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Title Estimation of Caribou Abundance Based on Radio Telemetry Data

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Description Estimation of population size of migratory caribou herds based on large scale aggregations monitored by radio telemetry. It implements the methodology found in the article by Rivest et al. (1998) about caribou abundance estimation. It also includes a function based on the Lincoln-Petersen Index as applied to radio telemetry data by White and Garrott (1990).

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caribou-package *Estimation of Caribou Abundance Based on Radio Telemetry Data*

Description

Estimation of population size of migratory caribou herds based on large scale aggregations monitored by radio telemetry. It implements the methodology found in the article by Rivest et al. (1998) about caribou abundance estimation. It also includes a function based on the Lincoln-Petersen Index as applied to radio telemetry data by White and Garrott (1990).

Details

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CONTEXT:

Migratory caribou forms aggregations at different seasons in their yearly life cycle, namely in the spring and fall migration, and also in summer following insect harassment. Postcalving aggregations that happened in July under warm and calm conditions are the most impressive and they are well known for long time by caribou biologists and by indigenous people. The Inuit that lived also in the tundra with caribou described this spectacular animal behavior as the moving mountains.

Rivest et al. (1998) proposed a new method for estimating caribou herd size based on photo-census of large scale aggregations. This method can also be used in other time of the year for caribou or for other wildlife species that live in open habitat like tundra. Here we provided some dataset examples for postcalving census done in Quebec and elsewhere in North America.

If you are using this tool to estimate wildlife abundance, please let us know and quote this paper: Rivest, L.-P., Couturier, S. and Crepeau, H. (1998). Statistical Methods for estimating caribou abundance using postcalving aggregations detected by radio telemetry. *Biometrics*, **54**(3), 865-876.

Author(s)

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References

Rivest, L.-P., Couturier, S. and Crepeau, H. (1998). Statistical Methods for estimating caribou abundance using postcalving aggregations detected by radio telemetry. *Biometrics*, **54**(3), 865-876.

White, G.C. and Garrott, R.A. (1990). *Analysis of wildlife radio-tracking data*. San Diego: Academic Press.

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abundance *Post-calving method for caribou abundance estimation*

Description

The function abundance applies the methodology found in Rivest et al. (1998) for estimating caribou abundance using postcalving aggregations detected by radio telemetry.

Usage

```
abundance(mat, n, model = c("H", "I", "T"), B, maxT.hat)

## S3 method for class 'abundance'
print(x,...)
```

Arguments

mat	A matrix containing in the first column the number of radio-collared animals in the detected (photographed) groups and in the second column the corresponding size of the detected groups.
n	A numeric: the total number of active collars during the census.
model	A character string indicating the model to determine the probability that a group with collared animals is detected p_i. It can be either "H" = homogeneity model, "I" = independence model or "T" = threshold model (see **Details**). The default is "H".
B	A numeric: a bound for the threshold model.
maxT.hat	A numeric: an upper bound used in the numerical computation of T.hat, the estimator for the total number of animals in a herd (used by the optimize function). Useful when a warning is generated about T.hat being equal to maxT.hat. The default is n*max(mat[,2]).
x	An object, produced by the abundance function, to print.
...	Further arguments to be passed to methods (see print.default).

Details

DETECTION MODELS

- homogeneity model (`model="H"`):

$$p_i = r \text{ if } X_i \geq 1$$

- independence model (`model="I"`):

$$p_i = 1 - (r^{X_i})$$

- threshold model (`model="T"`):

$$p_i = \begin{cases} 1 & \text{if } X_i \geq \texttt{B} \\ r & \text{if } 1 \leq X_i < \texttt{B} \end{cases}$$

where p_i is the probability that a group with collared animals is detected, X_i is the number of radio-collared in the detected (photographed) groups and r is a parameter related to the probability of detection. For the threshold model, `B` is a bound given as a function's argument.

Value

`mp`	The number of detected groups having radio-collared animals.
`xt`	The total number of radio-collared animals found in the detected groups.
`gnt`	The total number of animals counted in the detected groups.
`rr`	The estimated parameter related to the probability of detection.
`se_rr`	The estimated standard error of `rr`.
`mat_pi`	A matrix containing a sorted copy of the input matrix `mat` in the first two columns, the detection probabilities p_i in the third column and the probabilities that the group has at least one collared animal π_i in the last column.
`T.hat`	The estimator for the total number of animals in a herd.
`se_T.hat`	The estimated standard error of `T.hat`.
`loglikelihood`	The maximum value of the loglikelihood function for the detected model.
`randomness_test`	A vector with the statistic and the p-value of a score test for the randomness assumption available only for the homogeneity, independence and threshold model with B=2 or 3.
`call`	The function call (object of class "call").

