TÜBİTAK

Turkish Journal of Botany

http://journals.tubitak.gov.tr/botany/

Research Article

Turk J Bot
(2023) 47: 34-49
© TÜBİTAK
doi:10.55730/1300-008X.2742

Ecological quality status of the Turkish coastal waters by using a marine macrophytic biotic index (EEI-c)

Ergün TAŞKIN[1,3,*], İbrahim TAN[2], Murat ÇAKIR[3], Özge SUNGUR[1], Orkide MİNARECİ[1], Ersin MİNARECİ[1], Hakan ATABAY[2]

[1]Department of Biology, Faculty of Arts and Sciences, Manisa Celal Bayar University, Manisa, Türkiye
[2]TÜBİTAK MRC Environment and Cleaner Production Institute Gebze, Kocaeli, Türkiye
[3]Eser Deniz Ecological, Environmental Co., Technocity of Manisa Celal Bayar University, Manisa, Türkiye

Received: 07.07.2022 • **Accepted/Published Online:** 01.12.2022 • **Final Version:** 16.01.2023

Abstract: The present study includes the results of the second benthic macrophytes' monitoring period of a survey of ecological status from the Turkish coasts. The biotic index Ecological Evaluation Index (EEI-c) was used to assess the ecological status classes (ESC) and MA-LUSI the anthropogenic pressures. Sampling was made by the quadrat (20 × 20 cm) method, and the samples were collected from 93 sites in Turkish coastal waters between 2017 and 2019. In total, 240 taxa were found in the Turkish marine waters. Forty sites were classified into High ESC, 24 sites into Good, 12 sites into Moderate, 13 sites into Poor, and 4 sites into Bad ESC. The relationship between the pressure index MA-LUSI and EEIeqr values was also tested, and a negative correlation ($R^2 = 0.62$) was found.

Key words: Ecological quality, EEI-c, MA-LUSI, macroalgae, macrophytes, Türkiye

1. Introduction

Marine macroalgae and angiosperms are good bioindicators to assess the ecological status of coastal and transitional waters. They were proposed as one of the biological quality elements by the EU Water Framework Directive (EU, 2000, WFD, 2000/60/EC). In the last decades, many macrophyte biotic indices have been developed in different countries on the Mediterranean coasts (Orfanidis et al., 2001, 2011; Ballesteros et al., 2007; Romero et al., 2007; Sfriso et al., 2007, 2009, 2014; Gobert et al., 2009; Orfanidis et al., 2010, 2020; Lopez y Royo et al., 2010; Piazzi et al., 2015; Taşkın et al., 2018). The *Mar*ine *F*loristic *E*cological *I*ndex (MARFEI) was developed (Taşkın et al., 2018), and tested at 29 different sites (Taşkın et al., 2020a) in the Marmara Sea (Türkiye). Recently, the Benthic Ecological Assessment Rapid Index (BEARI) has been proposed as a new nondestructive method to assess the ecological quality classification of the coastal waters in the Marmara and Aegean Sea (Türkiye) (Taşkın, 2020).

Assessing anthropogenic pressures on coastal waters is essential to determine references and potential risk areas for monitoring strategies and management plans. Models (e.g., MONERIS, SWAT) or index [Land Uses Simplified Index (LUSI), LUSI for shallow water macroalgal communities (MA-LUSI), Pressure Index (PI)] methodologies can be used to evaluate anthropogenic pressure. In general, fast, convenient, and inexpensive index methods are preferred to use for the determination of pressures/impacts (Borja et al., 2011; Flo et al., 2011; Tan et al., 2017; Flo et al., 2019).

Marine benthic macrophytes are divided into two main groups (Ballesteros et al., 2007; Orfanidis et al., 2001, 2011; Sfriso et al., 2007, 2009, 2014; Taşkın et al., 2018; Taşkın, 2020): (a) the first group is sensitive, late-successional macroalgae (*Cystoseira sensu lato* spp., *Sargassum* spp., *Padina* spp., calcareous and crustose red algae *Corallina*, *Ellisolandia*, *Jania*, *Lithophyllum*, etc.) and seagrasses (*Cymodocea nodosa*, *Posidonia oceanica*, *Zostera marina*, *Z. noltei*) commonly found in pristine waters (Boudouresque, 1969; Ballesteros, 1990; Pergent, 1991), (b) the second group is the tolerant and opportunistic algae (filamentous *Cladophora*, *Ceramium*, *Ectocarpus*, *Polysiphonia*, sheet-like *Ulva*, Cyanobacteria colonies, etc.) which are commonly distributed in the human-impacted coastal waters (Orfanidis et al., 2003; Boudouresque et al., 2020).

The present study includes the second monitoring period of a survey about ecological status classes (ESC) on the Turkish coasts. The first one was conducted by Taşkın et al. (2020b). The study included 56 research stations in 17, 15, 13, and 11 coastal water bodies of Black Sea,

* Correspondence: ergun.taskin@cbu.edu.tr

Marmara Sea, Aegean Sea, and the Mediterranean Sea, respectively. The first monitoring program had contained less data, and to improve the first monitoring information, the second monitoring program was carried out. The MARFEI index was also tested in the second monitoring program from the Marmara Sea (Taşkın et al., 2020a). The Ecological Evaluation Index (EEI-c) (Orfanidis et al., 2011) was selected as a biotic index to assess the ecological status (ES) of the Turkish coasts. This paper aims (1) to assess the ecological status from 93 sampling stations using data from new monitoring studies in Türkiye, (2) to test the relationship between the pressure index (MALUSI) and EEI-c index, (3) to prepare the pressure-impact map. It will be useful for local decision-makers to assess the coastal eutrophication risk.

2. Materials and methods

2.1. Study area

The study includes different sampling sites on the Turkish coasts of the Seas (Black Sea, Marmara Sea, Aegean Sea, and the Mediterranean Sea). The coastline is characterized by the presence of many bays and gulfs (i.e., Gemlik Bay, Saros Bay, Edremit Bay, İzmir Gulf, Gökova Bay, Antalya Gulf, İskenderun Bay), commercial ports (İzmir, Mersin, Samsun, İskenderun, etc.), fishing and yachting harbors (Sinop, Trabzon, Çeşme, Bodrum, Göcek, Fethiye, Kaş, Antalya, İskenderun, etc.), and high or low coasts. Every summer between 2017 and 2019, samples were collected from 93 stations at 20, 29, 22, and 22 coastal water bodies of Black Sea, Marmara Sea, Aegean Sea, and Mediterranean Sea of Türkiye, respectively (Figure 1).

