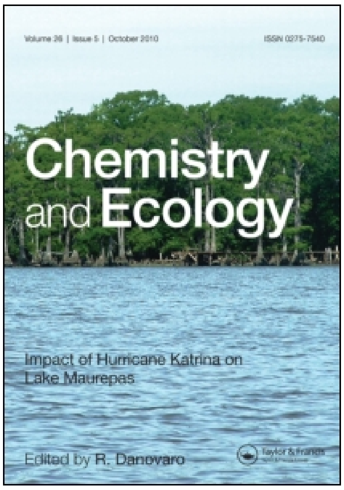

Chemistry and Ecology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713455114

A preliminary coastal wetland assessment procedure: Designing and testing an environmental sustainability index for Mediterranean lagoons

Alessandro Carletti[a]; Giulio A. De Leo[b]; Ireneo Ferrari[b]
[a] EC Joint Research Centre, Institute for Environment and Sustainability, Inland and Marine Water Unit, Italy [b] Dipartimento di Scienze Ambientali, Università degli studi di Parma, Parma, Italy

To cite this Article Carletti, Alessandro , De Leo, Giulio A. and Ferrari, Ireneo(2006) 'A preliminary coastal wetland assessment procedure: Designing and testing an environmental sustainability index for Mediterranean lagoons', Chemistry and Ecology, 22: 4, S15 — S35

To link to this Article: DOI: 10.1080/02757540600572578

URL: http://dx.doi.org/10.1080/02757540600572578

Chemistry and Ecology
August 2006, Vol. 22 (Supplement 1), pp. S15–S35

Taylor & Francis
Taylor & Francis Group

A preliminary coastal wetland assessment procedure: Designing and testing an environmental sustainability index for Mediterranean lagoons

ALESSANDRO CARLETTI*†, GIULIO A. DE LEO‡ and IRENEO FERRARI‡

†EC Joint Research Centre, Institute for Environment and Sustainability, Inland and Marine Water Unit, TP280, Via E. Fermi 1, I-21020 Ispra (VA), Italy
‡Dipartimento di Scienze Ambientali, Università degli studi di Parma, Parco Area delle Scienze, 43100 Parma, Italy

(Received 17 February 2005; in final form 22 September 2005)

Coastal wetlands are important and fragile transitional environments for their ecological, hydrological, and conservation value. Yet, in the last 50 yr, they have been subject to a high level of anthropogenic disturbance, ranging from habitat disruption to pollution. Even important economic activities that directly or indirectly depend upon the ecological integrity of these unique environments, such as tourism, extensive fish farming, and clam rearing, may exert remarkable pressures on coastal lagoons. As a consequence, it is important to derive a methodology that allows for an integrated assessment of the ecological integrity of wetlands areas and the sustainability of the commercial activities that depend on it. In this work, we have defined a rapid, user friendly, and cost-effective tool to assess wetland condition based on an aggregated index of sustainability (ESI), which combines three scores targeted to quantifying habitat availability, functionality performance, and anthropogenic pressures, respectively. Three data forms have been compiled for 17 sites included in the LaguNet network, thus showing that (meta)data can be collected from a great deal of information coming from research centres, environmental agencies, grey literature, management bodies, and, in some cases, field surveys. A Monte Carlo sensitivity analysis has been performed to assess the sensitivity of the results to uncertainty or errors in the allocation of weights to the three components of the index. A randomization test applied to the 10 000 Monte Carlo replicates has allowed us to assess the robustness of the final ranking. The methodology presented here can be regarded as a cost-effective way to summarize a great deal of information and to provide a preliminary screening evaluation to help decision-makers in wetland assessment and management.

Keywords: Coastal lagoons; Wetlands; Sustainability index; Sensitivity analysis; Ecological and economic assessment; Comparative benchmarking; Integrated assessment; Ecosystem function; Pollution; Anthropogenic disturbance; Water-framework directive

1. Introduction

The decisional problems that authorities involved in management and protection of coastal wetlands have to cope with on a daily basis are often characterized by the intrinsic and

*Corresponding author. Email: alessandro.carletti@jrc.it

Chemistry and Ecology
ISSN 0275-7540 print/ISSN 1029-0370 online © 2006 Taylor & Francis
http://www.tandf.co.uk/journals
DOI: 10.1080/02757540600572578

remarkable complexity of environments of great ecological, naturalistic, and recreational value, and as a consequence, a large variety of data needs to be gathered to carry out a comprehensive quantitative appraisal of different management alternatives. In order to guarantee the transparency of the decision-making process, great effort must be dedicated to the development of a simple, cost-effective, integrated assessment method, aimed at formulating an initial, basic judgement on the vulnerability and ecological integrity of wetland systems.

After the publication of the US Clean Water Act [1], a series of plans concerning the appraisal of the ecological functionality of wetlands have been launched in the United States; some of them have become prominent for their innovativeness, simplicity, and cost-effectiveness, and have been referred to in the literature as Rapid Assessment Methods (RAM). In Carletti *et al.* [2], we carried out a detailed comparative analysis of 17 of the most representative methods developed for coastal lagoons in North America. This analysis shows that time, simplicity, and costs of assessment are indeed crucial elements to foster a systematic and extensive application of any assessment procedure; methodologies that provide a screening evaluation on the basis of simple data sheet that can be completed with the minimum (often less than one day) of field-survey time are usually preferred to more detailed, scientifically rigorous but also time-consuming and expensive appraisal systems. Moreover, Carletti *et al.* [2] pinpoint that the possibility of using also non-expert personnel to retrieve information, such as volunteers with basic training, as well as simple, clear-cut procedures that do not require long-term or costly fieldwork or laboratory analyses are also important key factors for a successful extensive assessment of wetland status.

Until now, no rapid assessment method has been developed and/or applied in the Mediterranean context where the classification approach inspired by early work by Cowardin [3] has been largely prevalent. On the other hand, the European Water Framework Directive (WFD 2000/60/EC) firmly promotes an integrated approach to the management of all water bodies – including inland surface waters, ground waters, transitional, and coastal waters – in order to prevent their impairment and introduces the concept of (Good) Ecological Quality Status as a target to be achieved by 2015.

On the basis of the structure of the North American RAMs analysed in Carletti *et al.* [2], we have developed a first Rapid Assessment Method specifically dedicated to Mediterranean coastal lagoons. Our method is based on the construction of an integrated Environmental Sustainability Index (ESI) that allows for a preliminary assessment of the overall ecological conditions of a wetland and of the sustainability of economic activities occurring in the nearby catchment area.

We show that the information needed to compute ESI can be easily gathered in the field and only requires a basic knowledge of the many features of the wetland areas in terms of morphology, hydrology, adjacent land uses, human activities affecting lagoons and surrounding areas, pollutant loads, etc.

As for other integrated indices of sustainability, such as the Dashboard of Sustainability (http://esl.jrc.it/envind/dashbrds.htm) and the Ecological Footprint Analysis [4], we claim that the most effective use of ESI is in terms of comparative benchmarking of the sustainability performances of different wetland areas. In order to show this, we have derived ESI for a set of 17 Italian coastal lagoons of the LaguNet network [5], and we have ranked the sites according to their ESI so as to identify those lagoons whose environmental conditions are more compromised and require urgent intervention, as well as those lagoons characterized by a satisfactory balance between human activities and the conservation of ecology integrity.

