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Influence of ancient anthropogenic activities on the mangrove soil microbiome

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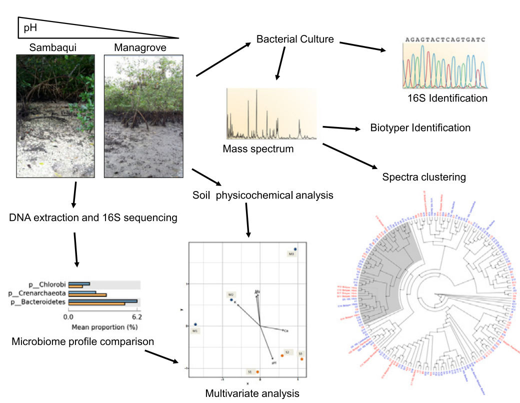
HIGHLIGHTS

- Impact of archeological Sambaqui soil on mangrove microbiome
- Changes in microbiome of pristine and archeological Sambaqui in mangrove soils
- Resilience of microbiome mangrove soil to changes in soil pH

GRAPHICAL ABSTRACT



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ABSTRACT

Mangroves are highly productive ecosystems located at the transition between the terrestrial and marine environments. Mangroves play an important role in carbon storage, nutrient cycling and support for the marine food web. Mangrove soils are formed by fine particles rich in organic carbon and are subject to constant fluctuations in oxygen, salinity and nutrient availability due to fresh water flux and tidal variations. Microbes play an important role in nutrient cycling in mangrove soils; however, studies on the mangrove soil microbiome are scarce. Here we compare the microbiome of pristine mangrove soil located in an environmentally protected area in Guaratuba, Southern Brazil, with the microbiome of mangrove soil affected by the presence of carbonaceous debris eroding from an archeological site known as Sambaqui. We show that although the Sambaqui site has a major effect on soil chemistry, increasing the soil pH by 2.6 units, only minor changes in the soil microbiome were detected indicating resilience of the microbial community to pH variations. The high alpha diversity indexes and predicted metabolic potential suggest that the mangrove soil microbiome not only provides important ecological services but also may host a broad range of microbes and genes of biotechnological interest.

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1. Introduction

The Atlantic forest biome hosts a significant portion of Brazilian biological diversity and is considered as a "hot spot" of biodiversity by UNESCO. This biome is one of the most threatened on the planet with <8% of its original forest remaining (Carnaval et al., 2009). The major remnants of continuous Atlantic forest are located on the cost of the Paraná state, due to the presence of several Public and Private Conservation Units within this region (Tiepolo, 2015).

A particularly important ecosystem within the Atlantic forest is the mangrove, representing waterlogged areas located at the transition between the terrestrial and marine environments in estuarine regions (Alongi, 2014). Due to their typical characteristics such as salinity, oxygen and pH variations, there are just few a plant species adapted to survive under these conditions (Alongi, 2014). Mangrove ecosystems are important environments for the protection and reproduction of many animal species, including arthropods, fish, amphibians, reptiles, birds and mammals (Hossain and Nuruddin, 2016).

Mangroves occupy 0.5% of the global coastal area (approximately 138,000 km^2), and Brazilian mangroves represent 7% of the global mangrove area (Alongi, 2014; Giri et al., 2011). Mangroves are highly productive ecosystems, providing support to the marine and terrestrial food web and contributing 10–15% to coastal sediment carbon storage; they export of 10–11% of the particulate terrestrial carbon to the ocean (Alongi, 2014). It has been estimated that the carbon biomass in mangrove soil is about three times the biomass that makes up the mangrove vegetation (Hossain and Nuruddin, 2016). The mangrove ecosystem is claimed to play an important role in climate regulation, contributing to carbon sequestration and helping counterbalance anthropogenic CO_2 emissions (Alongi, 2014). However, this ecosystem is disappearing at an alarming rate and its loss will contribute to climate change (Atwood et al., 2017). Anthropogenic activities such as city expansion, ports, contamination by oil spills, domestic sewage, agriculture and other uses are the main threat to this ecosystem (Alongi, 2014).

Mangrove sediments in Brazil are typically formed by river and marine alluvium deposits, with the texture mainly comprising silt and clay in the fine fractions, combined with high concentrations of organic matter and salts, resulting in a dark grey colour commonly defined as mud (Hossain and Nuruddin, 2016). The water tidal cover, along with fine texture and organic matter observed in mangrove sediments produce a gradient from aerobic conditions (on the surface), where degradation of organic matter occurs mainly through aerobic respiration, to anaerobic processes, creating conditions for anaerobic decomposition including sulphate reduction that produces H_2S giving the mangrove soil a typically strong odour (Hossain and Nuruddin, 2016; Ghizelini et al., 2012).

