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Potential impact of mangrove clearance on biomass and biomass size spectra of nematode along the Sudanese Red Sea coast

Rasha Adam Osman Sabeel [a, b, *], Ann Vanreusel [a]

[a] Ghent University, Marine Biology Research Group, Krijgslaan 281/S8, 9000 Ghent, Belgium
[b] University of Bahri, Department of Fisheries, P.O. Box: 1660/11111, Khartoum, Sudan

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ABSTRACT

The potential effect of mangrove clearance on nematode assemblage biomass, biomass size spectra (NBSS) and abundance/biomass curves (ABC) was investigated in three sites representing a varying degree of mangrove clearance as well as in three stations established at each sites representing high-, mid- and low-water levels. Results revealed significant differences in sediment and nematode characteristics between the three sites. Although both the cleared and the intact mangrove had comparable biomass values, clear differences in biomass size spectra and abundance biomass curves were observed. The results suggested that the variation in the silt fraction and the food quality positively affected the total biomass. Mangrove clearance has caused a shift from a unimodal to a bimodal biomass size spectrum at all water levels, owing to an increase in smaller-bodied opportunistic non-selective deposit feeding nematodes. The ABC further confirmed the effect of clearance by classifying the cleared mangrove as moderately to grossly disturbed.

1. Introduction

Mangrove forests constitute 0.7% of tropical forest area (Giri et al., 2011). They are ecologically important as they provide a habitat for a rich biodiversity (Nagelkerken et al., 2008). However, during the past century they experienced massive destruction from natural disturbance including cyclones and other storms, lightning, tsunami and floods; and human disturbance such as wood harvesting, trees felling, aquaculture, and pollution. The estimated world's original mangrove forest is less than half of what it once was (Spalding et al., 2010), primarily due to human disturbance (Field, 1999).

As pristine habitat, mangroves are generally considered as well-structured ecosystems inhabited by species representing a wide range of ecological strategies. When disturbed, a deviation from balanced conditions and pronounced changes in the ecosystem usually may occur. A variety of human disturbances, notably clearing of mangrove for agriculture, aquaculture, and urban and costal development (Alongi, 2002; Giri et al., 2008), can devastate and profoundly affect mangroves, by changing the average environmental conditions and eventually altering the associated faunal and floral communities. Consequently they reduce mangrove habitat complexity (Dye, 2006) and diminish their values as a provider of a number of ecosystem services such as feeding and nursery habitats for benthic fauna and fish, maintaining biodiversity, carbon export/sequestration, recycling nutrients, filtering pollutants, and assimilating waste (Barbier et al., 2011; Lee et al., 2014).

Meiofauna represent an important component of the benthic ecosystem. They play an important role in ecosystem processes, by stimulating organic matter degradation and nutrients recycling (Austen, 2004), by linking the smaller (e.g. bacteria) and larger organisms (e.g. macrofauna) in the marine benthic food web (Moens et al., 2005; Danovaro et al., 2007; Giere, 2009). Their unique particularity being small in size, highly diverse, with high turnover rates, and the absence of larval dispersion (Heip et al., 1985; Higgins and Thiel, 1988) allowed for their use as biological indicator of anthropogenic disturbance (Heip et al., 1988; Warwick, 1988; Moreno et al., 2008a). Nematodes in particular are more sensitive and able to respond rapidly to disturbances of varied nature, frequency and quantity (Schratzberger and Warwick, 1998, 1999) making them a useful tool to detect changes in marine sediments. They have been used as an early indicator of the changing environmental conditions reflecting the effects created by natural or anthropogenic disturbance, (e.g. Schratzberger et al., 2004; Steyaert et al., 2007; Moreno et al., 2008b; Liu et al., 2011) and to

* Corresponding author. Ghent University, Marine Biology Research Group, Krijgslaan 281/S8, 9000 Ghent, Belgium.
E-mail address: rasha.sabeel@ugent.be (R.A.O. Sabeel).

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assess the overall system quality (e.g. Marin et al. 2008; Moreno et al., 2011; Alves et al., 2013; Semprucci et al., 2013).

In addition to a number of taxonomic and trait-based indices such as taxonomic diversity, maturity index and trophic diversity (e.g. Bongers et al. 1991; Heip et al. 1985), also non-taxonomic approaches such as comparison of abundance-biomass curves (ABC) and the biomass size spectra (NBSS) were developed to study the structural and functional response of nematodes to changes in their environment. The later have especially been presented as advantageous over other methods and are widely used to describe the structure of marine ecosystems (Schwinghamer, 1981, 1983, 1985; Warwick, 1984; Vanreusel et al., 1995; Drgas et al., 1998; Vanaverbeke et al., 2003). Many authors have often tested whether or not the benthic size spectrum conformed to a bimodal pattern, while they attempted to explain these patterns found in different systems (Schwinghamer, 1981; Warwick, 1984; Drgas et al., 1998; Duplisea, 2000). NBSS are highly recommended for monitoring changes to habitats due to anthropogenic activities particularly because of their relation to metabolism and energy transfer through the community and their relative simplicity (Turnbull et al., 2014).

