Ecological Indicators 49 (2014) 228–236

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Which components of plant diversity are most correlated with ecosystem properties? A case study in a restored wetland in northern China

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ARTICLE INFO

Article history:
Received 17 April 2014
Received in revised form 26 September 2014
Accepted 1 October 2014

Keywords:
Dominance
Ecosystem services
Functional diversity
Taxonomical diversity
Wetlands

ABSTRACT

The relationship between plant diversity and ecosystem services is a controversial topic in ecology that may be due, at least in part, to the variety of methods used to define and quantify diversity. This study examined the relationship between plant diversity and 11 ecosystem properties of a restored wetland in northern China by considering four primary components of diversity (dominance, richness, evenness, and divergence). Each diversity component was expressed by eight taxonomic and functional diversity indices respectively. Results showed that trait-based functional diversity had a stronger correlation with ecosystem processes than non-trait taxonomic diversity did. Among the four components of diversity, dominance (in terms of mean trait value index) was the best in explaining the variation in ecosystem processing. Richness and divergence also had significant correlations with ecosystem properties in some instances. By contrast, evenness had no significant correlation with most of the studied ecosystem properties. Our results indicated that wetland ecosystem properties are significantly related to certain traits of the dominant species. Thus, the dominant species and functional traits should be considered before the number of species in managing diversity and enhancing certain ecosystem functions of wetlands, especially in the case of conservation.

1. Introduction

The past few decades have seen a rapid decline in global biodiversity, as well as a precipitous loss of ecosystem services (M.E.A., 2005), highlighting the critical need for a comprehensive understanding of the relationship between the two (Naeem et al., 1994; Chapin III et al., 2000; Hooper et al., 2005; Hillebrand and Matthiessen, 2009; MacDougall et al., 2013). However, the relationship between biodiversity and ecosystem services is still highly controversial (Schwartz et al., 2000; Kremen, 2005). While a number of studies have shown that the effect of species richness on ecosystem services is significantly positive (Engelhardt and Ritchie, 2001; Engelhardt and Ritchie, 2002 review in Balvanera et al., 2006 Zhu et al., 2012), the relationship is still highly controversial (Schwartz et al., 2000; Kremen, 2005). Indeed, several studies have argued against the existence of simple or direct relationships between diversity and ecosystem function at all (Grime, 1997; Wardle et al., 1997; Schwartz et al., 2000; Thompson et al., 2005). Moreover, while some studies have suggested that ecosystem services are influenced by the diversity of all species (Tilman et al., 1997; Petchey and Gaston, 2002), others posit that the functional traits of the dominant species overwhelmingly affect ecosystem services (Grime, 1998; Mokany et al., 2008). Also, some evidence suggests that functional diversity is more significant than non-trait based diversity in providing ecosystem services (Symstad, 2000; Moonen and Bàrberi, 2008). Clearly, the biodiversity/services debate requires a fundamental understanding of diversity and ecosystem services.

Diversity can be measured in a number of ways, and we propose that the variety of methods used to define and quantify diversity might be an important reason for the ecosystem 'biodiversity/services' debate. Diversity metrics quantify not only the number of species, but also the diversity of functional traits (Díaz et al., 2006). In addition to straightforward taxonomic diversity, the effects of functional diversity on ecosystem services have also drawn attention in recent years (Balvanera et al., 2006; Laliberté and

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http://dx.doi.org/10.1016/j.ecolind.2014.10.001
1470-160X/

Table 1
Four primary components of diversity and eight diversity indices applied as the expression of the components.

