

# THE PRESSURES AND THE ECOLOGICAL QUALITY STATUS OF THE MARMARA SEA (TURKEY) BY USING MARINE MACROALGAE AND ANGIOSPERMS

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**Abstract** – Marine benthic macroalgae and angiosperms are proposed as one of the biological quality elements to assess the ecological quality status of transitional and coastal waters by the European Water Framework Directive (WFD, 2000/60/EC).

In the present study, the *Marine Floristic Ecological Index* (MARFEI) was tested to assess the impacts by using marine benthic macrophytes (macroalgae and angiosperms) and pressures by using the Macroalgae-Land Uses Simplified Index (MA-LUSI) in the Marmara Sea (Turkey). Sampling of benthic macrophytes was made from 0÷5 m depth at 29 different sites during the summer periods of 2017, 2018 and 2019. The study revealed good ecological status class (ESC) for 6 sites, moderate for 11 sites, poor for 8 sites and bad for 4 sites. MARFEI<sub>eqr</sub> showed a negative linear relationship with the pressure index MA-LUSI.

## Introduction

Marine benthic macrophytes (macroalgae and angiosperms) are proposed as one of the biological quality elements to assess the ecological quality status of transitional and coastal waters by the European Water Framework Directive [1]. Several macrophyte indices, i.e. the Ecological Evaluation Index [2, 3], the CARtography of LITtoral (CARLIT) [4], the Macrophyte Quality Index (MaQI) [5, 6], have been proposed for the Mediterranean Sea.

The Sea of Marmara being bordered by Turkish territory; displays both coastal and marine water features, connected to the Black Sea by the Istanbul (Bosphorus) Strait and to the Aegean Sea by the Çanakkale (Dardanelles) Strait. Recently, the *Marine Floristic Ecological Index* (MARFEI) has been proposed especially for the Marmara Sea (Turkey) for the ecological quality classification of coastal waters [7].

In the present study, the *Marine Floristic Ecological Index* (MARFEI) was tested to assess the impacts by using marine benthic macrophytes (macroalgae and angiosperms) and pressures by using the Macroalgae-Land Uses Simplified Index (MA-LUSI) in the Marmara Sea (Turkey).

## Materials and Methods

Sampling of benthic macrophytes was made from 0÷5 m depth at 29 different sites during the summer periods of 2017, 2018 and 2019 as part of the national Integrated Marine Pollution Monitoring Programme (MoEU, Turkey) (Figure 1).

The material was collected by snorkeling from a 100 m x 100 m area per station [7], and specimens were preserved in 2÷5 % formaldehyde in sea water. Samples were studied using a light microscope (Nikon SE).

Physico-chemical parameters (salinity, temperature, pH, conductivity, turbidity, and dissolved oxygen), ortho-phosphate [8], and ammonium nitrogen [9] were also measured.

Land Uses Simplified Index (LUSI) is a method to assess the continental pressures (i.e. mariculture, sewage outfall, harbours, irregular fresh water inputs, sediment nutrient release, urban, commercial and industrial, agriculture) on coastal waters [10, 11]. This index has been developed by the Macroalgae Technical Group of the Mediterranean Geographical Intercalibration Group (MEDGIG), as called MA-LUSI (LUSI for shallow water macroalgal communities) [12].

Macrophytes (macroalgae and angiosperms) were classified into five ecological status groups: ESGI (IA, IB, IC; late-successional taxa such as *Cystoseira* spp., *Padina* spp., angiosperms, calcareous red algae, *Halimeda tuna*, etc.) and ESGII (IIA, IIB; opportunistic taxa such as filamentous *Ectocarpus* spp., *Ceramium* spp., *Cladophora* spp., and sheet-like green algae *Ulva* spp., etc.) [3, 7].

