Package 'incR'

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Type Package

Title Analysis of Incubation Data

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Description Suite of functions to study animal incubation.
At the core of incR
lies an algorithm that allows for the scoring of
incubation behaviour. Additionally, several functions
extract biologically relevant metrics of incubation such as off-bout number
and off-bout duration - for a review of avian incubation studies,
see Nests, Eggs, and Incubation: New ideas about avian reproduction (2015)
edited by D. Charles Deem-
ing and S. James Reynolds <doi:10.1093/acprof:oso/9780198718666.001.0001>.

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Depends R (>= 3.4.0), base, stats

Imports ggplot2, suncalc, lubridate, utils

Suggests codetools, knitr, rmarkdown

VignetteBuilder knitr

LazyData true

Encoding UTF-8

RoxygenNote 7.2.1

NeedsCompilation no

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R topics documented:

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incR   *incR: Analysis of animal incubation*

Description

This packages is formed by a suite of R functions that help the user to get useful biological information from raw time-series data of incubation temperatures. It is thought to be of interest for the study of uni-parental or intermittent incubating species.

Suggested workflow

Check the package vignettes to find a suggested workflow and calibrate the main function in incR.

incR functions

The current version of incR contains the following functions and three example data sets: incRprep, incRenv, incRscan, incRact, incRatt incRbouts and incRt, along with three example data sets.

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incRact   *Calculation of daily first incubation off-bout and last incubation on-bout*

Description

Using a vector of incubation scores, *incRact* calculates onset of activity (first off-bout in the morning), and end of daily activity (last on-bout in the evening) per day. A column for dates, named "date" is needed in the data argument.

Usage

```
incRact(data, time_column, vector.incubation)
```

Arguments

data   data frame containing a numeric vector of 1's and 0's (incubation scores), where "1" means "incubating individual inside nest" and "0" means "incubating individual outside the nests". This vector, under the name of incR_score is provided by incRscan in the first object (*incRscan_data*) of the returned list. A column named "date" is needed to refer to daily calculations.

time_column   (character class) name of the column containing times.

vector.incubation

                (character class) name of the vector containing incubation scores. incRscan produces this vector named "incR_score".

Value

a data frame containing fist off-bout and last on-bout per day in *data*.

Author(s)

Pablo Capilla-Lasheras

See Also

incRprep incRscan

Examples

```
#' # loading example data
data(incR_procdata)
incRact (data=incR_procdata,
            time_column="time",
            vector.incubation="incR_score")
```

---

incRatt   *Calculation of the percentage of daily time spent in nest*

Description

This function calculates percentage of day time spent inside nest based on the "inc.vector" variable produced by incRscan (or any other method). Current version do not discriminate day and night times.

Usage

```
incRatt(data, vector.incubation)
```

Arguments

data   data frame containing a time-series vector of 1's and 0's, where "1" means "in-
                        cubating individual inside nest" and "0" means "incubating individual outside
                        nest". This vector, under the name of "inc.vector" is provided by incRscan in
                        the first object of the returned list. A column named "date" is needed to refer to
                        daily calculations.

vector.incubation
                        name of the column (vector class) storing the information about the presence/absence
                        of the incubating individual in the nest.

Details

The 'date' column must have a 'year-month-day' format for this function to run correctly.

Value

Daily percentage of time in nest, returned in a data frame with one day per raw.

See Also

incRprep incRscan incRact

Examples

```
#' # loading example data
data(incR_procdata)
incRatt (data=incR_procdata,
                vector.incubation="incR_score")
```

---

incRbouts | *Calculation of the number of daily on- and off-bouts*

Description

Calculation of number and duration of incubation on- and off-bouts.

