

Package ‘EcoIndR’

September 1, 2017

Version 1.2

Title Ecological Indicators

Author Cástor Guisande González

Maintainer Cástor Guisande González <castor@uvigo.es>

Description Calculates several indices, such as of diversity, fluctuation, etc., and they are used to estimate ecological indicators.

License GPL (>= 2)

Encoding latin1

Depends R (>= 3.1.1)

Suggests vegan, shape, Rarity, splancs, plotrix, FD, picante

Repository CRAN

NeedsCompilation no

Date/Publication 2017-09-01 19:54:14 UTC

R topics documented:

DER	1
Rotifers	9

Index	11
--------------	-----------

DER	<i>DIFFERENTIATING SAMPLES USING RARITY, HETEROGENEITY, EVENNESS, TAXONOMIC, PHYLOGENETIC AND FUNCTIONAL DIVERSITY INDICES</i>
-----	--

Description

An algorithm for differentiating samples on the basis of the rarity, heterogeneity, evenness, taxonomic/phylogenetic and functional diversity indices that better reflect the differences among assemblages.

Usage

```
DER(data, Samples, Species, Taxon, TaxonFunc=NULL, TaxonPhyl=NULL,
pos=NULL, varSize="Richness", varColor="Rarity", Index=NULL, corr="sqrt",
palette= "heat.colors", size=c(1,5),digitsS=0, digitsC=2, ncolor=100,
transparency=1, references=TRUE, a=1.5, q=2.5, ResetPAR=TRUE, PAR=NULL,
dbFD=NULL, LEGENDS=NULL, TEXT=NULL, COLOR=c("#EEC591FF", "black", "grey50"),
file1="Diversity indices.csv", file2="Polar coordinates.csv",
file3="Indices and area of the polygon.csv", na="NA", dec=",", row.names=FALSE)
```

Arguments

data Data file with the taxonomy, abundance of the species and functional traits (optional). The format of the file must be: an optional column with the position of labels' samples in the DER plot (blue column) in the same order as the variables with the species' abundance in the samples (red columns), the columns with the taxonomy of the species (as many as needed, green columns), the columns with the abundance of the species in each sample (red columns) and optionally the columns with the functional traits of the species. Each row is an unique species, genus, family, etc.

Pos	Class	Subclass	Superorder	Order	Family	Genus	Species	F1.1	F0.1	G3.1	F2.1
2	Eurotatoria	Monogononta	Pseudotrocha	Plolima	Asplanchnidae	Asplanchnopus	multiceps				
4	Eurotatoria	Monogononta	Pseudotrocha	Plolima	Euchlanidae	Beauchampella	eudactylota				
3	Eurotatoria	Monogononta	Pseudotrocha	Plolima	Bredonidae	Bredonius	quadridentatus				
2	Eurotatoria	Monogononta	Pseudotrocha	Plolima	Notommatidae	Cephalodella	gibba	1			
3	Eurotatoria	Monogononta	Gnesiotrocha	Plosculariacea	Conochilidae	Conochilus	obsoletus				16
4	Eurotatoria	Monogononta	Pseudotrocha	Plolima	Euchlanidae	Dipleuchlanis	propatula				
4	Eurotatoria	Monogononta	Pseudotrocha	Plolima	Euchlanidae	Euchlanis	depidula	4	1	23	6
4	Eurotatoria	Monogononta	Pseudotrocha	Plolima	Euchlanidae	Euchlanis	sp1		3		
4	Eurotatoria	Monogononta	Pseudotrocha	Plolima	Bredonidae	Keratella	troica	2	10		5

Samples Variables with the abundance of the species in each sample: sampling sites, dates, etc.

Species Variable with the name of the species (without including the genus). It may be other node of the phylogenetic tree, such as the genus, family, etc., for genus level phylogenies, family level phylogenies, etc., but always without duplicates.

Taxon Variables with the taxonomy of the species (taxonomic diversity), as many levels as needed but without including the variable with the node of the argument *Species*.

TaxonFunc Optionally variables with the functional traits (functional diversity).