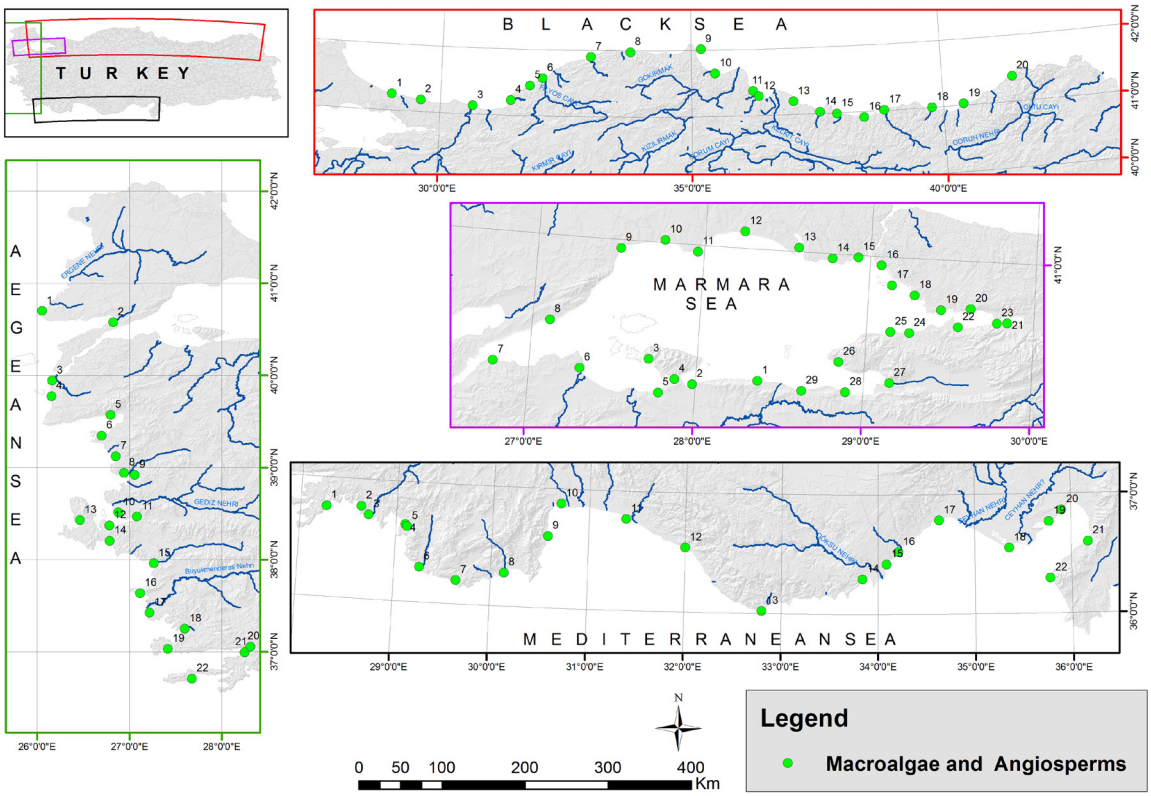

Figure 1. Sampling area on the coasts of Türkiye. [The Black Sea coasts: (1: Kilyos, 2: Şile, 3: Sakarya River-Karasu, 4: Krd.Ereğli, 5: Zonguldak, 6: Filyos, 7: Cide, 8: İnebolu, 9: Sinop, 10: Yakakent, 11: Kurupelit, 12: Samsun, 13: Yeşilırmak, 14: Fatsa, 15: Ordu, 16: Giresun, 17: Tirebolu, 18: Trabzon, 19: Rize, 20: Hopa). The Marmara Sea coasts: (1: Susurluk River-Boğaz, 2: Bandırma, 3: Kapıdağ, 4: Edincik, 5: Edincik-Enerji-SA, 6: Karabiga, 7: Lapseki, 8: Şarköy, 9: Tekirdağ, 10: M. Ereğlisi-West, 11: Marmara Ereğlisi, 12: Silivri, 13: Büyükçekmece, 14: Küçükçekmece, 15: Yenikapı, 16: Kadıköy, 17: İstanbul Isles, 18: Tuzla, 19: Eskihisar-MAM, 20: Hereke, 21: Kavaklıdere, 22: Kaytazdere, 23: Değirmendere, 24: Yalova, 25: Çınarcık, 26: Armutlu, 27: Gemlik, 28: Mudanya, 29: Susurluk River-East). The Aegean coasts: (1: Enez, 2: Saros Bay, 3: Yeniköy, 4: Dalyan-Geyikli, 5: Edremit Bay, 6: Ayvalık, 7: Dikili, 8: Çandarlı, 9: Yenişakran, 10: Gediz River-Homa D., 11: İzmir Bay, 12: Urla, 13: Ildır, 14: Sığacık, 15: Küçük Menderes, 16: Doğanbey, 17: Didim, 18: Güllük, 19: Bodrum, 20: Akyaka, 21: Gökova K.-Kapalı, 22: Datça). The Mediterranean coasts: (1: Marmaris, 2: Köyceğiz-İztuzu, 3: Dalaman, 4: Fethiye Outer Bay, 5: Fethiye İnner Bay, 6: Eşen River-Patara, 7: Kaş, 8: Finike, 9: Kemer, 10: Antalya, 11: Manavgat, 12: Alanya, 13: Anamur, 14: Taşucu, 15: Silifke, 16: Erdemli, 17: Mersin, 18: Karataş, 19: Yumurtalık, 20: Gölovası, 21: İskenderun, 22: Çevlik)]

2.2. Sampling

Sampling was made by quadrats (20 × 20 cm) for three replicates per station at a depth of 0.5–1 m, and samples were preserved in 2%–5% formaldehyde in seawater. Samples were studied using a light microscope (Nikon SE), and were kept in the personal herbaria of Ergün Taşkın (ET) in Manisa Celal Bayar University. Nomenclature was checked by Guiry and Guiry (2021).

2.3. Environmental parameters

At each sampling station, physico-chemical parameters (pH, temperature, dissolved oxygen, turbidity, conductivity, and salinity) were measured in the water column using the Water Quality Checker™ (DKK-TOA WQC 24). Samples were collected and transported to the laboratory to analyze nutrient concentration [Ortho-phosphate (Parsons et al., 1984), and ammonium nitrogen (Strickland and Parsons, 1972)]. Water samples were stored at +4 °C until spectrophotometric analysis at Manisa Celal Bayar University (Türkiye).

2.4. Pressure assessment methodology

The Land Uses Simplified Index (LUSI) was developed to assess eutrophication on coastal waters based on the anthropogenic land uses (urban, industrial, agricultural, and riverine) and the coastline morphology (Flo et al., 2011, 2019). The Macroalgae-Land Uses Simplified Index (MA-LUSI: LUSI for shallow water macroalgal communities) was used for shallow water macroalgal communities disturbed (i.e. mariculture, sewage outfall, harbors, irregular freshwater inputs, sediment nutrient release, urban, commercial and industrial, agriculture) by the Macroalgae Technical Group of the Mediterranean Geographical Intercalibration Group (MEDGIG) (MEDGIG; EC 2013). The MA-LUSI index data were obtained from the Corine land cover map, which affects a 1.5-km buffer zone around the sampling sites. MA-LUSI calculation was done by Taşkın et al. (2020b).

2.5. EEI application

Marine benthic macrophytes (macroalgae and angiosperms) were classified into five ecological status groups (ESG): ESGI includes thick perennial (ESG IA, *Ericaria crinita*, *Cystoseira corniculata*, *Posidonia oceanica*, etc.), thick plastic (ESG IB, *Cystoseira compressa*, *Gongolaria barbata*, *Padina pavonica*, etc.), and shade-adapted plastic species (ESG IC, *Corallina officinalis*, *Ellisolandia elongata*, *Jania* spp., *Lithophyllum* spp., *Peysssonnelia* spp., *Anayomene stellata*, *Halimeda tuna*, etc.), and ESGII includes succulent opportunistic (ESG IIA, *Dictyota* spp., *Gelidiella* spp., *Gelidium* spp., etc.) and filamentous and sheet-like opportunistic species (ESG IIB, *Ceramium* spp., *Chaetomorpha* spp., *Cladophora* spp., *Ectocarpus* spp., *Polysiphonia* spp., *Ulva* spp., etc.) (based on Orfanidis et al., 2011; and later Taşkın et al., 2018). According to Orfanidis et al., an ecological quality ratio of 0 to 1 was obtained with the formulation (2011) (see Taşkın et al. 2020b).

All statistical analyses (cluster analysis, Spearman rank order correlations, principal component analysis) were performed using PAST software (Hammer et al., 2001). Spearman Ordinal Correlations were used to examine the relationship between the metrics (biotics variables and physico-chemical parameters) (Table 1). Marked correlations are significant at $p < 0.05000$. Among biotics, the richness, ESG I, and EEI-c*eqr* showed significant positive correlations with salinity.

3. Results

3.1. Environmental parameters

Average values of physico-chemical parameters (pH, temperature, dissolved oxygen, turbidity, conductivity, and salinity) and nutrients (ortho-phosphate and ammonium nitrogen) of each sampling station are reported in Table 2. According to the 3-year average values in the Black Sea coasts, pH was 8.28, temperature was 25.73 °C, salinity was 16.42‰, oxygen was 5.90 mg L^{-1}, turbidity was 5.08, conductivity was 26352 S/m, phosphate was 3.33 µg L^{-1}, and ammonium nitrogen was 26 µg/L. In the Marmara Sea, the values were that pH was 8.28, temperature was 26.17 °C, salinity was 22.29‰, oxygen was 5.84 mg L^{-1}, turbidity was 2.51, conductivity was 34739 S/m, phosphate was 3.56 µg L^{-1}, and ammonium nitrogen was 34 µg/L. In the Aegean coasts, pH was 8.23, temperature was 26.82 °C, salinity was 36.54‰, oxygen was 5.86 mg L^{-1}, turbidity was 3.94, conductivity was 52356 S/m, phosphate was 3.76 µg L^{-1}, and ammonium nitrogen was 35 µg/L. In the Mediterranean coasts, pH was 8.28, temperature was 28.95 °C, salinity was 35.38‰, oxygen was 5.18 mg L^{-1}, turbidity was 4.07, conductivity was 51462 S/m, phosphate was 4.28 µg L^{-1}, and ammonium nitrogen was 32 µg/L. Black Sea had, on average, the lowest water temperature and salinity while oxygen and turbidity were the highest. The highest water temperature and salinity were found in the Mediterranean and Aegean coasts, and the lowest oxygen and turbidity were found in the Mediterranean coasts and the Marmara Sea, respectively.

Phosphate was relatively high in Sakarya (10.02 µg L^{-1}), İnebolu (8.39 µg L^{-1}) and Trabzon (7.18 µg L^{-1}) in the Black Sea, Kavaklıdere (9.98 µg L^{-1}) and Bandırma (9.62 µg L^{-1}) in the Marmara Sea, Sığacık (14.22 µg L^{-1}) and İzmir Gulf (12.70 µg L^{-1}) in the Aegean Sea, Fethiye Inner Bay (11.00 µg L^{-1}) and Manavgat (7.32 µg L^{-1}) in the Mediterranean. Ammonium was relatively high in Kavaklıdere, Bandırma, Edincik, İzmir Bay, Çevlik, Fethiye Inner Bay, Erdemli, respectively.

Principal Component Analysis (PCA) was used for the relationships between abiotic (physico-chemical

Table 1. Spearman rank order correlations (EEI_Türkiye). Marked correlations are significant at $p < 0.05000$.

	pH	*T(°C)*	*DO*	*Turb.*	*Cond*	*Sal*	*P*	*AN*	*Richness*	*ESG I*	*ESG II*	*EEI-c eqr*	*MALUSI*
pH	1.000												
T(°C)	0.29922	1.000											
DO	0.22214	–0.18891	1.000										
Turb.	–0.13204	–0.047789	0.027081	1.000									
Cond	0.037085	**0.42598**	–0.14793	–0.14668	1.000								
Sal	0.046254	0.4526	–0.14973	–0.14001	0.99515	1.000							
P	–0.13452	**0.14224**	–0.075451	**0.35662**	0.060999	0.047155	1.000						
AN	–0.10287	0.12586	0.073838	0.19564	**0.11437**	**0.10866**	**0.33523**	1.000					
Richness	0.1063	0.053387	0.046204	–0.40439	**0.45808**	**0.45898**	–0.38604	–0.14389	1.000				
ESG I	**0.10791**	0.051409	**0.19048**	–0.24423	**0.36007**	**0.36112**	–0.27804	–0.0035366	**0.75442**	1.000			
ESG II	0.012709	–0.35329	0.044519	**0.17231**	–0.5744	–0.57211	–0.010803	–0.062967	–0.39883	–0.58879	1.000		
EEI-c eqr	0.078864	**0.21657**	**0.11148**	–0.26416	**0.51821**	**0.51533**	–0.15557	0.05687	**0.68738**	**0.92464**	–0.82951	1.000	
MALUSI	–0.014591	–0.00077771	–0.12589	**0.19546**	–0.3325	–0.33696	0.16111	0.089528	–0.59313	–0.74811	**0.5638**	–0.7472	1.000

Table 2. The average values of the physico-chemical parameters of the each sampling stations (T: temperature, DO: dissolved oxygen; Turb.: turbidity, *zero values represent early morning hours; Cond.: conductivity; Sal.: salinity; P: phosphate; NH_4-N: ammonium nitrogen).

