Romanian Index for Hydrodynamics Assessment in Transitional and Coastal Waters on the North-Western Black Sea Coast (*Maria–Emanuela Mihailov, Valentina Coatu, Andra Oros, Florin – Laurențiu Constantinoiu, Lucian Duțu, Laura Boicenco, Luminița Lazăr*)	"Cercetări Marine" Issue no. 50 Pages 6 - 25	2020

ROMANIAN INDEX FOR HYDRODYNAMICS ASSESSMENT IN TRANSITIONAL AND COASTAL WATERS ON THE NORTH-WESTERN BLACK SEA COAST

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ABSTRACT

Under European regulations, like the Water Framework Directive (WFD 2000/60/EC), the member states should achieve the Good Ecological Potential (GEP) for all seawater bodies. Direct connections between the ecological status and hydrological conditions were not developed yet on the Romanian Black Sea coast. Using the Hydromorphological Quality Index (HQI) assessment tool developed by the European Protection Agency we assess the ecological risks objectives and detect the possible changes that may affect this status based on hydrodynamical features analysis. Long-term data series to establish the class boundaries for the period 2015 - 2018 year are used. Overall, the main trends likely to affect marine morphology are: climate change and associated sea-level rise, and the effect these have on coastal areas. For the Romanian Black Sea Coast, no water bodies were assessed as bad using the HQI.

Key-Words: Water Framework Directive, Hydromorphological Quality Index, Black Sea, Good Ecological Potential, hydrodynamics

AIMS AND BACKGROUND

To improve the quality of the waters and to protect them from various drivers, the European Union provide a very ambitious initiative through their policies, implemented through several directives. Drivers as pollution, floods, water scarcity, and hydromorphological changes, can affect the environment (G. Tsakiris, 2015).

The Water Framework Directive (WFD) establishes a set of objectives to be implemented by the European Member States (EC 2000; EC 2017; Wilby et al., 2006; Ramos et al., 2018). The main purpose of the directive is to establish a framework for inland surface waters, transitional waters, coastal waters and groundwater protections. As mentioned in WFD Article 4(1), the ecological flows are considered within the context as "*a hydrological regime consistent with the achievement of the environmental objectives of the WFD in natural surface water bodies (...)*". Classification of the surface water through the assessment of ecological status or potential and surface water chemical status is required. The hydrological regime, a relevant variable that affects the surface coastal waters ecological status, is part of the hydromorphological quality elements as is described in WFD Annex V 1.2.

The definition of coastal waters with EU environmental legislation is precisely stated in the directive and large deviations seem to be due to misinterpretations of the definition (Liquete et al., 2010). The coastal water bodies are defined in WFD article 2(7) as „ *(…) surface water on the landward side of a line, every point of which is at a distance of one nautical mile on the seaward side from the nearest point of the baseline from which the breadth of territorial waters is measured, extending where appropriate up to the outer limit of transitional waters*" (WFD 2000/60/EC). The WFD admits the physical boundaries of the water starting from the environment with its limitations (G. Tsakiris, 2015). Those can be achieved by preventing additional deterioration by protecting and improving the status of the water resources and the aquatic environment. The sustainable yield of a hydrogeological system applied to a basin, according to Devlin and Sophocleous (2005) and Kalf and Woolley (2005), can be derived from the conservation of mass principles, whereby the difference between inflow and outflow fluxes will equal the change of water storage in the basin (Mencio et al., 2010). It must be noted that the environmental assessment of determined sites can be biased because the coastal delimitation does not necessarily correspond to ecological boundaries, and the 1 nm line misses the largest part of wide eutrophic plumes which must be delineated and monitored (Ferreira et al., 2010).

Despite the progress, significant hydromorphological pressures are observed for 40% of transitional and coastal waters according to EEA, 2012. Based on the data gathered in WISE WFD database, more than half of the surface water bodies hold less than good ecological status or potential, the water bodies of rivers and transitional waters are having more pressures than the lake and coastal water bodies (Fig. 1).

