Multipliers and Indirect Methods

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

- Section 3.1.4 in Buckland et al. (2001)
- Sections 9.2-9.4 in Buckland et al. (2015)
    - Crossbill lure study code https://synergy.st-andrews.ac.uk/ds-manda/#crossbill-lure-case-study

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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

$$\hat{D} = \frac{n}{2wL\hat{P}_a} \cdot \frac{1}{\hat{g}(0)}$$

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

$$\hat{D} = \frac{n}{2wL\hat{P}_a} \cdot \frac{1}{0.5} = \frac{n}{wL\hat{P}_a}$$

- In point transect sampling if one quarter of the circle was surveyed: $c = 0.25$

$$\hat{D} = \frac{n}{k\pi w^2 \hat{P}_a} \cdot \frac{1}{0.25}$$

- 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)

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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

$$\hat{D} = \frac{n}{2wL\hat{P}_a\hat{c}} \qquad cv(\hat{D}) = \sqrt{\{cv(n)\}^2 + \{cv(\hat{P}_a\}^2 + \{cv(\hat{c})\}^2}$$

For point transect sampling

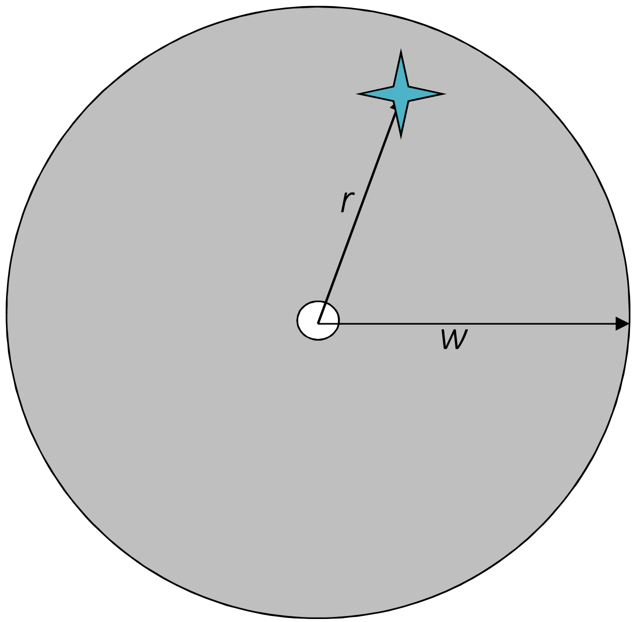
$$\hat{D} = \frac{n}{k\pi w^2\hat{P}_a c} \qquad cv(\hat{D}) = \sqrt{\{cv(n)\}^2 + \{cv(\hat{P}_a\}^2 + \{cv(\hat{c})\}^2}$$

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

$$\hat{D}_{cues} = \frac{n}{\pi w^2 \hat{P}_a}$$ cues per unit area

And if you searched for time $T = \sum_{i=1}^{k} time\ spent\ at\ point\ t$

$$\hat{D}_{cues/T} = \frac{n}{\pi w^2 \hat{P}_a T}$$ cues per unit area, per unit time

Note: the standard point transect estimator is

$$\hat{D} = \frac{n}{k\pi w^2 \hat{P}_a}$$

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Cue Counting: animal density

