Supplementary Materials for

Quantifying dynamical response diversity and its influences on ecosystem stability

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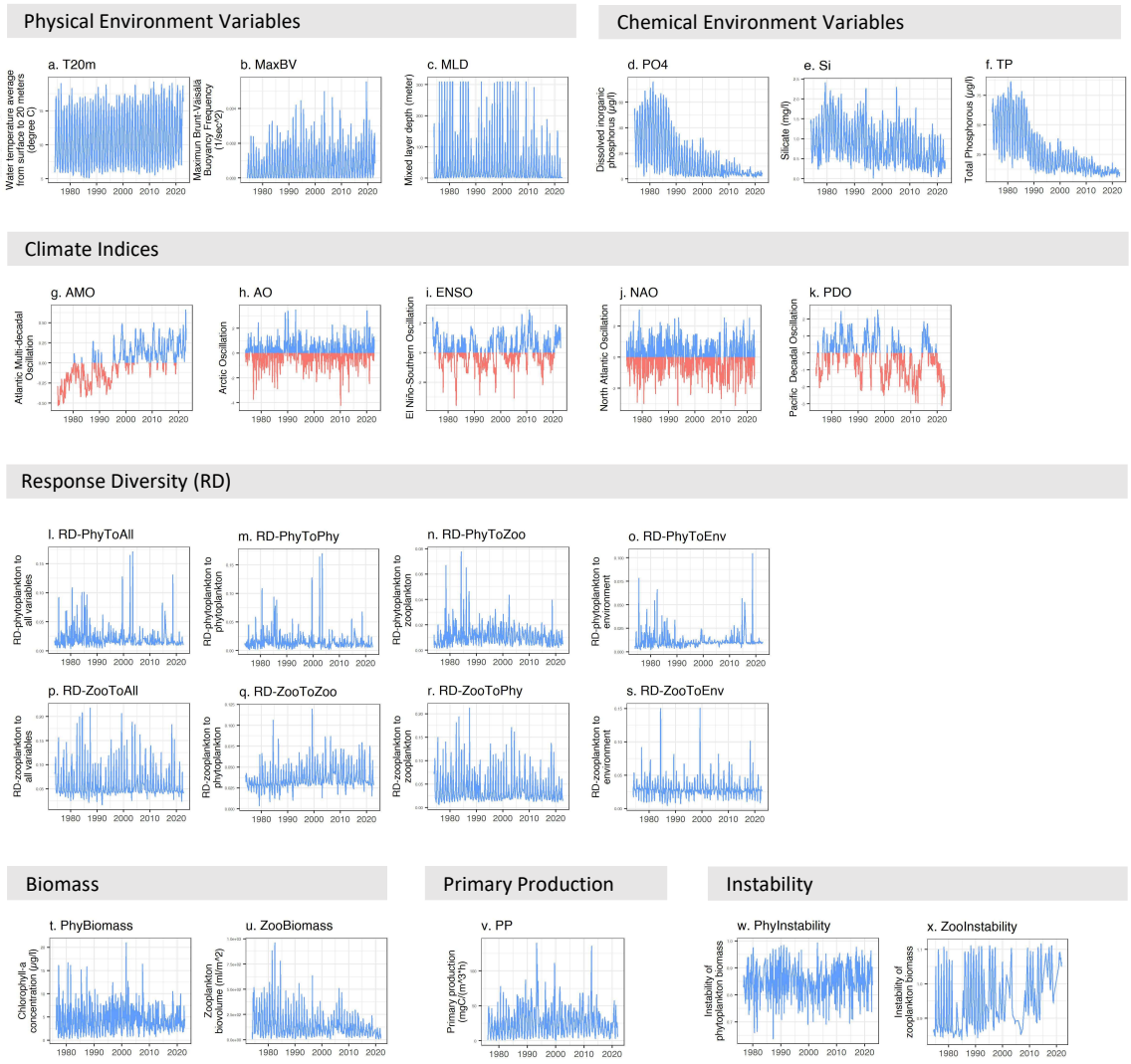
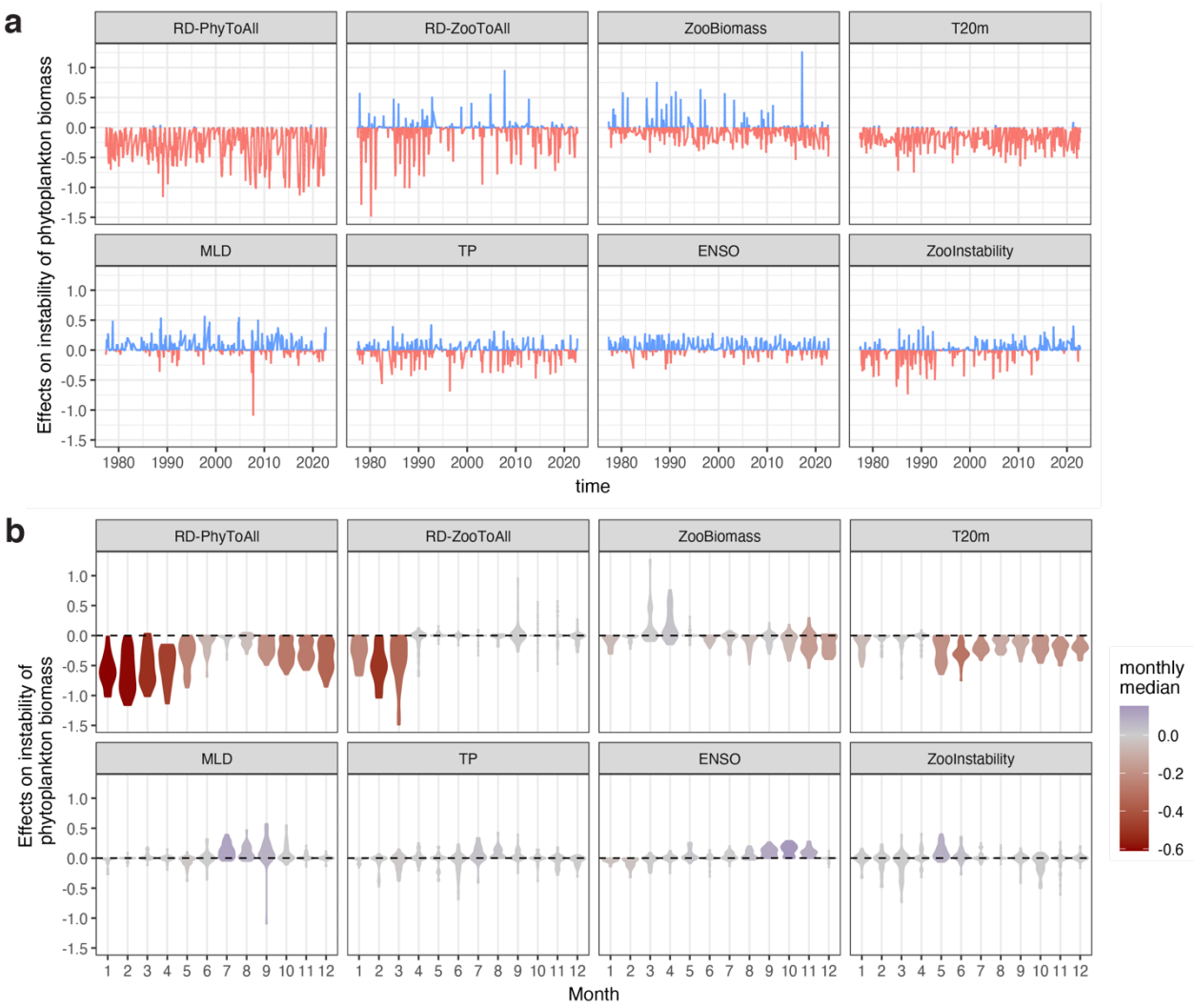
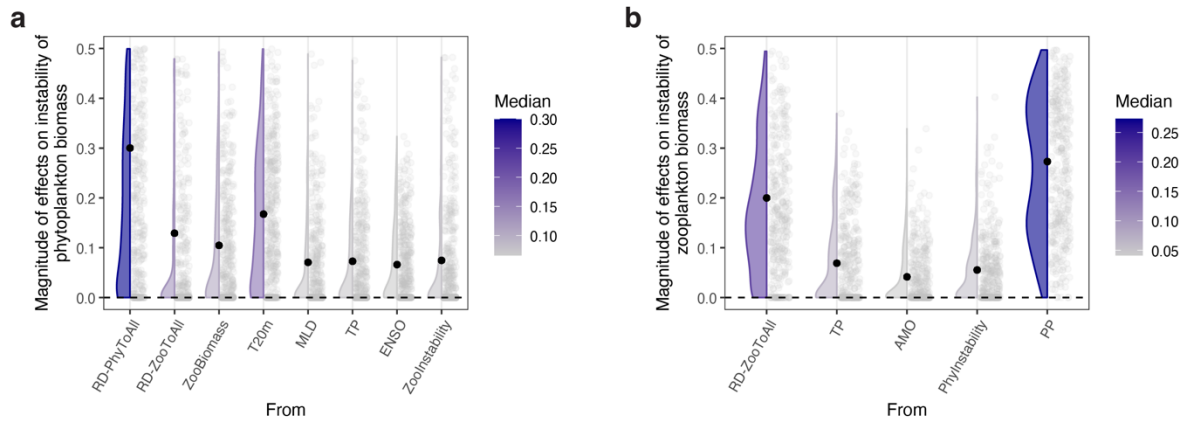


