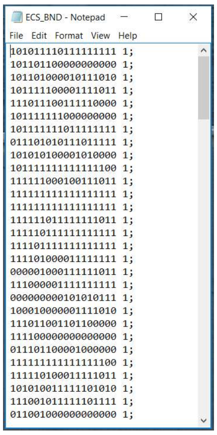


5. Mark-recapture analytical methods:
closed population models

$\hat{N}$?

Multi-sample estimation models

- Closed population models to estimate <u>population size</u>
  - If we can assume that the population does not change during the study
    - No birth, death, permanent immigration or emigration
    - Population size remains constant
- Open population models
  - Appropriate if the population is changing during the study
    - But often difficult to apply to estimate population size
  - Mostly used to estimate <u>survival rates</u>

Mark-recapture assumptions (revisited)

- Marks are unique (no ‘twins’)
- Marks cannot change or be lost
- Marks are recognized on recapture and are correctly reported and recorded
- In the simplest models:
  - Marking does not affect future catchability
  - All animals have the same probability of being captured on each sampling occasion
  - Usually assume complete mixing between sampling occasions
  - **Note** that these assumptions can be relaxed in some models
- For <u>closed population models</u>, the population is closed to:
  - Births, deaths, permanent immigration and emigration

Closed population models in software *CAPTURE*

Range of models to estimate population size that allow capture probability to vary in different ways

- Model M_0
  - Capture probability is constant (null model)
- Model M_t
  - Capture probability varies with sampling occasion (t = time)
- Model M_b
  - Capture probability different after first capture (b = behaviour)
- Model M_h
  - Capture probability varies among individuals (h = heterogeneity)
- Models M_{tb} M_{th} M_{bh}
  - Combinations

Running *CAPTURE*

- Implemented within *MARK*
- Very easy to run
  - Useful first option for closed population model analysis
- Goodness of fit tests run to determine which model is likely to be most appropriate
  - But not a formal model selection process

Closed population models in *MARK*

- Much more flexible than *CAPTURE*
- User-defined models to account for variation in capture probability, including heterogeneity
- Rigorous way to choose best model
  - Akaike's Information Criterion (AIC)

Akaike's Information Criterion (AIC)

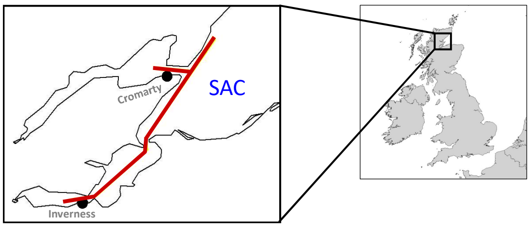
$$AIC = -2 \log_e(L) + 2q$$

- ***L*** is the maximized likelihood
  - The likelihood is a statistical function relating the parameters of a model to the data
- ***q*** is the number of model parameters
- AIC is a balance between model fit and model complexity
- Use to select among different models
- Model with smallest AIC has most support from the data
  - If two models have a difference in AIC of less than 2 units, they are considered to have more or less equivalent support from the data
- Can only use AIC when the data are the same

Accounting for heterogeneity in different ways

- Two methods available:
  - 1. Assume all individuals have different capture probabilities
    - Model as a distribution (Chao model)
    - Method used in *CAPTURE*
  - 2. Assume there are two (or more) groups of animals
    - Each group has a constant capture probability
    - Mixture model (Pledger model)
    - Method used in *MARK*
- Which method is most appropriate?
  - Resident and transient animals?
  - Individual variability in capture probabilities?
  - Probably don't know – try both

Bottlenose dolphins in the Moray Firth



- Small population off eastern Scotland
  - Core area in Moray Firth
  - Systematic photo-id surveys since 1990

Bottlenose dolphins - turning pictures into data

- Representative sample
  - Complete surveys in inner Moray Firth 1990-1992
  - Additional surveys in outer Moray Firth in 1992
- Good quality photographs
- "Well-marked" animals
  - Definition depends on analysis
  - Dorsal fin nicks

Wilson, B., Hammond, P.S. & Thompson, P.M. (1999). Ecological Applications 9: 288-300.

Bottlenose dolphins – analytical methods

- Estimate number of "well-marked" animals ($\boldsymbol{N_{wm}}$)
  - Annual estimates (1990, 1991, 1992)
  - Data from summer months
    - May - September
    - Average of 2 sampling occasions per month
  - Closed population models that can account for heterogeneity
  - Separate estimators for left and right sides – and then combined
- Estimate proportion of "well-marked" animals in population ($\boldsymbol{p_{wm}}$)
  - Fully photographed groups

$$\hat{N}_{total} = \frac{\hat{N}_{wm}}{\hat{p}_{wm}}$$

Estimates of population size

- Estimated number of well-marked animals
  - Left side: **73** (SE = 12) Right side: **80** (SE = 11)
- Estimated proportion of well-marked animals in population
  - Left side: **0.57** (SE = 0.043) Right side: **0.61** (SE = 0.035)
- Population size in 1992 (most representative sample)
  - **129** (SE = 15)
  - CV = 12%

Bottlenose dolphin study – points to consider

- Representative sample?
  - Wide spatial coverage
- Interaction between choice of mark and type of analysis
  - Mark must last longer than study period
- Heterogeneity of capture probabilities
  - Present despite efforts to minimise in the field
    - Photograph every animal encountered
    - Photograph as many animals as possible
  - Need to use appropriate (closed) model
- Estimate of proportion of "well-marked" animals
  - Photograph every animal encountered

Summary

- Two types of mark-recapture models
  - Closed population models
  - Open population models
- Closed models
  - Allow capture probability to vary
    - Heterogeneity of capture probabilities
  - Program *CAPTURE* (implemented within *MARK*)
  - Program *MARK*