biomonitoring of ecological status of marine coastal habitats based on seaweeds

Reduced Species Lists (RSL)

Ecological Status Groups (ESG + ESG ratio) → **Subjective Quality Status**

% Chlorophyta, % Rhodophyta, % opportunists **Ecological Quality Ranking**

Table 2
Descriptions of the different functional groups used in placing species into the two ecological status groups indicating functional groups as modified by Wells (2002) from Littler et al. (1983)

	Functional groups
ESG 1	Late successionals or perennials including • Coarsely branched and highly corticated forms • Thick, leathery and corticated forms • Jointed calcareous forms • Crustose forms including those microscopic forms found epiphytically or endophytically
ESG 2	Opportunists or annuals including • Unicellular and epiphytic, endophytic, epizoic and endozoic microscopic forms • Foliose, thin, membranous and sheet-like forms • Uniseriate filamentous forms • Multiseriate and/or corticated filamentous forms

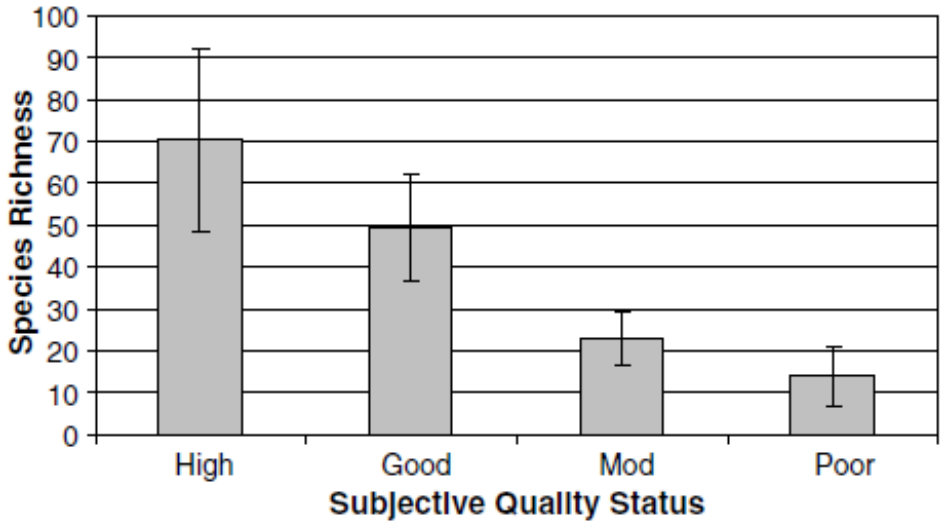

Fig. 2. Trend of average species richness recorded for each of the predicted ecological quality status classes from the benthic marine algae database with error bars signifying standard deviation.

Wells et al., 2007, Mar. Pollut. Bull.

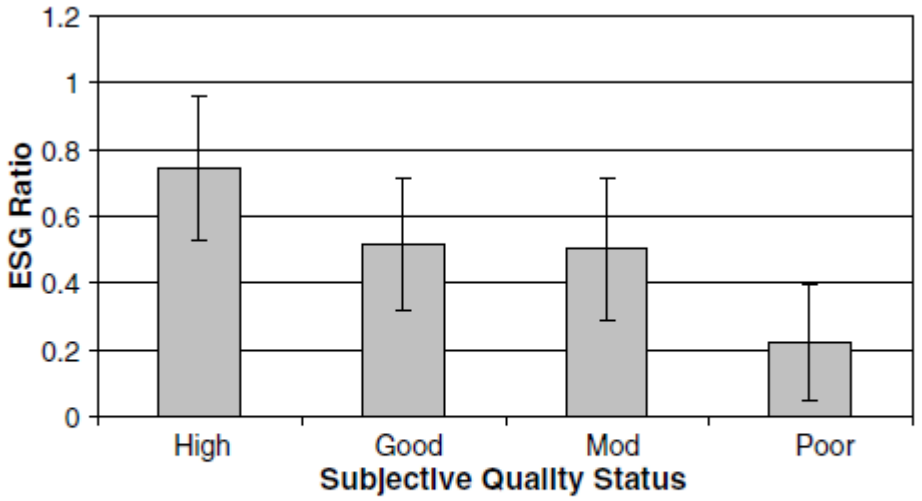

Fig. 5. Trend of average ESG ratio recorded for each of the predicted ecological quality status classes from the benthic marine algae database with error bars signifying standard deviation.