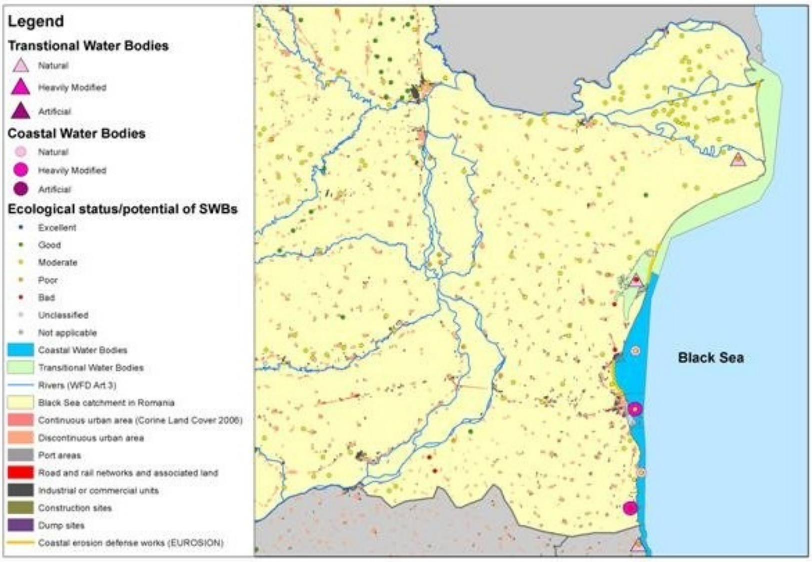

Fig. 1. Natural, heavily modified and artificial surface water bodies on the Black Sea region (Romania) coastal and transitional waters with catchment area (EEA, 2012)

In the same report (EEA, 2012) it is underline / show that for two regional seas of Europe (Greater North Sea and the Black Sea) and eight Member States (the UK, Spain, Malta, the Netherlands, Cyprus, Poland, Slovenia and Romania), more than 10% of their coastal water bodies are identified as heavily modified or artificial.

Furthermore, for the Romanian Black Sea region two coastal water bodies are reported as heavily modified and two as natural. Both HMWBs (heavily modified water bodies) are located along with ports (Constanta and Mangalia), affected by coastal pressures with a high impact on nearshore/coastal habitats. Coastal water bodies have moderate status/potential except for HMWB in the long narrow coastal bay (about 7km) along Mangalia with a bad potential. Two natural transitional water bodies are designated in the Danube Delta with lagoons along the northern part of the Black Sea coast of Romania. They are of poor and bad status respectively. Ecological status/potential of freshwater water bodies close to the coastline is manly moderate (Fig. 1).

Hence, probably, the most critical issue in the geographic delimitation between the WFD and the MSFD relates to transitional waters and, in particular, to the cases where these waters extend beyond the 1 nm.

Several methodological approximations are being used by the EU Member States and have been developed and implemented in water bodies to assess gaps in ecological flows (EU Technical Report, 2015). The summary of these methods based on their integrated indicators and implementation areas are presented in Table 1 (Ferreira et al., 2007, 2011; Ramos et al., 2018; King et al., 2008; EC, 2015; UKTAG, 2013).

Table 1. Hydromorphological assessment methods in European Countries used under WFD, *(source:http://wiki.reformrivers.eu/index.php/European_methods_for_WFD, https://circabc.europa.eu/)*

Country	**Method/s**	**Key reference**	**Status concerning the WFD**
Austria	Guidelines for assessing the Hymo status of running waters	Muhlmann (2010)	It is the official method for the assessment of hymo conditions to support the ecological status assessment (WFD)
Belgium	N/A		N/A
Bulgaria	N/A		N/A
Cyprus	N/A		N/A
Czech Republic	HEM	Langhammer (2017; 2009)	Recommended by the Ministry of Environment
Denmark	DSHI	Pedersen and Baattrup-Pedersen (2003)	Officially used in the National Monitoring programme; recommended by authors
England and Whales	RHS; EFI	Raven er al. (1997)	RHS is the commonly used in England and Whales since 2000's; EFI has been developed by the EA
Estonia	N/A		It seems there is any official method but only a proposal N/A
Finland	N/A		N/A
France	CarHyCE; Syrah&Aurah-CE; ROE&ICE	Onema (2010); Chandesris et al. (2008); Valette et al. (2010)	CarHyCE - used as the official method. Syrah&Aurah-CE, ROE&ICE have been developed to comply WFD requirements
Germany	LAWA-FS; LAWA-OS	LAWA (2000; 2002a; 2002b)	LAWA-FS is the most commonly used (but