Usage

```
incRbouts(data, vector.incubation, dec_time, temp, sampling.rate)
```

Arguments

data
: data frame containing a time-series vector of 1's and 0's, where "1" means "incubating individual inside nest" and "0" means "incubating individual outside nest". This vector, under the name of "inc.vector", is provided by incRscan in the first object of the returned list. A column named "date" is needed to refer to daily calculations.

vector.incubation
: name of the column (vector class) storing the information about the presence/absence of the incubating individual in the nest.

dec_time
: (character class) name of the column with decimal time.

temp
: (character class) name of the column with incubation temperatures.

sampling.rate
: time difference between two consecutive recording points. Effectively, the rate at which data points were recorded (e.g. 1 data point per 50sec). The time units of the returned object will depend on the units of this argument.

Value

This function returns a list with two objects. The first object, named total_bouts, is a list of individual on- and off-bouts, giving information about their start time, duration, start nest temperature and final nest temperature. The second object, day_bouts, provides a summary of on- and off-bouts per day of observation. This second table shows number and mean duration of on- and off-bout per day. Mean times are shown in those time units you specify the argument *sampling.rate*.

Author(s)

Pablo Capilla-Lasheras

See Also

incRprep incRscan incRact incRatt

Examples

```
#' # loading example data
data(incR_procdata)
incRbouts (data=incR_procdata,
           vector.incubation="incR_score",
           dec_time="dec_time",
           temp="temperature",
           sampling.rate=240) # sampling rate in seconds.
```

---

incRenv   *Matching environmental and nest temperatures*

Description

This function takes a data frame with recordings of environmental temperature and another with
nest temperatures and merges both by time. The user can do this work manually, however, incRenv
is thought to automate data preparation (in combination with incRprep) to use incRscan after.
Code to update and improve this function provided by Natalie van Dis.

Usage

```
incRenv(
  data.nest,
  data.env,
  env.temperature.name,
  env.date.name,
  env.date.format,
  env.timezone
)
```

Arguments

data.nest   data frame containing nest temperature recordings. It must have two compulsory
                   columns 'date' and 'hour' displaying dates and the hour of each observation.
                   These two columns are provided if the user uses incRprep before.

data.env   data frame containing environmental temperatures to be merged with nest tem-
                   perature records. Please, provide date and time of each observation in one
                   unique column as requested for incRprep.

env.temperature.name
                   name of the column containing temperature recordings in the *data.env* data
                   frame.

env.date.name   name of the column containing date and time in the *data.env* data frame.

env.date.format
                   format of *env.date.name*. Similar to incRprep.

env.timezone   time zone of the environmental recordings. Similar to incRprep.

Details

This function is thought to be used after `incRprep` as it uses some of the additional variables created by `incRprep`.

Value

The original *data.nest* with an additional column for hour-averaged environmental temperature. This new variable is thought to serve as *env_temp* in `incRscan`.

Author(s)

Pablo Capilla-Lasheras

See Also

`incRprep incRscan`

Examples

```
data(incR_envdata)  # environmental data
head (incR_envdata)

data(incR_rawdata)  # loading nest data
head (incR_rawdata)

# the first step in to format the raw data using incRprep
new.data <- incRprep (data=incR_rawdata,
                      date.name= "DATE",
                      date.format= "%d/%m/%Y %H:%M",
                      timezone="GMT",
                      temperature.name="temperature")

# then use incRenv to merge environmental data
new.data2 <- incRenv (data.nest = new.data,
                      data.env = incR_envdata,
                      env.temperature.name = "env_temperature",
                      env.date.name = "DATE",
                      env.date.format = "%d/%m/%Y %H:%M",
                      env.timezone = "GMT")

head (new.data2, 3)
```

---

incRenv_old   *Matching environmental and nest temperatures - Old version*

Description

This function takes a data frame with recordings of environmental temperature and another with nest temperatures and merges both per unit of time. The user can do this work manually, however, incRenv is thought to automate data preparation (in combination with incRprep) to use incRscan after.

