

Package ‘windAC’

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Title Area Correction Methods

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Description Post-construction fatality monitoring studies at wind facilities are based on data from searches for bird and bat carcasses in plots beneath turbines. Bird and bat carcasses can fall outside of the search plot. Bird and bat carcasses from wind turbines often fall outside of the searched area. To compensate, area correction (AC) estimations are calculated to estimate the percentage of fatalities that fall within the searched area versus those that fall outside of it. This package provides two likelihood based methods and one physics based method (Hull and Muir (2010) <[doi:10.1080/14486563.2010.9725253](https://doi.org/10.1080/14486563.2010.9725253)>, Huso and Dalthorp (2014) <[doi:10.1002/jwmg.663](https://doi.org/10.1002/jwmg.663)>) to estimate the carcass fall distribution. There are also functions for calculating the proportion of area searched within one unit annuli, log logistic distribution functions, and truncated distribution functions.

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calcAC

Calculate the area correction value(s) with confidence intervals

Description

Use a fitted carcass density distribution and data describing the search area to calculate area correction values and confidence intervals using a parametric bootstrap approach.

Usage

```
calcAC(
  distribution,
  paramVec,
  varcovVec = NULL,
  proportionSearchDF,
  distanceCol,
  proportionCol,
  additionalCol = NULL,
  nBoot = NULL,
```

```

    truncBounds = NULL,
    ciLevel = 0.9,
    randomSeed = NULL,
    ...
)

```

Arguments

distribution	Character indicating the distribution, passed to getDistanceProbability .
paramVec	Numeric vector for the parameters associated with distribution. Assumed to be in the same order as the function indicated by <code>distribution</code> .
varcovVec	Numeric vector for the variances and covariances for <code>paramVec</code> , default is <code>NULL</code> , see details.
proportionSearchDF	Data frame with at least two columns: distance of the outer edge of an annulus from turbine and proportion of area searched within each annulus.
distanceCol	Character indicating the column name for the distance from turbine
proportionCol	Character indicating the column name for the proportion of area searched.
additionalCol	Character vector, default is <code>NULL</code> , indicating additional columns of how the area correction value should be calculated, see details and examples.
nBoot	Integer, indicating the number of parametric bootstrap replicates to use. Default is <code>NULL</code> , and not confidence intervals are produced.
truncBounds	Numeric, indicating bounds for the area correction calculation, see details. Default is <code>NULL</code> , and the bounds are set to $c(0, Inf)$.
ciLevel	Numeric, default is 0.9, desired confidence level for the bootstrap confidence interval.
randomSeed	Numeric value of random seed, default is <code>NULL</code> .
...	Additional arguments passed to getDistanceProbability and rmvnorm .

Details

The function [getDistanceProbability](#) is used to calculate the probability (fraction of carcasses) in the intervals between distances in `proportionSearchDF`.

The `truncBounds` argument defaults to zero as a lower bound and infinity as the upper bound. If a single value is provided, it is assumed as the upper bound with zero as the lower bound. If two or more values are provided, the $\max(\text{truncBounds})$ is the upper bound and $\min(\text{truncBounds})$ is the lower bound.

If `varcovVec` is `NULL`, then parametric bootstrapping is impossible and a confidence interval is not estimated. The `varcovVec` should be in such an order that correctly fills the lower triangle including the diagonal. The first column is filled, then the second, and so on. This forms the variance-covariance matrix for the parameters.

If `nBoot` is greater than zero, a parametric bootstrap is done. Bootstrap parameters are generated using the [rmvnorm](#) function.

If the `additionalCol` argument is not `NULL`, separate area corrections are estimated for each unique value within the column.

Value

windAC object

See Also

[weightedLikelihood](#) [weightedDistribution](#) [getDistanceProbability](#)

Examples

```
## proportion of area searched data
data(proportionAreaSearched)

## no parametric bootstrap
noBootstrap <- calcAC(distribution = 'gamma',
  paramVec = c(2.483323, 0.02495139),
  varcovVec = NULL,
  proportionSearchDF = proportionAreaSearched,
  distanceCol = 'distanceFromTurbine',
  proportionCol = 'proportionAreaSearched',
  additionalCol = 'plotType')

## with a parametric bootstrap

withBootstrap <- calcAC(distribution = 'gamma',
  paramVec = c(2.483323, 0.02495139),
  varcovVec = c(0.041189428, 0.0008825275, 2.118081e-05),
  proportionSearchDF = proportionAreaSearched,
  distanceCol = 'distanceFromTurbine',
  proportionCol = 'proportionAreaSearched',
  additionalCol = 'plotType',
  nBoot = 10)
```

carcassDistance

Carcass distance example data set

Description

Example data set of carcass distance found during searches under wind turbines.

Usage

```
data(carcassDistance)
```

Format

A data frame with 56 rows and 6 variables:

season The season in which that carcass was found.

plotType The plot type (either FULL or RP) that was being searched when the carcass was found.

proportionTurbineType The proportion of turbines that have that plot type. For plotType=FULL the value is 0.1 and 0.9 for plotType=RP.

distanceFromTurbine Meters, carcass distance from the turbine.

compassBearingDegree Degrees, the compass bearing from the turbine to the carcass location. Zero degrees is north, 90 degrees is east, etc.

probabilityDetection The summarized probability of detection from the bias trial information.

Details

The fictitious wind farm has 100 turbines. For 90 turbines the search plot consists of the turbine pad and the road out to 100 meters (RP = road and pad). The remaining 10 turbines had full plots (FULL) that are circular with a radius of 100 meters. The wind farm was searched during two seasons: Spring and Fall.

The example carcasses are all the same size class (bats).

Bias trials are also done to account for searcher efficiency and carcass removal. These results are summarized as a probability of detection in the data set.

References

<https://tethys.pnnl.gov/publications/us-fish-wildlife-service-land-based-wind-energy-guidelines>

circleBoxInt

Integration of the intersection of a rectangle and a circle

Description

Calculates the area of the intersection between a rectangle and a circle.

