

Package ‘lakemorpho’

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Title Lake Morphometry Metrics

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Description Lake morphometry metrics are used by limnologists to understand, among other things, the ecological processes in a lake. Traditionally, these metrics are calculated by hand, with planimeters, and increasingly with commercial GIS products. All of these methods work; however, they are either outdated, difficult to reproduce, or require expensive licenses to use. The 'lakemorpho' package provides the tools to calculate a typical suite of these metrics from an input elevation model and lake polygon. The metrics currently supported are: fetch, major axis, minor axis, major/minor axis ratio, maximum length, maximum width, mean width, maximum depth, mean depth, shoreline development, shoreline length, surface area, and volume.

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calcLakeMetrics	<i>Calculate all Lake Morphometry Metrics</i>
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Description

This function is a wrapper function for all of the metrics. It calculates each metric for an input lakeMorphoClass. This returns a list of all metrics

Usage

```
calcLakeMetrics(
  inLakeMorpho,
  bearing,
  pointDens,
  slope_quant = 0.5,
  correctFactor = 1,
  zmax = NULL
)
```

Arguments

inLakeMorpho	an object of lakeMorphoClass . Output of the lakeSurroundTopo function would be appropriate as input
bearing	Numeric that indicates the bearing of the desired fetch.
pointDens	Number of points to place equidistant along shoreline for lakeMaxLength or density of lines to test for lakeMaxWidth and lakeFetch .
slope_quant	The slope quantile to use to estimate maximum depth. Defaults to the median as described in (Hollister et. al, 2011).
correctFactor	Value used to correct the predicted maximum lake depth. Defaults to 1. Corrections are simply accomplished by multiplying estimated max depth by correction factor. Correction factors can be determined empirically by regressing the predicted depth against a known maximum depth while forcing the intercept through zero. The slope of the line would then be used as the correction factor(Hollister et. al, 2011).
zmax	Maximum depth of the lake. If none entered and elevation dataset is included in inLakeMorpho, lakeMaxDepth is used to estimate a maximum depth.

Value

Returns a list with all lake metrics calculated for a given input lakemorpho object

References

- Florida LAKEWATCH (2001). A Beginner's guide to water management - Lake Morphometry (2nd ed.). Gainesville: Florida LAKEWATCH, Department of Fisheries and Aquatic Sciences. [Link](#)
- Hollister, J. W., W.B. Milstead (2010). Using GIS to Estimate Lake Volume from Limited Data. *Lake and Reservoir Management*. 26(3)194-199. [doi:10.1080/07438141.2010.504321](#)
- Hollister, J. W., W.B. Milstead, M.A. Urrutia (2011). Predicting Maximum Lake Depth from Surrounding Topography. *PLoS ONE* 6(9). [doi:10.1371/journal.pone.0025764](#)

Examples

```
data(lakes)
calcLakeMetrics(inputLM, bearing = 45, pointDens = 25)
```

exampleElev

Elevation Data for lakemorpho examples

Description

This example data is a RasterLayer of a small subset of the National Elevation Dataset named exampleElev.

Format

RasterLayer of 1094 x 1419 and 30 meter resolution

exampleLake	<i>Lake Data for lakemorpho examples</i>
-------------	--

Description

This example data is a SpatialPolygonsDataframe of lakes named exampleLakes. These lakes are originally from the [NHDPlus V2](#) dataset.

Format

SpatialPolygonDataframe with 115 lakes, each with 13 variables

inputLM	<i>lakemorpho class data for lakemorpho examples</i>
---------	--

Description

This example lakemorpho class was generated using lakeSurroundTopo with the included exampleElev and exampleLake data.

Format

lakemorpho class

lakeFetch	<i>Function to calculate fetch along an input bearing</i>
-----------	---

Description

The function calculates the maximum in lake distance of a line along an input bearing.

Usage

```
lakeFetch(inLakeMorpho, bearing, addLine = TRUE)
```

Arguments

inLakeMorpho	An object of lakeMorphoClass . Output of the lakeSurroundTopo function would be appropriate as input
bearing	Numeric that indicates the bearing of the desired fetch
addLine	Boolean to determine if the selected max length line should be added to the inLakeMorpho object. Defaults to True. Note that the line is returned in the same projection as the input data.

Value

Returns a numeric value indicating the length of the longest line in the lake along the input bearing. Units are the same as the input data.

