Tauranga Harbour Mangrove Management Literature Review

Bay of Plenty Regional Council
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5 Quay Street
PO Box 364
Whakatāne 3158
NEW ZEALAND

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BAY OF PLENTY REGIONAL COUNCIL
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6 Rata Street
PO Box 364
Mt Maunganui 3118
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Prepared by Robert Win, Stephen Park and Amy Quinn

Cover Photo:
Waikareao Estuary, Tauranga Harbour, Amy Quinn

Executive summary

The purpose of this literature review was to review all scientific information and data, as well as identify knowledge gaps, around mangrove management in New Zealand. The intent was that this review would then feed into the development of an environmental decision-making framework for mangrove management, mapping locations in Tauranga Harbour where mangrove management could be environmentally supported or not.

The main conclusion that can be drawn from this literature review is that mangrove forests vary considerably from location to location in their ecology, productivity, role in food webs, the diversity and abundance of flora and fauna they support and their response to changing conditions in estuaries and harbours. This means that managing mangroves from a harbour-wide perspective is difficult to achieve. A better approach is site-specific assessments of mangrove habitat quality and ecological values to determine if management through removal is needed and if so, will it achieve restoration of this habitat to sandier substrates. Mangroves grow in the 'natural environment' where changes in environmental gradients (shore height, exposure, hydrodynamic connectivity and salinity), as well as anthropogenic impacts (sedimentation, nutrients) and other associated environmental degradation (changing climate) all, affect where and why mangroves grow in our estuaries.

The topic of mangrove removal is a challenging, politically vibrant topic, with polarising opinions both for and against removal. The rapid expansion of mangrove forests in recent decades has resulted in community support for estuarine restoration projects focusing on the removal of mangroves. Often the objectives of the removal include a desire by residents to restore open estuary sandflat conditions to reinstate the navigational, recreational and amenity value of areas colonised by mangroves.

Knowledge gaps remain in relation to the response of estuarine habitats to mangrove removal e.g. whether the removal will result in the restoration of sandier mudflat habitat, or how mangroves will respond to continued environmental changes and their ecological roles in New Zealand estuaries. Recent studies indicate that mangrove management (removal) needs to be considered on a regional basis due to differences in mangrove physical characteristics, estuarine hydrology and sediment characteristics from location to location.

After undertaking this literature review it is clear that there are a number of gaps in knowledge that would need to be filled if a Harbour-wide mangrove management framework was to be completed. The resources and expenditure involved to address these gaps are likely prohibitive due to the level of detail needed and the limited timeframes that the information would be valid. It may be more appropriate to provide clear decision-making steps based on the policy framework of the Regional Coastal Environment Plan once operative, and to apply these decision-making steps on a site-by-site basis

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Part 1: Introduction

1.1 Background - mangrove ecology and management

Mangrove forests in many tropical areas are declining due to coastal development, aquaculture, farming and resource extraction (Laegdsgaard and Johnston 2001; Valiela *et al.* 2001, Lovelock & Ellison 2007, Lovelock *et al.* 2010); however mangroves in northern New Zealand are naturally expanding in many estuaries. This is demonstrated in Tauranga Harbour by Park (2004) where mangrove extent has doubled over the last fifty years, with further expansion predicted. It is generally accepted that the main cause of rapid mangrove expansion is increasing levels of silt and mud entering waterways; leading to sedimentation which provides shallower, muddy areas where mangroves can grow (Hume 2003, Ellis *et al.*, 2004). Increased sedimentation is caused by anthropogenic changes in land use, such as clearance of native bush and reclamation of coastal wetlands. Other factors also play a role, including increased nutrients (fertiliser and effluent run-off from agricultural land and urban areas) and changing climate (less frequent and severe frosts enabling greater seedling survival) (McLeod & Salm 2006,Morrisey *et al.* 2010).

The New Zealand mangrove, called Manawa by Māori comprises a single species *Avicennia marina var. australasica* which has been present in New Zealand for at least 19 million years according to fossilised pollen records (Mildenhall 2001). Mangroves occur mainly in sheltered intertidal habitats north of their southernmost range of Ōhiwa Harbour on the east coast and Kawhia Harbour on the west coast (Park, 2004, Morrisey *et al.* 2010). Mangrove habitats and associated communities contribute to coastal diversity by providing ecosystem services such as habitat for fish, invertebrates and bird species (Morrisey *et al.* 2007, 2010).

1.1.1 History of mangrove management in Tauranga

Since 2009 the Bay of Plenty Regional Council has been involved in the management of mangroves in support of community groups. Management actions include the removal of mature mangroves in some areas and the control of seedlings in others. Mangrove removal is a controversial issue with polarising opinions, with appropriate management a priority to address mangrove expansion and the root cause of expansion the increased sedimentation rates in Tauranga Harbour.

The issue with mangrove expansion from a community perspective is that mangroves cause the loss of open water, reduced recreational access, loss of kaimoana and biodiversity (e.g. bird roosting sites).The primary goal of mangrove removal in Tauranga Harbour was to restore open estuary sandflat conditions in areas that have been colonised by mangroves since the 1970s. A sandier substrate is anticipated to increase the area of suitable habitat for wading and roosting birds and marine life; increase visual amenity values; and increase public access by removing a dense monoculture of mangroves extending up to 100 m from the shoreline (Harrison Grierson Consultants 2012). However there is a clear need for a robust assessment to whether this will actually occur if mature mangroves are removed.

Mangrove management was first instigated by the Land Care Trust through the formation of estuary care groups such as the Waikaraka Estuary Managers in 1997. The Mangrove Steering Group was formed in 2001 and it was discovered that removal of mangroves was not supported in the Bay of Plenty Regional Coastal Plan. The first consent to remove seedlings by hand was granted in 2004 to Tauranga City Council.

In 2009 the Bay of Plenty Regional Council applied to mechanically remove 110 ha of mangroves from the harbour. This was completed using a tracked machine with a mulching head to leave mangrove biomass in-situ. Concerns were raised about the impacts of mulched mangroves on the benthic ecology, as tidal flushing was not removing mulch from the managed areas as expected. It has been shown that removal areas at some locations are developing sandier habitats; however other areas show very little recovery (White 2014). The Council is now trialling a mangrove seedling mowing machine to achieve a ‘holding the line’ approach to manage mangroves in the harbour. Stump removal of previously cleared areas is still ongoing.

In 2015 there are 10 estuary care groups with 11 distinct management areas within Tauranga Harbour, with each group holding individual mangrove removal consents. The Bay of Plenty Regional Council’s role in removing mangroves is to assist with the consenting process to gain consents and provide support to estuary care groups.

