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Ecological communities and habitats of Whangateau Harbour 2009

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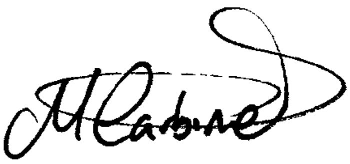

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Ecological communities and habitats of Whangateau Harbour 2009

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1 Executive Summary

In October 2009, the Auckland Regional Council (ARC) contracted the National Institute of Water and Atmospheric Research Ltd (NIWA) to visit Whangateau Harbour for the purposes of: a) updating the existing subtidal and intertidal habitat map of the Harbour developed in 2000; b) establishing seven intertidal sites for ecological monitoring; and c) collecting sediment from these sites for chemical analysis.

Ground truthing the subtidal and intertidal habitats showed some minor changes since 2000. Subtidally, three main benthic habitat types were observed, based on the proportion of shell hash, 1) sand, 2) sand and shell mix, and 3) shell hash. The epifauna was dominated by the starfish *Patiriella regularis* and *Coscinasterias calamaria*. High density patches of *Paphies australis* (pipi) were identified in several areas, and patches of a larger bivalve, *Gari stangeri*, were observed in the channel mouth and deeper areas of the outer channel. Intertidally, transects surveyed within the Harbour in October 2009 and recent aerial photography revealed some intertidal habitat change. These changes were predominantly in the southern section of the Harbour; south of the Broadlands Drive Causeway. Some discrete mangrove patches expanded and an increase in the tree density of others occurred. The largest seagrass patches had also changed in shape but covered a comparable area to those mapped in 2000.

The ecological monitoring programme was designed to investigate the health of the Harbour and detect any changes in the intertidal macrofaunal communities in response to changes and development in the surrounding catchment. Sediment contaminant information was collected to allow comparison to other regional monitoring programmes. Locations for the seven intertidal sites were selected using the existing habitat map and knowledge of catchment uses, taking into consideration the rationale behind monitoring in other estuaries in the region and the potential for land use changes in the Whangateau catchment. Within each of these seven locations, a site was positioned in a relatively homogeneous mid-tide area. Sediment characteristics of the sites ranged from <1% to 14% mud content and 9% to 41% medium sand. Organic content was low at all sites (<3%). Sites were dominated by a variety of organisms: sites 1 and 2 were dominated by crustaceans and bivalves, sites 3, 5 and 7 by a polychaete, crustacean and bivalve mix, site 4 by molluscs and crustaceans, and site 6 by polychaetes and crustaceans.

Macrofaunal community composition in Whangateau was similar to other Auckland East Coast estuaries. Greatest similarity was observed with sites in Okura, then with Orewa and Puhoi. The southern estuaries in the Whitford embayment showed the lowest similarity to the monitored sites. Monitoring in Whangateau Harbour will, therefore, be easily integrated into the Estuarine Monitoring framework and analyses already conducted by the ARC.

2 Introduction

Whangateau Harbour is one of the most important and highly valued estuaries on the Auckland east coast (Kelly 2009). It is a shallow harbour of 750 hectares, with over 90 percent of the water being exchanged on each ebb tide. Freshwater inputs into the Harbour are relatively low and drainage channels are a small component of the total landscape. Consequently, extensive intertidal flats, predominantly medium to coarse grained sands with a low percentage of mud (<4% Boyd 1972, from Kelly 2009) comprise ~85 % of the area. It contains a diverse range of habitats including sandflats of varying composition, saltmarsh, seagrass meadows and mangrove forests. Endemic wading birds and nationally threatened species are present (Kelly 2009). Food sources for birds are present both subtidally, populations of *Paphies australis* (Pipi) and *Paphies subtriangulata* (Tuatua), and intertidally, *Austrovenus stutchburyi* (Cockles). However, the recent natural mass-mortality event in 2009 has had a significant impact on the cockle population (Tricklebank *pers. com.*).

