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INVESTIGATIONS OF INTERCONNECTIONS OF PHYSICAL-CHEMICAL AND PHYTOPLANKTON CHARACTERISTICS IN THE NORTH-WESTERN PART OF THE BLACK SEA (ZMIINYI ISLAND AREA)

The aim of paper is estimation of interconnections of the Danube River runoff, physical-chemical and phytoplankton characteristics in the north-western part of the Black Sea on the example of the Zmiinyi Island coastal waters. Material for analysis comprised results of hydrological and hydrochemical characteristics of marine environment, photosynthetic pigments concentration and phytoplankton species composition, which have been measured every decade in one point of coastal waters of Zmiinyi island. The results of statistical analysis of the data for 2004-2014 on the coastal waters of the Zmiinyi Island located in the north-western Black Sea 40 km far from the Danube Delta have been considered and analysed in the article. It has been shown that the state of phytoplankton community characteristics is mostly influenced by salinity, transparency and nitrate content, whose levels are formed under the influence of the Danube water runoff. Analysis of phytoplankton community characteristics depending on three types of water masses has shown that the highest values of biomass and abundance, both in general for phytoplankton and for its separate taxonomic groups have been registered in water masses having salinity from 10 to 14‰ formed under the Danube runoff influence.

Keywords: Black Sea, coastal water, Zmiinyi island, Danube runoff, phytoplankton, salinity, nutrients, MSFD, TRIX index, Chlorophylls

INTRODUCTION

The Black Sea is vulnerable to pressure of land-based pollution from its catchment area where 23 countries are located that causes degradation of the sea's aquatic ecosystem through eutrophication. As was shown in [3, 11], the EU Marine Strategy Framework Directive (MSFD) [4] aims at achieving or maintaining a Good Environmental Status (GES) by 2020 in the territorial waters of the EU Member States. GES is defined in Art. 3(5) of the MSFD [2] and it must be determined on the basis

of the qualitative descriptors in Annex I. Pursuant to Art.9(3) of the MSFD, the Commission adopted on 1 September 2010 a "Decision on criteria and methodological standards on good environmental status of marine waters" [2], which is largely structured on the basis of the list of descriptors of MSFD.

Eutrophication of the Black Sea and the rivers has harmful environmental, socio-economic and human health impacts, causing the death of animals and fish, degrading waters used for both drinking and irrigation, impacting recreation among others. Annual economic losses for the Black Sea from environmental problems were estimated to be approximately 500 million USD in only the fishery and tourism industries [1].

Results of previous studies of the coastal waters ecosystem adjacent to the Zmiinyi Island in the Black Sea [6-9] have also shown that the main factor influencing the North-Western Black Sea (NWBS) water quality is eutrophication caused by nutrients input from coastal and land-based sources, reaching the sea mainly through river inrunoff and atmospheric transport. The Marine Research Station "Zmiinyi Island" of the Odessa National I.I. Mechnikov University (MRS of ONU), active since 2003, is carrying out a set of hydrological, hydrochemical, hydrobiological and other observations, that is enabling us to use the TRIX trophic index [12], which integrally considers four parameters (Chlorophyll ***a***, Total Phosphorous and Nitrogen, Dissolved Oxygen) to determine sea water quality for living organisms [14].

The objective of paper is estimation of interconnections between the Danube River runoff, physicochemical and phytoplankton characteristics in the North-Western part of the Black Sea on the example of the Zmiinyi Island coastal waters.

MATERIALS AND METHODS

The results of observations of the " Zmiinyi Island" MRS of ONU, situated in the north-western part of the Black Sea (NWBS) about 35-40 km far from the Danube Delta (45°15'22.0" N and 30°12'03.8" E), on hydrological and hydrochemical characteristics of marine environment (pH, oxygen, salinity, temperature, transparency), nutrients (total and mineral phosphorus, nitrite, nitrate, ammonium and total nitrogen), photosynthetic pigments concentration (chlorophylls ***a***, ***b*** and ***c***, Pheophytin, Margalef's index) and phytoplankton species composition, abundance and biomass, which measured every 10-days from May to December during 2004-2014 in the station ZPR on 2 horizons (0 and 8 m) [12, p. 71, fig. 2.19], have been the sources data for this study. Additionally were used the data on monthly averaged values of Danube River runoff through the Kiliya Arm, which is regularly measured by the Danube Hydrometeorological Observatory. Determination of chlorophylls ***a, b, c*** concentrations were done using standard spectrometric method [13] Salinity, oxygen, pH and nutrients were determined using routine methods [5]. Trophic index (TRIX) was calculated according to the equation [14] in order to determine the trophic level of coastal waters adjacent to the Zmiinyi Island, which characterized the trophicity of marine environment: low trophic level (TRIX <4), medium (TRIX=4-5), high –

(TRIX=5-6) and very high (TRIX >6) that corresponded to the categories of water trophicity: oligotrophic, mesotrophic, eutrophic and hypertrophic. Water samples for phytoplankton determination were sampled and processed using methods described in [12].