1.1.2 Environment Court judgement

The 2013 Environment Court judgement ([2013] NZEnv 173) highlighted the need for a robust scientific framework to assess whether the removal of mangroves is warranted. It was clear from the court decision that the basis of management of mangroves must recognise that they are indigenous vegetation and a natural part of northern New Zealand’s estuaries. Further, the judgment noted that previous management and consents granted by the council may have been in breach of the preservation requirement of Section 6(a) of the Resource Management Act 1991 (RMA). Accordingly, there needs to be clear justification provided to remove mangroves beyond mere public dislike or impacts on amenity value. The court also found that mangroves have a clear ecological value and their removal has no ecological benefit as sandy mudflat habitats are well represented in the harbour. It was agreed however, that there were some benefits to the removal of mangroves in areas for amenity, recreational access, cultural importance and protection of ecologically valuable sites such as high-tide bird roosts which maybe sufficient to justify the removal of mangroves. The judgement also stated that the previous assessment of granted consents was inadequate, granted in a vacuum, and based only on the general principles of the RMA.

It was also suggested that catchment management plans are an appropriate approach to better manage the issues arising from the proliferation of mangroves, provided they meet the various criteria identified in council policy. Overall, the judgement concluded that there must be clear benefits to the harbour for removal of mangroves for amenity, recreational, cultural, access and ecological purposes.

1.2 Objectives

The objective of this literature review is to review all scientific information and data as well as identify knowledge gaps around mangrove management in New Zealand. It will also identify options to fill these gaps.

This review will then make recommendations on a process for the next steps, with the intent to develop an environmental decision-making framework for mangrove management. The framework will map Tauranga Harbour in terms of locations where mangrove management could be environmentally supported or not. This depends on whether management is an appropriate decision, taking into account predictions of climate change, sea level rise, sediment impacts and any other relevant considerations.

1.3 Methodology

An extensive literature search was undertaken. The main references were from New Zealand literature, with some minor contributions from international literature where local examples were lacking. Local studies focused on the Auckland, Thames and Bay of Plenty regions. International literature was mainly from within Australia. Peer reviewed literature was accessed by internal reference documents and via Google Scholar searches. The key words used in the searches included: mangrove management, mangrove expansion, temperate mangroves, sediment, mangrove ecology/biology and New Zealand mangroves. The information obtained from this literature was supplemented by personal discussions with key Council staff, particularly those who were involved in the mangrove removal projects.

Part 2: Literature review

2.1 Tauranga Harbour

Tauranga Harbour is located on New Zealand's northeast coast in the Bay of Plenty. It is the largest estuary in the region, impounded by a barrier island (Matakana Island) and two entrances flanked by barrier tombolos, Mount Maunganui at the southern entrance and Bowentown to the north (Ellis *et al.* 2013). The harbour is shallow and covers an area of 201 km^2 with 66% of its total area being intertidal. It has three main basins with the largest being the northern and southern basins (separated at low-tide) and the smaller town reach basin in the far south. At mean high water the northern basin has a volume of approximately 178 million m^3 and the southern basin a volume of 278 million m^3. There are more than 20 small sub-estuaries around the harbour. The northern harbour basin has a catchment area of 270 km^2 and a mean freshwater inflow of 4.1 m^3/s or 0.1% of the harbour volume per tidal cycle. The southern catchment has a total area of 1,030 km^2 and a mean freshwater inflow of 30.5 m^3/s, which is 0.48% of the harbour volume per tidal cycle. The total harbour catchment covers an area of approximately 1,300 km^2 and is well developed with extensive urban horticultural and agricultural use (Park 2004, Ellis *et al.* 2013).

2.2 Mangrove ecology

2.2.1 Ecology

Worldwide mangroves are a taxonomically diverse group of salt-tolerant plants that comprise over 70 species (Duke 1991). Mangroves range in size from large 20 m trees to stunted shrubs that inhabit the intertidal margins of low energy coastal and estuarine environments over a wide range of latitudes (Tomlinson 1986, Duke 1991). Mangroves grow in a wide tidal range from Mean High Water Spring (MHWS) tide down to Mean Sea Level (MSL) in ideal environmental conditions (Swales *et al.* 2007). They have a variety of special adaptations such as aerial roots and waxy leaves that allow them to flourish in an environment too harsh for most other plant species (Swales *et al.* 2009).

Mangroves are characteristically associated with warm tropical and subtropical shorelines, with only a few species found in colder climates. The New Zealand mangrove is a single temperate species, the grey mangrove, known locally as Manawa (*Avicennia marina* subsp*. australasica*). Manawa is the most southerly growing species in the world, with its New Zealand distribution limited to the north of the North Island extending south to 38^{o}05' at Kawhia Harbour on the west coast and 38^{o}03' at Ōhiwa Harbour on the east coast (Harty 2009). Their distribution is limited by cold weather conditions (frosts) and poor dispersal of propagules due to a lack of favourable currents, tides and large distances between suitable habitats (de Lange and de Lange 1994). In the far south of their range, plants grow as low spreading shrubs reaching around 1 m in height (Park 2004). In more northern harbours mangroves can grow to 5 m or more and form large forested areas (de Lange and de Lange 1994). In Tauranga Harbour mangroves are generally closed canopied and small (<1.5 m high) with growth rates of between 3 and 7.5 cm per year (Stokes 2010). Fecundity is generally high with seedling densities on the surrounding mudflats ranging from <1 to 14 per m^2 (Stokes, Healy and Cooke 2010).

The New Zealand mangrove is considered a native species and it, or a very similar species, has been part of the plant life here for approximately 6,000-6,500 years (Morrisey *et al.* 2007). Pollen in sediment cores from Poverty Bay puts the range approximately 140 km south of its current natural limit in New Zealand (Mildenhall 2001). Worldwide Avicennia marina occurs in both northern and southern hemispheres of the globe, but the subspecies (australasica) is confined to New Zealand, south-eastern Australia and Lord Howe Island (Crisp et al. 1990, Duke 1991).

Mangroves are typically found within the upper half of the intertidal zone, being most numerous nearer the high-tide mark in calm coastal areas and estuaries. They develop from seed propagules, which establish themselves on suitable substrates with high mud content (Park 2004). Muddy substrates are high in nutrients, but low in oxygen (anoxic); to adapt to these anoxic conditions mangroves have large root systems. This root system provides a raft for the tree to support itself, with breathing roots above the ground surface called pneumatophores allowing air to be carried into the root system. Mangroves also have waxy leaf surfaces and specialised breathing pores (stomata) which limit water loss in saline environments. These adaptions allow mangroves to be very productive with prolific growth measured in many areas (Morrisey et al. 2007).