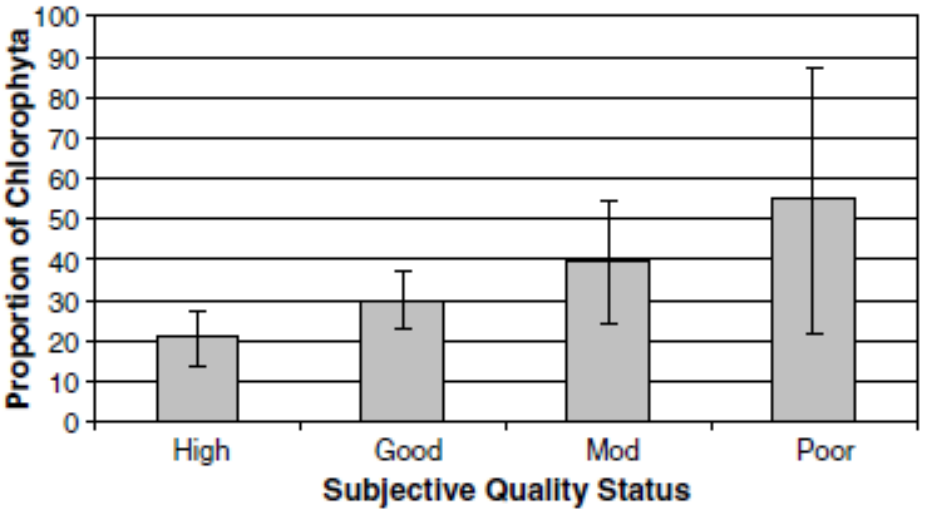

Fig. 3. Trend of average proportion of green species recorded for each of the predicted ecological quality status classes from the benthic marine algae database with error bars signifying standard deviation.

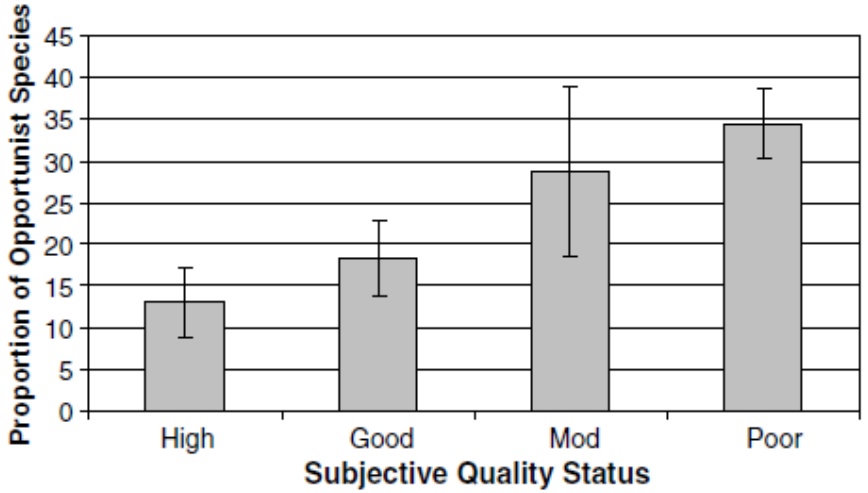

Fig. 6. Trend of average proportion of opportunist species recorded for each of the predicted ecological quality status classes from the benthic marine algae database with error bars signifying standard deviation.

