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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:

\[ r_T = aa * (T - T_{min})^{bb} * (T_{max} - T)^{cc} \]

where \( r_T \) is the development rate, \( T \) the temperature, \( T_{min} \) the minimum temperature, \( T_{max} \) the maximum temperature, and \( aa, bb, \) and \( cc \) constants.
References


bayoh_03 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:

\[ rT = aa + bb \times T + cc \times e^T + dd \times e^{-T} \]

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

References

doi:10.1079/BER2003259
Beta2 equation of development rate as a function of temperature.

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:

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

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

References

doi:10.1016/j.ecolmodel.2015.09.012
**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.

**References**

doi:10.1016/01681923(95)02236Q
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:

\[ r_T = aa \times (T - Tmin) - (bb \times e^{T - Tm}) \]

where \( r_T \) is the development rate, \( T \) the temperature, \( Tmin \) the minimum temperature, and \( aa, bb, \) and \( Tm \) fitted coefficients.

References

http://www.e-periodica.ch
Equation:

\[ rT = aa \times T \times (T - Tmin) \times (Tmax - T)^{\frac{1}{2}} \]

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

References

doi: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:

\[ rT = aa \times T \times (T - Tmin) \times (Tmax - T)^{\frac{1}{bb}} \]

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.

References

doi:10.1093/ee/28.1.22
| campbell_74 | 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:

\[ rT = aa + bb \times T \]

where \( rT \) is the development rate, \( T \) the temperature, \( bb \) the slope, and \( aa \) the point at which the line crosses the \( rT \) axis when \( T = 0 \).
Simplified beta type equation of development rate as a function of temperature.

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:

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

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

References

doi: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.

References

doi:10.1155/2012/123405

**Description**

Davidson equation of development rate as a function of temperature.

**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:

\[ r_T = \frac{K}{1 + e^{aa + bb \times T}} \]

where \( r_T \) is the development rate, \( T \) the temperature, \( K \) the distance between the upper and lower asymptote of the curve, \( aa \) the relative position of the origin of the curve on the abscissa, \( bb \) the degree of acceleration of development of the life stage in relation to temperature.
devRate: A package to quantify the relationship between development rate and temperature in ectotherms.

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 exist 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.

devRateEqStartVal

Default starting values for each equation listed in the devRateEqList object.

Description

Default starting values for each equation listed in the devRateEqList object.

Usage

devRateEqStartVal

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.

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",]
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

\[
\text{devRateIBM}(\text{tempTS, timeStepTS, models, numInd = 100, stocha, timeLayEggs = 1})
\]

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

```
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.
umInd 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

forecastLactin2_95 <- devRateIBMdataBase(
  tempTS = rnorm(n = 20, mean = 20, sd = 1),
  timeStepTS = 10,
devRateIBMgen

devRateIBMgen(eq = lactin2_95,
              species = "Sesamia nonagrioides",
              lifeStages = c("eggs", "larva", "pupa"),
              numInd = 10,
              stocha = 0.015,
              timeLayEggs = 1)

---

devRateIBMgen  Number of generations

Description

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

Usage

devRateIBMgen(ibm)

Arguments

ibm  The phenology model returned by devRateIBM function.

Value

The simulated number of generations.

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)
devRateIBMgen(ibm = forecastTsolanivora)
devRateIBMparam  

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

Description

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

Usage

devRateIBMparam(
  tempTS,
  timeStepTS,
  eq,
  myParam,
  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).
myParam       The known parameters for the equation (a list of list for each life stage).
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).

Details

Please note that this function is experimental and only works for the briere2_99 equation.

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

# with only one life stage
forecastX <- devRateIBMparam(
  tempTS = rnorm(n = 20, mean = 20, sd = 1),
  timeStepTS = 10,
  eq = briere2_99,
  myParam = list(
    list(
      aa = 0.0002,
      Tmin = 10,
      Tmax = 36.1,
      bb = 2.84
    ),
    numInd = 10,
    stocha = 0.015,
    timeLayEggs = 1
  )
)

# with two life stages
forecastXX <- devRateIBMparam(
  tempTS = rnorm(n = 20, mean = 20, sd = 1),
  timeStepTS = 10,
  eq = briere2_99,
  myParam = list(
    lifeStage01 = list(
      aa = 0.0002,
      Tmin = 10,
      Tmax = 36.1,
      bb = 2.84
    ),
    lifeStage02 = list(
      aa = 0.0004,
      Tmin = 8,
      Tmax = 35,
      bb = 2.8
    ),
    numInd = 10,
    stocha = 0.015,
    timeLayEggs = 1
  )
)

---

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

