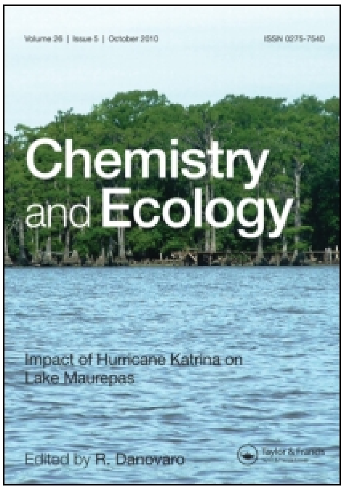


**Chemistry and Ecology**
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713455114

# Rapid Quality Index (R-MaQI), based mainly on macrophyte associations, to assess the ecological status of Mediterranean transitional environments

A. Sfriso[a]; C. Facca[a]; P. F. Ghetti[a]
[a] Department of Environmental Sciences, University of Venice, Venice, Italy

**To cite this Article** Sfriso, A. , Facca, C. and Ghetti, P. F.(2007) 'Rapid Quality Index (R-MaQI), based mainly on macrophyte associations, to assess the ecological status of Mediterranean transitional environments', Chemistry and Ecology, 23: 6, 493 — 503
**To link to this Article: DOI:** 10.1080/02757540701702918
**URL:** http://dx.doi.org/10.1080/02757540701702918

*Chemistry and Ecology*
Vol. 23, No. 6, December 2007, 493–503

Taylor & Francis
Taylor & Francis Group



# Rapid Quality Index (R-MaQI), based mainly on macrophyte associations, to assess the ecological status of Mediterranean transitional environments

A. SFRISO*, C. FACCA and P. F. GHETTI

Department of Environmental Sciences, University of Venice,
Calle Larga S. Marta 2137, 30123 Venice, Italy

*(Received 31 July 2006; in final form 9 May 2007)*

A rapid index for the quality status assessment of Mediterranean transitional environments is proposed. It is based on the study of macrophyte associations (macroalgae and seagrasses) and the gross determination of some environmental parameters. The index was set up in 19 sampling sites of the Venice lagoon monitored during one year on a monthly basis taking into account the flora, the main contaminants and some other variables indicating the presence of gradients of stress conditions. Results were compared and intercalibrated with measurements carried out in Sacca di Goro, placed in Po delta, and in Lesina and Orbetello lagoons.

*Keywords*: Transitional environments; Ecological indices; Environmental quality; Seagrasses; Macroalgae

## 1. Introduction

The entering into force of the European Water Framework Directive 2000/60/EC in December 2000 promoted many specific studies for the assessment and the knowledge of the ecological quality status of marine coastal waters and transitional environments. The objective was to reach a condition of good environmental quality by 2015. Previous studies [1–4] proposed the assessment of the trophic status of marine coastal waters by the Trophic Index, an index based on the elaboration of two groups of environmental variables: the availability of trophic factors and the biological productivity. The former was obtained by measuring the concentration of inorganic nitrogen and phosphorus in the water and the latter by the oxygen and chlorophyll *a* concentrations. The index can be applied to coastal waters, but it is unsuitable for transitional environments (i.e. lagoons, bays, estuaries) because of the high environmental changes due to the proximity of the mainland, the shallowness of the bottoms and the presence of seagrasses and macroalgae which, in these environments, are largely dominating over phytoplankton (the only primary producer considered in that index).

*Corresponding author. E-mail: sfrisoad@unive.it

*Chemistry and Ecology*
ISSN 0275-7540 print/ISSN 1029-0370 online 
http://www.tandf.co.uk/journals
DOI: 10.1080/02757540701702918

Other studies on the transitional environments started, especially in Spain and Greece [5–10] and proposed to investigate macrobenthic communities (AZTI Marine Biotic Index—AMBI) [5–7] and macroalgal assemblages (Ecological Evaluation Index—EEI) [8–10] because they have a relatively long life span and are sessile or quite sedentary organisms. Compared with the physicochemical parameters, the biological communities, which consist of different species, are expected to tolerate the environmental stress differently, even for a short time, and can change their structure and taxonomic composition according to the environmental conditions.

During the same years, an index for the assessment of the quality of transitional environments based on the Rhodophyceae/Chlorophyceae (R/C) ratio has been suggested [11, 12]. The rationale is based on the fact that, generally, the number of Chlorophyceae prevails in eutrophic and polluted environments, whereas Rhodophyceae are predominant in good environmental conditions. Subsequently, the index was integrated with the Mean Macroalgal Score Index (MMSI) by which a score, ranging from 0 to 2, was assigned to each macroalgal taxon. Value 0 was associated with the macroalgae that dominate in highly polluted or stressed areas, whereas a score of 2 was assigned to macroalgae that colonize more pristine environments but are missing in stressed environments, and score 1 when they are almost indifferent to the environment [13]. The three ecological groups were identified by taking into account the physico-chemical characteristics (water transparency, salinity, oxygen concentrations, sediment grain size, etc.), the trophic conditions (nutrient concentrations), and contamination (heavy metals and organic micro-pollutant concentrations) levels of selected sampling sites in the Venice lagoon [13], for which a wide literature and long-term data sets are available. In fact, the index was set up in Venice, where abundant literature on contaminants is available.

