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Ecological evaluation of transitional and coastal waters: A marine benthic macrophytes-based model

S. ORFANIDIS[1], P. PANAYOTIDIS[2] and N. STAMATIS[1]

[1] National Agricultural Research Foundation, Fisheries Research Institute, 640 07 Nea Peramos, Kavala, Greece
e-mail: sorfanid@otenet.gr

[2] National Center for Marine Research, 16604 Athens, Greece

Abstract

A model to estimate the ecological status and identify restoration targets of transitional and coastal waters was developed. Marine benthic macrophytic species (seaweeds, seagrasses) were used to indicate shifts in the aquatic ecosystem from the pristine state with late-successional species (Ecological State Group I) to the degraded state with opportunistic (ESG II) species. The first group comprises species with a thick or calcareous thallus, low growth rates and long life cycles (perennials), whereas the second group includes sheet-like and filamentous species with high growth rates and short life cycles (annuals). Seagrasses were included in the first group, whereas Cyanophyceae and species with a coarsely branched thallus were included in the second group.

The evaluation of ecological status into five categories from high to bad includes a cross comparison in a matrix of the ESGs and a numerical scoring system (Ecological Evaluation Index). The model could allow comparisons, ranking and setting of priorities at regional and national levels fulfilling the requirements of the EU Water Frame Directive. A successful application of the model was realized in selected lagoons of the Macedonian and Thrace region (North Greece) and in the Saronic Gulf coastal ecosystems (Central Greece).

Key words: Ecological status, Water quality, Phytobenthos, Seaweeds, Seagrasses, Functional groups, Water Framework Directive

Introduction

The term "classes of ecological status" is used in the text of the EU frame Directive for Water Policy (WFD, 2000/60/EC) in order to describe the degree of human impact on the biological communities living in a water body. Five classes of quality (high, good, moderate, low and bad) are foreseen, the high class reflecting pristine, undisturbed conditions of the ecosystem.

The concept of "ecological status" (or ecological quality status) was elaborated during the early 90's, to be used in a new frame of European water policy. For the purposes of the Directive "ecological water quality is an overall expression of the structure and function of the biological community taking into account natural physiographic, geographical and climatic factors as well as physical and chemical conditions, including those resulting from human activities" (EEC, 1994).

Transitional and coastal waters are some of the most productive ecological systems on Earth and are recognized to be of extremely high "value" to human society. However, they are being severely threatened by anthropogenic pressure and climate change induced sea level rise (CROOKS & TURNER, 1999). For the management of these ecosystems it is critical to identify the key biological signals (impacts) that indicate the intensity of anthropogenic stress or ecological status.

Cumulative evidence indicates that impacts are best investigated at the population or community level (LOBBAN & HARRISON, 1994; CROWE *et al.,* 2000) and this requires an approach that integrates an ecological assessment into the more traditional chemical and physical evaluation (GIBSON *et al.,* 2000). However, the diagnosis of the ecological status is often a difficult task because of spatial and temporal variability in community features as a result of changes in physical and chemical conditions (ORFANIDIS *et al.,* 2001). One possibility for overcoming this complexity is to study communities from a functional point of view (groups of functionally similar species). At a functional level, communities appear to be much more temporally stable and predictable than when examined at the species level (STENECK & WALTING, 1982; STENECK & DETHIER, 1994). For example, anthropogenic stress shifts the community structure towards dominance of opportunistic species (BOROWITZKA M. A., 1972; REGIER & COWELL, 1972).

Marine benthic macrophytes (phytobenthos) are mentioned in the WFD as a "quality element" for the classification of marine coastal areas. They include two fundamentally different groups of plants, the seaweeds (macroscopic algae) and the seagrasses (vascular plants). These macrophytes form the structural base for some of the most productive ecosystems in the world (MANN, 1973; McROY & LLOYD, 1981), including rocky and soft bottom intertidal and subtidal zones, coral reefs, lagoons and salt marshes.

The three major taxonomic groups of seaweeds, Chlorophyceae, Phaeophyceae and Rodophyceae, although representing distinct evolutionary lines show similar ranges of morphologies. It would thus seem likely that this similarity of form is adaptive, conferring fitness on phyletically diverse organisms growing in a common habitat. The recognition of the importance of morphology has led to ecological classifications of seaweeds based on thallus morphology, longevity and life history (FELDMANN, 1951; CHAPMAN & CHAPMAN, 1976; RUSSEL, 1977). More recently, LITTLER & LITTLER (1980) have proposed a functional-form model. This model was tested and verified experimentally: the functional characteristics of plants, such as photosynthesis, nutrient uptake, and grazer susceptibility, are related to morphology and surface area: volume ratios (LITTLER, 1980; LITTLER & ARNOLD, 1982; LITTLER & LITTLER 1984). Seaweeds and seagrasses comprise two evolutionary and physiologically different groups (LARKUM *et al.,* 1989; HEMMINGA & DUARTE, 2000; LOBBAN & HARRISON, 1994) but have often been examined together because of morphological-functional similarities and the apparent overlap in habitats.

Because marine benthic macrophytes are mainly sessile organisms, they respond directly to the abiotic and biotic aquatic environment, and thus represent sensitive indicators of its changes. A good example is water eutrophication. It is well documented that elevated concentrations of nitrogen and phosphorus in the water column do not necessarily indicate highly eutrophic conditions, neither do low concentrations necessarily indicate absence of eutrophication (CLOERN, 2001). The reason is that nutrient concentrations in the water column are related to nutrient load as well as to other biological and chemical processes. A reliable signal of increasing eutrophication is the replacement of late successional, perennial seaweeds, like *Cystoseira* spp. and *Fucus* spp. by opportunistic species like *Ulva* spp. and *Enteromorpha* spp. (HARLIN, 1995; SCHRAMM & NIENHUIS, 1996; SCHRAMM, 1999). Several examples of impacts of anthropogenic stress on marine phytobenthic communities are shown in Table 1.

Marine benthic macrophytes, in particular seagrasses, also provide substrate, habitat and shelter for plants and animals, including economically important species (HARMELIN-VINIEN *et al.,* 1995; POLLARD, 1984; EDGAR, 1999 a, b). Since the canopy of leaves diminishes wave energy and currents (FONSECA & CALAHAN, 1992), they also significantly affect sediment stability (FONSECA, 1996) and the retention of particles (BULTHUIS *et al.,* 1984; DAUBY *et al.,* 1995).

The appliance of the WFD obligates all the members of European community first to evaluate the ecological status and then to identify restoration targets of their transitional and coastal waters. The aim of this paper was (1) to develop a model for the estimation of ecological status and identification of restoration targets of transitional and coastal waters, and (2) to apply this model in selected lagoons of the Eastern Macedonia and Thrace region (North Greece) and in the Saronic Gulf (Central Greece) coastal waters.

