Package ‘ectotemp’

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Title  Quantitative Estimates of Small Ectotherm Temperature Regulation Effectiveness

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Description  Easy and rapid quantitative estimation of small terrestrial ectotherm temperature regulation effectiveness in R. ectotemp is built on classical formulas that evaluate temperature regulation by means of various indices, inaugurated by Hertz et al. (1993) <doi:10.1086/285573>. Options for bootstrapping and permutation testing are included to test hypotheses about divergence between organisms, species or populations.

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ectotemp-package

ectotemp-package  ectotemp: Quantitative Estimates of Small Ectotherm Temperature Regulation Effectiveness

Description

Easy and rapid quantitative estimation of small terrestrial ectotherm temperature regulation effectiveness in R. ectotemp is built on classical formulas that evaluate temperature regulation by means of various indices, inaugurated by Hertz et al. (1993) <doi: 10.1086/285573>. Options for bootstrapping and permutation testing are included to test hypotheses about divergence between organisms, species or populations.

Details

ectotemp builds on work by Hertz et al. (1993, and references therein), Christian and Weavers (1996), and Blouin-Demers and Weatherhead (2001). Users of this package do not need to be particularly experienced in R, but are expected to be familiar with the background, appropriate choice, and caveats of the available functions (Hertz et al. 1993, Christian and Weavers 1996, Wills and Beaupre 2000, Blouin-Demers and Nadeau 2005).

The aim of the ectotemp package is to facilitate easy and rapid estimation of small, terrestrial ectotherm temperature regulation effectiveness after data describing field-active body temperatures ($T_b$), environmental (operative) temperatures ($T_e$) and preferred temperatures (the set-point range, $T_{set}$) have been collected. The package provides functions for the following types of analyses:

- The **accuracy of temperature regulation ($db$)** and associated descriptive statistics, which estimate the degree to which ectotherms experience body temperature outside of their set-point range;
- The **thermal quality of the habitat ($de$)** and associated descriptive statistics, which estimate the degree to which environmental temperature matches the set-point range;
- Choice between several approaches to **calculate effectiveness of temperature regulation ($E$)**, including bootstrap resampling of the original distributions of $T_b$ and $T_e$ to determine confidence interval for the mean, and permutation tests for between-population or species comparisons;
- **Exploitation of the thermal environment ($Ex$)**, i.e., the amount of time when field body temperatures ($T_b$) are within the set-point range, relative to the total amount of time during which this could have been possible as indicated by operative temperatures ($T_e$).
Author(s)

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References


See Also

Useful links:

- https://github.com/wouterbeukema/ectotemp

Description

Bootstrapping of the effectiveness of temperature regulation (E) from the original distributions of Te and Tb as described by Hertz et al. (1993). One can choose the number of resamples and has the option to calculate E as defined by Hertz et al. (1993) or Blouin-Demers & Weatherhead (2001). See calculate_E_hertz and calculate_E_blouin for more information about these two indices. The thermal quality of the habitat (de) and accuracy of temperature regulation (db) are calculated as part of this formula, so it is not necessary to run calculate_de and calculate_db before running this function.

Usage

bootstrap_E(te, tb, tset_low, tset_up, index, n)

Arguments

te A vector containing operative temperatures.
tb A vector containing body temperature measurements.
tset_low  Lower boundary of a species or population set-point range that was determined through thermal preference trials in a temperature gradient. This may be a named double vector containing the lower boundary value, or simply the value itself.

tset_up  Upper boundary of the set-point range.

index  Either 'hertz' or 'blouin'.

n  The desired number of samples drawn with replacement.

Value

The mean E and its 95 percent confidence interval obtained through resampling with replacement n times.

References


See Also

calculate_E_hertz and calculate_E_blouin.

Examples

te <- na.omit(bufbuf[,"te"])
tb <- na.omit(bufbuf[,"tb"])
E_bootstrapped <- bootstrap_E(te, tb,
19.35, 26.44,
'hertz',
1000)

bufbuf  Common toad body temperatures and associated operative temperatures

Description

Active field body temperature data of Belgian common toads (Bufo bufo) and associated operative temperature data from agar models, collected during nocturnal surveys in spring. Data are in degrees Celsius.