Country	**Method/s**	**Key reference**	**Status concerning the WFD**
			not formally selected); LAWA-OS has been nationally accepted in the 1sr „River Basin District Analysis 2004"
Greece	N/A		N/A
Hungary	N/A		N/A
Ireland; Rep. Of Ireland	RHAT	Murphy and Toland (2012)	Developed specifically for WFD compliance
Italy	MQI; IARI; CARAVAGGIO	Rinaldi et al. (2013); ISPRA (2011); Buffagni et al. (2005)	MQI, IARI and CARAVAGGIO for the overall hydromorphological assessment; CARAVAGGO for the reference sites
Latvia	Method for assess Hymo changes	Sigita Sulca (2012) (PPT)	Nationally used in the definition of hydromorphological changes in RBDP (River Basin District Projects)
Lithuania	N/A		N/A
Luxembourg	N/A		N/A
Malta	No national method established		No national method established
The Netherlands	Handboek HYMO	Dam et al. (2007)	It allows to monitor and analyse hymo quality elements. It has not been officially selected
Poland	MHR	Ilnicki et al. (2009; 2010)	It is officially approved for the hydromorphological assessment of rivers
Romania	Criteria and parameters for assess of HyMo significant pressures and designation of HMWB		For the designation of HMWBs
Scotland	MimAS	UKTAG (2008)	It is a proposal tool to support the assessment and monitoring of the ecological status

Country	Method/s	Key reference	Status concerning the WFD
			(morphological alteration and risk) of rivers
Slovakia	HAP-SR	NERI&SHMI (2004); Lehotsky&Greskova (2007)	It is proposed method for the definition of ecological status of rivers in the Slovak Republic
Slovenia	SIHM	Tavzes & Urbanic (2009)	The national method for the application of MSFD
Spain	IHF; QBR	Pardo et al. (2002); Munne & Prat (1998)	Both methods are widely used by Water Agencies for the hydromorphological assessment for the WFD
Sweden	Assessment criteria for Hymo quality elements; BiotopeMap	Hallde'n et al. (2002)	Criteria for the assessment of the hydromorphological quality elements to support the good and high ecological status. The BiotopeMap is the most common field method to collect/inventory environmental variables

To achieve an overall study and to understand the interaction between two connected and interactive environments (sea and land) and the dynamics processes on Romanian Black Sea coastal zones, was considered the historical data to assess the current status using the Hydromorphological Quality Index (HQI) assessment tool developed by Keogh et al. (2020).

EXPERIMENTAL

We analyse only the hydrodynamical features that will be called metrics as were established in Keogh et al. (2020).

For this study are used long-term data series from NIMRD and MHD databases to establish the GEP values and the TracC-MimAS (UKTAG, 2013) scores that characterize the 2015-2018 years, as follows:

- For sea-level - in-situ data recorded at Sulina (1858 – 1990), Constanta (1933 – 2018), Tomis Port (1975 – 1990) and Mangalia (1976 - 1990) are used. Data are correlated; duplicates are cut out and used for multiyear averages to determine the thresholds values. Reference period, for GEP variation limits and background values, is 1933 – 2014.
- For changes in wave regime, for GEP variation limits and background values for metric 6a, is analysed based on measured data (1950 – 2015 period) from NIMRD and MHD and data from FNMOC-WW3-MEDIT model (https://www.usno.navy.mil/FNMOC), Marine Copernicus Platform (www.marine.copernicus.eu).
- Danube River nitrogen data - the average value was used as reported by the International Commission for the Protection of the Danube (ICDPR, https://www.icpdr.org/) at Reni station (45.28N and 28.13E). Long-term monthly average Danube river discharge (m^3/s) from upstream the Delta monitoring station - Reni or Isaccea - is used to monitor the river loads of substances to the Black Sea (Fig. 2).

