

Supplementary Materials

Exploring Mesozooplankton Insights by Assessing the Ecological Status of Black Sea Waters Under the Marine Strategy Framework Directive

Table S1. Descriptive statistics of mesozooplankton biomass values (mg/m³), on marine reporting units and warm season from 1960 – 2002.

Warm season								
Transitional Waters	N	Average	Median	Min.	Max.	75th Percentile	90th Percentile	Std. Dev
1960-1969	20	123	128	8.4	280	210	240	99
1977-1980	23	264	84	1.7	1641	291	730	412
1981-1990	35	10488	250	2.0	116010	11712	27243	23117
1991-2002	58	1247	132	0.1	32505	464	1991	4517
Coastal Waters								
1960-1969	266	108	32	0.0	2452	79.0	215.1	294.8
1977-1980	71	96.8	25.2	0.1	1360.9	83.2	144.2	224.6
1981-1990	194	2137.0	60.2	0.0	87743.7	554.8	3169.0	9723.2
1991-2002	100	775.5	115.4	0.0	9492.5	786.4	1961.2	1613.1
Marine waters								
1960-1969	113	37.4	15.2	0.0	316.1	38.8	73.0	62.8
1977-1980	286	70.8	19.7	0.0	2282.3	53.4	142.4	188.3
1981-1990	404	1147.7	50.4	0.0	76391.5	264.6	1420.8	5837.3
1991-2002	225	624.9	38.4	0.0	15177.6	227.3	1263.1	1975.4

Table S2. Descriptive statistics of Copepoda biomass values (mg/m³), on marine reporting units and warm season from 1960 – 2002.

Warm season								
Transitional Waters	N	Average	Median	Min.	Max.	75th Percentile	90th Percentile	Std. Dev
1960-1969	20	58.2	45.6	6.8	243.6	87.0	101.2	56.6
1977-1980	23	142.8	19.1	1.6	1056.1	148.8	379.1	255.3
1981-1990	35	197.5	14.5	0.0	2761.7	120.2	525.9	493.8
1991-2002	58	28.0	5.3	0.0	418.7	18.3	57.3	70.0
Coastal Waters								
1960-1969	266	44.4	11.4	0.0	2452.0	28.7	65.7	205.2
1977-1980	71	39.8	15.1	0.1	691.4	39.8	70.9	92.1
1981-1990	194	83.5	8.5	0.0	1951.0	49.5	142.9	246.5
1991-2002	100	7.6	1.7	0.0	143.4	7.2	17.2	18.5
Marine Waters								
1960-1969	113	20.9	10.8	0.0	232.4	24.8	44.9	32.3
1977-1980	286	30.6	10.0	0.0	1401.9	24.2	51.6	100.9
1981-1990	404	33.6	10.7	0.0	765.7	27.6	68.6	79.0
1991-2002	225	15.4	2.6	0.0	239.5	14.9	44.1	31.7

Table S3. Descriptive statistics of *Noctiluca scintillans* biomass values (mg/m³), on marine reporting units and warm season from 1960 – 2002.

Warm season								
Transitional Waters	N	Average	Median	Min.	Max.	75th Percentile	90th Percentile	Std. Dev
1960-1969	15	438.0	10.6	1.3	257.9	48.8	124.0	72.2
1977-1980	23	52.6	3.1	0.0	538.6	12.0	89.1	143.3
1981-1990	35	10184.8	230.5	0.0	115248.0	11413.8	25294.1	22923.8
1991-2002	58	611.0	11.3	0.0	11370.7	289.5	1881.3	1732.5
Coastal Waters								
1960-1969	66	264.4	39.1	0.0	5687.1	111.4	392.0	908.2
1977-1980	71	595.3	158.6	0.0	4798.1	596.7	2291.3	972.1
1981-1990	194	1953.7	2.0	0.0	87024.0	170.8	2826.6	9603.4
1991-2002	100	534.8	10.8	0.0	9227.7	325.6	1484.1	1362.5
Marine Waters								
1960-1969	37	74.7	12.5	0.4	486.0	105.3	241.4	117.5
1977-1980	286	406.0	21.5	0.0	10193.6	211.4	958.0	1082.7
1981-1990	404	1079.7	8.3	0.0	76016.6	123.9	1328.7	5795.9
1991-2002	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table S4. Threshold values for defining the ecological status according to Copepoda biomass (mg/m³).

