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Integrative Systems to assess Ecological status and Recovery

Funded by the European Union under the 7th Framework Programme,
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Exploring the robustness and reliability of several macrophyte-based classification methods to assess the ecological status of coastal and transitional ecosystems

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Key words: uncertainty analysis; Water Framework Directive; biological quality elements; risk of misclassification

Abstract

One of the main aims of the WISER Project (Water bodies in Europe: Integrative Systems to assess Ecological status and Recovery) is to evaluate the robustness and reliability of the different indices developed by the EU members, addressing all water categories, organism groups and environmental stressor types. This is to be done mainly through the use of uncertainty analysis, one of the most powerful tools to assess the main weaknesses of biotic indices that allow the identification of the factors contributing to the potential misclassification of the ecological status class of water bodies (Clarke and Hering 2006). The estimation of uncertainty is a central element in WFD-compliant assessment methods, since they are based on biological communities that show both spatial and temporal heterogeneity, and because errors will be introduced during sampling and analytical stages (Kelly et al. 2009). If the major sources of variability are known, they can potentially be minimised through the re-design of sampling schemes (additional sampling sites or frequency), through improved training by operating procedures, CEN (European Committee for Standardization) guidance, taxonomic training or through the use of model-based assessment methods. For this reason, ecological status classification results should always be given in terms of probabilities depending upon the variability associated with these communities over time and space (Hering et al. 2010). However, only a small proportion of classification methods have put this into practice and the uncertainty analyses available in the literature are scarce at the moment (Staniszewski et al. 2006, Kelly et al. 2009, Bennett et al. 2011).

The objective of this contribution is to analyse the uncertainty associated to several WFD-compliant classification methods based on macrophytes (both macroalgae and seagrasses) that have been developed by different EU Member States (Table 1). Specifically, we attempt to determine which sources of variability (factors) associated with the sampling design of the different indices most greatly influence the ecological status classification of water bodies. In addition, we also observed how the boundary values between status classes can affect the general pattern of uncertainty displayed by the different factors in each index.

The analyses are based on both official and non-official EQR datasets from the different indices that include some of the key sources of variability associated with the design and implementation of a regional scale biomonitoring program (e.g. spatial scales of sampling, the temporal scale of sampling, the human-associated source of error). However, the number and nature of factors examined that potentially contribute to the uncertainty of the EQR estimations of coastal water bodies differ among the indices, especially due to differences in

Table 1. Main characteristics of some of the indices included in this study.

Index	Country of application	Target species	Metric/s used	References
MSMDI *Multi Species Maximum Depth Index*	*Norway*	*Saccharina latissima* *Chondrus crispus* *Rhodomela confervoides* *Coccotylus truncata* *Phyllophora pseudoceranoides* *Halidrys siliquosa* *Delesseria sanguinea* *Phycodrys rubens* *Furcellaria lumbricalis*	*Lower depth limit*	–
EDL *Eelgrass Depth Limit*	*Denmark*	*Zostera marina*	*Lower depth limit*	*Krause-Jensen et al., 2005*
POMI *Posidonia oceanica Multivariate Index*	*Spain, Croatia*	*Posidonia oceanica*	*Physiological, morphological, population (density) and community, integrated onto a single scale using Principal Component Analysis*	*Romero et al., 2007*
EEI-c *Ecological Evaluation Index*	*Italia*	*Cymodocea nodosa-ESG IA* *Ruppia cirrhosa-ESG IA* *Cystoseira barbata-ESG IB* *Gracilaria bursa-pastoris-ESG IIA* *Cladophora spp.-ESG IIB* *Ulva spp.-ESG IIB*	*Coverage (%) of 5 different Ecological Status Groups clustered hierarchically into two ESG's*	*Orfanidis et al., 2011*
EI *Ecological Index*	*Bulgaria*	*Cystoseira barbata-ESGI* *Cystoseira crinite- ESGI* *Corallina spp.- ESGI* *Gelidium latifolium- ESGI* *Zostera noltii- ESGI* *Zostera marina- ESGI* *Potamogeton pectinatus- ESGII* *Ulva spp.- ESGII* *Cladophora spp.- ESGII* *Ceramium spp.- ESGII* *Chaetomorpha spp.- ESGII* *Polysiphonia spp.- ESGII*	*Biomass proportion (%) of different macrophyte species classified in 2 different Ecological Status Groups: sensitive (ESGI) and tolerant (ESGII)*	*Dencheva in press*
SQI *Seagrass Quality Index*	*Portugal*	*Zostera noltii*	*- Taxonomic Composition (TC)* *- Bed Extent (BE)* *- Shoot Density (SD)*	–

