Analysis of Stratified Surveys

Section 3.7 of Buckland et al. (2001)

Section 2.3 of Buckland et al. (2015)

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Stratification

- Why stratify?
- Stratification by:
  - Geographic area
  - Survey
  - Species / cluster size
- Decisions during analysis
- Alternatives to stratification

Stratification is used to:

- reduce variance and improve precision
- and for producing estimates in regions of interest

Stratification criteria:

- AREA or GEOGRAPHIC REGION
  - the study region is partitioned into smaller regions

- SURVEY
  - used when different surveys cover the same geographic area

- POPULATION/SPECIES/CLUSTER SIZE
  - same geographic region containing different ‘sub-stocks’

Types of stratification

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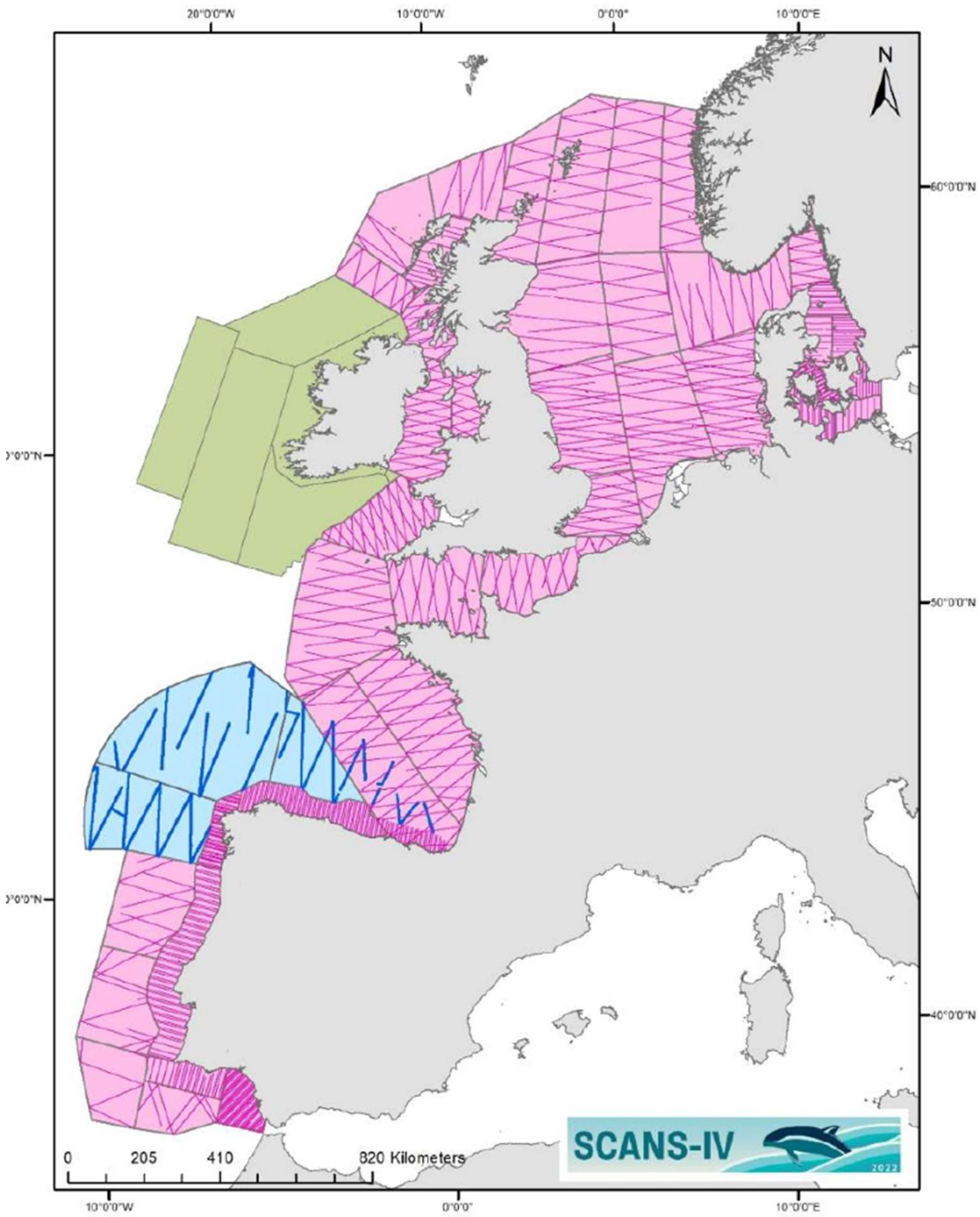
Example geographic stratification: SCANS IV (2022)

