



Guidelines for
**Managing Mangrove
(Mānawa) Expansion**
in New Zealand

To provide guidance on the best techniques to manage mangrove expansion, while maintaining the ecological integrity of estuaries and harbours.



New Zealand Mangrove – Mānawa

Avicennia marina subsp. *australasica*



Guidelines for Managing Mangrove (Mānawa) Expansion in New Zealand

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Acknowledgments:

This guide was developed with funding from the Ministry for Business, Innovation and Employment (MBIE) under Contract Number C01X1002. The guidelines are based on information from a range of field and experimental studies funded through this and preceding FRST, MSI and MBIE contracts; by NIWA core funding from the Freshwater and Estuaries Centre; and by surveys and monitoring of mangrove clearances by Auckland Council and Waikato Regional Council. We thank Waikato Regional Council, Auckland Council, Northland Regional Council and Bay of Plenty Regional Council who have provided information on regional mangrove management, and NIWA and council colleagues who assisted with field work. Photos are mainly those of the authors or Rebecca Gladstone-Gallagher unless otherwise specified.

Citation:

Lundquist, C., Carter, K., Hailes, S., Bulmer, R. (2017) Guidelines for Managing Mangroves (Mānawa) Expansion in New Zealand. *NIWA Information Series* No. 85. National Institute of Water & Atmospheric Research Ltd. <http://www.niwa.co.nz/managingmangroveguide>

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ISBN 978-0-473-39180-5

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Graphic design: Aarti Wadhwa

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Introduction

The native New Zealand mangrove species (*Avicennia marina* subsp. *australasica*) has been in New Zealand for thousands of years.

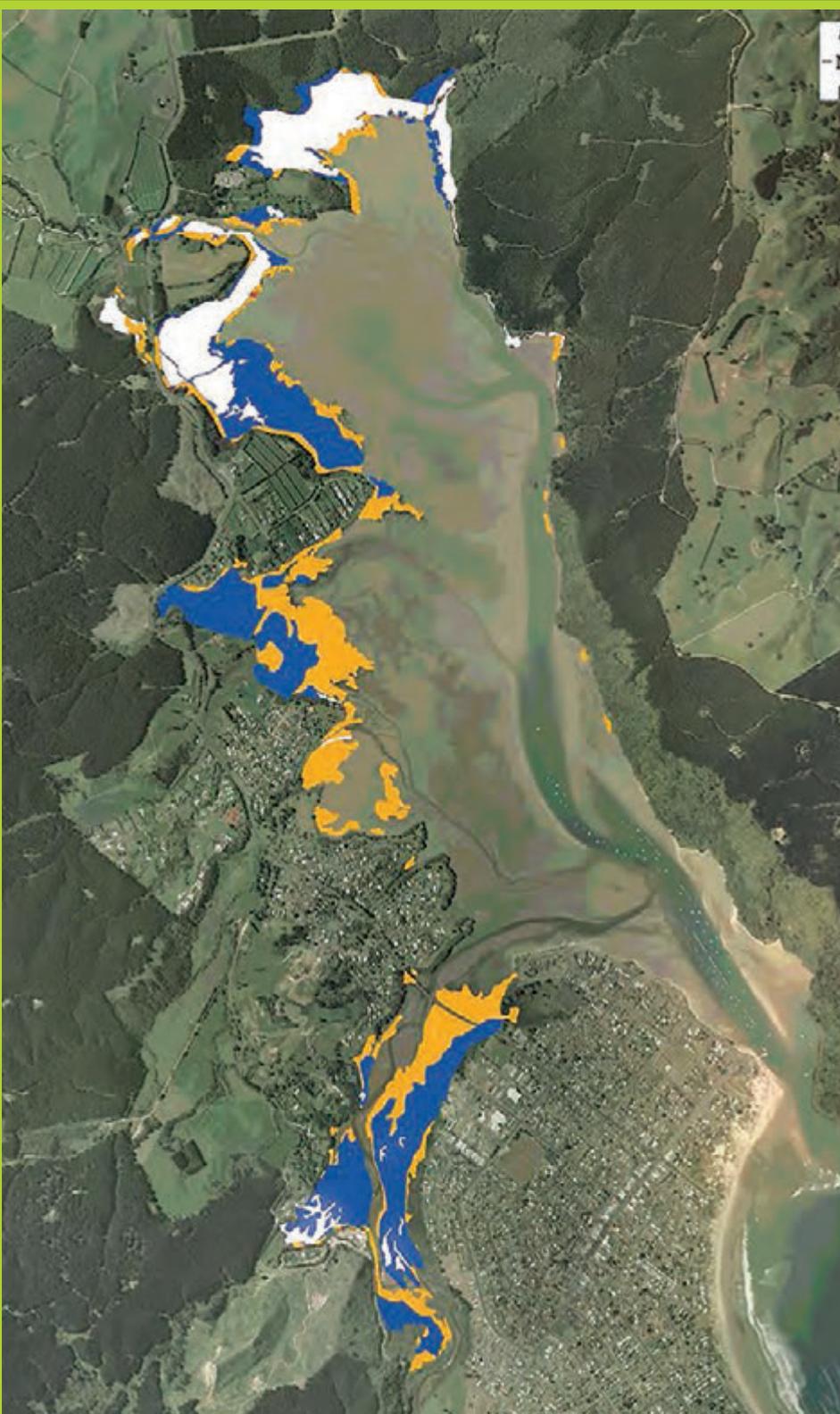
Mangroves are distributed within the upper half of the North Island of New Zealand, where warmer temperatures are optimal for survival. Temperate (i.e., not tropical) mangroves are also found in Australia and the United States of America, and comprise about 2% of global mangrove forests.

Over the past half century, mangroves have expanded in extent in New Zealand, mainly seaward across tidal flats (for example in Whangamata Harbour, Figure 1).

Mangrove expansion has been attributed to increased sediment runoff from the surrounding land and catchment, and activities such as causeway construction altering hydrodynamic conditions. This has increased the suitability of many estuarine areas for mangroves, through increasing muddiness, reducing current flows and exposure, and increasing the height of tidal flats.

Research from the Firth of Thames has found that muddy sediments are typically deposited before mangroves expand into new areas, rather than mangroves causing an increase in deposition of muddy sediments (Swales et al. 2015).

Figure 1: Aerial view of Whangamata Harbour and the extent of area occupied by mangroves in 1944 (white), 1978 (blue) and 2002 (orange). Figure: Waikato Regional Council.



Until recently little was known about the effects of mangrove removal on the environment, or the best practices for mangrove removal to minimise or avoid adverse impacts and achieve desired removal outcomes.

In order to address this knowledge gap, NIWA has surveyed mangrove removal sites throughout the country. Data collected has shown that removal of mangroves rarely results in a return of sand flats, and often has detrimental effects on the local ecosystem and amenity (sight and smell).

Many methods of removing mangroves have been used with varied success. These include manually pulling small seedlings, removal using chainsaws and axes at above ground level, and mechanical removal using tractors and diggers to remove vegetation and some below-ground root material.

The information collected to date can help provide guidance regarding the likely results of removing mangroves. Furthermore, this guide can advise on where mangrove removal is unlikely to achieve desired outcomes, or is likely to be very costly to maintain in a mangrove-free state.

