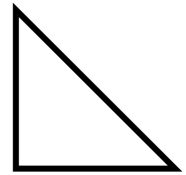
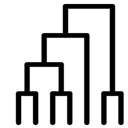
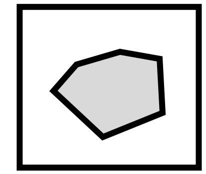
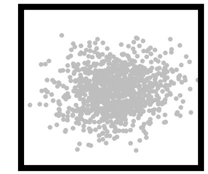
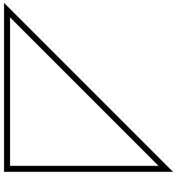
Metric computation

				
Observation-based metrics				
○ Originality	×	×		×
○ Uniqueness	×	×		
○ Contribution		×	×	×
Group-based metrics				
○ Richness		×	×	×
○ Divergence	×	×		×
○ Regularity	×	×		×
Between groups metrics				
○ Distance	×	×		×
○ Overlap		×	×	×

Metric computation



A. Observation-based metrics

	obs1	obs2	obs3	obs4	obs5	obs6	obs7
obs2	1						
obs3	2	1.5					
obs4	3	2.5	4				
obs5	0.5	2	5	6			
obs6	1	5	0.5	2	1		
obs7	2	2	6	1	1.5	2	
obs8	3	1	2	2	1	3.5	1

For observation 1

$$Originality_1 = \frac{(1+2+3+0.5+1+2+3)}{7} = 1.78$$

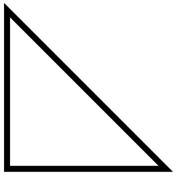
$$Uniqueness_1 = 0.5$$

$$Contribution_1 = NA$$

For originality, possibility to weight each distance with the relative abondance of the other species of the pair. No need to weight for uniqueness.

Grenié, M. et al. (2017). funrar: An R package to characterize functional rarity. *Diversity and Distributions*, *23*(12), 1365-1371.

Metric computation



B. Group-based metrics

	obs1	obs2	obs3	obs4	obs5	obs6	obs7
obs2	1						
obs3	2	1.5					
obs4	3	2.5	4				
obs5	0.5	2	5	6			
obs6	1	5	0.5	2	1		
obs7	2	2	6	1	1.5	2	
obs8	3	1	2	2	1	3.5	1

$$Richness = NA$$

Mean Pairwise distance (MPD)

$$Divergence = \frac{(1 + 2 + 1.5 + 3 + 2.5 + 4)}{6} = 2.33$$

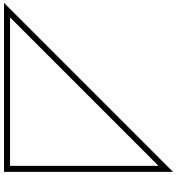
$$Regularity = FEve$$ See details in Villeger et al. 2018

Possibility to weight each distance with the product of the relative abondance of the two species.

Indices RaoQ and FDis are also available for divergence but all are highly correlated between each others. See also Hill numbers for similar indices with different weights for abundance.

Villéger, S. et al. (2008). New multidimensional functional diversity indices for a multifaceted framework in functional ecology. Ecology, 89(8), 2290-2301.

Metric computation



C. Between groups metrics

The distance between the red and green is the mean of the pairwise distance calculated between the species of the two communities.

	obs1	obs2	obs3	obs4	obs5	obs6	obs7
obs2	1						
obs3	2	1.5					
obs4	3	2.5	4				
obs5	0.5	2	5	6			
obs6	1	5	0.5	2	1		
obs7	2	2	6	1	1.5	2	
obs8	3	1	2	2	1	3.5	1

$$Distance_{G,R} = \frac{(0.5 + 2 + 5 + 6 + 1 + \ ...)}{16} = 2.56$$

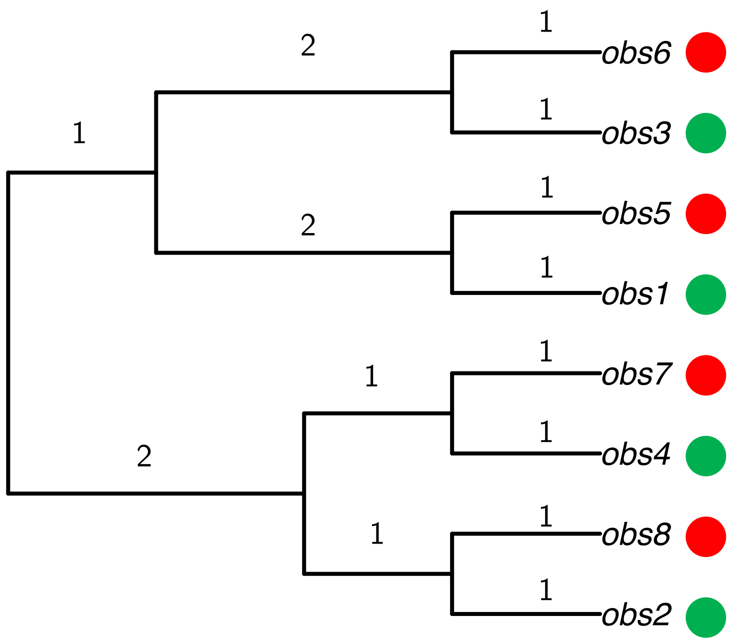
$$Beta\ Jaccard_{G,R} = NA$$

Possibility to weight each distance with the product of the relative abondance of the two species.

Index RaoQ for Beta diversity is also available for distance but it is highly correlated with the one above.

