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WESTERN BLACK SEA EUTROPHICATION STATUS ACCORDING TO BLACK SEA EUTROPHICATION ASESSMENT TOOL, BEAST– MISIS CRUISE RESULTS

LAZAR LUMINITA[1], BOICENCO LAURA[1], BEKEN COLPAN[2], DZHUROVA BORYANA[3], MONCHEVA SNEJANA[3], SHTEREVA GALINA[3†], VASILIU DAN[4]

[1] National Institute for Marine Research and Development "Grigore Antipa", NIMRD, Constanta, Romania
[2]The Scientific and Technological Research Center of Turkey, TUBITAK, Marmara Research Center - Environment Institute, Gebze, Turkey
3Institute of Oceanology, Bulgarian Academy of Sciences, IO-BAS, Varna, Bulgaria
[4] National Research and Development Institute for Marine Geology and Geoecology, GeoEcoMar, Constanta, Romania

ABSTRACT

The paper presents results from the cruise done in the frame of the MISIS project in the Western Black Sea on a sampling network consisted of three transects: Romania, Bulgaria, Turkey and one intercalibration station, covering coastal, shelf, and open waters. A core set indicators was chosen for the eutrophication assessment of the Western Black Sea in respect with Descriptor 5 criteria (MSFD) and the intercalibration exercise, grouped as follows: causes of eutrophication – nutrients levels – concentrations of phosphate, and nitrogen oxidised forms in water column; direct effects of eutrophication – chlorophyll *a* concentrations in water column and indirect effects of eutrophication – bottom water dissolved oxygen content. Based on the data collected in the cruise, on the reference values and acceptable deviations of these parameters (specific for each country) it was tested the integrative tool for eutrophication assessment proposed by the Black Sea Commission through the Baltic2Black project, BEAST (**B**lack Sea **E**utrophication **AS**sessment **T**ool). Based on the BEAST results the eutrophication status of the Western Black Sea in summer 2013 was High-Good for coastal and open waters and Poor – High for shelf waters. The only one "poor" status responsible for not achieving the Good Ecological Status was the shelf station from Romanian transect where the phosphate and silicate concentrations were highest. Due to no correlation of BEAST with salinity (interpreted as no influence of the river discharge) and in absence of any other quantified anthropogenic influences it is to note that the poor eutrophication status was mainly influenced by the currents and winds regime and the water mixing phaenomena.

Keywords: Black Sea, eutrophication, nutrients, chlorophyll a, BEAST

AIMS

The aim of the paper is to test an integrative tool for the eutrophication assessment (BEAST) at the regional level (sub-basin) comprising of the Western Black Sea and three of its six riparian countries and to provide information based on data achieved on a common cruise (MISIS Joint cruise, 2013).

BACKGROUND

The enhanced eutrophication was one of the main environmental issues of the Black Sea in the '80s – early '90s[1,2,3]. Consequently, prior to become an "European" sea together with EU joining of Romania and Bulgaria, important steps were taken in order to prevent the reduction of nutrients income as mainly responsible for the effects[3,4]. The main was the signing the Convention on the Protection of the Black Sea Against Pollution (Bucharest, 1992) by all six riparian countries followed after two years by the Danube River Protection Convention (Sofia, 1994). However, there have found decreasing nutrients input slightly earlier, most probably due to the economic decrease of the Eastern European countries, resulted in the first recovery signs (decreasing of phytoplankton blooms, improvement of bottom oxygen regime, increasing of benthic macro fauna[2]. Thus, patterns in the long-term data indicated three alternative states in the Black Sea's NWS ecosystem, comprising a low production system before 1970, a highly productive eutrophic system during the 1980s, and a relatively low production intermediate system after the early 1990s both shifting accompanied by different limiting nutrient (first N, than P)[5]. Nowadays, even it is reported the reduced input of nutrients from Danube, particularly phosphorus, the eutrophication reduction is still subject of the Black Sea Strategic Action Plan (2009) implemented by the Black Sea Commission (EcoQ3) and the Marine Strategy Framework Directive (2008) through the Descriptor 5. The latter consider that the Good Environmental Status (GES) has been achieved when the biological community remains well-balanced and retains all necessary functions in the absence of undesirable disturbance associated with eutrophication (e.g. excessive algal blooms, low dissolved oxygen, declines in sea grasses, kills of benthic organisms and/or fish) and/or where there are no nutrient-related impacts on sustainable use of ecosystem goods and services[6]. Subsequently, the European Commission has selected a set of indicators which could be taken into account in the eutrophication status assessment[7] used as core set indicators in our assessment.