The aim of this manual is to provide guidance for managing mangrove expansion, while maintaining the ecological integrity of estuaries and harbours.

Healthy mangrove stand in Waikareao Estuary, Tauranga Harbour.



Mangrove ecosystem services

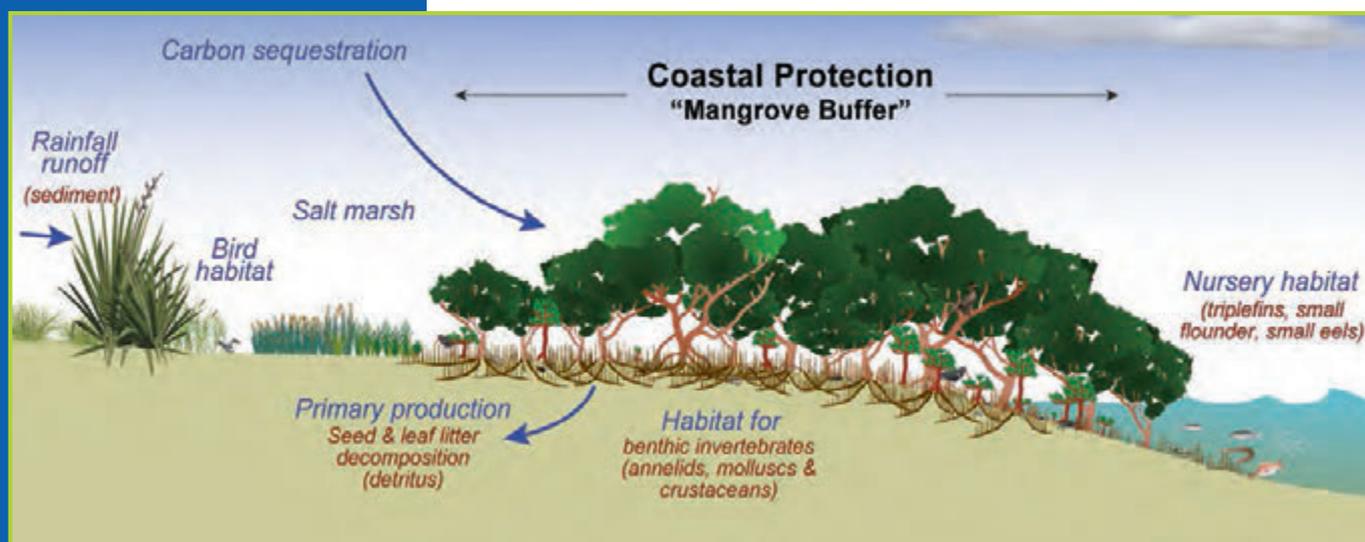
The services (physical and biological) which mangroves provide at small and large scales are often overlooked.

Mangroves provide many physical and ecological functions in New Zealand estuaries. Mangroves provide a buffer zone and protection from erosion of the coastline. Policy 26(2) of the New Zealand Coastal Policy Statement recognises the potential for mangroves to provide a natural defense against coastal hazards.

Ecologically, mangroves provide energy and organic matter in the form of leaf, seed and woody debris to the environment which is incorporated into the foodweb, thus supporting a diversity of animal life including both estuarine and terrestrial fauna and flora.

Mangroves and other coastal vegetation also have an important role in sequestering carbon, and are, therefore, important in contributing to New Zealand's international role in mitigating against climate change.

Figure 2: Ecosystem services provided by coastal mangroves in New Zealand. Figure: Max Oulton.



Management of catchments

Catchment management decisions, such as those that result in increased conversion of land for agriculture, forestry or urban use, have downstream implications for the health of estuaries. Sediment from land enters estuaries and raises the height of tidal flats, and increases the area that is suitable for mangroves to colonise. Controlling and reducing the input of sediment into estuaries is an important aspect of reducing expansion of mangroves.

The best way to manage the expansion of mangroves over the long term is to limit the amount of sediment reaching the coastline from the surrounding land.

In addition, increased nutrient inputs associated with land development, agriculture and horticulture ultimately end up at the coast. When nutrient concentrations increase, evidence suggests that mangroves grow faster which increases their potential to produce more reproductive seeds (Nicholls et al. 2004, Schwarz 2003).

Essentially, the removal of mangroves is a temporary fix unless further management steps are taken to minimise the input of land-based sediments and nutrients entering waterways.

A. High intensity development



B. Low intensity development



Figure 3: Illustration of the impacts on estuaries and waterways when the surrounding land is highly modified (Scenario A, top) and less modified (Scenario B, bottom). Figure: Max Oulton.

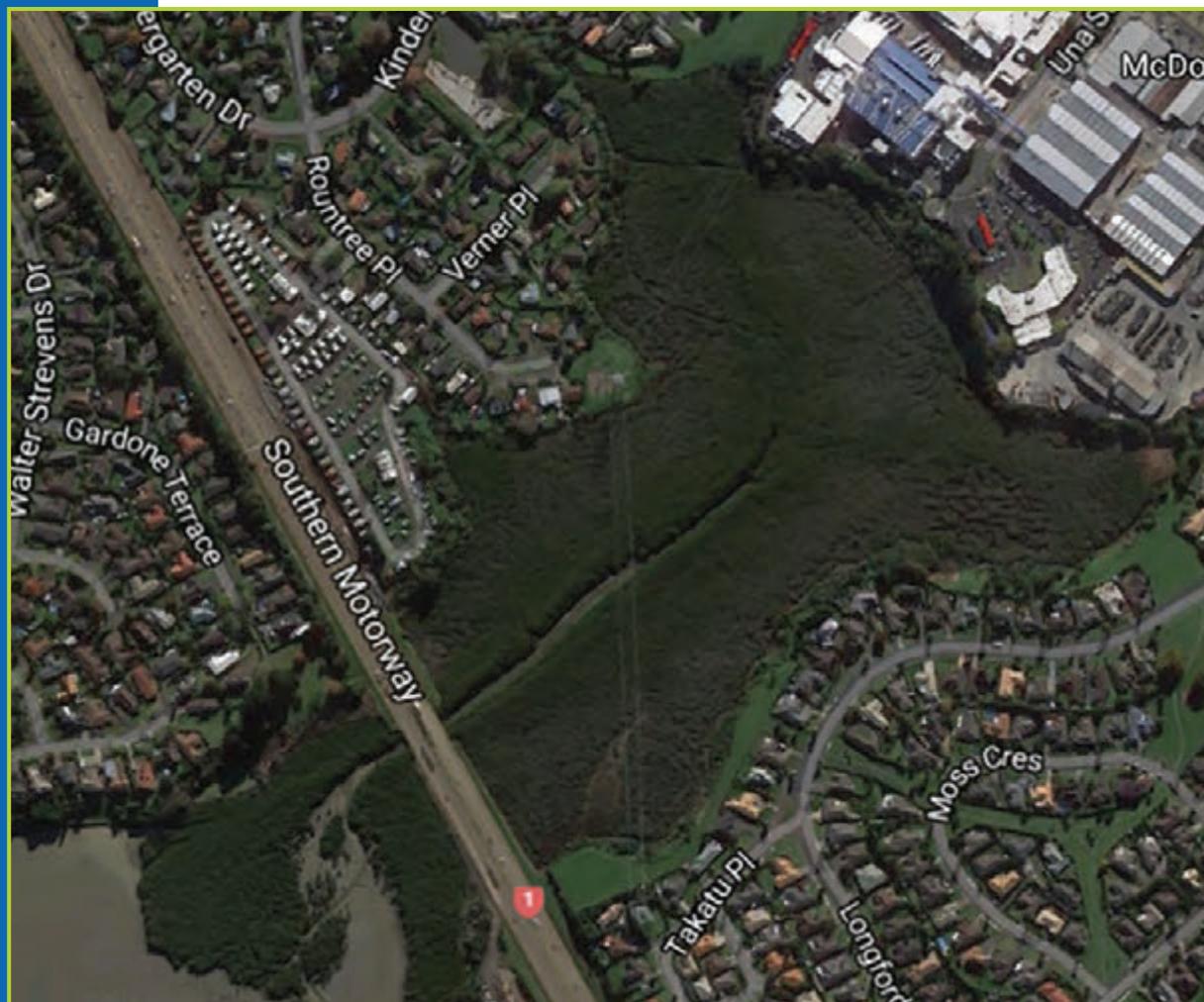
Changing the coastal hydrodynamic environment