Metric computation

! Distances in a tree are called cophenetic distances



A. Observation-based metrics

For observation 1

Cophenetic distance in the tree between obs1 and obs2 is 1+2+1+2+1+1=8

$$Originality_1 = \frac{(8+6+8+2+6+8+8)}{7} = 6.57$$

$$Uniqueness_1 = 2$$

$$Contribution_1 = 1 + \frac{2}{2} + \frac{1}{4} = 2.25$$

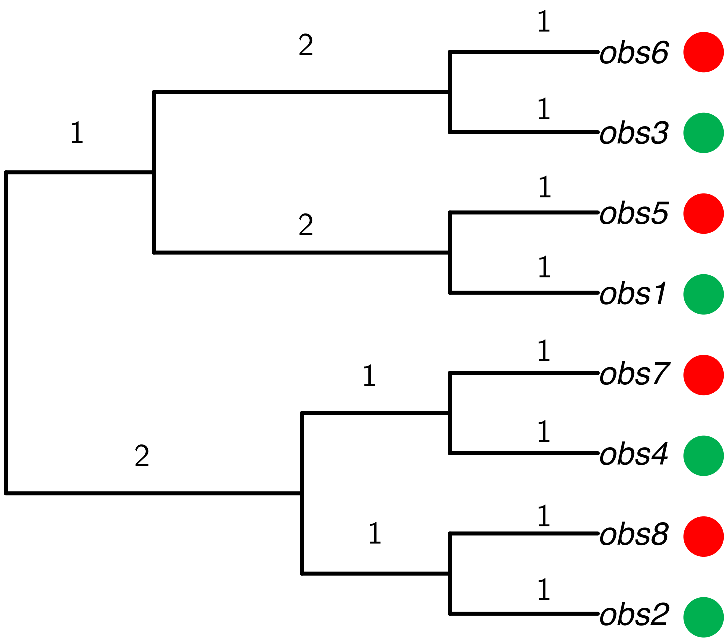
Branch length divided by the number of species sharing the branch

Possibility to weight each distance with the product of the relative abondance of the two species.

Sum of the contribution is equal to the sum of all the branch lengths in the tree. Possibility to weight each contribution with the relative abondance of the species.

Isaac, N. J., Turvey, S. T., Collen, B., Waterman, C., & Baillie, J. E. (2007). Mammals on the EDGE: conservation priorities based on threat and phylogeny. *PloS one*, *2*(3), e296.

Metric computation



B. Group-based metrics

Sum of the branch lengths (Petchey & Gaston 2002)

$$Richness = 1 + 1 + 2 + 2 + 1 + 2 + 1 + 1 + 1 + 1 = 13$$

Mean pairwise cophenetic distance

$$Divergence = \frac{(8 + 6 + 8 + 8 + 4 + 8)}{6} = 7$$

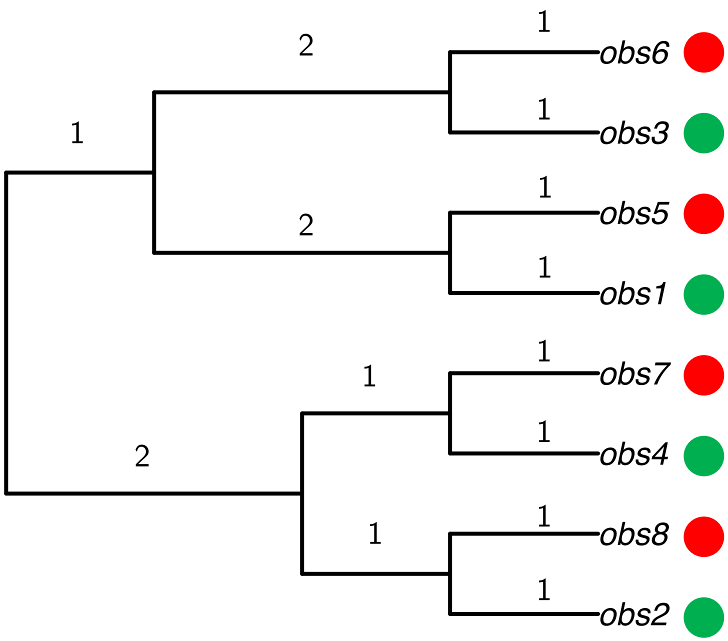
Possibility to weight each distance with the product of the relative abondance of the two species.

Indices RaoQ with trees is also available for divergence but all are highly correlated between each others. See also Hill numbers for similar indices with different weights for abundance.

Petchey, O. L., & Gaston, K. J. (2002). Functional diversity (FD), species richness and community composition. *Ecology letters*, *5*(3), 402-411.

Metric computation

B. Group-based metrics



For *evenness*, we need the contribution of the four species in the green community: obs1=3.5; obs2=3; obs3=3.5; obs4=3

Camargo's formula

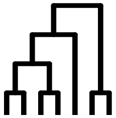
$$\textcolor{green}{Evenness} = 1 - \frac{|2.25-2| + |2.25-2.25| + |2.25-2| + |2-2.25| + |2.25-2.25| + |2.25-2|}{6} = 0.84$$

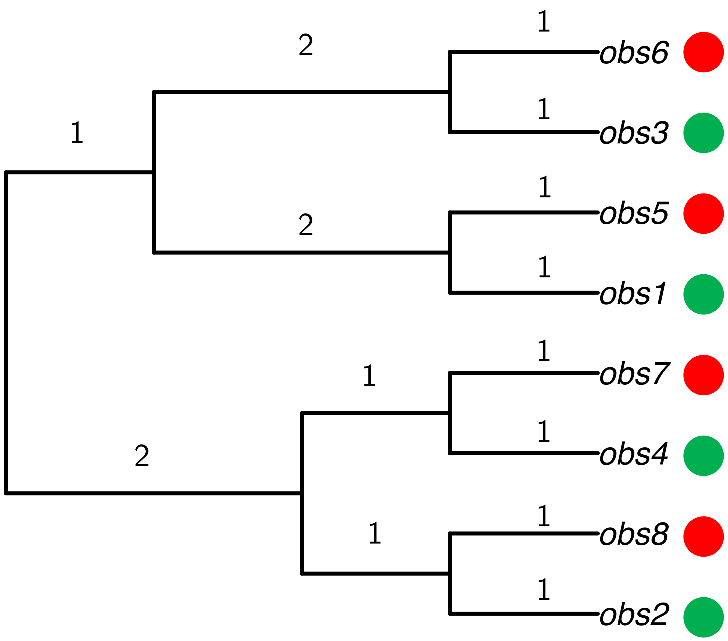
1-the sum of the absolute difference between pairs of contributions divided by the number of pairs.

