# 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.

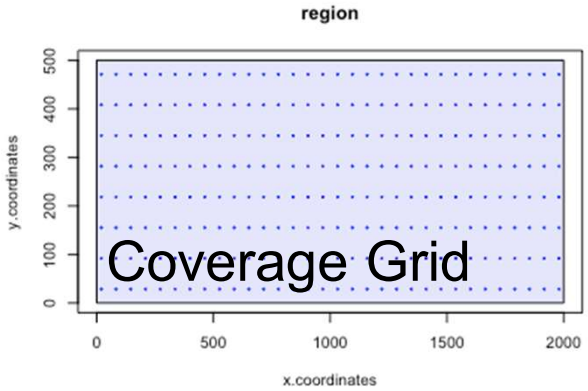
Survey – a single realisation of a design

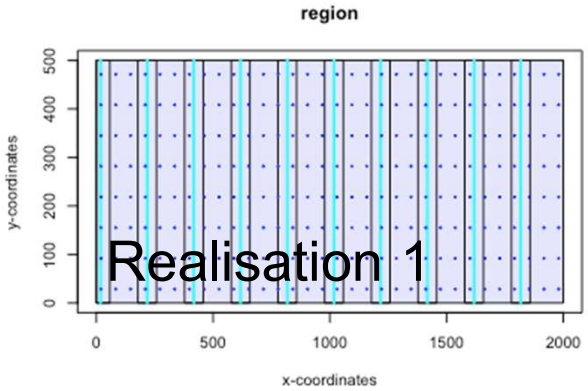
Sampler – a sample unit

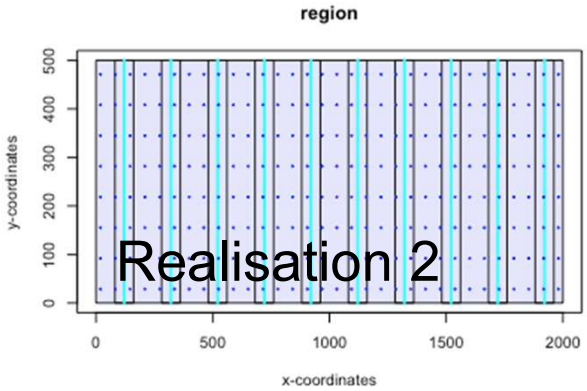
- Strip (line transect)
- Circle (point transect)

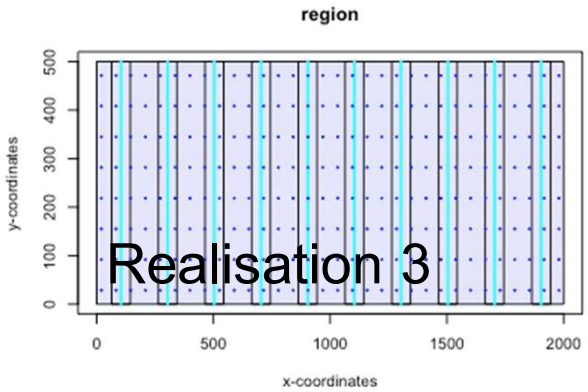
Coverage score – the average number of times a particular point in the study region will be inside a simulated “covered area”

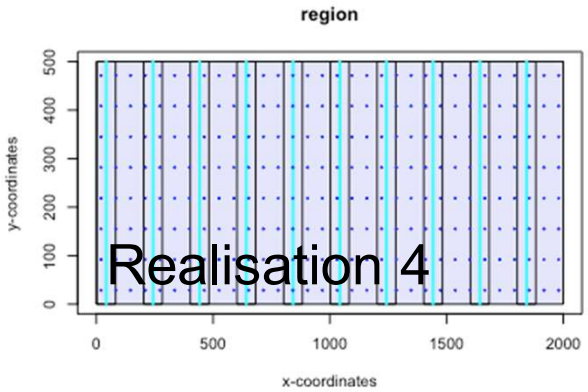
# Coverage

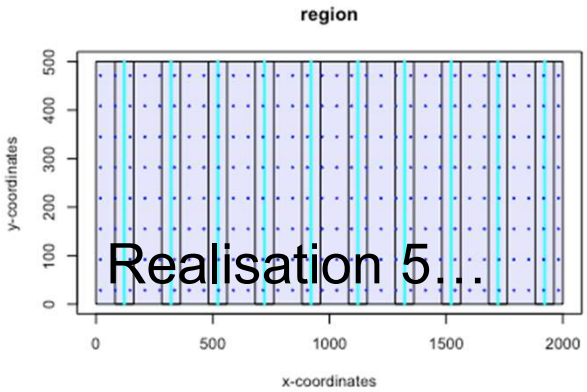
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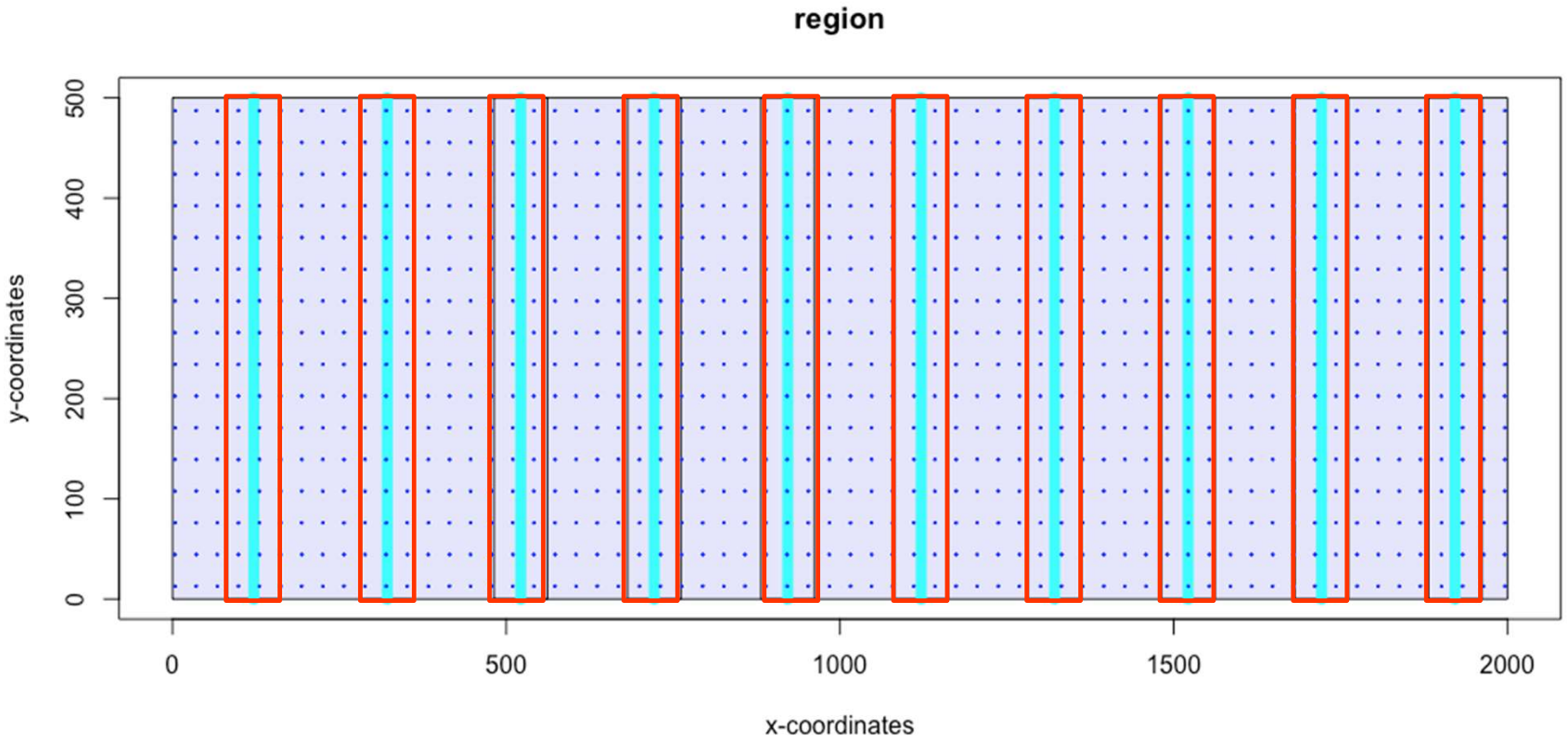
# Coverage

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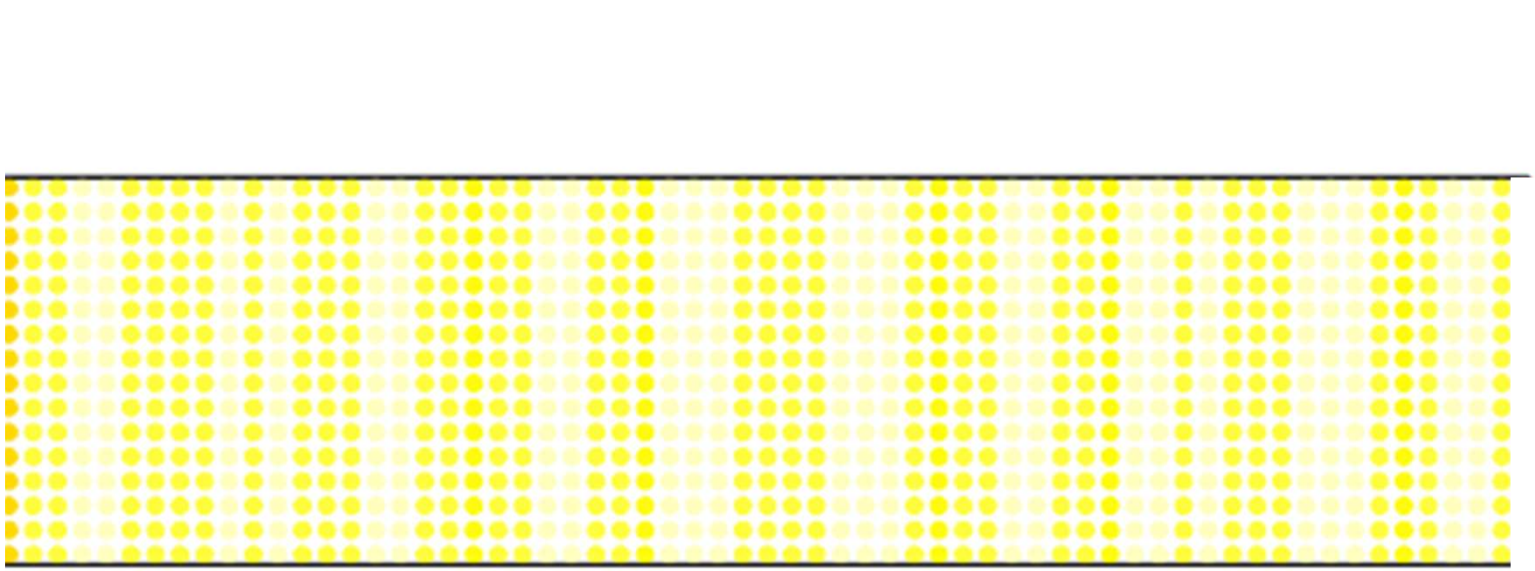
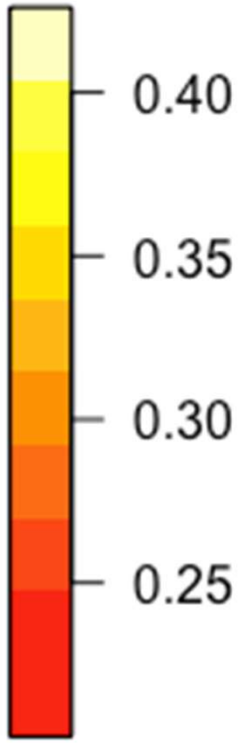
# Coverage