Standard statistical approaches including correlation analysis ($p < 0.05$) have been applied to find interrelationships between studied constituents. Significance tests for comparison of the average values using Student t-test (normal distribution) have been calculated. All the analyses have been carried out with STATISTICA (version 6.1 for Windows, StatSoft, Inc., 1984 – 2004).

RESULTS AND DISCUSSION

Detailed analysis of results of salinity studies in the Zmiinyi Island coastal waters in 2004-2014 has shown that all the data from the measured series within the limits 10.0-19.2 ‰ can be divided into three groups connected with three types of water masses: 1 (10.0-14.0 ‰) – water masses formed under the influence of the Danube runoff, 2 (14.1-17 ‰) – typical well mixed water masses from the NWBS and 3 (>17 ‰) – masses from open waters of the Black Sea. Analysis of mean values of all the studied characteristics in the Zmiinyi Island coastal waters, which we calculated for the above mentioned three types of water masses (table 1) has shown significant differences in the studied characteristics.

At that, big differences were registered for characteristics of phytoplankton and nutrients depending on the level of salinity. Analysis of characteristics depending on three types of water masses has shown that increase of the river water runoff brings down water salinity significantly (2-fold) and increases the content of total, nitric and ammonium nitrogen in marine water and total N and B of phytoplankton near the island respectively 2.2, 4.7, 9.5 and 6 times. It has been shown that pollution with nutrients entering the sea with river water runoff entails more than 4-fold increase in chlorophyll ***a*** concentration.

Analysis of changes in chlorophylls concentrations depending on the Danube River water runoff has shown that concentrations of chlorophylls *a*, *в* and *c* under low salinity (Type 1) were respectively 4.2; 3.4 and 1.2 times higher than in marine water (Type 3). The most significant changes in concentration were observed for chlorophyll *a*, while chlorophyll *c* content in waters of any salinity stayed practically the same. We have already shown that concentrations of chlorophylls in different types of water were changing similarly to the concentrations of nitrogen compounds, the values of which reached maximum in water with the lowest salinity (Type 1). So, we may conclude that pollution with the nutrients entering the sea with the Danube water entails more than 4-fold increase of chlorophyll *a* concentration in marine coastal waters of the Zmiinyi Island.

Analysis of nitrogen compounds content oscillations in the Zmiinyi Island coastal waters depending on the influence of different types of marine waters and transformed river waters has shown the existence of close correlative relationships

between salinity and concentrations of nitric, ammonium and total nitrogen. Phosphate content was practically the same for all types of water (7.9-8.3 mkgP/dm^3) and total phosphorus content grew with increase of salinity from 17.7 to 20.7 mkgP/dm^3, which might evidence that the main body of phosphorus compounds was coming with marine waters and not with river ones.

Table 1

Mean values of surface water parameters near the Zmiinyi Island coast for 3 types of water masses: 1 (10.0-14.0 ‰), 2 (14.1-17 ‰) and 3 (>17 ‰)

Parameter/Type of waters	1	2	3	Total
Number of samples	114	357	167	638
Salinity, ‰	12.9±0.1	15.7±0.1	17.7±0.1	15.7±0.1
Temperature, °C	19.9±0.5	19.6±0.3	16.4±0.4	18.8±0.2
Transparency, m	3.1±0.2	5.5±0.1	7.0±0.2	5.4±2.4
pH	8.4±0.02	8.4±0.01	8.3±0.02	8.34±0.01
Oxygen, µg/L	8.9±0.14	8.2±0.07	8.4±0.06	8.4±0.05
Oxygen, %	105.7±1.2	97.6±0.6	93.8±0.6	98.0±0.5
Ptotal, µgP/L	21.3±1.4	22.4±1.77	23.8±2.2	22.6±1.2
Pmin, µgP/L	10.4±0.9	9.9±1.3	12.2±1.33	10.6±0.81
Ntotal, µgN/L	853.1±84.3	544.7±18.3	496.6±24.9	584.0±19.3
NNO_3, µgN/L	114.7±14.8	44.6±5.0	22.1±2.6	50.1±4.0
NNH_4, mkgN/L	104.0±18.5	55.4±6.6	26.2±3.6	52.9±4.7
Chlorophyll ***a***, µg/L	3.3±0.4	1.3±0.1	0.8±0.1	1.6±0.1
Chlorophyll ***b***, µg/L	1.5 ±0.2	0.7±0.1	0.5±0.04	0.8±0.05
Chlorophyll ***c***, µg/L	1.0±0.1	0.7±0.04	0.7±0.07	0.7±0.03
Pheophytin ***a***, µg/L	3,3±0.4	1.1±0.1	0,6±0.1	1.4±0.1
MPDI	3.1±0.05	3,2±0.03	3,3±0.05	3.2±0.03
TRIX	5.6±0.07	5.1±0.04	5.0±0.06	5.1±0.03