Expansion of mangroves may be influenced by human-induced changes that reduce water flow in estuaries.

The construction of causeways and other large structures changes the hydrodynamics of estuaries, and often results in a slowing of water flow through certain areas. This creates low-flow areas that facilitate the deposition of muddy sediments that are more suitable for mangrove establishment.

Historically, mangroves were found primarily in tidal creeks in upper regions of estuaries and harbours. Now many of these small tidal creeks are infilled with sediment and mangroves.

Figure 4: Illustration of tidal inlet with restricted flow due to causeway construction, resulting in mangrove colonisation, Pahurehure Inlet, Auckland. Figure: Google Maps.



Climate change and the impact on mangroves

What effect will climate change have on mangrove spread?

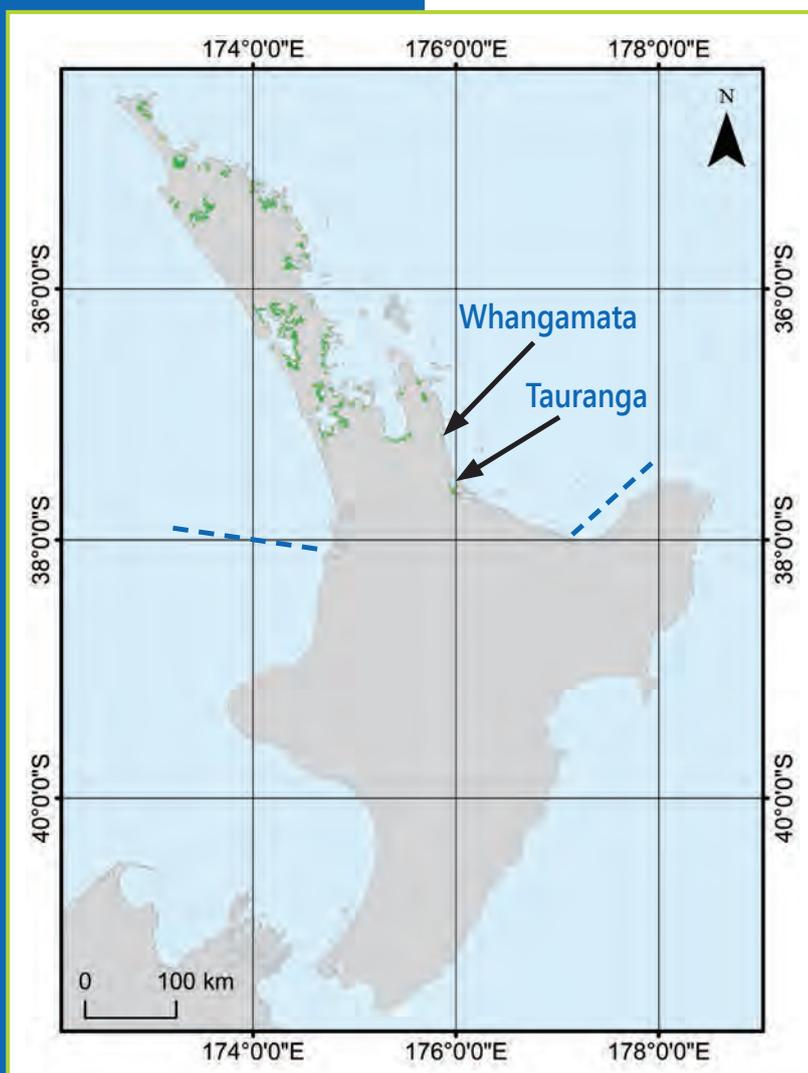
New Zealand mangroves occupy North Island estuaries north of 38°S. The southern limit is likely determined by a combination of seawater temperatures, frequency and severity of frosts, and lack of suitable habitat, in addition to being limited by seed dispersal and distances between suitable habitats (Morrisey et al. 2007, 2010).

The depth at which mangroves are found in estuaries is as low as the mean tide level where the seabed is submerged for less than six hours per tidal cycle. Mangroves currently occupy 58% of potential mangrove habitat in the eastern Auckland area and have increased by 0.8% to 8.4% per annum since the 1940s–1960s (Swales et al. 2009).

Models have been used to predict changes in the extent of mangrove habitats in Auckland east coast estuaries in response to climate change (Swales et al. 2009, McBride et al. 2016).

These models suggest that sediment supply and sea level rise both drive changes in suitable mangrove habitat. In most scenarios with current or increasing sediment supply, suitable mangrove habitat is maintained or expanded, often predicted to increase in extent by >50%. In most cases, sediment supply is sufficient to maintain mangrove distributions through the building of bed level height due to sediment deposition. In contrast, for scenarios with reduced sediment supply, large decreases are predicted for mangroves in upper intertidal zones as sediment supply is not sufficient to maintain mangrove distributions in the face of sea level rise (McBride et al. 2016).

Figure 5: The current distribution of mangroves in New Zealand, showing the southern natural limit at Kawhia Harbour on the west coast and Ohiwa Harbour on the east coast (Morrisey et al. 2007).



History and regulatory framework

In the early 1990s, many estuary care groups were established by interested locals with the intention of removing mangroves as one aspect of restoring estuary health.

Many small manual removals were carried out by estuary care groups in the 1990s and 2000s (both consented and illegal). The first large mechanical removals were consented in 2010 in Tauranga Harbour (including Waikaraka, Te Puna, Waikareao and other estuaries).

In recent decades, the number of resource consent applications to remove all or part of mangrove stands has increased. Motivation for mangrove removal includes:

- to improve recreation and amenity values
- to return habitats to firm sand flats
- to restore seagrass and shellfish beds
- to restore access and navigation to the coast
- for maintenance and use of structures such as jetties
- to improve functioning of drainage systems
- for flood protection.