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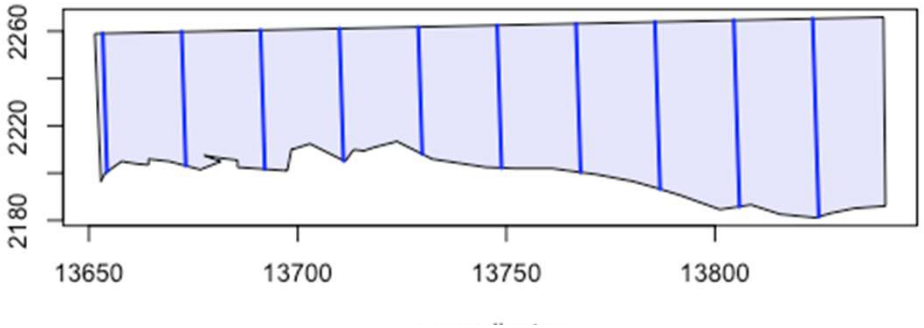
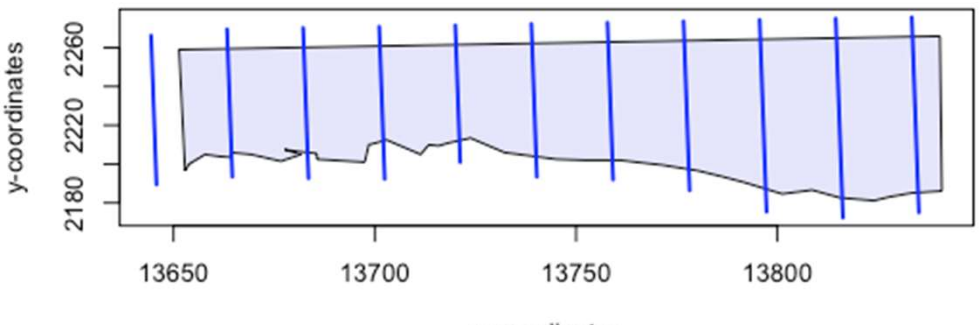
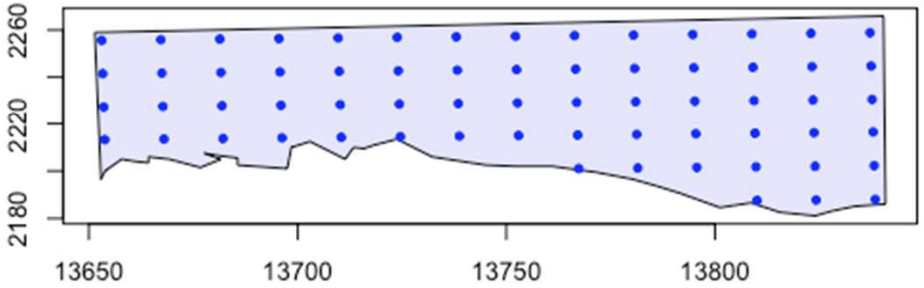
# Minus v Plus Sampling

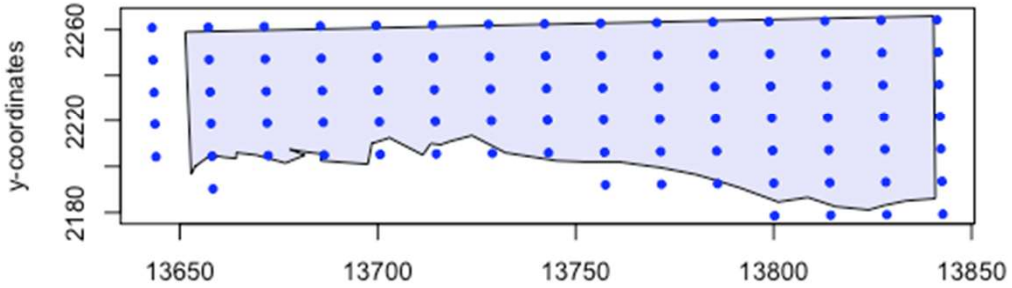



MINUS SAMPLING

PLUS SAMPLING

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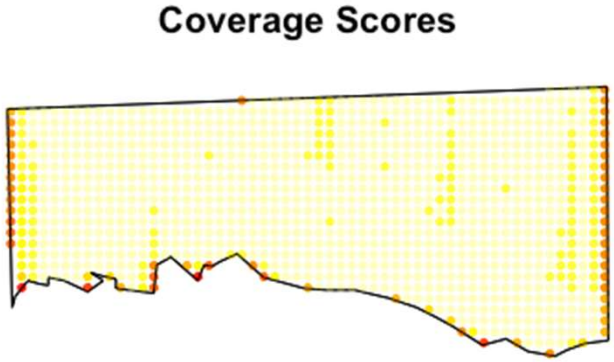
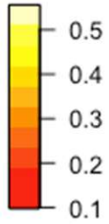
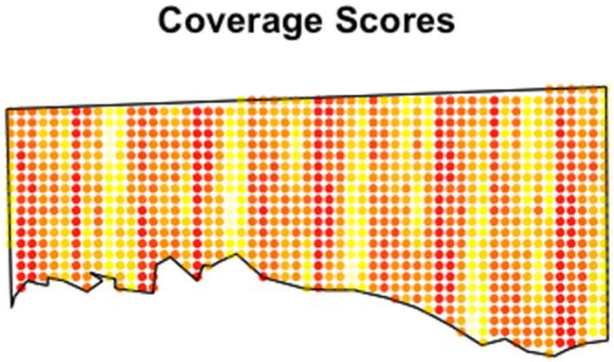
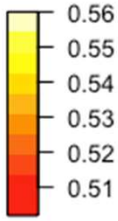
# Coverage for 500 repetitions

Lines



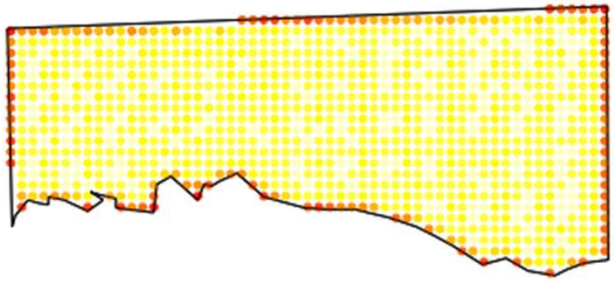



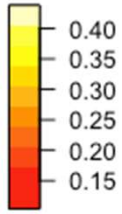



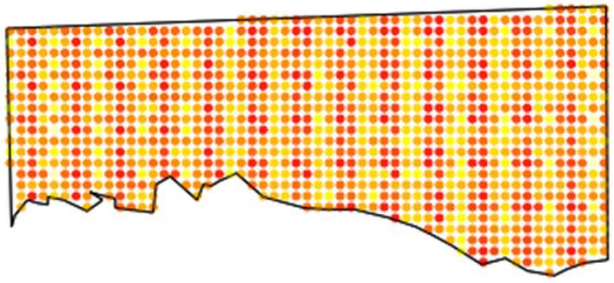

MINUS SAMPLING

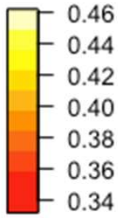
PLUS SAMPLING

Points





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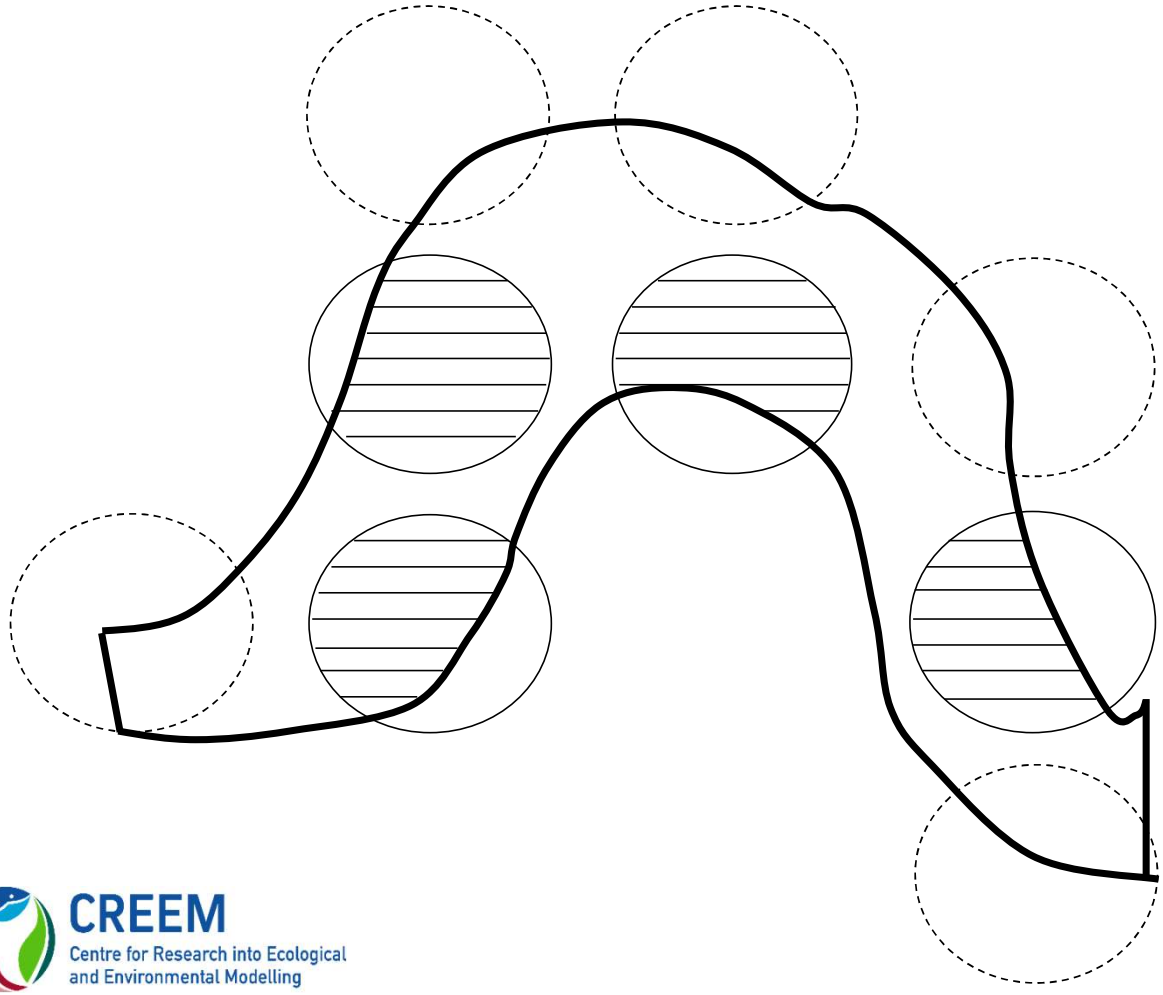
# Minus Sampling – Point Transects



