

Package ‘GeNetIt’

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Type Package

Title Spatial Graph-Theoretic Genetic Gravity Modelling

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Description Implementation of spatial graph-theoretic genetic gravity models.
The model framework is applicable for other types of spatial flow questions.
Includes functions for constructing spatial graphs, sampling and summarizing associated raster variables and building unconstrained and singly constrained gravity models.

Depends R (>= 4.2.0), nlme

Imports exactextractr, terra, sf, sfnetworks, igraph, dplyr,
tidygraph, spdep

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License GPL-3

URL <https://github.com/jeffreyevans/GeNetIt>

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adj_matrix	<i>Binary adjacency matrix</i>
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Description

Creates a binary matrix of adjacencies based on from-to graph relationships (joins)

Usage

```
adj_matrix(i, j = NULL)
```

Arguments

i	a vector or, if j = NULL a data.frame with two columns indicating from-to relationships (joins)
j	If specified, i must be a vector of same length and the i,j vectors must represent joins

Value

A binary matrix

Author(s)

Jeffrey S. Evans <jeffrey_evans@tnc.org> and Melanie A. Murphy <melanie.murphy@uwo.edu>

Examples

```
library(sf)
data(ralu.site, package="GeNetIt")

p <- as(ralu.site, "sf")
g <- knn.graph(p[c(1,5,8,10,20,31),])
plot(st_geometry(g))

( ind <- sf::st_drop_geometry(g[,1:2])[1:10,] )

adj_matrix(ind)

adj_matrix(g$i[1:10], g$j[1:10])
```

area.graph.statistics *Statistics for edges (lines) based on a defined scale (area).*

Description

Samples rasters for each edge and calculates specified statistics for buffer distance

Usage

```
area.graph.statistics(...)
```

Arguments

... Parameters to be passed to the modern version of the function

Note

Please note that this function has been deprecated, please use graph.statistics with the buffer argument.

build.node.data *Build node data*

Description

Helper function to build the origin/destination node data structure.

Usage

```
build.node.data(x, group.ids, from.parms, to.parms = NULL)
```

Arguments

x	A data.frame containing node (site) data
group.ids	Character vector of unique identifier that can be used to join to graph
from.parms	Character vector of independent "from" variables
to.parms	Character vector of independent "to" variables. If NULL is the same as from.parms

Value

data.frame

Note

Unless a different set of parameters will be used as the destination (to) there is no need to define the argument "to.parms" and the "from.parm" will be used to define both set of parameters.

The resulting data.frame represents the origin (from) and destination (to) data structure for use in gravity model. This is node structure is also know in the gravity literature as producer (from) and attractor (to).

Author(s)

Jeffrey S. Evans <jeffrey_evans@tnc.org> and Melanie A. Murphy <melanie.murphy@uwo.edu>

Examples

```
data(ralu.site)

# Build from/to site (node) level data structure
site.parms = c("AREA_m2", "PERI_m", "Depth_m", "TDS")
site <- build.node.data(sf::st_drop_geometry(ralu.site),
                      group.ids = c("SiteName"),
                      from.parms = site.parms )
```

compare.models

Compare gravity models

Description

Prints diagnostic statistics for comparing gravity models

Usage

```
compare.models(...)
```

Arguments

... gravity model objects

Details

Results include model name, AIX, BIC, log likelihood, RMSE and number of parameters

Value

data.frame of competing model statistics

Author(s)

Jeffrey S. Evans <jeffrey_evans@tnc.org> and Melanie A. Murphy <melanie.murphy@uwo.edu>

References

Murphy M.A., R. Dezzani, D.S. Pilliod & A.S. Storfer (2010) Landscape genetics of high mountain frog metapopulations. *Molecular Ecology* 19(17):3634-3649