Usage

```
circleBoxInt(R, S, L, ...)
```

Arguments

R	Numeric, circle radius.
S	Numeric, short side of the rectangle
L	Numeric, long side of the rectangle
...	Currently ignored.

Details

The rectangle is defined with lower left corner being the origin and upper right corner at (L, S). The area returned is the intersection between the circle, centered at the origin, and the rectangle.

If $R \leq S$ then $(\pi R^2)/4$ is returned.

If $R \geq \sqrt{S^2 + L^2}$ then $L * S$ is returned.

If $R \leq L$ then $R^2 * \sin^{-1}(S/R)/2 + S * \sqrt{(R^2 - S^2)}/2$ This is the area of a circle in the first quadrant between the horizontal line $y = S$

if $R > L$ and $R < \sqrt{S^2 + L^2}$ then

$$(R^2 * \sin^{-1}(S/R)/2 + S * \sqrt{(R^2 - S^2)}/2) - (R^2 * \sin^{-1}(B/R)/2 + S * \sqrt{(R^2 - B^2)}/2) + B * L$$

where $B = \sqrt{R^2 - L^2}$. In this case there is part of the circle to the right of the rectangle. First set of parenthesis is the area of the circle below S, the second set is the area below B. Subtracting the two gives the area between B and S. The rectangle defined by B and L needs to be added back in.

Value

Numeric value

Examples

```
radius <- 115
short <- 80
long <- 100
circleBoxInt(R=radius,S=short,L=long)

## not run
## the integral is the area inside the polygon

x <- seq(0,max(radius,long),length=100)
outlineY <- function(x,R,S,L){
  suppressWarnings(y <- sqrt(R^2-x^2))
  y[x>R] <- 0
  y[x>L] <- 0
  y[y>=S] <- S
  return(y)
}
y <- outlineY(x=x,R=radius,S=short,L=long)
plot(x,y,type='l',ylim=c(-10,short))
text(long,0,label='L',pos=1)
text(0,short,label='S',pos=1)
text(long,sqrt(radius^2-long^2),label='B',pos=4)
```

estTWL

*Truncated Weighted Likelihood Estimation***Description**

Maximum likelihood estimation of a (possibly truncated) probability density function is completed with weights on the likelihood.

Usage

```
estTWL(fatDist, fatW, distribution, plotBounds = NULL, ...)
```

```
weightedLikelihood(fatDist, fatW, distribution, plotBounds = NULL, ...)
```

Arguments

fatDist	Vector of fatality distances from the turbine.
fatW	Vector of weights, to weight the likelihood for estimation. This must be the same length as fatDist and is assumed to be in the same order as fatDist.
distribution	Character indicating the distribution for weightedLikelihood or vector for estTWL.
plotBounds	Vector of length 1 or 2. If the length is 2 (or greater) the max value is used as the upper truncation bound and the min value is used as the lower truncation bound. If the length is 1 this value is taken as the upper truncation bound and zero is set as the lower truncation bound. The default is NULL, in which case the bounds are zero and positive infinity.
...	Additional arguments passed to <code>optim</code> .

Details

The truncated likelihood for a single observation is

$$L^*(\theta|x_i) = \frac{f(x_i|\theta)}{\int_a^b f(y|\theta)dy}$$

Where x_i is fatDist, θ is the vector of parameters to be estimated, a and b correspond to the plotBounds and $f()$ is the distribution chosen.

The truncated weighted likelihood is

$$TWL(\theta|\underline{x}) = \prod_{i=1}^n L^*(\theta|x_i)^{w_i}$$

Where $n=\text{length}(\text{fatDist})$ and w_i is fatW.

The truncated weighted likelihood is then estimated using standard maximum likelihood techniques. See `estTWL` for examples.

Value

Data frame of the parameter estimates for the distribution with fit statistics.

See Also

[calcAC](#)

Examples

```
## load the data
data(carcassDistance)
data(proportionAreaSearched)

## add proportion of area searched to each carcass
carcDist <- merge(carcassDistance,proportionAreaSearched,
by=c('plotType','distanceFromTurbine'),all.x=TRUE)

## create the weight for each carcass
carcDist$w <- with(carcDist,1/(proportionAreaSearched*probabilityDetection))

twlOutput <- with(carcDist,estTWL(fatDist=distanceFromTurbine,fatW=w,plotBounds=c(0,100),
distribution=c('norm','weibull','gamma')))
```

 estWD

Weighted Distribution Estimation

Description

Maximum likelihood estimation of a weighted probability density function is completed. is done on a weighted distribution. The weighted distribution is a typical probability density distribution multiplied by a weight function. The weight function can be used to truncate the distribution by returning zero beyond some threshold value.

Usage

```
estWD(fatDist, weightFun, distribution, ...)
```

```
weightedDistribution(fatDist, weightFun, distribution, ...)
```

Arguments

fatDist	Vector of fatality distanes from the turbine.
weightFun	R function that is multiplied by the probability distribution, see details.
distribution	Character indicating the distribution for weightedDistribution or vector for estWD.
...	Additional arguments passed to weightFun or optim .

Details

The function `estWD` is a convenient wrapper function to `weightedDistribution`, for fitting multiple distributions.

The weight function should return a (relative) probability of detection at every distance. Typically this is the proportion of area searched. The function `weightFun` is set up to take a table of proportion of area searched and return values in a function format.

Let $h(x)$ be the weight function (`weightFun`), $f(x|\theta)$ be a probability density function (specified by distribution), x be the vector of carcass distances from the turbine (`fatDist`), and θ be the parameter vector to be estimated. The weighted distribution is

$$f_d(x|\theta) = \frac{h(x)f(x|\theta)}{\int h(y)f(y|\theta)dy}$$

The likelihood that is maximized is

$$L_d(\theta|\underline{x}) = \prod_{i=1}^n \frac{h(x_i)f(x_i|\theta)}{\int h(y)f(y|\theta)dy}$$

Value

Data frame of the parameter estimates with fit statistics.