No	Station name	pH	T(°C)	DO (mg L^{-1})	Turb. (NTU)*	Cond.(S/m)	Sal. (‰)	PO_4 µmol × 10^{-2}	NH_4 µmol × 10^{-4}
1	Kilyos	8.26	23.47	5.78	2.33	27633.33	17.37	1.1	6.7
2	Şile	8.22	25.27	5.96	1.16	27766.67	17.33	1.2	23.3
3	Sakarya River-Karasu	8.29	26.75	5.39	3.79	20650.00	12.59	10.6	12.2
4	Krd.Ereğli	8.30	26.50	5.80	0.67	26750.00	16.70	3.3	8.9
5	Zonguldak	8.39	25.00	6.43	15.76	26900.00	16.80	2.3	12.2
6	Filyos	8.25	26.23	6.26	0.92	24866.67	15.63	2.5	11.1
7	Cide	8.25	23.60	6.04	11.19	27500.00	17.27	4.1	11.1
8	İnebolu	8.29	25.03	5.66	18.95	27700.00	17.23	8.8	11.6
9	Sinop	8.45	25.97	7.28	0.65	27666.67	17.23	2.3	21.1
10	Yakakent	8.29	26.97	5.75	4.38	27466.67	17.20	2.3	15.5
11	Kurupelit	8.23	26.70	5.10	5.27	27000.00	16.95	3.2	11.6
12	Samsun	8.32	26.83	8.84	1.12	27500.00	17.27	3.6	18.8
13	Yeşilırmak	8.16	26.00	5.47	2.50	27266.67	17.03	3.2	13.3
14	Fatsa	8.09	24.33	5.63	21.56	21666.67	13.23	2.9	9.4
15	Ordu	8.27	26.17	5.61	1.13	26233.33	16.17	1.2	13.9
16	Giresun	8.25	25.87	5.66	1.98	26733.33	16.70	2.0	17.2
17	Tirebolu	8.23	26.43	5.48	0.75	25600.00	15.93	3.3	13.9
18	Trabzon	8.29	26.10	5.36	3.68	26066.67	16.17	7.6	15.5
19	Rize	8.43	25.60	5.48	2.73	26733.33	16.60	1.8	21.6
20	Hopa	8.31	25.73	4.93	1.05	27333.33	17.07	2.8	24.9
21	Susurluk River-Boğaz	8.18	28.23	5.80	2.42	33633.33	21.63	4.5	17.2
22	Bandırma	8.24	26.85	5.03	1.95	33700.00	21.40	10.1	43.8
23	Kapıdağ	8.38	26.55	6.19	1.37	36650.00	23.65	1.8	8.3
24	Edincik	8.59	26.40	9.74	0.90	36600.00	23.40	1.8	8.9
25	Edincik-Enerji-SA	8.00	28.10	6.15	2.83	35750.00	23.20	2.4	38.8
26	Karabiga	8.22	28.75	4.70	2.46	34250.00	22.20	2.8	14.4
27	Lapseki	8.36	28.50	5.35	1.20	33500.00	21.70	2.3	17.7
28	Şarköy	8.41	28.13	6.77	2.55	34700.00	22.47	2.1	10.5
29	Tekirdağ	8.31	27.30	5.26	0.87	34300.00	22.00	4.2	22.7
30	M. Ereğlisi-West	8.27	27.75	5.10	4.21	34000.00	21.95	2.9	9.4
31	Marmara Ereğlisi	8.26	24.70	4.90	0.00	34800.00	22.00	2.7	13.9
32	Silivri	8.41	28.60	6.90	1.30	33400.00	21.55	2.5	18.3
33	Büyükçekmece	8.24	26.90	5.70	4.21	33800.00	21.75	6.6	10.5
34	Küçükçekmece	8.31	24.70	5.44	6.00	34900.00	22.10	5.6	28.3
35	Yenikapı	8.19	25.70	5.15	4.93	32300.00	20.70	3.0	13.9
36	Kadıköy	8.13	24.30	5.45	5.50	34300.00	22.00	2.3	15.0
37	İstanbul Isles	8.24	23.40	4.60	1.80	36100.00	23.50	1.9	7.2
38	Tuzla	8.16	24.75	5.10	3.20	34100.00	21.55	3.1	16.1
39	Eskihisar-MAM	8.19	24.55	5.05	0.96	35150.00	22.60	2.7	21.6
40	Hereke	8.28	24.80	5.69	0.80	35833.33	22.97	3.3	18.3

Table 2. (Continued).

41	Kavaklıdere	8.18	24.23	5.27	1.70	35000.00	22.40	10.5	53.8
42	Kaytazdere	8.30	25.20	5.35	4.10	37400.00	23.80	3.4	16.1
43	Değirmendere	8.34	24.80	8.40	1.22	35850.00	23.10	6.5	27.2
44	Yalova	8.25	25.60	5.28	0.00	36500.00	23.20	3.7	18.8
45	Çınarcık	8.43	26.20	8.00	4.31	32900.00	21.15	4.0	20.5
46	Armutlu	8.35	25.25	6.29	0.90	35500.00	22.85	1.9	7.2
47	Gemlik	8.39	24.90	6.08	5.00	35900.00	22.70	3.5	17.2
48	Mudanya	8.30	26.50	5.20	4.76	33850.00	21.85	3.1	9.4
49	Susurluk River-East	8.23	27.20	5.45	1.42	32750.00	21.10	3.4	23.3
50	Enez	7.89	27.20	12.25	1.25	48450.00	32.40	3.3	21.6
51	Saros Bay	8.22	26.53	6.63	4.01	52666.67	35.63	1.7	24.9
52	Yeniköy	8.25	22.05	6.46	1.81	55400.00	37.80	1.4	10.5
53	Dalyan-Geyikli	8.21	24.90	5.40	1.47	51000.00	34.40	2.9	23.8
54	Edremit Bay	8.14	22.80	8.60	2.70	53600.00	36.60	8.6	18.3
55	Ayvalık	8.23	26.70	5.02	1.70	56200.00	37.60	4.1	7.8
56	Dikili	8.02	26.75	4.90	6.95	54150.00	36.90	2.1	24.4
57	Çandarlı	8.09	25.70	5.85	2.53	55150.00	37.60	2.3	20.0
58	Yenişakran	8.17	23.57	6.06	2.05	55133.33	37.17	3.6	16.1
59	Gediz River-Homa D.	8.37	29.30	4.75	23.90	56700.00	68.05	4.3	28.8
60	İzmir Bay	8.24	30.43	4.57	8.40	54800.00	37.37	13.4	32.7
61	Urla	8.42	29.07	5.78	1.07	55033.33	37.47	2.9	15.0
62	Ildır	8.32	27.03	5.70	0.00	55033.33	37.13	1.8	18.8
63	Sığacık	8.25	26.65	5.95	9.80	53200.00	35.45	15.0	25.5
64	Küçük Menderes	8.22	27.57	5.16	12.60	54533.33	36.67	6.0	22.7
65	Doğanbey	8.25	28.90	5.64	7.45	50350.00	33.75	4.1	23.3
66	Didim	8.38	29.30	5.15	3.30	55000.00	37.40	0.4	11.1
67	Güllük	8.29	28.43	4.99	0.70	53333.33	35.87	3.1	20.0
68	Bodrum	8.34	27.10	4.37	0.00	53500.00	36.80	0.4	3.9
69	Akyaka	7.97	23.50	5.31	1.87	31500.00	19.83	3.0	20.0
70	Gökova K.-Kapalı	8.23	27.40	5.94	0.55	37600.00	24.40	2.3	24.4
71	Datça	8.33	28.70	4.44	0.00	54800.00	36.90	1.9	6.1
72	Marmaris	8.28	26.63	3.90	0.10	55000.00	37.07	3.4	18.3
73	Köyceğiz-İztuzu	8.22	27.15	5.45	0.95	52950.00	35.60	4.8	20.5
74	Dalaman	8.26	28.67	5.97	0.47	53666.67	36.30	2.8	8.9
75	Fethiye Outer Bay	8.28	29.60	4.73	3.53	52000.00	35.33	4.5	16.1
76	Fethiye İnner Bay	8.05	30.40	3.50	36.45	42000.00	27.90	11.6	31.6
77	Eşen River-Patara	8.33	28.13	5.06	19.30	36620.00	24.90	4.5	6.7
78	Kaş	8.15	23.33	5.61	0.40	40633.33	26.27	3.5	7.8
79	Finike	8.17	23.10	5.13	1.77	46533.33	30.33	3.3	23.3
80	Kemer	8.37	29.93	4.88	0.10	53766.67	36.37	3.0	15.0
81	Antalya	8.26	29.77	5.01	0.37	52733.33	35.80	4.8	19.4
82	Manavgat	8.24	28.70	5.85	1.95	53900.00	36.50	7.7	8.3
83	Alanya	8.24	30.75	4.31	1.75	54100.00	36.90	3.7	12.7
84	Anamur	8.26	30.00	3.57	0.00	54100.00	36.90	2.1	9.4

Table 2. (Continued).

85	Taşucu	8.44	29.10	9.20	0.25	54600.00	37.15	1.4	18.3
86	Silifke	8.30	29.15	6.04	0.45	53700.00	36.40	5.9	11.1
87	Erdemli	8.31	29.10	6.35	1.45	52600.00	35.60	4.7	31.0
88	Mersin	8.28	30.50	5.96	2.00	53350.00	36.35	2.7	22.2
89	Karataş	8.33	30.59	5.57	3.00	54500.00	37.50	6.3	27.2
90	Yumurtalık	8.36	29.83	5.90	5.50	52750.00	35.85	5.6	26.1
91	Gölovası	8.38	30.29	5.92	4.75	54200.00	37.05	5.4	20.5
92	İskenderun	8.28	32.50	0.00	0.00	54900.00	38.00	1.3	6.1
93	Çevlik	8.38	29.67	6.05	4.95	53550.00	36.55	6.3	32.7

parameters) and biotic (ESG I, ESG II, richness, etc.) parameters at the Turkish coasts (54.11% of total variance represented by the first two axes, Figure 2). PCA showed that the Aegean (Ayvalık, Bodrum, Çandarlı, Datça, Didim, Dikili, Sığacık, Urla, Yeniköy-Çanakkale, etc.) and the Mediterranean (Finike, Marmaris, Kaş, Kemer, Manavgat, Yumurtalık, Karataş, Çevlik, etc.) sites were usually characterized by the highest values of salinity, temperature, richness, ESG I (sensetive, late-successional taxa) and EEI-c*eqr*. Both the Marmara Sea (i.e. Kapıdağ, Lapseki, Şarköy) and the Black Sea (i.e. Sinop, Şile, Kilyos) regions were also characterized by the highest ESG I, richness, and EEI-c*eqr* values. Many sites in the Black Sea and Marmara Sea are characterized by ESG II (tolerant and opportunistic taxa).

