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MACROPHYTOBENTHIC COMMUNITIES FROM THE ROMANIAN BLACK SEA COAST - INDICATORS OF THE ECOLOGICAL STATUS OF COASTAL WATER BODIES

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ABSTRACT

Macrophytobentic communities answer to marine environment changes by modifying their qualitative and quantitative structure and can be used as indicators of changes in the marine environment. The paper presents the results for the Romanian Black Sea coast after the application of EI index (Ecological Index), developed to answer the Water Framework Directive requirements and used in the intercalibration exercise between Romania and Bulgaria. The results are expressed in relation to the average value of the species fresh biomass. The EI is reported to the EQR index (Ecological Quality Ratio), common for all biological elements according to WFD. The EI was applied to the 2011-2014 data set, providing an overview of the ecological status of the coastal zone according to the biological element macroalgae and angiosperms. The index has met the requirements of the Water Framework Directive and will be used in the future under the Marine Strategy Directive, which requires to maintain or achieve good environmental status. To validate the results, the response of the ecological index at the anthropogenic pressures from the coastal zone was tested throught the application of the pressure index LUSI_BS (Black Sea Land Use Simplified Index), developed during the Romania-Bulgaria intercalibration process.

Key-Words: Macroalgae, Water Framework Directive, Marine Strategy Framework Directive, Good environmental status, fresh biomass, pressure index

AIMS AND BACKGROUND

The submerged vegetation (macroalgae and marine phanerogams) represents a major component of primary producers, which forms the existence and development basis of life in marine environment, a real engine of marine ecosystem's material and energy flows. It is an important part of the food chain, a feeding and breeding area for zoobenthic communities that carry-out their vital processes within the thickets formed by macrophytes [1]. The macroalgae are an unique domain able to maintain the ecological balance in the marine coastal environment. The widespread reduction and disappearance of algal species over recent decades in the Black Sea due to the influence of anthropogenic pressures, caused a disruption of the functiong of marine coastal ecosystems and their food chains (eg. reduction of the zoobenthic communities, including various fish species) [2, 3, 4, 5].

Anthropogenic activities produce the nutrient enrichment of coastal waters, a direct effect being the development of macroalgae opportunistic species and an indirect one, sometimes with long-term consequences, the reduction and disappearance of perennial sensitive species [6]. In order to assess the ecological state of coastal waters, the ecological index (EI) was developed, based on the theory that the anthropogenic impact changes the state of an ecosystem, and turns it into an area where opportunistic R-selected species dominates instead of the K-selected sensitive ones [7]. This paper aims to characterize the coastal water bodies (both Northern and Southern sector) from an ecological point of view by applying and verifying the Ecological Idnex to the specific conditions of the Romanian Black Sea coast.

MATERIALS AND METHODS

The data used in this report encompass the period 2009-2014. The samples were collected from 11 stations, along the coastal strip Năvodari - Vama Veche (Năvodari, Pescărie, Casino Constanţa, Agigea, Eforie North, Eforie South, Tuzla, Costineşti, Mangalia, 2 Mai and Vama Veche), at depths between 1 and 3 m (Fig. 1). 3 replicates at each depth (1,2 and 3 m) were collected by means of a square frame with a side of 20 cm. The samples were entirely collected, including the holdfast for macroalgae and rhizomes for phanerogams, for a correct estimation of the fresh biomass.

