Distance sampling online workshop

Analysis in R: Covariates in the detection function

CREEM, Univ of St Andrews – October 2018

1 Using survey data

In this practical, we use some real data to fit different detection function models and estimate density and abundance. The data were collected during line transect surveys of duck nests in Monte Vista National Wildlife Refuge, Colorado, USA in 1967 and 1968. Twenty transects, each 25.75km in length were walked 5 times over the two years. Total transect length of 128.75km (25.75 × 5) and a distance out to 2.4m was searched. Consult Anderson and Pospahala (1970) for a description of the survey. Distances of detected nests have been provided in a 'csv' text file in a basic format required by 'Distance'. The columns in the the file are:

The Monte Vista National Wildlife Refuge.

- Study.Area - name of the study region (Monte Vista NWR)
- Region.Label - identifier of regions or strata (in this case there is only one region and it is set to 'Default')
- Area - size of the stratum
- Sample.Label - line transect identifier
- Effort - length of each transect
- distance - perpendicular distances (m).

The distances allow different key functions/adjustments to be fitted in the detection function model and, by including the transect lengths and area of the region, density and abundance can be estimated.

1.1 Objectives of the practical

1. Import a text file
2. Understand the structure of a data frame
3. Fit different key functions/adjustments in the detection function model
4. Explore the model object i.e. `ddf` and `dht`
5. Create a data frame
6. Estimate density and abundance using `ds`.

1.2 Importing the data

To let R (R Core Team, 2018) know where to look for files (and also where to save the R workspace and '.Rmd' files) we can set the 'working directory'; from the menu along the top of the `RStudio` window click on 'Session > Set Working Directory > Choose Directory' and select your chosen directory, for example 'C:/workshop'.

Load the data into `R` with the following command:

```r
nests <- read.csv(file = "datasets/ducks-area-effort.csv",
    header = TRUE)
```

This command is made up of several components:

- read.csv is a function to read data files of type 'csv' (comma-separated values),
- the function has two arguments specified; file specifies the name of the data file and header=TRUE specifies that the first row of the data file contains the names of the data columns.
- the <- symbol has assigned the data set to an object called nests. Note that there is now an object called nests listed on the 'Environment' tab.

To check that the data file has been read into R correctly, use the head and tail 'functions' to look at the top and bottom rows of the data, respectively. To look at the first few rows of nests type the following command.

```
head(nests, n = 2)
```

```
##   Region.Label  Area Sample.Label Effort
## 1      Default 40.47            1 128.75
## 2      Default 40.47            1 128.75
##   distance
## 1     0.06
## 2     0.07
```

The head function as used above displays the first 6 records of the named object. The argument n controls the number of rows to display. To display the *last* 2 records in the data, type the command:

```
tail(nests, n = 2)
```

```
##     Region.Label  Area Sample.Label Effort
## 533      Default 40.47           20 128.75
## 534      Default 40.47           20 128.75
##     distance
## 533     2.38
## 534     2.13
```

The object nests is a dataframe object made up of rows and columns. Use the function dim to find out the dimensions of the data set (i.e. the total number of rows and columns):

```
dim(nests)
```

```
## [1] 534   5
```

Another way to look at a data frame is to move to the 'Environment tab' in R-Studio and click on the rectangle (with the grid); this opens a new tab showing the data.

1.3 Summarising the perpendicular distances

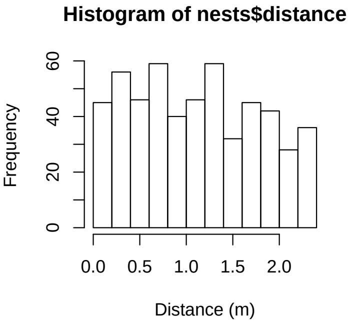
To access an individual column within a data frame use the $ symbol, for example to summarise the distances:

```
summary(nests$distance)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu. 
##   0.010   0.540   1.080   1.117   1.670 
##    Max. 
##   2.400
```

Similarly to plot the histogram of distances, the command is:

```
hist(nests$distance, xlab = "Distance (m)")
```



1.4 Fitting different models

To use the ds function, load the Distance package (Miller, 2017).

