Macrophytobenthic coenoses as indicators of the eutrophication level in Varna bay (Bulgarian Black Sea Coast)

Kristina H. Dencheva

Institute of Oceanology, Bulgarian Academy of Sciences, PO Box 152, 9000 Varna, Bulgaria, e-mail: dencheva@io-bas.bg

Received: June 25, 2006 ▷ Accepted: September 28, 2006

Abstract. Degradation of biological structures during the last decades in Varna bay is a consequence of the increased eutrophication level of the ecosystem and results in economic losses of valuable living resources and reduction of the coastal zone recreation potential. The aim of the present paper is assessment of the eutrophication level in five sites located in Varna bay, on the basis of the ecological status of macrophytobenthic communities. The application of a set of macroalgal morpho-functional parameters and indices gives grounds to rank the investigated sites by their eutrophication status as follows: the Channel area and cape Gala with the highest eutrophication level, and the Traka transect with the lowest.

Key words: active surface parameters, eutrophication, macrophytobenthos

Introduction

Human activities in the last decades have greatly accelerated eutrophication by increasing the rate at which nutrients and organic substances enter the aquatic ecosystem of Varna bay from the surrounding watersheds (Stojanov 1991). These substances overstimulate the growth of algae, creating conditions that interfere with the recreational use of coastal ecosystems and the health of indigenous fish, plant and animal populations (Moncheva & al. 2001; Prodanov & al. 2001; Stefanova & al. 2005). Degradation of biological structures of the ecosystem in parallel with marine water quality deterioration, reduce the resource value of the ecosystem, so that recreation, fishing, hunting and aesthetic enjoyment are hindered. Health – related problems can also occur. Under such conditions plant communities are the first to react to the eutrophication factor. Ecological effects comprise decrease of biodiversity, structural alterations, such as substitution of some species with others of a shorter life cycle and highly specific surface (Minicheva 1993).

The aim of this paper is the application of a set of new morpho-functional parameters and indices for the assessment of macrophytobenthic communities ecological status as bioindicator of the eutrophication level in Varna bay.

Material and methods

Five transects were explored – Varna bay (Gala, Veteran, Traka- south and Traka-north) and the Channel (Fig. 1). A total number of 358 samples were collected in 1998 (spring, summer and autumn) from the littoral zone, down to 5 m depth, applying diving technique, according to the method of squares (Vodianitskaya 1936). Qualitative samples from the winter season were processed too.

A set of new morpho-functional parameters of algae surface was employed in the phytocoenoses analysis, as described in Minicheva & al. (2003), based on relation between the specific surface ratio (S/W) of the macrophyte species and their pho-