Possibility to weight each contribution with the relative abondance of the species.

Camargo, J.A. (1993) Must dominance increase with the number of subordinate species in competitive interactions? *Journal of Theoretical Biology*, **161**, 537–542.

Metric computation





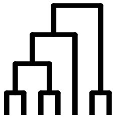
C. Between groups metrics

As for the dissimilarity matrix, the distance between the red and green is the mean of the pairwise distance calculated between the species of the two communities.

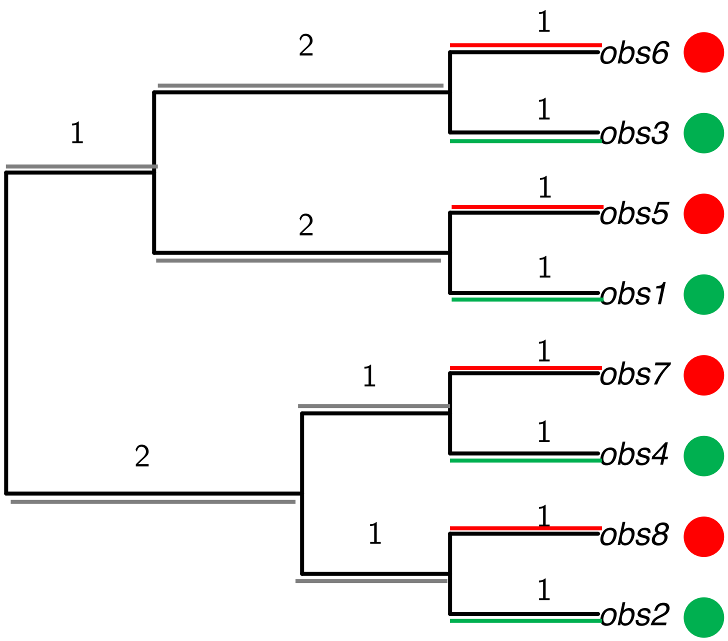
$$Distance_{G,R} = \frac{(2+6+8+8+8+\ \dots)}{16} = 5.75$$

Possibility to weight each distance with the product of the relative abondance of the two species.

Metric computation



C. Between groups metrics



$$Beta\ Jaccard_{G,R} = \frac{b + c}{a + b + c}$$

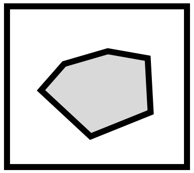
a = Shared branch lengths between green and red
b = Branch lengths found only in green
c = Branch lengths found only in red

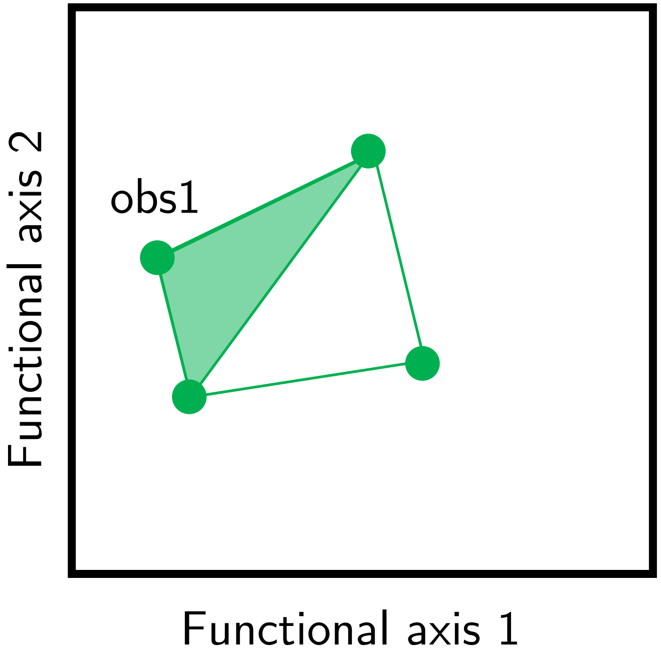
$$Beta\ Jaccard_{G,R} = \frac{(4 + 4)}{4 + 4 + 9} = 0.47$$

Possibility to weight each branch length with the relative abondance of the species.

Cardoso, P., Rigal, F., Carvalho, J. C., Fortelius, M., Borges, P. A., Podani, J., & Schmera, D. (2014). Partitioning taxon, phylogenetic and functional beta diversity into replacement and richness difference components. *Journal of Biogeography*, *41*(4), 749-761.

Metric computation





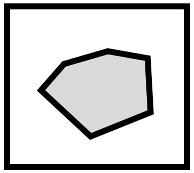
A. Observation-based metrics

$$Originality \quad = NA$$

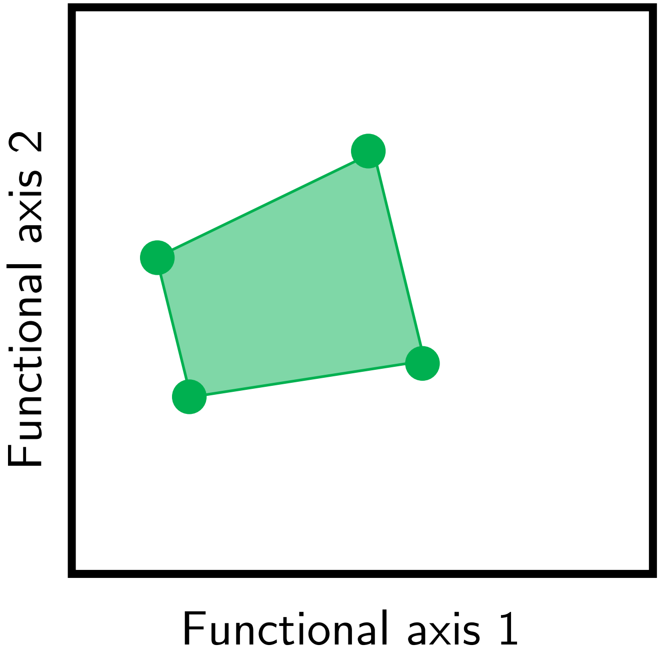
$$Uniqueness \quad = NA$$

Contribution of each observation to the total surface/volume of a convex hull is calculated as the difference in surface/volume between the total convex hull and a second surface/volume lacking this specific observation.

