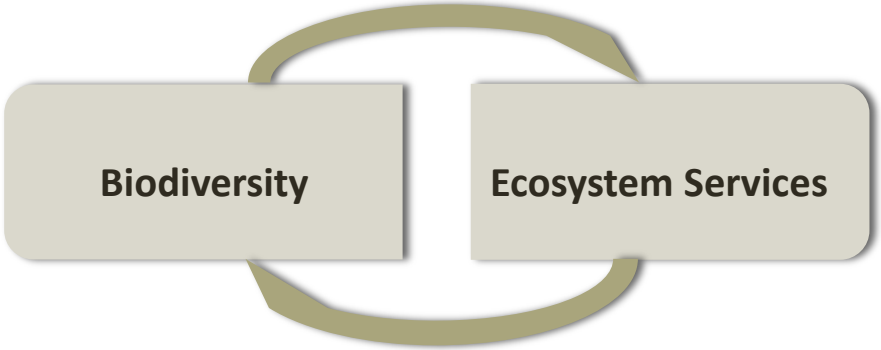
Which component of plant diversity is more correlated with ecosystem properties?

A case study on a restored wetland in North China

Presenter: Yiran Zhang, Ph.D student
Institute of Environmental Research, Shandong University
Email: zhangyiran@mail.sdu.edu.cn

Debate

The relationship between biodiversity and ecosystem services has been highly controversial.