Given the unique physicochemical characteristics of mangrove soil such as oxygen, salinity and pH variations, this ecosystem is very diverse in microbial life forms (Mendes and Tsai, 2018) and hence it is a promising repository of microbes and genes of biotechnological interest (Thatoi et al., 2013). There are only a few studies that describe the composition, ecology and dynamics of the mangrove soil microbiome in Brazil (Ghizelini et al., 2012).

Shell middens are archeological sites found in coastal zones all over the globe. These sites are spread all over the Brazilian coast line and are known as Sambaquis (Okumura and Eggers, 2005; Gernet et al., 2014). Sambaquis consist mostly of mollusc shells that are waste products of meals eaten by groups of hunter-fisher-gatherer indigenous people that lived in the area between 2000 and 10,000 years ago (Scheel-Ybert, 2001). Sites reaching up to several meters high and areas up to 300,000 m^3 have been described (Parmalee and Klippel, 1974; Estevez et al., 2001).

The structure of Sambaqui is typically arranged in layers with varying composition that are likely to reflect the occupation of these sites by different groups (Fig. 1), with the bottom layer representing the debris of the most ancient groups. It is common to find stone artifacts, cooking fire and human remains inside the Sambaqui suggesting that these sites were general waste deposits. Some Sambaqui sites have been characterized at the social-cultural anthropological perspective (Parmalee and Klippel, 1974; Simpson and Barrett, 1996). However, there is no report on pedology or microbiome analysis of Sambaqui soils.

Several Sambaqui sites have been described along the coast of Paraná state in Brazil (Bigarella, 2011). In this study we focused on a

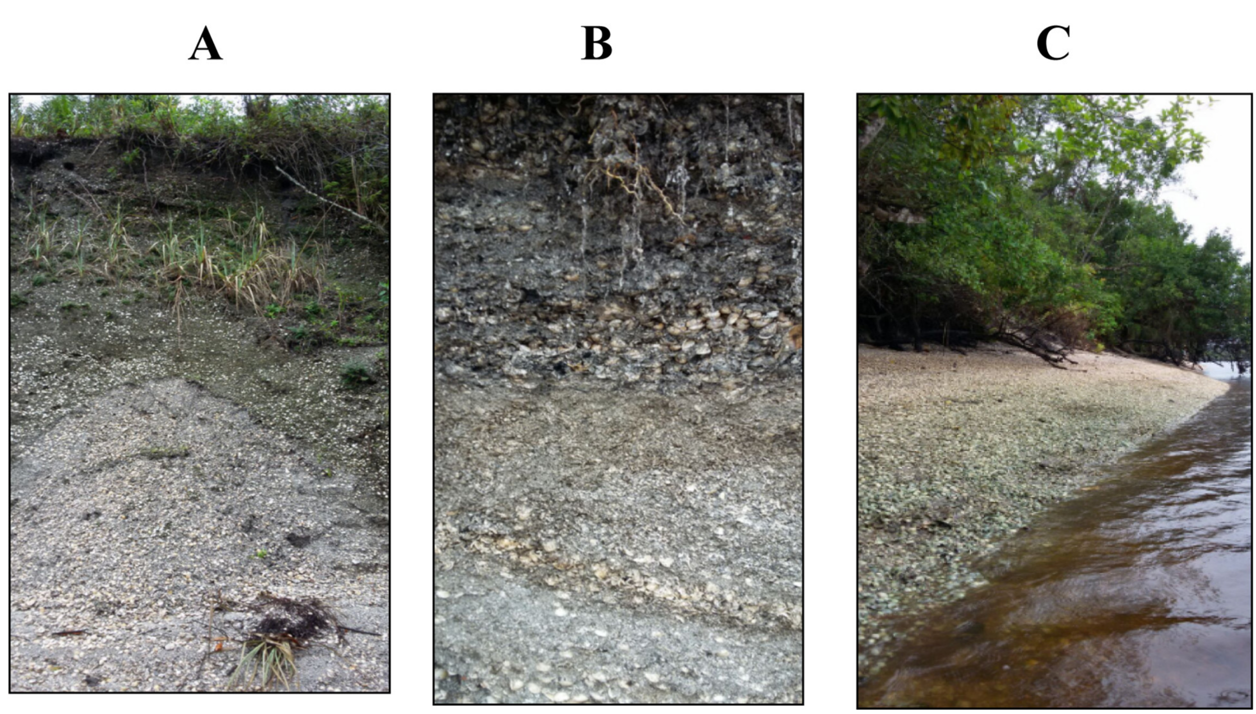

Fig. 1. The Sambaqui Boguaçú, Southern Brazil. (A) View of the Sambaqui from the left margin of the Boguaçú river. The top is 7 m high from the river level at low tide. (B) Different layers of shell debris that represent the chronological history of the site. (**C**) View from the base of the Sambaqui at the left margin of the Boguaçú river.