```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)
devRateIBMPlot(ibm = forecastTsolanivora, typeG = "density", threshold = 0.1)
devRateIBMPlot(ibm = forecastTsolanivora, typeG = "hist")
```

Description

Display information about an equation

Usage

```r
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)
```
devRateMap

Predict development rate from a matrix of temperatures

Description

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

Usage

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

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

devRateModel(eq, temp, devRate, startValues, dfData = NULL, algo = "GN", ...)
Arguments

- **eq**
  The name of the equation. See `devRateEqList` for the list of equations.
- **temp**
  The temperature (vector).
- **devRate**
  The development rate (days)^{-1} (vector).
- **startValues**
  Starting values for the regression (list).
- **dfData**
  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).
- **algo**
  The abbreviated name of the algorithm used for model fitting ("GN" for Gauss-Newton algorithm, "LM" for Levenberg-Marquardt algorithm; "GN" is the default value).
- ... 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 dfData.

NULL is returned when an unknown algorithm is entered.

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,
)```
devRateModelAll

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,
    dfData = myDF)

devRateModelAll  Fitting all models listed in devRateEqList to a development rate
dataset

Description

This function fits all models listed in devRateEqList to a development rate dataset and then calculates a series of indices of goodness-of-fit for each fitted model.

Usage

devRateModelAll(
    dfData,
    eqList = devRate::devRateEqList,
    eqStartVal = devRate::devRateEqStartVal,
    propThresh = 0.01,
    interval = c(0, 50),
    ...
)

Arguments

dfData  A data.frame with the temperature in the first column and the development rate in the second column.

eqList  A list of models that can be retrieved from the object devRateEqList. The default value is the object devRateEqList.

eqStartVal  A list of starting values for each model. The default value is the object devRateEqStartVal.

propThresh  The proportion of maximal development rate used as a threshold for estimating XTmin and XTmax for asymptotic equations (default value is 0.01)

interval  A vector containing the lower and upper boundaries of the interval of temperatures in which metrics are searched.

...  Additional arguments for the devRateModel function.
Details

Equations stinner_74 and lamb_92 are fitted and the resulting nls objects are showed in the first
element of the returned list, however indices of goodness-of-fit are not provided. Equation camp-
bell_74 is not fitted (simple linear model).

Value

An object of class list with two elements. The first element is a list with all the nls objects. The
second element is a data.frame. In the data.frame, the first column corresponds to model names
and the second column to the number of parameters. The columns 3 to 6 correspond to the results
of the function devRateQlStat, i.e. RSS, RMSE, AIC, and BIC. The columns 7 to 11 correspond
to the results of the function devRateQlBio, i.e. CTmin, CTmax, Topt, XTmin, and XTmax.

Examples

myDf <- exTropicalMoth$raw$egg
devRateModelAll(dfData = myDf)

devRatePlot(eq, nlsDR, rangeT = 10, optText = TRUE, spe = TRUE, ...)

Description

Plot the empirical points and the regression

Usage

devRatePlot(eq, nlsDR, rangeT = 10, optText = TRUE, spe = TRUE, ...)

Arguments

eq The name of the equation.
nlsDR The result returned by the devRateModel function.
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
topleft 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,
             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, doPlots = FALSE)

Arguments

myNLS An object of class NLS
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

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)

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)
**Biological likelihood of nls fits**

**Description**

Return a table of 5 metrics of development (CTmin, CTmax, Topt, XTmin, XTmax)

**Usage**

```r
devRateQlBio(nlsDR, propThresh = 0.01, eq, interval = c(0, 50))
```

**Arguments**

- `nlsDR`: A list of nls objects.
- `propThresh`: The proportion of maximal development rate used as a threshold for estimating XTmin and XTmax for asymptotic equations (default value is 0.01)
- `eq`: A list of equations used for nls fitting.
- `interval`: A vector containing the lower and upper boundaries of the interval of temperatures in which metrics are searched.

**Details**

NULL is returned when nlsDR or eq are not a list.

**Value**

An object of class `data.frame` with development metrics (CTmin, Ctmax, Topt, XTmin, XTmax) in columns and nls objects in rows.

**Examples**