Metric computation



B. Group-based metrics



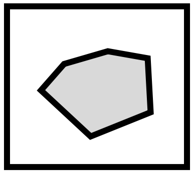
Richness is the minimum convex hull which includes all the species of the group; Richness is then the surface / volume inside this hull.

$Divergence = NA$

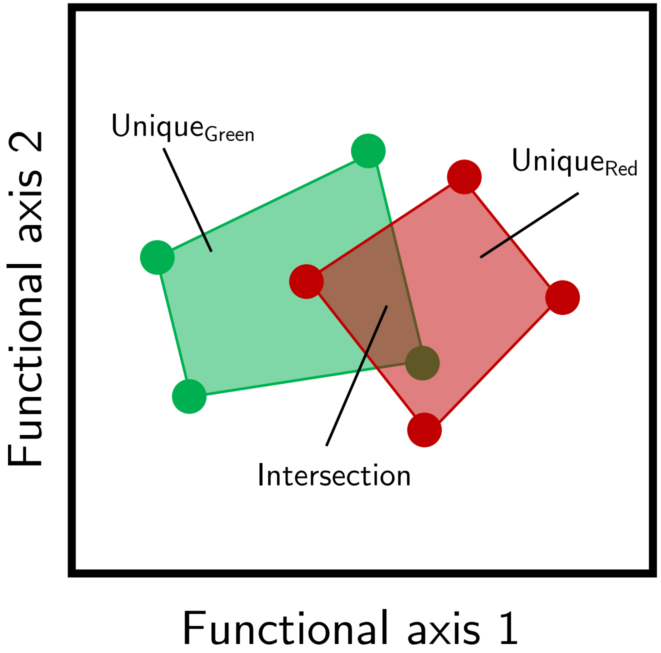
$Evenness = NA$

Cornwell, W. K., Schwilk, D. W., & Ackerly, D. D. (2006). A trait-based test for habitat filtering: convex hull volume. *Ecology*, *87*(6), 1465-1471.

Metric computation



C. Between groups metrics

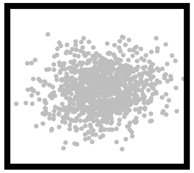


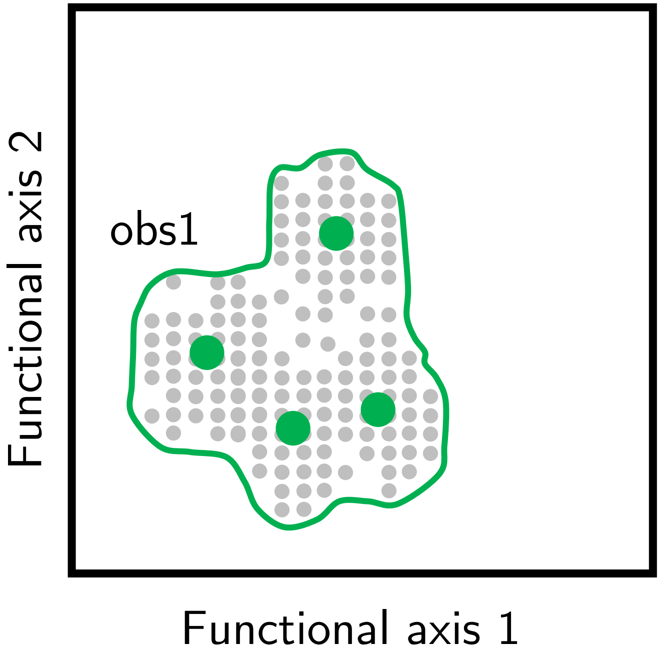
$$Distance_{G,R} = NA$$

$$Beta\ Jaccard_{G,R} = \frac{Unique_{Green} + Unique_{Red}}{Unique_{Green} + Unique_{Red} + Intersection}$$

Cornwell, W. K., Schwilk, D. W., & Ackerly, D. D. (2006). A trait-based test for habitat filtering: convex hull volume. *Ecology*, *87*(6), 1465-1471.

Metric computation





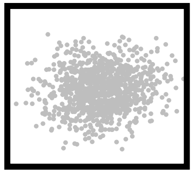
Incorporating abundance data:

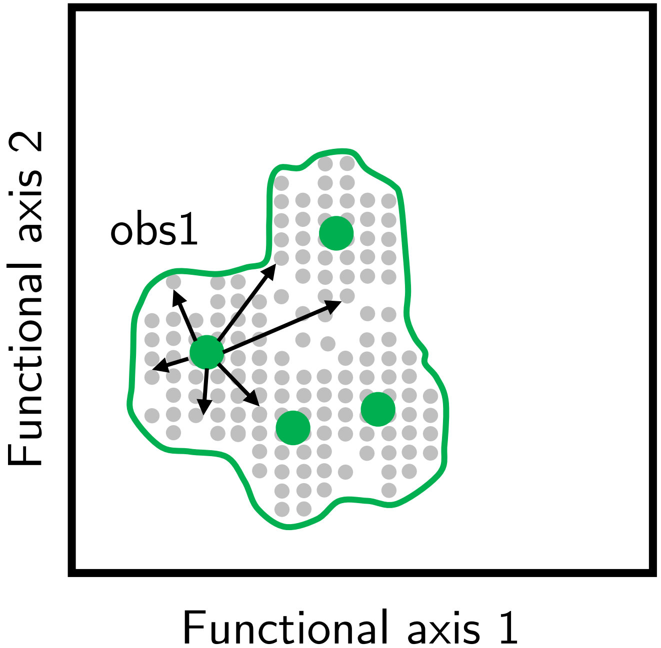
Each observation can be weighted by replicating it based on its abundance in the estimation of the hypervolume. If Obs1 is replicated 10 times (e.g. 10 individuals for a species), it will appears 10 times during the construction of hypervolume.