In all cases, the procedures and protocols of the relevant regional council should be followed, and typically involve applying for a resource consent. Policy 11(b)(iii) in the New Zealand Coastal Policy Statement clarifies that to protect indigenous biological diversity of the coastal environment we must *“avoid significant adverse effects and avoid, remedy or mitigate other adverse effects of activities on indigenous ecosystems and habitats that are only found in the coastal environment and are particularly vulnerable to modification, including estuaries, lagoons, coastal wetlands, dunelands, intertidal zones, rocky reef systems, eelgrass and saltmarsh.”*

Furthermore, sections 12(1)(c) and (e) of the Resource Management Act (RMA) state that *“no person may, in the coastal marine area, destroy, damage or disturb the foreshore or seabed in a manner that has, or is likely to have, an adverse effect on the foreshore or seabed, or on plants or animals or their habitat, unless expressly allowed by a rule in a regional coastal plan or a resource consent.”*

To obtain consents for mangrove management, advice from the relevant regional council should be sought, and national policy documents and both local and district planning documents should be consulted to provide guidance for consent requirements.

Factors affecting mangrove removal outcomes

Site characteristics influence the outcome after mangrove removal.

It is important to assess the wider estuarine area before considering mangrove removal. A study carried out by NIWA examined around 40 removal sites with varying site characteristics (small to large; sheltered to exposed; muddy to sandy sediment) and using different removal methods. This study revealed that exposed and sandy sites had a higher chance of erosion of muddier sediments after mangroves were removed, while sheltered and muddy sites showed only minimal, if any, erosion of muddy sediments.

If land-based sediment inputs have been addressed, and removal of mangrove is being considered, a thorough site assessment should be made specifically looking at:

- the hydrodynamics acting on the site (tides, currents and waves)
- the sediment type (mud, sand and gravel)
- evaluation of the ecological values of the proposed removal site
- the proximity to other ecologically important areas
- sediment loads
- historic and future catchment uses and activities
- the distribution of mangroves within the estuary.

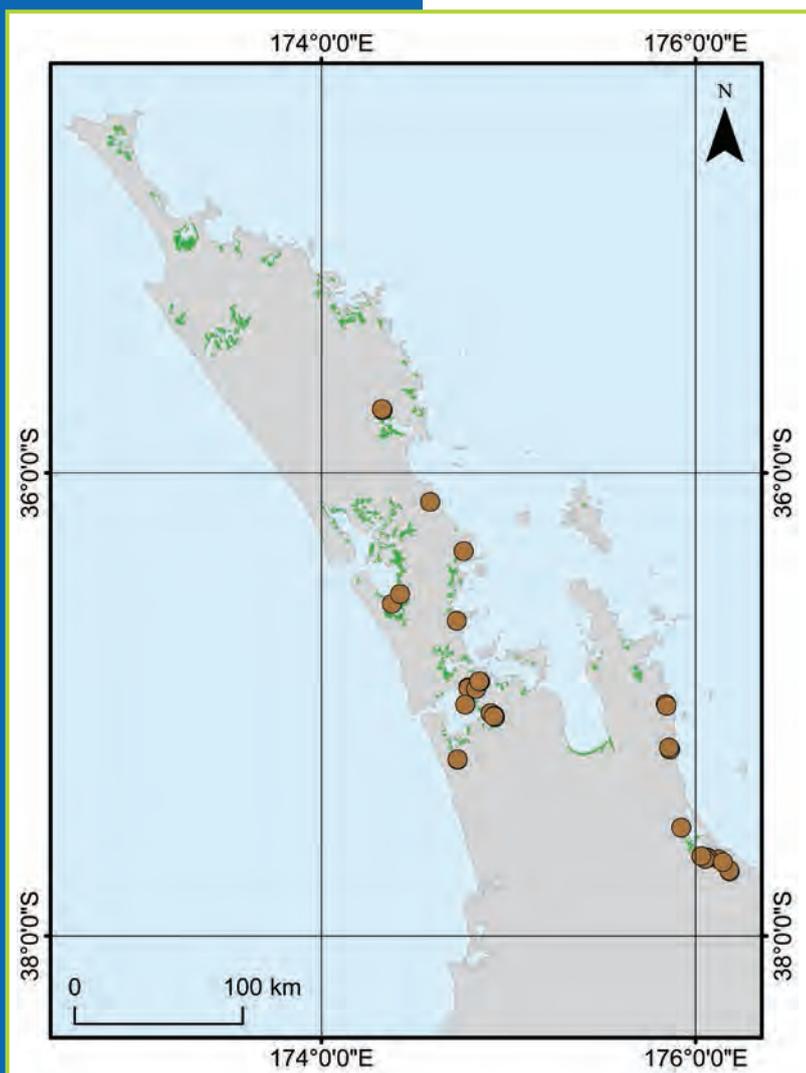


Figure 6: Map showing the location of ~40 removal sites surveyed by NIWA.

Managing expectations and realistic time-frames

Many mangrove removal areas have shown both immediate and long-term adverse impacts, which include anoxic (lacking oxygen, often black in colour and smelling of sulphur) sediments, minimal dispersal or decomposition of mangrove debris, high levels of hydrogen sulfide associated with rotting plant material, bacterial mats, large and prolonged algal blooms, and vehicle track marks persistent for many years after removal.

A change to sandy sediments is not guaranteed with mangrove removal, though resource consent applicants often assume this will occur. Rather, the return to sandier sediment after mangrove removal is site specific and depends on choosing the right method for the area. Transition to sand flats is unlikely after mangrove removal in areas that have insufficient hydrodynamic flow.

Methods of removal are not always successful. Effective long term management of mangrove colonisation requires a reduction in sediment and nutrient loads from the catchment. The removal of the cut mangrove debris reduces adverse impacts in all areas (see page 20).



Extensive algal growth following a removal at Omokoroa Estuary.

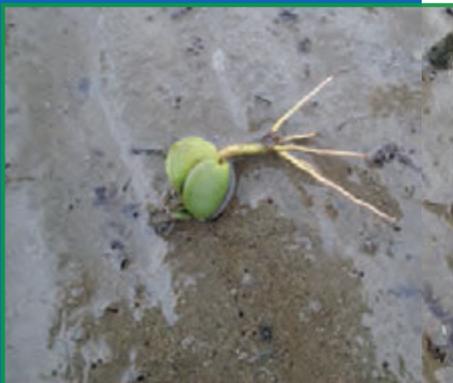


Bacterial bloom after mechanical mulching in Tauranga Harbour, 2010.

Best removal practices

Many methods for mangrove management have been used, with varying results and long term impacts. The aim of many mangrove removals is to transition sites to sandy habitat. See diagram below for a brief overview of advantages and disadvantages of various techniques for managing mangroves.

Least



Seedling Removal

- Can be used in all environments (different exposures and tidal regimes)
- Must be carried out regularly
- Used to maintain previous removal areas and contain spread
- Relatively inexpensive to carry out depending on total area of interest
- Minimal effect on the environment
- Can be accessed by foot or using a small boat or kayak.



Manual Removal

- Most common method used to remove adult mangroves
- Labour intensive method
- Generally carried out in small and easily accessible areas by foot or using a small boat or kayak
- Best used in areas with firm sediment, but can be used in muddy areas
- Better method to use in less exposed areas, such as estuaries with limited tidal flushing or wave exposure.



