Package ‘devRate’

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Type Package

Title Quantify the Relationship Between Development Rate and Temperature in Ectotherms

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Suggests knitr, rmarkdown, testthat

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BugReports https://github.com/frareb/devRate/issues

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Analytis equation of development rate as a function of temperature.

Description

Usage
analytis_77

Format
A list of eight elements describing the equation.

- **eq** The equation (formula object).
- **eqAlt** The equation (string).
- **name** The name of the equation.
- **ref** The equation reference.
- **refShort** The equation reference shortened.
- **startVal** The parameters found in the literature with their references.
- **com** An optional comment about the equation use.
- **id** An id to identify the equation.

Details
Equation:
\[
rT = aa \ast (T - Tmin)^{bb} \ast (Tmax - T)^{cc}
\]

where \( rT \) is the development rate, \( T \) the temperature, \( Tmin \) the minimum temperature, \( Tmax \) the maximum temperature, and \( aa, bb, \) and \( cc \) constants.

Source
http://dx.doi.org/10.1111/j.1439-0434.1977.tb02886.x
Bayoh and Lindsay equation of development rate as a function of temperature.

Description


Usage

bayoh_03

Format

A list of eight elements describing the equation.

eq The equation (formula object).
eqAlt The equation (string).
name The name of the equation.
ref The equation reference.
refShort The equation reference shortened.
startVal The parameters found in the literature with their references.
com An optional comment about the equation use.
id An id to identify the equation.

Details

Equation:

$$r_T = aa + bb \cdot T + cc \cdot e^T + dd \cdot e^{-T}$$

where $r_T$ is the development rate, $T$ the temperature, and $aa,$ $bb,$ $cc,$ and $dd$ empirical constant parameters.

Source

http://dx.doi.org/10.1079/BER2003259
Description


Usage

beta_16

Format

A list of eight elements describing the equation.

eq The equation (formula object).
eqAlt The equation (string).
name The name of the equation.
ref The equation reference.
refShort The equation reference shortened.
startVal The parameters found in the literature with their references.
com An optional comment about the equation use.
id An id to identify the equation.

Details

Equation:

\[ rT = rm \times \left( \frac{T2 - T}{T2 - Tm} \right) \times \left( \frac{T - T1}{Tm - T1} \right)^{\frac{Tm - T1}{T2 - T1}} \]

where \( rT \) is the development rate, \( T \) the temperature, \( T1, T2, \) and \( Tm \) the model parameters.

Source

http://dx.doi.org/10.1016/j.ecolmodel.2015.09.012
beta_95  Beta equation of development rate as a function of temperature.

Description


Usage

beta_95

Format

A list of eight elements describing the equation.

- **eq**  The equation (formula object).
- **eqAlt**  The equation (string).
- **name**  The name of the equation.
- **ref**  The equation reference.
- **refShort**  The equation reference shortened.
- **startVal**  The parameters found in the literature with their references.
- **com**  An optional comment about the equation use.
- **id**  An id to identify the equation.

Details

Equation:

\[ rT = e^{\mu} \ast (T - Tb)^{aa} \ast (Tc - T)^{bb} \]

where \( rT \) is the development rate, \( T \) the temperature, \( \mu, aa, \) and \( bb \) the model parameters, \( Tb \) the base temperature, and \( Tc \) the ceiling temperature.

Source

http://dx.doi.org/10.1016/0168-1923(95)02236-Q
Description


Usage

bieri1_83

Format

A list of eight elements describing the equation.

- **eq**: The equation (formula object).
- **eqAlt**: The equation (string).
- **name**: The name of the equation.
- **ref**: The equation reference.
- **refShort**: The equation reference shortened.
- **startVal**: The parameters found in the literature with their references.
- **com**: An optional comment about the equation use.
- **id**: An id to identify the equation.

Details

Equation:

\[ r_T = aa \times (T - T_{min}) - (bb \times e^{T - T_m}) \]

where \( r_T \) is the development rate, \( T \) the temperature, \( T_{min} \) the minimum temperature, and \( aa, bb, \) and \( T_m \) fitted coefficients.

Source

[http://www.e-periodica.ch](http://www.e-periodica.ch)
Briere et al equation 1 of development rate as a function of temperature.

Description


Usage

briere1_99

Format

A list of eight elements describing the equation.

- eq The equation (formula object).
- eqAlt The equation (string).
- name The name of the equation.
- ref The equation reference.
- refShort The equation reference shortened.
- startVal The parameters found in the literature with their references.
- com An optional comment about the equation use.
- id An id to identify the equation.

Details

Equation:

\[ r_T = aa \times T \times (T - T_{min}) \times (T_{max} - T)^{\frac{1}{2}} \]

where \( r_T \) is the development rate, \( T \) the temperature, \( T_{min} \) the low temperature developmental threshold, \( T_{max} \) the lethal temperature, and \( aa \) an empirical constant.

Source

http://dx.doi.org/10.1093/ee/28.1.22
Briere et al equation 2 of development rate as a function of temperature.

Description

Usage
briere2_99

Format
A list of eight elements describing the equation.

- **eq** The equation (formula object).
- **eqAlt** The equation (string).
- **name** The name of the equation.
- **ref** The equation reference.
- **refShort** The equation reference shortened.
- **startVal** The parameters found in the literature with their references.
- **com** An optional comment about the equation use.
- **id** An id to identify the equation.

Details
Equation:

\[ rT = aa \times T \times (T - Tmin) \times (Tmax - T)^{0.5} \]

where \( rT \) is the development rate, \( T \) the temperature, \( Tmin \) the low temperature developmental threshold, \( Tmax \) the lethal temperature, and \( aa \) and \( bb \) empirical constants.

Source
http://dx.doi.org/10.1093/ee/28.1.22
Campbell et al. equation of development rate as a function of temperature.

**Description**


**Usage**

campbell_74

**Format**

A list of eight elements describing the equation.

- **eq** The equation (formula object).
- **eqAlt** The equation (string).
- **name** The name of the equation.
- **ref** The equation reference.
- **refShort** The equation reference shortened.
- **startVal** The parameters found in the literature with their references.
- **com** An optional comment about the equation use.
- **id** An id to identify the equation.