See Also

[calcAC](#)

[weightFun](#)

Examples

```
## load the data
data(carcassDistance)
data(proportionAreaSearched)

#####
## fit for fall carcasses found on road and pad (RP)
distanceFallRP <- subset(carcassDistance,plotType=='RP'&season=='fall',
select=distanceFromTurbine,drop=TRUE)

fallRPfit <- estWD(fatDist=distanceFallRP,weightFun=weightFun,
distribution=c('norm','gamma','weibull'),propTable=proportionAreaSearched,type='RP',
typeCol='plotType',distanceCol='distanceFromTurbine',propCol='proportionAreaSearched',
maxDistance=100)

#####
## fit for fall carcasses found on full plots
distanceFallFP <- subset(carcassDistance,plotType=='FULL'&season=='fall',
select=distanceFromTurbine,drop=TRUE)
```

```
fallFPfit <- estWD(fatDist=distanceFallFP,weightFun=weightFun,
distribution=c('norm','gamma','weibull'),propTable=proportionAreaSearched,type='FULL',
typeCol='plotType',distanceCol='distanceFromTurbine',propCol='proportionAreaSearched',
maxDistance=100)
```

geometricRectanglePropSearchTable

Create proportion of area searched table for a rectangular full plot

Description

Calculate the areas of intersection of a series of nested annuli with a rectangle.

Usage

```
geometricRectanglePropSearchTable(
  side1,
  side2 = side1,
  mastRadius,
  annulusWidth = 1,
  ...
)
```

Arguments

side1	Numeric, length of the side of the rectangle
side2	Numeric, length of the second side of the rectangle, default is side1 which produces a square.
mastRadius	Integer, radius of the turbine mast.
annulusWidth	Integer, width of annulus, default is 1
...	Currently ignored.

Details

Searches are conducted around a turbine within a rectangle for bird and bat carcasses. This function creates a data frame of proportion of area searched within each annulus ring. The turbine is assumed to be centered within the rectangle.

Value

Data frame of proportion of area searched for each annulus. distanceFromTurbine column represents the outer radius of each annulus.

See Also

geometricRoadPadPropSearchTable circleBoxInt

Examples

```
## square 50 x 50
propSearch <- geometricRectanglePropSearchTable(side1 = 50,
                                                mastRadius = 2)
```

```
## square 50 x 70
propSearch <- geometricRectanglePropSearchTable(side1 = 50,
                                                side2 = 70,
                                                mastRadius = 2)
```

geometricRoadPadPropSearchTable

Calculate the areas of intersection of a series of nested annuli with an idealized access road and turbine pad.

Description

Calculate area of annulus bisected by 2 parallel lines (e.g. a road of a road/pad plot).

Usage

```
geometricRoadPadPropSearchTable(
  padRadius,
  roadWidth,
  maxSearchRadius,
  mastRadius,
  annulusWidth = 1,
  ...
)
```

Arguments

padRadius	Integer, radius of turbine pad from the center of the turbine.
roadWidth	Integer, width of road leading to turbine pad.
maxSearchRadius	Integer, maximum search distance from the center of turbine.
mastRadius	Integer, radius of the turbine mast.
annulusWidth	Integer, width of annulus, default is 1.
...	Currently ignored.

Details

Searches are conducted on the road and turbine pad around wind turbines for bird and bat fatalities. This function creates a data frame of proportion of area searched within each annulus ring on an idealized road and pad. The turbine is assumed to be centered on a perfectly circular turbine pad with radius `padRadius`, and a perfectly straight access road of width `roadWidth` is oriented from the center of the circle away from the turbine. (The resulting road and pad looks like rather like a lollipop.)

The `mastRadius` argument is to account for the area taken up by the turbine mast.

The arguments `padRadius`, `roadWidth`, `mastRadius`, and `annulusWidth` are all rounded to the nearest integer. The `maxSearchDistance` is rounded up (ceiling function) to an integer. If half units are needed, then convert to a smaller unit. See examples.

Value

Data frame of proportion of area searched for each annulus. `distanceFromTurbine` column represents the outer radius of each annulus.

See Also

`geometricRectanglePropSearchTable` `circleBoxInt`

Examples

```
pad <- 10 #meters, turbine pad radius
road <- 4 #meters, width of the road to the turbine pad
maxDistance <- 100 #meters, max distance
mast <- 2 #meters, turbine mast radius

## proportion are area searched at each annulus
propSearch <- geometricRoadPadPropSearchTable(padRadius = pad,
                                              roadWidth = road,
                                              maxSearchRadius = maxDistance,
                                              mastRadius = mast)

head(propSearch, 20)

## if half meter annulus rings are desired:
convert <- 100 # meters * 100 = centimeters

## units in centimeters
propSearchHalfMeter <- geometricRoadPadPropSearchTable(padRadius = pad * convert,
                                                       roadWidth = road*convert,
                                                       maxSearchRadius = maxDistance * convert,
                                                       mastRadius = mast * convert,
                                                       annulusWidth = 50) ##50cm = half a meter

head(propSearchHalfMeter, 30)

## convert back to meters
propSearchHalfMeter$distanceFromTurbine <- propSearchHalfMeter$distanceFromTurbine/convert
head(propSearchHalfMeter, 30)
```

`getDistanceProbability`*Calculate probabilities within one unit increments.*

Description

Probabilities are calculated between specified increments for a given distribution and parameter values.