The function ds requires a data frame to have a column called distance, we specify the name of the data frame as follows:

```
nest.model1 <- ds(nests, key = "hn", adjustment = NULL,
    convert.units = 0.001)
```

```
## Fitting half-normal key function

## Key only model: not constraining for monotonicity.

## AIC= 928.134
```

The convert.units argument ensures that the correct units are specified - in this example, distances are in metres, lengths in km and the area in km^2. Think of this argument as a multiplier used to transform units of transect effort into units of perpendicular distance (e.g., 5km × 0.001 = 5000m).

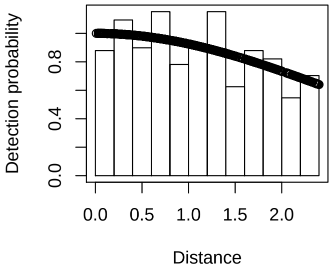
This call to ds fits a half-normal key function with no adjustment terms. Summarise the fitted model:

```
summary(nest.model1$ddf)
```

```
## 
## Summary for ds object
## Number of observations :  534
## Distance range         :  0  -  2.4
## AIC                    :  928.1338
## 
## Detection function:
##  Half-normal key function
## 
## Detection function parameters
## Scale coefficient(s):
##              estimate        se
## (Intercept) 0.9328967 0.1703933
## 
##                        Estimate          SE
## Average p             0.8693482  0.03902053
## N in covered region 614.2533225 29.19683067
##                             CV
## Average p           0.04488481
## N in covered region 0.04753223
```

Plot the detection function with the histogram having 12 bins:

```
plot(nest.model1, nc = 12)
```



To fit different detection functions, change the `key` and `adjustment` arguments. For example to fit a half-normal key function with cosine adjustment terms, use the command:

```
nest.model2 <- ds(nests, key = "hn", adjustment = "cos")
```

By default, AIC selection will be used to fit adjustment terms of up to order 5.

Question: Have any adjustment terms been selected?

```
##
## Summary for ds object
## Number of observations :  534
## Distance range         :  0  -  2.4
## AIC                    :  928.1338
##
## Detection function:
##  Half-normal key function
##
## Detection function parameters
## Scale coefficient(s):
##              estimate        se
## (Intercept) 0.9328967 0.1703933
##
##                        Estimate          SE
## Average p             0.8693482  0.03902053
## N in covered region 614.2533225 29.19683067
##                             CV
## Average p           0.04488481
## N in covered region 0.04753223
```

Answer: No adjustment terms have been included in the preferred model, because there is only a single row in the list of `Detection function parameters`.

To fit a hazard rate key function with Hermite polynomial adjustment terms, then use the command:

```
nest.model3 <- ds(nests, key = "hr", adjustment = "herm")
```

```
summary(nest.model3$ddf)
```

```
##
## Summary for ds object
## Number of observations :  534
## Distance range         :  0  -  2.4
## AIC                     :  929.7934
##
## Detection function:
##  Hazard-rate key function
##
## Detection function parameters
## Scale coefficient(s):
##              estimate        se
## (Intercept) 0.9190194 0.2081042
##
## Shape coefficient(s):
##              estimate        se
## (Intercept) 0.2899026 0.6393387
##
##                        Estimate          SE
## Average p             0.8890698  0.04958136
## N in covered region 600.6277685 34.59620441
##                               CV
## Average p           0.05576768
## N in covered region 0.05760007
```

Use the help command to find out what other key functions and adjustment terms are available.

Question: Is there much difference in the probability of detecting a nest given it is within the maximum detection distance between the three models fitted to the duck nest data?

Answer: No, there is barely any difference between the estimated probability of detection. For the first two models, P_a= 0.869 and for the hazard rate model, P_a = 0.889.