The surrounding catchment contains a range of different land-uses, including agriculture and horticulture to the west and forested areas to the north. Residential and commercial developments have increased in recent years, especially on the Mangatawhiri Spit. However, the harbour has high water quality (Scarsbrook 2008) and low levels of metal and organic (e.g., PAH) contaminants, although there are localised areas affected by stormwater and farm runoff (De Luca-Abbott et al., 2001). Estuarine sediments near two historic landfill sites at the north of the Harbour (near Tramcar Bay) were found to have elevated concentration of heavy metals (mercury, zinc, copper; Kelly 2009 and references therein). The potential for contaminant impacts is likely to increase as the area becomes increasingly urbanised and as infrastructural improvements increase human access to the Harbour. These pressures are of concern as the high value of the Whangateau Harbour and Omaha settlement is intrinsically linked to the quality of the natural resources.

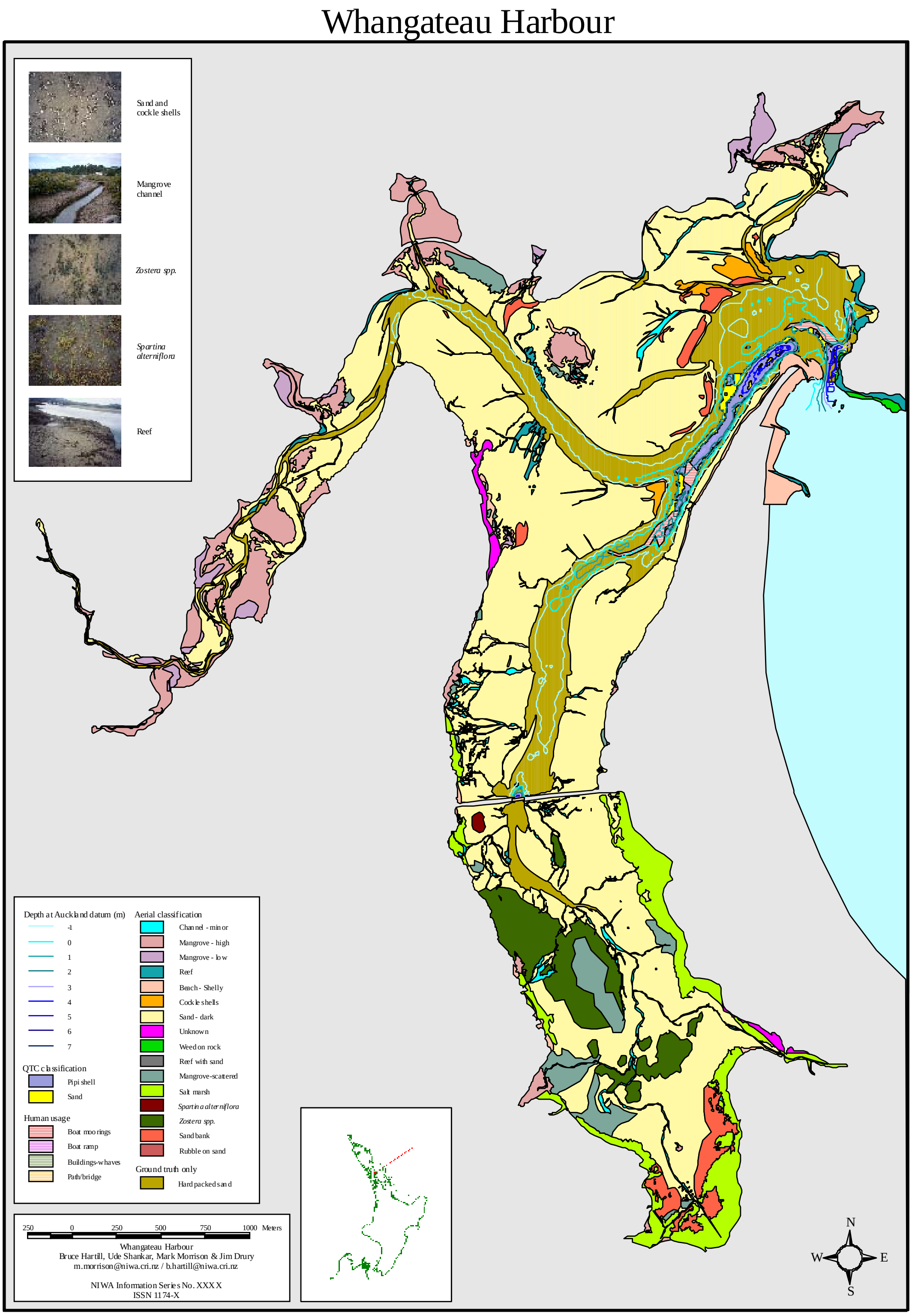
With both natural and anthropogenic factors influencing the integrity of the Whangateau Harbour biota, effective management and monitoring are of paramount importance (Cole et al., 2009). Current information on the habitats and communities of the Whangateau Harbour is based on the habitat map created by Hartill et al. (2000) (Figure 1). However, due to changes in land-use, habitats may also have changed and up-to-date information is required. Also, currently there is no routine monitoring of soft-sediment ecology, other than annual surveying of *Austrovenus stutchburyi* in a localised area (close to Tramcar Bay) by Dr Pilditch (University of Waikato) and annual surveys of shellfish by the Whangateau Harbour Care Group (Lews Bay and Causeway).