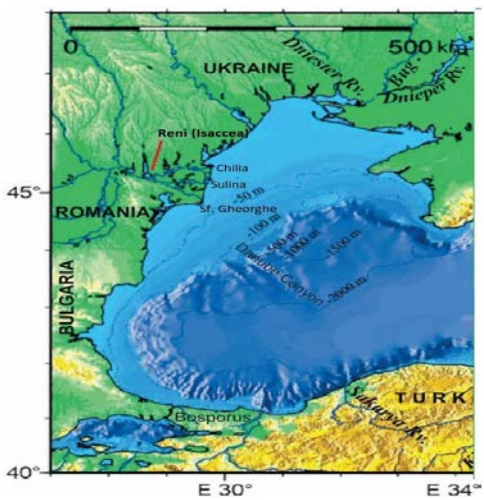

Fig. 2. Black Sea morphology, a detailed view of the north-western Black Sea area *(adapted after Popescu et al., 2015)*

Long-term data collection is useful to realize the summary statistics such as the annual mean and annual percentiles, and, mainly through pooled data, the shape of the statistical distributions underlying these summary statistics. For changes in sea temperature, water masses analysis and other sea components are used data gathered during oceanographic cruises along the Romanian Black Sea coast, during 2015 – 2018. Were data being incomplete, satellite and modelling data are used to fill the data gaps.

For the Romanian Black Sea coast, 4 (four) water bodies were established according to WFD, from North to South: transitional waters between ***Chilia – Periboina,*** coastal waters between ***Periboina – Cap Singol, Cap Singol – Eforie, Eforie – Vama Veche.***

RESULTS AND DISCUSSION

Metric 5a. Change in tidal regime

An important indicator for the coastal environmental status assessment is the sea level which shows a spatio-temporal dynamic influenced by a series of general or local hydrodynamic factors. The importance of the measurements lies in the fact that its evolution determines the shoreline position and with the combined action of waves and sea currents, the erosion-rate of the littoral and therefore, the respective beach surface. The impacts of sea-level rise induced by global warming and anthropogenic factors on the global and local scale, and the rise is accelerated during 20th century with a rate of 1.7 mm/yr and since 1993 the rise is continuing with a global rate of 3.2 (± 0.4) mm/yr (Church J and White N, 2011)

According to Malciu V. (2013), based on long-term data analysis from 1933 to 2005 using five-year mean (pentads) of annual values, the Danube inflow shows a decreasing trend and the sea-level is rising on the Romanian Black Sea coast. Influenced by the Danube inflow, the constant rise is also due to other causes and it can be assumed that one of them is the ice meltdown and the global thermal increase (Malciu V., 2013).

Due to the general north to south shoreline orientation of the Romanian Black Sea coast, strong winds (north-eastern, eastern, and south-eastern) determines the sea-level rise through the effect of moving the water masses toward the shore. Reversely, the westerly winds (north-west, west, southwest), transport the seawater away from the shore as an effect, the surface of the beach increasing significantly. Mihailov et al. (2016) show that wind variations are largely responsible for the positive sea level trends in the north-western Black Sea coast that confirms previous results (Malciu V., 2013) that the northern and north-eastern winds regime leads to increased sea levels.

Using the TracC-MimAS classification, the Romanian Black Sea waters are less than 2m - microtidal (based on Davies, 1964; Keogh et al., 2020) and **the score** is equivalent with **0 (no change)**. For the analysed period (2015 – 2018), the limits are determined considering the minimum of 0.075cm and a maximum of 0.45cm (Table 2).