3.2. Species diversity

In this study, a total of 233 marine macroalgae [53 Phaeophyceae (brown algae), 127 Rhodophyta (red algae), and 53 Chlorophyta (green algae)] and seven aquatic angiosperms taxa were sampled at specific and subspecies levels from different localities on the Turkish coasts between 2017 and 2019 (Table 3). While the most taxa were found on the Aegean coasts (154 taxa), followed by the Mediterranean coasts (151 taxa), the Marmara Sea (113 taxa), and the Black Sea coasts (112 taxa), respectively. The most taxa were found in Sinop (55 taxa), Şile (53 taxa) and Kilyos (45) in the Black Sea (Table 4, Figure 3), Şarköy (65 taxa), Kapıdağ (63 taxa), and Lapseki (59 taxa) in the Marmara Sea (Table 4, Figure 3), Ayvalık (75 taxa), Urla (70 taxa), and Didim (68 taxa) on the Aegean coasts (Table 4, Figure 3), Kaş (56 taxa), Marmaris (55 taxa), and Antalya (53 taxa) on the Mediterranean coasts (Table 4, Figure 3).

3.3. Ecological status class (ESC) analysis

ESG I and ESG II (%) total coverage, EEI-c value, EEI-c $_{EQR}$, ecological status class (ESC), and pressure data (MA-LUSI index) from sampling sites are given in Table 4. The study revealed high ecological status for 40 sites (4 Black Sea, 3 Marmara Sea, 17 Aegean Sea, and 16 Mediterranean Sea), good for 24 sites (9 Black Sea, 8 Marmara Sea, 3 Aegean Sea, and 4 Mediterranean Sea), moderate for 12 sites (3 Black Sea, 8 Marmara Sea, and 1 Aegean Sea), poor for 13 sites (2 Black Sea, 9 Marmara Sea, and 1 Mediterranean Sea), and bad for 4 sites (2 Black Sea, 1 Marmara Sea, and 1 Aegean Sea) (Table 4). While the Aegean and Mediterranean coasts of Türkiye mostly show the best conditions, (high and good ecological quality status) moderate, poor and bad ecological quality status is generally recorded in the Marmara Sea and the Black Sea. The coastal slope of the Black Sea increases from West to East. Therefore, coastal stations in the East do not reflect terrestrial pressures very well. Since the macroalgae stations are closer to the coastal areas, they can better show the interaction with the terrestrial areas behind them.

Sinop (96.83%) has the highest total ESG I (late-successional and sensitive taxa) coverage on the Black Sea coast, followed by Rize (78.12%), Yakakent (74.14%), and Şile, respectively, where sensitive species *Gonglaria barbata*, *Cystoseira bosphorica* (Sinop, Rize, Yakakent and Şile), and angiosperm *Zostera marina* (Sinop only) are found. On the other hand, the highest total coverage area of EGS II was recorded in Samsun (78.38%), followed by Sakarya River-Karasu (53.45%). The highest total ESG I coverage in the Sea of Marmara was found at Şarköy (91.68%), Lapseki (77.97%), and Kapıdağ (77.58) stations, where the angiosperm *Cymodocea nodosa* is dominant. The highest total coverage (%) of ESG I was found in Edremit Bay (121.64 %) in the Aegean Sea on the Turkish coast (Table 4), and Edremit Bay followed by Saros Bay (101.31%), Yeniköy (89.09%), and Dalyan-Geyikli (82.76%) in the Aegean Sea. The species were not found at Bostanlı station (İzmir Bay) (ESG II 54.04%). Fethiye Inner Bay (ESG II 45.86%) and Mersin Bay (ESG II 38.33%) have been affected by anthropogenic activities, and these two stations have the highest ESG II (40.6 %) coverage compared to other stations on the Mediterranean coast (Table 4). The EEI-c values of the stations on the Turkish coast and the Bray-Curtis cluster analysis applied to the scope of ESG I (IA, IB, IC) and ESG II (IIA, IIB) were also performed

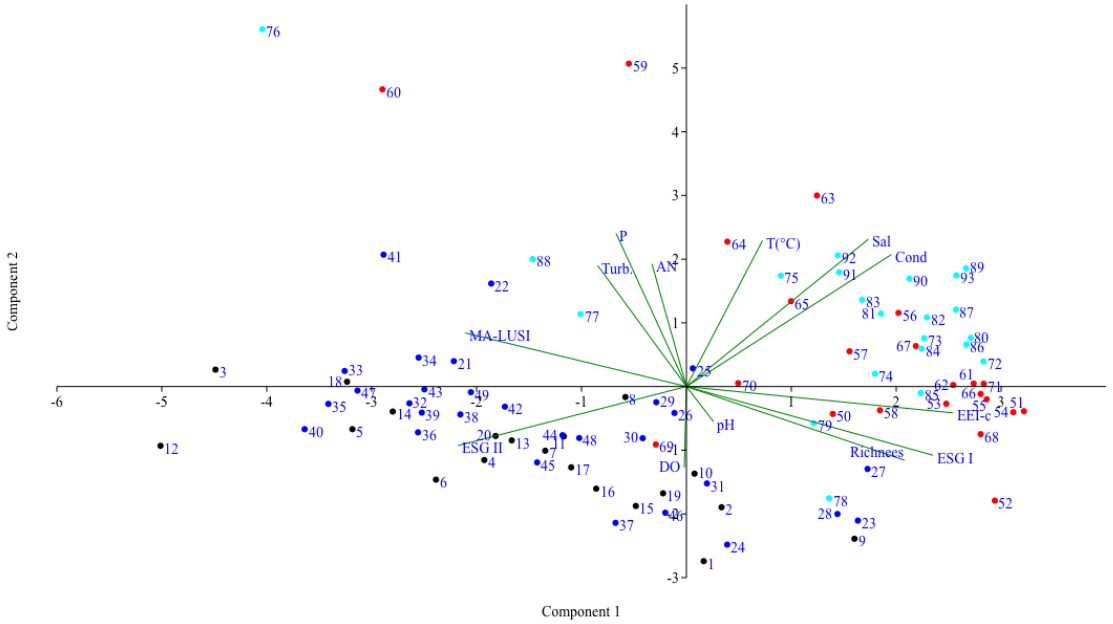

Figure 2. Principal component analysis (PCA) showing the relationships among abiotic and biotic parameters from the Turkish coasts. [The Black Sea coasts: (1:Kilyos, 2: Şile, 3: Sakarya River-Karasu, 4: Krd.Ereğli, 5: Zonguldak, 6: Filyos, 7: Cide, 8: İnebolu, 9: Sinop, 10: Yakakent, 11: Kurupelit, 12: Samsun, 13: Yeşilırmak, 14: Fatsa, 15: Ordu, 16: Giresun, 17: Tirebolu, 18: Trabzon, 19: Rize, 20: Hopa). The Marmara Sea coasts: (21: Susurluk River-Boğaz, 22: Bandırma, 23: Kapıdağ, 24: Edincik, 25: Edincik-Enerji-SA, 26: Karabiga, 27: Lapseki, 28: Şarköy, 29: Tekirdağ, 30: M. Ereğlisi-West, 31: Marmara Ereğlisi, 32: Silivri, 33: Büyükçekmece, 34: Küçükçekmece, 35: Yenikapı, 36: Kadıköy, 37: İstanbul Isles, 38: Tuzla, 39: Eskihisar-MAM, 40: Hereke, 41: Kavaklıdere, 42: Kaytazdere, 43: Değirmendere, 44: Yalova, 45: Çınarcık, 46: Armutlu, 47: Gemlik, 48: Mudanya, 49: Susurluk River-East). The Aegean coasts: (50: Enez, 51: Saros Bay, 52: Yeniköy, 53: Dalyan-Geyikli, 54: Edremit Bay, 55: Ayvalık, 56: Dikili, 57: Çandarlı, 58: Yenişakran, 59: Gediz River-Homa D., 60: İzmir Bay, 61: Urla, 62: Ildır, 63: Sığacık, 64: Küçük Menderes, 65: Doğanbey, 66: Didim, 67: Güllük, 68: Bodrum, 69: Akyaka, 70: Gökova K.-Kapalı, 71: Datça). The Mediterranean coasts: (72: Marmaris, 73: Köyceğiz-İztuzu, 74: Dalaman, 75: Fethiye Outer Bay, 76: Fethiye İnner Bay, 77: Eşen River-Patara, 78: Kaş, 79: Finike, 80: Kemer, 81: Antalya, 82: Manavgat, 83: Alanya, 84: Anamur, 85: Taşucu, 86: Silifke, 87: Erdemli, 88: Mersin, 89: Karataş, 90: Yumurtalık, 91: Gölovası, 92: İskenderun, 93: Çevlik)]

Table 3. Species diversity in the sampling stations from the coasts of Türkiye.

	Black Sea coasts	Marmara Sea	Aegean Sea coasts	Mediterranean Sea coasts	Total taxa
Phaeophyceae	21	23	38	30	53
Rhodophyta	60	57	72	80	127
Chlorophyta	28	31	38	36	53
Spermatophyta	3	2	6	5	7
Total taxa	112	113	154	151	240

(Figure 4), and all sampled stations were gathered under two clusters (37% similarity). The first cluster consisted of stations with the higher coverage (%) of ESG I (IA, IB, IC) (i.e. Saros Bay, Edremit Bay, Dikili, Kaş, Anamur, Çevlik) and the lower coverage (%) of ESG IIB. The second cluster was gathered under two clusters, and first one consisted of stations with the higher coverage (%) of ESG I (IA, IB, IC) and ESG IIB (Bandırma Enez, Edincik, Kapıdağ, Mudanya, Rize, Sinop, Tekirdağ, Urla, Yakakent), while the second cluster consisted of the highest coverage (%) of ESG II (IIB) (i.e. Hereke, Mersin, Samsun, Silivri, Trabzon, Tuzla). The highest EEI-c values were found in Sinop (10.00) and Yakakent (8.51) on the Black Sea coast, Lapseki (8.95), and Kapıdağ (8.52) on the Marmara Sea coast, Saros Bay and Edremit Bay (10.00), Dalyan-Geyikli (9.71), and Dikili (9.69) on the Aegean coast, and Erdemli and Karataş (10.00), Silifke (9.90), and Marmaris (9.84) on the Mediterranean coast (Table 4).