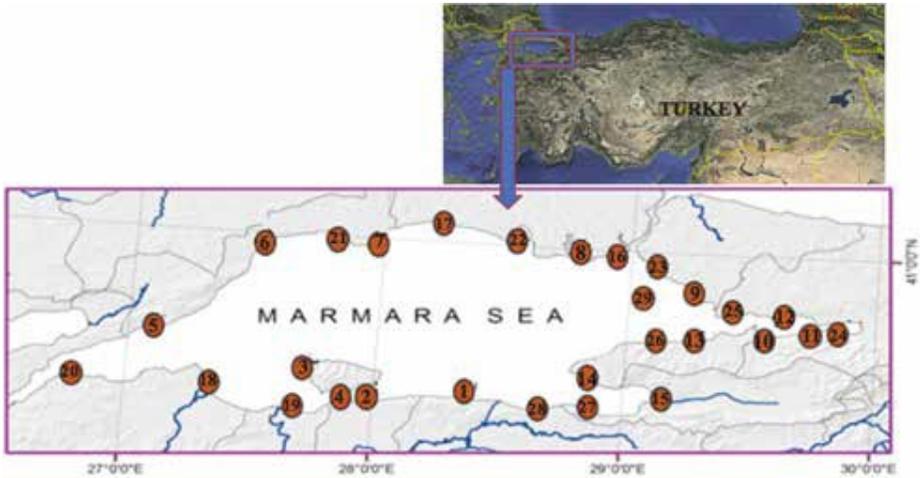


Figure 1 - Sampling stations in the Marmara Sea (Turkey). (1: Susurluk Ağızı; 2: Bandırma; 3: Kapıdağ; 4:Edincik; 5:Şarköy; 6: Tekirdağ; 7: Marmara Ereğlisi; 8: Küçükçekmece; 9: Tuzla; 10: Kavaklıdere; 11: Kaytazdere; 12: Hereke; 13: Yalova; 14: Armutlu; 15: Gemlik; 16: Yenikapı; 17: Silivri; 18: Karabiga; 19: Edincik-Enerji Sa; 20: Lapseki; 21: M. Ereğlisi-Batı; 22: B.Çekmece; 23: Kadıköy; 24: Değirmendere; 25: Eskihisar-MAM; 26: Çınarcık; 27: Mudanya; 28: Susurluk-Doğu; 29: Adalar-İstanbul).

Ecological Quality Ratio (EQR) between 0 and 1 was obtained by the formulation of MARFEI (bad=0÷0.20; poor=0.20÷0.40; moderate=0.40÷0.60; good=0.60÷0.80; high=0.80÷1) [7]. The relationship between pressures and MARFEI<sub>egr</sub> values has been calculated using the MA-LUSI index.

Formula:  $MARFEI_{egr} = (4*\%IA + 3*\%IB + 2*\%IC) / (1*IIA + 0,5*IIB)$ .

## Results

Physicochemical properties were found as average for three years in the coasts of the Marmara Sea as pH 8.28, temperature 26.17 °C, salinity ‰ 22.29, oxygen 5.84 mg/L, turbidity 2.51, conductivity 34739 µS, orthophosphate 3.56 µg/L, and ammonium nitrogen 34 µg/L. Phosphate was especially found as high in the monitoring sites Hereke, Gemlik, Kavaklıdere, Küçükçekmece, and these sites are affected by anthropogenic impact, and poor or bad ecological quality. The green algae *Ulva* and *Cladophora*, the red algae *Ceramium* and *Polysiphonia* are found dominantly. The highest value of ammonium nitrogen was measured in Kavaklıdere (97 µg/L).

