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Responses of Algal Communities of the North-Western Black Sea to the Impact of Local, Regional, and Global Factors*

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ABSTRACT

Reactions of phytobentos and phytoplankton communities of the northwestern part of the Black Sea to the factors of local, regional, and global levels were investigated using techniques of morphofunctional ecology and methodology of a holistic approach. The effect of factors of each level on algal communities was estimated using a scale with seven grades. The strongest negative impact on communities of benthic algae at the local level resulted in intensive transformation of natural habitats in the coastal zone. At the regional level, processes of significant reduction of algal communities due to a decreasing eutrophication of the sea were discovered. At the global level, climate anomalies seem to be the main reason for the growth of negative trends in algal communities; in the last decade they became a significant factor affecting production, structure, and functional organization of benthic and plankton communities of algae.

KEYWORDS: algal communities, transformation of biotopes, eutrophication, climate change, Black Sea.

INTRODUCTION

The Black Sea is characterized by a high level of cross-border anthropogenic impacts on the biological components of its ecosystem including plant communities represented mostly by unicellular and multi-cellular algae. The Black Sea is also an important transport region. Each year over 50, 000 ships pass through the Bosphorus. Their ballast water contaminates the sea with alien species of flora and fauna (Alexandrov, 2004). The Black Sea is of strategic importance for the Eurasian continent. Therefore, for the past 20 years six

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countries with borders on the Black Sea, with financial support from the Global Environment Facility and the European Union, have been made political, institutional and organizational efforts for its protection and restoration. Since October 2000 these activities have been coordinated by the Secretariat of the Black Sea Commission (BSC) with headquarters in Istanbul.

The north-west part of the Black Sea (NWBS) is the most shallow and productive region located to the north of 44 ° 40 'N and bounded by conventional line from Cape Tarkhankut (Crimean Peninsula) to Zmeinyi Island (Figure **1**). This area refers to the economic zone of Ukraine. The total area of NWBS is 49,900 km^2, water volume is 2,700 km^3, and the average depth is 54.1 m (Zaitsev et al., 2006). NWBS area includes the coastal and shelf areas accepting runoff from three major European rivers (the Danube, Dniester, and Dnieper), in total up to 270 km^3 per year^{-1} (Simonov & Altman, 1991). A large portion of the shelf zone is located at a depth of 20-50 m. Shallow depth and intensive river discharge form a unique environment for the high biological productivity and concentration of biological diversity in this region. Hallmark of the biological component of this area are clusters of red algae of genus *Phyllophora* Grev., forming favorable habitats for diverse aquatic organisms. Over the past half-century structure of *Phyllophora* communities has drastically changed due to human impact.

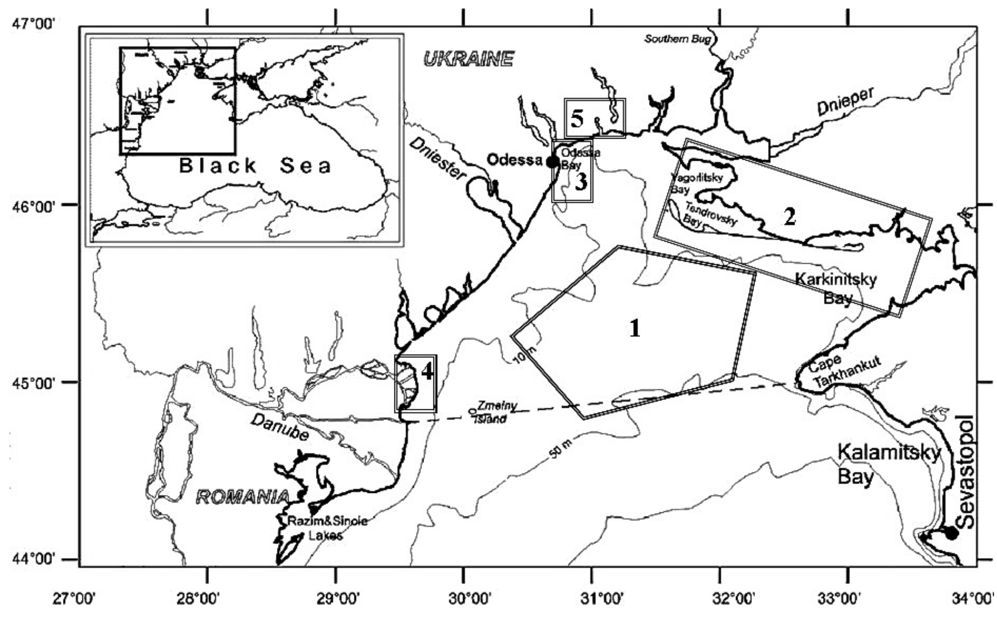

Figure **1**. Study area: *1* – Zernov's *Phyllophora* Field; *2* − Karkinitsky, Tendrovsky and Yagorlytsky Bays; *3* − Odessa Region; *4* − Danube Delta front; *5* − Dofinovsky, Grigorivsky and Tiligulsky estuaries

Members of this genus are the indicators of the current state of the NWBS ecosystem (Minicheva, 2007; Minicheva et al., 2009). In the last decade NWBS has become a testing ground of numerous international research projects of the Black Sea Commission because here the response of biological components in the ecosystem to different types of human impacts are the most evident. Now the NWBS is recognized as a "hotspot" where it is possible to access and monitor the entire Black Sea ecosystem.