TaxonPhyl Optionally the name of the RData file of the class phylo with the phylogeny. The file must be in the working directory.

pos Optionally it is possible to indicate a column with the position of labels' samples in the DER plot. It must be as many as the number of samples and in the same order than the variables described in the argument *Samples*. Values of 1, 2, 3 and 4, respectively indicate positions below, to the left of, above and to the right of the specified coordinates.

varSize This variable defines the size of the bubble in the DER plot.

varColor This variable defines the color gradient of the bubbles in the DER plot.

Index	The four/five indices used in the DER algorithm. If it is NULL the algorithm select one, index of rarity, one of heterogeneity, one of evenness one of taxonomy and one of the functional group (if functional traits are provided in the argument <i>TaxonFunc</i>) that achieve a higher dispersion among samples in a polar coordinates system.
corr	Character string specifying the correction method to use, in the function <code>dbFD</code> , when the species-by-species distance matrix cannot be represented in a Euclidean space. Options are "sqrt" (default), "cailliez", "lingoes" or "none".
palette	The color gradient of the bubbles may be one of these palettes: "heat.colors", "terrain.colors", "gray.colors", "topo.colors" or "cm.colors", or any other option defined by the user.
size	Range of size of the bubbles. Two values: minimum and maximum size.
digitsS	Number of digits of the bubble size legend.
digitsC	Number of digits of the color legend.
ncolor	Gradient color of the color legend.
transparency	Transparency of the color gradient, from 0 to 1.
references	If it is TRUE the reference points are depicted on the DER plot.
a	Scale of Rényi diversity.
q	Scale of Tsallis diversity.
ResetPAR	If it is FALSE, the default condition of the function PAR of the package StatR is not placed and maintained those defined by the user in previous graphics.
PAR	It accesses the function PAR of the package StatR that allows to modify many different aspects of the graph.
dbFD	It accesses the function <code>dbFD</code> which allows to specify the arguments that calculates the functional diversity indices.
LEGENDS	It allows to modify the legend of the bubble size.
TEXT	It allows to modify the text of the labels in the bubbles.
COLOR	A vector with three values: color of the ellipse, color of the points in the legend of the size of the bubbles and color of the references points in the ellipse, respectively.
file1	CSV FILES. Filename with values of total abundance, richness and the rarity, heterogeneity, evenness, taxonomic, phylogenetic and functional diversity indices of each sample.
file2	CSV FILES. Filename with the polar coordinates of all samples considering the four/five selected indices.
file3	CSV FILES. Filename with the area of the convex hull ($\alpha=6$) and Euclidean distance obtained in the polar coordinates system for all combinations of the indices.
na	CSV FILE. Text that is used in the cells without data.
dec	CSV FILE. It defines if the comma "," is used as decimal separator or the dot ".".
row.names	CSV FILE. Logical value that defines if identifiers are put in rows or a vector with a text for each of the rows.

Details

DER algorithm

The steps of DER algorithm are described below:

1. The function DER calculates the most often used indices (see below): a total of 39 indices that includes 2 of rarity, 14 of heterogeneity, 7 of evenness, 2 of taxonomic diversity, 8 of phylogenetic diversity and 6 of functional diversity. It is important to mention that the indices included in the groups of phylogenetic diversity and functional diversity, each explores a different facet of phylogenetic diversity (Kembel et al., 2010) and functional diversity (Laliberté et al., 2010), respectively.

Rarity indices

Leroy Leroy et al. (2012; 2013)

Rarity. This index is a novel contribution of this package, where S is the number of species (species richness), s is the number of samples, r_{ij} is the number of records of the species i in the sample j , R is the total number of records considering all the species in all samples.

$$R = 1 - \frac{\sum_{i=1}^S \sum_{j=1}^s \frac{r_i}{R}}{S}$$

Heterogeneity indices

In Shannon-Wiener	Wiener, (1939; 1948; 1949)
and log Shannon-Wiener	Shannon (1948); Shannon and Weaver (1949)
Fisher's alpha	Fisher et al. (1943)
Simpson	Simpson (1949)
Inverse Simpson	Williams (1964)
Brillouin	Brillouin (1956)
Margalef	Margalef (1959)
Rényi entropy	Rényi (1961)
Menhinick	Menhinick (1964)
McIntosh	McIntosh (1967)
Inverse Berger-Parker	Berger and Parker (1970)
Hill- Rényi and Hill-Tsallis	Hill (1973)
Tsallis entropy	Patil and Taillie (1982); Tsallis (1988)