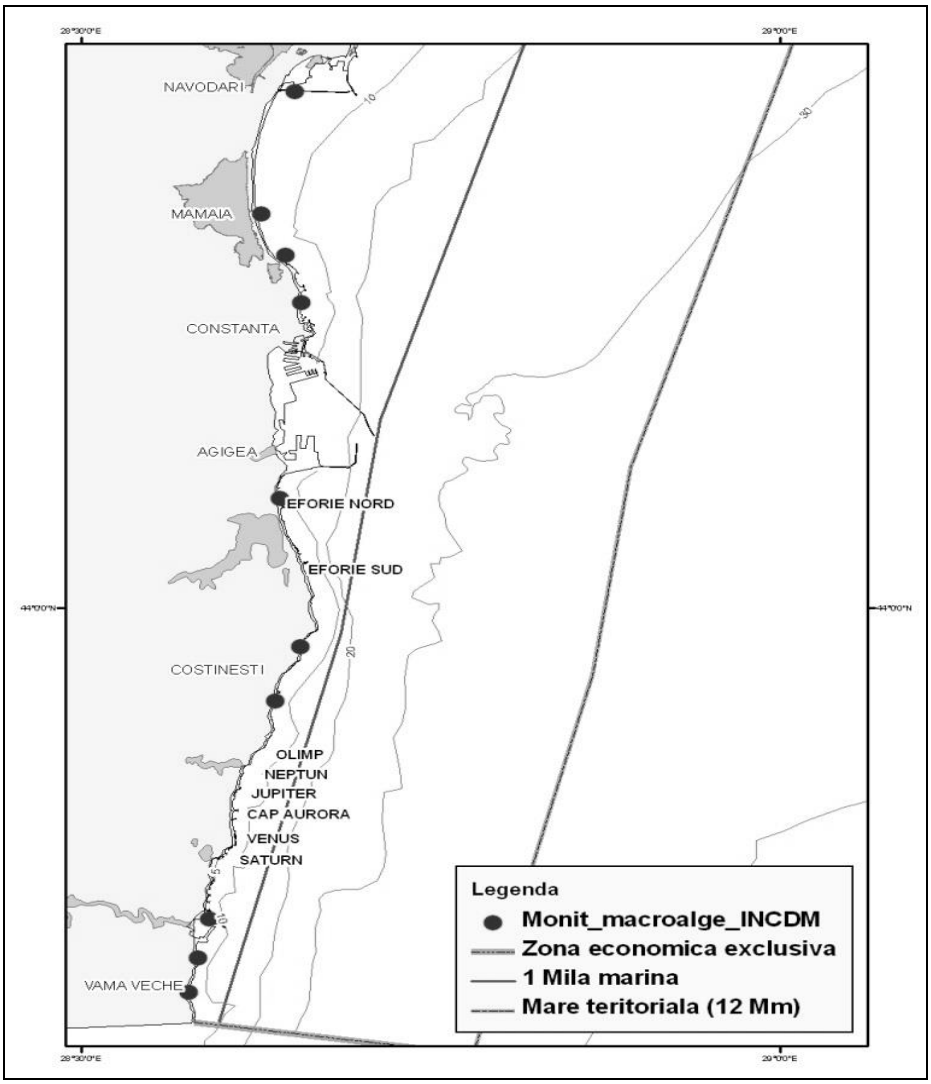


Fig.1. Romanian macroalgae sampling map

Samples were placed in labeled bags (the name of the station, sampling date and depth is noted), and submitted to a qualitative (species identification, species list preparation) and quantitative (weighing of samples and biomass estimation by multiplying with the coefficient 25) analysis. The quantitative evaluation is necessary for applying the ecological index (EI). Only species with 0.5 $g.m^{-2}$ and higher biomass were taken into account. Species with a lower biomass of 0.5 $g.m^{-2}$, have only accidental presence in that area, or have no significant input to the structure and functioning of the phytobenthic community, and are not considered for the index application.

The EI was firstly applied to the common water body between Romania and Bulgaria (the southern sector of the Romanian shore - Eforie Sud - Vama Veche), and

lately (after the Commission accepted the methodology) the application has expanded for the entire Romanian coastal areas. The EI was developed to answer the Water Framework Directive (WFD) requirements and it will be used in the future under the Marine Strategy Directive (MSFD), which requires to maintain or achieve good environmental status [8]. All of the 5 ecological classes, as required by the WFD can be adapted to determine good environmental status (GES) under the MSFD, according to the biological element 'macroalgae and marine phanerogams'. It can be considered that 'High Ecological Status' and 'Good Ecological Status' represent GES, while the other ecological classes, namely Moderate, Poor and Bad Ecological Status characterize an environment included in non-GES (acc. to Table 1). Using macroalgae and marine phanerogams and applying the EI, the demands of the Descriptors 1, 5 and 6 are met, out of a total of 11 qualitative descriptors.