Component	Diversity indices			
	Taxonomic diversity	Calculation method	Functional diversity	Calculation method
Dominance			Mean trait value[e]	$\mathrm{MTV}=\sum_{i=1}^{S'} p_i \times \ln x_i$
Richness	Species richness[a]	S	Functional group richness[f]	F
Evenness	Pielou's evenness[b]	$J=\left(-\sum_{i=1}^{s} p_i \times \ln p_i\right)/\ln S$	Functional regularity[g]	$\mathrm{FRO}=\sum_{i=1}^{s-1} \min\left(\frac{\mathrm{EW}_{i,i+1}}{\sum_{l=1}^{S}\mathrm{EW}_{i,i+1}}, \frac{1}{S-1}\right)$ With $\mathrm{EW}_{i,i+1}=\frac{x_{i+1}-x_i}{p_{i+1}+p_i}$
Divergence	Shannon's diversity[c]	$H'=-\sum_{i=1}^{s} p_i \times \ln p_i$	Functional divergence[h]	$\mathrm{FD}=\sum_{i=1}^{s} p_i(\ln x_i - \ln X)^2$ with $\ln X=\sum_{i=1}^{S} p_i \times \ln x_i$
	Simpson's diversity[d]	$D=1-\sum_{i=1}^{s} p_i^2$		

S: number of all species; S': number of dominant species; p_i: relative abundance of species i; x_i: single functional trait value of species i.
[a] Colwell, 2009,
[b] Ricotta and Avena, 2003,
[c] Shannon, 1948,
[d] Simpson, 1949,
[e] Garnier et al., 2004,
[f] Tilman et al., 1997,
[g] Mouillot et al., 2005,
[h] Mason et al., 2003.

Legendre, 2010; Polley et al., 2013). Numerous diversity indices exist, but it has been generally measured using four primary components: dominance, richness, evenness, and divergence (Mason et al., 2005; Mokany et al., 2008). Dominance refers to the functional traits of the dominant species in a community, whereas richness, evenness and divergence refer to species number and functional traits of all species (Mason et al., 2005; Mokany et al., 2008). The four components of diversity can be measured by various taxonomic and functional diversity indices (Table 1). On the other hand, the labels of properties, processes, functions and services are helpful in understanding the ecosystem biodiversity/services debate. A cascade model summarized the distinction of these labels (Haines-Young and Potschin, 2010) (Fig. 1). Combination of many ecosystem properties, processes and functions could produce a particular ecosystem service, and may also lead to the generation of other kinds of service outputs. Ecosystem services fundamentally are products of ecosystem properties. Thus, studying the relationship between diversity components and ecosystem properties might be more helpful to fundamentally understand the biodiversity/services debate.

Using these four components of diversity (dominance, richness, evenness, and divergence), this study focused on the correlations between diversity and 11 ecosystem properties in a restored wetland in North China. We hypothesize that the four components of diversity might have different correlations with ecosystem properties. The four components of diversity were measured using eight taxonomic and functional diversity indices. Correlations between diversity indices and ecosystem properties were analyzed using Pearson's correlation and factor analyses. Based on these results, we identified potential ecological mechanisms that would

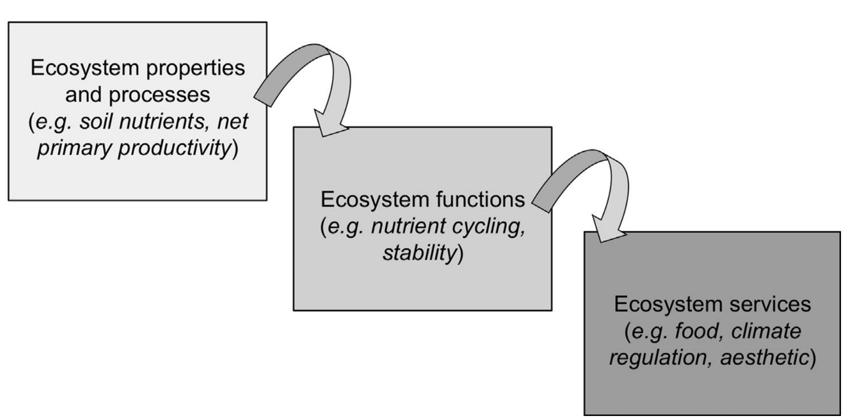

Fig. 1. Cascade model distinguishing ecosystem properties, processes, functions and services. (modified from Haines-Young and Potschin 2010).