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RH: disparate views on disparity.

Disparate views on disparity.

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Abstract

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(Keywords: disparity)

Introduction

Disparity, as a concept or set of toolkits is used a lot in biology and is more and more used every year.

In most of these papers, they trace back the disparity concept to seminal papers from the 90s: Gould (1989, 1991); Briggs et al. (1992); Wills et al. (1994); Foote (1994, 1996); Jernvall et al. (1996); Foote (1997). However, being such a broad and obvious concept, it can probably be stretched back to way earlier.

Prentice et al. (2011) define disparity as: "a term widely (albeit not always consistently) used to describe the range of forms in a group of organisms, or the difference among different body plans".

Biological data are complex; understanding the ecology and evolution of species often requires that we analyse multiple variables that covary with each other, and through space and time. One solution to this problem is to analyse data in a multivariate framework. Multivariate analyses aim to capture and incorporate this multidimensional complexity, while providing outputs that are interpretable in a physical world of only three dimensions. Classical multidimensional species features that have been analysed through multivariate data ranges from their morphology (Raup, 1966), to their functional traits (Díaz et al., 2016). However, such analysis are not limited at the species level and can also be applied to ecosystems (Donohue et al., 2013).

Key multidimensional features of species that have important roles in ecology and evolution include morphology, functional traits. etc. etc. Many of these can be