In this context, besides of the riparian EU countries obligations (Romania and Bulgaria) to meet the requirements of the EU Directives (particularly WFD and MSFD) there is a strong need to have powerful tools to assess the Black Sea eutrophication at regional level. Therefore, this assessment aims to a harmonized approach of the eutrophication assessment at the (sub) basin level – the Western Black Sea.

EXPERIMENTAL

The data were achieved in the frame of the scientific program conducted on board of R/V AKADEMIK during the MISIS Joint Cruise in the period 22.07 – 31.07.2013, in Romanian, Bulgarian and Turkish waters covering the western part of the Black Sea. The network sampling consisted of three transects: Romania (stations 1-7), Bulgaria (stations 8-12), Turkey (stations 14-18) and an intercalibration one (station 13) covering coastal (stations 1, 12 and 18) shelf (stations 2, 3, 4, 5, 9, 10, 11, 15, 16 and 17) and open waters (stations 6, 7, 8, 14, and 13). Stations were sampled in the water column 0-200m[8](Fig.1).

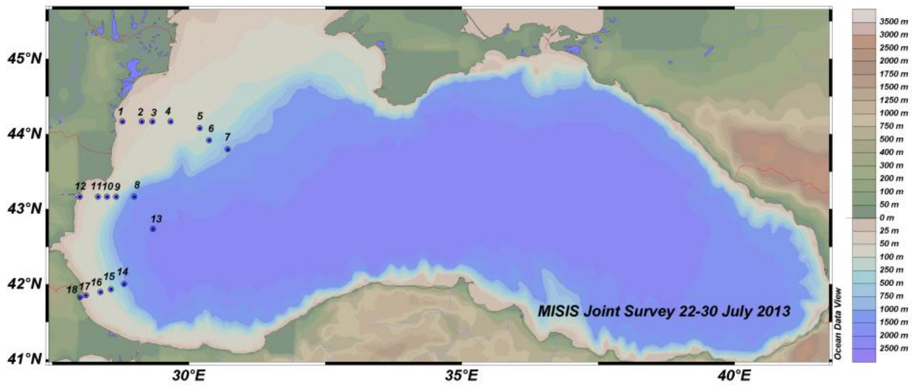


Fig.1 – Map of network stations – MISIS Joint Survey, July 2013

Table 1: The network stations – MISIS cruise, July 2013

Station	Bottom depth [m]	Type	Sampled depths [m]	Country	N
MO1	33,0	Coastal	0, 14, 32	Romania	3
MO2	47,0	Shelf	0, 5, 16, 46	Romania	4
MO3	54,0	Shelf	0, 8, 25, 52	Romania	4
MO4	65,0	Shelf	0, 15, 40, 63	Romania	4
MO5	100,0	Shelf	0, 16, 41, 76, 96	Romania	5
MO6	500,0	Open waters	0, 15, 42, 87, 112, 166, 174, 188, 200	Romania	9
MO7	1000,0	Open waters	0, 16, 46, 87, 113, 131, 139, 147, 165, 200	Romania	10
MO8	1167,0	Open waters	0, 12, 39, 65, 85, 107, 123, 143, 174, 200	Bulgaria	10
MO9	92,7	Shelf	0, 21, 43, 65, 90	Bulgaria	5
MO10	76,1	Shelf	0, 11, 25, 50, 74	Bulgaria	5
MO11	39,9	Coastal	0, 15, 25, 38	Bulgaria	4
MO12	23,2	Coastal	0, 12, 22	Bulgaria	3
MO13	2015,5	Open waters	0, 46	Intercalibration	
MO14	1118,0	Open waters	0, 19, 21, 65, 83, 100, 107, 118, 135, 200	Turkey	10
MO15	101,0	Shelf	0, 20, 34, 74, 96	Turkey	5
MO16	75,6	Shelf	0, 24, 65, 74	Turkey	4
MO17	53,0	Shelf	0, 16, 25	Turkey	3
MO18	25,0	Coastal	0, 21, 50	Turkey	3
Total					**91**

A core set indicators was chosen for the eutrophication assessment of the western Black Sea in respect with the descriptor's 5 criteria, the intercalibration exercise and BEAST requirements – nutrients levels – concentrations of phosphate and nitrogen oxidised forms[9]; chlorophyll *a* concentrations and bottom dissolved oxygen saturation only for the stations with depths up to

65m (Winkler method, onboard[9]). The samples were analysed in each country laboratory (Bulgaria – IO-BAS, Romania - NIMRD and Turkey – TUBITAK) and despite some differences in terms of methodological aspects, the results of the intercalibration exercise between the cruise participants showed generally satisfactory agreements for nutrients and chlorophyll *a* measurements[10,11].