Examples

```
library(nlme)
data(ralu.model)

x = c("DEPTH_F", "HLI_F", "CTI_F", "cti", "ffp")
( null <- gravity(y = "DPS", x = c("DISTANCE"), d = "DISTANCE",
  group = "FROM_SITE", data = ralu.model, fit.method = "ML") )
( gm_h1 <- gravity(y = "DPS", x = x, d = "DISTANCE", group = "FROM_SITE",
  data = ralu.model, ln = FALSE, fit.method="ML") )
( gm_h2 <- gravity(y = "DPS", x = x[1:3], d = "DISTANCE", group = "FROM_SITE",
  data = ralu.model, ln = FALSE, fit.method="ML") )
( gm_h3 <- gravity(y = "DPS", x = x[c(4:5)], d = "DISTANCE", group = "FROM_SITE",
  data = ralu.model, ln = FALSE, fit.method="ML") )
#( gm_h4 <- gravity(y = "DPS", x = x[c(4:5)], d = "DISTANCE", group = "FROM_SITE",
#  data = ralu.model, ln = FALSE, fit.method="REML") )

compare.models(null, gm_h1, gm_h2, gm_h3)
```

 covariates

Subset of raster data for Columbia spotted frog (Rana luteiventris)

Description

Subset of data used in Murphy et al., (2010)

Format

A 30m LZW compressed tiff:

rows 426

columns 358

resoultion 30 meter

projection "+proj=utm +zone=11 +datum=NAD83 +units=m +no_defs +ellps=GRS80 +towgs84=0,0,0"

cti Compound Topographic Index ("wetness")

err27 Elevation Relief Ratio

ffp Frost Free Period

gsp Growing Season Precipitation

hil Heat Load Index

nlcd USGS Landcover

References

Murphy M.A., R. Dezzani, D.S. Pilliod & A.S. Storfer (2010) Landscape genetics of high mountain frog metapopulations. *Molecular Ecology* 19(17):3634-3649

dmatrix.df

Distance matrix to data.frame

Description

Coerces distance matrix to a data.frame object

Usage

```
dmatrix.df(x, rm.diag = TRUE)
```

Arguments

x Symmetrical distance matrix
rm.diag (TRUE/FALSE) remove matrix diagonal, self values.

Value

data.frame object representing to and from values

Note

Function results in data.frame object with "X1" (FROM), "X2" (TO) and "distance" columns. The FROM column represents to origin ID, TO represents destination ID and distance is the associated matrix distance. These results can be joined back to the graph object using either the origin or destination ID's.

Author(s)

Jeffrey S. Evans <jeffrey_evans@tnc.org> and Melanie A. Murphy <melanie.murphy@uwo.edu>

Examples

```
library(sf)
pts <- data.frame(ID=paste0("ob",1:15), x=runif(15, 480933, 504250),
                  y=runif(15, 4479433, 4535122))
pts <- st_as_sf(pts, coords = c("x", "y"),
               crs = 32611, agr = "constant")

# Create distance matrix
dm <- st_distance(pts)
class(dm) <- setdiff(class(dm), "units")
attr(dm, "units") <- NULL
colnames(dm) <- pts$ID
rownames(dm) <- pts$ID

# Coerce to data.frame with TO and FROM ID's and associated distance
dm.df <- dmatrix.df(dm)
head(dm.df)
```

dps

dps genetic distance matrix for Columbia spotted frog (Rana luteiventris)

Description

Subset of data used in Murphy et al., (2010)

Format

A 29 x 29 genetic distance matrix:

References

Murphy M.A., R. Dezzani, D.S. Pilliod & A.S. Storfer (2010) Landscape genetics of high mountain frog metapopulations. *Molecular Ecology* 19(17):3634-3649

flow *Convert distance to flow*

Description

Converts distance to flow (1-d) with or without data standardization

Usage

```
flow(x, standardize = FALSE, rm.na = FALSE, diag.value = NA)
```

Arguments

x	A numeric vector or matrix object representing distances
standardize	(FALSE/TRUE) Row-standardize the data before calculating flow
rm.na	(TRUE/FALSE) Should NA's be removed, if FALSE (default) they will be retained in the results
diag.value	If x is a matrix, what diagonal matrix values should be used (default is NA)