Avicennia marina produces a large number of resilient vegetative propagules in New Zealand and elsewhere in the world (Alfaro 2006a, 2010). The resilient nature of these propagules allows for continuous development and growth throughout their dispersal stages (Fountain & Outred, 1991). In many areas of the world mangrove propagules are grazed extensively by marine fauna, with low success rates of propagule establishment and seedling survival (Sheaves and Maloney 2000, Cannicci *et al.* 2008). In New Zealand, Alfaro (2006a) found that few grazers exploit mangrove propagules or leaves; this allows mangroves in the local context to have a high seedling survival rate.

2.2.2 Climatic limits

Generally mangroves are limited to subtropical climates where the mean water and air temperatures are generally 20^{o}C. However, the actual geographical distribution is generally limited by ground frost occurrence. Overnight temperatures below 4^{o}C induce physiological stress, depressing photosynthetic rates due to physical damage to leaves and propagules (Morrisey *et al.* 2007). Freeze-injury decreases the likelihood of successful seedling production, establishment and long-term survival of saplings (Beard 2006, Walbert 2002).

2.2.3 Trapping of sediments

Mangroves enhance Sediment Accumulation Rates (SAR) by altering water flow (attenuation of waves and currents) (Morrisey 2007). The physiology of mangrove aerial root (pneumatophore) systems encourages the settlement of fine sediments such as silt, clays and organic matter. Sediments are transported into mangrove habitats from rivers and streams (Nicolls and Ellis 2002) with the greatest accumulation occurring on the seaward fringe or along tidal channels (Dingwall 1984, Clarke 1993, Furukawa *et al.* 1997). Swales *et al.* (2007) found in the Firth of Thames, that after mangrove colonisation, sedimentation accretion rates increased from 20 mm/yr to over 100 mm/yr leading to rapid increases in tidal mudflat elevation and further colonisation by mangroves. Sediment accumulation rates differ markedly between mangrove stands depending on local conditions such as geomorphology, coastal hydrology/oceanography and sediment inputs (Jennerjahn and Ittelkott 2002).

2.2.4 Erosion control and shoreline protection

Mangroves with their extensive root systems slow the flow of water and attenuate waves, preventing them from reaching the shoreline in exposed areas (Swales *et al.* 2009). As a result, mangroves can play a role in controlling coastal erosion, providing shoreline protection in some areas (Jennerjahn & Ittekkot 2002).

2.2.5 Natural aging of estuaries – role of mangroves

By colonising high shore intertidal areas mangroves contribute to the natural aging of estuaries by increasing sedimentation (Dingwall 1984). This leads to accelerating infilling and the creation of intertidal flats (Young and Harvey 1996). The aging of estuaries is a natural geomorphological process (Green 2006). However, the aging process can be dramatically accelerated by biological and anthropogenic factors such as the development of catchments and the expansion of mangroves which accelerate sediment infilling (Hume and Swales 2003) (see Figure 1 for clarification of aging process).

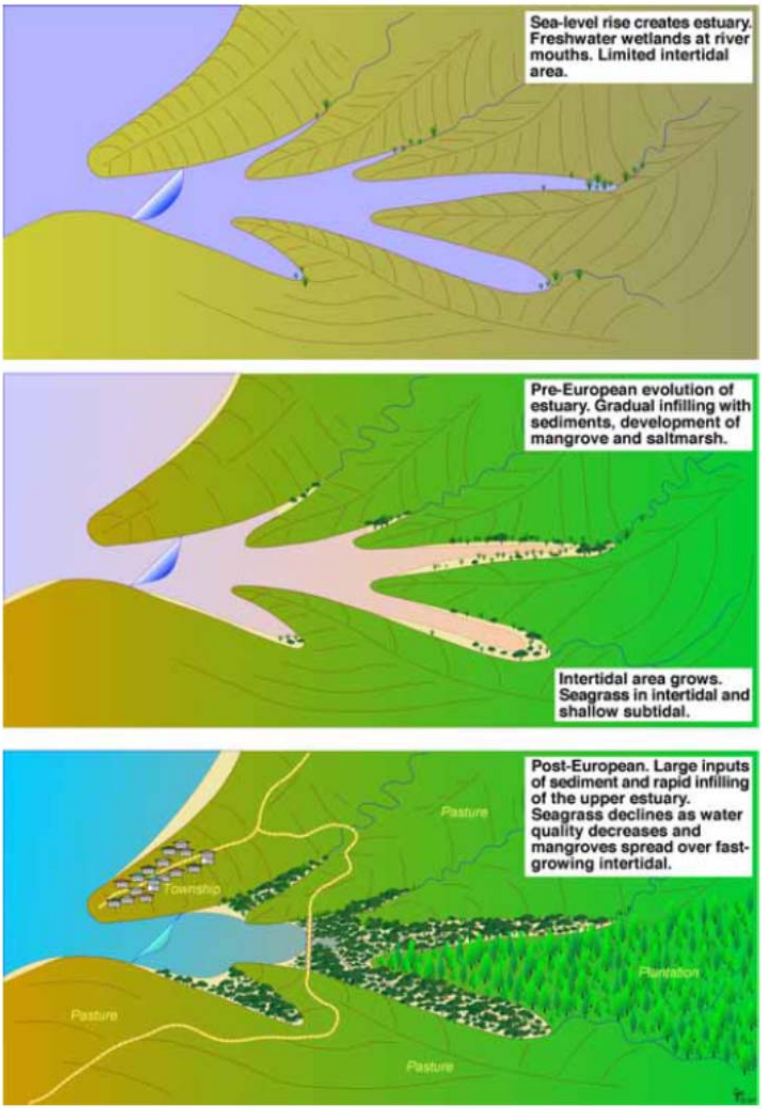

Figure 1 *Natural aging of an estuary, from its formation at the end of post-glacial sea level rise (6500 years) to present. The diagrams show the gradual infilling of sub-estuaries and the narrowing and shallowing of low-tidal channels in main estuary (source: Morrisey et al. 2007).*

2.2.6 **Productivity of mangroves**

The productivity of mangroves is measured by the amount of leaf, twig, reproductive parts and other litter that they produce each year. Mangrove productivity worldwide can be high with rates of up to 5-6 tonnes produced per year. Rates vary significantly depending on the size of tree and the latitude in which it grows (Saenger & Snedaker 1993). Research from New Zealand reveals significant variation in reported rates of litterfall, with rates generally below the maximum values reported in subtropical and temperate regions. Stokes (2010) found that for the short growth form of mangroves in Tauranga Harbour has an annual litter production of round 3.3 t/ha/yr. Gladstone-Gallagher, Lundquist and Pilditch (2014) found an annual mean litter production of 3 to 5 t/ha/yr dry weight in the Waitemata Harbour, northern New Zealand.

2.2.7 **Food sources**

Primary production (as litterfall) from mangroves may enter the surrounding food webs by direct grazing or detrital processes. Decomposition is mainly through bacteria and fungi decomposition. Nutritional value and availability to consumers increases over time as the material decomposes (Woodroffe 1985b).