All following metrics can be calculated with or without abundance data.

Isaac, N. J., Turvey, S. T., Collen, B., Waterman, C., & Baillie, J. E. (2007). Mammals on the EDGE: conservation priorities based on threat and phylogeny. *PloS one*, *2*(3), e296.

Metric computation





A. Observation-based metrics

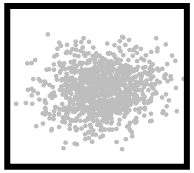
For observation 1

Originality$_1$ is average distance between each observation to a sample of stochastic points within the boundaries of the hypervolume

Uniqueness$_1$ = *NA*

Isaac, N. J., Turvey, S. T., Collen, B., Waterman, C., & Baillie, J. E. (2007). Mammals on the EDGE: conservation priorities based on threat and phylogeny. *PloS one*, *2*(3), e296.

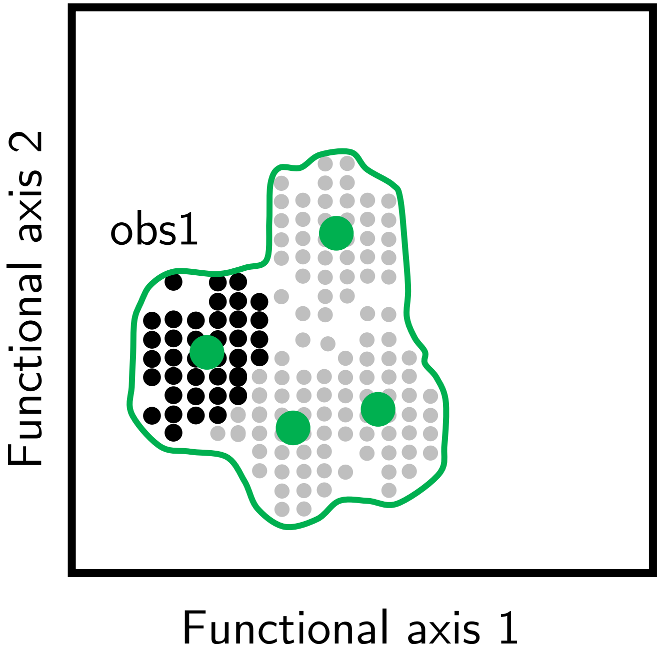
Metric computation



A. Observation-based metrics

For observation 1

Originality$_1$ is average distance between each observation to a sample of stochastic points within the boundaries of the hypervolume



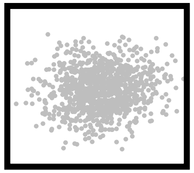
Uniqueness$_1$ = NA

Contribution$_1$ is measured as the proportion of random points that is closer to obs1 multiplied by the total hypervolume of the group.

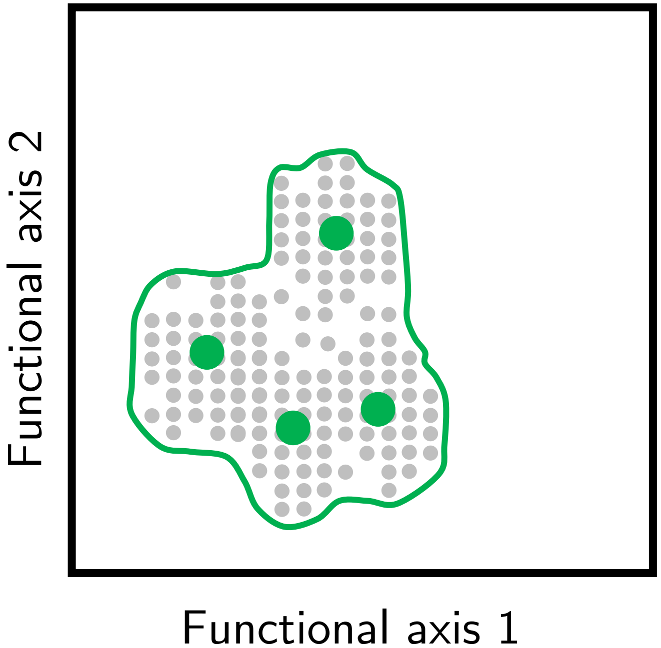
Contribution can also be measured using the « leave one out » apporach as for convex-hull.

Isaac, N. J., Turvey, S. T., Collen, B., Waterman, C., & Baillie, J. E. (2007). Mammals on the EDGE: conservation priorities based on threat and phylogeny. *PloS one*, *2*(3), e296.

Metric computation



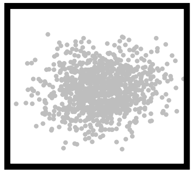
B. Group-based metrics



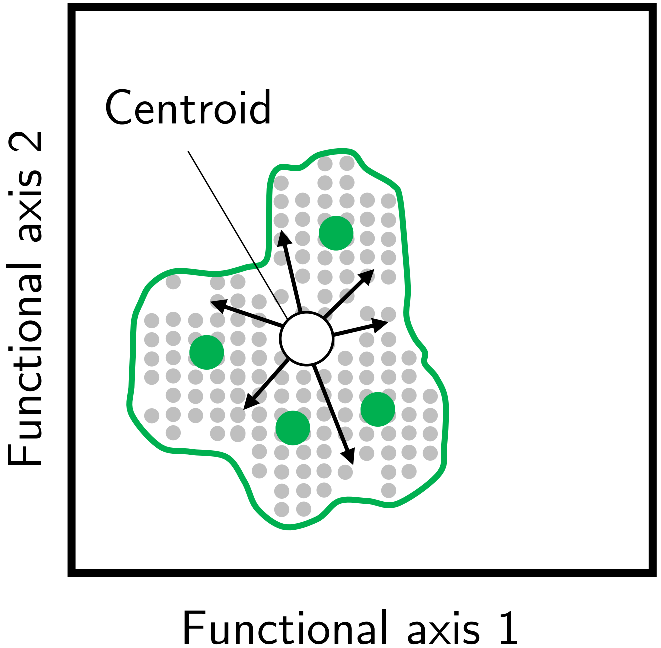
Richness is the total surface/volume of the functional hyperspace.