**Details**

Equation:

\[ r_T = a_0 + b_0 \cdot T \]

where \( r_T \) is the development rate, \( T \) the temperature, \( b_0 \) the slope, and \( a_0 \) the point at which the line crosses the \( r_T \) axis when \( T = 0 \).

**Source**

http://dx.doi.org/10.2307/2402197
compDifDays

Compute the inverse of the number of days between dates

Description

compDifDays computes the inverse of the difference between dates from a vector made of dates.

Usage

```r
compDifDays(vecDates, dateFormat = "%d/%m/%y")
```

Arguments

- `vecDates`: A vector with dates.
- `dateFormat`: The format of dates (see `strptime`).

Value

A vector with the inverse of the difference between dates.

Examples

```r
compDifDays(vecDates = c("28/12/15", "12/01/16", "25/01/16", "28/02/16", "15/03/16"))
compDifDays(vecDates = c("28/12/15", "12/01/14", "25/01/16", "28/02/16", "15/03/16"))
compDifDays(vecDates = c("28/12/15", "12/01/16", "25/01/16", ",", ""))
```

compDifDaysDf

Compute the inverse of the number of days between dates from a data frame.

Description

Compute the inverse of the number of days between dates from a data frame.

Usage

```r
compDifDaysDf(dfDates, dateFormatDf = "%d/%m/%y")
```

Arguments

- `dfDates`: A data.frame with dates (samples in columns and dates in rows).
- `dateFormatDf`: The format of dates (see `strptime`).

Value

A data.frame with the inverse of the difference between dates.
Examples

```r
myDays <- data.frame(egg = c("28/12/15", "28/12/15", "28/12/15", "28/12/15"),
                      larva1 = c("12/01/16", "12/01/16", "12/01/16", "13/01/16"),
                      larva2 = c("25/01/16", "26/01/16", "25/01/16", "29/01/16"),
                      pupa = c("12/02/16", "10/02/16", "14/02/16", "09/02/16"),
                      imago = c("28/02/16", "25/02/16", "27/02/16", "26/02/16"),
                      death = c("15/03/16", "12/03/16", "19/03/16", "20/03/16"))
compDifDaysDf(dfDates = myDays, dateFormat = "%d/%m/%y")
```

Description


Usage

damos_08

Format

A list of eight elements describing the equation.

- `eq` The equation (formula object).
- `eqAlt` The equation (string).
- `name` The name of the equation.
- `ref` The equation reference.
- `refShort` The equation reference shortened.
- `startVal` The parameters found in the literature with their references.
- `com` An optional comment about the equation use.
- `id` An id to identify the equation.

Details

Equation:

\[ r_T = aa \times \left( bb - \frac{T}{10} \right) \times \left( \frac{T}{10} \right)^{cc} \]

where \( r_T \) is the development rate, \( T \) the temperature, and \( aa, \ bb, \) and \( cc \) empirical constant parameters.

Source

http://dx.doi.org/10.1093/jee/101.5.1557
Inverse second-order polynomial equation of development rate as a function of temperature.

Description

Usage
damos_11

Format
A list of eight elements describing the equation.

eq  The equation (formula object).
eqAlt  The equation (string).
name  The name of the equation.
ref  The equation reference.
refShort  The equation reference shortened.
startVal  The parameters found in the literature with their references.
com  An optional comment about the equation use.
id  An id to identify the equation.

Details
Equation:

\[ r_T = \frac{aa}{1 + bb \cdot T + cc \cdot T^2} \]

where \( r_T \) is the development rate, \( T \) the temperature, and \( aa, bb, \) and \( cc \) empirical constant parameters.

Source
http://dx.doi.org/10.1155/2012/123405
Davidson equation of development rate as a function of temperature.

Description


Usage
davidson_44

Format

A list of eight elements describing the equation.

- eq: The equation (formula object).
- eqAlt: The equation (string).
- name: The name of the equation.
- ref: The equation reference.
- refShort: The equation reference shortened.
- startVal: The parameters found in the literature with their references.
- com: An optional comment about the equation use.
- id: An id to identify the equation.

Details

Equation:

\[ r_T = \frac{K}{1 + e^{a_T + b_T T}} \]

where \( r_T \) is the development rate, \( T \) the temperature, \( K \) the distance between the upper and lower asymptote of the curve, \( a \) the relative position of the origin of the curve on the abscissa, \( b \) the degree of acceleration of development of the life stage in relation to temperature.

Source

http://dx.doi.org/10.2307/1326
Description

The devRate package allows quantifying the relationship between development rate and temperature in ectotherm organisms.

Citation

Please use citation("devRate") to cite the devRate package and/or Rebaudo F, Struelens Q, Dangles O. Modelling temperature-dependent development rate and phenology in arthropods: The devRate package for r. Methods Ecol Evol. 2017;00:1-7. https://doi.org/10.1111/2041-210X.12935. Author’s affiliation: UMR EGCE, Univ. ParisSud, CNRS, IRD, Univ. ParisSaclay, Gif-sur-Yvette, France

Overview

The devRate package provides three categories of functions:
- to find development rate information about a specific organism (Order, Family, Genus, species): which equations were used and what are the associated parameters (e.g., helpful to estimate starting values for your empirical data sets);
- to relate development rate and temperature; and
- to plot your empirical datasets and the associated fitted model, and/or to plot development curves from the literature.

Usage

You can use the package:
- to get development rate curves as a function of temperature for a specific organism (hundred of examples from the literature are included in the package);
- to know which equations exists and which are most used in the literature; and
- to relate development rate with temperature from your empirical data, using the equations from the package database.

Installation instructions

install.packages("devRate")

Documentation

The package includes two vignettes (long-form documentation):
- quickUserGuide: Using devRate package to fit development rate models to an empirical dataset
- modelEvaluation: Model evaluation using Shi et al. 2016 study
devRateEqList

The list of all available equations of development rate as a function of temperature.

Description

The list of all available equations of development rate as a function of temperature.

Usage

devRateEqList

Format

An object of class `list` of length 37.

devRateFind

Find models for species

Description

Find models for species

Usage

devRateFind(orderSP = "", familySP = "", species = "")

Arguments

- `orderSP` Find models by Order.
- `familySP` Find models by Family.
- `species` Find models by species (Genus species).