Relative rates of decay vary with latitude (Mackey and Smail 1996). In New Zealand litter decay rates are fairly consistent with temperate areas of the world. However, litter decay is an order of magnitude slower than tropical areas (Morrisey *et al.* 2007). Gladstone-Gallagher, Lundquist and Pilditch (2014) found that leaves placed on the mud surface decompose faster than those buried due to anaerobic processing in the sediments. The slow decomposition and limited grazing (Alfaro 2006a) compared to tropical habitats suggests that mangrove productivity utilisation by temperate food webs is limited at temperate latitudes.

2.1 **Mangroves as habitats**

Relatively few studies have investigated mangroves as habitats for animal and plant assemblages in New Zealand. In tropical environments mangroves support an abundant and diverse range of algae and invertebrates (Morrisey *et al.* 2007). In temperate estuarine habitats, mangroves have been found to support a lower abundance and diversity of fauna compared to tropical habitats (Alfaro *et al.* 2006a). Further Alfaro (2006a, 2006b) found the diversity and abundance of fauna in mangroves was significantly lower than in adjacent mudflats and seagrass beds. The lower diversity and abundance of fauna and flora living in mangroves stands is generally driven by the nature of the sediment. Fine mud and silt dominates New Zealand mangrove sediments and is not the preferred habitat for estuarine invertebrates such as shellfish (Morrisey *et al.* 2007). Other limiting factors include tidal exposure and salinity variation due to tidal sea water mixing with fresh water run-off.

Marine fauna found in New Zealand mangroves include crabs, polychaete worms, isopods, amphipods, bacteria, various snails and whelks, cockles, barnacles, mussels and oysters (Taylor 1983, Ellis *et al.* 2004, Morrisey *et al.* 2003, Alfaro 2006a). Mangroves are also likely to support a wide range of terrestrial animals, such as insects and spiders, but our knowledge of these is very limited (Morrisey *et al.* 2007).

Mangroves also provide habitat for macroalgae, which grow on and among their trunks and pneumatophores. Mangroves have been found to a support high abundance of Neptune's necklace (*Hormosira banksii)* and *Catenella nipae* (Taylor 1983). Where mangroves occur at low densities on sandier shores, seagrass beds also occur in the gaps among the trees. Higher on the shore, saltmarsh plants may intermingle with the upper edge of the mangrove forest (Taylor 1983, Alfaro 2006a).

2.1.1 Importance to fish

Tropical mangrove systems are well documented as supporting diverse and abundant fish assemblages including providing critical nursery habitats for many commercial fishery species (Nagelkerken *et al.* 2000, 2001). Mangroves forests in tropical systems are generally composed of multiple species, with complex root growth forms (such as buttress roots) and are permanently submerged. This enables mangroves to provide a complex habitat for fish with abundant prey and protection from predation (Morrisey *et al.* 2007).

Fish assemblages in New Zealand mangrove forests have had very little quantitative research. A study by Morrisey *et al.* (2007) found 19 different fish species within mangrove habitats, of these, 88% of the fish caught were abundant small semi-pelagic schooling species (yellow-eyed mullet (*Aldrichetta forsteri*), grey mullet (*Mugil cephalus*), estuarine triplefin (*Grahamina nigripenne*), and pilchard (*Sardinops neopilchardus*)). Of the remaining species, two were commercially important and they were found in low numbers (snapper (*Pagrus auratus)*, and kahawai (*Arripis trutta)).* The large numbers of the small species are important prey species for larger commercially important fish species, thus it can be assumed that mangrove habitat is a useful habitat to prey fish species in New Zealand.

2.1.2 Importance to birds

There is little published information on the use of mangroves by birds in New Zealand. However, evidence suggests that a number of bird species make extensive use of mangroves for roosting, feeding and breeding. No bird species are totally dependent on mangroves; however a range of bird species occur regularly, including banded rail, white-faced heron, harriers, kingfishers, welcome swallow and pūkeko (Morrisey *et al.* 2007). Other species that have been observed include grey warblers, silvereyes, fantails, shinning cuckoos, bitterns, royal spoonbill and roosting colonies of pied and little black shags (Cox 1977, Crisp *et al.* 1990).

2.2 Mangrove expansion New Zealand

Historical accounts of mangrove forest extent in New Zealand indicate substantial loss of mangroves occurred during the first half of the 20th Century (Morrisey *et al.* 2010). This was through the reclamation of land for farming (e.g. Granville 1947), landfills, roads, ports and causeways that restrict tidal flow (Swales *et al.* 2009). From a Tauranga perspective, Park (2004) measured mangrove cover from 1943 and did not find any significant loss, however it is possible that the loss or gain occurred prior to this date. Evidence exists of land reclamation in Tauranga Harbour where coastal saltmarsh and wetland have been drained to create farmland or for urban and industrial developments. Anecdotal evidence suggests grazing of livestock in saltmarsh and mangroves was common practice also.

More recently mangrove expansion has occurred throughout northern New Zealand (Park *et al.* 2004, Swales *et al.* 2007, and Lindquist *et al.* 2013). Mangrove species (especially *Avicennia* sp.) colonise newly created suitable habitats readily (Saenger *et al.* 1977). An estimate by the Land Cover Database (Terralink, New Zealand Ministry of Agriculture and Forestry) in 1997 estimated a New Zealand total area of mangroves at 22,200 ha, which is likely to be greater in 2015. Numerous studies suggest that the total area of mangroves is increasing as mangroves consolidate their distribution in areas where they were historically present and have colonised new areas where previously they did not occur (Morrisey *et al.* 2007).

In Tauranga Harbour, Park (2004) revealed extensive increases in mangrove area from the 1970s to 2004. Is it estimated that there has been a 117% overall increase in mangroves in the past 50 years. However, considerable variation was found in the amount of expansion between sub-estuaries. For example Tanners Point and Blue Gum Bay both contained 0.2 ha of mangroves in 1951; but by 2003 Tanners Point contained 26 ha and Blue Gum Bay only 2.8 ha. Further, Stokes, Healy and Cooke (2010) found that mangrove expansion in Welcome Bay and Waikareao went from <1% in 1943 in both sub-estuaries to 9% in Welcome Bay and 6% in Waikareao in 2003. An example of dramatic and rapid expansion of mangroves is in the Firth of Thames. In the 1960s mangroves were only 50 m wide, and by 2002 mangroves had expanded nearly 1 km seaward (Swales *et al.* 2007).

2.2.1 Causes of mangrove expansion

The key drivers of mangrove expansion include estuary infilling and vertical accretion of mudflats from land derived sediments (sedimentation), increased nutrient inputs, climate warming or a combination of the above (Young and Harvey 1996, Schwarz 2002, Swales *et al.* 2007, Morrisey *et al.* 2007, 2010, Lovelock *et al.* 2010 and Lundquist *et al.* 2014).