In October 2009, the Auckland Regional Council (ARC) contracted the National Institute of Water and Atmospheric Research (NIWA) to visit Whangateau Harbour for the purposes of providing up-to-date information on the benthic habitats of the Harbour. In shallow estuarine and marine waters, benthic macrofaunal communities are nationally and internationally considered a good parameter for evaluating health and impacts (Thrush et al 1988, Hewitt 2000, Anderson et al 2003, Pinto et al 2009), especially with respect to longer-term changes that may occur in response to human pressures. Benthic macrofauna are a critical component of estuarine and shallow coastal systems, providing food for humans, fish and birds, and an important link in the exchange of material (nutrients, oxygen and carbon) between the seafloor and the water column. They are relatively sedentary, and thus provide integration over time of changes occurring at a location, and have proven very responsive to anthropogenic pressures. Assessment of benthic macrofaunal communities is consistent with monitoring approaches used in other Auckland harbours e.g. Manukau, Mahurangi, Waitemata, Kaipara (Hailes and Hewitt 2009, Cummings and Halliday 2009, Townsend 2010, Hailes et al. 2010).

The project was comprised two parts:

- First, a new habitat map was to be created and compared with the habitat map established in 2000, to provide an indication of the rate of change of habitat types over the 10 year period.
- Second, seven intertidal sites were to be established and sampled for benthic macrofauna, sediment characteristics and chemical contamination in October 2009 and April 2010 (macrofauna and sediment characteristics only). A preliminary analysis of the October 2009 data is presented in this report. These data were to be used to (1) provide a starting point for longer-term monitoring consistent with the Estuarine Monitoring Programme being carried out at Puhoi, Waiwera, Orewa, Okura, Mangemangeroa, Turanga and Waikapoua; (2) assess the State of the Environment (SOE) using recently developed ARC indicators; and (3) provide information on sediment contaminants for comparison with regional monitoring data.

Figure 1:
Habitat map of the Whangateau Harbour developed by Hartill et al. (2000).