Mechanical Removal

- Labour intensive method used to remove adult mangroves
- Small strip clearances on the seaward side of stands are most successful
- Works best in exposed areas of firm sediment and good tidal flushing
- Causes the most disruption to the environment and generally takes the longest to recover
- Least impact when tyre tracking minimised to <10% of area.

Disturbance

Most

Figure 7: Comparison of most common mangrove methodologies.

Seedling removal

The least destructive method of controlling the spread of mangroves is to remove seedlings.

This method is appropriate for all estuary types where access is relatively easy by foot or using a small boat. Most mangrove seeds disperse and colonise during summer months, and a large proportion of seedlings do not survive early autumn (Figure 8).

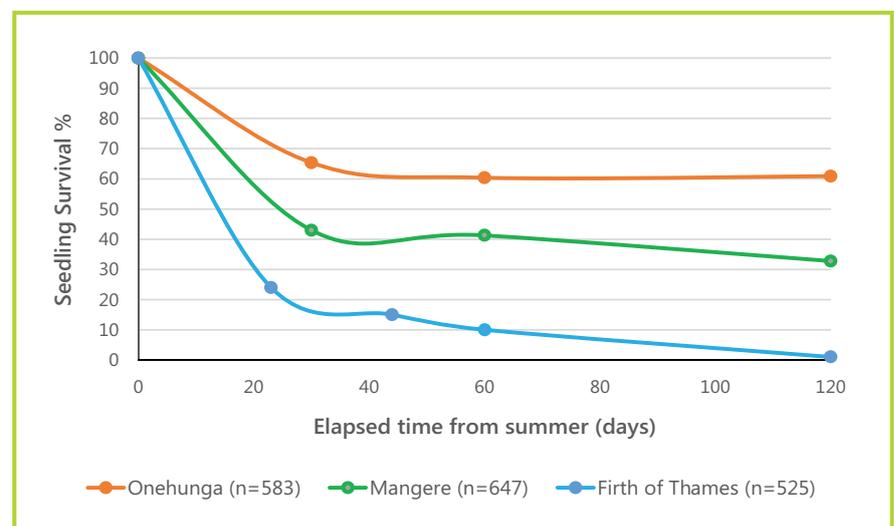
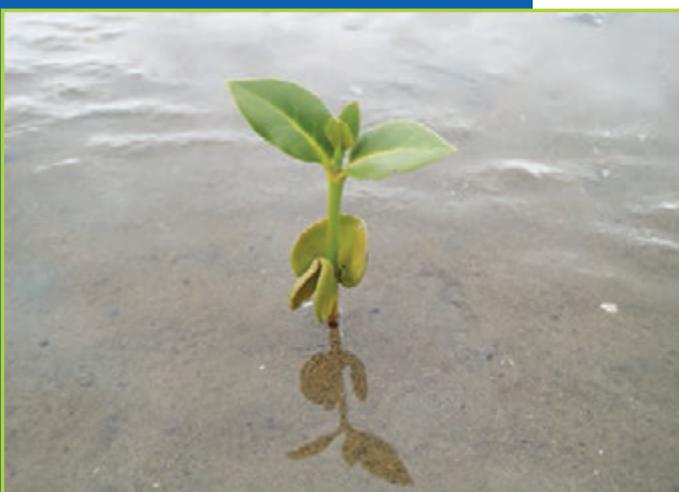


Figure 8: The percentage of mangrove seedlings surviving at three sites: Firth of Thames, Onehunga and Mangere, Manukau Harbour, Auckland.

The proportion of seedlings that survive differs between sites. Some exposed locations have low survival (e.g., Firth of Thames), while at other sheltered locations (e.g., Mangere, Onehunga) between 30% to 60% of seedlings survive through to the winter months.

It is most effective to wait until natural die-off of seedlings has occurred over early autumn, and remove all surviving seedlings in May or June, targeting seedling removal to when there are naturally lower numbers to reduce the effort required.



Mangrove seedling.

Seedling management should be conducted regularly to avoid re-establishment. Seedlings (and seed propagules) less than 10 cm in height should be removed from the site once pulled out, as they are capable of re-establishing.

Older seedlings (greater than 30 cm) are more difficult to pull out as they become more solidly established, requiring more strength to remove them. Barnacles also colonise the stems of the older seedlings making them likely to cause injury when removed with bare hands.

Many councils define seedlings based on height. Check with local councils to see if resource consent is required for seedling removal, and what your council defines as the maximum size of seedlings.



High density of mangroves seeds are found at the edge of the forest.

Mangere Inlet Kiwi Rail site showing rapid seedling recolonisation two years after removal of a strip clearing.



Removal of adult mangroves

Of the removal methods investigated, the manual approach has been used most extensively in both small and large mangrove removals.

Manual removal

This method involves use of a chainsaw or an axe, and mangroves are cut centimetres above the sediment surface, leaving the stump visible. This method is labour-intensive, but it can be used in both firm, sandy sediments and in softer, muddier sediments.

Disturbance from footprints/trampling of the sediment is minimal and is considerably less than disturbance from tractors during mechanical removals. Anoxic sediment, macroalgal blooms, and bacterial blooms are also typically less using this method compared to mechanical methods. Despite this, there is still no guarantee that manual removal will result in changes to a sandier habitat.

The disadvantages of this method are the intensity and cost of labour, especially for community groups trying to carry out removals. Manual removal requires physical labour and health and safety regulations should be taken into account.



Kiwi Rail site, Mangere Inlet, Manukau Harbour.

Mechanical removal

This method requires machinery to cut up the above-ground mangrove material and either remove the material or mulch it on-site. This method has better outcomes in areas which have firm and sandy sediments, and are exposed to high wave and tidal action because:

- tractors have difficulty accessing muddy areas
- there are much larger impacts of mechanical tracking in muddy areas, than sandy areas.

While tractor specifications often imply low impacts, observed impacts in terms of tyre tread disturbances are far larger and longer lasting than anticipated based on manufacturer specifications.

In many of the estuaries where this method has been used, disturbed sediment from tracking and machinery is still common and sites have not transitioned to a sandier state many years after mangrove removals. This is despite being undertaken in a variety of sites ranging from muddy to sandy and from sheltered to exposed sites. A concern associated with mechanical removal is the disturbance caused by the tyre tracks compressed into the sediment.

In Whangamata Harbour, a new mechanical method was trialled, attempting to reduce the impacts that had previously been observed in mechanical removals. Here, tyre track disturbance was actively minimised during removals by limiting tracking to around 10-20% of the removal site. Fewer adverse impacts were observed in terms of the amount of anoxic sediment, macroalgal blooms, and bacterial blooms.

Mechanical removal has been implemented since 2010, especially where large areas of mangrove forest have been consented for removal, and where sufficient funding is available to employ contractors.

Tracking seen in Whangamata Harbour following mechanical removal, emphasising minimisation of tracking disturbance. Photo: Emily O'Donnell.



Off-site disposal of vegetation

Generally, mangroves grow in areas where water flow is low, and tidal flushing is slow. Therefore, when mulched mangrove material is left on a removal site it is slow to disperse, or more commonly, it remains on site for many years.

