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Is the vertical distribution of meiofauna similar in two contrasting microhabitats? A case study of a macrotidal sandy beach

T.F. Maria[a,*], M.G. Silva Filho[b], T.P. Souza[b], J. Vanaverbeke[c,d], A. Vanreusel[c], A.M. Esteves[b]

[a] Laboratório de Ecologia Bêntica, Departamento de Ecologia e Recursos Marinhos, Universidade Federal do Estado do Rio de Janeiro (UNIRIO), Rio de Janeiro, Brazil
[b] Laboratório de Meiofauna, Departamento de Zoologia, Universidade Federal de Pernambuco, Pernambuco, Brazil
[c] Department of Biology, Marine Biology Section, Ghent University, Ghent, Belgium
[d] Royal Belgian Institute of Natural Sciences, Operational Directorate Natural Environment (OD Nature), Marine Ecology and Management, Belgium

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ABSTRACT

Tides are an important forcing factor of macrotidal sandy beaches because they are directly responsible for the local morphodynamic conditions. Macrotidal beaches may harbor different microhabitats such as sandbars and runnels. We evaluated the influence of tides on the vertical distribution of meiofaunal organisms, particularly nematodes, in these two microhabitats at De Panne Beach, on the North Sea coast of Belgium. The 11 meiofaunal groups found were Acari, Amphipoda, Copepoda, Gastrotricha, Nematoda, Oligochaeta, Ostracoda, Polychaeta, Rotifera, Tardigrada and Turbellaria. The nematodes were identified to species level; the 147 species found included 112 in the sandbar and 117 in the runnel. Only turbellarians and nematodes migrated upward during low tide in the sandbar. The response of the nematodes was species-specific; during low tide, they migrated upward in the sandbar and downward toward deeper layers of the sediment in the runnel. These migration patterns were attributed to the feeding strategies in the sandbar (i.e. possible increase of diatom biomass in the surface layer due to high solar incidence), while environmental variables best explained the migration patterns in the runnel (i.e. preferred grain size and amount of total organic carbon). These results suggest a dissimilar vertical migration of the meiofauna over the tidal cycle in the two microhabitats. We attribute the vertical distribution of nematode species and some other meiofaunal groups to active migration toward preferred sites with more food or better environmental conditions. This study also indicated that other variables such as predation and competition, rather than the commonly studied physical variables should be included in future sampling designs of sandy-beach meiofauna assessments, since the environmental variables measured here could not fully explain the vertical distributions of the major meiofaunal groups or the community as a whole.

1. Introduction

Sandy beaches, which occur in almost all coastal zones in temperate and tropical areas, are among the most dynamic marine ecosystems (McLachlan and Turner, 1994). They are also one of the least-stable environments in the coastal zone because of wave-energy absorption (McLachlan and Brown, 2006). The morphodynamic state of sandy beaches is shaped by the action of waves and tides (Wright and Short, 1984; Masselink and Short, 1993), although tides have been considered as non-essential in regulating beach morphology (Davies, 1964).

Macrotidal ridge-and-runnel beaches have a wide and gently sloped intertidal zone and a nearshore zone with a low-energy wave climate (Masselink et al., 2006). Even though macrotidal beaches are morphologically stable, ultradissipative beaches tend to have intertidal sandbars intercalated with runnels (Masselink and Short, 1993). Sandbars are intertidal bars that are submerged by incoming tides and re-emerge as the water ebbs, while runnels remain submerged during the entire tidal cycle, accumulating organic matter, and therefore may be a stabler environment for sandy-beach organisms (Gingold et al., 2010). Although subject to different hydrodynamic conditions, these two microhabitats may not show consistent physical-chemical differences, e.g. grain size and pigment content (Maria et al., 2012). Ecological studies have largely neglected the fauna in runnels since they are thought to harbor a similar fauna to the subtidal area. This assumption is based on their constant submersion even during low tide, although recent studies have shown that this habitat harbors a different nematode community from the subtidal (Gingold et al., 2010; Maria et al., 2012).

In intertidal areas of coastal ecosystems such as sandy beaches and tidal flats, meiofaunal organisms migrate actively or passively in the

* Corresponding author.
E-mail address: tatiana_fabricio@yahoo.com.br (T.F. Maria).

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sediment over a tidal cycle (Boaden and Platt, 1971; McLachlan et al., 1977; Sherman and Coull, 1980; Steyaert et al., 2003; Maria et al., 2011) in response to the temporal variability of physical and chemical (e.g. water content, light intensity, temperature, oxygen levels, salinity) and biological conditions (e.g. prey movements and competition). Passive migration occurs when individuals are transported upward or downward due to the oscillation of the groundwater level (Sherman and Coull, 1980; Maria et al., 2012) in consequence of the rise and fall of tides. Meiofauna may actively migrate in response to several factors such as desiccation, oxygen availability and biological interactions. In this case, species can avoid harsh conditions such as high temperature or increasing salinity in the surface layers due to the decrease of water content, by migrating downward during low tide (Palmer, 1986) and returning to the surface when the interstitial environmental conditions improve (McLachlan et al., 1977; Steyaert et al., 2001). Other grazer species can migrate upward during low tide, responding to increased diatom production in the uppermost sediment (Steyaert et al., 2001); and finally, the migration patterns of some species follow those of their prey (Steyaert et al., 2001; Maria et al., 2012).

