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Denitrification activity in mangrove sediments varies with associated vegetation

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ABSTRACT

To test the hypothesis that mangrove vegetation associated sediment characteristics could influence an ecologically important function such as denitrification, a study was carried out at the Divar mangrove ecosystem in Goa, India. The composition of intertidal mangroves was assessed based on which the down-core (0–10 cm) variation in environmental variables and denitrification activity (DNT) associated with dominant vegetation types was examined. Our observations revealed a distinct zonation pattern of mangroves with the dominance of *Rhizophora mucronata* (RM) in the lower intertidal zone followed by *Avicennia marina* (AM) in the mid region. *Acanthus ilicifolius* (AI) was restricted to the upper intertidal zone (UIZ) which was characterized by relatively lower sediment temperatures, higher porewater salinity and intense reducing conditions. A zonation pattern in occurrence of DNT was also observed. Denitrification activity generally decreased with depth and increased in intensity from the seaward to the landward side. Maximum DNT of 4.06 ± 0.44 nmol N_2O g^{-1} h^{-1} was recorded in the surficial AI sediments followed by AM and RM sediments. Surface plant litter content also increased from the lower to UIZ. A negative relationship of NH_4^+ and total organic carbon content ($n = 15$, $r = -0.388$, $p < 0.05$) in AI sediments was observed. This suggested that re-mineralization of accumulated organic matter (up to $3.07 \pm 0.58\%$ at 0–2 cm) enhanced NH_4^+ availability in the porewater which in turn could support nitrification-denitrification. Thus, degradation of vegetation-derived organic matter was important in sustaining nutrients mainly towards the landward side proving our hypothesis that vegetation could have an influence on DNT, albeit indirectly.

1. Introduction

Research on biogeochemical cycles in coastal environments has intensified following evidence that wetlands have a strong impact on human activities and on water quality. One such ecologically important coastal ecosystem is mangroves which occupy ~ 14 million hectares in tropical and subtropical regions of the world (Giri et al., 2011). They provide a range of ecosystem services like soil formation, wood production, fish spawning grounds, carbon (C) storage and nutrient cycling (Murdiyarso et al., 2015). However, over the past few decades, there has been an alarming loss (1–2% y^{-1}) of these valuable ecosystems globally (Duke et al., 2007). This loss has been attributed to human related activities viz., land competition for aquaculture, agriculture, infrastructure, coastal landfill, tourism (FAO, 2007), overexploitation for timber, fish, crustaceans, shellfish, alteration of hydrology, pollution and global warming (Alongi, 2002). Duke et al. (2007) predict that any further decline in mangrove area is likely to be followed by accelerated functional losses.

The occurrence of biogeochemically important microbially-mediated processes like denitrification (Chiu et al., 1996; Yu et al., 2008) and anammox in mangrove sediments contribute to eutrophication control by mitigating excess inorganic nutrients (Fernandes et al., 2012). Mangrove sediments are largely anaerobic and NO_3^- availability is a major factor controlling denitrification activity (DNT) (Fernandes and LokaBharathi, 2011). Some other environmental parameters known to influence DNT include variation in oxygen concentrations (Bonin and Raymond, 1990), quantity and quality of organic matter (Bonin et al., 1999; McCarty and Bremner,