Evenness indices

Simpson	Simpson (1949)
Pielou	Pielou (1966)
McIntosh	McIntosh (1967)
Hill-Rényi numbers	Hill (1973)
Heip	Heip (1974)
Camargo	Camargo (1992)
Smith and Wilson's Index	Smith and Wilson (1996)

Taxonomic diversity indices

Taxonomic diversity	Warwick and Clarke (1995; 1998; 2001)
and Taxonomic distinctness	Clarke and Warwick (1998)

Phylogenetic diversity indices

Faith's phylogenetic diversity	Faith (1992)
Mean pairwise phylogenetic distance	Webb et al. (2008)
Mean nearest taxon distance	Webb et al. (2008)
Phylogenetic species richness	Helmus et al. (2007)
Phylogenetic species variability	Helmus et al. (2007)
Phylogenetic species evenness	Helmus et al. (2007)
Phylogenetic species clustering	Helmus et al. (2007)
Quadratic entropy	Rao (1982)

Functional diversity indices

Rao's quadratic entropy	Botta-Dukát (2005)
Functional group richness	Petchey and Gaston (2006)
Functional richness	Villéger et al. (2008)
Functional evenness	Villéger et al. (2008)
Functional divergence	Villéger et al. (2008)
Functional dispersion	Laliberté and Legendre (2010)

2. Each index is transformed to a scale range between 0 and 1 for all samples with the following equation:

$$\frac{(\text{index of the sample} - \text{min})}{(\text{max} - \text{min})}$$

where *min* and *max* are the minimum and maximum values of the index considering all samples, respectively.

3. With the standardized values of the indices, the algorithm calculates the polar coordinates of all samples with all possible combinations among all groups of indices. Therefore, in each combination an index of each group of rarity, heterogeneity (species richness is included in this group), evenness, taxonomic/ phylogenetic diversity and functional diversity (if it is included functional traits in the analysis) is used for calculating the polar coordinates of all samples. In the group of taxonomic/phylogenetic diversity the user must use either taxonomy or a phylogenetic tree, so either taxonomic diversity or phylogenetic diversity indices are used in the algorithm. The X and Y polar coordinates for each sample are estimated using the following equations:

$$X = \sum_{i=1}^4 |z_j| \cos(\alpha) \quad Y = \sum_{i=1}^4 |z_j| \sin(\alpha)$$

where *z* is the standardized value of the index *j* of the four groups considered.

Each index is assigned an angle (α). Degrees to radians angle conversion is carried out assuming that 1 degree = 0.0174532925 radians.

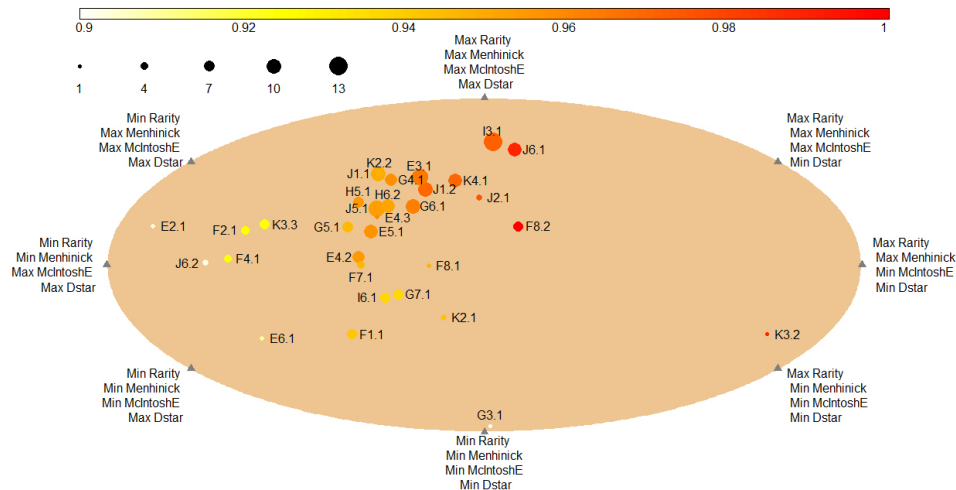
4. With the polar coordinates of the samples obtained for each combination, it is calculated the convex hull (alpha = 6) and the mean Euclidean distance, and the values are saved in a file.
5. The algorithm selects the combination of indices with the highest value of the mean between convex hull and mean Euclidean distance among samples, therefore priority is given to maximize dispersion among samples (see Fig. 1). The polar coordinates of the selected combination are depicted on a diagram, where it is possible to see the differences in rarity, heterogeneity, evenness and taxonomic/phylogenetic diversity and/or functional diversity (if it is included) among assemblages.
6. Finally, DER function allows the user to select the four/five indices to be used in the diagram, so the algorithm of selecting the combination with the maximum dispersion among samples is not applied.

