Supplementary Information

Long-term wetland biomonitoring highlights the differential impact of land use on macroinvertebrate diversity in Dongting Lake in China

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- <u>Two Supplementary Notes:</u>
- <u>Five Supplementary Tables:</u>
- <u>Ten Supplementary Figures:</u>

Supplementary Note 1: Monitoring methods of phytoplankton, macroinvertebrate, and Nutrients.

In-situ monitoring was carried out from 1988 to 2018. No data for 2002, 2003, 2015, and 2016 due to objective reasons such as water level changes. In the 1990s, four sites started routine biological monitoring, and 3 (Site NZ, PT, and YG) and 1 (Site HLH) sites were added in 2003 and 2008, finally forming a total of eight national monitoring sections. All transects were sampled every year in three seasons (January, May, and September). Duplicate samples were collected from three locations for each transect, 100 m from the left and right bank and the middle of the section.

Macroinvertebrate samples were sampled with a 1/16 m^2 modified Peterson dredger. The samples with animal specimens were sieved, washed through a 40-mesh copper sieve, and placed in a sealed pocket for storage. On the same day, after screening and washing, the samples were put into the white porcelain dissecting plate and sorted under cold light. Then, put the selected animal sample into a 50 ml sample bottle and fix it with a 10% formalin solution. The animals were identified and fixed in the laboratory. Specimen identification mainly referred to relevant literature and was identified at the genus level. The sampling of macroinvertebrates referred to the corresponding monitoring technical specifications (SOP). Although these specifications have been updated and published, the main method content has not changed. These standardized operations ensure the accuracy of sampling data and results. For example, China National Environmental Monitoring Center published "Technical Specifications for Biological Monitoring (Water Environment Part)" in 1986; compiled and published "Handbook of Aquatic Biological Monitoring" in 1993. Secondly, the collection, identification, and analysis of all samples were completed by Dongting Lake Eco-Environment Monitoring Centre of Hunan Province, which is one of the earliest watershed monitoring and management centers in my country, which can ensure the continuity of work, the unity of methods, and the quality of data.

Phytoplankton samples were collected by filtering 20 L of water through a plankton net (20 mesh). The precipitates were fixed with Lugol's solution for 48 hours and counted under the microscope. For Nutrients, the duplicated 1 L surface water samples were used to measure nutrient variables, including total phosphorus (TP) and total nitrogen (TN), following the Chinese national standard "Environmental quality standards for surface water (GB 3838-2002)". Finally, the results of samples from different seasons but in the same year were averaged before analysis.

Supplementary Note 2 Traits of macroinvertebrate.

We collected 29 categories belonging to six traits (*Supplementary Table 3*). The six groups of functional diversity information selected were from published books and articles [1-14]. If the species studied were not included in the above data, the relevant traits of the species were determined according to the taxonomic characteristics of the species and the actual measurement.

Supplementary Tables

Supplementary Table 1 Locations and sampling summary for eight sites.

Site	*ED*	*HLH*	*LJ*	*MPH*	*NZ*	*PT*	*WZ*	*YG*
Longitude	112.999	112.831	112.993	112.229	112.289	112.106	112.424	112.872
Latitude	29.339	28.823	29.158	28.956	29.063	28.915	28.817	28.783
Altitude	25.398	23.365	37.711	29.375	30.602	30.164	32.266	25.273
1988	+	-	+	+	-	-	+	-
1989	+	-	+	+	-	-	+	-
1990	+	-	+	+	-	-	+	-
1991	+	-	+	+	-	-	+	-
1992	+	-	+	+	-	-	+	-
1993	+	-	+	-	-	-	+	-
1994	+	-	+	+	-	-	+	-
1995	+	-	+	+	-	-	+	-
1996	+	-	+	+	-	-	+	-
1997	+	-	+	+	-	-	+	-
1998	+	-	+	+	-	-	+	-
1999	+	-	+	+	-	-	+	-
2000	+	-	+	+	-	-	+	-
2001	+	-	+	+	-	-	+	-
2002	-	-	-	-	-	-	-	-
2003	-	-	-	-	-	-	-	-
2004	+	-	+	+	+	+	+	+
2005	+	-	+	+	+	+	+	+
2006	+	-	+	+	+	+	+	+
2007	+	-	+	+	+	+	+	+
2008	+	+	+	+	+	+	+	+
2009	+	+	+	+	+	+	+	+
2010	+	-	+	+	+	+	+	+
2011	+	+	+	+	+	+	+	+
2012	+	+	+	+	+	+	+	+
2013	+	-	+	+	+	+	+	-
2014	+	-	+	+	+	+	+	-
2015	-	-	-	-	-	-	-	-
2016	-	-	-	-	-	-	-	-
2017	+	-	+	+	+	+	+	-

Note: "+" indicates a sampling conducted, and "-" indicates missing data.

