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Assessment of Physical Changes after Mangrove Removal: Whangamata Harbour 2008

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Prepared by:
Debra Stokes

For:
Environment Waikato
PO Box 4010
HAMILTON EAST

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Peer reviewed by:
Catherine Beard

Date 23 June 2009

Approved for release by:
Bala Tikkisetty

Date 23 June 2009

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Executive summary

In September 2005, unauthorised clearance of mangroves took place in the Moanaanuanu Estuary, Whangamata Harbour. Two hectares of mangrove vegetation were removed on this occasion; a subset of which was also mown with a tractor to remove seedlings and pneumatophores (above-ground breathing roots). Three studies were subsequently undertaken by Environment Waikato to investigate the environmental impacts of this vegetation clearance, the most recent of which is a monitoring programme designed to document the physical environment of mangrove, bare intertidal and 'cleared' habitats, and in so doing, record any temporal changes that occur in the physical setting as a result of mangrove removal.

Sediment cores were taken and epifaunal counts carried out in the following areas:
1. cleared and mown mangrove habitat (site WMA)
2. cleared but not mown mangrove habitat (site WMB)
3. recently cleared mangrove habitat (site WMC)
4. intact mangrove habitat (site WMD)
5. bare (undisturbed) intertidal flat habitat (site WME)

Sample analyses confirmed that surface sediments in the 2005 cleared mown site (WMA) are similar in 2008 to those in the existing mangrove habitat, with over 50% mud present at both sites. Silty (mud-dominated) sediments occur to depths greater than 5 cm in the cleared site WMA, suggesting that the mud is either continuing to accumulate and/or is not being redistributed after mangrove removal.

Core stratigraphy revealed silty sands to depths below 12 cm at all cleared sites, suggesting that it would be some time, if at all, before these sites evolve to a purely sandy environment under the present-day hydrodynamic regime. Surface sediments in cleared sites WMB and WMC were dominated by fine and medium sands (with some mud), indicating that some of the mud particles have been winnowed out over time, but that any further significant coarsening of sediments may either not occur, or will occur very slowly. Further core sampling will provide valuable information on erosion of fine sediments over time at these sites.

The rate of biomass decomposition influences how surface sediment characteristics change over time, as the mass of fine roots remaining in the sediment still functions to trap fine sediment particles until such time that the roots decompose and break down completely. Sizes and ages of (former) trees at sites WMA, WMB and WMC are unknown because they were cleared before any such measurements could be taken. Interestingly however, the below-ground biomass average of 3.47 kg m^2 in the highly impacted cleared site (WMA) is higher than that which has been measured in healthy (intact) mangrove habitat in an estuary in Tauranga Harbour (Stokes and Healy submitted). The other cleared sites also still have relatively high levels of root biomass with over 1 kg (dry weight) of root material per square metre.

There are two possible explanations for the significantly greater mass of root material found at the highly impacted cleared site (WMA) compared with all other sampling sites; firstly that the highly anoxic and hydrodynamically quiet environment is inhibiting decomposition and breakdown processes, and secondly that these processes have been further inhibited by sediment compaction resulting from vehicle use in the area. Compaction reduces the erosion potential of surface sediments and slows down decomposition processes by creating a highly anoxic zone (as demonstrated by the black colour of the sediments).

Surface macrofauna were generally only present in low numbers at all sites. Analyses of temporal trends in the data indicate that benthic invertebrate abundance and diversity are increasing with time and that the disparity in population structure between the mangrove site and the cleared site may decrease as time goes on. However, given

that manual (and consented) removal of mangrove seedlings is now a regular occurrence, and that the below-ground environment has been significantly altered in places, the cleared sites are unlikely to revert back to mangrove habitat. The changes observed in the sediment composition and the structure of benthic communities in the cleared areas, along with a significant decline in benthic faunal abundance and species richness indicate that the cleared sites have not recovered within the observation period (2005 – 2008).

The results from this study provide some insight into the physical characteristics of the mangrove habitat at Moanaanuanu Estuary, and the intertidal areas that were cleared of mangroves. The high mud content and below ground biomass documented at one of the cleared sites highlights the importance of considering the intertidal position and hydrodynamics of a site before planning the removal of any coastal vegetation.