FUNCTIONS

The index Fisher alpha was estimated with the function `fisher.alpha`, the index Rényi with the function `renyi`, the index Tsallis with the function `tsallis`, the taxonomic diversity and taxonomic distinctness with the functions `taxa2dist` and `taxondive`, all of them of the package `vegan` (Oksanen et al., 2016). The ellipse is depicted with the function `plotellipse` of the package `shape` (Soetaert, 2016). The convex hull (alpha=6) was calculated with the function `areapl` of the package `splancs` (Bivand et al., 2016). The color legend of DER plot was depicted with the function `color.legend` of the package `plotrix` (Lemon et al., 2016). The rarity index of Leroy was calculated with the functions `rWeights` and `Irr`, both of the package `Rarity` (Leroy et al., 2012; 2103; Leroy, 2016). The functional diversity indices were calculated with the function `dbFD` of the package `FD` (Laliberté et al., 2015). The phylogenetic indices were calculated with the functions `psv`, `psr`, `pse`, `psc`, `raoD`, `mntd`, `mpd` and `pd` of the package `picante` (Kembel et al. 2010 2016)

EXAMPLE

The example without functional diversity is a dataset with the abundance of rotifers species in ponds (see table 1 in Mazuelos et al., 1993). In the argument `Index` were selected `Rarity`, `Menhinick`, `McIntoshE` and `Dstar`, which are the indices selected by the algorithm when `Index=NULL` (default option). The sample G3.1 had the lowest values of the indices of rarity, heterogeneity, evenness and taxonomic diversity and the pond I3.1 the highest values for all indices.



Value

It is depicted a plot of polar coordinates estimated with the rarity, heterogeneity, evenness, taxonomic/phylogenetic and functional diversity indices, CSV files are saved with all the indices, the polar coordinates estimated with the indices specified in the argument *Index* or estimated by the algorithm, and the area of the convex hull and mean Euclidean distance obtained in the polar coordinates system for all combinations of the indices.