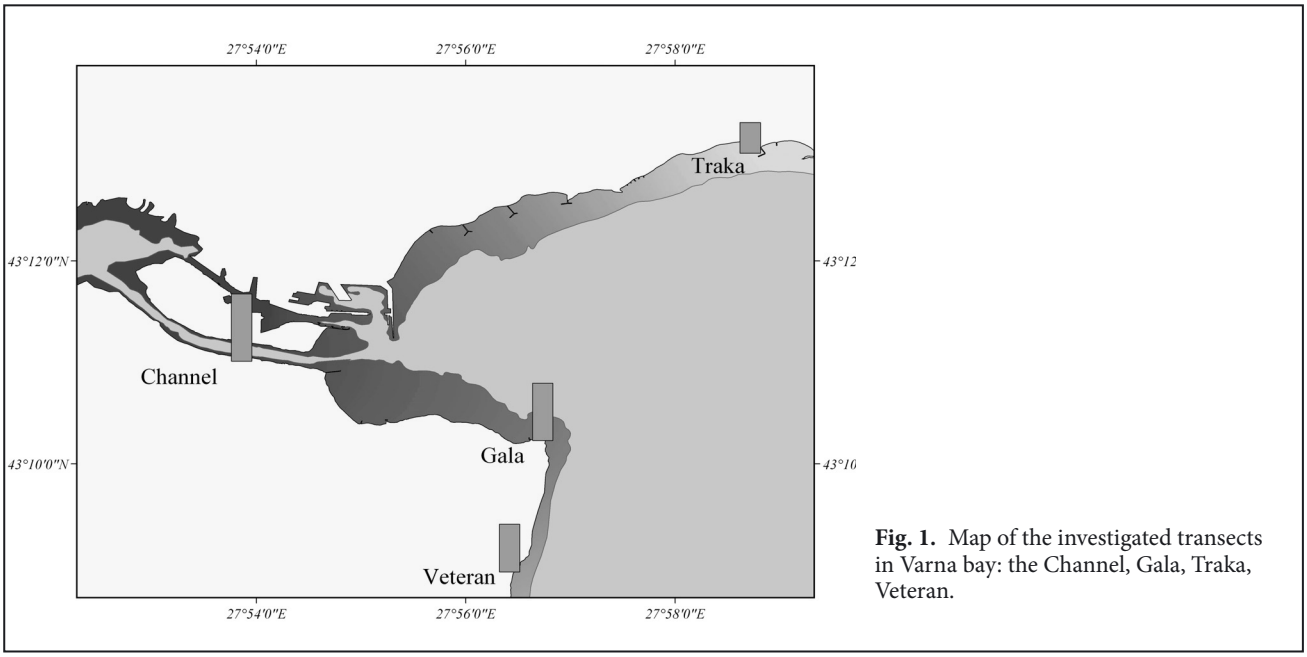

Fig. 1. Map of the investigated transects in Varna bay: the Channel, Gala, Traka, Veteran.

tosynthetic rates, methabolic and cathabolic processes (Haylov & Parchevskii 1983; Firsov 1984). Initially, the structure and functioning of species composition depends on the eutrophication level: a high eutrophication level is associated with species of higher specific surface. The S/W ratio [m^2 /kg] is estimated by the method of Minicheva (1993), according to which the macrophytes are divided into two basic structural types: lamellar and cylindrical. For the lamellar type, the specific surface (S/W) is proportional to the thickness of the thallus S/W = f(h), while for the cylindrical type, correlation between S/W and the diameter of the plant is established S/W = f(d). The thickness or diameter of the thallus is measured in micrometers under the microscope (at least 250 measurements are necessary for a reliable result).

The other parameter used – specific surface of the populations (S/Wp) – not only gives the morphological peculiarities of the species, but also the structure of their populations. In the method (Minicheva 1993), S/Wp is proposed for indirect assessment of the functional capacity of populations .

The calculation of the index of population surface (IPS) is performed by the following equations (Minicheva & al. 2003):

$$\mathbf{IPS = S/Wp \,.\, Bp}$$

where "**Bp**" is the biomass of the population.

The index of phytocoenoses surface (IPhS) is estimated by the equation:

$$\mathbf{IPhS = \sum S/Wpi \,.\, Bpi}$$

where "**i**" is the number of populations that form the phytocoenoses. This parameter characterizes the active surface area of the community per square meter of the substrate, and is dimensionless. The IPhS increases when the eutrophication level is higher.

Phytoexpertiza software was used for calculation of the production. Furthermore, a number of classical methods were applied: saprobic composition of macrophytes (Gutnik 1975; Eryomenko 1980) and floristic index of Cheney (P) as an ecological characteristic of water quality, where higher values of the floristic index correspond to a higher eutrophication level (Gutnik 1989). The biomass data were statistically processed (Lakin 1980).

Results and discussion

In Varna bay and the adjacent channel the macrophyte communities were characterized by the following taxonomic/floristic structure: 12 species of the *Chlorophyta* type, 7 *Rhodophyta* and 3 *Phaeophyta*, of which 8 were polysaprobic, 12 mesosaprobic and 2 oligosaprobic.

The average values of the species-specific surface along the investigated transects are presented in Fig. 2. While the highest values were typical for the Channel site (respectively 96.85 $m^2.kg^{-1}$) and cape

Gala (77.18 $m^2.kg^{-1}$), the lowest measured ones stood for Traka (correspondingly 35.34 $m^2.kg^{-1}$), followed by Veteran (60.59).

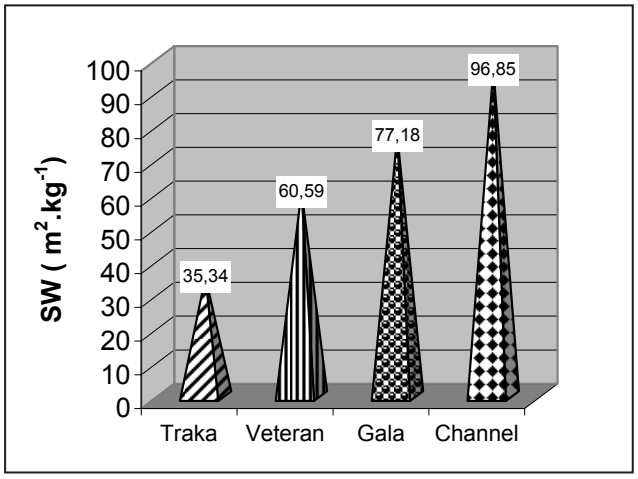

Fig. 2. Comparison of the average annual specific surface values (S/W) along the investigated transects.

