Macrophytobenthos

Kristina Dencheva
Institute of Oceanology, BAS,Varna
e-mail : Dencheva@io-bas.bg

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1. Introduction

For the purposes of the EU Water frame Directive, ecological water quality is an overall expression of the structure and function of the biological community taking into account geographical and climatic factors as well as physical and chemical conditions, including those, resulting from human activities (Orfanidis & al., 2001). The coastal waters that concentrate the most life forms and productivity are being severely threatened by anthropogenic pressure. The management of these ecosystems requires a special approach that can assess the intensity of anthropogenic stress or ecological status.

Human activities in last decades greatly accelerate eutrophication by increasing the rate at which nutrients and organic substances enter aquatic ecosystem from their surrounding watersheds in Varna and Bourgas bay (Stojanov 1991, Rojdestvenskii 1986, 1993). 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 (Dencheva, 1996; Moncheva & al. 2001; Prodanov & al. 2001; Stefanova & al. 2005). The degradation of biological structures of the ecosystem, with parallel worsening of marine water quality, decrease the resource value of ecosystem such that recreation, fishing, hunting and aesthetic enjoyment are hindered. Health related problems can occur. In these conditions, the plants first react to the eutrophication factor. Ecological effects are decrease of biodiversity, substitution of some species with other filamentous with shorter life cycle and high specific surface (Minicheva 1993).

The aim of this project is to estimate the present trophic level and to asses the ecological state as it is proposed in European Water Frame Directive. The operative solution of this problem is possible with the help of new, original , cost-effective approaches of expertise of the state of marine coastal zones, with complex of morpho-functional parameters.

Marine macrophytes penetrate biogenic elements directly with whole their surface from the marine environment and thus represent sensitive indicators of its changes. They are very important biological elements for estimation of the ecological status, because, growing in the nearest coastal zone, macrophytobenthic communities first react to the pollution from land sources.

2. Material and methods

Nine transects were explored in Varna bay, Varna lake, Beloslav lake and Bourgas Bay (Figure 1).

Figure 1: Map of the investigated transects. Beloslav lake (1), Varna lake (2,3), Varna bay (Trakata-6, Treta buna-5, Galata-4), Bourgas bay (Sveti Vlas-7, 8, Maslen nos-9).

Coordinates of sampling sites were processed with JPS and are presented in Table 1.

Table 1: Coordinates of investigated transects.

Transect	Koordinates
Beloslav lake1	N43°11.643’ E027°43.027’
Varna lake 2	N43°11.937’ E027°48.515’
Varna lake3	N43°11.135’ E027°50.217’
Galata 4	N43°10.245’ E027°56.607’
Treta buna 5	N43°12.432’ E027°57.558’
Trakata 6	N43°13.114’ E027°58.826’
Sveti Vlas 7	N42°42.536’ E027°43.920’
Bourgas bay 8	N42°30.231’ E027°32.047’
Maslen nos 9	N42°19.970’ E027°45.566’

In total 257samples were collected from the summer season in 2008 year from the littoral zone up to 5 m depth with the help of diving technique, according to the method of squares (Morozova-Vodianitskaya, 1936). The method of hydrobotanical transects was used (Gutnik, 1975).

For the aims of the WFD some models for estimation of the ecological status were applied. One of them was proposed by Minicheva & al., 2003 calculation of the specific surface of macrophytes and the other is Ecological Evaluation Index of Orfanidis, (2001) - modified by us as estimation of biomass percent correlation between tolerant and sensitive species.

In phytocoenoses analysis, complex of new morpho-functional parameters of algae surface was used (Minicheva et al, 2003) and briefly, the essence is the following.
It is well known and prooved in the literature, the relation between the specific surface (S/W) of macrophyte species and their photosynthetic rates and metabolic and catabolic plant processes. Consequently, S/W as a structure-functional characteristic of species is applied and gives information about the intensity of functioning of the species. The structure and functioning of species composition depends on eutrophication level. When the level of eutrophication is higher, the species with higher specific surface prevail. S/ W is the correlation between whole surface of the species and his biomass. This parameter is estimated by the method of G. G. Minicheva [1993], according to which, the macrophyte species are divided into two basic groups-lamellar and cylindrical types of structure, as for the first, 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 thalluses is measured in micrometers by mycroscope with the help of micrometer (250 measurements are necessary for reliable result). The specific surface of macrophytes is estimated in m^2 /kg by the above mentioned formulae, (G. G. Minicheva, 1993). The parameters-specific surface of populations (S/Wp), give an account not only for the species morphological peculiarities, but the structure of their populations. In the method, (G. G. Minicheva, 1993) S/Wp is proposed for indirect functional assessment of populations. For reliable estimation of S/W of populations, this method comprises preliminary calculated number of plants, which is necessary to be processed.

The estimation of Ecological evaluation index (EEI) of Orfanidis (2001) is modified and based on biomass estimation. The biomass percent correlation between ESG II group (tolerant species) and Ecological state group I (ESG I) - sensitive species was measured.
Sampling sites were chosen according to criteria's and aim of this project. Bourgas and Varna bay are the biggest ports in Bulgarian Black sea coast. They play very important role in international communications and are economically valuable zones. That is why, the monitoring and maintaining of good ecological state is very important.

Bourgas bay was expected to be the transect with very bad conditions. It is well documented in literature that this region is very hazardous because of high concentrations of biogenic elements (phosphates and nitrates) and low values of dissolved oxigen (Rojdestvenskii 1986, 1993) and phytoplankton blooms (Atanasova V, V.Velikova, S Manasieva.1995) . Svety Vlas (north part of Bourgas bay) and Maslen nos (south part) are more distant from basic sources of pollution.
Similar is the situation in Varna bay. As reported in the literature, the concentrations of nutrients and the intensity and frequency of phytoplankton blooms were higher in cape Galata (Stoianov, 1991; Velikova & al.1999) related mainly to the impact of Varna and Beloslav lakes and the channel current, entering the bay(Stojanov,1991; Doncheva & al. 2003; Doncheva & Moncheva 2004).

3. Ecological status of coastal waters and coastal lakes

From the investigated transects 2008 year, summer season, 32 species were established. 12 species belong to Chlorophyta type, 4- Phaeophyta and 13 are from Rhodophyta. One angiosperm Zostera noltii was defined and 2 species from other groups. 9 species belonged to sensitive, or K- strategies, and 21are tolerant or r-strategies or belong to second ecological state group-ESGII as is defined by Orfanidis, 2001. (Table 2).

Table 2: Floristic structure of macrophytes from the investigated transects and ecological state groups (ESG). 1. Beloslav lake 2.Varna lake 3.Varna lake 4.Galata 5.Treta buna 6.Trakata 7.Sveti Vlas 8.Bourgas. 9.Maslen nos.