Small Cetaceans in European Atlantic waters and the North Sea



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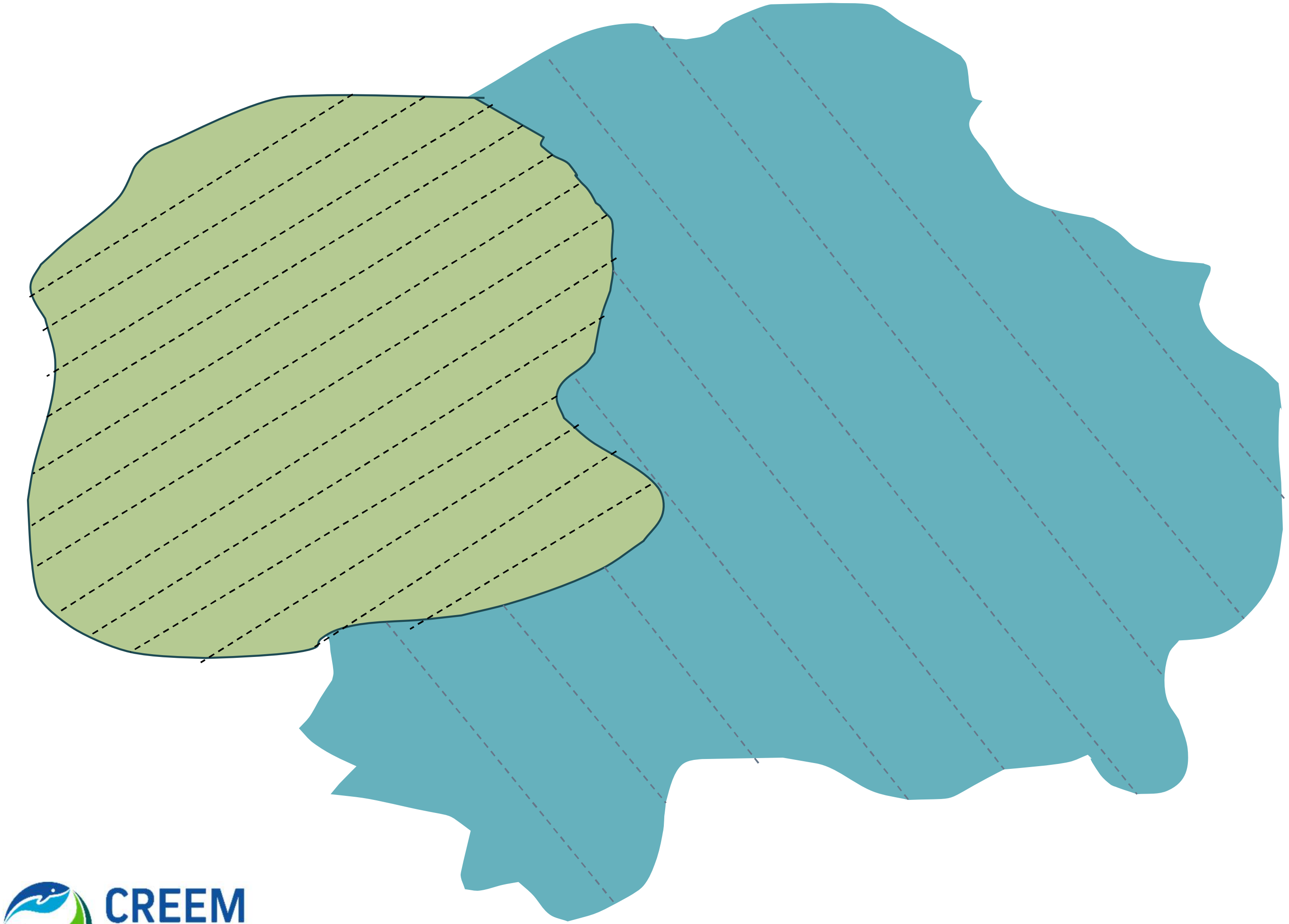
Geographic stratification