Note: MPDI – Margalef's pigment diversity index

Analysis of distribution of the main characteristics of phytoplankton (abundance, biomass and species number) for the 12 taxa of microalgae and Cyanobacteria in the period 2004-2014 has shown the following (table 2).

Table 2

Average values of abundance (N, cells·10^6·m^{-3}) and biomass (B, mg·m^{-3}) of the main taxa of phytoplankton registered in water masses of types: 1 (10.0-14.0 ‰), 2 (14.1-17 ‰) and 3 (>17 ‰)

Taxa	Parameter	Type 1	Type 2	Type 3	Total
Total	Average N	11929±1801	3614±351	1969±365	4667±410
	Average B	6942±836	4172±325	1565±226	3988±253
1	Average N	6264±686	2181±349	954±140	2539±239
	Average B	4488±765	2602±283	749±134	2409±213
2	Average N	568±119	254±34	132±45	273±31
	Average B	1255±227	1214±168	763±167	1095±111
3	Average N	360±98	268±109	188±113	285±69
	Average B	57±26	22±11	12±5	31±10
4	Average N	12629±5451	736±213	2984±2018	4315±1547
	Average B	40±17	27±12	72±57	39±13
5	Average N	584±160	634±65	462±71	590±50
	Average B	47±8	64±6	50±7	58±5
6	Average N	667±468	41±20	6±2	202±127
	Average B	524±368	40±21	8±3	163±100
7	Average N	38±23	51±48	3±1	20±16
	Average B	2±0.1	23±8	15±6	17±5
8	Average N	750±386	211±51	124±17	222±49
	Average B	77±65	16±6	7±2	18±7
9	Average N	680±102	422±62	393±98	461±47
	Average B	29±6	12±1	6±1	14±1
10	Average N	0	457±146	55±9.7	256±92
	Average B	0	9±3	1±0.1	5±2
11	Average N	1±0.1	6±3	3±2	4±1
	Average B	8±2	51±28	28±16	39±15
12	Average N	162±35	165±66	159±74	163±41
	Average B	113±75	46±26	50±24	64±25

Note: 1 – Bacillariophyta, 2 – Dinophyta, 3 – Chlorophyta, 4 – Cyanobacteria, 5 – Haptophyta, 6 – Euglenophyceae, 7 – Heterokontophyta, 8 – Chrysophyceae, 9 – Cryptophyceae, 10 -Choanoflagellatea, 11 – Ebriodyophyceae, 12 – Ochrophyta.

Maximal biomass of phytoplankton was observed in the desalinated water (14.1-17.0 ‰) and it was 5 times higher than the maximal values for marine waters (>17 ‰). Species belonging to Bacillariophyta taxon were the main dominant group.

Average biomass value of Dinophyta taxon was lower than that of Bacillariophyta and average number of species was approximately the same. The cells of Chlorophyta and Cyanobacteria taxa are small and do not create big biomass. Using average monthly values for the period of studies (2004-2014) an analysis of distribution of total phytoplankton biomass and the main taxa in water masses having different salinity has been performed.

The results of analysis of this data have shown that the average value of total microalgae abundance and biomass in desalinated water (Type 1) exceeded significantly the average abundance and biomass in marine water (Type 3) due to the community's specific species composition. Bacillariophyta developed similarly intensively in water of both Type 1 and Type 2, which evidenced the capability of the majority of those species to withstand salinity oscillations.

Every year in spring and autumn the marine Bacillariophyta species reached the level of 'blooming' due to nutrients inrunoff into the coastal waters of the island with river water, while freshwater Bacillariophyta were registered only in the moments of river water impact. Minimal biomass of Bacillariophyta was registered in water of Type 3 (the highest salinity).

