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Relative influence of sediment variables on mangrove community assembly in Leizhou Peninsula, China

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A B S T R A C T

Effective conservation of mangroves requires a complete understanding of vegetation structure and identification of the variables most important to their assembly. Using canonical correspondence analysis (CCA) combined with variation partition, we determined the independent and joint effects of sediment variables, including physicochemical characteristics and heavy metals, on mangrove community assemblies in the overstory and understory in Leizhou Peninsula, China. The results indicated that the contributions of sediment physicochemical variables to community assembly were greater than were those of heavy metals, particularly in overstory vegetation. However, the independent contributions of heavy metals were higher in understory mangrove vegetation than in the overstory. The TOC, TP, and salinity of the sediment, distance from the coastline, and concentration of As were limiting factors for mangrove assembly in overstory vegetation, while understory vegetation may be affected to a greater degree by the distance from the coastline, electrical conductivity, and concentration of As and Pb in the sediment.

1. Introduction

Mangrove vegetation encompasses a group of trees or shrubs that grow in the tidal waters along tropical and subtropical coastlines. The mangrove ecosystem provides important services, such as food, wood, chemical pharmaceutical production, and other aesthetic values, and offers such critical ecological functions as coastal protection, land stabilization, water purification, and CO_2 fixation. However, mangroves often are located in fragile habitats, and very few mangrove systems can be restored to their original state once they have been destroyed (Tam and Wong, 2000). It has been shown that most remaining coastal wetlands have been degraded or altered because of land conversion or altered hydrodynamic and sediment conditions, and will continue to be lost throughout the twenty-first century (Duke et al., 2007; Friess et al., 2012). Effective conservation of mangrove systems, including protective regulations and restoration efforts, require comprehensive knowledge of the vegetation structure of these forests, the identification of variables important to them, and an understanding of their interactions.

A range of factors that influence mangrove vegetation has been studied. For example, the degree of tidal inundation may play an important role in structuring mangrove distribution (Satyanarayana et al., 2002). Soil redox potential, salinity, pH, and concentrations of nutrients, sulfide, and phytotoxins also serve as important determinants of mangrove vegetation (Mckee, 1995; Krauss et al., 2008). Further, mangrove seedling distributions have been shown to be attributable to dispersal patterns in the intertidal zone, which appear to be controlled by physicochemical variables (Mckee, 1995). Canopy and substratum heterogeneity also influence the recruitment of the mangrove *Avicennia marina* (Minchinton, 2001).

In additional, heavy metals, primarily from industrial areas, commonly are retained within mangrove sediments (Machado et al., 2002). Uptake of excess metals by mangroves can initiate sub-cellular metabolic reactions that may cause damage at the cellular level or lead to whole plant phytotoxic responses, including visible inhibition of growth and increased mortality. Photosynthetic pigments and peroxidase activity are sensitive biological indicators of Cu, Zn, and Pb stress in *Avicennia marina* (MacFarlane and Burchett, 2002). MacFarlane and Burchett reported an LC_{50} of 580 μg/g zinc (artificial sediments incubated with zinc [II] for 2 weeks) for *A. marina* seedlings; this value approaches the upper range of total zinc reported for some mangrove sediment samples (MacFarlane and Burchett, 2002; Bayen, 2012).

Overall, a variety of factors affects mangrove species assembly, and these variables often are correlated highly. However, only a few studies have examined the independent and joint effects of these potential variables on mangrove vegetation. Ordination algorithms are an appropriate choice to explore the relation between vegetation development and

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environmental variables (Dahdouh-Guebas et al., 2002), and are useful in examining the relative importance of these explanatory variables and their independent and joint effects.

Thus, in this study, two sets of possible explanatory variables for mangrove vegetation were determined: (1) the physicochemical characteristics of the habitat, and (2) the concentrations of heavy metals in the habitat sediment. We conducted repeated analyses in the overstory and understory of the mangrove vegetation, respectively. And constrained ordination combined with variation partitioning among sets of explanatory variables was applied to examine the relative importance of these variables and their independent and joint effects (Matthews et al., 2009; Li et al., 2016). The purpose of this study was to explore the dominant variables that contribute to the mangrove community assemblies in the overstory and understory and to examine their relative importance in Leizhou Peninsula, China. This type of research can generate results that may be important for mangrove conservation and management objectives (e.g., the establishment, protection, and management of afforestation).

2. Methods

2.1. Study sites and sampling

The study was conducted on the Leizhou Peninsula, which shelters the largest natural mangrove reservoir in China and is governed by Zhanjiang, Guangdong (Gao et al., 2009). The mean annual precipitation and evaporation in this area are approximately 1390–1760 mm and 1700–2200 mm, respectively, with a mean annual temperature of 22–23 °C (Rumisha et al., 2012). The area supports 22 mangrove species, including 13 true mangrove species, and nine semi-mangrove species (Parker, 1997).