As the relative importance of the three macro-descriptors used to compute ESI in terms of Anthropogenic Impact, Ecological Functionality, and Habitat status and diversity is affected by some degree on subjectivity, we have also carried out a sensitivity analysis of the ESI ranking through a Monte Carlo approach to explicitly include uncertainty in parameter estimations.

We show that the use of simple randomization tests performed on the results of the Monte Carlo analysis [6] allows us to evaluate the robustness of the ranking and to identify statistically significant differences in the environmental performances of the lagoons under study.

The paper is organized as follows: in section 1, we define the ESI and how it is computed; in section 2, we compute ESI for 17 Italian lagoons; then, in section 3, we perform a sensitivity analysis of ranking based on a Monte Carlo approach. Finally, in section 4, we discuss the results and the limits of our methodology.

2. Material and methods

2.1 *Definition of the environmental sustainability index*

The Rapid Assessment Method presented in this work is based on the computation of an Environmental Sustainability Index (ESI) that allows a preliminary judgement to be formulated on the environmental quality of coastal lagoons as a function of simple information that can be collected through on-site inspections, cartographic analyses, and good basic knowledge of land uses and ecological features of the study areas. All this information is generally available without the necessity for long, expensive monitoring campaigns and analyses. ESI is computed as a normalized weighted sum of three sub-indices (macro-descriptors): the Anthropic Impact Index (AII), the Ecological Functionality Index (EFI), and the Habitat Availability Index (HAI), as illustrated in figure 1. Each of the sub-indices is defined on a arbitrary scale between 0 and 1, where 0 denotes poor ecological or environmental conditions, while 1 denotes the best condition with reference to that specific index. The three macro-descriptors are described in detailed below.

2.1.1 Anthropic Impact Index – AII. The Anthropic Impact Index (AII) is aimed at quantifying the level of anthropogenic pressure occurring in the wetland area. AII is computed in turn as the weighted sum of two further sub-indices (figure 2), a Nutrient Load Index, to account for organic load in the lagoon, and a Naturalness Index, to account for all other disturbance factors, such as noise, land use, water contamination, etc., as described in the following.

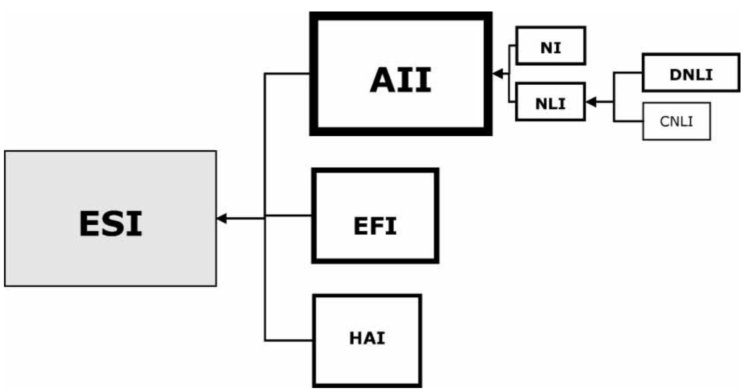

Figure 1. Structure of the ES Index: AII denotes Anthropogenic Impact Index, EFI for Ecological Functionality Index, HAI for Habitat Availability Index, NI for Naturalness Index, NLI for Nutrient Load Index, and DNLI and CNLI for Distributed and Concentrated Nutrient Load Index, respectively. See text for explanation.

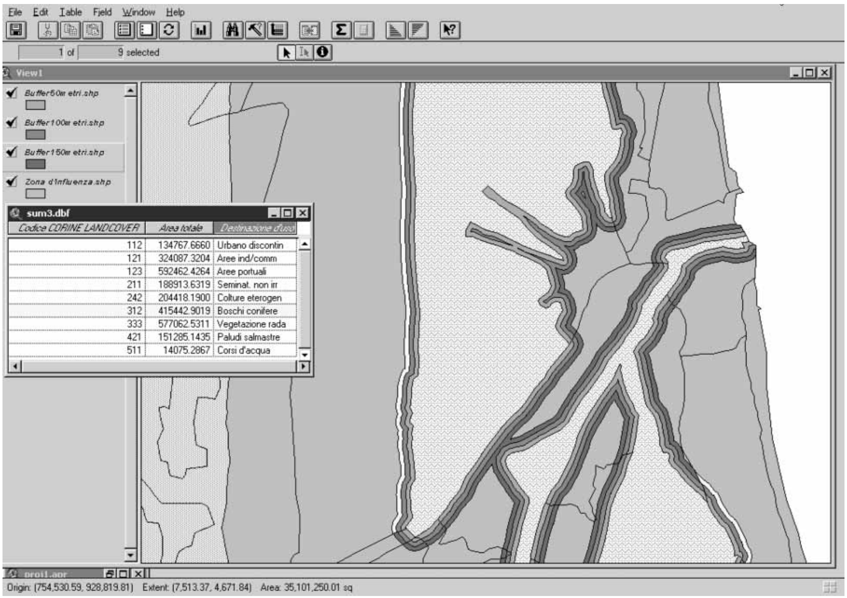

Figure 2. GIS application for NLI calculation in Piallassa Baiona.

2.1.2 Naturalness Index – NI. The Naturalness Index (NI) is a qualitative index inversely related to the importance of anthropogenic pressures due to economic and recreational activities in a 2 km area of influence around the lagoon; its estimation is carried out by answering a simple field questionnaire (see Appendices) in which a score, defined on a arbitrary scale between 0 and 1, is associated with each question to characterize the level of wilderness and the intensity of the disturbance or the impacts caused by various human activities (such as agricultural, industrial, extractive or recreational activities, evidence of dystrophic crisis, and documented contaminant effects).

2.1.3 Nutrient Load Index – NLI. The Nutrient Load Index (NLI) provides an estimation of the importance of the nutrient load in the lagoon. NLI is computed by accounting for diffuse load and for concentrated (point-source) load in lagoon inlets. The concentrated nutrient load index (CNLI) is defined on a qualitative scale on the basis of the estimation of DIN and DIP loads (dissolved inorganic N and P, respectively) per area unit on the coastal lagoon: quality scores have then been assigned according to the DIN and DIP ranges as described in table 1. The final score for point-source load is computed as a simple arithmetic average of DIN and DIP scores.

The importance of diffuse load is indirectly estimated through proxy indicators of land use, that is in terms of the presence of activities, such as intensive agriculture, that can potentially

Table 1. Quality classes for DIN and DIP parameters.

DIN (mmol m^{-2} d^{-1})	Score	DIP (mmol m^{-2} d^{-1})	Score
<0.1	3	<0.05	3
0.1–1	2	0.05–0.1	2
1–5	1	0.1–0.5	1
>5	0	>0.5	0

cause important diffuse loads of organic nutrient in the lagoon. It is computed by means of a survey of land use typologies corresponding to Corine Land cover classes [7] in a 2 km area of influence around the lagoon. In fact, as in other North American RAMs [2], we have assumed that the organic pollution occurring in the catchment area, but outside the 2 km belt, can possibly reach the lagoon only through surface water bodies or sewage pipelines whose organic load is already accounted for in CNLI from point-sources. As a consequence, only the activities occurring in the 2 km belt around the lagoon are assumed to potentially contribute to diffuse load. This is of course an approximation that is considered acceptable anyway in the development of RAMs to keep the assessment as simple and as rapid as possible [2].