2.2.2 Sedimentation

Land derived sediments are the main cause of estuary infilling and is a natural coastal process (Hume *et al.* 2007). Coastal geomorphology, estuary size and shape, combined with the interactions between stream and river processes, tidal exchange and wave action, determine the amount of sediment that accumulates in estuarine areas. The rate of infilling has accelerated due changing land practices increasing the erosion of soils into waterways leading to higher SAR (Walling 1999, Nichol *et al.* 2000, Beard 2006, Swales *et al.* 2009).

Sedimentation in many New Zealand estuaries and harbours have increased following human settlement (Hume and Dahm 1992). At the peak of catchment land use changes following European settlement (mid 1800s), catchment yields were several times greater than pre-European yields of several tonnes/km/yr (Prosser *et al.* 2001). Urban development has been a more recent cause of increased SAR (Williamson 1993). Erosion of exposed soil during the development process, and erosion of stream banks following development result in often-rapid deposition of sediment, particularly following rainfall events (Prosser *et al.* 2001).

Once sediment reaches the estuary, it is initially deposited in the upper estuary around stream mouths and tidal creeks. Once deposited, the accreting sediments raise the elevation of sandflats to a level that allows mangrove seedlings to colonise (Swales *et al.* 2007). Mangroves then establish and sedimentation rates then further increase due to the presence of pneumatophores and trunks which increase the drag-induced dampening of water flow, speeding up the sedimentation process (Young and Harvey 1996).

2.2.3 **Climate change**

Climate change affects the growth and distribution of mangroves due to increasing average temperatures, greater sedimentation rates and higher concentrations of carbon dioxide in the air (McLeod & Salm 2006). The predicted increased intensity and frequency of rainfall events will lead to greater SAR in estuaries allowing greater mangrove colonisation (Ellison 1994, Field 1995). The migration of mangroves to higher latitudes is also predicted to occur due to the reduction in periodic extremes in temperature (frosts), which allow greater seedling survival rates (McLeod & Salm 2006, Alongi 2008, Lundquist *et al.* 2011, Cavanaugh *et al.* 2014).

2.2.4 **Nutrients**

Increased nutrient input (nitrogen and phosphorus) from catchment run-off increases growth rates of mangroves (Morrisey *et al.* 2007). Overseas research has shown that nutrient limitation patterns in mangrove systems are complex, with essential nutrients not uniformly distributed throughout forests and interactions exist to limit one or more nutrients (Feller *et al.* 2003, Morrisey *et al.* 2010). In New Zealand elevated nutrient loading is thought to play a role in the acceleration of mangrove spread, enhancing growth rates and biomass (Yates *et al.* 2004), and increasing mangrove potential to produce propagules (Cavanaugh *et al.* 2014).

2.2.5 **Effects on estuaries**

Once established, mangrove stands influence sediment processes (grain size and deposition rates), water movement and ecology. These processes can then lead to greater mangrove expansion, growth and productivity (Lundquist *et al.* 2014). An example is the Firth of Thames where high SAR rates (100 mm/yr) have led to rapid elevation of mudflats ideal for mangrove expansion (Swales *et al.* 2007). It is not understood whether mangroves will eventually become other habitats (i.e. saltmarsh or freshwater wetlands) due to their expansion down-shore, or if they will eventually reach a balance point where mangrove habitat expansion is limited by tidal elevation. In some areas mangroves are expanding at such a fast rate that they may colonise other habitats such as intertidal mudflats, seagrass beds and saltmarsh.

Few examples exist where saltmarsh has been lost due to mangrove invasion, as the expansion of mangroves is generally seawards and saltmarsh generally occur on the higher shore where mangroves cannot occupy. Very limited invasion of the lower edge of saltmarsh has been observed in Tauranga with healthy saltmarsh communities appearing resistant to invasion (Park 2004). However, in areas where sparse, disturbed saltmarsh (such as vehicle tracks or damage by stock grazing) exist, or where channels through the marsh allow mangrove propagules to be transported, saltmarsh is vulnerable to colonisation.

The colonisation of intertidal flats by mangroves may also deprive wading birds of feeding and roosting areas. Loss of high-tide roosting areas has been documented in parts of the inner Firth of Thames (Swales *et al.* 2007). The use of roosting sites by shorebirds has steadily decreased with greater mangrove cover. This change has been particularly noticeable for wrybills, golden plovers, red knots and whimbrels (Morrisey *et al.* 2007). Conversely mangrove expansion can also benefit those birds commonly using mangroves to feed, roost and breed. There is a long-standing debate about the significance of gain or loss of feeding and roosting habitat to wading birds at the population level. There is currently a knowledge gap with insufficient information to assess population-level effects of mangrove expansion on wading birds.

2.3 Tauranga Harbour mangrove expansion

For residents living close to Tauranga Harbour, mangroves and associated muddy substrates are seen to impact negatively for the following reasons:

(i) They hinder water access for recreation.

(ii) Their expansion can lead to habitat loss for certain intertidal sandy shore benthic organisms.

(iii) The muddy substrate associated with mangroves is regarded as aesthetically unpleasant.

(iv) Concerns that mangroves increase flooding hazards for coastal properties in the upper estuary (Stokes, Healy and Cooke, 2010).

The main cause of the expansion of mangroves is the increased sedimentation rates in Tauranga Harbour which are the direct result of historic clearance of native catchment vegetation, including wetlands, and the ongoing development of catchments (Park 2004). Several studies have been commissioned with the National Institute of Water and Atmosphere (NIWA) to investigate sedimentation rates and sources within the harbour and catchments.

2.3.1 Southern Tauranga Harbour Sediment Study - NIWA (2009)

The Council contracted NIWA to conduct the Tauranga Harbour Sediments Study with the objectives to:

(v) Assess the relative contributions of catchment sediment sources surrounding the southern Tauranga Harbour,

(vi) Assess the characteristics of significant sediment sources from the catchment, and

(vii) Investigate the fate (dispersal and deposition) of catchment sediments through Tauranga Harbour.

The project also addressed issues such as:

(i) Which catchments are more important as priority areas for focusing resources to reduce sedimentation in the harbour?

(ii) What are the likely effects of existing and the future urban development on the harbour?

(iii) How can the appropriate regulatory agencies most effectively address sedimentation issues, and what management intervention could be appropriate?

(iv) Are there any reversal methods, such as mangrove control and channel dredging that may be effective in managing sedimentation?