3.4. Biotic index (EEI-c) and the pressure index (MA-LUSI)

The MA-LUSI index includes direct (marine culture, sediment nutrient release, sewage outflow, irregular

Table 4. The Ecological Quality Ratio by EEI-c_{EQR}, Ecological Status Class (ESC) and pressures data (MA-LUSI index) on the coasts of Türkiye. (*Taşkın et al., 2020b; **New monitoring stations)

No	Station	Species richness	Total coverage (%)		EEI-c value	EEI-c eqr	ESC	ESC*	MA-LUSI Index
			ESG I	ESG II					
1	Kilyos	45	60.84	32.75	7.75	0.72	G	G	3
2	Şile	53	70.76	32.29	8.32	0.79	H	G	5.25
3	Sakarya River-Karasu	20	0.00	53.45	2.09	0.01	B	B	10.5
4	Krd.Ereğli	26	35.00	35.76	5.89	0.49	G	**	10
5	Zonguldak	23	4.00	43.54	2.95	0.12	P	P	7
6	Filyos	27	28.25	45.16	4.81	0.35	M	M	8.75
7	Cide	22	34.69	27.03	6.47	0.56	G	G	3.75
8	İnebolu	43	66.20	34.09	7.95	0.74	G	G	3.75
9	Sinop	55	96.83	24.83	10.00	1.00	H	H	3.375
10	Yakakent	30	74.18	32.05	8.51	0.81	H	G	3.75
11	Kurupelit	23	46.34	31.17	6.98	0.62	G	**	6.25
12	Samsun	23	0.11	78.38	1.20	0.00	B	B	14.06
13	Yeşilırmak	17	30.33	33.22	5.72	0.46	M	M	5
14	Fatsa	24	25.56	29.10	5.64	0.45	M	P	8.75
15	Ordu	41	67.69	35.80	7.91	0.74	G	**	8
16	Giresun	37	62.87	41.63	7.25	0.66	G	G	7
17	Tirebolu	30	46.01	34.63	6.71	0.59	G	G	6
18	Trabzon	27	13.83	41.31	3.91	0.24	P	P	11.3
19	Rize	38	78.12	35.35	8.46	0.81	H	G	7
20	Hopa	23	39.61	41.81	5.82	0.48	G	M	7
21	Susurluk River-Boğaz	29	10.14	37.17	3.85	0.23	P	P	9
22	Bandırma	39	30.49	42.78	5.12	0.39	M	P	7.5
23	Kapıdağ	63	77.58	34.11	8.52	0.82	H	G	3
24	Edincik	49	50.63	39.71	6.67	0.58	G	G	3.75
25	Edincik-Enerji-SA	45	53.34	35.94	7.08	0.64	G	**	3.75
26	Karabiga	39	46.66	37.49	6.56	0.57	G	**	3.75
27	Lapseki	59	77.97	28.71	8.95	0.87	H	**	2.25
28	Şarköy	65	91.68	42.98	8.49	0.81	H	H	4.21875
29	Tekirdağ	30	56.00	33.88	7.39	0.67	G	G	5.25
30	M. Ereğlisi-West	39	48.05	41.54	6.39	0.55	G	**	4.687
31	Marmara Ereğlisi	46	52.25	35.44	7.05	0.63	G	G	3.375
32	Silivri	27	9.84	49.29	3.14	0.14	P	**	10
33	Büyükçekmece	34	3.00	53.08	2.37	0.05	P	**	10.93
34	Küçükçekmece	42	2.73	39.49	3.06	0.13	P	P	9.375
35	Yenikapı	20	11.83	56.76	2.94	0.12	P	**	10
36	Kadıköy	36	29.35	53.18	4.46	0.31	M	**	11.3
37	İstanbul Isles	41	58.00	62.84	5.79	0.47	M	**	2.8125
38	Tuzla	31	17.85	39.83	4.33	0.29	M	P	8.75
39	Eskihisar-MAM	26	14.92	49.56	3.54	0.19	P	**	8
40	Hereke	22	0.22	73.64	1.34	0.00	B	B	7

Table 4. (Continued).

41	Kavaklıdere	20	8.55	41.12	3.48	0.18	P	P	6
42	Kaytazdere	30	15.13	40.16	4.09	0.26	M	M	6.25
43	Değirmendere	22	13.70	42.39	3.84	0.23	P	**	8
44	Yalova	45	36.73	49.91	5.15	0.39	M	M	7
45	Çınarcık	41	33.77	55.24	4.67	0.33	M	**	4.5
46	Armutlu	41	51.09	45.04	6.36	0.54	G	G	3.75
47	Gemlik	18	0.00	42.07	2.67	0.08	P	P	10
48	Mudanya	34	55.74	42.85	6.77	0.60	G	**	8.75
49	Susurluk River-East	31	30.50	47.11	4.87	0.36	M	**	9.375
50	Enez	39	64.98	21.66	8.84	0.86	H	**	4
51	Saros Bay	66	100.31	23.36	10.00	1.00	H	H	2.8125
52	Yeniköy	64	89.09	31.54	9.22	0.90	H	H	1.125
53	Dalyan-Geyikli	55	82.76	22.14	9.71	0.96	H	**	3
54	Edremit Bay	57	121.64	13.79	10.00	1.00	H	**	3
55	Ayvalık	75	74.16	25.68	9.01	0.88	H	H	4.5
56	Dikili	41	70.19	15.09	9.69	0.96	H	**	4.5
57	Çandarlı	42	56.40	18.87	8.57	0.82	H	H	5.625
58	Yenişakran	48	79.79	30.00	8.94	0.87	H	**	4.5
59	Gediz River-Homa D.	15	19.17	33.86	4.81	0.35	M	**	9.375
60	İzmir Bay	24	0.00	54.04	2.06	0.01	B	B	11.25
61	Urla	70	80.06	28.12	9.10	0.89	H	G	6.25
62	Ildır	53	68.98	18.06	9.37	0.92	H	H	4.6875
63	Sığacık	33	62.28	11.99	9.52	0.94	H	**	3.75
64	Küçük Menderes	40	41.33	22.95	7.25	0.66	G	G	7.5
65	Doğanbey	35	48.65	26.10	7.50	0.69	G	**	3
66	Didim	68	67.66	25.38	8.69	0.84	H	H	4.5
67	Güllük	55	60.83	19.62	8.77	0.85	H	G	5
68	Bodrum	66	61.14	18.42	8.89	0.86	H	H	4.5
69	Akyaka	35	42.46	18.58	7.68	0.71	G	G	4.6875
70	Gökova K.-Kapalı	28	40.43	9.54	8.30	0.79	H	**	5
71	Datça	53	59.66	14.83	9.11	0.89	H	H	3
72	Marmaris	55	73.82	15.54	9.84	0.98	H	H	3.75
73	Köyceğiz-İztuzu	39	67.66	14.01	9.65	0.96	H	**	2.81
74	Dalaman	51	54.25	23.49	8.06	0.76	H	G	5.63
75	Fethiye Outer Bay	21	38.71	14.71	7.73	0.72	G	M	4.69
76	Fethiye İnner Bay	12	0.00	45.86	2.47	0.06	P	**	9.38
77	Eşen River-Patara	20	29.09	19.56	6.62	0.58	G	**	6.56
78	Kaş	56	69.55	28.75	8.53	0.82	H	H	3.00
79	Finike	43	75.65	29.61	8.77	0.85	H	H	3.75
80	Kemer	47	65.16	11.20	9.76	0.97	H	**	4.50
81	Antalya	53	63.97	23.11	8.67	0.83	H	G	6.56
82	Manavgat	38	67.20	13.94	9.63	0.95	H	**	3.00
83	Alanya	44	46.54	22.19	7.67	0.71	G	G	4.50
84	Anamur	52	57.63	25.02	8.15	0.77	H	H	3.75

Table 4. (Continued).

85	Taşucu	42	70.95	17.99	9.48	0.93	H	H	6.56
86	Silifke	39	76.83	16.65	9.90	0.99	H	**	2.25
87	Erdemli	36	81.93	14.69	10.00	1.00	H	**	2.25
88	Mersin	31	7.92	38.33	3.59	0.20	P	P	12.50
89	Karataş	44	80.63	15.63	10.00	1.00	H	**	3.75
90	Yumurtalık	35	68.10	15.29	9.56	0.94	H	**	3.00
91	Gölovası	34	60.55	19.40	8.78	0.85	H	**	6.60
92	İskenderun	42	24.96	14.54	6.70	0.59	G	G	6.60
93	Çevlik	51	72.03	16.14	9.70	0.96	H	**	3.00