Usage

```
incRenv_old(
  data.nest,
  data.env,
  env.temperature.name,
  env.date.name,
  env.date.format,
  env.timezone
)
```

Arguments

data.nest	data frame containing nest temperature recordings. It must have two compulsory columns 'date' and 'hour' displaying dates and the hour of each observation. These two columns are provided if the user uses incRprep before.
data.env	data frame containing environmental temperatures to be merged with nest temperature records. Please, provide date and time of each observation in one unique column as requested for incRprep.
env.temperature.name	
	name of the column containing temperature recordings in the *data.env* data frame.
env.date.name	name of the column containing date and time in the *data.env* data frame.
env.date.format	
	format of *env.date.name*. Similar to incRprep.
env.timezone	time zone of the environmental recordings. Similar to incRprep.

Details

This function is thought to be used after incRprep as it uses some of the additional variables created by incRprep.

Value

The original *data.nest* with an additional column for hour-averaged environmental temperature. This new variable is thought to serve as *env_temp* in incRscan.

Author(s)

Pablo Capilla-Lasheras

See Also

incRprep incRscan

Examples

```
data(incR_envdata)  # environmental data
head (incR_envdata)

data(incR_rawdata)  # loading nest data
head (incR_rawdata)

# the first step in to format the raw data using incRprep
new.data <- incRprep (data=incR_rawdata,
                      date.name= "DATE",
                      date.format= "%d/%m/%Y %H:%M",
                      timezone="GMT",
                      temperature.name="temperature")

# then use incRenv to merge environmental data
new.data2 <- incRenv_old (data.nest = new.data,
                      data.env = incR_envdata,
                      env.temperature.name = "env_temperature",
                      env.date.name = "DATE",
                      env.date.format = "%d/%m/%Y %H:%M",
                      env.timezone = "GMT")

head (new.data2, 3)
```

---

incRplot   *Quick visualisation of incubation temperatures, on-bouts and off-bouts*

Description

After incRscan has been used, incRplot provides a quick visualisation of the incubation temperature trace with coloured on- and off-bouts. Environmental temperatures can also be added to the plot

Usage

```
incRplot(
  data,
  time.var,
  day.var,
  inc.temperature.var,
  env.temperature.var = NULL,
  vector.incubation
)
```

Arguments

`data`	data table with incubation temperature data
`time.var`	Character string. Name of the variable with time of the day for temperature data. Please, have time in decimal hours. If [incRprep](#) has been previously used, "dec_time" can be used.
`day.var`	Character string. Name of the variable with date for temperature observation. No specific format is needed. If [incRprep](#) has been previously used, "date" can be used.
`inc.temperature.var`	
	Character string. Name of the variable with incubation temperatures.
`env.temperature.var`	
	Character string. Name of the variable with environmental temperatures. If no value is provided, a plot with no environmental temperatures is produced.
`vector.incubation`	
	name of the binary variable storing information about the presence/absence of the incubating individual in the nest. If [incRscan](#) has been used, "incR_score" can be used.

Value

Plot of incubation temperature, on-bouts and off-bouts with (optional) environmental temperatures. The plot is generated using [ggplot2](#).The user can customised the appearance of the plot using tools within [ggplot2](#)(see example)

See Also

[incRscan](#)

Examples

```
# loading example data
data(incR_procdata)
my_plot <- incRplot(data = incR_procdata[complete.cases(incR_procdata$temperature),],
                    time.var = "dec_time",
                    day.var = "date",
                    inc.temperature.var = "temperature",
                    env.temperature.var = "env_temp",
                    vector.incubation = "incR_score")

# see your plot
my_plot

# add new labels (ggplot2 required)
my_plot + ggplot2::labs(x = "New X label", y = "New Y label")
```

---

incRprep	*Data preparation for incubation analysis in incR*

Description

Preparing incubation time series for further analysis. This function takes a data file containing a temporal series of temperature recordings and adds some the extra variables needed to use further functions embedded in the incR package. It simply accommodates a raw data frame, reformatting date and time columns automatically.

