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Using indicator groups to represent bird phylogenetic and functional diversity

Joaquim Trindade-Filho [a], Fernando Landa Sobral [a], Marcus Vinicius Cianciaruso [b], Rafael Dias Loyola [b,*]

[a] Programa de Pós-graduação em Ecologia e Evolução, Universidade Federal de Goiás, Goiânia, Goiás, Brazil
[b] Departamento de Ecologia, Universidade Federal de Goiás, Goiânia, Goiás, Brazil

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ABSTRACT

Land-use intensification causes species losses reducing phylogenetic and functional trait diversity as well as ecosystem function. Phylogenetic (PD) and functional (FD) diversity of regional assemblages have been identified as a key to understanding ecosystem and community functioning, yet it has been rarely included in conservation planning. The use of indicator groups to represent species richness is by far the most common measure used for developing plans to conserve current and future biodiversity. Could indicator groups be used for representing PD and FD of whole assemblages? Using a continuous measure of PD and FD derived from phylogenies and quantitative functional traits of species and their functional relationships, we assessed the effectiveness of 16 indicator groups in representing these evolutionary and functional components of biodiversity to answer this question. We focused our analyses on the entire set of 854 bird species occurring in the Atlantic Forest Biodiversity Hotspot, as a case study. We show that a particular bird order (Apodiformes) is the most effective surrogate group to capture PD, while the Charadriiformes and restricted-range species are the most effective surrogate group to capture FD. Their use as a shortcut to conservation planning is likely to guarantee the conservation of evolutionary and ecosystem processes through the representation of the unique species, as well as ecosystem stability in the long term, with the representation of the redundant species.

1. Introduction

The use of indicator groups that are effective in representing the biodiversity of a given area is a timely topic for research. This is because human activities threaten many thousands of species with extinction (Baillie et al., 2004; Mace et al., 2005) at the same time that conservation efforts are limited by time and money. In addition, it is not possible to survey the distributions of all organisms, neither to understand all their ecological roles and nor the evolutionary history of all species. Thus, groups of species, which can be defined taxonomically or according to specific traits (see Manne and Williams, 2003) can be used as a tool to embrace several aspects of biodiversity. Accordingly, many studies demonstrated that distinct indicator groups are effective in representing species richness across various spatial scales (Pinto et al., 2008; Loyola et al., 2007; Lawler et al., 2003; Larsen et al., 2009; Trindade-Filho and Loyola, 2011). These studies assume that species richness is a good surrogate for other aspects of biodiversity, such as the amount of evolutionary history or the diversity of ecological roles species can have in a given site. However, there is evidence that species richness is not a good surrogate for these aspects of biodiversity (Gómez et al., 2010; Devictor et al., 2010). In addition, the consequences of human activities go beyond the loss of species and several studied reported losses of both evolutionary history and functional trait diversity at different spatial scales (Purvis et al., 2000; Flynn et al., 2009; Mayfield et al., 2010).

One of the first suggestions to overcome the limitation of species richness in representing other aspects of biodiversity was the use of phylogenetic diversity (PD) measures (Faith, 1992). PD provides additional value to theoretical and applied ecology by distinguishing species according to their evolutionary pathway (Schweiger et al., 2008), therefore reflecting the tempo and mode of divergence across the Tree of Life. In addition, there is evidence that extinctions are not randomly distributed across phylogenies (Purvis et al., 2000) and species vulnerability is expected to be phylogeneticaly clustered. As a consequence, if vulnerable species are closely related one would expect to have higher loss of PD than expected by chance when these species went extinct. Further, certain clades are more vulnerable to anthropogenic pressures than others (Purvis, 2008), causing portions of Earth's evolutionary history to be disproportionately altered (Thuiller et al., 2011). Yet many have suggested that PD is an important aspect of biodiversity with relevant importance for conservation, although this approach has seldon been incorporated into conservation strategies (but see Carvalho et al., 2010 for a recent approach).

Somehow simultaneously, the unprecedented rates and global extent of current biodiversity loss (Pimm et al., 1995) have

* Corresponding author. Address: Departamento de Ecologia, Instituto de Ciências Biológicas, Universidade Federal de Goiás – UFG, Caixa Postal 131, CEP, 74001-970 Goiânia, GO, Brazil. Tel.: +55 62 3521 17 28; fax: +55 62 3521 11 90.
E-mail address: avispa@gmail.com (R.D. Loyola).

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prompted a rapidly growing body of research exploring its functional consequences (Chapin et al., 1998; Loreau et al., 2001; Flynn et al., 2009; Mayfield et al., 2010). These studies have found that declines in species richness impair ecosystem functions, undermining the provisioning of ecosystem services and the ecosystem processes that support human well-being. Techniques for measuring biological diversity have developed in step with theoretical advances in linking species diversity and ecosystem function (Naeem, 1998; Tilman, 1999; Díaz and Cabido, 2001). This relation has resulted in a growing focus on the diversity and values of functional traits that influence ecosystem functioning, as a tool for explaining the role of organisms in ecosystems and the ecological impacts of their loss (Petchey and Gaston, 2006; Flynn et al., 2009). Additionally, the functional traits of species, while providing information on resource use and habitat requirements of species, have the potential to elucidate the processes governing biodiversity patterns and assembly rules driven by functional traits (Mason et al., 2007; Gómez et al., 2010; Mayfield et al., 2010). Nonrandom distributions of species' traits could indicate that processes such as limiting similarity or environmental filtering are responsible for the structure local assemblages (Holdaway and Sparrow, 2006; Petchey et al., 2007).