To provide an estimation of diffuse load, a Land Use Score (LUS), derived from literature [8–10] and corrected on the basis of personal considerations of the authors, has been associated with each land-use typology; the lower the score (*i.e.* environmental quality), defined on an arbitrary scale between 0 and 1, the higher the importance of diffuse organic discharge. The overall importance of diffuse nutrient load for the area of influence around the lagoon is thus computed as the weighed average of the land-use scores, where the weights are given by the ratio between the area A_i covered by each land use typology i and the total surface area of the 2 km belt around the lagoon:

$$\mathrm{DNLI} = \frac{\sum_{i=1}^{n} A_i * \mathrm{LUS}_i}{\sum A_i}.$$

The overall Nutrient Load Index, NLI, is then computed as a weighted sum of the concentrated (CNLI) and diffuse load (DNLI). As CNLI is derived throughout direct, quantitative measures of DIN and DIP, and refers to the actual pollution from point-sources, while DNLI is indirectly estimated through proxy-indicators of land use and refers to the potential diffuse load, we have decided to weight the former twice as much as the latter. As a consequence:

$$\mathrm{NLI} = 2\mathrm{CNLI} + \mathrm{DNLI},$$

and the sum is then normalized to 1.

Finally, the AII is then expressed as a normalized sum of the NI and the NLI scores.

2.1.4 Ecological Functionality Index – EFI. The Ecological Functionality Index (EFI) provides an indication of the importance and consistency of the functions and services that lagoon ecosystems carry out, such as flood protection, water-quality regeneration, habitat and species conservations, erosion prevention, recreation features, and fish and shellfish farming. For the estimation of EFI, it is necessary to obtain answers to a set of multiple-choice questions: a score ranging from 0 to 1, where 0 represents the lowest quality level and 1 the highest is associated with each answer, and the overall score is calculated as the average score of all questions.

2.1.5 Habitat Availability Index – HAI. The Habitat Availability Index (HAI) is a measure of habitat heterogeneity and integrity, based on features such as substrate material, plant biodiversity, food availability, etc. This index has been derived and modificated from a similar index developed by the Massachusetts Office of Coastal Zones Management [11], and by the Florida Department of Environmental Resources [12]. Also, in this case, it is necessary to answer a questionnaire, articulated in two parts, the first focused on the zone of influence (surrounding area) the other centred on the assessment of habitat quality in the wetland site, as shown in table 2 (see also Appendices for the complete form).

Table 2. Part of a data sheet for landscape assessment, used to compute the Natural Index (NI) (the full form is reported in the Appendix).

Indicator	Options	Score
Part 1: Landscape (surrounding area, 2000 m)		
Dominant land use	Forest, open land	3
	Low density residential	2
	Medium-high-density residential	1
	Industrial, commercial, transports	0
Waterproofed surface percentage	<5%	3
	5–10%	2
	11–20%	1
	>20%	0
Natural vegetation percentage	>50%	3
	30–50%	2
	10–29%	1
	<10%	0
Wetland area/drainage basin area ratio	>10%	3
	6–10%	2
	2–5%	1
	<2%	0
Main pollution sources	No identifiable source	3
	Sewage sludge	2
	Fertilizers/pesticides from agriculture activities	1
	Commercial/industrial waste, urban sewage	0

A score between 0 and 3 is associated with each answer. An average score is computed for each of the two sections, and then, the final Habitat Availability Index is computed as the average of the scores of each section.

2.1.6 Computation of the Environmental Status Index – ESI. The value of the Environmental Status Index (ESI) is then computed as the weighted sum of the three macro-descriptors, with weights equal to $w_1 = 5$, $w_2 = 3$ and $w_3 = 2$ for AII, EFI, and HAI, respectively, namely:

$$\mathrm{ESI} = w_1\mathrm{AII} + w_2\mathrm{EFI} + w_3\mathrm{HAI}.$$

In fact, according to a series of experiences and case studies developed by the Med Wet programme [13], we have assumed that the level of anthropogenic disturbance represented by AII exerts the most important role in the determination of our Environmental Sustainability Index, as it pushes coastal ecosystems away from whatever is their natural status. A sensitivity analysis will be carried out, as shown in the following sections, so as to assess the sensitivity of the results to change and/or errors in the determination of the weight structure used to sum up the three macro-descriptors.

2.2 *ESI application to 17 representative Italian coastal lagoons*

The RAM method derived here has been applied to evaluate the ESI index for 17 coastal transitional systems located along Italian coastline (figure 3). These lagoons are site studies of

Figure 3. Seventeen Italian coastal lagoons where the ES Index was computed.

the 'LaguNet' ecological research network [5] aimed at building up a system of competences about Mediterranean transitional ecosystems with particular attention on the application of LOICZ biogeochemical model [14].

LaguNet coastal sites are quite heterogeneous for morphological and biochemical features and land-use vocations, in terms of fish and shellfish farming, tourism, recreational/naturalistic activities, and so on. Many are subjected to some restriction and conservation attempts, others are located in heavily urbanized areas, and only a few are scarcely influenced by human activities. For all these reasons, wetlands considered in the LaguNet network can thus be considered an ideal set of lagoons to test the application of our Rapid Assessment Method, for their wide representativeness and the possibility of controlling for the ESI results.

2.3 *Data sources*

Bibliographic data, cartographic data, and direct field observations have been used as the source of information to compute ESI, as described hereafter.

2.3.1 Bibliographical data. Descriptive data for site characterization have been gathered from the documentation available in the LaguNet network; other important sources of information have been documents and publications, such as a 'Wetland Environmental Status Report', produced in the project 'Integrated Management of Wetlands' [15] and grey literature from local administrations (regions, provinces, municipalities), consortia for fishery management, etc.

2.3.2 Cartographical data. We have utilized digital maps containing land-use coverage (Corine Landcover), and Technical Regional Maps, for quantifying the anthropogenic impact in the zones of influence; in some cases, when available, information has been integrated using digital orthophotos and satellite images (ASTER) downloaded from the web.

2.3.3 Data from direct observation. A comprehensive inspection has been carried out in one of the considered sites (Sacca di Goro) so as to verify the correspondence of the information gathered from different sources through direct observation. A remarkable correspondence has been found between field data and bibliographical/cartographical data. In particular, there is a total agreement between typological and morphological description provided in the LaguNet Information Sheet [16] and the information gathered onsite. The same level of correspondence has been observed also between the biological descriptors provided in the Po River Delta Report [15] and those derived from field surveys.