- 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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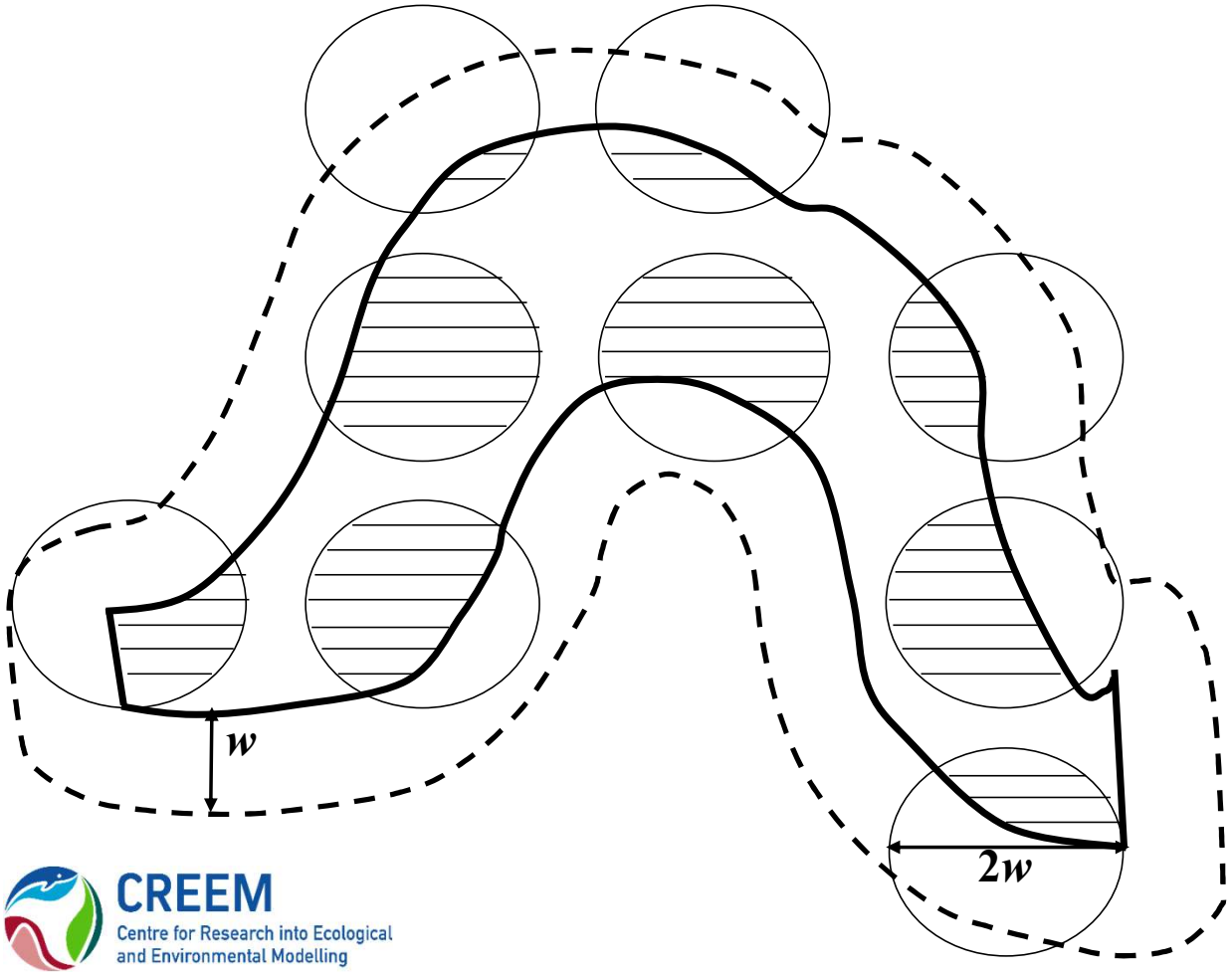
# Plus Sampling – Point Transects




- 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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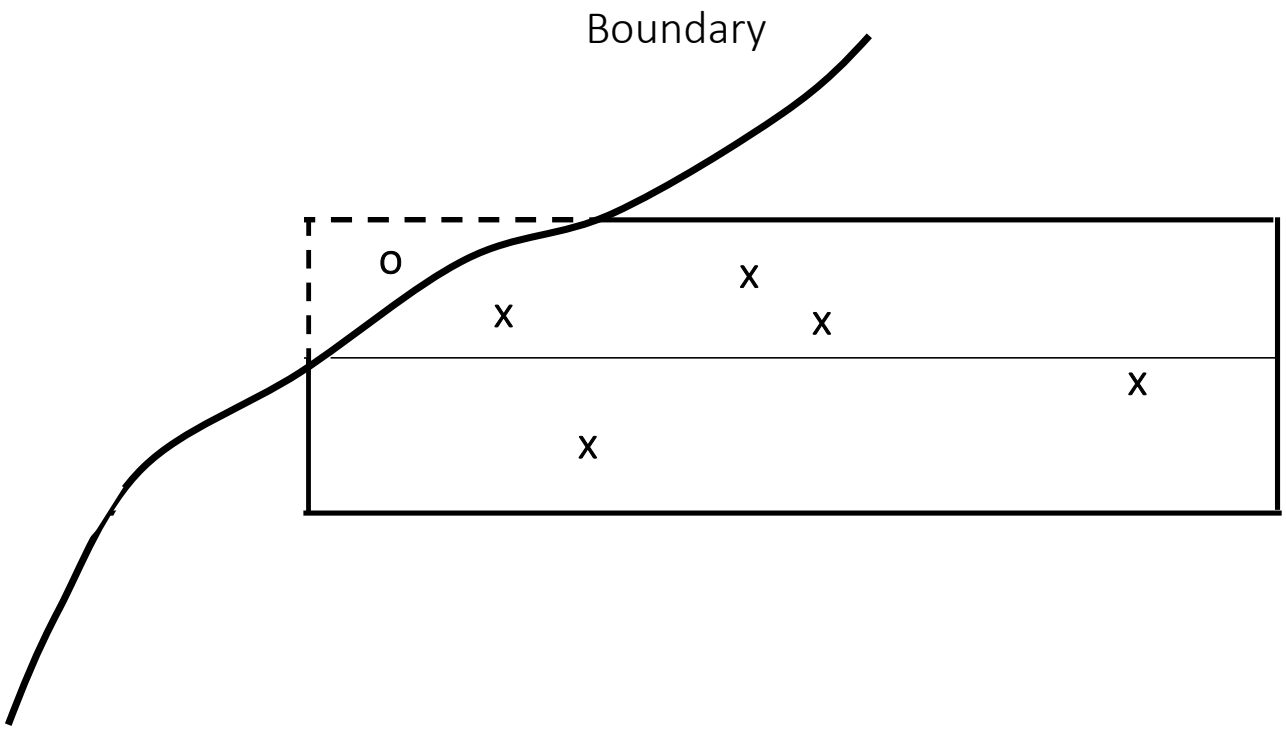
# Minus Sampling – Line Transects

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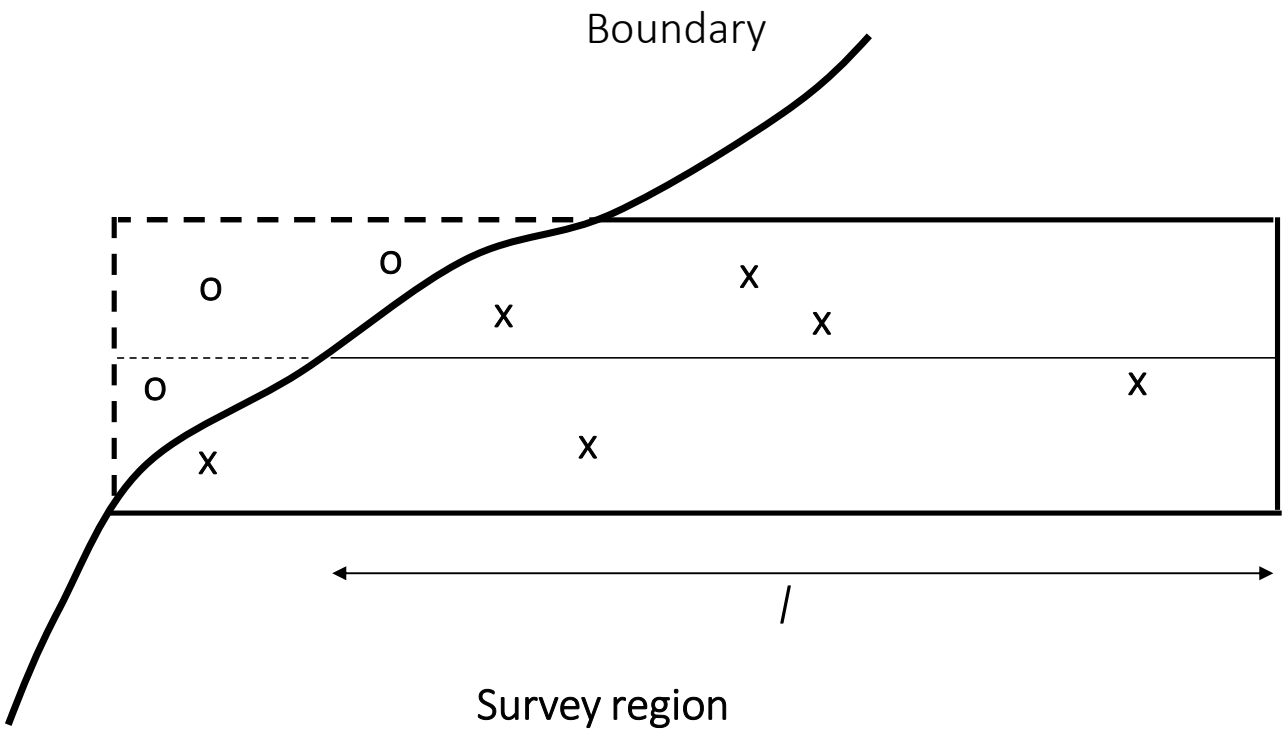
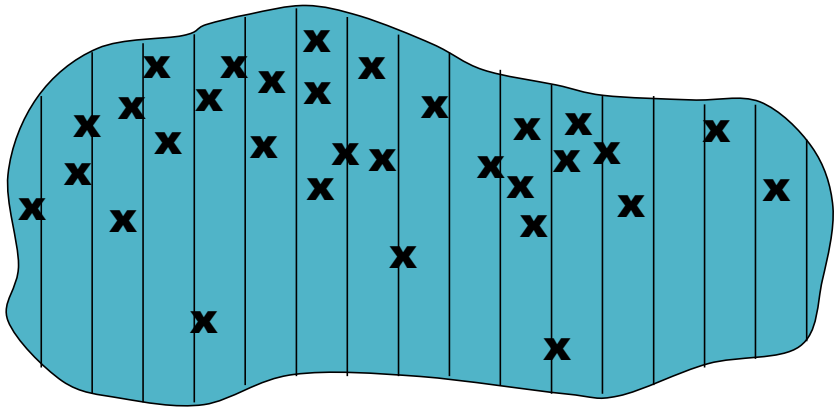
# Plus Sampling – Line Transects