Species	Sampling sites									ESG
	1	2	3	4	5	6	7	8	9	
Chlorophyta										
1. *Cladophora vagabunda* (Linnaeus) Hoek	+	+	+	+	+	+	+	+	+	II
2. *Cladophora albida* (Nees) Kützing				+						II
3. *Cladophora coelothrix* Kützing						+				II
4. *Ulva linza* Linnaeus					+	+				II
5. *Ulva intestinalis* Linnaeus	+	+	+	+	+	+	+	+	+	II
6.Ulva prolifera O.F.Müller								+		II
7. *Ulva compressa* Linnaeus	+	+	+							II
8. *Ulva flexuosa* Wulfen					+	+				II
9. *Ulva rigida* C.Agardh			+	+	+	+	+	+	+	II
10 *Chaetomorpha linum* (O.F.Müller) Kützing							+		+	II
11 *Chaetomorpha ligustica* (Kützing) Kützing	+			+						II
12. *Ulothrix implexa* (Kützing) Kützing			+				+	+		II
Phaeophyta										
13. *Cystoseira barbata* (Stackhouse) C. Agardh	+					+			+	I
14. *Cystoseira crinita* Duby	+					+	+		+	I
15. *Zanardinia prototypus* (Nardo) P.C. Silva	+								+	I

16. *Sphacelaria cirrosa* (Roth) C. Agardh									+	II
Rhodophyta										
17. *Ceramium rubrum* C. Agardh			+	+	+	+	+	+	+	II
18. *Ceramium diaphanum* var. *elegans* (Roth) Roth				+	+	+				II
19. *Polysiphonia subulifera* (C.Agardh) Harvey							+		+	II
20.P. denudata (Dillvin) Greville ex Harvey					+		+			II
21.P. elongata (Hudson) Sprenqel					+	+			+	I
22 *Corallina officinalis* Linnaeus	+				+				+	I
23 *Osmundea pinnatifida* (Hudson) Stackhouse	+								+	I
24 *Callithamnion corymbosum* (Smith) Lyngbye				+	+		+			II
25 *Gelidium latifolium* Bornet ex Hauck	+								+	I
26. *Gelidium crinale* (Hare ex Turner) Gailon						+	+			II
27. Goniotrichum elegans (Chauvin) Zanardini					+	+				II
28. Acrochaetium virgatulum (Harvey)Batters	+		+	+	+		+	+		II
29. *Phyllophora crispa* (Hudson) P.S. Dixon									+	I
Anthophyta										
30. *Zostera noltii* Hornemann						+		+		I
Cyanobacteria										
31, Calothrix aeruginea(Kützing) Thuret								+		
32. *Lyngbya majuscula (Dillwin)Harvey*	+	+				+				
Bacillariophyta	+	+	+							

On Figure 2 is revealed the biomass of macrophytobenthic communities from the investigated transects:

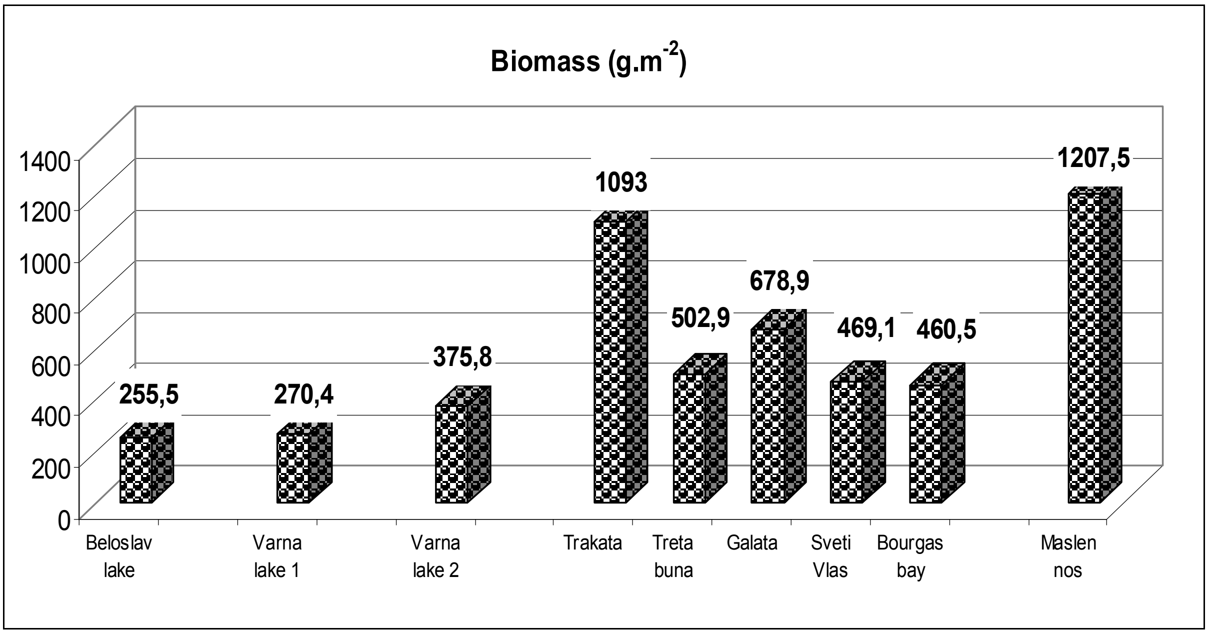


Figure 2: Macrophytobenthic communities biomass (g.m-2) from the investigated transects. 1. Beloslav lake 2.Varna lake 3.Varna lake 4.Galata 5.Treta buna 6.Trakata 7.Sveti Vlas 8.Bourgas. 9. Maslen nos.

The lowest biomass was registered in Varna and Beloslav lakes and it is explicable with the high nutrient loading and pollution from industrial complexes near the lakes (Stojanov, 1991; Doncheva & al. 2003; Doncheva & Moncheva 2004). The highest biomass was in Maslen nos, because this zone is characterized with most pure waters (Rojdestvenskii, 1993).

The next important index that characterizes macrophytes as reliable indicators is the specific surface(S/W) On Figure 3 is evident that the highest values of the specific surface are these in Beloslav and Varna lake, followed by transect Bourgas bay. The specific surface increases with higher level of eutrophication. Because Bourgas bay and Varna and Beloslav lakes are the most polluted zones of Bulgarian Black sea coast (Rojdestvenskii 1993; Stojanov, 1991; Doncheva & al. 2003; Doncheva & Moncheva 2004), the registered values of specific surface are high. The lowest values of S/W are calculated for Maslen nos transect.

