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Driving forces of organic carbon spatial distribution in the tropical seascape

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ABSTRACT

An important ecosystem service of tropical coastal vegetation including seagrass beds and mangrove forests is their ability to accumulate carbon. Here we attempt to establish the driving forces for the accumulation of surface organic carbon in southern Thailand coastal systems. Across 12 sites we found that in line with expectations, seagrass beds ($0.6 \pm 0.09\%$) and mangrove forests ($0.9 \pm 0.3\%$) had higher organic carbon in the surface (top 5 cm) sediment than un-vegetated mudflats ($0.4 \pm 0.04\%$). Unexpectedly, however, mangrove forests in this region retained organic carbon, rather than outwell it, under normal tidal conditions. No relationship was found between organic carbon and substrate grain size. The most interesting finding of our study was that climax and pioneer seagrass species retained more carbon than mixed-species meadows, suggesting that plant morphology and meadow characteristics can be important factors in organic carbon accumulation. Insights such as these are important in developing carbon management strategies involving coastal ecosystems such as offsetting of carbon emissions. The ability of tropical coastal vegetation to sequester carbon is an important aspect for valuing the ecosystems. Our results provide some initial insight into the factors affecting carbon sequestration in these ecosystems, but also highlight the need for further research on a global scale.

1. Introduction

The ability of coastal vegetation to sequestration carbon has been established as a keystone aspect in coastal zone management (Nellemann et al., 2009; Smith, 1981). In particular, connected tropical ecosystems such as mangrove forests and seagrass beds can accumulate 70% of organic carbon (OC) available in their local marine and terrestrial areas (Macreadie et al., 2014; Nellemann et al., 2009). There are three main processes that control how plants/trees and their associated ecosystems can sequester carbon. Firstly, mangrove trees and seagrass plants photosynthesize to acquire carbon from the atmosphere; seagrass plants can also sequester carbon from the water (Alongi, 2014; Lee et al., 2007). Secondly, organisms within the ecosystems such as macroalgae and microalgae can also assimilate carbon (Alongi, 2014; Lavery et al., 2013). Lastly, the ecosystems can sequester carbon via the transport and deposition of particulate organic material (POM) transported from within and between ecosystems and the catchment area (Alongi, 2014; Gillis et al., 2014b). Here we concentrate on how seagrass beds and mangroves forests sequestrate particulate carbon.

Sequestration rates for mangrove forests (174 g C m^{-2} y^{-1}) and seagrass beds (138 g C m^{-2} y^{-1}) are generally high compared to non-vegetated estuary and shelf areas (17–45 g C m^{-2} y^{-1}), making this a important topic for greater understanding (Alongi, 2014; McLeod et al., 2011).

Seagrass beds can receive carbon from both the sea and the land. For example, up to 50% of OC found in seagrass beds is from allochthonous sources (Kennedy et al., 2010). Seagrasses can also be a significant source of nutrients to other environments in the tropical seascape (Gillis et al., 2014b). Due to seagrass bed ability to reduce the water current and accumulate POM they can sequestrate sequester carbon 35 times faster than terrestrial systems, such as rainforests (Kennedy et al., 2010; Macreadie et al., 2014). Mangrove forests also reduce the current velocities, facilitating sedimentation of carbon rich POM both from within and outside the forest (Bouillon et al., 2008). As these systems are typically located where steams, channels and rivers drain upland environments, they potentially receive nutrients from a variety of terrestrial sources (Kristensen et al., 2008). As such, mangrove forest sediments have the potential to accumulate very large carbon pools. Approximately 75% of the total sediment pool in mangrove forests is carbon (Alongi, 2014).

There are many factors that determine the amount, availability and composition of organic carbon content in the soils within seagrass

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meadows and mangrove forests (Mateo et al., 2006; McLeod et al., 2011). Seagrass beds and mangrove forests are depositary environments where the roots or leaves reduce the water flow to allow for fine sediment deposition (Kristensen et al., 2000; Papadimitriou et al., 2005; Tue et al., 2012). Therefore sedimentological characteristics such as grain size are likely correlated with the organic carbon content. Previous work has indicated that finer sediments have higher OC content because of greater surface area, relative to coarse sediments (Krishna Prasad and Ramanathan, 2008; Ranjan et al., 2010).

The supply of organic carbon from allochthonous sources, such as connected ecosystems in the coastal environment and upper catchment terrestrial areas, are essential to consider for accumulation rates. Investigating the connectivity between seagrass beds and mangrove forests is especially important because these systems are dominated by ecosystem engineers (mangrove trees and seagrass plants) that both donate/export and trap organic material (Gillis et al., 2014b). Movement of OM can be altered by tidal inundation; therefore, the spatial distribution of mangroves forests and seagrass beds in the seascape and their location within the bay will also affect the movement. The physical aspects (length, breadth, area) of the bay in which the ecosystems are located will also influence tidal inundation, which in turn affects OC movement.