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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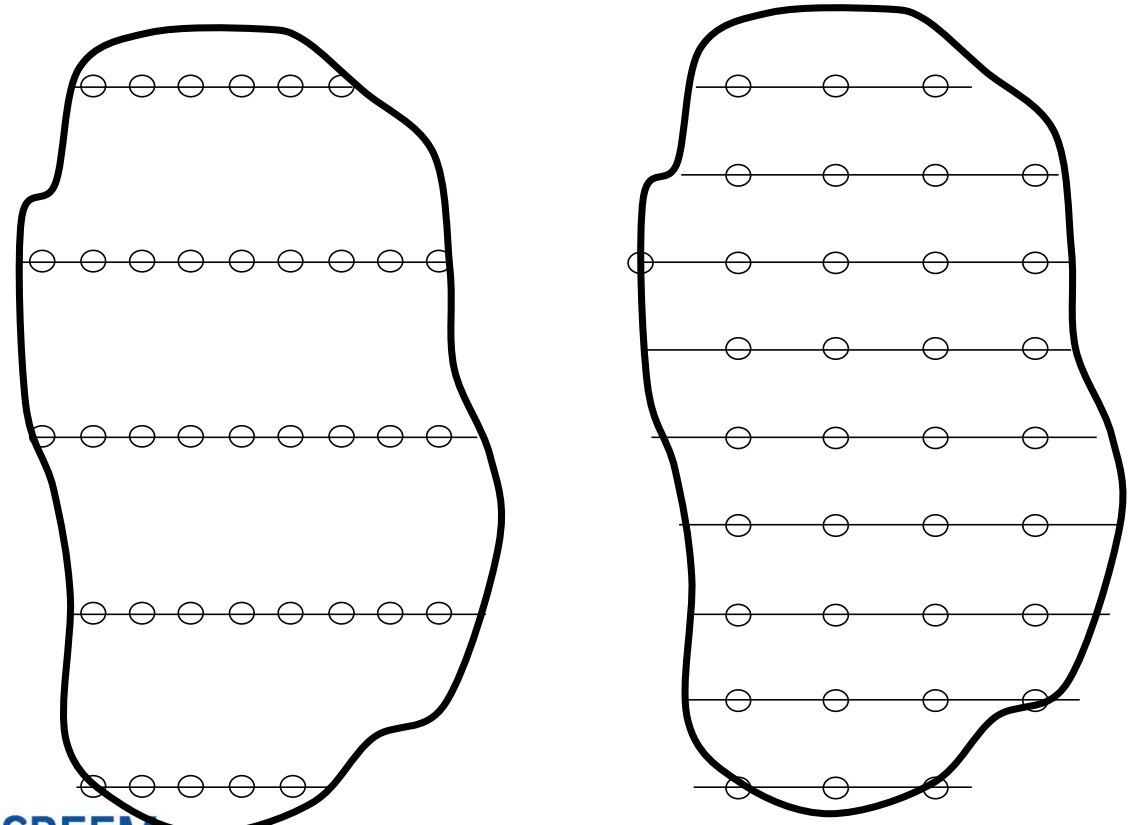
# Systematic Sampling



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
- Can have **overlap** of samplers in the pure simple random sampling design
- 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

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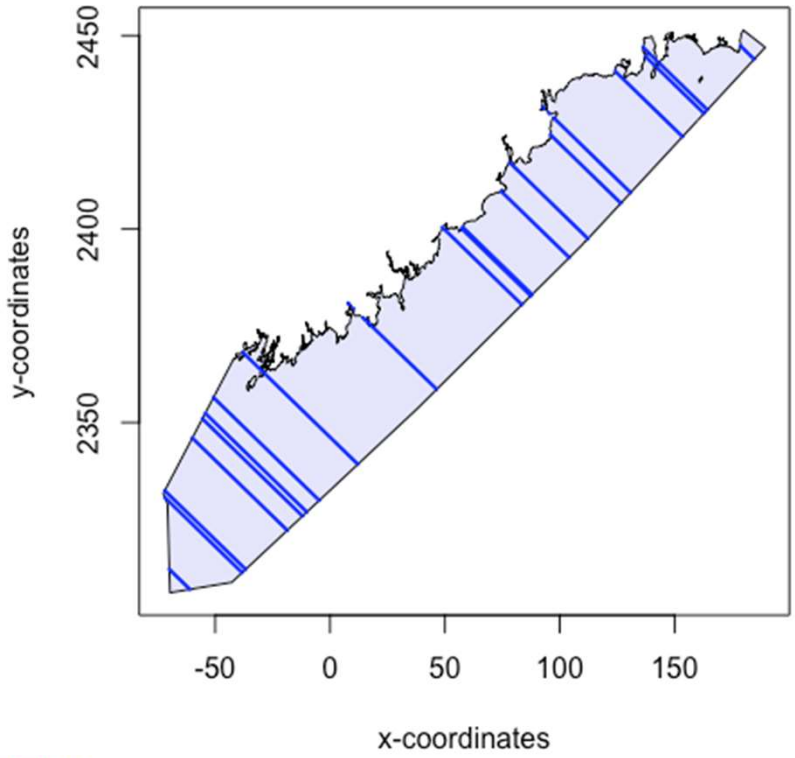
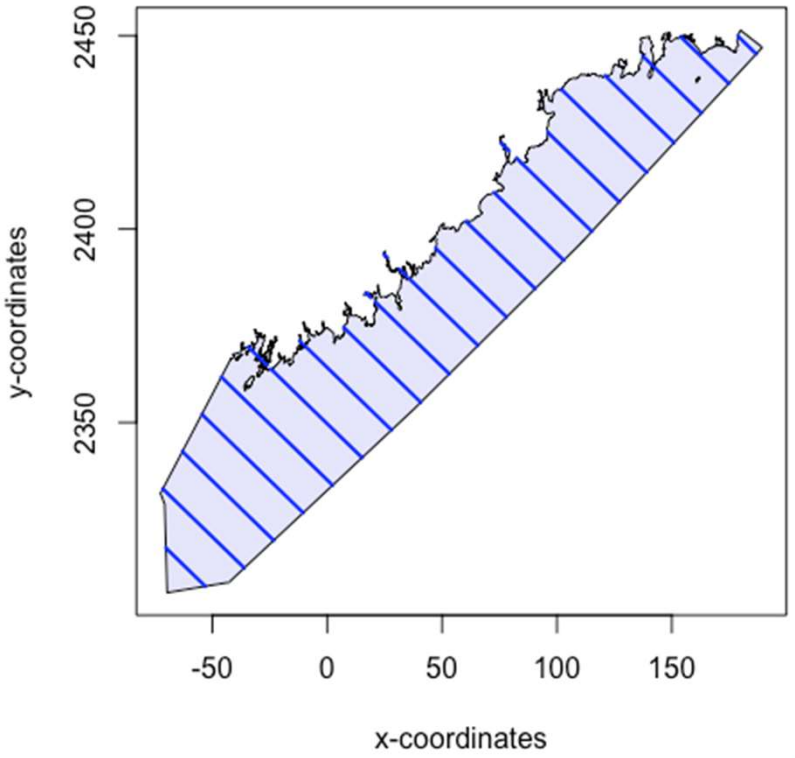
# Parallel Line Transect Designs

Random Parallel Design




Systematic Parallel Design

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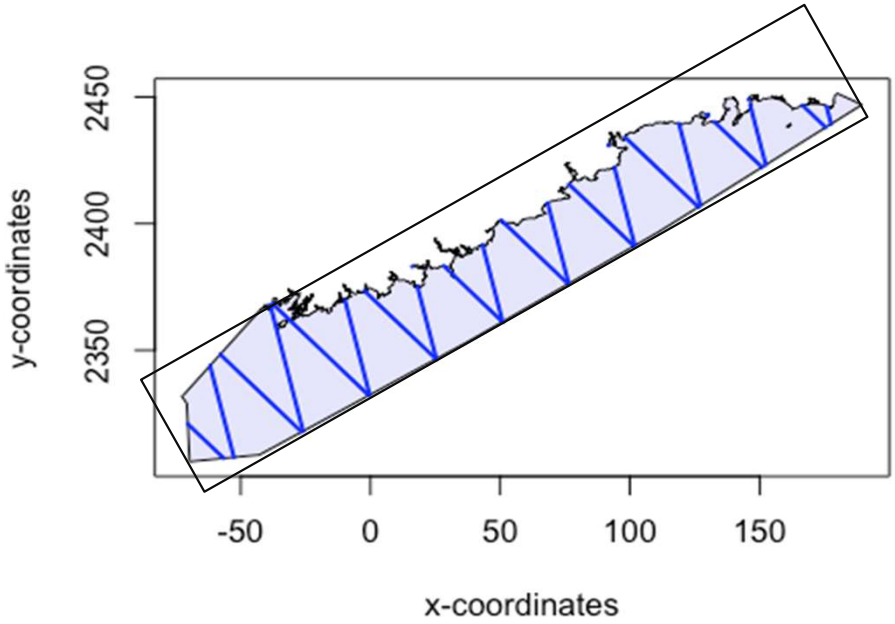
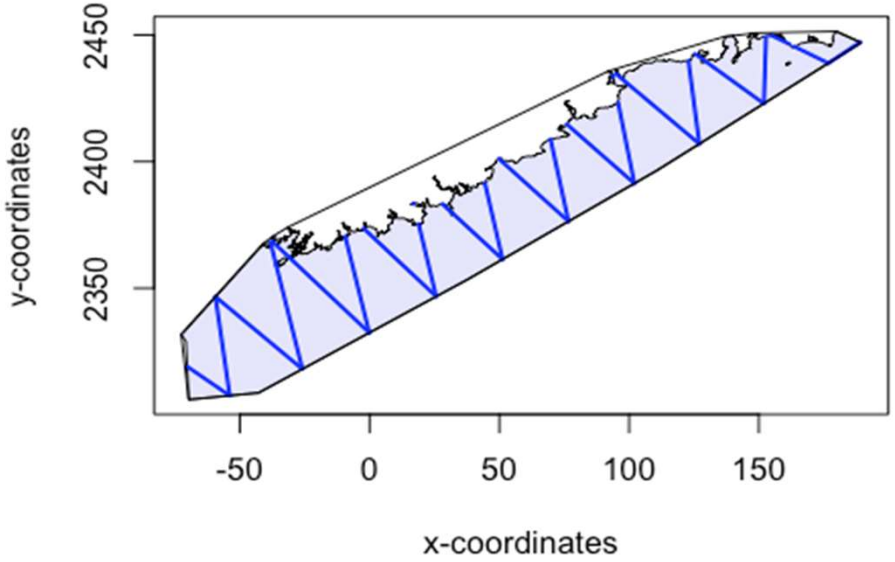
# Equal Spaced Zigzag Designs