The values of Chlorophyta biomass were the highest in the desalinated water of Type 1, while maximal Chlorophyta abundance value was registered in water of Type 2. Changes in Dinophyta practically do not depend on the content of phosphate and nitrate dissolved in water, as most of the species are not the real autotrophs and refer to heterotrophic organisms. The maximal values of Dinophyta characteristics (abundance, biomass and number of species) have also been observed under marine and river waters mixing. At that, maximal biomass of Cyanobacteria was observed in marine water (Type 3) while maximal Cyanobacteria abundance value was registered in water of Type 1. In July-August, 2010 an extreme 'bloom' of Cyanobacteria *Nodularia spumigena* Mertens et Born. was registered, which spread from Odessa and deteriorated water quality near the Zmiinyi Island [8]. Every year in spring and autumn the marine Bacillariophyta species reached the level of 'blooming' due to nutrients inrunoff into the coastal waters of the island with river water. Freshwater species Chlorophyta, Chrysophyceae, Euglenophyceae and Desmidiaceae (*Closterium lineatum* Ehr. et Ralfs) were registered only in the periods of the Danube water runoff impact.

Cross-correlation analysis of physicochemical and hydrobiological data shows (table 3) that maximal correlation coefficients were registered between salinity and transparency (r=0.61), ammonium-ion (r=-0.65) and the Danube runoff (r=-0.49), as well as between transparency and ammonium-ion content (r=−0.53), Chl ***a*** (r=−0.50), Chl ***b*** (r=−0.48), Ph ***a*** (r=−0.51), TRIX (r=−0.47), the Danube runoff (r=−0.42), N_{phyto} (−0.43) and B_{phyto} (−0.41). The statistical interrelations between the Danube water runoff and other characteristics should be especially underlined. High

Table 3

Cross-Correlation Coefficients of characteristics in the Zmiinyi Island coastal waters- in 2004-2014

Parameter	Salinity,	D, m	T	PO_4	P_{total}	NO_3	NH_4	N_{total}	Chl *a*	Chl *b*	Chl *c*	Ph *a*	MPDI	TRIX	Danube runoff	N Phyto	B Phyto
Salinity	1	**0.61**	−0.15	−0.04	0.04	**−0.34**	**−0.65**	**−0.38**	**−0.40**	**−0.41**	−0.11	**−0.43**	0.20	**−0.32**	**−0,49**	**−0.37**	**−0.31**
D, m	**0.61**	1	-0,17	-0,08	0.04	**−0.31**	**−0.53**	**−0.25**	**−0.50**	**−0.48**	**−0.26**	**−0.51**	**0.33**	**−0.47**	**−0.42**	**−0.43**	**-0,41**
T,	−0.15	-0.17	1	0.03	0.05	−0.15	**0.36**	−0.08	−0.02	−0.01	0.04	0.00	**0.27**	−0.23	−0.08	0.01	**−0.30**
PO_4	−0.04	-0.08	0.03	1	**0.65**	0.013	0.09	0.03	0.08	0.10	0.19	0.07	−0.06	**0.26**	−0.15	−0.02	0.05
P_{total}	0.04	0.04	0.05	**0.65**	1	0.13	0.09	−0.01	0.01	0.01	0.08	0.0	−0.02	**0.28**	−0.13	−0.02	0.06
NO_3	**−0.34**	**−0.31**	−0.15	0.013	0.13	1	0.03	**0.25**	**0.30**	**0.31**	−0.01	**0.29**	**0.24**	**0.32**	**0.51**	0.19	0.07
NH_4	**−0.65**	**−0.53**	**0.36**	0.09	0.09	0.03	1	**0.39**	**0.32**	**0.37**	**0.48**	**0.35**	0.21	0.24	0.18	0.17	−0.02
N_{total}	**−0.38**	**−0.25**	−0.08	0.03	−0.01	**0.25**	**0.39**	1	0.08	0.09	−0.01	0.08	−0.13	**0.43**	0.17	0.07	0.10
Chl ***a***	**−0.40**	**−0.50**	−0.02	0.08	0.01	**0.30**	**0.32**	0.08	1	**0.96**	**0.33**	**0.92**	**−0.40**	**0.51**	**0.28**	**0.28**	**0.55**
Chl ***b***	**−0.41**	**−0.48**	−0.01	0.10	0.01	**0.31**	**0.37**	0.09	**0.96**	1	**0.37**	**0.90**	**−0.39**	**0.50**	**0.25**	**0.29**	**0.55**
Chl ***c***	−0.11	**−0.26**	0.04	0.19	0.08	−0.01	**0.48**	−0.01	**0.33**	**0.37**	1	**0.23**	−0.18	**0.36**	0.01	0.23	**0.44**
Ph ***a***	**−0.43**	**−0.51**	0.00	0.07	0.0	**0.29**	**0.35**	0.08	**0.92**	**0.90**	**0.23**	1	**0.37**	**0.49**	**0.26**	**0.33**	**0.48**
MPDI	0.20	**0.33**	**0.27**	−0.06	−0.02	**0.24**	0.21	−0.13	**−0.40**	**−0.39**	−0.18	**0.37**	1	**−0.52**	−0.12	−0.09	**−0.28**
TRIX	**−0.32**	**−0.47**	−0.23	**0.26**	**0.28**	**0.32**	0.24	**0.43**	**0.51**	**0.50**	**0.36**	**0.49**	**−0.52**	1	0.04	**0.26**	**0.46**
Danube runoff	**−0,49**	**−0.42**	−0.08	−0.15	−0.13	**0.51**	0.18	0.17	**0.28**	**0.25**	0.01	**0.26**	−0.12	0.04	1	0.13	0.02
N Phyto	**−0.37**	**−0.43**	0.01	−0.02	−0.02	0.19	0.17	0.07	**0.28**	**0.29**	0.23	**0.33**	−0.09	**0.26**	0.13	1	**0.28**
B Phyto	**−0.31**	**−0.41**	**−0.30**	0.05	0.06	0.07	−0.02	0.10	**0.55**	**0.55**	**0.44**	**0.48**	**−0.28**	**0.46**	0.02	**0.28**	**1**
NSC	**11**	**13**	**3**	**2**	**2**	**9**	**8**	**5**	**12**	**12**	**7**	**12**	**8**	**13**	**6**	**7**	**10**
Rank	**3**	**1**	**10**	**11**	**11**	**5**	**6**	**9**	**2**	**2**	**7**	**2**	**6**	**1**	**8**	**7**	**4**

