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Heavy metal accumulation in *Littoraria scabra* along polluted and pristine mangrove areas of Tanzania

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Anthropogenic activities result in heavy metal accumulation and adverse morphological effects in the mangrove gastropod Littoraria scabra.

Abstract

The periwinkle *Littoraria scabra* was collected at polluted and pristine mangrove sites along the Tanzanian coastline, including Msimbazi, Mbweni (i.e. Dar es Salaam) and Kisakasaka, Nyamanzi and Maruhubi (i.e. Zanzibar). Periwinkles were morphologically characterized, sexed and their heavy metal content was determined using ICP-MS. Analysis revealed that *L. scabra* from polluted areas contained higher soft tissue heavy metal levels, were significantly smaller and weighed less compared to their conspecifics from the unpolluted mangroves. The current morphological observations may be explained in terms of growth and/or mortality rate differences between the polluted and non-polluted sites. Although a variety of stressors may account for these adverse morphological patterns, our data suggest a close relationship with the soft tissue heavy metal content. Compared to soft tissue heavy metal levels that were measured in *L. scabra* along the same area in 1998, most metals, except for arsenic, chromium and iron have decreased dramatically.

Keywords: Dar es Salaam; Heavy metals; *Littoraria scabra*; Mangrove; Zanzibar

1. Introduction

Intense anthropogenic activities have recently led to the contamination of marine ecosystems (e.g. Langston, 1990; De Kock and Kramer, 1994; Galloway et al., 2002). The occurrence of pollutants in excess of natural loads has become a problem of increasing concern. Indeed, the development of coastal zones throughout the world has put immense pressures on biological communities that inhabit these areas (e.g. Ferletta et al., 1996; Temu, 2001). In Africa this situation has arisen as a result of rapid population growth, increased urbanisation, expansion of industrial activities, exploration and exploitation of natural resources, extension of irrigation and lack of financial resources and environmental regulations (e.g. Mwaguni and Munga, 1997; Temu, 2001).

For instance, Tanzania, a developing country on the Western Coast of the Indian Ocean, is experiencing increasing impacts of environmental degradation due to an increased urbanisation and industrialization (e.g. Semesi, 1992; Silima et al., 1994; Mgana and Mahongo, 1997). Its population density and level of industrial activities have markedly increased during the past three decades, converting vast open, once pristine forests and ecosystems into residential or industrial areas (Machiwa, 1992). The latter has resulted in an uncontrolled disposal of domestic and industrial wastes (Machiwa, 1992). Msimbazi river, located in Dar es Salaam, receives for instance untreated wastes from industrial and anthropogenic effluents with average effluent rates of 256 m^3/h with peak values of 606 m^3/h (Ak'habuhaya and Lodenius, 1988; Mgana and Mahongo, 1997). All pollutants such as PAHs, PCBs and heavy metals are taken by the river and accumulate

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in the coastal and mangrove sediments where they pose a threat to the intertidal communities (e.g. Van Brugen, 1990; Machiwa, 1992). The Western Indian Ocean Marine Science Association (WIOMSA) surveys have shown that coastal waters in all major coastal town and cities in Tanzania and the island of Zanzibar are polluted (Van Brugen, 1990; Machiwa, 1992; Ferletta et al., 1996; Engdahl et al., 1998).

Mangrove sediments have been shown to have a high capacity to accumulate materials discharged to the near shore marine environment (Harbison, 1986). This is mainly due to the anaerobic as well as rich sulphide and organic matter content that favours the retention of water-borne heavy metals. Subsequent oxidation of sulphides between tides mobilizes the previously trapped metals, increasing their bioavailability (e.g. Silva et al., 1990; Clark et al., 1998; Tam and Wong, 2000). As a result elevated concentrations of heavy metals have been recorded in mangrove sediments, which often reflect the long-term pollution caused by human activities (e.g. Lacerda et al., 1992; Perdomo et al., 1999; Harris and Santos, 2000; Tam and Wong, 2000; MacFarlane, 2002; Preda and Cox, 2002).

Despite efforts undertaken to evaluate pollution levels in and around Dar es Salaam and the East African coastline in general, very few studies have considered the accumulation of pollutants in and the effect they have on the local marine fauna and flora. Recently, De Wolf et al. (2001) have measured heavy metals in the soft tissue of the gastropod *Littoraria scabra* along the mangroves of Dar es Salaam. The authors showed that this gastropod accumulated considerable amounts of heavy metals, reflecting the pollution sources in the study area. Against this background we want to re-assess the soft tissue heavy metal content in *L. scabra* along the mangroves of Dar es Salaam and Zanzibar and compare the current metal levels with those that were published in 2001 (De Wolf et al., 2001). In addition we want to investigate the shell morphology of *L. scabra* and assess potential environmental related adverse morphological effects.