The project area was defined as the southern harbour, extending from Matahui Point to the harbour entrance at Mount Maunganui. The prediction timeframe for sedimentation was 2001 to 2050. The study consists of six modules including:

(i) Specification of scenarios used to drive the models (Parshotam *et al.* 2008),

(ii) Catchment sediment modelling (Pritchard and Gorman 2009),

(iii) Harbour bed sediments (Hancock, Hume and Swales 2009),

(iv) Harbour modelling (hydrodynamic and sediment models) (Parshotam *et al.* 2009, Elliot, Parshotam and Wadhwa 2009),

(v) USC-3 model (develops predictions of sedimentation and bed sediments) (Green 2009a 2009b),

(vi) Assessment of predictions for management (Hume, Green and Elliot 2009).

Modelling found that sediments entering the southern harbour increases with the area of catchment. Sediment loads were greatest from the Wairoa River Catchment (42.4% of the total load to southern harbour). Overall, low rates of sedimentation and evidence of deep mixing of surface sediments from cores indicate that large areas of intertidal flats in the Southern Harbour are not long-term sinks for fine terrigenous sediments. Potential depositional environments include tidal flats, tidal creeks, sheltered bays, mangroves and saltmarsh habitats. These include areas where sediments are trapped along the fringes of sub-estuaries (Welcome Bay) and sheltered sub-estuaries close to river mouths (Te Puna).

In response to predicted climate change conditions, catchment and harbour processes will change. Sediment load from freshwater inputs will increase by 40.6% by 2051 due to the predicted increased frequency and intensity of rainfall events (Hume, Green and Elliot 2009). Furthermore, the way in which the harbour is affected by sedimentation will change, due to greater freshwater input and sediment loads modifying hydrodynamics. As a consequence, the harbour will be less able to transport sediment offshore. In higher sub-estuaries, sedimentation will increase by 17 to 97% depending on the sub-estuary.

The catchment sedimentation model's key results were: land slope, soil type, rainfall and land use all have a significant impact on sediment yields, which lead to a complex pattern of sediment generation in the southern harbour. The highest generation areas in terms of yield occur in pasture areas, steep slopes and soils which are poorly drained. Pasture covers 33.7% of the southern catchments, and makes the largest contribution of 63.7% to the sediment load (tonnes per year). Native bush and pine plantation cover 44.2% and are generally in steeper, higher-rainfall areas of the catchment and only contribute 27.8% of sediment load. Orchards and cropland were predicted to make small contributions to sediment load to the estuary. Most of the sediment entering the harbour in the southern harbour is from the Wairoa (42.4% of the total load). The Apata sub-catchment has highest yield due to pasture land use, moderate slope and rainfall.

To conclude the study, NIWA made recommendations for management by integrating the sediment model predictions with information obtained from an expert panel. Sub-estuaries were identified with high potential of adverse effects from sedimentation including: Rangataua Bay, Welcome Bay, Waimapu, Waikareao, Waikaraka and Te Puna. The sub-catchments with the highest potential for mitigation of sedimentation included: Waitao, Kaitemako and Waimapu. The sub-catchments where mitigation would be optimal due to the potential for adverse effects from sediment and the opportunity for mitigation is high were identified as **Waitao, Kaitemake, Waimapu, Kopurererua, Oturu and Te Puna.** By intervening in these catchments it is expected to reduce sedimentation to sub-estuaries such as Rangataua Bay, Welcome Bay, Waimapu, Waikareao, Waikaraka and Te Puna.

Key opportunities to mitigate sediment impacts include:

(i) The retirement of steeper pasture areas or establishment of pine plantation in such areas,

(ii) Opportunities for enhanced floodplain deposition in Waitao and Waimapu sub-catchments,

(iii) Some minor improvements that can be made to forestry management in several catchments, and

(iv) Current earthwork controls to be maintained to mitigate run-off.

2.3.2 The Importance of bank erosion as a source of suspended sediment within the Kopurererua Catchment - NIWA 2014

Bay of Plenty Regional Council commissioned NIWA to investigate bank erosion and mass land movement of streams and rivers in the Tauranga Harbour to better understand sediment sources from the catchments. A report by Hughes and Hoyle (2014) investigated the Kopurererua Catchment to determine the contribution of bank sediment to the river system by radionuclide sediment tracing and suspended sediment concentration monitoring near the catchment outlet. Further as part of the study, a literature review was conducted on the effectiveness of previous catchment interventions which investigated reducing sediment delivery from river banks to rivers by planting riparian vegetation (Hughes, Hicks & Hoyle 2013).

The literature review found that most studies attribute the exclusion of livestock from riparian areas as a reason for measured improvements or differences in sediment loads. Only one study specifically stated that riparian planting resulted in a reduction in bank erosion or sediment yield. Due to the dominance of different erosion processes in different areas of the catchment, reach-specific solutions to bank erosion need to be considered.

The radionuclide tracing component found that the three primary sources of interest, hill slope (radionuclide rich), mass slumping and stream bank and bed cutting (radionuclide poor) could be well differentiated using the ratio between radionuclides from nuclear bomb-derived fallout and those naturally occurring in rock. Results indicate 95 to 99% of the sediment found in end-of-catchment sediment deposits has low radionuclide content, suggesting that sediments found in the estuary are derived from mass slumping of steep hill country, stream banks/bed cutting and not from hill slope surface erosion.

A field inspection of the catchment found that large amounts of sediment is being delivered to the stream from the upper reaches of both the Tautau and Kopurererua streams by mass slumping and slips. Bank erosion is the source of sediment along the middle reaches of the catchment and that the lower reaches are relatively straight and stable compared to the upper catchment.

A key recommendation from the study was to further differentiate sediment sources and to establish a strategic Suspended Sediment Concentration (SSC) programme. This would enable clear delineation of the sources of sediments along the Kopurererua Catchment reaches.

2.4 Mangrove management in New Zealand

The issue of mangrove habitat expansion in New Zealand is a contentious issue, with the public's desire to maintain open shoreline space creating considerable conflict. Park (2004) stated that many people viewed the rapid expansion of mangroves as unnatural and adverse biological phenomena. Although mangroves are a natural part of the ecosystem, they are well adapted to spread quickly and there may be valid reasons for controlling them. For example, restoring sandy habitats that are being consumed by mangroves might lead to an overall increase in estuary biodiversity and human amenity. On the other hand, mangrove control would prevent the estuary from "ageing naturally", although just what this means in estuaries that already have unnaturally high sediment inputs is open to debate (Green 2003).

In an attempt to establish a more integrated estuary management process a number of "estuary care" groups have been formed in partnership with regional bodies. These care groups work towards developing and implementing estuary management plans, however, much of the associated work undertaken within these management plans is to remove mangroves (Harty 2009).