*Effect of **species richness** on ecosystem processing is significantly positive (Engelhardt and Ritchie, 2001; Engelhardt and Ritchie, 2002; Zhu et al., 2012);
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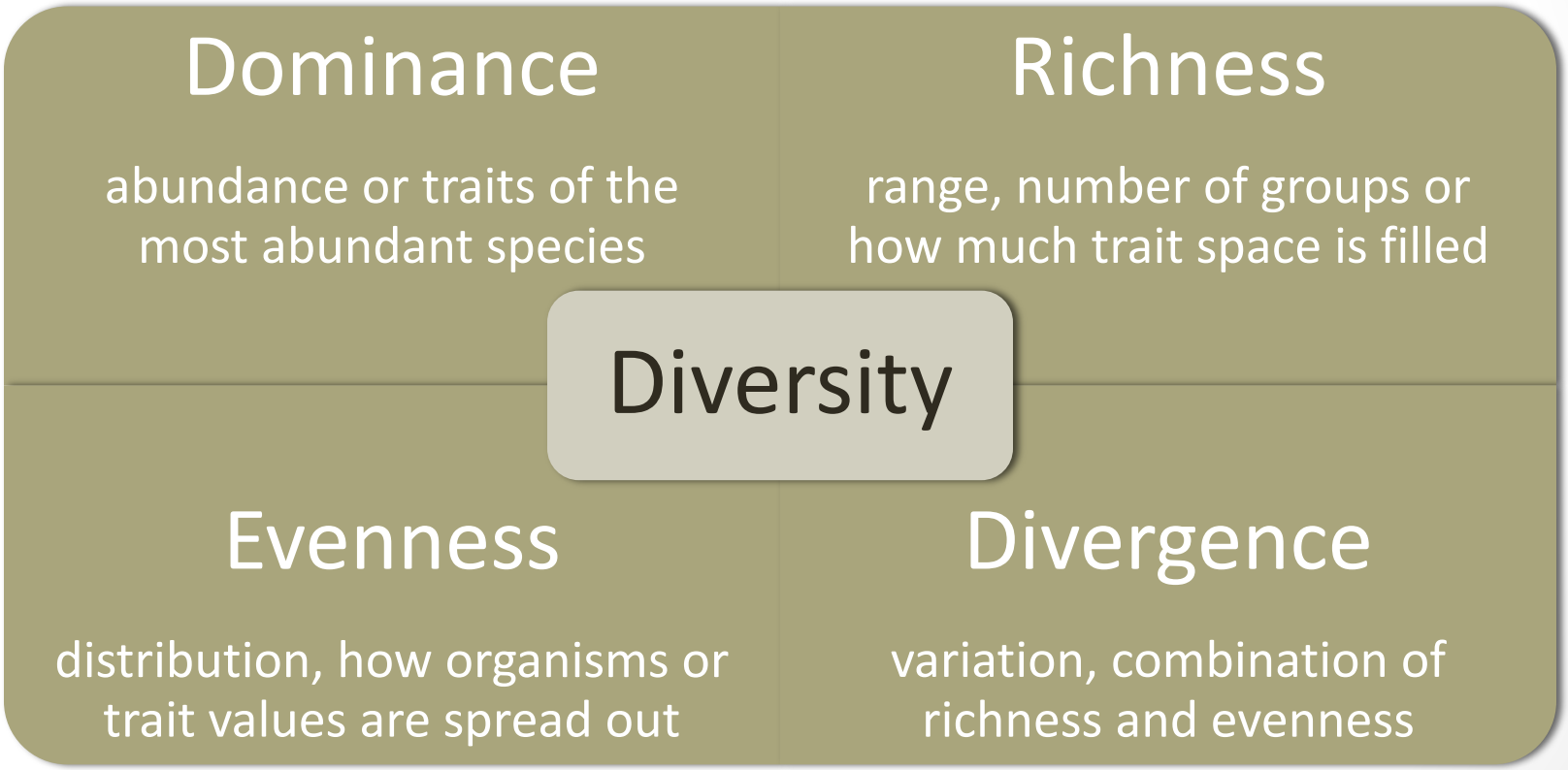
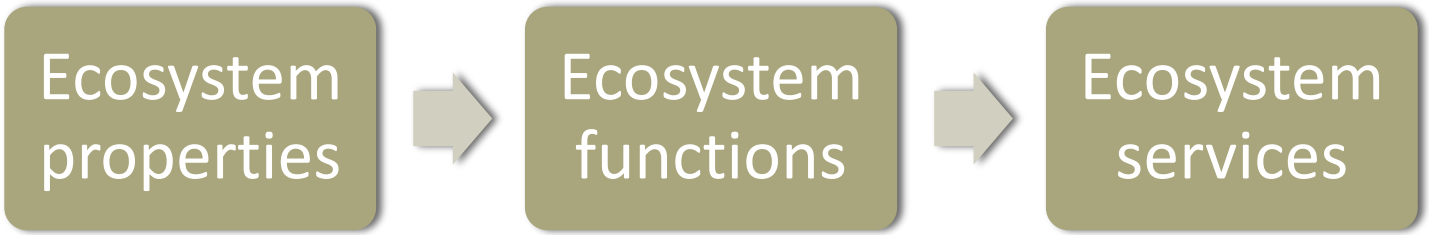
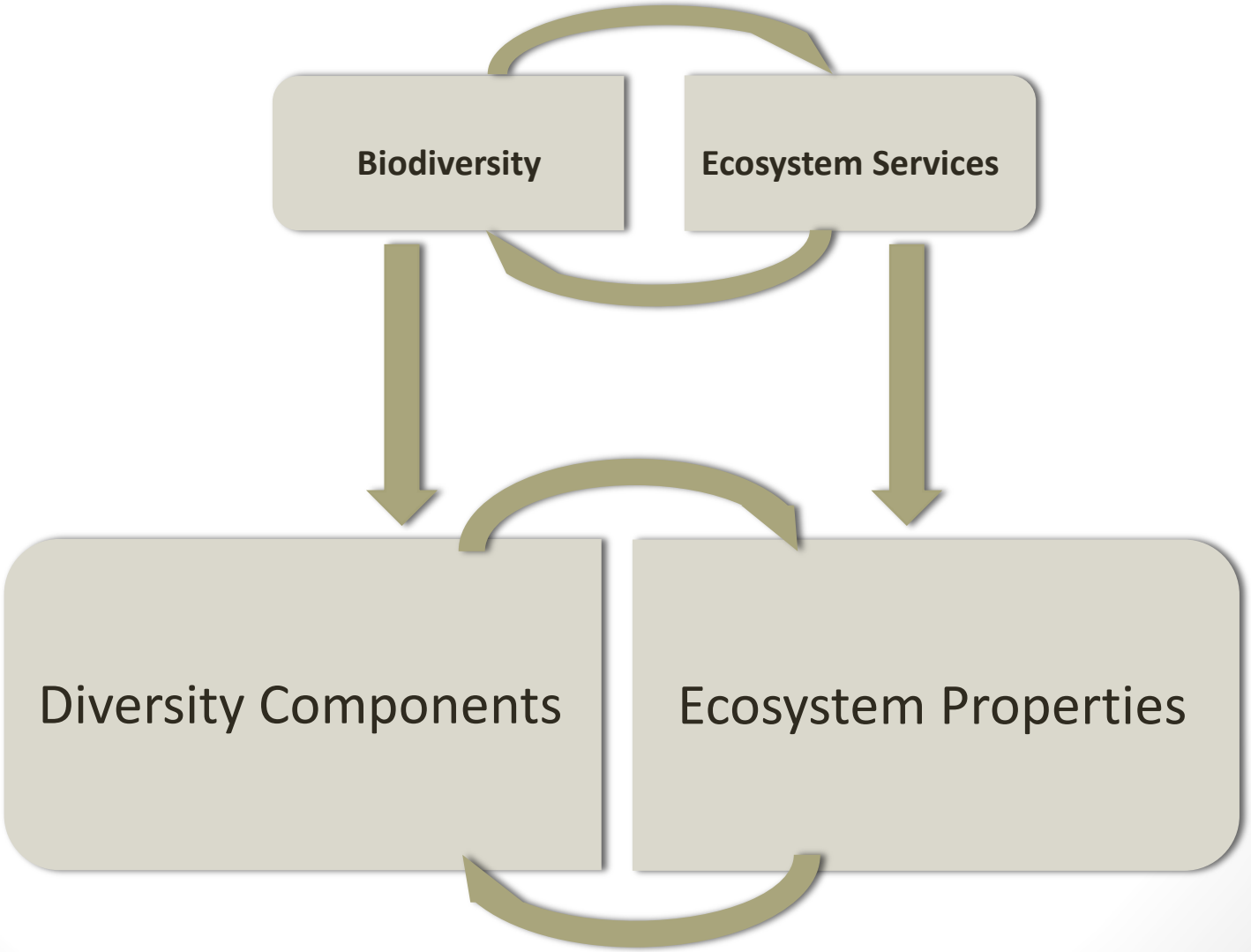
Primary Components of Diversity