3 Methodology

3.1 Habitat Mapping

3.1.1 Subtidal

In February 2010, a drop-camera survey was undertaken to acquire video footage from 82 subtidal sites in the Whangateau Harbour (Figure 2). The sites spanned the area which had previously been mapped (Hartill et al., 2000) with additional sites in the Harbour mouth and inlet. Photographic data from the video footage was used to analyse the main habitat type and dominant epifauna at each site. The drop-camera procedures followed that outlined in Chiaroni et al. (2010). In brief, broad scale subtidal video footage was collected using a high resolution Tritech Typhoon camera with 470 lines of horizontal resolution. The camera was mounted in a depressor frame with integrated lights. Drops of the camera were run for a distance of approximately 10 m; but where habitats changed during a drop, another 10 m section was sampled.

This information could then be used to update the map where habitats had changed or where sampling had not been previously possible (e.g., due to occupied boat moorings, Figure 1). Benthic substrate information was ascertained from the video and spatially referenced labelled data points could be layered on top of the original map. In areas where habitat change had occurred, new habitat boundaries could be derived to reflect the change (interpolation zones). The original habitat map by Hartill et al., (2000) had classified subtidal benthic habitats predominantly into two types 'Sand' and 'Pipi Bed'. Further refinement was made to this classification, identifying sites on their proportion of different materials. Consequently, three main subtidal habitats were identified: 'Sand', 'Sand+Shell hash' and 'Shell hash'. In areas that had not been sampled in the 2000 survey, new layers were added to the habitat map. An important caveat for the approach used is that for areas containing shell hash, information was unavailable as to whether (and what proportion of) the shell hash contains live or dead individuals. This could only have been achieved through direct quantitative sampling. Epifaunal community information was used as a qualitative guide, as direct quantitative sampling was beyond the scope of the project.

Figure 2:

The location of the 82 drop-camera sites in the subtidal region of the Whangateau Harbour.

3.1.2 Intertidal

In October 2009, the distribution and extent of different intertidal habitats was assessed using a series of transect surveys. Over a two day period over 50 km of surveying was undertaken. Labelled waypoints were entered into a Garmin GPSmap76CX and track marks were used to define the edges and areas of distinct habitat types (i.e., sand, mangroves, seagrass, saltmarsh and channel edges). In addition, photographs and audio recorded notes were used to detail important features quickly while the mapping was undertaken. The collected waypoints and track marks were imported into ArcGIS 9 software and overlaid on the existing habitat map (Hartill et al., 2000). This enabled any changes in the intertidal habitats to be identified, and the habitat map to be updated. Furthermore, as not all of the harbour could be surveyed via transects, aerial photography (2008) and Google Earth imagery (2008) were used to assess the habitat types in some areas. This aerial imagery was particularly important in the areas where surveying was prevented due to excessively dense vegetation. The habitat map was also updated to reflect the two hectares of mangroves which were illegally removed in May 2010 from the western shore just south of the Causeway (information provided by R. Grace *pers. com.*).