References

Florida LAKEWATCH (2001). A Beginner's guide to water management - Lake Morphometry (2nd ed.). Gainesville: Florida LAKEWATCH, Department of Fisheries and Aquatic Sciences. [Link](#)

Examples

```
data(lakes)
lakeFetch(inputLM, 45)
```

lakeMajorAxisLength *Calculate the length of the major axis for lake*

Description

Major axis length is defined as the maximum length spanning the convex hull of a lake.

Usage

```
lakeMajorAxisLength(inLakeMorpho, addLine = TRUE)
```

Arguments

inLakeMorpho	An object of lakeMorphoClass . Output of the lakeSurroundTopo function would be appropriate as input
addLine	Boolean to determine if the selected major axis line should be added to the inLakeMorpho object. Defaults to True

Value

This returns a numeric value indicating the length of the major axis in the lake. Units are the same as the input data.

References[Wikipedia](#)

Kirillin, G., Engelhardt, C., Golosov, S. and Hintze, T., 2009. Basin-scale internal waves in the bottom boundary layer of ice-covered Lake Mueggelsee, Germany. *Aquatic ecology*, 43(3), pp.641-651.

Examples

```
data(lakes)
lakeMajorAxisLength(inputLM)
```

lakeMaxDepth	<i>Estimate maximum lake depth</i>
--------------	------------------------------------

Description

This function uses slope and distance to estimate max depth. This is based on the assumption that the slope of the surrounding topography is similar to the bathymetry of the lake (Hollister et. al 2011).

Usage

```
lakeMaxDepth(inLakeMorpho, slope_quant = 0.5, correctFactor = 1)
```

Arguments

inLakeMorpho	An object of <code>lakeMorphoClass</code> . Output of the <code>lakeSurroundTopo</code> function would be appropriate as input
slope_quant	The slope quantile to use to estimate maximum depth. Defaults to the median as described in (Hollister et. al, 2011).
correctFactor	Value used to correct the predicted maximum lake depth. Defaults to 1. Corrections are simply accomplished by multiplying estimated max depth by correction factor. Correction factors can be determined empirically by regressing the predicted depth against a known maximum depth while forcing the intercept through zero. The slope of the line would then be used as the correction factor(Hollister et. al, 2011).

Value

Returns a numeric value of the predicted maximum depth

References

Hollister, J. W., W.B. Milstead, M.A. Urrutia (2011). Predicting Maximum Lake Depth from Surrounding Topography. PLoS ONE 6(9). [doi:10.1371/journal.pone.0025764](https://doi.org/10.1371/journal.pone.0025764)

Florida LAKEWATCH (2001). A Beginner's guide to water management - Lake Morphometry (2nd ed.). Gainesville: Florida LAKEWATCH, Department of Fisheries and Aquatic Sciences. [Link](#)

Examples

```
data(lakes)
lakeMaxDepth(inputLM)
```

lakeMaxLength	<i>Calculate maximum lake length</i>
---------------	--------------------------------------

Description

Maximum lake length is defined as the longest open water distance of a lake. This function determines the maximum lake length of lake by comparing the lengths of a user defined number of lines. The user specifies a number of points to distribute along the lake shoreline and the point to point line lengths are checked for multiple intersections (i.e. line not just open water), starting with the longest line first. Function is currently very sensitive to pointDens and slows down considerably for larger values. Small values of point dens are acceptable for lakes without complex shorelines. Care needs to be taken in selecting an appropriate pointDens and multiple values should be checked to ensure stability in the estimates.

Usage

```
lakeMaxLength(inLakeMorpho, pointDens, addLine = TRUE)
```

Arguments

inLakeMorpho	An object of lakeMorphoClass . Output of the lakeSurroundTopo function would be appropriate as input
pointDens	Number of points to place equidistant along shoreline. The maximum point to point distance that does not also intersect the shoreline is used. To total of $n*(n-1)/2$ comparisons is possible, but in practice is usually significant less.
addLine	Boolean to determine if the selected max length line should be added to the inLakeMorpho object. Defaults to True

Value

This returns a numeric value indicating the length of the longest line possible in the lake. Units are the same as the input data.