2.3.4 Sensitivity analysis using the Monte Carlo method. As usually happens when a multi-criteria analysis is applied, the final rank of the coastal lagoons, derived on the basis of the ESI index, obviously depends on the actual value of the weights used in equation (3) to sum up the three macro-indices AII, EFI, and HAI: in fact, it is possible that even small variations in just one weight can produce a rank reversal, that is a change in the position achieved by two or more lagoons in the overall rank. On the other hand, the relative importance of the three macro-descriptors, as expressed by their weights, although derived on the basis of a series of experiences and case studies developed by the Med Wet programme [13], is affected by some level of uncertainty and/or subjectivity. As a consequence, it is crucial to analyse if and how ranking changes when slightly different weight are chosen to aggregate the assessment criteria to compute the final score. We have thus performed a sensitivity analysis of the final ranking of the 17 considered lagoons with respect to changes in the weighted used to compute ESI with equation (7).

The sensitivity analysis has been carried out by using a Monte Carlo method [17], as described hereafter:

(1) for each assessment criteria (AII, EFI, and HAI), a reasonable range of variation of the corresponding weight ($w^{\min};_i\, w^{\max};_i\, i = 1, 2, 3$) has been defined, as shown in table 3;
(2) for every weight, we have defined a truncated beta probability distribution function ranging between $w^{\min};_i$ and $w^{\max};_i$ and with expected value $w;^{-}{}_i$ as in equation (4);
(3) we then draw a random value $\hat{w;}_i$ from the beta function of every weight w_i;
(4) the set of three weights $\hat{w;}_i$ drawn from their respective beta distribution has been used to compute a new value of the ESI index for all the lagoons, and the corresponding rank has been derived;

Table 3. Weights with ranges of variation used to sum up the three sub-indices to compute ESI.

Index	Mean weight	Range of variation	Distribution
AII	5	4–7	beta (1.5, 3.0)
EFI	3	2–4	beta (1.5, 1.5)
HAI	2	1–3	beta (1.5, 1.5)

Note: The beta distribution has been used in the Monte Carlo sensitivity analysis, as explained in the text.

(5) we replicated steps (3) and (4) 10 000 times;
(6) we used the 10 000 replicates to derive a number of statistics on ESI and the position in the rank assumed by each lagoon, as described in the following section.

2.3.5 Comparison with the California RAM. It is interesting to assess whether the ranking provided by our ESI index is similar to, or different from, that obtained by using other Rapid Assessment Methods derived in North America. We have thus applied the California RAM [18] to our set of 17 lagoons. California RAM (CRAM), developed by the San Francisco Bay Area Wetland Monitoring Program, is based on 13 environmental indexes and incorporates concepts and methods of other existing procedures, such as the Ohio Rapid Assessment Method [19], the HGM approach [20] and the Washington State Wetland Rating System [21]. As a consequence, it can be considered quite representative of other North American methods. According to CRAM, a score ranging from A (best performance) to D (worst) is derived for each of the 13 indexes. We have then transformed the qualitative judgment in a cardinal system by assigning three points to score A, two to B, one to C, and zero to D, and we have thus computed the aggregated score for each lagoon as the sum of the scores corresponding to the 13 indexes. The final value has again been converted into quantitative classes by assigning to

Table 4. Values of the three sub-indices and of ESI for the 17 Italian lagoons of the LaguNet Network.

Lagoon	Code	Rank	AII	EFI	HAI	Mean ESI	Min	Max	Range
Marinello	A1	1	0.98	0.86	0.76	9.0 ± 0.009	0.877	0.927	0.049
Torre Guaceto	A4	2	0.94	0.73	0.81	8.5 ± 0.020	0.708	0.836	0.127
Alimini	A3	3	0.85	0.86	0.77	8.4 ± 0.004	0.830	0.850	0.020
Aquatina di Frigole	A5	4	1.00	0.62	0.67	8.2 ± 0.008	0.830	0.879	0.049
Stagnone Marsala	A6	5	0.86	0.85	0.61	8.1 ± 0.016	0.776	0.881	0.104
Goro	A2	6	0.93	0.53	0.64	7.8 ± 0.010	0.778	0.833	0.055
Capo feto	A11	7	0.85	0.55	0.81	7.5 ± 0.013	0.697	0.776	0.078
Lesina	A9	8	0.56	1.00	1.00	7.5 ± 0.007	0.670	0.712	0.042
Lagune Pontine	A13	9	0.81	0.53	0.88	7.4 ± 0.016	0.706	0.806	0.100
Varano	A7	10	0.79	0.69	0.70	7.4 ± 0.012	0.697	0.771	0.073
Comacchio	A10	11	0.85	0.64	0.56	7.3 ± 0.012	0.717	0.787	0.070
S'ena Arrubia	A12	12	0.65	0.79	0.77	7.2 ± 0.006	0.693	0.733	0.040
Orbetello	A8	13	0.69	0.61	0.81	6.9 ± 0.004	0.730	0.758	0.028
Venezia	A14	14	0.56	0.75	0.65	6.3 ± 0.007	0.608	0.650	0.042
Capo Peloro	A15	15	0.69	0.49	0.59	6.1 ± 0.007	0.589	0.632	0.043
Baiona	A17	16	0.52	0.48	0.24	4.6 ± 0.011	0.422	0.482	0.059
Rada di Augusta	A16	17	0.41	0.47	0.56	4.5 ± 0.006	0.444	0.475	0.031

Note: Basic statistics on ESI have been computed on the basis of the 10 000 Monte Carlo replicates. Lagoons are ranked according to decreasing value of ESI.

Table 5. Matrix of the significance of the differences between the *ESI* values of any two lagoons.

A_i	A_j $A_i > A_j$	Laghetti Marinello A1	Sacca di Goro A2	Laghi Alimini A3	Torre Guaceto A4	Aquatina di Frigole A5	Stagnone Marsala A6	Lago di Varano A7	Laguna di Orbetello A8	Laguna di Lesina A9	Valli di Comacchio A10	Capo Feto A11	S'ena Arrubia A12	Lagune Pontine A13	Laguna di Venezia A14	Capo Peloro A15	Rada Di Augusta A16	Piallassa Baiona A17
Laghetti Marinello	A1	–	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
Sacca di Goro	A2	0.000	–	0.000	0.001	0.130	0.173	***0.913***	**1.000**	0.805	***0.938***	0.804	**1.000**	***0.932***	**1.000**	**1.000**	**1.000**	**1.000**
Laghi Alimini	A3	0.000	**1.000**	–	0.138	0.887	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Torre Guaceto	A4	0.000	**0.999**	0.862	–	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
Aquatina di Frigole	A5	0.000	0.870	0.113	0.000	–	0.823	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
StagnoneMarsala	A6	0.000	0.827	0.000	0.000	0.177	–	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
Lago di Varano	A7	0.000	0.087	0.000	0.000	0.000	0.000	–	**1.000**	0.298	0.728	0.000	***0.931***	0.460	**1.000**	**1.000**	**1.000**	**1.000**
Laguna di Orbetello	A8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	–	0.000	0.001	0.000	0.001	0.000	**1.000**	**1.000**	**1.000**	**1.000**
Laguna di Lesina	A9	0.000	0.195	0.000	0.000	0.000	0.000	0.702	**1.000**	–	**0.996**	0.295	***0.938***	0.702	**1.000**	**1.000**	**1.000**	**1.000**
Valli di Comacchio	A10	0.000	0.062	0.000	0.000	0.000	0.000	0.272	**1.000**	0.004	–	0.018	0.775	0.058	**1.000**	**1.000**	**1.000**	**1.000**
Capo Feto	A11	0.000	0.196	0.000	0.000	0.000	0.000	**1.000**	**1.000**	0.705	**0.982**	–	**0.997**	0.899	**1.000**	**1.000**	**1.000**	**1.000**
S'ena Arrubia	A12	0.000	0.000	0.000	0.000	0.000	0.000	0.069	**1.000**	0.062	0.225	0.003	–	0.001	**1.000**	**1.000**	**1.000**	**1.000**
Lagune Pontine	A13	0.000	0.068	0.000	0.000	0.000	0.000	0.540	**1.000**	0.299	***0.943***	0.101	**0.999**	–	**1.000**	**1.000**	**1.000**	**1.000**
Laguna di Venezia	A14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	–	***0.941***	**1.000**	**1.000**
Capo Peloro	A15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.059	–	**1.000**	**1.000**
Rada Di Augusta	A16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	–	0.326
Piallassa Baiona	A17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.674	–