In the course of environmental assessment of any ecosystem the most important and difficult aspect is determining the direction of the processes taking place in the biological component. The answer to the question "What kind of process is it, degradation or restoration?" is both important for the Black Sea ecosystem in general and for NWBS as its "hotspot". A correct answer to this question requires a compliance with certain conditions: clearly defined boundaries of the study area, the time period in which unidirectional ecological processes are observed, i.e., separation of the impacts of anthropogenic and natural factors. The NWBS is a good research model for studying the vector of ecological processes occurring in the Black Sea ecosystem in a specific time period.

The state of the main biotic communities of the NWBS, described in detail in the 1960s is regarded as the "natural norm" for this area (Vinogradov, 1967). The stage of "ecological trouble", which lasted from the mid 70s and 90s of the last century, had been estimated by experts as “a change and degradation” (Zaitsev & Mamaev, 1997). The increased eutrophication of the sea caused frequent water blooms, reduction of *Phyllophora* areas, fish kills and loss of biodiversity. At the end of the past century and the beginning of the present century, as a result of comprehensive studies of the Odessa branch of the Institute of Biology of the Southern Seas of NAS, the trend towards stabilization and credible processes of the NWBS ecosystem recovery was recorded (Zaitsev et al., 2006).

At present, determining what type of process is going on − “degradation or restoration?” still remains the main task for international experts studying the Black Sea ecosystem by means of modern methods of socio-ecological modeling (Langmead et al., 2009). In the present paper we try to provide answers to determining the direction of processes with the use of micro- and macroalgal communities as environmental indicators.

The biological value of marine ecosystems is determined by the rate of environmental processes in the sea (Alexandrov et al., 2010). The intensification of primary production processes (for example, due to eutrophication) results in loss of biodiversity. Plants are the first biological element in the chain of production and transformation of organic matter in the ecosystem. Therefore, the most logical and direct way of the estimation of the rate of environmental processes is the use of plant communities as indicators. In marine ecosystems benthic and pelagic autotrophic communities consist mostly of algae. In accordance with European standards of assessment of environmental status of marine ecosystems (Ecological Status Class), phytoplankton and macroalgae are recognized as indicators (Biological Quality Elements; Directive 2005/56/EC ..., 2008), and so we used them in our study.

The complex of abiotic factors of the NWBS was reviewed according to the principles of a holistic approach and the hierarchical organization of ecosystems (Mikhailov, 2008). Natural and anthropogenic factors affecting phytoplankton and macroalgae on local, regional, and global levels were investigated. The response of algal communities of the NWBS to the impact of factors of different hierarchical levels was assessed using the method of morphological and functional evaluation of aquatic vegetation, based on the parameters of the surfaces of unicellular and multi-cellular algae (Minicheva, 1996, 1998).

The aim of this study was to find the methods of quantitative estimation of the response of algal communities of the NWBS to the fluctuations in the intensity of factors on local, regional, and global levels. We investigated:

- the peculiarities of local, regional, and global factors influencing the algal communities of NWBS at present the time;
- changes of variability and intensity of impact of different level factors on the production and floristic composition of phytoplankton and phytobenthos over the last decade;
- the ratio of the local, regional, and global factors' impact and their contribution to the change of regional primary production and the structural and functional organization of algal communities.

MATERIALS AND METHODS

In the study we used the data on the state of NWBS planktonic and benthic plant communities obtained during 2000-2011, from the sites of continuous monitoring: the Danube Delta front, Odessa Bay (Cape Bolshoy Fontan − Cape Severnyi), Dofinovsky, Grigorivsky and Tiligulsky estuaries; and in the studied areas of the shelf zone: Large (Zernov's) *Phyllophora* Field; Karkinitsky Bay (Small *Phyllophora* Field), Jarylgachsky, Tendrovsky, and Yagorlytsky bays (Figure **1**). In the analysis the data on changes in climate, and physical and chemical characteristics of the aquatic environment of the NWBS over the same period were used.

