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Assessment of the ecological status of Mediterranean French coastal waters as required by the Water Framework Directive using the *Posidonia oceanica* Rapid Easy Index: PREI

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ABSTRACT

This paper describes the PREI (*Posidonia oceanica* Rapid Easy Index), a method used to assess the ecological status of seawater along Mediterranean French coasts. The PREI was drawn up according to the requirements of the Water Framework Directive (WFD 2000/60/EC) and was tested on 24 and 18 stations in PACA (Provence-Alpes-Côtes d'Azur) and Corsica, respectively. The PREI is based on five metrics: shoot density, shoot leaf surface area, *E*/*L* ratio (epiphytic biomass/leaf biomass), depth of lower limit, and type of this lower limit. The 42 studied stations were classified in the first four levels of status: high, good, moderate and poor. The PREI values ranged between 0.280 and 0.847; this classification is in accordance with our field knowledge and with our knowledge of the literature. The PREI was validated regarding human pressure levels ($r^2 = 0.74$). (http://eurex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:327:0001:0072:EN:PDF).

1. Introduction

The seagrass *Posidonia oceanica* (L.) Delile is an endemic species of the Mediterranean Sea. It forms monospecific meadows widely distributed between the surface and 44 m depth in the clearest waters (Malta, France (Var, Corsica)) (Augier and Boudouresque, 1979; Boudouresque et al., 1990; Borg and Schrembi, 1995). These meadows cover large areas in coastal regions totalling a global surface area of 37,000 km^2 (1–2% of the bottom of the Mediterranean Sea (Pasqualini et al. 1998; Boudouresque et al., 2006). *Posidonia* meadows constitute an engineering ecosystem playing a major ecological, geological and economic role in coastal zones (Boudouresque and Meinesz, 1982; Pergent-Martini et al., 1994; Francour, 1997; Boudouresque, 2004). The meadows are sensitive to human disturbance such as coastal development, pollution, increasing water turbidity and trawling (Boudouresque et al., 2000, 2006). They are now listed as a priority natural habitat in Annex I of the EC Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (EEC, 1992) but the loss of covering has been described in a large number of regions around the Mediterranean Sea.

Programmes for monitoring *Posidonia* beds initiated in Europe (Spain, France, Italy) have allowed the definition of the quality of coastal waters (Boudouresque et al., 2007), and *P. oceanica* is regularly used as a bioindicator because of its sensitivity to disturbance (Pergent-Martini, 1998; Gosselin et al., 2006; Leoni et al., 2006; Montefalcone, 2009).

Due to the increase in anthropogenic pressure on ecosystems and the associated water quality decline, the European Union has engaged a new strategy to conserve and recover the ecological quality of the marine environment. In order to attain this objective, the Water Framework Directive (WFD) has established the basis of policies for the monitoring, protection and enhancement of the status of aquatic systems in the Member States. The main goal of the WFD is to achieve (or maintain at least) a "good water status" for all the European waters by 2015. To this end, this directive defines the concept of ecological status as the quality of the structure and functioning of ecosystems associated with homogenous water bodies. The evaluation of the status of each water body is based on the use of some organisms or groups of organisms sensitive to anthropogenic pressures: biological quality elements (BQEs).

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Phytoplankton, macroalgae, angiosperms and benthic fauna are the BQEs to be considered (Devlin et al., 2007). According to the WFD, biological variables indicative of the status of these BQEs should be used for evaluation and monitoring purposes. On the basis of previous work on the bioindicating of water global quality by *P. oceanica*, this species was chosen for the Mediterranean area as the angiosperm BQE (Med-GIG, 2007). As permitted by the WFD, each member state, involved in this BQE, can define its own method to evaluate the state of the *P. oceanica* meadow.