Table 2. Proposed GEP values for the sea level on the Romanian Black Sea coast (1933 – 2014) and 2015- 2018 period variation limits

Parameter	GEP variation limits and background values (based on reference period)	Multiannual average (1933 – 2014)	2015 – 2018 Variation limits	2015 – 2018 (average period)
Sea level (m)	(-0.17) ÷ 0.5	0.17	0.075 ÷0.45	0.24

Metric 6a. Change in wave regime

Romanian wave regime is characterized by high variability, the persistence of a certain direction or speed is generally a matter of hours and reaches a few days only if intense winter storms occur. Therefore, the proposed background values for the parameters characteristic of the wave regime are common for all typologies, respectively all water bodies on the Romanian Black Sea coast.

As stated in Mihailov et al. (2013), only the waves from the five directions in the eastern half-circle are present, and 92% of waves propagate from NE-E-SE. Largest average height value for the waves coming from north direction (1.8m) is due to the strong prevailing winds blowing from this direction, especially in the cold season. In the same paper, for near-shore waters, a return period of 50 years was determined for 6.9m wave height. There are also rare events, during strong storms, with a wave height greater than 6m (maximum degree of agitation of the sea, on the Douglas scale, in the coastal zone ~~of~~ is 5-7 degree). Calculated return period about 30 years for high waves: 6.5 m in February 2012 and ~ 6m recorded in January 1981. Same authors settled the maximum values as 5m at Mangalia for the 1980-1990 period and 11m at Gloria (2007-2009 periods).

Using the spectral analysis and sea wave's parameters statistics, the background values for the Romanian Black Sea coast are established in Table 3.

For WFD, Romania reported for all four (4) water bodies' background values for wave's regime, based on historical and 2015 – 2016 data measurements. To assess the environmental wave regime status, for each water bodies, data from Marine Copernicus platform (https://marine.copernicus.eu/) was extracted and analysed. For the 2015 – 2018 periods, for all four water bodies, the wave parameters values were within the proposed background values (Fig. 3).

Table 3. Proposed GEP values for the sea waves on the Romanian Black Sea coast (1971 – 2015) and 2015- 2018 period variation limits

Parameter	GEP and background values	Multiannual average (1971 – 2015)	2015 – 2018 period
Height (m)	0.2 – 6.0	0.86	0.023 – 2.93
Period (s)	0.1 – 10.8	4.65	
Length (m)	0.0 – 102.0	22	
Direction	NNE, ENE, E, ESE, SE		Predominant E, S, ESE, ENE

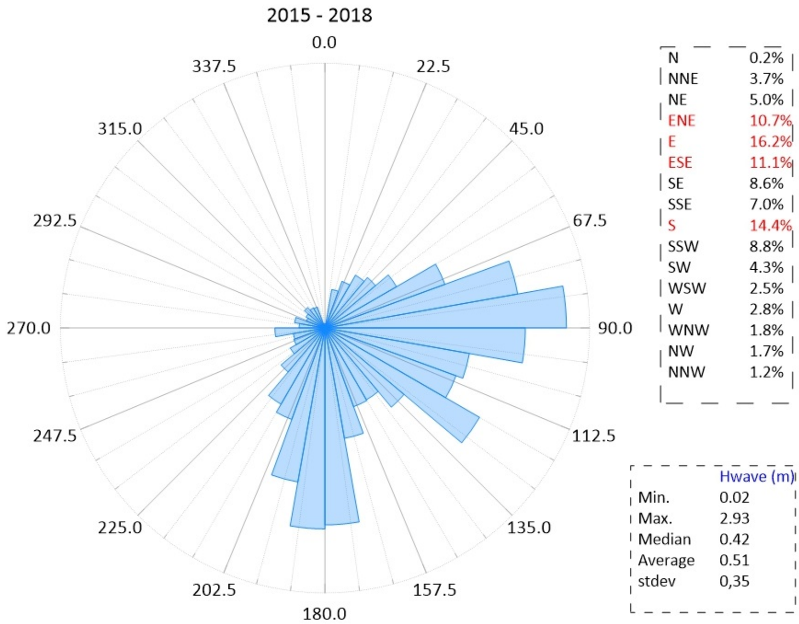

Fig. 3. Waves parameters statistics for North-Western Black Sea coastal zones, 2015 – 2018 period (https://marine.copernicus.eu/)

Using the TracC-MimAS classification, the Romanian Black Sea waters **score** is equivalent with **0 (no change,** Minor change, <5% of the water body area influenced by structures). The score is determined considering the minimum and the maximum of the analysed period (2015 – 2018) for all wave's parameters.