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

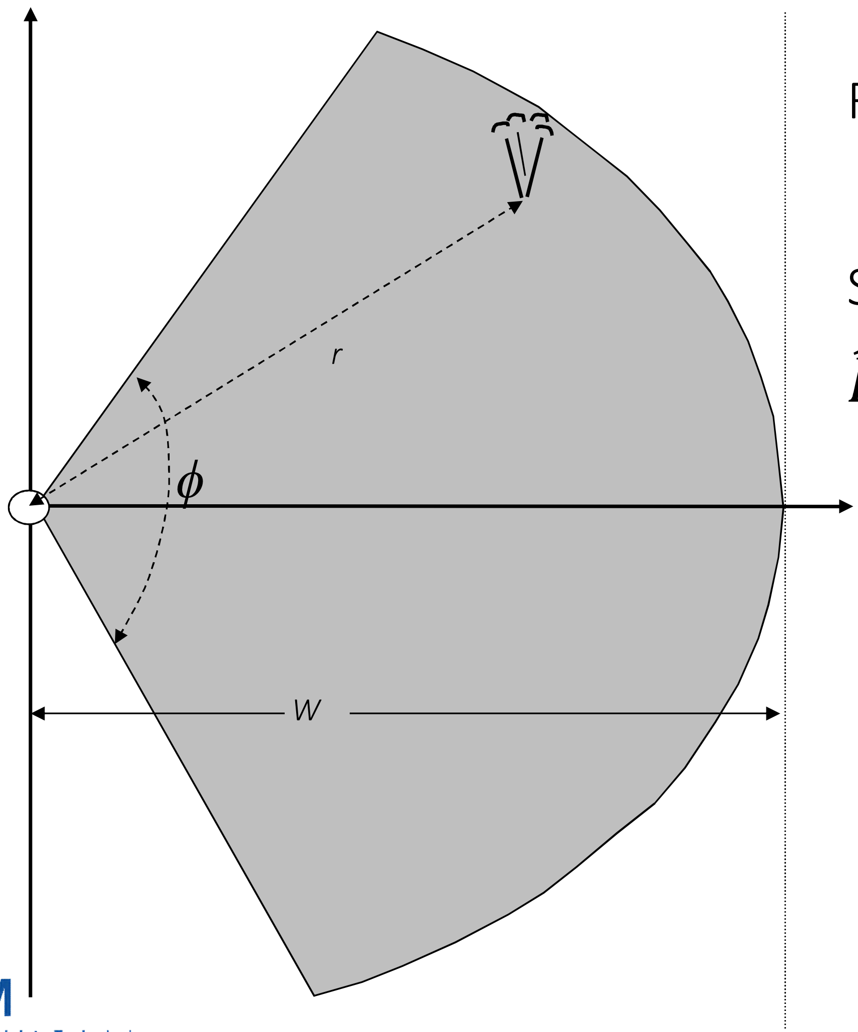
$$\widehat{D}_{animals} = \frac{\widehat{D}_{cues/T}}{\widehat{\eta}}$$

where $\hat{\eta}$ is the estimated number of cues per animal, per unit time

New component of variance

$$cv^2(\widehat{D}_{animals}) \approx cv^2(\widehat{D}_{cues/T}) + cv^2(\hat{\eta})$$

Cue Counting: line transects



Fraction of circle searched: $\frac{\phi}{2\pi}$ (ϕ in radians)

So that:

$$\widehat{D}_{cues} = \left(\frac{n}{\pi w^2 \hat{P}_a}\right) \div \left(\frac{\phi}{2\pi}\right) = \frac{2n}{w^2 \hat{P}_a \phi}$$

cues per unit area.

And if you searched for time *T*

$$\widehat{D}_{cues/T} = \frac{2n}{w^2 \hat{P}_a \phi T}$$

cues per unit area, per unit time.

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Setting up a cue counting analysis

Note, reserved name

Set up the cue rate information

```
cuedata <- list(creation = data.frame(rate = 25, SE = 5, df=1))
```

$\hat{\eta}$

This creates an object called `cuedata` – it looks like this

```
$creation
  rate SE df
1  25   5  1
```

Survey data object requires (at least) the following columns:

- distance
- Effort (this is the search time at each transect, T)

A cue counting analysis

Use the `ds` function to estimate detection probability of cues (with half normal key function)

```
df.hn <- ds(data=CueCountingExample, key="hn", transect="point")
```

Use the `dht2` function to convert density of cues to density of animals

```
dht2(model=df.hn, flatfile=CueCountingExample,
     strat_formula=~1, multipliers=cuedata,
     sample_fraction=0.5)
```

This is the cue rate information created previously

Also specify sampling fraction, $\frac{\phi}{2\pi}$
here a sampling fraction of 0.5 has been applied

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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,

$$\widehat{D}_d = \frac{n}{2wL\hat{P}_a} \qquad \text{= dung density}$$

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

$$\hat{G} = \frac{\widehat{D}_d}{\hat{d}} \qquad \text{= dung production per day per unit area}$$

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

$$\widehat{D} = \frac{\hat{G}}{\hat{r}} = \frac{\widehat{D}_d}{\hat{d}\hat{r}} \qquad \text{= animal density}$$

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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