1 Introduction

In September 2005, unauthorised clearance of mangroves took place in the Moanaanuanu Estuary, Whangamata Harbour. Two hectares of mangrove vegetation was removed on this occasion; a subset of which was also mown with a tractor to remove seedlings and pneumatophores (above-ground breathing roots).

Three studies were subsequently undertaken by Environment Waikato to investigate the environmental impacts of this vegetation clearance. The first study focused on the effects of incineration of mangrove detritus (Riddell, 2005), the second looked at impacts of mangrove removal on vegetation (Wildland Consultants, 2005), and the third assessed the effects of vegetation removal on benthic fauna. Environment Waikato collected a series of benthic samples in November 2005, and again in November 2006. Analysis of the 2005 samples was reported by Felsing (2006) and a comparison of the 2005 and 2006 results was discussed in a report by Stokes (2008).

1.1 Aims and objectives

It is expected that the revised monitoring programme (as described in Section 2) will allow us to document the physical environment of mangrove, bare intertidal and 'cleared' habitats, and in subsequent years, record any temporal changes that occur in the physical setting as a result of mangrove removal. This was undertaken with the following objectives:

- To determine whether the fine sediment (mud) is being flushed away from the cleared areas and if so, over what time frame.

- To understand what extent the mangrove below-ground biomass is degrading. This will have implications for sediment trapping and rate of flushing of clay and silt particles.

- To understand the changes (if any) that are occurring to surface faunal diversity.

- To know whether high impact removal methods (e.g., use of tractors) influence rates of change/recovery.

This is to be achieved by the following methods:

- Investigation of spatial and temporal changes to surface sediment texture.
- Analyses of sediment cores to understand past sedimentary environments.
- Measurement of temporal changes in below-ground biomass following mangrove removal.
- Undertake surface counts of surface-dwelling macrofauna.

2 Methods

Five habitats in the cleared and undisturbed areas were sampled:

1. WMA: cleared and mown habitat (in 2005/06 reports this is Site A)
2. WMB: cleared but not mown habitat (in 2005/06 reports this is Site B)
3. WMC: recently cleared habitat (in 2005/06 reports this is Site C)
4. WMD: mangrove habitat (undisturbed)
5. WME: bare (undisturbed) intertidal flat habitat

Table 1: (to be taken as full days)Coordinates locating one corner of each of the five sampling areas

Location	Easting	Northing
WMA (cleared and mown in 2005)	2764634	6440639
WMB (cleared in 2005)	2764526	6440676
WMC (cleared 2007)	2764550	6440547
WMD (intact mangroves)	2764429	6440409
WME (unvegetated intertidal flats)	2764402	6440582

Figure 1: Sampling point locations in Moanaanuanu estuary, Whangamata Harbour

Within each of the areas a 50 x 50 m quadrat was marked out then subdivided into 10 sampling sub-sites/stations. A sampling location within each sub-site was then randomly selected and the following samples and information were collected:

- One 30 cm sediment core (diameter 5 cm). The corer was borrowed from Earth & Ocean Sciences Department at Waikato University (courtesy of Chris McKinnon). Each extracted core was tightly wrapped in clingfilm to maintain its shape during transport back to the lab at Environment Waikato.

- Three 25 cm x 25 cm quadrat counts of epifauna (including crab holes); seedlings; % macroalgae cover; % microalgae cover; pneumatophores.

- Five replicate bulked sediment samples were collected from the top 20 mm of surface sediment within each site for the following analysis:
  - LaserSizer grain size analysis (University of Waikato);
  - Total organic content – Hills Laboratory;
  - Chlorophyll A analysis (NIWA).

On return to Environment Waikato, the sediment cores were placed in a pvc cradle and cut in half lengthways. Sediment texture and colour changes along the core were recorded. On completion of stratigraphic logging, both halves of the core were passed though a 0.5 mm sieve and any mangrove root material collected. Root material was weighed wet and again after drying to constant weight at 60°C.

3 Results

3.1 Sediment cores

3.1.1 High impact cleared site – WMA (cleared and mown 2005)

Surface sediments in the cleared and mown site consisted of black slightly-sandy silt with over 50% mud, which graded from olive black at around 6 cm below the surface to gray toward the base of the core (~ 20 cm). Sediment texture ranged from sandy silt in the upper 5 – 8 cm, to silty sand at around 13 cm, grading to a slightly coarser slightly-silty sand and fine sand below 13 cm. Root material was observed to depths of around 20 cm, with dense roots found in the upper 7 cm.