The results of the pressures data (MA-LUSI index), MARFEI<sub>egr</sub>, and ecological status class (ESC) of the sampling stations are given in Table 1. The study revealed good ecological status class (ESC) for 6 sites (Kapıdağ, Edincik, Şarköy, Edincik-Enerji Sa, and Marmara Ereğlisi-Batı), moderate for 11 sites (Bandırma, Tekirdağ, Marmara Ereğlisi, Yalova, Armutlu, Karabiga, Eskihisar-MAM, Çınarcık, Mudanya, Susurluk-Doğu, and Adalar-İstanbul), poor for 8 sites (Susurluk-Ağzı, Tuzla, Kavaklıdere, Kaytazdere, Yenikapı, Silivri, Kadıköy, and Değirmendere) and bad for 4 sites (Küçükçekmece, Hereke, Gemlik, and Büyükçekmece) (Table 1 and Figure 2).

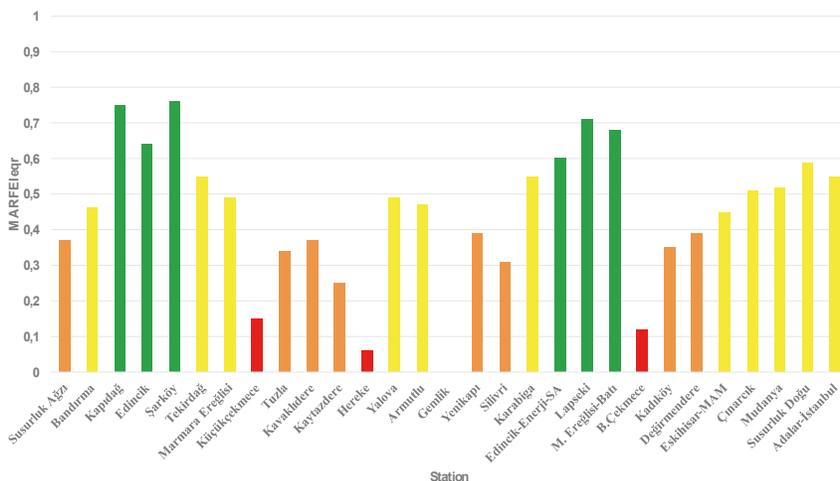


Figure 2 - The Ecological Quality Ratio (EQR) of the sampling sites in the Marmara Sea (Turkey) by the MARFEI index.

Table 1 - The Ecological Quality Ratio by  $MARFEI_{eqr}$ , ecological status class (ESC), and pressures data (MA-LUSI index) in the Marmara Sea (Turkey). (B: Bad, P: Poor, M: moderate, G: Good)

No	Station	MA-LUSI	$MARFEI_{eqr}$	Ecological status class (ESC)
1	Susurluk Ağzı	9	0,37	P
2	Bandırma	7,5	0,46	M
3	Kapıdağ	3	0,75	G
4	Edincik	3,75	0,64	G
5	Şarköy	4,21	0,76	G
6	Tekirdağ	5,25	0,55	M
7	Marmara Ereğlisi	3,37	0,49	M
8	Küçükçekmece	9,37	0,15	B
9	Tuzla	8,75	0,34	P
10	Kavaklıdere	6	0,37	P
11	Kaytazdere	6,25	0,25	P
12	Hereke	7	0,06	B
13	Yalova	7	0,49	M
14	Armutlu	3,75	0,47	M
15	Gemlik	10	0,00	B
16	Yenikapı	10	0,39	P
17	Silivri	10	0,31	P
18	Karabiga	3,75	0,55	M
19	Edincik-Enerji-SA	3,75	0,60	G
20	Lapseki	2,25	0,71	G
21	M. Ereğlisi-Batı	4,68	0,68	G
22	Büyükçekmece	10,93	0,12	B
23	Kadıköy	11,30	0,35	P
24	Değirmendere	8	0,39	P
25	Eskihisar-MAM	8	0,45	M
26	Çınarcık	4,5	0,51	M
27	Mudanya	8,75	0,52	M
28	Susurluk Doğu	9,37	0,59	M
29	Adalar-İstanbul	2,81	0,55	M