Two levels of multipliers in Distance

Create a data object containing the rate, standard error (and degrees of freedom) of the multipliers, E.g.

```
mult <- list(creation = data.frame(rate = 25, SE = 5),
             decay    = data.frame(rate = 163, SE = 13))
```

Note, reserved names

The object `mult` looks like this:

```
$creation
  rate SE
1   25  5
$decay
  rate SE
1  163 13
```

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Use two levels of multipliers in analysis

Use the `ds` function to estimate detection probability of dung pellets, $\widehat{D}_d$

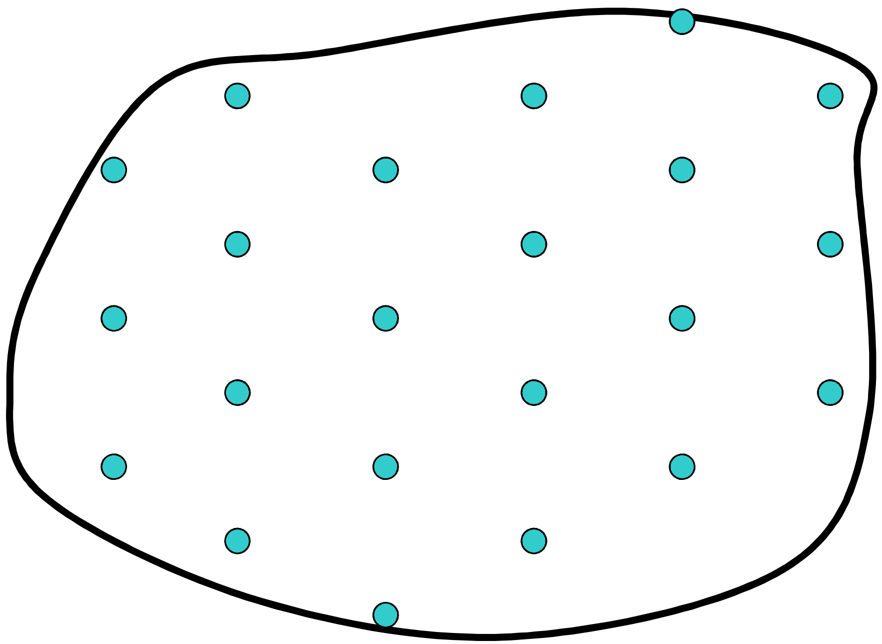
Use the `dht2` function to convert density of dung to density of animals, $\widehat{D}$

```
dht2(model, flatfile, strat_formula, multipliers=mult)
```

Two levels of multipliers

Trapping and lure point transects

These use just one trap (or lure) per sampling plot:

