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Development of an Angiosperm Quality Assessment Index (AQuA-Index) for ecological quality evaluation of Portuguese water bodies—A multi-metric approach

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ABSTRACT

Salt marsh vegetation is one important biological element for establishing the ecological quality status (EQS) while evaluating transitional waters (TW). This intertidal plant community is sensitive to the most important pressures present in estuaries. In this study, an ecological index based multi-metric was established taking into account the species composition and ecological relations in Portuguese salt marsh habitats. During the AQuA-Index elaboration it was found that the parameters that respond better to the variability of ecological conditions present nowadays are the Shannon Diversity Index, the Shannon Maximum Diversity Index, the number of halophytic species, the Margalef Diversity Index and the Pielou Equitability Index. The application of the AQuA-Index index to eight TW systems varying in morphology and pressures, demonstrated that the metric responds to the ecological quality of each system. Also, it showed some advantages in comparison with other approaches, in zones with a relevant proportion of middle and upper marsh and where historical data were not available. This way the AQuA-Index proved to be an efficient Index for ecological quality assessment, using salt marsh vegetation as indicator.

1. Introduction

With the implementation of the Water Framework Directive (WFD, 2000/60/EC), the European Union member states are impelled to monitor the ecological quality of all their water bodies and elaborate an efficient management plan in order to solve potential problems of their transitional waters (TW). In order to implement a transnational monitoring scheme 5 biological quality elements (BQE) were defined for the ecological quality assessments: benthic invertebrate fauna, fish fauna, phytoplankton, macroalgae and marine angiosperms. At the time of the WFD implementation, marine angiosperms only included sea grasses. With the Guidance Document No. 5 (Working Group 2.4, COAST, 2003) it was recommended that, in transitional waters (TW), the intertidal areas from the highest tide limit to the lowest tide limit should be included in the monitoring program. With this new amendment, salt marsh vegetation was also included as part of the marine angiosperms biological quality element (BQE).

In the Habitat Directive (92/43/EEC), was already stated that salt marshes are very important and sensitive habitats. Annex V of the WFD indicates the taxonomic composition and abundance as key elements for identifying the ecological status classes in TW. Actually, the WFD provides a clear definition of reference conditions: the taxonomic composition of angiosperms that corresponds totally or almost totally to undisturbed conditions, without detectable changes in angiosperm abundance due to anthropogenic activities. The WFD text (WFD, 2000/60/EC) presents a classification scheme based on the first three principal conditions: high, good and moderate. This classification takes into account all the above mentioned biological quality elements in order to rank the water body (WB), and in ultimate analysis, the transitional water system in terms of its ecological quality rank by comparison with the high status definition (CIS Guidance no.13, 2003). The responsibility of the remaining classifications of poor and bad status is of each member state. In the end when all the quality elements (hydromorphological, physic-chemical and biological) are integrated, for a water body to achieve a high ecological status, all these elements must be assessed individually to have the high state (Best et al., 2007).

Salt marshes are present in almost all the Portuguese estuarine and coastal lagoon systems with a high intertidal coverage percentage. They normally occur in areas hydrologically with low-energy allowing the sediment to settle down, the shoreline to elevate and expand and the establishment of halophyte species (Boorman, 2003). In spite of this rather hydrologically stable environments,

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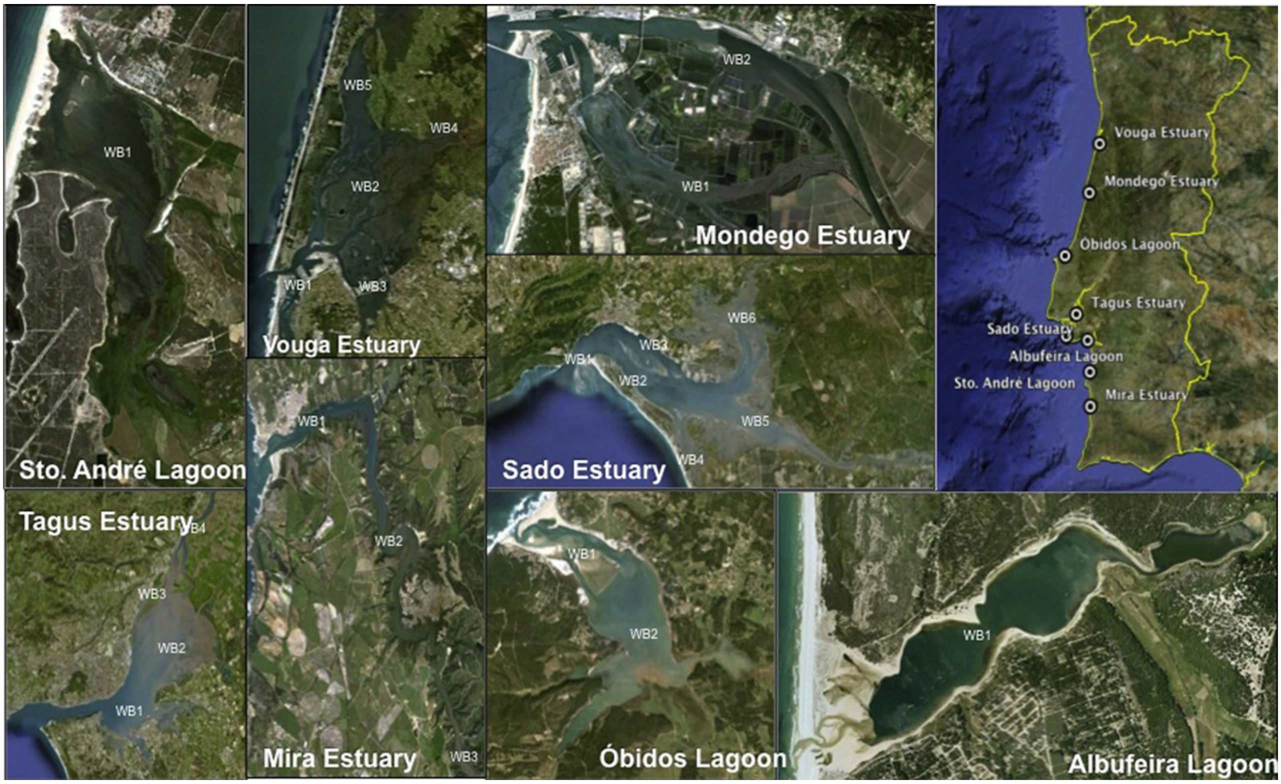