Thus the presence of species of high functional activity indicated the high level of eutrophication in the Channel. According to the average specific surface of the macrophyte species, Varna bay (Table 1) could be characterized as mesothrophic, while the Channel as strongly eutrophicated, which is in good agreement with the results of the chemical analysis reported for the region (Stoyanov 1991; Shtereva & al. 1999).

Table 1. Relationship between the average specific surface values of macrophytobenthic coenoses and the trophy.

Region	Varna bay	Channel
Average specific surface of the species	57.7	96.85
Trophy of the ecosystem	Mesotrophic	Eutrophic

Obviously, the average values of the specific surface of dominant species could be used for express assessment of the intensity of productivity in coastal ecosystems.

As Fig. 3 shows, the average macrophyte biomass decreases along the gradient from the Traka transect to the Channel: Traka (1035.75 $g.m^{-2}$) – Veteran (574.7 $g.m^{-2}$) – cape Gala (401.8 $g.m^{-2}$) – the Channel (435.2 $g.m^{-2}$). A comparative analysis with the specific surface results has revealed an inverse trend along the investigated sites: the biomass decreases, and the specific surface increases with the increase of eutrophication level, a correlation reported in other investigations too (Gutnik 1975).

As for the changes in the last years, a typical feature was the decrease in the bay of the biomass of *Cystoseira barbata* Agardh, an indicator species of clean waters. This olygosaprobic macrophyte with low specific surface and big size was substituted by other polysaprobic species of higer specific surface, such as *Cladophora vagabunda* Hoek, *Enteromorpha intestinalis* Link and *Ceramium rubrum* Agardh, a trend established for other eutrophic zones along the Black Sea Coast, too (Dencheva 1996).

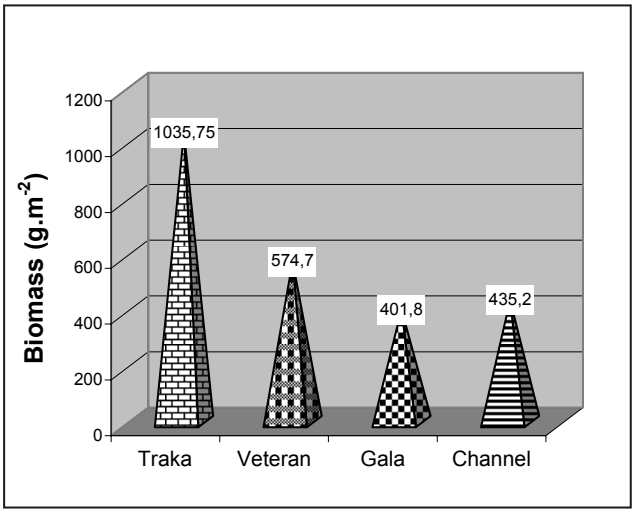

Fig. 3. Comparison of the average annual biomass along the investigated transects.

The trend in distribution of the production corresponds well to the pattern of biomass variation. The highest production was recorded in the Traka transect (0.779 $kg.m^{-2}$ per month) and the lowest in the Channel (0.731 $kg.m^{-2}$ per month) (Fig. 4).

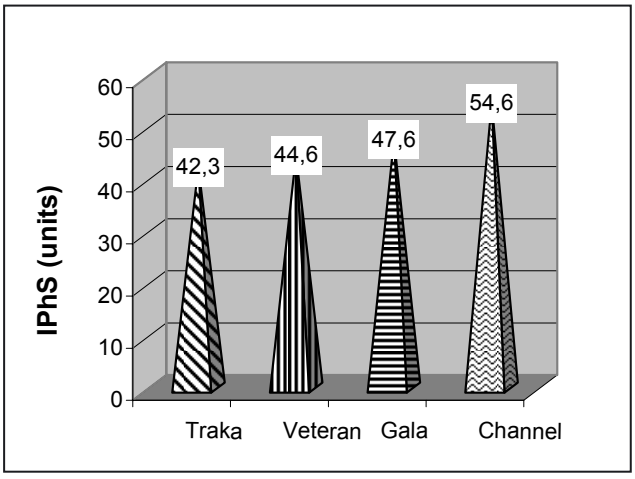

Fig 4. Comparison of the average annual production along the investigated transects.