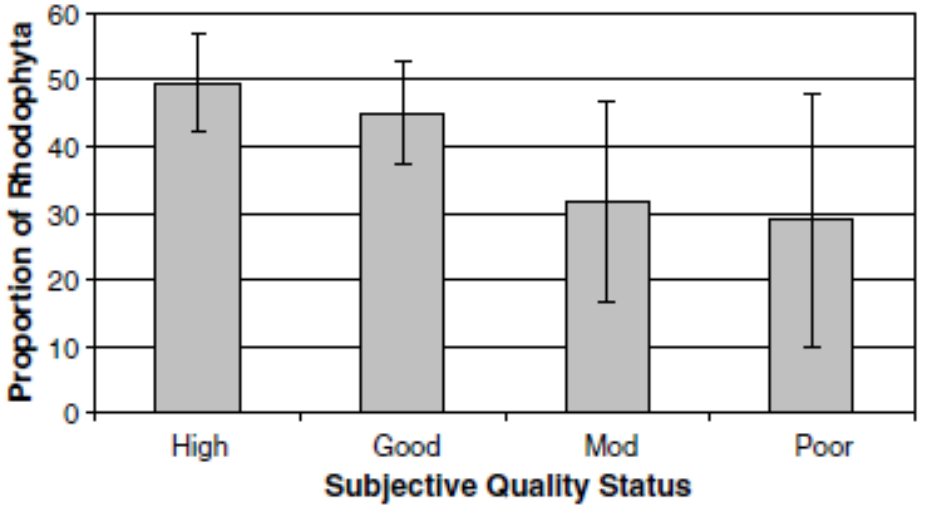

Fig. 4. Trend of average proportion of red species recorded for each of the predicted ecological quality status classes from the benthic marine algae database with error bars signifying standard deviation.

Wells et al., 2007, Mar. Pollut. Bull.

Table 3
The metric scoring system with classification status ranges for macroalgae species richness, chlorophyta, rhodophyta and opportunist proportions, ESG ratios and shore descriptions as described and calculated from the field sampling sheet in Table 1

Quality	Bad	Poor	Moderate	Good	High
EQR	0–0.2	0.2–0.4	0.4–0.6	0.6–0.8	0.8–1.0
Species richness	⩽5	6–19	20–31	32–54	⩾55
Proportion of chlorophyta	61–100	46–60	36–45	26–35	⩽25
Proportion of rhodophyta	0–15	15–24	25–34	35–44	⩾45
ESG ratio	0–0.1	0.1–0.29	0.3–0.39	0.4–0.64	⩾0.65
Proportion of opportunists	41–100	31–40	21–30	16–20	⩽15
Shore descriptions	N/A	15–18	12–14	8–11	1–7

Table 7
Boundaries values for RSL, ESG, green, red and opportunist proportions for Scotland/Northern England area

Scotland and Northern England score system					
	0	1	2	3	4
	Bad	Poor	Moderate	Good	High
RSL	0	<17	17–19	20–29	>30
ESG	0	<0.6	0.6–0.69	0.7–0.89	⩾0.9
Greens	100	>26	>21.0–26.0	16.0–21.0	⩽15.0
Reds	0	<37.0	N/A	38.0–44.0	⩾45.0
Opportunist	100		>15		⩽15
Shore description	N/A	15–18	12–14	8–11	1–7

Table 6
The Macroalgal reduced species list for tool applied to long term species records from Granton and Joppa in the Firth of Forth

Site name	RSL	ESG	% Chloro	% Rhodo	% Oppor	Shore description
Granton						
19th Century total	30	1.31	6.67	56.67	13.33	13
Wilkinson, Scanlan 1986–1987	33	0.74	21.21	36.36	21.21	13
Wells, 1999–2001	34	0.70	23.53	38.24	23.53	13
Joppa						
Traill 1881–1886	55	0.96	9.09	50.91	12.73	16
Wilkinson, Scanlan 1986–1987	37	0.61	18.92	51.35	21.62	16
Wells, 1999–2001	36	0.64	19.44	50.00	22.22	16

Wells et al., 2007, Mar. Pollut. Bull.