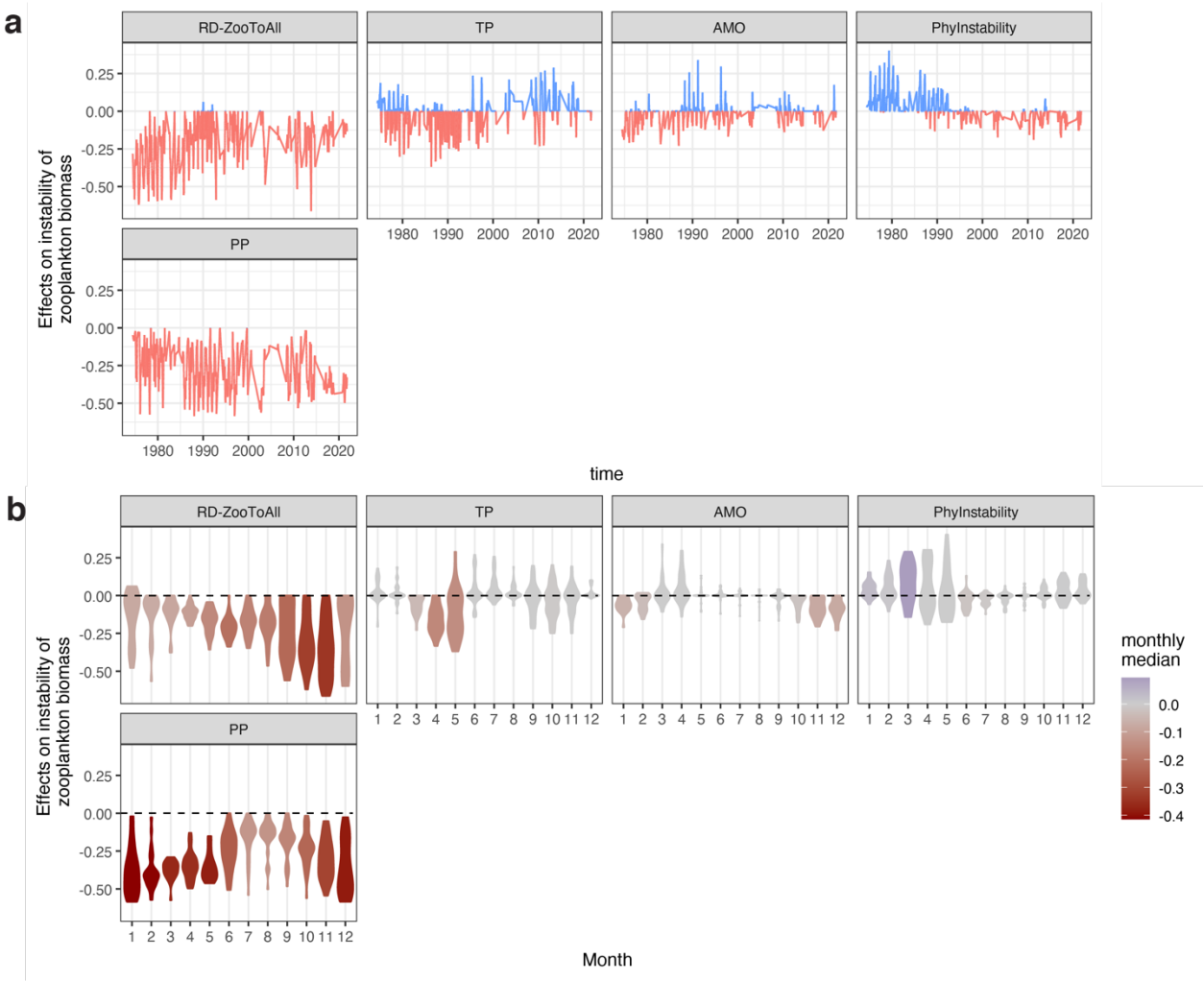
SI Figure 1. Monthly time series data of environmental variables, response diversity, plankton biomass, primary production, and plankton instability. The acronym of each variable used in this work is shown on top of each panel. The full name is shown as the Y-axis label.