Processing of Ecosystem Services



Understanding the debate



Hypothesis

- Different components of diversity might have different correlations with ecosystem properties, which can provide sight into the ecosystem biodiversity-services debate.
- Different correlations between diversity components and ecosystem properties might indicate ecological mechanisms for the relationship between diversity and ecosystem services.

Study Area

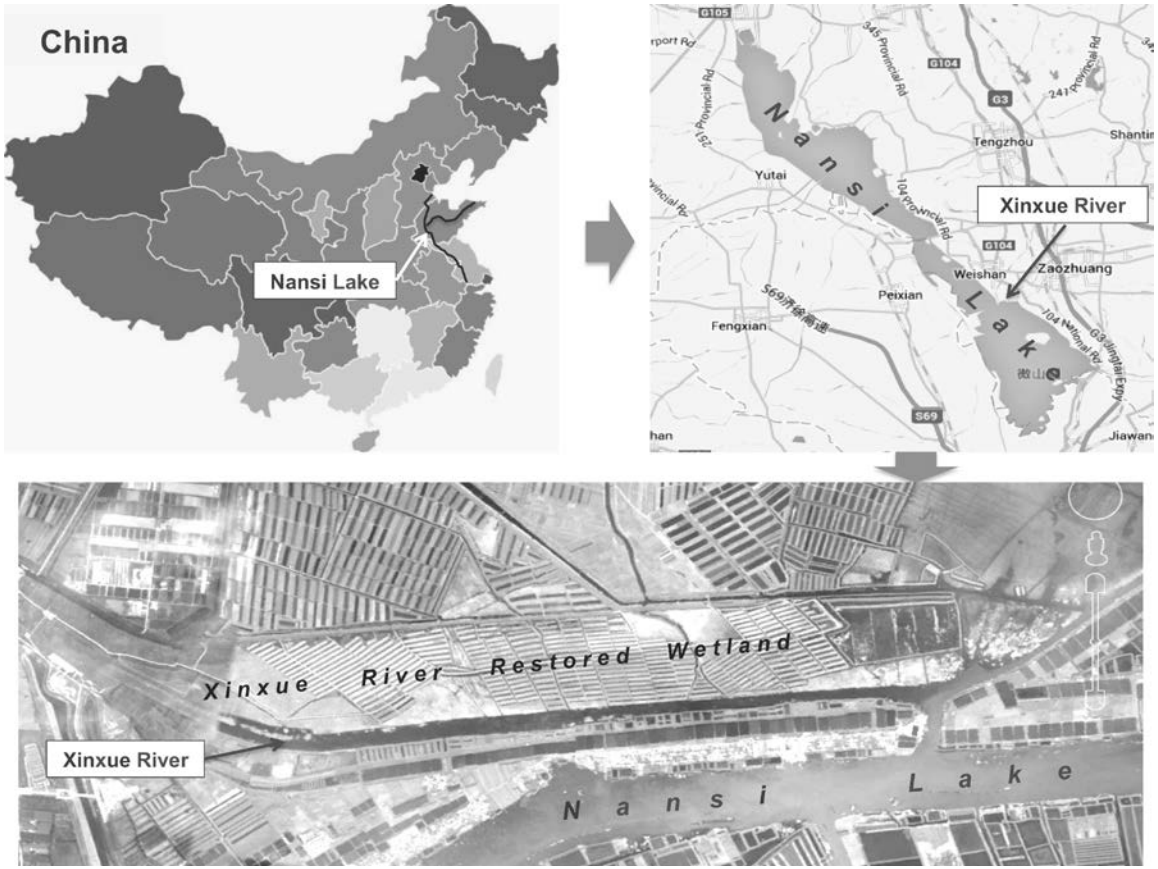


Fig. 1. Studied wetland in Nansi Lake, China

Methodology

Diversity Components & Diversity Indices

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]	$MTV = \sum_{i=1}^{S'} p_i * \ln x_i$
Richness	Species richness[a]	S	Functional group richness[f]	F
Evenness	Pielou's evenness[b]	$J = (-\sum_{i=1}^{S} p_i * \ln p_i) / \ln S$	Functional regularity[g]	$FRO = \sum_{i=1}^{s-1} \min\left(\frac{EW_{i,i+1}}{\sum_{l=1}^{S} EW_{i,i+1}}, \frac{1}{S-1}\right)$ With $EW_{i,i+1} = \frac{x_{i+1}-x_i}{p_{i+1}+p_i}$
Divergence	Shannon's diversity[c]	$H' = -\sum_{i=1}^{S} p_i * \ln p_i$	Functional divergence[h]	$FD = \sum_{i=1}^{S} p_i(\ln x_i - \ln X)^2$ With $\ln X = \sum_{i=1}^{S} p_i * \ln x_i$
	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.

Methodology

Two Ecological Mechanisms

selection effect

- Which gives rise to correlations between diversity and ecosystem processing through interspecific competition, which causes the dominance of species with certain traits.

complementarity effect

- the niche differentiation or facilitation between species or groups increases ecosystem processing above that expected from individual species or group.

Loreau and Hector, 2001

Methodology

Diversity components,Indices & Mechanisms

Table 2
Diversity components of eight indices and the ecological mechanisms they represent.

Diversity indices	Dominance	Richness	Evenness	Ecological mechanisms
Species richness (*S*)	-	√	-	Complementary effect
Pielou's evenness (*J*)	-	-	√	Complementary effect
Shannon's diversity (*H'*)	-	√	√	Complementary effect
Simpson's diversity (*D*)	-	√	√	Complementary effect
Mean trait value (*MTV*)	√	-	-	Selection effect
Functional group richness (*F*)	-	√	-	Complementary effect & Selection effect
Functional regularity (*FRO*)	-	-	√	Complementary effect & Selection effect
Functional divergence (*FD*)	-	√	√	Complementary effect & Selection effect

Results

Table 3
Pearson's correlation analysis for diversity indices and ecosystem properties, showing the eight most-correlated ecosystem properties (n = 84).