Based on the direct ratio between specific surface and functioning intensity of the macrophytes, the values of the active surface area of macrophytes, or the in-

tensive surface of phytcoenoses (IPhS) per square meter of the substrate, consequently could be regarded as specific characteristics of the autothrophic process in any area of the ecosystem. The horizontal and vertical distribution of the IPhS (units) depends on factors determining the biomass dynamics and the specific surface of macrophytes, among which the intensity of the inflow of matter and energy and the substrate are the key elements.

Spatial variation of the average annual intensive phytocoenoses surface (IPhS) presented in Fig. 5 was in conformity with the trends established for the other parameters discussed above, an increase along the gradient Traka – Channel: IPhS Traka (42.3) – IPhS Veteran (44.6) – IPhS Gala (47.6) – IPhS Channel (54.6).

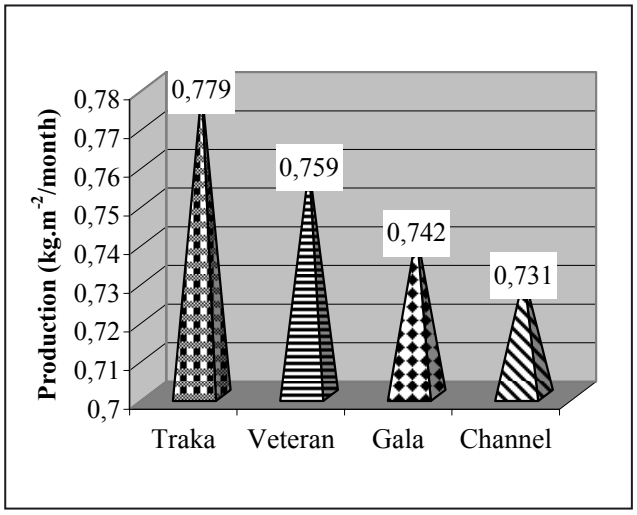

Fig. 5. Comparison of the average annual phytocoenotic surface indexes (IPhS) along the investigated transects.

The average IPhS in the Varna bay region was 44.8, while in the Channel transect it was 54.6 units (Table 2), suggesting that this parameter is a reliable indicator of the level of anthropogenic impact.

Table 2. Average IPhS values in Varna bay, the Channel, Odessa bay.

Region	Varna bay	Channel	Odessa bay
IPhS (units)	44.8	54.6	50–60

The average calculated values of IPhS in Varna bay and the Channel (49.7), were close to the values recorded in Odessa bay, where a high level of eutrophication was indicated (Minicheva 1989). Therefore, according to the values of all estimated parameters, Varna bay could be characterised as one of the ecologically hazardous regions along the Bulgarian Black Sea Coast.

It is generally agreed that the macrophytes are good bioindicators of changes in marine environmental conditions, included as a key biological element for ecological quality assessment in WFD. The effect from increased nutrient loading is decline of diversity, biomass, disappearance of some typical species, and their substitution by other macrophytes, distinguished by their shorter life cycle and higher specific surface.

The presently calculated floristic indices, as compared to earlier periods, indicate an increased level of eutrophication (P = 6.3) (Table 3).

Table 3. Comparison of the floristic indices of macrophytobenthic coenoses in Varna bay from different periods of investigation.

Period	1904–1939	1969–1972	1994	1998
Floristic index (P)	4.3	5.3	5.8	6.3

Community alterations were mainly due to disappearance of a substantial number of species from the *Rhodophyta* and *Phaeophyta* phylums and decrease of the oligosaprobic species (Dencheva 1996).

Conclusions

The higher intensity of the autothrophic process in the Channel, expressed by the IPhS values calculated per m^2 of the hard substrate, and specific surface values, signify the highest level of eutrophication, corresponding to the high nutrients loading of the bay from this zone (Stojanov 1991; Doncheva & Moncheva 2004).

The values of biomass, production, specific surface, and intensive phytocoenotic surface indicate the following gradient between the investigated transects in Varna bay: Traka –Veteran – Gala, along which the level of eutrophication increases. As reported, the concentrations of nutrients and the intensity and frequency of phytoplankton blooms were higher in cape Gala (Stojanov 1991; Velikova & al. 1999), related mainly to the impact of lake Varna and the Channel current into the bay (Stojanov 1991; Doncheva & al. 2003; Doncheva & Moncheva 2004).