Details

The function looks for the species in the database and returns the number of occurrences for each model.

Value

A data.frame with the name of the equations, the number of occurrences in the database, and the number of parameters for each equation.
devRateIBM

Forecast ectotherm phenology as a function of temperature and development rate models

Description

Forecast ectotherm phenology as a function of temperature and development rate models

Usage

devRateIBM(tempTS, timeStepTS, models, numInd = 100, stocha, timeLayEggs = 1)

Arguments

tempTS The temperature time series (a vector).
timeStepTS The time step of the temperature time series (a numeric in days).
models The models for development rate (a list with objects of class nls).
numInd The number of individuals for the simulation (an integer).
stocha The standard deviation of a Normal distribution centered on development rate to create stochasticity among individuals (a numeric). Either a single number (same stochasticity for all stages) or a vector of length corresponding to the number of models used (different stochasticity for the phenological stages).
timeLayEggs The delay between emergence of adults and the time where females lay eggs in time steps (a numeric).

Value

A list with three elements: the table of phenology for each individual, the models used (nls objects), and the time series for temperature.

Examples

devRateFind(orderSP = "Lepidoptera")
devRateFind(familySP = "Gelechiidae")
## detailed example:
devRateFind(species = "Tuta absoluta")
## campbell_74 model has been used for T. absoluta
## Parameters from the campbell equation can be accessed by:
## campbell_74$startVal[campbell_74$startVal["genSp"] == "Tuta absoluta",]
Examples

data(exTropicalMoth)
forecastTsolanivora <- devRateIBM(
  tempTS = rnorm(n = 100, mean = 15, sd = 1),
  timeStepTS = 1,
  models = exTropicalMoth[[2]],
  numInd = 100,
  stocha = c(0.015, 0.005, 0.01),
  timeLayEggs = 1)

---

**devRateIBMdatabase**

*Forecast ectotherm phenology as a function of temperature and development rate models available in the package database*

Description

Forecast ectotherm phenology as a function of temperature and development rate models available in the package database

Usage

devRateIBMdatabase(tempTS, timeStepTS, eq, species, lifeStages, 
  numInd = 10, stocha, timeLayEggs = 1)

Arguments

tempTS The temperature time series (a vector).
timeStepTS The time step of the temperature time series (a numeric with 1 = one day).
eq The name of the equation (e.g., lactin2_95).
species The species for the model (e.g., "Sesamia nonagrioides").
lifeStages The life stages available for the species and the model.
numInd The number of individuals for the simulation (an integer).
stocha The standard deviation of a Normal distribution centered on development rate to create stochasticity among individuals (a numeric).
timeLayEggs The delay between emergence of adults and the time where females lay eggs in time steps (a numeric).

Value

A list with three elements: the table of phenology for each individual, the models used (nls objects), and the time series for temperature.
Examples

```r
forecastLactin2_95 <- devRateIBMdataBase(
  tempTS = rnorm(n = 20, mean = 20, sd = 1),
  timeStepTS = 10,
  eq = lactin2_95,
  species = "Sesamia nonagrioides",
  lifeStages = c("eggs", "larva", "pupa"),
  numInd = 10,
  stocha = 0.015,
  timeLayEggs = 1
)
```

---

<table>
<thead>
<tr>
<th>devRateIBMgen</th>
<th>Number of generations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Description

Computes the number of generations from the individual-based model fit.

Usage

```r
devRateIBMgen(ibm)
```

Arguments

- `ibm` The phenology model returned by `devRateIBM` function.

Value

The simulated number of generations.

Examples

```r
data(exTropicalMoth)
forecastTsolanivora <- devRateIBM(
  tempTS = rnorm(n = 100, mean = 15, sd = 1),
  timeStepTS = 1,
  models = exTropicalMoth[[2]],
  numInd = 10,
  stocha = 0.015,
  timeLayEggs = 1)
devRateIBMgen(ibm = forecastTsolanivora)
```
devRateIBMPlot

Plot phenology table

Description
Plot phenology table

Usage
devRateIBMPlot(ibm, typeG = "density", threshold = 0.1)

Arguments
- ibm: The phenology model returned by devRateIBM function.
- typeG: The type of plot ("density" or "hist").
- threshold: The threshold rate of individuals for being represented in a density plot (a numeric between 0 and 1).

Value
Nothing.

Examples
data(exTropicalMoth)
forecastTsolanivora <- devRateIBM(
  tempTS = rnorm(n = 100, mean = 15, sd = 1),
  timeStepTS = 1,
  models = exTropicalMoth[[2]],
  numInd = 10,
  stocha = 0.015,
  timeLayEggs = 1)
devRateIBMPlot(ibm = forecastTsolanivora, typeG = "density", threshold = 0.1)
devRateIBMPlot(ibm = forecastTsolanivora, typeG = "hist")

devRateInfo

Display information about an equation

Description
Display information about an equation

Usage
devRateInfo(eq)
**Arguments**

- `eq`  
  The name of the equation.

**Value**

- Nothing.

**Examples**

```r
devRateInfo(eq = davidson_44)
devRateInfo(eq = campbell_74)
devRateInfo(eq = taylor_81)
devRateInfo(eq = wang_82)
```

---

**Description**

Create a map from a temperature matrix and a development rate curve.

**Usage**

```r
devRateMap(nlsDR, tempMap)
```

**Arguments**

- `nlsDR`  
  The result returned by the devRateModel function.

- `tempMap`  
  A matrix containing temperatures in degrees.

**Details**

The `devRateMap` function is designed for a single ectotherm life stage, but the resulted matrix of development rate can be performed for each life stage in order to obtain the whole organism development. Input temperatures should preferably cover the organism development period rather than the whole year.

**Value**

- A matrix with development rates predicted from the model.