For example, the PosWare (system for coastal water classification by using *P. oceanica* as quality element according to WFD) (Buia et al., 2005; Silvestre et al., 2006), the POMI (multivariate index based on the seagrass *P. oceanica*) (Romero et al., 2007 and corrigendum), Valencian CS (Fernandez Torquemada et al., 2006, 2008) and BiPO (Biotic index using *P. oceanica*) (Lopez y Royo, 2008), have been developed to evaluate the status of coastal waters based on the *P. oceanica* BQE (Table 1; see also Table 9).

This paper describes the PREI (*P. oceanica* Rapid Easy Index) method used along PACA (Provence-Alpes-Côte d'Azur) and Corsican coasts to implement the assessment of French coastal waters using *P. oceanica* under the WFD. It presents the first results and validations (agreement of metrics used with the impact of anthropic pressure).

2. Methodology

2.1. Selection and measurement of the metrics

A lot of descriptors (or metrics) have already been used to assess the health status of *P. oceanica* meadows around the Mediterranean Sea (Pergent-Martini et al., 2005). These metrics provide information:

(i) at different levels (population and community levels, individual, tissue...);
(ii) on different types of disturbance;
(iii) with different times of response (week, year, century...) (Table 2).

In this study, we calculated the PREI with five metrics measured in *P. oceanica* meadows to define the ecological status of French coastal waters according to the WFD recommendations: (1) shoot density, (2) shoot surface, (3) *E/L* (ratio between epiphytic biomass and leave biomass) measured on shoots sampled at the same depth; (4) depth of the lower limit and (5) type of this limit (regressive, progressive or stable).

Firstly, these metrics were selected because they provide pertinent information on the vitality of the meadow (at the individual and population level) for a wide spectrum of disturbance (water transparency, nutrient concentrations and eutrophization, sedimentary dynamics, grazing pressure...) regularly described in the Mediterranean Sea (Pergent-Martini et al., 2005). As such, they constitute unequivocal indicators of *P. oceanica* (Dale and Beyeler, 2001). They are also easy to obtain with a good cost-efficiency ratio and low technological investment.

2.2. Calculation of EQR and classification of water body

According to the WFD, the classification of ecological status is based on the deviation of the status of the BQE from its potential status under pristine conditions (reference conditions: RC). This ecological status is expressed using a scale going from 1 (RC) to 0 (worst conditions where the BQE is badly affected or missing). The ratio between the status of a given BQE noted in a station and its status in the reference conditions is called the Ecological Quality Ratio (EQR).

To calculate this EQR, a definition of RC has to be made. RC describe the characteristics in undisturbed conditions. These conditions should be established using (i) the best spatial analysis (data from undisturbed sites), (ii) palaeoecological and historical data, (iii) modelling using existing or historical data and (iv) expert judgment. Due to the impossibility of *P. oceanica* surviving in extremely degraded environments (Boudouresque et al., 2006; Romero et al., 2007), its presence defines the quality of water bodies above a "bad" status (Romero et al., 2007). The "bad" condition has been defined as a condition corresponding to a recorded recent die-off of the meadow (<5 years) due to identified anthropogenic impacts (Med-GIG, 2007).

Table 1
Four methods based on *Posidonia oceanica* in the WFD to assess the ecological status of Mediterranean coastal waters.

	Metrics	Methods	Reference
Posware	– shoot density, – width of the intermediate leaf, – leaf production, – rhizome production, – rhizome elongation	Combined in a datawarehouse (Autoclass C, miner 3D, and fuzzy clustering analyses)	Buia et al. (2005)
POMI	– shoot density, – meadow cover, – percentage plagiotropic rhizomes, – shoot leaf surface, – percentage foliar necrosis, P, N and sucrose content in rhizomes, – $\delta\ ^{15}N$ and $\delta\ ^{34}S$ isotopic ratio in rhizomes, – N content in epiphytes, – Cu, Pb, and Zn content in rhizomes	Combined using Principal Component Analysis (PCA)	Romero et al. (2007)
Valencian CS	– shoot density, – meadow cover, – dead matte cover, – percentage of plagiotropic rhizomes, – rhizome baring/burial, – shoot leaf surface area, – percentage of foliar necrosis, – herbivore pressure, – leaf epiphyte biomass	Combined using Principal Component Analysis (PCA)	Fernandez Torquemada et al. (2006, 2008)
BIPo	– lower depth limit, – lower limit type, – shoot density, – shoot leaf surface	Combined by averaging metric scores	Lopez y Royo (2008)