Oceanological and hydrological methods. Water salinity and the temperature of water and air were taken for analysis as factors affecting algal communities. High-water and low-water years were statistically valid selected according to the annual Danube discharge volumes. Solar fluxes on the surface of macroalgae biotopes were calculated on the main astronomical, geographical, and meteorological factors (Bolshakov & Bolshakov, 2010). In assessing the role of anthropogenic sources of coastal water pollution in the Odessa district of the NWBS, we relied on information of regional offices of the Ministry of Environment and Natural Resources of Ukraine.

Methods of morphofunctional evaluation of benthic and planktonic algae. To estimate phytoplankton and phytobentos communities, along with species composition, abundance, and biomass of algae, we used the indices of algal surface (Minicheva et al., 2003).

"Environmental activity" of macrophytes and phytoplankton was characterized by the index of specific surfaces of populations $(S/W)_{cm}$; the index of phytocoenosis surface reflected the intensity of the autotrophic process (Minicheva, 1998). More than 1,800 of quantitative samples of macrophytobenthos were analyzed, 15,000 of morphometric parameters of macrophytes were measured. Phytoplankton communities were analyzed on the basis of 697 quantitative samples. Twelve and half thousand groups of one-size cells were recorded. In allocating one-size groups, 1 to 7 morphometric parameters were measured depending on the complexity of the cell shape.

Method for pigments determined. The content of photosynthetic pigments in phytoplankton was determined by a standard technique (Lorenzen & Jeffrey, 1980).

RESULTS AND DISCUSSION

Reaction of algal communities to the impact of local factors. In marine ecosystems, the effect of local factors is the strongest in coastal biotopes. Coastal plant communities are the first to undergos various natural and anthropogenic influence of adjacent lands. The following descriptions include the different levels of impact affecting algal communities; each level has its own peculiarities and governing factors of influence.

<u>Peculiarities of local influence</u>: Factors affect small water areas adjacent to the coastal zone resulting in a slight heterogeneity of the aquatic environment and biotopes. The main components of the local anthropogenic impacts are:

- point sources of pollution (municipal and industrial discharges);
- transformation of coastal biotopes (coastal and hydro-engineering construction);
- recreational pressure.

The most noticeable effect of local factors were manifested within coastal cities. Odessa is the largest coastal city of the NWBS with a population of over 1 million people. It occupies about 70 km of coastline. Various sources of local pollution on this territory have an impact on the adjacent marine area 10 km wide. Suspended and dissolved organic matter, mineral nitrogen and phosphorus, surfactants, and oils fall into the sea. The maximum contribution to eutrophication of coastal waters of the Odessa region is made by partially treated domestic wastewater discharging into the sea by stations of biological waste-water treatment (71% of the supply of mineral nitrogen, 91% of mineral phosphorus, and 59% of organic matter). Storm-water runoff (28%) significantly contributes to the organic pollution of the sea as well. The treatment facilities of small seaports (of Odessa satellite towns) add 8% mineral nitrogen and phosphorus to the marine environment.

Drainage runoff and industrial wastewaters supply more than 20% of nitrates. The impact of local sources stimulates the autotrophic communities and causes changes in their structural and functional organization, including a change in the dominant species of algae. Changes in the morphofunctional organization of coastal plant communities of macrophytes can be observed at a distance of several tens to hundreds of meters from the source of constant pollution. Typical for Odessa coast phytocenoses dominated by red algae-macrophytes from genus *Ceramium* Roth $(S/W)_{cm}$ − 25-30 $m^2 \cdot kg^{-1}$) are replaced by communities of green and blue-green algae: *Cladophora* Kütz., *Ulothrix* Kütz., *Lyngbya* C. Agardh ex Gomont, *Spirulina* Turpin ex Gomont. The ecological activity of transformed phytocenoses may increase to 200-300 $m^2 \cdot kg^{-1}$. Episodic pollution sources (storm water) can affect the quality of coastal waters within 4-6 days after heavy rains fall. In the first day after the rain, total primary production of phytoplankton increases by 5-45% (Tuchkovenko et al., 2011).

The most evident anthropogenic component of local influence on coastal macrophyte communities is the transformation of the shoreline related to coast protection, industrial, recreational, and private villas' construction in the coastal zone. Natural rocks and stones of the Odessa coast, the favourable habitats for macrophytes, are entombed under the artificial beaches or replaced by concrete breakwaters, traverses and other hydrotechnical constructions. Such a change in the properties of biotope elicits reorganization of coastal vegetation. Phytocenoses of macrophytes on artificial surfaces demonstrate simplification of the composition, transition to monodominance, loss of mosaic structure, and the prevalence of horizontal distribution of algal complexes.