Isaac, N. J., Turvey, S. T., Collen, B., Waterman, C., & Baillie, J. E. (2007). Mammals on the EDGE: conservation priorities based on threat and phylogeny. *PloS one*, *2*(3), e296.

Metric computation



B. Group-based metrics

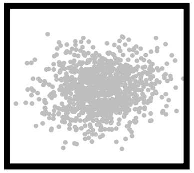


Richness is the total surface/volume of the functional hyperspace.

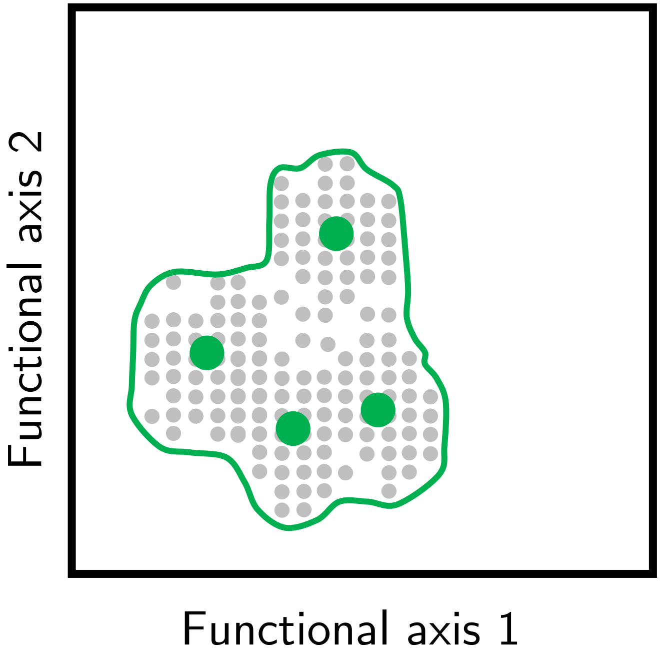
Divergence is calculated as the average distance between a sample of stochastic points and the hypervolume centroid.

Isaac, N. J., Turvey, S. T., Collen, B., Waterman, C., & Baillie, J. E. (2007). Mammals on the EDGE: conservation priorities based on threat and phylogeny. *PloS one*, *2*(3), e296.

Metric computation



B. Group-based metrics



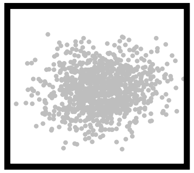
Richness is the total surface/volume of the functional hyperspace.

Divergence is calculated as the average distance between a sample of stochastic points and the hypervolume centroid.

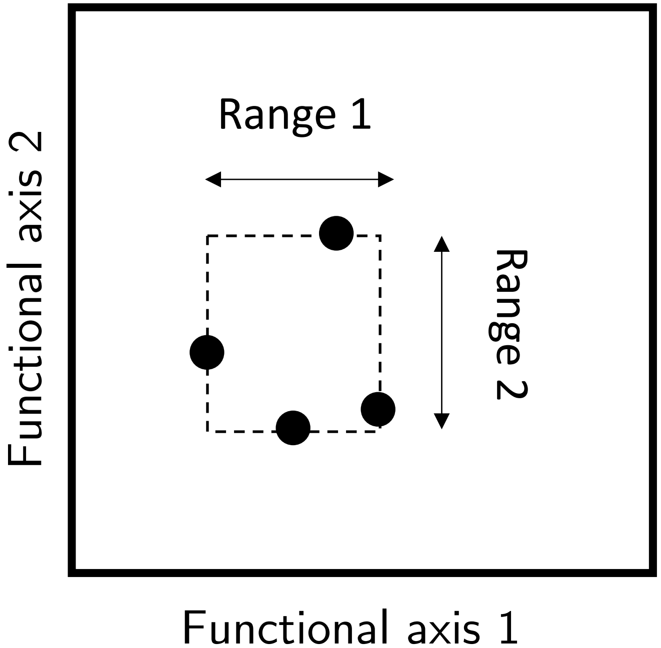
Evenness is calculated as the overlap between the calculated hypervolume and a second, imaginary hypervolume where traits are evenly distributed within their possible range (and abundance evenly distributed between the observations!)

Isaac, N. J., Turvey, S. T., Collen, B., Waterman, C., & Baillie, J. E. (2007). Mammals on the EDGE: conservation priorities based on threat and phylogeny. *PloS one*, *2*(3), e296.

Metric computation



B. Group-based metrics



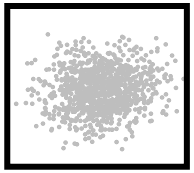
Richness is the total surface/volume of the functional hyperspace.

Divergence is calculated as the average distance between a sample of stochastic points and the hypervolume centroid.