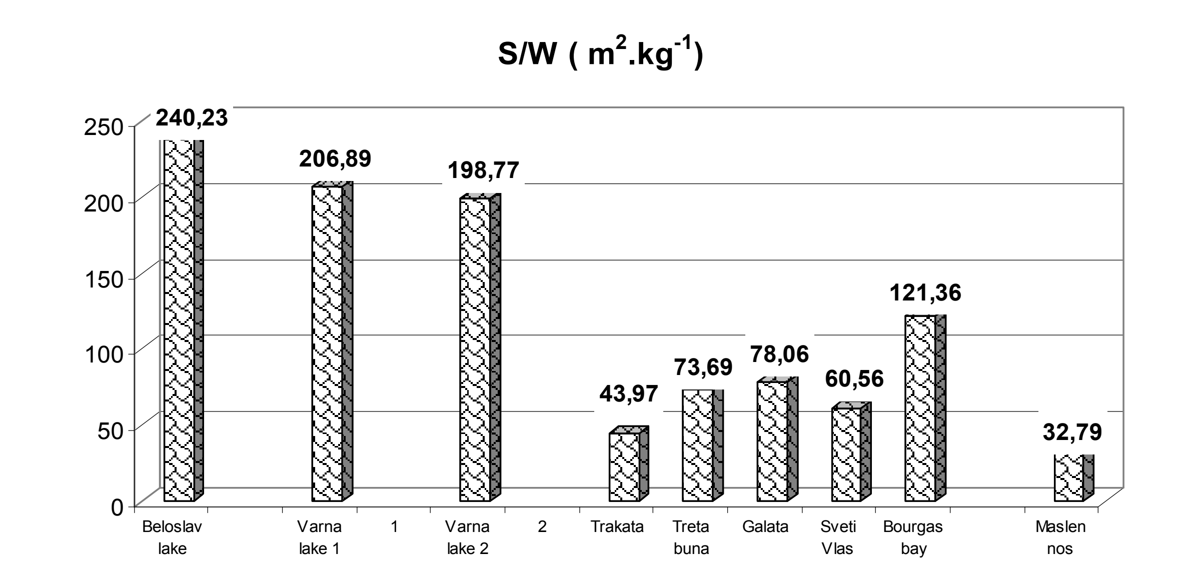


Figure 3: Specific surface values (S/W) of macrophytobenthic communities from investigated transects.

Based on the monitoring transects the following ecological quality ratios and boundaries of different state classes were developed for the Specific Surface Index from previous project:

Table 3: EQR of Specific Surface Index.

	High	Good	Moderate	Poor	Bad
S/W	15 ≤ S/W <25	25 ≤ S/W <45	45 ≤ S/W <75	75 ≤ S/W <100	100 ≤ S/W
EQR	> 0.91	0.73	0.45	0.23	≤ 0.23

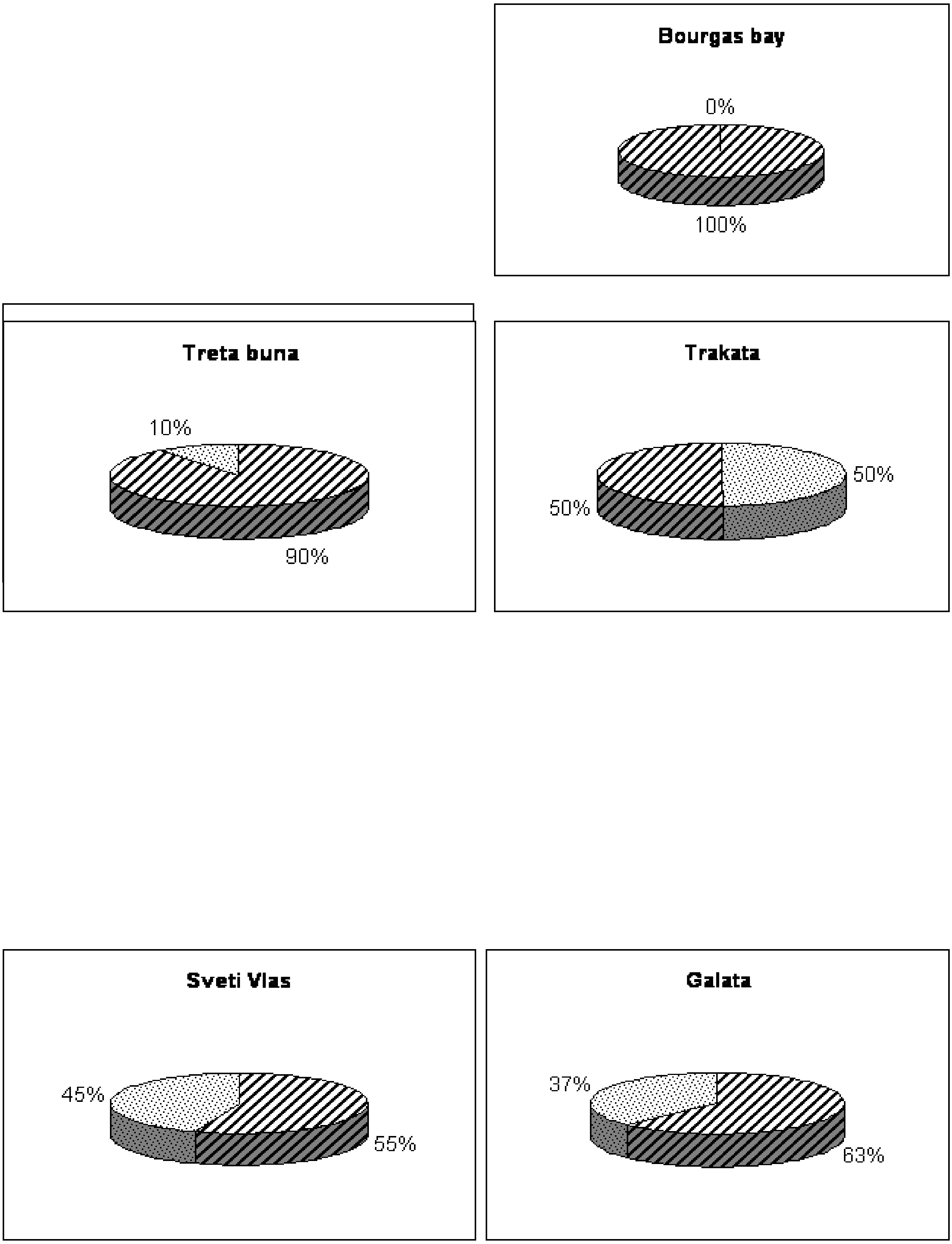
According to values of S/W, defined for ecological state classes we can establish the following state for investigated transects (Table 4).

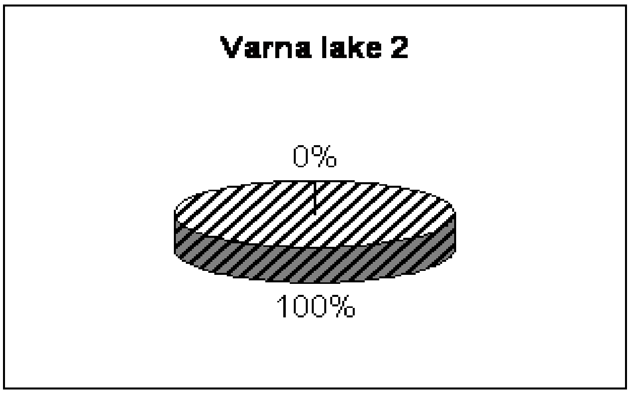
Table 4: Ecological status based on the Specific Surface Index

Transect	Values of the specific surface of macrophytes (S/W)	Ecological status
Maslen Nos	32.79	Good
Bourgas bay	121.36	Bad
Svety Vlas	60.56	Moderate
Galata	78.06	Poor
Treta buna	73.69	Moderate
Trakata	43.97	Good
Varna lake2	198.77	Bad
Varna lake1	206.89	Bad
Beloslav lake	240.23	Bad

On Figure 4 are presented percent correlations of biomass between macrophyte species from the two ecological state groups, defined by Orfanidis, 2001.
In Maslen nos and Trakata is the highest percent of biomass of sensitive to pollution species. Varna, Beloslav lakes and Bourgas bay transects are characterized with absence of sensitive and 100% biomass of tolerant species (ESGII).