Usage

```
getDistanceProbability(  
  q,  
  distribution,  
  param1,  
  param2 = NA,  
  tbound = c(-Inf, Inf),  
  unitSize = 1,  
  ...  
)
```

Arguments

<code>q</code>	Vector of quantiles.
<code>distribution</code>	Character value; specifying the desired probability distribution, see ptrunc .
<code>param1</code>	Numeric; value of the first parameter of the specified distribution.
<code>param2</code>	Numeric; default is NA. Value of the second parameter of the specified distribution, if applicable.
<code>tbound</code>	Numeric vector specifying the lower and upper truncation bounds. Default is <code>c(-Inf, Inf)</code> .
<code>unitSize</code>	Numeric; either of length one or equal to <code>length(q)</code> , specific the desired width for the probability calculation. Default is 1.
<code>...</code>	Currently ignored.

Details

This is a wrapper function that uses the [ptrunc](#) function. The basic calculation is `ptrunc(q, ...)` - `ptrunc(q-abs(unitSize), ...)`

Value

Vector of probabilities

See Also

[ptrunc](#)

Examples

```
## normal distribution
getDistanceProbability(q=8,distribution='norm',param1=10,param2=1)
pnorm(8,mean=10,sd=1)-pnorm(8-1,mean=10,sd=1)

## larger unitSize
getDistanceProbability(q=12,distribution='norm',param1=10,param2=1,unitSize=4)
pnorm(12,mean=10,sd=1)-pnorm(12-4,mean=10,sd=1)
```

getDistributionFunction

Getting distribution functions

Description

Determines if the distribution functions are available. This is intended for internal use only.

Usage

```
getDistributionFunction(type, dist, ...)
```

Arguments

type	Character, typically either 'r', 'q', 'p', or 'd'.
dist	Character, typically something like 'norm', 'gamma', etc.
...	Currently ignored.

Details

It is determined that `paste0(type, dist)` is a function and returns that function. The nature of the returned function is not verified.

Value

Function, the first function in the search path that matches the name `paste0(type, dist)`.

Examples

```
fun <- getDistributionFunction(type="q",dist="norm")
```

`getDistributionSummary`*Summary statistics from the fitted distribution*

Description

Summary statistics are calculated for the distribution with parameter estimates. Right now only the median is produced.

Usage

```
getDistributionSummary(distribution, paramVec, truncBounds = NULL, ...)
```

Arguments

<code>distribution</code>	String indicating which distribution to use.
<code>paramVec</code>	Numeric vector for the parameters associated with distribution. Assumed to be in the same order as the function indicated by <code>distribution</code> .
<code>truncBounds</code>	Numeric, indicating bounds for the area correction calculation, see details. Default is <code>NULL</code> , and the bounds are set to <code>c(0, Inf)</code> .
<code>...</code>	Additional arguments to integrate .

Details

The `truncBounds` argument defaults to zero as a lower bound and infinity as the upper bound. If a single value is provided, it is assumed as the upper bound with zero as the lower bound. If two or more values are provided, the `max(truncBounds)` is the upper bound and `min(truncBounds)` is the lower bound.

Value

Data frame with the summary statistics.

Examples

```
getDistributionSummary('norm', c(40, 25), truncBounds=c(-Inf, Inf))
```

```
getDistributionSummary('norm', c(40, 25), truncBounds=NULL)
```

```
getDistributionSummary('norm', c(40, 25), truncBounds=c(0, 30))
```

```
getProportionAreaSearched
```

Create proportion of area searched table from spatial data

Description

Calculate the proportion of area searched around wind turbine based on turbine location data and polygons of search area.

Usage

```
getProportionAreaSearched(
  turbinePoints,
  turbineName,
  turbinePlots,
  turbineMastRadius,
  maxDistance,
  nQuadSegs = 1000
)
```

Arguments

turbinePoints	sf data.frame of point geometries and a turbineName column indicating the turbine names
turbineName	Character, indicating the variable name for the turbine names in turbinePoints and plot names in turbinePlots
turbinePlots	sf data.frame of polygon geometries indicating the search area around the turbine points and a turbineName column indicating the turbine names
turbineMastRadius	Integer of length 1. The radius of the turbine mast
maxDistance	Integer indicating how far from the turbine that searches occurred
nQuadSegs	integer; number of segments per quadrant (fourth of a circle), for all or per-feature; see details

Details

The `sf` package is used to calculate overlapping areas between the searched area `turbinePlots` and one unit annulus around the `turbinePoints`. The annuli increase out to a distance of `maxDistance`. The `nQuadSegs` argument is passed directly to `sf::st_buffer`

Caution: the function does some basic checks on the spatial objects but it is assumed that the points and polygons do not have any boundary, geometry, or other issues.

Value

Data frame of proportion of area searched for each annulus around each turbine point. `distanceFromTurbine` column represents outer radius of each annulus.

Examples

```
data(turbineSpatial)

propSearch <- getProportionAreaSearched(
  turbinePoints = turbineSpatial$turbinePoints,
  turbineName = 'turbName',
  turbinePlots = turbineSpatial$turbinePlots,
  turbineMastRadius = 2,
  maxDistance = 10,
  nQuadSegs = 100
)
```

getStartValue

Calculate the start values to be passed to the optimizer.

Description

Calculate start values for [weightedLikelihood](#) or [weightedDistribution](#).

Usage

```
getStartValue(x, distribution, w = rep(1, length(x)), ...)
```

Arguments

x	Numeric vector of the data observations.
distribution	String indicating which distribution to use.
w	Numeric Vector of weights. This is assumed to be in the same order as x. Default is a vector of ones the same length as x.
...	Currently ignored.

Details

This function is intended for internal purposes only and is called by [weightedLikelihood](#) and [weightedDistribution](#). The function calculates the weighted mean and weighted variance and performs a method of moments approach to obtain start values for the likelihood estimation.

Value

Vector of estimated parameters for the distribution.

Examples

```
x <- rnorm(100,10,5)

getStartValue(x, 'norm')
mean(x)
sd(x)
```

 hallingstad

Data sets from Hallingstad et al. 2018

Description

List containing two data frames from Hallingstad et al. 2018

Usage

```
data(hallingstad)
```

Format

The carcass element is a data frame with 26 rows and 3 variables:

study The name of the study for that wind farm.

species The species of the carcass found.

distanceFromTurbine The distance (meters) from the turbine of the location of the found carcass.