1.5 The ds object

The objects created with ds (e.g. nest.model1) are made up of two parts. We can list them using the names function as below:

```
names(nest.model1)
```

```
## [1] "ddf" "dht"
```

The detection function information is in the ddf part and the density and abundance estimates are stored in the dht part. To access each part, then the $ can be used (as with columns in a data frame). For example to see what information is stored in the ddf part, we can use the names function again:

```
names(nest.model1$ddf)
```

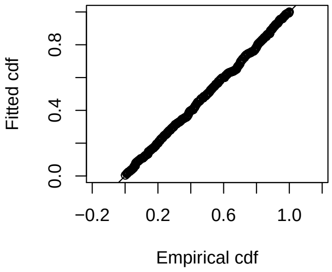
```
##  [1] "call"          "data"
##  [3] "model"         "meta.data"
##  [5] "control"       "method"
##  [7] "ds"            "par"
##  [9] "lnl"           "hessian"
## [11] "dsmodel"       "criterion"
## [13] "fitted"        "Nhat"
## [15] "name.message"
```

1.6 Goodness of fit

Before making inference from the detection function we have fitted, we should evaluate the model. First assessment is goodness of fit, accomplished using the function `gof_ds`:

```r
gof_ds(nest.model1)
```

```
##
## Goodness of fit results for ddf object
##
## Distance sampling Cramer-von Mises test (unweighted)
## Test statistic = 0.0353634 p-value = 0.955416
```



Calling the function `gof_ds` with the default arguments and exact distance data, a *q-q* plot is produced along with the unweighted Cramer-von Mises goodness of fit test.

Question: Interpret the q-q plot and CvM test results for the duck nest data.

Answer: The half-normal detection function fits the duck nest data very well. All points of the q-q plot fall on the diagonal line and the p-value associated with the CvM test statisic is very large (>> 0.05) indicating a good fit of the model to the data.

1.7 Estimating density and abundance

So far, we have concentrated on the detection function but, with more information such as transect lengths and the area of the region, we can estimate density and abundance. The second component of a `ds` object, contains this additional information. This information can be viewed with:

```r
str(nest.model1$dht$individuals, max = 1)
```

```
## List of 8
##  $ bysample      :'data.frame':  20 obs. of  9 variables:
##  $ summary       :'data.frame':  1 obs. of  9 variables:
##  $ N             :'data.frame':  1 obs. of  7 variables:
##  $ D             :'data.frame':  1 obs. of  7 variables:
##  $ average.p     : num 0.869
##  $ cormat        : num [1, 1] 1
##  $ vc            :List of 3
##  $ Nhat.by.sample:'data.frame':  20 obs. of  9 variables:
```

This `dht` object contains considerable information. However, focus upon three tables generated by the `summary()` function: summary statistics, abundance and density. Dig more deeply into the content of these tables.

Summary information

This provides information about the survey:

- size of study area,
- area covered by sampling effort
- length of all transects
- number of detections
- number of transects
- encounter rate (ER) number of detections per unit transect length and its associated variability

```r
nest.model1$dht$individuals$summary
```

Region	Area	CoveredArea	Effort	n	k	ER	se.ER	cv.ER
Default	40.47	12.36	2575	534	20	0.2073786	0.0079708	0.0384358

Abundance estimates
Estimated density multiplied by the size of the study area.

```r
nest.model1$dht$individuals$N
```

Label	Estimate	se	cv	lcl	ucl	df
Total	2011.232	118.8493	0.05909276	1788.907	2261.188	99.55689

Density estimates
Density estimated using the formula

$$\hat{D} = \frac{n}{a\hat{P}_a}$$

where n (number of nests)=534, a (covered area)=12.36 and $\hat{P}_a$ (probability of detection)=0.8693

```r
nest.model1$dht$individuals$D
```

Label	Estimate	se	cv	lcl	ucl	df
Total	49.69687	2.936725	0.05909276	44.2033	55.87318	99.55689

References

Anderson, D. R. and R. S. Pospahala. 1970. Correction of bias in belt transect studies of immotile objects. The Journal of Wildlife Management, **34**:141–146. URL http://www.jstor.org/stable/3799501.

Buckland, S. T., E. A. Rexstad, T. A. Marques, and C. S. Oedekoven. 2015. Distance Sampling: Methods and Applications. Springer. URL https://www.springer.com/gb/book/9783319192185.

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