Independent variable	Aboveground biomass	Soil moisture	Soil clay	Soil pH	SOM	STP	SAP	NH_4-N
Species richness	**0.228***	**-0.496****	**-0.326***	0.251	-0.273	0.199	**-0.434****	**-0.456****
Pielou's evenness	-0.065	-0.194	-0.395**	-0.221	0.075	0.036	0.000	-0.185
Shannon's diversity	0.059	**-0.413****	**-0.402****	0.017	-0.180	0.101	-0.271	**-0.379****
Simpson's diversity	0.036	**-0.334***	**-0.431****	-0.068	-0.140	0.077	-0.196	**-0.299***
FRO (HA)	0.309**	0.037	-0.106	0.014	0.065	-0.098	0.146	0.039
FRO (LAA)	-0.104	0.037	-0.178	-0.151	0.040	0.150	0.081	0.054
FRO (MH)	0.256*	0.054	-0.165	-0.306*	0.097	-0.173	0.186	0.075
FRO (MLA)	-0.213	-0.208	-0.191	-0.032	0.042	-0.010	-0.100	0.051
FD (HA)	0.089	-0.166	-0.125	-0.109	0.010	-0.113	-0.102	-0.263
FD (LAA)	**-0.417****	0.108	-0.254	-0.194	0.067	-0.106	-0.103	-0.176
FD (MH)	0.225	-0.340*	-0.192	-0.120	0.017	-0.039	-0.189	-0.323*
FD (MLA)	**0.529****	-0.200	-0.347*	-0.356*	0.040	-0.010	-0.090	-0.309*
FD (LS)	-0.155	-0.175	-0.327*	0.010	-0.107	0.032	-0.266	-0.240
FD (GF)	**0.550****	**0.570****	0.113	**-0.544****	**0.301***	**-0.384****	**0.423****	0.238
FD (LF)	-0.152	-0.269	-0.271	-0.113	0.032	0.000	-0.147	-0.211
Mean trait value (HA)	0.057	0.147	**0.399****	-0.071	0.243	0.022	0.281*	0.109
Mean trait value (LAA)	**0.393****	-0.129	-0.103	**-0.295***	0.014	0.032	0.148	-0.229
Mean trait value (MH)	-0.193	-0.035	0.236	-0.010	0.076	-0.062	0.175	0.128
Mean trait value (MLA)	-0.119	-0.138	-0.075	-0.279*	0.020	-0.063	0.087	-0.194
Mean trait value (LS)	-0.032	0.283*	0.255	0.108	0.151	-0.047	0.210	0.264
Mean trait value (GF)	-0.231*	**-0.680****	-0.234	**0.440****	**-0.311***	**0.471****	**-0.464****	**-0.378****
Mean trait value (LF)	0.041	**0.320***	**0.430****	0.065	-0.030	**-0.328***	**0.310***	**0.284***

** $p < 0.01$, * $p < 0.05$.
Trait Codes: HA=height of adults; LAA=leaf area of adults; MH=maximum height; MLA=maximum leaf area; LS=life span; LF=life form; GF=growth form.
Ecosystem Processes Codes: SOM= soil organic matter; STP=soil total phosphorus; SAP=soil available phosphorus; NH_4-N=soil ammonia nitrogen