References

Florida LAKEWATCH (2001). A Beginner's guide to water management - Lake Morphometry (2nd ed.). Gainesville: Florida LAKEWATCH, Department of Fisheries and Aquatic Sciences. [Link](#)

Examples

```
library(lakemorpho)
data(lakes)
lakeMaxLength(inputLM, 25)
```

lakeMaxWidth

*Function to find line representing maximum lake Width***Description**

Maximum lake width is defined as the maximum in lake distance that is perpendicular to the maximum lake length. As no definition specifies whether or not the maximum lake width should intersect the line of maximum length, this function assumes that it does not, but may be forced to find the maximum width line that is perpendicular to and intersects with the maximum lake length line. This function calculates the equation of the perpendicular line and repeats that line pointDensity number of times and returns the longest of those lines.

Usage

```
lakeMaxWidth(inLakeMorpho, pointDens, intersect = FALSE, addLine = TRUE)
```

Arguments

inLakeMorpho	An object of <code>lakeMorphoClass</code> . Output of the <code>lakeSurroundTopo</code> function would be appropriate as input
pointDens	Number of points to place equidistant along the <code>lakeMaxLength</code> . A line that crosses at that point and extends from shore to shore is calculated.
intersect	Boolean to force max width to intersect the max length line. for many lakes this will return the same line.
addLine	Boolean to determine if the selected max length line should be added to the inLakeMorpho object. Defaults to True

Value

Returns a numeric value indicating the length of the longest line perpendicular to the maximum length line.

References

Florida LAKEWATCH (2001). A Beginner's guide to water management - Lake Morphometry (2nd ed.). Gainesville: Florida LAKEWATCH, Department of Fisheries and Aquatic Sciences. [Link](#)

Examples

```
library(lakemorpho)
data(lakes)
lakeMaxWidth(inputLM, 25)
```

lakeMeanDepth	<i>Function to return lake Mean Depth</i>
---------------	---

Description

Calculates average depth of lake as a mean of lake volume divided by lake surface area

Usage

```
lakeMeanDepth(inLakeMorpho, zmax = NULL, slope_quant = 0.5, correctFactor = 1)
```

Arguments

inLakeMorpho	An object of <code>lakeMorphoClass</code> . Output of the <code>lakeSurroundTopo</code> function would be appropriate as input
zmax	Maximum depth of the lake. If none entered and elevation dataset is included in inLakeMorpho, <code>lakeMaxDepth</code> is used to estimate a maximum depth.
slope_quant	The slope quantile to use to estimate maximum depth. Defaults to the median as described in (Hollister et. al, 2011).
correctFactor	This a factor used by <code>lakeMaxDepth</code> to correct the predicted maximum lake depth. Defaults to 1.

Value

Returns a numerica value for the mean depth of the lake

References

Florida LAKEWATCH (2001). A Beginner's guide to water management - Lake Morphometry (2nd ed.). Gainesville: Florida LAKEWATCH, Department of Fisheries and Aquatic Sciences. [Link](#)

Examples

```
data(lakes)
lakeMeanDepth(inputLM)
```

lakeMeanWidth *Function to return lake Mean Width*

Description

Mean lake width is the result of lake surface area divided by the maximum length.

Usage

```
lakeMeanWidth(inLakeMorpho)
```

Arguments

inLakeMorpho An object of [lakeMorphoClass](#). Output of the [lakeSurroundTopo](#) function would be appropriate as input

Value

Returns a numeric value for the mean width of the lake

References

Florida LAKEWATCH (2001). A Beginner's guide to water management - Lake Morphometry (2nd ed.). Gainesville: Florida LAKEWATCH, Department of Fisheries and Aquatic Sciences. [Link](#)

Examples

```
data(lakes)
lakeMaxLength(inputLM, 25)
lakeMeanWidth(inputLM)
```

lakeMinorAxisLength *Calculate the length of the minor axis for lake*

Description

Minor axis length is defined as the minimum length spanning the convex hull of a lake.

Usage

```
lakeMinorAxisLength(inLakeMorpho, addLine = TRUE)
```

Arguments

inLakeMorpho	An object of lakeMorphoClass . Output of the lakeSurroundTopo function would be appropriate as input
addLine	Boolean to determine if the selected minor axis line should be added to the inLakeMorpho object. Defaults to True

Value

This returns a numeric value indicating the length of the minor axis in the lake. Units are the same as the input data.

References

[Wikipedia](#)

Examples

```
data(lakes)
lakeMinorAxisLength(inputLM)
```

lakeMinorMajorRatio *Calculate the ratio of the minor axis length to major axis length*

Description

Major axis length is defined as the maximum length spanning the convex hull of a lake. Minor axis length is defined as the minimum length spanning the convex hull of a lake.

