Notes on Two Criticisms and Proposed Remedies

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A criticism: failure to satisfy the twinning property

The proposed functional diversity ${}^{q}FD(Q)$ (Eq. 4b of the main text) when $q = 0$ reduce to Walker's (1999) FAD (functional attribute diversity). Thus the measure ${}^{q}FD(Q)$ basically extends FAD to incorporate species abundances. The properties of FAD have been extensively discussed in the literature. One major criticism about FAD and thus about our measure is that FAD does not satisfy the twinning criterion: functional diversity should not increase if a species with identical traits (twin species) is added to the assemblage. We would like to add the following comments and proposed a remedy:

(a) The measure ${}^{q}FD(Q)$ which is a genuine Hill number quantifies "the effective total distance" in an assemblage; the measure is in the unit of "distance" not "species". By contrast, the conventional species-equivalent approach (e.g., Eq. 2d in the main text) produces an index in the unit of "species", not "distance". The perspectives of the two approaches are thus different.

(b) The quantifying targets/aspects of the two approaches are also different. The conventional species-equivalent measure mainly quantifies ecosystem biomass, production, stability to perturbation by environmental stresses, or other relevant quantities (Tilman 1996). Thus, functionally redundant species should have almost no effect; the twinning property makes sense. By contrast, our measure, like FAD from "distance-equivalent" perspective, quantifies the community resilience or adaptive capacity in the face of environmental changes (Walker et al. 1999); functionally redundant species can help buffer the impact of species loss on ecosystem function. Consequently, the "twinning property" is not necessary. From a "distance-equivalent" measure that aims to quantify community resilience, for those functionally redundant species, as indicated by Diaz and Cabido (2001) "the disappearance of one or more of those [functionally redundant] species does not affect that ecosystem process in a significant way, because the remaining species can compensate for it." Walker (1995) even described ecological redundancy is a good property. Therefore, the twinning property alone cannot be used as a criterion to select a favorable index without considering the goals of the study and the nature of the focal system.

(c) If the goal of the study requires the twinning property from a "species-equivalent" perspective, then in applying our functional diversity measures, we suggest that species with identical traits should be grouped into one "functional species" (Ricotta 2005) or "functional unit" (Schmera, Erös and Podani, 2009), and all our measures should be computed based on functional units instead of species. That is, replace all species in our paper by functional units so that the twinning property is satisfied; see Ricotta (2005) and Schmera, Erös and Podani (2009) for details.

(d) As indicated by many authors, functional diversity is not expressible as a single number or just a few measures. There is no consensus about how to quantify and compare functional diversity among multiple assemblages; different perspectives lead to measures that quantify different aspects of traits space. Different perspectives lead different required properties. For functional diversity, perhaps a better way is to consider various perspectives, rather than just one perspective.

A criticism about functional (dis)similarity measures

The functional similarity or overlap measures are derived in Eqs. 9a, 10a, 11 and 12 in the main text. Our paper is based on a distance-based perspective so that each of the corresponding functional dissimilarity measures attains the maximum value of unity under the condition that *N* assemblages are completely distinct (i.e., no shared species and thus no shared distnces). This is another criticism about our measure from a "species-equivalent" perspective. However, we can readily modify our method so that each of the modified dissimilarity measures attains the maximum value of unity under the following condition: *N* assemblages are completely distinct and any species-pair from different assemblages are maximally distinct. The modification includes the following steps:

(1) Determine a level τ of maximal distinction between any two species. This maximal distance level can be chosen as the theoretical upper bound of a distance metric (e.g. Gower distance has an upper bound of unity) or a fixed constant that is larger than any species-pairwise distance in the data.

(2) Based on Eqs. (6a) and (6b) in the main text, we calculate the functional gamma diversity ${}^{q}FD_{\gamma}^{*}$ by assuming that the *N* assemblages are completely distinct (i.e.

no shared species) and the functional distance for any two species from different assemblages is τ.

(3) Calculate the alpha diversity (Eqs. 7a and 7b) and obtain the maximum value of the functional beta diversity of order q as

$$ {}^{q}M = \frac{{}^{q}FD_{\gamma}^{*}}{{}^{q}FD_{\alpha}}. $$

(4) Modify our functional overlap or similarity measures as follows.

(4a) Modify Eq. (9a) in the main text to

$$ C_{qN}^{*}(Q) = \frac{({}^{q}M)^{2(1-q)} - [{}^{q}FD_{\beta}(Q)]^{1-q}}{({}^{q}M)^{2(1-q)} - 1}. $$

(4b) Modify Eq. (10a) in the main text to

$$ U_{qN}^{*}(Q) = \frac{[1/{}^{q}FD_{\beta}(Q)]^{1-q} - (1/{}^{q}M)^{2(1-q)}}{1 - (1/{}^{q}M)^{2(1-q)}}. $$

(4c) Modify Eq. (11) in the main text to

$$ S_{qN}^{*}(Q) = \frac{1/[{}^{q}FD_{\beta}(Q)] - 1/({}^{q}M)^{2}}{1 - 1/({}^{q}M)^{2}}. $$

(4d) Modify Eq. (12) in the main text to

$$ V_{qN}^{*}(Q) = \frac{({}^{q}M)^{2} - {}^{q}FD_{\beta}(Q)}{({}^{q}M)^{2} - 1}. $$

References

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