2. Material and methods

L. scabra samples were taken between 10/09/2005 and 12/09/2005 at polluted (i.e. Msimbazi, Maruhubi) and relatively pristine mangrove areas (i.e. Mbweni, Kisakasaka, Nyamanzi) (i.e. Ak'habuhaya and Lodenius, 1988; Machiwa, 1992; Basha and Kombo, 1994; Mgana and Mahongo, 1997; Mohammed, 1997; Sesabo et al., 2006) along the coastline of Dar es Salaam and Zanzibar (Fig. 1). From each site 20 specimens were morphologically characterized. Shell height (HS) and width (WS) were measured to the nearest 0.05 mm using calipers, while the total weight (TW) and soft tissues body weight (BW) were determined to the nearest 0.01 mg. The shells of the periwinkles were subsequently broken and the sex was determined based on the presence/absence of a penis using a binocular microscope. Individual soft tissue samples were digested in a microwave oven, adding a mixture (5:1) of nitric acid (70%) and peroxic acid (30%). The digested samples were stored at 4 °C until further analysis. Aluminium, arsenic, cadmium, chromium, copper, iron, manganese, lead and zinc were measured in the soft tissue samples by means of inductively coupled plasma mass spectroscopy (ICP-MS), using a Varian spectrophotometer. Analytical efficiency was checked using standard reference material (*Mytilus edulis*, CRM 278R), digested and analysed in the same way as the soft tissue samples. Recovery percentages are given in Table 2.

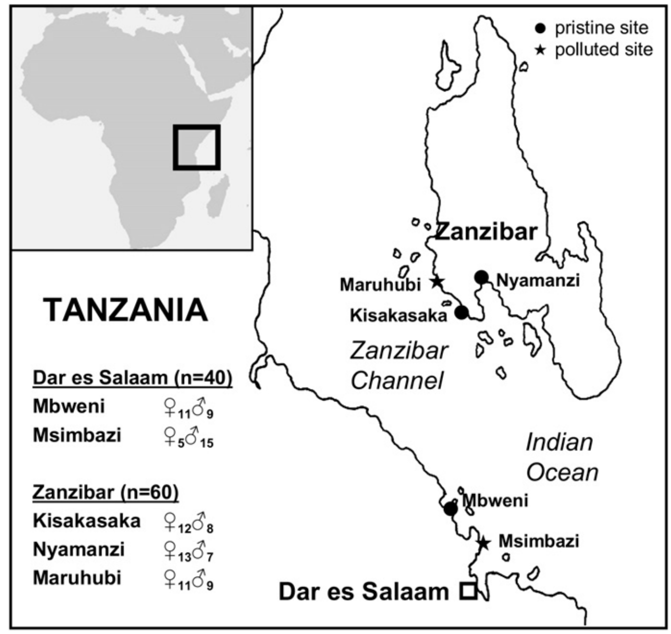

Fig. 1. Sampling area and sampling sites.

The morphometric characteristics (i.e. TW, BW, HS, WS) were analysed by means of a two way multivariate analysis of variance (2-MANOVA), comparing the fixed factor sex and the random factor site and subsequent post hoc sheffé tests. Because of the unbalanced nature of the design (i.e. factor "sex", Fig. 1), the type III SS was considered. Means and standard deviations of the morphological data set were used to plot the different sites. Interpopulational differences in metal content, expressed as μg/g dry weight were analysed using individual two way analysis of variance (2-ANOVA) tests, contrasting the fixed factor sex and the random factor site. Mean values and standard deviations were plotted and graphically compared to the metal data obtained from 1998 (De Wolf et al., 2001).

Finally, the morphological and metal data sets were combined in a canonical discriminant analysis (CDA). The mean values of the first two canonical roots were subsequently used to plot the study sites in a 2-dimensional graph. The dependent variables that were responsible for the observed patterning among the sites were superimposed as vectors on the 2-dimensional CDA plot. All statistical analyses were performed using the software package, Statistica v. 5.0 and a significance level of 5% was used throughout.

3. Results

The results of a 2-MANOVA for shell height, shell width, total weight and body weight, contrasting the fixed factor sex and random factor site are presented in Table 1. Significant morphological differences were only observed among the sampling sites (Table 1; $p_{site} < 0.001$). Post hoc testing revealed that *L. scabra* specimens from Nyamanzi, Kisakasaka

Table 1
Summary of the 2-MANOVA, contrasting the fixed effect "sex" and the random effect "site" for possible differences in shell morphology

Effect	Wilk's λ	F	df1	df2	P
Site	0.194	11.83	16	266.4	<0.001*
Sex	0.913	2.06	4	87	0.093
Site × sex	0.802	1.25	16	266.4	0.233