Based on the data achieved for surface concentrations, on the reference values and acceptable deviations of the parameters (specific for each country) it was tested the integrative tool for the eutrophication assessment proposed by the Black Sea Commission through the Baltic2Black project, named BEAST (**B**lack Sea **E**utrophication **AS**sessment **T**ool) which runs on MS Excel. BEAST categories are divided into three criteria: C1 - causes of eutrophication, C2 - direct effects and C3 - indirect effects indicating the main cause-effect relationships in the eutrophication process[12]. Each criterion could have a set of indicators (based on availability and expert choice). The result of each indicator status is done by EUT_Ratio and it is included, according to its own weight (chose by expert), into a qualitative response: high, good, moderate, poor and bad. Within the categories, BEAST is averaging the parameters or taking a weighted mean (according to the significance of the parameter or the data quality) while, between the categories, the One-Out-All-Out-principle (OOAO) is applied (the worst assessment of a quality element determines the overall assessment result). The result is another qualitative response, the "Final eutrophication status": high, good, moderate, poor and bad.

For the Western Black Sea eutrophication assessment, based on one summer cruise (MISIS, July 2013), it was used a core set indicators (due to their availability, reference conditions availability and relevance) as follows:

- C1 - causative factors – surface nutrients concentrations (PO_4 - ortophosphate, TNOx – sum of nitrate and nitrite) weighted as 50% each.
- C2 - direct effects – phytoplankton blooms – surface chlorophyll *a* (as an estimate of the Total biomass)
- C3 - indirect effects – bottom dissolved oxygen (%) (effective only for coastal and shelf waters up to 50m bottom depth due to the natural features of the Black Sea)

The reference conditions used and for the EU MS (Romania and Bulgaria) were acquired as a MSFD obligation while for Turkey represented the results of one national project.

All maps were made with Ocean Data View (ODV) software version 4.7.3, a computer program for the interactive exploration that displays data in two basic ways: either by showing the original data at the data locations as colored dots of user-defined size or by projecting the original data onto equidistant or variable resolution rectangular grids and then displaying the gridded fields. The gridded fields of method 2 are actually data products and that small scale or extreme features in the data may be modified or lost as a consequence of the gridding procedure (DIVA gridding)[13]. All ODV representations done within the scope of this assessment have used the method 2 (data products).

RESULTS AND DISCUSSION

By applying BEAST, were achieved 17 qualitative results (one for each station) grouped in high, good, and poor eutrophication status and 5 assigned values (from 1-High to 5 – Bad). In order to assess the GES it was chose the threshold between Good-Moderate statuses as GES boundary (Table 2 and Fig.2a). Therefore, except one station (MO4), GES was achieved for entirely studied area. In this case, our attention was particularly drawn to the condition of data

from the location with poor status and differences compared with the others.

Table 2: Qualitative results of BEAST tool for eutrophication assessment – Western Black Sea, July 2013