both the metrics used and their sampling designs. First of all, the total variance and variance components associated to each factor were estimated for all indices using a linear mixed effects model in the lme4 package of R (Version 2.10.1, R_Development_Core_Team 2009). It is important to note that variability among water bodies, whilst important in the analysis of variance components, is not discussed in this study because by definition they should differ in their ecological status. Posteriorly, the uncertainty in ecological status classification was estimated using WISERBUGS (WISER Bioassessment Uncertainty Guidance Software®, Clarke 2010). WISERBUGS helps determine whether an observed ecological status classification is indeed the most probable classification for a particular site, given the inherent sources of variability. Because the current study was interested in the uncertainty in classification generated by a particular factor (rather than the probability of misclassifying individual sites), the probability of misclassification for each factor was determined along the full range of possible observed EQR values (0 - 1).

Generally for all factors, the probability of misclassification peaks when a site's observed EQR score is very close to the boundary between two status classes, usually around 50%. In contrast, when the observed EQR falls in the middle of a status class the probability of misclassification declines to the minimum. Probabilities of misclassification >50% may indicate that the associated variability is actually higher than the EQR range of the status class. The magnitude of these maximum and minimum uncertainty levels differ greatly among factors and indices as a result of the differences in the variance extracted.

Our results show that spatial scales of variability (above and below the water body scale) have different influence in the ecological classification status of water bodies depending on the index. For example, the uncertainty associated to the factor region was high in EDL and POMI indices (Figs. 1a and 1b), which may indicate that it was separating groups of water bodies of similar quality status. Below the water body spatial scale, variability among sites showed also a high uncertainty associated in EDL, MSMDI and EI indices (Figs. 1a, 2a and 3b) compared to POMI, SQI and EEI-c (Figs. 1b, 2b and 3a), indicating that the spatial heterogeneity displayed by these biological communities was not properly captured in their corresponding sampling designs. In order to absorb part of this spatial variability and minimize the risk of misclassification, the sampling effort must be increased to include a greater number of sites within water bodies and, in each one, to collect several sub-samples and average metric values. In contrast, the temporal scale of sampling did not promote important levels of uncertainty in the ecological status classification of water bodies in any of the indices that included this factor (EDL, POMI, MSMDI, EI and SQI; Figs. 1a, 1b, 2a and 3b respectively). This indicates that the EQR scores of water bodies are fairly consistent throughout the years, for which the frequency of sampling could be decreased without greatly reducing the precision of ecological status estimates. Surprisingly, low levels of uncertainty were also attributed to differences among surveyors (Figs. 1b and 2a). This may be attributed to the fact that these macrophyte-based indices do not require complicated taxonomic identifications, which can greatly affect the precision of the EQR estimations in the case of other classification methods based on diatoms (Kelly et al. 2009) or freshwater macrophyte communities (Staniszewski et al. 2006). Finally, we observed that the risk of misclassifying the quality status of water bodies is also affected by the width of the status class in which the EQR score falls, as reported in Kelly et al. (2009), with narrower classes leading to greater probabilities of misclassification. Thus, indices in which the EQR range is not equally split into the 5 official classes (EDL, POMI and EEI-c) present, for a certain variance associated to a factor, changing uncertainty levels depending on the status class (Figs. 1a, 1b and 3a). This fact may have drastic implications for bio-monitoring programs, because a greater sampling effort may need to be assigned to water bodies whose EQR score falls within the narrower status classes, in order to reduce their associated variability and increase the confidence of the classification.

