Estuarine, Coastal and Shelf Science 134 (2013) 11–18

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

# Vegetation and sediment characteristics in an expanding mangrove forest in New Zealand

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ARTICLE INFO

*Article history:*
Received 11 October 2012
Accepted 28 September 2013
Available online 12 October 2013

*Keywords:*
carbon accumulation
sediment analysis
carbon isotope ratio
mangroves
remote sensing
New Zealand, Auckland

ABSTRACT

Mangrove expansion in inlets has been widely observed in the North Island of New Zealand over recent decades. There is just one mangrove species in New Zealand, *Avicennia marina* var. *resinifera*. Our main objective was to investigate the response of mangroves to sedimentary patterns. Remote sensing and GIS was used to quantify the change in mangrove area. Vegetation and sediment characteristics were studied across seasons from December 2009 to August 2010. Comparison of digital images in 1940 and 2003 revealed that the mangrove area in our study inlet had increased by 21%. The mangroves created a rim of high fringe mangroves surrounding high-density but low height trees in the interior. The relatively low pH level and seasonally fluctuating pore water total dissolved salt (TDS) concentration reveal potentially stressful conditions in the interior mangrove zone, which may influence the forest structure in the interior.

Total organic carbon (TOC), $\delta^{13}C_{org}$ and $\delta^{15}N$ along the transect indicated an increase of autochthonous organic carbon in the surface substrate landwards. The highest carbon accumulation was not observed in the fringe zone, in spite of it having the most vigorous growth of mangroves. Instead, the highest $\delta^{13}C$ value ($-23.36 \pm 0.42‰$, averaged over depth) and lowest C:N ratio ($13.1 \pm 2.0$) in the fringe mangrove core reflected the preservation of allochthonous organic material in the fringe zone. Under the protection of seaward fringe mangroves, mangrove-derived carbon is retained and stored in the interior sediment.


## 1. Introduction

Mangroves are marine tidal and estuarine forests that cover approximately 75% of tropical and subtropical coastlines between 25° N and 25° S (Alongi, 2002). In certain locations, their range extends beyond these limits due to the movement of warm waters away from the equator (Ellison, 2009). These areas include the east coast of Africa, Australia, and New Zealand, where the single mangrove species, *Avicennia marina* var. *resinifera*, extends to around 38°S.

In contrast to the trend of a loss of at least 35% of the world's mangrove forests in recent decades (Feller et al., 2010), mangrove forests have expanded in New Zealand (Harty, 2009). Most expansions of the native mangrove were seaward and restricted to sheltered estuaries and harbour inlets (Morrisey et al., 2007; Swales et al., 2007). The expansion occurring in New Zealand estuaries has been attributed to increased sediment yields caused by erosion from land-use change, including deforestation, agriculture and urbanization (Swales et al., 2002; Harward et al., 2006; Lovelock et al., 2007). Additionally, artificial structures, such as causeways and road and rail embankments may alter the hydrodynamic environment by creating a barrier to the open sea (Walsby, 1992). This combination of increased sedimentation and altered hydrology may have created conditions that facilitated mangrove establishment and seaward migration.

Mangrove expansion has led members of the public calling for their "management" or removal in New Zealand (Harty, 2009; Stokes et al., 2010). However, mangroves capture carbon from the air, sea and freshwater runoff from land, so such removal may result in a significant loss of carbon to marine waters (Feller et al., 2010), and other negative environmental impacts such as increased estuarine turbidity and coastal erosion. With the debate on the management of mangroves in New Zealand continuing, a more comprehensive understanding of the mechanisms of mangrove expansion is urgently required (Stokes et al., 2010). Research used

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0272-7714/$ – see front matter 
http://dx.doi.org/10.1016/j.ecss.2013.09.017

to focus on mangroves' adaptive features that contribute to their resilience from natural or anthropogenic disturbances, except those strategies regarding gradual shoreline evolution (Alongi, 2008; Reef et al., 2010). The present study aims to examine how a single-species mangrove forest has adapted to sedimentary change. We documented the spatial expansion of mangrove forests using remote sensing and geographic information system (GIS) tools, investigated the temporal and spatial patterns of population and sedimentary features across vegetation zones and assessed the link between the above-ground vegetation characteristics and sediment organic carbon accumulation using 1.5 m deep cores.

## 2. Materials and methods

### 2.1. Study area and digital image procedure

Auckland has a nearly subtropical, warm-temperate, oceanic climate, with a mean summer and winter temperature of 19 °C and 12 °C, respectively. Mean annual rainfall of 1300 mm is distributed throughout the year, with summer months averaging 90 mm and winter months averaging 140 mm (McClure, 2012). Tides in northern New Zealand are semi-diurnal, with a mean spring tide of approximately 2 m, ranging from 1.6 to 2.9 m. Our study area was located in Motu Manawa (Pollen Island) Marine Reserve in the Waitemata Harbour of Auckland city. In 1955, a causeway (State Highway 16) was built across the inlets. A black-and-white photograph of the study area was taken in 1940 by New Zealand Aerial Mapping [scale: 1 inch = 30 chains (1:23,740)], and two photogrammetric maps at a scale of 1:25,000 were completed in 1943 and 1944 by the Department of Lands & Survey NZ. A coloured orthophotograph at a scale of 1:50,000 was created in 2003. The selection of this remote sensing material was based on the consideration of the dates before and after the construction of the causeway.