Supplementary Table 2 Results of fitting linear models for time scales based on tipping points in *Supplementary Figure 2*.

Parameters	*Time Scale*	*R2*	*Slope*	*p-value*
Human land-use intensity	Overall	0.126	0.014	< **0.001*** **
	1988–1995	*-0.128*	*-0.001*	*0.767*
	1996–2008	*0.193*	*0.033*	***0.001****
	2009–2017	*0.008*	*-0.016*	*0.260*
Mean annual temperature	Overall	0.185	0.024	**0.021***
	1988–1995	*-0.196*	*0.032*	*0.692*
	1996–2008	*0.051*	*0.028*	*0.247*
	2009–2017	*0.231*	*0.065*	*0.155*
Input charge from the river	Overall	0.077	-8.409	0.102
	1988–1996	*0.379*	*24.458*	*0.083*
	1997–2008	*0.443*	*-42.151*	***0.021****
	2009–2017	*0.032*	*37.592*	*0.324*
Total nitrogen	Overall	0.378	0.039	< **0.001*** **
	1988–2005	*0.009*	*0.011*	*0.263*
	2006–2009	*0.122*	*0.112*	***0.042****
	2010–2017	*-0.031*	*-0.007*	*0.757*
Total phosphorus	Overall	0.055	0.002	**0.031***
	1988–1993	*0.637*	*-0.009*	*0.066*
	1994–2000	*0.009*	*0.005*	*0.315*
	2001–2017	*0.157*	*-0.005*	***0.003****
Algal bloom	Overall	0.158	16414.096	< **0.001*** **
	1988–2012	*0.218*	*21815.664*	*<* ***0.001****
	2013–2017	*0.159*	*-49922.593*	*0.11*
Species richness	Overall	0.241	-0.647	< **0.001*** **
	1988–2000	*0.001*	*-0.838*	*0.326*
	2001–2011	*0.163*	*-1.271*	***0.003****
	2012–2017	*-0.067*	*-0.275*	*0.740*
Functional redundancy	Overall	0.212	-0.054	< **0.001*** **
	1988–1993	-0.28	-0.105	0.746
	1994–2000	-0.064	-0.056	0.652
	2001–2017	0.101	-0.061	**0.008****
Taxonomic dissimilarity	Overall	0.01	0.002	**0.034***
	1988–2000	*0.103*	*0.009*	***0.003****
	2001–2011	*0.022*	*-0.009*	***0.021****
	2012–2017	*0.051*	*0.019*	***0.033****
Functional dissimilarity	Overall	0.044	0.006	**0.001****
	1988–1998	*-0.017*	*-0.002*	*0.833*
	1999–2008	*-0.01*	*-0.001*	*0.891*
	2009–2017	*0.139*	*0.028*	***0.004****

Supplementary Table 3 Functional trait classification of macroinvertebrates.

Traits	Class	Score	ID
Maximum adult length	Extremely small (< 0.99 cm)	1	B1
	Small (1.00~1.99 cm)	2	B2
	Medium (2.00~2.99 cm)	3	B3
	Large (3.00~5.99 cm)	4	B4
	Extremely large (> 6.00 cm)	5	B5
Body shape	Threadlike	1	F1
	Dorsal flat	2	F2
	Lateral flat	3	F3
	Oval	4	F4
	Conical	5	F5
	Cylindrical	6	F6
Adult movement ability	No mobility	1	M1
	Weak mobility	2	M2
	Medium mobility	3	M3
	Strong mobility	4	M4
Life habit	Burrower	1	H1
	Sprawler	2	H2
	Clinger	3	H3
	Swimmer	4	H4
Functional feeding group	Predator	1	FG1
	Collector	2	FG2
	Filter feeder	3	FG3
	Scrapers	4	FG4
	Shredders	5	FG5
	Omnivore	6	FG6
Life cycle	Extremely short (< 1 a)	1	L1
	Short (1~3 a)	2	L2
	Long (3~5 a)	3	L3
	Extremely long (> 5 a)	4	L4

