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Human impacts on functional and taxonomic homogenization of plateau fish assemblages in Yunnan, China

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ABSTRACT

Human activities and the consequent extinctions of native species and invasions of non-native species have been changing the composition of species assemblages worldwide. These anthropogenic impacts alter not only the richness of assemblages but also the biological dissimilarity among them. However, much of the research effort to date has focused on changes in taxonomic dissimilarity (i.e. accounting for species composition) whether assessments of functional dissimilarity (i.e. accounting for the diversity of biological traits) are much more scarce, despite revealing important complimentary information by accounting for changes in the diversity of biological traits. Here, we assess the temporal (1950s against 2000s) changes in both taxonomic and functional dissimilarities of freshwater fish assemblages across lakes from the Yunnan Plateau in China. The Jaccard index to quantify the changes in both taxonomic and functional dissimilarity. We then partitioned dissimilarity to extract its turnover component and measured the changes in the contribution of turnover to dissimilarity. We found that functional and taxonomic homogenization occurred simultaneously. However, patterns between these two processes differed for some lakes. Taxonomic and functional homogenizations were stronger when the historical level of taxonomic dissimilarity among assemblages was high. The impact of extinctions of native species and invasions of non-native species on homogenization was otherwise complex to disentangle with no significant effect of any of the studied environmental factors. In agreement with other studies, our study proved that change in taxonomic dissimilarity cannot be used to predict changes in functional dissimilarity and, as an indicator of ecosystem functioning, functional dissimilarity should be used together with taxonomic dissimilarity to attain a more holistic understanding of human impacts on natural ecosystems.

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1. Introduction

Human activity and ecosystem disruption are strongly correlated, regardless of local fish biodiversity (Bellwood et al., 2003). Habitat alteration and biotic invasions are the two leading causes of global environmental change and biodiversity loss. As for freshwater ecosystems, fish extinction and invasion have occurred worldwide (Baxter et al., 2004; Seifert et al., 2015). Although species richness is decreasing on a global scale, species richness at the local and regional scales increases when the number of invasive non-native species greatly exceeds the number of native species becoming extinct (Sax et al., 2002; Winter et al., 2009; Matsuzaki et al., 2013).

The extinction of native species and invasion of non-native species should both lead to taxonomic homogenization (i.e. increase in the similarity of species composition among species assemblages over time), a trend documented for many other taxa across the world (Lockwood et al., 2000; Spear and Chown, 2008; Olden et al., 2011). However, much less evidence has been gathered on the impact of invasions and extinctions on the functional facet of biodiversity (Matsuzaki et al., 2013), or on its relationship with co-occurring changes in taxonomic dissimilarity among assemblages (Villéger et al., 2014). Therefore, it will provide a better understanding of the potential consequences of biodiversity change on ecosystem functioning by assessing the level of functional homogenization than just by measuring the level of taxonomic homogenization (Villéger et al., 2014).

Here, we assess the temporal (1950s against 2000s) changes in both taxonomic and functional dissimilarities of freshwater fish assemblages across lakes from the Yunnan Plateau in China. These lakes have experienced high rates of extinction of native species and invasion of non-native species over the past 60 years. Based on historical (1950s, prior to extinctions and invasions) and current (2000s, after extinctions and invasions) comprehensive datasets of strictly freshwater fish assemblages for nine plateau lake basins of Yunnan China, we explored the effects of species extinctions and invasions on the taxonomic and functional dissimilarities between fish faunas assemblages following the methodological frameworks of Baselga (2012) and Villéger et al. (2013). From a macroecological perspective, our study had three primary objectives. First, we assessed the temporal changes in these biodiversity facets following invasions of non-native species and extinctions of native species. Second, we quantified the correlation between the change in functional dissimilarity and the change in taxonomic dissimilarity to test whether the latter could be used as a proxy for the former (i.e., redundancy between both metrics). Finally, we investigated the relative effects of historical dissimilarity and the number of extinctions and invasions on changes in taxonomic and functional dissimilarities.

2. Materials and methods

2.1. Measuring dissimilarity and contribution of turnover

Based on species composition, taxonomic dissimilarity can be defined as the percentage of species present only in one assemblage within a pair of assemblages, and it can be measured with the Jaccard index (Villéger et al., 2014).

$$\beta_{\text{diss}} = \frac{b + c}{a + b + c}$$

where a is the number of species shared by the two assemblages and b and c are the number of species unique to each assemblage. However, only use this index could not describe the dissimilarity very exactly, thus Baselga (2012) partitioned the index into two parts: a nestedness and a turnover component. The turnover component accounts for the number of species replaced and the species richness in the poorest assemblage:

$$\beta_{\text{turnover}} = \frac{2 \times \min(b, c)}{a + 2 \times \min(b, c)}.$$

As turnover is a component of dissimilarity, its relative contribution to dissimilarity was more clear to measure, hereafter denoted P_{turn} (Toussaint et al., 2014):

$$P_{\text{turn}} = \frac{\beta_{\text{turnover}}}{\beta_{\text{diss}}} = \frac{2 \times \min(b, c)}{a + 2 \times \min(b, c)} \times \frac{a + b + c}{b + c}.$$

This partitioning of taxonomic dissimilarity has been recently transferred to functional dissimilarity (Villéger et al., 2013). Indeed, the functional richness of an assemblage can be measured as the volume of the convex hull shaping all the species in a multidimensional functional space (Villéger et al., 2008). The functional dissimilarity between two assemblages can thus be assessed using the percentage of overlap in this functional space. So it is possible to define the quantity a as the volume of the functional space shared by the two assemblages and b and c as the volume of the functional space they fill independently, respectively (Villéger et al., 2014).