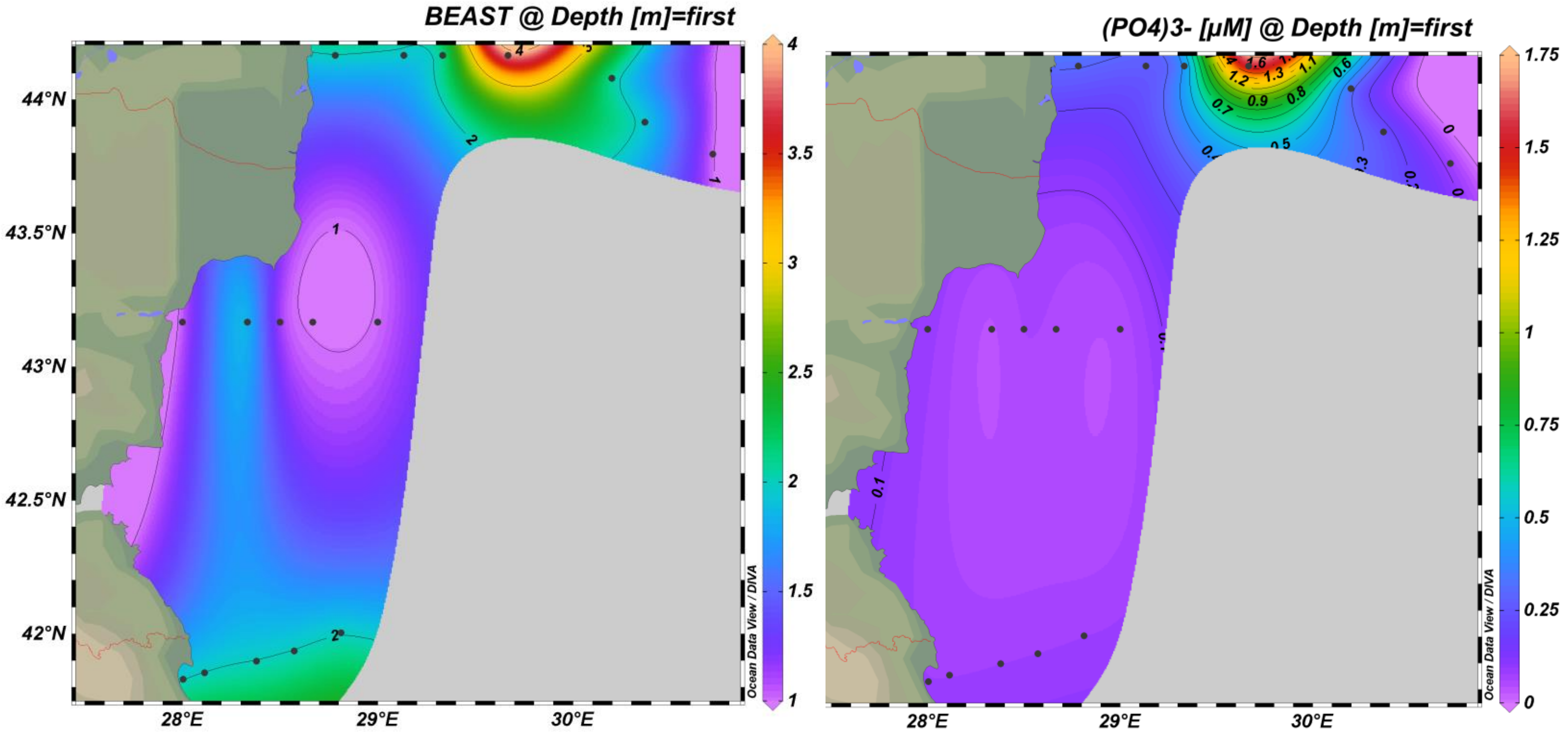
Transect	Station	Type	BEAST	Assigned value	GES
Romania	MO1	Costal	Good	2	GES
	MO2	Shelf	Good	2	GES
	MO3	Shelf	Good	2	GES
	MO4	Shelf	Poor	4	Non-GES
	MO5	Shelf	Good	2	GES
	MO6	Open	Good	2	GES
	MO7	Open	High	1	GES
Bulgaria	MO12	Coastal	High	1	GES
	MO11	Shelf	Good	2	GES
	MO10	Shelf	High	1	GES
	MO9	Shelf	High	1	GES
	MO8	Open	High	1	GES
Turkey	MO18	Coastal	Good	2	GES
	MO17	Shelf	Good	2	GES
	MO16	Shelf	Good	2	GES
	MO15	Shelf	Good	2	GES
	MO14	Open	Good	2	GES

The maximum phosphate concentrations were found in the Romanian shelf waters, located nearby the NW rivers influence area (Table 3). Thus, the 0.10µM isoline delimits two significant different areas (t-test, p=0.0251) with average concentrations of 0.45µM respectively 0.07µM. The main difference between areas consists of the highest variability of the values from the northern part (Fig.2b).

Table 3: Main statistics for parameters used in the BEAST tool

Type of water body	**N**	**Surface PO4, µM**		**Surface TNOx, µM**		**Surface Chl *a*, µg/L**		**Bottom Dissolved oxygen saturation (%)**	
		Min.	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
Coastal	**3**	0.08	0.31	0.27	1.90	0.350	3.435	59.82	60.74
Shelf	**10**	0.04	1.63	0.17	1.62	0.144	3.143	66.17	76.20
Open waters	**4**	0.05	0.25	0.03	1.60	0.116	0.350	na	na

Considering the reference value for phosphate in the Romanian marine waters (0.15µM) and 50% acceptable deviation resulting in a target value of 0.23µM, the maximum value (1.63µM) from the station MO4 (Romanian shelf) definitely influenced the BEAST result and failure to achieve GES status (Fig.2a and 2b).



(a) (b)

Fig.2 – (a) BEAST and phosphate (b) surface distribution – Western Black Sea, July 2013

Analysing the water column phosphate distribution for the overall Romanian transect (7 stations) it was observed the maximum concentration (4.15µM) at the interface water sediment in the station MO5 (bottom depth 100m) which is situated at the external edge of the shelf, in the neighbourhood of station MO4 (Fig.3). It is to note also that silicate concentrations in the stations MO4 and MO5 followed the same distribution being very well correlated with phosphate (r^2=0.79)(Fig.4). Meanwhile, the bottom dissolved oxygen showed hypoxic conditions in the station MO5 (39.4µM representing 12.18%) (Fig.5) and a good negative correlation with phosphate (r^2=-0.61) and silicate (r^2=-0.46) concentrations.