MRU	Transitional Waters		Coastal Waters		Marine Waters	
Warm season	GES	Non-GES	GES	Non-GES	GES	Non-GES
	>45	<45	>65	<65	>45	<45

Table S5. Threshold values for defining the ecological status according to Mesozooplankton biomass (mg/m³).

MRU	Transitional Waters		Coastal Waters		Marine Waters	
Warm season	GES	Non-GES	GES	Non-GES	GES	Non-GES
	>240	<240	>210	<210	>70	<70

Table S6. Threshold values for defining the ecological status according to *Noctiluca scintillans* biomass (mg/m³).

MRU	Transitional Waters		Coastal Waters		Marine Waters	
Warm season	Ges	Non-Ges	Ges	Non-Ges	Ges	Non-Ges
	<240	>240	<350	>350	<240	>240

Table S7. Descriptive statistics of environmental parameters in the warm season of 2013–2020.

Transitional waters								
Variable	Valid N	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Std.Dev.
T[°C]	51	20.89	21.39	14.90	25.13	18.29	23.18	3.05
S [‰]	51	10.71	11.25	0.19	18.50	6.62	15.15	5.25
O ₂ [μM]	51	332.54	313.96	252.78	495.60	289.40	372.90	56.08
O ₂ [%]	43	125.67	124.90	88.80	175.50	111.70	136.48	20.02
PO ₄ [μM]	51	0.59	0.47	0.01	3.04	0.18	0.82	0.56
SiO ₄ [μM]	51	24.27	16.30	1.20	95.76	7.07	31.58	23.78
NO ₂ [μM]	51	2.97	0.88	0.03	50.85	0.23	1.32	7.89
NO ₃ [μM]	51	8.66	5.59	0.07	52.00	2.52	12.30	9.10
NH ₄ [μM]	51	7.80	5.76	0.14	38.09	0.92	12.86	8.46
Coastal waters								
T[°C]	112	21.70	22.85	16.10	26.50	18.92	23.95	2.91
S [‰]	112	14.52	15.20	2.71	19.07	12.81	17.06	3.21
O ₂ [μM]	115	312.02	305.47	214.37	449.50	275.55	343.10	48.39
O ₂ [%]	97	122.47	121.22	76.68	192.50	111.71	130.50	16.69
PO ₄ [μM]	115	0.35	0.26	0.01	2.28	0.11	0.42	0.37
SiO ₄ [μM]	115	6.10	4.82	0.83	27.40	2.78	7.98	4.68
NO ₂ [μM]	115	2.65	0.62	0.01	42.26	0.12	1.41	6.06
NO ₃ [μM]	115	5.68	2.54	0.01	69.23	1.39	6.46	9.09
NH ₄ [μM]	115	8.29	5.94	0.12	38.45	1.20	13.18	7.76
Marine waters								
T[°C]	126	22.52	23.46	15.28	27.12	20.00	24.75	2.89
S [‰]	126	15.36	16.03	0.11	19.91	14.23	17.75	3.21
O ₂ [μM]	127	310.79	299.67	119.24	451.51	266.62	350.50	55.71
O ₂ [%]	106	124.59	123.67	45.25	173.50	111.21	136.58	18.96
PO ₄ [μM]	127	0.24	0.15	0.01	1.08	0.07	0.35	0.21
SiO ₄ [μM]	127	5.78	3.23	0.05	45.02	1.96	6.01	6.97
NO ₂ [μM]	127	1.65	0.30	0.02	27.96	0.12	1.12	3.99

NO ₃ [μM]	127	4.40	2.19	0.30	56.27	1.21	4.26	6.82
NH ₄ [μM]	127	8.67	6.39	0.34	53.62	2.99	11.41	8.12

Table S8. List of identified mesozooplankton taxa in the Black Sea, warm season of 2013–2020.