The ABC method is based on the comparison of abundance and biomass distributions of the present species in a sample (Warwick, 1986; Warwick et al., 1987), and may illustrate the differential performance of those distributions in response to specific environmental conditions (Warwick, 1986; McManus and Pauly, 1990; Meire and Dereu, 1990; Warwick and Clarke, 1994). Therefore, this method may allow identifying to what extent communities are affected by disturbances. With increasing disturbance, slow-growing species cannot cope with the change, and the system is increasingly dominated by r-selected species (fast-growing, small, opportunistic). Consequently the biomass curve will be lower than the abundance curve. An advantage of the method is that it does not require a spatial or temporal control against which to compare the index (Clarke and Warwick, 1994).

Despite the potential ecological importance of Sudanese mangrove, they face a number of threats including, but not limited to, mangrove clearing. In addition to the limited information on their ecology, there is a lack of understanding on how specific activities such as clearing can impact these ecosystems. By relating nematode biomass structure, functional attributes and environmental variables, valuable information on the conditions of the ecosystem regarding disturbance can be drawn.

This study focused on answering two specific questions: (i) what is the effect of mangrove clearance on the pattern of nematode biomass and biomass size spectra?, and (ii) weather the aforementioned nematode characteristics can potentially be a good tool for detecting human impact on mangrove, in particular, mangrove clearance? The main aim was to address our limited understanding of the influence of mangrove clearance on the ecological quality of the mangrove habitats by assessing the environmental quality of different sites representing varying degree of mangrove clearance (i.e. intact mangrove, cleared mangrove and bare sand flat) located along Sudanese Red Sea coast.

The specific aims were to:

1. Examine the patterns of nematode biomass and NBSS under varying degree of mangrove clearance:
2. Compare biomass and abundance patterns for nematode genera
3. Evaluate the relationships between sediment properties and patterns in nematode biomass.

The hypotheses tested are that (i) nematode biomass, size spectra, and distribution of abundance and biomass do not show differences between and within sites with different environmental quality and (ii) there is no relation between the aforementioned nematode characteristics and the observed patterns in sediment features. The resulting assessment will be useful for detecting the ecological change using nematode biomass as a descriptor of anthropogenic disturbance (clearance) on mangrove ecosystems.

2. Material and methods

2.1. Study site

The study was performed at the southern part of the Sudanese coastal line. The area is characterized by a semi-arid climate with a mean daily temperature of 29 °C in winter and 42 °C in summer. Annual rainfall averaged 164 mm and tides are unusual with a mean spring tide of 0.1 m. Three sites representing varying degree of mangrove clearance were sampled for nematodes at 3 water levels (Fig. 1a). The granulometric properties of the sediment measured in all sites and water levels are shown in Table S1 and discussed in detailed in Sabeel et al. (2014). Site 1 is a bare sand flat, characterized by a high sand content (57–80%), larger median grain size (87–119 μm), and moderately to very poorly sorted sediment. Site 2 is recently cleared from mangrove trees (3–5 years before sampling event). The sediment has a sand content of 12–77%, a median grain size between 19 and 138 μm, and poorly to very poorly sorted sediment. Site 3 is an intact mangrove, with *Avicennia marina* stands. It has a high mud content (37–82%), a finer median grain size (23–125 μm), and very poorly sorted sediment. Distance between site 1 & 2 is about 1.2 km, while the distance between site 2 & 3 is about 10 km. To determine the effect of mangrove clearance on nematode in relation to water level, three stations corresponding to different water levels were established at each site parallel to each other along a water level gradient of about 100 m length (Fig. 1b). These stations were referred to as: (i) high-water (HW), which is just below the water line mark during the high-water level; (ii) mid-water (MW) without mangrove stand in the bare sand flat habitat, with remnants of mangrove trunks in the cleared mangrove habitat, and with mangrove stands in the mangrove habitat; and (iii) low-water (LW), which is just above the water line mark at lower water level. The distance from the higher water mark to the lower water mark at each water level zone i.e. the high-, mid- and low-water levels is 40 m, 45 m and 15 m respectively (Fig. 1b). Sites were chosen based on the topographic similarity to facilitate the comparsion of the sediment and faunistic characteristics between sites.

2.2. Sampling and sample processing

In each water level at each site three sediment samples to a depth of 5 cm were collected using cylindrical hand corers (5.64 cm, 25 cm^2 surface area). The complete sediment columns were immediately fixed in 4% neutral formaldehyde filtered seawater solution. Nematodes were extracted from the sediment by centrifugation with Ludox (Heip et al., 1985). All nematodes retained by a 32 μm sieve were stained with Rose Bengal of 1% concentration. At each water level 3 additional core samples were taken for granulometry. Detailed description of the collection and the analysis procedures of the environmental data are presented in Sabeel et al. (2014).

Nematodes were sorted and identified to genus level at high magnification under a binocular stereomicroscope (Leica DLMB, magnification 100×) and a compound microscopes (1000× magnification) using the pictorial key to nematode genera (Warwick et al., 1998), and the NeMys online identification key (Deprez et al., 2005). The abundance of nematodes was determined by counting all nematodes in each samples and converted to