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RESEARCH ARTICLE

Ecological quality of the Sea of Marmara (Turkey) assessed by the Marine Floristic Ecological Index (MARFEI)

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Abstract

Benthic macrophytes (macroalgae and angiosperms) are proposed as biological elements to assess the ecological status of coastal and transitional waters within the EU Water Framework Directive. In the present paper, a sampling of benthic macrophytes was made from 0-5 m depth at 25 different sites of the Sea of Marmara (Turkey) in 2015 and the *Mar*ine *F*loristic *E*cological *I*ndex (MARFEI) was applied. Macrophytes were classified into five ecological status groups: ESGI (IA, IB, IC; late-successional taxa such as *Cystoseira* spp., angiosperms, calcareous algae) and ESGII (IIA, IIB; opportunistic taxa such as filamentous and sheet-like green algae). The study revealed good ecological status class (ESC) for 1 site, moderate for 11 sites, poor for 10 sites, and bad for 3 sites. $MARFEI_{EQR}$ showed a strong negative linear relationship with the pressure index MA-LUSI. Nevertheless, the results of this study have to be validated by similar studies in other georgaphical areas.

Keywords: Angiosperms, MARFEI, pressures, marine algae, taxonomy

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Introduction

The EU Water Framework Directive (WFD, 2000/60/EC) requires the establishment of monitoring programs to assess the ecological status in coastal and transitional waters throughout Europe. To facilitate this task, macroalgae and

angiosperms were proposed as key biological quality elements. Marine benthic macrophytes, especially seagrasses and perennial macroalgae, are sensitive to anthropogenic activities, especially those linked with nutrient input and degradation of light regime in the water leading to eutrophication. For this reason several macrophyte indices have been proposed for the Mediterranea eco-region. These indices include the following: the Ecological Evaluation Index (EEI) (Orfanidis *et al.* 2001, 2011), the *Posidonia oceanica* multivariate index (POMI) (Romero *et al.* 2007), the CARtography of LITtoral (CARLIT) (Ballesteros *et al.* 2007), the Macrophyte Quality Index (MaQI) (Sfriso *et al.* 2007, 2009), the *Posidonia oceanica* Rapid Easy Index (PREI) (Gobert *et al.* 2009), and the Alien Biotic Index (ALEX) (Çınar and Bakır 2014; Piazzi *et al.* 2015). Recently, EEI and CARLIT for coastal waters, and EEI and MAQI for transitional waters have been succesfully intercalibrated by the Mediterranean Geographic Intercalibration Group (MEDGIG) (EC 2013), to ensure that good ecological status represents the same level ecological quality across the Mediterranean eco-region.

EEI has been applied in Greece, Cyprus, and Slovenia (Orfanidis *et al.* 2001, 2011; Panayotidis *et al.* 2004; Orlando-Bonaca *et al.* 2008). Nikolić *et al.* (2011) tested both CARLIT and EEI to measure the ecological status of the Adriatic coast of Croatia. Macrophyte biotic indices (EEI, CARLIT, and MaQI) were tested for the ecological quality classification of Turkish coastal and transitional waters by Taşkın and Öztürk (2014a, b), Taşkın *et al.* (2013, 2016), Dağlar and Taşkın (2015), Taşkın (2015).

In the present study, a new method, namely, the *Mar*ine *F*loristic *E*cological *I*ndex (MARFEI), was tested to assess the ecological status classes at 25 sites of the Sea of Marmara (Turkey). The concept of the MARFEI index is similar to EEI, and it is based on the obvious and universal pattern that "anthropogenic disturbance, e.g. pollution, eutrophication, shifts the ecosystem from pristine to more degraded states, and where opportunistic species are dominant" (Orfanidis *et al.* 2001). The relationship between the pressure index MA-LUSI and $MARFEI_{EQR}$ is also tested.

Materials and Methods

Study area

The Sea of Marmara is bordered completely by Turkey. It connects the Black Sea to the Aegean Sea, and it is connected to the Black Sea by the Istanbul (Bosphorus) Strait and to the Aegean Sea by the Çanakkale (Dardanelles) Strait. There are many islands (the Marmara Island, Paşalimanı Island, Prices Islands, etc.) in the Sea of Marmara. Sampling was made at 25 localities in the Sea of Marmara (Turkey) in 2015 (Figure 1).