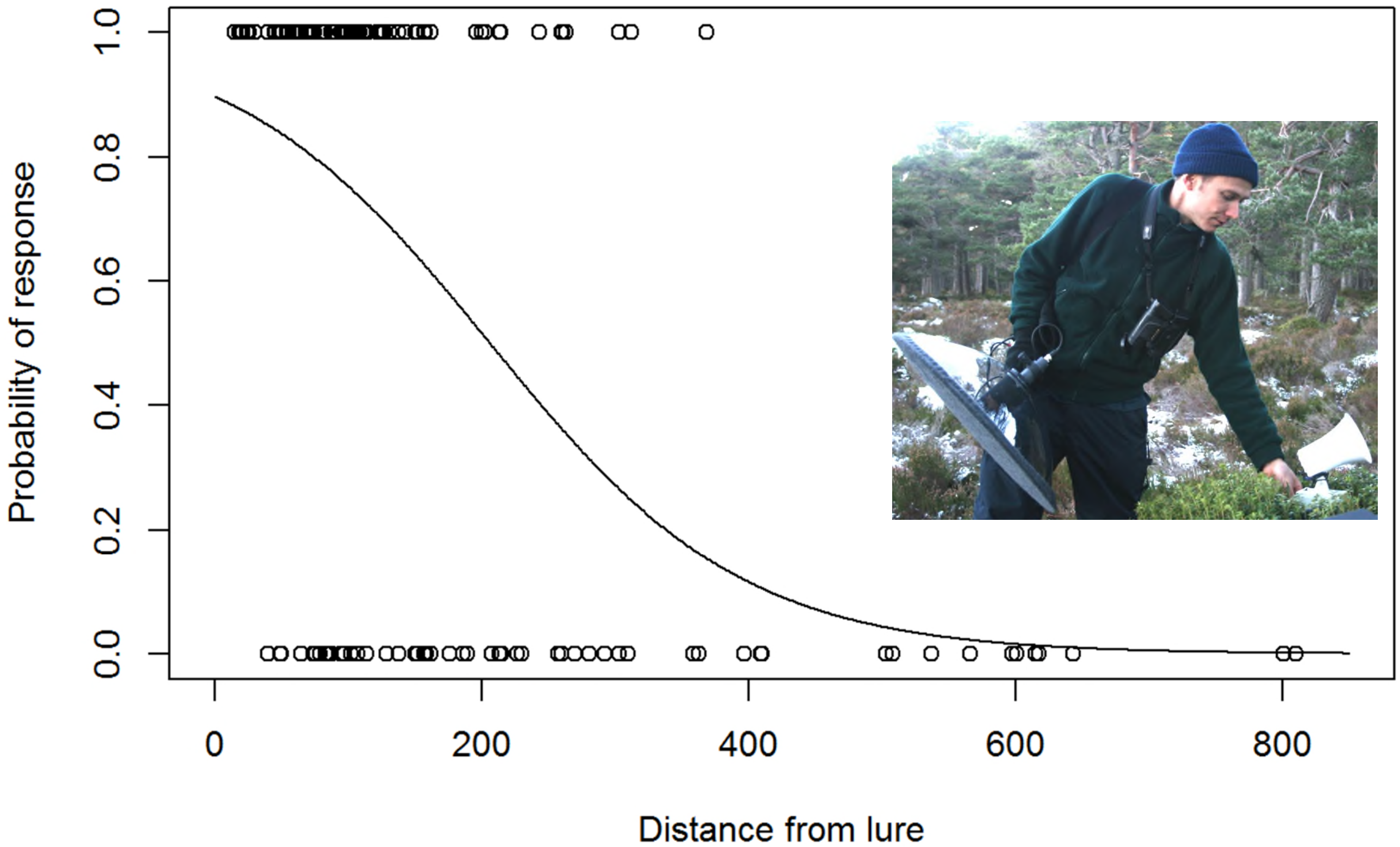


Estimating the detection function

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[a]



[a]Buckland, S.T., Summers, R.W., Borchers, D.L. and Thomas, L. 2006. Point transect sampling with traps or lures. Journal of Applied Ecology **43**, 377-384

- Section 9.2.1 of Buckland et al. (2015) and https://synergy.st-andrews.ac.uk/ds-manda/#crossbill-lure-case-study

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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