The weight element is a data frame with 2414 rows and 7 variables:

study The name of the study for that wind farm.

distanceFromTurbine The distance (meters) from the turbine for the outer radius of a one meter ring or annulus.

detectionProbability The probability of detection, incorporating search efficiency and carcass persistence, for a given study and distance from turbine.

proportionAreaSearch The proportion of area searched within the ring (annulus).

scaledNumberTurbine The number of turbines at a study divided by the total number of turbines for all studies considered, does not change with distance from turbine.

scaledFatalityRate The fatality rate at a study divided by the sum of the fatality rates across all studies considered, does not change with distance from turbine.

finalWeight The product of detectionProbability*proportionAreaSearched*scaledNumberTurbine*scaledFatali

Details

A list of data frames, with two elements named carcass and weight.

References

Hallingstad EC, Rabie PA, Telander AC, Roppe JA, Nagy LR (2018) Developing an efficient protocol for monitoring eagle fatalities at wind energy facilities. PLoS ONE 13(12): e0208700. <https://doi.org/10.1371/journal.pone.0208700>

hullMuirAreaCorrection

Calculate an area correction based on the Hull and Muir (2010) maximum distance and a triangular distribution as proposed by Huso and Dalthorp (2014).

Description

Calculate the maximum fall distance from a turbine using the regression model from Hull and Muir (2010). Calculate the carcass fall probabilities between one-unit increments of a right triangle distribution as proposed by Huso and Dalthorp (2014). Use the probabilities and proportion of area searched to calculate an area correction value.

Usage

```
hullMuirAreaCorrection(
  hubHeight,
  bladeRadius,
  lowerBound = 0,
  upperBound = Inf,
  proportionSearchDF,
  distanceCol,
  proportionCol,
  additionalCol = NULL,
  ...
)
```

Arguments

hubHeight	Numeric, turbine hub height.
bladeRadius	Numeric, turbine blade radius.
lowerBound	Numeric, default is zero, see triangleProb .
upperBound	Numeric, default is Inf, see triangleProb .
proportionSearchDF	Data frame with at least two columns: distance from turbine and proportion of area searched at each distance.
distanceCol	Character string indicating the distance column in proportionSearchDF.
proportionCol	Character string indicating the proportion column in proportionSearchDF.
additionalCol	Character vector, default is NULL, indicating additional columns of how the area correction value should be calculated, see examples.
...	Currently ignored.

Details

The maximum Hull and Muir distances are calculated using `hullMuirMaxDistance` and the carcass fall probabilities are calculated using `triangleProb`. The probabilities are multiplied by the proportion of area searched from `proportionSearchDF` by distance. These products are summed across distances by size class and `additionalCol`.

The distances in the `distanceCol` will be rounded to the nearest integer for matching up with the probabilities. The distances, `hubHeight`, and `bladeRadius` are assumed to be in the same units.

Value

Data frame of size class, `additionalCol` columns, and area correction

References

Hull, C. L., & Muir, S. (2010). Search areas for monitoring bird and bat carcasses at wind farms using a Monte-Carlo model. *Australasian Journal of Environmental Management*, 17(2), 77-87.

Huso, M. & Dalthorp, D (2014). Accounting for Unsearched Areas in Estimating Wind Turbine-Caused Fatality. *The Journal of Wildlife Management*. 78. 10.1002/jwmg.663.

See Also

`hullMuirMaxDistance` `triangleProb`

Examples

```
## proportion of area searched data
data(proportionAreaSearched)

hullMuirAreaCorrection(hubHeight = 87.5, bladeRadius = 62.5,
  proportionSearchDF = proportionAreaSearched,
  distanceCol = 'distanceFromTurbine',
  proportionCol = 'proportionAreaSearched',
  additionalCol = 'plotType')

## without additional columns but must separate the proportion of area searched
## data frame
hullMuirAreaCorrection(hubHeight = 87.5, bladeRadius = 62.5,
  proportionSearchDF = subset(proportionAreaSearched, plotType == 'RP'),
  distanceCol = 'distanceFromTurbine',
  proportionCol = 'proportionAreaSearched')

hullMuirAreaCorrection(hubHeight = 87.5, bladeRadius = 62.5,
  proportionSearchDF = subset(proportionAreaSearched, plotType == 'FULL'),
  distanceCol = 'distanceFromTurbine',
  proportionCol = 'proportionAreaSearched')
```

hullMuirMaxDistance *Calculate the Hull and Muir (2010) maximum distance*

Description

Calculate the maximum fall distance from a turbine using the regression model from Hull and Muir (2010).

Usage

```
hullMuirMaxDistance(hubHeight, bladeRadius, ...)
```

Arguments

hubHeight	Numeric, turbine hub height.
bladeRadius	Numeric, turbine blade radius.
...	Currently ignored.

Details

Using the linear regression coefficients from Hull and Muir (2010), a maximum distance is calculated. This is done for three size classes (bats, small birds (SB), and large birds (LB)) separately.

It is assumed that hubHeight and bladeRadius have the same units.

Note: Hull and Muir (2010) used the range of 65 m < hubHeight < 94 m and 33 m < bladeRadius < 55 m. Anything outside of this range is extrapolation and should only be done with care.

Value

data frame of maximum distance by size class, hubHeight, and bladeRadius. Distance will be in the same units as were provided for hubHeight and bladeRadius

References

Hull, C. L., & Muir, S. (2010). Search areas for monitoring bird and bat carcasses at wind farms using a Monte-Carlo model. *Australasian Journal of Environmental Management*, 17(2), 77-87.