Generated inside a minimum bounding rectangle




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

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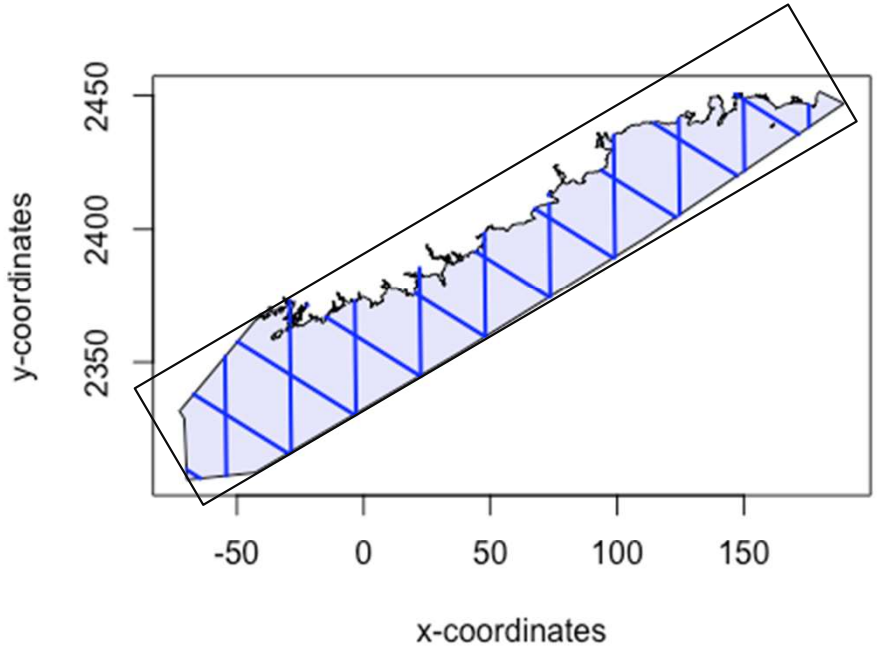
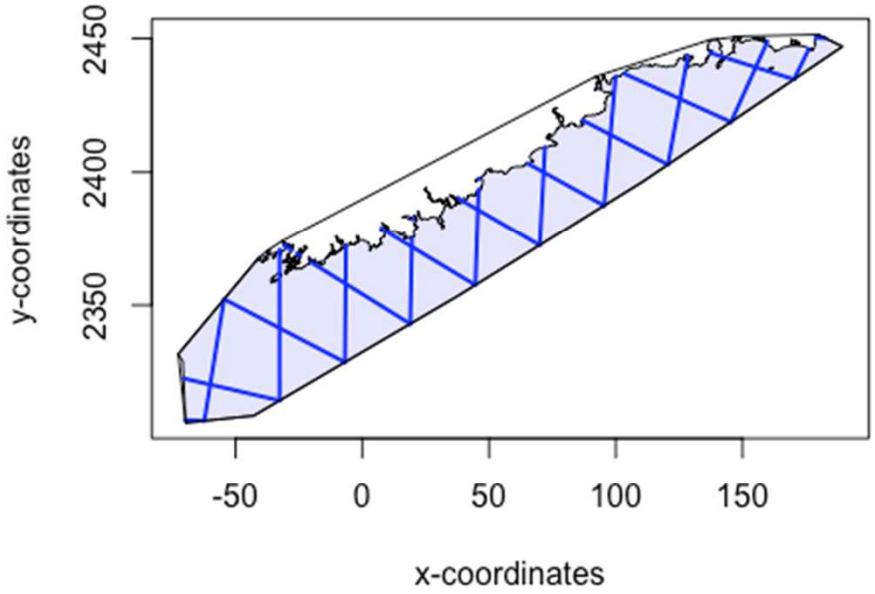
# Complementary Equal Spaced Zigzags

Generated inside a minimum bounding rectangle




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

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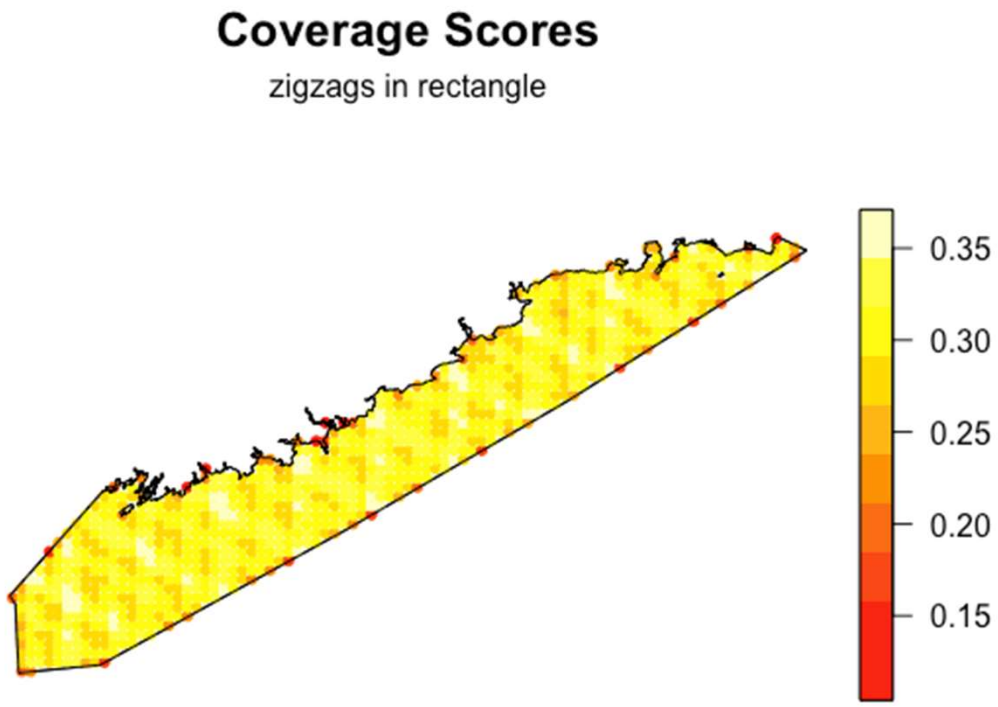
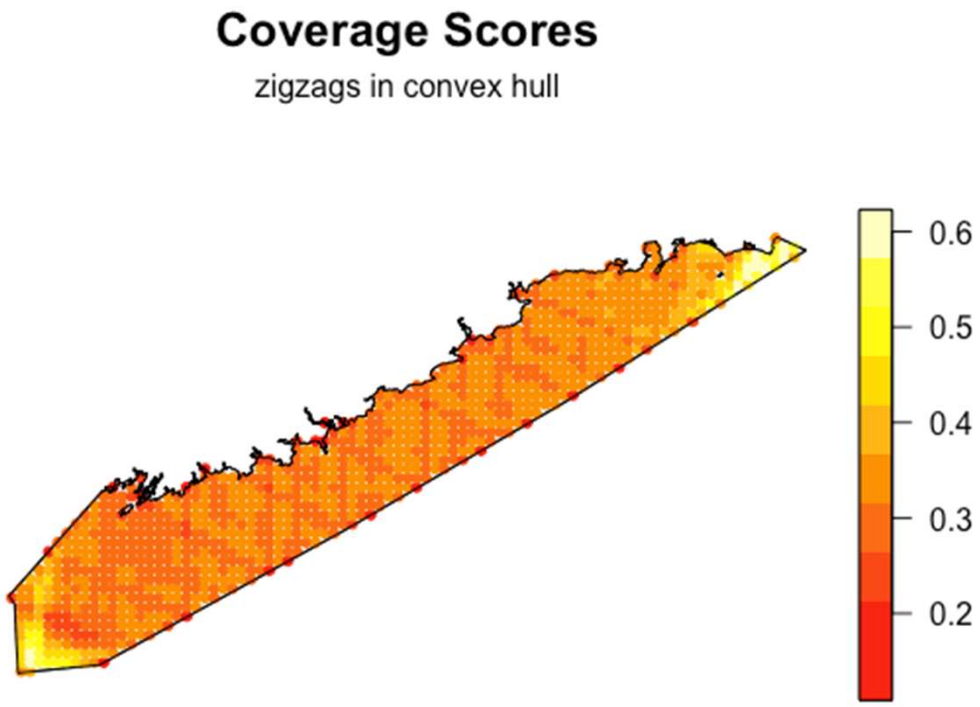
# Complementary Equal Spaced Zigzags

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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.

# Segmented Line Designs

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# Fixed length transects

Systematic segmented trackline

Systematic segmented grid

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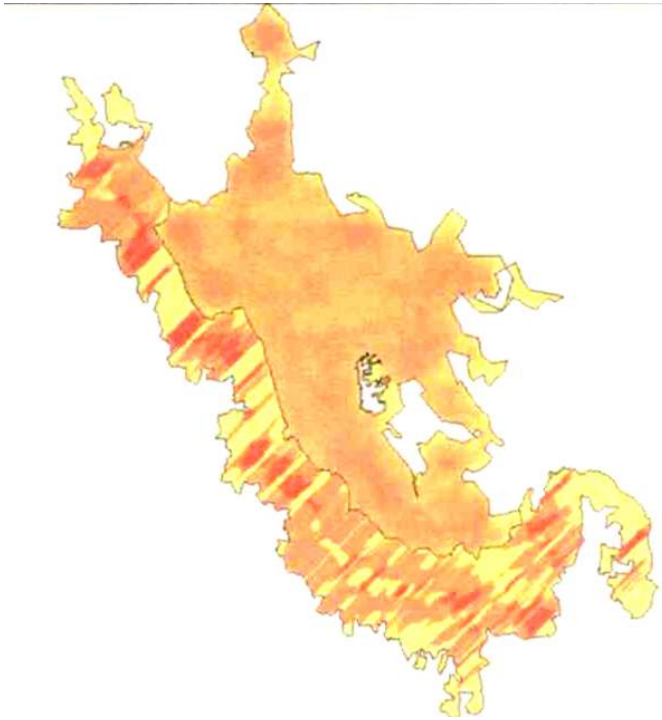
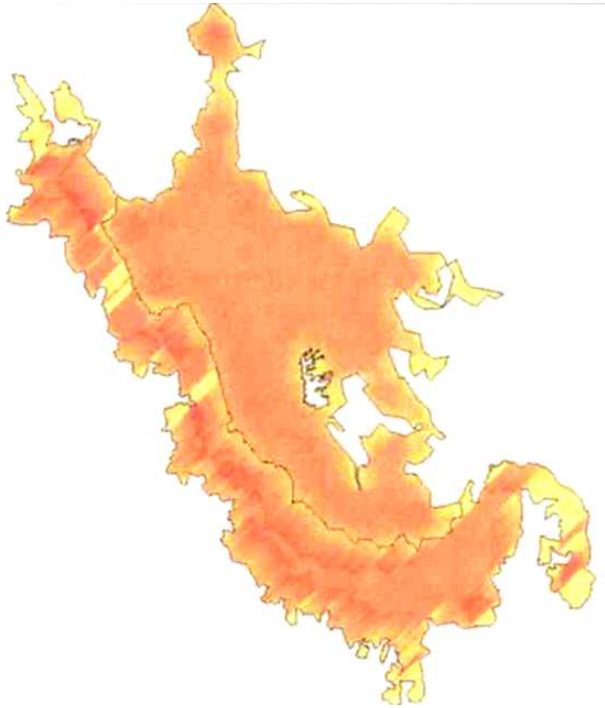
# Edge Effects - push segments more than half in all the way in and discard others

