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Do nematode and macrofauna assemblages provide similar ecological assessment information?

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ABSTRACT

Do nematode and macrofauna assemblages provide similar ecological assessment information? To answer this question, in the summer of 2006, subtidal soft-bottom assemblages were sampled and environmental parameters were measured at seven stations covering the entire salinity gradient of the Mondego estuary. Principal components analysis (PCA) was performed on the environmental parameters, thus establishing different estuarine stretches. The ecological status of each community was determined by applying the Maturity Index and the Index of Trophic Diversity to the nematode data and the Benthic Assessment Tool to the macrofaunal data. Overall, the results indicated that the answer to the initial question is not straightforward. The fact that nematode and macrofauna have provided different responses regarding environmental status may be partially explained by local differentiation in micro-habitat conditions, given by distinct sampling locations within each estuarine stretch and by different response-to-stress times of each benthic community. Therefore, our study suggests that both assemblages should be used in marine pollution monitoring programs.

1. Introduction

The introduction of biological features in the assessment of environmental quality is one of the innovations of recent monitoring programs, as required by the Water Framework Directive of the European Union (WFD, 2000/60/EC). Regarding communities of benthic invertebrates, those of macrofauna have been traditionally used to assess and evaluate ecological integrity. In fact, organisms comprising the benthic macrofauna are considered to be good indicators of coastal and estuarine ecological conditions for several reasons (see Pinto et al., 2009 for detailed references), including their taxonomic diversity and the abundance of many taxa, their wide range of physiological tolerance to stress and the variability of their feeding modes and life-history strategies. These traits allow the benthic macrofauna to respond to a wide range of environmental changes. Moreover, these organisms are relatively sedentary and thus cannot easily escape unfavorable conditions, which makes them reliable indicators of local pressure. In addition, some taxa are relatively long-lived and thus reflect the effects of environmental conditions integrated over longer periods of time. In terms of their study, benthic macrofauna are relatively easy to sample quantitatively and, compared to other, smaller sediment-dwelling organisms, they have been fairly well studied scientifically, with taxonomic keys available for most groups.

Specific indicators that can be used to determine macrofaunal abundance, diversity, and the presence/absence of sensitive species were proposed and subsequently tested in assessments of the environmental quality of coastal and estuarine systems (e.g., Borja et al., 2004; Bald et al., 2005; Simboura et al., 2005; Muxika et al., 2007; Rosenberg et al., 2004; Teixeira et al., 2009). Nevertheless, it may well be the case that meiofauna can also suitably reflect the ecological conditions present in a particular system. In fact, meiofaunal communities, namely, those of nematode, have generated considerable interest as potential indicators of anthropogenic disturbances in aquatic ecosystems (e.g., Coull and Chandler, 1992; Gheskiere et al., 2005; Gyedu-Ababio and Baird, 2006; Heip et al., 1988; Hoess et al., 2006; Lee and Correa, 2007; Moreno et al., 2008; Schratzberger and Warwick, 1999; Schratzberger et al., 2004; Shaw et al., 1983; Steyaert et al., 2007; Warwick, 1993). For instance, Kennedy and Jacoby (1999) maintained that meiofauna has several potential assessment advantages over macrofauna, such as small size, high abundance, ubiquitous distribution, rapid generation times, fast metabolic rates, and the absence of a planktonic phase, resulting in a shorter response time and higher sensitivity to

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certain types of disturbance. Moreover, due to their ecological characteristics, meiofaunal organisms can act as suitable indicators of changes in environmental conditions over small spatial scales (e.g., Li et al., 1997; Soetaert et al., 1994; Steyaert et al., 2003). According to Bongers and Ferris (1999), if environmental scientists had to draft a group of organisms that would specifically serve to monitor and measure biodiversity and the impact of stressors, then the blueprint for those organisms would certainly closely match the characteristics of nematodes. However, while there are many general indices of biological diversity, only a few specific but limited tools have been developed for nematodes. Among these are the Maturity Index (Bongers, 1990), which is based on the allocation of taxa according to life strategy, ranging from colonizers (*r*-strategists in the broad sense) to persisters (*K*-strategists), and the Index of Trophic Diversity (Heip et al., 1985). Both have been widely used as proxies in environmental assessments based on nematode assemblages (e.g., Beier and Traunspurger, 2001; Bongers et al., 1991; Danovaro and Gambi, 2002; Gyedu-Ababio et al., 1999; Gyedu-Ababio and Baird, 2006; Heip et al., 1985; Moreno et al., 2008; Soetaert et al., 1995).