In the last decade, the intensity of transformation of the coastline reached a maximum. The speed of transformation of the Odessa coastline provides insight to the current intensity of this process in the coastal biotopes of the Black Sea ecosystem. The Odessa Bay coastline (Cape Bolshoy Fountain – Cape Severny) is 28 km long. Two km of the shore had been transformed in the 1800s during the Odessa Sea Port construction and 6.5 km during port expansion. In the 1960s 12 km of the coast were involved in the coast protection of urban beaches (Figure **2**).

In the last decade, the number of tourists in the Ukraine, e.g., in recreational areas of the NWBS coast, increased. The tourism by itself, as a component of local impact, has lesser direct effect on plant communities. However, the "tourists arriving for beach holidays" indirectly influence coastal communities of macrophytes and phytoplankton. Construction of artificial beaches, hydro-entertainment facilities, and boat marinas cause a reduction of the natural rocky habitats. A large number of bathers in the sea may increase trophic levels of water stimulating the development of unicellular algae with high environmental activity.

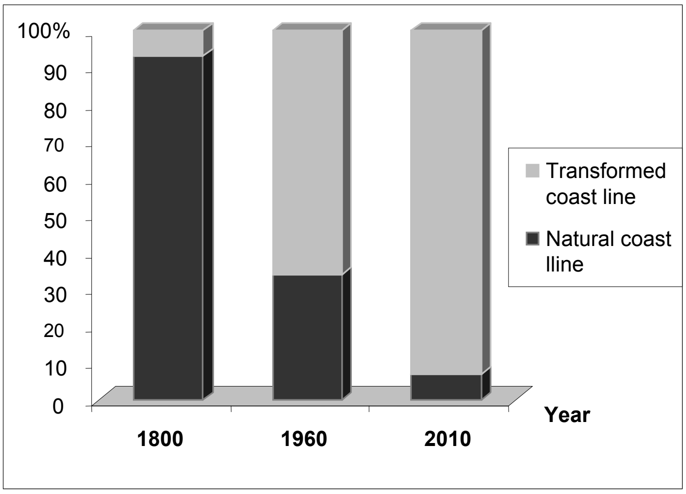

Figure **2**. Transformation of Odessa Bay shoreline for 210-year period

Reaction of algal communities to the impact of regional factors. The next hierarchical level of response of algal communities of NWBS to anthropogenic factors is the regional level. Features of the regional impact: the factors affect integrated water areas with relationship between environmental elements; background characteristics of the marine environment and biotopes connect with physiographical features of the region.

The main anthropogenic components of regional impact:

− the amount and quality of river discharge (eutrophication as a result of economic activity);

− shipping (oil pollution);

− invasion of alien species.

The main regional peculiarity of NWBS is that three major European rivers, the Danube, Dniester, and Dnieper flow in to an extensive shallow shelf area. This geographical phenomenon to a large extent, determines regional features and spatial heterogeneity of the biological component of the NWBS ecosystem. The maximal intensity of the primary production and, accordingly, of the environmental activity of algal communities is observed in the delta of largest river: the Danube. The lowest productivity was recorded in the small bays of NWBS (Yagorlytsky, Tendrovsky, Karkinitsky) protected from the river runoff (Figure **3**).

In contrast to the relatively stable spatial-regional differences in environmental activism of algal complexes, the direction of temporal dynamics of the autotrophic process in the NWBS in recent decades allows us to answer the main questions concerning degradation or restoration. Obviously, the changes in functioning of aquatic vegetation of the NWBS are associated with fluctuations in the volume and quality of the supplying river flow. Different historical periods of NWBS eutrophication caused changes in the structural and functional organization of macrophytobenthos of the coastal area and the shelf, as well as free-floating phytoplankton communities. In assessing the dynamics of eutrophication of the NWBS we distinguish four periods: *The natural state* (before 1960), *Intensive eutrophication* (the beginning of the 1970s), *Stabilization* (mid-1990s) and *Sustainable trend of de-eutrophication* (the beginning of the 21st century, Minicheva et al., 2008).