```r
myDf <- data.frame(temp = seq(from = 0, to = 50, by = 10),
                   rT = c(0.001, 0.008, 0.02, 0.03, 0.018, 0.004))
myNLS <- list(
  devRateModel(eq = janisch_32, df = myDf, startValues = list(aa = 0.2, bb = 0.1, Dmin = 10, Topt = 30), algo = "LM"),
  devRateModel(eq = kontodimas_04, df = myDf, startValues = list(aa = 1, Tmin = 7, Tmax = 40), algo = "LM"),
  devRateModel(eq = poly2, df = myDf, startValues = list(a0 = 1, a1 = 1, a2 = 1),
```
devRateQlStat

Statistical indices of the nls goodness-of-fit

Description
Return a table of multiple statistical indices of goodness-of-fit

Usage
devRateQlStat(nlsDR)

Arguments
nlsDR A list of nls objects.

Details
NULL is returned when nlsDR is not of type list. AIC and BIC are calculated using the RSS (Burnham and Anderson, 2002).

Value
A data.frame with statistical indices in columns (RSS, RMSE, AIC, BIC) and nls objects in rows.

Examples
myDf <- data.frame(  
  temp = seq(from = 0, to = 50, by = 10),  
  rT = c(0.001, 0.008, 0.02, 0.03, 0.018, 0.004))
damos_08Fit <- devRateModel(  
  eq = damos_08,  
  dfData = myDf,  
  startValues = list(aa = 1, bb = 1, cc = 1),  
  algo = "LM")kontodimas_04Fit <- devRateModel(  
  eq = kontodimas_04,  
  dfData = myDf,  
  startValues = list(aa = 1, Tmin = 7, Tmax = 40),  
  algo = "LM")poly2Fit <- devRateModel(  
  eq = poly2,  
  dfData = myDf,  
  startValues = list(a0 = 1, a1 = 1, a2 = 1),  
  algo = "LM")
dRGetMetrics

```r
dRGetMetrics(  
  nlsDR = list(damos_08Fit, kontodimas_04Fit, poly2Fit)
)
```

---

**dRGetMetrics**

**Life traits from Thermal Performance Curve**

**Description**

Compute life traits from a Thermal Performance Curve

**Usage**

```r
dRGetMetrics(  
  nlsDR,  
  prec = 0.1,  
  lowTempLim = 0,  
  highTempLimit = 60,  
  devLimit = 0.01,  
  printOut = FALSE
)
```

**Arguments**

- `nlsDR` The object obtained from the `devRateModel` function.
- `prec` The precision for the temperature (default = 0.1 degree celsius).
- `lowTempLim` The minimum temperature for the metrics (default = 0 degree celsius).
- `highTempLimit` The maximum temperature for the metrics (default = +60 degree celsius).
- `devLimit` The development rate considered as null (default = 0.01).
- `printOut` A logical to print the result (default = FALSE).

**Value**

A matrix with one column and one row for each metric. The metrics names are the row names.

**Examples**

```r
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)
meEggs <- devRateModel(  
  eq = taylor_81,  
  temp = rawDevEggs[,1],  
  devRate = rawDevEggs[,2],  
  startValues = list(Rm = 0.05, Tm = 30, To = 5)
)
myMetrics <- dRGetMetrics(nlsDR = meEggs, printOut = TRUE)
```
Life traits from the ectotherm database

Usage

```r
dRGetMetricsInfo(
  eq,
  prec = 0.1,
  lowTempLim = 0,
  highTempLimit = 60,
  devLimit = 0.01,
  devThresh = 0.1,
  lifeStage = "all",
  colId = "genSp",
  printOut = FALSE
)
```

Arguments

- `eq` The name of the equation.
- `prec` The precision for the temperature (default = 0.1 degree celsius).
- `lowTempLim` The minimum temperature for the metrics (default = 0 degree celsius).
- `highTempLimit` The maximum temperature for the metrics (default = +60 degree celsius).
- `devLimit` The development rate considered as null (default = 0.01).
- `devThresh` The threshold in development rate to compute min and max temperature (default = 0.1).
- `lifeStage` The life stage on which the life traits should be computed (default = "all"; specify "" to take into account all life stages).
- `colId` The organism information for each column (default = genSp; choices = "ordersp" for Order, "familysp" for Family, "genussp" for Genus, "species" for species, and "gensp" for Genus and species).
- `printOut` A logical to print the result (default = FALSE).

Value

A matrix with one column per organism and one row for each metric. The metrics names are the names of each row.

Examples