3.2 Estuarine Monitoring

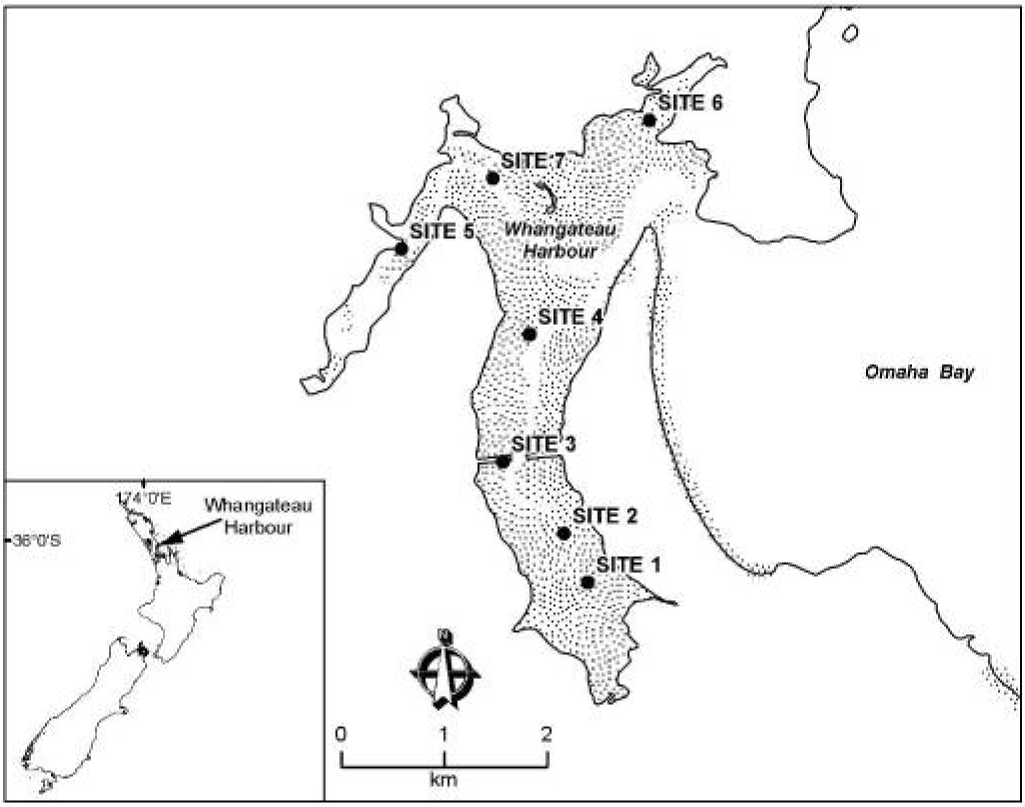
3.2.1 Site Selection

The general locations of the seven Estuarine Monitoring sites were determined using available information, including the habitat map of Whangateau Harbour developed by NIWA in 2000 (Hartill et al., 2000) and aerial photography showing land use and potential contaminant inputs. The chosen locations were required to span the estuary in such a way that they were likely to reflect gradients in deposition of terrestrial-based sedimentation and any potential gradients in sediment contamination and changes in land use. During the intertidal habitat mapping, the seven locations were visited and a monitoring site was established at each location (Figure 3, Table 1). Each site was 50 x 25 m in dimension and covered and area of 1250 m^2. These sites were homogenous in composition, located between mid to low tide, and avoided mangrove, seagrass and oyster beds, in order to facilitate comparisons between sites both within Whangateau and with sites monitored by the ARC in other estuaries.

Table 1:
GPS Coordinates (WGS84, decimal degrees) of the intertidal monitoring sites in Whangateau Harbour.

	Southing	Easting
Site 1	36° 35.1918	174° 77.2606
Site 2	36° 34.7673	174° 76.9974
Site 3	36° 34.1472	174° 76.3209
Site 4	36° 33.0310	174° 76.5834
Site 5	36° 32.3028	174° 75.1830
Site 6	36° 31.1403	174° 77.8388
Site 7	36° 31.6745	174° 76.1569

Figure 3:
Map of Whangateau Harbour displaying the seven monitoring sites.



3.2.2 Sample Collection

On each sampling occasion (October 2009 and April 2010), six macrofaunal cores (13 cm diam., 15 cm deep) and six sediment cores (2 cm diam., 2 cm deep) were collected from each site. To provide an adequate spread of cores over the site, each was divided into six equal sections and one macrofaunal core and one sediment core sample was taken from a random location within each section. Furthermore, surface sediment scrapes (top 2 cm) were collected from within each 'section' and amalgamated into two replicates for chemical analysis.

Macrofauna core samples were sieved through a 500 µm mesh and the residues stained with rose bengal and preserved in 70 % isopropyl alcohol. Sediment samples were frozen prior to analysis.