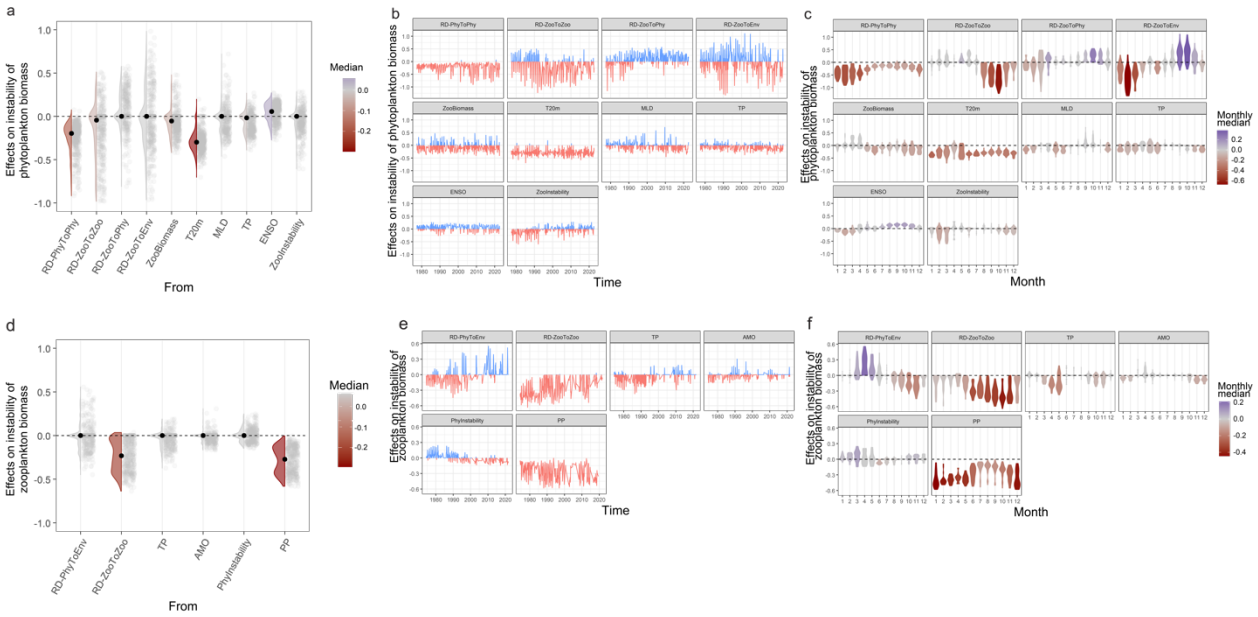
SI Figure 2. Monthly time series and seasonal variation of the effects of increasing the selected variables on phytoplankton instability. Panel **(a)** shows the time series of the effect of each selected variable; red indicates negative, and blue indicates positive effects. Panel **(b)** summarizes the seasonal variation. The violin color indicates the median effect. The target variable is instability, and thus, negative values indicate buffering effects against instability. RD-PhyToAll represents the response diversity of the phytoplankton community to all other plankton genera and environmental variables, and likewise for RD-ZooToAll. For the explanation of other variable names, see SI Figure 1. Analyses based on more detailed levels of response diversity are provided in SI Figure 5.