Representative study locations were selected based on information from Zhanjiang Mangrove National Nature Reserve and field surveys. Twenty-six sites dominated by forested mangrove communities were selected randomly (Fig. 1). We sampled at low tide from the middle of October through November 2012. Sampling site geo-positions (latitude and longitude) were determined using a Garmin global positioning system with a spatial accuracy of approximately ±5 m. Distances from the sampling sites to the coastline were calculated in ArcGIS 10.0 with data from satellite images.

At every site, a sample transect was established parallel to the shoreline, with three sub-sample plots (10 × 10 m size). In every sub-sample plot, all mangrove individuals were identified and their number, diameters (at 1.3 m for adults, at half-height for plants under 2 m tall, and above the uppermost intersection of the prop roots for *Rhizohpora*) (Fromard et al., 1998; Stephen and Han, 2008), height, and crown diameter were recorded. In understory vegetation, all plant species (<1.3 m in height (Alatalo, 1981; Stephen and Han, 2008)) were identified and measured in terms of abundance (number of individuals), coverage, and height within the sub-plot (5 × 5 m size).

Further, in each sub-sample plot, three sediment cores 15 cm deep and 5 cm in diameter were collected randomly around the roots of mangroves using a homemade stainless sediment core sampler and mixed to obtain one homogenized sample. All sediment samples were packed in plastic bags and transported to the lab immediately. The samples were air dried and sieved through a 2-mm plastic sieve; stones and plant debris were removed with tweezers. Approximately 20 g of each sample were ground in an agate mortar and passed through a 150-μm

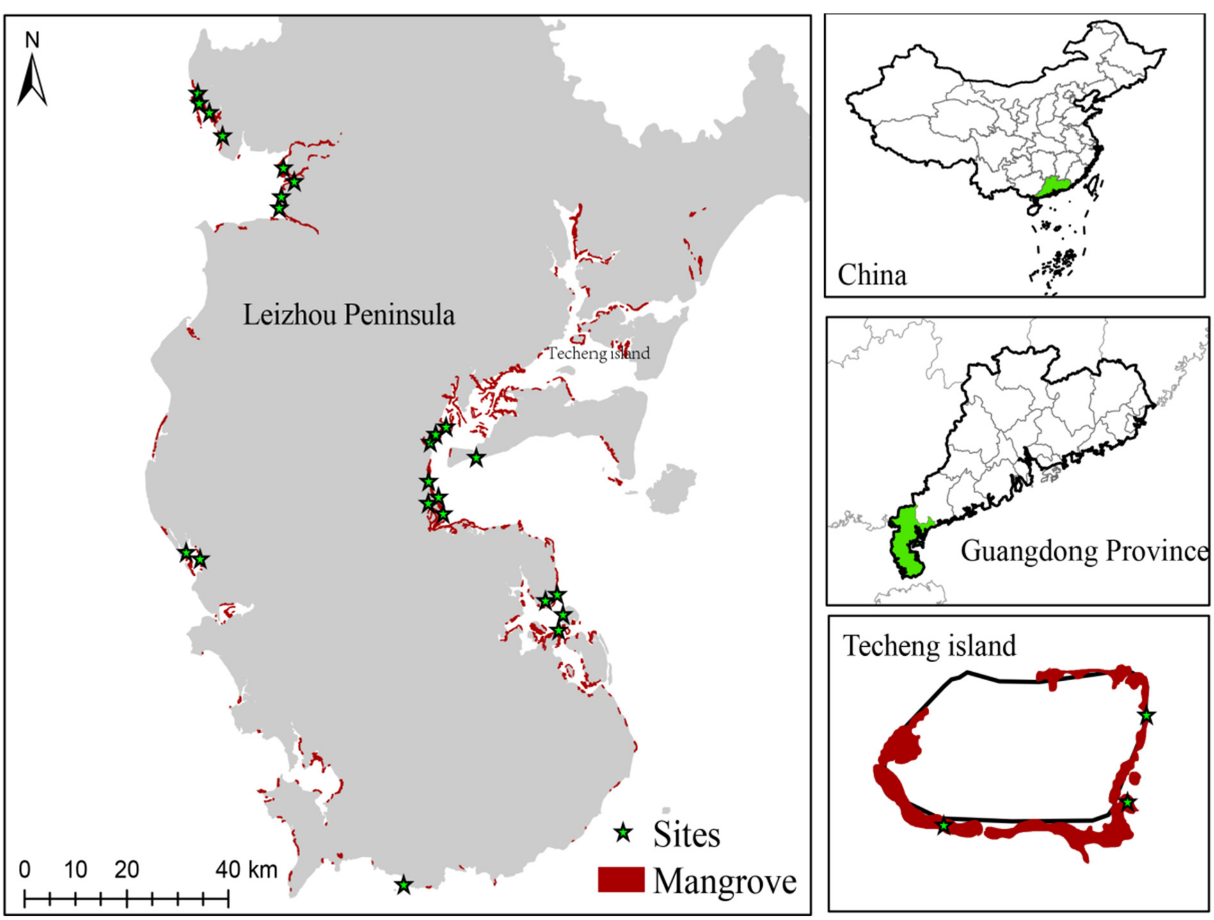

Fig. 1. Location of sampling sites in mangrove swamp in Leizhou Peninsula, China.

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