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Structuring factors and recent changes in subtidal macrozoobenthic communities of a coastal lagoon, Arcachon Bay (France)

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Abstract

Fourteen years after a previous investigation in Arcachon Bay (SW France), the quantitative distribution of subtidal macrozoobenthic communities was assessed in 2002 through a stratified sampling strategy involving a larger number of stations (89 vs. 18) than in 1988. A total of 226 taxa were recorded. Cluster Analysis and Correspondence Analysis identified nine station groups corresponding to benthic faunal assemblages and their characteristic species. Multiple Discriminant Analysis showed that the main environmental factors influencing the distribution of faunal assemblages were sediment parameters and distance from the ocean. Depth was a minor structuring factor. At the scale of the lagoon, biogenic structures such as *Zostera marina* beds, *Crepidula fornicata*-dominated bottoms or dead oyster shell bottoms did not display any particular assemblage of infauna. Comparison with previous quantitative data from the 1988 survey provided more precision on the distribution of benthic assemblages and revealed community changes at a 14-year scale. These modifications reflected a general increase of silt and clay content in the sediment in the internal parts of channels, inducing community change. These changes can be correlated to the recent first signs of a moderate eutrophication process which have appeared, since 1988, through the development of green macroalgae in some parts of the lagoon. This trend was enhanced in transverse channels with reduced hydrodynamics and led to muddy areas where green macroalgae tended to accumulate. Locally, the dredging of sandbanks induced stronger currents and allowed the marine influence to occur, and also induced community change. These observations confirm that surveys of macrobenthic communities are useful tools to assess coastal ecosystem change even in moderately disturbed environments.

Keywords: macrofauna; community structure; temporal changes; benthic surveys; diversity; coastal lagoons; Arcachon Bay

1. Introduction

Surveys of macrozoobenthic communities are useful tools for assessing short- and long-term changes in marine ecosystems, and thus for discriminating between natural and man-induced disturbances. However, most surveys have been conducted in areas undergoing severe catastrophic events such as oil spills (e.g. Dauvin, 2000; Stark et al., 2003), dystrophic crises (Lardicci et al., 1997), sewage discharge (Fallesen, 1992), metal contamination (Warwick, 2001) or major invasion by introduced species (Chauvaud et al., 2000). Long-term studies in less damaged benthic ecosystems are still scarce (Beukema et al., 2000, 2002; Boström et al., 2002) probably because funding is more difficult to find for less spectacular events. Nevertheless, baseline databases to assess temporal

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changes in ecosystems has long been recognized as a prerequisite for such studies.

Arcachon Bay, a mesotidal coastal lagoon on the SW coast of France, is a major centre for oyster farming and spat production and a recreational area. During the past 30 years, the most severe environmental problems occurring in the bay have been oyster recruitment failure and shell malformations due to TBT in the 1970s (Alzieu et al., 1986), and occasional macroalgal blooming due to increased eutrophication in the late 1980s and early 1990s (Auby et al., 1994; Bachelet et al., 2000). Oyster farming has rapidly recovered since the banning of TBT in antifouling paints in 1982 (Ruiz et al., 1996) and macroalgal blooms have significantly diminished since the 1990s, although nitrogen input still remains high (De Wit et al., 2005). More recently, hydrodynamical and morphological changes inside the bay, generated by natural migration of sand bars at the oceanic opening, have led the local authorities to undertake engineering operations which combined dredging of some channels and tidal flats and refilling of beaches. The overall project involves a volume of about 4 million m^3 of sediment. Both eutrophication and dredging activities may have significant effects on benthic fauna, which necessitates knowledge on the quantitative distribution of benthic assemblages in Arcachon Bay. While such a basic knowledge exists for the intertidal areas of the bay (Castel et al., 1989; Bachelet and Dauvin, 1993; Bachelet et al., 2000; Blanchet et al., 2004), only a single quantitative study has been published for the macrozoobenthos of subtidal areas in Arcachon Bay (Bachelet et al., 1996). Moreover, the latter study was conducted in 1988 and was restricted to a limited number of stations (18) in muddy and sandy channels. In the present work, a higher sampling effort (89 stations) allowed inclusion of some habitats typical of the bay, such as *Zostera marina* beds, *Crepidula fornicata* bottoms and oyster shell habitats. The aims of this study were (1) to describe the main subtidal benthic communities occurring in the lagoon and to update former available data; (2) to identify the main physical parameters affecting their distribution in the lagoon; (3) to assess macrozoobenthic community changes since the 1988 study by Bachelet et al. (1996), and consequently to test macrozoobenthos as a tool to detect environmental modifications.

2. Material and methods

2.1. Study area

Arcachon Bay (44°40′ N, 1°10′ W) is a triangular-shaped coastal lagoon situated on the south-western Atlantic coast of France (Fig. 1). Tidal range varies between 0.9 and 4.9 m depending on site and tide coefficient (Gassiat, pers. commun.). This 180-km^2 lagoon opens to the Atlantic Ocean by a narrow channel (2–3 km wide and about 12 km long). In the inner lagoon (156 km^2), tidal channels (41 km^2) penetrate between large intertidal areas (115 km^2). Most of these tidal flats (60%, i.e. 70 km^2) are covered by *Zostera noltii* meadows.

The lagoon receives freshwater inputs from its north-eastern and southern parts and mostly by the river Leyre situated in the south-eastern part of the bay. The balance between marine and continental water inputs and the slow renewal of water by tide induce salinity and temperature gradients. These gradients were studied by Bouchet (1993) who identified three main water masses along a west–east axis: the most oceanic waters display a narrower range of annual variation of both salinity (34–35) and temperature (9–21 °C) than the most internal waters (annual variations 22–32 and 1–25 °C for salinity and temperature, respectively). Intermediate waters display intermediate range of salinity (27–33) and temperature (6–23 °C).

2.2. Sampling procedure

Benthic macrofauna was sampled according to a stratified sampling strategy, as defined by Cochran (1977) (Table 1). At each station two samples were obtained by scuba divers manipulating a 15×15 cm Ekman grab penetrating 15 cm deep into the sediment. Each sample, consisted of two pooled grab contents (i.e. a total sampled area of 0.09 m^2 per station), which was placed in a plastic bag to prevent loss during ascent. The sediment was sieved through a 1-mm mesh; the remaining fraction was fixed in 4% buffered formalin and stained with Rose Bengal. An additional grab sample was taken for grain size analysis of the upper 3 cm sediment layer. At each station, depth was recorded by divers and subsequently corrected for tide effect. All samples were collected during late winter 2001 to early spring 2002 to avoid the main recruitment period.

In the laboratory, macrofauna was sorted, identified to the species level whenever possible and counted. Biomass was determined as ash-free dry weight (AFDW) after desiccation (60 °C, 48 h) and calcination (550 °C, 2 h). Sediment grain size was determined using a Malvern Master Sizer laser-diffractometer.

2.3. Data analysis

Three levels of multivariate analyses were applied: classification by Cluster Analysis (1), ordination by Correspondence Analysis (2), and Discriminant Analysis (3). These analyses were used (1) to classify stations according to their species composition into homogeneous groups; (2) to ordinate these stations in a reduced