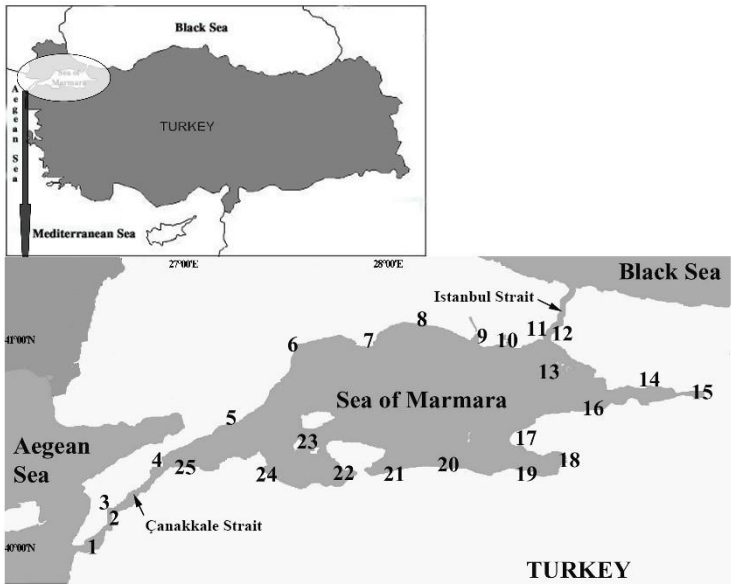

Figure 1. Research area and sampling stations in the Sea of Marmara (Turkey) [1-İntepe; 2-Çanakkale; 3-Eceabat; 4-Gelibolu; 5-Şarköy; 6-Tekirdağ; 7-M.Ereğlisi; 8-Silivri; 9-B.Çekmece; 10-K.Çekmece; 11-Haliç; 12-Üsküdar; 13-Princes Islands; 14-Hereke; 15-Kocaeli; 16-Yalova; 17-Armutlu; 18-Gemlik; 19-Mudanya; 20-Susurluk River-Boğaz; 21-Bandırma; 22-Erdek; 23-Paşalimanı Island; 24-Karabiga; 25-Lapseki]

Sampling

The material was collected by snorkeling from a 100 x100 m area per station in May and November 2015, and specimens were preserved in 2-5% formaldehyde in sea water. Samples were studied using a light microscope (Nikon SE), and voucher specimens are deposited in the personal herbaria of Ergün Taşkın (ET) in the Department of Biology of the Manisa Celal Bayar University (Manisa, Turkey). Nomenclature was checked against Guiry and Guiry (2018).

Environmental parameters

Physico-chemical parameters (salinity, temperature, pH, conductivity, turbidity, and dissolved oxygen) were measured by Water Quality Checker™ (DKK-TOA WQC 24). Ortho-phosphate (Parsons *et al.* 1984), and ammonium nitrogen (Strickland and Parsons, 1972) were also measured (Table 1).

Table 1. The average physico-chemical parameters of the sampling stations (T: temperature, DO:dissolved oxygen; Turb.: turbidity; Cond.: conductivity; Sal.: salinity; P: phosphate; AN: ammonium nitrogen)

Stations	pH	T(°C)	DO (mg/L)	Turb. (NTU)	Cond. (S/m)	Sal. (‰)	P (mg/L)	AN (mg/L)
İntepe	8.42	20.1	8.25	0	3.78	23.8	0.325	0.045
Çanakkale	8.30	16	6.7	0	3.68	22.9	0.297	0.049
Eceabat	8.41	16.3	8.6	0	3.68	23.3	0.322	0.045
Gelibolu	8.16	15.41	6.09	0	3.56	21.9	0.289	0.048
Şarköy	8.44	15.1	9.75	0	3.54	21.8	0.259	0.046
Tekirdağ	8.26	18.3	7.56	2	3.29	20.4	0.298	0.054
Marmara Ereğlisi	8.29	23.2	7.3	10.2	3.14	19.5	0.304	0.045
Silivri	8.20	23.6	7.5	19.6	2.48	15.1	0.311	0.049
Büyükçekmece	8.50	19.4	10.1	11.9	2.98	18.3	0.289	0.042
Küçükçekmece	8.82	18.9	10.26	13.6	2.16	13.1	0.262	0.041
Haliç	7.91	14.9	5.93	0.9	2.56	15.2	0.274	0.05
Üsküdar	8.17	12.4	7.58	0	3.03	17.8	0.237	0.048
Princes Islands	8.38	17.2	9.32	3.7	3.19	19.4	0.249	0.041
Hereke	8.32	18.5	4.81	5.2	3.15	19.3	0.251	0.043
Kocaeli	8.65	18.9	9.56	1.4	3.51	21.9	0.249	0.042
Yalova	8.30	17.1	7.65	0	3.52	22	0.292	0.046
Armutlu	8.59	21.8	9.5	12.1	3.39	21.3	0.263	0.038
Gemlik	8.32	23	6.56	37	2.12	12.7	0.264	2.161
Mudanya	8.54	20.5	8.86	1.1	2.83	17.3	0.308	0.042
Susurluk River-Boğaz	8.67	22.7	11.45	2.3	3.05	18.9	0.287	0.049
Bandırma	8.39	21	8.37	5	3.46	21.6	0.289	0.051
Erdek	8.38	18.1	8.43	0.7	3.83	24.1	0.285	0.052
Paşalimanı Island	8.35	17.6	8.05	0	3.5	21.6	0.333	0.055
Karabiga	8.54	23.3	10.35	2.7	3.59	22.7	0.31	0.051
Lapseki	8.48	19.7	9.2	2.7	3.65	22.8	0.156	0.059

Pressure data

The Macroalgae-Land Uses Simplified Index (MA-LUSI) has been developed as an improvement of LUSI index (Flo *et al.* 2011) using pressures affecting the benthic macrophytes. The MA-LUSI index takes under account the pressures from mariculture, sewage outfall, harbours, irregular fresh water inputs, sediment nutrient release, urban, commercial and industrial, agriculture, and background trophic status affect a 3 km buffer zone around the sampling site. It has been developed by the MEDGIG of macroalgae (EC 2013).

Data analysis

Macrophytes (macroalgae and angiosperms) were classified into five ecological status groups, ESGI (IA, IB, IC; late-successional taxa such as *Cystoseira* spp., angiosperms, calcareous algae), and ESGII (IIA, IIB; opportunistic taxa such as filamentous and sheet-like green algae) (Orfanidis *et al.* 2011) (Appendix 1). Ecological quality ratio (EQR) between 0 and 1 was obtained by the formulation (bad=0-0.20; poor=0.20-0.40; moderate=0.40-0.60; good=0.60-0.80; high=0.80-1).