Table 1. EI and EI-EQR of macrophytobenthic communities for different status classes

Biomass proportions of sensitive and tolerant species	EI	Ecological state class (acc. WFD)	EI-EQR	Ecological state class (acc. MSFD)
80-100% ESGI	7.8-10	High	0.837 – 1	GES
60-80% ESGI	6-7.8	Good	0.644 – 0.837	
40-60% ESGI	4-6	Moderate	0.429 – 0.644	non - GES
0-40% ESGI	2-4	Poor	0.214 – 0.429	
0% ESGI	< 2	Bad	< 0.214	

EI was calculated according to Dencheva et al. (2014) original method, with the corrections from the IC technical report, according to the Commission's suggestions [9,10]. Each species identified was included in ecological groups according to its tolerance to environmental conditions, namely ESG IA, ESG IB, ESG IC – perennial species indicator of less eutrophic areas, and ESG IIA, ESG IIB, ESG IICa, ESG IICb - opportunistic species able to thrive in eutrophic areas with a high reproductive capacity (eg. *Ceramium*, *Cladophora*, *Ulva*). Main criteria in differentiating the species into sensitivity groups was species morphology, biology and growth rates, as well as observational and experimental evidence of their sensitivity to eutrophication in the specific conditions of the Black Sea [11,12].

The average biomass of sensitive (ESGI) and tolerant (ESGII) species from all the samples collected from replicate transects is calculated. The index is expressed as the proportion of sensitive and tolerant species average biomasses at each transect. As a value of EI, the biomass proportion of the most sensitive group is taken into consideration. EI takes values in the range of 0-10, divided in five classes: 0-2 - bad status, > 2 - 4 – poor status, > 4 - 6-moderate, > 6 – 7.8 good and > 7.8 - 10-high status (Table 1). The proportion of each ESG group within the two main groups ESG I and ESG II was corrected with a coefficient. The criteria for this correction were distribution along the eutrophication gradient, phenotypic plasticity and growth rate.
Weight coefficients were defined for different subgroups as follows:

ESG IA–coef=1
ESGIB-coef=0.8
ESGIC-coef=0.6
ESGIIA-coef=0.6
ESGIIB-coef=0.8
ESGIIC-coef=1

To calculate the value of EI the following rules and formulas are applied:

- When ESGI=0, ESGII(A +B) = 0: EI-bad (0-1) = [ESGIICa/ESGII]
- When ESGI=0 and 0%>ESGII(A+B)≤ 100% is a bad status and EI takes values between 1-2.

EI-bad(1-2)
=[(ESGIIA/(ESGIIA+ESGIIB+ESGIIC))*0.6+(ESGIIB/(ESGIIA+ESGIIB+ESGIIC)*0.8]+1

- When ESGI is between 0 - 40%, EI takes values between 2 - 4 and is a poor status.

EI-poor(2-4)
=[(ESGIA/(ESGI+ESGII))*1+(ESGIB/(ESGI+ESGII))*0.8+(ESGIC/(ESGI+ESGII))*0.6]*5)+2

- When the proportion of sensitive species is between 40-60%, EI is between 4-6.

EI high, good, moderate (4-10)
=[(ESGIA/(ESGI+ESGII))*1+(ESGIB/(ESGI+ESGII))*0.8+(ESGIC/(ESGI+ESGII))*0.6]*10

To ensure comparability in accordance with the WFD, the EI values ranging from 0 to 10 can be transformed into Ecological Quality Ratios (EQR) from 0 to 1, meaning the ratio between the value of the observed biological parameter and the expected value under the reference conditions, as follows:

EI_EQR= (EI obtained value/RC value), where the referent value is RC=9,32 [10].