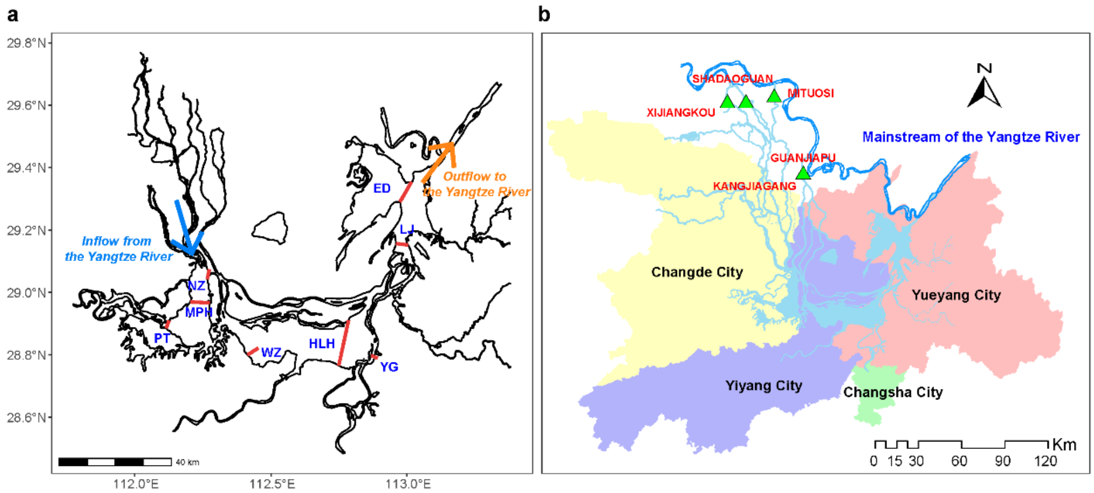
Supplementary Table 4 Decadal patterns of macroinvertebrate taxonomic and functional groups.

Category	*Indices*	*Class/Life form*	*R^2*	*slope*	*p-value*
Taxonomic group	Abundance	*Clitellata*	0.00	-0.07	0.463
		Oligochaeta	0.00	0.77	0.246
		Gastropoda	-0.01	0.14	0.890
		Bivalvia	**0.04**	**-2.23**	**0.013***
		Insecta	**0.04**	**-3.14**	**0.010***
		Crustacea	-0.01	1.52	0.693
	Relative abundance	*Clitellata*	0.00	0.00	0.418
		Oligochaeta	**0.07**	**0.01**	**0.001****
		Gastropoda	0.02	0.00	0.062
		Bivalvia	0.00	0.00	0.205
		Insecta	**0.05**	**-0.01**	**0.004****
		Crustacea	0.00	0.00	0.393
	Species Richness	***Clitellata***	**0.05**	**-0.01**	**0.005****
		Oligochaeta	0.01	-0.02	0.181
		Gastropoda	0.01	-0.04	0.136
		Bivalvia	**0.16**	**-0.11**	**< 0.001*****
		Insecta	**0.27**	**-0.28**	**< 0.001*****
		Crustacea	**0.05**	**-0.02**	**0.006****
Functional group	Abundance	Swimmer	-0.01	0.09	0.611
		Burrower	**0.07**	**-2.47**	**0.002****
		Sprawler	0.01	-1.27	0.117
		Clinger	0.02	-0.37	0.075
	Relative abundance	**Swimmer**	**0.03**	**0.01**	**0.029***
		Burrower	**0.07**	**-0.01**	**0.002****
		Sprawler	0.01	0.01	0.140
		Clinger	0.00	0.00	0.305
	Species Richness	**Swimmer**	**0.03**	**-0.02**	**0.029***
		Burrower	**0.16**	**-0.06**	**< 0.001*****
		Sprawler	**0.09**	**-0.07**	**< 0.001*****
		Clinger	**0.20**	**-0.05**	**< 0.001*****

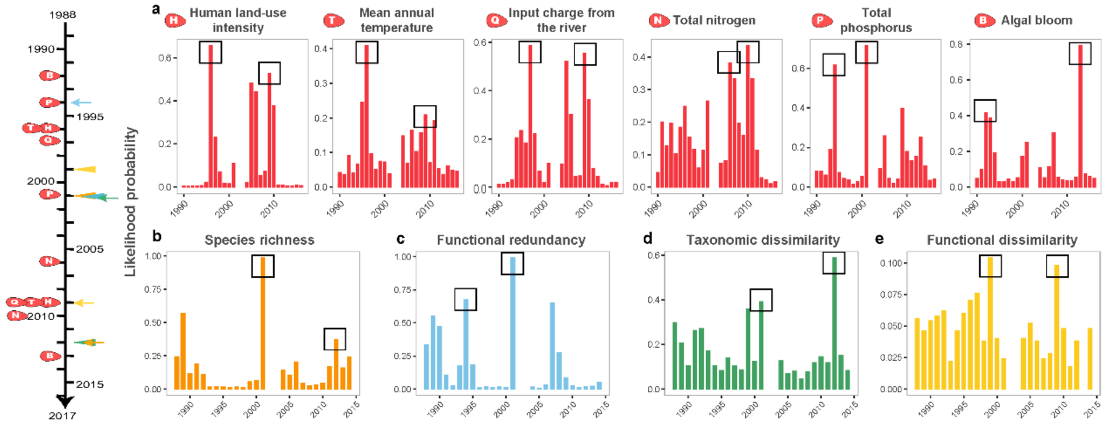
Supplementary Table 5 Gauging sites.