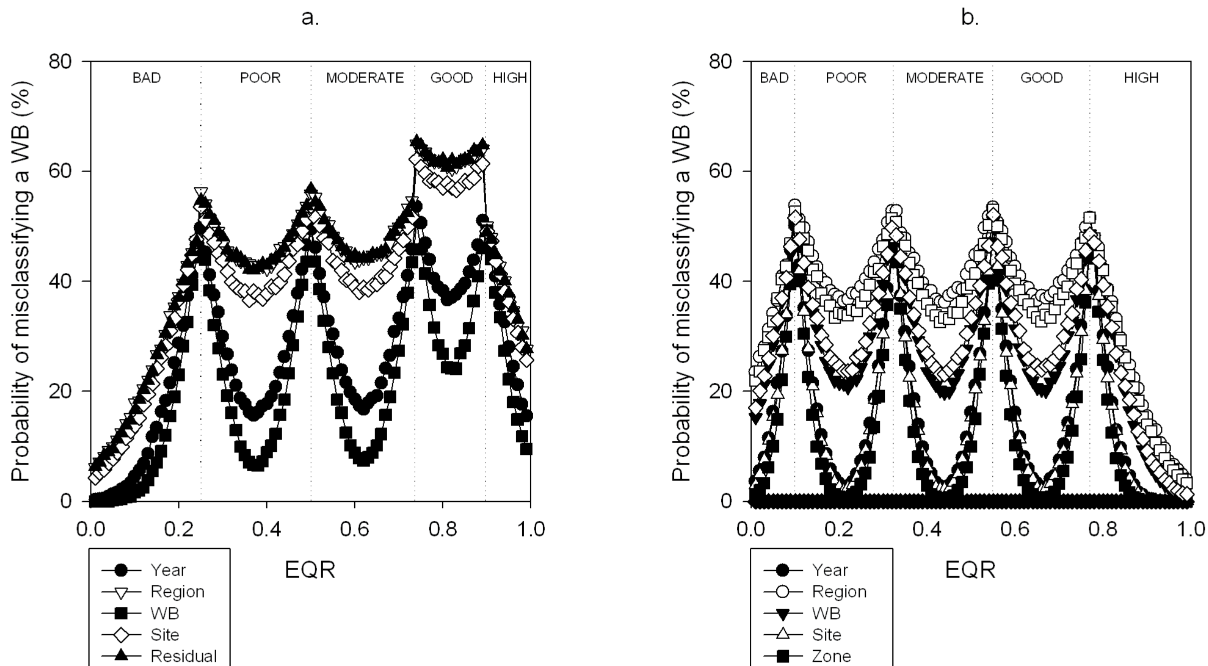

Figure 1. Probability of misclassifying the ecological status associated to the different factors analysed for the EDL (a) and POMI (b) indices. Vertical dashed lines represent the boundaries of each status class. For EDL: Bad = 0 – 0.249; Poor = 0.25 – 0.499; Moderate = 0.5 – 0.739; Good = 0.74 – 0.899; High = 0.9 – 1. For POMI: Bad = 0 – 0.099; Poor = 0.1 – 0.324; Moderate = 0.325 – 0.54; Good = 0.55-0.774 and High = 0.775 – 1.