Formula;

$$\mathrm{MARFEI}_{\mathrm{EQR}} = (4 * \%\mathrm{IA} + 3 * \%\mathrm{IB} + 2 * \%\mathrm{IC})/(1 * \mathrm{IIA} + 0{,}5 * \mathrm{IIB})$$

The relationship between pressures and $\mathrm{MARFEI}_{\mathrm{EQR}}$ values was calculated using the MA-LUSI index.

Results and Discussion

Physicochemical parameters were found as pH min. 7.91 – max. 8.82, temperature (°C) min. 12.4 – max. 23.6, salinity min. 12.7 – max. 23.8, dissolved oxygen (mg/L) min. 4.81 – max. 11.45, turbidity (NTU) min. 0 – max. 37, conductivity (S/m) min. 2.12 – max. 3.78, phosphate (mg/L) min. 0.156 – max. 0.333, and ammonium nitrogen (mg/L) min. 0.038 – max. 2.161 in the Sea of Marmara. The lowest temperature was measured in Üsküdar (12. 4 °C) because of Bosphorus streams from the Black Sea to the Aegean Sea via the Sea of Marmara. The highest value of ammonium nitrogen was measured in Gemlik (2.161 mg/L).

The Çanakkale Strait is situated between the Aegean Sea and the Sea of Marmara and has sandy, stony and rocky bottoms. Five stations (İntepe, Çanakkale, Eceabat, Gelibolu, and Lapseki) were selected on the coast of the Strait characterized by salinity between 21.9‰ and 23.8‰. *Cystoseira* spp., *Padina pavonica*, calcareous red algae, and the marine angiosperms *Posidonia oceanica* and *Cymodocea nodosa* were abundant there. Şarköy station was located in the Sea of Marmara and was characterized by sandy and partially by stony substratum covered by *Cystoseira barbata*, *Cymodocea nodosa*, calcareous red algae, and the green algae *Ulva* spp. and *Cladophora* spp. Tekirdağ and Marmara Ereğlisi had sandy and stony substratum, and these stations have been affected by harbours. Silivri, Büyükçekmece, Küçükçekmece, Haliç, and Üsküdar were all impacted by the antropogenic activities of the city of İstanbul, and opportunistic algae (*Ulva* spp., *Cladophora* spp., *Ceramium* spp., and blue-green algae) are found as dominant. The calcareous red algae *Corallina officinalis* and *Ellisolandia elongata* were abundant in Üsküdar station, where it is effected by the Bosphorus stream. Princes Islands (Adalar) consist of nine Islands (Büyükada, Heybeliada, Burgazada, Kınalıada, Sedef Adası, Yassıada, Sivriada, Kaşık Adası), and Tavşan

Adası (Neandros Island), and sampling was mainly made in Büyükada. Hereke and Kocaeli have a sandy and partially stony substratum. This area is impacted by commercial and industrial activities, and opportunistic algae (*Ulva rigida*, *Gracilaria gracilis*, etc.) were dominant. Yalova and Armutlu stations were characterized by sandy and stony substrata, and both sensitive (*Cystoseira barbata*, *Cymodocea nodosa*, calcareous red algae) and opportunistic algae (*Ulva* spp. and *Cladophora* spp.) were present there. Gemlik was very much impacted by commercial, industrial activities, and urbanization, and *Ulva rigida*, *Ceramium virgatum*, and blue-green algae were dominant. Mudanya has a stony and sandy substratum, and *Cystoseira barbata* and calcareous red algae were common. Susurluk River-Boğaz was characterized by sandy and partially by stony substratum, and it is affected by Susurluk River, and opportunistic algae dominated. Bandırma was impacted by urbanization as well as by harbour and shipping pressures, and that was characterized by blooms of opportunistic algae. Paşalimanı Island was characterized by sandy and by stony substratum, and both sensitive and opportunistic algae were found in abundance. Erdek and Karabiga stations were impacted by agriculture; they had a stony and sandy substratum. The alien and invasive green alga *Codium fragile* subsp. *fragile* was generally common in all stations of the Sea of Marmara from coast to depths of 20 m.

A total of 276 seaweed and marine angiosperm taxa [89 Phaeophyceae (brown algae), 139 Rhodophyta (red algae), 45 Chlorophyta (green algae), and three Spermatophyta] at specific and infraspecific levels are reported from 25 different localities in the Sea of Marmara (Appendix 1). The highest number of taxa was found in Paşalimanı Island (157 taxa), and Şarköy (154 taxa), İntepe (152 taxa), and Gelibolu (134), while the lowest number of taxa was found in Kocaeli (28 taxa), Hereke (30 taxa), Susurluk River-Boğaz (31 taxa), Gemlik (32 taxa), and Silivri (36 taxa), respectively.

Macrophytes (macroalgae and angiosperms) are known as good bio-indicators and as biological elements to assess the ecological status of coastal and transitional waters according to WFD. The Marine Floristic Ecological Index (MARFEI) used the number of taxa of five ESG's (ESG IA, IB, IC, and ESG IIA, IIB) (Orfanidis *et al.* 2011) in the Sea of Marmara. The Sea of Marmara is high marine traffic area moderately affected by anthropogenic disturbances except in locations near urban or industrial centers such as Instanbul. Indeed, MARFEI classified the Marmara Sea as various status, 1 site (İntepe) was classified as good ESC, 11 sites (Eceabat, Şarköy, Marmara Ereğlisi, Üsküdar, Yalova, Armutlu, Mudanya, Erdek, Paşalimanı Island, Karabiga, and Lapseki) as moderate, 10 sites (Çanakkale, Gelibolu, Tekirdağ, Silivri, Küçükçekmece, Büyükçekmece, Gemlik, Susurluk River-Boğaz, Prices Islands, and Bandırma) as poor, and 3 sites (Kocaeli, Hereke, and Haliç) as bad ESC (Table 2 and Figure 2). The relationship between the pressure MA-LUSI index and $MARFEI_{EQR}$ was tested, and a negative linear relationship was found (Figure 3). In Kocaeli, Haliç, and Gemlik sites that were under the influence of heavy pollution due to existense of urban, commercial