In this context, all the available information led to the idea that the resuspension of phosphorus from sediments in hypoxic bottom waters could be one of the mechanisms contributing to the nutrient regeneration in the water column (station MO4). The process was also strongly influenced by the physical parameters, particularly bottom oxygen saturation, but also temperature and salinity which contributed to increased stratification during the summer season[14].

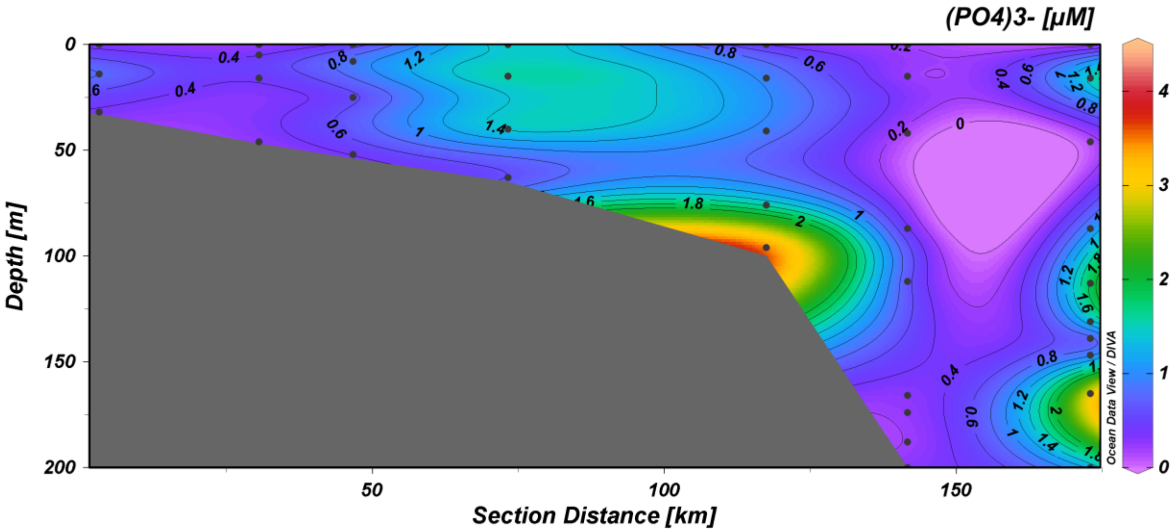


Fig.3 – Vertical distribution of phosphate concentrations – Romanian transect, July 2013

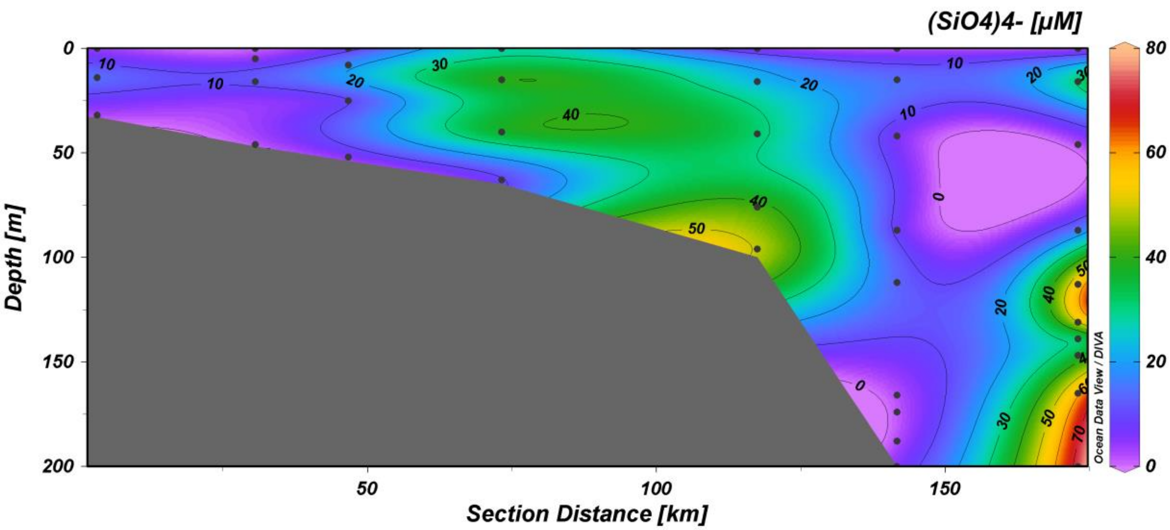


Fig.4 - Vertical distribution of silicate concentrations – Romanian transect, July 2013