Results obtained by applying these indices are useful but time-consuming, and require important professional skills. The sampling procedures and the taxonomic determinations are too laborious and expensive, especially those referred to the benthic macrofauna (AMBI and EEI). In some cases, the number of taxa considered was too restricted (i.e. 36 taxa in Orfanidis *et al*. [9]; 60 taxa in Panayotidis *et al.* [10]; *c*. 65 taxa in Orfanidis *et al.* [8]) and referred only to some small lagoons in the Saronic Gulf, in eastern Macedonia, and in Trace region. Moreover, the taxa reported in their papers are mainly species characteristic of 'Good' and 'High' quality environments. On the contrary, the indices previously proposed [11–14] take into consideration a larger number of macroalgae with taxa referring to a range of environmental conditions (from 'Bad' to 'High'), but require expert personnel on macroalgal taxonomy and ecology.

The present paper reports the results of investigations which allow the R/C ratio and MMSI to be improved by means of a rapid assessment of the ecological status of transitional environments. The new index is structured as a dichotomic key, based on the presence/absence of some seagrasses and/or macroalgae and the variability of several physico-chemical parameters such as water transparency, salinity, and oxygen saturation. Five ecological classes can be identified, ranging from highly polluted and dystrophic-hypertrophic environments to almost unpolluted and mesotrophic.

## 2. Materials and methods

### 2.1 *Study areas*

The rapid environmental quality index was set up in Venice lagoon, which is the largest and most polymorphous Mediterranean transitional environment and validated in Lesina and Orbetello lagoons and in Sacca di Goro in the Po delta.

The Venice lagoon, placed in the Northern Adriatic Sea, has a total surface of 549 km$^2$ and a mean depth of *c*. 1 m. It communicates with the sea through three large mouths, 400–900 m

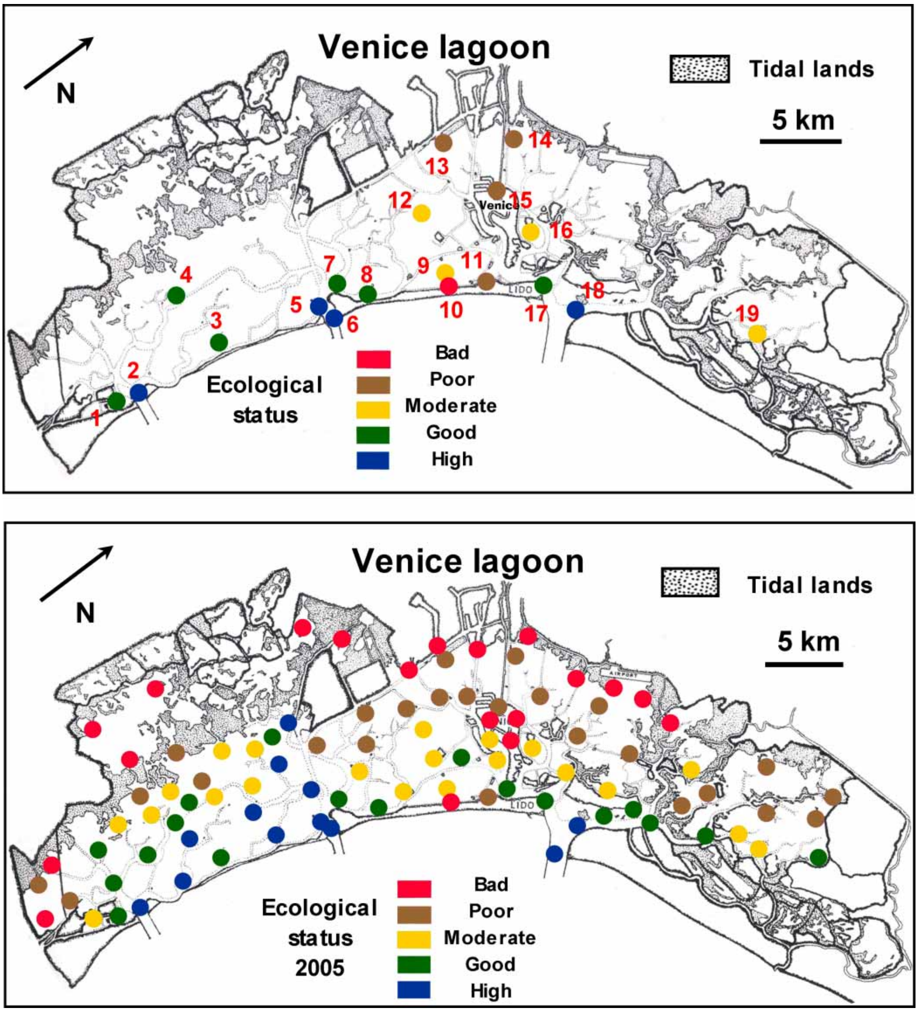


Figure 1. (a) Ecological quality assessment of the Venice stations sampled on a monthly basis for one year. There, the R/C ratio, the MMSI, and the R-MAQI were set up. (b) Assessment of the whole lagoon by using the R-MAQI in summer 2005.

wide and 12–20 (up to 50) m in depth. About 60% of the lagoon water is exchanged with sea water at any tidal cycle, but areas close to the mainland in the northern and southern basins show tidal exchanges up to 15–20 d long. The lagoon exhibits all the extreme environmental conditions which characterize transitional environments, i.e. areas with high water hydrodynamics and areas confined, areas mesotrophic and hyper-dystrophic, areas which are low or highly contaminated, hyperhaline, mesohaline or hypohaline, etc. These different environmental conditions make it the most suitable environment for our purposes, and 19 sampling sites were monitored monthly for one year (figure 1a). The results were processed for the R/C ratio and the MMSI set-up. Successively, in summer 2004–2005, all the other considered lagoons (figure 2) were monitored for the validation of the indices and the R-MAQI was drawn.

