

Supplementary material to article:

Qualitative model of the causal interactions between phytoplankton, zooplankton, and environmental factors in the Romanian Black Sea.

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Table S1. Sample size for each season and marine reporting unit

Number of collected samples	Marine reporting units			Total
	Variable Salinity	Coastal	Marine	
Spring	55	80	105	240
2008	5	15	15	35
2009	1			1
2010	16	6	14	36
2012	9	20	15	44
2013	9	14	16	39
2014	8	16	20	44
2016	4	2	7	13
2017	3	7	18	28
Summer	43	89	85	217
2008	9	22	6	37
2009	8	2		10
2010		9	2	11
2011	12	20	18	50
2013		9	5	14
2014		5	7	12
2015		1	4	5
2016	2	3	11	16
2017	3	4	16	23
2018	9	14	16	39
Total	98	169	190	457

Table S2. Descriptive statistics of physicochemical parameters and dissolved nutrients in Black Sea waters (2008-2018)

Variable	Valid N	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Std.Dev.
T [°C]	1977	14.41	12.47	0.80	27.80	7.92	21.72	7.28
S [‰]	1973	15.90	16.78	0.11	24.22	14.74	18.13	3.30
O ₂ [μM]	1995	317.63	316.60	69.20	677.00	282.30	352.40	58.60
O ₂ [%]	1733	109.93	106.60	4.10	282.31	95.50	124.50	23.80
PO ₄ [μM]	2001	0.32	0.18	0.00	43.40	0.08	0.31	1.20
SiO ₄ [μM]	1998	11.96	6.20	0.00	395.20	3.10	12.60	22.46
NO ₂ [μM]	1970	0.76	0.23	0.00	50.85	0.11	0.56	2.64
NO ₃ [μM]	1999	4.07	2.21	-1.01	73.38	1.28	4.27	6.21
NH ₄ [μM]	1975	4.85	2.54	0.00	158.78	1.16	5.82	8.81

Table S3. Phytoplankton and zooplankton abundances and biomasses for each marine reporting unit and season

Variable	All Groups, Descriptive Statistics				
	Valid N	Mean	Minimum	Maximum	Std.Dev.
ZPK Total Density [ind/m ³]	457	10743	68.771	194808	18639
ZPK Total Biomass [mg/m ³]	457	419	0.893	10103	801
FPK Total Density [cells/L]	457	1416013	3120	39740000	3391445
FPK Total Biomass [mg/m ³]	457	1109	0.92	12186	1481
Season=Spring, MRU=Variable Salinity					
ZPK Total Density [ind/m ³]	55	5329	68.77	54614	9998
ZPK Total Biomass [mg/m ³]	55	97	0.89	909	159
FPK Total Density [cells/L]	55	3348294	99200	16624220	3621219
FPK Total Biomass [mg/m ³]	55	1340	69.51	7313	1312
Season=Spring, MRU=Coastal					
ZPK Total Density [ind/m ³]	80	7043	245.61	47678	8718
ZPK Total Biomass [mg/m ³]	80	248	3.431	3888	509
FPK Total Density [cells/L]	80	1812332	6720	27242200	4098981
FPK Total Biomass [mg/m ³]	80	1055	0.92	8384	1396
Season=Spring, MRU=Marine					
ZPK Total Density [ind/m ³]	105	4185	324.88	29161	5533
ZPK Total Biomass [mg/m ³]	105	207	4.857	2187	424
FPK Total Density [cells/L]	105	2214675	3120	39740000	5014953
FPK Total Biomass [mg/m ³]	105	1155	5.56	12186	1707
Season=Summer, MRU=Variable Salinity					
ZPK Total Density [ind/m ³]	43	21059.3	545.25	124583	24578
ZPK Total Biomass [mg/m ³]	43	711.5	25.95	3180	870
FPK Total Density [cells/L]	43	939905.1	28400	5336800	1101273
FPK Total Biomass [mg/m ³]	43	2256.2	150.89	9747	2504
Season=Summer, MRU=Coastal					
ZPK Total Density [ind/m ³]	89	22039.1	874.34	194808	31704

ZPK Total Biomass [mg/m ³]	89	816	16.57	10103	1353.2
FPK Total Density [cells/L]	89	304085.8	25460	1614960	328248.3
FPK Total Biomass [mg/m ³]	89	887.8	136.56	3031	593.5
Season=Summer, MRU=Marine					
ZPK Total Density [ind/m ³]	85	8784	132.31	49373	8811.7
ZPK Total Biomass [mg/m ³]	85	484.3	40.153	3037	578
FPK Total Density [cells/L]	85	211230.6	7540	1433200	252807.1
FPK Total Biomass [mg/m ³]	85	603.2	2.35	6609	913.4