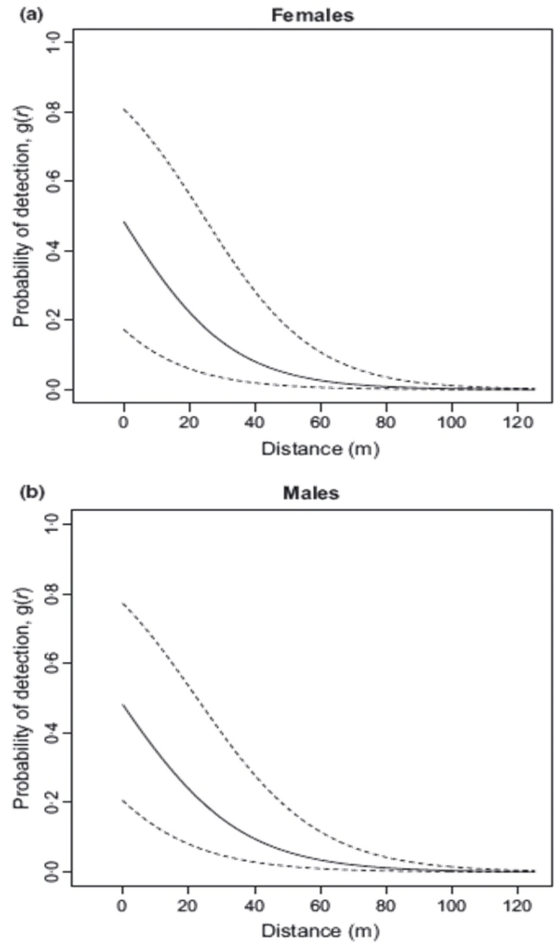


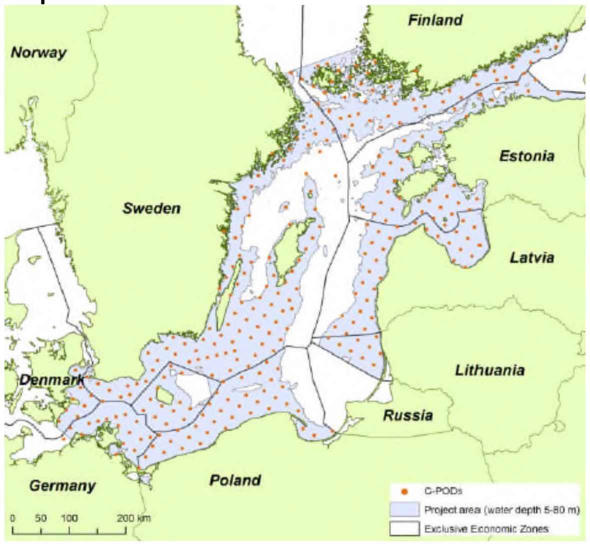
Fig. 2. Mean detection function plot (solid line) corresponding to the best model for the female (Panel A, b0 = −0·065, b1 = −0·059) and male (Panel B, b0 = −0·073, b1 = −0·054) trial data that had the lowest Akaike's Information Criterion (AIC) value of all the models fitted (where a year-effect was not included in the model). Dashed lines indicate the 2·5th and 97·5th percentiles (as calculated based on 10,000 samples of the estimated random effects distribution).

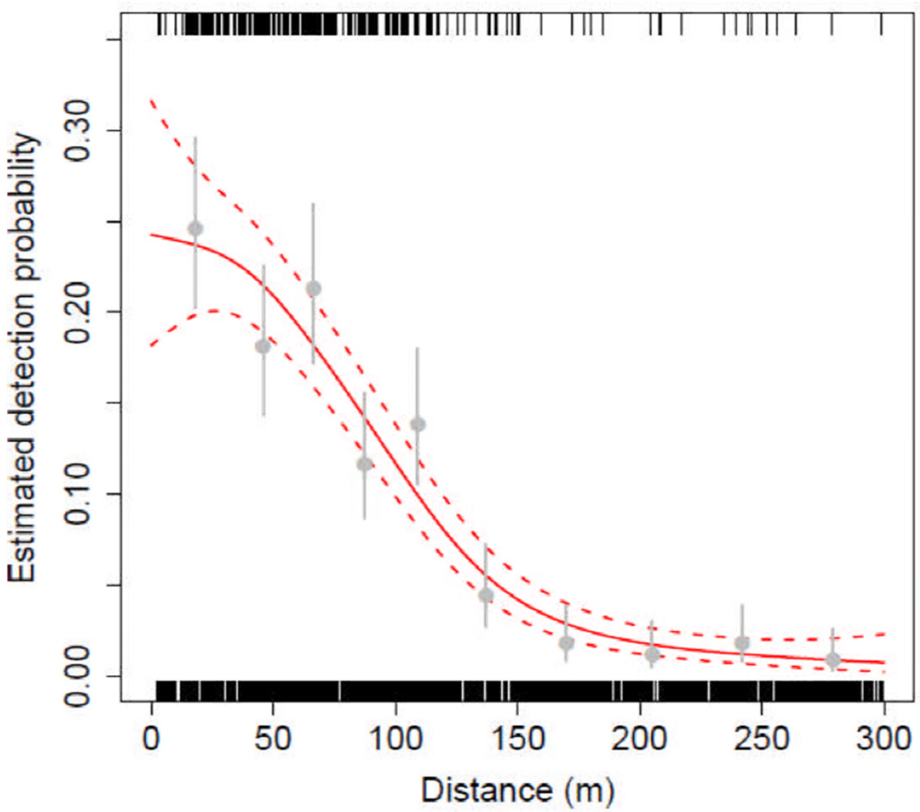
Potts, J.M., S.T. Buckland, L. Thomas and A. Savage. 2012. Estimating abundance of cryptic but trappable animals using trapping point transects: a case study for Key Largo woodrats. Meth. Ecol. and Evol. 3:695-703.

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





Example detection function
(data from Line Kyhn)

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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