Table 2
List of main descriptors of *P. oceanica* used in monitoring and their responses to different impacts, 1: community descriptors, 2: individual descriptors, 3: physiological descriptors (Pergent-Martini et al., 2005; Boudouresque et al., 2006; Romero et al., 2007).

Type	Variable	Impact or stress	Response
1	Shoot density (shoot/m^2)	Reduction of light availability. Burial. Direct elimination due to trawl fishing, boat anchoring, coastal construction, etc.	Shoot density decrease (shoot mortality)
	Cover (%)	Reduction of light availability. Burial. Direct elimination due to trawl fishing, boat anchoring, coastal construction, etc.	Vegetal coverage decrease
	"Matte" structure	Disturbance on sedimentary flux. Burial. Boat anchoring, coastal construction, etc.	Fragilization of the "matte" structure
	Epiphyte biomass (mg/cm^2)	Reduction of light availability	Epiphyte biomass decrease
		Eutrophication	Epiphyte biomass increase, except if compensated by herbivores
	N content in epiphyte	Eutrophication	Increase in tissues
	Species associated to meadow	Reduction of light availability. Burial. Direct elimination due to trawl fishing, boat anchoring, coastal construction, etc.	Decrease of biodiversity
2	Foliar area (cm^2/shoot)	Reduction of light availability Eutrophication (turbidity increase due to phytoplankton development)	Leaf surface increase to optimize photosynthetic productivity
	Foliar necrosis (% leaves with necrosis /shoot)	Eutrophication	Possible consumption by herbivores due to nutrient increase
		Reduction of light availability. Prolonged anoxia (burial). Other stress factors (e.g. toxins, pathogens, hypersalinity)	Increase in necrosis in tissues
	Lepidochronology	Reduction of light availability, sediment resuspension…	Changes in foliar productivity and the growth rate of the rhizomes
	Plagiotropic rhizomes (%)	Reduction of light availability, sediment resuspension…	Decrease of percentage of plagiotropic rhizomes
3	Sucrose content	Reduction of light availability due to eutrophication, sediment resuspension… Burial	Decrease of carbon reserves in rhizomes
	Nitrogen and phosphorus content	Eutrophication	Increase of nutrient content in plant
		Reduction of light availability	Increase of nutrient content (nitrogen) in leaves due to low growth under low light conditions
		Anoxia in sediment	Decrease of nutrients accumulated in rhizomes due to negative effects on the availability and uptake of nutrients by roots
	$\delta\ ^{15}$N and $^{\delta\ 34}$S	Eutrophication	Increase of $\delta\ ^{15}$N
		Anoxia in sediment	Increase of $\delta\ ^{34}$S
	Metal traces: Cu, Zn and Pb	Metal contamination	Increase of metals in tissues. Effects on photosynthetic activity (Cu, Pb, Zn)

On this basis, considering that no pristine conditions could be found in the studied area, we postulated RC as a "theoric optimal site", corresponding to the best values of each metric noted in the field. We defined EQR' as an index integrating the averaging of the chosen individual metrics:

- EQR′ = (*N* density + *N* leaf surface area + *N* (*E*/*L*) + *N* lower limit)/3.5 with:
- – *N* density = value measured −0/reference value −0;
- – *N* leaf surface area = value measured −0/reference value −0; 0 being considered as the worst value for the density and for the leaf surface area;
- – $N\ (E/L) = [1 - (E/L)] \times 0.5$;
- – *N* lower limit = $(N' - 17)/(\text{reference value} - 17)$, 17 m being considered as the worst lower limit for *Posidonia* meadows

N' = depth noted on the field + λ, where $\lambda = 0$ (stable limit), $\lambda = 3$ (progressive limit) or $\lambda = -3$ (regressive limit).