```r
dRGetMetricsInfo(eq = taylor_81)
dRGetMetricsInfo(eq = taylor_81, devThresh = 0.1)
```
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

Description

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

Usage

harcourtYee_82

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:

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

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

**References**

doi:10.1093/ee/11.3.581

---

 hilbertLogan_83 | Holling type III equation of development rate as a function of temperature.

---

**Description**


**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:

\[ r_T = \phi \times \left( \frac{(T - T_b)^2}{(T - T_b)^2 + aa^2} \right) - e^{-\frac{T_{max} - (T - T_b)}{deltaT}} \]

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

References

doi: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:

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

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

References

doi:10.1111/j.13652311.1932.tb03305.x

<table>
<thead>
<tr>
<th>kontodimas_04</th>
<th>Kontodimas et al. equation of development rate as a function of temperature.</th>
</tr>
</thead>
</table>

Description


Usage

kontodimas_04
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:

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

where \( r_T \) is the development rate, \( T \) the temperature, \( T_{min} \) the minimum temperature, \( T_{max} \) the maximum temperature, and \( a_a \) a constant.

References

[https://academic.oup.com/ee/article/33/1/1/477793/](https://academic.oup.com/ee/article/33/1/1/477793/)

lactin1_95  |  *Lactin et al. equation 1 of development rate as a function of temperature.*

Description


Usage

lactin1_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.
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:

\[ rT = e^{aa \times T} - e^{aa \times Tmax - \frac{Tmax - T}{deltat}} \]

where \( rT \) is the development rate, \( T \) the temperature, and \( aa \), \( Tmax \), and \( deltaT \) fitted parameters.

References

doi: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:

\[ rT = e^{aaT} - e^{aaT_{\text{max}} - \frac{T_{\text{max}} - T}{\text{delta}T}} + bb \]

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

References

doi:10.1093/ee/24.1.68

Lamb equation of development rate as a function of temperature.

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:

\[ rT = Rm \cdot e^{-\frac{1}{2} \cdot \left( \frac{T - T_{\text{max}}}{To} \right)^2} \]

and

\[ rT = Rm \cdot e^{-\frac{1}{2} \cdot \left( \frac{T - T_{\text{max}}}{T_1} \right)^2} \]

where \( rT \) is the development rate, \( T \) the temperature, \( Rm \) the maximum development rate, \( T_{\text{max}} \) the optimum temperature, and \( To \) and \( T_1 \) the shape parameter giving the spread of the curve.
References

doi:10.1093/ee/21.1.10

Logan et al. equation 10 of development rate as a function of temperature.

Description


Usage

logan10_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:

\[
rT = \alpha \left( \frac{1}{1 + cc \cdot e^{-bb \cdot T}} - e^{-\frac{T_{max} - T}{\delta T}} \right)
\]

where \( rT \) 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.

References

doi:10.1093/ee/5.6.1133
Description


Usage

1logan6_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:

\[ r_T = \phi \times (e^{bb \times T} - e^{bb \times T_{max}} - \frac{T_{max} - T}{\delta T}) \]

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, \( \phi \) the developmental rate at some base temperature above developmental threshold, and \( bb \) a constant.

References

doi:10.1093/ee/5.6.1133
perf2_11  

Performance-2 equation of development rate as a function of temperature.

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:

\[ r_T = cc \ast (T - T_1) \ast (1 - e^{k \ast (T - T_2)}) \]

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 \( cc \) and \( k \) constants.

References

doi: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:

\[ r_T = a_0 + a_1 \times T + a_2 \times T^2 \]

where \( r_T \) is the development rate, \( T \) the temperature, and \( a_0, a_1, \) and \( a_2 \) 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

- 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:

\[ rT = a_0 + a_1 \times T + a_2 \times T^2 + a_3 \times T^3 + a_4 \times T^4 \]

where \( rT \) is the development rate, \( T \) the temperature, and \( a_0, a_1, a_2, a_3, \) and \( a_4 \) are constants.

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:

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

where \( rT \) is the development rate, \( T \) the temperature, \( T1 \) and \( T2 \) the minimum and maximum temperatures at which rate of growth is zero, \( \sqrt{cc} \ast k1 \) 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.

**References**

- doi:10.1128/jb.149.1.15.1982

**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:

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

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.

References

doi:10.1093/esa/sav121

Description

Usage

regniere_12
Eq
The equation (formula object).