Results

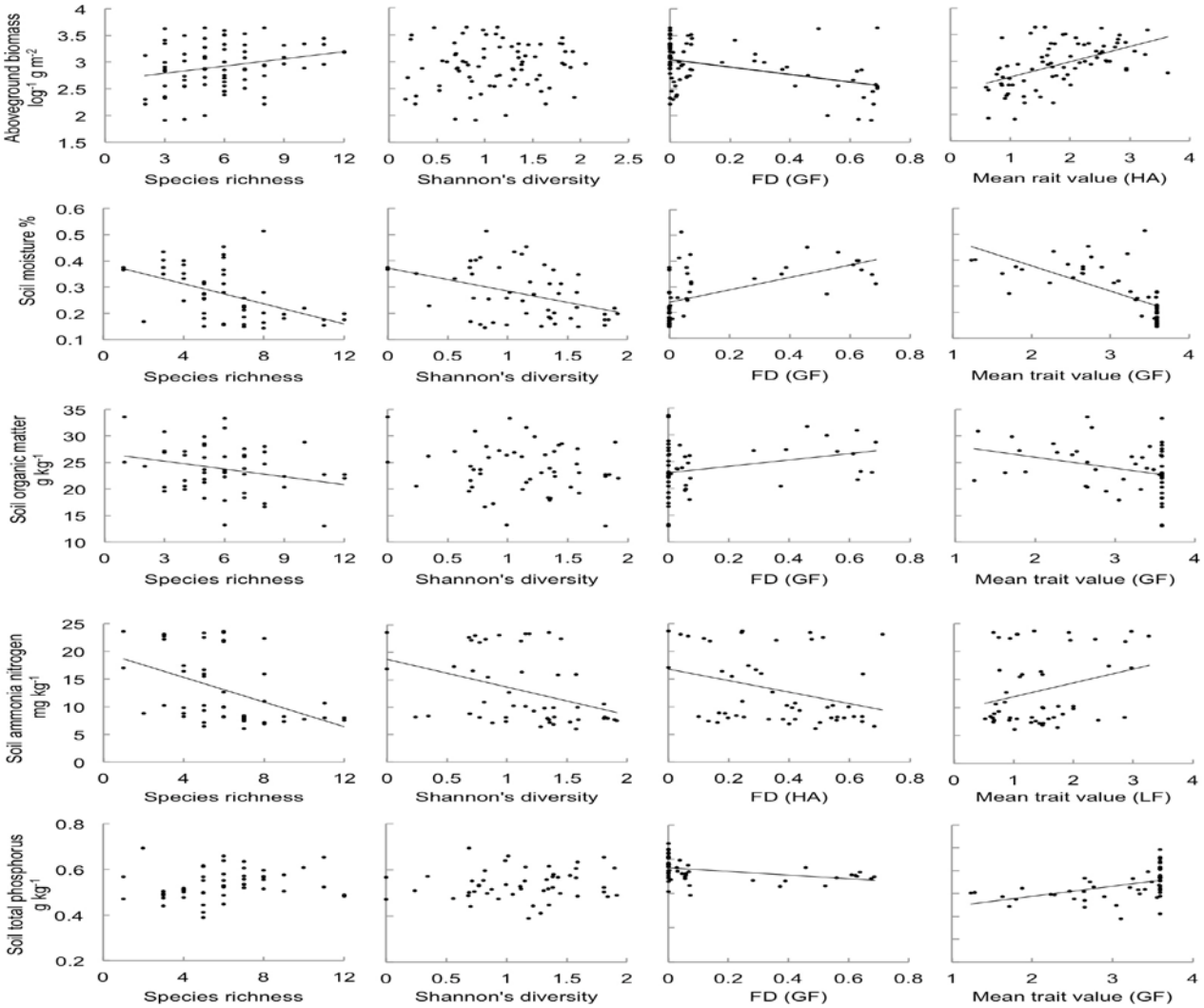


Fig. 2. Relationship between a range of diversity indices and ecosystem processes, showing the best-explained ecosystem processes with the best diversity indices (n=84).

Results

Table 4
Rotated factor loading matrix of factor analysis for ecosystem processes and taxonomic diversity indices (n = 84).