Several concepts of mangrove management are currently under debate, with a range of intervention strategies involving the removal of mangroves. At one end is the low impact "non-intervention" approach to mangrove management, which allows mangroves to remain intact and allows the natural processes of mangrove expansion to occur. This style of management is more suited to relatively stable mangrove areas where little expansion has occurred in the mangrove forest over several decades. A middle-road approach, which allows adult plants to remain intact, is the prevention of further expansion into areas where they have been identified as potentially decreasing or removing existing values (aesthetic, ecological, or economic). This approach involves the annual removal of first-year seedlings, and requires ongoing and active management, coupled with the participation by local community groups. In contrast, there is push from some areas of the community to undertake a relatively high-impact control approach, with the large-scale removal of all adult plants, saplings and seedlings back to pre-determined baseline levels. The aim of this management is to preserve and restore the ecology of habitats threatened by mangrove expansion (for example; saltmarsh, seagrass beds, mudflat); to restore aesthetic values in an estuary (e.g. open water views and dispersal of sediment); and to maintain access-ways to, and throughout a harbour or estuary.

Longer term understanding of the environmental effects from removal is limited as long-term recovery trajectories in sediment characteristics and benthic community structure poorly studied at most removal sites (Lundquist *et al.* 2014). Further, few if any studies have demonstrated the effectiveness of removal in achieving stated management objectives, such as dispersal of accumulated fine sediments and restoration of ecology. Lindquist *et al.* (2014) found little recovery of mangrove removal sites towards typical sandflat habitats in either the sediment characteristics and benthic composition in the Auckland region over a post removal period of three months to eight years.

Regardless of which approach is used to manage mangroves, cost effectiveness may only be achieved by evaluating mangrove areas on a site-by-site basis. Research has established that the processes and effects of removal vary according to the type of mangrove community, whether it is stable or dynamic, and site-specific physical, hydrological and ecological characteristics.

2.5 Mangrove removal

A number of methods have been employed to remove adult mangroves and seedlings, ranging from hand removal using chainsaws and scrub bars to mechanical removal utilising wide tracked machinery. The disposal of vegetation has also varied, ranging from complete removal of all above-ground biomass and disposal off site, to burning onsite, or mulching onsite to decompose.

2.5.1 Effects of mangrove removal

Alfaro (2010) looked at the effects of mangrove removal on the community ecology of mangrove stands and surrounding habitats in Mangawhai Estuary. The results of this study indicate that removal of mangroves altered the sediment characteristics and abundance of macrofauna within the habitat. Lundquist *et al.* (2012) investigated the physical and ecological impacts associated with mechanical removal using mechanical mulching in Tauranga Harbour and found that after a 12 month period, mulched areas show minimal recovery to sandflat communities. Mulch biomass still remained onsite, with limited dispersal or decomposition of mulch material. Erosion of sediment was also very slow, with only 5 to 19% decreases in total area over 12 months. A study from White (2014) in Tauranga Harbour suggests that the removal of mangroves usually creates detrimental environmental effects on the short to mid-term, however some recovery recorded in some sandier areas.

2.5.2 Recovery in Tauranga Harbour

Recovery of mangrove removal areas within Tauranga Harbour is occurring very slowly, with only a few areas returning towards sandier habitats including Matua, Waikaraka and Waikareao (Wildlands Consultants 2003, Park 2012, White 2014). Other sites in the harbour have not returned to sandier habitats at all (Lundquist *et al.* 2012, Park 2012). Site specific factors influence the return of mangroves to sandier habitats, including differences in hydrodynamics (wind-wave action exposure and tidal currents), sediment inputs, freshwater influx and local sediment characteristics (i.e. depth of mud to clean sand). The sites that have returned to sandier habitats are generally located in wave and wind exposed areas with large wind fetch, near tidal creeks and channels with strong tidal currents (Lundquist *et al.* 2014).

The size of mangrove removal is thought to have an effect on the recovery of mangroves. Small areas (<20 m in width) that were removed by hand have been found to recover faster than mangroves removed mechanically over large areas (Lundquist 2012). For example Lundquist *et al.* (2012) found that changes in benthic community and sediments at Te Puna and Waikaraka (where mechanical removal and mulching occurred) reveal significant impacts on benthic communities and few signs of recovery to typical sandier habitats (in terms of sediment characteristics or benthic community composition) over a 12 month period. Park (2012) concluded that two years post removal, cleared areas at Waikareao and Matua Estuaries were changing in sediment characteristics towards that typical of bare sandflat.

Given sufficient time it seems likely that species diversity will increase to similar levels to other mudflat areas, however these conclusions are based on two estuaries that are sandier in character with high wave exposure and may not be representative of all removal areas in Tauranga Harbour.

Part 3: Summary of literature

- The mangrove (*Avicennia marina* subsp. *Australasica)* is a New Zealand native and has been in New Zealand around 19 million years.
- Mangroves are an important part of the natural vegetation sequence of habitats in estuaries and harbours.
- Mangrove productivity in New Zealand is low compared to tropical mangroves; however it is similar to mangroves growing in other temperate regions.
- Mangroves support a range of marine flora and fauna, such as macroalgae, crabs, worms, mud snails and whelks, barnacles and shellfish. The abundance and species richness present is generally lower than adjacent habitats.
- High abundances of small pelagic fish have been found in mangroves, which are prey species for larger commercially important fish species.
- While many native bird species make use of mangroves for roosting, feeding and breeding, no bird species are totally dependent on mangroves in New Zealand.
- The relatively recent expansion of mangroves in many estuaries and harbours is a ‘natural’ response to the unnatural increase in sediments from catchments following native forest clearance and subsequent land development.
- Increased inputs of nutrients (particularly nitrogen and phosphorus) from catchment run-off can increase the growth rate and productivity of mangroves and may play a part in their rapid expansion.
- Changes in the hydrodynamics in estuaries due to increasing sedimentation rates can affect the areas in which mangroves may grow.
- Several aspects of climate change affect the growth, productivity and distribution of mangroves, resulting in an increase in growth and distribution due mainly to increased sedimentation.
- Although mangrove expansion is a wide-spread phenomenon in northern New Zealand, it is also site-specific and variable and depends on environmental factors such as temperature, salinity, wave exposure, nutrient input and sediment loading.
- Once established, mangrove stands influence estuarine sediment processes, further raising the height of surrounding mudflat and altering the sediment characteristics, which promotes greater mangrove expansion.
- It is unknown whether mangrove expansion will take over other habitats, like seagrass, saltmarsh and sandy mudflat.
- Recent, rapid expansion of mangroves has affected human access to and use of the coastal environment. Amenity value has also been impacted.
- Mangrove management is a contentious issue with community expectations driving management and not science.
- Removal of mangroves does not necessarily result in recovery to sandier mudflat communities.
- Removal of mangroves results in short to mid-term environmental impacts.
- Longer term trends after mangrove removal is difficult to discern at this stage.

- Once mangrove stands have established it is difficult to restore to open mudflats.
- Mangrove Management is best directed to limiting further expansion.
- Further investigations are needed to satisfactorily be able to produce a management framework for mangrove management in Tauranga Harbour.