\textit{eqAlt} The equation (string).

name The name of the equation.

ref The equation reference.

\textit{refShort} The equation reference shortened.

\textit{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{equation}
\text{eq} = \text{eqAlt} = \text{name} = \text{ref} = \text{refShort} = \text{startVal} = \text{com} = \text{id} = T = Tb = Tm = \phi = \text{bb} = \text{deltab} = \text{deltam} = 1 - 5.
\end{equation}

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

References

\texttt{doi:10.1016/j.jinsphys.2012.01.010}

---

\textit{rootsq\_82} Root square equation of development rate as a function of temperature.

Description


Usage

\textit{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:

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

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

References

- doi:10.1128/jb.149.1.15.1982

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:

\[
 r_T = \frac{p_{25} * T^{2.7316} * e^{\frac{aa}{1298}} \left(1 - \frac{1}{T + 273.16} \right)}{1 + e^{\frac{dd}{1298}} * \left(1 - \frac{1}{T + 273.16} \right)}
\]

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 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.

**References**

doi: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:

\[
rT = \frac{p25 \cdot T + 273.16 + e^{\frac{aa}{298} \cdot (\frac{1}{298} - \frac{1}{T+273.16})}}{1 + e^{\frac{bb}{298} \cdot (\frac{1}{298} - \frac{1}{T+273.16})}}
\]

where \( rT \) is the development rate, \( T \) the temperature, \( p25 \) 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 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.

References

[10.1016/00225193(81)902460](https://doi.org/10.1016/00225193(81)902460)

**schoolfield_81** *Schoolfield et al. equation of development rate as a function of temperature.*

Description


Usage

**schoolfield_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:

\[ rT = \frac{p_{25} \cdot \frac{T + 273.16}{298} \cdot e^{\frac{aa}{T + 273.16}} \cdot \left(\frac{1}{e^{\frac{bb}{T + 273.16}}} + \frac{1}{e^{\frac{cc}{T + 273.16}}} + \frac{1}{e^{\frac{dd}{T + 273.16}}} + \frac{1}{e^{\frac{ee}{T + 273.16}}} \right)}{1 + e^{\frac{aa}{T + 273.16}} \cdot \left(\frac{1}{e^{\frac{bb}{T + 273.16}}} + \frac{1}{e^{\frac{cc}{T + 273.16}}} + \frac{1}{e^{\frac{dd}{T + 273.16}}} + \frac{1}{e^{\frac{ee}{T + 273.16}}} \right)} \]

where \( rT \) is the development rate, \( T \) the temperature, \( p_{25} \) 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, \( bb \) 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.

**References**

[doi:10.1016/00225193(81)902460](https://doi.org/10.1016/00225193(81)902460)

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**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:

\[
    rT = (T + 273.16) \times e^{\frac{aa - bb}{1.087}} - \frac{cc - dd}{1.087} + e^{\frac{ff - gg}{1.087}}
\]

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

References

doi:10.1016/00225193(77)90265X

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:

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

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 \( cc, k1, \) and \( k2 \) constants.

References

doi:10.1016/j.aspen.2010.11.008

stinner_74 Stinner et al equation of development rate as a function of temperature.

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.
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:

\[ rT = \frac{C}{1 + e^{k1+k2*2T}} \]

and

\[ rT = \frac{C}{1 + e^{k1+k2*(2*Topt-T)}} \]

where \( rT \) is the development rate, \( T \) the temperature, \( Topt \) the optimum temperature, \( k1 \) and \( k2 \) constants. "[...] the relationship [is] inverted when the temperature is above an optimum [...] T = 2 * Topt - T for T >= Topt." Stinner et al. 1974.

References

doi:10.4039/Ent1065195

taylor_81 Taylor equation of development rate as a function of temperature.

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:

\[ rT = R_m + e^{-\frac{1}{2} \left( \frac{T - T_m}{T_m} \right)^2} \]

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

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:

\[ rT = \frac{1}{\frac{1}{a_a + \frac{\text{bb}}{T + 298.15}} \cdot \frac{\text{cc}}{T + 298.15} + \frac{\text{dd}}{T + 298.15} \cdot \frac{\text{ee}}{T + 298.15} + 1} \]

where \( rT \) is the development rate, \( T \) the temperature, and \( a_a, \text{bb}, \text{cc}, \) and \( \text{dd} \) are thermodynamic parameters.
Wang and Engel equation of development rate as a function of temperature.

Equation:
\[ r_T = 2 \times (T - T_{min})^{aa} \times (T_{opt} - T_{min})^{aa} - (T - T_{min})^{2 \times aa} \]

\[(T_{opt} - T_{min})^{2 \times aa}\]

where \( r_T \) is the development rate, \( T \) the temperature, \( T_{min} \) the minimum temperature, \( T_{opt} \) the optimum temperature, and \( aa \) a constant.

References

doi:10.1016/S0308-521X(98)000286
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:

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

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

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