Table 8
Final scores for each time period at Joppa and Granton for each of the characteristics of RSL, ESG, proportion of Chlorophyta, Rhodophyta and opportunist species

Site name	RSL	ESG	% Chloro	% Rhodo	% Oppor	Shore description	Final score	Quality status
Granton								
19th Century total	4	4	4	4	4	2	22	High
Wilkinson, Scanlan 1986–1987	4	3	2	1	2	2	14	Good
Wells, 1999–2001	4	3	2	3	2	2	16	Good
Joppa								
Traill 1881–1886	4	4	4	4	4	1	21	High
Wilkinson, Scanlan 1986–1987	4	2	3	4	2	1	16	Good
Wells, 1999–2001	4	2	3	4	2	1	16	Good

Wells et al., 2007, Mar. Pollut. Bull.

Ecological Evaluation Index (EEI) for assessing Ecological Status Classes (ESC)

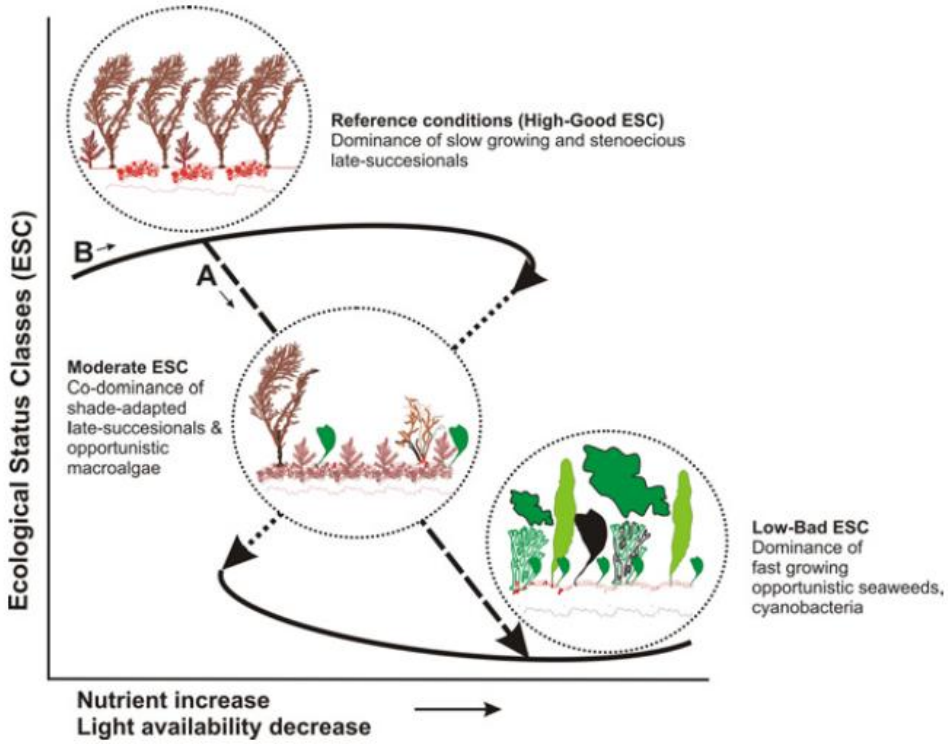

Fig. 1: Conceptual model of two alternative stable states of macroalgal communities across an ecological status gradient in coastal waters. A conventional (A) and dynamic (B) view of successional changes (Modified from ORFANIDIS *et al.,* 2005, 2008; VIAROLI *et al.,* 2008).

