Original Articles

Associations among taxonomic diversity, functional diversity and evolutionary distinctiveness vary among environments

Federico Morelli[a],[*], Yanina Benedetti[a], Paolo Perna[b], Riccardo Santolini[c]

[a] Czech University of Life Sciences Prague, Faculty of Environmental Sciences, Department of Applied Geoinformatics and Spatial Planning, Kamýcká 129, CZ-165 00 Prague 6, Czech Republic
[b] Terre.it Srl, largo Decio Filipponi n°30/a, Palazzo Costa, 62028 Sarnano, MC, Italy
[c] Department of Economics, Society & Politics, University of Urbino Carlo Bo, Campus E. Mattei, 61029, Urbino, PU, Italy

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ABSTRACT

Diversity metrics are commonly used to measure or quantify species-level biodiversity in a given area. In recent decades, ecologists developed many measures and indices in order to quantify a larger proportion of information about communities or species assemblages. Commonly these measures are based on species richness or species evenness, in relation to their relative abundance. Among the most common diversity metrics are the indices of taxonomic diversity, functional diversity and phylogenetic diversity. These metrics are often used to assess effectiveness of conservation planning.

One concern on the use of many diversity metrics, especially in modeling, is the potential redundancy among these indices and measures. Many scientists explored the associations among different diversity metrics, finding clear patterns. For instance, functional richness and the functional diversity (FD) index are both positively correlated with species richness, while functional evenness should be unrelated to species richness. Furthermore, explorations focusing on associations between phylogenetic diversity and taxonomic or functional diversity metrics are few. However, despite the importance of the types of environment has on biotic assemblage rules, there are no studies comparing the association among diversity metrics across different type of environments.

Here, we found higher values of taxonomic diversity, functional richness and Rao's quadratic entropy (RaoQ) in farmland than in forests and grasslands. Forest bird communities were characterized by a large amount of evolutionary history as reflected by community evolutionary distinctiveness (CED). Furthermore, associations among diversity and community metrics in bird communities differ across types of environments. Within functional diversity metrics, associations between functional richness and RaoQ as well as associations between functional evenness and divergence were always positive, independently of the type of environment. The associations between functional richness and evenness or divergence, as well as functional evenness and RaoQ, changed strength and direction of correlation between different types of environment.

In conclusion, a) large scale conservation planning strategies have to consider that different environments support different dimensions of bird diversity, and b) when modeling many diversity metrics, associations among diversity and community metrics can also change across environments.

1. Introduction

The effectiveness of conservation initiatives is commonly measured using surrogates of biodiversity (Margules et al., 2002). The use of surrogates or bioindicators represents shortcuts in ecology: a cost-effective strategy in order to study extremely complex systems (Lindenmayer et al., 2015; Rodrigues et al., 2007). For example, for several decades hotspots of biodiversity were used as tools to define the core area and the boundaries of protected area networks (Barnard et al., 1998; Lascelles et al., 2012; Lombard, 1995), often focusing selection on species richness (Bonn and Gaston, 2005). Species richness, which together with species abundance defines taxonomic diversity (TD), has mainly focused on macro-ecological studies, because it is one of the characteristics of communities relatively easy to obtain, and it is cost-effective for quantifying and interpreting data from a given species assemblage (Cadotte and Davies, 2010). However, the current focus is shifting to other aspects of diversity, as for instance functional and phylogenetic components, which have the capacity to define processes underlying patterns in species assemblages (Petchey and Gaston, 2002; Thompson et al., 2015). In effect, action plans for biodiversity

conservation and management strategies aim to integrate different aspects of biodiversity, including taxonomic and functional and phylogenetic diversity (Jetz et al., 2014; Wiens et al., 2008). Among the group of animals focused as candidate biodiversity surrogates, many bioindicators are based on species such as birds (Grantham et al., 2010). Birds occurrence is potentially an useful surrogate for several reasons: birds are widely distributed, easy to detect, and breeding bird records are among the species distribution data sets easiest to obtain due to the popularity of birding all over the world (Carrascal et al., 2012; Padoa-Schioppa et al., 2006).

The diversity metrics most used in ecology are derived from species composition, and belong to one the three categories of diversity mentioned above. Functional diversity (FD) measures the range, abundance and distribution of species traits such as body mass, feeding guild and breeding characteristics, linking species diversity with ecosystem function (Laureto et al., 2015; Ricotta and Moretti, 2011; Villéger et al., 2008). Biodiversity metrics focused on functional aspects of biodiversity constitute an additional tool to the traditional taxonomic approach (Aubin et al., 2013; de Bello et al., 2010). Finally, phylogenetic diversity is used in ecology and macro-ecology because the branching pattern on a phylogenetic tree reflects accumulation of phenotypic and genetic, but also behavioral and phenological differences among evolutionary lineages (Harvey and Pagel, 1991). In fact, ecologists developed different phylogenetic metrics, potentially useful for answering many ecological questions (Tucker et al., 2016). More and more studies are focusing on all these components of biodiversity, because it is clear how each component can explain a different dimension of ecosystems, and these can also be linked to different mechanisms and sources of variation, as land use composition and environmental heterogeneity. Recent studies explored the importance to consider separately the response of each component of biological diversity to environmental factors or drivers (Morelli et al., 2017; Tribot et al., 2016). Each component of diversity or community metric can be used to describe a different aspect of a given assemblage of species, to assess different ecosystem functions (Clark et al., 2012; Petchey and Gaston, 2002). However, even if the use of many diversity metrics is advisable in ecology, one potential concern, especially in modeling, could be the redundancy among the diversity and community metrics.