References

- Berger, W.H., Parker, F.L. (1970) Diversity of planktonic Foramenifera in deep sea sediments. *Science*, 168: 1345-1347.
- Bivand, R., Rowlingson, B., Diggle, P., Petris, G., Eglén, S. (2016) Spatial and Space-Time Point Pattern Analysis. R Package Version 2.01-39. <https://CRAN.R-project.org/package=splancs>
- Botta-Dukát, Z. (2005) Rao's quadratic entropy as a measure of functional diversity based on multiple traits. *Journal of Vegetation Science*, 16: 533-540.
- Brillouin, L. (1956) *Science and information theory*. New York: Academic Press.
- Camargo, J.A. (1992) New diversity index for assessing structural alterations in aquatic communities. *emphBulletin of Environmental Contamination and Toxicology*, 48, 428-434.
- Clarke, K.R. & Warwick, R.M. (1998). A taxonomic distinctness index and its statistical properties. *Journal of Applied Ecology*, 35: 523-531.
- Faith, D.P. (1992) Conservation evaluation and phylogenetic diversity. *Biological Conservation*, 61: 1-10.
- Fisher, R.A., Corbet, A.S. & Williams, C.B. (1943) The relation between the number of species and the number of individuals in a random sample of animal population. *Journal of Animal Ecology*, 12: 42-58.
- Heip, C. 1974. A new index measuring evenness. *Journal of the Marine Biological Association of the United Kingdom*, 54: 555-557.
- Helmus, M.R., Bland, T.J., Williams, C.J., Ives, A.R. (2007) Phylogenetic measures of biodiversity. *The American Naturalist*, 169: E68-E83.
- Hill, M.O. (1973) Diversity and evenness: a unifying notation and its consequences. *Ecology*, 54: 427-432.
- Hurlbert, S.H. 1971. The nonconcept of species diversity: a critique and alternative parameters. *Ecology*, 52: 577-586.
- Kembel, S.W., Cowan, P.D., Helmus, M.R., Cornwell, W.K., Morlon, H., Ackerly, D.D., Blomberg, S.P., Webb, C.O. (2010) Picante: R tools for integrating phylogenies and ecology. *Bioinformatics*, 26: 1463-1464.
- Kembel, S.W., Ackerly, D.D., Blomberg, S.P., Cornwell, W.K., Cowan, P.D., Helmus, M.R., Morlon, H. & Webb, C.O. (2016) R tools for integrating phylogenies and ecology. R Package Version 1.6-2. <https://CRAN.R-project.org/package=picante>
- Laliberté, E. & Legendre, P. (2010) A distance-based framework for measuring functional diversity from multiple traits. *Ecology*, 91: 299-305.
- Laliberté, E., Legendre, P. & Shipley, B. (2015) Measuring functional diversity (FD) from multiple traits, and other tools for functional ecology. R package version 1.0-12. Available at: <https://CRAN.R-project.org/package=FD>.

- Lemon, J., Bolker, B., Oom, S., Klein, E., Rowlingson, B., Wickham, H., Tyagi, A., Eterradossi, O., Grothendieck, G., Toews, M., Kane, J., Turner, R., Witthoft, C., Stander, J., Petzoldt, T., Duursma, R., Biancotto, E., Levy, O., Dutang, C., Solymos, P., Engelmann, R., Hecker, M., Steinbeck, F., Borchers, H., Singmann, H., Toal, T. & Ogle, D. (2016) Various plotting functions. R package version 3.6-3. Available at: <https://CRAN.R-project.org/package=plotrix>.
- Leroy, B., Petillon, J., Gallon, R., Canard, A. & Ysnel, F. (2012) Improving occurrence-based rarity metrics in conservation studies by including multiple rarity cut-off points. *Insect Conservation and Diversity*, 5, 159-168.
- Leroy, B., Canard, A. & Ysnel, F. (2013) Integrating multiple scales in rarity assessments of invertebrate taxa. *Diversity and Distributions*, 19, 794-803.
- Leroy, B. (2016) Calculation of Rarity Indices for Species and Assemblages of Species. R package version 1.3-4. Available at: <https://CRAN.R-project.org/package=Rarity>.
- Oksanen, J., Blanchet, F.G., Kindt, R., Legendre, P., Minchin, P.R., O'Hara, R.B., Simpson, G.L., Solymos, P., Henry, M., Stevens, H. & Wagner, H. (2016) Community Ecology Package. R package version 2.4-0. Available at: <https://CRAN.R-project.org/package=vegan>.
- Patil, G.P. & Taillie, C. (1982) Diversity as a concept and its measurement. *Journal of the Acoustical Society of America*, 77: 548-561.
- Pielou, E.C. (1966) The measurement of diversity in different types of biological collections. *Journal Theoretical Biology*, 13: 131-144.
- Petchey, O.L. & Gaston, K.J. (2002) Functional diversity (FD), species richness and community composition. *Ecology Letters*, 5: 402-411.
- Margalef, R. (1958) Information theory in ecology. *General Systems*, 3: 36-71.
- Mazuelos, N., Toja, J. & Guisande, C. (1993) Rotifers in ephemeral ponds of Doñana National Park. *Hydrobiologia*, 255/256: 429-434.
- McIntosh, R.P. (1967) An index of diversity and the relation of certain concepts to diversity. *Ecology*, 48: 392-404.
- Menhinick, E.P. (1964) A comparison of some species-individual diversity indices applies to samples of field insects. *Ecology*, 45: 859-861.
- Rényi, A. (1961) On measures of information and entropy. *Proceedings of the fourth Berkeley Symposium on Mathematics, Statistics and Probability Vol. 1*: 547-561.
- Rao, C.R. (1982) Diversity and dissimilarity coefficients: a unified approach. *Theoretical Population Biology*, 21: 24-43.
- Shannon, C.E. (1948) A Mathematical Theory of Communication. *Bell System Technical Journal*, 27 (4): 379-423, 623-656.
- Shannon, C.E. & Weaver, W. (1949) *The Mathematical Theory of Communication*. The University of Illinois Press, Illinois.
- Simpson, E.H. (1949) Measurement of diversity. *Nature*, 163: 688.
- Smith, B. & J.B. Wilson (1996) A consumer's guide to evenness indices. *Oikos*, 76: 70-82.
- Soetaert, K. 2016. Functions for plotting graphical shapes, colors. R package version 1.4.2. Available at: <https://CRAN.R-project.org/package=shape>.
- Spellerger, I.F. & Fedor P.J. (2013) A tribute to Claude Shannon (1916-2001) and a plea for more rigorous use of species richness, species diversity and the "Shannon-Wiener" Index. *Global Ecology and Biogeography*, 12: 177-179.