Inlets	***Gauging site***	***Longitude***	***Latitude***
SONGZIHE	XIJIANGKOU	111.7833	30.18333
	SHADAOGUAN	111.9167	30.18333
TAIPINGKOU	GUANJIAPU	112.3228	29.73398
OUCHIKOU	MITUOSI	112.1213	30.21695
	KANGJIAGANG	112.3222	29.73553

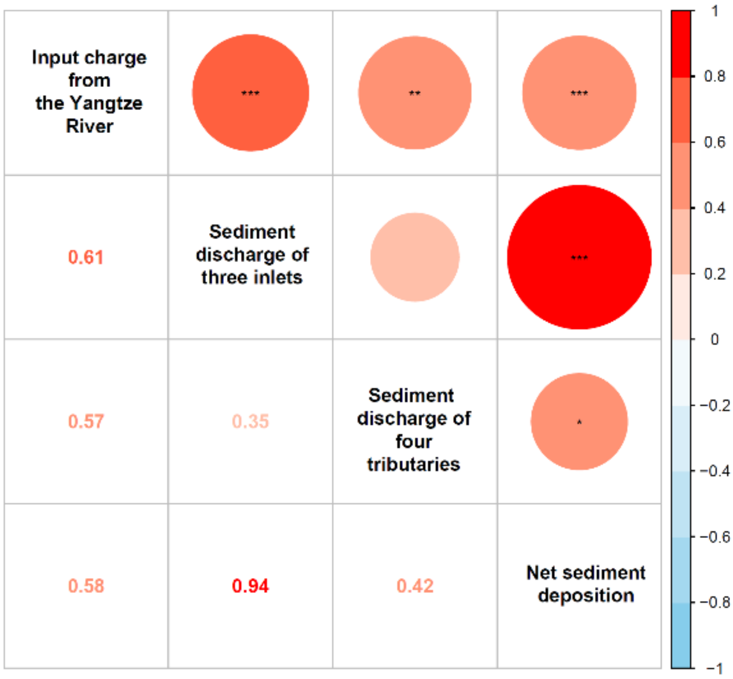
Supplementary figures



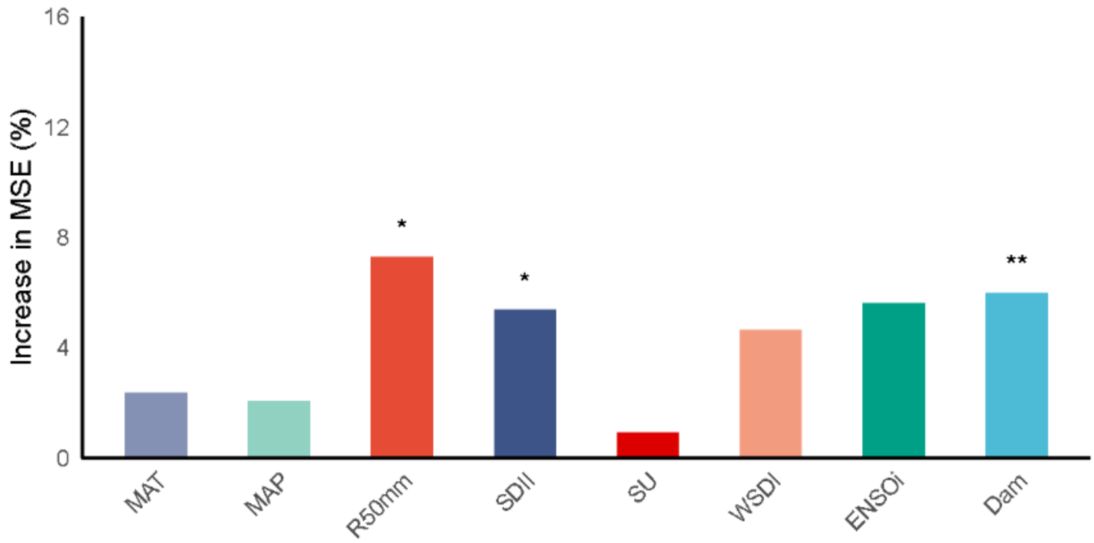
Supplementary Figure 1 Sampling sites (a) and gauging sites (b) at Dongting Lake.