What if, in an alternative approach, the best characteristics of meiofauna and macrofauna could be taken advantage of to obtain complementary information allowing more precise environmental monitoring? Several studies have compared the response of meio- and macrobenthos community structure to disturbances and pollution (e.g., Austen et al., 1989; Austen and Widdicombe, 2006; Bolam et al., 2006; Schratzberger et al., 2003; Warwick, 1988; Warwick et al., 1990; Whomersley et al., 2009; Widdicombe et al., 2009). As far as we know, in the few field studies in which the spatial patterns of meiofauna (or nematode) and macrofauna have been simultaneously compared, changes in both assemblages as a response to natural gradients were found to be scattered across a small number of habitats: a high-energy surf zone (McLachlan et al., 1984), glacial fjords (Bick and Arlt, 2005; Somerfield et al., 2006), a Brazilian atoll (Netto et al., 1999), Brazilian mangroves (Netto and Gallucci, 2003), an abyssal site in the NE Atlantic (Galéron et al., 2001), NE Atlantic slopes (Flach et al., 2002), offshore of the West UK coast (Schratzberger et al., 2004, 2008), the Thames estuary (UK) (Attrill, 2002), Mediterranean sandy beaches (Covazzi et al., 2006; Papageorgiou et al., 2007), and the Eurasian Arctic Ocean (Kröncke et al., 2000). These investigations have demonstrated the fundamental advantage of a multi-species approach, with the inclusion of many taxonomic and functional groups that have a broad range of sensitivities to any given environmental regime (Attrill and Depledge, 1997). This is particularly true for estuarine systems, where assessment of the environmental ecological conditions must account for their greater natural variability. Transitional waters are indeed more complex than other categories of surface waters. Indeed, conditions in areas close to the mouth of the estuary, where the marine influence is strong, are highly distinct from the polyhaline and mesohaline inner parts of the estuary, and differ, in turn, from the oligohaline conditions and fresh tide influence found at the estuarine head (Elliott and McLusky, 2002). The natural stressors resulting from the presence of gradients such as these throughout the system could mask the response of potential indicators (Dauvin, 2007; Elliott and Quintino, 2007). Therefore, prior to the use of environmental quality assessment tools, the different components that make up the system should be accounted for.

The principal aim of this work was to determine whether subtidal nematode and macrofauna assemblages could provide a comparable assessment of ecological conditions. In addition, we examined whether both assemblages (with their own specific tools and approaches) were able to characterize *a priori* defined estuarine stretches, and compared the changes in nematode and macrofauna community structure that occurred along a natural estuarine gradient.

2. Materials and methods

2.1. Study site

The Mondego River basin comprises an area of approximately 6670 km^2, including a large alluvial plain consisting of high-quality agricultural land. The river's estuary (Fig. 1) (western coast of Portugal; 40°08′ N, 8°50′ W) is 21 km long and constitutes a relatively small (860 ha) warm-temperate polyhaline system. At a distance of 7 km from the sea, Murraceira Island splits the estuary into two arms with very different hydrological characteristics. The North arm is deeper (5–10 m during high tide) and is the river's main navigation channel, receiving most of the freshwater input (27 m^3 s^{-1} in dry years up to 140 m^3 s^{-1} in rainy years; mean annual average of 79 m^3 s^{-1}). It is therefore strongly influenced by seasonal fluctuations in river flow. The main pressures disturbing the Mondego's North arm mainly come from the facilities associated with the harbor at Figueira da Foz, specifically, dredging activities that cause physical disturbance of the bottom sediments. The South arm is shallower (2–4 m during high tide), with large areas of intertidal mudflats (almost 75% of the area) that are exposed during low tide (Neto et al., 2008). It is considered to be the richest area of the estuary in terms of productivity and biodiversity (Marques et al., 1993). According to Veríssimo et al. (in press), the upstream areas (oligo and mesohaline stretches) are essentially characterized by higher nutrients concentrations, coming from the Mondego River's catchment area, especially direct runoff from the 15,000 ha of cultivated land (mainly rice fields) in the lower river valley (Neto et al., 2008; Teixeira et al., 2008). The South arm is mainly distinguished by fine sediments and higher sediment organic matter content and, in general, the downstream stretches show higher values of salinity, dissolved oxygen and transparency (Veríssimo et al., in press). Pereira et al. (2005) determined the concentration of major (Al, Si, Ca, Mg, Fe), minor (Mn), and trace elements (Zn, Pb, Cr, Cu, Ag, Cd, Hg) and organochlorine compounds in 24 stations along the entire estuarine area and concluded that all sediment samples showed low levels of contamination reflecting the weak industrialization of the region. Even though, the higher incorporation of elements was registred in muds deposit in the inner part of the South arm.

In addition to the aforementioned disturbances, the estuary also supports industrial activities, salt-extraction, aquaculture farms, and seasonal tourism activities that are centered around Figueira da Foz.

2.2. Sampling strategy

In the summer of 2006, the subtidal soft-bottom assemblages (nematodes and macrofauna) were sampled at seven sampling stations (St4, St13, St18, St19, St21, St23, and St25), located along the North and South arms of the Mondego estuary (Fig. 1). The sampling stations were previously classified according to one of the five Venice salinity classes (Venice System, 1959): freshwater < 0.5 (St25), oligohaline 0.5–5 (St21 and St23), mesohaline >5–18 (St18 and St19), polyhaline >18–30 (no station), and euhaline >30 (St4 and St13), according to bottom salinity information.

2.2.1. Environmental data

Simultaneous with the sampling of the benthic invertebrates, the salinity, temperature (°C), pH, and dissolved oxygen (DO) (mg L^{-1}) of the bottom water were measured *in situ* using *a YSI* "*Professional plus*" field probe, and the Secchi depth recorded. Additionally, water samples were collected for measurement of nitrate (N–NO_3^-) (μmol L^{-1}) and nitrite (N–NO_2^-) (μmol L^{-1}), ammonium (N–NH_4^+) (μmol L^{-1}), and phosphate (P–PO_4^{3-}) (μmol L^{-1}) concentrations, and subsequently analyzed in the laboratory