Usage

```
incRprep(data, date.name, date.format, timezone, temperature.name)
```

Arguments

data	raw data from incubation time series. It must contain a column with date and time information for each observation (e.g. "2017-05-01 21:01"). The function is written to handle date and time concatenated in one unique column (see example below).
date.name	name of the date and time column
date.format	format for date and time column. It must be a character object as specified in the function `strptime`. `incRprep` assumes that the date and time column contains date and time, If date and time are in different columns, please, concatenate them in one column before running the function.
timezone	time zone for time calculations. See `strptime`. documentation for more details.
temperature.name	
	name of the column storing temperature information.

Value

The original data frame with additional columns for:

1. index: a running number identifying every row in the data set.
2. time: in '
3. hour: in 'H' format.
4. minute: in 'M' format.
5. second: in 'S' format.
6. date: in 'Y-m-d' format.
7. dec_time: time in decimal hours (e.g. "22:30" becomes 22.5).
8. temp1: difference between the *i*th temperature value and the *i-1* one.

Author(s)

Pablo Capilla-Lasheras

Examples

```
# loading example data
data(incR_rawdata)
new.data <- incRprep (data=incR_rawdata,
                      date.name= "DATE",
                      date.format= "%d/%m/%Y %H:%M",
                      timezone="GMT",
                      temperature.name="temperature")
head (new.data, 3)
```

---

incRscan   *Automated scoring of incubation*

Description

This is the core algorithm of incR and classifies time points as 1's or 0's depending on whether or
not the incubating individual is considered to be on the eggs. The algorithm uses night variation to
daily calibrate itself to temperature variation when the incubating individual is assumed to be on the
eggs. A major assumption of this algorithm is that there is a period of time in which temperature
can be assumed to be constant or representative of time windows of constant incubation. This time
window is defined by two arguments: lower.time and upper.time. The function is optimised to
work using a data frame produced by [incRprep](#).

Usage

```
incRscan(
  data,
  temp.name,
  lower.time,
  upper.time,
  sensitivity,
  temp.diff,
  temp.diff.threshold,
  maxNightVariation,
  env.temp
)
```

Arguments

data	data frame for analysis. It must contained four columns named as follow: date, temp1, dec_time and index, where temp1 is the difference between the *ith* and *i-1th* temperature recordings; dec_time is time in decimal hours; and index is a running number from 1 to *N*, *N* being the total number of observations. [incRprep](#) returns a data frame with these variables and the correct names, ready to be passed through incRscan.
temp.name	(character object) name of the column containing temperature data in data.
lower.time	lower limit of time window for calibration (numeric).

`upper.time`	upper limit of time window for calibration (numeric).
`sensitivity`	ratio of reduction in temperature threshold. When nest temperature does not drop close to environmental temperatures, this value can be kept to 1. If nest temperature follows environmental temperature at any point, then adjustment of this value may be required to detect short on/off-bouts at lower nest temperatures (see details).
`temp.diff`	deprecated. Use temp.diff.threshold.
`temp.diff.threshold`	
	threshold for temperature difference between `env.temp` and an observation which triggers the sensitivity parameter.
`maxNightVariation`	
	maximum temperature variation between two consecutive points within the calibrating window that is considered normal of this period. If this variation value is surpassed, the calibrating window is discarded and a previous night is used for calibration.
`env.temp`	name of a column containing environmental temperatures.

Value

The function returns a list with two objects. The first object, named incRscan_data, is the original data frame with an extra column named 'incR_score'. This variable is formed by 1's and 0's, representing whether the incubating individual is inside (1) or outside the nest (0).

The second object, named incRscan_threshold, is a data frame with one day per row. Four columns tell the user the thresholds employed to calculate the 'incR_score' column. A fifth column accounts for the ratio between temperature variation in the calibrating window and the variation in temperature between 11am and 3pm for each day morning. The lower this value the more clear the pattern between night and day variation and, therefore, stronger the signal in the data. This value may serve the user as an indication of the signal / noise ratio in the analysed data set.

Details

For further details about the calculation performed by [incRscan](), consult the package vignettes and the associated publications.