H: High, G: Good, M: Moderate, P: Poor, B: Bad

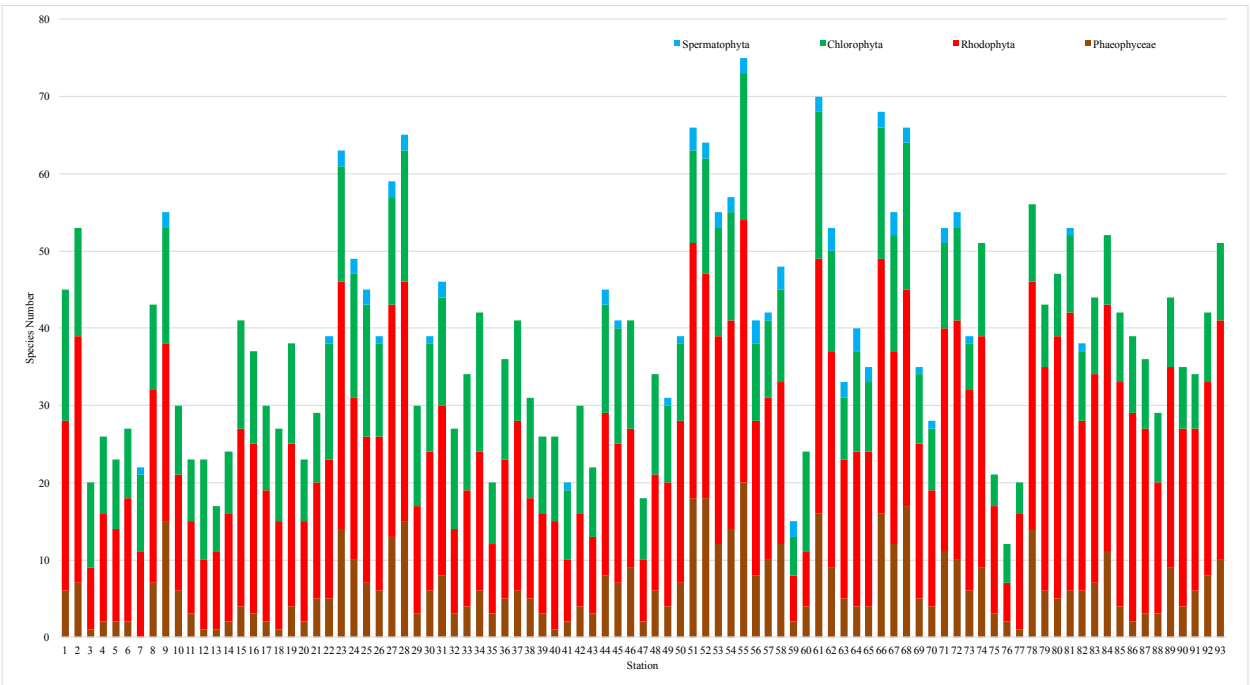

Figure 3. Species number of macroflora in the Turkish coasts. [The Black Sea coasts: (1: Kilyos, 2: Şile, 3: Sakarya River-Karasu, 4: Krd.Ereğli, 5: Zonguldak, 6: Filyos, 7: Cide, 8: İnebolu, 9: Sinop, 10: Yakakent, 11: Kurupelit, 12: Samsun, 13: Yeşilırmak, 14: Fatsa, 15: Ordu, 16: Giresun, 17: Tirebolu, 18: Trabzon, 19: Rize, 20: Hopa). The Marmara Sea coasts: (21: Susurluk River-Boğaz, 22: Bandırma, 23: Kapıdağ, 24: Edincik, 25: Edincik-Enerji-SA, 26: Karabiga, 27: Lapseki, 28: Şarköy, 29: Tekirdağ, 30: M. Ereğlisi-West, 31: Marmara Ereğlisi, 32: Silivri, 33: Büyükçekmece, 34: Küçükçekmece, 35: Yenikapı, 36: Kadıköy, 37: İstanbul Isles, 38: Tuzla, 39: Eskihisar-MAM, 40: Hereke, 41: Kavaklıdere, 42: Kaytazdere, 43: Değirmendere, 44: Yalova, 45: Çınarcık, 46: Armutlu, 47: Gemlik, 48: Mudanya, 49: Susurluk River-East). The Aegean coasts: (50: Enez, 51: Saros Bay, 52: Yeniköy, 53: Dalyan-Geyikli, 54: Edremit Bay, 55: Ayvalık, 56: Dikili, 57: Çandarlı, 58: Yenişakran, 59: Gediz River-Homa D., 60: İzmir Bay, 61: Urla, 62: Ildır, 63: Sığacık, 64: Küçük Menderes, 65: Doğanbey, 66: Didim, 67: Güllük, 68: Bodrum, 69: Akyaka, 70: Gökova K.-Kapalı, 71: Datça). The Mediterranean coasts: (72: Marmaris, 73: Köyceğiz-İztuzu, 74: Dalaman, 75: Fethiye Outer Bay, 76: Fethiye İnner Bay, 77: Eşen River-Patara, 78: Kaş, 79: Finike, 80: Kemer, 81: Antalya, 82: Manavgat, 83: Alanya, 84: Anamur, 85: Taşucu, 86: Silifke, 87: Erdemli, 88: Mersin, 89: Karataş, 90: Yumurtalık, 91: Gölovası, 92: İskenderun, 93: Çevlik)]

freshwater inflows, port) and indirect pressures (urbanization, trade and industry, agriculture). Each type of pressure has its own scores. MA-LUSI has been tested for all sampled stations (Table 4). On the Black Sea coasts, Samsun (MA-LUSI=14.06), Trabzon (MA-LUSI=11.3), Sakarya River-Karasu (MA-LUSI=10.5) were found to be the most stressed and disturbed stations by anthropogenic activities, while Kilyos (MA-LUSI=3.0), Sinop (MA-

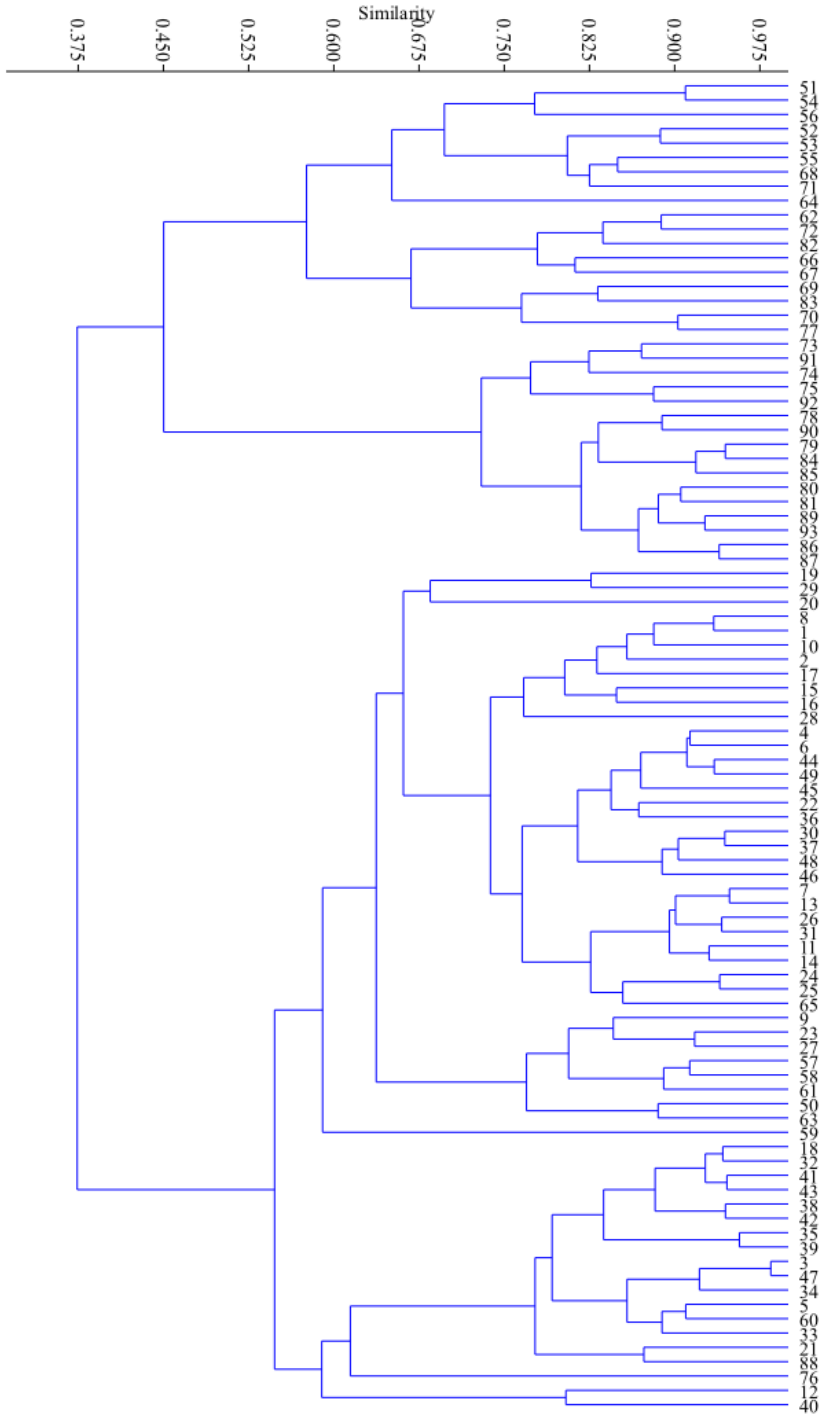

Figure 4. Bray-Curtis similarity index between the coverage ESGs (ESG IA, IB, IC and ESG IIA, IIB) and EEI-c results in the Turkish coasts. [The Black Sea coasts: (1: Kilyos, 2: Şile, 3: Sakarya River-Karasu, 4: Krd.Ereğli, 5: Zonguldak, 6: Filyos, 7: Cide, 8: İnebolu, 9: Sinop, 10: Yakakent, 11: Kurupelit, 12: Samsun, 13: Yeşilırmak, 14: Fatsa, 15: Ordu, 16: Giresun, 17: Tirebolu, 18: Trabzon, 19: Rize, 20: Hopa). The Marmara Sea coasts: (21: Susurluk River-Boğaz, 22: Bandırma, 23: Kapıdağ, 24: Edincik, 25: Edincik-Enerji-SA, 26: Karabiga, 27: Lapseki, 28: Şarköy, 29: Tekirdağ, 30: M. Ereğlisi-West, 31: Marmara Ereğlisi, 32: Silivri, 33: Büyükçekmece, 34: Küçükçekmece, 35: Yenikapı, 36: Kadıköy, 37: İstanbul Isles, 38: Tuzla, 39: Eskihisar-MAM, 40: Hereke, 41: Kavaklıdere, 42: Kaytazdere, 43: Değirmendere, 44: Yalova, 45: Çınarcık, 46: Armutlu, 47: Gemlik, 48: Mudanya, 49: Susurluk River-East). The Aegean coasts: (50: Enez, 51: Saros Bay, 52: Yeniköy, 53: Dalyan-Geyikli, 54: Edremit Bay, 55: Ayvalık, 56: Dikili, 57: Çandarlı, 58: Yenişakran, 59: Gediz River-Homa D., 60: İzmir Bay, 61: Urla, 62: Ildır, 63: Sığacık, 64: Küçük Menderes, 65: Doğanbey, 66: Didim, 67: Güllük, 68: Bodrum, 69: Akyaka, 70: Gökova K.-Kapalı, 71: Datça). The Mediterranean coasts: (72: Marmaris, 73: Köyceğiz-İztuzu, 74: Dalaman, 75: Fethiye Outer Bay, 76: Fethiye İnner Bay, 77: Eşen River-Patara, 78: Kaş, 79: Finike, 80: Kemer, 81: Antalya, 82: Manavgat, 83: Alanya, 84: Anamur, 85: Taşucu, 86: Silifke, 87: Erdemli, 88: Mersin, 89: Karataş, 90: Yumurtalık, 91: Gölovası, 92: İskenderun, 93: Çevlik)]

LUSI=3.37), Cide, İnebolu, and Yakakent (MA-LUSI=3.75) were found to be the least stressful stations. The MA-LUSI index showed maximum values in Kadıköy (MA-LUSI=11.3), Büyükçekmece (MA-LUSI=10.93), Silivri, Yenikapı, and Gemlik (MA-LUSI=10.0) on the shores of the Sea of Marmara where opportunistic taxa (*Ulva*, *Cladophora*, *Ceramium*, etc.) are abundant.

