Multipliers and Indirect Methods

- Why and how we use multipliers
- Cue counting
- Indirect surveys
- Lure and trapping point transects
Multipliers in Distance

Multipliers are constants that are used to scale the final density estimate. Click 'Help' to find out more about multipliers.

Tick the boxes beside the multipliers you wish to add. Distance will then create fields in your dataset for you to enter the multiplier value and, if appropriate, its standard error (SE) and degrees of freedom (DF). You enter these values later when you are entering the rest of your data.

Add multipliers for:

- Surveys where sampling fraction is not 1
- Surveys where g(0) is less than 1
- Cue count surveys
- Indirect surveys of Dung
- Other

Fields added

- Sampling fraction
- g0
- Cue rate
- Dung production rate
- Dung disappearance time
- Generic multiplier

Create fields for SE and DF?

- N
- Y

Adds appropriate fields to Global data layer
Multipliers

- If \( g(0) < 1 \), then the standard method of analysis will produce a density estimate that is proportional to the true density. Then true density (without clusters) is estimated using

\[
\hat{D} = \frac{n\hat{f}(0)}{2L} \cdot \frac{1}{\hat{g}(0)}
\]

These are called multipliers.

- In some surveys, cues (whale blows, bird songs) are the object of detection rather than the animal itself.
- For instantaneous cues (whale blows, bird songs) animal density, \( D \), is estimated by cue density \( D_c \) divided by cue rate \( r \)

\[
\hat{D} = \frac{\hat{D}_c}{r}
\]
**Multipliers: examples**

The multiplier, denoted by $c$, might be

- a known constant
  - sampling fraction $\neq 1$

- a parameter, or product of parameters, to be estimated
  - $\hat{g}(0) < 1$
  - some proportion of the population is surveyed
  - cue counting
  - indirect surveys
Examples: sampling fraction ≠ 1

One-sided line transect sampling: \( c = 0.5 \) to represent the fraction of the strip surveyed

\[
\hat{D} = \frac{nf(0)}{2L} \cdot \frac{1}{0.5} = \frac{nf(0)}{L}
\]

In point transect sampling if one quarter of the circle was surveyed: \( c = 0.25 \)

\[
\hat{D} = \frac{n\hat{h}(0)}{2\pi k} \cdot \frac{1}{0.25}
\]

Point transect sampling with each point visited five times: \( c = 5 \)

Cue counting where \( c \) is the proportion of the circle covered by the observation sector (see later)
Examples: parameters to be estimated

• Surveys where $g(0) < 1$

• Surveys in which only a proportion of the population is surveyed:
  • $c = p$ where $p$ is the proportion surveyed,
  • usually must be estimated,
  • e.g. desert tortoises, seabirds on land/at sea, whales with long dive times

• Cue counting where $c$ is the cue rate

• Indirect surveys e.g. dung/nest surveys (see later)
Multipliers: variance

Remember the multiplier is denoted by $c$.

If $c$ must be estimated (by $\hat{c}$) then this additional variance needs to be included in the density variance.

For line transect sampling

$$\hat{D} = \frac{n\hat{f}(0)}{2L\hat{c}}$$

$$cv(\hat{D}) = \sqrt{\{cv(n)\}^2 + \{cv[\hat{f}(0)]\}^2 + \{cv(\hat{c})\}^2}$$

For point transect sampling

$$\hat{D} = \frac{n\hat{h}(0)}{2\pi k\hat{c}}$$

$$cv(\hat{D}) = \sqrt{\{cv(n)\}^2 + \{cv[\hat{h}(0)]\}^2 + \{cv(\hat{c})\}^2}$$
Cue counting: point transects

Point transect survey where distance to detected cue is recorded
Cue is single burst of song (instantaneous cue)
Valid even if birds are moving during the count

Cue density is

\[ \hat{D}_{\text{cues}} = \frac{n\hat{h}(0)}{2\pi} \]

Cues per unit area

And if you searched for time

\[ T = \sum_{i=1}^{k} \text{time spent at point } i \]


And if you searched for time

\[ \hat{D}_{\text{cues}} / T = \frac{n\hat{h}(0)}{2\pi T} \]

Cues per unit area, per unit time

Note: the standard point transect estimator is

\[ \hat{D} = \frac{n\hat{h}(0)}{2\pi k} \]
Cue Counting: animal density

We want animal density, not cue density per unit time, so

\[
\hat{D}_{\text{animals}} = \frac{\hat{D}_{\text{cues}} / T}{\hat{\eta}}
\]

Where \( \hat{\eta} \) is the estimated number of cues per animal, per unit time

New component of variance

\[
CV^2[\hat{D}_{\text{animals}}] \approx CV^2[\hat{D}_{\text{cues}} / T] + CV^2[\hat{\eta}]
\]
Cue Counting: line transects

Fraction of circle searched: \( \frac{\phi}{2\pi} \)

(\( \phi \) in radians)

So that:

\[
\hat{D}_{\text{cues}} = \left( \frac{n\hat{h}(0)}{2\pi} \right) \div \left( \frac{\phi}{2\pi} \right) = \frac{n\hat{h}(0)}{\phi}
\]
cues per unit area.