Fig. 1. Transitional waters maps and respective water body locations.

salt marshes are subjected to the long-term dynamic nature of coastal processes (waves, tides, currents, sediment supply), as well as local geology and the relative sea level movement. This leads to natural cycles of erosion and accretion which may span decades or hundreds of years (Carpenter and Pye, 1996).

Chemically salt marshes are also affected, since tidal flooding often brings large amounts of organic matter, nutrients and contaminants. These substances settle in the salt marsh and accumulate in their sediments and biota (Caçador et al., 2000). Thus, salt marshes are considered to be important sinks of both contaminants and nutrients (Caçador et al., 1993, 2009; Davy, 2000; Mitsch and Gosselink, 2000; Duarte et al., 2010). Salt marsh vegetation is inevitably affected by these hydrological and chemical constrains, reflecting them in its community structure (Caçador et al., 2007). This vegetation type consists in a number of limited species with halophytic characteristics (salt tolerance), adapted to regular submersion, root hypoxia and other unfavourable conditions factors inherent to the aquatic medium (Best et al., 2007; Boorman, 2003). Being ecosystems with an high importance and with their inclusion in the WFD, several works have embraced the development of metrics including the salt marsh species and community structure as Index for the ecological quality status assessment throughout aquatic vegetation (Garcia et al., 2009; Best et al., 2007; Foden and Brazier, 2007; De Jong, 2004). In the referred studies several approaches were taken, evaluating the species position and their drawback, relative abundance, biomass and community relationships.

In the present work, the authors aimed for two essential objectives: (1) to develop a classification Index for salt marshes, according to the WFD guidelines, gathering all the considered aspects found in similar studies, in order to develop and test a possible methodology for the determination of the ecological quality status in transitional waters; (2) develop a more advantageous, cheap and of rapid assessment method that does not requires the existence of historical reference conditions for comparison of the obtained EQS classifications.

2. Materials and methods

2.1. Study areas and vegetation survey

The eight evaluated transitional systems (Tagus, Sado, Mira, Mondego and Vouga estuaries, Santo André, Albufeira and Óbidos coastal lagoons; Fig. 1) were evaluated for the presence of salt marsh vegetation and sub-divided in WBs, where this biological element were present, according to their physic-chemical and hydrological characteristics, with the exception of the Santo André and Albufeira lagoons, on which only a WB was considered due to its reduced transitional area and homogenous water characteristics. Several transects were established in each WB salt marshes, in order to cover the more representative area possible. Each transect was surveyed by foot and the species identified and their abundance (occupied area in m^2) registered meter by meter (Braun-Blanquet, 1979). Transects location and of each stand was recorded using GPS. This data was matched with aerial photographs from recent flights, provided by the Army Geographic Institute (www.igeoe.pt) where the total area covered by salt marsh vegetation and by each species was measured using ArcGis software. The more important characteristics of the evaluated transitional and coastal systems are found in Table 1.

2.2. Ecological diversity parameters

Using the area and registered abundances of all the surveyed species, several ecological diversity indices were calculated: Shannon Diversity (H'), Maximum Shannon Diversity (H'_{max}), Simpson Diversity (D), Specie Richness (S), Pielou Evenness (J), Margalef Diversity Index and Menhinick Index (Shannon, 1948; Simpson,