**Examples**

```r
myT <- 5:15
myDev <- -0.05 + rnorm(n = length(myT), mean = myT, sd = 1) * 0.01
myNLS <- devRateModel(eq = campbell_74, temp = myT, devRate = myDev,
  startValues = list(aa = 0, bb = 0))
myMap <- devRateMap(nlsDR = myNLS, tempMap = matrix(rnorm(100, mean = 12, sd = 2), ncol=10))
```
**devRateModel**

Compute non-linear regression

**Description**

Determine the nonlinear least-squares estimates of the parameters of a nonlinear model, on the basis of the *nls* function from package *stats*.

**Usage**

```r
devRateModel(eq, temp, devRate, startValues, df = NULL, ...)```

**Arguments**

- `eq` The name of the equation.
- `temp` The temperature.
- `devRate` The development rate \((\text{days})^{-1}\)
- `startValues` Starting values for the regression.
- `df` A data.frame with the temperature in the first column and the development rate in the second column (alternative to the use of temp and devRate).
- `...` Additional arguments for the *nls* function.

**Details**

StartValues for equations by Stinner et al. 1974 and Lamb 1992 are composed of two equations: one for the temperatures below the optimal temperature and another for the temperatures above the optimal temperature. For these equations, `startValues` should be a list of two lists, where the second element only contain starting estimates not specified in the first element, e.g., for Stinner et al.: `startValues <- list(list(C = 0.05, k1 = 5, k2 = -0.3), list(Topt = 30)),` and for Lamb 1992: `startValues <- list(list(Rm = 0.05, Tmax = 35, To = 15), list(T1 = 4))`

The temperature should be provided as a vector in argument `temp` and development rate in another vector in argument `devRate`. However, it is possible to use the function with a data.frame containing the temperature in the first column and the development rate in the second column, using the argument `df`.

**Value**

An object of class *nls* (except for Stinner et al. 1974 and Lamb 1992 where the function returns a list of two objects of class *nls*).
Examples

```r
## Example with a linear model (no starting estimates)
myT <- 5:15
myDev <- -0.05 + rnorm(n = length(myT), mean = myT, sd = 1) * 0.01
myNLS <- devRateModel(eq = campbell_74, temp = myT, devRate = myDev)
## Example with a non-linear model (starting estimates)
myT <- seq(from = 0, to = 50, by = 10)
myDev <- c(0.001, 0.008, 0.02, 0.03, 0.018, 0.004)
myNLS <- devRateModel(eq = stinner_74, temp = myT, devRate = myDev,
startValues = list(list(C = 0.05, k1 = 5, k2 = -0.3), list(Topt = 30)))
## Example with a data.frame instead of two vectors for temperature and
## development rate
myDF <- data.frame(myT, myDev)
myNLS <- devRateModel(eq = campbell_74, df = myDF)
```

---

**devRatePlot**

*Plot the empirical points and the regression*

**Description**

Plot the empirical points and the regression

**Usage**

```r
devRatePlot(eq, nlsDR, temp, devRate, rangeT = 10, optText = TRUE,
spe = TRUE, ...)
```

**Arguments**

- `eq`: The name of the equation.
- `nlsDR`: The result returned by the `devRateModel` function.
- `temp`: The temperature.
- `devRate`: The development rate \( \text{days}^{-1} \)
- `rangeT`: The range of temperatures over which the regression is plotted. This argument may be overwritten depending on the equation.
- `optText`: A logical indicating whether the name of the equation should be written in the top right corner of the plot.
- `spe`: A logical indicating if special plotting rules from literature should apply.
- `...`: Additional arguments for the plot.

**Value**

Nothing.
Examples

```r
myT <- 5:15
myDev <- -0.05 + rnorm(n = length(myT), mean = myT, sd = 1) * 0.01
myNLS <- devRateModel(eq = campbell_74, temp = myT, devRate = myDev,
                      startValues = list(aa = 0, bb = 0))
devRatePlot(eq = campbell_74, nlsDR = myNLS, temp = myT, devRate = myDev,
            spe = TRUE, pch = 16, lwd = 2, ylim = c(0, 0.10))
```

---

**devRatePlotInfo**

*Plot thermal performance curves from the literature*

Description

Plot thermal performance curves from the literature

Usage

```r
devRatePlotInfo(eq, sortBy = "genSp", stage = "all", ...)
```

Arguments

- `eq` The name of the equation.
- `sortBy` The filter to separate species ("ordersp", "familysp", "genussp", "species", "genSp").
- `stage` The life stage of the organism ("all", "eggs", "L1", "L2", "L3", "L4", "L5", "larva", "pupa", "prepupa", "female", "male", ...)
- `...` Additional arguments for the plot.

Value

Nothing.

Examples

```r
devRatePlotInfo(eq = davidson_44, sortBy = "genSp", xlim = c(0, 40), ylim = c(0, 0.05))
devRatePlotInfo(eq = campbell_74, sortBy = "familysp", xlim = c(-10, 30), ylim = c(0, 0.05))
devRatePlotInfo(eq = taylor_81, sortBy = "ordersp", xlim = c(-20, 60), ylim = c(0, 0.2))
devRatePlotInfo(eq = wang_82, sortBy = "ordersp", xlim = c(0, 50), ylim = c(0, 0.06))
devRatePlotInfo(eq = stinner_74, sortBy = "ordersp", xlim = c(0, 50), ylim = c(0, 0.06))
```
**devRatePrint**

**Report model output from the NLS fit**

**Description**

Provide a custom output of the NLS fit.

**Usage**

```
devRatePrint(myNLS, temp, devRate, doPlots = FALSE)
```

**Arguments**

- **myNLS**: An object of class NLS
- **temp**: The temperature
- **devRate**: The development rate (days)\(^{-1}\)
- **doPlots**: A boolean to get the residual plot (default = FALSE)

**Value**

A list of six objects (summary of the NLS fit; confidence intervals for the model parameters; test of normality; test of independence; AIC, BIC)

**Examples**