Usage

```
lakeMinorMajorRatio(inLakeMorpho, addLine = TRUE)
```

Arguments

inLakeMorpho	An object of lakeMorphoClass . Output of the lakeSurroundTopo function would be appropriate as input
addLine	Boolean to determine if the selected major and minor axis lines should be added to the inLakeMorpho object. Defaults to True

Value

This returns a vector of numeric values indicating the length of the major and minor axes of the lake. Units are the same as the input data.

References

[Link](#)

Examples

```
data(lakes)
lakeMinorMajorRatio(inputLM)
```

lakemorpho	<i>Lake Morphometry in R</i>
------------	------------------------------

Description

Lakemorpho provides a number of functions to calculate a standard suite of lake morphometry metrics. Most of the metrics are measurements of the shape of the lake. Metrics that rely on depth have traditionally been calculated with bathymetry data. In the absence of bathymetry data it is possible to estimate maximum depth from surrounding topography. Lakemorpho uses this approach to also estimate maximum depth, mean depth, and volume.

Details

This development version of this package is available at <https://github.com/USEPA/lakemorpho/>

References

Florida LAKEWATCH (2001). A Beginner's guide to water management - Lake Morphometry (2nd ed.). Gainesville: Florida LAKEWATCH, Department of Fisheries and Aquatic Sciences. [Link](#)

Hollister, J. W., W.B. Milstead (2010). Using GIS to Estimate Lake Volume from Limited Data. Lake and Reservoir Management. 26(3)194-199. [doi:10.1080/07438141.2010.504321](https://doi.org/10.1080/07438141.2010.504321)

Hollister, J. W., W.B. Milstead, M.A. Urrutia (2011). Predicting Maximum Lake Depth from Surrounding Topography. PLoS ONE 6(9). [doi:10.1371/journal.pone.0025764](https://doi.org/10.1371/journal.pone.0025764)

lakeMorphoClass	<i>Function to create a lakeMorpho class - this is input to all other methods</i>
-----------------	---

Description

This is a helper function that creates a lakeMorpho class object

Usage

```
lakeMorphoClass(
  inLake,
  inElev = NULL,
  inCatch = NULL,
  inLakeDist = NULL,
  lakeOnEdge = F
)
```

Arguments

inLake	input lake SpatialPolygons object. Required.
inElev	input elevation model raster object
inCatch	input catchment SpatialPolygons object, can be buffer around lake
inLakeDist	input euclidean distance raster that measures distance from shore to any pixel in the lake
lakeOnEdge	Boolean indicating if inCatch (or lake Buffer) extends beyond extent of elevation data

Value

Returns an object of class 'lakeMorpho'

See Also

lakeSurroundTopo

lakeShorelineDevelopment

Function to calculate shoreline development

Description

Shoreline development is a measure of the complexity of the lake shoreline. It is simply the ratio of the shoreline length (i.e. perimeter) to the perimeter of an equally sized circle.

Usage

```
lakeShorelineDevelopment(inLakeMorpho)
```

Arguments

inLakeMorpho An object of [lakeMorphoClass](#). Output of the [lakeSurroundTopo](#) function would be appropriate as input

Value

Returns a numeric value for the shoreline development of the lake

References

Florida LAKEWATCH (2001). A Beginner's guide to water management - Lake Morphometry (2nd ed.). Gainesville: Florida LAKEWATCH, Department of Fisheries and Aquatic Sciences. [Link](#)

Examples

```
data(lakes)
lakeShorelineDevelopment(inputLM)
```

lakeShorelineLength *Function to calculate shoreline length*

Description

This function returns the length of the shoreline of the lake and is simply the perimeter of the input lake polyogn.

Usage

```
lakeShorelineLength(inLakeMorpho)
```

Arguments

inLakeMorpho An object of [lakeMorphoClass](#). Output of the [lakeSurroundTopo](#) function would be appropriate as input

Value

Returns a numeric value for the length of the lake shoreline

References

Florida LAKEWATCH (2001). A Beginner's guide to water management - Lake Morphometry (2nd ed.). Gainesville: Florida LAKEWATCH, Department of Fisheries and Aquatic Sciences. [Link](#)

Examples

```
data(lakes)
lakeShorelineLength(inputLM)
```

lakeSurfaceArea *Return lake surface area*

Description

This function simply retruns the area of the lake SpatialPolygons that is part of the [lakeMorphoClass](#) class.