3.1.2 Impacted cleared site – WMB (cleared 2005)

Surface sediments in the cleared (but not mown) site were also mostly olive black/black with mean grain size of 230 µm (± 14) (Figure 4). Texture in the upper 3-5 cm was mostly silty sand, then black sediments between 5 cm and 15 cm were dominated by sandy- silt or silty sand. Below 15 cm gray sediments consisted mostly of medium and fine sand. A shell bed, consisting of variable percentages of shellhash, full single shells and large fragments of cockle shell in a sandy matrix, was present in half of the cores below 15 cm,

3.1.3 Recently impacted cleared site – WMC (cleared 2007)

The upper 5 cm of the cores in the site cleared of mangroves in 2007 were dominated by olive-black sandy silt and silty sand, with surface sediments of 116 µm (±12). Root material was dense in the upper 5 cm and present within the remainder of the cores. The sediments remained mostly olive black but graded to a gray or grayish olive below around 10 cm in some cores.

3.1.4 Mangrove habitat (undisturbed)- WMD

Surface sediments within the mangrove habitat consisted of watery black silts, which appeared to be consistent in the upper 5 to 10 cm, along with dense root material. Dense mangrove roots and silt and fine sand were present at greater depths.

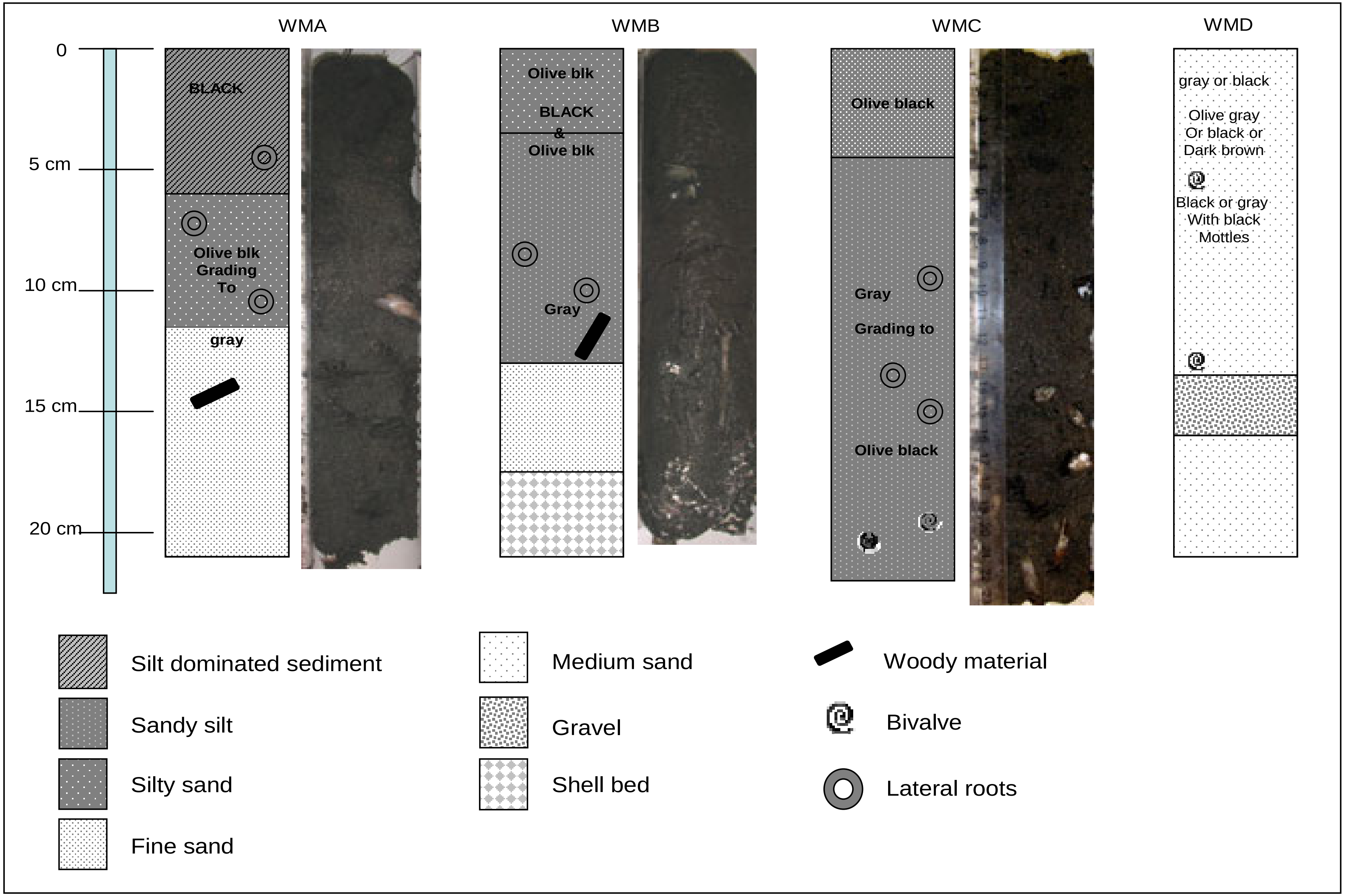
The watery nature of the sediment in the mangrove site prevented intact cores being extracted with the same corer that was used at the other sites. As such, the descriptions are based on samples that were collected using a larger corer and sieved on-site (rather than being returned to the lab).