Variables	Species richness			Pielou's evenness			Shannon's diversity			Simpson's diversity		
	f1	*f2*	*f3*	*f1*	*f2*	*f3*	*f1*	*f2*	*f3*	*f1*	*f2*	*f3*
A-biomass	-0.06	-0.04	**0.86**	-0.11	-0.15	**0.82**	-0.16	0.14	0.82	-0.19	0.20	0.79
SOM	0.83	0.16	-0.24	0.84	0.12	-0.22	0.83	0.16	-0.21	0.84	0.14	-0.19
STN	0.90	0.07	0.02	0.90	0.02	0.09	0.87	0.18	0.07	0.87	0.18	0.09
STP	0.32	**-0.64**	0.32	0.27	-0.75	0.26	0.35	**-0.49**	0.56	0.32	**-0.46**	0.61
SAP	0.30	**0.80**	-0.01	0.35	0.76	0.08	0.23	**0.77**	-0.20	0.25	**0.72**	-0.27
SAN	0.80	0.23	-0.18	0.82	0.21	-0.13	0.79	0.27	-0.18	0.79	0.25	-0.17
NH_4-N	0.62	0.39	-0.30	0.66	0.35	-0.24	0.63	0.34	-0.32	0.64	0.30	-0.34
Clay/%	0.17	**0.72**	0.24	0.20	0.66	0.28	0.07	**0.76**	0.04	0.08	**0.78**	-0.01
Moisture	0.43	**0.63**	-0.41	0.51	0.64	-0.27	0.43	**0.56**	-0.50	0.46	**0.50**	-0.53
PH	-0.54	0.13	0.62	-0.56	0.12	0.62	-0.63	0.23	0.48	-0.65	0.28	0.44
%Cover	-0.23	-0.29	0.68	-0.28	-0.40	0.57	-0.28	-0.16	0.72	-0.30	-0.12	0.71
DI [a]	-0.14	-0.59	0.28	0.00	-0.11	**-0.49**	-0.19	**-0.66**	-0.09	-0.16	**-0.67**	-0.16
% Variance	27	49	68	29	49	66	28	49	68	29	49	68

a, DI, diversity indices =Species richness, Shannon's diversity or Simpson's diversity.
Ecosystem property codes: A-biomass-aboveground biomass; SOM= soil organic matter; STN=soil total nitrogen; STP=soil total phosphorus; SAP=soil available phosphorus; SAN=soil available nitrogen; NH_4-N=soil ammonia nitrogen

Results

Table 5
Rotated factor loading matrix of factor analysis for ecosystem processes and functional divergence index (n = 84).

Variables	*FD* (HA)			*FD* (LAA)			*FD* (LS)			*FD* (LF)		
	f_1	f_2	f_3	f_1	f_2	f_3	f_1	f_2	f_3	f_1	f_2	f_3
A-biomass	-0.22	-0.07	**0.75**	-0.19	-0.12	**0.75**	-0.20	0.19	0.81	-0.09	**0.84**	0.07
SOM	0.84	0.12	-0.18	0.85	0.14	-0.13	0.83	0.15	-0.19	0.84	-0.23	0.11
STN	0.87	0.05	0.11	0.88	0.03	0.09	0.87	0.18	0.09	0.89	0.02	0.07
STP	0.27	-0.68	0.42	0.27	-0.70	0.37	0.34	-0.47	0.60	0.30	0.41	-0.64
SAP	0.32	0.80	0.07	0.32	0.77	0.05	0.23	**0.75**	-0.24	0.33	-0.09	0.78
SAN	0.83	0.25	-0.03	0.81	0.22	-0.09	0.79	0.27	-0.17	0.82	-0.16	0.21
NH_4-N	0.67	0.36	-0.19	0.68	0.37	-0.17	0.64	0.36	-0.30	0.64	-0.33	0.32
Clay/%	0.12	0.70	0.17	0.15	0.70	0.27	0.06	**0.76**	0.00	0.17	0.11	0.75
Moisture	0.52	0.62	-0.29	0.52	0.63	-0.28	0.45	0.56	-0.49	0.46	**-0.48**	0.55
PH	-0.64	0.17	0.51	-0.62	0.15	0.54	-0.66	0.24	0.44	-0.55	0.59	0.25
%Cover	-0.33	-0.31	0.65	-0.32	-0.35	0.64	-0.30	-0.15	0.70	-0.26	0.68	-0.23
DI*	-0.21	-0.27	**-0.56**	-0.14	-0.27	**-0.61**	-0.18	**-0.58**	-0.16	0.11	**-0.89**	0.18
% Variance	31	50	67	30	50	67	29	48	67	28	53	71

*DI, diversity indices=*FD*(HA), *FD*(LAA), *FD*(LS) or *FD*(LF).

Results

Table 6
Rotated factor loading matrix of factor analysis for ecosystem processes and mean trait value index (n = 84).