Note: Each cell reports that the fraction of times lagoon A_i (listed in the rows) has an *ESI* score higher than lagoon A_j (listed in the columns) as resulting from the 10 000 Monte Carlo replicates. Figures exceeding 95% are shown in bold, and those exceeding 90% in bold and italic.

Table 6. Final ranking of the 17 coastal lagoons in five quality classes.

Class	Lagoon	Code	ESI	Non-significant difference	Weak significance	Strong significance
A (≥9)	Laghetti Marinello	A1	9.0			
	Torre Guaceto	A4	8.5	A4 ∼ A3		>> than all the remaining lagoons
B (≥8 and <9)	Laghi Alimini	A3	8.4	A3 ∼ A4, A5		>> than all the remaining lagoons
	Aquatina di Frigole	A5	8.2	A5 ∼ A3, A6		>> than all the remaining lagoons
	Stagnone Marsala	A6	8.1	A6 ∼ A5, A2		>> than all the remaining lagoons
C (≥7 and <8)	Sacca di Goro	A2	7.8	A2 ∼ A6, A11, A9	A2 > A13, A7, A10	>> than all the remaining lagoons
	Capo Feto	A11	7.5	A11 ∼ A2, A9, A13		>> than all the remaining lagoons
	Laguna di Lesina	A9	7.5	A9 ∼ A11, A13, A7	A9 > A12	>> than all the remaining lagoons
	Lagune Pontine	A13	7.4	A13 ∼ A9, A7	A13 > A10	>> than all the remaining lagoons
	Lago di Varano	A7	7.4	A7 ∼ A13, A10	A7 > A12	>> than all the remaining lagoons
	Valli di Comacchio	A10	7.3	A10 ∼ A7, A12		>> than all the remaining lagoons
	S'Ena Arrubia	A12	7.2	A12 ∼ A10		>> than all the remaining lagoons
D (≥6 and <7)	Laguna di Orbetello	A8	6.9			>> than all the remaining lagoons
	Laguna di Venezia	A14	6.3		A14 > A15	>> than all the remaining lagoons
	Capo Peloro	A15	6.1			>> than all the remaining lagoons
E (5–6)	–	–	–	–	–	–
F (<5)	Piallassa Baiona	A17	4.6	A17 ∼ A16		>> than all the remaining lagoons
	Rada di Augusta	A16	4.5	A16 ∼ A17		>> than all the remaining lagoons

Note: The notation '$Ai \sim Aj$' means that the lagoon Ai is not significantly better than Aj; '$Ai > Aj$' means that the lagoon Ai is weakly better than Aj (significance level $\alpha = 10\%$); '$Ai >> Aj$' means that the lagoon Ai is significantly better than Aj (significance level $\alpha = 5\%$). Statistics are computed on the 10 000 bootstrap *ESI* replicates, as explained in the text. A graph pivoted on a specific lagoon identifies a sub-group of lagoons with similar *ESI*. None of the lagoons scored from 5 to 5.9, so class E is empty.

class A lagoons whose final CRAM score is equal or larger than 30, B between 25 and 30, C between 20 and 25, D between 15 and 20, E between 10 and 15, and F smaller than 10. The final ranking has thus been confronted with that of ESI.

3. Results

The mean value of ESI along with main statistics on range of variation and standard deviation derived from the 10 000 Monte Carlo replicates for 17 coastal sites of LaguNet network are reported in table 4. The corresponding ranking is also shown in the same table.

In order to assess whether even small differences in ESI are significant or not, the 10 000 Monte Carlo replicates have been used to test whether a lagoon achieves a position in the ranking (or, equivalently, an ESI value) significantly higher (or lower) than the position achieved by each of the other sites (significance level $\alpha = 5\%$). Results of the randomization test are shown in table 5.

We have then used this information to groups lagoons in classes in which environmental performances, as measured by ESI, are significantly better (or worse) than in the following (or previous) class. Within a class, lagoons are characterized by ESI values which are not significantly different among each others. The final corresponding ranking is reported in table 6 in six quality classes according to the ESI value attained by the lagoons and the corresponding significance of the difference.

In table 7, we report the ranking obtained with the California RAM and compare it with that derived by using ESI. For seven lagoons out of 17, the classification provided by the two indices is just the same (that is, a lagoon obtains the same judgement regardless of the method used); for eight lagoons, there is a difference of one class; for two of them – that is Laghi Marinello and Piallassa Baiona – there is a difference of two or more classes.

Table 7. Comparison between CRAM classification and that obtained by using ESI.

	CRAM		ESI		
	Rank	Class	Rank	Class	Class difference
Alimini	1	B	3	B	0
Torre Guaceto	2	B	2	B	0
Stagnone Marsala	3	B	5	B	0
Varano	4	B	10	C	+1
Lagune Pontine	5	C	9	C	0
Orbetello	6	C	13	D	+1
Goro	7	C	6	C	0
Aquatina di Frigole	8	C	4	B	−1
Comacchio	9	C	11	C	0
Venezia	10	C	14	D	+1
Capo Feto	11	D	7	C	−1
S’Ena Arrubia	12	D	12	C	−1
Marinello	13	D	1	A	−3
Lesina	14	D	8	C	−1
Baiona	15	D	16	F	+2
Capo Peloro	16	E	15	D	−1
Rada di Augusta	17	F	17	F	0

Note: In the last column, we report how many classes CRAM classification is above (if positive) or below (if negative) than the ESI classification.

4. Discussion and conclusions

The methodology presented here has allowed us to summarize a great deal of information to derive an aggregated index of sustainability that has been then used to perform a comparative benchmarking of sites that are quite different from each others for their morphologic features and land-use vocations. At the top of the ranking there are lagoons such as Laghetti Marinello (a small littoral area located in the Patti Gulf (Messina, Italy) that currently includes five little deep ponds), Torre Guaceto (a Nature Reserve characterized by a salt marsh area), and Alimini (a complex ecosystem composed by a salt-marsh, Lake Alimini Grande, connected with a freshwater lake, the Alimini Piccolo, through a natural canal 1.5 km long). These systems could realistically become part of a reference lagoon network for the characterization of the optimal conditions as required in the Water Framework directive (WFD 2000/60/CE).