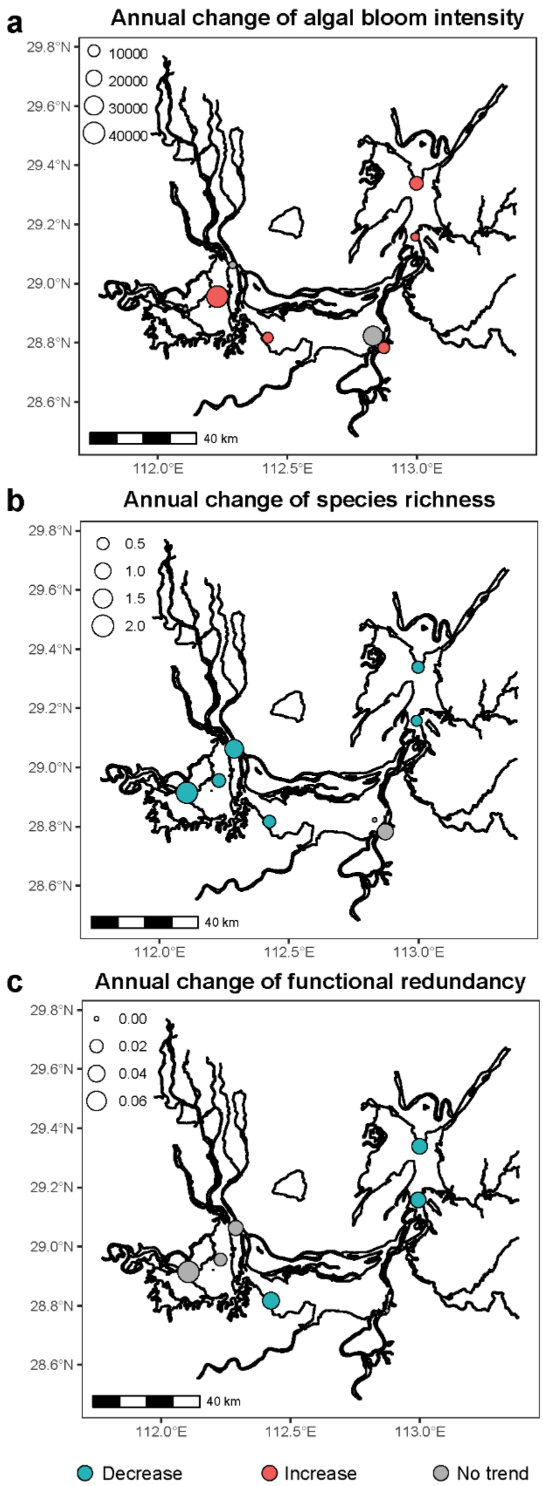
Supplementary Figure 2 Temporal tipping points of environmental conditions and diversity of macro-invertebrates analyzed by the Bayesian change point (bcp) tests. Species richness (a), functional redundancy (b), taxonomic dissimilarity (c), and functional dissimilarity (d).