To validate the ecological index values, the EI-EQR was tested against the anthropogenic pressures, knowing that the coastal water bodies are submitted to a continous human impact, due to the urban development. For that purpose a modified version of the LUSI pressure index was applied which was adapted to the specific conditions of the W Black Sea coast and local anthropogenic pressures on macroalgal communities (LUSI_BS). Pressure values for direct impacts were calculated based on land usage from the Corine Land Cover 2006 database (the most recent available for Romania), in accordance with Flo et al. (2011)[13]. Taking into account the strong local influence of inputs of nutrients from land by wetlands and rivers outflow, land use was calculated for watersheds adjacent to the sampling sites along the coast. In coastal areas with no river beds and watersheds, land use was determined in land territories ~5 km

around the sampling stations. LUSI_BS values were calculated based on 3 km buffers of the evaluated territories, using the scoring table of Flo et al. (2011) for percentage of different categories land use (Fig. 3). Indirect impacts were assessed, adding additional scores (0 to 3), based on data for nitrogen and phosphorus inputs from point sources (waste water treatment plants, untreated waters, river inputs), proximity to major ports and touristic centers, and proximity to water bodies in degraded state. A correction number, based on the shape of the coastline and possible confinement of water circulation was also applied (acc. to Flo et al., 2011) [13].

The final LUSI score was calculated with the following formula:
LUSI_BS=(Score urban + score agricultural + score industrial + score typology + others significant pressures) * Correction number

RESULTS AND DISCUSSION

The EI, currently applied at the Romanian shore, reflects the ecological state of the marine ecosystem, simplifying a complex reality. Analyzing a complete data set, the EI provides useful informations regarding the macrophytobenthic communities and their possible qualitative (the appareanc/dissapereance of a species) and quantitative changes. The index was applied both Northern and Southern sector.

After the application of the EI-EQR for the coastal water bodies Periboina-Cap Singol and Cap Singol-Vama Veche, all of the 5 ecological classes - Bad Poor, Moderate, Good, High Ecological Staus were fully covered. Periboina-Cap Singol was sampled along 3 stations (Năvodari, Pescarie, Cazino Constanța) and the index obtained values were low, higher only at Năvodari, due to the presence of the *Zostera-Stuckenia-Ruppia* association. In the water body Cap Singol-Vama Veche, at Agigea, Eforie Nord, Eforie Sud and Tuzla, as a result of increased nutrient inputs from harbour and treatement plants influences, opportunistic species dominate, hence lower index value and Bad Ecological Status were obtained. In highly eutrophic conditions, macrophytobenthic communities obtain a very simplified patchy structure, with monospecific character, with a lower number of opportunistic species, that thrive, especially during the summer season (the opportunistic genera *Ulva*, *Cladophora* and *Ceramium*).

Higher values were obtained for the Romanian shore in the Southern part (from Costinesti to Vama Veche) due to the presence of the perennial species *Cystoseira barbata* and *Zostera noltei*). This high productivity of the key species means also a higher biodiversity. The extreme Southern part 2 Mai – Vama Veche is shelter for some important phytobenthic species (*Cystoseira barbata, Corallina officinalis, Lomentaria clavellosa, Hildenbrandtia rubra, Zannichellia palustris*) and a rich associated fauna, hence it has a marine protected area status.

The increase of the index value from North to South can be noticed (towards a higher ecological state), with the highest values at Vama Veche, where the anthropogenic activity is low, and the natural, rocky substrate offers good conditions for the development of typical Black Sea macrophytobenthic communities, in particular

of the *Cystoseira barbata-Ulva rigida* association. Although the High Ecological Status has not been reached yet at Vama Veche, there is tendency for a gradual increase of the EI-EQR between 2011-2014 and the improvement of the ecological state. Taking into account the lower pressure index value, and the presence of well-developed *Cystoseira barbata* fields, it's possible that in the future this high ecological state will be reached (Fig. 2).