Note: bold – $p<0.01$; NSC-The number of significant correlations.

values of correlation coefficients were registered with transparency (r=−0.43), salinity (r=−0.49) and nitrate content (r=0.51). These interconnections show an important role of the Danube water runoff in the forming of photosynthesis processes, as well as salinity and nutrient regime in the marine area adjacent to the Danube Delta.

Close correlation was registered also for the TRIX and such parameters as salinity (r=−0.32), transparency (D) (r=−0.47), concentration of total nitrogen (N_{total}) (r=0.43) and phosphorus (P_{total}) (r=0.28), chlorophyll ***a*** (r=0.52), b (r=−0.50), pheophytin a (r=0.49), MBDI (R=0.52) and B_{phyto} (r=0.46) that enables us to link the cases of water quality deterioration near the Zmiinyi Island coasts only with the impact of the Danube waters, which come up to the island as the result of advective surface transport.

All the coefficients of correlation for nitrogen compounds and salinity, transparency and temperature are negative, which shows that concentrations of nitrogen compounds grow with decrease of salinity. At that, the correlation coefficients between concentrations of all the nitrogen compounds and chlorophylls are positive, which evidences the predominant role of nutrient nitrogen compounds in phytoplankton functioning. Correlation analysis of phosphorus concentration changes depending on salinity (as an indicator of transformed river water spreading in the sea) revealed no reliable associations. Correlation coefficients of phosphate and total phosphorus with salinity were very low making -0.04 and 0.04. This way we arrived at grounded conclusion that river water runoff did not influence concentration of phosphorus compounds in the sea near the Zmiinyi Island.

Analysis of statistical relationships between water runoff of the Danube through the Kiliya Arm with physicochemical characteristics of coastal waters in the Zmiinyi Island area in 2004-2014 has shown a significant negative correlation (r=−0.49). between average monthly runoff values and marine surface water salinity near the island It has been shown that under maximal values of river water runoff the salinity of marine waters went down to 13 ‰, while under minimal runoff values it stayed within the range 15.3-17.4 ‰. Analysis of interrelations between the Danube water runoff and nutrients content in the Zmiinyi Island coastal waters has revealed a close correlation (r=0.51) between the runoff value and nitric nitrogen content in the marine surface water. However, practically no correlation has been revealed for other nitrogen compounds. Analysis of interrelations with phosphorus compounds has revealed very weak negative correlation, i.e. phosphorus concentration went down with the increase of the river water runoff values. Close correlation was found between river runoff value and water transparency (r=−0.41, p>0.001), which demonstrated the reduction of transparency with the increase of runoff. This evidences the fact that the Danube water carries a lot of suspended matter into the sea. To assess the impact of nitrogen and phosphorus compounds concentrations on phytoplankton community of the Zmiinyi Island coastal waters we have carried out analysis of statistical interrelations existence between the nutrients concentrations and the phytoplankton species composition, biomass and abundance, as well as photosynthetic pigments, which are the generally recognized indicators of phytoplankton community's status.