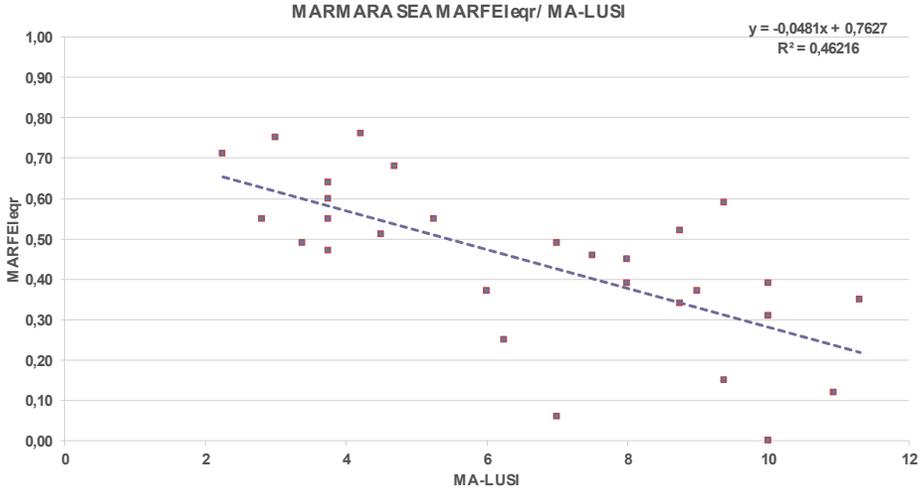


Figure 3 - Relation between the MARFEI<sub>eqr</sub> index and pressure data (MA-LUSI index) in the Marmara Sea (Turkey).

The MARFEI<sub>eqr</sub> index values and pressures data (with MA-LUSI index) was tested, and a negative correlation ( $R^2=0.46$ ) was found between pressures and impacts in the sampling sites (Figure 3).

## Discussion

The Marmara Sea is high marine traffic area moderately affected by anthropogenic disturbances (i.e. urban, industrial) [7]. The Marine Floristic Ecological Index (MARFEI) was proposed to assess the ecological status class of the coastal waters for the Marmara Sea in 2018, and 25 sites were studied, and the good ecological status class (ESC) for one site (İntepe), moderate for 11 sites (Eceabat, Şarköy, Marmara Ereğlisi, Üsküdar, Yalova, Armutlu, Mudanya, Erdek, Paşalimanı Island, Karabiga, and Lapseki), poor for 10 sites (Çanakkale, Gelibolu, Tekirdağ, Silivri, Küçükçekmece, Büyükçekmece, Gemlik, Susurluk River-Boğaz, Princes Islands, and Bandırma) and bad for 3 sites (Kocaeli, Hereke, and Haliç) were classified by MARFEI [7]. In the present study, six sites (Kapıdağ, Edincik, Şarköy, Edincik-Enerji Sa, and Marmara Ereğlisi-Batı) are found as the good ecological status class.

Recently, the Ecological Evaluation Index (EEI-c) was tested to assess the impact by using marine benthic macrophytes (macroalgae and angiosperms) in the Turkish marine waters, and the sampling was made from 56 stations which are 15 stations from the Marmara Sea [13]. In the study, revealed high ecological status class (ESC) for one site (Şarköy), good for 5 sites (Kapıdağ, Edincik, Tekirdağ, Armutlu, and Marmara Ereğlisi), moderate for 2 sites (Yalova, and Kaytazdere), poor for 6 sites (Susurluk-Ağzı, Bandırma, Küçükçekmece, Tuzla, Kavaklıdere, and Gemlik) and bad for one site (Hereke) [13]. Because of the sampling effort

of the two indice (MARFEI and EEI-c) in the same time, the results of the present study are similar to EEI-c results.

## Conclusion

The Marine Floristic Ecological Index (MARFEI) can be used to assess of the ecological status class (ESC) of the coastal and transitional waters in the Marmara Sea (Turkey). However, MARFEI is a destructive method to assess of the ESC, and it is needs more time to describe the taxa, and need experts.

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