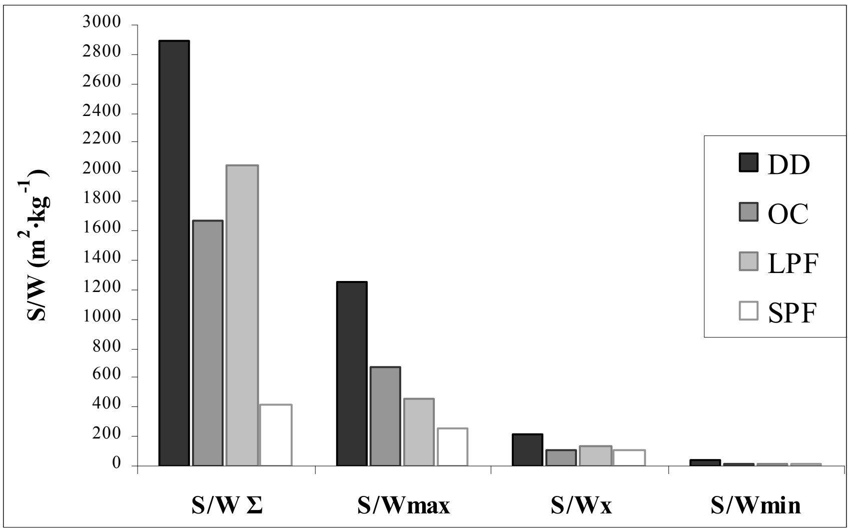

Figure **3**. Total (S/W_{Σ}), maximal (S/W_{max}), average (S/W_x), and minimal (S/W_{min}) parameters of the rows of Environmental Activity of macrophytes in different areas of the North-Western Black Sea (DD − Danube Delta, OC − Odessa coast, LPF − Large *Phyllophora* Field, SPF − Small *Phyllophora* Field (Karkinitsky, Tendrovsky, Yagorlytsky Bays)

Long-term studies of phytoplankton illustrate the reaction of the most sensitive component of the autotrophic link on the dynamics of eutrophication. The value of environmental activism (S/W) of phytoplankton varied at different stages of eutrophication of the NWBS. During the period of "intensive eutrophication", environmental activity of the dominant species of phytoplankton had grown in 5, 7 times. At present their activity is 4-fold decreased (Figure **4**).

The most significant changes concern the biomass of phytoplankton. During the period of "intensive eutrophication", it increased 16.5-fold (from 1.03 to 17.02 g m^{-3}). In the beginning of the 21st century phytoplankton biomass had decreased 14 times, almost reaching the level of the period of "natural state" (Figure **4**). The concentration of chlorophyll *a,* in the periods under review, did not vary sharply; it only increased nearly 4-fold from the mid-1960s to mid-1980s and fell to 1.4 times by the end of the 2000-ies (Figure **4**).

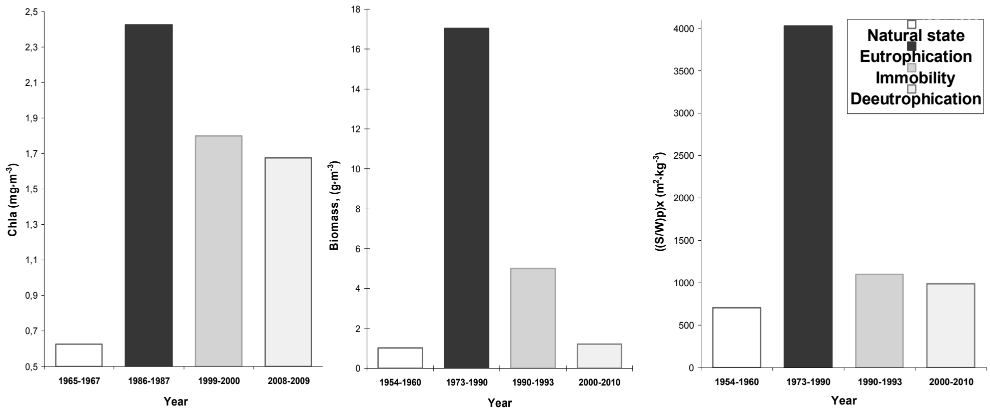

Figure **4**. Average concentration of chlorophyll *a* ($mg{\cdot}m^{-3}$), biomass ($g{\cdot}m^{-3}$), and specific surface ($m^2 \cdot kg^{-1}$) of dominant species of the populations of North-Western Black Sea phytoplankton (1973-1990; data from Zaitsev et al., 2007)

Rearrangement of the structural and functional organization of macrophytes' communities for studied periods was even more evident, as accompanied by the change of dominant species of coastal vegetation. The most notable event in the transition from the period of the "natural state" to "intensive eutrophication" was the disappearance of a large perennial kelp *Cystoseira barbata* (Good. et Wood) Agardh with a low specific surface area − SSA; $(S/W)_n$ − 12 $m^2 \cdot kg^{-1}$), replaced with a complex of species with higher ecological activity (*Ceramium*, *Polysiphonia* Grev., *Cladophora*: $(S/W)_n$ from 25 to 60 $m^2 \cdot kg^{-1}$). The present period of "sustainable trend of de-eutrophication" is characterized by numerous examples of recovering plant communities and improving the state of populations of macroalgae with low specific surface, which are recognized as indicators of good environmental status. The example of recent environmental improvements is the restoration of the *C. barbata* population in Tiligulsky estuary (Minicheva et al., 2012).