Vegetative material should always be removed from sites following mangrove removal. Mulched material, when left on site, smothers the sediment, causing anoxia (lack of oxygen), and is associated with the release of hydrogen sulphide gas. The odour is offensive and can be harmful to human health. Large algal blooms have also been associated with mangrove mulch areas, fed by nutrient released from both mulch and the sediments buried underneath (Lundquist et al. 2012).

Post-removal monitoring and observations have revealed that the mulched material often does not get washed away and decomposes slowly, resulting in long-term adverse impacts which have been observed to continue at least five years after removal.



Mangrove mulch remaining on the seabed after mechanical removal at Welcome Bay, Tauranga. Photo taken in 2013, approximately three years after removal.

A number of illegal removals have resulted in above-ground vegetation being left on site. Studies show that woody debris is likely to take decades to decompose (Gladstone-Gallagher et al. 2014).

Removal of all above-ground vegetation from a site is the best option to promote recovery of the site after removal of mangroves. This can be achieved using a barge or helicopter to move the mangrove material to another location for disposal.

Experience also shows that removals should cut adult mangroves as close to the sediment as possible. When branches are removed only at heights above where the water level reaches at high tide, adult trees are able to resprout.

Burning of mangrove material on site in piles has also occurred. However, it is necessary to minimise mud content within the piles/stacks, as this has been shown to prevent successful burning. Testing of burn pile emissions have concluded that emissions are within environmental thresholds, though additional consent requirements do apply to allow burning of mangrove material. However, many recent large-scale removals have not had success at burning material on-site, and off-site disposal of vegetation is recommended.



Mangrove vegetation stacked in preparation for burning.



Vehicle removing mangrove from Mangere Inlet.



Above ground biomass left on site in Pahurehure Inlet resprouting.

Below-ground root biomass

A large proportion of mangrove biomass is found below the sediment surface.

Using both manual and mechanical methods, the above-ground biomass (leaves, branches and trunks) is typically removed leaving the below-ground biomass (root system) intact. However, a large portion of the mangrove tree biomass is within the root system, which extends extensively underground. In mangrove forests in New Zealand up to 87% of total biomass is below ground as part of roots and pneumatophore structures (Bulmer et al. 2016).

Studies show that root biomass may take decades to decompose after mangroves are removed (Gladstone-Gallagher et al. 2014), and the presence of fine root material likely delays erosion of muddy sediments. High densities of root material are still present at many sites years after mangrove removal (Lundquist et al. 2014).

Methods for removing below-ground biomass have been trialled where the main stump and surrounding dense root material were removed using a digger. Main stump removal has been used in both mechanical (e.g., Whangamata) and manual removal consents (e.g., Onehunga). However, due to the fine and soft nature of the root material, root extraction is largely unsuccessful and results in considerable sediment disturbance.



Stump from a manual removal at Mangawhai Estuary.



Moanaanuau Estuary, Whangamata Harbour. Remaining underground root biomass in 2010, approximately five years after clearance.

Optimising removal locations and shapes

Clearing of thin, seaward strips of mangroves increases the likelihood that sites will transition to sandflats.

Post-removal monitoring of many sites throughout the North Island has indicated that the edges of removal areas are more likely to transition to characteristics similar to nearby sandy sediment than areas within the middle and the shoreward edge of clearances. Strip clearances on the seaward side of a mangrove forest maximise this 'edge effect'.

Strip clearances on the shoreward side of a mangrove forest have limited flow and are slow to recover. Strip pathways through the middle of mangrove forests are rapidly recolonised by seeds from neighbouring trees. Large clearances are also slow to recover.

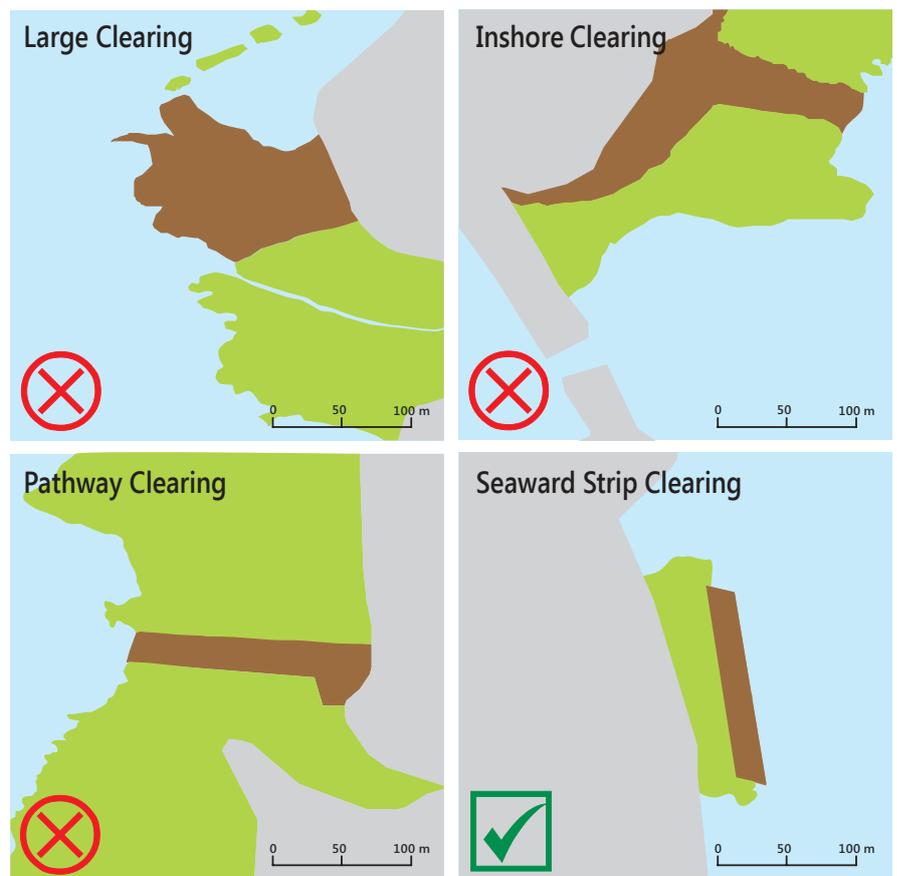


Figure 9: Schematic representations of three clearances that are not recommended (red cross) and a thin strip on the seaward boundary which is most ideal (green tick).

Use of mangroves by fish

When the tide is in, fish species such as mullet, pilchards, eel, triplefins and parore may be found in waters surrounding mangroves. However, these species are also commonly observed in other estuarine habitats and none have been shown to require mangroves for survival.

The maximum water depth and amount of time the tide is in influence how suitable a location is for fish. Most mangrove forests in New Zealand are only covered for a few hours per tidal cycle and water levels are less than 30 cm.

Diet studies suggest that most fish found in mangroves are feeding on plankton in the water column, and not on animals living in mangrove sediments.



Grey and yellow eye mullet at edge of mangrove forest. Photo: Roger Grace.



Flounder at edge of mangrove forest. Photo: Roger Grace.

Use of mangroves by birds

Birds use mangroves as an important habitat for foraging, roosting and nesting. This includes species such as banded rail, fernbirds, herons, bitterns, spoonbills, kingfishers, chaffinches, warblers, harriers, swallows, silver eyes, fantails, cuckoos, shags, and pukeko. For example, banded rail commonly feed on worms, snails, crabs and other insects in a range of estuarine habitats, yet remain close to vegetation such as mangrove or saltmarsh for cover against predators. They breed in spring and summer, and juveniles are common during autumn.