Figure 4: Percent correlation of biomass between macrophyte species from the two ecological state groups-ESG I and ESG II. (1. ESG II - tolerant species biomass; 2. ESGI-sensitive species biomass)





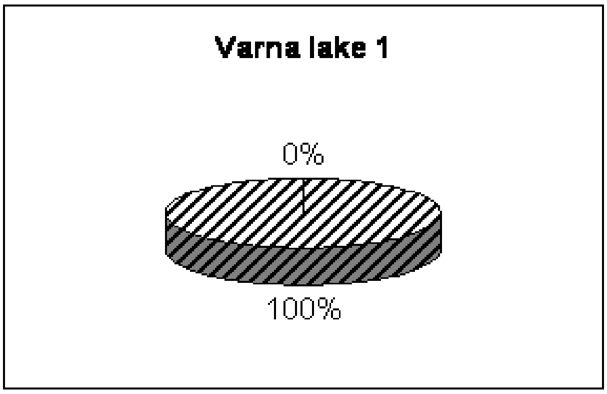


Table 5 shows values and boundaries for the ecological state classes for the Ecological Evaluation Index.

Table 5: EQR of Ecological Evaluation Index (EEI)

	High	Good	Moderate	Poor	Bad
EEI	10 ≥ EEI > 8	8 ≥ EEI > 6	6 ≥ EEI > 4	4 ≥ EEI > 2	2 ≥ EEI > 0
EQR	> 0.8	0.6	0.4	0.2	≤ 0.2

According to these values defined for ecological state classes we can establish the following state for investigated transects.

Table 6: Ecological status based on the Ecological Evaluation Index (EEI)

Transect	Ecological evaluation index - EEI	Percent correlation ratio of biomass between ecological state groups-ESG	Ecological status
Maslen Nos	7.5	75%:25%	Good
Bourgas bay	0	0%:100%	Bad
Svety Vlas	4.5	45%:55%	Moderate
Galata	3.7	37%:63%	Poor
Treta buna	1	10%:90%	Bad
Trakata	5	50%:50%	Moderate
Varna lake2	0	0%:100%	Bad
Varna lake1	0	0%:100%	Bad
Beloslav lake	0	0%:100%	Bad

In general, there is a good agreement between the assessments done based on the different metrics (EEI and S/W) for all stations (Table 7).

Table 7: Comparison of the results of the different metrics per transect.

Transect	Ecological evaluation index – EEI	Ecological status	Values of the specific surface of macrophytes (S/W)	Ecological status
Maslen Nos	7.5	Good	32.79	Good
Bourgas bay	0	Bad	121.36	Bad
Svety Vlas	4.5	Moderate	60.56	Moderate
Galata	3.7	Poor	78.06	Poor
Treta buna	1	Bad	73.69	Moderate
Trakata	5	Moderate	43.97	Good
Varna lake2	0	Bad	198.77	Bad
Varna lake1	0	Bad	206.89	Bad
Beloslav lake	0	Bad	240.23	Bad

The final ecological status, based on lower value of different metrics is presented on Table 8.

Table 8: Final ecological status based on macrophyte metrics

	Transect	**Final ecological status**
Coastal waters	Maslen Nos	Good
	Bourgas bay	Bad
	Svety Vlas	Moderate
	Galata	Poor
	Treta buna	Bad
	Trakata	Moderate
Coastal lakes (Varna)	Varna lake1	Bad
	Varna lake2	Bad
	Beloslav lake	Bad

A translation of these results towards the defined water bodies in Bulgaria gives the following result (Table 9).

Table 9: Ecological status of the biological quality element "Macrophytes" per coastal water body (WB) and for the coastal lakes (Varna)

WB	Region	Monitoring points (transects)	WB code	Type	Ecological status
4	Kaliakra cape - Ilandzhik cape	Trakata?	BG2BS000C004	CW602330	Moderate
5	Varna bay	Galata, Treta buna	BG2BS000C005	CW602330	Bad
8	Bourgas bay (<30 m)	Bourgas bay	BG2BS000C008	CW602330	Bad
		Svety Vlas	BG2BS000C008	CW602330	Moderate
9	Protected site of Koketrays	/	BG2BS000C009	CW602310	?
10	Bourgas bay (>30 m)	Maslen nos	BG2BS000C010	CW602321	Good
11	Akin cape – Korakya cape	/	BG2BS000C011	CW602310	
	Coastal lakes (Varna)	Varna lake			Bad
		Beloslav lake			Bad

4. Historical data of investigated transects and tendencies

Historical data about macrophytes only exist for Varna Bay. For Bourgas bay the historical data are very limited. Varna and Beloslav lake are investigated for the first time in 2008 (current project). We have not any data for macrophytobenthos in this region.

4.1. Varna bay

During the last years, the coastal phytocoenoses in Varna bay were influenced by the deteriorated environmental conditions which led to structural changes in the qualitative composition. Calculated and compared with previous period of investigation, the floristic indices at present characterize increased level of eutrophication (Table 10).

Table 10: Comparison of the floristic indices of macrophytobenthic coenoses in Varna bay from the different periods of investigation.

Period	1904-1939	1969- 1972	1994	1999
Floristic index (p)	4.3	5.3	6.5	7

A comparative analysis shows that the number of macrophyte species registered in previous investigations (1904-1972) in the Varna region (Dimitrova, 1978) are significantly higher than these established at 1994, 1999 (Dencheva 1994; 1996) (Table 11). The disappearance of a great number of species from Rhodophyta and Phaeophyta has been observed (Table 11) and a decrease of oligosaprobic species (Table 12) which is possibly due to the increased level of eutrophication in the last decades.

Table 11: Changes in species structure of different types of macrophytes in Varna bay.

Type	1904-1939	1962-1972	1994	1999
Chlorophyta	10	9	13	13
Phaeophyta	11	6	4	3
Rhodophyta	37	23	14	8
Total	58	38	31	24

Table 12: Changes in saprobic structure of macrophytes in Varna bay in the years of investigation.

Period	1904-1939	1969-1972	1994	1999
Oligosaprobic	37	23	7	2
Mesosaprobic	16	11	18	14
Polysaprobic	5	4	6	8

Typical oligosaprobic species such as *Ralfsia verrucosa, Stilophora tuberculosa, Nereia filliformis, Dictiota dichotoma, Cladostephus verticillatus* are not registered at present in this region.

Dominant in biomass are the polysaprobic and mesosaprobic species of macrophytes such as *Ceramium rubrum, Callithamnion corrymbosum, Enteromorpha intestinalis, Ulva rigida*,

Bryopsis plumosa. Similar floristic structure is established for the Odessa bay, Ukrain (Minicheva, 1989).
. In Varna bay, the biomass of this species was estimated to be 7 $kg.m^{-2}$ for the period 1966-1969 and 1.1$kg.m^{-2}$ for 1997 up to maximal depth 2m. These data indicate reduction of this species biomass in Varna bay in horizontal (more than three fold).

Year 1998

On Figure 5 the average values of the specific surface of species along the investigated transects in 1998 are presented. It is clear, that the highest values are in the channel, (respectively 115.7 $m^2.kg^{-1}$), and the lowest are in Trakata (respectively 35.34 $m^2.kg^{-1}$).