Usage

data(bufbuf)
**calculate_db**

**Description**

This function determines the degree to which ectotherms experience body temperatures outside their set-point range, better known as the accuracy of temperature regulation (db) as described by Hertz et al. (1993). Descriptive statistics are automatically computed as well.

**Usage**

```
calculate_db(tb, tset_low, tset_up)
```

**Arguments**

- `tb`: A vector containing body temperature measurements.
- `tset_low`: Lower boundary of a species or population set-point range that was determined through thermal preference trials in a temperature gradient.
- `tset_up`: Upper boundary of the set-point range.

**Value**

Degree to which ectotherms experience body temperatures outside their set-point range (db), and associated descriptive statistics.

**References**


**Examples**

```
tb <- na.omit(bufbuf[,"tb")
db_stats <- calculate_db(tb, 19.35, 26.44)
```
**calculate_de**  
*Calculate thermal quality of the habitat*

**Description**

This function calculates the thermal quality of the habitat (de) from the perspective of the focal species or population as described by Hertz et al. (1993). Descriptive statistics are automatically computed as well.

**Usage**

```r
calculate_de(te, tset_low, tset_up)
```

**Arguments**

- `te`: A vector containing operative temperatures.
- `tset_low`: Lower boundary of a species or population set-point range that was determined through thermal preference trials in a temperature gradient.
- `tset_up`: Upper boundary of the set-point range.

**Value**

Thermal quality of the habitat (de) and associated descriptive statistics.

**References**


**Examples**

```r
te <- na.omit(bufbuf[, "te"])
d_de_stats <- calculate_de(te, 19.35, 26.44)
```

---

**calculate_Ex**  
*Exploitation of the thermal environment*

**Description**

This function determines the extent to which organisms exploit their thermal environment (indexed by Ex) following Christian and Weavers (1996). Ex is given by the amount of time when field body temperatures (Tb) are within the set-point range, relative to the total amount of time during which this could have been possible as indicated by operative temperatures (Te). The higher the Ex value, the more an organism exploits its thermal environment when the environment is permissive. The user-supplied vectors containing Te and Tb data are assumed to use the same time unit.
calculate_E_blouin

Usage

calculate_Ex(te, tb, tset_low, tset_up)

Arguments

te A vector containing operative temperatures. These data should be in the same time unit as the tb data.

tb A vector containing body temperature measurements.

tset_low Lower boundary of a species or population set-point range that was determined through thermal preference trials in a temperature gradient. This may be a named double vector containing the lower boundary value, or simply the value itself.

tset_up Upper boundary of the set-point range.

Value

Ex index, indicating thermal exploitation of the environment during a user-determined period of time.

References


Examples

te <- na.omit(ichalp[,"te"])

 tb <- na.omit(ichalp[,"tb"])

Ex <- calculate_Ex(te, tb, 14.44, 18.33)

---

calculate_E_blouin Thermoregulation effectiveness sensu Blouin-Demens & Weatherhead

Description

This function calculates an often-used variant of the original formula to determine effectiveness of temperature regulation of Hertz et al. (1993). The concerning variant was proposed by Blouin-Demens & Weatherhead (2001), who argued that interpretation of the formula of Hertz et al. (1993) is confounded by the fact that different combinations of the mean thermal quality of the habitat (de) and mean accuracy of temperature regulation (db) might lead to similar E values. As such, Blouin-Demens & Weatherhead (2001) proposed use of E = de - db, which quantifies the extent of departure from perfect thermoconformity. Positive E values indicate active temperature regulation, negative values represent active avoidance of suitable thermal habitat, and values around 0 suggest thermoconformity. The thermal quality of the habitat (de) and accuracy of temperature regulation (db) are calculated as part of this formula, so it is not necessary to run calculate_de and calculate_db before running this function.
Usage

```r
calculate_E_blouin(te, tb, tset_low, tset_up)
```

Arguments

- `te`: A vector containing operative temperatures.
- `tb`: A vector containing body temperature measurements.
- `tset_low`: Lower boundary of a species or population set-point range that was determined through thermal preference trials in a temperature gradient. This may be a named double vector containing the lower boundary value, or simply the value itself.
- `tset_up`: Upper boundary of the set-point range.