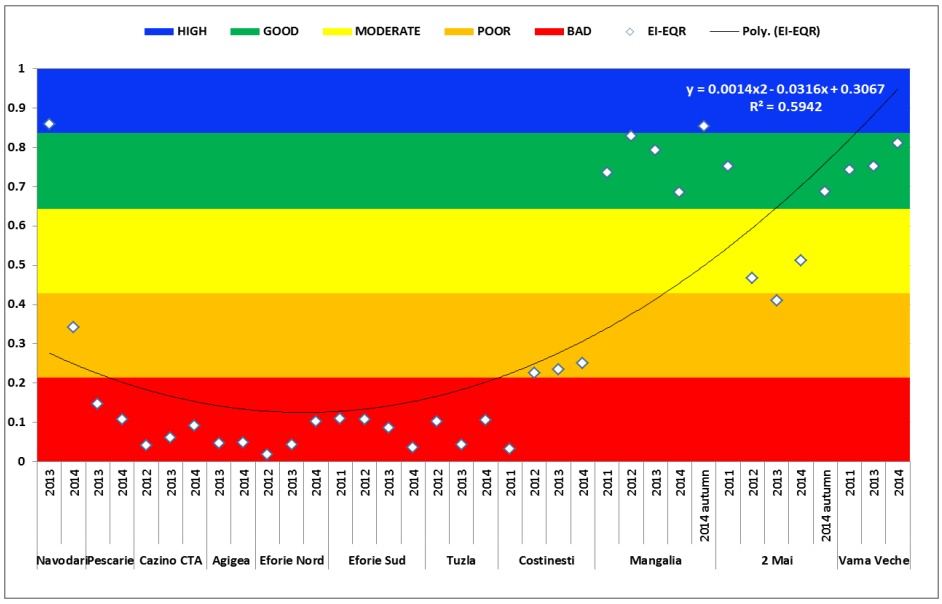
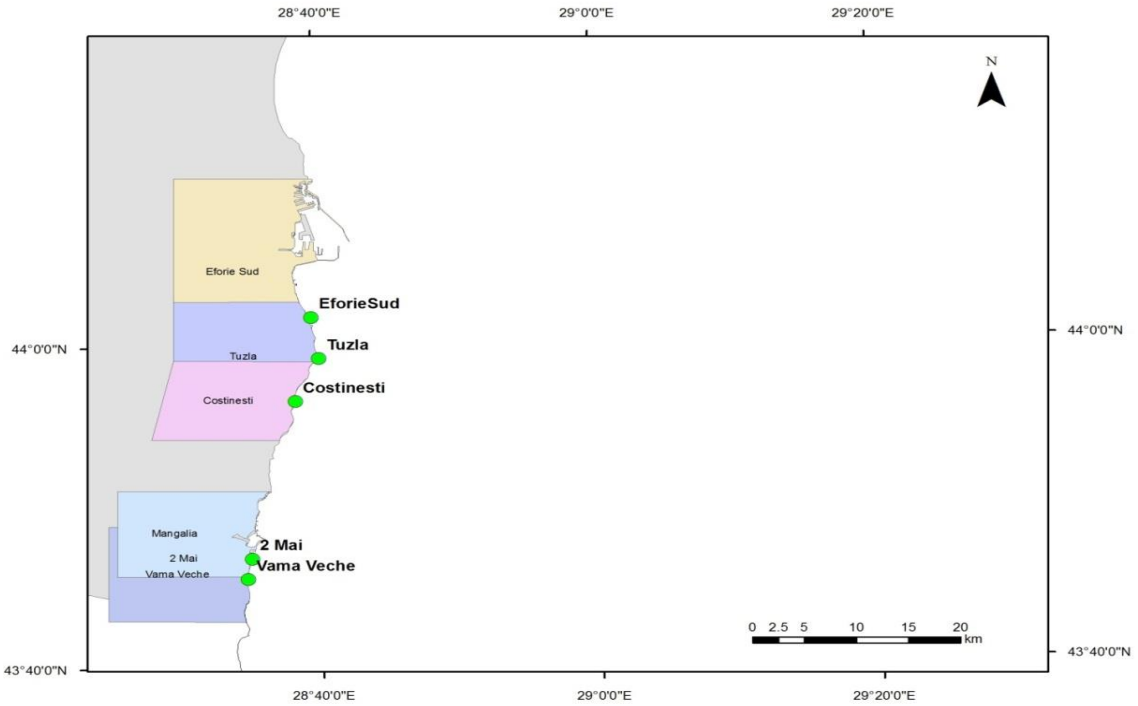


Fig. 2. Ecological state class (between 2009-2014)

The following values of LUSI_BS (3 km buffer of watersheds – Fig. 3) for the southern part of the Romanian shore were obtained with the highest values at Eforie Sud and Mangalia (value 6), and the lowest at Vama Veche (value 3) (table 2).