Chlorophyll ***a*** content in the Zmiinyi Island coastal waters corresponded to meso-eutrophic status. As it has been shown in Table 3, the oscillations of chlorophylls concentration are statistically connected with the changes in nitric and ammonium nitrogen content, as well as with salinity values. The closest negative correlation was revealed between salinity and chlorophylls ***a*** and ***в*** (r=−0.40 and −0.41).

Rating of statistical analysis results (table 3) for all the in-situ data on the number of significant interconnections shows that water transparency and TRIX have the biggest number of statistical correlations (NSC) with the studied characteristics of marine ecosystem (rank=1, NSC=13). It has been followed by (rank=2, NSC=12) such parameters as Chl ***a***, Chl ***b***, Ph ***a***, which is the evidence of the fact that these characteristics depend on big quantity of natural parameters. Further come salinity (rank=3, NSC=11) and phytoplankton biomass (rank=4, NSC=10). Nutrient compounds of nitrogen (nitrate (rank=5, NSC=9) and ammonium-ion, rank=6, NSC=8) occupy respectively 5th and 6th places. Margalef's pigment diversity index (rank=6, NSC=8) also ranks no. 6. Then follow phytoplankton abundance and Chl c (rank=7, NSC=7), Danube runoff (rank=8, NSC=6) and N_{total} (rank=9, NSC=5). The least quantity of statistical interconnections was registered for temperature (rank=10, NSC=3) and phosphorus compounds (rank=11, NSC=2).

CONCLUSIONS

The studies performed have shown that the state of phytoplankton community, salinity and nutrient regimes of the Zmiinyi Island coastal waters are mostly influenced by advective water masses transport from the Danube mouth and the open part of the sea. At that, the biggest changes happen to salinity and transparency of marine water, as well as content of nitrate, which evidences the importance and necessity of their constant monitoring in the open part of the sea, also using the TRIX.

Analysis of the Danube River water runoff has shown that the river runoff does not influence the concentration of phosphorus compounds in marine water near the Zmiinyi Island, however increase of the river water runoff brings down water salinity significantly and increases the content of total, nitric and ammonium nitrogen and biomass and number of most of phytoplankton taxa.

Analysis of oscillations of chlorophylls content depending on environmental factors has shown that the oscillations were connected with changes in nitric and ammonium nitrogen content, as well as with water salinity, transparency,biomass and number of phytoplankton. It has been shown that pollution with nutrients entering the sea with river water runoff entails more than 4-fold increase in chlorophyll ***a*** concentration in marine water near the Zmiinyi Island.