Descriptive core logs, representative of the characteristics recorded for an average of 7 cores per site, are presented in Figure 2.

3.1.5 Bare unvegetated intertidal flats (undisturbed) - WME

Surface sediments on the unvegetated intertidal flats were dominated by fine and medium sands, with a mean grain size of 393 µm (medium sand). Surface colours ranged from yellowish brown to olive black. Coarse sand and gravel were found at depths of around 10 to 18 cm in some locations. Occasional wedge shells and cockles were also found between 9 cm and 15 cm. Sediments below the surface were mostly gray to black sands and gravels.

Figure 2: Representative core stratigraphy of each cleared site (WMA, WMB and WMC) and the unvegetated intertidal habitat (WME)



3.2 Surface sediment analysis

The mangrove site (WMD) and the highly impacted cleared site (WMA) were dominated by muddy surface sediments. Mangrove sediment consisted of an average of 64% mud**, while WMA sediments contained around 56% mud (Figure 4). These two sites display similar volumes of very fine, fine and medium sand classes. Cleared sites WMB and WMC were also similar in sediment texture, with around 25% mud, around 10% very fine sand, 35 - 40% fine sand and 25% medium sand. Surface sediments in the unvegetated intertidal flat, WME, were dominated by fine and medium sand, and less than 10% mud.

** Note: mud is made up of clay-sized and silt-sized particles.

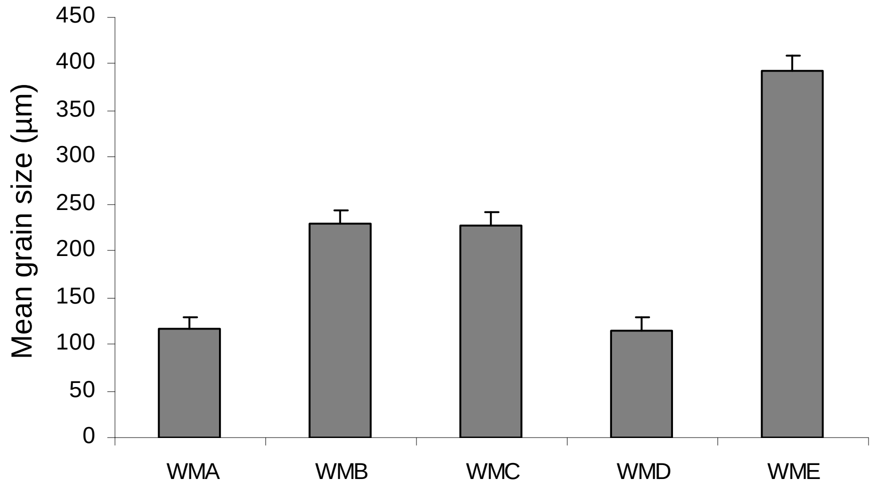


Figure 3: Mean grain size (bars indicate standard error) at at sites WMA (cleared and mown 2005); WMB (cleared 2005); WMC (cleared 2007), WMD (intact mangrove) and WME (unvegetated intertidal flat).