On the contrary, the bottom of the list is occupied by wetlands such as Rada di Augusta, Pialassa Baiona, and Capo Peloro, which are characterized by high anthropogenic pressures that impair their ecological functionality and resilience. It is worth noting that high ranking lagoons do not necessarily correspond to protected areas.

As illustrated in table 6, the randomization test on the significance of the difference – performed on the 10 000 Monte Carlo replicates (table 5) – shows that Laghetti Marinello always ranks at the top of the list, followed by a group of four lagoons (Torre Guaceto, Alimini, Aquatina di Frigole, and Stagnone Marsala) with quite similar ESI scores. The two lagoons with the worst ESI performance are always Rada di Augusta and Piallassa Baiona, even though, in this case, none of the two prevails significantly on the other. Thanks to the Monte Carlo analysis, it is thus possible to group lagoons in five classes of decreasing environmental quality. Even though some of the differences between ESI values within the same class may be statistically significant, wetland areas belonging to the same class are characterized by similar sustainability indices.

Consequently, our analysis has shown that the ranking derived through the Monte Carlo sensitivity analysis to explicitly include the uncertainty in the determination of ESI weighting structure certainly provides a much more significant picture than that one would obtain by using only a given set of weights and offers a quantitative guidance to group reference sites according to their environmental sustainability performances.

With reference to the US experience, our method has been developed in consideration of the peculiar features of a set of Mediterranean lagoons, and consequently, it differs from North American methods for the number and type of information required to compute, in particular, the anthropogenic index AII. This is clearly evidenced by the difference in the final classification of Laghetti Marinello and Piallassa Baiona provided by the California RAM with respect to ESI. The two lagoons are both in class D according to CRAM. On the contrary, they are respectively at the top (class A) and the bottom (class F) of the ESI ranking. This five-class difference between the two lagoons is explained by the sensitivity of ESI to anthropogenic pressures which are considerable in Piallassa Baiona (notwithstanding its naturalistic and biodiversity values) but almost negligible in Laghetti Marinello. The same applies also for other heavily impacted sites, such as Laguna di Orbetello and Laguna di Venezia, and a fairly pristine environment, such as Aquatina di Frigole: these three lagoons all belong to the same quality classes C according to CRAM, while, according to ESI, there is a two-class difference between Aquatina di Frigole (B) and Orbetello and Venezia (D). The difference between ESI and CRAM is due to the fact that CRAM bases its judgement on comprehensive ecological and environmental criteria such as connectivity, buffer zone, hydrodynamic, morphology, and biotic community structure but does not account in detail for the presence of factors of potential anthropogenic disturbance (except for a generic stressor checklist). This may not be relevant for the North American context, where there is a substantial number of well-conserved sites, while it is important for the Mediterranean area, where almost every coastal transitional site is the result of decades of exploitation, pollution, and land-use alteration and reclamation. In this sense, the North American rapid assessment methods can be considered more oriented to assess the ecology integrity of wetland, while our RAM provides a glimpse also of the environmental sustainability as it explicitly accounts for anthropogenic pressures. This does not mean that ESI can be used to derive estimates of long-term fate of coastal lagoons or of the actual impact of human activities. As for other aggregated indices of sustainability, such as the Dashboard of Sustainability and the Ecological Footprint, ESI simply provides a snapshot of the balance among wilderness (status), functions, and anthropogenic pressures.

From the North American Rapid Assessment Methods, our procedure has inherited the simplicity of implementation that allows for a preliminary assessment of the environmental sustainability of coastal transitional ecosystems with reasonable times and costs and technical requirements that do not necessarily need the involvement of a large panel of experts with a long history of work in the field. Personnel typically working in environmental protection agencies and having some knowledge of monitoring and land-use data treatment can easily fill up the questionnaire after a short specific training in the subject.

As shown in the application to the 17 Italian lagoons, rather than providing an absolute assessment of environmental quality, the methodology presented here is useful to perform a comparative benchmarking of the environmental performances of a number of studied sites; in this sense, our method can provide extra information to help decision-makers to identify a network of reference wetlands or to define a priority list of intervention – in the case of limited budget – for the recovery of ecological integrity of wetland areas. Moreover, if historical data are available, ESI can also be used to identify trend of variations through time of the sustainability performances of a specific coastal lagoon, so as to outline whether the overall conditions are improving or worsening under current management practices.

The application of this methodology to 17 Italian lagoons has allowed us to verify that ESI index can be really computed in no more than 2–5 d of work for each site to retrieve the necessary information to complete the questionnaires. The level of precision can be improved whenever GIS applications, land-use maps, or field campaigns are available, for instance to estimate of the distributed nutrient load. In this sense, the methodology presented in this work should be regarded as a truly rapid and cost-effective way to derive a first preliminary assessment of wetland environmental performance.

On the other hand, it is obvious that this preliminary evaluation cannot be considered definitive per se, but it then needs to be complemented, as clearly illustrated in the Coastal Wetland Ecosystem Protection Project of the Massachusetts Office of Coastal Zones Management [11] by more detailed field and laboratory analyses and modelling work that will be carried out if and when more time and economic and human resources are made available to increase the accuracy and robustness of the first screening appraisal [2].

Despite the typical limitations of any Rapid Assessment methodology, our method provides a simple but formal way to use a great deal of information that is usually available for a wetland site, at least at the qualitative level, but that could not be used in a more rigorous assessment because of the lack of detailed, quantitative field of laboratory analyses that are usually much more expensive and time-consuming to gather. On the other hand, the procedure here illustrated to compute the Environmental Sustainability Index, by explicitly acknowledging the multifaceted aspects of wetland sustainability assessment, allows us to increase the transparency of the decision-making process and to overcome the problem of purely subjective evaluations by avoiding decisions based on non-formalized and implicit considerations in terms of economic convenience, past experience, personal feeling, pure guess, and rule of thumb.

We are thus confident that our ESI index, complemented by the Monte Carlo sensitivity analysis to explicitly include uncertainty in the weighting structure, is indeed useful to carry out a draft screening of Mediterranean coastal lagoons with the explicit aim to reach a preliminary integrated assessment of the level of anthropogenic pressures and of the ecological functions and services of these transitional systems.

References

[1] The Clean Water Act (CWA). 33 U.S.C. ss/1251 et seq. (1977).

[2] A. Carletti, G.A. De Leo, I. Ferrari. A critical review of representative wetland rapid assessment methods in North America. In *Aquatic Conservation: Marine and Freshwater Ecosystems*, Vol. 14, Issue S1, pp. S103–S113, Wiley, Chichester, UK (2004).

[3] L.M. Cowardin, V. Carter, F.C. Golet, E.T. LaRoe. *Classification of Wetlands and Deepwater Habitats of the United States*, US Department of the Interior, Fish and Wildlife Service, Washington, DC. Northern Prairie Wildlife Research Center Home Page, Jamestown, ND (1979).

[4] M. Wackernagel, W. Rees. *Our Ecological Footprint: Reducing Human Impact on the Earth*. New Society, Gabriola Island, BC (1996).