Station	LUSI_BS value as indication of direct impacts (agriculture, industry, urban areas) and indirect impacts (sewage outfall, riverine input, tourism, harbours) in coastal area
Eforie South	6
Tuzla	4.5
Costinesti	5
Mangalia	6
2 Mai	4
VamaVeche	3

Fig. 3. Romanian southern sector map - LUSI buffers calculation (3 km)
Table 2. LUSI_BS values for the Romanian southern part

The corellation between EI_EQR and LUSI_BS, meaning between the ecological state and the pressure index, is negative and significant ($p<0,01$ $r^2=0.67$), confirming the decrease in water quality and degradation of ecological state with increasing athropogenic pressures (Fig. 4.)

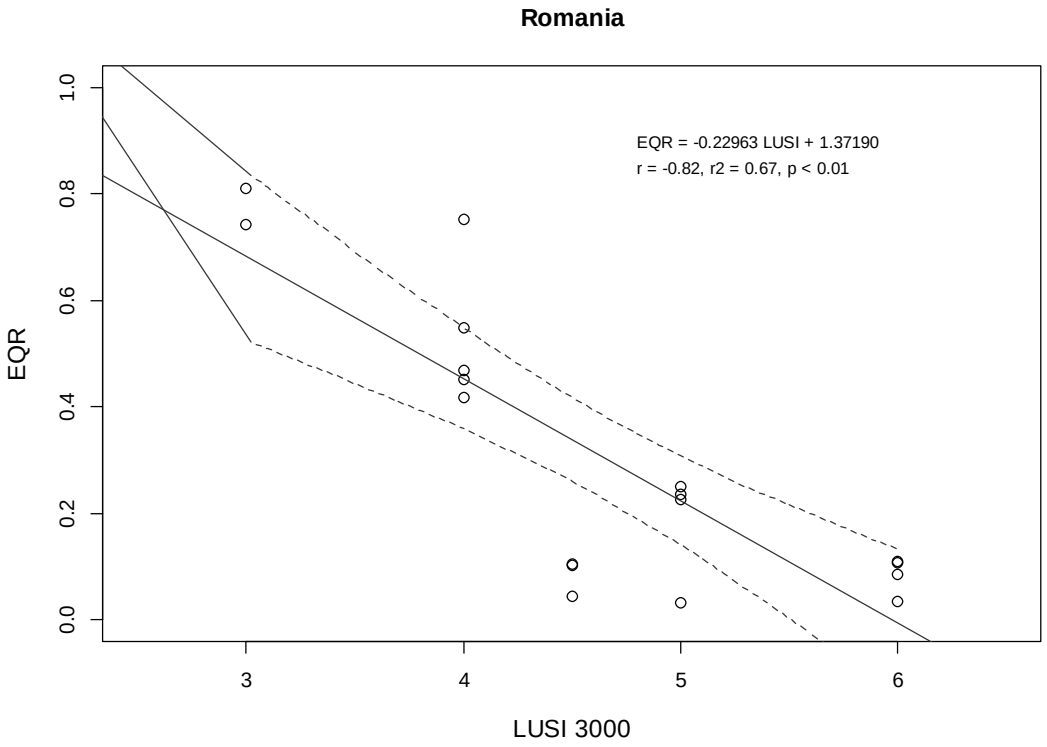


Fig. 1. Pearson linear correlation between EI_EQR values and LUSI_BS (3000 m buffers) for Romania southern sector Eforie South - Vama Veche ($p<0.01$ $r^2=0.67$)

CONCLUSIONS

- The Ecological Index (EI) is a suitable method for the evaluation of the ecological state of coastal water bodies, in accordance with the WFD requirements.
- All of the five ecological classes - Bad Poor, Moderate, Good, High Ecological Status were fully covered for the Romanian coastal water bodies.
- Higher index values were obtained in the southern part of the Romanian shore (Costinești- Vama Veche), due to the presence of the perennial sensitive species.
- The corellation between the ecological and the pressure index is negative and significant.

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