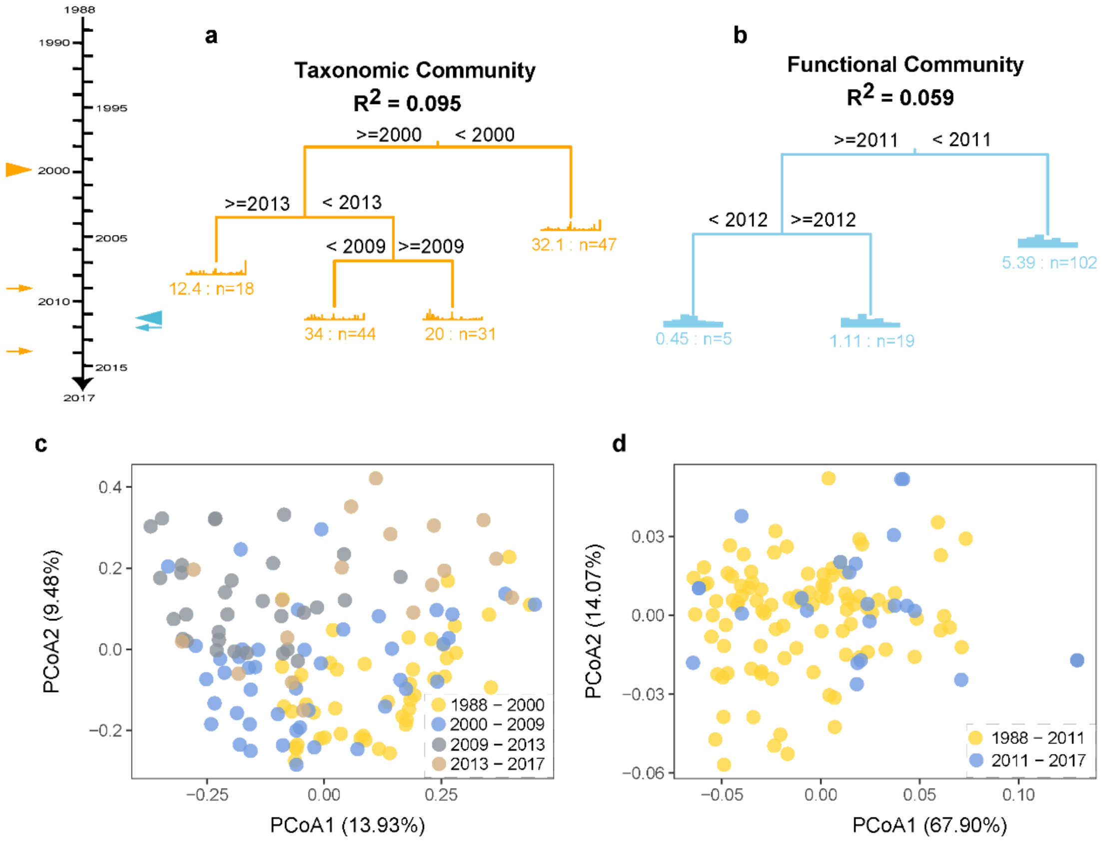
Supplementary Figure 3 Correlation of the input charge from the Yangtze River with other hydrological parameters.



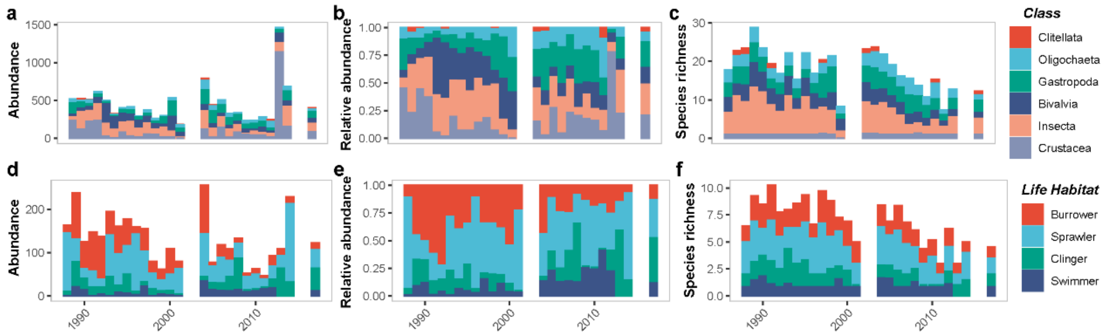
Supplementary Figure 4 Climate-derived and dam-derived controls on the connectivity between the Yangtze River and Dongting Lake. % MSE (Mean square error) was used to represent the relative importance of explanatory parameters. MAT, mean annual temperature; MAP, mean annual precipitation; R50mm, the number of rainstorm days; SDII, simple precipitation intensity index; SU, number of summer days; WSDI, warm spell duration index; ENSOi, yearly anomalies of ENSO event; Dam, the construction of the Three Gorges Dam. Markers of significance: * 0.01< p < 0.05, ** 0.001< p < 0.01.



