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Meiofauna and nematode community characteristics indicate ecological changes induced by geomorphic evolution: A case study on tidal creek systems

Yongfen Du[a,b,*], Shu Gao[c], Xiaoshou Liu[d], Dandan Wang[a,b], Longhui Zhang[a,b], Jeroen Ingels[e]

[a] School of Geographic and Oceanographic Sciences, Nanjing University, Nanjing 210023, China
[b] Key Laboratory of Coast and Island Development (Nanjing University), Ministry of Education, Nanjing 210023, China
[c] State Key Laboratory for Estuarine and Coastal Research, East China Normal University, Shanghai 200062, China
[d] College of Marine Life Sciences, Ocean University of China, Qingdao 266003, China
[e] Florida State University, Coastal and Marine Laboratory, 3618 Coastal Highway 98, St Teresa, 32358 FL, USA

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ABSTRACT

The meiofauna represent a highly informative faunal group for ecological evaluation in marine ecosystems, but few studies have investigated their spatial distribution patterns in tidal creeks. As an important component of the tidal flat, tidal creeks tend to have unique, contrasting habitats associated with erosion and accretion beds within a short distance of each other. The gradient represented by these habitats is expected to have consequences on the meiofauna and nematode communities. Based on sediment samples from two tidal creeks on a tidal flat covered with very fine-grained sediments, we show that there are distinct relationships between the benthic habitats, meiofauna/nematode communities and the erosion/accretion status of the tidal creek bed. Although there were no differences in sediment grain size between the eroding and accretion sides of the creek, higher sedimentary phaeopigment, total organic carbon and water contents were observed at the accreting side compared to the eroding side. The meiofauna exhibited a significant spatial variability between the two sides. The dominant taxon, nematodes, was more abundant on the accretion side, whilst copepods were more abundant on the erosion side of the creeks. The nematode/copepod ratio was in agreement with the observation that more pollutants and/or organic matter settled down on the accretion side. A total of 53 nematode genera were identified, belonging to 3 orders and 22 families. The prevalence of tolerant nematode genera such as *Desmodora, Sabatieria* and *Viscosia*, suggested that nematodes inhabiting highly dynamic environments are well adapted to the physical disturbance. Our results show that geomorphic evolution as implied by erosion/accretion patterns are reflected in the meiofauna and nematode communities and can be assessed using different community characteristics.

1. Introduction

Meiofauna, a collective term for one of the most diversified communities of the marine realm, include small organisms, unicellular protozoa and multicellular metazoans that live in aquatic sediments, encompassing 24 of the 35 animal phyla (Giere, 2009). Four of these taxonomic groups are particularly valuable in geosciences: nematodes, copepods, foraminifers and ostracods. The first two are generally the most abundant taxa and are widely used in modern ecological studies. Their unique ecological characteristics (i.e., high abundance and diversity, widespread distribution, rapid generation times, and high metabolic rates) make them excellent candidates to test various ecological hypotheses (Nascimento et al., 2012; Bonaglia et al., 2014) and provide the much-needed data that can provide the basis for environmental assessments (Kennedy and Jacoby, 1999; Austen and Widdicombe, 2006; Liu et al., 2015) and climate change response studies (Ingels et al., 2012; Zeppilli et al., 2015; Sweetman et al., 2017). The well-known ability of meiofauna to serve as bio-indicators has led to a number of studies investigating meiofauna responses to hydrodynamic processes, various types and intensities of physical and biogeochemical disturbances, and ecological changes in general. Much less attention has been given to the potential of meiofauna to serve as indicators of geomorphic processes and evolution, such as in tidal creeks for instance; and this despite our understanding that they play important roles in many sedimentary functions (Schratzberger and Ingels, 2017).

Tidal creeks form important geomorphological features over a tidal

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[*] Corresponding author at: School of Geographic and Oceanographic Sciences, Nanjing University, 163 Xianlin Road, Qixia district, Nanjing 210023, China.
E-mail address: duyongfen@nju.edu.cn (Y. Du).

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flat, the formation of which is caused by tidal force scouring, particularly during the late ebb and overflow periods of the flood phase (Zhang and Wang, 1991). In coastal wetlands, tidal creeks represent an effective circulatory system, through which water, sediment, organic matter, nutrients and pollutants are transported in and out throughout a tidal cycle (Fagherazzi and Furbish 2001; Wu and Gao, 2013). These circulatory processes affect the biogeochemical and geomorphic patterns which can influence resident benthos at different spatial and temporal scales (Vanaverbeke et al., 2002). Tidal creeks generate unique geomorphic features that influence environment-ecological dynamics on a relatively small spatial scale: at a bend of the creek, erosion takes place on one side but accretion occurs on the other; as a result, the two sides comprise different habitats, with transition from an eroding to an accretionary habitat occurring over a distance of only a few meters. Differences between the accretion and erosion sides are mainly caused by sediment heterogeneity differences and related sediment retention and biogeochemistry as well as the stabilizing role of benthic components such as the microphytobenthos, which all affect meiofauna community composition and biodiversity distribution (e.g. Du et al., 2012, 2014). The spatial heterogeneity in tidal creeks offer a natural laboratory, whereby meiofaunal community characteristics can serve as informative parameters that are relevant to geomorphic evolution.