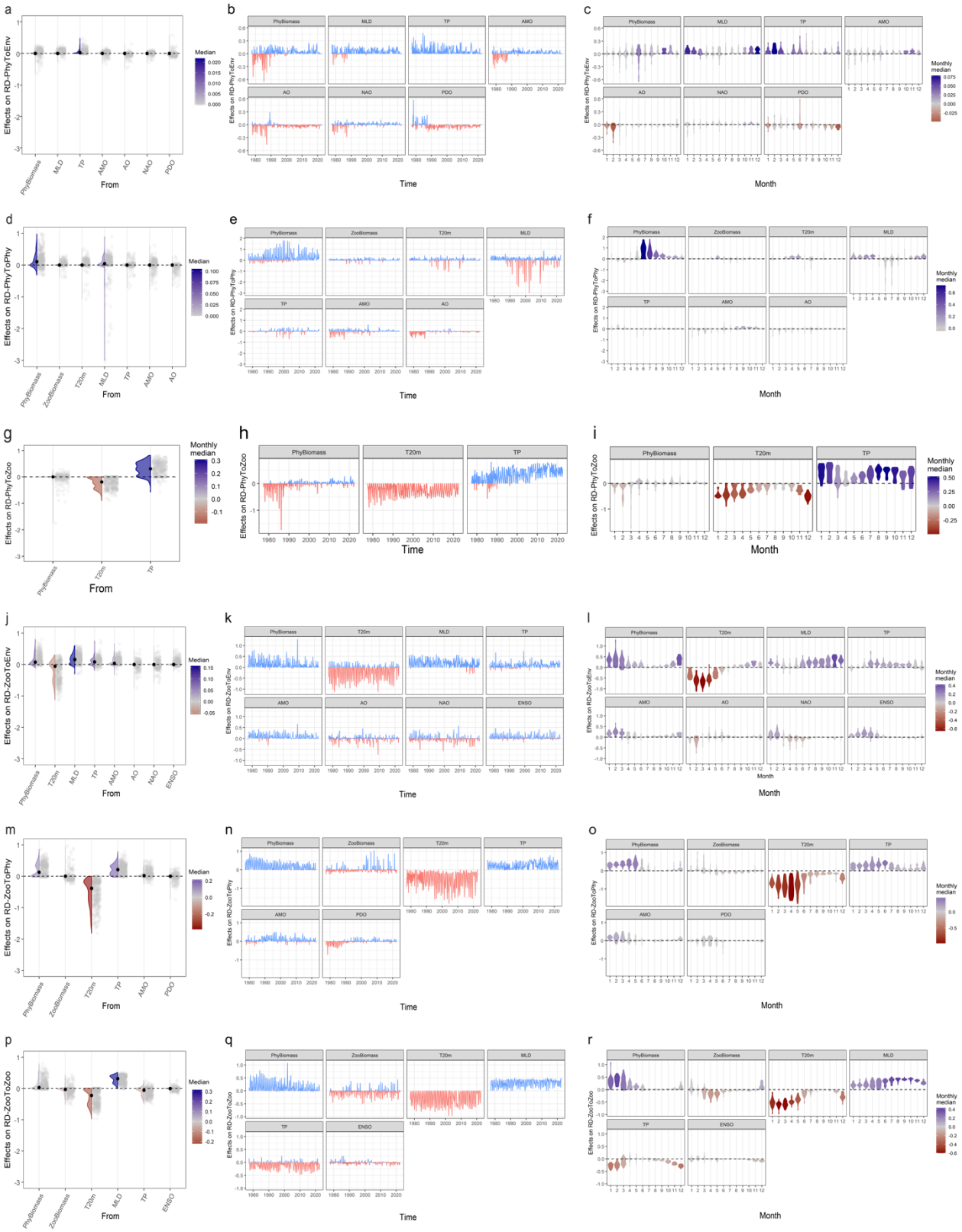
SI Figure 3. Magnitudes of the effects of increasing the selected variables on (a) phytoplankton and (b) zooplankton instability. Here, only the magnitude of the effect is considered, regardless of whether the effect is positive or negative. The violin color indicates the median effect.