Materials and Methods

A. Development of the model

In the context of developing methodology suitable for evaluation of ecological status in transitional and coastal waters, a series of steps was followed:

(1) Identification of the basic concept that best describes the impact of anthropogenic stress to community from a synthesis of existing literature in Table 1.

(2) Identification a set of bio-indicators that respond directly to anthropogenic stress. A synthesis of existing literature in Table 1.

(3) Identification of functional groups that predict function of communities in pristine and degraded ecosystems. The existence of the functional-form model for seaweeds (LITTLER, 1980) and its relevance for describing functional characteristics of ecosystem, e.g. productivity, was used as a basic milestone. However, a new synthesis that incorporates seagrasses with seaweeds in a functional type scheme was needed.

(4) Development of a numerical scoring system that expresses the ecosystem status to a number. A good example of this procedure was the methodology followed by BRICKER *et al.* (1999) to assess eutrophic conditions in USA estuaries.

B. Case studies

The model was tested in selected lagoons of the Macedonian and Thrace region (North Greece) and in the Saronic coastal ecosystems (Central Greece).

Eastern Macedonian and Thrace lagoons

The investigated lagoons are located in the Eastern Macedonia and Thrace region, where one of the most extensive Greek fresh water-estuarine systems exists. They belong to the Nestos River (Vassova, Eratino, Agiasma, Keramoti) and Vistonida estuarine system (Fanari) catchments. Their value in ecological (Natura 2000 network) and economic (fish aquaculture) terms is high. Along the western coasts of the Nestos River Delta a series of four elongated bar-built lagoons exist (Figure 1). They consist of a shallow (up to 1.5 m) area and several artificially constructed channels (up to 3 m in depth). The fresh water sources of the lagoons are mainly agricultural run-offs

Table 1
Examples of impact of anthropogenic stress on marine benthic macrophytic communities.

Anthropogenic stress	**Benthic macrophytes**	**Impact**	**Literature**
Eutrophication	Seaweeds	Dominance of opportunistic species, seaweed blooms, decline of diversity	HARITONIDIS (1978), DIAPOULIS & HARITONIDIS (1987), CHRYSSOVERGIS & PANAYOTIDIS (1995), LAZARIDOU *et al.* (1997), SCHRAMM & NIENHUIS (1996), SCHRAMM (1999), LOTZE *et al.* (1999), LOTZE & SCHRAMM (2000)
	Seagrasses	Large scale and regional decline of meadows, dominance of fleshy seaweeds	LARKUM *et al.* (1989), HEMMINGA & DUARTE (2000)
Organic matter, Siltation	Seaweeds	Light reduction and alteration of hard substrate affects community structure	LOBBAN & HARRISON (1994)
	Seagrasses	Decline of meadows through reduction of light and accumulation of organic matter in sediment	HEMMINGA & DUARTE (2000)
Heavy metals	Seaweeds	Inhibition of reproduction and development, changes in community structure	LOBBAN & HARRISON (1994), COELHO *et al.* (2000), CROWE *et al.* (2000)
	Seagrasses	No direct effect has been observed	LARKUM *et al.* (1989)
Oil splits	Seaweeds	Short term growth reduction in intertidal species	LOBBAN & HARRISON (1994)
	Seagrasses	No direct effect has been documented	
Global warming	Seaweeds	Changes in distribution patterns are expected	BREEMAN (1990), PAKKER & BREEMAN (1994)
	Seagrasses	Changes in distribution patterns are expected	HEMMINGA & DUARTE (2000)
Increase of salinity	Seaweeds	Further expansion in estuarine ecosystems	LOBBAN & HARRISON (1994)
	Seagrasses	Species displacement, e.g. *Cymodocea* instead of *Ruppia*	KAMERMANS *et al.* (1999), present study
Trawling	Seaweeds	Damage of sublittoral stands	BLADER *et al.* (2000)
Fishing	Seagrasses	Fragmentation - decline of meadows	SÀNCHEZ-JEREZ & RAMOS (1996), BLADER *et al.* (2000)

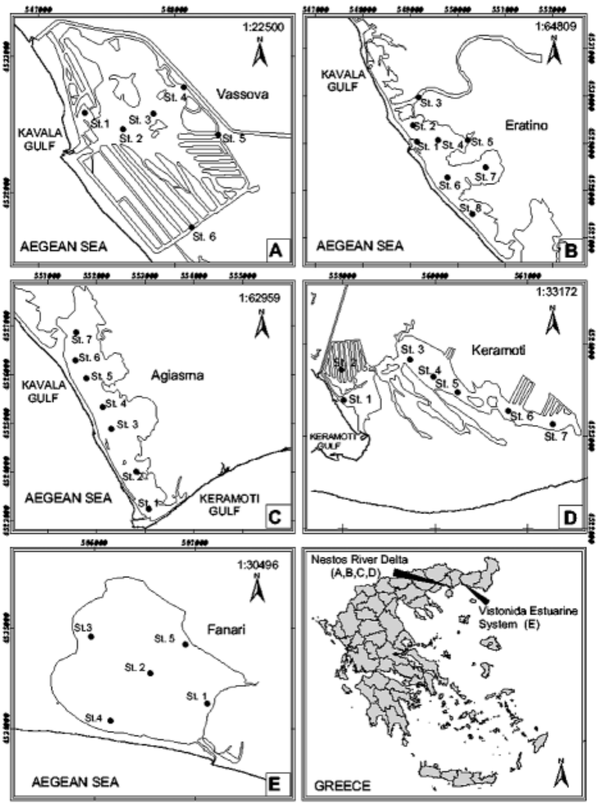

Fig. 1: A GIS-based map of the studied lagoons in the Eastern Macedonia and Thrace region, North Greece (St. = sampling station).

coming in from surrounding drainage channels and the old bed of the Nestos River. The Fanari lagoon consists of a uniform shallow area (up to 2 m in depth) having a narrow connection to the sea (Figure 1). The main fresh water sources of the lagoon are the autumn-winter rainfalls.

