

# Mark-recapture analysis of photo-identification data to assess abundance

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# Background to mark-recapture

- Closed population models
  - Petersen (1890s), Lincoln (1930), Jackson (1933), Schnabel (1938)
- Open population models
  - Cormack (1964), Jolly (1965), Seber (1965)
- Computer software for estimation
  - CAPTURE, JOLLY, POPAN, SURGE, RELEASE, MARK



## Program MARK

- Industry standard for estimation of abundance and survival rates
- <http://www.phidot.org/software/mark/>
- Applications of mark-recapture
  - Wildlife population assessment (insects, fish, reptiles, birds, mammals)
  - Human demography, epidemiology and HIV

Buckland, ST, Goudie, IJB & Borchers, DL (2000). Wildlife population assessment: past developments and future directions. *Biometrics* 56: 1-12.

# Collars, tags, bands and brands



Fig. 1. Stages of hot-brand healing in a juvenile Steller sea lion (*Eumetopias jubatus*), shown as (A) day of brand, (B) one week post-brand, (C) three weeks post-brand, and (D) eight weeks post-brand.

# Photo-identification of natural markings



# The basis of mark-recapture abundance estimation

- Capture, mark and release a sample of animals ( $n_1$ )
- Allow population to mix
- Capture a second sample of animals ( $n_2$ )
- Determine how many are already marked ( $m_2$ )
- Equate proportion marked in second sample with proportion marked in population ( $N$ ):

$$\frac{m_2}{n_2} = \frac{n_1}{N}$$

- Population size is estimated as:

$$\hat{N} = \frac{n_1 n_2}{m_2}$$

# Capture histories

Animal	S <sub>1</sub>	S <sub>2</sub>
Alpha	1	0
Bravo	1	0
Charlie	1	0
Delta	1	1
Echo	1	0
Foxtrot	0	1
Golf	0	1
Hotel	0	1
India	1	0
Juliet	1	1
Kilo	0	1
Lima	0	1
Mike	0	1
November	1	0
Oscar	1	1
...	...	...

# Capture histories

Animal	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>5</sub>	...
Alpha	1	0	0	0	0	...
Bravo	1	0	1	0	1	...
Charlie	1	0	0	0	0	...
Delta	1	1	0	1	0	...
Echo	1	0	0	1	0	...
Foxtrot	0	1	0	0	0	...
Golf	0	1	0	0	1	...
Hotel	0	1	1	0	0	...
India	1	0	1	0	1	...
Juliet	1	1	1	1	0	...
Kilo	0	1	1	0	0	...
Lima	0	1	0	1	0	...
Mike	0	1	0	1	0	...
November	1	0	0	0	1	...
Oscar	1	1	0	0	1	...
...	...	...	...	...	...	...

# Mark-recapture assumptions for data

- Marks are unique (no 'twins')

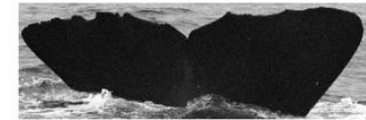


- Marks cannot change or be lost

1. query: photo no 51324; year 2000



2. photo no 8831; 1989



3. photo no 21399; 1991



4. photo no 37626; 1999



- Marks are recognized on recapture and are correctly reported and recorded



## Photo-identification of natural markings



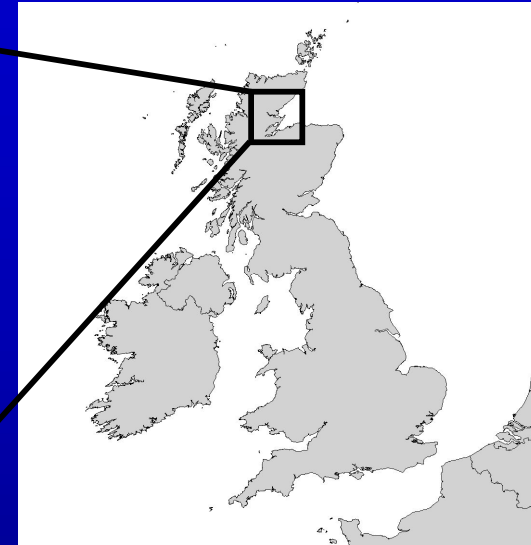
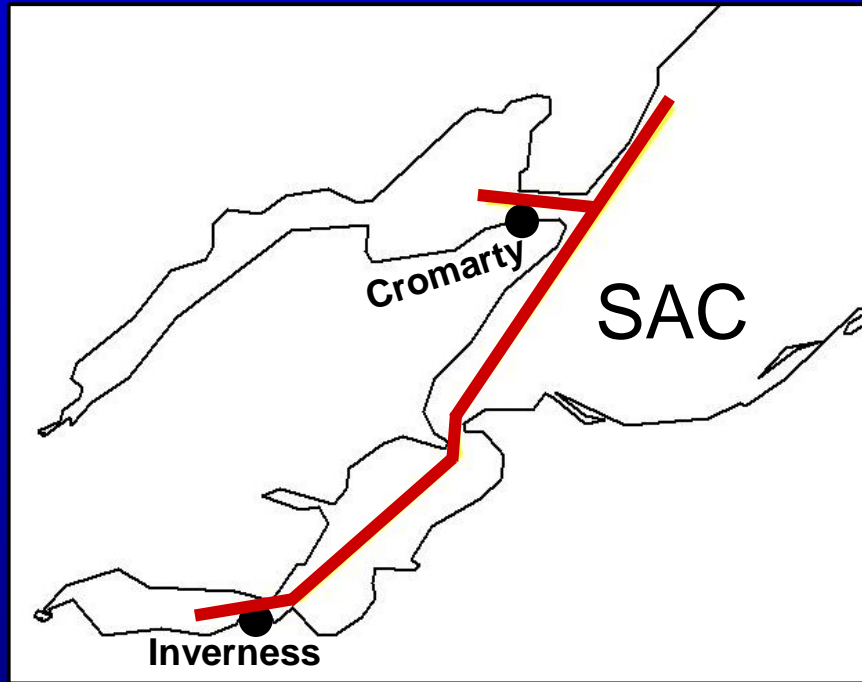
- Advantages and disadvantages:
  - No physical capture or marking (✓)
  - Appropriate marks are unique and cannot be lost (✓)
    - But marks may change (✗)
  - Recognition of marks may not be certain (✗)
    - Distinctness of marks
    - Quality of photographs
  - Animals have different capture probabilities (✗)
    - Probability of being encountered
    - Probability of being photographed
    - Probability of being recognized