No.	Taxa	Aphia id	Transitional waters	MRU	
				Coastal waters	Marine waters
Dinophyceae (Class)					
1	<i>Noctiluca scintillans</i> (Macart.) Kof. & Swezy, 1921*	109921	+	+	+
CRUSTACEA (Arthropoda)					
Branchiopoda (Class)					
Cladocera (infraorder)					
2	<i>Bosmina (Bosmina)</i> <i>longirostris</i> O. F. Müller, 1785*	148379	+	+	
3	<i>Chydorus sphaericus</i> O.F. Müller, 1785*	148406	+		+
4	<i>Daphnia longispina</i> O.F. Müller, 1785*	148373	+		
5	<i>Diaphanosoma brachyurum</i> Liévin, 1848*	234063			+
6	<i>Evadne spinifera</i> O.F. Müller, 1867*	106274	+	+	+
7	<i>Penilia avirostris</i> Dana, 1849*	106272	+	+	+
8	<i>Pleopis polyphemoides</i> Leucart, 1859*	247981	+	+	+
9	<i>Podon sp.</i> Lilljeborg, 1853*	10629		+	
10	<i>Pseudevadne tergestina</i> Claus, 1877*	106278	+	+	+
Copepoda					
Calanoida					
11	<i>Acartia (Acartiura) clausi</i> Giesbrecht, 1889*	149755	+	+	+
12	<i>Calanus euxinus</i> Hulsemann, 1991*	104463	+	+	+
13	<i>Centropages ponticus</i> Karavaev, 1895*	104498	+	+	+
14	<i>Paracalanus parvus</i> Claus, 1863*	104685	+	+	+
15	<i>Pseudocalanus elongatus</i> Boeck, 1872*	104515	+	+	+
16	<i>Harpacticoida</i> Sars G.O., 1903*	1102	+	+	+
Cyclopoida					

No.	Taxa	Aphia id	Transitional waters	MRU	
				Coastal waters	Marine waters
17	<i>Oithona similis</i> Claus, 1863*	106656	+	+	+
18	<i>Oithona davisae</i> Ferrari F.D. & Orsi, 1984*	353995	+	+	+
19	<i>Cyclops</i> sp. Müller O.F., 1785*	149782	+	+	+
Monstrilloida					
20	CIRRIPIEDIA (larvae: nauplii, cypris)- <i>Balanus</i> **	1082	+	+	+
MALACOSTRACA					
21	Decapoda (larvae: zoea, mysis)**	1130	+	+	+
MYSIDACEA					
22	<i>Mesopodopsis slabberi</i> van Beneden, 1861*	120072	+		+
23	GASTROPODA **	101	+	+	+
24	BIVALVIA (veliger larvae)**	105	+	+	+
25	POLYCHAETA **	883	+	+	+
CHAETOGNATHA *					
26	<i>Parasagitta setosa</i> Müller, 1847*	105443	+	+	+
APPENDICULARIA					
27	<i>Oikopleura (Vexillaria) dioica</i> Fol, 1872*	103407	+	+	+

* holoplankton, ** meroplankton.

Table S9. Descriptive statistics of mesozooplankton biomass in the warm season of 2013–2020.

Variable	Transitional waters							Std. Dev.
	Valid N	Mean	Median	Min.	Max.	Lower Quartile	Upper Quartile	
<i>Noctiluca scintillans</i> (mg/m ³)	51	635.21	58.22	0.00	13357.39	5.19	271.00	1978.96
Copepoda (mg/m ³)	51	86.20	30.50	0.76	599.17	11.78	98.87	126.52
Cladocera (mg/m ³)	51	40.08	3.54	0.00	633.18	0.35	20.02	111.83
Meroplankton (mg/m ³)	51	153.90	32.44	0.00	1743.10	5.47	175.93	300.72
Other groups (mg/m ³)	51	65.22	1.57	0.00	1177.75	0.35	16.11	184.06
Mesozooplankton (mg/m ³)	51	345.39	150.21	0.89	2976.53	48.16	381.59	552.69
Coastal waters								
<i>Noctiluca scintillans</i> (mg/m ³)	115	763.10	265.14	0.00	7067.67	18.77	793.70	1235.77
Copepoda (mg/m ³)	115	84.67	31.44	0.98	821.34	8.21	96.74	146.49
Cladocera (mg/m ³)	115	47.66	10.61	0.09	814.63	4.04	30.77	123.53
Meroplankton (mg/m ³)	115	100.24	36.94	0.34	729.74	13.01	99.61	146.48
Other groups (mg/m ³)	115	105.61	11.31	0.00	1592.04	0.54	121.11	230.59
Mesozooplankton (mg/m ³)	115	338.19	170.80	4.81	3034.93	57.05	447.62	467.08