```r
myT <- 5:15
myDev <- -0.05 + rnorm(n = length(myT), mean = myT, sd = 1) * 0.01
myNLS <- devRateModel(eq = campbell_74, temp = myT, devRate = myDev,
                       startValues = list(aa = 0, bb = 0))
devRatePrint(myNLS, temp = myT, devRate = myDev)

rawDevEggs <- matrix(c(10, 0.031, 10, 0.039, 15, 0.047, 15, 0.059, 15.5, 0.066,
                        13, 0.072, 16, 0.083, 16, 0.100, 17, 0.100, 20, 0.100, 20, 0.143, 25, 0.171,
                        25, 0.200, 30, 0.200, 30, 0.180, 35, 0.001), ncol = 2, byrow = TRUE)
mEggs <- devRateModel(eq = taylor_81, temp = rawDevEggs[,1], devRate = rawDevEggs[,2],
                       startValues = list(Rm = 0.05, Tm = 30, To = 5))
devRatePrint(myNLS = mEggs, temp = rawDevEggs[, 1], devRate = rawDevEggs[, 2])
```
exTropicalMoth

Tropical moth development rate at constant temperatures.

Description

This is a sample dataset to be used in the package examples. In this example, we used data from Crespo-Perez et al. (2011) on the potato tuber moth Tecia solanivora (Lepidoptera: Gelechiidae), a major crop pest in the central Andes of Ecuador. We used Web Plot Digitizer (Rohatgi 2015) to extract the data on development rate as a function of temperature.


Usage

exTropicalMoth

Format

A list of two elements with a list of three elements.

raw The raw data extracted from Crespo-Perez et al. 2011.

eggs raw temperatures and development rates
larva raw temperatures and development rates
pupa raw temperatures and development rates

model The nls object returned by the devRateModel function.

eggs nls object
larva nls object
pupa nls object

harcourtYee_82

Harcourt and Yee equation of development rate as a function of temperature.

Description


Usage

harcourtYee_82
Format

A list of eight elements describing the equation.

- **eq** The equation (formula object).
- **eqAlt** The equation (string).
- **name** The name of the equation.
- **ref** The equation reference.
- **refShort** The equation reference shortened.
- **startVal** The parameters found in the literature with their references.
- **com** An optional comment about the equation use.
- **id** An id to identify the equation.

Details

Equation:

\[ rT = a_0 + a_1 \ast T + a_2 \ast T^2 + a_3 \ast T^3 \]

where \( rT \) is the development rate, \( T \) the temperature, and \( a_0, a_1, a_2, \) and \( a_3 \) are constants.

Source

[http://dx.doi.org/10.1093/ee/11.3.581](http://dx.doi.org/10.1093/ee/11.3.581)

---


**Usage**

hilbertLogan_83

**Format**

A list of eight elements describing the equation.

- **eq** The equation (formula object).
- **eqAlt** The equation (string).
- **name** The name of the equation.
- **ref** The equation reference.
The equation reference shortened.

The parameters found in the literature with their references.

An optional comment about the equation use.

An id to identify the equation.

Details

Equation:

\[ rT = \phi \ast \left( \left( \frac{(T - Tb)^2}{(T - Tb)^2 + aa^2} \right) - e^{-\frac{T_{max} - (T - Tb)}{deltaT}} \right) \]

where \( rT \) is the development rate, \( T \) the temperature, \( Tb \) the minimum temperature for development, \( deltaT \) the width of high temperature boundary area, \( Tmax \) the maximum temperature, and \( aa \) a constant.

Source

http://dx.doi.org/10.1093/ee/12.1.1

Description


Usage

janisch_32
Format

A list of eight elements describing the equation.

eq The equation (formula object).

eqAlt The equation (string).

name The name of the equation.

ref The equation reference.

refShort The equation reference shortened.

startVal The parameters found in the literature with their references.

com An optional comment about the equation use.

id An id to identify the equation.

Details

Equation:

\[ r_T = \left( \frac{D_{\text{min}}}{2} \times (e^{aa(T-Topt)} + e^{bb(T-Topt)}) \right)^{-1} \]

where \( r_T \) is the development rate, \( T \) the temperature, \( Topt \) the optimum temperature, \( D_{\text{min}}, aa, \) and \( bb \) constants.

Source

http://dx.doi.org/10.1111/j.1365-2311.1932.tb03305.x

Description


Usage

kontodimas_04
Equation:

\[ rT = aa \ast (T - Tmin)^2 \ast (Tmax - T) \]

where \( rT \) is the development rate, \( T \) the temperature, \( Tmin \) the minimum temperature, \( Tmax \) the maximum temperature, and \( aa \) a constant.

Source

http://ee.oxfordjournals.org/content/33/1/1

Description


Usage

lactin1_95
The development rate, \( r_T \), as a function of temperature, \( T \), and fitted parameters is given by:

\[
r_T = e^{aa \times T} - e^{aa \times T_{max}} - \frac{T_{max} - T}{\Delta T}
\]

where \( r_T \) is the development rate, \( T \) the temperature, and \( aa, T_{max}, \) and \( \Delta T \) fitted parameters.

Source

http://dx.doi.org/10.1093/ee/24.1.68

Description


Usage

lactin2_95

Format

A list of eight elements describing the equation.

eq The equation (formula object).
eqAlt The equation (string).
name The name of the equation.
ref The equation reference.
refShort The equation reference shortened.
startVal The parameters found in the literature with their references.
com An optional comment about the equation use.
id An id to identify the equation.
Details

Equation:

\[ rT = e^{aa_T} - e^{aa_{T_{\text{max}} - T_{\text{max}} - T_{\text{max}} - T_{\text{deltaT}}}} + bb \]

where \( rT \) is the development rate, \( T \) the temperature, and \( aa, bb, T_{\text{max}}, \) and \( \text{deltaT} \) fitted parameters.

Source

http://dx.doi.org/10.1093/ee/24.1.68

Description


Usage

lamb_92

Format

A list of eight elements describing the equation.

- eq: The equation (formula object).
- eqAlt: The equation (string).
- name: The name of the equation.
- ref: The equation reference.
- refShort: The equation reference shortened.
- startVal: The parameters found in the literature with their references.
- com: An optional comment about the equation use.
- id: An id to identify the equation.

Details

Equation:

\[ rT = Rm \ast e^{-\frac{1}{2\pi}(\frac{T - T_{\text{max}}}{T_{\text{deltaT}}})^2} \]

and

\[ rT = Rm \ast e^{-\frac{1}{2\pi}(\frac{T - T_{\text{max}}}{T_{\text{deltaT}}})^2} \]