The studied lagoons were visited between summer 1999 and summer 2001. The lagoons of Agiasma and Keramoti were visited in August 2000; the lagoon of Eratino was visited in July 1999 and in winter 2001; the lagoon of Vassova was visited in summer 2000 and in winter 2001; the lagoon of Fanari was visited in November 2000 and in July 2001. In each lagoon representative stations (32 in total) were sampled taking into account hydrological and morphological characteristics (Figure 1). At stations with obvious patchiness of the benthic vegetation a second relevé (55 in total) was taken for verification. The sampling was destructive, by using a 30 cm x 50 cm x 100 cm (width x length x height) metallic stainless frame and a net. Each sample was carefully sorted and identification at species level, except Cyanophyceae mats, was attempted. For the identification and classification of species the following literature was used: COPPEJANS (1983), ATHANASIADIS (1987), BURROWS (1991), RIBERA *et al.* (1992), GALLARDO *et al.* (1993), MAGGS & HOMMERSAND (1993), LAZARIDOU (1994) and FLETCHER (1995). The abundance of species was estimated as % coverage in the sampling area (15 cm^2 = 1% of the sampling area) in horizontal projection

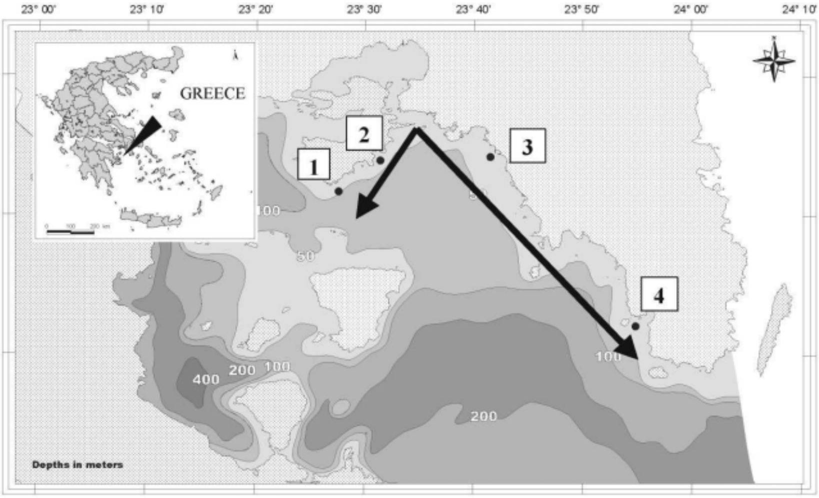

Fig. 2: Benthic macroalgal sampling stations in the Saronic Gulf.

(BOUDOURESQUE, 1971; VERLAQUE, 1987). Species were classified into functional form groups (FFg) according to LITTLER & LITTLER (1980, 1984).

Saronic Gulf

The Saronic Gulf is an embayment of the Aegean Sea (northeast Mediterranean) lying between 37°30'N and 38°00'N (Figure 2). The length of the coastline is about 744 km, the surface about 2.866 km^2, the maximum depth about 400 m and the mean depth about 100 m. The Saronic Gulf is bordered by the coasts of Attica in the north and by the coasts of the Peloponnise in the west and south west. The gulf communicates with the Aegean in the east through an approximately 50 km wide open connection. Rocky calcareous shores are the dominant element of the coastline. The present study refers to the coastline of Attica, about 182 km long.

Four sampling stations were chosen in the upper infralittoral zone (0.5 to 1 meter in depth) across two axes with a gradual attenuation of pollution (Figure 2). Stations 1 and 2 were located on an axis starting from the outfall towards the western part of the gulf, whereas stations 3 and 4 were located on an axis starting from the outfall towards the eastern part of the gulf. The choice of the sampling stations aimed to reflect the ecological status of the Inner and Outer Gulf as they are described based on hydrological data (COAHMAN *et al.,* 1976). Five samplings were carried out from August 1998 to September 2001 in order to monitor different seasonal aspects of the vegetation. The sampling was destructive, using a quadrat size of 20 cm x 20 cm (400 cm^2), which is considered to be the representative minimal sampling area for infralittoral communities in the Mediterranean (DHOND & COPPEJANS, 1977; BOUDOURESQUE & BELSHER, 1979). Additionally, underwater photos of the vegetation at each sampling station were taken.

Each sample was carefully sorted and identification at species level was attempted. Phaeophyceae, Chlorophyceae and Rhodophyceae were identified and classified according to RIBERA *et al.* (1992), GALLARDO *et al.* (1993) and ATHANASIADIS (1987), respectively. The abundance of species was estimated as % cover in the sampling area (4

Table 2

Functional characteristics and growth strategies of marine benthic macrophytes (GRIME, 1979, 2001; LITTLER & LITTLER, 1980, 1984; LARKUM & DEN HARTOG, 1989; LARKUM *et al.*, 1989; DUARTE, 1995; HEMMINGA & DUARTE, 2000).

Ecological State Group	**Functional form group**	**External morphology**	**Internal anatomy**	**Productivity**	**Longevity (Succession)**	**Growth Strategies (sensu Grime)**	**Genera**
II	A. Sheet-Group	Thin tubular and sheet like (foliose)	Uncorticated, one-several cells thick	High	Annuals (Opportunistic)	Ruderal	*Ulva, Enteromorpha, Scytosiphon* (erect phase), *Dictyota*
II	B. Filamentous-Group	Delicately branched (filamentous)	Uniseriate, multiseriate or lightly corticated	High	Annuals (Opportunistic)	Ruderal	*Cyanophyceae, Chaetomorpha, Cladophora, Polysiphonia, Ceramium, Spyridia*
II	C. Coarsely Branched-Group	Coarsely branched upright	Corticated	Species specific	Annuals (Mid-successional)	Stress-tolerant-Ruderal or Stress-tolerant-Competitors	*Acanthophora, Caulerpa, Chordaria, Gracilaria, Laurencia, Liagora*
I	D. Thick Leathery-Group	Thick blades and branches	Differentiated, heavily corticated thick walled	Low	Perennials (Late-successional)	Competitors	*Cystoseira, Chondrus, Fucus, Laminaria, Padina, Sargassum, Udotea*
I	E. Jointed Calcareous-Group	Articulated, calcareous, upright	Calcified genicula, flexible intergenicula	Low	Perennials (Late-successional)	Competitors	*Amphiroa, Corralina, Galaxaura, Halimeda, Jania*
I	F. Crustose-Group	Epilithic, prostrate, encrusting	Calcified or uncalcified parallel cell rows	Low	Perennials (Late-successional)	Competitors	*Hydrolithon, Lithothamnion, Peyssonnelia, Porolithon*
I	G. Seagrasses	Highly differentiated from foliose to cylindrical (Leafs, rhizomes, roots, flowers, fruits)	Hghly differentiated (epidermis, mesophyll, vascular system)	Low	Perennials (Pioneers to late-successional)	Stress-tolerant	*Cymodocea, Posidonia, Ruppia*

cm^2 = 1% of the sampling area) in horizontal projection (BOUDOURESQUE, 1971; VERLAQUE, 1987). In cases where the coverage of morphologically similar species could not be measured precisely, the species were grouped together (as spp.) in order to avoid artificial dissimilarity between stations. Species were classified into FFg according to LITTLER & LITTLER (1980, 1984).