and industrial sewage outfall, and harbours, MA-LUSI values were maximum, and the green algae *Ulva* spp. and *Cladophora* spp., and the red algae *Ceramium* spp. and *Gracilaria gracilis* were at highest abundance. On the other side, in the less impacted, pristine sites of İntepe, Lapseki, Mudanya, Şarköy, Armutlu, Erdek, Eceabat, and Paşalimanı Island, MA-LUSI values were found minimum and the late-successional, sensitive macroalgae (*Cystoseira* spp., *Padina pavonica*, calcareous algae, etc.) and marine angiosperms (*Posidonia oceanica*, *Cymodocea nodosa*) were most abundant.

The macrophyte biotic indices EEI, CARLIT, MaQI have been applied in several studies to assess the ESC's of Turkish coastal and transitional waters (Taşkın and Öztürk 2014a,b; Taşkın *et al.* 2013, 2016; Dağlar and Taşkın 2013, 2015; Taşkın 2015). MARFEI is supplementary to EEI index designed to assess the ESC in sites where only presence-absence benthic macrophyte data are available giving the possibility also to use in water quality assessment the old check-lists available within the Mediterranean Sea.

In conclusion, MARFEI after its validation in other geographical areas could be recommended for future monitoring activities for Turkish coastal and transitional waters having as a prerequisite a thorough knowledge of benthic macrophyte biodiversity.

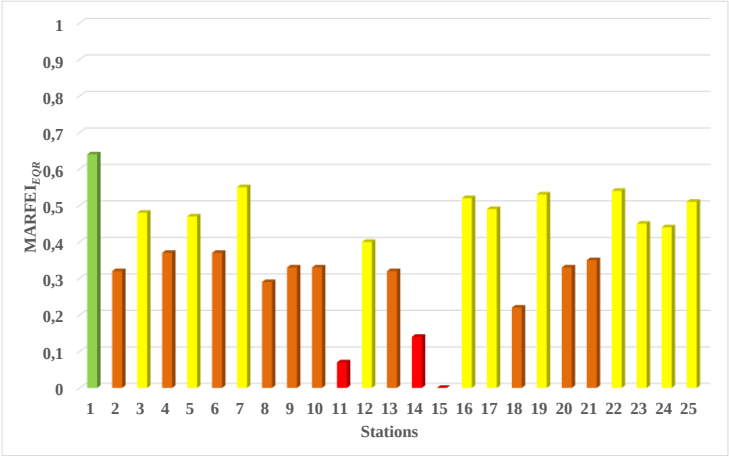

Figure 2. The Ecological Quality Ratio of station in the Sea of Marmara (Turkey) by MARFEI$_{EQR}$. [1-İntepe; 2-Çanakkale; 3-Eceabat; 4-Gelibolu; 5-Şarköy; 6-Tekirdağ; 7-M.Ereğlisi; 8-Silivri; 9-B.Çekmece; 10-K.Çekmece; 11-Haliç; 12-Üsküdar; 13-Princes Islands; 14-Hereke; 15-Kocaeli; 16-Yalova; 17-Armutlu; 18-Gemlik; 19-Mudanya; 20-Susurluk River-Boğaz; 21-Bandırma; 22-Erdek; 23-Paşalimanı Island; 24-Karabiga; 25-Lapseki]

Table 2. The Ecological Quality Ratio by MARFEI$_{EQR}$ and pressures data (MA-LUSI index) in the Sea of Marmara (Turkey)

Stations	MARFEI*eqr*	MA-LUSI	Species richnees
İntepe	0,64	2	152
Çanakkale	0,32	5	87
Eceabat	0,48	3	131
Gelibolu	0,37	4	134
Şarköy	0,47	3	154
Tekirdağ	0,37	7	68
Marmara Ereğlisi	0,55	5	76
Silivri	0,29	7,8125	36
Büyükçekmece	0,33	6,25	41
Küçükçekmece	0,33	7,8125	54
Haliç	0,07	12,5	39
Üsküdar	0,4	6,25	55
Princes Islands	0,32	2,8125	125
Hereke	0,14	8,75	30
Kocaeli	0	10,9375	28
Yalova	0,52	5	70
Armutlu	0,49	3	71
Gemlik	0,22	12,5	32
Mudanya	0,53	4	67
Susurluk River-Boğaz	0,33	3,75	31
Bandırma	0,35	5	75
Erdek	0,54	4	84
Paşalimanı Island	0,45	2	157
Karabiga	0,44	3,75	73
Lapseki	0,51	2	127