Table S4. One-way ANOVA for Biological parameters grouped by MRU (calculated with STATISTICA)

Variable	Analysis of Variance (ANOVA) Marked effects are significant at p < .05000							
	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
ZPK Total Density [ind/m ³]	7.04E+09	2	3.52E+09	1.51E+11	454	3.33E+08	10.56079	0.000033
ZPK Total Biomass [mg/m ³]	4.51E+06	2	2.25E+06	2.88E+08	454	6.34E+05	3.55501	0.029379
FPK Total Density [cells/L]	1.04E+14	2	5.18E+13	5.14E+15	454	1.13E+13	4.5787	0.010747
FPK Total Biomass [mg/m ³]	5.03E+07	2	2.52E+07	9.50E+08	454	2.09E+06	12.02381	0.000008

ZPK Total Density [ind/m³]: The F-statistic is 10.56, and the p-value is 0.000033. Since the p-value is less than 0.05, we reject the null hypothesis. There are significant differences in total density among MRUs.

ZPK Total Biomass [mg/m³]: The F-statistic is 3.56, and the p-value is 0.029379. Again, the p-value is less than 0.05, indicating significant differences in total biomass among MRUs.

FPK Total Density [cells/L]: The F-statistic is 4.58, and the p-value is 0.010747. Once more, the p-value is less than 0.05, suggesting significant differences in total density.

FPK Total Biomass [mg/m³]: The F-statistic is 12.02, and the p-value is 0.000008. The p-value is well below 0.05, indicating significant differences in total biomass.

In summary, the ANOVA results show that the biological parameters (density and biomass for phytoplankton and zooplankton) significantly vary among different MRUs.

Table S5. Corellations between biological and environmental parameters in FCM, waters with variable salinity

[illegible]

Table S6. Corellations between biological and environmental parameters in FCM, coastal waters

[illegible]

Table S7. Corellations between biological and environmental parameters in FCM, marine shelf waters

	Variable	T [°C]	S [‰]	PO ₄ [μM]	SiO ₄ [μM]	NO ₃ [μM]	NO ₂ [μM]	NH ₄ [μM]	Bacillariophyceae (cells/L)	Chlorophyceae (cells/L)	Chrysophyceae (cells/L)	Dinoflagellata incertae sedis (cells/L)	Cryptophyceae (cells/L)	Dictyochophyceae (cells/L)	Dinophyceae (cells/L)	Euglenoidae (cells/L)	Prasinophyceae (cells/L)	Prymnesiophyceae (cells/L)	Trebouxiophyceae (cells/L)	Ulvothyceae (cells/L)	Cladocera (ind/m3)	Meroplankton (ind/m3)	Cyanophyceae (cells/L)	Copepoda (ind/m3)	Ebriophyceae (cells/L)	Chlorodendrophyceae (cells/L)	Conjugatophyceae (cells/L)	Fusulinata (cells/L)	
T [°C]									-0.17		-0.17																		
S [‰]									0.32	0.35		0.19																	
PO ₄ [μM]									0.32	0.2																			
SiO ₄ [μM]																													
NO ₃ [μM]															0.23														
NO ₂ [μM]															0.26										0				
NH ₄ [μM]															0.39											0.24			
Bacillariophyceae (cells/L)															0.4											-0.23			
Chlorophyceae (cells/L)																													
Chrysophyceae (cells/L)																													
Dinoflagellata incertae sedis (cells/L)																													
Cryptophyceae (cells/L)																													
Dictyochophyceae (cells/L)																													
Dinophyceae (cells/L)																													
Euglenoidae (cells/L)																													
Prasinophyceae (cells/L)																													
Prymnesiophyceae (cells/L)																													
Trebouxiophyceae (cells/L)																													
Ulvothyceae (cells/L)																													
Cladocera (ind/m3)																													
Meroplankton (ind/m3)																													
Cyanophyceae (cells/L)																													
Copepoda (ind/m3)																													
Ebriophyceae (cells/L)																													
Chlorodendrophyceae (cells/L)																													
Conjugatophyceae (cells/L)																													
Fusulinata (cells/L)																													
* empty cells = no significant correlations																													