3.2.3 Sediment Analysis

Sediment core samples were divided in two and analysed for grain size and organic matter content. The sample for sediment grain size analysis had organic matter removed by digestion in hydrogen peroxide. Wet sieving was then used to separate the sample into fractions of gravel (particles >2 mm); coarse sand (particles 2 mm-500 µm); medium sand (particles 500 µm-250 µm); fine sand (particles 250 µm-63 µm); and mud (particles <63 µm), which were then dried (60°C) and weighed. Before drying, the mud fraction was analysed by pipette analysis for proportions of silt and clay. The sample for organic content analysis was dried at 60 °C to a constant weight and combusted for 5.5 hours at 400 °C. Organic content was determined by the difference in weight of the sample prior to and after combustion. This data was used in a principle component analysis (on normalised data) to compare how similar sites were to each other, and to determine sediment characteristics at each site.

3.2.4 Chemical Analysis

Chemical analyses were performed by R J Hill Laboratories Ltd (Hamilton) using standard ARC methods and protocols as outlined in Mills and Williamson (2009). Measurements were made of total organic content, PAHs (polycyclic aromatic hydrocarbons) and total PAH, and heavy metals (iron, manganese, arsenic, cadmium, chromium, mercury, nickel, copper, lead and zinc). Chemical analysis was performed on total recoverable acid digested < 500 µm dry sieved fractions for all metals, and also, for copper, lead and zinc, on weak acid digestion of the < 63 µm wet sieved fraction.

3.2.5 Macrofaunal Analysis

Macrofaunal samples were sorted, identified to the lowest practical taxonomic level and enumerated. After identification, individual *Paphies australis*, *Austrovenus stutchburyi* and *Macomona liliana* were placed into size classes. The size classes for *Austrovenus* and *Macomona* were <5 mm, 5 – 10 mm and then in 10 mm increments.

Paphies australis size-classing was the same, although they were rarely observed. Data collected in October 2009 was analysed for community composition and biodiversity. The five most dominant taxa were determined and average and standard errors of the number of taxa, number of individuals and Pielou's evenness (values ranging between 0 and 1, with 1 indicating high evenness) were calculated. The total number of taxa found over the six cores at each site was also determined. Multivariate analysis of community composition was conducted on Bray-Curtis similarities from loge (x+1) transformed data. Non-metric multidimensional scaling, randomised analysis of similarities and pairwise analysis of dissimilarities between sites were conducted using Primer E.

This data was also assessed using three recently developed 'State of the Environment' indicators:

- The Benthic Health Model is a multivariate model of community health relative to stormwater contamination represented by concentrations of total extractable copper, lead and zinc (Anderson et al., 2006). It is referred to as "BHMcont" in this report.
- A similar model has recently been developed to model health relative to changing mud content, known as "BHMmud" (Hewitt and Ellis 2010).
- A functional diversity index, NIWACOOBII, has been developed to ecosystem functioning for intertidal non-vegetated benthic communities, in the Auckland Region (van Houte-Howes and Lohrer 2010). Note that this index was developed based on 10 replicate samples per site.