Tsallis, C. (1988) Possible generalization of Boltzmann-Gibbs statistics. *Journal of Statistical Physics*, 52: 479-487.

Villéger, S., Mason, N.W.H. & Mouillot, D. (2008) New multidimensional functional diversity indices for a multifaceted framework in functional ecology. *Ecology* 89: 2290-2301.

Webb, C.O., Ackerly, D.D. & Kembel, W. (2008) Phylocom: software for the analysis of phylogenetic community structure and trait evolution. *Bioinformatics*, 24: 2098-2100.

Wiener, N. (1939) The ergodic theorem. *Duke Mathematical Journal*, 5: 1-18.

Wiener, N. (1948) *Cybernetics*. Wiley, New York.

Wiener, N. (1949) *The interpolation, extrapolation, and smoothing of stationary time series*. Wiley, New York.

Examples

```
#An example without functional diversity
```

```
data(Rotifers)
```

```
DER(data=Rotifers, Samples=c("J1.1","K4.1","G3.1","F2.1","K2.2","F8.2","F8.1",
"F1.1","F4.1","J2.1","E5.1","H5.1","K3.2","E4.2","I6.1","K2.1","J5.1","I3.1",
"K3.3","G5.1","E6.1","J1.2","J6.1","G7.1","G6.1","G4.1","E3.1","E4.3","E2.1",
"H6.2","F7.1","J6.2"), Species="Species", Taxon=c("Class","Subclass",
"Superorder","Order","Family","Genus"), pos="Pos", Index=c("Rarity","Menhinick",
"McIntoshE", "Dstar") )
```

Rotifers

ABUNDANCE OF ROTIFERS IN PONDS

Description

Abundance of species of rotifers in ponds of Doñana National Park (Spain), which were obtained from Table 1 of Mazuelos et al. (1993).

Usage

```
data(Rotifers)
```

Format

An data frame with 40 columns: position of the label of the pond in the DER plot, 7 columns with the taxonomy of the species and the rest of columns are the abundance of the species of rotifers in the ponds.

References

Mazuelos, N., Toja, J., & Guisande, C. (1993) Rotifers in ephemeral ponds of Doñana National Park. *Hidrobiologia*, 255/256: 429-434.

Index

*Topic **DER**
DER, 1
*Topic **Rotifers**
Rotifers, 9

areapl, 6

color.legend, 6

dbFD, 3, 6
DER, 1

fisher.alpha, 6

Irr, 6

plotellipse, 6

renyi, 6
Rotifers, 9
rWeights, 6

taxa2dist, 6
taxondive, 6
tsallis, 6