SI Figure 4. Monthly time series and seasonal variation of the effects of increasing the selected variables on zooplankton instability. Panel **(a)** shows the time series of the effect of each selected variable; red indicates negative, and blue indicates positive effects. Panel **(b)** summarizes the seasonal variation. The violin color indicates the median effect. The target variable is instability, and thus, negative values indicate buffering effects against instability. RD-ZooToAll represents the response diversity of the zooplankton community to all other plankton genera and environmental variables. For the explanation of other variable names, see SI Figure 1. Analyses based on more detailed levels of response diversity are provided in SI Figure 5.



SI Figure 5. The effects of increasing the selected variables on (a, b, c) phytoplankton and (d, e, f) zooplankton instability with more detailed levels of response diversity indices. The violin plots show how the **(a)** phytoplankton or **(d)** zooplankton total biomass instability was influenced by different categories of response diversity and environmental variables. Panels **(b & e)** show the time series of the effect of each selected variable; red indicates negative, and blue indicates positive effects. Panels **(c & f)** summarize the seasonal variation. The violin color indicates the median effect. The target variable is instability, and thus, negative values indicate buffering effects against instability. For the explanation of variable names, see SI Figure 1.



SI Figure 6. Effects of increasing environmental variables and plankton biomass on different categories of response diversity of the phytoplankton and zooplankton

community. Response diversity was inferred based on how phytoplankton responded to **(a, b, c)** environmental variables, **(d, e, f)** other genera of phytoplankton (i.e., within-trophic level responses), and **(g, h, i)** genera of zooplankton (i.e., cross-trophic level responses); how zooplankton responded to **(j, k, l)** environmental variables, **(m, n, o)** genera of phytoplankton (i.e., cross-trophic level responses), and **(p, q, r)** other genera of zooplankton (i.e., within-trophic level responses). The violin plots summarize the environmental effects on **(a, d, g, j, m, p)** each level of response diversity. Panels **(b, e, h, k, n, q)** show the time series of the effect of each selected variable; red indicates negative, and blue indicates positive effects. Panels **(c, f, i, l, o, r)** summarize the seasonal variation. The violin color indicates the median effect. For the explanation of variable names, see SI Figure 1.

Supplementary Tables

Table S1. Results of the Convergent Cross Mapping (CCM) for identifying the causal variables of the instability of phytoplankton total biomass (PhyInstability) and zooplankton total biomass (ZooInstability), respectively. The table summarizes the CCM skill and p-value (in the bracket) calculated using 100 seasonal surrogates. Bold values indicate significant CCM results (i.e., $p < 0.05$); - indicates that the variable is not included in the analysis for the respective instability index. Only the significant variables were included in the MDR-Smap analysis.