The lagoon of Lesina is *c*. 50 km$^2$ wide, has an average depth of 0.8 m but communicates with the southern Adriatic sea only by two narrows (*c*. 4–20 m wide) and shallow (*c*. 2–4 m) inlets: the Acquarotta and Schiapparo canals. Therefore, water exchange is very much reduced, and salinity is affected by the seasonal rainfalls and the small river inflows. Lesina lagoon is very homogeneous and appears as a highly confined environment. There, four sampling sites

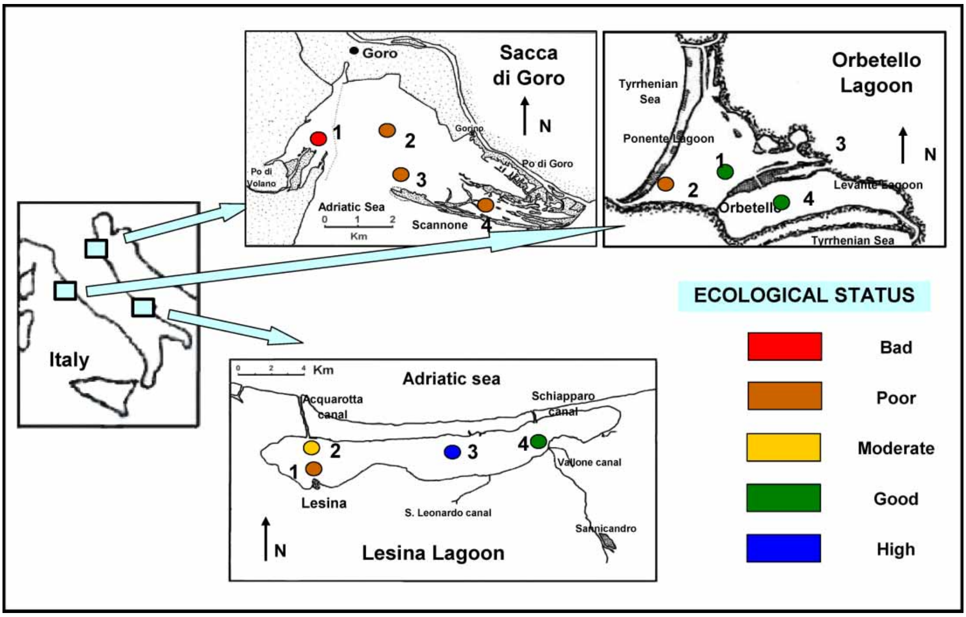


Figure 2. Validation of the R/C ratio, the MMSI, and the R-MaQI in some stations at Lesina and Sacca di Goro, in 2004, and at Orbetello, in 2005.

covering the main differences of that environment have been selected. Sampling occurred in May and July 2004.

Sacca di Goro is a large marine embayment with a *c*. 20 km$^2$ surface and a 60 cm depth, which is located south of the Po delta. It communicates with the northern Adriatic sea through a shallow (*c*. 1 m depth) mouth *c*. 1.5 km wide which extends from the Volano Lido and the 'Scannone', a long sandy bank which widens year by year reducing the lagoon inlet. The lagoon receives waters from the Po di Volano, Po di Gorino, and other canals regulated by pumping systems. Sampling occurred in May and July 2004 in four stations which cover the main environmental differences.

The lagoon of Orbetello has a total surface of 27 km$^2$ and a mean depth of 1–1.5 m, and is divided into two basins (the Ponente lagoon: *c*. 15 km$^2$ and the Levante lagoon: *c*. 12 km$^2$) by the city of Orbetello and the bridge with connects the city with the Argentario rocky promontory. The Ponente lagoon is connected to the sea through two small, shallow, and narrow canals: the Nassa canal (0.5 km long) and the Fibbia canal (3 km long), whereas the Levante lagoon communicates with the sea through the Ansedonia canal (1.5 km long). As a consequence, also, that lagoon shows a very reduced water exchange, especially the Ponente basin, where macroalgal blooms and anoxia are frequently recorded. In the Ponente basin, three sampling sites were selected: one in the centre of the basin, where environmental conditions are good, and the others close to the Nassa oyster-farm and Porto Scalo, where environmental conditions are strongly affected by aquaculture and urban pollution. Another station was selected in the centre of the Levante basin where environmental conditions are similar to those found in the central part of the Ponente lagoon. Sampling occurred in early August 2005.

## 2.2 *Macrophytes and environmental parameters*

Macroalgae and seagrasses have been collected both by hand, during low tides, and/or by scuba divers. Each area had a diameter of *c*. 100 m which allowed the sampling strategy to be optimized for both hard and soft substrata. All the taxa were sorted and examined fresh, when possible, or after fixation with 4% formaldehyde, neutralized with hexamethylenetetramine, using a stereoscope and a light microscope. Also, when possible, all the macrophytes were determined at species, subspecies, variety, and form level by means of the most recent taxonomic keys and species revisions [15, 16].

Water oxygen saturation was measured by an oximeter (Oxi 196 by the Wissenschaftlich-Technische Werkstätten GmbH, Weilheim, Germany) equipped with a battery stirrer BR 190. Salinity was determined according to the argentometric method [17], while water transparency was measured by means of the Secchi disk.