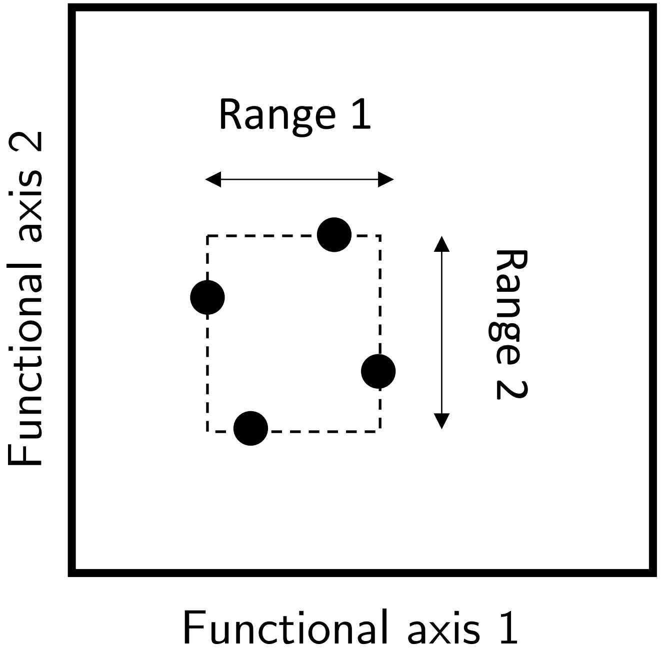
Evenness is calculated as the overlap between the calculated hypervolume and a second, imaginary hypervolume where traits are evenly distributed within their possible range

Isaac, N. J., Turvey, S. T., Collen, B., Waterman, C., & Baillie, J. E. (2007). Mammals on the EDGE: conservation priorities based on threat and phylogeny. *PloS one*, *2*(3), e296.

Metric computation



B. Group-based metrics



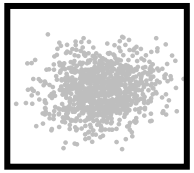
Richness is the total surface/volume of the functional hyperspace.

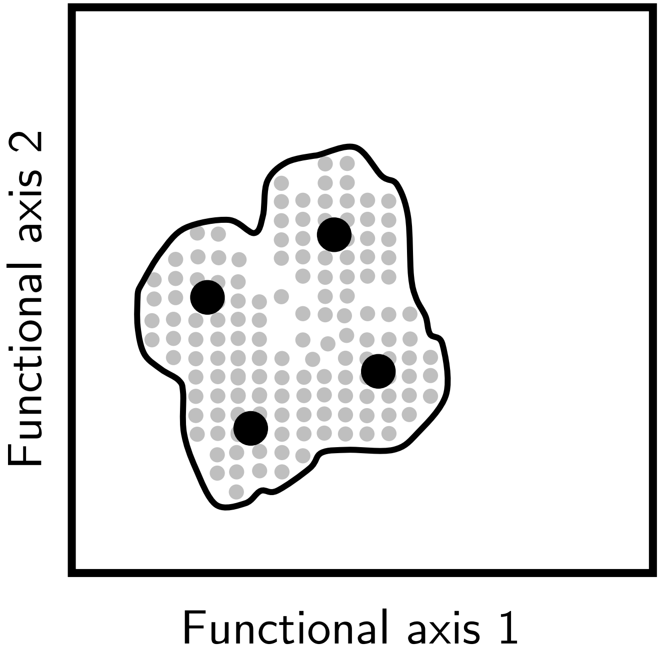
Divergence is calculated as the average distance between a sample of stochastic points and the hypervolume centroid.

Evenness is calculated as the overlap between the calculated hypervolume and a second, imaginary hypervolume where traits are evenly distributed within their possible range

Isaac, N. J., Turvey, S. T., Collen, B., Waterman, C., & Baillie, J. E. (2007). Mammals on the EDGE: conservation priorities based on threat and phylogeny. *PloS one*, *2*(3), e296.

Metric computation





B. Group-based metrics

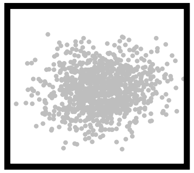
Richness is the total surface/volume of the functional hyperspace.

Divergence is calculated as the average distance between a sample of stochastic points and the hypervolume centroid.

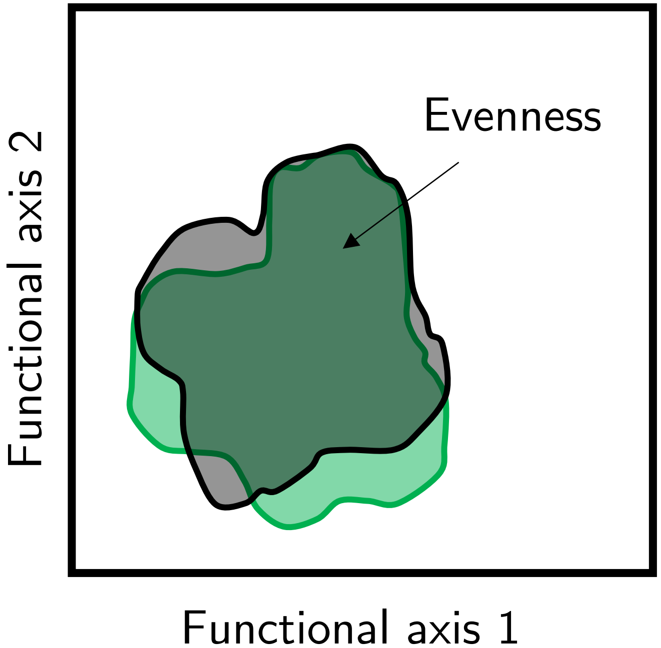
Evenness is calculated as the overlap between the calculated hypervolume and a second, imaginary hypervolume where traits are evenly distributed within their possible range

Isaac, N. J., Turvey, S. T., Collen, B., Waterman, C., & Baillie, J. E. (2007). Mammals on the EDGE: conservation priorities based on threat and phylogeny. *PloS one*, *2*(3), e296.

Metric computation



B. Group-based metrics



Richness is the total surface/volume of the functional hyperspace.

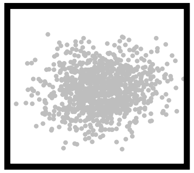
Divergence is calculated as the average distance between a sample of stochastic points and the hypervolume centroid.

Evenness is calculated as the overlap between the calculated hypervolume and a second, imaginary hypervolume where traits are evenly distributed within their possible range.