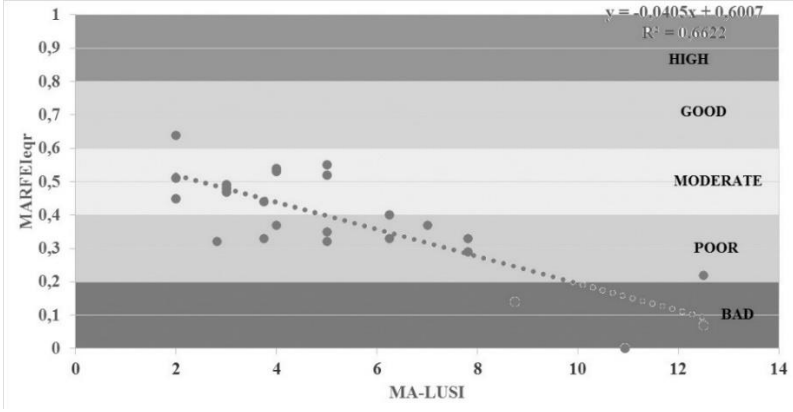

Figure 3. Relation between MARFEI$_{EQR}$ and pressure data (MA-LUSI index) in the Sea of Marmara (Turkey)

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Denizel Floristik Ekolojik İndeks (DENFEİ) Metodu ile Marmara Denizi'nin (Türkiye) ekolojik durumunun belirlenmesi

Öz

AB Su Çerçeve Direktifi'nde kıyı ve geçiş sularının ekolojik durumunun değerlendirilmesi için bentik makrofitler (makroalgler ve angiospermler) biyolojik element olarak önerilmektedir. Bu çalışmada, 2015 yılında Marmara Denizi'nin (Türkiye) 25 farklı noktasından 0-5 m derinlikten bentik makrofitler örnekledi ve Denizel Floristik Ekolojik İndeks (DENFEİ) uygulanmıştır. Makrofitler, ESGI (IA, IB, IC; *Cystoseira* spp., angiospermler, kalkerli algler gibi geç gelişimsel gösteren taksonlar) ve ESGII (IIA, IIB; ipliksi ve yapraksı yeşil algler gibi fırsatçı taksonlar). Bu çalışmada, 1 nokta için iyi, 11 nokta için orta, 10 nokta için zayıf ve 3 nokta için kötü ekolojik durum sınıfında (EDS) tespit edilmiştir. DENFEİ$_{EKO}$, baskı indeksi MA-LUSI ile kuvvetli negatif bir doğrusal ilişki göstermiştir. Bu çalışmanın sonuçları diğer coğrafik bölgelerde benzer çalışmalarla da doğrulanmalıdır.

Anahtar kelimeler: Angiospermler, baskılar, deniz algleri, DENFEI, taksonomi

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Appendix 1. The Ecological State Groups (ESG*) of marine benthic macrophytes (macroalgae and angiosperms)
(IA, IB, IC=sensitive taxa; IIA, IIB=tolerant-opportunist taxa).

Taxa	ESG
MACROALGAE	
Acetabularia acetabulum (L.) P.C.Silva	IC
Acinetospora crinita (Carmichael) Sauvageau	IIB
Acrochaetium crassipes (Børgesen) Børgesen	IIB
Acrochaetium mahumetanum Hamel	IIB
*Acrochaetium microscopicum (*Nägeli *ex* Kützing) Nägeli	IIB
Acrochaetium parvulum (Kylin) Hoyt	IIB
Acrochaetium savianum (Meneghini) Nägeli	IIB
Acrochaetium secundatum (Lyngbye) Nägeli	IIB
Acrochaetium virgatulum (Harvey) Batters	IIB
Acrodiscus vidovichii (Meneghini) Zanardini	IIA
Acrosorium ciliolatum (Harvey) Kylin	IIB
Aglaothamnion sp.	IIB
Aglaothamnion tenuissimum (Bonnemaison) Feldmann-Mazoyer	IIB
Aglaothamnion tripinnatum (C.Agardh) Feldmann-Mazoyer	IIB
Alsidium corallinum C.Agardh	IIA
Amphiroa rigida J.V. Lamouroux	IC
Anotrichium furcellatum (J.Agardh) Baldock	IIB
Anotrichium tenue (C.Agardh) Nägeli	IIB
Antithamnion cruciatum (C.Agardh) Nägeli	IIB
Antithamnion hubsii E.Y.Dawson	IIB
Arthrocladia villosa (Hudson) Duby	IIA
Asperococcus bullosus J.V.Lamouroux	IIA
Asperococcus ensiformis (Della Chiaje) M.J. Wynne	IIA
Asperococcus fistulosus (Hudson) W.J.Hooker	IIA
Bangia atropurpurea (Mertens *ex* Roth) C.Agardh	IIB
Blidingia marginata (J.Agardh) P.Dangeard ex Bliding	IIB
Boergeseniella fruticulosa (Wulfen) Kylin	IIB
Boergeseniella thuyoides (Harvey) Kylin	IIB
Botrytella micromora Bory de Saint-Vincent	IIB
Botrytella parva (Takamatsu) H.-S. Kim	IIB
Bryopsis corymbosa J.Agardh	IIB
Bryopsis hypnoides J.V.Lamouroux	IIB
Bryopsis plumosa (Hudson) C.Agardh	IIB
Callithamnion corymbosum (Smith) Lyngbye	IIB
Caulerpa cylindracea Sonder	IIB
Ceramium ciliatum var. *robustum* (J.Agardh) Mazoyer	IIB
Ceramium cimbricum H.E.Petersen	IIB
Ceramium circinatum (Kützing) J.Agardh	IIB
Ceramium deslongchampsii Chauvin ex Duby	IIB
Ceramium diaphanum (Lightfoot) Roth	IIB
Ceramium secundatum Lyngbye	IIB
Ceramium siliquosum f. *minusculum* (Feldmann-Mazoyer) Gómez Garreta, T.Gallardo, M.Ribera, Cormaci, G.Furnari, G. Giaccone & C.F.Boudour.	IIB
Ceramium siliquosum var. *elegans* (Roth) G. Furnari	IIB
Ceramium siliquosum var. *lophophorum* (Feldmann-Mazoyer) Serio	IIB
Ceramium tenerrimum (G.Martens) Okamura	IIB
Ceramium tenerrimum var. *brevizonatum* (H.E. Petersen) Feldmann-Mazoyer	IIB
Ceramium virgatum Roth	IIB
Ceramium virgatum var. *implexo-contortum* (Solier) G.Furnari	IIB
Chaetomorpha ligustica (Kützing) Kützing	IIB