- Strata are geographic areas.
- Density estimates are required for each stratum and for the entire study area.

$$\hat{D} = \sum_{i=1}^{m} \frac{A_m}{A_{total}} \hat{D}_m$$

$$var(\hat{D}) = \sum_{i=1}^{m} \left(\frac{A_m}{A_{total}}\right)^2 var(\hat{D}_m)$$

where

- $\hat{D}_i$ is estimated density for the i^th^ stratum and
- A_i is area of the i^th^ stratum

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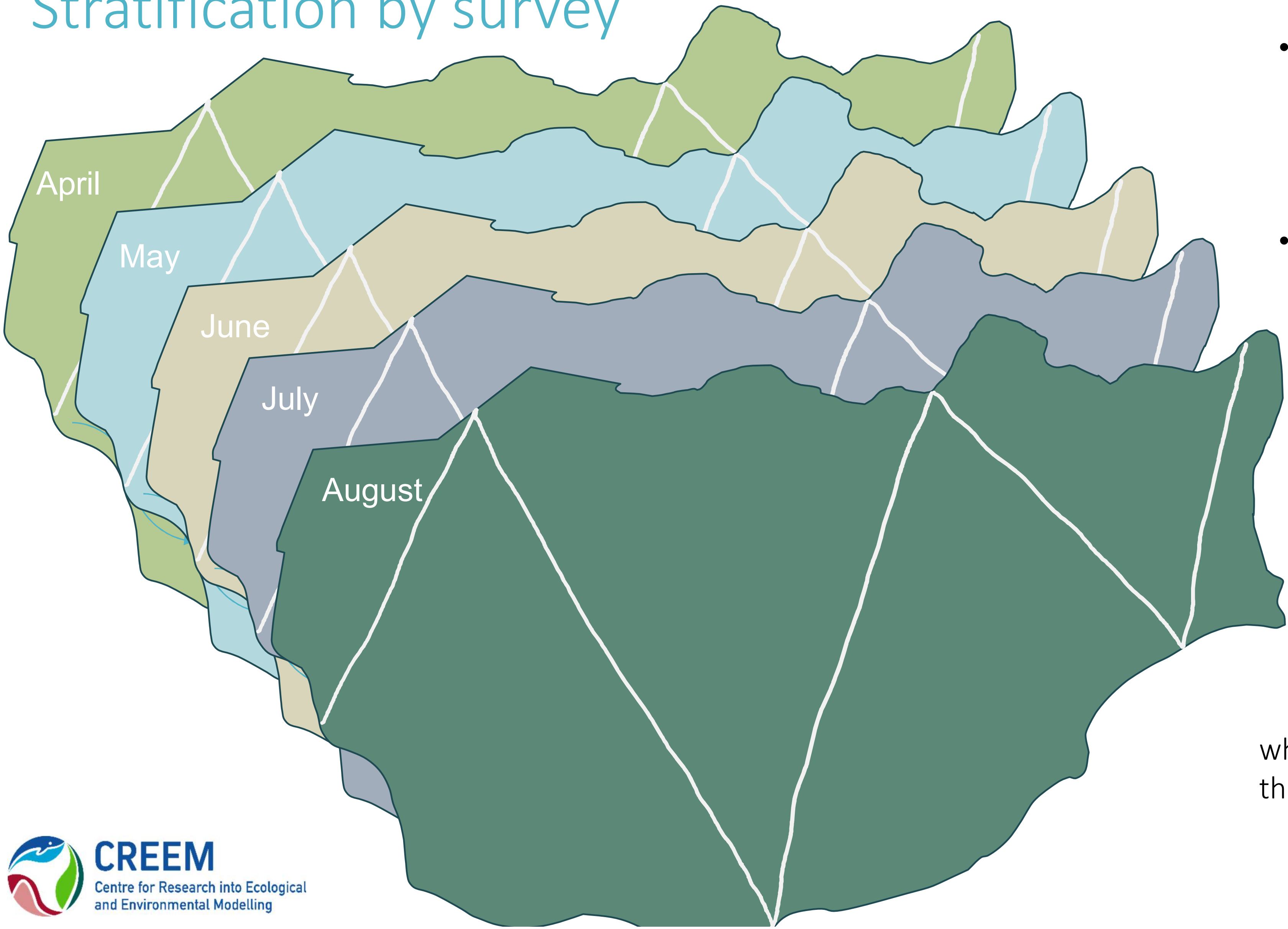
Stratification by survey



