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Meiobenthic communities in permanently open estuaries and open/closed coastal lagoons of Uruguay (Atlantic coast of South America)

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ABSTRACT

This study aimed to determine if estuarine meiofaunal communities of Uruguay (South America) vary between permanently open estuaries and open/closed coastal lagoons, or if they respond to the sediment composition. In Uruguay, estuaries and coastal lagoons vary in the degree of connectivity to the sea and in the sediment composition; sediments in estuaries are characterized by fine-medium sands but sediments vary from lagoon to lagoon (either fine-medium or coarse sand). Taxa richness (total = 16) showed less temporal variability in lagoons than in estuaries, due to patterns of presence/absence of the less abundant taxa. However, no major response to habitat was found in the most abundant groups: polychaetes (6% of total fauna) were on average 5% more abundant in lagoons than in estuaries. Some level of zonation, within estuaries and lagoons, was found in the most abundant groups, nematodes (63% of total fauna) and copepods (15%) in response to medium and fine sands. In addition, sediment type modulated seasonal patterns in the frequency of presence/absence in ostracods, polychaetes and oligochaetes. For instance, in polychaetes and ostracods the increase in the frequency of absences, occurring from summer to winter, was stronger in lagoons and estuaries dominated by fine sands. The lagoon habitat appears to ameliorate the effects of unfavourable (winter) conditions in less abundant meiofaunal taxa. In summary, sediment fractions explain spatial patterns in the average abundance of organisms (e.g. nematodes) as well as the seasonal changes in frequency of presence/absence (e.g. polychaetes).

1. Introduction

Estuaries are characterized by a high environmental heterogeneity, involving a complex association between environmental variables and biota (Roy et al., 2001; Alves et al., 2009). Benthic organisms are key components in estuaries as they play an important role in mass transfer to higher levels of the food web (Gray and Elliott, 2009). Spatial patterns of benthic organisms are typically heterogeneous as a consequence of the natural variation in the abiotic conditions of the habitat (Phillips and Fleeger, 1985). Many studies have investigated the effects of biotic and abiotic factors in structuring benthic estuarine communities, but have predominantly focused on the larger macrofauna as they are easily sampled and identified when compared to the smaller meiofauna (Hack et al., 2007).

The meiofauna represents an important component of benthic communities (Coull, 1999) and in estuaries is an important nexus between primary producers and higher trophic levels (Nozais et al., 2005). In addition bioturbation generated by meiofaunal activity can facilitate the oxygenation of the substrate, thus stimulating the activity of the microorganisms responsible for the remineralization of organic matter (Higgins and Thiel, 1988; Nozais et al., 2005). Given the trophic and bioturbating role of meiofauna, it is relevant to understand the responses of this group to environmental conditions in estuaries. At the scale of a single estuary, significant spatial heterogeneity in abundance and composition of subtidal meiobenthic communities has been associated with gradients of salinity, particle size and water nutrients (Alves et al., 2009; Tang et al., 2012). At the regional scale there is the open question of whether meiofauna distributional patterns vary among different types of estuaries. This is important because distributional patterns

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of benthic organisms can be scale-dependent in response to the scale-dependent nature of the variation in physical gradients and biotic interactions (Santos et al., 1996; Legendre et al., 1997; Sandulli and Pickney, 1999; Pinto and Bemvenuti, 2003; Steyaert et al., 2003; Thrush et al., 2005; Giménez et al., 2005, 2014).

Estuarine habitats can be categorized into several physiographic types such as coastal lagoons, estuaries and fjords (Nichols and Biggs, 1985; Kjerfve and Magill, 1989; Day et al., 2012). These habitats are characterized by different geomorphology and hydrology that may lead to important site to site variability in the composition and abundance of meiofauna. Coastal lagoons are shallow bodies of water, which remain temporarily closed from the ocean by a sandbar, while estuaries are permanently opened to the sea (Mitsch and Gosselink, 1993; Giller and Malmqvist, 1998). Open systems are characterized by higher salinity and lower temperature than intermittently closed estuaries (Lill et al., 2013) and estuarine meiofauna may respond according to species-specific patterns of tolerance to thermal or osmotic conditions. Alternatively, meiofauna responses may depend on life history. A reduction in macrofauna of marine origin or in fauna that depend on the sea to complete their development have been reported in estuarine systems that remain closed for long time (Dye and Barros, 2005a; McKay et al., 2010; Vivier et al., 2010). Since most meiofauna is of marine origin (Warwick, 1971), the degree of isolation might lead to important differences between assemblages from open/closed and permanently open estuarine systems. However, while the macrofaunal responses to estuarine habitat type are well known (Teske and Wooldridge, 2001, 2003; Giménez et al., 2005, 2014,; Dye and Barros, 2005a; Vivier et al., 2010), little is known about the responses of meiofauna.