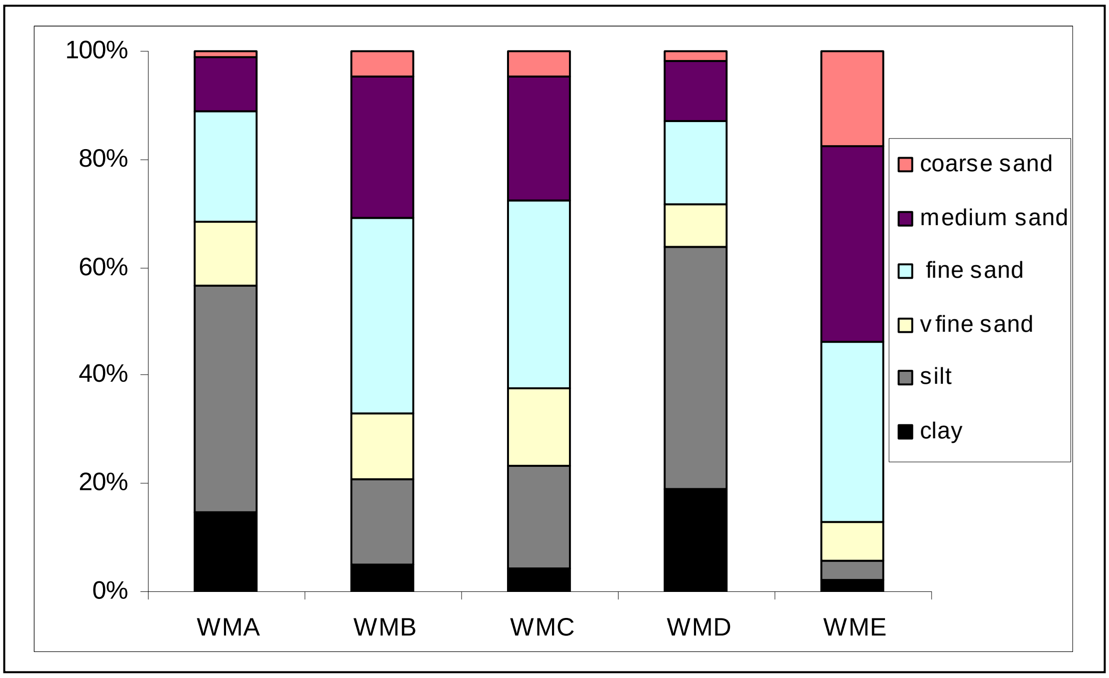


Figure 4: Surface sediment composition (% clay, silt, fine, medium and coarse sand) at sites WMA (cleared and mown 2005); WMB (cleared 2005); WMC (cleared 2007), WMD (intact mangrove) and WME (unvegetated intertidal flat).

3.3 Below-ground biomass

The highest proportion of mangrove root material (below-ground biomass) was present at Site WMA with an average of 3.47 kg m^2. This was significantly greater than at the other three sites ($p < 0.001$), including the mangrove habitat, which contained below-ground biomass averaging 2.17 kg m^2 (Figure 4),. The difference was mostly due to a significantly larger volume of fine roots present. Post-hoc tukey test results are displayed in Table 2.