- Replicate surveys have been conducted; e.g. week-long surveys conducted monthly or concurrently by different platforms.
- Interest lies in the average density across surveys and variability between surveys.

$$\hat{D} = \sum_{i=1}^{M} \frac{L_m}{\sum_{k=1}^{M} L_k} \hat{D}_m$$

$$\mathrm{var}(\hat{D}) = \sum_{m=1}^{M} \frac{\left(\hat{D}_m - \bar{\hat{D}}\right)^2}{M-1}$$

where L_i is effort associated with the i^{th} survey

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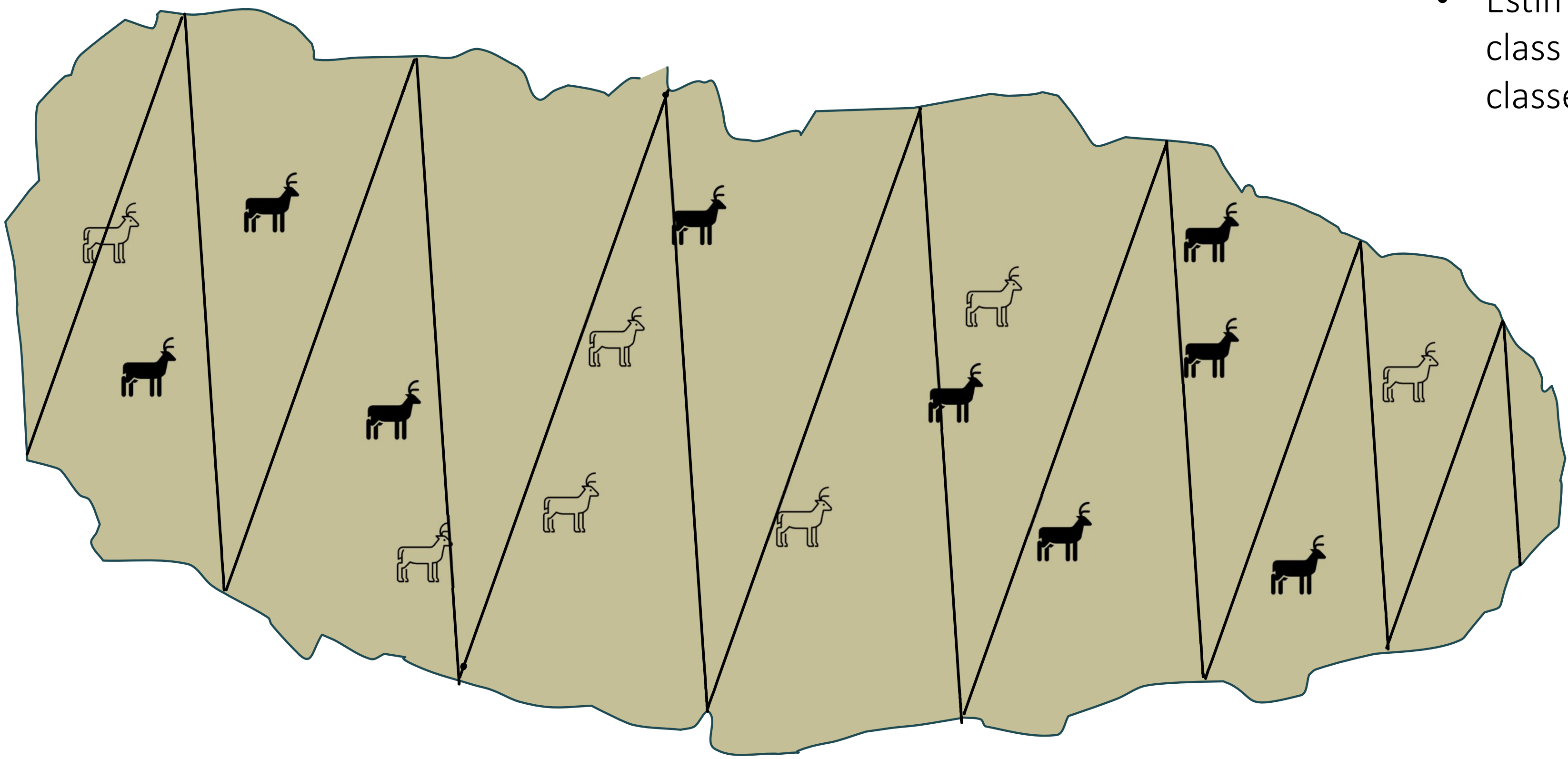
Post-stratification (stratification by object class)