The foraging, roosting and nesting behaviour of birds should be considered in mangrove removal and seedling maintenance operations (and are a requirement in certain regions e.g., under the Auckland Unitary Plan). Consents for mangrove removal should minimise impacts on banded rail and other birds by:

- minimising or avoiding negative impacts on food sources
- retaining buffers of vegetative habitat which can be used for shelter and breeding
- being timed to avoid impacts on breeding (e.g., during winter for banded rail).



Two banded rail amongst mangrove seedlings in Tairua Harbour. Photo: Wildlands.

Impacts on adjacent habitats

In Whangamata, potential impacts on adjacent seagrass and saltmarsh were monitored following mangrove removal. Seagrass distribution and density was found to vary over time, however, this was attributed to normal seasonal variation. Similarly, no adverse impacts on saltmarsh were observed, other than at machinery access points (Bulmer and Lundquist, 2016).

Mangrove removal has the potential to result in negative impacts on adjacent habitats such as saltmarsh, seagrass and shellfish beds.

In other locations, such as Waikareao Estuary in Tauranga, a gradual seaward erosion of saltmarsh was observed following removal of the mangrove buffer. In the Manukau Harbour, mangroves were mulched, and mulch was transported by wave action to the shore, smothering adjacent saltmarsh habitat. Anoxic sediment and nutrient release resulting in algal blooms were also observed in Tauranga following mechanical mulching of mangrove. Despite concerns prior to removals, adjacent shellfish beds appeared unaffected by the mangrove removals (Lundquist et al. 2012).

Methods used to monitor changes in the distribution or density of adjacent habitats following mangrove removal typically include biomass estimates for shellfish, and percent cover estimates for vegetation, as well as walking the perimeter of adjacent habitats to see if the distribution of the habitat changes over time.

Potential impacts on adjacent habitats may be minimised or avoided by selecting appropriate removal sites and methods (page 15). Other important considerations include selecting access points to mangrove removal areas which minimise or avoid trampling adjacent habitat types.



Waikareao Estuary, Tauranga, January 2016. Gradual erosion of saltmarsh where mangrove buffer was removed in 2010.

Post-removal monitoring

Monitoring of removal areas allows evaluation of long-term success.

Generally, consents for removal of mangroves aim to:

- return the site to a sandy habitat
- see a return of previous habitats with recovery of either shellfish or seagrass.

Consent monitoring should include both monitoring for immediate adverse impacts (e.g., anoxia, algal blooms) and long term monitoring to determine if sites are returning to sandier states. Typically, sites take 5-10 years to return to sandier states (if successful). Consent conditions should also include protocols to allow change of methods or stop further removals if adverse impacts occur.

In order to quantify if these aims are being achieved, both baseline (i.e., before removal) and post-removal monitoring of the site should be carried out. Characteristics that are useful to monitor include sediment characteristics (mud content and compaction), remaining root biomass, saltmarsh and bank erosion, mangrove recolonisation, seagrass (extent and density), seedling establishment, and fauna living within the sediment.

Monitor	Why?
Sediment characteristics (mud content)	Indication of whether the sediment is getting muddier or sandier.
Sediment characteristics (compaction)	Indication of whether the sediment is getting muddier or sandier.
Remaining root biomass	Indication of sediment erosion and decomposition of mangrove biomass.
Saltmarsh and bank erosion	Indication of whether removal has had an impact on other important habitats that are no longer protected from exposure by a buffer of mangroves.
Mangrove encroachment	Are mangroves continuing to expand into the neighbouring habitats?
Seagrass & shellfish bed extent and density	Are mangrove removals causing negative impacts to neighbouring habitats?
Benthic fauna	Is the sediment fauna community becoming more similar to a sandy tidal flat or does it still resemble a mangrove community?
Macroalgae	Indication of a release of nutrients.
Anoxic/black sediment	Indication of smothering and limited or no oxygen in the sediment.
Bacterial bloom	Indication of anoxic sediments.
Seedling numbers	Are mangroves recolonising removal areas?

Table 1: Common parameters monitored when evaluating impacts of mangrove removal. (Stokes et al. 2016).

Adaptive management of mangrove removals involves removing mangroves in stages.

Monitoring is used at each stage to assess the environmental outcome.

This information is then used to determine what removal methods are used in the next stage to best achieve objectives (e.g., to transition sites to sandy habitats).

Annual (or more frequent) monitoring should be undertaken within removal sites and neighbouring areas. An example of monitoring has been recorded in Lundquist et al. (2012) where three removal sites were monitored in Waikaraka and Te Puna Estuary (Tauranga). Data collected from within the mulched areas and adjacent unvegetated sediment were able to provide insights into the long-term success rates of this mangrove removal strategy. This data demonstrated the occurrence of adverse impacts such as bacterial and macroalgal blooms and persistent anoxic sediments.

Monitoring in Whangamata Harbour, where new methods (including tracking minimisation and removing mangrove vegetative) were trialled, has revealed which methods show faster transition to sandflat, namely smaller manual clearances on the seaward edge of mangrove forests. These results have been used to inform future removal methods at Whangamata, and elsewhere in an adaptive management approach.



Transect line measuring seedling colonisation and growth rates at Mangere Inlet, Manukau Harbour.



Monitoring to measure recovery of sediments and decomposition/erosion of mangrove roots (below-ground biomass) at Pahurehure Inlet, Manukau Harbour.

New equipment being trialled

New techniques and equipment are being adapted for use in managing mangrove expansion.

The main concern with tractors and mulching equipment is the tracking which causes compaction of the sediment and has been associated with large adverse impacts and slow recovery. It is also very common for the machinery to get stuck in the muddy sediment. Community groups and councils have been investigating other forms of machinery to access areas for potential manual mangrove and seedling removal. An off-road ARGO vehicle has been trialled in Auckland (Manukau Harbour Restoration Society, Auckland).



Manukau Harbour Restoration Society member trialling an ARGO vehicle in Mangere Inlet.

An innovative, purpose-built hovercraft mower has been designed, constructed and certified for use in the Bay of Plenty. The hovercraft, which is designed to minimise surface disturbance to the estuary, is now ready to be put to the test through 11 estuaries within Tauranga Harbour. With promising test runs in two estuaries so far, it is expected that the hovercraft will prove a successful seedling management method throughout Tauranga Harbour.



Mangrove hovercraft mower in Athenree Estuary. Photo: Bay of Plenty Regional Council.

Mangrove removal costs

Mangrove removal costs vary widely, in part due to the non-routine requirements of the work (such as operating machinery in soft muddy sediment during low tide), the contentious nature of the projects which often require notified consent processes and substantial iwi and community consultation, and the variety of methods used. Limited information is available on the cost of previous mangrove removal operations.