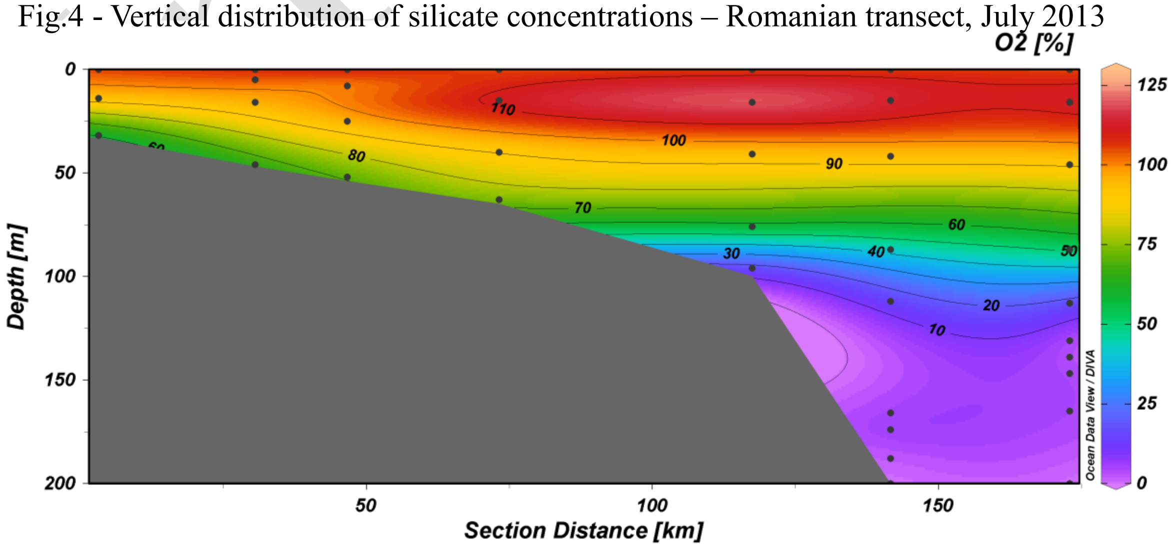


Fig.5 - Vertical distribution of dissolved oxygen saturation – Romanian transect, July 2013

The nitrogen oxidized forms, TNOx (sum of nitrite and nitrate), recorded maximum values on the Romanian transect (Table 3) remarking again the station MO4 for the highest concentration (1.62µM) into the shelf waters. However, besides the riverine loads which delineates through the 1.00µM isoline the northern and southern areas (significantly different, t-test, $p<0.0001$), due to comparable values with coastal waters it is highlighted the anthropogenic influence of the Constanta's area, both port and WWTP and the influence of the Varna's area, the second largest bay along the Bulgarian Black Sea coast (Fig.6). Nevertheless, the highest concentrations are specific to the natural variability of the area which didn't represent an influence for the failure to achieve GES.