These factors suggest that vertical migration may occur when physical and biological features of the interstitial environment oscillate. In a macrotidal ridge-and-runnel beach, meiofaunal organisms are unlikely to migrate vertically in runnels because these microhabitats undergo subtler physical oscillations since they are always covered by water during tidal cycling; whereas meiofauna are likely to migrate in the sandbar. Therefore, the vertical distributions of higher meiofaunal taxa and nematode species will differ between these microhabitats. This study investigated the vertical distribution of the meiofaunal community (especially nematodes) in two contrasting sandy-beach microhabitats, sandbars and runnels, in order to determine if the meiofaunal communities of these two microhabitats show different vertical migration patterns over a tidal cycle. Because meiofauna individuals can redistribute themselves in the sediment over a tidal cycle (Boaden and Platt, 1971; McLachlan et al., 1977; Maria et al., 2011), our first hypothesis (H_1) was that the vertical profiles of higher meiofauna taxa would differ between the two microhabitats over the tidal cycle; and our second hypothesis (H_2) was that the vertical migration patterns of the nematode species would also differ between these microhabitats.

2. Material and methods

2.1. Study area

De Panne Beach is located in front of the nature reserve 'Westhoek Reservaat' (51°05′30″N, 02°34′01″E) on the coast of Belgium near the border with France (Fig. 1A). The beach is 4 km long and is an ultra-dissipative, semi-exposed sandy beach with a semi-diurnal macrotidal regime. The intertidal zone is approximately 440 m wide, with some runnels intercalated with several sandbars parallel to the waterline. The beach slope is about 1:90 to 1:100 and the mean spring and neap tide

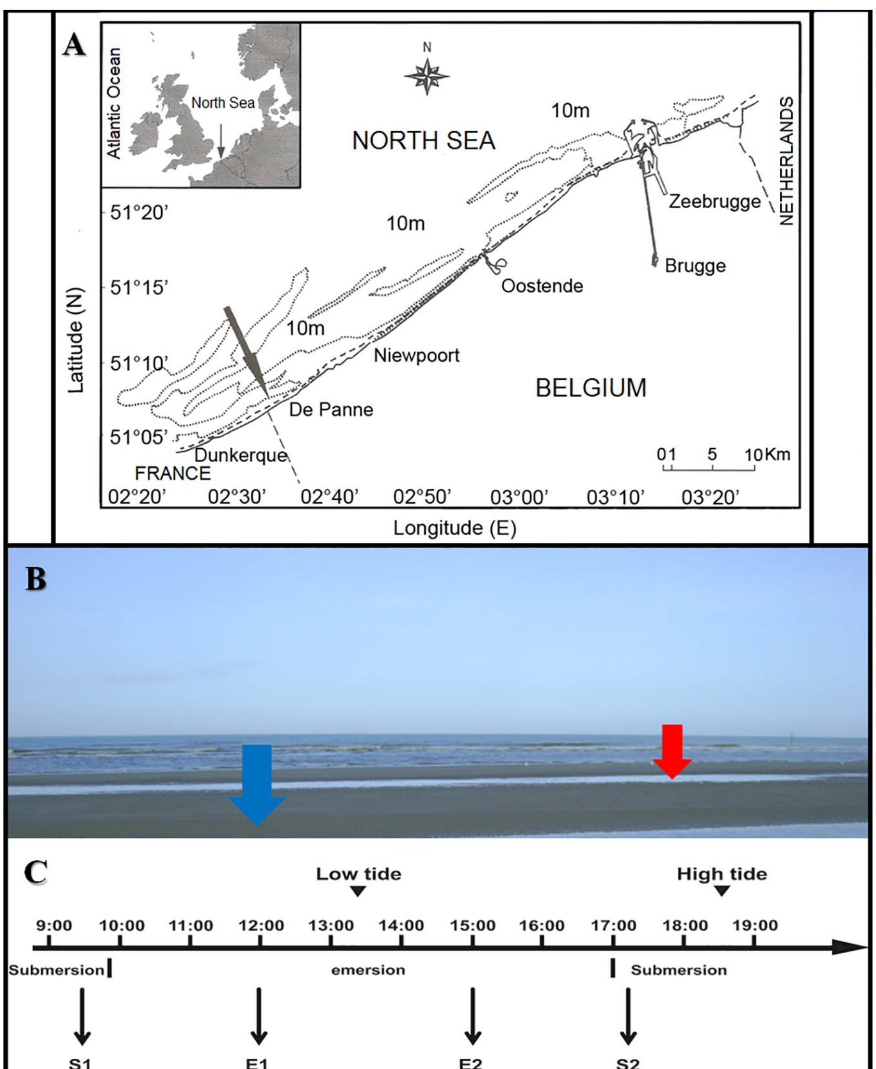

Fig. 1. A: Geographic localization of the studied beach on the Belgian Coast, sampling area is indicated by an arrow; B: De Panne beach and its microhabitats, which are indicated by arrows (red arrow: runnel, blue arrow: sandbar). C: Sampling strategy scheme showing the different times of sampling throughout the tidal cycle. S1 and S2: first and second high tide period, respectively; E1 and E2: first and second low tide period, respectively. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)