# Options for estimating abundance

- Closed population models
  - If population doesn't change (much) during study
    - i.e. no birth, death, immigration or emigration
  - Series of 2-sample estimates
  - Multi-sample estimates
  - Multi-site estimates
    - Exchange rates between sites
- Open population models
  - For long studies when population is changing
  - Estimates typically imprecise
- Heterogeneity of capture probabilities

Hammond PS (1986). Estimating the size of naturally marked whale populations using capture-recapture techniques. Reports of the International Whaling Commission (Special Issue 8): 253-82

# Bottlenose dolphins in the Moray Firth



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



# Turning pictures into data

- Representative sample
- Good quality photographs
- “Well-marked” animals
  - Definition depends on analysis



# Analytical methods

- Estimate number of “well-marked” animals ( $n$ )
  - Annual estimates (1990, 1991, 1992)
  - Data from summer months
    - May – September
    - ~ 2 sampling occasions per month
  - Closed population models that can account for heterogeneity
  - Separate estimators for left and right sides – then combined
- Estimate proportion of “well-marked” animals in population ( $p$ )
  - Fully photographed groups

$$\hat{N} = \frac{\hat{n}}{\hat{p}}$$



## Estimates of abundance

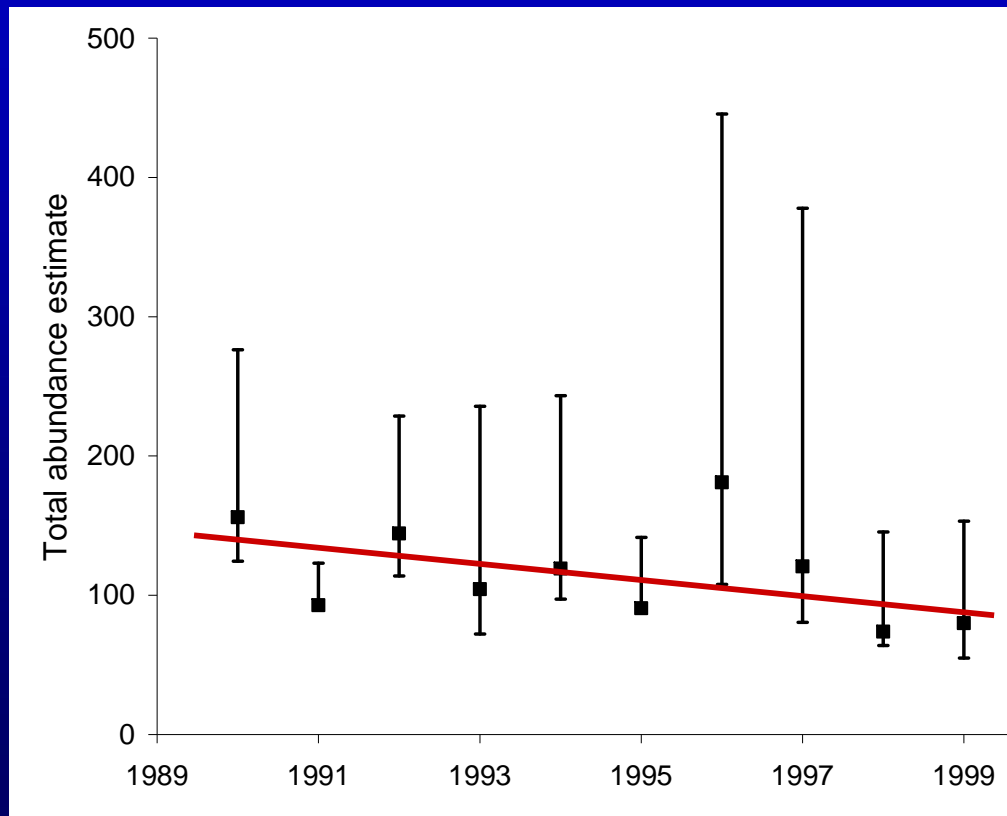
- Estimated number of “well-marked” animals
  - Left side: 73 (SE = 12)                      Right side: 80 (SE = 11)
- Estimated proportion of “well-marked” animals in population
  - Left side: 0.57 (SE = 0.043)                      Right side: 0.61 (SE = 0.035)
- Abundance in 1992 (most representative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