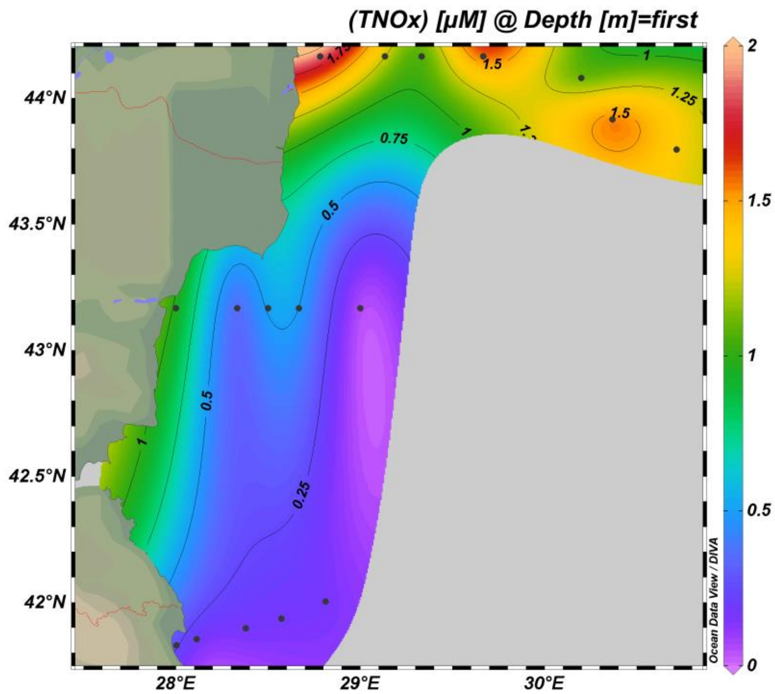
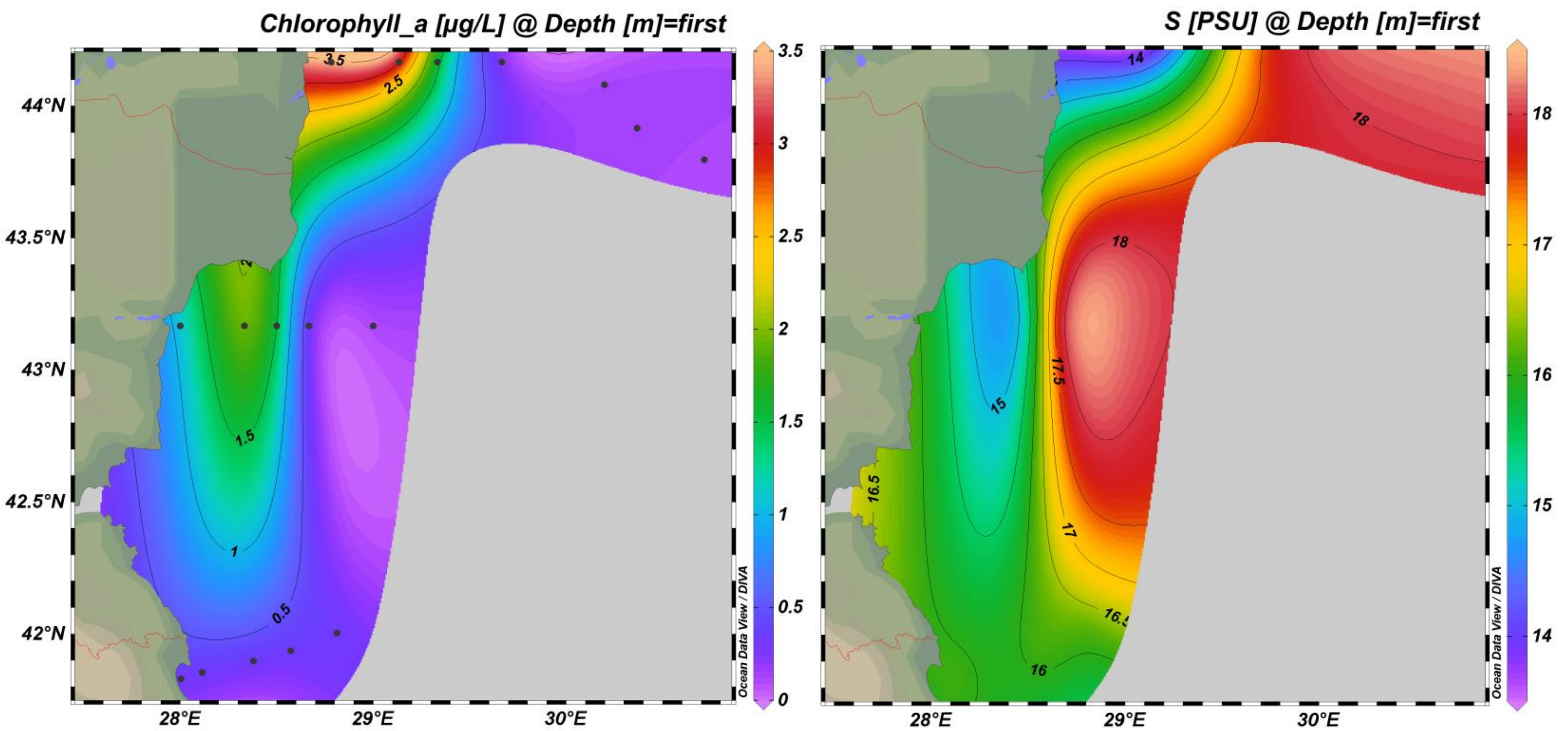


Fig.6 – Nitrogen oxidized forms (TNOx) surface distribution – Western Black Sea, July 2013

Chlorophyll a concentrations at surface oscillated from 0.12µg/L to 3.14µg/L with a significant decreasing gradient from Romanian to Bulgarian coastal waters (Fig.7a). Actually, the decreased values are coinciding with the salinity increasing trend being very well correlate (r^2 = -0.85) indicating an influence of the salinity on the phytoplankton biomass (Fig.7b).