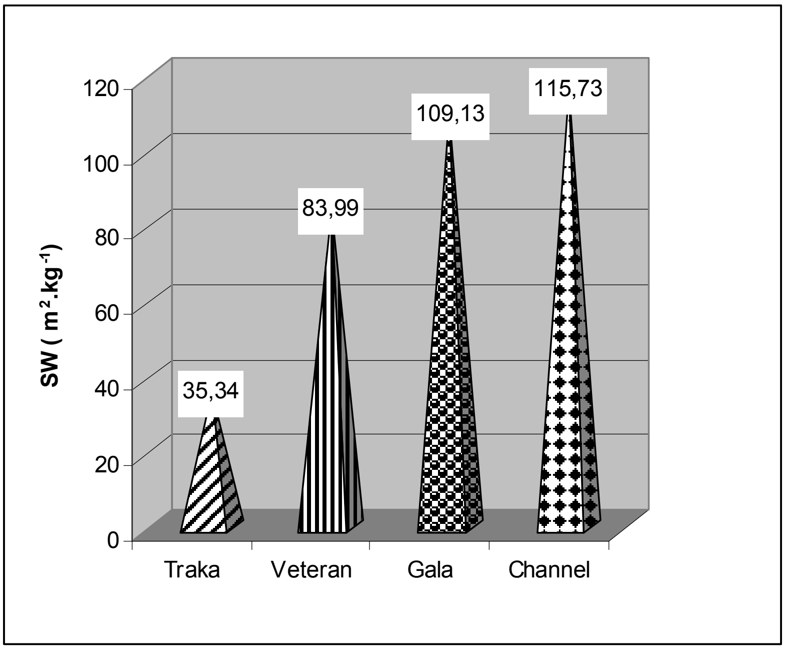


Figure 5: Comparison of average annual specific surface values (S/W) along the investigated transects (1998).

Presence of species with high functional activity reveals high level of eutrophication in the channel. According to average values of specific surface of macrophyte species, Varna bay (Table 13) is characterized as a mesothrophic region while the high average value of S/W in the channel determines it as strongly eutrophicated.

Table 13: Relationship between average specific surface values of macrophytobenthic coenoses and the trophy (1998).

Region	Varna Bay	Channel
Average specific surface of the species	76.15	115.73
Trophy of the ecosystem	Mesotrophic	Eutrophic

In this way, the average values of specific surface of dominant species of the investigated transects, could be used to express-assessment of the intensity of productivity processes in the coastal ecosystems.

On Figure 6 the average values of macrophyte biomass in the investigated transects are presented. It is obvious that these parameters decrease in direction from the Trakata transect to the channel, namely Trakata (1035.75g.m-^{2}) - Veteran (574.7 g.m-^{2}) - Galata cape (401.8 g.m-^{2}) and the channel (444.1 g.m-^{2}). The obtained results from the biomass are similar with these, established for the values of specific surface of macrophytes, but with reverse sign (the biomass decreases, and the specific surface increases with increase of eutrophication level). According to Kalugina-Gutnik, the biomass values reduce with the enhancement of the eutrophic level (Kalugina-Gutnik, 1975). This circumstance supports the fact, that the channel and Galata. transects are influence the most from the increased euthrophication in Varna bay (Stoianov,1991).

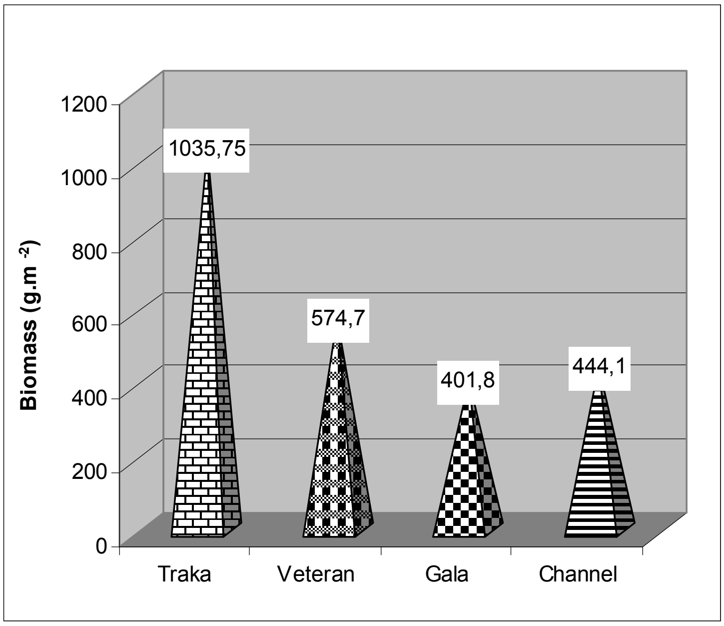


Figure 6: Comparison of average annual biomass values along the investigated transects (1998).

1999-2002

About the changes in the last years, especially characteristic is the lowering *of Cystoseira barbata* (Agardh, 1821) biomass in the bay-species indicator of pure waters. This oligosaprobic macrophyte with low specific surface and big size is substituted with other polysaprobic species as *Cladophora vagabunda* (Hoek,1963), *Enteromorpha intestinalis* (Link, 1820), *Ceramium rubrum* (Agardh-1810) with high specific surface.
According to average values of intensive phytocoenotic (IPhS) surface (Minicheva, 1989) and biomass of marophytobenthic communities, Traka transect (Table 14) is characterized as moderately eutrophicated, while the high average value of the specific surface and low biomass in the channel determines it as strongly eutrophicated.

Table 14: Relationship between average intensive photosynthetic surface and biomass values of macrophytobenthic communities and trophy (1999-2002).

Region	Traka	Channel
Average IPhS of species	41.6	61
Average biomass	911.8	484.6

The analysis of dominants in the floristic structure of the region in the period 1999-2002 with the specific surface parameters of the population, allows to get tentative idea about the intensity of processes, passing in plant communities. According to Minicheva, the mass species from the floristic composition along the investigated transects conventionally are divided in specific surface values:

a) under $10m^2.kg^{-1}$
b) from 10 to $30m^2.kg^{-1}$
c) over $30m^2.kg^{-1}$.

The majority of species (92%) with high level of functional activity, belongs to the most eutrophicated zone from the investigated ecosystem-the channel, from which the basic contaminants enter the bay (Stojanov,1991), followed by Galata transect (83%) and Veteran (72%). In Trakata transect, 33% belong to macrophytes with specific surface from 10 to 30 $m^2.kg^{-1}$. Here, the lowest percentage of values over $30m^2.kg^{-1}$(67%) are found. Species with S/W under 10 $m^2.kg^{-1}$ are not registered. (Fig.7).