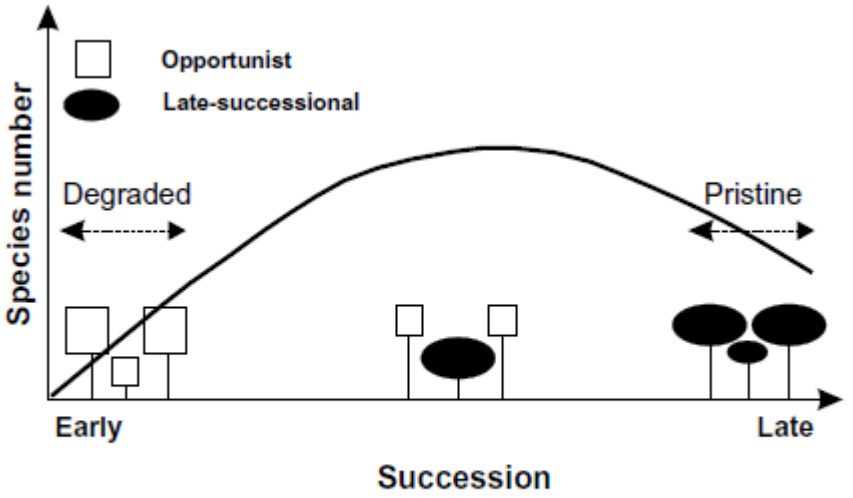

Fig. 4. Successional model from Orfanidis et al. (2001, 2003) along with intermediate disturbance hypothesis (Connell, 1978).

Table 4
List of species and average coverage (151 samples) of macrophytes expressed as % of the sampling surface

Species	ESG	Coverage (%)
Chlorophyceae		
Acetabularia acetabulum (Linnaeus) P.C. Silva	I	0.68
Anadyomene flabellata J.V. Lamouroux	I	0.17
Bryopsis spp.	II	0.31
Cladophora spp.	II	2.74
Codium effusum (Rafinesque) Chiaje	II	0.05
Codium fragile subsp. *tomentosoides* (van Goor) P.C. Silva	II	0.02
Flabellia petiolata (Turra) Nizamuddin	I	0.58
Halimeda tuna (J. Ellis & Solander) J.V. Lamouroux	I	2.52

Orlando-Bonaca et al., 2008, Mar. Pollut. Bull.

Orfanidis et al., 2011, Medit. Mar. Sci.