where \( rT \) is the development rate, \( T \) the temperature, \( Rm \) the maximum development rate, \( T_{\text{max}} \) the optimum temperature, and \( T_0 \) and \( T_1 \) the shape parameter giving the spread of the curve.
Logan et al. equation 10 of development rate as a function of temperature.

Equation:

\[ r_T = \alpha \frac{1}{1 + cc \times e^{-bb \times T}} - e^{-\frac{T_{max} - T}{\delta T}} \]

where \( r_T \) is the development rate, \( T \) the temperature, \( T_{max} \) the maximum temperature, \( \delta T \) the width of the high temperature boundary layer, and \( \alpha \) and \( bb \) constants.

Source

http://dx.doi.org/10.1093/ee/5.6.1133
Logan et al. equation 6 of development rate as a function of temperature.

Description


Usage

10gan6_76

Format

A list of eight elements describing the equation.

  eq  The equation (formula object).
  eqAlt The equation (string).
  name The name of the equation.
  ref  The equation reference.
  refShort The equation reference shortened.
  startVal The parameters found in the literature with their references.
  com  An optional comment about the equation use.
  id   An id to identify the equation.

Details

Equation:

\[ rT = \phi (e^{bbT} - e^{bbT_{max} - \frac{T_{max} - T}{\delta T}}) \]

where \( rT \) is the development rate, \( T \) the temperature, \( T_{max} \) the maximum temperature, \( \delta T \) the width of the high temperature boundary layer, \( \phi \) the developmental rate at some base temperature above developmental threshold, and \( bb \) a constant.

Source

http://dx.doi.org/10.1093/ee/5.6.1133
Description


Usage

perf2_11

Format

A list of eight elements describing the equation.

eq The equation (formula object).
eqAlt The equation (string).
name The name of the equation.
ref The equation reference.
refShort The equation reference shortened.
startVal The parameters found in the literature with their references.
com An optional comment about the equation use.
id An id to identify the equation.

Details

Equation:

\[ rT = cc \times (T - T1) \times (1 - e^{k \times (T - T2)}) \]

where \( rT \) is the development rate, \( T \) the temperature, \( T1 \) and \( T2 \) the conceptual lower and upper developmental thresholds at which development rates equal zero, and \( cc \) and \( k \) constants.

Source

http://dx.doi.org/10.1016/j.aspen.2010.11.008
poly2

Second-order polynomial equation of development rate as a function of temperature.

Description

A simple second-order polynomial equation.

Usage

poly2

Format

A list of eight elements describing the equation.

- eq: The equation (formula object).
- eqAlt: The equation (string).
- name: The name of the equation.
- ref: The equation reference.
- refShort: The equation reference shortened.
- startVal: The parameters found in the literature with their references.
- com: An optional comment about the equation use.
- id: An id to identify the equation.

Details

Equation:

\[ rT = a0 + a1 \times T + a2 \times T^2 \]

where \( rT \) is the development rate, \( T \) the temperature, and \( a0, a1, \) and \( a2 \) are constants.

poly4

Fourth-order polynomial equation of development rate as a function of temperature.

Description

A simple fourth-order polynomial equation.

Usage

poly4
Format

A list of eight elements describing the equation.

- **eq**: The equation (formula object).
- **eqAlt**: The equation (string).
- **name**: The name of the equation.
- **ref**: The equation reference.
- **refShort**: The equation reference shortened.
- **startVal**: The parameters found in the literature with their references.
- **com**: An optional comment about the equation use.
- **id**: An id to identify the equation.

Details

Equation:

\[ rT = a0 + a1 \times T + a2 \times T^2 + a3 \times T^3 + a4 \times T^4 \]

where \( rT \) is the development rate, \( T \) the temperature, and \( a0, a1, a2, a3, \) and \( a4 \) are constants.

<table>
<thead>
<tr>
<th>ratkowsky_82</th>
<th>Ratkowsky equation of development rate as a function of temperature (Shi modification).</th>
</tr>
</thead>
</table>

Description


Usage

ratkowsky_82
Format

A list of eight elements describing the equation.

- **eq** The equation (formula object).
- **eqAlt** The equation (string).
- **name** The name of the equation.
- **ref** The equation reference.
- **refShort** The equation reference shortened.
- **startVal** The parameters found in the literature with their references.
- **com** An optional comment about the equation use.
- **id** An id to identify the equation.

Details

Equation:

\[ rT = \left( \sqrt{cc} \times k1 \times (T - T1) \times (1 - e^{k2*(T-T2)}) \right)^2 \]

where \( rT \) is the development rate, \( T \) the temperature, \( T1 \) and \( T2 \) the minimum and maximum temperatures at which rate of growth is zero, \( \sqrt{cc} \times k1 \) the slope of the regression as in the rootsq_82 equation, and \( k2 \) a constant. The Ratkowsky model designed for microorganisms has been modified by Shi et al. 2011 to describe the temperature-dependent development rates of insects.

Source

- [http://jb.asm.org/content/149/1/1](http://jb.asm.org/content/149/1/1)
- [http://jb.asm.org/content/154/3/1222](http://jb.asm.org/content/154/3/1222)

---

**Description**


**Usage**

ratkowsky_83
Format

A list of eight elements describing the equation.

eq The equation (formula object).
eqAlt The equation (string).
name The name of the equation.
ref The equation reference.
refShort The equation reference shortened.
startVal The parameters found in the literature with their references.
com An optional comment about the equation use.
id An id to identify the equation.

Details

Equation:

\[ r_T = \left( cc \times (T - T_1) \times (1 - e^{k \times (T - T_2)}) \right)^2 \]

where \( r_T \) is the development rate, \( T \) the temperature, \( T_1 \) and \( T_2 \) the minimum and maximum temperatures at which rate of growth is zero, \( cc \) the slope of the regression as in the rootsq_82 equation, and \( k \) a constant. The Ratkowsky model designed for microorganisms has been modified by Shi et al. 2016 to describe the temperature-dependent development rates of insects.