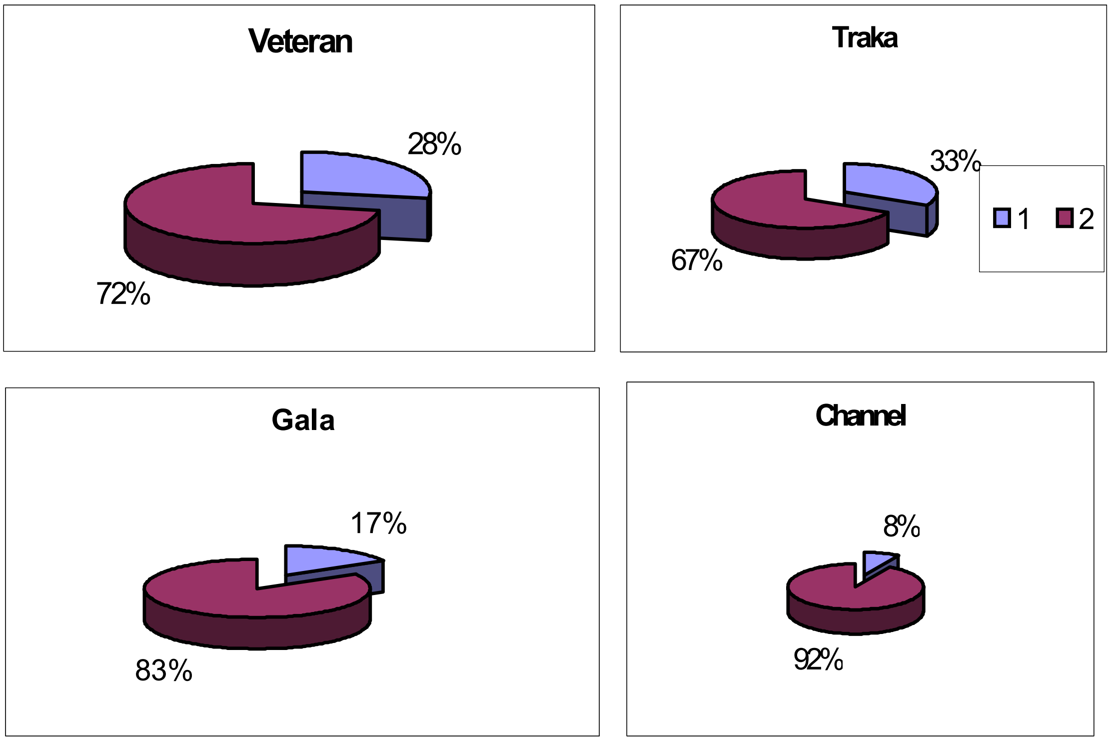


Figure 7: Comparison of the specific surface of macrophytes along the investigated transects (1999-2002) (1. S/W<$30m^2$. kg^{-1}; 2. S/W>$30m^2.kg^{-1}$)

On Figure 8 the average values of the specific surface of species (S/W) along the investigated transects (1999-2002) are presented. It is clear, that the highest values are found in the channel (respectively 95.59 $m^2.kg^{-1}$), and the lowest in Trakata (respectively 43.68 $m^2.kg^{-1}$). Presence of species with high functional activity reveals high level of eutrophy in the channel.

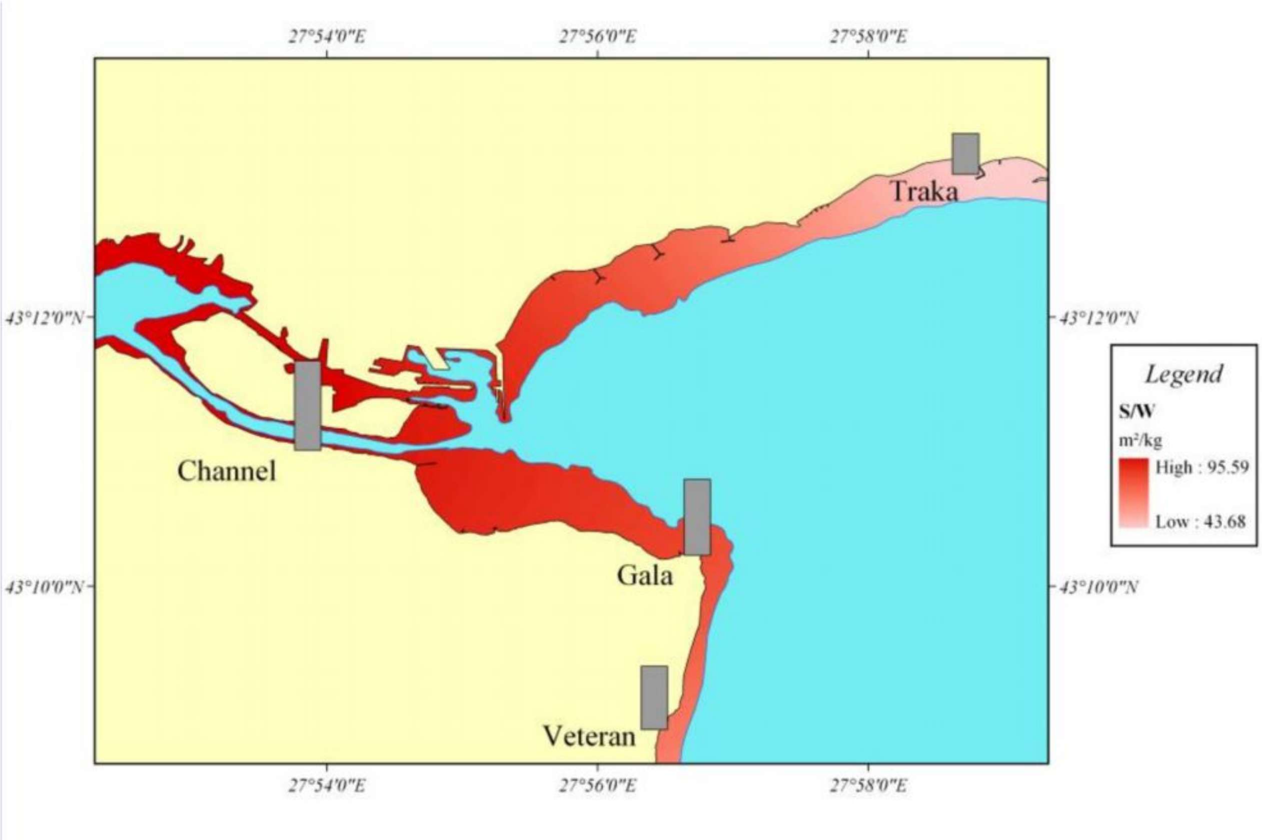


Figure 8: Comparison of average multiannual specific surface values along the investigated transects (1999-2002).

Figure 9 presents the average values of macrophyte biomass in the investigated transects. It is obvious that these parameters decrease in direction from the Trakata transect to the channel, namely Trakata (911.8g.m^{-2})-Veteran (613.83 g.m^{-2}), Galata cape (512.7 g.m^{-2}) and the channel (484.6 g.m^{-2}).The obtained results from the biomass are similar with these, established for the values of specific surface of macrophytes, but with reverse sign (the biomass decreases, and the specific surface increases with the increase of the eutrophication level.). According to Kalugina-Gutnik, the biomass values reduce with the enhancement of the eutrophic level [Kalugina-Gutnik, 1975]. This circumstance supports the fact, that the channel and Galata transects are under the strongest influence from the increased euthrophy entering Varna bay through the Channel from Varna and Beloslav lakes.