Systematic segmented trackline



Systematic segmented grid



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

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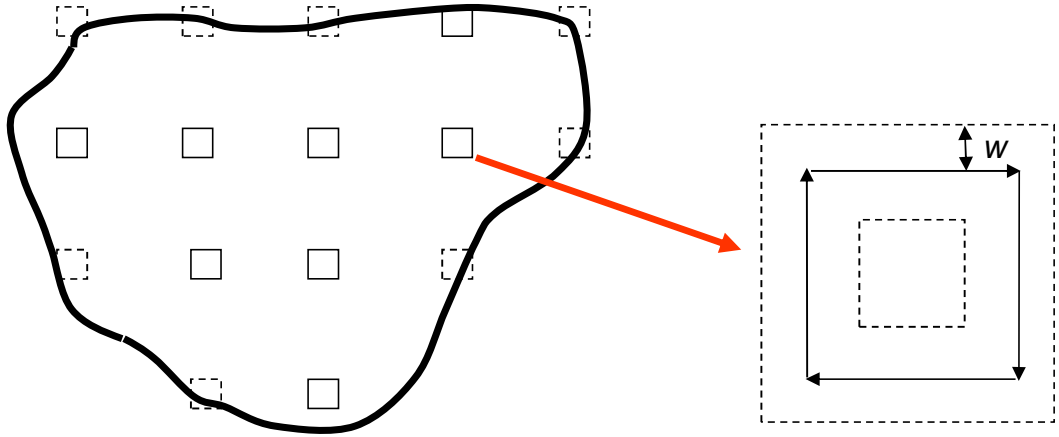
# Comparison of Segmented Designs

- 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, 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)

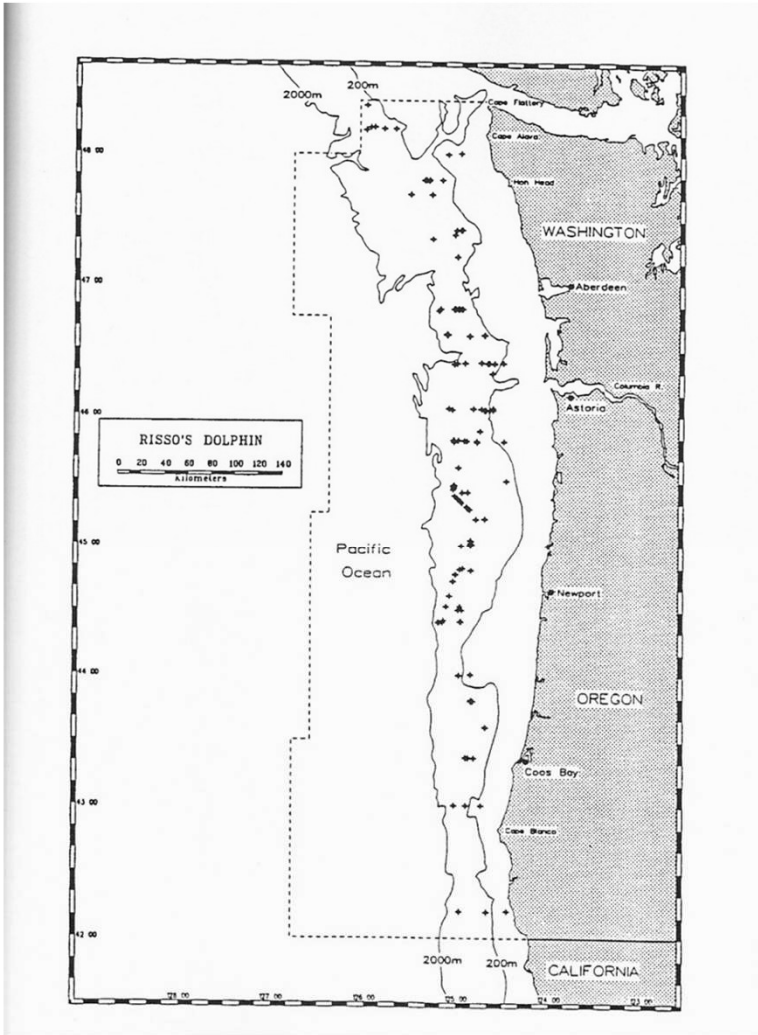
## What to stratify?

- 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).

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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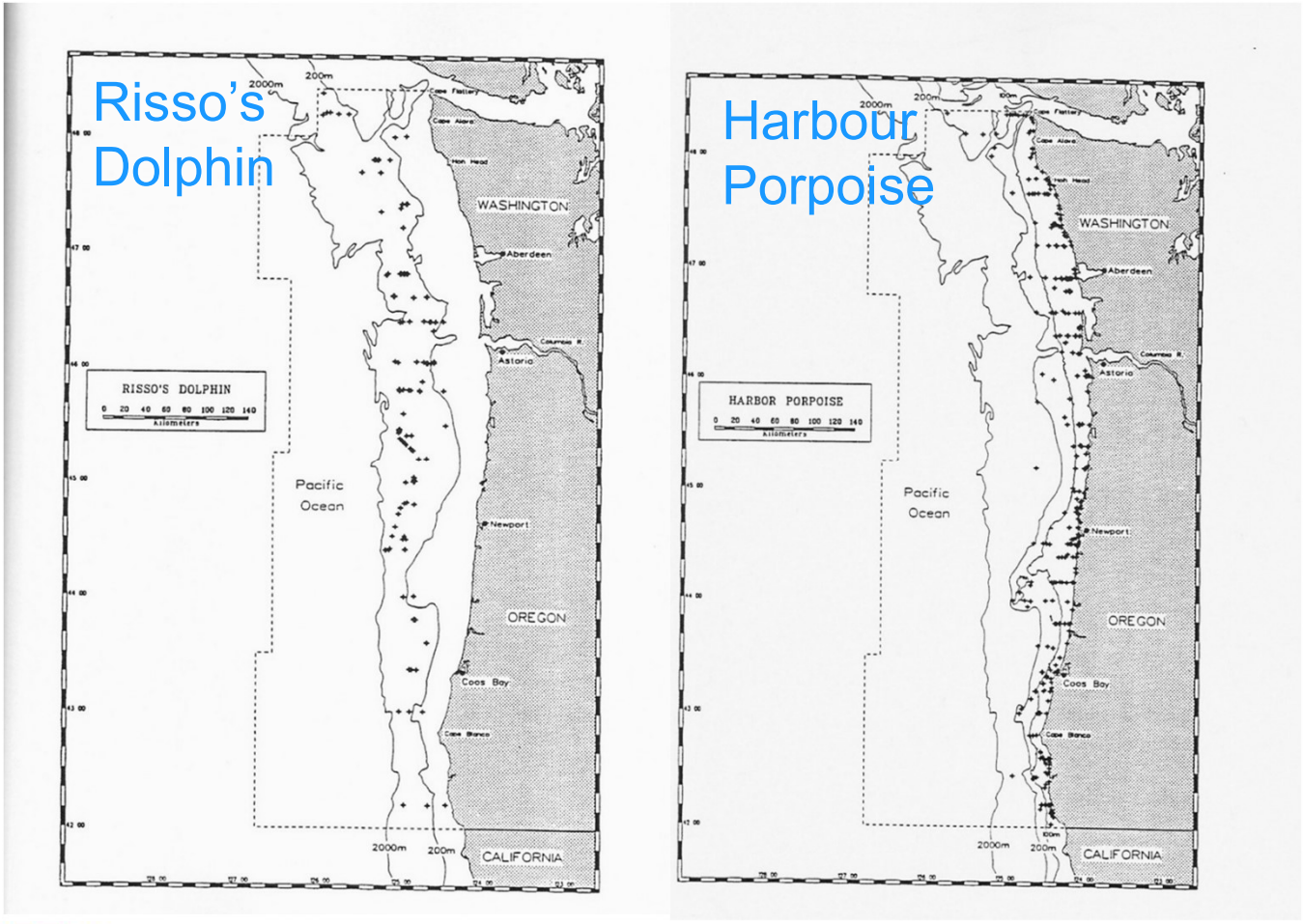
# Stratification (Spatial) – Risks!