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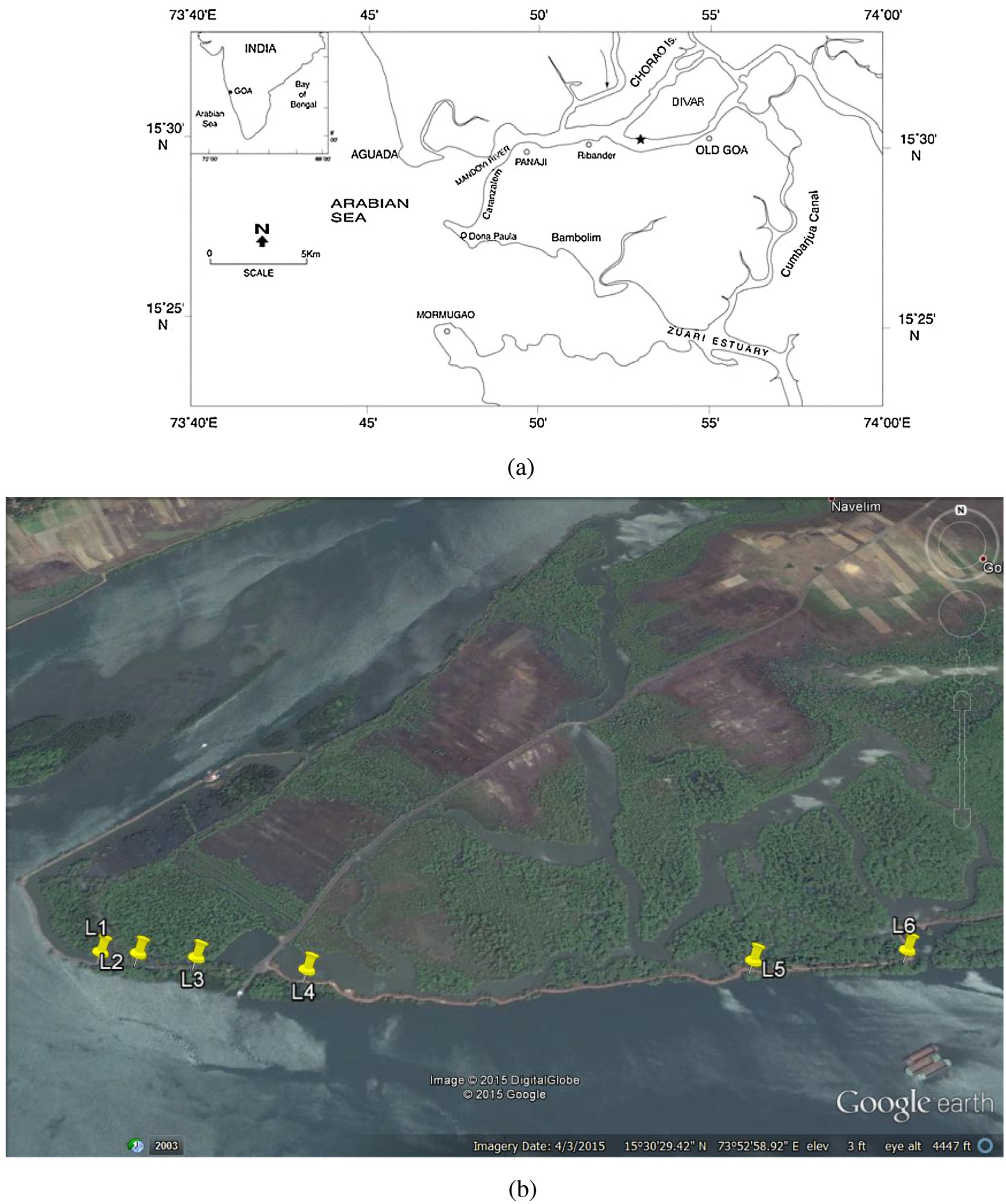

Fig. 1. Study area located at Divar island (⋆) along the river Mandovi (a) and locations (L1 to L6) for study of mangrove composition in intertidal region (b). Sediment samples for physico-chemical and microbiological analyses were retrieved from location 3 (L3; *R. mucronata* and *A. marina* associated sediments) and 5 (L5; *A.ilicifolius* associated sediments).

1993; Hill and Cardaci, 2004; Qin et al., 2005; Welti et al., 2012) sediment temperature (Holtan-Hartwig et al., 2002; El-Sayed, 2003), sediment pH (Rust et al., 2000; Simek et al., 2002), bioturbation (Gilbert et al., 1995) and trace metal content (Labbé et al., 2003; Fernandes et al., 2013). So far, little information is available on the influence of vegetation-associated sediment characteristics on N removal processes like denitrification. Some studies have indicated that community type, vegetation cover, biomass, and plant invasion are significantly correlated with DNT (Bachand and Horne, 2000; Evans et al., 2001; Hernandez and Mitsch, 2007; Yang et al., 2007). Planting of high-productivity species has been suggested as an eco-