Variables	Mean trait value (HA)			Mean trait value (LAA)			Mean trait value (LS)			Mean trait value (LF)		
	f_1	f_2	f_3	f_1	f_2	f_3	f_1	f_2	f_3	f_1	f_2	f_3
A-biomass	-0.26	-0.19	**0.80**	-0.13	-0.12	**0.77**	-0.19	0.18	0.80	-0.10	**0.85**	0.12
SOM	0.87	0.14	0.01	0.84	0.12	-0.20	0.85	0.16	-0.16	0.84	-0.23	0.11
STN	0.85	-0.01	0.12	0.90	0.06	0.12	0.87	0.14	0.10	0.89	0.04	0.09
STP	0.22	**-0.76**	0.25	0.28	**-0.71**	0.33	0.31	-0.50	0.59	0.31	0.45	-0.61
SAP	0.30	**0.74**	0.10	0.34	**0.78**	0.05	0.27	**0.76**	-0.22	0.31	-0.13	0.78
SAN	0.81	0.21	-0.04	0.81	0.22	-0.13	0.80	0.19	-0.19	0.81	-0.18	0.21
NH_4-N	0.70	0.37	-0.01	0.64	0.30	-0.33	0.65	0.35	-0.28	0.64	-0.34	0.31
Clay/%	0.14	**0.67**	0.44	0.17	**0.66**	0.18	0.10	**0.73**	-0.01	0.16	0.09	0.76
Moisture	0.54	**0.64**	-0.18	0.50	**0.63**	-0.32	0.48	0.55	-0.48	0.45	-0.52	0.53
PH	-0.69	0.07	0.39	-0.57	0.17	0.62	-0.65	0.26	0.44	-0.57	0.56	0.27
%Cover	-0.39	-0.43	0.51	-0.29	-0.37	0.61	-0.31	-0.13	0.71	-0.28	0.66	-0.17
DI *	0.23	0.21	**0.65**	-0.09	-0.36	**-0.54**	0.10	**0.59**	0.27	-0.12	**0.82**	-0.34
% Variance	32	52	67	29	49	67	29	49	67	28	52	71

*DI, diversity indices=mean trait value (HA), (LAA), (LS) or (LF).

Conclusions

- We found that dominance in terms of mean trait value is of primary importance in determining the correlations between diversity and ecosystem functions, thus indicating that ecosystem processes are mainly related to certain species traits of dominant species, and the selection effect might be the dominant ecological mechanism during the wetland restoration process.

- Moreover, richness and divergence also had significant correlations with ecosystem processing in some instances, which indicates that complementarity effect exists and may partly influence ecosystem processing, but mostly in a negative way.

Conclusions

- Our results suggest that dominant species and plant functional traits should be considered over species numbers when managing diversity and certain ecosystem functions in a wetland ecosystem, especially in the restoration case.

- We believe that the aspect of the primary components of diversity provides insight into the relationship between diversity and ecosystem functions, and can serve as a reference for the management of ecosystem diversity and services. Thus, more studies should be conducted based on this aspect.

Take Home Messages

- Dominance, richness, evenness and divergence are the primary components of diversity.
- Ecosystem properties are significantly related to certain traits of the dominant species.
- Richness and divergence had correlations with ecosystem properties in some instances.
- Selection effect dominantly exists during wetland restoration.
- Dominant species and functional traits should be the priority in wetland management.

Debate

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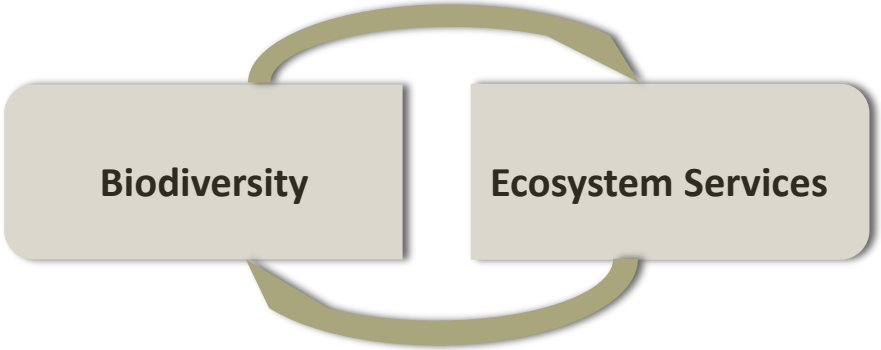

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- Thank you!