Author(s)

Pablo Capilla-Lasheras

See Also

[incRprep incRenv]()

Examples

```
# incR_procdata is a dataframe processed by incRprep and incRenv.
# it contains suitable information to run incRscan
data(incR_procdata)
```

```
incubation.analysis <- incRscan (data=incR_procdata,
                                 temp.name="temperature",
                                 lower.time=22,
                                 upper.time=3,
                                 sensitivity=0.15,
                                 temp.diff.threshold=5,
                                 maxNightVariation=2,
                                 env.temp="env_temp")
inc.data <- incubation.analysis[[1]]
inc.thresholds <- incubation.analysis[[2]]
```

---

incRscan_v2   *Scoring of incubation based on a fixed temperature threshold*

Description

Modified version of incRscan. Data points are assigned to incubation on/off-bout based on a fixed
temperature threshold for the difference in nest temperature expected when an off-bout starts.

Usage

```
incRscan_v2(
  data,
  temp.name,
  sensitivity,
  temperature_threshold,
  temp.diff.threshold,
  env.temp
)
```

Arguments

data   data frame for analysis. It must contained four columns named as follow: date,
                    temp1, dec_time and index, where temp1 is the difference between the *ith* and
                    i-1th temperature recordings; dec_time is time in decimal hours; and index
                    is a running number from 1 to *N*, *N* being the total number of observations.
                    [incRprep](#) returns a data frame with these variables and the correct names, ready
                    to be passed through incRscan.

temp.name   (character object) name of the column containing temperature data in data.

sensitivity   percentage of reduction in temperature threshold. When nest temperature does
                    not drop close to environmental temperature, this value can be kept to 1. If nest
                    temperature follows environmental temperature at any point, then, adjustment of
                    this value may be required to detect short on/off-bouts at lower nest temperatures
                    (see details).

temperature_threshold
                    Maximum temperature difference between two consecutive nest temperature
                    recordings allowed for an on-bout. When the difference in nest temperature

between two consecutive recordings is higher than this value, an off-bout is detected.

temp.diff.threshold

threshold for temperature difference between env.temp and an observation which triggers application of the sensitivity parameter.

env.temp   name of a column containing environmental temperatures.

Value

The function returns the original data frame with a new column named 'incR_score'. This new variable is formed by 1's and 0's, representing whether the incubating individual is inside ("1") or outside the nest ("0"). #' @section Details: See [incRenv](#) for more details

Author(s)

Pablo Capilla-Lasheras

See Also

[incRprep](#) [incRenv](#) [incRscan](#)

Examples

```
# incR_procdata is a data frame processed by incRprep and incRenv.
# It contains suitable information to run incRscan
data(incR_procdata)

incubation.analysis <- incRscan_v2 (data=incR_procdata,
                                    temp.name="temperature",
                                    temperature_threshold = 0.75,
                                    sensitivity=0.15,
                                    temp.diff.threshold=5,
                                    env.temp="env_temp")
```

---

incRt   *Calculation of temperature average and variance for customised time windows*

Description

Calculation of temperature average and variation between two customised time periods per day. Time windows can be defined by the user using the limits argument, defined by bird activity time (using the activity.times parameter) or set according to twilight times if coordinates are provided (coor).

Usage

```
incRt(
  data,
  temp.name,
  limits = NULL,
  coor = NULL,
  activity.times = FALSE,
  civil.twilight = FALSE,
  time.zone = NULL,
  ...
)
```

Arguments

data
: data frame containing a time-series vector of 1's and 0's (incubation scores), where "1" means "incubating individual inside nest" and "0" means "incubating individual outside the nests". This vector, under the name of incR_score, is provided by incRscan in the first object of the returned list. A column named "date" is needed to refer to daily calculations.

temp.name
: (character object) name of the column containing temperature data in data.

limits
: vector of length 2 giving the time limits for calculations. For example, 'c(6,20)' would calculate temperature averages and variances for two time periods, from 6 to 20 and from 20 to 6 of the next day. 'civil.twilight' and 'activity.times' must be FALSE to allow the use of 'limits'.