Appendix 1. Continued

Chaetomorpha linum (O.F.Müller) Kützing	IIB
Champia parvula (C.Agardh) Harvey	IIA
Chondracanthus acicularis (Roth) Fredericq	IIA
Chondria capillaris (Hudson) M.J. Wynne	IIA
Chondria dasyphylla (Woodward) C.Agardh	IIA
Chondria mairei G.Feldmann	IIA
Chroodactylon ornatum (C. Agardh) Basson	IIB
Chylocladia verticillata (Lightfoot) Bliding	IIA
Cladophora albida (Nees) Kützing	IIB
Cladophora coelothrix Kützing	IIB
Cladophora dalmatica Kützing	IIB
Cladophora flexuosa (O.F.Müller) Kützing	IIB
Cladophora glomerata (L.) Kützing	IIB
Cladophora hutchinsiae (Dillwyn) Kützing	IIB
Cladophora laetevirens (Dillwyn) Kützing	IIB
Cladophora lehmanniana (Lindenberg) Kützing	IIB
Cladophora nigrescens Zanardini	IIB
Cladophora pellucida (Hudson) Kützing	IIB
Cladophora prolifera (Roth) Kützing	IIB
Cladophora rupestris (L.) Kützing	IIB
Cladophora sericea (Hudson) Kützing	IIB
Cladophora vagabunda (L.) C.Hoek	IIB
Cladosiphon contortus (Thuret) Kylin	IIB
Cladosiphon mediterraneus Kützing	IIB
Cladosiphon zosterae (J. Agardh) Kylin	IIB
Cladostephus spongiosus (Hudson) C.Agardh	IIA
Codium fragile subsp. *fragile* (Suringar) Hariot	IIB
Codium tomentosum Stackhouse	IIB
Codium vermilara (Olivi) Delle Chiaje	IIB
Colaconema codicola (Børgesen) H.Stegenga, J.J.Bolton, & R.J.Anderson	IIB
Colaconema daviesii (Dillwyn) Stegenga	IIB
Colpomenia peregrina Sauvageau	IIA
Colpomenia sinuosa (Mertens *ex* Roth) Derbès *et* Solier	IIA
Compsothamnion thuyoides (Smith) Nägeli	IIB
Corallina officinalis L.	IC
Corynophlaea umbellata (C. Agardh) Kützing	IIB
Cutleria chilosa (Falkenberg) P.C. Silva	IB
Cystoseira amentacea var. *stricta* Montagne	IA
Cystoseira barbata (Stackhouse) C.Agardh	IB
Cystoseira bosphorica Sauvageau	IA
Cystoseira compressa (Esper) Gerloff *et* Nizamuddin	IB
Cystoseira crinita Duby	IA
Cystoseira foeniculacea (L.) Greville	IA
Cystoseira foeniculacea f. *tenuiramosa* (Ercegovic) A.Gómez Garreta, M.C. Barceló, M.A. Ribera & J.Rull Lluch	IA
Dasya baillouviana (S.G.Gmelin) Montagne	IIB
Dasya corymbifera J.Agardh	IIB
Dasya hutchinsiae Harvey	IIB
Dasya rigidula (Kützing) Ardissone	IIB
Dermocorynus dichotomus (J.Agardh) Gargiulo, M.Morabito & Manghisi	IIA
Dictyota dichotoma (Hudson) J.V.Lamouroux var. *dichotoma*	IIA
Dictyota dichotoma var. *intricata* (C.Agardh) Greville	IIA
Dictyota fasciola (Roth) J.V.Lamouroux	IIA
Dictyota linearis (C.Agardh) Greville	IIA