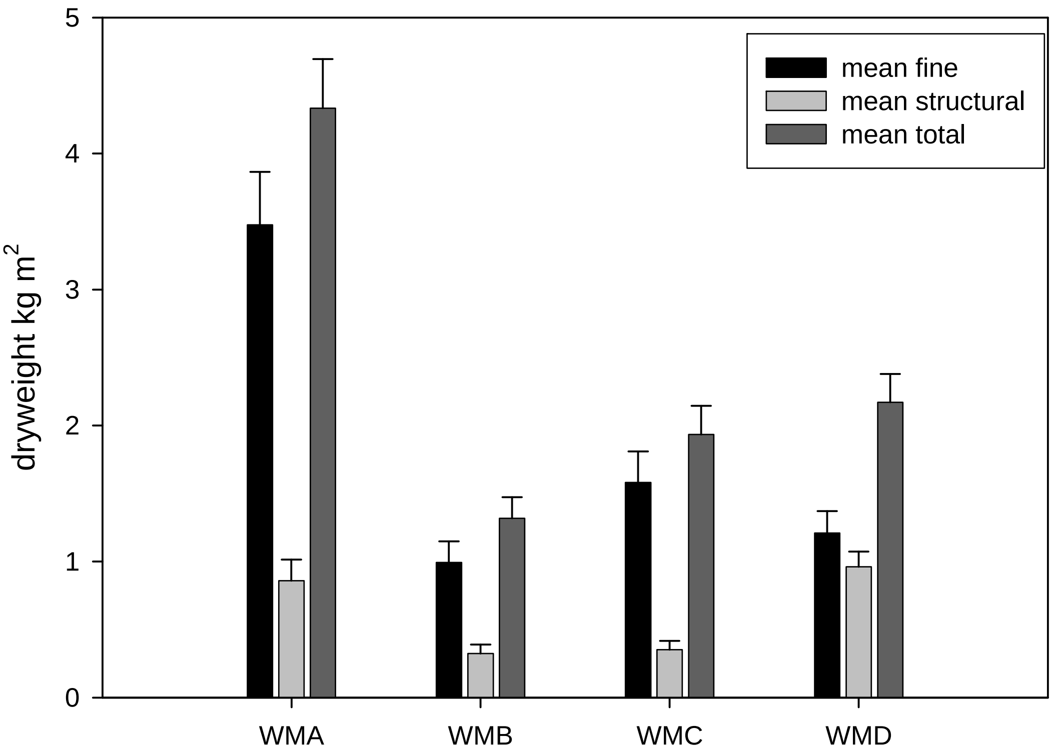


Figure 5: Dry weight (kg m^2) of below-ground biomass, structural roots and fine roots at sites WMA (cleared and mown 2005); WMB (cleared 2005); WMC (cleared 2007) and WMD (intact mangrove habitat).

Table 2: Post-hoc Tukey test significance values after One-Way ANOVA on square root transformed data of total biomass, % fine roots and % structural roots. Sites WMA (cleared and mown 2005); WMB (cleared 2005); WMC (cleared 2007) and WMD (intact mangrove).

Fine roots	**WMA**	**WMB**	**WMC**	**WMD**
WMA		<0.0001	0.0001	0.0001
WMB			0.137	0.812
WMC				0.525
Structural roots	WMA	WMB	WMC	WMD
WMA		0.006	0.011	0.851
WMB			0.990	0.0008
WMC				0.001
Total biomass	WMA	WMB	WMC	WMD
WMA		0.0001	0.0001	0.0001
WMB			0.114	0.019
WMC				0.849

3.4 Surface fauna

Overall very few epifauna were present. The mud-snail *Amphibola* was present in low and patchy numbers in all the cleared areas but absent from both mangrove and intertidal flat sites. *Zeacumantus lutulentus* (horn-snail) numbers were also low, with an average of 5 or fewer per quadrat in cleared areas WMB, WMC and the intertidal flats WME (Figure 6).