[5] P. Viaroli, G. Giordani, C.N. Murray, J.M. Zaldivar. LaguNet: Italian Lagoon Observational Network, Proceedings of the First Italian IGBP Conference 'Mediterraneo e Italia nel Cambiamento Globale: un ponte fra scienza e società' Paestum (Salerno) 14–16 November 2002 (2002).

[6] E.S. Edgington. *Randomization Tests*, 2nd ed., Dekker, New York (1987).

[7] EC. CORINE Land Cover Technical Guide, Report EUR 12585EN, Office for Publications of the European Communities, Luxembourg (1993).

[8] R.R. Horner. Water quality criteria/pollutant loading estimation/treatment effectiveness estimation. In *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*, R.R. Horner *et al.* Washington, DC: Terrene Institute and US Environmental Protection Agency (1992).

[9] W.M. Marsh. *Landscape Planning: Environmental Applications*, 3rd ed., New York, Wiley (1998).

[10] US EPA. *Methods for Evaluating Wetland Condition: Land-Use Characterization for Nutrient and Sediment Risk Assessment*, Office of Water, US Environmental Protection Agency, Washington, DC (2002).

[11] Massachusetts Office of Coastal Zone Management. Coastal Wetland Ecosystem Protection Project. Available online at: http://www.state.ma.us/czm/wacwepp.htm (accessed 10 January 2004).

[12] Florida Department of Environmental Protection. *Standard Operating Procedures for Biological Assessment*. Biological Section, Division of Administration and Technical Services, Department of Environmental Protection, Florida (1996).

[13] P.T. Vives. *Monitoring Mediterranean Wetlands: A Methodological Guide, MedWet Publication*, Wetlands International, Slimbridge, UK and ICN, Lisbon (1996).

[14] G. Giordani, P. Viaroli. Modello biogeochimico loicz, breve descrizione tecnica. Trasporto dei nutrienti negli ambienti acquatici di transizione lungo le coste italiane: valutazione dei flussi e delle funzioni dell'ecosistema. Available online at: http://www.dsa.unipr.it/lagunet/documenti/brevedescrizione.pdf (accessed 13 February 2004).

[15] Regione Emilia-Romagna, Assessorato Territorio, Programmazione e Ambiente. 'Integrated Management of wetlands – Gestione Integrata di zone umide', Bologna – Italy, May 1998 (1998).

[16] P. Viaroli, G. Giordani, E. Cattaneo, J.M. Zaldívar, C.N. Murray, E.A. Fano, G. Castaldelli, S. Bencivelli Sacca di Goro Lagoon – Italy. Available online at: http://www.dsa.unipr.it/lagunet/infosheet/02-goro.pdf (accessed 13 February 2006).

[17] F.V. Jensen. *Bayesian Networks and Decision Graphs*, Springer, New York (2001).

[18] J.N. Collins, E. Stein, M. Sutula. DRAFT California Rapid Assessment Method (CRAM) for Wetlands, v 3.0 User's Manual and Scoring Forms, http://www.wrmp.org/docs/cram/draft_cramv3.pdf (accessed 13 February 2006).

[19] J.J. Mack. *Ohio Rapid Assessment Method for Wetlands, Manual for Using Version 5.0. Ohio EPA Technical Bulletin Wetland/2001-1-1*. Ohio Environmental Protection Agency, Division of Surface Water, 401 Wetland Ecology Unit, Columbus, OH (2001).

[20] M. Brinson. A hydrogeomorphic classification for wetlands. Final report, prepared for US Army Corps of Engineer, August 1993 (1993).

[21] Washington State Department of Ecology (WADOE). Washington State Wetlands Rating System – Technical Report 93–74 (1993).

Appendix 1

Table A1. Naturalness index.

Indicator	Options	Score
Wetland area		
Dystrophic crisis	Absent	1
	Not documented	0.75
	Not frequent	0.25
	Regular	0
Contamination (toxic/persistent compounds)	Absent	1
	Not documented	0.75
	Limited	0.25
	Heavy	0
Av.1	Average	
Urban area		
Density	Not urbanized	1
	Residential (<1.25 buildings ha^{-1})	0.75
	Residential (da 1.25 a 5 buildings ha^{-1})	0.5
	Residential (>5 buildings ha^{-1})	0.25
	Industrial, commercial	0
Sewage	Absent	1
	Sewer	0.75
	Septic	0.25
Roads	Absent	1
	Not paved, dirt	0.75
	Paved, tight	0.5
	Paved, wide	0.25
Stormwaters	Absent	1
	Sewer	0.75
	Direct	0
Landfill/waste	Absent	1
	Trattati	0.75
	Non-trattati	0
Runoff/erosion signs	Absent	1
	Minimum	0.75
	Medium	0.25
	Serious	0
Green areas	Absent	1
	Little	0.5
	Many	0
Agricultural area		
Agricultural types	Absent	1
	Cereals	0.25
	Orchards	0.75
	Vineyards	0.5
	Pastures	0.25
Dairy/livestock runoff	Absent	1
	Sewer	0.75
	Do not discharge in wetland	0.5
	Directly discharge in wetland	0
Animals have direct access to wetland	No	1
	Yes	0
Irrigation withdrawal from or discharge to wetland	Yes	1
	No	0
Pesticide use	Absent	1
	Evident	0
Forested area		
Cutting	Absent	1
	Recent cutting evidence	0

(*continued*)

Table A1. Continued.

Indicator	Options	Score
Boating		
Docks	Absent	1
	Present	0.5
Moorings	Absent	1
	Present	0.5
Other		
Evidence of flow alteration, ditching, diking, or fill	Absent	1
	Some modification, no tidal restriction	0.75
	Slight tidal restriction (<1/3)	0.5
	Moderate tidal restriction (>1/3)	0.25
	Severe tidal restriction (>2/3)	0
Recreational activities in the area	Absent	1
	Present	0.75
Sand or gravel extraction	Absent	1
	Present	0.25
Av.2	Average	
	Final score	Av1 + Av2

Appendix 2

Table A2. Habitat availability index.

Indicator	Options	Score
Part 1: Landscape (surrounding area, 2000 m)		
Dominant land use	Forest, open land	3
	Low-density residential	2
	Medium-high-density residential	1
	Industrial, commercial, transports	0
Waterproofed surface percentage	<5%	3
	5–10%	2
	11–20%	1
	>20%	0
Natural vegetation percentage	>50%	3
	30–50%	2
	10–29%	1
	<10%	0
Wetland area/drainage basin area ratio	>10%	3
	6–10%	2
	2–5%	1
	<2%	0
Main pollution sources	No identifiable source	3
	Sewage sludge	2
	Fertilizers/pesticides from agriculture activities	1
	Commercial/industrial waste, urban sewage	0
Part 2: Lagoon		
Tidal fluctuations		
	Some artificial control	2
	Severe constriction of the estuary outlet, shoreline Modification	1
	Cut off from normal tidal fluctuation	0
Erosion	No evidence	3
	Some evidence of bank erosion	2
	Bank erosion well established	1
	Severe bank erosion	0

(*continued*)

Table A2. Continued.