Examples

```
hubHeights <- rnorm(10, mean = 87.5, sd = 10)
bladeRadii <- rnorm(10, mean = 62.5, sd = 10)

hullMuirMaxDistance(hubHeight = hubHeights, bladeRadius = bladeRadii)
```

LogLogistic

*Log-Logistic Distribution***Description**

The probability density function, cumulative density function, inverse cumulative density function, random generation for the log logistic distribution.

Usage

```
dlllog(x, shape = 1, scale = 1, log = FALSE, ...)
```

```
llogSummaryStats(shape, scale)
```

```
pllog(q, shape = 1, scale = 1, lower.tail = TRUE, log.p = FALSE, ...)
```

```
qllog(p, shape = 1, scale = 1, lower.tail = TRUE, log.p = FALSE, ...)
```

```
rllog(n, shape = 1, scale = 1, ...)
```

Arguments

x	Vector of quantiles.
shape	Shape parameter.
scale	Scale parameter.
log	Logical; if TRUE, log densities are returned.
...	Currently ignored.
q	Vector of quantiles.
lower.tail	Logical; if TRUE (default), probabilities are P(X <= x) otherwise, P(X > x).
log.p	Logical; if TRUE, probabilities p are given as log(p).
p	Vector of probabilities.
n	Number of observations. If length(n) > 1, the length is taken to be the number required.

Details

If X is a random variable distributed according to a logistic distribution, then Y = exp(X) has a log-logistic distribution.

The log-logistic distribution with parameters shape = a and scale = s has density

$$f(x) = \frac{\left(\frac{1}{a \cdot \exp(s)}\right) \left(\frac{x}{\exp s}\right)^{\frac{1}{a}-1}}{\left(1 + \left(\frac{x}{\exp s}\right)^{1/a}\right)^2}$$

for $x \geq 0$, $a > 1$, and $s > 0$.

The median is $\exp(s)$, mean is

$$\frac{a\pi * \exp(s)}{\sin(a * \pi)}$$

for $1/a > 1$. The variance is

$$(\exp(s))^2 \left(\frac{2 * \pi * a}{\sin(2 * \pi * a)} - \frac{(a * \pi)^2}{\sin^2(a * \pi)} \right)$$

for $1/a > 2$. The mode is

$$\exp(s) \left(\frac{(1/a) - 1}{(1/a) + 1} \right)^a$$

for $1/a > 1$ otherwise it is zero.

Value

dlllog returns vector of the densities.

pllog returns a vector of probabilities.

qllog returns a vector of quantiles.

rllog returns a vector of random log-logistic variates.

See Also

[dlogis](#) [plogis](#) [qlogis](#) [rlogis](#)

Examples

```
y <- rllog(5, shape=1, scale=1/3)
dlllog(x=y, shape=1, scale=1/3)
dlogis(x=log(y), location=1/3, scale=1)/y

pllog(q=y, shape=1, scale=1/3)
qllog(p=seq(0, 1, by=.25), shape=1, scale=1/3)
```

```
print.windAC
```

```
Print windAC object
```

Description

Print windAC object.

Usage

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

Arguments

x A windAC object.
 ... Currently ignored.

Details

see [calcAC](#)

Value

Print for windAC object

proportionAreaSearched

Proportion of area searched example data set

Description

An example data set of the proportion of area searched within 1 m annuli around turbines at a wind farm.

Usage

```
data(proportionAreaSearched)
```

Format

A data frame with 400 rows and 3 variables:

plotType Either FULL or RP, the type of plot searched at the turbine

distanceFromTurbine The outer radius distance from the turbine, for the one unit annulus.

proportionAreaSearched The proportion of area searched within the annulus at the turbine.

Details

Plots around turbines are searched for bird and bat carcasses. The area searched is summarized into the proportion of area searched with one unit annuli (or rings). The distance here corresponds to the outer radius of the annuli.

For example: plotType distanceFromTurbine portionAreaSearched RP 11 0.12441226

This row is corresponds to the annulus with outer radius of 11 and inner radius of 10. The proportion of area search on RP (road and pad) plot types is 0.12441226, or approximately 12 percent.

secondDerivative *secondDerivative*

Description

Computes numeric second derivatives (Hessian) of an arbitrary multidimensional function at a particular location.

Usage

```
secondDerivative(loc, FUN, ..., eps = 1e-06)
```

Arguments

loc	The location (a vector) where the second derivatives of FUN are desired.
FUN	An R function to compute second derivatives for. This must be a function of the form <code>FUN <- function(x, ...)</code> where <code>x</code> is the parameters of the function (e.g., location <code>loc</code>). FUN must return a single value (scalar), the height of the surface above <code>x</code> , i.e., FUN evaluated at <code>x</code> .
...	Additional arguments to FUN.
eps	Radius argument, see details. Default is $10e-7$.

Details

This function uses the "5-point" numeric second derivative method advocated in numerous numerical recipe texts. During computation of the second derivative, FUN will be evaluated at locations within a hyper-ellipsoid with cardinal radius $2 * loc * eps^{0.25}$.

If those radii don't work for your function, make `eps` a parameter to this function and change it, possibly varying by dimension.

A handy way to use this function is to call an optimization routine like `nlm` with FUN, then call this function with the optimized values (solution) and FUN. This will yield the hessian at the solution rather than the hessian at the previous step of the optimization.

Value

Matrix

Examples

```
func <- function(x){-x*x} # second derivative should be -2
secondDerivative(0,func)
secondDerivative(3,func)
```

```
func <- function(x){3 + 5*x^2 + 2*x^3} # second derivative should be 10+12x
secondDerivative(0,func)
secondDerivative(2,func)
```

```
func <- function(x){x[1]^2 + 5*x[2]^2} # should be rbind(c(2,0),c(0,10))
secondDerivative(c(1,1),func)
secondDerivative(c(4,9),func)
```

triangleProb	<i>Calculate probabilities from a triangle distribution based on Hull and Muir (2010) maximum distance as proposed by Huso and Dalthorp (2014).</i>
--------------	---

Description

Calculate the probabilities between one-unit increments of a right triangle distribution.