- Objects are of different species or sexes.
- Estimates are desired for each object class as well as a total density across classes.

$$\hat{D} = \sum_{m=1}^{M} \hat{D}_m$$

$$\text{var}(\hat{D}) = \sum_{m=1}^{M} \text{var}(\hat{D}_m)$$

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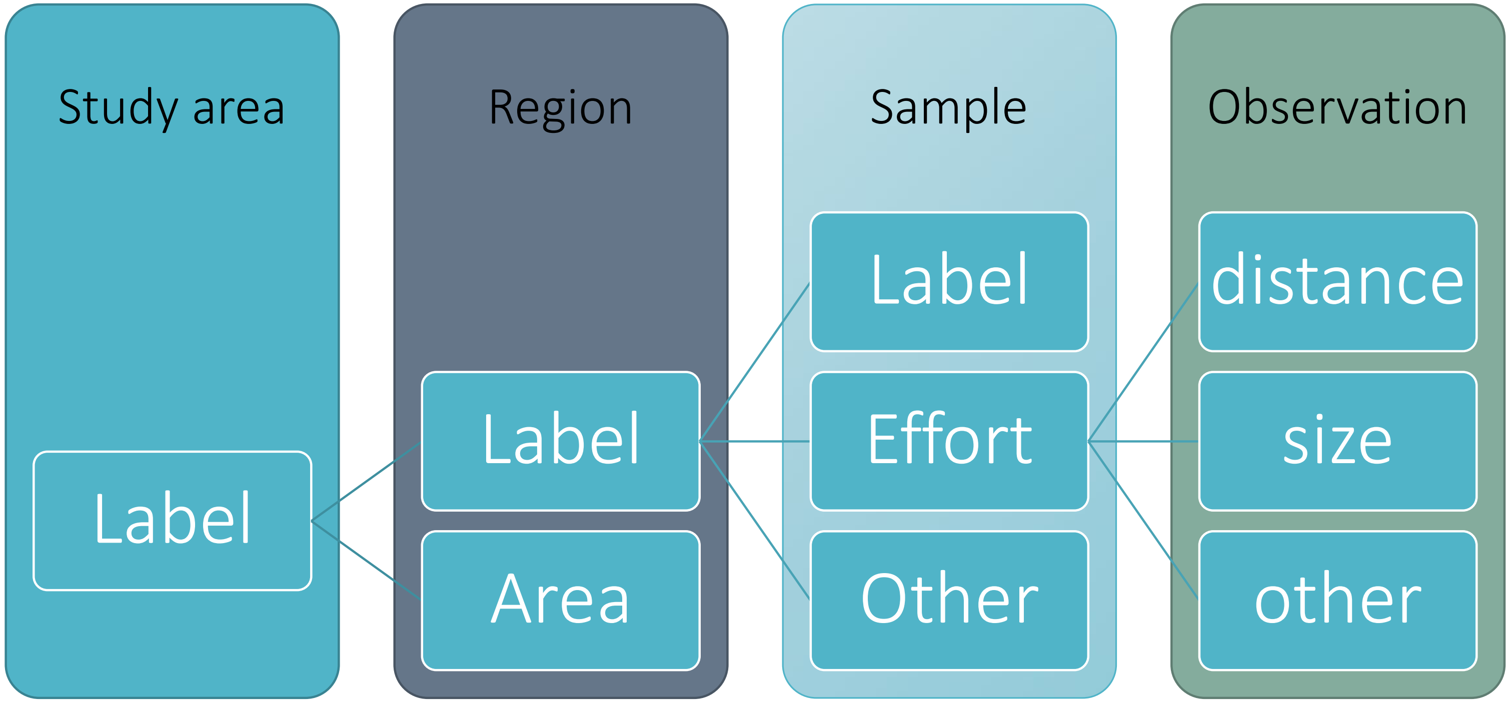
Data organisation hierarchy