As considered by Romero et al. (2007) for the definition of the POMI index, we arbitrarily assigned an EQR value of 0.100 for the "bad" status boundary; the other EQR boundaries were obtained by dividing the remaining scale (from 0.100 to 1) into four categories of equal amplitude (Table 3). Therefore, where *P. oceanica* existed, the EQR was computed as follows:

- EQR = (EQR′ + 0.11)/(1 + 0.10).

2.3. Application of the method to the French Coast

The PREI index was applied in two French hydrographic districts (zones defined by article 2 of the WFD) representing a coastal of 1840 km (Gobert et al., 2008): Corsica and PACA.

In total, 42 stations were sampled, distributed as follows: 24 in PACA and 18 in Corsica (Fig. 1). These studied sites comprised different human impact conditions (low to highly impacted). All stations were characterized by the presence of *P. oceanica* meadows that therefore excluded a bad classification (EQR < 0.100).

Around Corsica, meadows colonize sandy and/or rocky bottom in very clear waters with very low island discharges (Gosselin et al., 2006). The PACA area is characterized by sandy or rocky or mixed meadows colonizing clear waters with low natural continental discharge (Blanc and Jeudy de Grissac, 1978). But two stations located at the extreme west of this region (Ponteau and Couronne) are exposed to the impact of the Rhône estuary and the "Mistral" wind (NW wind), inducing general high turbidity and sedimentary deposit (Blanc and Jeudy de Grissac, 1978; Sartoretto, 1996).

The sampling was performed at a 15 m depth in April (2007) to prevent the masking effects of depth and seasonal variability (Middelboe et al., 2003; Alcoverro et al., 1995). At each station, shoot density, depth and type of lower limit were noted *in situ* by a scuba diver. Twenty shoots of *P. oceanica* were collected for the laboratory measurements (biometry and *E*/*L*). Methods used to obtain each metric are detailed in Table 4.

The mean value of each metric was used to calculate the EQR′ and EQR of each station as described above.

2.4. Definition of RC

Topography, salinity, turbidity, hydrodynamism, genetics,… clearly influence shoot biometry and meadow structure (i.e. Procaccini and Mazzella, 1998). The meadows of the two studied areas:

Table 3
Boundaries and colour codes for the different levels of ecological status.

EQR	Ecological status	Color code
1–0.775	High	Blue
0.774–0.550	Good	Green
0.549–0.325	Moderate	Yellow
0.324–0.100	Poor	Orange
<0.100–0	Bad	Red