Effect \ Cause	ZooBio--mass	PhyBio--mass	RD-PhyToAll	RD-ZooToAll	RD-PhyToPhy	RD-PhyToZoo	RD-PhyToEnv	RD-ZooToZoo	RD-ZooToPhy	RD-ZooToEnv
PhyInstability	**0.5 (<0.01)***	-	**0.21 (<0.01)***	**0.33 (<0.01)***	**0.14 (0.02)***	0.1 (0.11)	0.04 (0.18)	**0.27 (<0.01)***	**0.26 (<0.01)***	**0.36 (<0.01)***
ZooInstability	-	0.34 (0.1)	0.14 (0.19)	**0.41 (0.03)***	0.08 (0.24)	0.18 (0.37)	**0.22 (<0.01)***	**0.45 (<0.01)***	0.38 (0.15)	0.25 (0.43)

Effect \ Cause	T20m	MLD	TP	AMO	AO	NAO	PDO	ENSO	ZooInst--ability	PhyInst--ability	PP
PhyInstability	**0.62 (<0.01)***	**0.47 (<0.01)***	**0.5 (<0.01)***	0.11 (0.14)	0.05 (0.19)	0.05 (0.17)	**0.11 (0.05)***	**0.11 (0.02)***	**0.69 (<0.01)***	-	-
ZooInstability	0.79 (0.59)	0.36 (0.43)	**0.64 (<0.01)***	**0.22 (0.02)***	0.04 (0.23)	0.02 (0.33)	0.05 (0.17)	0.06 (0.18)	-	**0.47 (<0.01)***	**0.41 (<0.01)***

Table S2. Results of the Convergent Cross Mapping (CCM) for identifying the causal variables of the six categories of response diverisity, respectively. The table summarizes the CCM skill and p-value (in the bracket) calculated using 100 seasonal surrogates. Bold values indicate significant CCM results (i.e., $p < 0.05$); - indicates that the variable is not included in the analysis for the respective instability index. Only the significant variables were included in the MDR-Smap analysis.

Effect \ Cause	ZooBiomass	PhyBiomass	T20m	MLD	TP	AMO	AO	NAO	PDO	ENSO
RD-PhyToPhy	**0.19 (0.02)***	**0.27 (<0.01)***	**0.34 (<0.01)***	**0.35 (<0.01)***	**0.29 (0.01)***	**0.08 (0.04)***	**0.16 (<0.01)***	0.07 (0.08)	0.07 (0.12)	0.06 (0.06)
RD-PhyToZoo	0.24 (0.1)	**0.16 (0.01)***	**0.43 (0.02)***	0.24 (0.07)	**0.31 (0.05)***	0.12 (0.1)	0.08 (0.08)	0.05 (0.17)	0.05 (0.14)	0.02 (0.26)
RD-PhyToEnv	0.1 (0.26)	**0.18 (<0.01)***	0.27 (0.12)	**0.23 (0.02)***	**0.24 (0.02)***	**0.11 (0.04)***	**0.12 (<0.01)***	**0.07 (0.05)***	**0.07 (0.05)***	0.01 (0.47)
RD-ZooToZoo	**0.44 (<0.01)***	**0.29 (<0.01)***	**0.74 (<0.01)***	**0.39 (<0.01)***	**0.52 (<0.01)***	0.15 (0.06)	0 (0.41)	0.01 (0.39)	0.06 (0.09)	**0.19 (<0.01)***
RD-ZooToPhy	**0.32 (<0.01)***	**0.29 (<0.01)***	**0.69 (<0.01)***	0.33 (0.09)	**0.55 (<0.01)***	**0.15 (0.03)***	0.02 (0.31)	0 (0.4)	**0.1 (0.01)***	0.02 (0.26)
RD-ZooToEnv	0.28 (0.24)	**0.38 (<0.01)***	**0.71 (<0.01)***	**0.34 (<0.01)***	**0.52 (<0.01)***	**0.18 (0.01)***	**0.11 (0.01)***	**0.1 (0.02)***	0.04 (0.25)	**0.12 (0.01)***