Some studies have focused on disentangling associations between taxonomic and functional components of diversity (Baraloto and Hérault, 2012; Devictor et al., 2010; Seymour et al., 2015; Villéger et al., 2012). For example, it is well known that some components of functional diversity, such as functional richness (FRic) or FD index of Petchey and Gaston, are positively correlated with species richness (Cumming and Child, 2009; Petchey and Gaston, 2002). For this reason, multidimensional functional diversity indices were proposed to avoid issues related to this strong association, when modeling contemporary both taxonomic and functional diversity (Villéger et al., 2008). The spatial mismatch between patterns of taxonomic and functional richness can be focused by indicating potential loss of ecosystem services, as suggested by Cumming & Child (2009). Some studies found a negative association between the number of species and the functional evenness (FEve) (Farias and Jaksic, 2009), while other studies showed that FEve and functional divergence (FDiv) are relatively independent of other indices (Mouchet et al., 2010). Even within the range of functional diversity indices, some relationships seem to be clear: Functional richness and evenness are orthogonal to each other (i.e. vary independently of each other), and functional divergence is expected to be unrelated to richness and evenness (Mason et al., 2005). Furthermore, other findings showed that functional diversity is correlated with community biomass, while phylogenetic diversity is correlated with community abundance (in phytoplankton assemblages), revealing different associations between both components of diversity (Thompson et al., 2015). These differences are evident when comparing spatial patterns among communities. Villéger et al. (2012) found low functional β-diversity among species assemblages in contrast to the high

taxonomic diversities found among the same assemblages (in fish species communities).

However, considering the strong influence that environments may have on species occurrence and distribution, as well as the combined effects of landscape compositional and configurational heterogeneity for each component of species diversity, especially focusing on bird communities (Farias and Jaksic, 2009; Morelli, 2013; Santana et al., 2017), we may hypothesize that strength and significance of associations among taxonomic, functional and evolutionary diversity may vary considerably depending on the type of environment. Heterogeneous environments offer more available niches and thus opportunities for resource partitioning in species assemblages, potentially increasing both taxonomic (Kisel et al., 2011) and functional diversity (Schoener, 1974). But the relationship between landscape heterogeneity and functional diversity could be less significant in agro ecosystems (Lee and Martin, 2017), because anthropogenic landscapes affect the strength of environmental filtering and land-use intensification can drive a decline of functional trait diversity in communities (Mayfield et al., 2010). Furthermore, some aspects of landscape heterogeneity as configurational heterogeneity can produce more pronounced effects on diversity metrics in grassland than in other types of environment (Morelli et al., 2013; Perović et al., 2015). This is because even little variation in land use configuration or spatial arrangement (e.g. small patches scattered) in grasslands can represent a greater source of variation than in less homogeneous environments such as farmlands or shrub. On the other hand, a disturbance gradient, as represented by urbanization could mainly acting at the level of functional diversity, leading to biotic homogenization (Devictor et al., 2008; McKinney and Lockwood, 1999). Urbanization could also change the amount of evolutionary uniqueness of bird assemblages, as found in some studies (Ibáñez-Álamo et al., 2016; Morelli et al., 2016).

We can hypothesize that asymmetric relationship between diversity metrics could be an indicator of intrinsic assemblage rules, relatively independent from the type of environment. Furthermore, considering that functional evenness is measuring the regularity of the distribution of abundance in functional space, we can hypothesize that differences in association between number of species and functional evenness can be used to focus on the potential ecological resilience of communities (Mason et al., 2005). Last but not least, understanding whether arithmetical associations among diversity and community metrics are changing in different environments should provide new insights on conservation planning strategies across large spatial scales, as well as improve the predictive capacities of modeling community composition.

The aim of this study was to compare strength and direction of associations among the most commonly used community and diversity metrics, calculated on bird assemblages, in different environments by using a large dataset on breeding birds in Italy.

2. Methods

2.1. Study area and bird data collection

Data on bird community composition were collected in the Marche region, Central Italy (centroid of study area: 43°46′N; 12°42′E) in different environments ranging from 0 to circa 2000 m a.s.l., between the Apennines chain and the Adriatic coast. Climate in the Marche region is temperate and characterized by high spring and summer temperatures and a marked summer drought (Pesaresi et al., 2014). This area was also subject to previous studies (Morelli, 2013, 2013a; Morelli et al., 2013, Morelli et al., 2014). Data on bird species were collected by expert ornithologists using bird point counts, carried out during the breeding season (April-June) of 2014. Point counts were used because they provide a standardized methodology in ecology (Bibby et al., 1992). All points, separated by at least 200 m, were visited once between 06:00 and 10:00 for 10 min, only under favorable weather conditions (without rain or strong wind). All diurnal bird species