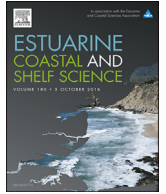




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Structure of mangrove meiofaunal assemblages associated with local sediment conditions in subtropical eastern australia

Maizah M. Abdullah ^{a, b, *}, S.Y. Lee ^a^a Australian Rivers Institute & School of Environment, Griffith University Gold Coast Campus, Queensland 4222, Australia^b School of Marine Science and Environment, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia

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ABSTRACT

Meiofauna are ubiquitous but poorly-studied components of soft-bottom marine habitats around the world, including mangroves. The dynamic environmental conditions and heterogeneous sediments of mangroves present challenges to understanding the structure of mangrove meiofaunal assemblages at various spatial and temporal scales. In this study, we investigated the meiofaunal assemblage structure of sediments colonised by three mangrove species, namely, *Avicennia marina*, *Rhizophora stylosa* and *Aegiceras corniculatum*, at three locations in subtropical eastern Australia. Spatial and temporal variations were tested by sampling at the three mangrove locations (i.e. Tallebudgera, Currumbin and Terranora) in autumn, with samplings repeated at Tallebudgera at two other times broadly representing during dry/cool winter and wet/hot summer seasons. We examined the variability of the sediment environments within each of the different mangrove species, and investigated how meiofaunal assemblages would respond to the particular changes in their habitats to result in differences in assemblage structure between and within sites. Total meiofaunal density was highest in Tallebudgera and Currumbin and lowest in Terranora (mean density of 424, 393 and 239 ind.10 cm⁻², respectively). In Tallebudgera, the density was higher in winter and summer (mean density of 546 and 530 ind.10 cm⁻², respectively). The meiofaunal assemblage in this study shows a trend and association with the environmental variables. High availability of food proxies such phaeopigments, Chl *a* or TOC, with moderate tannin content and appropriate habitat structure (sediment particle size, belowground root biomass and/or moisture content provide the best condition for the meiofauna to achieve the highest density. However, given the complex dynamic habitats and the spatial heterogeneity of the mangrove environments across different locations and seasons, no clear generalization could be made regarding the key environmental variables that predominantly shape the meiofaunal assemblages' structure.

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1. Introduction

Meiofauna are ubiquitous in soft-sediment marine environments and contribute significantly to ecosystem functioning (Montagna, 1984; Coull, 1999; Wołowicz et al., 2011; Nascimento et al., 2012). Despite their abundance and ubiquity, detailed knowledge of the taxonomy, biology and interactions of the meiofauna, and their role in the functioning of mangrove ecosystems, is lacking (Nagelkerken et al., 2008). The close association of meiofauna with the sediment matrix in their habitat means that

any changes in interstitial chemistry are expected to result in fast response in the meiofaunal assemblage, suggesting significant potential of the use of meiofauna in assessing anthropogenic impacts (Kennedy and Jacoby, 1999). In addition, meiofauna spend their whole lifetime within these habitats and have limited motility. Another major contributing factor is the short life-span of meiofaunal taxa, which means that population, and thus assemblage, fluctuations can be temporally significant, with very fast response towards change in local environmental conditions. The meiofauna may therefore act as good temporal indicators of sediment conditions in soft-sediment habitats such as estuaries.

Estuarine sediments are highly diverse in their physico-chemical properties as well as temporally dynamic. One of the important features characterising tropical estuarine sediments is

* Corresponding author. School of Marine Science and Environment, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia.

E-mail address: maizah@umt.edu.my (M.M. Abdullah).

the soluble and condensed tannins leached from mangrove roots and litter, produced by the trees for chemical defence against herbivores, which impregnate the sediment (Alongi, 2009). Tannins have long been proposed to have a negative effect on the meiofauna (Alongi, 1987a, b). However, the variability of the tannin content in mangrove habitats, and its implications for the meiofauna is largely unknown. Besides, the aboveground structures of different mangrove species shape the heterogeneity or complexity of the habitat, with implications for both physical (e.g. degree of shading) and biotic (e.g. predator abundance) conditions. While this heterogeneity and the resulting conditions are poorly known (Kamal et al., 2014), they probably influence the structure of the animal assemblage including the meiofauna. Such feedback between mangrove species and their associated fauna has been demonstrated for sesarmid crabs (Lee and Kwok, 2002).

While the belowground roots also contribute to the heterogeneity of the habitat for infauna, this aspect of mangrove habitat complexity is even less studied. Little is known about how belowground mangrove roots may influence the meiofauna (Sahoo et al., 2013). For example, fine roots may either exert a negative impact by occupying space in the meiofaunal habitat, but also may provide micro-habitats or support meiofauna trophically through the provision of organic exudates. Also, different mangrove roots help aerate the sediment at various levels, resulting in different sulphide concentrations among sediments colonised by co-occurring species (McKee et al., 1988; Kryger and Lee, 1996). Estuarine macrofauna such as crabs may also shape meiofaunal assemblages through physical, e.g. bioturbation, or trophic interactions (Abdullah and Lee, 2016).