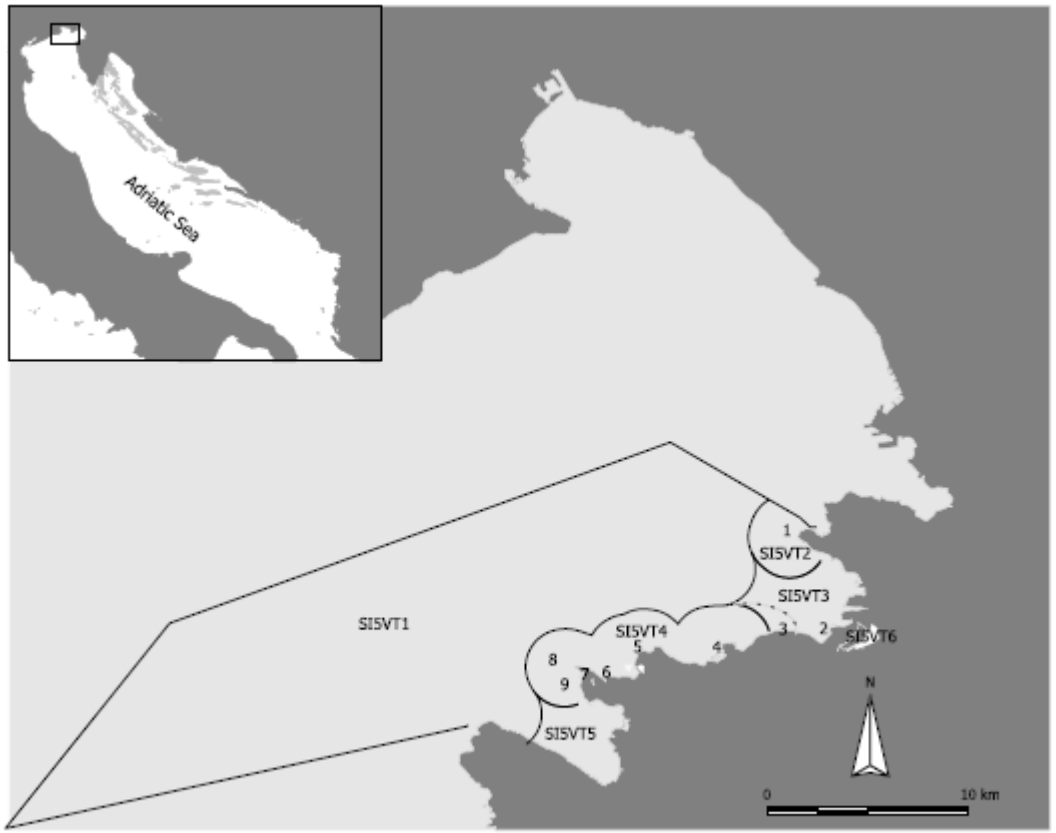

Fig. 1. The map of the study area with water bodies (from Ministry of Environment and Spatial planning, 2005) and some relevant sites (1 – Debeli r Nature Monument; 2 – Koper; 3 – Habitat of *Posidonia oceanica*; 4 – Izola; 5 – Strunjan Nature Reserve; 6 – Pacug; 7 – Fiesa; 8 – Cape Madona Natu Monument; 9 – Piran).

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Halimeda tuna (J. Ellis & Solander) J.V. Lamouroux	I	2.52
Ulva rigida C. Agardh	II	0.83
Valonia utricularis (Roth) C. Agardh	II	0.29
Phaeophyceae		
Cladostephus spongiosus f. *verticillatus* (Lightfoot) Prud'homme van Reine	II	0.56
Cystoseira barbata (Stackhouse) C. Agardh	I	4.98
Cystoseira compressa (Esper) Gerloff & Nizamuddin	I	4.67
Cystoseira corniculata (Turner) Zanardini	I	0.01
Cystoseira sauvageauana G. Hamel	I	1.13
Cystoseira sp.	I	0.17
Dictyopteris polypodioides (A.P. de Candolle) J.V. Lamouroux	II	1.96
Dictyota dichotoma (Hudson) J.V. Lamouroux	II	3.45
Dictyota linearis (C. Agardh) Greville	II	2.04
Halopteris spp.	II	1.09