Source

https://doi.org/10.1093/aesa/sav121
Format

A list of eight elements describing the equation.

eq The equation (formula object).
eqAlt The equation (string).
name The name of the equation.
ref The equation reference.
refShort The equation reference shortened.
startVal The parameters found in the literature with their references.
com An optional comment about the equation use.
id An id to identify the equation.

Details

Equation:

\[ rT = \phi \ast \left( e^{bb \ast (T - Tb)} \ast \frac{Tm - T}{Tm - Tb} \ast e^{-bb \ast \frac{T - Tb}{Tm - Tb}} - \frac{T - Tb}{Tm - Tb} \ast e^{bb \ast \frac{(Tm - Tb) - (Tm - T)}{Tm - Tb}} \right) \]

where \( rT \) is the development rate, \( T \) the temperature, \( Tb \) the minimum temperature, \( Tm \) the maximum temperature and \( \phi \), \( bb \), \( deltab \), and \( deltam \) constants (see source for more details).

Source

http://dx.doi.org/10.1016/j.jinsphys.2012.01.010

---

rootsq_82  
Root square equation of development rate as a function of temperature.

---

Description


Usage

rootsq_82
Format

A list of eight elements describing the equation.

**eq** The equation (formula object).
**eqAlt** The equation (string).
**name** The name of the equation.
**ref** The equation reference.
**refShort** The equation reference shortened.
**startVal** The parameters found in the literature with their references.
**com** An optional comment about the equation use.
**id** An id to identify the equation.

Details

Equation:

\[ r_T = (bb \ast (T - Tb))^2 \]

where \( r_T \) is the development rate, \( T \) the temperature, \( bb \) the slope of the regression line, and \( Tb \) a conceptual temperature of no metabolic significance.

Source

[http://jb.asm.org/content/149/1/1](http://jb.asm.org/content/149/1/1)

---

**schoolfieldHigh_81**  
Schoolfield et al. equation of development rate as a function of temperature for intermediate to high temperatures only.

Description


Usage

**schoolfieldHigh_81**
Format

A list of eight elements describing the equation.

- **eq** The equation (formula object).
- **eqAlt** The equation (string).
- **name** The name of the equation.
- **ref** The equation reference.
- **refShort** The equation reference shortened.
- **startVal** The parameters found in the literature with their references.
- **com** An optional comment about the equation use.
- **id** An id to identify the equation.

Details

Equation:

\[ rT = \frac{p25 \times T + 273.16 \times e^{\frac{\Delta a}{298} \times \left( \frac{1}{298} - \frac{1}{T + 273.16} \right)}}{1 + e^{\frac{\Delta d}{298} \times \left( \frac{1}{298} - \frac{1}{T + 273.16} \right)}} \]

where \( rT \) is the development rate, \( T \) the temperature, \( p25 \) the development rate at 25 degrees Celsius assuming no enzyme inactivation, \( \Delta a \) the enthalpy of activation of the reaction that is catalyzed by the enzyme, \( \Delta b \) the change in enthalpy associated with low temperature inactivation of the enzyme, \( \Delta c \) the temperature at which the enzyme is 1/2 active and 1/2 low temperature inactive, \( \Delta d \) the change in enthalpy associated with high temperature inactivation of the enzyme, and \( \Delta e \) the temperature at which the enzyme is 1/2 active and 1/2 high temperature inactive.

Source

http://dx.doi.org/10.1016/0022-5193(81)90246-0

Description


Usage

schoolfieldLow_81
Format

A list of eight elements describing the equation.

**eq**  The equation (formula object).

**eqAlt**  The equation (string).

**name**  The name of the equation.

**ref**  The equation reference.

**refShort**  The equation reference shortened.

**startVal**  The parameters found in the literature with their references.

**com**  An optional comment about the equation use.

**id**  An id to identify the equation.

Details

Equation:

\[
  r_T = \frac{p_{25} \times \frac{T+273.16}{298} \times e^{\frac{aa}{T+273.16}} \times (\frac{1}{T+273.16})}{1 + e^{\frac{bb}{T+273.16}} \times (\frac{1}{T+273.16})}
\]

where \( r_T \) is the development rate, \( T \) the temperature, \( p_{25} \) the development rate at 25 degrees Celsius assuming no enzyme inactivation, \( aa \) the enthalpy of activation of the reaction that is catalyzed by the enzyme, \( bb \) the change in enthalpy associated with low temperature inactivation of the enzyme, \( cc \) the the temperature at which the enzyme is 1/2 active and 1/2 low temperature inactive, \( dd \) the cange in enthalpy associated with high temperature inactivation of the enzyme, and \( ee \) the temperature at which the enzyme is 1/2 active and 1/2 high temperature inactive.

Source

http://dx.doi.org/10.1016/0022-5193(81)90246-0
**Format**

A list of eight elements describing the equation.

- **eq** The equation (formula object).
- **eqAlt** The equation (string).
- **name** The name of the equation.
- **ref** The equation reference.
- **refShort** The equation reference shortened.
- **startVal** The parameters found in the literature with their references.
- **com** An optional comment about the equation use.
- **id** An id to identify the equation.

**Details**

Equation:

\[
rT = \frac{p25 \times \left( T + 273.16 \right) + e^{\frac{aA}{T + 273.16}} \times \left( \frac{1}{298} - \frac{1}{T + 273.16} \right) + e^{\frac{aB}{T + 273.16}} \times \left( \frac{1}{298} - \frac{1}{T + 273.16} \right)}{1 + e^{\frac{aA}{T + 273.16}} \times \left( \frac{1}{298} - \frac{1}{T + 273.16} \right) + e^{\frac{aB}{T + 273.16}} \times \left( \frac{1}{298} - \frac{1}{T + 273.16} \right)}
\]

where \( rT \) is the development rate, \( T \) the temperature, \( p25 \) the development rate at 25 degree Celsius assuming no enzyme inactivation, \( aA \) the enthalpy of activation of the reaction that is catalyzed by the enzyme, \( aB \) the change in enthalpy associated with low temperature inactivation of the enzyme, \( cC \) the temperature at which the enzyme is 1/2 active and 1/2 low temperature inactive, \( dD \) the change in enthalpy associated with high temperature inactivation of the enzyme, and \( eE \) the temperature at which the enzyme is 1/2 active and 1/2 high temperature inactive.