Value

A vector or matrix representing flow values

Author(s)

Jeffrey S. Evans <jeffrey_evans@tnc.org> and Melanie A. Murphy <melanie.murphy@uwyo.edu>

Examples

```
#### On a distance vector
flow(runif(10,0,1))
flow(runif(10,0,500), standardize = TRUE)

# With NA's
d <- runif(10, 0,1)
d[2] <- NA
flow(d)
flow(d, rm.na=TRUE)

#### On a distance matrix
dm <- as.matrix(dist(runif(5,0,1), diag = TRUE, upper = TRUE))
flow(dm)
```

graph.metrics	<i>Graph Metrics</i>
---------------	----------------------

Description

Metrics on structural properties of graph (at nodes)

Usage

```
graph.metrics(  
  x,  
  node.pts,  
  node.name = NULL,  
  direct = FALSE,  
  metric = c("betweenness", "degree", "closeness")  
)
```

Arguments

x	knn graph object from GeNetIt::knn.graph (sf LINESTRING)
node.pts	sf POINT or sp SpatialPointsDataFrame object used as nodes to build x
node.name	Column name in node.pts object that acts as the provides the unique ID. If not defined, defaults to row.names of node.pts
direct	(FALSE/TRUE) Evaluate directed graph
metric	...

Note

Please note; graph metrics are not valid for a saturated graph (all connections)

Author(s)

Jeffrey S. Evans <jeffrey_evans@tnc.org> and Melanie A. Murphy <melanie.murphy@uwyo.edu>

Examples

```
library(sf)  
data(ralu.site, package="GeNetIt")  
  
graph <- knn.graph(ralu.site, row.names=ralu.site$SiteName,  
  max.dist = 2500)  
plot(st_geometry(graph))  
  
( m <- graph.metrics(graph, ralu.site, "SiteName") )  
  
ralu.site <- merge(ralu.site, m, by="SiteName")  
# plot node betweenness
```

```
plot(st_geometry(graph), col="grey")
plot(ralu.site["betweenness"], pch=19, cex=1.25, add=TRUE)
# plot node degree
plot(st_geometry(graph), col="grey")
plot(ralu.site["degree"], pch=19, cex=1.25, add=TRUE)
```

graph.statistics *Statistics for edges (lines)*

Description

Extracts raster values for each edge and calculates specified statistics

Usage

```
graph.statistics(x, r, stats = c("min", "mean", "max"), buffer = NULL)
```

Arguments

x	sp SpatialLinesDataFrame or sf LINE object
r	A terra SpatRast or raster rasterLayer, rasterStack, rasterBrick object
stats	Statistics to calculate. If vectorized, can pass a custom statistic function.
buffer	Buffer distance, radius in projection units. For statistics based on edge buffer distance

Value

data.frame object of statistics

Note

If the buffer argument is specified that, raster values within the specified buffer radius are extracted and included in the derived statistic(s). Else-wise, the statistics are derived from raster values that directly intersect each edge.

Author(s)

Jeffrey S. Evans <jeffrey_evans@tnc.org> and Melanie A. Murphy <melanie.murphy@uwo.edu>

Examples

```

library(sf)
library(terra)

data(ralu.site)
xvars <- rast(system.file("extdata/covariates.tif", package="GeNetIt"))

( dist.graph <- knn.graph(ralu.site, row.names = ralu.site$SiteName,
                        max.dist = 1500) )

skew <- function(x, na.rm = TRUE) {
  if (na.rm) x <- x[!is.na(x)]
  sum( (x - mean(x)) ^ 3) / ( length(x) * sd(x) ^ 3 )
}

# Moments on continuous raster data
system.time( {
  stats <- graph.statistics(dist.graph, r = xvars[[-6]],
                          stats = c("min", "median", "max", "var", "skew"))
} )

# Proportional function on nominal raster data
p <- function(x) { length(x[x < 52]) / length(x) }

system.time( {
  nstats <- graph.statistics(dist.graph, r = xvars[[6]],
                           stats = "p")
} )

# Based on 500m buffer distance around line(s)
system.time( {
  stats <- graph.statistics(dist.graph, r = xvars[[-6]],
                          stats = c("min", "median", "max", "var", "skew"),
                          buffer = 500)
} )