## 3. Results and discussion

### 3.1 *Index set-up*

R-MAQI is a routine ecological index based on the presence/absence of some seagrasses and/or macroalgae and the variability of some physico-chemical parameters such as water transparency, salinity, and oxygen saturation. In the present study, this index was set up by taking into account the previous indices based on the Rhodophyceae/Chlorophyceae ratio and the ecological role of some taxa which are more suitable to put in evidence opposite environment quality conditions. The new index is easy and rapid to apply, and does not need specialized expertise. The assessment of the environment is mainly qualitative, and the identification of its ecological status to a well precise class is immediate, also in the presence or absence of macrophytes.

The dichotomic key set up for the rapid quality assessment of Mediterranean transitional environments is reported in table 1. In soft substrata, the presence/absence of seagrasses allows a rapid distinction between the 'Bad–Poor' and 'Moderate–Good–High' environmental quality classes. The subsequent separation into intermediate categories can be obtained by taking into consideration seagrass species, the population structure and the association with some macroalgae. In hard substrates and in the 'Bad–Poor' classes of soft substrates, the class distinction is based on some macroalgae presence/absence and abundance. When the number of taxa is low, it should be integrated with the observation of the possible blooming of some nitrophilous species and the determination of some physico-chemical parameters. For example, in areas where macroalgae are sporadically present or reach very low biomasses, in the presence of turbid waters and extremely variable environmental conditions, they allow an immediate classification in the 'Bad' environmental quality condition. On the contrary, areas which are colonized by a low number of taxa blooming during the year (such as some species of Ulvaceae, Cladophoraceae, and Gracilariaceae) are characterized by a higher environmental quality and are classified as a 'Poor' class, although after blooming, usually a collapse follows. In the 'Moderate' class, the number of Rhodophyceae overcomes that of Chlorophyceae. The 'Good' and 'High' classes are discriminated by the presence or dominance of species which grow in high-quality environments and are characterized by low pollutant and nutrient concentrations [13], high water transparency, good water oxygenation, and low environmental (salinity, nutrient concentration) changes.

In general, a higher number of taxa is associated with 'Good-' or 'High'-quality conditions. However, sometimes, environments colonized by a low number of species, but with a high environmental score, can exhibit better conditions than an environment with a higher number of taxa but represented by species with a low score. Table 2 reports a list of the species found in the four lagoons along with the associated scores. Some of these species were present in the past but are now missing [18].

Table 1. Dichotomic key for a rapid quality assessment of the transitional environments.

**Hard substrata:** Absence or presence of a low number of macroalgal taxa, mostly Chlorophyceae.
**Soft substrata:** Absence of seagrasses ........ **1**

**Hard substrata:** The number of Rhodophyceae is as high as Chlorophyceae.
**Soft substrata:** Presence of seagrasses........ **3**

**1)** Macrophyte are missing or almost missing. Dominance of some taxa of Chlorophyceae, especially Ulvaceae and Cladophoraceae. Seasonal growth of some Rhodophyceae or Phaeophyceae but with negligible biomass. Waters are very turbid and seasonally changeable but, on average, Secchi disk is <0.5–0.8 m, due both to phytoplankton blooms and sediment re-suspension phaenomena. Presence of anoxic sediments and persistent water anoxia in spring-summer. High variability of environmental parameters such as transparency and salinity.

**Ecological status: BAD**

**1)** Seasonal growth of some (10–30) macroalgae, but some of them can bloom ........ **2**

**2)** Presence of a low macroalgal number. Monospecific macroalgal blooms can occur, especially Ulvaceae, Clodophoraceae and Gracilariaceae.
Water turbid, seasonally changeable but for long periods <1 m.
Oxygen saturation seasonally up to 300–400%, followed by macroalgal biomass collapse and anoxia.

**Ecological status: POOR**

**2)** Presence of many macroalgal taxa but, no one absolutely dominant. Seagrasses begin to be present ........ **3**

**3) Soft substrata:**
Presence of poor *Ruppia* spp., *Nanozostera noltii* and/or *Zostera marina* populations. *Cymodocea nodosa* is very rare.
**Hard substrata:**
Macroalgal biomass composed by many taxa of Chlorophyceae and Rhodophyceae, but the number of the latter begins to be higher.
Waters are quite transparent (1–2 m) for most of the year. Anoxia are lacking but hypoxic conditions can occur.

**Ecological status: MODERATE**

**3)** Presence of many macroalgal taxa with high quality score. High biomasses of laminar Ulvaceae are missing. The Rhodophyceae number is clearly prevailing on the Chlorophyceae one.
Seagrass beds well organised ........ **4**

**4) Soft substrata:**
*Ruppia* spp., *Nanozostera noltii* and/or *Zostera marina* beds are well organised. *Cymodocea nodosa* can be present.
Many macroalgae can be associated to seagrass populations. The latter can also show high Chlorophyceae (i.e. *Chaetomorpha linum*, filamentous Ulvaceae), or more rarely Rhodophyceae (*Gracilaria* spp., *Polysiphonia* spp., etc.), biomasses.
**Hard substrata:**
Macroalgal biomass composed by many taxa, characterized by high environmental score (Table 2), which are sensible to the environment stress. Dominance of some taxa such as *Ceramium* spp., *Dictyota* spp. *Sargassum muticum*, etc. Presence of calcified seaweeds.
Transparent waters (2–3 m) for most of the year. Environmental parameters such as oxygen and salinity show only long period or seasonal changes.