Appendix 1. Continued

Dictyota spiralis Montagne	IIA
Ectocarpus crouaniorum Thuret	IIB
Ectocarpus fasciculatus Harvey	IIB
Ectocarpus siliculosus (Dillwyn) Lyngbye	IIB
Ectocarpus siliculosus var. *dasycarpus* (Kuckuck) Gallardo	IIB
Ectocarpus siliculosus var. *hiemalis* (P.L. *et* H.M. Crouan *ex* Kjellman) Gallardo	IIB
Ectocarpus siliculosus var. *penicillatus* C. Agardh	IIB
Ectocarpus sp.	IIB
Elachista stellaris J.E. Areschoug	IIB
Ellisolandia elongata (J.Ellis & Sol.) K.R.Hind & Saunders	IC
Erythrotrichia sp.	IIB
Erythrotrichia carnea (Dillwyn) J.Agardh	IIB
Eudesme virescens (Carmichael *ex* Berkeley) J. Agardh	IIB
Falkenbergia rufolonosa (Harv.) F. Schmitz Tetrasporophyte of Asparagopsis armata Harv.	IIB
Feldmannia globifera (Kützing) Hamel	IIB
Feldmannia irregularis (Kützing) G. Hamel	IIB
Feldmannia lebelii (P.L. *et* H.M. Crouan) G. Hamel	IIB
Feldmannia mitchelliae (Harv.) H.-S.Kim	IIB
Feldmannia padinae (Buffham) G. Hamel	IIB
Feldmannia paradoxa (Montagne) G. Hamel	IIB
Feldmannia paradoxa var. *donatiae* (Ercegovic) Antolic & Span	IIB
Ganonema farinosum (J.V. Lamouroux) K.C. Fan *et* Yung C. Wang	IC
Gayliella flaccida (Harvey ex Kützing) T.O.Cho & L.J. McIvor	IIB
Gayliella mazoyerae T.O.Cho, Fredericq & Hommersand	IIB
Gayralia oxysperma (Kützing) K.L.Vinogradova ex Scagel *et al.*	IIB
Gelidiella nigrescens (Feldmann) Feldmann & G.Hamel	IIA
Gelidium crinale (Hare *ex* Turner) Gaillon	IIA
Gelidium pusillum (Stackh.) Le Jolis	IIA
Gelidium serra (S.G.Gmelin) E.Taşkın & M.J. Wynne	IIA
Gelidium spinosum (S.G.Gmelin) P.C.Silva	IIA
Giraudia sphacelarioides Derbès *et* Solier	IIB
Gracilaria bursa-pastoris (S.G.Gmelin) P.C.Silva	IIA
Gracilaria gracilis (Stackh.) M.Steentoft, L.M. Irvine & W.F.Farnham	IIA
Gymnogongrus griffithsiae (Turner) Martius	IIA
Haliptilon attenuatum (Kützing) Garbary *et* Johansen	IC
Haliptilon virgatum (Zanardini) Garbary & H.W.Johansen	IC
Halopithys incurva (Hudson) Batters	IB
Halopteris filicina (Grateloup) Kützing	IIA
Halopteris scoparia (L.) Sauvageau	IIA
Halothrix lumbricalis (Kützing) Reinke	IIB
Halurus flosculosus (J. Ellis) Maggs & Hommers.	IIB
Halymenia latifolia P.Crouan & H.Crouan ex Kützing	IIA
Halymenia sp.	IIA
Hecatonema terminale (Kützing) Kylin	IIB
Herposiphonia secunda (C. Agardh) Ambronn	IIB
Herposiphonia tenella (C.Agardh) Ambronn	IIB
Heterosiphonia crispella (C. Agardh) M.J. Wynne	IIB
Hincksia fuscata (Zanardini) P.C. Silva	IIA
Hincksia granulosa (J.E. Smıth) P.C. Silva	IIB
Hincksia sandriana (Zanardini) P.C. Silva	IIB
Hydrolithon farinosum (J.V.Lamouroux) D. Penrose *et* Y.M. Chamberlain	IC
Hypnea musciformis (Wulfen) J.V. Lamouroux	IIA
Hypoglossum hypoglossoides (Stackhouse) F.Collins *et* Hervey	IIA

Appendix 1. Continued

Jania adhaerens J.V.Lamouroux	IC
Jania rubens (L.) J.V.Lamouroux	IC
Kallymenia requienii (J.Agardh) J.Agardh	IIA
Kuckuckia spinosa (Kützing) Kornmann	IIB
Kutzingiella battersii (Bornet) Kornmann	IIB
Laurencia obtusa (Huds.) J.V.Lamouroux	IIA
Laurencia pyramidalis Bory *ex* Kützing	IIA
Laurencia uvifera (Forssk.) Børgesen	IIA
Lithophyllum corallinae (P.L. *et* H.M.Crouan) Heydrich	IC
Lithophyllum cystoseirae (Hauck) Heydrich	IC
Lomentaria clavellosa (Lighfoot *ex* Turner) Gaillon	IIA
Lomentaria clavellosa f. *urvillei* (J.V.Lamouroux) E.Taşkın	IIA
Lomentaria ercegovicii Verlaque, Boudour., Meinesz, Giraud & Marcot Coqueugniot	IIA
Lophosiphonia cristata Falkenberg	IIB
Lophosiphonia obscura (C. Agardh) Falkenberg	IIB
Melobesia membranacea (Esper) J.V. Lamouroux	IC
Meredithia microphylla (J. Agardh) J. Agardh	IIA
Mesogloia lanosa P.L. *et* H.M. Crouan	IIB
Mesogloia leveillei (J. Agardh) Meneghini	IIB
Mesogloia vermiculata (J.E. Smith) S.F. Gray	IIB
Mesophyllum lichenoides (J. Ellis) M. Lemoine	IC
Microcoryne ocellata Strömfelt	IIB
Microspongium globosum Reinke	IIB
Mikrosyphar polysiphoniae Kuckuck	IIB
Myriactula arabica (Kützing) Feldmann	IIB
Myriactula rivulariae (Suhr) Feldmann	IIB
Myrionema orbiculare J. Agardh	IIB
Myrionema strangulans Greville	IIB
Myriotrichia clavaeformis Harvey	IIB
Nemacystus flexuosus (C. Agardh) Kylin var. *giraudyi* (J. Agardh) de Jong	IIB
Neosiphonia elongella (Harvey) M.S. Kim & I.K.Lee	IIB
Neosiphonia sertularioides (Grateloup) K.W.Nam & P.J.Kang	IIB
Nitophyllum punctatum (Stackhouse) Greville	IIA
Osmundea pelagiensis G.Furnari	IIA
Osmundea pinnatifida (Hudson) Stackhouse	IIA
Osmundea spectabilis (Postels & Ruprecht) K.W.Nam	IIA
Padina pavonica (L.) Thivy	IB
Palisada patentiramea (Mont.) Cassano, Sentíes, Gil-Rodríguez & M.T. Fujii	IIA
Palisada perforata (Bory) K.W.Nam	IIA
Percursaria percursa (C.Agardh) Rosenvinge	IIB
Petalonia fascia (O.F. Müller) Kuntze	IIB
Petalonia zosterifolia (Reinke) Kuntze	IIB
Peyssonnelia dubyi P.Crouan & H.Crouan	IC
Peyssonnelia squamaria (S.G. Gmelin) Decaisne	IC
Phaeophila dendroides (P.L. Crouan et H.M. Crouan) Batters	IIB
Phyllophora crispa (Huds.) P.S.Dixon	IIA
Phymatolithon calcareum (Pallas) W.H.Adey & D.L.McKibbin	IC
Phymatolithon lenormandii (Aresch.) W.H.Adey	IC
Pneophyllum confervicola (Kützing) Y.M.Chamberlain	IC
Pneophyllum fragile Kützing	IC
Polysiphonia atra Zanardini	IIB
Polysiphonia breviarticulata (C.Agardh) Zanardini	IIB
Polysiphonia brodiei (Dillwyn) Sprengel	IIB
Polysiphonia denudata (Dillwyn) Greville *ex* Harvey	IIB