```

gravity

Gravity model

Description

Implements Murphy et al., (2010) gravity model via a linear mixed effects model

Usage

```
gravity(
```

```

y,
x,
d,
group,
data,
fit.method = c("REML", "ML"),
ln = TRUE,
constrained = TRUE,
...
)

```

Arguments

y	Name of dependent variable
x	Character vector of independent variables
d	Name of column containing distance
group	Name of grouping column (from or to)
data	data.frame object containing model data
fit.method	Method used to fit model c("REML", "ML")
ln	Natural log transform data (TRUE/FALSE)
constrained	Specify constrained model, if FALSE a linear model (lm) is run (TRUE/FALSE)
...	Additional argument passed to nlme or lm

Details

The "group" factor defines the singly constrained direction (from or to) and the grouping structure for the origins. To specify a null (distance only or IBD) model just omit the x argument.

By default constrained models are fit by maximizing the restricted log-likelihood (REML), for maximum likelihood use the type="ML" argument which is passed to the lme function. If ln=TRUE the input data will be log transformed

Value

formula Model formula call
fixed.formula Model formula for fixed effects
random.formula Model formula for random (group) effects (only for constrained models)
gravity Gravity model
fit Model Fitted Values
AIC AIC value for selected model
RMSE Root Mean Squared Error (based on bias corrected back transform)
log.likelihood Restricted log-likelihood at convergence
group.names Column name of grouping variable
groups Values of grouping variable

x data.frame of x variables
 y Vector of y variable
 constrained TRUE/FALSE indicating if model is constrained

Note

Depends: nlme, lattice

Author(s)

Jeffrey S. Evans <jeffrey_evans@tnc.org> and Melanie A. Murphy <melanie.murphy@uwo.edu>

References

Murphy, M. A. & J.S. Evans. (in prep). GenNetIt: graph theoretical gravity modeling for landscape genetics

Murphy M.A., R. Dezzani, D.S. Pilliod & A.S. Storfer (2010) Landscape genetics of high mountain frog metapopulations. *Molecular Ecology* 19(17):3634-3649

See Also

[groupedData](#) for how grouping works in constrained model

[lme](#) for constrained model ... options

[lm](#) for linear model ... options

Examples

```
library(nlme)
data(ralu.model)

# Gravity model
x = c("DEPTH_F", "HLI_F", "CTI_F", "cti", "ffp")
( gm <- gravity(y = "DPS", x = x, d = "DISTANCE", group = "FROM_SITE",
               data = ralu.model, ln = FALSE) )

#' # Plot gravity results
par(mfrow=c(2,3))
for (i in 1:6) { plot(gm, type=i) }

# log likelihood of competing models
x = c("DEPTH_F", "HLI_F", "CTI_F", "cti", "ffp")
for(i in x[-1]) {
  x1 = c(x[1], x[-which(x %in% i)])
  ll <- gravity(y = "DPS", x = x1, d = "DISTANCE", group = "FROM_SITE",
               data = ralu.model, ln = FALSE)$log.likelihood
  cat("log likelihood for parameter set:", "(",x1,")", "=", ll, "\n")
}

# Distance only (IBD) model
gravity(y = "DPS", d = "DISTANCE", group = "FROM_SITE",
```

```
data = ralu.model, ln = FALSE)
```

gravity.es

Effect Size

Description

Cohen's D effect size for gravity models

Usage

```
gravity.es(x, actual.n = FALSE, alpha = 0.95)
```

Arguments

x	gravity model object
actual.n	(FALSE/TRUE) Use actual N or degrees of freedom in calculating Confidence Interval
alpha	confidence interval

Details

Calculate Cohen's D statistic for each effect in a gravity model object

Value

data.frame of parameter effect size

Author(s)