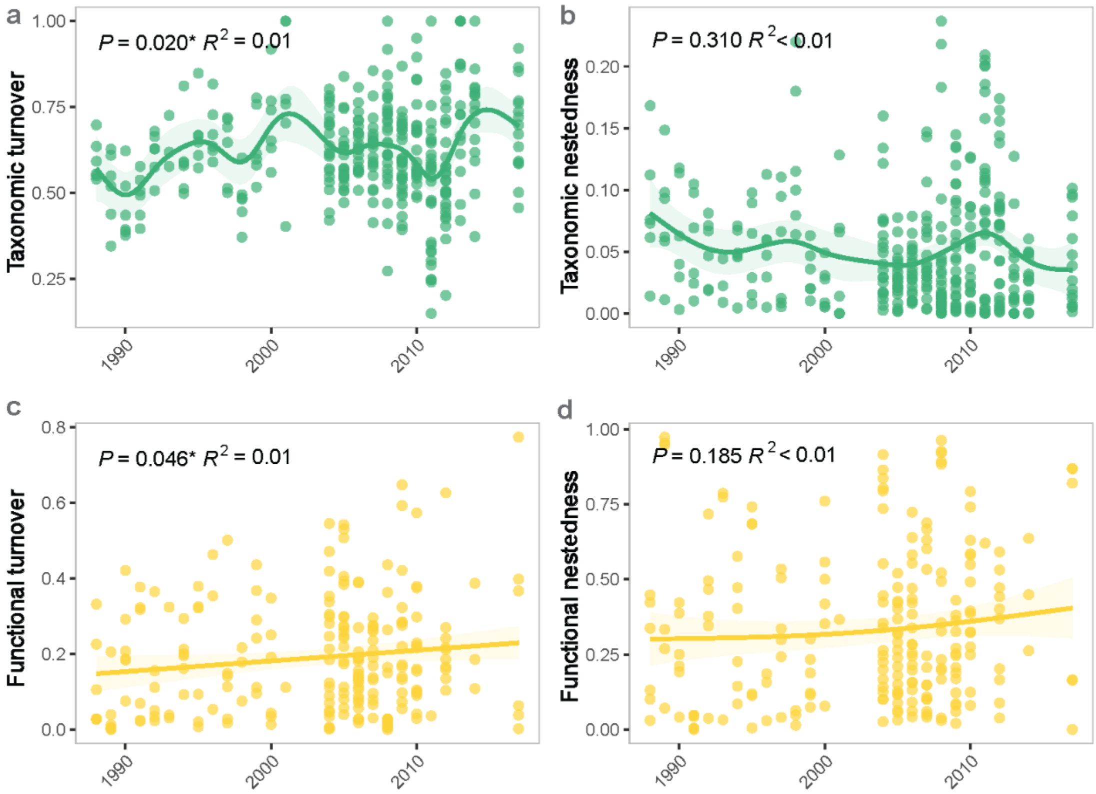
Supplementary Figure 5 Annual change of algal bloom intensity (a), species richness (b), and functional redundancy (c). Red and blue points represent significant increasing and decreasing patterns, and nonsignificant ($p >= 0.05$) patterns were in grey. The size of the point was scaled with annual change magnitude.



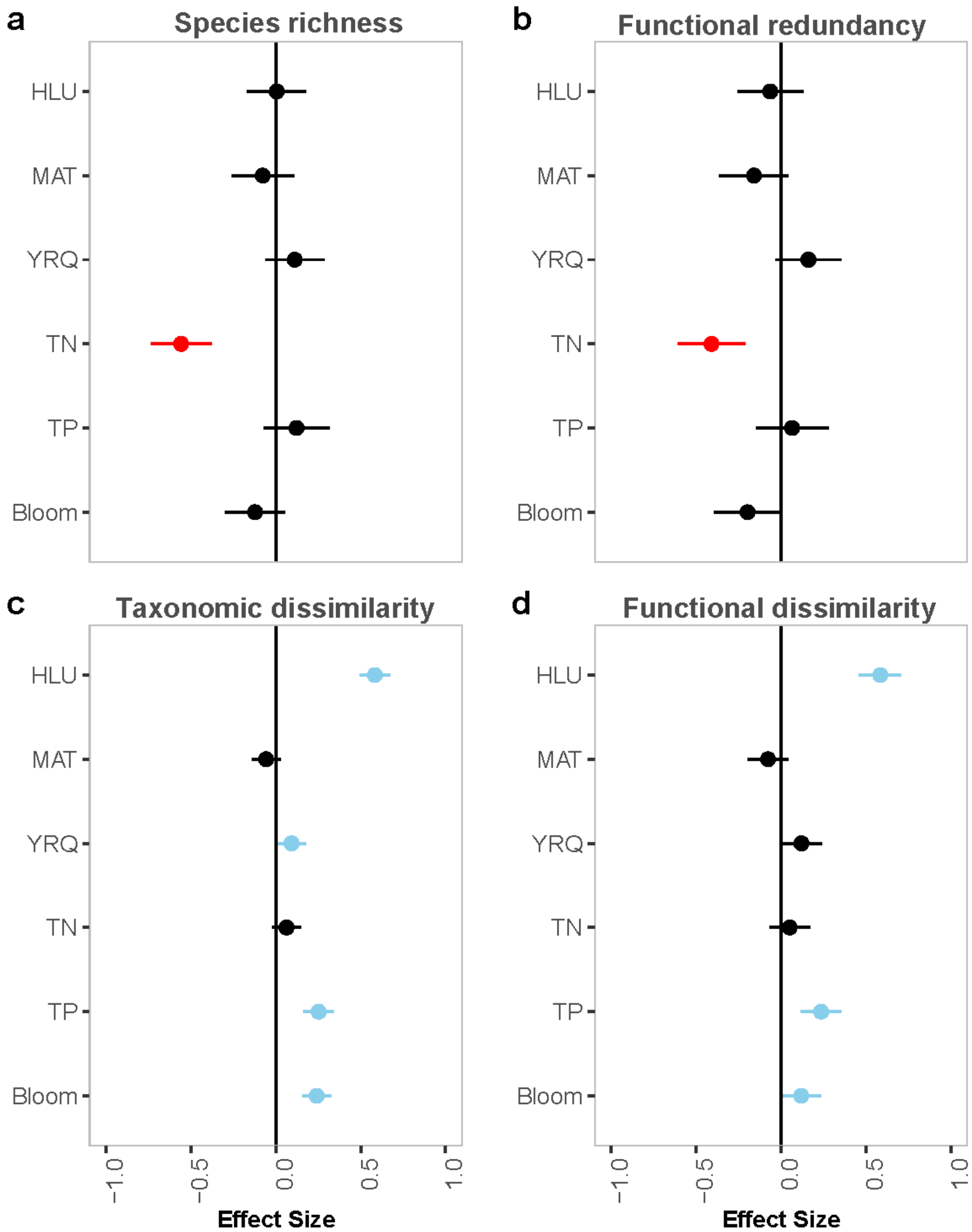
Supplementary Figure 6 Temporal tipping points and PCoA plots of taxonomic (a, c) and functional (b, d) community of macroinvertebrates.