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References

Rivest, L.-P., Couturier, S. and Crepeau, H. (1998). Statistical Methods for estimating caribou abundance using postcalving aggregations detected by radio telemetry. *Biometrics*, **54**(3), 865-876.

See Also

petersen

Examples

```
data(GRH93)
abundance(GRH93, n=92) # default model="H"
abundance(GRH93, n=92, model="H")
abundance(GRH93, n=92, model="I")
abundance(GRH93, n=92, model="T", B=2)
abundance(GRH93, n=92, model="T", B=4)
abundance(GRH93, n=92, model="T", B=6)
```

BEH00 *Bluenose-East Caribou Herd 2000 Data*

Description

Population size of the Bluenose-East caribou herd (Northwest Territories, Canada) from a postcalving survey in June-July 2000.

Usage

```
data(BEH00)
```

Format

16 by 2 numeric matrix, with the following columns:

`xi` number of radio-collared animals in the detected (photographed) groups

`gni` size of the detected groups

Details

During this survey, 33 collars were active (Patterson et al. also made calculation considering that 30 collars were active because 3 caribou were never located after collaring).
23 collars (70%) were photographed among the 16 detected groups.

Note

This data set excludes the six groups without radio-collared animal from Table 1 of Patterson et al. (2004) since they cannot be included in the estimates of the total population size.

For the last three groups, the size `gni` has been modified according to what Patterson et al. (2004) did (38% of what appears in Table 1).

Source

Patterson, B. R., Olsen, B. T. and Joly, D. O. (2004). Population estimate for the Bluenose-East caribou herd using post-calving photography. *Arctic*, **57**, 47-58.

Examples

```
petersen(BEH00, M=33)
abundance(BEH00, n=33, model="H")
```

GRH01 *George River Herd 2001 Data*

Description

Population size of the George River (Riviere George) herd (Quebec) from a postcalving survey in July 2001.

Usage

```
data(GRH01)
```

Format

27 by 2 numeric matrix, with the following columns:

`xi` number of radio-collared animals in the detected (photographed) groups

`gni` size of the detected groups

Details

During this survey, 109 collars were active.
56 collars (57%) were photographed among the 27 detected groups.

Source

Couturier, S., Jean, D., Otto, R. and Rivard, S. (2004). *Demography of the migratory tundra caribou (Rangifer tarandus) of the Nord-du-Quebec region and Labrador*. Min. Ressources naturelles, Faune et Parcs, Quebec. 68 p. ISBN: 2-550-43725-X

Examples

```
petersen(GRH01, M=109)
abundance(GRH01, n=109, model="H")
abundance(GRH01, n=109, model="I")
abundance(GRH01, n=109, model="T", B=2)
abundance(GRH01, n=109, model="T", B=4)
abundance(GRH01, n=109, model="T", B=6)
```

GRH10 *George River Herd 2010 Data*

Description

Population size of the George River (Riviere George) herd (Quebec) from a postcalving survey in July 2010.

Usage

```
data(GRH10)
```

Format

13 by 2 numeric matrix, with the following columns:

`xi` number of radio-collared animals in the detected (photographed) groups

`gni` size of the detected groups

Details

During this survey, 71 collars were active.
43 collars (61%) were photographed among the 13 detected groups.

Source

Couturier, S., unpubl. data

Examples

```
petersen(GRH10, M=71)
petersen(GRH10, M=71, S=1000)
abundance(GRH10, n=71, model="H")
abundance(GRH10, n=71, model="I")
abundance(GRH10, n=71, model="T", B=2)
abundance(GRH10, n=71, model="T", B=4)
abundance(GRH10, n=71, model="T", B=6)
```

GRH93 *George River Herd 1993 Data*

Description

Population size of the George River (Riviere George) herd (Quebec and Labrador) from a postcalving survey in July 1993.

Usage

```
data(GRH93)
```

Format

28 by 2 numeric matrix, with the following columns:

`xi` number of radio-collared animals in the detected (photographed) groups

`gni` size of the detected groups

Details

During this survey, 92 collars were active.
73 collars (79%) were photographed among the 28 detected groups.

Source

Rivest, L.-P., Couturier, S. and Crepeau, H. (1998). Statistical Methods for estimating caribou abundance using postcalving aggregations detected by radio telemetry. *Biometrics*, **54**(3), 865-876.