coor
: coordinates for the location where temperature was recorded, formatted as decimal degrees N/S, decimal degrees E/W. When 'civil.twilight' is TRUE, 'coor' allows the user to define sunrise and sunset times based on the getSunlightTimes function (in suncalc package).

activity.times
: TRUE or FALSE. Set as TRUE when time periods for calculation are defined by incRact. Data must contain a column named 'incR_score' for the use of incRact.

civil.twilight
: TRUE or FALSE. Set as TRUE when time periods for calculation are to be defined by civil twilight times - calculated using getSunlightTimes. If 'civil.twilight = TRUE', 'coor' and 'time.zone' need to be specified.

time.zone
: time zone for getSunlightTimes dawn and dusk calculations.

...
: use parameters in incRact if *activity.times* = TRUE.

Value

a data frame containing temperature means and variance for the defined time window.

Author(s)

Pablo Capilla-Lasheras

See Also

incRprep incRscan incRact getSunlightTimes

Examples

```
# loading example data
data(incR_procdata)

# calculation based on chosen times from 6am to 7pm and 7pm to 6am
incRt (data=incR_procdata,
        temp.name="temperature",
        limits=c(6,19),
        coor=NULL,
        civil.twilight=FALSE,
        activity.times=FALSE,
        time.zone=NULL)

# calculation based on activity times
incRt (data=incR_procdata,
        temp.name="temperature",
        limits=NULL,
        coor=NULL,
        civil.twilight=FALSE,
        activity.times=TRUE,
        time.zone=NULL,
        time_column="time",                # extra argument needed for incRact
        vector.incubation="incR_score") # extra argument needed for incRact

# calculation based on civil twilight
incRt (data=incR_procdata,
        temp.name="temperature",
        limits=NULL,
        coor=c(42,0.89),
        civil.twilight=TRUE,
        activity.times=FALSE,
        time.zone="GMT")
```

---

incR_envdata   *An example data set of environmental temperatures to test the use of*
                             link{incRenv}.

Description

A dataset containing environmental temperatures for the study area where the data in [incR_rawdata](#) were collected. This raw data set was produced by an iButton device (Maxim Integrated).

Usage

```
incR_envdata
```

Format

A data frame with 1570 rows and two variables, representing two days of environmental temperature recordings at two different locations in one study site.

DATE a date-time column. Both elements, date and time, are concatenated in one column.

env_temperature environmental temperature recordings.

Details

use this data set to try out link{incRenv} after the very first application of incRprep using incR_rawdata.

---

incR_procdata   *An example of incubation temperature time-series after the use of*
                                 incRprep *and* incRenv.

Description

A dataset containing temperatures, time and date for a blue tit nest. It also includes variables added by incRprep and incRenv. The raw data set incR_rawdata was produced by an iButton device (Maxim) and represents raw data to start the analysis of incubation behaviour

Usage

incR_procdata

Format

A data frame with 954 rows and 11 variables, representing two days of nest temperatures.

DATE a date-time column. Both elements, date and time, are concatenated in one column.

temperature nest temperature recordings.

index running number from first to last observation.

time

hour

minute

second

date

dec_time time in decimal hours.

temp1 difference between the *ith* and the *ith-1* nest temperature recording.

env_temp environmental temperature, calculated per as hour average using incRenv.

incR_score Incubation scores (0/1) as calculated by incRscan

Details

see incRprep and incRenvfor more details on the variables of this data set and how it was produced.

---

incR_rawdata　　　　　　　*An example of incubation temperature time-series*

Description

A dataset containing date, time and temperatures for a blue tit nest. This data set was produced by an iButton device (Maxim Integrated) and represents raw data to start the analysis of incubation behaviour.

Usage

```
incR_rawdata
```

Format

A data frame with 954 rows and 2 variables, representing three days of nest temperatures.

DATE a date-time column. Both elements, date and time, are concatenated in one column

temperature temperature recordings in Celsius

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