Jeffrey S. Evans <jeffrey_evans@tnc.org> and Melanie A. Murphy <melanie.murphy@uwyo.edu>

References

Murphy M.A., R. Dezzani, D.S. Pilliod & A.S. Storfer (2010) Landscape genetics of high mountain frog metapopulations. *Molecular Ecology* 19(17):3634-3649

Cohen, J. (1988) *Statistical power for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum

Examples

```
library(nlme)
data(ralu.model)

x = c("DEPTH_F", "HLI_F", "CTI_F", "cti", "ffp")
gm_h1 <- gravity(y = "DPS", x = x, d = "DISTANCE", group = "FROM_SITE",
               data = ralu.model, ln = FALSE, method="ML")

gravity.es(gm_h1)
```

knn.graph *Saturated or K Nearest Neighbor Graph*

Description

Creates a kNN or saturated graph SpatialLinesDataFrame object

Usage

```
knn.graph(
  x,
  row.names = NULL,
  k = NULL,
  max.dist = NULL,
  long.lat = FALSE,
  drop.lower = FALSE
)
```

Arguments

x	sf POINTS object
row.names	Unique row.names assigned to results
k	K nearest neighbors, defaults to saturated (n(x) - 1)
max.dist	Maximum length of an edge (used for distance constraint)
long.lat	(FALSE/TRUE) Coordinates are longitude-latitude decimal degrees, in which case distances are measured in kilometers
drop.lower	(FALSE/TRUE) Drop lower triangle of matrix representing duplicate edges ie, from-to and to-from

Value

SpatialLinesDataFrame object with:

- i Name of column in x with FROM (origin) index
- j Name of column in x with TO (destination) index
- from_ID Name of column in x with FROM (origin) region ID
- to_ID Name of column in x with TO (destination) region ID
- length Length of each edge (line) in projection units or kilometers if not projected

Note

...

Author(s)

Jeffrey S. Evans jeffrey_evans@tnc.org and Melanie A. Murphy melanie.murphy@uwyo.edu

References

- Murphy, M. A. & J.S. Evans. (in prep). "GenNetIt: gravity analysis in R for landscape genetics"
 Murphy M.A., R. Dezzani, D.S. Pilliod & A.S. Storfer (2010) Landscape genetics of high mountain frog metapopulations. *Molecular Ecology* 19(17):3634-3649

Examples

```
library(sf)
data(ralu.site, package="GeNetIt")

# Saturated spatial graph
sat.graph <- knn.graph(ralu.site, row.names=ralu.site$SiteName)
head(sat.graph)

# Distanced constrained spatial graph
dist.graph <- knn.graph(ralu.site, row.names=ralu.site$SiteName,
                       max.dist = 5000)

opar <- par(no.readonly=TRUE)
par(mfrow=c(1,2))
plot(st_geometry(sat.graph), col="grey")
  points(st_coordinates(ralu.site), col="red", pch=20, cex=1.5)
  box()
  title("Saturated graph")
plot(st_geometry(dist.graph), col="grey")
  points(st_coordinates(ralu.site), col="red", pch=20, cex=1.5)
  box()
  title("Distance constrained graph")
par(opar)
```

node.statistics

raster statistics for nodes

Description

returns raster value or statistics (based on specified radius) for node

Usage

```
node.statistics(x, r, buffer = NULL, stats = c("min", "median", "max"))
```

Arguments

x	sp class SpatialPointsDataFrame object
r	A rasterLayer, rasterStack or rasterBrick object
buffer	Buffer distance, radius in projection units
stats	Statistics to calculate. If vectorized, can pass a custom statistic function.