Indicator	Options	Score
Nature of substrate	Sand, silt/mud	3
	Predominantly sand	2
	Predominantly organic peat	1
	Rocks, cobbles, peat	0
Vegetation diversity	4 Cowardin classes	3
	3 Cowardin classes	2
	2 Cowardin classes	1
	<2 Cowardin classes	0
Food sources (macrophytes, algae, periphyton, organic matter)	Abundance	3
	Some	2
	Macrophytes absence	1
	Some organic matter	0
Degree of human activities in the lagoon	Absent	3
	Low	2
	Moderate	1
	High	0
Connectivity	Direct forested connection with other habitats	3
	No direct connection: proximity (<500 m) with other Habitats	2
	No direct connection: other habitats located from 500 to 2000 m	1
	No direct connection: other habitats located beyond 2000 m	0
Buffer wideness	250 m (almost 75% of the perimeter of the wetland site)	3
	50–250 m (almost 75% of the perimeter of the wetland site)	2
	15–50 m (almost 75% of the perimeter of the wetland site)	1
	15 m (almost 75% of the perimeter of the wetland site)	0
Percentage of perimeter with at least a 30 m wide buffer	80%	3
	50–80%	2
	20–49%	1
	<20%	0
Mixture degree of vegetated	Open waters: 25–75% of total area; remaining area is densely vegetated	3
areas and open waters	Open waters: 25–75% of total area; vegetation forms a perimeter strip	3
	Open waters: 5–25% of total area; Open waters: remaining area is covered by diffuse and/or dense vegetation	2
	Open waters: 5–25% of total area; vegetation forms a perimeter strip	2
	Open waters: 75–100% of total area; vegetation forms a perimeter strip	1
	Other cases; open waters <5% or >75%	0

Appendix 3

Table A3. Ecological functionality index.

	Options	Score
Ecological integrity of the lagoon		
Percentage of invasive plant species	<5%	1
	5–20%	0.5
	>25%	0.1
Number of tidal restrictions	None	1
	1	0.5
	>1	0.1
Type of tidal restrictions	None	1
	Flow adequate	0.5
	Inadequate (flow extremely restricted)	0.1
Ditching	absent	1
	In linear pattern	0.5
	In grid pattern	0.1
Ecological integrity of the zone of influence		
Dominant land use in 150 m around wetland site	Forested, open water or similar	1
	Rural residential	0.5
	Industrial, commercial, high-density residential	0.1
Ratio of the number of buildings and the total wetland area	<2.5 km^{-2}	1
	2.5–12.5 km^{-2}	0.5
	>12.5 km^{-2}	0.1
Percentage of upland border with a 150 m woodland buffer	>70%	1
	30–70%	0.5
	<30%	0.1
Total surface of roads, parking lots, driveways	<3%	1
	3–6%	0.5
	>6%	0.1
Shoreline anchoring		
Type of wetland	Salt marshes originated from interclusion by estuarine sedimental structures; directly connected with open sea, delimited by sandy fringes	1
	salt marshes originated from marine ingression on coastal plains	0.5
	salt marshes originated from sedimentation of structures such as barriers	0.1
Morphology	No evidence of banks	1
	Vegetated banks	0.5
	Not vegetated banks	0.1
Flood events prevention		
Lagoon surface area	>0.2 km^2	1
	0.05–0.2 km^2	0.5
	<0.05 km^2	0.1
Type of wetland	Salt marshes originated from interclusion by estuarine sedimental structures; directly connected with open sea, delimited by sandy fringes	1
	Salt marshes originated from marine ingression on coastal plains	0.5
	Salt marshes originated from sedimentation of structures such as barriers	0.1
Percentage of vegetated buffer zone upland	>70%	1
	30–70%	0.5

(*continued*)

Table A3. Continued.

	Options	Score
	<30%	0.1
Surface waters connections	Direct	1
	Proximity (<100 m) to other water bodies	0.5
	Distance (>100 m) from other water bodies	0.1
Wildlife habitat		
Lagoon surface area	See above	
Ecological integrity of the lagoon	See above	
Type of tidal restrictions	See above	
Habitat diversity	7–9 habitat classes	1
	4–6 habitat classes	0.5
	<4	0.1
Aquatic bed	Abundant	1
	Present, not abundant	0.5
	Absent	0.1
Percentage of perimeter border with a 150 m woodland, agricultural or idle land buffer	>70%	1
	30–70%	0.5
	<30%	0.1
Proximity to freshwater wetlands	Direct connection	1
	Proximity (<400 m)	0.5
	Distance (>400 m)	0.1
Water quality protection		
Lagoon surface area	See above	
Number of tidal restrictions	See above	
Type of tidal restrictions	See above	
Use potential		
Shellfish		
	Present and open for harvest	1
	Present but currently closed for harvest	0.5
	Absent	0.1
Hunting	Site currently used by hunters	1
	Site accessible but not used by hunters	0.5
	Site not accessible	0.1
Wildlife observation	See wildlife habitat function score	
Boat passage	Possible	1
	Not possible for morphology and bathymetry of the Wetland site, but possible in adjacent water bodies	0.5
	Not possible for morphology and bathymetry of the Wetland site and of adjacent water bodies	0.1
Boat access	Docks/access point for boats within 500 m from the site	
	Docks/access point for boats distant from 500 to 1000 m from the site	
	Docks/access point for boats distant more than 1000 m from the site	
Offroad public parking	Within 10 min walking	1
	More than 10 min, less than 20	0.5
	More than 20 min	0.1
Handicap accessibility		
	Special constructed handicap accessibility	1
	Access via existing roads and trails	0.5
	Not accessible	0.1
Visitor centre and trail maintenance	Present	1
	Trails but no visitor centre	0.5
	Absent	0.1
Aesthetic quality		
Ecological integrity of the lagoon	See above	

(*continued*)

Table A3. Continued.

	Options	Score
Wildlife observation	See wildlife habitat function score	
Dominant visible land-use surrounding wetland site	Woodland, agricultural land, open space	1
	Rural, residential	0.5
	Industrial, commercial, transportation use, high Density residential	0.1
Appearence from the primary viewing locations	Undisturbed and natural	1
	Limited disturbance	0.5
	Severe detractors	0.1
Noise level at the primary viewing locations	Low and natural	1
	Moderate, some noise	0.5
	Loud, traffic and industrial noise	0.1
Odors at the primary viewing locations	Natural only	1
	Some unnatural	0.5
	Unnatural odor continuously	0.1
Education potential		
Wildlife observation	See wildlife habitat function score	
Visitor centre and trail maintenance	See above	
Proximity to other habitats	3 or more habitat types within a short walk	1
	2 habitat types within a short walk	0.5
	Other habitat not within a short walk	0.1
Offroad public parking	See above	
Student (visitors) safety	No known safety hazards	1
	Hazards present but easily avoidable	0.5
	Hazards present and not easily avoidable	0.1
Handicap accessibility	See above	
Noteworthiness		
Wetland is habitat for listed threatened or endangered species	Currently used by threatened/endangered species	1.00
	Not used	0.1
Important biological, geological, hydrological features	Present	1.00
	Absent	0.1
Important historical/archaeological site	Known site	1.00
	No particular relevance	0.1
Wetland located in urban area	Industrial, commercial, high-density residential area	1.00
	Rural area	0.1
Long term research site	Yes	1.0
	No	0.00