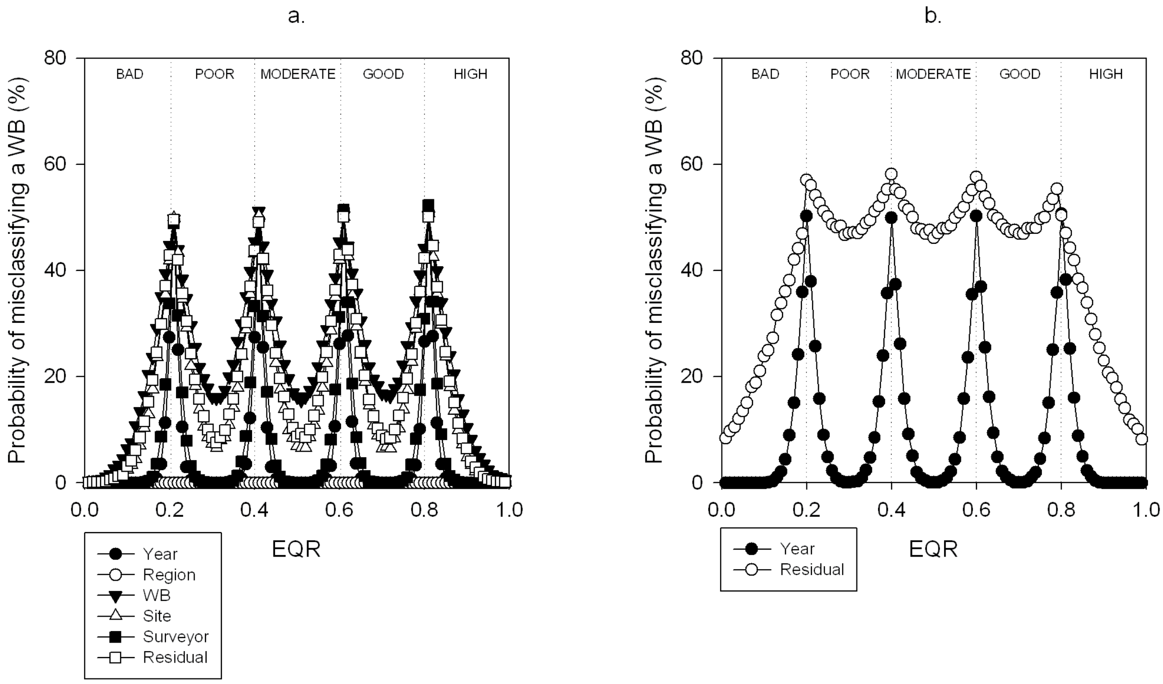

Figure 2. Probability of misclassifying the ecological status associated to the different factors analysed for the MSMDI (a) and SQI (b) indices. Vertical dashed lines represent the boundaries of each status class; for both indices: Bad = 0 – 0.2; Poor = 0.21 – 0.4; Moderate = 0.41 – 0.6; Good = 0.61-0.8 and High = 0.81 – 1.

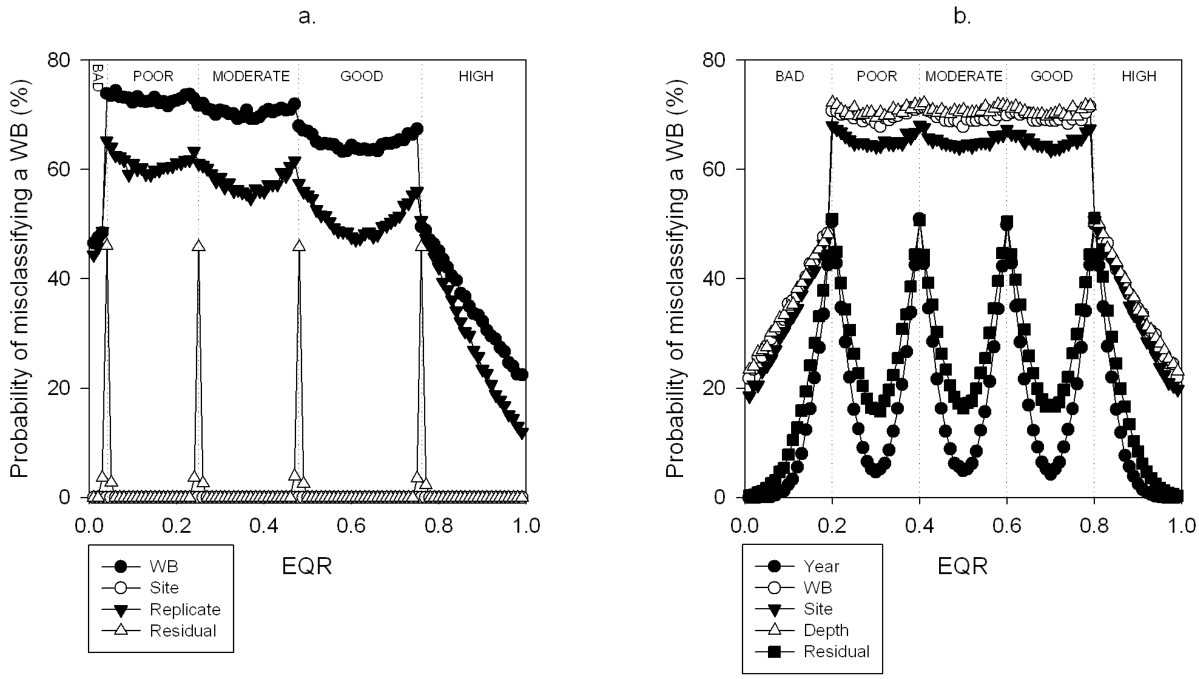

Figure 3. Probability of misclassifying the ecological status associated to the different factors analysed for the EEI-c (a) and EI (b) indices. Vertical dashed lines represent the boundaries of each status class. For EEI-c: Bad = 0 – 0.04; Poor = 0.041 – 0.25; Moderate = 0.26 – 0.48; Good = 0.49-0.76 and High = 0.77 – 1. For EI: Bad = 0 – 0.2; Poor = 0.21 – 0.4; Moderate = 0.41 – 0.6; Good = 0.61-0.8 and High = 0.81 – 1.

The current study is in line with one of the main objectives of the WISER Project, helping to gain insight into the robustness and reliability of some of the ecological status classification methods proposed for European waters under the WFD. Applying uncertainty analysis to extensive bio-monitoring datasets, we have been able to detect the main weaknesses of these indices and provide robust foundation for improving their monitoring programmes, as well as guide decisions in future management plans. Besides, this study highlights the importance of extensive data series, essential to improve the methodologies proposed to assess the ecological status of coastal and transitional ecosystems under the WFD.

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