Urban population, industry, and port activities in the Marmara Sea are mainly in the provinces of İstanbul, Bursa, Bandırma, and Kocaeli. Although the coasts of these provinces have high MA-LUSI values, their EQR values are low (Table 4). In 2020 and 2021, there will be intense mucilage on the shores of İstanbul, Bursa, Bandırma, and Kocaeli in the Marmara Sea. In addition, this study shows that these provinces have high MA-LUSI and low EQR values.

Lapseki was the least stressed station (MA-LUSI=2.25) with the lowest total coverage of fleshy and filamentous/leaf-like opportunistic species (ESG II=28.71%). The least affected and undisturbed stations on the Aegean and Mediterranean coasts such as Yeniköy-Çanakkale (MA-LUSI=1.12), Silifke and Erdemli (MA-LUSI=2.25), Saros Bay and Köyceğiz-İztuzu (2.81) were characterized by sensitive and late successor taxa (*Cystoseira s.l.*, *Padina pavonica*, red calcareous algae, *Posidonia oceanica*, *Cymodocea nodosa*, etc.). Figure 5 shows the analysis of negative correlations (R^2 = 0.62, p = 1.3258E-32) between pressures (with MA-LUSI index) and EEI-c_{EQR} in coastal areas of Türkiye.

4. Discussion

The first comprehensive assessment of ecological quality status was made by Taşkın et al. (2020b) using macrophytes in Turkish coastal waters for the national monitoring program. The study revealed a high ESC for 15 sites, good for 21 sites, and moderate for 6 sites, poor for 10 sites, and bad for 4 sites. In this study, EEI-c was tested to assess ecological status classes at 93 stations for the second national monitoring program, with most stations in High/Good (68.82%) ecological status classes, with a few stations showing moderate (12.90%) and poor/bad (18.28%) conditions. Antalya, Dalaman, Urla, Güllük, Rize, Şile, Yakakent, and Kapıdağ were reported as a good ecological status class (Taşkın et al. 2020b) while they were found as a high ecological status class in the present study (Table 4). The relationship between the first (2014–2016) and the second (this study) (2017–2019) monitoring results was tested in the coasts of Türkiye and a strong correlation was found (R^2 = 0.89) (Figure 6).

MA-LUSI index assesses pressures of anthropogenic activities, and it is used for shallow water macroalgal communities disturbed. In the present study, due to urbanization and harbor and commercial activities, the most stressed sites were found to be in the Marmara Sea.

The higher coverage (%) of ESG IA and ESG IB were found in the Aegean Sea stations (i.e. Saros Bay, Bodrum, Ildır), while the higher coverage (%) of ESG IC were found in the Mediterranean coasts stations (i.e. Taşucu, Silifke, Erdemli, Finike). The shade-forming macroalgae are declining in some sampling areas (Antalya, Anamur, Silifke, Erdemli, etc.) along the Mediterranean coast of Türkiye and have been replaced by articulated Corallinales (*Corallina officinalis*, *Ellisolandia elongata*, *Jania rubens*, etc.) (*E.Taşkın, pers. observ.*).

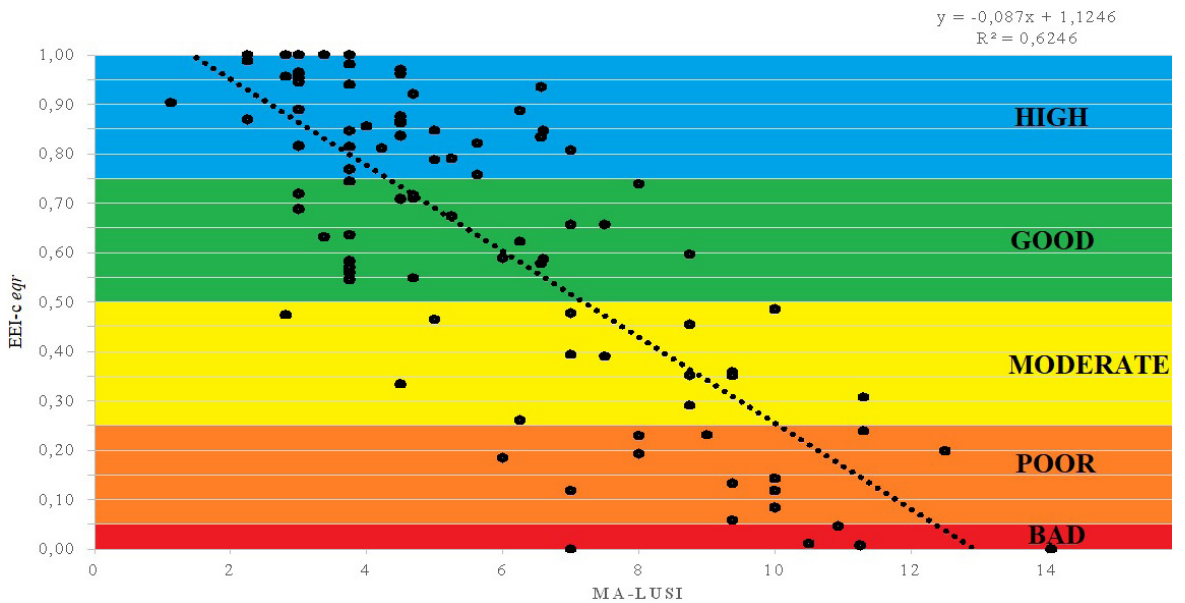

Figure 5. The relation between EEI-c_{EQR} and pressure data (MA-LUSI index) in the coasts of Türkiye.

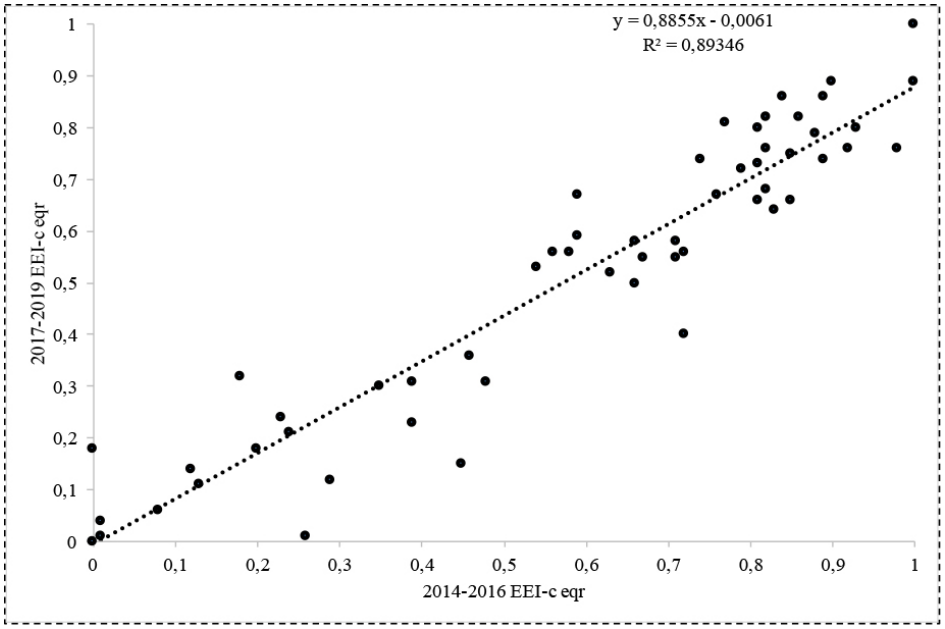

Figure 6. The relationships between the first (2014–2016) and the second (this study) (2017–2019) monitoring results in the coasts of Türkiye.

Marine benthic macrophytes (macroalgae and angiosperms) are the most sensitive bioindicators organisms of the abiotic and biotic changes in the aquatic environment (Orfanidis et al., 2001; Sfriso et al., 2014), where nutrients are abundant and impacted by pressures species composition changes from sensitive angiosperms and macroalgae (i.e. *Posidonia oceanica*, *Cystoseira* s.l.) to the dominance of opportunistic species (i.e. *Ulva* and *Cladophora*) (Orfanidis et al., 2001, 2011; Sfriso et al., 2007, 2009). In this study, several sampled sites (i.e. Sakarya River-Karasu, Samsun, Gemlik, Hereke, Bostanlı-İzmir Inner Bay, Mersin Bay) were heavily affected by anthropogenic activities (such as commercial, industrial activities, harbor, and urbanization), and the opportunistic macroalgae *Ulva*, *Cladophora*, and *Ceramium* were dominant. *Ulva* blooms were shown seasonally in Bostanlı-İzmir Inner Bay of the Aegean coasts.

The Ecological Status Classes (ESC) of the sampling sites were in relationship with the abiotic data, for example, some stations (i.e. Sakarya, Trabzon, Kavaklıdere, Bandırma, İzmir Gulf, Fethiye Inner Bay) with high phosphate were revealed as a bad, poor, moderate ecological status class.

Mediterranean canopy forests (canopy forming macroalgae, ex. *Cystoseira* s.l.) are affected by many threats, including deteriorating water quality, coastal development, herbivore outbreaks, and invasive species (Airoldi et al., 2014). Coverage of *Cystoseira* s.l. (%) in Slovenia's coastal waters is declining, but not yet replaced by articulated Corallinales and mussel beds (Orlando-Bonaca et al., 2021). *Cystoseira* s.l. species are affected by anthropogenic stress, and they were common in the pristine sites in this study. However, *Gongolaria barbata* was found in Trabzon, which is one of the most stressed stations. The perennial species (i.e. *Cystoseira foeniculacea*, *Posidonia oceanica*, etc.) are more affected by anthropogenic stress than semiperennial and filamentous and sheet-like opportunistic species.