**Ecological status: GOOD**

**4) Soft substrata:**
Seagrass beds very dense and well organised. *Cymodocea nodosa*, if present, is abundant. *Ruppia* spp.negligible or missing or coupled with macroalgae with high environmental score.
Macroalgae are numerous, especially Rhodophyceae, but each taxon, rarely presents abundant biomasses. Many taxa are epiphytic species.
**Hard substrata:**
Presence of many taxa which are sensible to eutrophication, pollution, turbidity or other environmental stress (Table 2). Calcified species are numerous (*Corallina* spp., *Hydrolithon* spp., *Lithophyllum* spp. etc.).
Waters are clear (>3 m) for most of the year.
Environmental parameters such as oxygen and salinity show low seasonal changes. Sediments are mostly coarse or sandy and well oxidised.

**Ecological status: HIGH**

Table 2. Seaweed characterizing the environments with "High" quality status.

| | |
|---|---|
| Chlorophyceae | |
| 1 | ***Bryopsis duplex*** De Notaris |
| 2 | ***Caulerpa prolifera*** (Forsskål) Lamouroux |
| 3 | ***Chaetomorpha linum*** (O. F. Müller) Kützing |
| 4 | ***Cladophora hutchinsiae*** (Dillwyn) Kützing |
| 5 | ***Cladophora liniformis*** Kützing |
| 6 | ***Cladophora pellucida*** (Hudson) Kützing |
| 7 | ***Cladophora prolifera*** (Roth) Kützing |
| 8 | ***Codium bursa*** (Linnaeus) Agardh |
| 9 | ***Flabellia petiolata*** (Turra) Nizamuddin |
| 10 | ***Halimeda tuna*** (J. Ellis & Solander) J. V. Lamouroux |
| 11 | ***Monostroma obscurum*** (Kützing) J. Agardh |
| 12 | ***Polyphysa parvula*** (Solms-Laubach) Schnetter *et* Bula Meyer |
| 13 | ***Valonia aegagropila*** C. Agardh |
| 14 | ***Valonia utricularis*** (Roth) C. Agardh |
| Phaeophyceae | |
| 15 | ***Cladosiphon zosterae*** (J. Agardh) Kylin |
| 16 | ***Cladosiphon mediterraneus*** Kützing |
| 17 | ***Cladostephus spongiosum*** (Hudson) C. Agardh f. ***verticillatum*** (Lightfoot) Prud'homme van Reine. |
| 18 | ***Cystoseira amantacea*** (C. Agardh) Bory var. ***amantacea.*** |
| 19 | ***Cystoseira compressa*** (Esper) Gerloff & Nizamuddin |
| 20 | ***Cystoseira corniculata*** (Turner) Zanardini**.** |
| 21 | ***Cystoseira schiffneri*** Hamel f. ***tenuiramosa*** (Ercegović) Giaccone. |
| 22 | ***Cystoseira tamariscifolia*** (Hudson) Papenfuss**.** |
| 23 | ***Cutleria multifida*** (J. E. Smith) Greville |
| 24 | ***Dictyota fasciola*** (Roth) J. V. Lamouroux var. ***fasciola.*** |
| 25 | ***Dictyopteris polypodioides*** (A. P. De Candolle) J. V. Lamouroux |
| 26 | ***Fucus virsoides*** J. Agardh |
| 27 | ***Padina pavonica*** (Linnaeus) Thivy |
| 28 | ***Punctaria tenuissima*** (C. Agardh) Greville |
| 29 | ***Sargassum acinarium*** (Linnaeus) Setchell |
| 30 | ***Sargassum hornschuchii*** C. Agardh |
| 31 | ***Sphacelaria cirrosa*** (Roth) C. Agardh |
| 32 | ***Sphacelaria rigidula*** Kützing |
| 33 | ***Stictyosiphon soriferus*** (Reinke) Rosenvinge |
| 34 | ***Taonia atomaria*** (Woodward) J. Agardh f. ***atomaria.*** |
| 35 | ***Taonia pseudociliata*** (J. V. Lamouroux) Nizamuddin & Godeh |
| Rhodophyceae | |
| 36 | ***Alsidium corallinum*** C. Agardh |
| 37 | ***Anotrichium furcellatum*** (J. Agardh) Baldock |
| 38 | ***Antithamnionella elegans*** (Berthold) J. H. Price & D. John var. ***elegans*** |
| 39 | ***Bonnemaisonia asparagoides*** (Woodward) C. Agardh |
| 40 | ***Centroceras clavulatum*** (C. Agardh) Montagne |
| 41 | ***Ceramium ciliatum*** (J. Ducluzeau) var. ***ciliatum*** |
| 42 | ***Ceramium ciliatum*** (J. Ducluzeau) var. ***robustum*** (J. Agardh) Feldmann-Mazoyer |
| 43 | ***Ceramium cimbricum*** H. E. Petersen in Rosenvinge |
| 44 | ***Ceramium circinatum*** (Kützing) J. Agardh |
| 45 | ***Ceramium codii*** (H. Richards) Feldmann-Mazoyer |
| 46 | ***Ceramium deslongchampsii*** Chauvin *ex* Duby |
| 47 | ***Ceramium diaphanum*** (Lightfoot) Roth |
| 48 | ***Ceramium flaccidum*** (Kützing) Ardissone |
| 49 | ***Ceramium tenerrimum*** (G. Martens) Okamura |
| 50 | ***Champia parvula*** (Agardh) J. Agardh |
| 51 | ***Chondracanthus acicularis*** (Roth) Fredericq |
| 52 | ***Chondracanthus teedei*** (Roth) J. V. Lamouroux |

(*continued*)

Table 2. Continued.