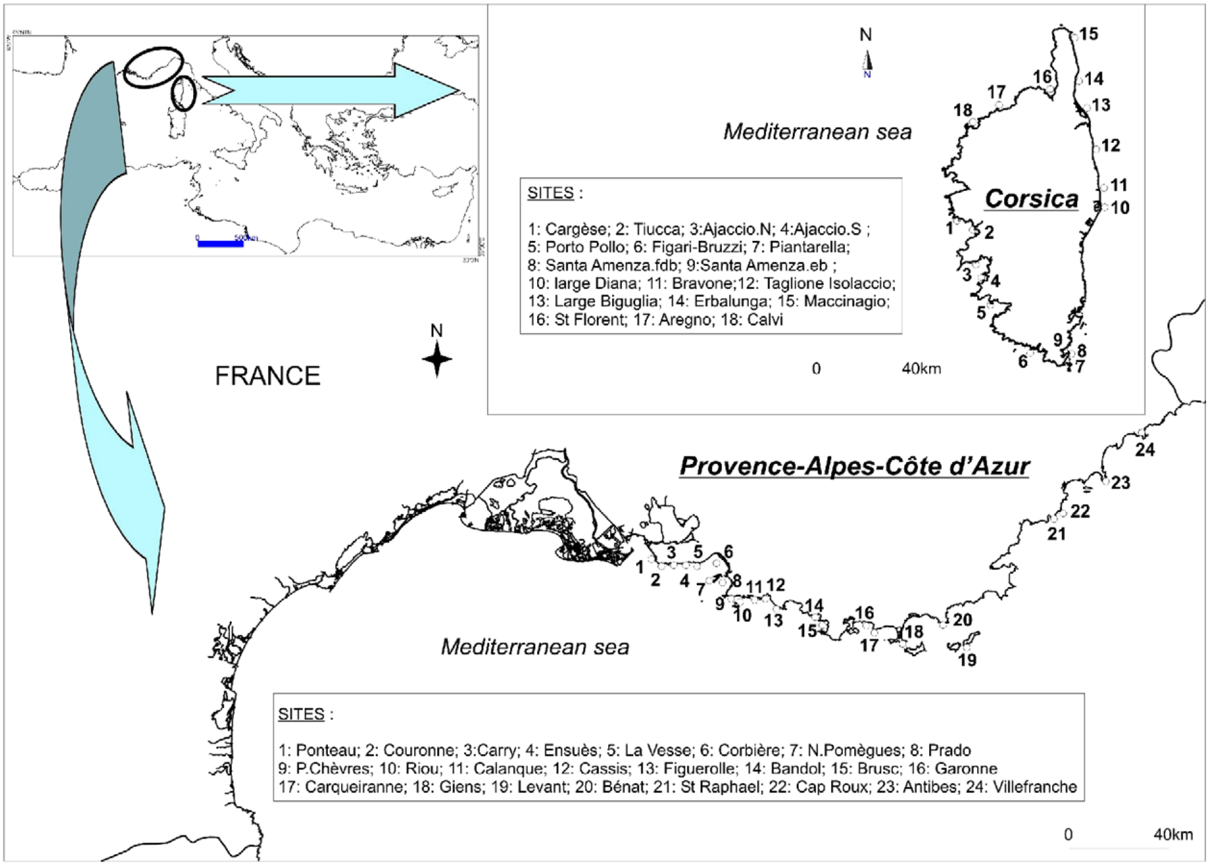

Fig. 1. Location of the 42 sampling marine sites in the two studied French Hydrographic Districts (PACA and Corsica).

Table 4
List of metrics used in the PREI, unit and methodology used to obtain the results for each metric.

PREI metrics and units	Methodology and references
Shoot density (shoot m^{-2})	Quadrat 20 × 20 cm Soullard et al. (1994) 20 measurements at 15 m depth
Lower depth limit (m)	Noted *in situ* by scuba diver
Type of this limit (regressive, progressive, stable)	Noted *in situ* by scuba diver according to the classification of Meinesz and Laurent (1978)
E/*L*	On 20 shoots sampled at 15 m depth: measurement of total dry weight of epiphyte and leaf (adult + intermediate) Dauby and Poulicek (1995)
Leaf surface area (cm^2 shoot^{-1})	On 20 shoots sampled at 15 m depth: measurement of total leaf surface area according to the methodology of Giraud (1979)

(Corsica and PACA) also exhibit differences within the French basin in relation to the topography. Around Corsica, the seawater is characterized by oligotrophic conditions (low nutrient concentration, low turbidity...). In PACA, natural continental discharges are more important (Goffart et al., 2002; Gobert et al., 2002...).

In our study, the most important difference appears for the lower depth limit. We only considered the lower depth of meadows with stable limits to avoid anthropogenic effects (five both in Corsica and in PACA); mean values were 37 m ± 1 for Corsica and 25 m ± 3 for PACA. For this parameter, the spatial variation is evident and is related to light penetration and to turbidity (Elkalay et al., 2003).

Knowing this spatial variability, the RC (Table 5) to calculate the EQR were determined separately for the 2 hydrological districts (Corsica and PACA).

The reference value was defined for each metric in each district. The RC were calculated using data obtained in April 2007; furthermore we used our field data together with literature data in order to establish the lower depth limit, (e.g. Boudouresque et al., 2000; Mayot, 2007...).