Part 4: Gap Analysis

The debate surrounding the values of New Zealand mangroves, particularly their importance and ecological role in coastal ecosystems, has led to a greater focus on research in recent times. Previously the information on which New Zealand mangrove values were based was gleaned from a small number of historical studies, anecdotal evidence and comparisons with overseas mangrove systems. This has proved inadequate in some cases, not only from a community perspective on how mangrove management should proceed, but also for the governing agencies tasked with the responsibility of implementing this management.

Significant gaps still exist in knowledge around where and how mangrove management should occur. It was clearly noted in the 2013 Environment Court judgement that the decisions to remove mangroves were previously inadequate. If an application to remove mangroves is made, there needs to be a clear justification in terms of access, amenity, cultural or ecological need, i.e. the protection of a high-tide bird roost, around structure or reducing flooding risks.

The greatest challenge in the management of mangroves from an ecological perspective is that:

1 No significant ecological harm will be caused by the removal,

2 Sufficient evidence is available to indicate that the area will recover towards a sandier mudflat habitat, and

3 Removal will achieve a higher value ecological habitat, thus improving the ecological health and resilience of the estuary.

Below is a table of gaps and options to fill those gaps:

Gap theme	Gap	Options to fill this gap	Outcomes
Obtain new data			
Modelling	Need for harbour-wide hydrodynamic modelling of sub-estuary for information affecting mangrove clearance success.	Undertake modelling exercise or similar study to investigate for each sub-estuary: the distance of mangroves from or to a large channel or the harbour mouth, wave stirring and re-suspension of sediments, tide currents, freshwater inflows, estuary shelter and wind fetch and shape.	Greater understanding of areas where mangrove removal may successfully lead to restoring sandier mudflat habitats.
Modelling/GIS information	Sufficient catchment landuse information and sediment loading is lacking in harbour.	Undertake study to obtain catchment information such as catchment size, slope, land use, soil type and discharges (nutrients, sediments etc.).	Greater resolution of priority catchments for intervention.
Modelling	Tauranga Harbour Sediment Study for northern harbour similar to that completed in southern.	Similar to the southern harbour study, but with greater definition around catchments and estuaries of priority.	Information regarding sediment loading and priority catchments and sub-estuaries for intervention.

Gap theme	Gap	Options to fill this gap	Outcomes
Sedimentation study	Sediment inputs (loading) and sediment accumulation rates for all sub-estuaries in harbour.	Sediment Accumulation Rate (SAR) study of all sub-estuaries.	Quantitative data on which sub-estuaries have greatest SAR for prioritisation and monitoring of health.
Hydraulic modelling and gauging	Freshwater sediment loading and flux in harbour (event monitoring of sediments).	Information on sediment loads and sediment removal from estuaries (SAR).	Greater knowledge of how estuaries are coping with different sediment loads entering the harbour and which sub-estuaries are of greatest priority for sediment reduction.
Monitoring and modelling	Sediment transport (re-suspension) rates down-shore harbour-wide.	Tracking sediment down-shore after an event in estuaries and tracking re-suspension/deposition rates within estuaries.	Knowledge around sediment rates within the harbour. Identifying depositional areas and paths in which sediment is flushed from harbour.
Investigation	Sediment profiles and characteristics harbour wide in all sub-estuaries i.e. depth of mud and underlying substrate type (clean sand).	Undertake study within sub-estuaries of sediment profiles and depth of mud to clean sand.	Gives indication of possibility of successful restoration of estuaries back to sandier mudflats after mangrove removal.
Monitoring	Mangrove below ground biomass decomposition rates.	Study of decomposition rates of below ground biomass due to slow rates observed in other areas. Mangrove roots continue to bind sediments even after they are removed from area.	Gives indication of timeframes greater erosion towards sandier habitats once mangrove roots are no longer binding sediments.
Investigation	Sediment contamination within mangroves i.e. heavy metals, pesticides and nutrients.	Study to sample mangrove areas to gain greater understanding of contaminant trapping properties and areas that are contaminated.	Greater clarity of ecosystem services of mangroves for removal of contaminants and identifies areas where mangroves should not be removed if sediments are contaminated.
Investigation	Unknown down-shore impacts of sediment movement on seagrass and other valued habitats.	Study to gain better understanding of down-shore impact of sediment on seagrass, mudflat and sub-tidal areas after mangrove removal with greater down-shore sediment movement.	Greater understanding of effects of mangrove removal on down-shore seagrass and mudflat habitats.

4.1 Recommendations from gap analysis

Due to the number of projects and knowledge gaps that need to be addressed before it would be possible to undertake a harbour-wide assessment of where successful removal of mangroves could be undertaken, it is recommended that a Harbour-wide mangrove management framework is not developed. The management of mangroves is site specific and needs to be treated as such. Management plans and investigations need to occur at a sub-estuary scale to discern whether the removal of mangroves is appropriate (i.e. justified for amenity, access, cultural and ecological reasons) and will be successful in rehabilitation of estuaries to sandier mudflat habitats. Or where it might be more appropriate to manage mangroves in a 'hold the line' approach, where removal of seedlings to halt mangrove expansion is undertaken.

Managing mangroves cannot occur with a one-size-fits-all approach, site specific management needs to occur to achieve successful outcomes for both the community use and ecological health of the harbour.

To clarify:

1. Recommend not developing a Harbour-wide mangrove management framework.
2. Mangroves need to be managed on a sub-estuary basis to gain best outcomes for the harbour through the development of management strategies and catchment management plans.
3. Site specific management strategies are needed to deal with mangrove expansion.
4. Ecological benefits and parameters for successful rehabilitation need to be clearly identified if mangrove removal is needed or will be successful.
5. There needs to be a clear focus on managing sedimentation, which is the key driver of mangrove expansion and the biggest cause of biodiversity loss in the harbour, not the natural response of mangroves.

Part 5: Conclusion

1. Considerable time, resources and expenditure needed to achieve desired management framework for harbour, which may only be relevant for a short time due to dynamic nature of estuaries
2. Mangrove systems are complex and are highly variable from location to location.
3. Sub-estuaries and catchments are highly variable in sedimentation rates, hydrological gradients and ecological sensitivity.
4. Most important factor in driving mangrove expansion is increased sedimentation, which is the key issue to be addressed in Tauranga Harbour.
5. Success of mangrove removal depends on a range of variables that need to be considered on a site-by-site basis.
6. Further information would be necessary if a Harbour-wide decision making framework is to be developed. This would require considerable time, resources and expenditure and the framework may only be relevant for a short time due to dynamic nature of estuaries.
7. It may be more appropriate to provide clear decision-making steps based on the policy framework of the Regional Coastal Environment Plan once operative. The decision making steps would be on a site-by-site basis, taking into account the costs and benefits of the management action.

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