Metric 7a. Change in river flow

The Danube River presents several particularities imposed by the complex interaction between freshwater excess and the marine environment as a receptor. The Danube hydrological regime is characterized by its location in the temperate zone, the factor that determines the area dynamics. The river discharge is an important environmental component, due to the impact on the Black Sea at the convergence between marine and freshwaters, on salt balance and salinity gradients, estuarine and sea circulation patterns, water quality, seawaters rich nutrients, productivity, as well as on distribution and abundance of the marine ecosystem (Mihailov *et al*. 2013, Batzer and Sharitz, 2006).

According to DDNIRD report (2010), the Danube discharges about 29 kt/y of total phosphorus (TP) and 478 kt/y of total nitrogen (TN) into the Black Sea. Was stated that, despite the achieved reductions, pollution loads are still high enough to threaten the biodiversity and affect the fishery and recreational value of the Black Sea (Sommerwerk N. et al., 2010).

To establish the GEP values for the Danube flow, the monthly average flow data of the Danube river recorded between 1981 - 2010 were analysed (the data were retrieved from http://hypeweb.smhi.se/europehype/time-series/ platform). Thus, drive us to appreciate the discharge values between 1889.03m^3/s – 14673.33m^3/s. The assessment (Table 4) was done considering the minimum, maximum and monthly average of the Danube river during the specified period. The metric 7a is dedicated only for transitional water body ***Chilia – Periboina (RO – TT03)***.

For 2015 - 2018, using the TracC-MimAS classification, the Romanian Black Sea waters **score** is equivalent with **0 (no change,** Minor change in freshwater input < 5% change). The score is determined considering the minimum (of 2940.00 m^3/s) and the maximum (12272.63 m^3/s) of the analysed period (2015 – 2018) for the Danube river discharge (all 3 branches: Chilia, Sulina, and Sf. Gheorghe).

Table 4. Proposed GEP values for the Danube discharge (1971–2015) and variation limits for 2015- 2018 period

Parameter	GEP variation limits and background values	Multiannual average	Average (2015 – 2018)
Danube discharge (m^3/s)	1889.03 – 14673.33	6390.21	5882.73

Metric 9a. Change to stratification or degree of mixing

The vertical distribution of the water temperature depends on the thermal regime of the atmosphere and the sea dynamical factors (currents and wave) that generate the water mass mixing. Intense seawater mixing usually reaches depths of 100–150m, and only seldom 200 m. Intermediate and deep-water masses (88% of the sea volume), although in a continuous but slow exchange with the upper layers, undergo only slight variations of their thermohaline parameters.

The Black Sea is characterized by four layers: the surface quasi-homogeneous layer (SQL), Cold Intermediate Layer (CIL), the halocline, the anoxic layer (rich in hydrogen sulphide) (Mihailov *et al*., 2013, 2016; Murray et al., 1991; Özsoy et al., 1993; Stanev et al., 2004). In the North-Western Black Sea, the upper layer waters separate from the cold waters (CIL) by a layer with strong density gradients (seasonal thermocline), during the warm season, which prevents mixing and thermally isolate the bottom waters with low temperatures.

Mihailov *et al.* (2013, 2016) shows that the temperature data reveal a slight warming trend for the SQL while for the shelf cold water (SCW) - identified by the 8°C isotherm upper depth - thermohaline structure remained practically constant. Also, in the same studies, the salinity exhibited a decreasing trend for the entire water column and was asset a minimum of the sea surface temperature in 1985 (about 0.12°C) and a maximum in 2006 (28.50°C), in the offshore southern Romanian waters.