For density and leaf surface area, the reference values were calculated as the mean of the three higher values of the considered metric after the maximum one was discarded. For *E*/*L*, we postulated that 0 was the reference value, which corresponded to a non epiphyted shoot.

3. Results

The 42 studied stations were classified in the first four levels of status: high, good, moderate and poor. The PREI values ranged between 0.280 and 0.847 (Table 6). Two meadows (8%) received the status of poor in PACA (Corbière and Villefranches); 16% and 22% were qualified as moderate, 62% and 67% as good, 13% and 11% as high both in the PACA area and along the coast of Corsica. The mean PREI EQR in PACA was slightly lower than along the coast of Corsica (0.609 and 0.635, respectively).

Along the French Mediterranean coasts, a large proportion of economic activities are based on tourism. The coastal zone is dedicated to tourists (hotels, marinas, camping,...) but the area has also seen an increase in population and in urbanization (Benoit

Table 5
Reference conditions for each metric in the two studied French Hydrographic Districts (PACA and Corsica).

	CORSICA	PACA
Shoot density (shoot/m^2)	483	675
Leaf surface area (cm^2/shoot)	546	465
E/*L*	0	0
Lower depth limit (m)	41	34

Table 6
PREI values calculated in Corsica and PACA.

CORSICA		PACA	
Station	PREI	Station	PREI
Cargèse	0.668	Ponteau	0.360
Tiucca	0.630	Couronne	0.525
Ajaccio-nord	0.564	Carry	0.680
Ajaccio-sud	0.495	Ensuès	0.686
Porto Pollo	0.386	La Vesse	0.465
Figari-Bruzzi	0.619	Corbière	0.305
Piantarella	0.597	Nord Pomègues	0.628
Sant'Amanza fdb	0.542	Prado	0.636
Sant'Amanza eb	0.671	P. Chèvres	0.477
Large Diana	0.689	Riou	0.677
Bravone	0.779	Calanque	0.584
Taglio Isolaccio	0.690	Cassis	0.563
Large Biguglia	0.721	Figuerolle	0.660
Erbalunga	0.741	Bandol	0.682
Maccinagio	0.650	Brusc	0.634
St Florent	0.478	Carqueiranne	0.708
Aregno	0.789	Garonne	0.583
Calvi	0.724	Levant	0.802
		Giens	0.819
		Bénat	0.764
		St Raphael	0.690
		Cap Roux	0.847
		Antibes	0.560
		Villefranche	0.280

and Comeau, 2005). The levels of pollution are difficult to establish regarding the very high variability of sources (type of pollution, local or diffuse source…).

In order to verify the robustness of our PREI, we calculated an anthropization index. The anthropization index was defined as the sum of 7 impact factors affecting the seawater quality and/or biotope quality: fish farming, industrial development, agriculture, tourism, fishing, commercial ports and urbanization. Each impact factor was classified from 0 (no impact) to 5 (dramatic effect on the meadow) according to criteria listed in Table 7.

The proximity of the study stations to Marine Protected Areas (Francour et al., 2001) and literature data was also taken into account. (Boudouresque et al., 2000).

The quality of seawater expressed by our anthropization index was negatively correlated with the PREI (Fig. 2).

The lowest anthropization indices (=1) were attained by 3 Corsican and 3 PACA stations (Bravone, Erbalunga, Aregno and Levant, Blénat, Cap Roux, respectively); Ponteau and Corbière (PACA District) were the highest anthropized stations with an index of 20.