While the interactions between biological and physical characteristics of mangrove sediments is vital to the function of these complex habitats, how meiofaunal assemblage structure is related to environmental conditions at various spatial scales is still obscure. The fact that different mangrove plants have different environmental niches, and affect their surroundings differently, makes it difficult to assess the extent tree diversity influences meiofaunal diversity (Nagelkerken et al., 2008). Nevertheless, data on some macrofaunal groups suggest a positive correlation between tree and faunal species richness (Lee, 2008). Most of the previous studies on mangrove-associated meiofauna generally focused on their vertical distribution (e.g. Vanhove et al., 1992; Somerfield et al., 1998; Sahoo et al., 2013) or the broad environmental gradients influencing generic meiofaunal distributions, such as tidal height, salinity, oxygen availability, and sediment properties such as organic content and granulometry (Somerfield et al., 1998; Coull, 1999; Tolhurst et al., 2010). A few studies focused on more specific variables such as the effects of mangrove leaf litter and pneumatophores on meiofaunal assemblages (Gwyther, 2003; Gwyther and Fairweather, 2005).

In this study, we investigated meiofaunal assemblage structure of sediments colonised by three mangrove species, namely, *Avicennia marina*, *Rhizophora stylosa* and *Aegiceras corniculatum*, at three locations in subtropical eastern Australia. This study aimed to examine the variability of the sedimentary environments within each forests of the different mangrove species, and to see how meiofaunal assemblages might respond to potential environmental drivers at different scales. The environmental variables were chosen based on the hypothesis that these variables may influence the meiofauna in different ways, i.e. those acting as proxies for food availability (phaeopigments, Chl α , and TOC), habitat structure (sediment particle size, belowground root biomass, and moisture) and also deterrents (tannin content). We predict that meiofaunal assemblages would respond to differences in the environmental variables associated with different mangrove species across different locations and seasons.

2. Materials and methods

2.1. Study area

Our study comprised three mangrove locations (Fig. 1): Tallebudgera Creek (28° 6'30.77"S 153°26'48.13"E) and Currumbin Creek (28° 7'51.39"S 153°28'44.92"E) located in Southeast Queensland, and Terranora (28°13'28.38"S 153°30'32.58"E) in northern New South Wales. This region of Australia has typical hot wet summers (December–February) and cool dry winters (June–August) with transitional conditions in autumn (March–May) and spring (September–November). The two locations in Queensland are on the southern Gold Coast and have been gazetted as Fish Habitat Area (FHA) by the Queensland government. The creeks flow directly into the Coral Sea of the South Pacific Ocean, have low sediment trapping efficiency and low sedimentation rates. There are several distinct mangrove vegetation zones as described by Shine et al. (1973), including *Avicennia marina* and *Rhizophora stylosa* zones located at the low intertidal areas, and the *Aegiceras corniculatum* zone located at the high intertidal area. Mangroves on Currumbin Creek are located at the low estuary and are also dominated by *A. marina*, *R. stylosa* and *A. corniculatum*.

The Terranora mangrove fringes Terranora Broadwater, located in the northeast of New South Wales, adjacent to the Queensland border. The Broadwater is a shallow estuarine lake of approximately 0.5–1.5 m depth and acts as the receiving waters for the freshwater catchment that discharges into Terranora Creek. It is influenced by tidal flow coming from the Tweed River estuary and freshwater inputs from the western sub-catchments from Bilambil and Duroby Creeks. *A. marina* is the dominant species, with lesser occurrences of *R. stylosa* and *A. corniculatum* near to the mudflats bordering the Broadwater.

2.2. Field sampling

The boundaries of the mesh sizes used were 500 μm and 62 μm as upper and lower limits, respectively. Field samplings for the environmental variables and the meiofauna samples were divided into two approaches: Firstly, to measure the spatial variation of the meiofauna and the environmental variables associated with different mangrove stands (*A. marina*, *R. stylosa* and *A. corniculatum*) from the three locations (Tallebudgera, Currumbin and Terranora). These locations were used as replicates of individual mangrove species. The samplings at all three locations were performed in one season (autumn, May 2014). Secondly, temporal variations of the meiofaunal assemblages associated with the three mangrove species were measured by repetitive samplings in autumn, winter, and summer (May 2014, July 2014 and January 2015, respectively) at one location, i.e. Tallebudgera.

Nine replicate cores ($n = 9$) of mangrove soil samples were taken randomly at each mangrove site with a cut syringe tube (internal diameter 2.67 cm). Sediment samples were collected within the aerial root zones of the *A. marina* and *R. stylosa* mangroves to reflect species-specific soil conditions down to 5 cm in depth. Meanwhile, sediment samples for the *A. corniculatum* mangrove (which does not have aerial roots) were collected within the shades of the tree. The same soil cores were used for meiofauna and root biomass analysis, to represent the biomass of the belowground roots inhabited by the meiofauna within the same sediment. At the sites with thicker fibrous roots such as within the *R. stylosa* mangrove, the syringe was pushed with the foot into deeper sediment to make sure that it did not under-sample, and the required length (5 cm) of the cored sediments were collected. Additional soil cores ($n = 9$) were collected for analysis of tannin, moisture and total organic contents, and for particle size analysis

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