**Source**

http://dx.doi.org/10.1016/0022-5193(81)90246-0

---

**Description**


**Usage**

sharpeDeMichele_77
Format

A list of eight elements describing the equation.

- **eq** The equation (formula object).
- **eqAlt** The equation (string).
- **name** The name of the equation.
- **ref** The equation reference.
- **refShort** The equation reference shortened.
- **startVal** The parameters found in the literature with their references.
- **com** An optional comment about the equation use.
- **id** An id to identify the equation.

Details

Equation:

\[
\begin{align*}
    r_T &= \frac{(T + 273.16) \times e^{aa - \frac{bb}{T + 273.16}} \times e^{cc - \frac{dd}{T + 273.16}} \times e^{ff - \frac{gg}{T + 273.16}}}{1 + e^{cc - \frac{dd}{T + 273.16}} + e^{ff - \frac{gg}{T + 273.16}}} \\
    \end{align*}
\]

where \( r_T \) is the development rate, \( T \) the temperature, and \( aa, bb, cc, dd, ff, \) and \( gg \) thermodynamic parameters.

Source

[http://dx.doi.org/10.1016/0022-5193(77)90265-X](http://dx.doi.org/10.1016/0022-5193(77)90265-X)

---

**shi_11**  
*Shi equation of development rate as a function of temperature.*

Description


Usage

shi_11
Format

A list of eight elements describing the equation.

eq The equation (formula object).
eqAlt The equation (string).
name The name of the equation.
ref The equation reference.
refShort The equation reference shortened.
startVal The parameters found in the literature with their references.
com An optional comment about the equation use.
id An id to identify the equation.

Details

Equation:

\[ r_T = cc \times (1 - e^{-k_1 \times (T - T_1)}) \times (1 - e^{k_2 \times (T - T_2)}) \]

where \( r_T \) is the development rate, \( T \) the temperature, \( T_1 \) and \( T_2 \) the conceptual lower and upper developmental thresholds at which development rates equal zero, and \( cc \), \( k_1 \), and \( k_2 \) constants.

Source

http://dx.doi.org/10.1016/j.aspen.2010.11.008

Description


Usage

stinner_74

Format

A list of eight elements describing the equation.

eq The equation (formula object).
eqAlt The equation (string).
name The name of the equation.
ref The equation reference.
refShort The equation reference shortened.
The development rate, $r_T$, can be described by the following equations:

\[ r_T = \frac{C}{1 + e^{k_1 + k_2 T}} \]

and

\[ r_T = \frac{C}{1 + e^{k_1 + k_2 (2T_{\text{opt}} - T)}} \]

where $r_T$ is the development rate, $T$ the temperature, $T_{\text{opt}}$ the optimum temperature, $k_1$ and $k_2$ constants. "[...] the relationship [is] inverted when the temperature is above an optimum [...] $T = 2^* T_{\text{opt}} - T$ for $T \geq T_{\text{opt}}$."

Source

http://dx.doi.org/10.4039/Ent106519-5

Description


Usage

taylor_81

Format

A list of eight elements describing the equation.

eq The equation (formula object).
eqAlt The equation (string).
name The name of the equation.
ref The equation reference.
refShort The equation reference shortened.
startVal The parameters found in the literature with their references.
com An optional comment about the equation use.
id An id to identify the equation.
Details

Equation:

\[ r_T = R_m \ast e^{-\frac{1}{2} \ast \left(\frac{T - T_m}{T_0}\right)^2} \]

where \( r_T \) is the development rate, \( T \) the temperature, \( R_m \) the maximum development rate, \( T_m \) the optimum temperature, and \( T_0 \) the rate at which development rate falls away from \( T_m \).

Source

http://www.jstor.org/stable/2460694

Description


Usage

wagner_88

Format

A list of eight elements describing the equation.

eq The equation (formula object).
eqAlt The equation (string).
name The name of the equation.
ref The equation reference.
refShort The equation reference shortened.
startVal The parameters found in the literature with their references.
com An optional comment about the equation use.
id An id to identify the equation.
Details

Equation:

\[ r_T = \frac{1}{1 + e^{-\theta \left( \frac{a_T - e}{e + T} \right)}} \]

where \( r_T \) is the development rate, \( T \) the temperature, and \( a_a, b_b, c_c, \) and \( d_d \) are thermodynamic parameters.

Source

https://doi.org/10.1093/aesa/77.2.208
http://dx.doi.org/10.1093/aesa/81.4.539

wangengel_98 Wang and Engel equation of development rate as a function of temperature.

Description


Usage

wangengel_98

Format

A list of eight elements describing the equation.

- eq The equation (formula object).
- eqAlt The equation (string).
- name The name of the equation.
- ref The equation reference.
- refShort The equation reference shortened.
- startVal The parameters found in the literature with their references.
- com An optional comment about the equation use.
- id An id to identify the equation.

Details

Equation:

\[ r_T = \frac{2 \ast (T - T_{min})^{aa} \ast (T_{opt} - T_{min})^{aa} - (T - T_{min})^{2 \ast aa}}{(T_{opt} - T_{min})^{2 \ast aa}} \]

where \( r_T \) is the development rate, \( T \) the temperature, \( T_{min} \) the minimum temperature, \( T_{opt} \) the optimum temperature, and \( aa \) a constant.
Wang et al. equation of development rate as a function of temperature.

**Description**


**Usage**

wang_82

**Format**

A list of eight elements describing the equation.

- **eq** The equation (formula object).
- **eqAlt** The equation (string).
- **name** The name of the equation.
- **ref** The equation reference.
- **refShort** The equation reference shortened.
- **startVal** The parameters found in the literature with their references.
- **com** An optional comment about the equation use.
- **id** An id to identify the equation.

**Details**

Equation:

\[ r_T = \frac{K}{1 + e^{-r(T-T_0)}} \times (1 - e^{\frac{T-T_L}{aT}}) \times (1 - e^{\frac{T-H-T}{aT}}) \]

where \( r_T \) is the development rate, \( T \) the temperature, and \( K, r, T_0, TH, \) and \( TL \) constants.

**Source**

http://en.cnki.com.cn
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*Topic datasets

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