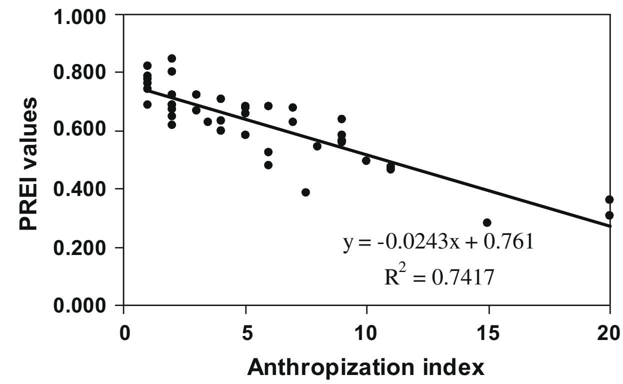

Fig. 2. Regression between the anthropization index of water bodies and the classification obtained by the PREI index.

Most of the Corsican sites had a high or good ecological status with a mean anthropization index of 3.8.

Corsican coasts are subject to a lower anthropogenic pressure (no high level industrial activities and no highly urbanized areas) than continental zones.

Four stations were classified as moderate: Ajaccio-sud, Porto Pollo, Sant'Amanza fdb, Saint Florent. The Ajaccio-sud site is in a semi-closed area where sewers, marinas and aquaculture are active. Porto Pollo is an enclosed area principally developed for tourism; anchoring systems which do not damage the seafloor are installed but it seems that urban discharges are uncontrolled. The site Sant'Amanza fdb is an enclosed zone, which is subject to the effects of fish farming in a well developed tourist zone. Saint Florent is a semi-enclosed area where marina, fishing and agricultural activities are listed.

The case of Ajaccio-nord (high anthropization index: 10 – good ecological status) can be explained by the position of the sampling point: an open zone in an urbanized area where the anthropogenic pressures do not reach and do not affect the meadow.

The majority of stations in the PACA District (82%) were classified as having a high or good ecological status, with a mean anthropization index of 5.0. Four sites were considered as moderate: Ponteau, Couronne, La Vesse and Plateau des Chèvres. Ponteau is located in a Gulf (Gulf of Fos) highly impacted by human activities (anthropization index: 20) and directly exposed to the Rhône Delta water. According to this description, the EQR value is close to the boundary values between moderate and poor ecological status (EQR = 0.325). The case of Couronne (low anthropization index: 6 – moderate ecological status) can be explained by the exposure to Gulf of Fos water through the existence of the Nerthe countercurrent (Blanc and Jeudy de Grissac, 1978). EQR values for La Vesse and Plateau des Chèvres were consistent with a high level of anthropization index (11) (urbanization, commercial harbour, sewage outfall,…). Finally, two stations were considered to be in a poor ecological state: Corbière and Villefranche are particularly impacted by human activities linked to the proximity of big urban centres and portuary zones.

Table 7
List of impact factors and criteria used to calculate the anthropization index.

Impact factors	Criteria	Reference
Fish farming	Number, production	Benoit and Comeau (2005), Boudouresque et al. (2000), http://observatoire.oec.fr; http://www.corse.eaufrance.fr http://www.rhone-mediterranee.eaufrance.fr
Industrial development	Type, zoning	
Agriculture	Exploited surface, type of exploitation	
Tourism	Number of camping, marina, beach and second home; tourism fluxes (airport, ferries…)	
Fishing	Fishing, fleetfishing port, employment, type of activity (artisanal, deep-sea…)	
Commercial port	Harbour traffic, type of activities	
Urbanization	Sewer, population density	

Table 8
Variation in metrics and EQR between 2007 and 2008 for three stations classified as "good" by the PREI index. NS: non significant variation.

	Density	Leaf surface	*E/L*	EQR 2007	EQR 2008
Prado	−9% ($p < 0.05$)	+15% ($p < 0.0005$)	+41% ($p < 0.0005$)	0.631	0.632
Brusc	−2.3% (NS)	−1.4% (NS)	+120% ($p < 0.0005$)	0.628	0.623
Carqueiranne	−5.5% (NS)	+3.4% (NS)	+29% ($p < 0.05$	0.702	0.693

In order to test the robustness of the PREI index, we acquired in April 2008, new data on three stations classified as "good" with *P. oceanica* BQE: Prado, Brusc and Carqueiranne (PACA District). Results obtained show a very small variation in EQR values between 2007 and 2008, less than 1.5% (Table 8).