	Marine waters							
<i>Noctiluca scintillans</i> (mg/m ³)	127	448.90	144.53	0.00	3489.57	37.90	433.45	759.78
Copepoda (mg/m ³)	127	56.22	37.15	4.90	586.05	17.99	64.03	73.51
Cladocera (mg/m ³)	127	16.26	2.36	0.00	311.93	0.33	10.16	38.84
Meroplankton (mg/m ³)	127	11.12	1.29	0.00	234.82	0.32	6.44	32.29
Other groups (mg/m ³)	127	60.32	19.22	0.00	848.24	2.44	64.13	110.79
Mesozooplankton (mg/m ³)	127	143.91	78.03	7.04	1566.42	32.87	184.05	210.29

Table S10. Statistically significant correlation ($p < 0.05$) between the mesozooplankton groups and environmental factors, warm season of 2013–2020.

MRU=Transitional									
Marked correlations are significant at $p < .05000$									
N=43 (Casewise deletion of missing data)									
Variable	T[°C]	S[‰]	O ₂ [μM]	O ₂ [%]	PO ₄ [μM]	SiO ₄ [μM]	NO ₂ [μM]	NO ₃ [μM]	NH ₄ [μM]
<i>Noctiluca scintillans</i> (mg/m ³)	0.16	0.10	-0.19	-0.12	-0.08	0.03	-0.01	-0.07	-0.03
Copepoda (mg/m ³)	0.18	-0.05	-0.07	0.00	-0.06	-0.14	-0.12	-0.21	0.21
Cladocera (mg/m ³)	0.10	0.09	-0.06	0.01	-0.14	-0.21	-0.06	-0.18	0.22
Meroplankton (mg/m ³)	-0.31	0.04	0.23	0.11	-0.11	-0.06	0.06	0.24	0.15
Other groups (mg/m ³)	0.40	0.37	-0.24	-0.05	-0.27	-0.29	-0.11	-0.23	-0.22
Mesozooplankton (mg/m ³)	0.03	0.14	0.04	0.06	-0.22	-0.24	-0.08	-0.05	0.17
MRU=Coastal									
Marked correlations are significant at $p < .05000$									
N=97 (Casewise deletion of missing data)									
Variable	T[°C]	S[‰]	O ₂ [μM]	O ₂ [%]	PO ₄ [μM]	SiO ₄ [μM]	NO ₂ [μM]	NO ₃ [μM]	NH ₄ [μM]
<i>Noctiluca scintillans</i> (mg/m ³)	-0.01	-0.04	0.09	0.11	0.13	-0.24	0.02	-0.09	0.09
Copepoda (mg/m ³)	0.27	0.21	-0.28	-0.18	0.10	0.16	-0.06	0.68	-0.19
Cladocera (mg/m ³)	0.38	0.03	-0.26	-0.14	-0.10	-0.02	0.19	0.16	-0.22
Meroplankton (mg/m ³)	0.15	-0.29	0.08	0.12	-0.04	0.00	-0.02	0.03	-0.03
Other groups (mg/m ³)	0.40	0.37	-0.43	-0.27	-0.04	0.02	0.12	0.39	-0.28
Mesozooplankton (mg/m ³)	0.41	0.13	-0.31	-0.16	-0.01	0.07	0.05	0.50	-0.25
MRU=Marine									
Marked correlations are significant at $p < .05000$									
N=106 (Casewise deletion of missing data)									
Variable	T[°C]	S[‰]	O ₂ [μM]	O ₂ [%]	PO ₄ [μM]	SiO ₄ [μM]	NO ₂ [μM]	NO ₃ [μM]	NH ₄ [μM]
<i>Noctiluca scintillans</i> (mg/m ³)	0.09	-0.11	0.27	0.37	-0.12	-0.08	0.09	-0.05	0.02
Copepoda (mg/m ³)	0.05	0.07	-0.16	-0.16	-0.06	0.01	-0.05	-0.08	-0.06
Cladocera (mg/m ³)	0.38	0.18	-0.29	-0.19	-0.18	-0.22	-0.05	-0.14	-0.08
Meroplankton (mg/m ³)	-0.15	-0.20	0.16	0.09	0.23	0.21	0.01	0.35	0.14
Other groups (mg/m ³)	0.31	0.17	-0.33	-0.27	-0.21	-0.15	-0.03	-0.05	-0.12
Mesozooplankton (mg/m ³)	0.20	0.10	-0.24	-0.22	-0.11	-0.05	-0.04	-0.01	-0.07