Results

A. The ecological evaluation model

The concept - Ecological State Groups

Anthropogenic stress shifts the ecosystem from pristine to degraded state, where opportunistic species dominate. Table 2 shows a synthesis of the functional characteristics and growth strategies of marine benthic macrophytes. Marine benthic macrophytic species were classified into two ecological state groups (ESG), the late successional (I) and the opportunistic (II). The first group includes species of FFg D, E and F, i.e. species with a thick or calcareous thallus, low growth rates and long life cycles (perennials), whereas the second of FFg A and B, i.e. sheet-like and filamentous species with high growth rates and short life cycles (annuals). Seagrasses were included in the first group, whereas Cyanophyceae and species with a coarsely branched thallus were included in the second group.

Ecological Evaluation Index

The ecological evaluation index (EEI) is a number ranging from 2 to 10, indicating the overall ecological status of transitional and coastal waters (Table 3). To determine the EEI of an ecosystem the following procedure is used:

1. The area under examination is divided into relatively large representative non-overlapping permanent-polygons or -lines (PP or PL) and several relevées of benthic vegetation are obtained from each. All protocols can preferably include seasonal sampling following either destructive or non-destructive designs.

2. In each relevé the absolute abundance (%) of each ESG is estimated by its coverage. In cases where abundance is estimated as biomass or number of individuals the data have to be transformed to a comparable form.

3. The average abundance (%) of ESG I and II are cross compared in a matrix to determine the ecological status of the PPs or PLs in a range of five categories from high to bad (see Figure 3). A numerical scoring system was developed to correspond the ecological status categories to a numerical value (Table 3).

Table 3
A numerical scoring system for the evaluation of ecological status of transitional and coastal waters.

Numerical value of ecological categories	**Ecological Evaluation Index (EEI)**
High = 10	[≤10 - >8] = High
Good = 8	[≤8 - >6] = Good
Moderate = 6	[≤6 - >4] = Moderate
Low = 4	[≤4 - >2] = Low
Bad = 2	[2] = Bad

4. The surface area of each PP or the length of each PL is multiplied by their ecological status value and then divided by the sum of surface areas of PPs or lengths of the PLs. The area- or length-weighted values are then summed to obtain EEI and the ecological status category of the ecosystem (Table 3).

Example

A theoretical water system (WS) is divided in two PP (WSa, WSb), which cover 30 and 70% of its total area, respectively. The mean absolute coverage (%) of ESG I and II of sampled relevé in WSa was 45 and 20, respectively. This corresponds to the "good" ecological category (Figure 3) and to score 8 (Table 3). The mean absolute coverage (%) of ESG I and II of sampled relevé in WSb was 35 and 75, respectively. This corresponds to the

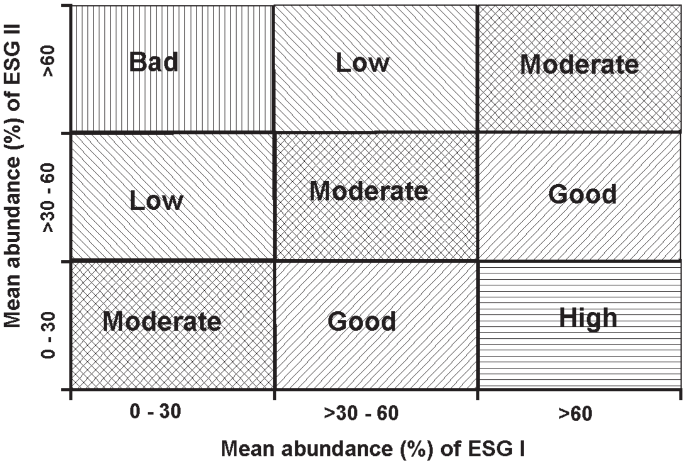

Fig. 3: A matrix based on the mean abundance (%) of ESGs to determine the ecological status of transitional and coastal waters.

"low" ecological category (Figure 3) and to score 4 (Table 3). The EEI of WS is following:

EEI = (8 x 0.3) + (4 x 0.7) = 2.4 + 2.8 = 5.2, which corresponds to the "moderate" ecological category.

B. Case studies

Macedonian and Thrace lagoons

Eighteen (18) seaweed (7 Chlorophyceae, 2 Phaeophyceae and 9 Rhodophyceae) and two seagrass species were identified in total (Table 4). The highest number of species was recorded in the Vassova lagoon (12 seaweeds and 2 seagrasses) and the lowest in the Fanari lagoon (4 seaweeds and one seagrass). By using the functional-form model the species were classified into seven FFg and two ESG. Three species and the Cyanophyceae mats were classified into ESG I, seventeen species into ESG II. The abundance of ESG II was higher than that of ESG I in all Delta Nestos lagoons. This trend was mainly due to high dominance of ESG II species in winter. In the Fanari lagoon there was a clear dominance of ESG I species. The ecological status of the lagoons was evaluated by using the EEI: three lagoons were classified into the low (Eratino, Keramoti, Vassova), one lagoon into the good (Agiasma) and one lagoon into the high (Fanari) ecological status category (Table 6). The overall ecological status of Delta Nestos catchments was evaluated as moderate (EEI=4.9).

The Saronic Gulf

Forty-seven (47) taxa were identified (10 Chlorophyceae, 14 Phaeophyceae and 23 Rhodophyceae) in total (Table 5). The number of taxa per sampling varied from 13 to 22 at Station (St.) 1, from 9 to 19 at St. 2, from 12-20 at St. 3 and from 16 to 28 at St. 4. A one-way ANOVA test showed that only at St. 2 the number of taxa was statistically different from the others. Coverage values varied from 132 to 310 at St. 1, from 132 to 331 at St. 2, from 117 to 289 at St. 3 and from 143 to 281 at St. 4. A one-way ANOVA test showed that the coverage values where not statistically different. By using the functional-form model the species were classified into six FFg and two ESG. Seventeen species were classified into ESG I, thirty species into ESG II. Species of ESG II were dominant in St. 2 and 3 whereas species of ESG I were dominant at St. 1 and 4. The ecological status of the Saronic Gulf

Table 4
Composition and abundance of marine benthic macrophytes in selected Macedonian and Thrace lagoons. Ch=Chlorophyceae, Ph=Phaeophyceae, Rh=Rhodophyceae, Se=Seagrass. S=Summer, W=Winter. St=Sampling station, RL= relevé. More details for the functional-form groups (FFg) and the ecological state groups (ESG) in Table 2.