| | |
|---|---|
| 53 | ***Chondria coerulescens*** (J. Agardh) Falkenberg |
| 54 | ***Chondria dasyphylla*** (Woodward) C. Agardh |
| 55 | ***Chondrophycus papillosus*** (C. Agardh) Garbary & Harper |
| 56 | ***Chylocladia verticillata*** (Lightfoot) Bliding |
| 57 | ***Corallina elongata*** J. Ellis & Solander |
| 58 | ***Corallina officinalis*** Linnaeus |
| 59 | ***Cryptonemia lomation*** (A. Bertoloni) J. Agardh |
| 60 | ***Dasya punicea*** (Zanardini) Meneghini *ex* Zanardini |
| 61 | ***Eupogodon spinellus*** (C. Agardh) Kützing |
| 62 | ***Gastroclonium reflexum*** (Chauvin) Kützing |
| 63 | ***Gelidium crinale*** (Turner) Gaillon |
| 64 | ***Gracilaria*** *cfr.* ***heteroclada*** (Montagne) J. Feldmann *et* G. Feldmann |
| 65 | ***Grateloupia dichotoma*** J. Agardh |
| 66 | ***Grateloupia filicina*** (J. V. Lamouroux) C. Agardh |
| 67 | ***Griffithsia opuntioides*** J. Agardh |
| 68 | ***Griffithsia schousboei*** Montagne |
| 69 | ***Haliptilon squamatum*** (Linnaeus) H. W. Johansen *et al.* |
| 70 | ***Haliptilon virgatum*** (Zanardini) Garbary & H. W. Johansen |
| 71 | ***Halymenia floresii*** (Clemente y Rubio) C. Agardh |
| 72 | ***Heterosiphonia plumosa*** (Ellis) Batters |
| 73 | ***Heterosiphonia japonica*** Yendo |
| 74 | ***Hildenbrandia rubra*** (Sommerfelt) Meneghini |
| 75 | ***Hydrolithon boreale*** (Foslie) Y. M. Chamberlain |
| 76 | ***Hydrolithon cruciatum*** (Bressan) Chanberlain |
| 77 | ***Hypnea musciformis*** (Wulfen) J. V. Lamouroux |
| 78 | ***Hypnea spinella*** (C. Agardh) Kützing |
| 79 | ***Janua longifurca*** Zanardini |
| 80 | ***Jania rubens*** (Linnaeus) J. V. Lamouroux var. ***corniculata*** (Linnaeus) Yendo. |
| 81 | ***Laurencia obtusa*** (Hudson) J. V. Lamouroux |
| 82 | ***Lithophyllum pustulatum*** (J. V. Lamouroux) Foslie |
| 83 | ***Lomentaria articulata*** (Hudson) Lyngbye var. ***articulata*** |
| 84 | ***Lomentaria ercegovicii*** Verlaque *et al.* |
| 85 | ***Lomentaria hakodatensis*** Yendo |
| 86 | ***Melobesia membranacea*** (Esper) J. V. Lamouroux |
| 87 | ***Nemalion helminthoides*** (Velley) Batters |
| 88 | ***Nitophyllum punctatum*** (Stackhouse) Greville |
| 89 | ***Osmundea truncata*** (Kützing) K.W. Nam & Maggs |
| 90 | ***Peyssonnelia dubyi*** P. *et* H. Crouan |
| 91 | ***Peyssonnelia polymorpha*** (Zanardini) F. Schmitz |
| 92 | ***Peyssonnelia squamaria*** (S. G. Gmelin) Decaisne |
| 93 | ***Phyllophora sicula (Kützing) Guiry et L.M. Irvine*** |
| 94 | ***Polysiphonia flocculosa (C. Agardh) Endlicher*** |
| 95 | ***Polysiphonia fucoides*** (Hudson) Greville |
| 96 | ***Pterothamnion crispum*** (Ducluzeau) Nägeli |
| 97 | ***Pterothamnion plumula*** (J. Ellis) Nägeli |
| 98 | ***Radicilingua reptans*** (Kylin) Papenfuss |
| 99 | ***Rytiphlaea tinctoria*** (Clemente) C. Agardh |
| 100 | ***Scinaia furcellata*** (Turner) J. Agardh |
| 101 | ***Spyridia hypnoides*** (Bory) Papenfuss |
| 102 | ***Wrangelia penicillata*** (C. Agardh) C. Agardh |

The environmental classification obtained by the macrophytes is very much related to the environmental conditions and/or the concentrations of contaminants of the Venice lagoon [13]. Seagrasses are lacking in the areas where contaminant levels are high, waters are turbid, or anoxia occur. Similarly, many species characterized by high scores are present only in areas where contaminant concentrations are low, waters are transparent, and anoxia does not occur. Also, the high seasonal variability of some parameters such as salinity, turbidity, and oxygen saturation usually characterizes 'Bad' or 'Poor' environments. In contrast, the areas which exhibit low seasonal variations, also in the presence of low salinity, can exhibit 'Good' or 'High' conditions.