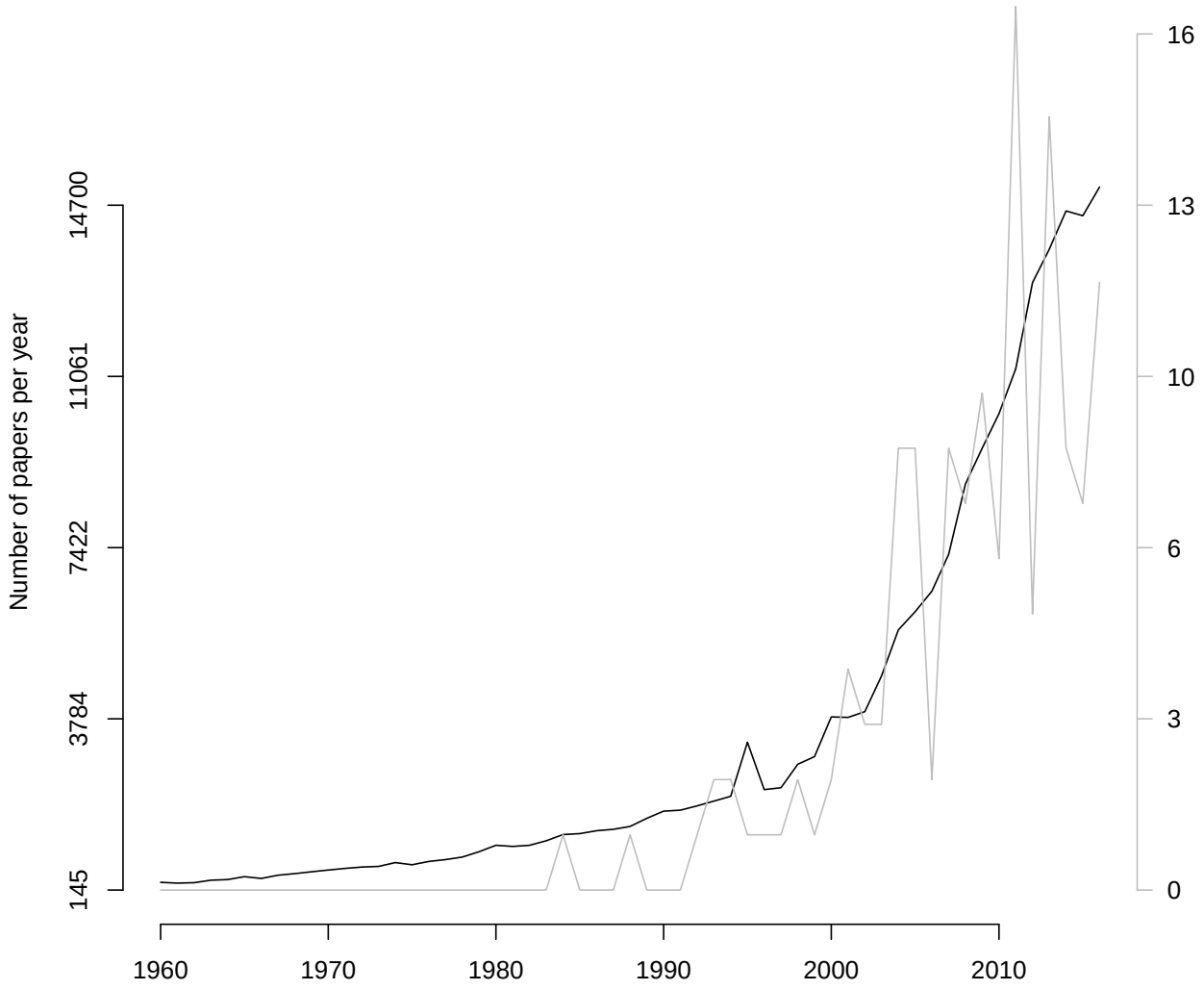

Figure 1: Number of papers on Google Scholar matching the search "morphological disparity" per year. In black, the match is in the paper and in grey, in the title.

represented as matrices, these can be used in our package. In the interests of clarity/brievety, we here focus on just one kind of data: morphological diversity.

Furthermore, we will also make a clear distinction between the multidimensional space which is a specific mathematical object and the disparity, which is a metric describing or summarising one or more aspects of this space.

Both can be defined in various ways depending on the authors, for example, disparity is defined as the weighted mean pairwise dissimilarity in Close et al. (2015) or the ellipsoid volume in Donohue et al. (2013) and the multidimensional space is defined as the morphospace in Raup (1966) and the morpho-functional space in Díaz et al. (2016).

The multidimensional space can be defined in many ways and arise from many mathematical transformations of the data such as the pairwise distance matrix (Close et al., 2015), a principal coordinates analysis (PCO; Brusatte et al., 2008), a principal components analysis (PCA; Zelditch et al., 2012), a multidimensional scaling (MDS; Donohue et al., 2013), etc. Similarly, disparity metrics (or indices; Hopkins and Gerber, 2017) can defined in many ways (e.g. Wills, 2001; Ciampaglio et al., 2001; Foth et al., 2012; Donohue et al., 2013; Hughes et al., 2013; Finlay and Cooper, 2015; Close et al., 2015; Díaz et al., 2016, or combinations thereof). Finally, difference between disparity metrics can also be measured in many ways: using NPMANOVA (e.g. Brusatte et al., 2008), multidimensional permutation test (e.g. Díaz et al., 2016) or even simple confidence interval overlap (e.g. Halliday and Goswami, 2016).

This variety of definitions and analysis have been developed in an equal variety of softwares such as `GINGKO` in javascript (Bouxin, 2005; De Caceres et al., 2007) or `geomorph` (Adams and Otárola-Castillo, 2013; Adams et al., 2017), `Claddis` (Lloyd, 2015), or `vegan` (Oksanen et al., 2007) in R (R Core Team, 2015). This results in the need to learn different languages (or at least - when restricted to R - different packages with different standards) as well as making analysis sometimes idiosyncratic and often complex to repeat since they are based on a particular feature from a particular software. For example, in the excellent and widely used `geomorph` package morphological disparity analysis can be ran using the `morphol.disparity` function. Unfortunately, however, the multidimensional space can only be defined as the ordination of the procrustes transform of geometric morphometric landmarks, the disparity can only be defined as the Procrustes variance and the difference between groups can only be measured through permutation tests (Zelditch et al., 2012; Adams and Otárola-Castillo, 2013; Adams et al., 2017).

Disparity is an old concept blabalbal

What *is* disparity

From a semantic view: morphospace or aspect of the morphospace?

From a biological view: what does an increase or a decrease in disparity represent?

Why do we need disparity

What are the fundamental questions we should use to answer disparity questions?

What are the questions we should not answer with disparity?

What is missing

Methods? Data?

Conclusion

Yay!

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References

Adams, D., M. Collyer, A. Kaliontzopoulou, and E. Sherratt. 2017. Geometric morphometric analyses of 2d/3d landmark data .

Adams, D. C. and E. Otárola-Castillo. 2013. geomorph: an r package for the collection and analysis of geometric morphometric shape data. Methods in Ecology and Evolution 4:393–399.

Bouxin, G. 2005. Ginkgo, a multivariate analysis package. Journal of Vegetation Science 16:355–359.

Briggs, D. E., R. A. Fortey, and M. A. Wills. 1992. Morphological disparity in the cambrian. Science 256:1670–1673.