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

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

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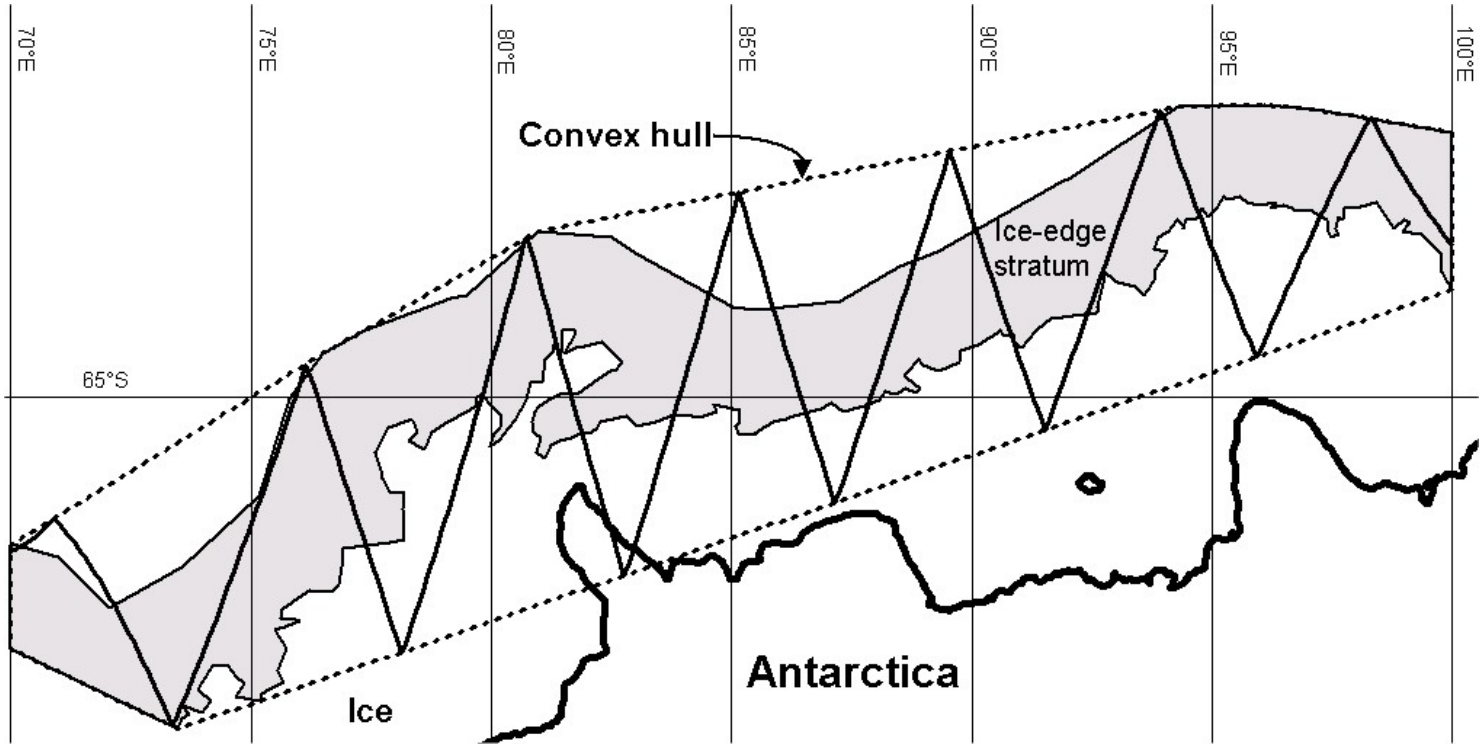
# Example Surveys

# Dealing with Complex Regions

Antarctic Minke whale shipboard survey

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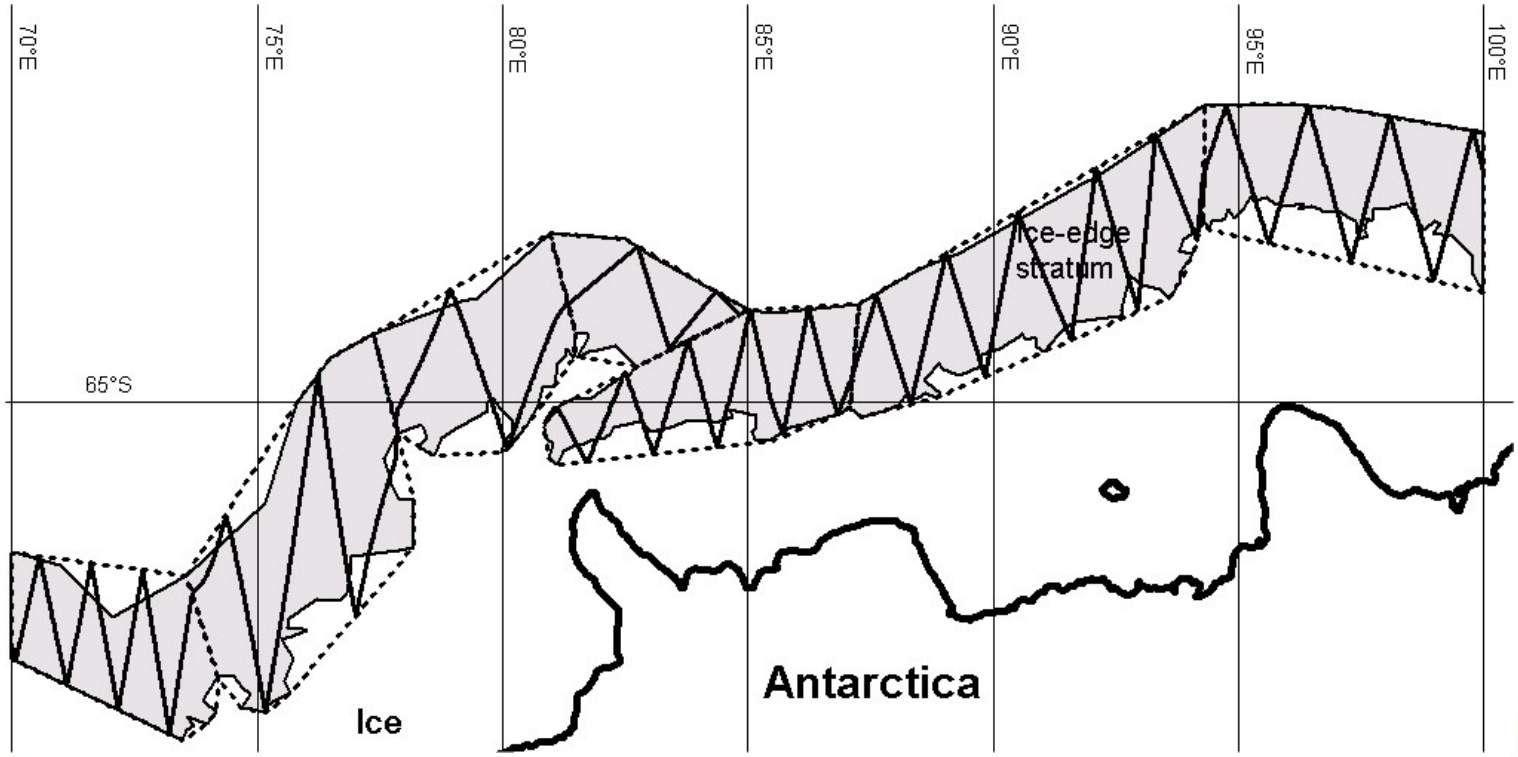
# Dealing with Complex Regions

Study region divided into suitable strata to increase efficiency

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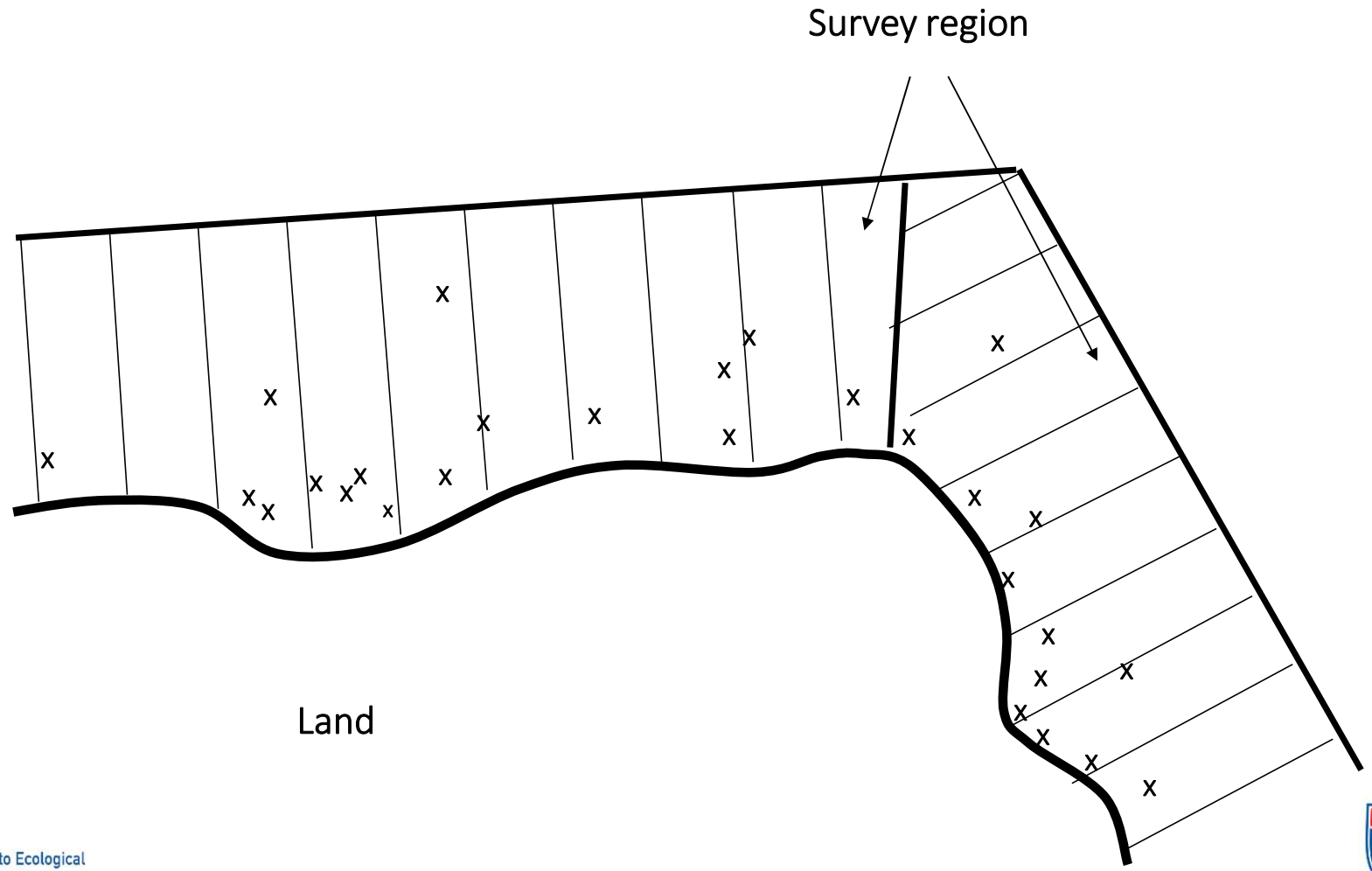
# Designing an inshore survey