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Analysis decisions arising from stratification

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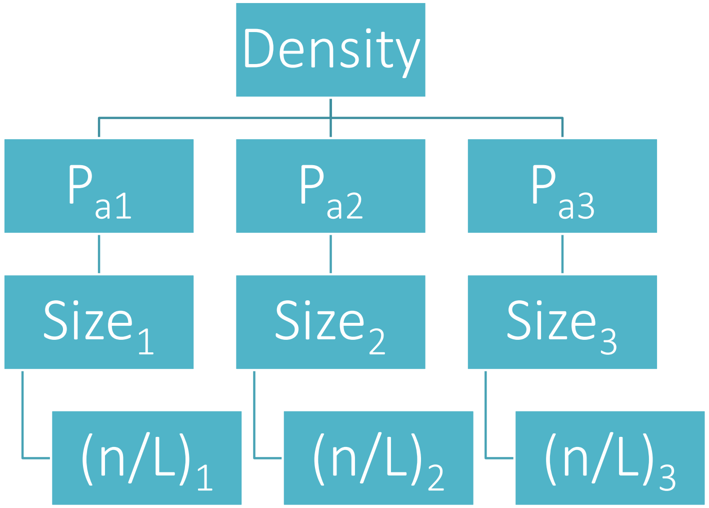
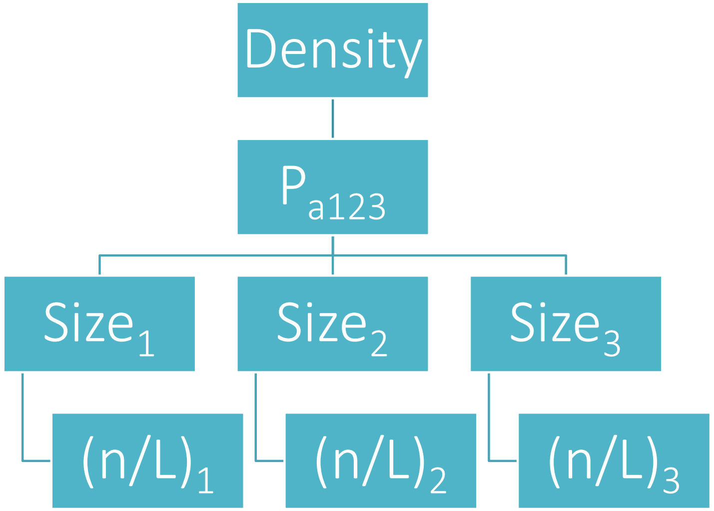
Example (3 strata):