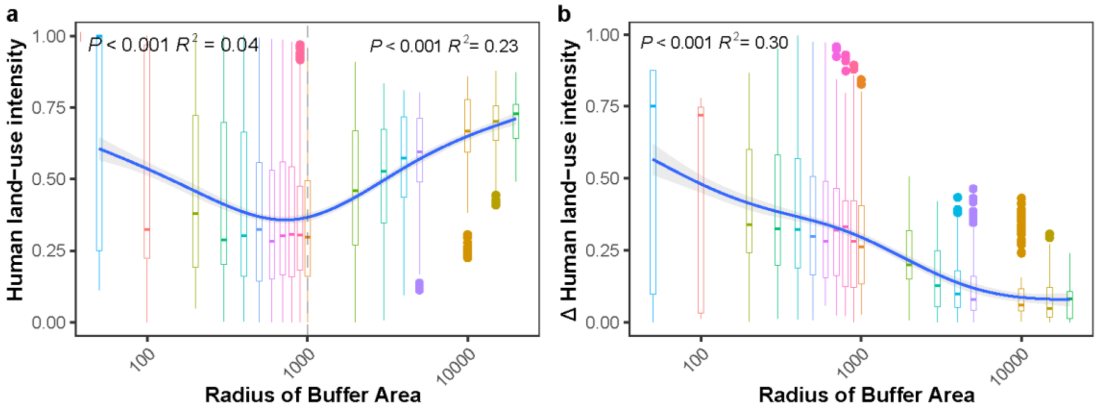
Supplementary Figure 7 Taxonomic (a–c) and functional (d–f) composition of macroinvertebrates. The figure illustrated the annual change of the abundance (a, d), relative abundance (b, e), and species richness (c, f) for the taxonomic classes and types of life habits of macroinvertebrates.



Supplementary Figure 8 Turnover and nestedness components for taxonomic (a–b) and functional dissimilarity (c–d). The colored envelope surrounding each line represents 95% of generalized additive models.



Supplementary Figure 9 Effect sizes of multiple factors for macroinvertebrates' alpha (a-b) and beta (c-d) diversity. Error bars represent 2σ variance. Black dots show insignificant negative effects, red dots indicate insignificant positive effects, and blue dots represent significant positive effects.



Supplementary Figure 10 Human land-use intensity across multiple distances. (a) Human land-use intensity; (b) differences in human land-use intensity between sites. The boxplots represent the interquartile range of human land-use intensity or differences from 1988 to 2017. The boxes span the interquartile range (IQR) between the first and the third quatiles, with the lines inside representing the medians. The whiskers extend to 1.5 times the IQR. Outliers are represented by points.

Supplementary References

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