Application of the proposed method, based on the estimation of structure- functional parameters of macrophytobenthic coenoses, proved relevant and could be used to assess and compare the level of authotrophic processes within and between any ecosystems.

References

Dencheva, K. 1996. Macrophytes – bioindicators of the water state in Varna bay. – Dokl. Bulg. Akad. Nauk., **49**(9-10): 123-126.

Doncheva, V.G., Moncheva, S.P., Malej, A., Fonda-Umani, S., Kamburska, L.T., Slabakov, H. & Christova, O.D. 2003**.** An assessment of the trophic state of marine coastal environment: Case studies – Varna Bay (Western Black Sea) and Gulf of Trieste (Northern Adriatic). – In: **Yilmaz, A.** (ed.), Proc. Second Int. Conf. "Oceanography of the Eastern Mediterranean and the Black Sea: Similarities and Differences between Two Interconnected Basins", October, 2002, Ankara, Turkey. Pp 500-508. Tubidak publishers, Ankara.

Doncheva, V. & Moncheva, S. 2004. Varna Bay Biogeochemical Budget / Black Sea http://data.ecology.su.se/mnode/Europe/Med_Aegean_BlackSea/Bulgaria/VarnaBay

Eryomenko, T. 1980. Methods for Studying of Marine Phytobenthos. Guidebook of Methods for Studying the Biological Analysis of Benthic Sediments. Hydromethedition, Leningrad (in Russian).

Firsov, K. 1984. Hierarhic structure – functional analysis of marine multicellular algae *Cystoseira barbata*. *PhD Thesis*. Inst. Biol., South. Seas, Sevastopol (in Russian, unpubl.).

Gutnik, A. 1975. Phytobenthos of the Black sea. Naukova Dumka. Kiev (in Russian).

Gutnik, A. 1989. Changes of species structure of phythobenthos in Lapsi bay for the period of 1964-1983. – Ekol. Morya, **31:** 7-11 (in Russian).

Haylov, M. & Parchevskii, N. 1983. Hierarhic Regulation of Marine Plants Structure and Function. Naukova Dumka, Kiev (in Russian).

Lakin, G. 1980. Biometry. Naukova Dumka, Kiev (in Russian).

Minicheva, G. 1993. Structure-functional pequliarities of macrophytobenthic commmunities formation. – Algologia**, 3**(1): 3-12 (in Russian).

Minicheva, G., Zotov, B. & Kosenko, M. 2003. Methodical recommendations for the morpho-functional indexes definition of unicellular and multicellular forms of aquatic vegetation. Inst. Biol. Southern Seas, NASU, Odessa.

Moncheva, S., Skretas, O., Pagou, K. & Krastev, A. 2001. Phytoplancton blooms in the Black Sea and Mediterranean coastal ecosystems subjected to anthropogenic eutrophication: similarities and differences. – Estuarine Coastal Shelf Sci., **53**: 281-285.

Prodanov, K., Moncheva, S., Konsulov, A., Kamburska, L., Konsulova, Ts. & Dencheva, K. 2001. Recent ecosystem trends along the Bulgarian Black Sea Coast. – Trudove Inst. Oceanol., **3**: 110-127.

Shtereva, G., Moncheva, S., Doncheva, V., Christova, O. & Shterev, I. 1999**.** Changes of the chemical parameters in the close-range coastal Black Sea area (Bulgarian section) as indication of the ecological characteristic of the environment. – Water Sci. Technol., **39**(8): 37-45.

Stefanova, K., **Todorova, V., Kamburska, L. & Dencheva, K.** 2005. The Black Sea ecosystem in front of the Bulgarian coast – research review and contemporary state. – In: **Petrova, A.** (ed.), Current state of Bulgarian biodiversity – problems and perspectives. Pp. 447-468. Bulgarian Bioplatform, Sofia (in Bulgarian).

Stojanov, A. 1991. Negative changes in the hydrochemical regime in Beloslav lake – Varna bay area. – In: Rational Use and Protection of Natural Resources of Varna Region, Varna. Pp. 38-46. Union of Scientists, Varna (in Bulgarian).

Velikova , V. Moncheva, S. & Petrova, D. 1999. Phytoplancton dynamics and red tides (1987–1997) in the Bulgarian Black Sea. – Water Sci. Technol., **39**(8): 27-36.

Vodianitskaya, N.1936. Quantitative assessment of benthic plants in the Black Sea. – Trudy Sevastopol'sk. Biol. Stantsii, **5**: 133-139 (in Russian).