At the beginning of the new millennium, the recovery processes were also observed in macrophyte communities of the central part of the north-western shelf, the Zernov's *Phyllophora* Field. Now, it is too early to start planning the restoration of *Phyllophora* biomass to the level it was in the last century. The replacement of *Phyllophora* by small filamentous algae observed in the last decade is a natural stage of the restorative succession of macrophyte communities. Specific surface areas of species from genus *Phyllophora*, on average is 8.7 $m^2 \cdot kg^{-1}$. The species replacing *Phyllophora* have much greater environmental activism: SSA of *Polysiphonia sanguinea* (C. Agardh) Zanardini is 80.0± 1.4 $m^2 \cdot kg^{-1}$; SSA of *Feldmannia irregularis* (Kütz.) G. Hamel is 303.2±16,2 $m^2 \cdot kg^{-1}$. The dynamics of the floristic composition confirms the trend of increasing species diversity of deep-water macrophyte communities in the north-western shelf. Even more active processes of restoration of phytocenoses compared to those of the shelf are observed in the coastal zone. As a result of the recovery processes in the NWBS, in Karkinitsky Bay at a depth of 10 m, the increase in biomass of *Ph. crispa* (Hudson) P.S. Dixon to the level of the 1970s was recorded.

Other anthropogenic components of the impact at the regional level (oil pollution, the introduction of alien species) do not sufficiently affect the algal communities of this region. At present, in the region of the NWBS, the tendency of reducing concentrations of petroleum products is registered; their concentrations in the marine environment do not exceed the values of maximum allowable concentration adopted in the Ukraine (Zaitsev et al., 2006). In the early 1990s, the arcto-boreal invasive species kelp *Desmarestia viridis* (O.F. Müll.) J.V. Lamour. was recorded over the whole area of the NWBS (Minicheva & Eremenko, 1993). Environmental activism of this species $(S/W)_n$ − 81 $m^2 \cdot kg^{-1}$) coincided with the intensity of the production process in the region, and the species has become abundant during the cold season. In recent decades, invasions of such magnitude and consequences in plant communities of the NWBS were not recorded.

Reaction of algal communities to the impact of global factors. Features of the global impact: the impact of factors effect the ecosystem of the World Ocean, forming the specificity and intensity of environmental processes, depending on climate and geographical location.

The main components of the global anthropogenic impact are:

- change in mean climate parameters;
- increased frequency of weather events;
- water pollution as a result of weather disasters.

Analysis of the average sea water temperature in the Odessa coast has showed that in the last decade the average annual temperature increases on 1.7 ^{o}C. No significant relationship was reported between average annual temperature and average annual values of environmental activity, abundance, biomass, and the index of coastal phytoplankton and phytobenthos (Minicheva et al., 2010).

Variability of abiotic factors and their anomalies cause much stronger responses in algal communities. In the last decade, due to climate change, the frequency and strength of weather anomalies have increased. As an example, a high degree of weather anomalies in the NWBS was observed in the winter-spring period of 2002-2003. A positive temperature anomaly in 2002 was 1.7 times higher than the standard deviation. A negative temperature anomaly in 2003 was 2.4 times higher than the standard deviation. A sequential combination of these temperature anomalies provoked a pronounced response of the coastal communities of macrophytes. As a result of intensive development of macrophytobenthos in the coastal zone, the production increased 2-fold compared to a regional average level.

The intensification of the production process was accompanied by a violation of the seasonal dynamics of species of macroalgae. A period of vegetation of winter macrophytes has moved in time on 6-7 weeks. The kelps of the cold period (*Dunaliella viridis, Punctaria latifolia* Grev., *Ectocarpus siliculosus* (Dillwyn) Lyngb.) occurred up to mid-July.

Another significant climatic anomaly was observed in 2010. Precipitation exceeded the annual by 200-350%. Temperature in August was above normal by more than 5 times. Climatic conditions in 2010 radically changed the morphology and function of the macrophytobenthos communities of the Odessa coast. Environmental activism of mass species phytobenthos increased from 30 to 300 $m^2 \cdot kg^{-1}$. Cyanobacteria of the genera *Lyngya* and *Spirulina* became dominants instead of the former dominating species of genera *Ceramium*, *Cladophora*, and *Enteromorpha* Link. Average environmental activism of species participating in the communities increased 2.5 times (S/W − 147 $m^2 \cdot kg^{-1}$). The index of plant community surfaces have reached the level of the 1980s (IPCS = 74 units; Figure **5**).