Value

data.frame object of at-node raster values or statistics

Note

If no buffer is specified, at-node raster values are returned

Author(s)

Jeffrey S. Evans <jeffrey_evans@tnc.org> and Melanie A. Murphy <melanie.murphy@uwo.edu>

Examples

```
library(sf)
library(terra)

data(ralu.site)
xvars <- rast(system.file("extdata/covariates.tif", package="GeNetIt"))

skew <- function(x, na.rm = TRUE) {
  if (na.rm) x <- x[!is.na(x)]
  sum( (x - mean(x)) ^ 3 ) / ( length(x) * sd(x) ^ 3 )
}

# without buffer (values at point)
system.time( {
  stats <- node.statistics(ralu.site, r = xvars[[-6]])
} )

# with 1000m buffer (values around points)
system.time( {
  stats <- node.statistics(ralu.site, r = xvars[[-6]], buffer = 1000,
    stats = c("min", "median", "max", "var", "skew"))
} )
```

plot.gravity

Plot gravity model

Description

Diagnostic plots gravity model with 6 optional plots.

Usage

```
## S3 method for class 'gravity'
plot(x, type = 1, ...)
```

Arguments

x	Object of class gravity
type	Type of plot (default 1, model structure I)
...	Ignored

Value

defined plot

Note

Plot types available: 1 - Model structure I, 2 - Model structure II, 3 - Q-Q Normal - Origin random effects, 4 - Q-Q Normal - Residuals , 5 - Fitted values, 6 - Distribution of observed verses predicted

Depends: nlme, lattice

Author(s)

Jeffrey S. Evans <jeffrey_evans@tnc.org> and Melanie A. Murphy <melanie.murphy@uwyo.edu>

References

Murphy, M. A. & J.S. Evans. (in prep). "GenNetIt: gravity analysis in R for landscape genetics"

Murphy M.A., R. Dezzani, D.S. Pilliod & A.S. Storfer (2010) Landscape genetics of high mountain frog metapopulations. *Molecular Ecology* 19(17):3634-3649

predict.gravity *Predict gravity model*

Description

predict method for class "gravity"

Usage

```
## S3 method for class 'gravity'
predict(
  object,
  newdata,
  groups = NULL,
  back.transform = c("none", "simple", "Miller", "Naihua"),
  ...
)
```

Arguments

object	Object of class gravity
newdata	New data used for obtaining the predictions, can be a data.frame or nffGrouped-Data
groups	Grouping factor acting as random effect. If used, must match levels used in model, otherwise leave it null and do not convert to groupedData
back.transform	Method to back transform data, default is none and log predictions will be returned.
...	Arguments passed to predict.lme or predict.lm

Details

Please note that the entire gravity equation is log transformed so, your parameter space is on a log scale, not just y . This means that for a meaningful prediction the "newdata" also needs to be on a log scale.

For the back.transform argument, the simple back-transform method uses the form $\exp(\hat{y})0.5 \cdot \text{variance}$ whereas Miller uses $\exp(\sigma) \cdot 0.5$ as the multiplicative bias factor. Naihua regresses $y \sim \exp(\hat{y})$ with no intercept and uses the resulting coefficient as the multiplicative bias factor. The Naihua method is intended for results with non-normal errors. You can check the functional form by simply plotting y (non-transformed) against the fit. The default is to output the log scaled predictions.

Value

Vector of model predictions

Author(s)

Jeffrey S. Evans <jeffrey_evans@tnc.org> and Melanie A. Murphy <melanie.murphy@uwyo.edu>

References

Miller, D.M. (1984) Reducing Transformation Bias in Curve Fitting The American Statistician. 38(2):124-126

Naihua, D. (1983) Smearing Estimate: A Nonparametric Retransformation Method Journal of the American Statistical Association, 78(383):605–610.