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REFERENCES

1. Borysova, O., Kondakov, A., Paleari, S., Rautalahti-Miettinen, E., Stolberg, F., Daler, D. (2005), *Eutrophication in the Black Sea region; Impact assessment and Causal chain analysis*, University of Kalmar, Kalmar, Sweden, 62 p.
2. Commission Decision of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters (2010/477/EU), hereafter referred to as the Commission Decision on GES criteria. *Official Journal of the European Union*, L 232, 2.9/2010, pp. 14-24
3 Crise, A., Kaberi, H., Ruiz, J. et al. (2015), A MSFD complementary approach for the assessment of pressures, knowledge and data gaps in Southern European Seas: The PERSEUS experience, *Marine Pollution Bulletin, Volume 95, Issue 1*, 15 June 2015, pp. 28–39.
4. Directive 2008/56/EC of the European parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). *Official Journal of the European Union*, L 164, 25.6.2008, pp. 19–40.
5. Grasshoff, K., Ehrhardt, M., Kremling, K. and Almgren, T. (1983), *Methods of seawater analysis*, Verlag Chemie, Weinheim, 577 p.
6. Kovalova, N., Medinets, V. (2012), "Comprehensive Assessment of Long-Term Changes of the Black Sea Surface Waters Quality in the Zmiinyi Island Area", *Turkish Journal of Fisheries and Aquatic Sciences* 12, pp. 485-491, ISSN 1303-2712.
7. Kovalova, N., Medinets, V. (2014), Results of phytoplankton pigments studies in the Zmiinyi Island coastal waters in the Black Sea, 2004-2012. *Vestnik Odesskogo Nationalnogo Universiteta*, 19 (3/22), pp. 44-68.
8. Kovalova, N., Medinets, V., Morozov, V., Derezyuk, N. (2014), Danube Runoff Influence on the Zmiinyi Island Coastal Water Quality and Microbiota and Phytoplankton Community, In Book of *abstracts of PERSEUS 2nd Scientific Workshop – Marrakesh 2014/* Giannoudi L., Streftaris, N., Papathanassiou, E., (eds), pp. 77. PERSEUS Project. ISBN: 978-96-9798-07-5
9. Medinets, S. (2014), The Black Sea Nitrogen Budget Revision in Accordance with Recent Atmospheric Deposition Study. *Turkish Journal of Fisheries and Aquatic Sciences*, 14, pp. 981-992. DOI: 10.4194/1303-2712-v14_4_18
10. Medinets, V., Derezyuk, N., Kovalova, N., Medinets. S. (2011), Toxic Algae Investigations in Coastal Waters of Zmiinyi Island. Materials of the *3-rd Bi-annual BS Scientific Conference and UP-GRADE BS-SCENE Project Joint Conference* (Ukraine, Odessa, 1-4 November 2011), pp. 52-53.
11. O'Higgins, T., A. Farmer, G. Daskalov, S. Knudsen, and L. Mee. (2014), Achieving good environmental status in the Black Sea: scale mismatches in environmental management, *Ecology and Society* 19(3), pp. 54. http://dx.doi.org/10.5751/ES-06707-190354
12. Ostrov Zmeinyi: Ekosistema pribrezhikh vod, (2008), [*The Zmiinyi Island: Ecosystem of Coastal Waters*], Medinets, V. I. (Ed.), Monograph. Odessa National I. I. Mechnikov University, Astroprint, Odessa, 228 p.
13. Rukovodstvo po metodam biologicheckogo analiza morskyh vod i donnikh osadkov, (1980), [*Guidelines in Methods of Biological Analyses of Marine Water and Bottom Sediments*], Leningrad, Gidrometeoizdat, 190 p.
14. Vollenveider, R.A., Giovanardi, F., Montanari, G. and Rinald, A. (1998), Characterization of the trophic conditions of marine coastal waters, with special reference to the NW Adriatic Sea, Proposal for a trophic scale, turbidity and generalized water quality index. *Environmetrics*, 9, pp. 329-357.

СПИСОК ИСПОЛЬЗОВАНОЙ ЛИТЕРАТУРЫ

1. *Borysova O.* Eutrophication in the Black Sea region; Impact assessment and Causal chain analysis [Текст] / O. Borysova, A. Kondakov., S. Paleari., E. Rautalahti-Miettinen, F. Stolberg, D.Daler // University of Kalmar, Kalmar, Sweden. – 2005. – 62p.
2. Commission Decision of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters (2010/477/EU), hereafter referred to as the Commission Decision on GES criteria. [Текст] // *Official Journal of the European Union*, L 232, 2.9/2010. - P. 14-24
3. *Crise A. A*. MSFD complementary approach for the assessment of pressures, knowledge and data gaps in Southern European Seas: The PERSEUS experience [Текст] / A. Crise, H. Kaber., J.Ruiz // *Marine Pollution Bulletin.* – 2015. – ***Volume 95, Issue 1***15. – P. 28–39.
4. Directive 2008/56/EC of the European parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive) [Текст] // *Official Journal of the European Union*, L 164, 25.6.2008. - P. 19–40.
5. *Grasshoff K.* Methods of seawater analysis [Текст] / K. Grasshoff, M. Ehrhardt, K. Kremling, T. Almgren // Verlag Chemie, Weinheim. – 1983. – 577 p.