Value

Effectiveness of temperature regulation (E) sensu Blouin-Demers and Weatherhead (2001).

References


See Also

- `calculate_E_hertz`

Examples

```r
te <- na.omit(bufbuf[, "te"])
tb <- na.omit(bufbuf[, "tb"])
E <- calculate_E_blouin(te, tb, 19.35, 26.44)
```

---

**calculate_E_hertz**

*Calculate thermoregulation effectiveness sensu Hertz, Huey & Stevenson*

Description

This function calculates the effectiveness of temperature regulation (E = 1 - (mean db / mean de)) as described by Hertz et al. (1993). The thermal quality of the habitat (de) and accuracy of temperature regulation (db) are calculated as part of this formula, so it is not necessary to run `calculate_de` and `calculate_db` before running this function.

Usage

```r
calculate_E_hertz(te, tb, tset_low, tset_up)
```
**Arguments**

- `te` A vector containing operative temperatures.
- `tb` A vector containing body temperature measurements.
- `tset_low` Lower boundary of a species or population set-point range that was determined through thermal preference trials in a temperature gradient. This may be a named double vector containing the lower boundary value, or simply the value itself.
- `tset_up` Upper boundary of the set-point range.

**Value**

Effectiveness of temperature regulation (E)

**References**


**See Also**

`calculate_de` and `calculate_db`.

**Examples**

```r
te <- na.omit(bufbuf[, "te"])
tb <- na.omit(bufbuf[, "tb"])
E <- calculate_E_hertz(te, tb, 19.35, 26.44)
```

**compare_E**

Compare E between species or populations using permutation

**Description**

To test whether or not distinct species or populations (hereafter 'entity') differed in their effectiveness of thermoregulation, Hertz et al. (1993) suggested comparing paired estimates of E obtained through bootstrapping. However, because sample sizes of active body temperatures (Tb) or operative temperatures (Te) may be small and could differ in size and variance, possibly leading to non-normality, we propose to use two-sided permutation testing instead of bootstrapping to build and compare distributions of E values.
Usage

```r
compare_E(
    datasp1,
    datasp2,
    tset_lowsp1,
    tset_upsp1,
    tset_lowsp2,
    tset_upsp2,
    index,
    n
)
```

Arguments

- **datasp1**: A dataframe with two columns named 'te' (containing operative temperatures) and 'tb' (containing body temperature measurements) of entity 1. Do not use capitals in column names.
- **datasp2**: A dataframe for entity 2 structured as indicated above.
- **tset_lowsp1**: Lower boundary of the set-point range of entity 1 that was determined through thermal preference trials in a temperature gradient. This may be a named double vector containing the lower boundary value, or simply the value itself.
- **tset_upsp1**: Upper boundary of the set-point range of entity 1.
- **tset_lowsp2**: Lower boundary of the set-point range of entity 2.
- **tset_upsp2**: Upper boundary of the set-point range of entity 2.
- **index**: Either 'hertz' or 'blouin'.
- **n**: The desired number of samples drawn without replacement.

Value

Permutation testing results including a graphical overview which displays the empirical (actual) difference in E between two entities, along with a null distribution of differences in permuted E values constructed from pooled data of both entities.

References


See Also

- `calculate_E_hertz`
- `calculate_E_blouin`
Examples

```r
bufbuf <- bufbuf
ichalp <- ichalp
E_diff <- compare_E(bufbuf, ichalp,
                   19.35, 26.44,
                   14.44, 18.33,
                   'blouin',
                   1000)
```

ichalp  
Alpine newt body temperatures and associated operative temperatures

Description

Active field body temperature data of Belgian alpine newts (*Ichthyosaura alpestris*) and associated operative temperature data from agar models, collected during nocturnal surveys in spring. Data are in degrees Celsius.

Usage

```r
data(ichalp)
```

Format

An object of class `data.frame` with 99 rows and 2 columns.

Source

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