The main source of variation is the ratio *E/L* but its impact is limited by low values (<0.2).

4. Discussion

The results of the ecological classification by the PREI are in accordance with our field knowledge and with our knowledge of the literature. The PREI, based on *P. oceanica* metrics that integrate responses at individual and community levels, is an efficient method to define the quality of coastal water.

Our indices reflect the main anthropogenic factors that were found to occur in littoral zones and the quality of seawater expressed by our anthropization index was negatively correlated with the PREI. The robustness of the PREI was checked on three stations prospected over two successive years.

Some indices, based on *P. oceanica*, have been proposed to assess Mediterranean coastal waters in accordance with the WFD (Tables 2 and 9) (Fernandez Torquemada et al., 2008; Romero et al., 2007; Lopez y Royo, 2008). An intercallibration exercise of *Posidonia* indices between countries in the WFD is in progress.

Table 9 presents a summary of some characteristics these indices.

Our index is a destructive technique, requiring scuba divers, using shoot density, the most adopted standardized descriptor (Montefalcone, 2009). All stations were sampled during a short period (10 days), which avoided seasonality effects. The PREI is both cost effective and easily applied. It requires scuba divers working on random punctual stations (15 m depth) and on positioned stations (depth limit).

Montefalcone (2009) recently recommended an integrated approach based on descriptors of water quality together with three ecological indices of ecosystem health (Conservation Index (Moreno et al., 2001), Substitution Index and Phase Shift Index) in order to discriminate the main components affecting the status of coastal ecosystems.

This approach is more complex and requires experienced divers (% of covering, knowledge of biology to determine substituting species) but was able to be tested in the Bay of Calvi near STARESO (with CI corresponding to good conservation status; SI and PSI corresponding to high conservation status on a 100 m transect at 10 m depth; Gobert, personal unpublished data, June 2009).

5. Conclusions

The Posidonia Rapid Easy Index (PREI) was used to assess the ecological status of Mediterranean French coastal waters in accordance with WFD requirements (EC, 2000) and with decisions taken within the Mediterranean Intercallibration Group (Med-GIG, working group (including authors of this paper) (Med-GIG, 2007). It is a reliable approach for estimating the state of *P. oceanica* meadows and the ecological status of seawater.

For the PREI, we selected metrics that were easy to obtain (with a minimum of laboratory analysis) and easy to measure (without requiring scientific expertise).

Cost effectiveness was also an important issue. The PREI was compared to the level of human pressure on the environment (anthropization indices); its robustness was tested by the acquisition of new data in 2008 on the same stations as in 2007. It can be easily used by coastal managers.

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Table 9
Comparison of the application of POMI, BIPo and PREI.

	PosWare	POMI	ECS Valencia	BIPo	PREI
Number of metrics	6	14	9	4	5
Sampling conditions	x		September–October 14–17 m	August–September 15 m and lower limit	April 15 m and lower limit
In situ measurement	x	Yes	Yes	Yes	Yes
Sampling effort		+++	++++	++	+
Laboratory measurement	x	Yes	Yes	No	Yes
Laboratory work		+++++	+++		+
Laboratory material	x	Sophisticated (ICPS; IRMS...)	Simple (quadrat, measure ribbon...)	Simple (quadrat, measure ribbon...)	Simple (quadrat, measure ribbon...)
Destructive method	x	Yes	Yes	No	Yes
Cost	x	Expensive	Cheap	Cheap	Cheap
Test of robustness					
against anthropic pressures	x	Yes	Yes	Yes	Yes
temporal variation	x	No	Yes	No	Yes
Geographical test	Italy	Catalan coast (Spain)	Valencia coast (Spain)	Corsican coast (France)	Corsican coast and PACA (France)

x: PosWare is based on data collected in a data warehouse, data coming from monitoring projects on large spatial and temporal scale.

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