Usage

```
triangleProb(hubHeight, bladeRadius, lowerBound = 0, upperBound = Inf, ...)
```

Arguments

hubHeight	Numeric, turbine hub height.
bladeRadius	Numeric, turbine blade radius.
lowerBound	Numeric, default is zero, see Details.
upperBound	Numeric, default is Inf, see Details.
...	Currently ignored.

Details

A right triangle is constructed with the 90 degree corner at the origin in the first quadrant of the cartesian plane. The lowerBound will move the left edge of the triangle to the right. The upperBound will truncate the triangle distribution at that value.

The maximum horizontal distance is calculated using [hullMuirMaxDistance](#). This is typically not a whole number and the [ceiling](#) is used. The maximum vertical distance is such that the area under the hypotenuse edge of triangle integrates to one. This is done using the equation for the area of a triangle.

The two points that make up the hypotenuse are used to calculate the slope and intercept of the line. The area under the line in one-unit increments is calculated using

$$\int_{x-1}^x mZ + b dZ = m(x - .5) + b$$

where m is the slope, b is the intercept, and x is a distance. Integrating between x-1 and x gives the probability between the one-unit increments.

All of this is done for three size classes (bats, small birds (SB), and large birds (LB)) separately. An additional size class (RAPTOR) is included and identical to the large bird result.

The [floor](#) function is applied to lowerBound.

It is assumed that hubHeight and bladeRadius have the same units.

Value

List of two data frames: the first has distances in one-unit increments (the outer distance), the probabilities between the distances, and a column indicating size class; the second gives the maximum distance of each size class.

References

Hull, C. L., & Muir, S. (2010). Search areas for monitoring bird and bat carcasses at wind farms using a Monte-Carlo model. *Australasian Journal of Environmental Management*, 17(2), 77-87.

Huso, M. & Dalthorp, D (2014). Accounting for Unsearched Areas in Estimating Wind Turbine-Caused Fatality. *The Journal of Wildlife Management*. 78. 10.1002/jwmg.663.

See Also

[hullMuirMaxDistance](#)

Examples

```
triResult <- triangleProb(hubHeight = 100, bladeRadius = 50, lowerBound = 0)
names(triResult) ## list names
triResult$maxDist ## max distance for each size class
head(triResult$triDistProb)
```

truncatedDistribution *Truncated Distributions*

Description

Truncated probability density function, truncated cumulative density function, inverse truncated cumulative density function, and random variates from a truncated distribution.

Usage

```
dtrunc(x, distribution, tbound = c(-Inf, Inf), ..., log = FALSE)
```

```
ptrunc(
  q,
  distribution,
  tbound = c(-Inf, Inf),
  ...,
  lower.tail = TRUE,
  log.p = NULL
)
```

```
qtrunc(
  p,
  distribution,
```

```

    tbound = c(-Inf, Inf),
    ...,
    lower.tail = TRUE,
    log.p = NULL
)

rtrunc(n, distribution, tbound = c(-Inf, Inf), ...)

```

Arguments

<code>x</code>	Vector of quantiles.
<code>distribution</code>	Character value specifying the desired probability distribution.
<code>tbound</code>	Numeric vector specifying the lower and upper truncation bounds. Default is <code>c(-Inf, Inf)</code> .
<code>...</code>	Additional arguments passed to the non-truncated distribution functions.
<code>log</code>	Logical; if TRUE, log densities are returned.
<code>q</code>	Vector of quantiles.
<code>lower.tail</code>	Logical; if TRUE (default), probabilities are $P(X \leq x)$ otherwise, $P(X > x)$.
<code>log.p</code>	Currently ignored.
<code>p</code>	Vector of probabilities.
<code>n</code>	A positive integer specifying the desired number of random variates.

Details

The non truncated distribution functions are assumed to be available. For example if the normal distribution is desired then used `distribution='norm'`, the functions then look for `'qnorm'`, `'pnorm'`, etc.

The `max(tbound)` and `min(tbound)` are considered the upper and lower truncation bounds, respectively.

The random variates are produced using the direct method (see Casella and Berger 2002).

Value

`dtrunc` returns a vector of densities.

`ptrunc` returns a vector of probabilities.

`qtrunc` returns a vector of quantiles.

`rtrunc` returns a vector of random variates.

References

G. Casella and R. L. Berger. Statistical inference. Vol. 2. Duxbury Pacific Grove, CA, 2002.

Examples

```
## dtrunc
# not truncated
dnorm(5,mean=5)
# truncated
dtrunc(x=5,distribution='norm',tbound=c(4,5.5),mean=5)

## ptrunc
#not truncated
pgamma(2,shape=3,rate=2)
# truncated
ptrunc(2, distribution = 'gamma', tbound=c(1,5),shape=3,rate=2)

## upper tail
# not truncated
pgamma(2,shape=3,rate=2,lower.tail=FALSE)
# truncated
ptrunc(2,distribution='gamma',tbound=c(1,5),shape=3,rate=2,lower.tail=FALSE)

## qtrunc
#not truncated
qnorm(p=.975)
# truncated
qtrunc(p=.975,distribution='norm',tbound=c(0,1))

## upper tail
# not truncated
qnorm(p=.975,lower.tail=FALSE)
# truncated
qtrunc(p=.975,distribution='norm',tbound=c(0,1),lower.tail=FALSE)

## rtrunc
rtrunc(n=5, distribution = 'gamma', tbound=c(2,5),shape=3,rate=2)
```

turbineSpatial

Data sets of spatial area searched at a wind farm

Description

List containing two spatial data frames

Usage

```
data(turbineSpatial)
```

Format

An object of class list of length 2.