Usage

```
lakeSurfaceArea(inLakeMorpho)
```

Arguments

inLakeMorpho an object of [lakeMorphoClass](#). Output of the [lakeSurroundTopo](#) function would be appropriate as input

Value

Returns a numeric value for the total surface area of the lake

References

Florida LAKEWATCH (2001). A Beginner's guide to water management - Lake Morphometry (2nd ed.). Gainesville: Florida LAKEWATCH, Department of Fisheries and Aquatic Sciences. [Link](#)

Examples

```
data(lakes)
lakeSurfaceArea(inputLM)
```

lakeSurroundTopo	<i>Calculate surrounding topography for lake</i>
------------------	--

Description

This function combines all input datasets into a [lakeMorphoClass](#). As a part of this combination, the surrounding topography is also determined. If no input catchments are used, it is assumed that a buffer equal to the maximum in lake distance is used. If an input catchment is used, then the surrounding topography is the land area represented by the catchments that intersect the lake. This function (and all of lakemorpho) expect clean polygons. No internal checking (e.g. for proper encoding of holes, etc.) is done.

Usage

```
lakeSurroundTopo(
  inLake,
  inElev = NULL,
  inCatch = NULL,
  reso = ifelse(!is.null(inElev), res(inElev)[1], 10)
)
```

Arguments

inLake	a SpatialPolygons or SpatialPolygonsDataFrame representing the input lake. Required.
inElev	a RasterLayer representing the elevation around the lake. Required.
inCatch	Optional SpatialPolygons or SpatialPolygonsDataFrame defining the Surrounding Topography. Default is NULL which uses a buffer equal to the maximum in lake distance.
reso	Optional resolution for raster output (e.g. lake distance). Defaults to the resolution of inElev

Value

Returns an object of class 'lakemorpho' that includes the surrounding topography of the lake.

Examples

```
data(lakes)
inputLM<-lakeSurroundTopo(exampleLake,exampleElev)
inputLM
```

 lakeVolume

Calculates Lake Volume in R

Description

This function returns lake volume for the input lake. The volume is calculated using maximum lake depth and maximum distance ratio to transform all pixels and thus, distances, to an estimated depth. These depths are multiplied by the area of the pixel and summed.

Usage

```
lakeVolume(
  inLakeMorpho,
  zmax = NULL,
  slope_quant = 0.5,
  correctFactor = 1,
  addBathy = FALSE
)
```

Arguments

- | | |
|---------------|--|
| inLakeMorpho | An object of lakeMorphoClass . Output of the lakeSurroundTopo function would be appropriate as input |
| zmax | Maximum depth of the lake. If none entered and elevation dataset is included in inLakeMorpho, lakeMaxDepth is used to estimate a maximum depth. |
| slope_quant | The slope quantile to use to estimate maximum depth. Defaults to the median as described in (Hollister et. al, 2011). |
| correctFactor | This a factor used by lakeMaxDepth to correct the predicted maximum lake depth. Defaults to 1. |
| addBathy | Logical to include a depth raster on the input lakeMorphoClass object. This is labelled as 'pseudoBathy' in the output. It is depth estimated using the maximum lake depth and maximum distance ratio. Might be useful for some applications but shouldn't be considered a replacement for a bathymetric survey. |

Value

Returns a numeric value for the total volume of the lake

References

Hollister, J. W., W.B. Milstead (2010). Using GIS to Estimate Lake Volume from Limited Data. Lake and Reservoir Management. 26(3)194-199. doi:10.1080/07438141.2010.504321

Florida LAKEWATCH (2001). A Beginner's guide to water management - Lake Morphometry (2nd ed.). Gainesville: Florida LAKEWATCH, Department of Fisheries and Aquatic Sciences. [Link](#)

Examples

```
data(lakes)
lakeVolume(inputLM, addBathy = TRUE)
```

plot.lakeMorpho *Default plotting of a lakeMorpho object*

Description

Plots the lakeMorpho class object showing the lake, surrounding topography, and in-lake distance

Usage

```
## S3 method for class 'lakeMorpho'
plot(x, dist = FALSE, length = TRUE, width = TRUE, fetch = FALSE, ...)
```

Arguments

x	input lakeMorpho class to plot
dist	Boolean to control plotting of in lake distance
length	Boolean to control plotting of max lake length line
width	Boolean to control plotting of max lake width line
fetch	Boolean to control plotting of fetch lines
...	allows for passing of other plot parameters

Examples

```
data(lakes)
plot(inputLM)
```

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