		Agiasma (S)							**Eratino (S)**							**Eratino (W)**										
		St. 1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	St.1	St.2	St.3	St.4	St.5	St.6	St.8	St. 1	St. 2	St. 3	St. 3	St. 4	St.5	St.5	St. 6	St. 6	St. 7	St. 7
Species	**FFg**	RL.1	RL.2	RL.3	RL.4	RL.5	RL.6	RL.7	RL.8	RL.9	RL.10	RL.11	RL.12	RL.13	RL.14	RL.15	RL.16	RL.17	RL.18	RL.19	RL.20	RL.21	RL.22	RL.23	RL.24	RL.25
Ecological State Group I																										
Cymodocea nodosa (Ucria) Ascherson (Se)	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cystoseira barbata C. Agardh (Ph)	D	0	0	0	0	0	0	0	40	30	25	70	45	55	25	3	3	0	0	15	0,5	2	10	15	0	0
Ruppia maritima Linnaeus (Se)	G	0	10	25	60	60	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total coverage (%)		***0***	***10***	***25***	***60***	***60***	***70***	***0***	***40***	***30***	***25***	***70***	***45***	***55***	***25***	***3***	***3***	***0***	***0***	***15***	***0.5***	***2***	***10***	***15***	***0***	***0***
Ecological State Group II																										
Acanthophora najadiformis (Delile) Papenfuss (Rh)	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chondria tenuissima (Goodenough &Woodward) C. Agardh (Rh)	C	0	0	5	5	5	0	0	5	7	0	0	4	0	0	4	3	0	0.5	10	25	25	10	15	2	10
Ceramium byssoideum Harvey (Rh)	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaetomorpha aerea (Dillwyn) Kützing (Ch)	B	0	0	0	2	5	10	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaetomorpha mediterranea (Kützing) Kützing (Ch)	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cladophora dalmatica Kützing (Ch)	B	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cladophora liniformis Kützing (Ch)	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyanophyceae	A	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0.5	1	85	85
Ectocarpus sp. (P)	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Entermorpha intestinalis (Linnaeus) Link (Ch)	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Entermorpha linza (Linnaeus) J. Agardh (Ch)	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gracilaria armata (C. Agardh) J. Agardh (Rh)	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	4	70	70	0.5	2	2	1	1	35	30
Gracilaria bursa-pastoris (Gmelin) Silva (Rh)	C	0	60	40	0	0	0	0	25	35	35	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0
Herposiphonia secunda f. tenella (C. Agardh) Wynne (Rh)	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lophosiphonia scopulorum (Harvey) Womersley (Rh)	B	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0
Lophosiphonia subadunca (Kützing) Falkenberg (Rh)	B	0	0	0	0	0	0	0	0	0	0	0	0	0	5	25	20	0.5	1	1	2	3	15	15	1	0.5
Polysiphonia elongata (Hudson) Sprengel (Rh)	B	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ulva rigida C. Agardh (Ch)	A	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0.5	0.5	0	0.5	15	0.5	0	0.5	1	0	0
Total coverage (%)		***90***	***62***	***46***	***7***	***10***	***10***	***27***	***30***	***42***	***35***	***0***	***44***	***0***	***35***	***30***	***27.5***	***70.5***	***72***	***28.5***	***30.5***	***30***	***27***	***33***	***123***	***126***

Table 4 (continued)

		Fanari (S)				**Fanari (W)**				**Keramoti (S)**							**Vassova (S)**							**Vassova (W)**							
		St.1	St.2	St.3	St. 4	St.1	St.2	St.3	St.4	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St. 1	St. 2	St.3	St. 4	St. 5	St. 6	St. 6	St. 1	St. 2	St. 3	St. 3	St. 4	St. 4	St. 5	St. 6
Species	**FFg**	RL.26	RL.27	RL.28	RL.29	RL.30	RL.31	RL.32	RL.33	RL.34	RL.35	RL.36	RL.37	RL.38	RL.39	RL.40	RL.41	RL.42	RL.43	RL.44	RL.45	RL.46	RL.47	RL.48	RL.49	RL.50	RL.51	RL.52	RL.53	RL.54	RL.55
Ecological State Group I																															
Cymodocea nodosa (Ucria) Ascherson (Se)	G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	55	1	0	0	0	0
Cystoseira barbata C. Agardh (Ph)	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55	0	55	60	60	0	0	0	0	0	0	0	0	0	0
Ruppia maritima Linnaeus (Se)	G	100	100	85	80	90	95	60	0	0	0	0	60	40	40	25	0	0	0	0	0	25	50	0	0	0	0	0	0	0	4
Total coverage (%)		***100***	***100***	***85***	***80***	***90***	***95***	***60***	***0***	***0***	***0***	***0***	***60***	***40***	***40***	***25***	***55***	***0***	***55***	***60***	***60***	***25***	***50***	***1***	***0***	***55***	***1***	***0***	***0***	***0***	***4***
Ecological State Group II																															
Acanthophora najadiformis (Delile) Papenfuss (Rh)	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
Chondria tenuissima (Goodenough & Woodward) C. Agardh (Rh)	C	0	0	0	0	0	3	2	15	0	0	0	0	0	0	0	0	0	0	0	4	0	0	2	2	0.5	3	15	15	10	2
Ceramium byssoideum Harvey (Rh)	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaetomorpha aerea (Dillwyn) Kützing (Ch)	B	0	0	0	0	0	0	1	3	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaetomorpha mediterranea (Kützing) Kützing (Ch)	B	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cladophora dalmatica Kützing (Ch)	B	0	0	0	0	5	1	5	60	4	0	0	0.5	60	40	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cladophora liniformis Kützing (Ch)	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyanophyceae	A	0	0	0	0	0	0	0	0	0	0	20	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ectocarpus sp. (P)	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Entermorpha intestinalis (Linnaeus) Link (Ch)	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
Entermorpha linza (Linnaeus) J. Agardh (Ch)	A	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0
Gracilaria armata (C. Agardh) J. Agardh (Rh)	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	3	4	1	40	80	80	15	3
Gracilaria bursa-pastoris (Gmelin) Silva (Rh)	C	0	0	0	0	0	0	0	0	3	0	100	5	0	0	0	0.5	35	4	10	15	15	20	0	0	0	0	0	0	0	0
Herposiphonia secunda f. tenella (C. Agardh) Wynne (Rh)	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lophosiphonia scopulorum (Harvey) Womersley (Rh)	B	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lophosiphonia subadunca (Kützing) Falkenberg (Rh)	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4	0	1	2	1	15	25
Polysiphonia elongata (Hudson) Sprengel (Rh)	B	0	0	0	0	5	2	5	0	4	0	0	0	0	0	0	40	0.5	30	15	10	0	0	0	0	0	0	0	0	0	0
Ulva rigida C. Agardh (Ch)	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65	0	0	0	0	0	60	0	10	15	1	0	0	1
Total coverage (%)		***0***	***0***	***0***	***0***	***10***	***6***	***13***	***78***	***14***	***100***	***120***	***26.5***	***60***	***40***	***50***	***40.5***	***102***	***34***	***25***	***29***	***15***	***20***	***68***	***10***	***11.5***	***59***	***98***	***96.5***	***41.5***	***31***

Table 5

Composition and abundance of marine benthic macrophytes in the Saronic Gulf. More details in Tables 2 and 3.