(a) (b)

Fig.7 – Chlorophyll *a* (a) and salinity (b) surface distributions - Western Black Sea, July 2013

The bottom dissolved oxygen saturation values were not available for all stations due to their bottom depths. Additionally, the anoxic natural features of the Black Sea do not permit to measure it as an eutrophication effect. Thus, the horizontal distribution contained the last measurement for each station which coincided with its depth up to 100m and represents 200m (water column) for stations with higher bottom depths (Fig.8). It is easily observed that the parameter is not available for open waters and could not be included as BEAST's criteria and GES assessment for descriptor 5. However, slightly hypoxic condition were observed in the coastal waters and even pronounced in the shelf waters due to the water masses stratification specific to summer season. None of the values became of significant importance in the BEAST assessment.

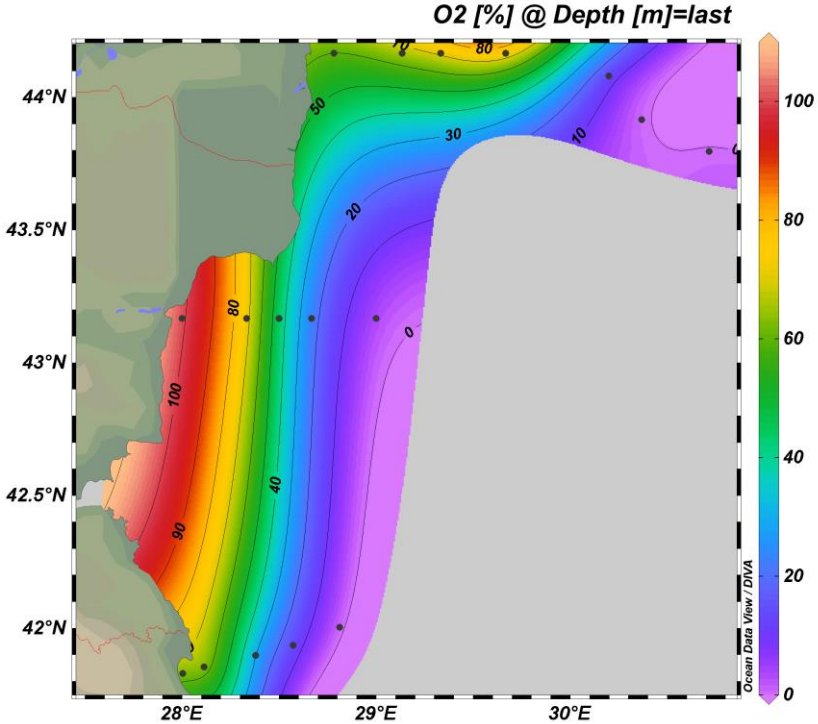


Fig.8 – Bottom dissolved oxygen saturation distribution – Western Black Sea, July 2013

CONCLUSIONS

The actual assessment of the eutrophication state of the Western Black Sea waters confirms the phenomenon complexity. The evaluation took into consideration a core set indicators (mainly based on their availability and established reference values) and contributed to define the actual state as good which, under the climate factors and the anthropogenic impact more pronounced in coastal and shelf waters, could easily passes to one extreme state (poor or high). Thus, based on the BEAST results the eutrophication status of the Western Black Sea in summer 2013 was High-Good for coastal and open waters and Poor – High for shelf waters. The only one “poor” status responsible for not achieving the GES is the shelf station from Romanian transect where the phosphate concentrations where highest.

Due to no correlation of BEAST with salinity (interpreted as no influence of the river discharge on the eutrophication status) and in absence of any other quantified anthropogenic influences it is to note that the poor eutrophication status could be influenced by the phosphate resuspension from the bottom hypoxic water-sediment interface, a process strongly influenced by the physical parameters and indirect by the hydrographic conditions.

The climate changes manifested through the alteration of the rivers hydrological regime, seawater temperature increase, intensification of the water masses stratification, winds and currents regime are important influencing factors of the current eutrophication state of the Western Black Sea waters.

In this study, neglecting the atmospheric deposition and other diffuse sources, we identified as main pathways of nutrients to the Western Black Sea being riverine inputs, direct discharges from coastal point sources and excess nutrients stored in bottom sediments which can enter the

water column.
BEAST could be an useful tool for the integrated eutrophication assessment at the regional level if the reference values of the criteria included are established by experts through defined methodologies specific to the Black Sea's features and revised periodically.
There is a need to further define the methodology used in the BEAST assessment tool. A user-friendly handbook, describing the functionality and giving guidance is needed. The handbook should include agreed criteria for setting confidence levels and rules for the aggregation of data.

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