And if you searched for time \( T \)

\[
\hat{D}_{\text{cues}/T} = \frac{n\hat{h}(0)}{\phi T}
\]
cues per unit area, per unit time.
Setting up a cue counting project

In this screen, you tell Distance about your survey methods. Click 'Help' to find out more about each option.

Type of survey
- Line transect
- Point transect
- Cue count

Observer configuration
- Single observer
- Double observer

Distance measurements
- Radial distance

Sampling fraction
This option has been moved to the Multipliers page.

Observations
- Single objects
- Clusters of objects
Setting up multipliers for cue counting

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Add multipliers for:

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- Y

Other
- Generic multiplier

Using a rangefinder to estimate distances. Photo: Rolf Koford
Cue counting project: example data

\[ \hat{\eta} \]

\[ \frac{\phi}{2\pi} \]

\[ T \]
Indirect surveys

• Useful when direct distance sampling of a population is difficult,
  • but estimating the density of some object produced by the animals is feasible

• Examples are dung surveys of deer, elephants, big cats and nest surveys of apes

• Production rate and the disappearance rate of the objects of interest need to be estimated

• Key difference between direct and indirect surveys
  • for direct surveys, an estimate of abundance at the time of the survey is obtained
  • for indirect surveys, the final estimate of abundance is an average over a time period corresponding to the mean time to decay of the object
Estimating animal density from indirect surveys

Example: a line transect survey of dung (the same procedure also applies to surveys of nests)

Use conventional methods to estimate the density of the object of interest, in this case we estimate dung density,

\[ \hat{D}_d = \frac{n \hat{f}(0)}{2L} \]  

= dung density

• Divide dung density by \( \hat{d} \) = estimated mean time to decay (in days say)

\[ \hat{G} = \frac{\hat{D}_d}{\hat{d}} \]  

= dung production per day per unit area

• Finally, divide by \( \hat{r} \) = estimated daily production of dung by one animal, (number of dung piles per day)

\[ \hat{D} = \frac{\hat{G}}{\hat{r}} = \frac{\hat{D}_d}{\hat{d} \cdot \hat{r}} \]  

= animal density
Estimating defecation rates

- Observe the animals in the wild in the study region, and record defecation rate

- Observe animals in captivity, in an environment as close as possible to that of the study region

- Put a known number of captive animals into a natural enclosure clear of dung
  - Leave them for a period that is less than the shortest decay time
  - Count, or estimate, the dung abundance at the end of the period
  - Defecation rate is then estimated from
    \[ \hat{r} = \frac{\text{number of dung piles}}{\text{number of animals} \times \text{number of days in enclosure}} \]

- Sample size is the number of animals, not the number of dung piles
- Similar considerations apply to nests
Estimating dung decay rates

• May vary spatially and seasonally and so carry out the decay rate study in the region and time leading up to the survey

• Define consistent criteria for determining whether dung has decayed

• Search for and mark fresh dung at a representative sample of sites at intervals of time which span the decay period of more persistent dung

• During the line transect survey, pay a single visit to each marked dung pile and record whether or not it has decayed (more visits may be required if the line transect survey is of long duration)

• Analyse the data using logistic regression with time between marking and the revisit as the explanatory variable (and possibly additional variables)

• Similar considerations apply to estimating nest decay rates
Specify how multiplier should be used

<table>
<thead>
<tr>
<th>Layer type containing multiplier</th>
<th>Field containing multiplier value</th>
<th>Field containing multiplier SE (optional)</th>
<th>Field containing multiplier DF (optional)</th>
<th>Operator</th>
<th>Cue rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global</td>
<td>G0</td>
<td>G0 SE</td>
<td>G0 df</td>
<td>/</td>
<td></td>
</tr>
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<td>Global</td>
<td>Sampling</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

**Operator**

- Operator ‘*’ means
  - Final density estimate = Density estimate * Multiplier value
- Operator ‘/’ means
  - Final density estimate = Density estimate * (1 / Multiplier value)

**Cue rate**

For cue count surveys, you should enter the cue rate field as a multiplier and tick the ‘Cue rate’ box in this row.
Trapping and lure point transects

These use just one trap (or lure) per sampling plot:
Estimating the detection function

We do not know the initial location of animals that are trapped or lured, so that distances from the point are unobserved.

We therefore need a sample of animals whose initial location is known. We then record whether each of these is trapped, or lured to the point.
Example: Scottish crossbills

- Section 9.2.1 of Buckland et al. (2015) and https://synergy.st-andrews.ac.uk/demanda/#crossbill-lure-case-study
Key Largo wood rats

• Over 4 years, 33 females and 22 males were radio collared
• More than 1000 trials (trap exposures) were conducted on these individuals
• Sex-specific random effects models were used to estimate detection probabilities as functions of distance of animal from trap
• Clearly these secretive animals are unlikely to be caught in traps even if the traps are atop the animal


Section 9.2.2 of Buckland et al. (2015)
Baltic harbour porpoise

- Hydrophones (C-PODs) placed in the Baltic
- Visual tracking of porpoises by observers set up the “trials”
- Logistic regression permits estimation of detection probability of porpoises at different distances from the hydrophones

See http://www.sambah.org for more details
Advantage

• We do not assume that detection at the point is certain – we allow $g(0)<1$

Disadvantage

• Trade assumptions for data
• We need to know the initial location of a number of animals, e.g. using radio-tagging or lure trials