		Station 1					Station 2					Station 3						Station 4			
Species	**FFg**	**aug. 98**	**mar. 99**	**jun. 99**	**jun. 01**	**sep. 01**	**aug. 98**	**mar. 99**	**jun. 99**	**jun. 01**	**sep. 01**	**aug. 98**	**mar. 99**	**jun. 99**	**jun. 01**	**sep. 01**	**aug. 98**	**mar. 99**	**jun. 99**	**jun. 01**	**sep. 01**
Ecological State Group I																					
Amphirhoa rigida (Rh) Montagne	**E**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	12
Anadyomene stellata (Ch) (Wulfen) Kützing	**E**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Corallina spp. (Rh)	**E**	1	8	3	0.01	0	1	45	44	73	40	1	14	2	0.01	0	4	0.01	0	0.01	0
Cystoseira crinita (Ph) (Desfontaines) Borry	**D**	0	0	0	0	0	0	0	0	0	0	40	0	46	0	0	0	0	0	0	0
Cystoseira crinitophylla (Ph) Ercegovic	**D**	65	45	54	50	90	0	0	0	0	00	0	0	0	0	0	90	64	57	90	90
Cystoseira compressa (Ph) (Esp.) Gerloff & Nizam.	**D**	15	20	12	10	0	0	0	0	0	0	0	0	0	0	0	15	34	2	10	19
Cystoseira mediterranea (Ph) Sauvageau	**D**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
Dermatolithon spp. (Rh)	**E**	0.01	0.01	0.01	0.01	20	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	15
Flabellia petiolata (Ch) (Tura) Nizanuddin	**E**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	4
Fosliella spp. (Rh)	**E**	0.01	0.01	0.01	0.01	10	0.01	0.01	0.01	0.01	0.01	1	0.01	0.01	0.01	1	0.01	0.01	0.01	0.01	25
Halimeda tuna (Ch) (Ellis & Solander) Lam.	**E**	0	0	0	0	0	0	0	0	0	0	0	4	0	0	20	4	0	0	0	0
Jania spp. (Rh)	**E**	16	20	15	7	80	1	0	0	12	2	80	0	18	16	80	26	16	3	40	22
Lithothamnion spp. (Rh)	**F**	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.01	0	4
Padina pavonica (Ph) (Linnaeus) Lamouroux	**D**	4	5	3	2	0	1	0	6	20	0	30	0	2	10	0	17	2	16	5	6
Peyssonnelia rosa-marina (Rh) (Boudouresque) Deniz.	**F**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1
Sargassum vulgare (Ph) C. Agardh	**D**	75	15	10	5	8	0	3	0	13	0	6	0	0	36	25	51	0	12	10	18
Taonia atomaria (Ph) (Woodward) J. Agardh	**D**	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
Ecological State Group II																					
Acanthophora delilei (Rh) Lamouroux	**C**	0	0	3	0	0	0	0	0	0	0	0	0	0	69	25	0	0	0	0	0
Bryopsis pennata (Ch) Lamouroux	**B**	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caulerpa racemosa (Ch) (Forskal) Lamouroux	**C**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	2	10	10	5
Ceramium diaphanum (Rh) (Roth) Harvey	**B**	0	4	0	0	0	0	0	0	0.01	0.01	0	0	0	0.01	0.01	0.01	0	0	0.01	1

Table 5 (continued)

		Station 1					Station 2					Station 3						Station 4			
Species	**FFg**	**aug. 98**	**mar. 99**	**jun. 99**	**jun. 01**	**sep. 01**	**aug. 98**	**mar. 99**	**jun. 99**	**jun. 01**	**sep. 01**	**aug. 98**	**mar. 99**	**jun. 99**	**jun. 01**	**sep. 01**	**aug. 98**	**mar. 99**	**jun. 99**	**jun. 01**	**sep. 01**
Ceramium ciliatum (Rh) (Ellis) Ducluzeau	**B**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Chondria dasyphylla (Rh) (Woodward) C. Agardh	**C**	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0
Cladophora spp. (Ch)	**B**	1	2	0	0.01	0	0	0	0	0	0	2	20	5	0	1	0	1	0	0	0
Codium fragile (Ch) (Suringar) Hariot	**B**	0	0	4	2	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
Colpomenia sinuosa (Ph) (Roth) de Notaris	**C**	0	9	0	2	0	0	0	6	10	0	0	0	0	5	0	0	0	0	0	0
Enteromorpha spp. (Ch)	**A**	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dictyopteris membranacea (Ph) (Staukhouse) Batters	**A**	67	0	2	5	0	99	28	21	60	80	0	24	0	30	5	0	0	6	10	0
Dictyota spp. (Ph)	**A**	1	0	0	2	0.01	0	64	2	0.01	0	1	40	0	0.01	0	15	0	0	0.01	0
Erythrotrichia spp. (Rh)	**A**	0.01	0.01	0.01	0.01	0.01	0.01	10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Gelidiella ramellosa (Rh) (Kütz.) Feldm. & Hamel	**C**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Gigartina acicularis (Rh) (Wulfen) Lamouroux	**C**	0	2	14	2	0	0	0	33	2	0	0	0	1	0	0	0	0	0	0	0
Gigartina tedii (Rh) (Roth) Lamouroux	**C**	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0
Gracilaria corallicola (Rh) Zanardini	**C**	0	0	0	0	4	0	0	0	0	0	0	0	0	0.01	0.01	0	0	0	0	0
Goniotrichum spp. (Rh)	**B**	0.01	0.01	0.01	0.01	0.01	0.01	10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Griffithsia schousboei (Rh) Montagne	**C**	3	0	0	0	0	2	0	0	1	0	0	0	0	0	0	1	0	0	0	0
Halopteris spp. (Ph)	**C**	10	25	10	3	2	0	0	0	1	0	60	20	0	1	10	7	22	35	5	0
Hypnea musciformis (Rh) (Wulfen) Lamouroux	**C**	15	2	0	0	0	1	0	0	0	0	55	2	0	0	0	1	0	0	0	0
Laurencia obtusa (Rh) (Hudson) Lamouroux	**C**	1	12	2	25	2	1	0	0	2	0	6	50	1	2	0	1	0	2	1	0
Lomentaria clavellosa (Rh) (Turner) Gaillon	**C**	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0
Lophosiphonia scopulorum (Rh) (Harv.) Wormesl.	**B**	0	0	0	0.01	4	0	0	0	0	0	0	0	0	0.01	0	0.01	0.01	0.01	0.01	0.01
Petalonia fascia (Ph) (Müller) O. Kuntze	**A**	0	50	2	10	0	0	58	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphacelaria spp. (Ph)	**B**	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.01	7	0.01	2	1
Scytosiphon lomentaria (Ph) (Lyngbye) Link	**A**	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polysiphonia spp. (Rh)	**B**	1	0	0	1	0	1	6	0	2	0	0	10	0	3	0	0.01	2	0	0.01	0.01
Ulva rigida (Ch) C. Agardh	**A**	34	6	8	6	0	74	80	13	33	10	7	64	42	74	5	1	34	0	0	0
Valonia utricularis (Ch) C. Agardh	**C**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1

Table 6
Ecological evaluation of the studied Macedonian and Thrace lagoons.