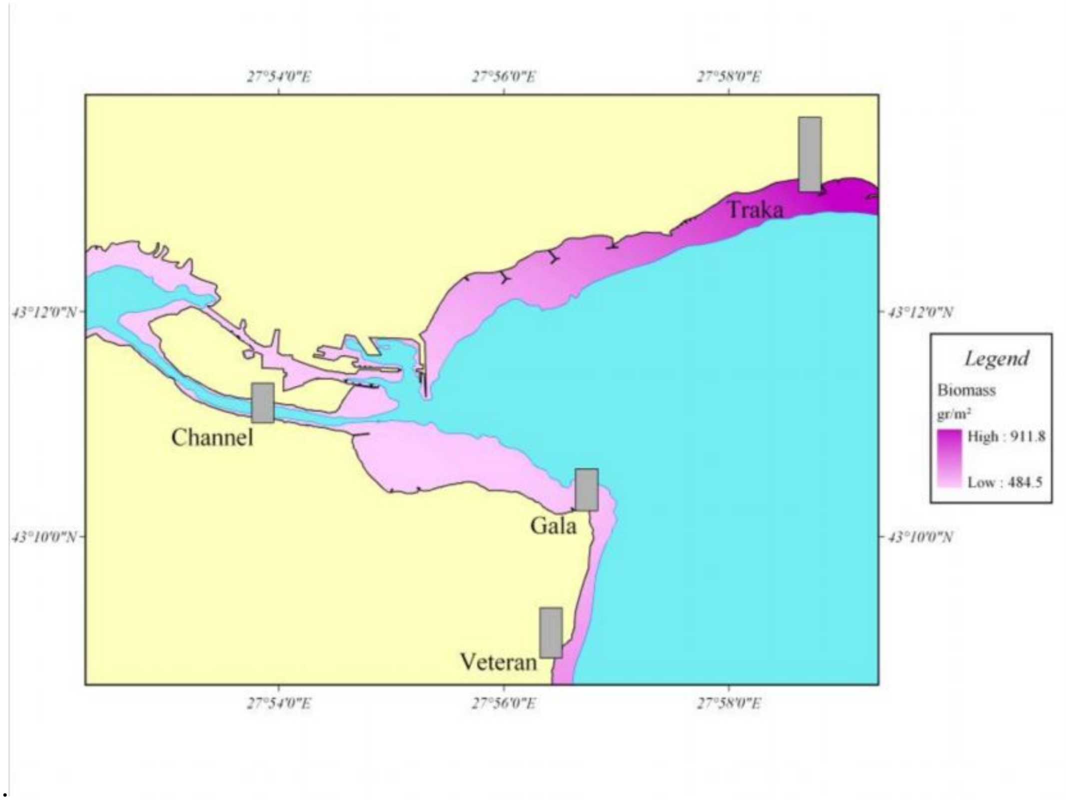


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Figure 9: Comparison of average multiannual biomass values along the investigated transects (1999-2002).

The calculated production, according to Minicheva, is highest (Figure 10) in Trakata and the Channel transects. The values in the channel are due to the presence of species with high specific surface and intensity of functioning and short life cycle, while in Trakata transect, production is high because of the presence of *Cystoseira* (high biomass, low specific surface).

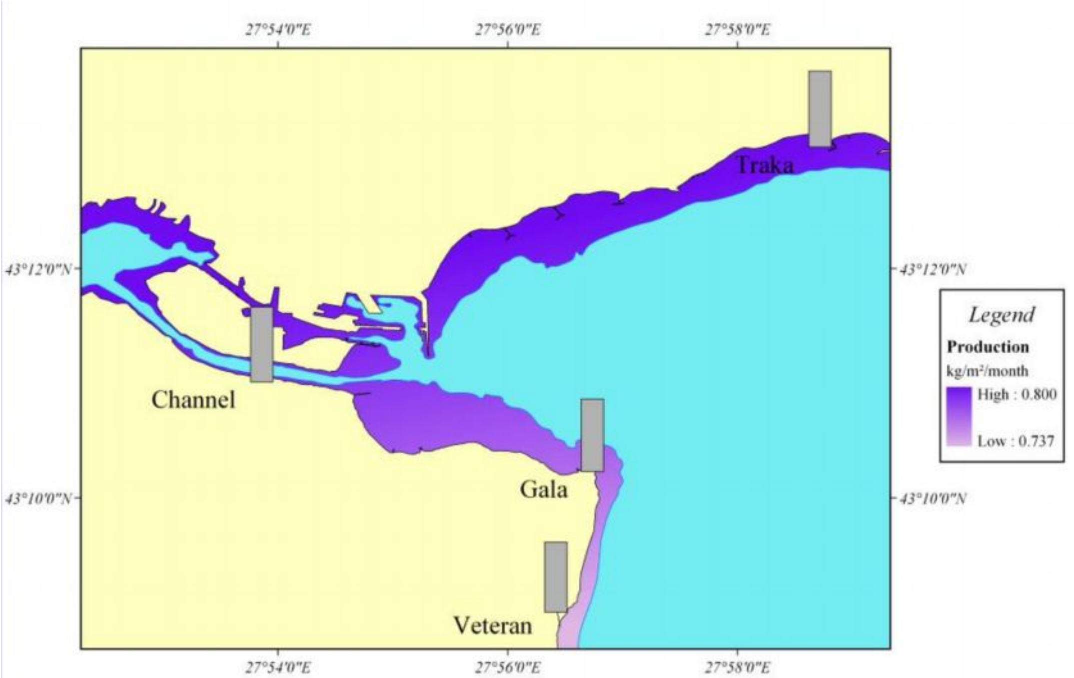

Figure 10: Comparison of production along the investigated transects in Varna bay (1999-2002).

Based on the direct ratio between the specific surface and the intensity of functioning of macrophytes, the values of the active surface area of macrophytes or the intensive surface of the phytcoenoses (IPhS), functioning per meter square of the substrate, consequently could be regarded as specific characteristic of the autothrophic process in any area of the ecosystem (Minicheva,1989). The average annual values of IPhS from the investigated transects (Figure 11), indicate the same tendency, established from the latter figures. The intensive phytocoenoses surface values increases in the following direction:IPhS Trakata (41.6) - IPhS Veteran (42.9) - IPhS Galata (49.7) - IPhS Channel (61).These values indicate increased level of eutrophication in this direction.