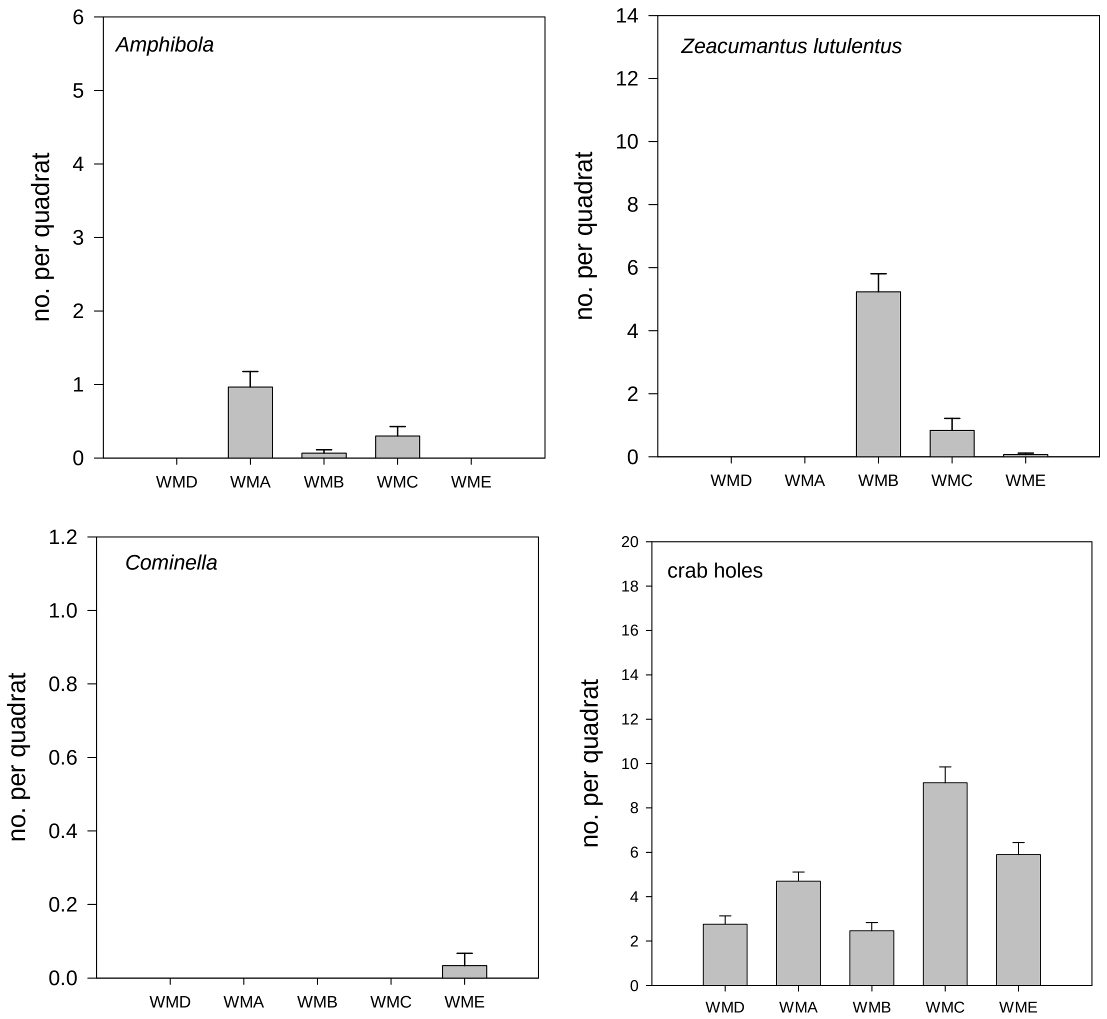


Figure 6: Abundance of surface macrofauna at sites WMD (intact mangrove habitat); WMA (cleared and mown 2005); WMB (cleared 2005); WMC (cleared 2007) and WME (bare intertidal flats).

4 Discussion

Sample analyses confirmed that surface sediments in the 2005 cleared mown site (WMA) are similar to those in the existing mangrove habitat, with over 50% mud present at both sites. The high mud content is not unexpected, given the location of the sites; close to the landward boundary of the estuary, where the combination of low tidal velocities and lower tidal inundation (relative to the other sites) creates a depositional environment rather than an erosive environment. Silty (mud-dominated) sediments occur to depths greater than 5 cm in the cleared site WMA, suggesting that the mud is either continuing to accumulate and/or is not being redistributed after mangrove removal.

Core stratigraphy revealed silty sands to depths below 12 cm at all cleared sites, suggesting that it would be some time, if at all, before these sites evolve to a purely sandy environment under the present-day hydrodynamic regime. Surface sediments in cleared sites WMB and WMC were dominated by fine and medium sands (with some mud), indicating that some of the mud particles have been winnowed out over time, but that any further significant coarsening of sediments may either not occur, or will occur very slowly. This hypothesis is supported by the fact that sedimentology of the sites is similar, even though they were cleared two years apart (2007 and 2005). Further core sampling will provide valuable information on erosion of fine sediments over time at these sites.