Appendix 1. Continued

Polysiphonia deusta (Roth) Sprengel	IIB
Polysiphonia elongata (Hudson) Sprengel	IIB
Polysiphonia kampsaxii Børgesen	IIB
Polysiphonia morrowii Harvey	IIB
Polysiphonia nodulosa J.Agardh	IIB
Polysiphonia opaca (C. Agardh) Moris *et* De Notaris	IIB
Polysiphonia sanguinea (C.Agardh) Zanardini	IIB
Polysiphonia scopulorum Harvey	IIB
Porphyra umbilicalis Kützing	IIB
Protectocarpus speciosus (Børgesen) Kornmann	IIB
Pseudochlorodesmis furcellata (Zanardini) Børgesen	IIB
Pseudolithoderma adriaticum (Hauck) Verlaque	IC
Pterocladiella capillacea (S.G.Gmelin) Santelices & Hommersand	IIA
Punctaria latifolia Greville	IIB
Punctaria plantaginea (Roth) Greville	IIB
Punctaria tenuissima (C. Agardh) Greville	IIB
Pyropia leucosticta (Thuret) Neefus *et* J.Brodie	IIB
Ralfsia verrucosa (Areschoug) Areschoug	IC
Rhizoclonium riparium (Roth) Harvey	IIB
Rhodochorton purpureum (Lightfoot) Rosenvinge	IIB
Rhodophyllis divaricata (Stackhouse) Papenfuss	IIA
Rhodymenia ardissonei (Kuntze) Feldmann	IIA
Rytiphlaea tinctoria (Clemente) C.Agardh	IIA
Sahlingia subintegra (Rosenvinge) Kornmann	IC
Sargassum vulgare C.Agardh	IB
Sauvageaugloia divaricata (Clemente) Cremades	IIB
Scytosiphon dotyi M.J. Wynne	IIB
Scytosiphon lomentaria (Lyngbye) Link	IIB
Spermatochnus paradoxus (Roth) Kützing	IIB
Spermothamnion repens (Dillwyn) Rosenvinge	IIB
Sphacelaria cirrosa (Roth) C. Agardh	IIA
Sphacelaria rigidula Kützing	IIA
Sphacelaria tribuloides Meneghini	IIA
Spongonema tomentosum (Hudson) Kützing	IIB
Spyridia filamentosa (Wulfen) Harvey	IIB
Stictyosiphon adriaticus Kützing	IIB
Stictyosiphon soriferus (Reinke) Rosenvinge	IIB
Stilophora nodulosa (C. Agardh) P.C. Silva	IIB
Stilophora tenella (Esper) P.C. Silva	IIB
Streblonema parasiticum (Sauvageau) De Toni	IIB
Striaria attenuata (C. Agardh) Greville	IIB
Stromatella monostromatica (P.Dangeard) Kornmann & Sahling	IIB
Stylonema alsidii (Zanardini) K.M. Drew	IIB
Stylonema cornu-cervi Reinsch	IIB
Trailliella intricata Batters (tetrasporophyte of *Bonnemaisonia hamifera* Hariot)	IIB
Ulothrix implexa (Kützing) Kützing	IIB
Ulva clathrata (Roth) C.Agardh	IIB
Ulva compressa L.	IIB
Ulva intestinalis L.	IIB
Ulva linza L.	IIB
Ulva polyclada Kraft	IIB
Ulva prolifera O.F.Müller	IIB
Ulva rigida C.Agardh	IIB
Ulva taeniata (Setchell) Setchell & N.L.Gardner	IIB

Appendix 1. Continued

Ulvella lens P.L.Crouan *et* H.M.Crouan	IIB
Ulvella leptochaete (Huber) R.Nielsen, C.J.O'Kelly & B.Wysor	IIB
Ulvella scutata (Reinke) R.Nielsen	IIB
Ulvella viridis (Reinke) R.Nielsen, C.J.O'Kelly & B.Wysor	IIB
Umbraulva dangeardii M.J. Wynne & G.Furnari	IIB
Vertebrata fucoides (Hudson) Kuntze	IIB
Vertebrata subulifera (C.Agardh) Kuntze	IIB
Vertebrata tripinnata (Harvey) Kuntze	IIB
ANGIOSPERMS	
Cymodocea nodosa (Ucria) Ascherson	IB
Posidonia oceanica (L.) Delile	IA
Zostera noltii Hornemann	IB