Only recently has research concentrated on determining which are the most important driving factors in controlling OC accumulation within tropical vegetation (Duarte et al., 2013; Lavery et al., 2013; McLeod et al., 2011). For seagrasses, inundation depth, external supply of OC, and productivity has been found to be an important consideration (Duarte et al., 2013; Lavery et al., 2013). Mangrove forest accumulation of carbon will also be influenced by external POM supply, tidal depth, as well as tidal extent and period. The few studies that have investigated sedimentation rates in mangrove forests (Alongi, 2014; McLeod et al., 2011), all emphasize the need for data from connected ecosystems in other global regions. To our knowledge, there have been no studies conducted that investigate the spatial variability of surface carbon between and within connected mangrove forests and seagrass beds. Given that these ecosystems are highly connected depository environments which both potentially donate OC to each other (Gillis et al., 2014b), establishing the driving forces and the spatial patterns of surface OC between ecosystems should be a research priority.

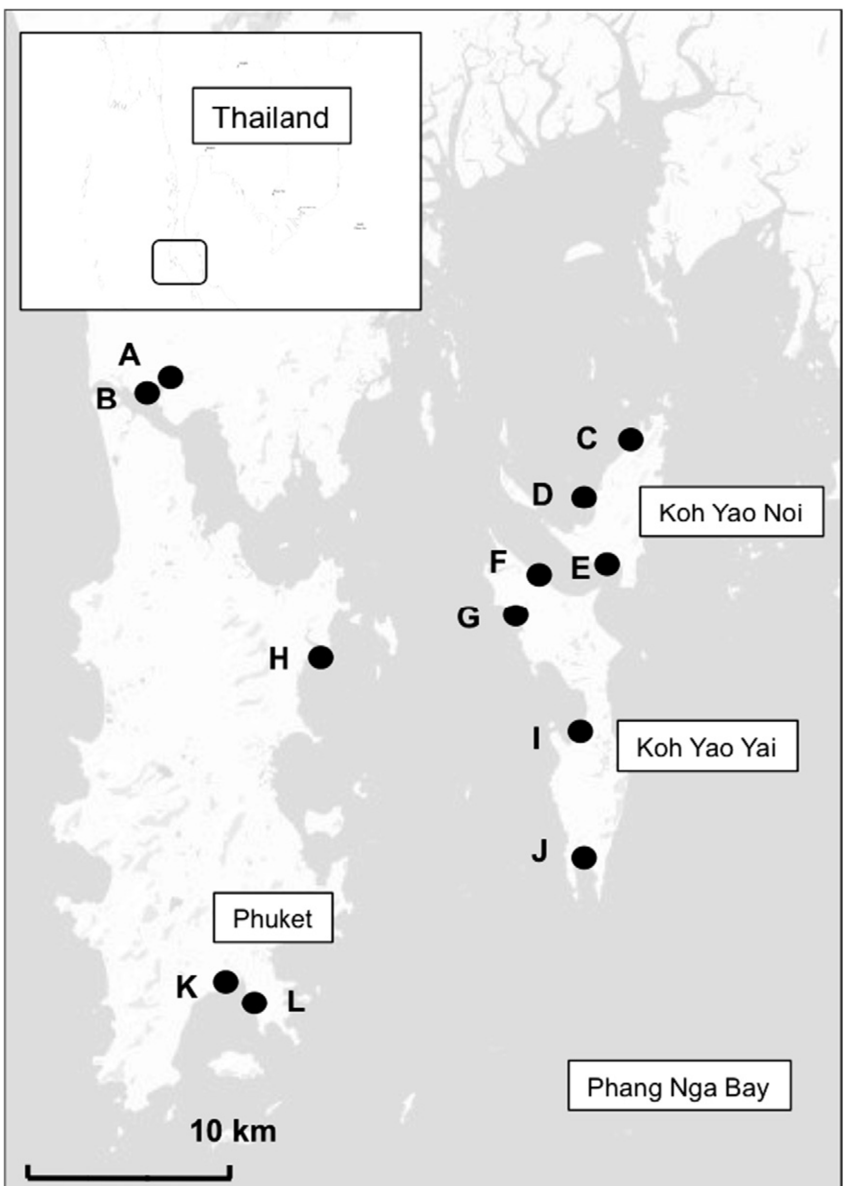

Fig. 1. Map showing location of 12 sites in Phang Nga Bay, Southern Thailand.