6. *Kovalova N.* Comprehensive Assessment of Long-Term Changes of the Black Sea Surface Waters Quality in the Zmiinyi Island Area[Текст] / N. Kovalova, V. Medinets // Turkish Journal of Fisheries and Aquatic Sciences. – 2012. – № 12. – P. 485-491 (2012), ISSN 1303-2712.
7. *Kovalova N.* Results of phytoplankton pigments studies in the Zmiinyi Island coastal waters in the Black Sea, 2004-2012 [Текст] / N. Kovalova, V. Medinets // Вісник Одеського національного університету, географічні та геологічні науки. – 2014. Т. 19, вип. 3(22), – С. 44 -59.
8. *Kovalova N.* Danube Runoff Influence on the Zmiinyi Island Coastal Water Quality and Microbiota and Phytoplankton Community [Текст] / N. Kovalova, V. Medinets, V. Morozov, N. Derezyuk // In Book of abstracts of PERSEUS 2nd Scientific Workshop – Marrakesh 2014 / Giannoudi L. Streftaris N., Papathanassiou E., (eds). - 2014. - P. 77. PERSEUS Project. ISBN: 978-96-9798-07-5
9. *Medinets S.* The Black Sea Nitrogen Budget Revision in Accordance with Recent Atmospheric Deposition Study [Текст] / S. Medinets // Turkish Journal of Fisheries and Aquatic Sciences, 2014, 14, P. 981-992 DOI: 10.4194/1303-2712-v14_4_18
10. *Medinets V.* Toxic Algae Investigations in Coastal Waters of Zmiinyi Island [Текст] / V. Medinets, N. Derezyuk, N. Kovalova, S. Medinets // Materials of the 3-rd Bi-annual BS Scientific Conference and UP-GRADE BS-SCENE Project Joint Conference. – Odessa, Ukraine, 1 – 4 November, 2011. – P. 52-53.
11. *O'Higgins T.* Achieving good environmental status in the Black Sea: scale mismatches in environmental management [Текст] / T. O'Higgins, A. Farmer, G. Daskalov, S. Knudsen, L. Mee // Ecology and Society. – 2014. – 19(3). – 54 p. http://dx.doi.org/10.5751/ES-06707-190354
12. Острів Зміїний: екосистема прибережних вод : монографія [Текст] / В. А. Сминтина, В. І. Медінець, І. О. Сучков [та ін.] ; за ред. В. І. Медінця; – Одеса: Астропрінт, 2008. – 228 с.
13. Руководство по методам биологического анализа морской воды и донных осадков [Текст] / под. ред. А. В. Цыбань. – Л: Гидрометеоиздат. – 1980. – 190 с.
14. *Vollenveider R. A.* Characterization of the trophic conditions of marine coastal waters, with special reference to the NW Adriatic Sea, Proposal for a trophic scale, turbidity and generalized water quality index[Текст] / R. A. Vollenveider, F. Giovanardi, G. Montanari, A. Rinald // Environmetrics. – 1998. – 9. – P. 329-357.

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ВИВЧЕННЯ ВЗАЄМОЗВ'ЯЗКІВ ФІЗИКО-ХІМІЧНИХ І ФИТОПЛАНКТОННЫХ ХАРАКТЕРИСТИК В ПІВНІЧНО-ЗАХІДНІЙ ЧАСТИНІ ЧОРНОГО МОРЯ (РАЙОН ОСТРОВА ЗМІЇНИЙ)

Резюме

У роботі розглядаються та аналізуються результати статистичного аналізу фізико-хімічних і фітопланктонних даних 2004-2014 рр. прибережних вод острова Зміїний, розташованого в північно-західній частині Чорного моря в 40 км від

дельти Дунаю. Показано, що на стан характеристик фітопланктонного угруповання найбільше впливають солоність, прозорість і концентрація нітратів та амонію, рівні яких формуються під впливом стоку Дунаю. Аналіз характеристик фітопланктонного угруповання в залежності від трьох типів водних мас показало, що найвищі значення біомаси і чисельності фітопланктону в цілому, а так само окремих його таксономічних груп реєструвалися у водах з солоністю 10-14 ‰, які сформовані під впливом стоку річки Дунай.

Ключові слова: Чорне море, прибережні води, острів Зміїний, стік Дунаю, фітопланктон, солоність, біогенні елементи, MSFD, TRIX індекс, хлорофіли

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ИЗУЧЕНИЕ ВЗАИМОСВЯЗЕЙ ФИЗИКО-ХИМИЧЕСКИХ И ФИТОПЛАНКТОННЫХ ХАРАКТЕРИСТИК В СЕВЕРО-ЗАПАДНОЙ ЧАСТИ ЧЕРНОГО МОРЯ (РАЙОН ОСТРОВА ЗМЕИНЫЙ)

Резюме

В работе рассматриваются и анализируются результаты статистического анализа физико-химических и фитопланктонных данных 2004-2014 гг. прибрежных вод острова Змеиный, расположенного в северо-западной части Черного моря в 40 км от дельты Дуная. Показано, что на состояние характеристик фитопланктонного сообщества больше всего влияют соленость, прозрачность и концентрация нитратов и аммония, уровни которых формируются под воздействием стока Дуная. Анализ характеристик фитопланктонного сообщества в зависимости от трех типов водных масс показало, что наивысшие значения биомассы и численности фитопланктона в целом, а так же отдельных его таксономических групп регистрировались в водах с соленостью 10-14 ‰, которые сформированы под влиянием стока реки Дуная.

Ключевые слова: Черное море, прибрежные воды, остров Змеиный, сток Дуная, фитопланктон, соленость, биогенные элементы, MSFD, TRIX индекс, хлорофиллы