	Typical Cost
Consenting	\$12,000 (non-notified) to \$230,000 (notified consent) per mangrove removal operation.
Physical removal of mangrove	\$1,000 to \$5,000 per hectare of mangrove removed, for both mechanical and manual removal methods. <i>However, physical removal costs are known to have exceeded \$50,000 per hectare. Cost of disposal are additional, and potential uses for mangrove mulch are being explored.</i>
Ongoing seedling removal	About \$1,000 per hectare per year. <i>Often overlooked in mangrove removal operations.</i>
Monitoring	Previous consents have spent less than \$5,000 to \$125,000 per removal operation. <i>Costs vary depending on the scale of the mangrove removal and the monitoring required. Monitoring has been undertaken as part of relatively few previous mangrove removal operations.</i>

Table 2: Typical costs associated with mangrove removals (Summarised from Murray, 2013; AC, 2015).

Who pays?

The cost of mangrove removal typically falls on the individual land owner or community group. In Whangamata, the community lobbied the local council and a targeted levy was established to fund mangrove removals, paid through rates.

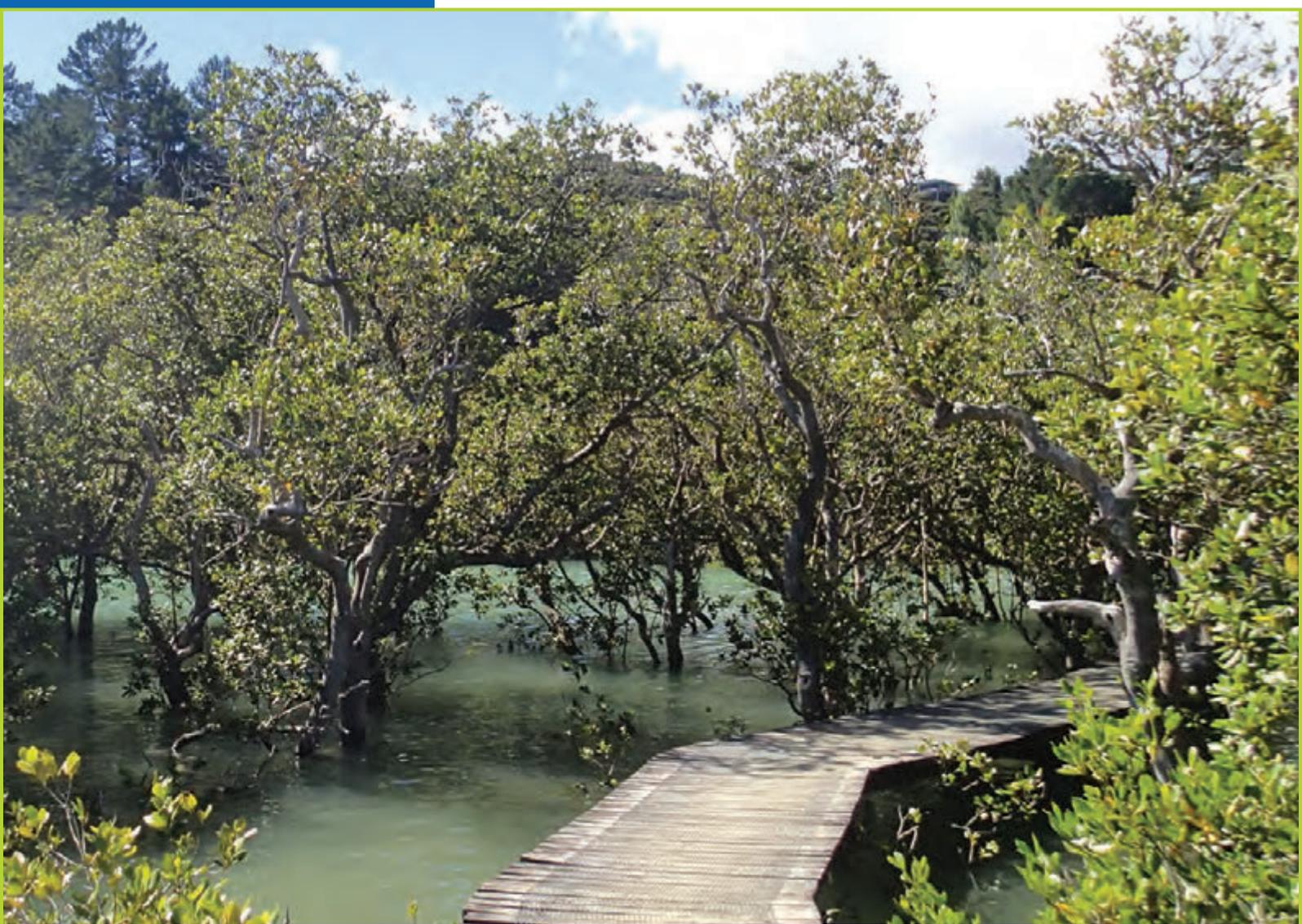
Mechanical removal, Whangamata Harbour, 2013.



Alternative management approaches

In many locations mangrove removal has not resulted in sites returning to sandy sediments, or conditions that support recreational access. In these instances, the most appropriate management strategy would likely have been not to remove mangroves, or to use alternative methods which may have been more likely to achieve removal objectives. Other strategies which can be considered that support access to, and use of, estuarine habitats, include installing boardwalks, or minor mangrove removal to enable boat or waka access.

Boardwalk near Paihia.



Summary

- In many instances mangrove removal does not lead to replacement by sand flats or a reduction in muddy sediment.
- To prevent estuarine habitats from becoming muddier, land use needs to be better managed to reduce sediment loads.
- Seedling removal is a low impact method of mangrove management. However, long-term maintenance is required to keep sites from being colonised (or recolonised).



Historical manual clearance at Patiki Inlet, ~10 years after clearance, Whangamata Harbour.

- The size of the patch removed should be considered carefully to maximise recovery – smaller patches recover faster. The method chosen will be partly determined by the size of the patch to be removed.
- The removal of mangroves should be conducted in small strips on the seaward boundary of a mangrove stand to maximise exposure to tidal and wave action.
- In all cases, the cut mangrove material should be removed from the site. Evidence suggests that material left on-site hinders or slows the ecological recovery of the area and is unsightly. Account for removal when considering methods.
- One of the most significant disturbances to the area, and also the recovery of a site, is the compression and disturbance of the sea bed, especially tracks from machinery. Consider using a less invasive method if possible.
- Pre-removal baseline data should be collected and compared with data collected during regular monitoring following removal. This provides an indication of the health of the area and whether removal objectives are being achieved.



Mangroves at mid-tide at Whangamata Harbour.

Resources available

Coastal Policy Statement

<http://www.doc.govt.nz/Documents/conservation/marine-and-coastal/coastal-management/nz-coastal-policy-statement-2010.pdf>

Resource Management Act

<http://www.mfe.govt.nz/rma>

Guidelines for community-focused ecological monitoring of mangrove habitats in estuaries (mangrove guidelines). Waikato Regional Council

<http://www.waikatoregion.govt.nz/PageFiles/3331/tr05-12.pdf>

Auckland Council Unitary Plan

<http://www.aucklandcouncil.govt.nz/EN/planspoliciesprojects/plansstrategies/Unitaryplan/Pages/home.aspx>

Ngā Waihotanga Iho – Iwi Estuarine Monitoring Toolkit

<https://www.niwa.co.nz/te-k%C5%ABwaha/research-projects/ng%C4%81-waihotanga-iho-iwi-estuarine-monitoring-toolkit>



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