Below-ground root biomass was measured to determine how much material remains post-clearance and by so doing, gain an idea of how quickly the root material is breaking down over time. The rate of biomass decomposition influences how surface sediment characteristics change over time, as the mass of fine roots remaining in the sediment still functions to trap fine sediment particles until such time that the roots decompose and break down completely. It is important to note in this case that interpreting biomass differences between sites is complicated by the fact that the amount of root material within any mangrove stand is (to some extent) related to the age and size of the trees (and that age and size often differ across a gradient from channel to land). Sizes and ages of (former) trees at sites WMA, WMB and WMC are unknown because they were cleared before any such measurements could be taken. Interestingly however, the below-ground biomass average of 3.47 kg m^2 in the highly impacted cleared site (WMA) is higher than that which has been measured in healthy (intact) mangrove habitat in an estuary in Tauranga Harbour (Stokes and Healy submitted). The other cleared sites also still have relatively high levels of root biomass with over 1 kg (dry weight) of root material per square metre.

There are two possible explanations for the significantly greater mass of root material found at the highly impacted cleared site (WMA) compared with all other sampling sites; firstly that the highly anoxic and hydrodynamically quiet environment is inhibiting decomposition and breakdown processes, and secondly that these processes have been further inhibited by sediment compaction resulting from vehicle use in the area. Compaction reduces the erosion potential of surface sediments and slows down decomposition processes by creating a highly anoxic zone (as demonstrated by the black colour of the sediments).

As we were unable to use the same coring device to sample the mangrove habitat, the biomass results are indicative only of the differences between mangrove habitat and the three cleared sites. If sampling is to be undertaken again in 12 or 24 months, an improved method of collecting an accurate volume of mangrove sediments would be beneficial for a more robust comparison of sediment characteristics at depths below the surface, and also for biomass. The lateral roots of the mangroves can often make coring difficult and effectiveness of sampling may be improved by cutting through the mangrove roots, then sliding a core into place. .

Surface macrofauna were generally only present in low numbers at all sites (Figure 6). Crab holes were observed in all sampled areas, and variation in the density of these did not appear to be related to either surface sediment type or distance from the tidal channel. The mudsnail, *Amphibola crenata*, was only found in the cleared areas, though typically < 2 individuals per quadrat (mudsnails are deposit feeders and are likely exploiting the food provided by the rotting mangrove roots). The carnivorous gastropod *Zeacumantus lutulentus* (hornshell) was present both in the cleared areas WMB and WMC and also on the bare intertidal flat. The whelk (*Cominella),* another carnivorous species, was also present on the bare intertidal flat. It's primary food source is the cockle (*Austrovenus stutchburyi)*, and so whelks are typically found in abundance where cockles are present (Jones and Marsden, 2005). As these gastropods were mostly absent from the sampled areasl, it is also likely that cockles are not abundant at this site.

Analyses of temporal trends in the data indicate that benthic invertebrate abundance and diversity are increasing with time and that the disparity in population structure between the mangrove site and the cleared site may decrease as time goes on. However, given that manual (and consented) removal of mangrove seedlings is now a regular occurrence, and that the below-ground environment has been significantly altered in places, the cleared sites are unlikely to revert back to mangrove habitat. It is highly probable in this case that the changes seen in benthic community structure will be permanent.

Ecological recovery of a disturbed site can be assumed to have occurred when the site returns to a condition that does not differ significantly from the state it was in prior to disturbance. In this case the study area was previously an intact mangrove forest. However, because a prior assessment of the clearance area was not possible given the circumstances under which the vegetation removal took place, the mangrove vegetation directly adjacent to the study area was used as a proxy for "undisturbed state". The changes observed in the sediment composition and the structure of benthic communities in the cleared areas, along with a significant decline in benthic faunal abundance and species richness indicate that the cleared sites have not recovered within the observation period (2005 – 2008).

The results from this study provide some insight into the physical characteristics of the mangrove habitat at Moanaanuanu Estuary, and the intertidal areas that were cleared of mangroves. Future sampling, following the same methodology, would provide valuable information relating to rates of physical change, i.e., sediment coarsening and belowground biomass decomposition. The high mud content and belowground biomass documented at one of the cleared sites highlights the importance of considering the intertidal position and hydrodynamics of a site before planning the removal of any coastal vegetation.

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