Examples

```
petersen(GRH93, M=92)
petersen(GRH93, M=92, S=4000)
abundance(GRH93, n=92, model="H")
abundance(GRH93, n=92, model="I")
abundance(GRH93, n=92, model="T", B=2)
abundance(GRH93, n=92, model="T", B=4)
abundance(GRH93, n=92, model="T", B=6)
```

LRH01 *Leaf River Herd 2001 Data*

Description

Population size of the Leaf River (Riviere aux Feuilles) herd (Quebec) from a postcalving survey in July 2001.

Usage

```
data(LRH01)
```

Format

17 by 2 numeric matrix, with the following columns:

`xi` number of radio-collared animals in the detected (photographed) groups

`gni` size of the detected groups

Details

During this survey, 120 collars were active.
23 collars (19%) were photographed among the 17 detected groups.

Note

The small sample size of this census was caused by technical and weather related problems in July 2001. This provided an opportunity to see the behaviour of the different models under low sampling regime.

Source

Couturier, S., Jean, D., Otto, R. and Rivard, S. (2004). *Demography of the migratory tundra caribou (Rangifer tarandus) of the Nord-du-Quebec region and Labrador*. Min. Ressources naturelles, Faune et Parcs, Quebec. 68 p. ISBN: 2-550-43725-X

Examples

```
petersen(LRH01, M=120)
abundance(LRH01, n=120, model="H")
abundance(LRH01, n=120, model="I")
abundance(LRH01, n=120, model="T", B=2)
# The threshold model with B >= 3 is equivalent
# to the homogeneity model for this data set
# because max(LRH01$xi)=2
```

petersen *Lincoln-Petersen estimator for caribou abundance*

Description

The function petersen estimates the total population size based on the Lincoln-Petersen Index as applied to radio telemetry data by White and Garrott (1990). It uses the Lincoln-Petersen estimator with Chapman's (1951) bias correction and the bias corrected standard error estimator of Seber (1970) and Wittes (1972).

Usage

```
petersen(mat, M, S = 0)

## S3 method for class 'petersen'
print(x,...)
```

Arguments

mat	A matrix containing in the first column the number of radio-collared animals in the detected (photographed) groups and in the second column the corresponding size of the detected groups.
M	A numeric: the total number of active collars during the census (equivalent to the argument n in the function abundance).
S	A numeric: the minimum size that define well aggregated groups. Only observations from well aggregated groups (containing at least S animals) are taken into account in the computation. The default is zero (every observation is included in the computation).
x	An object, produced by the petersen function, to print.
...	Further arguments to be passed to methods (see print.default).

Value

G	The number of well aggregated groups.
R	The total number of radio-collared animal observed in the well aggregated groups.
C	The total number of animals observed in the well aggregated groups containing at least one radio-collared animal during the survey.
T.hat	The modified lincoln-Petersen estimator for the total number of animals in a herd.
se_T.hat	The estimated standard error of LP_T.hat.
mat_aggre	A matrix containing a subset of the input matrix mat: the data for the well aggregated groups only.
call	The function call (object of class "call").

Author(s)

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Sophie Baillargeon <Sophie.Baillargeon@mat.ulaval.ca>

References

Chapman, D. G. (1951). Some properties of the hypergeometric distribution with applications to zoological sample censuses. *University of California Publications in Statistics*, **1**(7), 131-160.

Seber, G.A.F. (1970). The effects of trap response on tag recapture estimates. *Biometrics*, **26**, 13-22.

White, G.C. and Garrott, R.A. (1990). *Analysis of wildlife radio-tracking data*. San Diego: Academic Press.

Wittes, J.T. (1972). On the bias and estimated variance of Chapman's two-sample capture-recapture population estimate. *Biometrics*, **28**, 592-597.

See Also

abundance

Examples

```
data(GRH93)
petersen(GRH93, M=92) # default S=0
petersen(GRH93, M=92, S=4000)
```

WAH11 *Western Arctic Herd 2011 Data*

Description

Population size of the Western Arctic Herd (Alaska) from a postcalving survey in 2011.

Usage

```
data(WAH11)
```

Format

10 by 2 numeric matrix, with the following columns:

`xi` number of radio-collared animals in the detected (photographed) groups

`gni` size of the detected groups

Details

During this survey, 97 collars were active.
96 collars (99%) were photographed among the 10 detected groups.

Note

This data set provide the opportunity to test the models under very high sampling regime.

Source

Dau, J., unpubl. data

Examples

```
petersen(WAH11, M=97)
abundance(WAH11, n=97, model="H")
abundance(WAH11, n=97, model="I")
abundance(WAH11, n=97, model="T", B=2)
```

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