Widdows and Brinsley (2002) reviewed the role of the benthic community in relation to sediment erosion/accretion, mainly referring to the macrofauna community and microphytobenthos rather than meiofauna. As a result of the accreting processes of the sediments, fine particles settle down, which results in the increase of organic matter flux (Gao et al., 2012, 2016a) or other materials (e.g., various pollutants, Gao et al., 2016b). For instance, Sutherland et al. (1998) found that sediment Chl-*a* (an important food source of meiofauna) content increased with the decrease of sediment erosion rate. These benthic processes may affect meiofaunal assemblages via (microbial) trophic relations (Du et al., 2014), environmental pollution (e.g., Warwick, 1988) or sediment composition (Boufahja et al., 2016). The fact that eroding and accreting processes occur on the scale of meters in tidal creek systems means the meiofauna assemblages are likely to show observable differences between erosion/accretion habitats since that is the scale on which meiofauna heterogeneity is generally expressed (Giere, 2009). Although a number of studies have investigated the role of meiofauna as indicators of processes occurring on these kind of spatial scales, little attention has been paid to meiofauna community characteristics in relation to small-scale geomorphic evolution (Alves et al., 2013; Zeppilli et al., 2015).

This study aims to investigate the differences in meiofaunal community abundance, structure, diversity, and trophic composition under contrasting conditions at either side of tidal creeks and the associated differences in sedimentary composition. The following hypotheses were tested: i) there is no difference in meiofauna community abundance, structure, diversity and trophic composition in response to different erosion/accretion conditions of tidal creeks; and ii) some meiofauna community characteristics can be used as indicators of tidal creek geomorphic evolution.

2. Material and methods

2.1. Sampling area and strategy

The field work was carried out at the tidal creek systems in the Luoyuan Bay (26° 18′–30′N, 119° 35′–50′ E), which is located on the northeastern Fujian coast off the East China Sea (Fig. 1). Luoyuan Bay is a typical semi-enclosed embayment, covering 230 km^2 (Editor Board of China's Coastal Embayment, 1994). The region is characterized by a subtropical maritime climate, and a regular semi-diurnal tide. The average flood and ebb durations of the tide are 6.35 h and 6.07 h, respectively, with an average tidal range of 4.98 m. The currents within the bay are influenced mainly by the bathymetry/topography. On the southern and southwestern sides of the Luoyuan Bay lies a larger, well-developed area of tidal mudflats where the intertidal zone is 2–5 km wide, with a gentle tidal flat slope ($<$ 0.1%). Tidal creeks here are well developed, and the bottom sediments are mainly composed of clay and very fine silt which originate from the Yangtze River and a number of small rivers discharging into Zhejiang-Fujian coastal waters. The river-induced fine-grained sediments are transported by the shelf currents towards the study area (Editor Board of China's Coastal Embayment, 1994).

In order to identify the meiofauna communities under contrasting sedimentary conditions (i.e., erosion *vs* accretion conditions), two tidal creeks were selected as study sites. We chose a newly-formed tidal creek situated nearby the Fuxi village (FX, 26° 26.28′N, 119° 40.27′ E) with a width of approximately 2 m at low tide. The other tidal creek was older and situated at the Chishi village (CS, 26° 24.91′N, 119° 40.71′E) with a width of about 5 m at the low tide. Concave and convex banks were well developed in the two creeks. On each side of these tidal creeks, the top 4 cm of the sediment bed was collected for the analysis of meiofauna/nematode communities as well as the sedimentary characteristics (Fig. 1). Sampling was carried out during ebb on the 14th and 15th of January 2012, respectively. Eight randomly selected replicate sediment samples (32 in total) were taken at each side of the tidal creek using a modified syringe (30 mm inner diameter). Sediment was carefully extruded from the syringes. At each site 4 cores were stored in plastic bottles and fixed immediately with 10% buffered formalin solution for meiofaunal analysis. The other four cores were frozen in black plastic bags for grain size, total organic carbon (TOC), water content (WC), chlorophyll a (Chl-*a*) and phaeopigments (Phae) analyses.

2.2. Laboratory analyses

2.2.1. Measurements of environmental parameters

Organic carbon was determined using the loss on ignition (LOS) method (Dean, 1974; Heiri et al., 2001), which is based on the difference between the dry weight of each sample after oven-drying at 60 °C for 72 h and the weight obtained after combustion at 550 °C for 2 h, and expressed as percentage of the total weight. Water content of the sediment was determined as the percentage weight loss after drying the sediment at 60 °C for at least 72 h. Chlorophyll pigments were extracted from the frozen sample (approximately 2 g) using acetone. After storing in the fridge (4 °C, 24 h) and centrifugation (4000 rpm, 15 min), the supernatant was collected and measured using spectrophotometry (Environmental Sciences Section, ESS method 150.1, 1991), while the correction factor of Wang (1986) was used for the calculation of Phae content. The Chl-*a* and Phae contents were expressed in μg pigment mg^{-1} sediment. Sediment particle distribution was obtained using a Laser Diffraction Particle Size Analyzer (Mastersizer 2000, manufactured by the Malvern Instruments Limited, England), where 1–2 g of sediment sample was used and the relative error of repeated measurements was less than 3% (Cheng et al., 2001).

2.2.2. Analyses of meiofauna and nematodes

A density gradient centrifugation in colloidal silica was used for meiofauna extraction (Giere, 2009) modified following Du et al. (2009). Briefly, the formalin-fixed sediment samples were stained (1% Rose Bengal solution), and rinsed on a 500 μm mesh sieve stacked on a 31 μm mesh. All the residues on the 31 μm mesh were collected and centrifuged three times (900 × g, 5 min) with Ludox HS-40 (specific gravity 1.15; Aldrich Chemical Company). The collective supernatant was rinsed on a 45 μm and 31 μm sieve, and washed into a gridded Petri dish before identification. Following Higgins and Thiel (1988), meiofaunal individuals were sorted at higher taxon level and counted under a stereomicroscope (40× magnification). The meiofaunal abundance was expressed as ind.10 cm^{-2}. The total number of nematode and copepod individuals were used to calculate the Nematode/Copepod (N/C) ratio, which was analyzed according to the Raffaelli and Mason (1981)