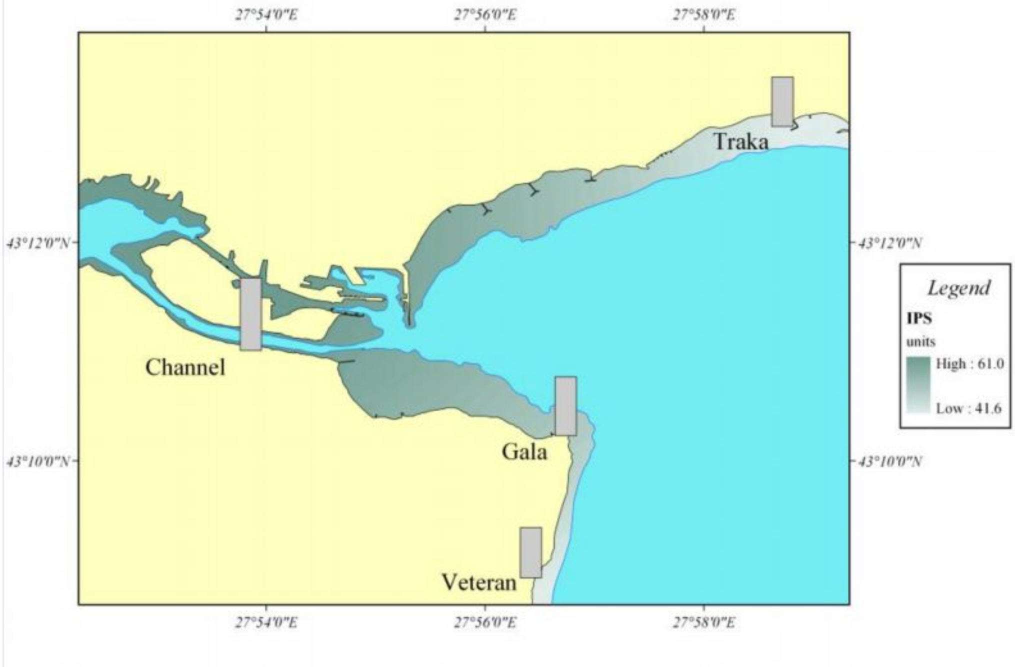

Figure 11: Comparison of average annual IphS values in Varna bay (1999-2002).

The level of the authotrophic process indirectly could be calculated and represented by the values of indexes of phytocoenotic surface (IPS). Consequently, this is a reliable parameter, indicating the level of anthropogenic effect and particularly the level of eutrophy in the investigated ecosystem. In Varna bay region, the following average values of IPS were estimated (Table 15).

Table 15: Average IPS values in Varna bay, channel for the 1999-2002 years of investigation and Odessa bay (Minicheva, 1989).

Region	Varna bay	Channel	Odessa bay
IPS/ 1999-2002	44.78	61	50 –60

The higer intensity of the authotrophic process in the channel, expressed by the IPS values, calculated per square meter from the hard substrate, establishes the highest level of eutrophication and it is absolutely explicable because of high concentration inputs of pollutants in the bay from this zone (Stoianov, 1991).
The calculated values of IPS in Varna bay are close to these established in Odessa bay , where a high level of eutrophication is registered (Minicheva, 1989). Therefore, Varna bay is characterized as one of the ecologically hazardous region for the Bulgarian Black sea coast. The eutrophication is due to high concentration of biogenic elements entering the bay, through the channel from Varna and Beloslav lakes (Stojanov 1991).

Biological tendencies: summary

Table 16 presents indexes of macrophytes in the years of investigation in **Varna Bay.**

Table 16: Biological tendencies Varna Bay (WB5)

WB	Transect/ year	EEI	S/W	Final ecological state
5	Galata 1998	0	77.83	Bad
	Galata 1999	0	90.86	Bad
	Galata 2001	0	87.53	Bad
	Galata 2007	0	98.48	Bad
	Galata 2008	3.7	78.06	Poor
	Treta buna 1998	1.9	55.44	Bad
	Treta buna 1999	1.9	73.13	Bad
	Treta buna 2001	1.4	47.1	Bad
	Treta buna 2002	0.6	61.03	Bad
	Treta buna 2007	0.0	91.35	Bad
	Treta buna 2008	1.0	73.69	Bad
4	Trakata 1998	6.6	28.44	Good
	Trakata 1999	7.4	31.45	Good
	Trakata 2001	8.0	30.9	Good
	Trakata 2002	7.9	34.32	Good
	Trakata 2007	8.0	48.41	Moderate
	Trakata 2008	5.0	43.97	Moderate

The above illustrated data for Varna bay establish the following tendencies:

- Since 1969 there was reduction of species structure and enhancement of polysaprobic and mesosaprobic species, and exchange with macrophytes with higher specific surface and short life cycle. The biomass of species with long life cycle and low specific surface decreases, and increases the biomass of species with short life cycle and higher specific surface. This tendency is actual for the last 10 years in Varna bay.
- There are some positive changes, registered this year. In Varna bay, sea grass *Zostera noltii* was registered for the first time from many years ago in Trakata transect and also big biomass of *Gelidiun crinale* and *Polysiphonia elongata*, but the status of Trakata for the last two years is still moderate.
- In Galata transect *Gelidium latifoloium* was found which was not typical for this transect. These are positive signs of recovering of some species. Also, the Ecological evaluation index and the specific surface in Galata this year are lower, than in previous investigations.

4.2. Bourgas bay

Table 17 presents indexes of macrophytes in the years of investigation in **Bourgas Bay.**

Table 17: Biological tendencies Bourgas bay

WB	Transect/ year	EEI	S/W	Final ecological state
8	Bourgas 2006	0	120.23	Bad
	Bourgas 2007	0	113.12	Bad
	Bourgas 2008	0	121.36	Bad
10	Maslen nos 1996	9.1	15.8	High
	Maslen nos 2007	8.7	22.49	High
	Maslen nos 2008	7.5	32.79	Good

For **Bourgas bay**, no historical data exist for macrophytes. The most recent data are from 2006. So, we can not comment tendencies, but from the literature and from our little study it is evident that this zone along the Bourgas town, especially the south part, where the industrial zone and port is, is in very bad condition and big risk.

The existing data for **Maslen nos** are scarce too. From Petrova (1975) we know that the biomass of *Cystoseira barbata* (1966-1969) was 10.3 kg.m-^{2} from 0-2m depth and now (2007-2008) it is 2 times lower and *Cystoseira barbata* is substituted mostly with *Cystoseira crinita*. The specific surface of this species is little higher than that in previous investigation. In the last years of investigation we can not mention other significant changes in species structure in this transect. In biomass there are no essential changes. The specific surface is little higher this year, in comparison with 2007 (Table 17). Generally, Maslen nos is a transect with good conditions (biological and hydrochemical) as it was mentioned in the report.
It is evident that the proposed metrics are with high sensitivity and complete each other and are reliable for assessment of ecological state

4.3. Varna and Bourgas lake

Varna and Beloslav lake are investigated for the first time in 2008 (current project). We have not any historical data for macrophytobenthos in this region.
The same is true for the Bourgas lakes.

5. Vulnerable zones

From the analysis above, our opinion is that at first place Varna and Beloslav lake are vulnerable zone because of:

- very high specific surface;
- lack of sensitive to pollution species with high specific surface and very short life cycle (microphytes take important place in lakes);
- very low biomass; and
- the fact that it is reduced in depth (it is due to the very low transparency and the high level of eutrophication and blooms of phytoplankton, Stojanov1991)

Varna and Bourgas bay (the part which is situated along the Bourgas town) also are vulnerable, especially their south parts.

6. Conclusions

The values of biomass, specific surface and ecological evaluation index indicate a high level of eutrophication for Varna, Beloslav lakes and Bourgas bay. It is proved that concentrations of biogenic elements and phytoplankton blooms are higher in these zones (Stojanov 1991; Velikova 1999; Rojdestvenskii 1986, 1993). The best values of the estimated metrics in Maslen nos are explicable due to the good ecological conditions in this zone and absence of sources of pollution close to this transect (Rojdestvenskii 1986, 1993).

The specific surface of macrophytes is a very sensitive metric and it is proved especially from the results, obtained for Varna and Beloslav lakes: the values of these metrics are indicative for more than 3 times higher eutrophication than in Varna bay and 2 times more than in Bourgas bay.

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