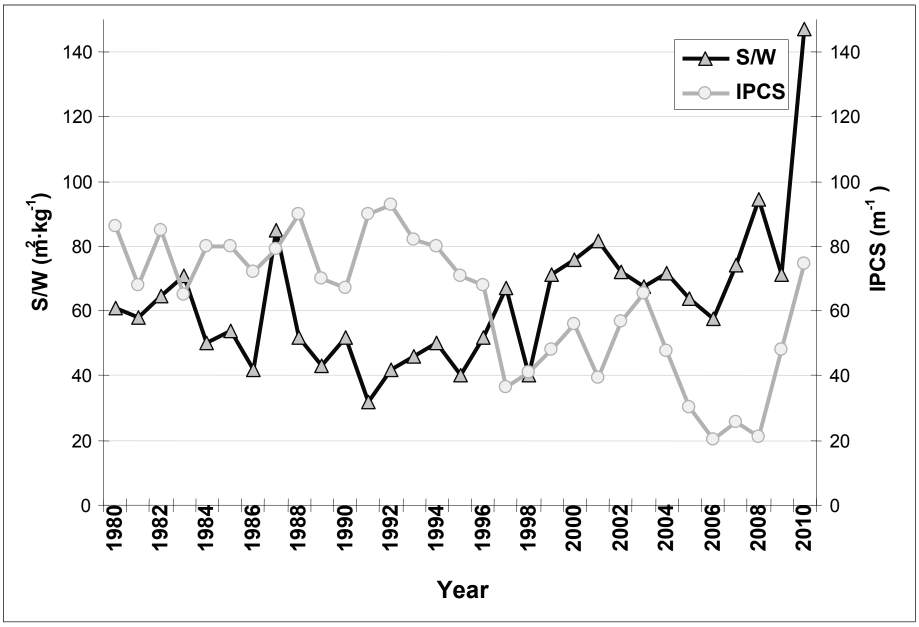

Figure **5**. Interannual variability of the specific surface area (S/W) and index of plant community surface (IPCS) of macrophyte communities in 1980-2010

As a result of the temperature anomaly in July 2010, the entire area of the NWBS was covered by water bloom of cyanobacteria *Nodularia spumigena* Mertens; its biomass increased up to 5 $kg \cdot m^{-3}$ (Alexandrov et al., 2010). The same strong reaction of phytolankton communities to abnormal weather conditions was observed in the estuaries of the NWBS. In the Tiligulsky estuary in July-August, the concentration of chlorophyll *a* increased by two orders (Figure **6**).

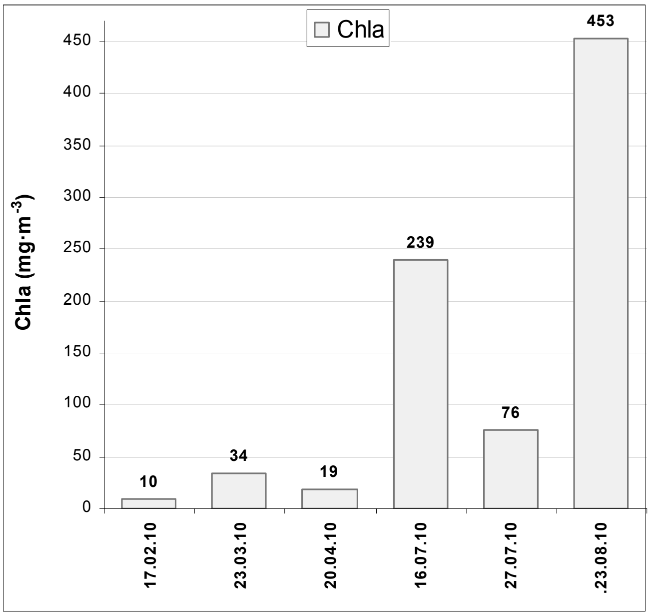

Figure **6**. Chlorophyll *a* concentration of phytoplankton in Tiligulsky estuary under climate anomalies in 2010

In this period in the estuary, the bloom of dinophyte planktonic algae *Prorocentrum micans* Ehrenb. was observed. Its biomass was 135 g · m^{-3} (usually it is less than 1 g · m^{-3}). The index of phytoplankton surfaces exceeded 40 units (the norm is 2-5 units).

Currently, in the NWBS no extensive effects on plant communities associated with abnormal weather conditions are recorded. The most likely danger is a man-made disaster resulting from poor weather conditions, such as what occurred in the Kerch Strait in November 2007. During a multi-day storm, 4 ships sunk and 11 ships were tossed ashore. Strong oil spills of the coastal zone as a result of oil tankers shipwrecked confirmed the growing danger of such situations for all sea areas, including the NWBS.

The ratio of the impact of local, regional, and global factors. For quantitative assessment of the response of NWBS algal communities to factors of different levels of impact, we propose the rating scale that includes seven categories of evaluation: three categories for assessment of mitigation, one category for an immutable condition, and three categories for assessing the degree of increases of the factor impact (Table 1).