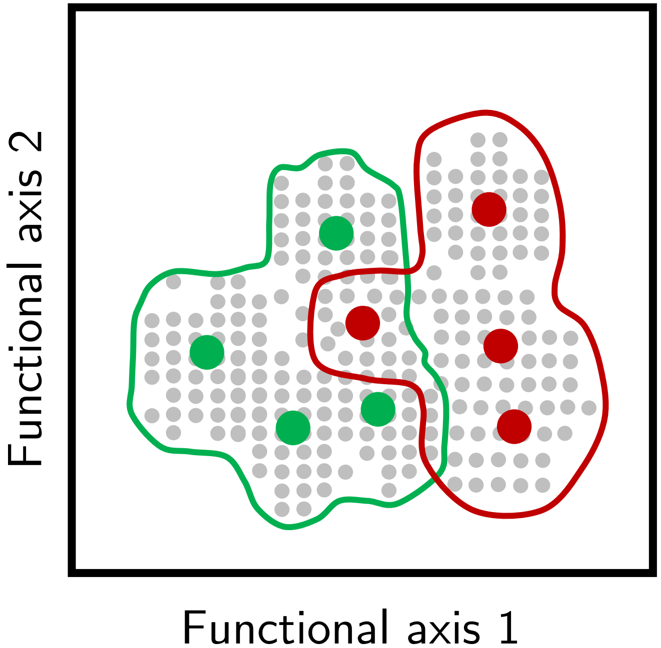
If the 2 hypervolumes are the same = overlap is max and evenness is 1.

Isaac, N. J., Turvey, S. T., Collen, B., Waterman, C., & Baillie, J. E. (2007). Mammals on the EDGE: conservation priorities based on threat and phylogeny. *PloS one*, *2*(3), e296.

Metric computation

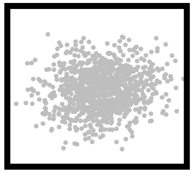


C. Between groups metrics

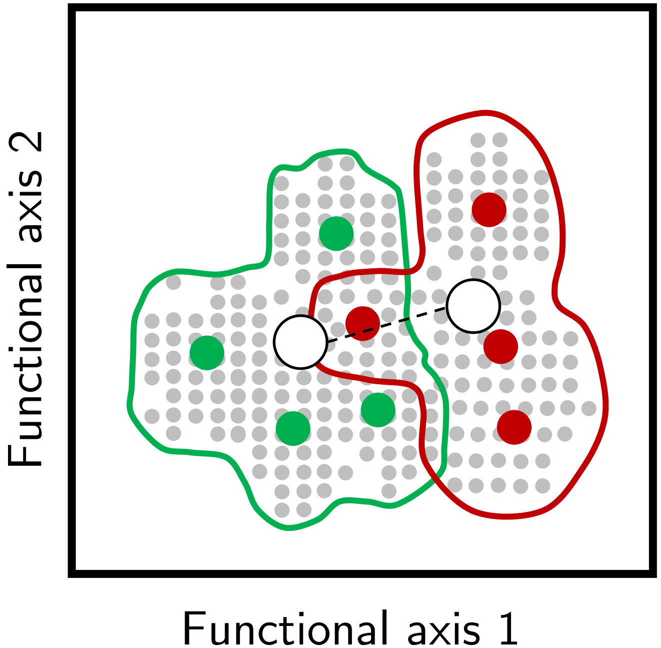


Isaac, N. J., Turvey, S. T., Collen, B., Waterman, C., & Baillie, J. E. (2007). Mammals on the EDGE: conservation priorities based on threat and phylogeny. *PloS one*, *2*(3), e296.

Metric computation



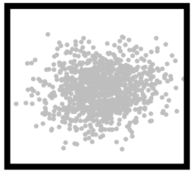
C. Between groups metrics



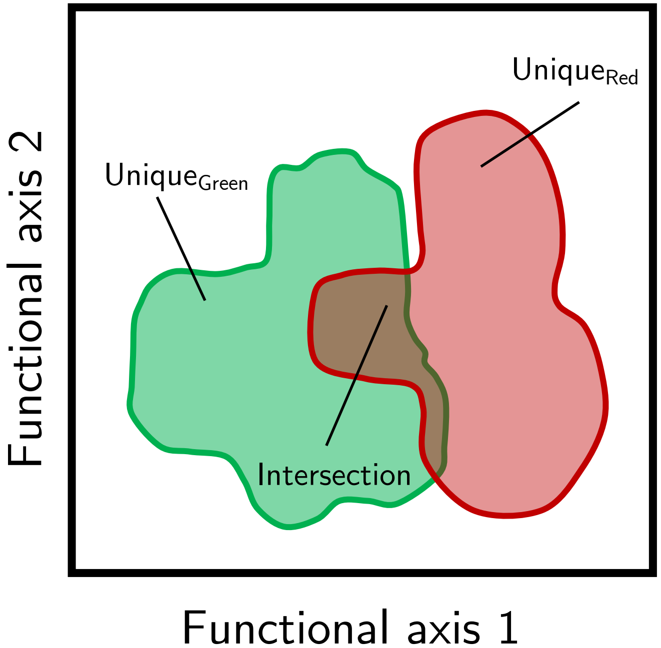
Distance = Still the possibility to calculate the distance between the hypervolume centroids as for the dissimilarity-based framework.

Isaac, N. J., Turvey, S. T., Collen, B., Waterman, C., & Baillie, J. E. (2007). Mammals on the EDGE: conservation priorities based on threat and phylogeny. *PloS one*, *2*(3), e296.

Metric computation



C. Between groups metrics



$Distance$ = Still the possibility to calculate the distance between the hypervolume centroids as for the dissimilarity-based framework.

$$Beta\ Jaccard_{G,R} = \frac{Unique_{Green} + Unique_{Red}}{Unique_{Green} + Unique_{Red} + Intersection}$$

Isaac, N. J., Turvey, S. T., Collen, B., Waterman, C., & Baillie, J. E. (2007). Mammals on the EDGE: conservation priorities based on threat and phylogeny. *PloS one*, *2*(3), e296.