Since seagrasses (*Posidonia oceanica*, *Cymodocea nodosa*, *Zostera* spp.) and canopy forming macroalgae have hosted many filamentous species in some stations (i.e. Lapseki, Şarköy, Sinop), ESG I is correlated positively with species richness.

The average salinity is different between the coasts of the Black Sea (14‰–18‰), the Marmara Sea (20‰–24‰), the Aegean Sea, and the Mediterranean Sea (35‰–38‰) of Türkiye, and the present study showed that the EEI-c is suitable for different salinity similar to the first monitoring program in agreement with PCA results.

In conclusion, macroalgae are known as good ecological indicators for monitoring studies, with their ecological importance and susceptibility to pressures (D'Archino and Piazzi, 2021). Macroalgae communities are often studied by destructive methods, but destructive methods are not suitable for use on sensitive macrophytes (D'Archino and Piazzi 2021). The Ecological Evaluation Index (EEI-c) has been reported as a suitable index to assess the ecological status using macrophytes (macroalgae and angiosperms) of Turkish coastal waters (Taşkın et al., 2020b).

Acknowledgements
The present study, was carried out with the project called "Integrated Pollution Monitoring in Turkish Seas (ÇŞB/ÇEDİDGM-TÜBİTAK/MAM; 2017-2019)" supported by the Ministry of Environment and Urbanization. We are grateful to Dr. Sotiris Orfanidis (Greece) for critically reviewing the manuscript.

References

Airoldi L, Ballesteros E, Buonuomo R, Van Belzen J, Bouma TJ et al. (2014). Marine Forests at Risk: Solutions to Halt the Loss and Promote the Recovery of Mediterranean Canopy-Forming Seaweeds. In: Proceedings of the 5th Mediterranean Symposium on Marine Vegetation (27-28 October 2014) (Langar, H., Bouafif, C., Ouerghi, A., edits.); Portorož, Slovenia 28–33.

Badreddine A, Abboud-Abi SM, Gianni F, Ballesteros E, Mangialajo L (2018). First assessment of the ecological status in the Levant Basin: Application of the CARLIT index along the Lebanese coastline. Ecological indicators 85: 37–47. https://doi.org/10.1016/j.ecolind.2017.10.006

Ballesteros E (1990). Structure and dynamics of the *Cystoseira caespitosa* (Fucales, Phaeophyceae) community in the North-Western Mediterranean. Scientia Marina 54: 155–168.

Ballesteros E, Torras X, Pinedo S, García M, Mangialajo L et al. (2007). A new methodology based on littoral community cartography dominated by macroalgae for the implementation of the European Water Framework Directive. Marine Pollution Bulletin 55: 172–180. https://doi.org/10.1016/j.marpolbul.2006.08.038

Borja A, Barbone E, Basset E, Borgersen G, Brkljacic M et al. (2011). Response of single benthic metrics and multi-metric methods to anthropogenic pressure gradients, in five distinct European coastal and transitional ecosystems. Marine Pollution Bulletin 62: 499–513. https://doi.org/10.1016/j.marpolbul.2010.12.009

Boudouresque CF (1969). Etude qualitative et quantitative d'un peuplement algal à *Cystoseira mediterranea* dans la région de Banyuls sur Mer. Vie et Milieu 20, 437–452.

Boudouresque CF, Blanfuné A, Ruitton S, Thibaut T (2020). Macroalgae as a tool for coastal management in the Mediterranean Sea. Handbook of Algal Science, Technology and Medicine 277–290. https://doi.org/10.1016/B978-0-12-818305-2.00017-6

D'Archino R, Piazzi L (2021). Macroalgal assemblages as indicators of the ecological status of marine coastal systems: A review. Ecological indicators 129: 107835. https://doi.org/10.1016/j.ecolind.2021.107835

EC (2013). Commission Decision of 20 September 2013 Establishing, Pursuant to Directive 2000/60/EC of the European Parliament and of the Council, the Values of the Member State Monitoring System Classifications as a Result of the Intercalibration Exercise and Repealing Decision 2008/ 915/EC. Official Journal of the European Union (L 266/1-47).

EU (2000). DIRECTIVE 2000/60/EC of the European parliament and of the council, of 23 October 2000, establishing a framework for Community action in the field of water policy. Official Journal of the European Communities, G.U.C.E. 22/12/2000, L 327.

Flo E, Camp J, Garcés E (2011). Assessment Pressure methodology, Land Uses Simplified Index (LUSI). (Personal communication WFD-CIS- phase II, Technical paper).

Flo E, Garcés E, Camp J (2019). Land Uses Simplified Index (LUSI): Determining Land Pressures and Their Link With Coastal Eutrophication. Frontiers in Marine Science 6, 10.3389/fmars.2019.00018.

Gobert S, Sartoretto S, Rico-Raimondino V, Andral B, Chery A et al. (2009). Assessment of three ecological status of Mediterranean French coastal waters as required by the Water Framework Directive using the *Posidonia oceanica* Rapid Easy Index: PREI. Marine Pollution Bulletin 58: 1727–1733. https://doi.org/10.1016/j.marpolbul.2009.06.012

Guiry MD, Guiry GM (2021). AlgaeBase. World-wide Electronic Publication. National University of Ireland, Galway, http://www.algaebase.org (Accessed 20 June 2021).

Hammer Ø, Harper DAT, Ryan PD (2001). PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1): 9pp.

Orfanidis S, Panayotidis P, Stamatis N (2001). Ecological evaluation of transitional and coastal waters: a marine benthic macrophytes-based model. Mediterranean Marine Science 2: 45–65. https://doi.org/10.12681/mms.266

Orfanidis S, Panayotidis P, Stamatis N (2003). An insight to the ecological evaluation index (EEI). Ecological indicators 3: 27–33. https://doi.org/10.1016/S1470-160X(03)00008-6

Orfanidis S, Panayotidis P, Ugland KI (2011). Ecological Evaluation Index (EEI) application: a step forward in functional groups, formula and reference conditions value. Mediterranean Marine Science 12: 199–231. https://doi.org/10.12681/mms.60

Orfanidis S, Papathanasiou V, Gounaris S, Theodosiou T (2010). Size distribution approaches for monitoring and conservation of coastal *Cymodocea* habitats. Aquatic Conservation Marine and Freshwater Ecosystems 20: 177–188. https://doi.org/10.1002/aqc.1069

Orfanidis S, Papathanasiou V, Mittas N, Theodosiou T, Ramfos A et al. (2020). Further improvement, validation, and application of CymoSkew biotic index for the ecological status assessment of the Greek coastal and transitional waters. Ecological indicators 118: 106727. https://doi.org/10.1016/j.ecolind.2020.106727

Orlando-Bonaca M, Pitacco V, Lipej L (2021). Loss of canopy-forming algal richness and coverage in the northern Adriatic Sea. Ecological indicators 125: 107501. https://doi.org/10.1016/j.ecolind.2021.107501

Parsons TR, Maita Y, Lalli CM (1984). A Manual of Chemical and Biological Methods for Seawater Analysis. Pons Point, N.S.W. Australia, Pergamon Press.

Pergent G (1991). Les indicateurs écologiques de la qualité du milieu marin en Méditerranée. Oceanis 17 (4): 341–350 (in French).

Piazzi L, Gennaro P, Ceccherelli G (2015). Suitability of the ALien Biotic IndEX (ALEX) for assessing invasion of macroalgae across different Mediterranean habitats. Marine Pollution Bulletin 97: 234–240. https://doi.org/10.1016/j.marpolbul.2015.06.011

Romero J, Martinez-Crego B, Alcoverro T, Perez M (2007). A multivariate index based on the seagrass *Posidonia oceanica* (POMI) to assess ecological status of coastal waters under the Water Framework Directive (WFD). Marine Pollution Bulletin 55: 196–204. https://doi.org/10.1016/j.marpolbul.2006.08.032

Sfriso A, Facca C, Bonometto A, Boscolo R (2014). Compliance of the macrophyte quality index (MaQI) with the WFD (2000/60/EC) and ecological status assessment in transitional areas: The Venice lagoon as study case. Ecological indicators 46: 536–547. https://doi.org/10.1016/j.ecolind.2014.07.012

Sfriso A, Facca C, Ghetti PF (2007). Rapid Quality Index, based mainly on Macrophyte Associations (R-MaQI), to assess the ecological status of the transitional environments. Chemistry and Ecology 23: 1–11. https://doi.org/10.1080/02757540701702918

Sfriso A, Facca C, Ghetti PF (2009). Validation of the Macrophyte Quality Index (MaQI) set up to assess the ecological status of Italian marine transitional environments. Hydrobiologia 617: 117–141. https://doi.org/10.1007/s10750-008-9540-8

Strickland JDH, Parsons TR (1972). A Practical Handbook of Seawater Analysis. Fisheries Research Board of Canada. The Alger Press, Ottawa, Canada.

Tan İ, Polat Beken Ç, Oncel S (2017). Pressure-Impact Analysis of the Coastal Waters of Marmara Sea. Fresenius Environmental Bulletin 26: 2689–2699.

Taşkın E (2020). A new non-destructive method for the assessment of the ecological status of coastal waters by using marine macrophytes. Journal of the Black Sea/Mediterranean Environment 26(1): 48–58.

Taşkın E, Tan İ, Minareci O, Minareci E, Atabay H, Polat Beken Ç (2020a). The pressures and the ecological quality status of the Marmara Sea (Türkiye) by using marine macroalgae and angiosperms. 8th International Symposium on Monitoring of Mediterranean coastal areas: Problems and measurement techniques. pp. 632-638.

Taşkın E, Tan İ, Minareci E, Minareci O, Çakır M et al.(2020b). Ecological quality status of the Turkish coastal waters by using marine macrophytes (macroalgae and angiosperms). Ecological indicators 112: 106107. https://doi.org/10.1016/j.ecolind.2020.106107

Taşkın E, Tsiamis K, Orfanidis S (2018). Ecological quality of the Sea of Marmara (Türkiye) assessed by the Marine Floristic Ecological Index (MARFEI). Journal of the Black Sea/Mediterranean Environment 24: 97–114.