Catchments	Lagoon	Sampling time	Area (km^2)	ESG I [Mean total (%) coverage]	ESG II [Mean total (%) coverage]	Ecological Status Category
Nestos River	1. Agiasma	Summer	3.92	32.1	36	Moderate (EEI=6)
	2. Eratino	Summer	2.96	41.4	26.6	Good
		Winter		4.41	54.3	Low
		Total		18.8	43.5	Low (EEI=4)
	3. Keramoti	Summer	0.974	23.6	58.6	Low (EEI=4)
	4. Vassova	Summer	0.785	43.6	37.9	Moderate
		Winter		7.63	51.9	Low
		Total		24.4	45.4	Low (EEI=4)
	Summary		*8.644*			*Moderate (EEI=4.9)*
Vistonida estuarine system	5. Fanari	Summer	1.93	91.3	0	High
		Autumn		61.3	26.8	High
		Total		76.3	13.4	High (EEI=10)

was evaluated by using the EEI: one station (St. 2) was classified into the low, two stations into the moderate (St. 1 and 3) and one station into the good (St. 4) ecological status category (Table 7). The overall ecological status of the Inner and Outer Saronic Gulf was evaluated as moderate (EEI=4.95) and good (EEI=6.38), respectively.

Discussion

The present model was developed to evaluate shifts from pristine to degraded states in transitional and coastal ecosystems by using a new ecological index (EEI). The EEI indicates the overall ecological status of transitional and coastal waters (Table 3) and allows water managers to compare, to rank and to set management priorities at regional and national levels.

The model used marine benthic macrophytic communities as bio-indicators because, as sessile primary producers, they respond directly to anthropogenic stress (Table 1). Since they are important structural and functional components of the transitional and coastal waters, inhabiting sediment (roots of seagrasses) as well as water (seaweeds and leaves of seagrasses), they can potentially provide an integrated measure of ecological status. Several other models to predict ecological status of different aquatic ecosystems by using one (HOLMES *et al.,* 1998; RITZ & TRUDGILL, 1999; AMOROS *et al.,* 2000) or several types of bio-indicators (BRICKER *et al.* 1999; GIBSON *et al.,* 2000; LAFONT *et al.,* 2001) have recently been developed. The main advantages of these models are: (1) Anthropogenic stress is evaluated from the community response (CROWE *et al.,* 2000) and (2) The evaluation does not include antagonistic response parameters like nutrient concentrations (driving force) and phytoplankton or seaweed biomass (impact) in the same matrix.

The marine benthic macrophytes were classified into two ESGs (Table 2) representing contrasting, alternative ecological states, e.g. pristine and degraded. Degraded marine environments are inhabited by annual species with high growth rates and reproductive

Table 7
Ecological evaluation of the studied stations in the Saronic Gulf.

Sampled Area	Sampling station	Coastline length (Km)	Sampling time	ESG I (% Coverage)	ESG II (% Coverage)	Ecological Status Category
Inner Saronic Gulf	Peristeria (St. 1)	10	August 1998	176	134	Moderate
			March 1999	113	139	Moderate
			June 1999	100	45	Good
			June 2001	74	58	Good
			September 2001	209	12	High
			mean	*134.4*	*77.6*	*Moderate (EEI=6)*
	Kaki Vigla (St. 2)	51	August 1998	3	178	Bad
			March 1999	48	283	Low
			June 1999	50	85	Low
			June 2001	118	116	Moderate
			September 2001	42	90	Low
			mean	*52.2*	*150.4*	*Low (EEI=4)*
	Agios Kosmas (St.3)	36	August 1998	158	131	Moderate
			March 1999	18	230	Low
			June 1999	68	49	Good
			June 2001	62	185	Moderate
			September 2001	126	48	Good
			mean	*86.4*	*128.6*	*Moderate (EEI=6)*
	Summary	97				*Moderate (EEI=4.95)*
Outer Saronic Gulf	Agios Nikolaos (St. 4)	85	August 1998	227	54	Good
			March 1999	117	74	Moderate
			June 1999	90	53	Good
			June 2001	159	28	High
			September 2001	216	8	High
			mean	*161.8*	*43.4*	*Good (EEI=8)*

potential (opportunistic, ESG II), whereas pristine environments are dominated by perennial species with low growth rates and reproductive potential (late-successional, ESG I). Many authors (REGIER & COWELL, 1972; MURRAY & LITTLER, 1978; SOUSA, 1980; DUARTE, 1995; HARLIN, 1995; SCHRAMM & NIENHUIS, 1996; SCHRAMM, 1999) have documented this pattern. LITTLER & LITTLER (1980) have extensively discussed the attributes that seem to improve the fitness of opportunistic and late-successional seaweeds and their hypothetical costs and benefits. Seaweeds with a sheet-like and filamentous thallus (FFg A and B) are generally more productive and grow in more temporally unstable habitats than thicker and calcareous seaweeds (FFg D, E and F), which are conspicuous in more constant environments (LITTLER & LITTLER, 1980; 1981; 1984, see also Table 2). Some species, however, through morphologically or ecologically dissimilar alternate phases (e.g. *Scytosiphon, Colpomenia, Petalonia*), have attributes of both extremes.

Prediction of function, like productivity, from morphology is not always simple, because in several cases there is not a clear relationship. For example, *Caulerpa van-bosseae* had much lower photosynthetic rates than other members of FFg-B and *Sargassum herporhizum* had much higher photosynthetic rates than other members of FFg-D (LITTLER & LITTLER, 1984). Similarly, species belonging to FFg-C had photosynthetic rates similar to members of FFg-B or FFg-D or were intermediate. In the present model the species belonging FFg C were classified into ESG II because several of its members, such as *Gracilaria* spp., *Acanthophora* spp., *Gigartina* spp., are dominant species in degraded marine ecosystems (CASABIANCA *et al.,* 1997; LAZARIDOU *et al.,* 1997; ORFANIDIS *et al.,* 2001). However, we agree with the conclusion that "functional group ranking realistically should be regarded as recognizable units along a continuum, each containing considerable variation of form and concomitant functional responses" (LITTLER & LITTLER, 1984).