### 3.2 *Transitional environment classification*

The assessment of the Venice stations by using R-MAQI is plotted in figure 1, and the results obtained for Lesina, Goro, and Orbetello lagoons are shown in figure 2. In Venice, all five classes of ecological status have been found, and in 19 stations sampled monthly during one year, *c*. 210 macroalgae and four seagrasses have been recorded. The environmental quality of those stations had already been assessed by applying the R/C ratio and MMSI [11–14]. However, according to the R-MAQI, the discrimination of five classes is relatively easy and immediate. Out of the examined stations, only station 10 displayed 'Bad' quality conditions. That station is situated in a very eutrophic and polluted canal of the Lido island where macroalgae are mainly represented by small filamentous Chlorophyceae, especially *Blidingia* spp. and *Ulva* spp. The 'Poor' environmental quality was recorded at stations 11, 13, 14, and 15, where the number of species was higher, and many of them bloomed during the year. In that case, the number of Rhodophyceae was always lower than the Chlorophyceae, and no seagrasses were found. Stations 9, 12, and 19 displayed 'Moderate' conditions of environmental quality, while station 9 was colonized also by the seagrass *Nanozostera noltii* (Horneman) Tomlinson *et* Posluzny, which showed only some patches. No seagrasses were found at station 12 and 19 likely due to the impact of the gears used to harvest the clam *Tapes philippinarum* Adams & Reeve. However, the number of Rhodophyceae was quite higher than Chlorophyceae. Conversely, conditions of 'Good' environmental quality were observed at stations 1, 3, 4, 7, 8, and 17, where seagrasses were associated with high biomasses of Chlorophyceae (i.e. *Chaetomorpha linum* (O. F. Müller) Kützing and filamentous Ulvaceae), or Rhodophyceae (*Gracilaria* spp., *Polysiphonia* spp., etc.). On the hard substrata, several genera such as *Ceramium* spp., *Dictyota* spp. *Sargassum muticum* (Yendo) Fensholt, and calcified macroalgae were particularly abundant. Finally, stations 2, 5, 6, and 18 showed conditions of 'High' environmental quality. In this case, seagrasses showed dense and well-structured populations, especially *Cymodocea nodosa* (Ucria) Ascherson and macroalgae of high ecological value such as many calcareous species (see table 2).

In summer 2005, the whole Venice lagoon was sampled and analysed for the R-MAQI (more than 90 stations), and the results are reported in figure 1b. The map shows conditions of 'Good' and 'High' environmental quality in the southern basin, except than in Valle di Brenta and in Valle Millecampi. Conditions of 'Poor' and 'Bad' environmental quality were observed in the central and northern basins near the mainland, between Venice, the industrial zone and Dese and Siloncello rivers. 'Moderate' and 'Good' conditions characterized the areas closed to Lido inlet and the main canals.

At Lesina, in May and July 2004, only 30 macroalgal taxa (i.e. 16 Chlorophyceae and 14 Rhodophyceae) and two seagrasses (*Ruppia cirrhosa* and *Nanozostera noltii*) were found. No Phaeophyceae have been recorded. In that lagoon all the ecological classes, except that defining a 'Bad' environmental quality, were present. Station 1, located close to Lesina centre, showed the worst environmental conditions. The station was covered by macroalgae, especially Cladophoraceae, reaching high biomasses. No seagrasses were found, and hypoxic conditions were recorded during the summer. Station 2 exhibited conditions of 'Moderate' environmental quality, as confirmed by the presence of scattered populations of *Nanozostera noltii* and a reduced number of Rhodophyceae in comparison with Chlorophyceae. Station 3 showed the best environmental conditions due to the presence of macroalgae of very high ecological value such as some calcareous species (*Hydrolithon* spp., *Lithophyllum* spp.) and the Chlorophycea

*Valonia aegagrophyla* C. Agardh. At Lesina, waters were very clear and oxygenated; the surface sediments were coarse and rich in shell debris. Also, seagrasses were found, especially *Nanozostera noltii*, which presented well-structured beds. Conversely, station 4, placed near a small freshwater inflow, showed 'Good' conditions. In that area, macrophytes were represented mainly by *Ruppia cirrhosa* and some filamentous Chlorophyceae.

In the lagoon of Orbetello, 21 macroalgae and two seagrasses (*Ruppia cirrhosa, Nanozostera noltii*) were recorded, but none of the studied areas exhibited a 'High' environmental quality. Conditions of 'Bad' environmental quality, were observed at station 3, where only some thalli of *Ulva laetevirens* Areschoug were recorded. In that station, waters were very turbid, and oxygen presented hypoxic conditions. Station 2 displayed conditions of 'Poor' environmental quality. This area was colonized by abnormal biomasses of *Chaetomorpha linum* (O. F. Müller) Kützing, a species that generally characterizes conditions of 'Good' and 'High' environmental quality. However, the area, placed near an oyster farm, was hypoxic with turbid waters, and the macroalgal population was under clear stress. In addition, Rhodophyceae were fewer in number than Chlorophyceae. Finally, stations 1 and 4 showed 'Good' conditions. Those areas exhibited good populations of *R. cirrhosa* and *N. noltii* and high biomasses of many macroalgae such as *Chaetomorpha linum* and *Cystoseira barbata* (Stackhouse) C. Agardh, but other species of high ecological value were rare.



The lagoon of Goro showed very homogeneous conditions. The four studied areas displayed conditions ranging from 'Bad' to 'Poor' environmental quality, and no seagrasses or Phaeophyceae were found. The lagoon was dominated by Ulvaceae. Station 1 displayed conditions of 'Bad' ecological quality, as macroalgae were almost lacking even from the hard substrata, and waters were highly turbid. Stations 2, 3, and 4 displayed conditions of 'Poor' environmental quality. At all stations, Rhodophyceae were almost completely absent, and the dominant species were laminar and filamentous Ulvaceae. At station 3, the environmental conditions were just better than those at stations 2 and 3 due to the presence of sandy sediments, but the influence of Po di Volano and Po di Gorino probably had a negative effect.