Full geographic stratification



Pooled detection across strata



Select strata and fit detection function to each strata

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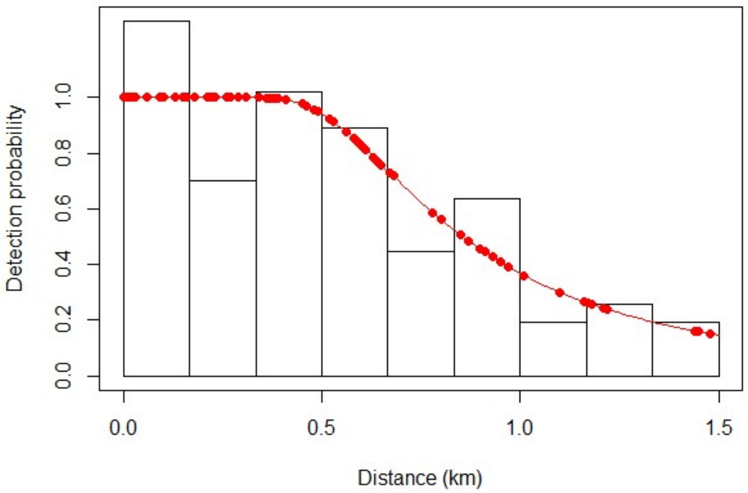
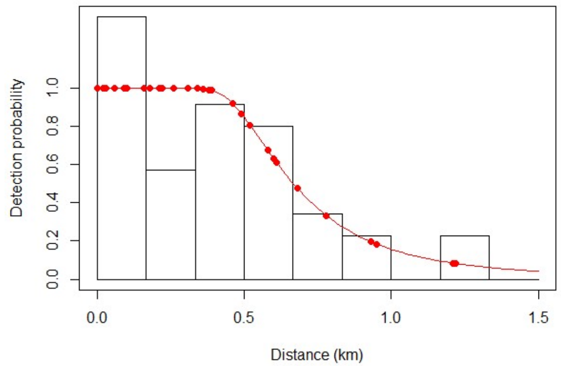
Pooled *vs* Stratified P_a

Pooled n=88

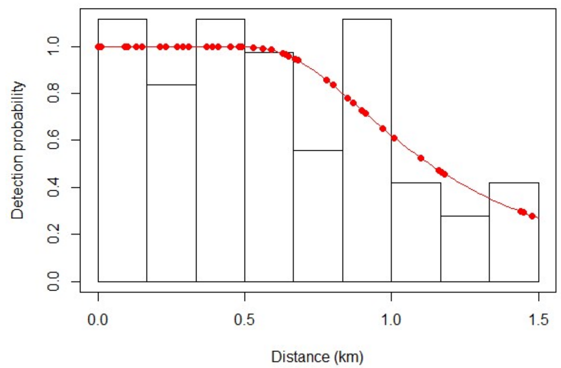


Stratified

Ideal habitat n=39



Marginal habitat n=49



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It is a Model Selection Problem

	Pooled	Stratum 1	Stratum 2	Stratum Sum
Log likelihood $\log_e(L)$	-180.490	-72.699	-104.676	-177.375
No. parameters (q)	2	2	2	4
AIC	364.980	149.398	213.352	362.75

Criterion for stratification of P_a:
Fit separate P_a for each strata if

$$AIC_{pooled} > \sum_{strata} AIC_{stratum}$$

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Alternatives to stratification

Alternatives to stratification

- Small sample sizes can lead to low precision in stratum-specific estimates

- An alternative approach to reducing bias due to heterogeneity is Multiple Covariates Distance Sampling (MCDS)
    - Covariates, other than distance, are incorporated into the scale parameter of the detection function

- MCDS can be used to fit the detection function at multiple levels e.g. stratum-specific density estimates can be obtained even with insufficient data to fit separate detection functions for each stratum