Comparing growth rates (DUARTE, 1995), resistance to herbivory (CEBRIAN & DUARTE, 1994), longevity and canopy height there were many similarities between seagrasses and seaweeds belonging to FFg-D (Table 2). In addition, both groups are late-successional forming climax communities. For example, *Posidonia oceanica* is a late-successional species in undisturbed areas of the Mediterranean Sea and *Cymodocea nodosa* is a late successional species in relatively more stressful habitats. *Zostera marina* is considered a colonizer as well as a climax species on the North European coasts (McROY & LLOYD, 1981).

Another often used model in plant ecology is GRIME'S (1977, 2001) C-S-R triangle, in which species can be categorized as: (1) Ruderal (opportunists), (2) Stress-tolerant, (3) Competitors (late-successional). While the three strategies are the extremes, many plants will show tradeoffs of the threetrait syndromes to some extent. Obviously, the sheet-like and filamentous species of LITTLER & LITTLER (1980) can be classified as ruderals in Grime's scheme and the thick and calcareous species as competitors. However, morphology seems not to be a criterion in identifying the seaweeds that follow a stress-tolerant strategy. Although in terrestrial environments, a stress-tolerant plant tends to have late-successional characteristics, the more stress-resistant marine algae, such as blue-greens, *Ulva* and *Enteromorpha,* are opportunistic species (LOBBAN & HARRISON, 1994; COELHO *et al.,* 2000). Although Grime's model has been extended and modified by STENECK & DETHIER (1994) in order to apply to functional groups of marine algae, it seems that it has limited usage as a predictive model in applied marine ecology. This conclusion is further strengthened by the categorization of seagrasses into the stress-tolerant group (LARKUM & DEN HARTOG, 1989) because of low diversity and the fact that they colonize habitats (shallow bays and estuaries) with low competition. This is, however, in contradiction with the high sensitivity of seagrasses to anthropogenic stress (Table 1).

On the axes of the matrix, the % of absolute abundance of the ecological groups (Figure 3) is represented. This was done because ecosystem function or processes, e.g. nutrient cycling, productivity, can be closely related to species abundance. To give an example, the particle and nutrient sink in two *Zostera* meadows in Sylt, North Sea, was positively correlated with their density (ASMUS & ASMUS, 2000). A positive relation between shoot density of seagrasses and fish and shrimp density was also documented (FONSECA *et al.,* 1996a, b). Because the stratification of marine benthic macrophytic communities includes several growth forms (canopies, understorey etc.) total coverage can be higher than 100% (see below). Consistent low values of total coverage, especially in seagrass meadows, are indicative of habitat destruction and fragmentation.

The model can classify the transitional and coastal waters into five ecological categories, from high to bad (EEC WFD, 2000/60), based on a cross comparison in a matrix of the two ESGs (Figure 3). In contrast to the available typologies, e.g. EEC Directive 92/43, this typology is based on ecological processes which can also predict restoration potentialities. According to the model, a restoration goal of a degraded aquatic environment could include an improvement of hydrological and ecological conditions to allow growth of seagrass in soft substratum (e.g. *Posidonia*) and seaweed communities of FFg-D (e.g. *Laminaria, Fucus, Cystoseira*) on hard substratum. Restoration of kelp communities and, in particular seagrass meadows in degraded aquatic environments is a well-known practice on the North American coast (FONSECA *et al.,* 1998; ROBLEDO *et al.,* 2000). These communities not only form the basis of natural, pristine marine environments (PANAYOTIDIS *et al.,* 2001) but also support many ecosystem services, e.g. sustain biodiversity (DEN HARTOG, 1970; PHILLIPS & MEŇEZ, 1988; NIENHUIS, 1992), maintain fish habitat (HARMELIN-VIVIEN *et al.,* 1995; POLLARD, 1984; BELL *et al.,* 1992; FRANCOUR, 1997; EDGAR, 1999b; BLADER *et al.,* 2000), offer detritus to the trophic chain (EDGAR, 1999a), maintain water quality (BULTHUIS *et al.,* 1984; DAUBY *et al.,* 1995; GACIA *et al.,* 1999; ASMUS & ASMUS, 2000), stabilize sediment and control erosion (FONSECA, 1996; ASMUS & ASMUS, 2000).

The test of the model in estuarine (Table 6) and coastal waters (Table 7) was successful because the results are in accordance with existing ecological conditions as documented before. During previous decades, the Nestos Delta Lagoons (moderate ecological status) were severely influenced by eutrophication because of point (phosphorus industry) and non-point (agriculture) sources of effluents (THEOCHARIS *et al.,* 2000; SYLAIOS & THEOCHARIS, 2002). Some ten years ago the problem was so severe that local water managers decreased the inflow of fresh-water sources into the lagoons. In contrast, the Fanari lagoon (high ecological status) seems to be un-affected by eutrophication because of limited fresh-water sources.

The inner parts of the Saronic Gulf (Central Greece) are considered among the most polluted Greek aquatic ecosystems because of proximity to the densely populated Athens basin. Earlier studies showed a gradual attenuation of the pollution caused by the central outfall of urban wastes towards the southern and eastern parts of the gulf (DIAPOULIS & HARITONIDIS, 1987; SIMBOURA *et al.,* 1995). This pattern was also documented in this study.

The ecological status of the tested areas showed temporal and spatial changes (Table 6 and 7). This is in agreement with ecological theory, which regards brackish waters and polluted areas as unpredictable environments (SANDERS, 1968; COGNETTI & MALTAGLIATI, 2000) with spatial and temporal changes in the intensity of disturbance (ORFANIDIS *et al.,* 2001). In the model, the final ecological status designated to an area is based on many seasonally sampled relevés, which reflects an average of environmental conditions existing during the investigation.

Conclusion

The ecological evaluation model developed in this study can be a valuable tool for transitional and coastal water managers in Europe and worldwide. It gives them the possibility to compare, to rank and to set priorities at regional and national levels quickly and without a demand for specialized knowledge of seaweed or seagrass taxonomy. Usage of the model could provide a comprehensive and objective picture of current ecological status, whereas a monitoring program could allow analysis of environmental degradation or improvement.

Marine benthic macrophytes were classified from functional form characteristics into two ecological groups that represent contrasting ecological states. Because of unclear limits between the proposed ESGs, a certain amount of research requirement is needed. The proposed EEI classified water ecosystems into five ecological categories from high to bad, where their exact limits still have to be tested.

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