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Development of a multimetric approach to assess perturbation of benthic macrofauna in *Zostera noltii* beds

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ABSTRACT

Biotic indices based on soft-bottom macrozoobenthic communities are currently used throughout Europe to assess the ecological quality of coastal and transitional water bodies according to the European Water Framework Directive. However, the performance of the currently available biotic indices still has to be tested against a variety of different impact sources. In particular, physical perturbations have received much less attention than other kind of disturbances. This study consisted in testing the capacity of currently available uni- (BOPA, AMBI and BENTIX) and multivariate (M-AMBI) Biotic Indices to assess the ecological impact of the destruction of a *Zostera noltii* seagrass bed in Arcachon Bay (France) following sediment deposits. Changes of habitat after this physical perturbation were hardly assessed by any of these Biotic Indices whereas analysis of the benthic community showed drastic changes of structure following the perturbation and no recovery after 15 months. This study demonstrates that these Biotic Indices must be integrated into a multimetric approach which describes better the biological integrity of the benthic community by including a complementary set of metrics. A new multimetric approach, named MISS (Macrobenthic Index of Sheltered Systems) is proposed. MISS correctly highlighted the destruction of the seagrass beds, by using 16 metrics describing the biological integrity of the macrofauna.

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1. Introduction

Within the European Water Framework Directive (WFD), benthic invertebrates are one of the biological elements to be used for the assessment of ecological quality status (EcoQ) of surface and transitional (estuaries and lagoons) water bodies. Benthic organisms can indeed be considered as potentially powerful indicators of marine ecosystems health because of their position at the sediment-water interface, and their relatively long and sedentary life (Pearson and Rosenberg, 1978; Dauer et al., 2000). Indeed, life at the sediment-water interface makes benthic organisms good integrators of the variations of both sediment and water column (Dauvin, 1993), their sedentary life makes most benthic animals unable to escape unfavourable conditions, and a long lifespan enables them to assess both accidental and chronic perturbations (Dauvin 1993, Reiss and Kröncke, 2005) and allows relatively low-frequency surveys. Finally, benthic macrofauna includes different species displaying different tolerance level to stresses, various feeding guilds and a diversity of life-history traits. In comparison with a purely chemical approach, benthic invertebrate community change testifies real ecological impact of disturbances, at community and ecosystem levels (Fano et al., 2003). As a consequence, benthic macroinvertebrate communities are the most consistently emphasized biotic components to evaluate biological integrity of aquatic systems (Dauvin, 2007).

Several biological indices based on the benthic macrofauna assemblages have been recently developed to assess EcoQ of marine waters within the WFD (Borja et al., 2000; Simboura and Zenetos, 2002; Rosenberg et al., 2004; Dauvin and Ruellet, 2007). These Biotic Indices (BIs) have been tested in a large number of situations (e.g. Salas et al., 2004; Labrune et al., 2006; Marín-Guirao et al., 2005; Muxika et al., 2005; Borja et al., 2006; Dauvin et al., 2007; Bigot et al., 2008; Callier et al., 2008), however a growing number of studies highlights their poor performance (Quintino et al., 2006; Zettler et al., 2007; Blanchet et al., 2008).

A recent study has tested the applicability of BIs for the EcoQ assessment of three French Atlantic coastal semi-enclosed ecosystems (Arcachon Bay, Marennes-Oléron Bay, and the Seine Estuary) (Blanchet et al., 2008). In these particular biotopes, BIs were not adapted. Indeed, sediment silt and clay content and the intertidal or subtidal location of the stations had influence on the EcoQ classification of the stations. The authors showed that in muddy environments, where sediment organic matter is naturally high, such indices displayed limitations and impaired the decision-making (see also Borja et al., 2003; Salas et al., 2004; Muniz et al., 2005; Muxika et al., 2005). More particularly, BIs always expressed worse quality in naturally muddy environment than in coarser sediment, within the same water body (Blanchet et al., 2008). For example, *Zostera noltii* beds were systematically classified in moderate or worse status because of the numerical abundance of species considered as opportunist or tolerant (Blanchet et al., 2008), whereas they were considered healthy and well vegetated (Blanchet et al., 2004), played their ecological key role in the ecosystem (Stoner, 1980; Orth et al., 1984; Edgar, 1990).

In this study, we present the results obtained during the survey of the macrozoobenthic assemblages of a *Zostera noltii* bed following its destruction by sediment deposits. Our objectives were (1) to describe the evolution of benthic assemblages before and after perturbation and (2) to test the performance of uni- and multivariate BIs designed for the implementation of the WFD. On the basis of these results, we proposed a new bio-assessment tool, called MISS (Macrobenthic Index for Sheltered Systems), which includes some of these BIs together with a set of complementary metrics that describe the biological integrity of a benthic assemblage into a multimetric approach.

2. Materials and methods

2.1. Study site

Arcachon Bay (44°40′N, 1°10′W) (Fig. 1) is a 180-km^2 macrotidal (tidal range=0.9 – 4.9 m) coastal lagoon situated on the South Western coast of France. The lagoon communicates with the Atlantic Ocean by a narrow channel and receives freshwater inputs from a small river (Leyre) situated in the South-Eastern end of the bay. The balance between marine and continental water inputs and the slow renewal of water by tides induces salinity and temperature gradients along a West-East axis (Bouchet, 1993). This lagoon is characterised by large intertidal flats (115 km^2) of which low tide regions are used for oyster farming. Most of these areas (70 km^2) are covered by the largest *Zostera noltii* seagrass bed in Europe (Auby and Labourg, 1996).

The background chemical pollution in Arcachon Bay is low. Its catchment area is dominated by pine forestry (79%) and intensive agriculture occupies only 9% of the surface (de Wit et al., 2005). As a consequence, nutrient inputs to the lagoon are moderate and their concentrations in water remain low (Castel et al., 1996, Bachelet et al., 2000). Some developments of green macroalgae (mainly *Monostroma obscurum* and *Enteromorpha* spp.) occurred in the early 1990s, but these signs of moderate eutrophication have not been observed since. The catchment area is poorly industrialised, and heavy metal contamination is low (Benoit, 2005). Consequently, the overall water quality of the lagoon can be considered as satisfying.

2.2. Perturbation of the Zostera noltii bed and monitoring strategy

In 2004, a small channel was dredged in order to allow free navigation. During the operations, 0.3 km^2 of the nearby *Zostera noltii* bed were covered by sediments (sand and mud) and destroyed. Two "impacted" sites (IS) located in the impacted area and two "control" sites (CS) situated in nearby un-impacted *Zostera noltii* meadow were monitored 3, 8 and 15 months after the operations (Fig. 1). The first 20 cm of the sediment were collected with a 0.0225-m^2 corer (4 replicates per sites). Sediment was sieved through a 1-mm mesh; the remaining fraction was fixed in 4% formalin and stained with Rose Bengal. Macrofauna was sorted, identified when possible to species level, and counted. Biomass was obtained as ash-free dry weight (AFDW) after dessication (60 °C, 48 h) and calcination (550 °C, 2 h). Additional sediment samples were collected at each site. Sediment grain-size was determined after sieving weighted dried sediment through a wet column of sieves with decreasing apertures (1000 μm, 500 μm, 250 μm, 125 μm and 63 μm).

2.3. Multivariate Analysis

Macrofaunal assemblages associated to both impacted (2 sites, 3 surveys: August 2005, January 2006, August 2006) and control (2 sites, 3 surveys: August 2005, January 2006, August 2006) sites were compared with that of 38 sites located in normally vegetated *Zostera noltii* beds sampled in 2002, using Non-Metric Multidimensional