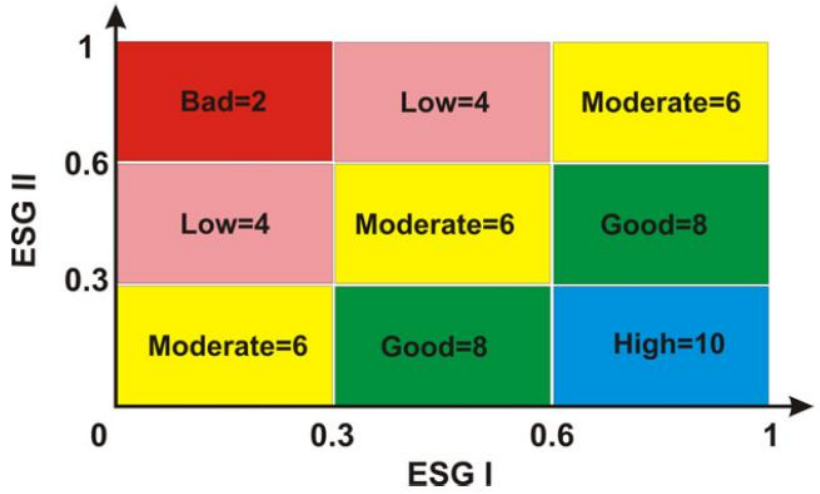


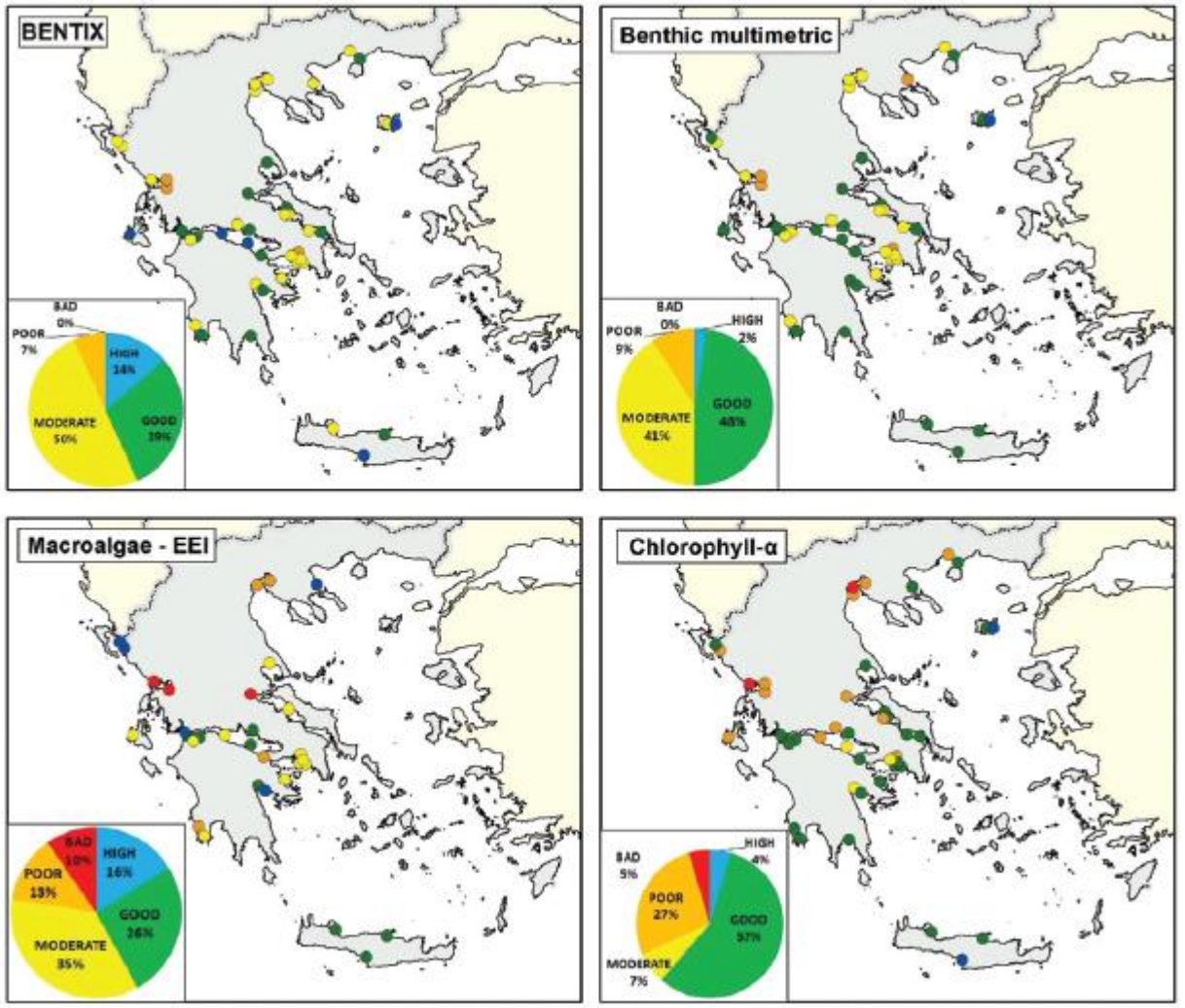
Fig. 2: Estimation of EEI and the equivalent ESCs from a matrix based on the mean abundance (%) of ESGs.

Table 7
Preliminary ecological status achieved by Slovenian coastal water bodies

Water Body	EEI	ESC
SI5VT2	8.28	High
SI5VT3	2.90	Poor
SI5VT4	8.99	High
SI5VT5	6.47	Good

Orlando-Bonaca et al., 2008, Mar. Pollut. Bull.

Orfanidis et al., 2011, Medit. Mar. Sci.



Simboura et al., 2015, Medit. Mar. Sci.