Examples

```
library(nlme)
data(ralu.model)

back.transform <- function(y) exp(y + 0.5 * stats::var(y, na.rm=TRUE))
rmse = function(p, o){ sqrt(mean((p - o)^2)) }

x = c("DEPTH_F", "HLI_F", "CTI_F", "cti", "ffp")

sidx <- sample(1:nrow(ralu.model), 100)
train <- ralu.model[sidx,]
```

```

test <- ralu.model[-sidx,]

# Specify constrained gravity model
( gm <- gravity(y = "DPS", x = x, d = "DISTANCE", group = "FROM_SITE",
              data = train, ln = FALSE) )

( p <- predict(gm, test[,c(x, "DISTANCE")]) )
  rmse(back.transform(p), back.transform(ralu.model[, "DPS"][-sidx]))

# With model sigma-based back transformation
( p <- predict(gm, test[,c(x, "DISTANCE")], back.transform = "simple") )
( p <- predict(gm, test[,c(x, "DISTANCE")], back.transform = "Miller") )
( p <- predict(gm, test[,c(x, "DISTANCE")], back.transform = "Naihua") )

# Using grouped data
test <- nlme::groupedData(stats::as.formula(paste(paste("DPS", 1, sep = " ~ "),
        "FROM_SITE", sep = " | ")),
  data = test[,c("DPS", "FROM_SITE", x, "DISTANCE")])

( p <- predict(gm, test, groups = "FROM_SITE") )
( y.hat <- back.transform(ralu.model[, "DPS"][-sidx]) )
  na.idx <- which(is.na(p))
  rmse(back.transform(p)[-na.idx], y.hat[-na.idx])

# Specify unconstrained gravity model (generally, not recommended)
( gm <- gravity(y = "DPS", x = x, d = "DISTANCE", group = "FROM_SITE",
              data = train, ln = FALSE, constrained=TRUE) )

( p <- predict(gm, test[,c(x, "DISTANCE")]) )
  rmse(back.transform(p), back.transform(ralu.model[, "DPS"][-sidx]))

```

print.gravity

Print gravity model

Description

summary method for class "gravity"

Usage

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

Arguments

x	Object of class gravity
...	Ignored

ralu.model	<i>Columbia spotted frog (Rana luteiventris) data for specifying gravity model. Note, the data.frame is already log transformed.</i>
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Description

Subset of data used in Murphy et al., (2010)

Format

A data.frame with 190 rows (sites) and 19 columns (covariates):

ARMI_ID Unique ID

FROM_SITE Unique from site ID

TO_SITE Unique to site ID

FST FST genetic distance

DPS DPS genetic distance

DISTANCE Graph edge distance

DEPTH_F At site water depth

HLI_F Heat Load Index

CTI_F Wetness Index

DEPTH_T At site water depth

HLI_T Heat Load Index

CTI_T Wetness Index

hli Heat Load Index

cti Wetness Index

ffp Frost Free Period

err27 Roughness at 27x27 scale

rsp Relative Slope Position

ridge Percent Ridge Line

hab_ratio Ratio of suitable dispersal habitat

References

Murphy M.A., R. Dezzani, D.S. Pilliod & A.S. Storfer (2010) Landscape genetics of high mountain frog metapopulations. *Molecular Ecology* 19(17):3634-3649

ralu.site	<i>Subset of site-level spatial point data for Columbia spotted frog (Rana luteiventris)</i>
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Description

Subset of data used in Murphy et al., (2010)

Format

An sf POINT object with 31 obs. of 17 variables:

SiteName Unique site name

Drainage Source drainage

Basin source basin

Substrate Wetland substrate

NWI USFWS NWI Wetland type

AREA_m2 Area of wetland

PERI_m Perimeter of wetland

Depth_m Depth of wetland

TDS ...

FISH Fish present

ACB ...

AUC ...

AUCV ...

AUCC ...

AUF ...

AWOOD ...

AUFV ...

References

Murphy M.A., R. Dezzani, D.S. Pilliod & A.S. Storfer (2010) Landscape genetics of high mountain frog metapopulations. *Molecular Ecology* 19(17):3634-3649

summary.gravity	<i>Summarizing Gravity Model Fits</i>
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Description

Summary method for class "gravity".

Usage

```
## S3 method for class 'gravity'  
summary(object, ...)
```

Arguments

object	Object of class gravity
...	Ignored

Note

Summary of lme or lm gravity model, AIC, log likelihood and Root Mean Square Error (RMSE) of observed verses predicted

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