The salinity distribution is a result of two opposite actions: thermal convection and the Danube River discharge. Nearby the Danube mouth determines a water temperature less than 6°C at the surface down to 35m depth (during cold season) and low salinities (a minimum salinity recorded about 0.12PSU in May 2008; and the average of 2.52PSU at the surface) that influence the entire Romanian Black Sea shelf thermal stratification and salinity distribution (Mihailov et al., 2013).

Three classes of water body's stratification were defined in Keogh et al. (2020) with a mixing degree based on *Potential Energy Anomaly (φ)* formula (Simpson et al., 1990):

$$(\emptyset) = \frac{1}{h}\int_{-h}^{0}(\bar{\rho} - \rho)g \cdot zdz; \qquad (1)$$

$$\bar{\rho} == \frac{1}{h}\int_{-h}^{0}\rho dz \qquad (1.1)$$

were *h* representing the water column depth and ρ is the seawater density (kg m^{-3}) at depth z and g is the acceleration due to gravity ($m \cdot s^{-1}$). The energy required per unit volume to generate the complete vertical mixing directly proportional to the strength of stratification is represented in the formula by (φ).

To calculate the energy of mixing, we computed the water density for each water body during the summer season, due to strong stratification. Using formula (1) and (1.2), the energy per unit volume for each water body is calculated in Table 5:

Table 5. Potential Energy Anomaly (φ) for Romanian Black Sea WFD water bodies

Water body	Φ (Jm^{-3}) for 2015- 2018	Water column
Chilia – Periboina (RO – TT03)	7.58	well mixed
Periboina – Cap Singol (RO_CT01)	36.58	well stratified
Cap Singol – Eforie (RO_CT02)	56.17	well stratified
Eforie – Vama Veche	59.33	well stratified

were $\Phi < 10\ J{\cdot}m^{-3}$ column is well mixed

$\Phi = 10 \div 30\ J{\cdot}m^{-3}$ column is partially stratified

$\Phi > 30\ J{\cdot}m^{-3}$ column is well stratified.

No changes in stratification for the four water bodies were observed in the North-Western Black Sea based on Mihailov et al. (2013, 2016) and 2015 – 2018 data. Using the TracC-MimAS classification, the Romanian Black Sea waters **score** is equivalent with **0 (no change to stratification).**

Metric 7b. Change in residence time

Water resides for different periods of time in different reservoirs and plays an important role in controlling phytoplankton biomass (Keogh et al., 2020; O'Boyle et al., 2015). The average length of time that water stays in a reservoir before moving to another is called the residence time for that reservoir.

In Keogh et al. (2020), two methods are used to estimate the residence time depending on the hydromorphological characteristics of the water body (O'Boyle et al., 2015).

In this paper, we are using residence time (Res_{time}) formula:

$$Res_{time} = \frac{\text{Total amount ion in seawater (kg)}}{Input\ rate\ (\frac{kg}{yr})} \qquad (2)$$

where,

$$Input\ rate = \frac{\text{Avg.ion conc.in rivers}\left(\frac{\text{kg}}{\text{km3}}\right)}{River\ discharge\ (\frac{km3}{yr})} \qquad (2.1.)$$

The Danube River is the most important source of liquid and solid discharges (Ludwig et al., 2009 and Mikhailov and Mikhailova, 2008), as the liquid contribution of 59% of the total water runoff into the Black Sea (from a total of 205 km^3/year) whereas the suspended particulate matter (SPM) contribution ranges between 36.3 and 52.4 million tons per year (about 48% of the total SPM load reaching the Black Sea) (Guttler et al., 2013). As concerns the freshwater influence in the Western Black Sea, through the variability of the abiotic environmental characteristics and qualitative/quantitative structure of a biota, Danube River presents the most productive part of the Black Sea ecosystem (inflow of nutrient-rich river waters).

