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Review

Addressing the mismatch between restoration objectives and monitoring needs to support mangrove management

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ABSTRACT

Restoration projects require an underpinning of science to maximise success at restoring ecological function. Occasionally wetland restoration objectives focus on clearing intertidal vegetation, including removal of introduced and rapidly expanding native species, such as the expansion of mangrove forests in New Zealand. Typical objectives of these restoration projects addressing mangrove expansion include restoring intertidal sites to historically sand-dominated substrates that are associated with higher societal and cultural values through recreational access, natural character (e.g., viewscape) and enhancement of shellfish resources. Historically, mangrove management occurred with minimal or no monitoring to confirm if these objectives were achieved, and with no consistent approach in terms of restoration methodology or monitoring used across the various management jurisdictions. This paper reviews the monitoring programs associated to date with restoration projects in New Zealand involving mangrove removal, with an aim to outline the key management considerations and environmental measures that should be included in future monitoring programs. Monitoring techniques that should be included in management activities that involve mangrove removals are summarised, highlighting methodologies to document changes in surface topography, sediment characteristics and various biological changes. The monitoring objectives have been categorised in three levels, relative to the complexity of the technique and the cost. We hope that this paper will be useful to any group or organisation around the globe who wish to document the extent and rate of change where mangrove vegetation has been cleared. Better documentation on successes and failures of management actions related to mangrove expansion can inform future management strategies, and prioritise cost-effective actions in locations that are likely to result in successful restoration of ecological function of estuarine habitats.

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1. Introduction

Estuaries bridge our terrestrial and marine environments; they are unique and diverse ecosystems that provide invaluable ecosystem services (Barbier et al., 2011). Saltmarsh, mangrove and seagrass vegetation are critical vegetated habitats in estuaries, providing food and protection for numerous estuarine species, including fish, bivalves, crustaceans and birds (Thrush et al., 2013). Unfortunately, estuaries are also sites where impacts from human activity are often amplified, deeming them some of the most heavily used and threatened systems on the planet (Lotze et al., 2006; Halpern et al., 2008). For example, the huge growth in aquaculture has resulted in an enormous loss of coastal/wetland vegetation, with shrimp farming contributing to some ~38% of global mangrove loss and other aquaculture has contributed to a further 14% loss (Ellison, 2008). Other direct impacts may be driven by land reclamation, dredging, port development and coastal urbanisation, while pollutants such as nutrients, metals and plastics from the surrounding catchment can accumulate within estuaries and harbours (Kennish, 2002). Such impacts can trigger dieback or profound shifts in the composition and health of coastal vegetation and other estuarine habitats (Thrush et al., 2003; Saintilan et al., 2014; Doughty et al., 2015). Degradation of coastal habitats can be addressed by removing threatening processes, however often restoration and rehabilitation is required to support ecosystem recovery (Ferrier and Jenkins, 2010).

Wetland restoration is a common management strategy applied around the globe, although most of this work is taking place in developed countries (see Bayraktarov et al., 2016 for review). A key objective is to restore ecosystem services and halt further loss of vegetation (Zhao et al., 2016). A recent review of 235 coastal restoration projects analysed the successes and costs, all of which involved some form of replanting or reseeding for restoration of coral reefs, seagrass, mangroves, saltmarshes or oyster reefs (Bayraktarov et al., 2016). In temperate regions of north America, replanting of saltmarsh has been central to the success of various restoration projects (Zedler et al., 2012). Elsewhere, mangrove rehabilitation programs have been implemented to restore forest cover and habitat functionality (Osland et al., 2012; Milbrandt et al., 2015). Rarely has removal of native vegetation been considered a restoration technique, however in recent times resource management agencies in New Zealand have removed mangroves in an attempt to restore tidal flat ecosystems (Harty, 2009; Morrisey et al., 2010; Lundquist et al., 2014).

Despite a substantial global decline in mangrove distribution (Giri et al., 2011), many temperate mangrove forests are increasing in distribution (Morrisey et al., 2010). In New Zealand, this typically occurs where sediment loads are high and mangroves colonise seaward across bare mudflats (Stokes et al., 2010; Lundquist et al., 2014; Swales et al., 2015). In southern Australia drought and limited sediment loads (leading to compaction) are suggested causes of landward colonisation by mangroves (Rogers et al., 2005; Saintilan and Rogers, 2013).

When discussing the various approaches to managing mangroves out of coastal and estuarine habitats, Elliott et al. (2007) suggest that for recovery to be truly successful, the community established has to be similar in species composition, population density and size and biomass structure to that which was present prior to mangroves, or similar to that described at a site where mangroves are not present. Understanding how a site responds to the eradication of some or all of its mangroves is vital if we are to develop and implement effective habitat management strategies. There is limited reporting on the impacts of mangrove removal activities in temperate mangrove systems, in both academic and grey literature. This limits the ability to adopt best practice mangrove management techniques that minimise adverse impacts and to identify cost-effective means to achieve restoration success. Furthermore, there is a real risk that an unsubstantiated paradigm shift will take hold in policy development whereby the removal of mangroves becomes identified as a positive ecosystem service. This is a possibility if monitoring of the impacts of their removal continues to be absent or minimal, and any management actions are assumed, but may not actually achieve restoration objectives.

This paper reviews the monitoring programs associated with mangrove eradication in New Zealand, and identifies the key monitoring protocols that should be included in mangrove removal activities. These measures should determine whether mangrove removal leads to the desired environmental outcomes, and also to inform future coastal management. New Zealand community groups and coastal management authorities have been clearing mangroves for over a decade now (de Luca, 2015). This provides us with the opportunity to explore the varied approaches to the removal of mangrove vegetation. Furthermore, we can use existing monitoring data to assess relative success of mangrove management activities to date in achieving restoration objectives.

1.1. Background — mangroves in New Zealand

Avicennia marina subsp. *australasica* is the only mangrove species occurring in New Zealand (Morrisey et al., 2010). Early European records document the presence of mangroves (Swales et al., 2015) and pollen analysis confirms the presence of mangrove pollen in sedimentary deposits older than 8000 years (Mildenhall, 2001), confirming that this is an indigenous plant of the North Island of New Zealand. Due to a combination of climate gradients (Beard, 2006) and dispersal limitation (de Lange and de Lange, 1994), mangroves are presently only found in harbours and bays in the northern half of the North Island, north of around latitude 38°. Phases of mangrove expansion have been mapped from aerial photographs dating back to the 1940s (see Swales et al., 2015). Rates of increase, and the periods during which colonisation was most rapid, have been variable over this time (Swales et al., 2007; Morrisey et al., 2010; Stokes et al., 2010). Drivers of mangrove expansion include estuarine infilling and associated changes in mean bed level (Ellis et al., 2004; Swales et al., 2007; Stokes et al., 2009), and decreased storm and wave activity linked to El Niño (Swales et al., 2015).

Reports produced in the 1970s (Chapman, 1976a, b) alerted authorities to dwindling mangrove habitat following land reclamation and grazing impacts. As a result, New Zealand mangroves were granted protected status under the New Zealand Coastal Policy (Harty, 2009). Local regulatory bodies such as Regional