Functional diversity (FD) is a biodiversity component that represents the extent of the functional differences among species based on the distinction of their morphological, physiological and ecological traits (Petchey and Gaston, 2006). Species loss may lead to a reduction in functional diversity depending on the intrinsic redundancy of assemblages (Petchey et al., 2007; Flynn et al., 2009). A decrease on the functional diversity of local and regional assemblages could have dramatic consequences for ecosystem functioning because the traits of species, not just the number of taxonomic units, ultimately drive biodiversity-ecosystem functioning relationships (Díaz and Cabido, 2001; Hooper et al., 2005). Because functional diversity consists of the range and values of key traits, assemblages with high number of species but low functional diversity can be said to have high functional redundancy (Naeem, 1998; Petchey et al., 2007). Functional redundancy occurs when co-existing species share similar trait states, which may reflect niche overlap if traits are defined in a biologically appropriate way (Díaz and Cabido, 2001). Functional redundancy provides resilience and resistance against the loss of functions and services provided by that assemblage if different species show compensatory responses following environmental change (Naeem, 1998). Conversely, when each species present in a community represents a unique combination of traits, FD will be higher indicating a high level of species niche complementarity.

In theory, preserving several components of biodiversity simultaneously could be achieved by maximizing the protection of taxonomic diversity within a systematic conservation planning framework (Margules and Pressey, 2000). Actually, past and current conservation strategies have focused on priority taxa or areas to protect rarity and endemism (e.g. Myers et al., 2000; Rodrigues et al., 2004; Kier et al., 2009; Loyola et al., 2009). By definition, a complementary network of sites that encompasses all species will capture all phylogenetic and functional diversity, although established reserves usually do not capture a significant amount of these biodiversity components (see Carvalho et al., 2010), and species richness is not always a good surrogate for PD and FD. This is supported by the concept that effective strategies towards biodiversity conservation require not only the inclusion of individual species, functions or lineages in protected areas, but also sets of species that ensure not only the functioning of ecosystems but also its resilience and stability and in addition preserve also the evolutionary relationships among species. Because studies have already demonstrated that phylogenetic and functional diversity might be lost faster than we lose species (Heard and Mooers, 2000; Petchey and Gaston, 2002b; Taylor et al., 2006; Purvis, 2008), preserving these different aspects of biodiversity poses a new and important challenge for conservation biology (Carvalho et al., 2010; Devictor et al., 2010; Mayfield et al., 2010).

The big issue here is that any well-planned strategy for the conservation of phylogenetic and functional diversity requires knowledge on the distribution of species, their evolutionary history and their functional traits. However, our knowledge of biodiversity is still negligible in comparison to the amount of unknown diversity, the urgency, importance and economical costs of the task of conserving it (Purvis and Hector, 2000; Carbayo and Marques, 2011). Therefore, conservation planners have been using surrogates for biodiversity such as indicator groups, when selecting sites of interest for conservation (Rodrigues and Brooks, 2007; Lawler and White, 2008). To meet indicator group criterion candidate groups need to have known geographic distribution (Loyola et al., 2007; Lawler and White, 2008), which is usually a problem; further, between-species interactions, their evolutionary history and species functional roles involve complex and often an unknown suite of traits and relationship among species, making the use of indicator groups even more interesting as a shortcut for proposing conservation action based on particular biodiversity features.

Here, we present for the first time an approach that uses indicator groups to represent phylogenetic and functional diversity, and discuss its theoretical and applied consequences for biodiversity conservation. We hypothesize that effective indicator groups of functional diversity should be formed by species sets that occupy many different habitats, thus covering a wide range of environmental conditions and spatial heterogeneity. Being so, they co-occur with habitat-specialized species leading to more complementary sets of species, and representing more species that are complementary in resource use (e.g. restricted-range species). For that, we used a set of 854 birds that inhabit the Atlantic Forest Biodiversity Hotspot and evaluated the effectiveness of sixteen indicator groups in representing bird phylogenetic and functional diversity. We conducted our analyses in two steps. First, we assessed the effectiveness of each indicator group in representing all species. With these results we constructed a species composition matrix represented by each indicator group. Then, we assessed their effectiveness in representing phylogenetic and functional diversity in the region. We provide new insights on the effectiveness of indicator groups to represent phylogenetic and functional diversity. Here we demonstrate that conservationists can use particular species to represent not only species richness but also the phylogenetic and functional diversity of whole assemblages, guaranteeing the maintenance of the evolutionary history of the species, ecosystem functioning and species trait diversity in the long term.

2. Methods

2.1. Data and scope of study

Despite the little knowledge on species distribution, their evolutionary history and functional traits for many taxonomic groups, we know this fairly well of birds. Birds are the best-studied class of organism, and several studies have established their significance as important mobile links in the dynamics of natural and human-dominated ecosystems (Stiles, 1985; Mols and Visser, 2002; Lundberg and Moberg, 2003). Birds are crucial for maintaining ecosystem function, persistence and resilience (Lundberg and Moberg, 2003; Flynn et al., 2009). Avian ecological functions encompass all three major linkages: genetic, resource and process (Sekercioglu, 2006). Given the ecological significance of birds this group is an excellent candidate for the indicator group approach.