TABLE 1. Evaluation scale of the factors effect on algal communities

Rating of factor impact	Category
Radical decrease	- - -
Significant decrease	- -
Considerable decrease	-
Unchanged status	0
Considerable increase	+
Significant increase	+ +
Radical increase	+ + +

TABLE 2. Assessment of the reaction of algal communities of NWBS to impact of factors of different level (2000-2011)

Level of factor impact	Antropogenous component	Category	Decision-making level
Local	Point sources of pollution	+	• State (Ukraine) • Regional (Odessa, Nikolayev, Kherson regions, AR Crimea)
	The transformation of coastal biotopes	+ + +	
	Recreation load	+ +	
Regional	The amount and quality of river runoff (eutrophication)	- -	• Euro-Asian
	Water transport (oil pollution)	-	
	Introduction of invasive species	-	
Global	Change in average climatic parameters	+	• World
	The growth of weather anomalies	+ +	
	Water pollution due to weather disasters	+	

For phytoplankton and phytobenthos communities of the NWBS, expert evaluation of the responses to the key factors of each of the three levels was carried out. As a result, a general picture of the ratio of intensity and vector of the anthropogenic impacts on the autotrophic component indicated that the Black Sea ecosystem was the most sensitive region for the last ten years (Table 2).

The table shows that the most acute problem of intensive transformation of coastal habitats, appearing in the last decade, can be solved by local and state authorities of the Ukraine. The problem of restoration of the Black Sea as a regional system can only be solved through joint efforts of the Euro-Asian countries of the Black Sea basin. The summation of the ratings for each level allows us to get an approximate quantitative estimation of the ratio of the factors on biological components at different levels of the Black Sea (for example, plant communities of the NWBS; Figure **7**).

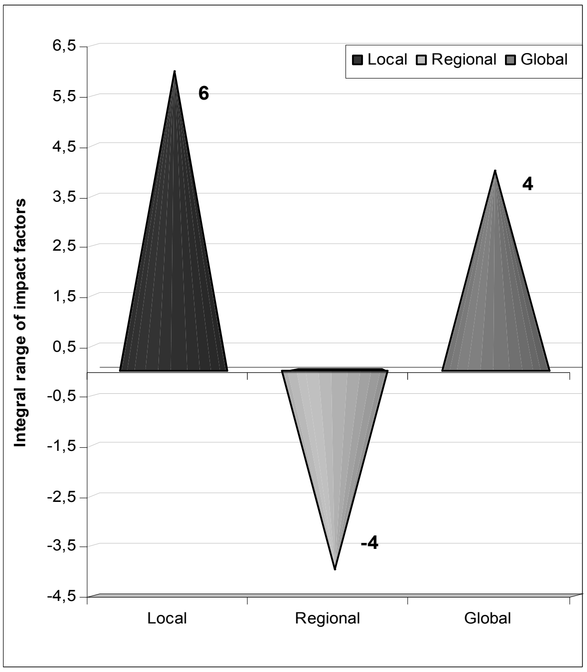

Figure **7**. The ratio of the integrated impact of local, regional and global factors on the NWBS algal communities (2000-2011)

Currently, the factors at the local level lead in the intensity of impact on marine plant communities (Figure **7**). Anthropogenic components (e.g., transformation of coastal biotopes) were marked by the highest score for this level (a radical increase: +6). The solution to this problem in the Ukraine can be achieved by introducing a wider European approach of integrated coastal zone management (ICZM), the adoption of the state law "On the coastal zone," planning in the interests of the natural components of sea coasts and other wetland ecosystems, and stronger control over construction in coastal areas.

The factors of influence at the regional level demonstrate the strongest decline taking place on algal communities of the NWBS; a minimal score (a significant decline: −4) was registered for eutrophication. Parameters of algal communities in recent decades confirm the trend for recovery in biological components of the Black Sea. This is a good example of how international cooperation and financial support coordinated by the Secretariat of the Black Sea Programme provide a positive environmental outcome.

In the last decade the growth in negative effects of weather anomalies on algal communities was recorded (a significant increase: +4). This problem may be solved only as a result of joint efforts to stabilize the planetary climatic conditions affecting both terrestrial and marine ecosystems.

CONCLUSIONS

Analysis of the responses of NWBS communities of phytoplankton and phytobenthos to different anthropogenic components of local, regional and global impact in the last decade has shown that:

− the greatest negative impact on the community of benthic algae is caused by transformation of the coastal zone as a result of intensive construction with the replacement of natural habitats by artificial once;

− reducing the level of eutrophication results in reliable recovery of plankton and benthos algal communities in coastal and offshore areas;

− increasing frequency of climate anomalies becomes serious factor that may considerably change the rate of environmental processes and structural-functional organization of phytocoenoses of the NWBS.

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