The printed 1940 aerial photograph and the 1943 and 1944 maps were scanned at 300 dpi and registered with the 2003 photograph in ArcGIS. All of the digitalized photographs were georeferenced to the New Zealand Map Grid (NZMG) coordinate system and visually interpreted. The mapped mangroves were

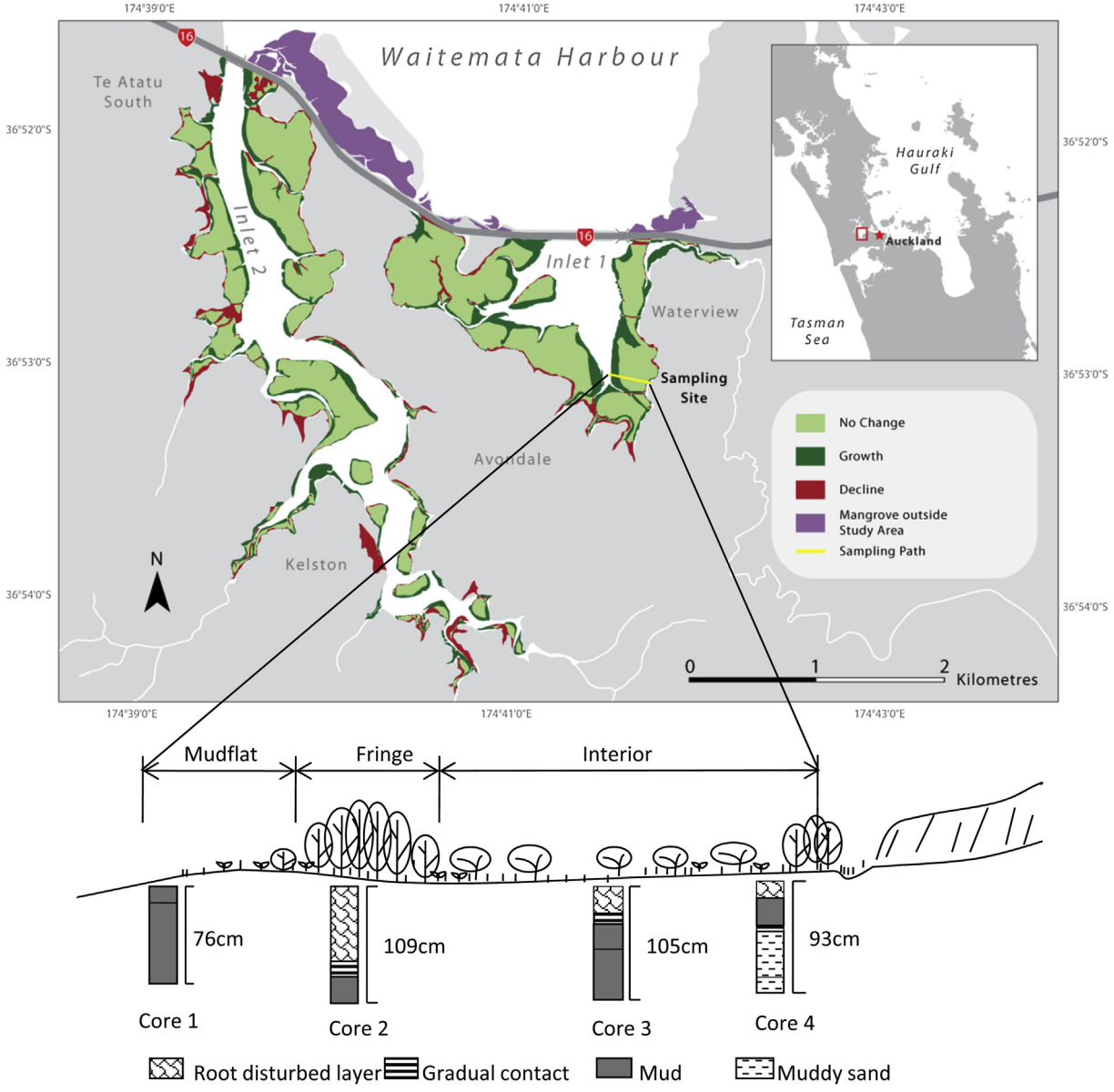


**Fig. 1.** The study area location and the extent of mangrove changes between 1940 and 2003, and the sampling transect and locations of sediment cores in the four vegetation zones.