Details

A list of data frames, with two elements named `turbinePlots` and `turbinePoints`. These are fictitious data for example purposes only. The `turbinePlots` element is a spatial polygon data frame with the polygons being the area searched round the turbines. The `turbinePoints` element is a spatial points data frame with the turbine locations.

 weightFun

weight function

Description

Generic weight function for use with `estWD`.

Usage

```
weightFun(
  x,
  propTable,
  type,
  typeCol,
  distanceCol,
  propCol,
  xFun = ceiling,
  maxDistance = NULL,
  ...
)
```

Arguments

<code>x</code>	Numeric vector.
<code>propTable</code>	Data frame contain the proportion of area searched by distance and plot type.
<code>type</code>	Character, indicating which plot type to subset <code>propTable</code> .
<code>typeCol</code>	Character, column name of the plot type in <code>propTable</code> .
<code>distanceCol</code>	Character, column name of the distance in <code>propTable</code> .
<code>propCol</code>	Character, column name of the proportion of area searched in <code>propTable</code> .
<code>xFun</code>	Function, default is <code>ceiling</code> , see details.
<code>maxDistance</code>	Numeric, default is <code>NULL</code> . If a value is given then <code>propTable</code> is subsetted to where <code>propTable[, distanceCol] <= maxDistance</code> .
<code>...</code>	Additional arguments passed to <code>xFun</code> .

Details

The `weightedDistribution` function requires the weights be described using a function. This allows integration to happen.

Typically `propTable` has integer values for the distances, but the function needs to take in any numeric values, the `xFun` function is how any numeric value can be matched up to the values in `propTable`. If the distances in `propTable` correspond to the outer radius of the annuli, for calculating proportion of area searched, then the `ceiling` is appropriate. If the distances in `propTable` correspond to the inner radius of the annuli then the `floor` might be more appropriate.

Value

Numeric vector of weights with length equal to `length(x)`, and with a 1:1 relationship to the values in `x`.

See Also

`estWD`

Examples

```
data(proportionAreaSearched)

d <- c(-300.23,14.3,16,75)

## RP proportion of area searched
weightFun(x=d,propTable=proportionAreaSearched,type='RP',typeCol='plotType',
distanceCol='distanceFromTurbine',propCol='proportionAreaSearched')
#[1] 0.00000000 0.08896480 0.08308577 0.01709869

## FULL plot proportion of area searched
weightFun(x=d,propTable=proportionAreaSearched,type='FULL',typeCol='plotType',
distanceCol='distanceFromTurbine',propCol='proportionAreaSearched')
# [1] 0 1 1 1

### with a max distance restriction
## RP proportion of area searched
weightFun(x=d,propTable=proportionAreaSearched,type='RP',typeCol='plotType',
distanceCol='distanceFromTurbine',propCol='proportionAreaSearched',maxDistance=40)
# [1] 0.00000000 0.08896480 0.08308577 0.00000000

## FULL plot proportion of area searched
weightFun(x=d,propTable=proportionAreaSearched,type='FULL',typeCol='plotType',
distanceCol='distanceFromTurbine',propCol='proportionAreaSearched',maxDistance=40)
# [1] 0 1 1 0
```

windAC

A package for calculating area correction values for fatality estimation at wind farms.

Description

Post-construction fatality monitoring studies at wind facilities are based on data from searches for bird and bat carcasses in plots beneath turbines. Bird and bat carcasses can fall outside of the search plot. Bird and bat carcasses from wind turbines often fall outside of the searched area. To compensate, area correction (AC) estimations are calculated to estimate the percentage of fatalities that fall within the searched area versus those that fall outside of it. This package provides two likelihood based methods and one physics based method (Hull and Muir (2010), Huso and Dalthorp (2014)) to estimate the carcass fall distribution. There are also functions for calculating the proportion of area searched within one unit annuli, log logistic distribution functions, and truncated distribution functions.

The two likelihood methods are the truncated weighted likelihood ([estTWL](#)) and the weighted distribution ([estWD](#)). Both use carcass distances from the turbine, accounting for unequal detection by distance, to estimate the distance distribution. Alternatively, a right triangle distribution can be used for the carcass density distribution with the max distance estimated ([hullMuirMaxDistance](#)) from the regression from Hull and Muir (2010) as proposed by Huso and Dalthorp (2014).

The area correction value is calculated from the combination of the carcass distance density and the proportion of area searched at each distance. The function [getProportionAreaSearched](#) uses the [sf](#) package to do this from turbine points spatial data and search area polygons. The functions [geometricRectanglePropSearchTable](#) and [geometricRoadPadPropSearchTable](#) also calculate proportion of area searched but assuming perfect geometric shapes, meaning no spatial data is required.

Search areas are often irregular. [proportionAreaSearched](#) summarizes the area searched into the proportion of area searched with one unit annuli (or ring).

Two sets of distribution functions are available. Log-logistic distribution functions (see [dllog](#)). These are a transformation of the logistic distribution and use the base R functions (see [dlogis](#)). The second is truncation functions (see [dtrunc](#)), that provide truncation for R function distributions.

Example data sets:

[carcassDistance](#) Example data set of carcass distances found during searches under wind turbines.

[hallingstad](#) List containing two data frames from Hallingstad et al. (2018).

[proportionAreaSearched](#) Example data set of the proportion of area searched around turbines.

References

Hallingstad EC, Rabie PA, Telander AC, Roppe JA, Nagy LR (2018) Developing an efficient protocol for monitoring eagle fatalities at wind energy facilities. PLoS ONE 13(12): e0208700. <https://doi.org/10.1371/journal.pone.0208700>

Huso, M. & Dalthorp, D (2014). Accounting for Unsearched Areas in Estimating Wind Turbine-Caused Fatality. The Journal of Wildlife Management. 78. 10.1002/jwmg.663.

Hull, C. L., & Muir, S. (2010). Search areas for monitoring bird and bat carcasses at wind farms using a Monte-Carlo model. *Australasian Journal of Environmental Management*, 17(2), 77-87.

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