Wilson, B., Hammond, P.S. & Thompson, P.M. (1999). Estimating size and assessing trends in a coastal bottlenose dolphin population. *Ecological Applications* **9**: 288-300.

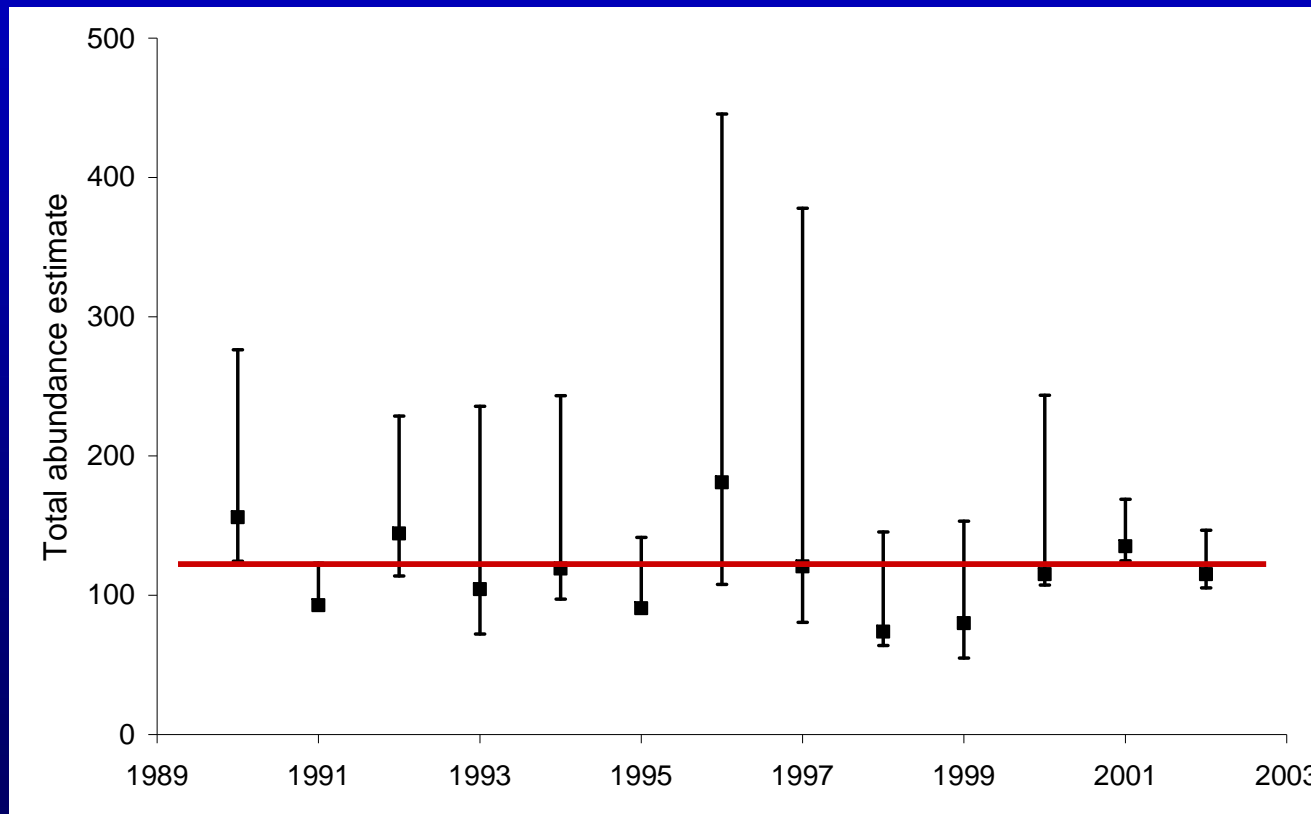
# Trends in abundance

- Additional analysis of time series of data
  - Moray Firth data through 1999 only: decline of about 5% per year



## Trends in abundance

- Include data from St Andrews Bay to 2002
  - Little evidence for change



# Summary

- Mark-recapture for population assessment
  - Statistically robust and widely used
  - But care is needed in application
- Photo-id of natural markings
  - Effective way to “capture” and “mark” some cetacean species
    - E.g. bottlenose dolphin, sperm whale, fin whale
- Estimates of abundance to inform conservation and management