Dye and Barros (2005b) found differences in structure and diversity of meiofauna assemblages between open and open/closed lakes of Australia, with opened lakes characterized by higher diversity of meiofauna and abundance of copepods, oligochaetes and turbellarians than closed lakes. Nevertheless, they did not find consistent responses to environmental variables that could explain the differences among lakes, so, hypothesized that isolation was the likely driving factor explaining the patterns. If isolation is important, then bar breaching in intermittently open/closed costal lagoons should lead to increases in abundance and richness. Bownes and Perissinotto (2012) studied the effect of bar breaching on the meiofaunal community at different sites of the St Lucia Estuary (South Africa) with consistent increases in meiofaunal density and richness in the inner shallow lake, where bar breaching increased salinity and depth. However, bar breaching led to a decrease in taxon richness at the mouth of the estuary showing a negative instead of a positive effect. Stronger negative effects of bar breaching were found in another South Africa estuary (Nozais et al., 2005) attributed to sand scouring. Thus, both disturbance and isolation may explain patterns of richness and abundance of meiofauna.

Studies explicitly evaluating the role of estuarine habitat type on meiofauna are challenging because they require sampling several estuarine sites, distributed over large spatial scales and using comparable sampling designs and devices. A major challenge is also the fact that such studies must address potential scale-dependent responses of the fauna to estuarine types: for instance, the response of fauna to estuarine type may occur at the scale of whole estuaries or may be restricted to specific zones. The Uruguayan coast, on the Atlantic coast of South America, offers the unique opportunity to test scale-dependent effects of estuarine habitat on meiofauna by comparing intermittently open/closed coastal lagoons with microtidal estuaries. In Uruguay, coastal lagoons are frequently breached and may be less isolated from the sea than lagoons in e.g. South Africa; in addition, this coast offers the opportunity to compare meiofauna from lagoons with those present in microtidal estuaries. Here, we report on the results of such comparison, based on sampling three open/closed coastal lagoons with three microtidal estuaries over several spatial scales. We therefore explicitly address potential scale-dependent responses to habitat type, considering whether responses to habitat may depend on estuarine zones or may occur at the scale of the whole estuarine sampled area. We also evaluated whether meiofaunal responded to key environmental variables (sediment composition, salinity and temperature). We applied techniques of generalized linear modelling considering the patchy distribution that characterizes meiofaunal species. We tested two hypotheses for patterns of meiofaunal distribution: (1) meiofauna responds to habitat (i.e. assemblages of lagoons differ from those of estuaries) either at the scale of whole estuarine sites or at the scale of zones within each estuarine site (defined as the outer zone, the inlet expose to open coastal waters, and the inner zone, more sheltered: Jorcín, 1999; Giménez et al., 2006, 2014); (2) meiofauna responds to sediment composition; thus, higher variation in the structure of assemblages is expected among lagoons than among estuaries. In the sampled sites, the sediment composition varied at the scale of lagoons, from fine to coarse sand, while all estuaries were characterized by medium to fine sand. At the temporal scales analyzed, temperature and salinity did not vary consistently between lagoons and estuaries, but varied mainly among sampling times reflecting seasonal patterns of the region (Giménez et al., 2014); we also tested if meiofauna responded to these variables.

2. Material and methods

2.1. Study area and sampling design

In 2008 we sampled six estuarine sites, three coastal lagoons and three estuaries at five times (January, April, May, July and October). All are located on the eastern Atlantic coast of Uruguay. The lagoons were: José Ignacio (34°50′ S, 54°40′ W), Garzón (34°48′ S, 54°34′ W) and Rocha (34°40′ S, 54°16′ W); the estuaries were: Solís Grande (34°47′ S, 55°23′ W), Maldonado (34°54′ S, 54°52′ W) and Valizas (34°20′ S, 53°47′ W) (Fig. 1).

An account of the main characteristics of the sampled sites is found in Giménez et al. (2014). Briefly, the lagoons are of the choked type (Conde et al., 2000), shallow and with a narrow entrance that is intermittently closed several times a year with the formation of a sandbar (Conde and Rodríguez-Gallego, 2002; Conde et al., 2003). The estuaries are also shallow and usually connected to the ocean all the year although the bar may close temporarily in exceptionally dry summers (unpubl. obs.). All sites are considered to have low anthropogenic impact (Defeo et al., 2009).

Within each site two zones were defined: the outer zone from the mouth of the estuary or lagoon to the line of dunes, and the inner zone from the dune field extending 1 km up estuary. This division responded to previous information suggesting that outer zones are characterized by sandy sediments and high hydrodynamic, while the inner zones, more sheltered, are dominated by muddy-sand sediments (Giménez et al., 2006). Both zones were located in the area where salinities range between 5 and 30. Each zone was divided into 20 transverse blocks, 50 m long and bounded by the margins of each estuary or lagoon. Three of these blocks were selected randomly prior to the first sampling event and three samples were taken within each block (total = 108 samples per sampling occasion). The approach of defining blocks within each zone responded to a considerable amount of information showing that benthic assemblages are characterized by small scale variation (Fraschetti et al., 2005).