Brusatte, S. L., M. J. Benton, M. Ruta, and G. T. Lloyd. 2008. Superiority, competition, and opportunism in the evolutionary radiation of dinosaurs. Science 321:1485–1488.

Ciampaglio, C. N., M. Kemp, and D. W. McShea. 2001. Detecting changes in morphospace occupation patterns in the fossil record: characterization and analysis of measures of disparity. Paleobiology 71:695–715.

Close, R., M. Friedman, G. Lloyd, and R. Benson. 2015. Evidence for a mid-Jurassic adaptive radiation in mammals. Current Biology .

De Caceres, M., F. Oliva, X. Font, and S. Vives. 2007. Ginkgo, a program for non-standard multivariate fuzzy analysis. Advances in Fuzzy Sets and Systems 2:41–56.

Díaz, S., J. Kattge, J. H. Cornelissen, I. J. Wright, S. Lavorel, S. Dray, B. Reu, M. Kleyer, C. Wirth, I. C. Prentice, et al. 2016. The global spectrum of plant form and function. Nature 529:167.

Donohue, I., O. L. Petchey, J. M. Montoya, A. L. Jackson, L. McNally, M. Viana, K. Healy, M. Lurgi, N. E. O'Connor, and M. C. Emmerson. 2013. On the dimensionality of ecological stability. Ecology Letters 16:421–429.

Finlay, S. and N. Cooper. 2015. Morphological diversity in tenrecs (Afrosoricida, Tenrecidae): comparing tenrec skull diversity to their closest relatives. PeerJ 3:e927.

Foote, M. 1994. Morphological disparity in Ordovician-Devonian Crinoids and the early saturation of morphological space. Paleobiology 20:320–344.

Foote, M. 1996. Ecological controls on the evolutionary recovery of post-Paleozoic Crinoids. Science 274:1492–1495.

Foote, M. 1997. The evolution of morphological diversity. Annual Review of Ecology and Systematics 28:129–152.

Foth, C., S. Brusatte, and R. Butler. 2012. Do different disparity proxies converge on a common signal? insights from the cranial morphometrics and evolutionary history of Pterosauria (Diapsida: Archosauria). Journal of evolutionary biology 25:904–915.

Gould, s. J. 1989. Wonderful Life: The Burgess Shale and the Nature of History. W. W. Norton & Co., New York.

Gould, S. J. 1991. The disparity of the burgess shale arthropod fauna and the limits of cladistic analysis: why we must strive to quantify morphospace. Paleobiology 17:411–423.

Halliday, T. J. D. and A. Goswami. 2016. Eutherian morphological disparity across the end-cretaceous mass extinction. Biological Journal of the Linnean Society 118:152–168.

Hopkins, M. J. and S. Gerber. 2017. Morphological Disparity Pages 1–12. Springer International Publishing, Cham.

Hughes, M., S. Gerber, and M. A. Wills. 2013. Clades reach highest morphological disparity early in their evolution. Proceedings of the National Academy of Sciences 110:13875–13879.

Jernvall, J., J. P. Hunter, M. Fortelius, et al. 1996. Molar tooth diversity, disparity, and ecology in cenozoic ungulate radiations. Science 274:1489–1492.

Lloyd, G. T. 2015. Claddis: Measuring Morphological Diversity and Evolutionary Tempo. R package version 0.1.

Oksanen, J., R. Kindt, P. Legendre, B. OHara, M. H. H. Stevens, M. J. Oksanen, and M. Suggests. 2007. The vegan package. Community ecology package 10:631–637.

Prentice, K. C., P. Ruta, and M. J. Benton. 2011. Evolution of morphological disparity in pterosaurs. Journal of Systematic Palaeontology 9:337–353.

R Core Team. 2015. R: a language and environment for statistical computing. R Foundation for Statistical Computing Vienna, Austria.

Raup, D. M. 1966. Geometric analysis of shell coiling: general problems. Journal of Paleontology Pages 1178–1190.

Wills, M. 2001. Morphological disparity: A primer. Pages 55–144 *in* Fossils, Phylogeny, and Form (J. M. Adrain, G. D. Edgecombe, and B. S. Lieberman, eds.) vol. 19 of *Topics in Geobiology*. Springer US.

Wills, M. A., D. E. G. Briggs, and R. A. Fortey. 1994. Disparity as an evolutionary index: A comparison of Cambrian and recent arthropods. Paleobiology 20:93–130.

Zelditch, M. L., D. L. Swiderski, and H. D. Sheets. 2012. Geometric morphometrics for biologists: a primer. Academic Press: Waltham.