## 4. Conclusions

We propose the application of the R-MAQI method for the classification of the ecological quality status of the Mediterranean transitional environments. This index is based mainly on the recognition and the presence/absence of some seagrasses and macroalgae, and represents an evolution of the R/C ratio and MMSI methods. The latter approaches produce the same results but are time-consuming and expensive, and require experts on macroalgal taxonomy and ecology. The R-MAQI method, suggested here as a routine assessment method, is almost instantaneous, relatively easy to apply, and cost-effective. The required knowledge is reduced to the recognition of some common macrophyte taxa, also to genus or family level along with the determination of few environmental parameters, such as water transparency, oxygen availability, and salinity variation.

## Acknowledgements

The environmental data used in this work were collected in the framework of the project 'Ecological integrity and trophic state indices for coastal and transition marine areas based on macroalgal taxonomic ratios, target species and nutrient concentrations' co-funded by the Italian Ministry of Education, University and Research (MIUR). The project was one of the five projects co-funded in the general plan 'NITIDA' (New trophic state and ecological integrity indicators of coastal marine and transitional environments) (in Italian) in 2003—prot. 2003051023_005.

Particular thanks to the anonymous reviewers for the useful suggestions and adjustments of the paper and to Dr. Orietta Zucchetta for the English editing.

## References

[1] F. Giovanardi, E. Tromellini. Statistical assessment of trophic conditions. Application of the OECD Methodology to the Marine Environment. Proc. Int. Conf. Marine Coastal Eutrophication. *Sci. Total Environ. Suppl.* 1992, 211–233 (1992).
[2] L. Ignatides, M. Karydis, P. Vounatsou. A possible method for evaluating oligotrophy and eutrophication based on nutrient concentration scales. *Mar. Pollut. Bull.*, **24**, 238 (1992).
[3] M. Innamorati, F. Giovanardi. Interrelationship between phytoplankton biomass and nutrients in the eutrophied areas of the Northwestern Adriatic Sea. Proc. Int. Conf. Marine Coastal Eutrophication. *Sci. Total Environ., Suppl.* 1992, 235 (1992).
[4] R. A. Vollenweider, F. Giovanardi, G. Montanari, A. Rinaldi. Characterization of the trophic conditions of marine coastal waters, with special reference to the NW Adriatic Sea: proposal for a trophic scale, turbidity and generalized water quality index. *Environmetric*, **9**, 329 (1998).
[5] A. Borja, J. Franco, V. Pérez. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. *Mar. Pollut. Bull.*, **12**, 1100 (2000).
[6] A. Borja, I. Muxika, J. Franco. The application of a Marine Biotic Index to different impact sources affecting soft-bottom benthic communities along European coasts. *Mar. Pollut. Bull.*, **46**, 835 (2003).
[7] A. Borja, J. Franco, V. Valencia, J. Bald, I. Muxika, M.J. Belzunce, O. Solaun. Implementation of the European water framework directive from the Basque country (northern Spain): a methodological approach. *Mar. Pollut. Bull.*, **48**, 209 (2004).
[8] S. Orfanidis, P. Panayotidis, N. Stamatis. Ecological evaluation of transitional and coastal waters: A marine benthic macrophytes-based model. *Mediterr. Mar. Sci.*, **2**, 45 (2001).
[9] S. Orfanidis, P. Panayotidis, N. Stamatis. An insight to the ecological evaluation index (EEI). *Ecol. Indic.*, **3**, 27 (2003).
[10] P. Panayotidis, B. Montesanto, S. Orfanidis. Use of low-budget monitoring of macroalgae to implement the European Water Framework Directive. *J. Appl. Phycol.*, **16**, 49 (2004).
[11] A. Sfriso, B. La Rocca. Seaweed updating in the littoral and shallow bottoms of the Venice lagoon (In Italian). *Lavori—Società Veneziana di Scienze Naturali*, **30**, 45 (2005).
[12] A. Sfriso, C. Facca, B. La Rocca, P. F. Ghetti. Set up of environmental quality indices based on seaweed taxonomic ratios for the assessment of transition marine areas: Venice, Lesina and Goro study cases. In APAT (Ed.), *Transition Waters Monitoring. Research and Institutional Monitoring. Comparison Between Different Experiences* (in Italian). Venezia 27–29 Ottobre 2004. Palazzo Labia, Venezia pp. 190–2001 (2006).
[13] A. Sfriso, C. Facca, P.F. Ghetti. Seaweeds and environmental variables to assess the ecological quality of transitional marine environments. *Biol. Mar. Mediterr.*, **13**, 178 (2006).
[14] A. Sfriso, B. La Rocca, E. Godini. Seaweed list in three areas of the Venice lagoon characterized by different trophic levels (In Italian). *Lavori -Società Veneziana di Scienze Natura1i*, **27**, 85 (2002).
[15] G. Furnari, M. Cormaci, D. Serio Catalogue of the benthic marine macroalgae of the Italian coast of the Adriatic Sea. *Bocconea*, **12**, 5 (1999).
[16] G. Furnari, G. Giaccone, M. Cormaci, G. Aloni, D. Serio. Marine biodiversity of the Italian coasts: Macrophytobenthos catalogne (in Italian). *Biol. Mar. Mediterr.*, **10**, 1 (2003).
[17] M. Oxner *The Determination of Chlorinity by the Knudsen Method and Hydrographical Tables*, G.M. Manufacturing, New York, pp. 63 (1962).
[18] A. Sfriso, D. Curiel. Check-list of marine seaweeds recorded in the last 20 years in Venice lagoon and comparison with the previous records. *Bot. Mar.*, **50**, 22 (2007).