The volume of water in transitional waters, corresponding to the Romanian Black Sea shelf represents 1359km^2. Using (2) and (2.1) formulas, the residence time of the Danube river inflow into the Black Sea waters varies in time from 0.7 to 1.1years. According to Friedrich et al. (2003), the nitrogen residence time in Danube Delta lakes is 60 days in low-water level conditions. For major chemical component, as data reported by ICDPR (https://www.icpdr.org/main/publications/databases), using above formula was determined a residence time of nitrogen for the Danube - Black Sea system waters of 2.66 months (or about 82days) for 2015 – 2018 period.

The Western Black Sea has a long history of change and decline associated with eutrophication influence (the early 1970s). Once the emitted nutrients reach the surface waters, they are subject to transport, transformation and retention (losses or storage) processes. In this context, a more detailed analysis is needed to successfully classify water bodies according to CEN (2014) and Keogh et al. (2020).

CONCLUSIONS

During Water Framework Directive implementation, many Member States have started to develop a typology for transitional and coastal waters. For the implementation of WFD requirements, following the typological justification of water body types and the classification of ecological quality, on the Romanian Black Sea coast were established four (4) water bodies from North to South, as follows: transitional waters – between Chilia – Periboina, and coastal waters between Periboina – Cap Singol, Cap Singol – Eforie, and Eforie – Vama Veche.

Using the indexed developed for hydromorphological condition for transitional and coastal waters, developed by Keogh et al. (2020), corresponding water bodies for North-Western Black Sea coast can be classed as no change or slight change for metrics: 5a, 6a, 7a, and 9a (Table 6).

Table 6. Metrics used and scoring system for determination of Hydromorphological Quality Index for the Romanian Black Sea coastal zones (see Keogh et al., 2020)

Metric	**Score**	**Score description**	**Romanian Black Sea Waters Score (all water bodies)**
5a Changes in the tidal regime, water level and current	0	no change	**0**
	1	slight change (<50% within a tidal category)	
	2	moderate change (<50% within a tidal category)	
	3	Major change. Tidal regime altered by one category. Microtidal to mesotidal, mesotidal to macrotidal etc.	
	4	Severe change. Tidal regime altered by two categories. Microtidal to macrotidal, macrotidal to microtidal	
6a: Change in wave regime	0	Minor change. <5% of the water body area influenced by structures	**0**
	1	Slight change. 5% to 15% of the water body area influenced by structures	
	2	Moderate change. 15% to 35% of the water body area influenced by structures.	
	3	Major change. 35% to 75% of the water body area influenced by structures	
	4	Severe change. >75% of the water body area influenced by structures.	
7a: Change in river flow	0	Minor change in freshwater input (< 5% change in LTAA)	**0**
	1	A slight change in freshwater input (5 to 15% change in LTAA)	

Metric	**Score**	**Score description**	**Romanian Black Sea Waters Score (all water bodies)**
	2	A moderate change in freshwater input (15% 35% change in LTAA)	
	3	Major change (> 35 change in LTAA)	
7b. Changes in Residence time	0	No change in residence time	**1 (needed more detailed analysis)**
	1	Slight change to residence time <50% within a residence time category	
	2	Moderate change to residence time >50% within a residence time category	
	3	A major change to residence time (days to weeks, weeks to months etc.)	
	4	Severe change to residence time (days to months, months to days)	
9a: Change to stratification	0	No change to stratification	**0**
	1	A slight change in stratification. >50% change within stratification category	
	2	A moderate change in stratification. (Stratified to partial stratified. Partially stratified to mixed. Mixed to partially stratified. Partially stratified to mixed.)	
	4	A major change in tidal regime. Changes from mixed to stratified and vice versa.	

The investigation conducted on the current environmental status of the Black Sea waters with respect to the requirements set by the EC Water Framework Directive can be considered very good based on physico-chemical parameters characterisation. Given the ecological importance of the analysed area and that beaches are a crucial resource for tourist attraction, determining the changes in the tidal regime, water stratification and water level that are altering the dynamics of low coastal areas can be of valuable support in the sustainable management, governance and ecological systems.

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