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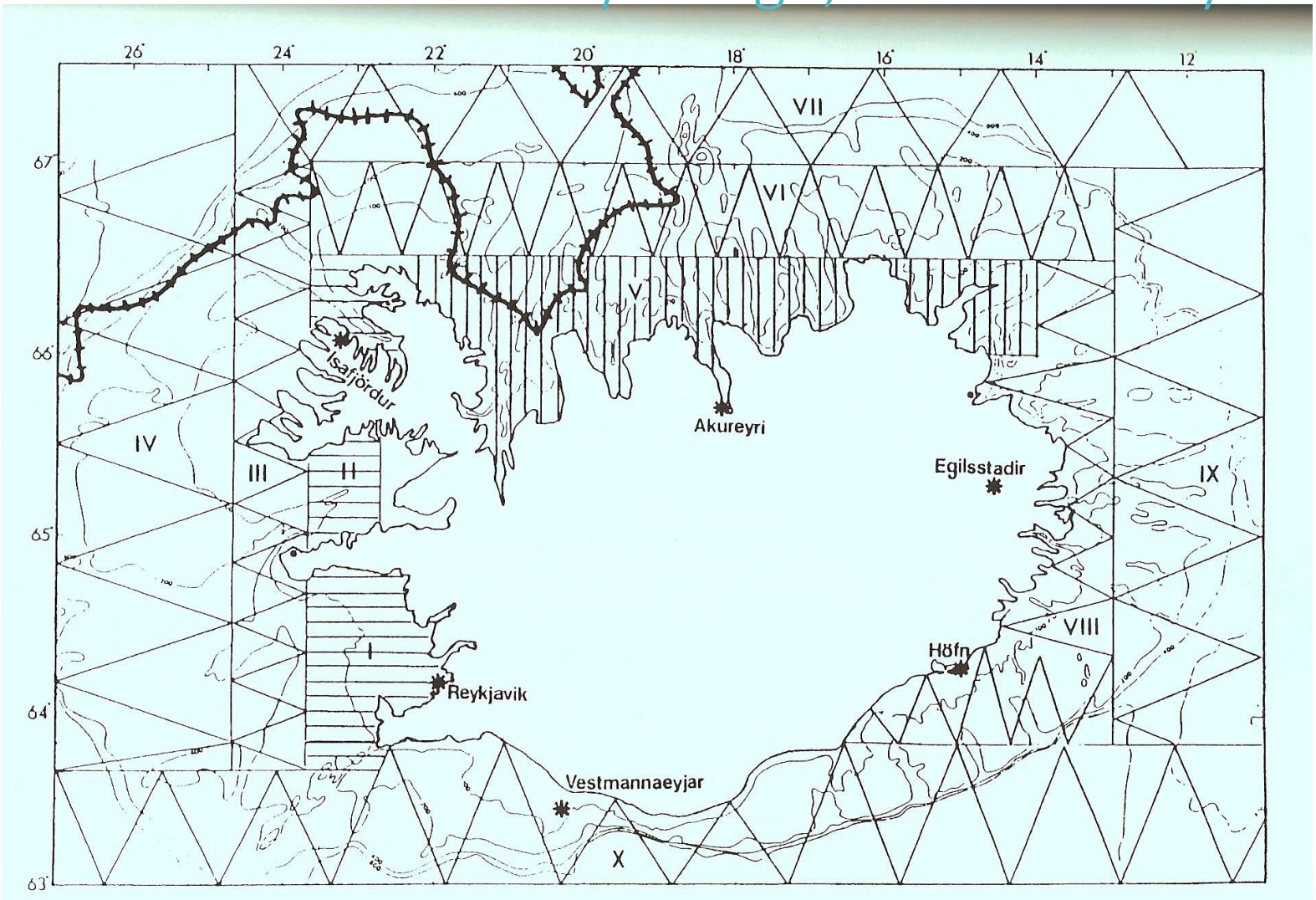
# Iceland – aerial survey design, whale survey

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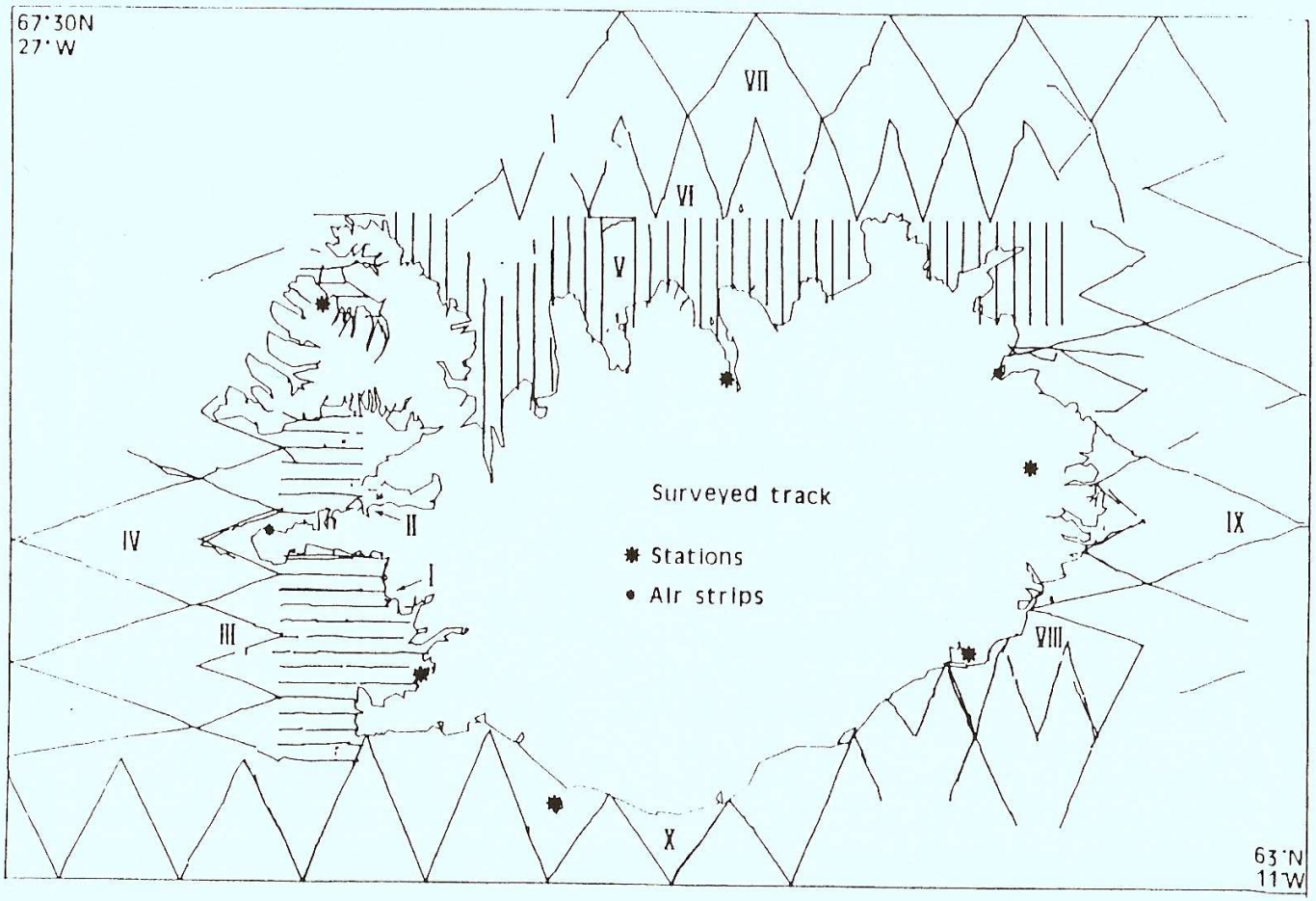
# Actual effort, Icelandic whale survey

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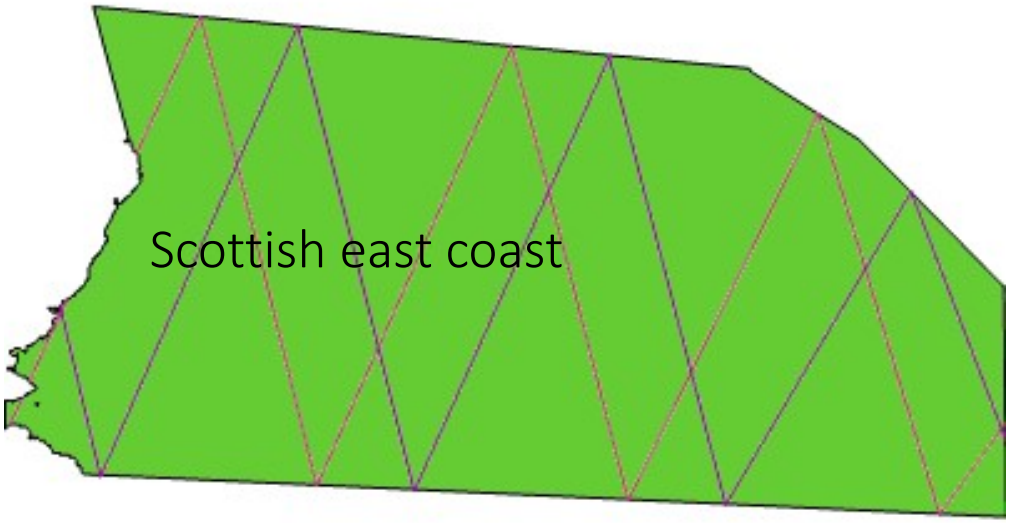
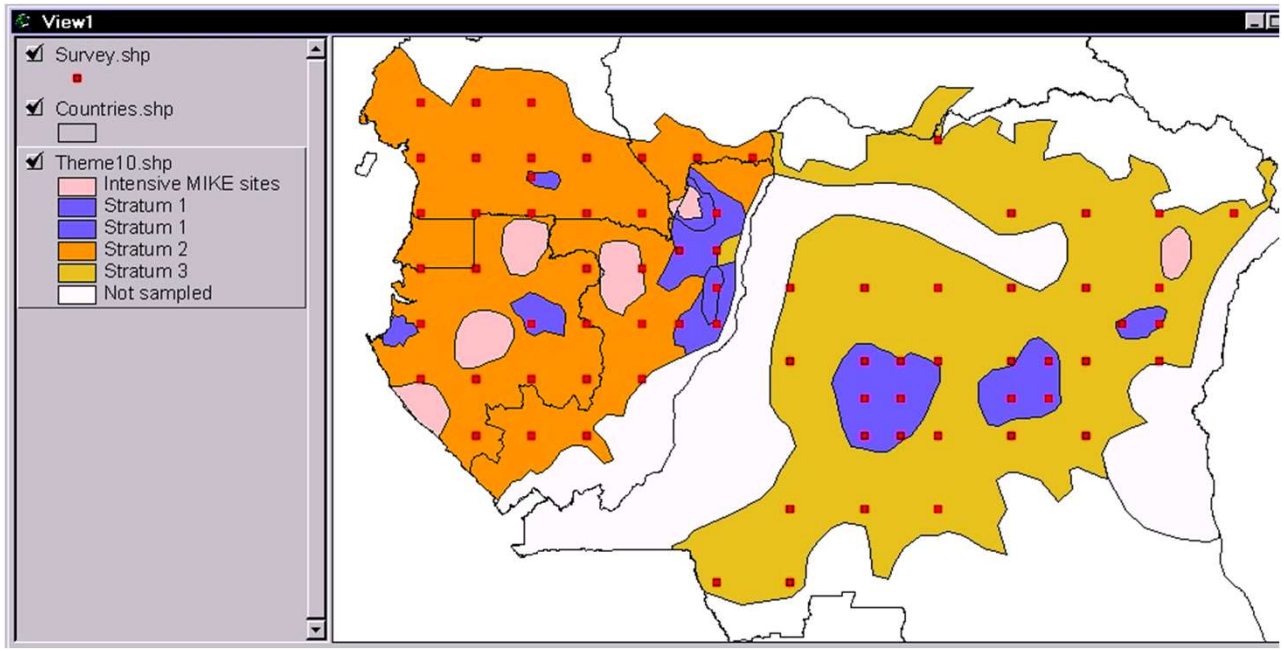
# Efficiency

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 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*