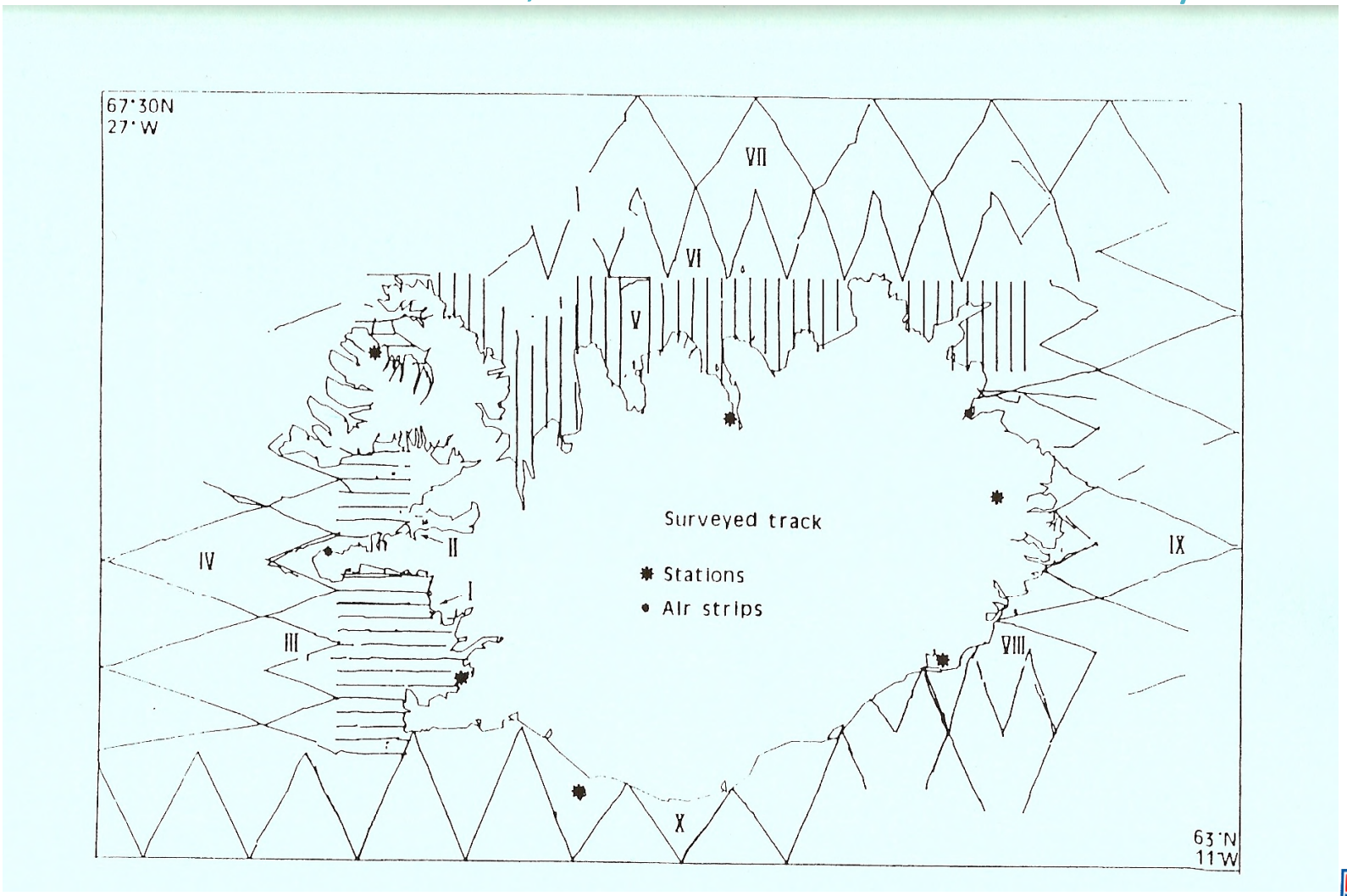
Actual effort, Icelandic whale survey



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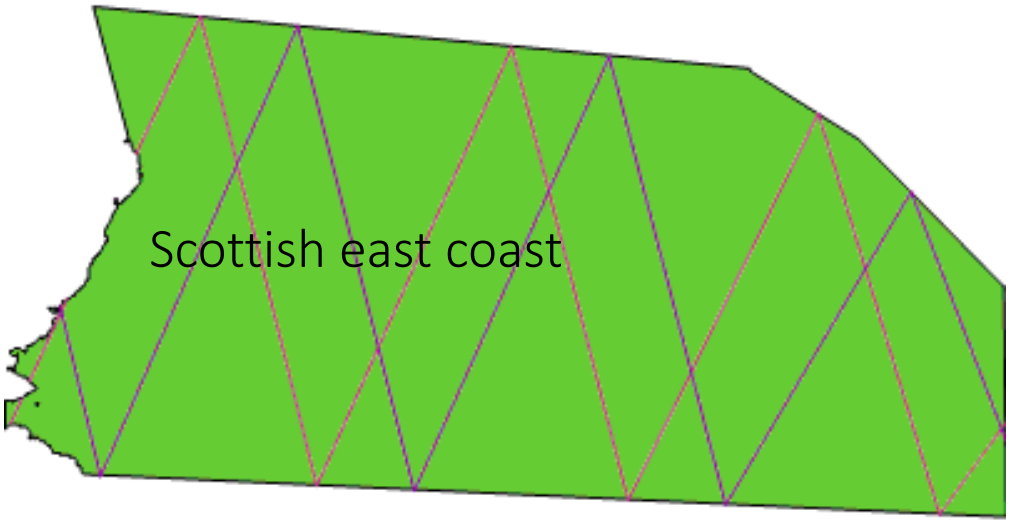
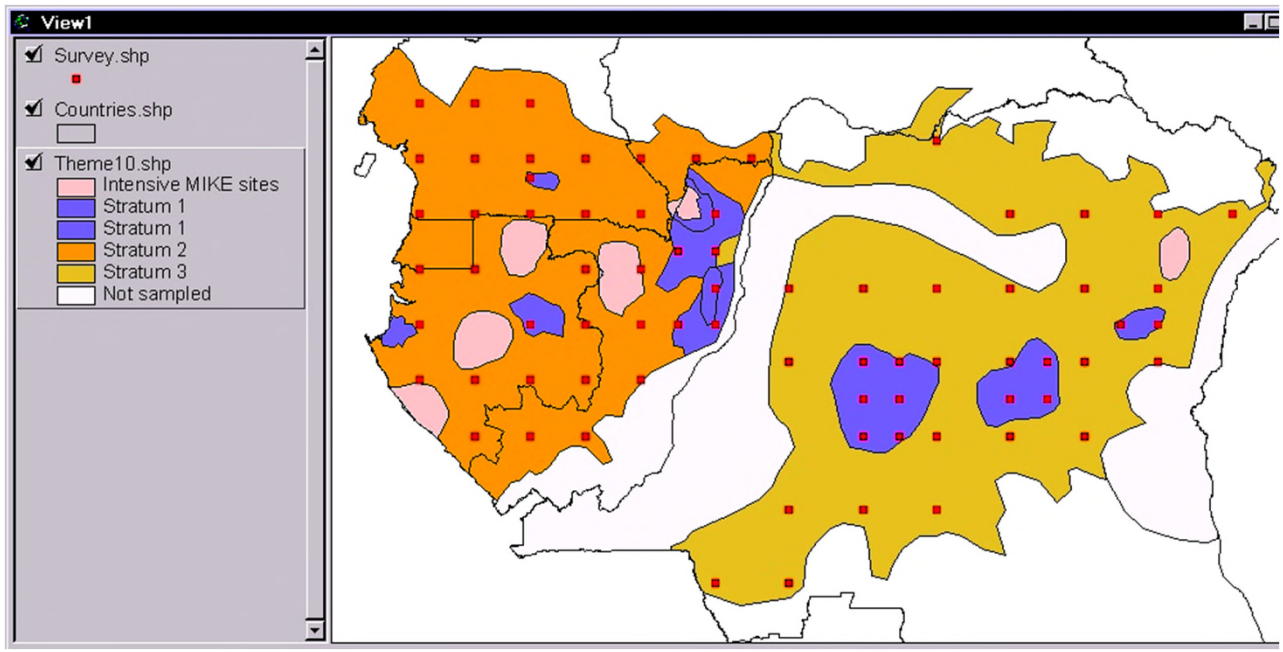
Efficiency

Example: SCANS II – ship survey in North Sea

Cross survey region twice



Monitoring the Illegal Killing of Elephants (MIKE)



Example showing complex nested strata: a nested grid

Effort allocation set using formulae in Section 7.2.2.3 of *Introduction to Distance Sampling*

(For more about this example, see Central Africa Pilot Project at https://cites.org/eng/prog/mike/pilot/index.shtml)

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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 usually 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!