4 Habitat Mapping

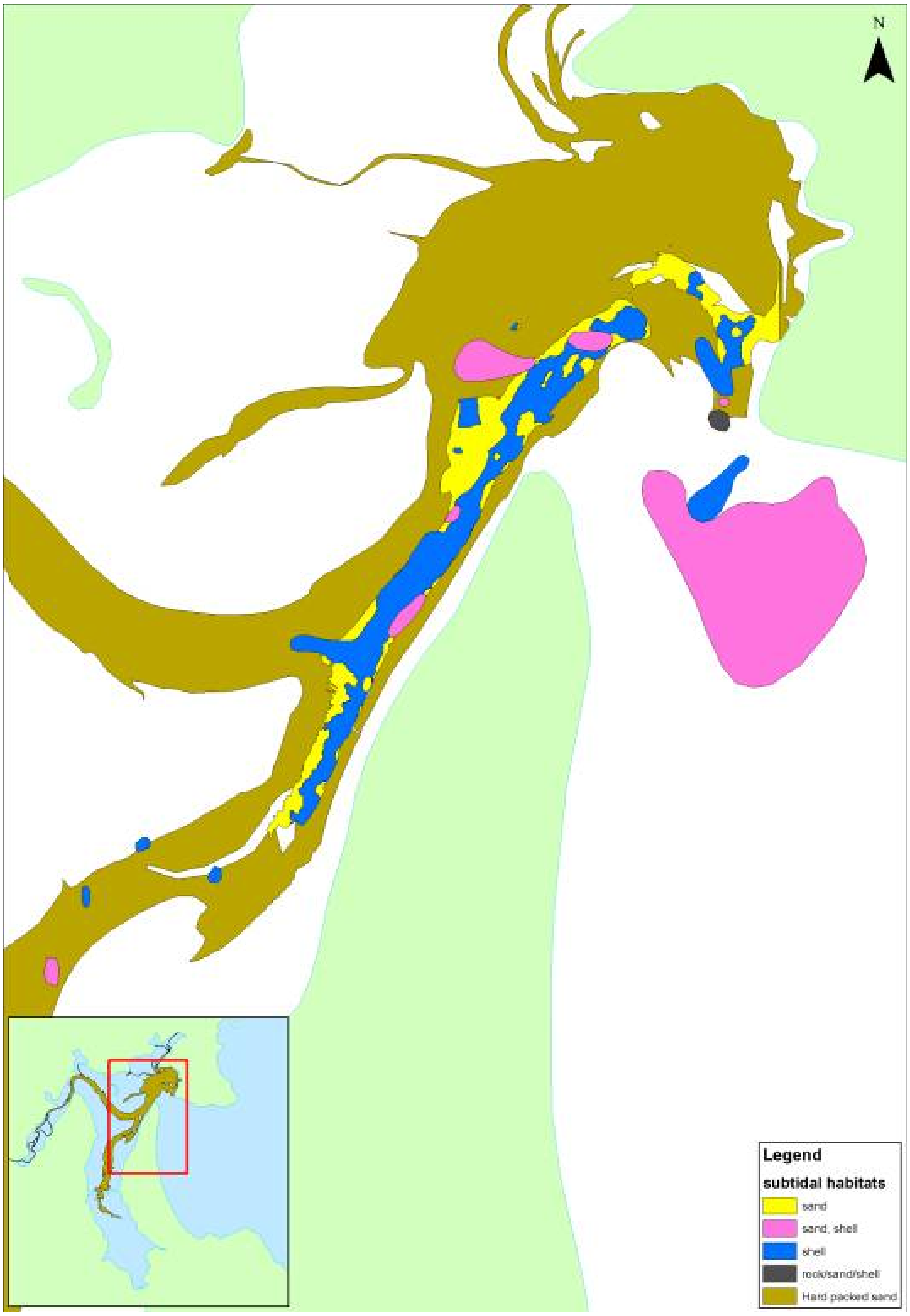
4.1 Subtidal

The subtidal area is mostly shallow (average depth 1.5m) and comprises 15% of the harbour area. The majority of the subtidal sediments are comprised of coarse silica sand and/or large patches of shell and shell fragments. Outside the harbour mouth, the habitat is predominantly 'Sand+Shell hash' (Figure 4). The harbour entrance itself is narrow and is bound on the western side by Mangatawhiri and on the northern and eastern sides by Ti Point. In the entrance there is a greater proportion of habitat containing rock, likely reflecting the stronger currents and the large volume of water that moves through this section on a tidal basis. Ripple features over the surface of the sediments were common throughout the entire subtidal area. The shore at Ti Point also consists of rock, boulders and sandstone. In comparison to the 2000 habitat map, subtidal habitats within the Harbour are largely unchanged and the differences between Figures 1 and 4 reflect a refinement of the classification. The subtidal channel is still largely comprised of a long bar of shell hash that is fringed on the western edge by sandier sediment. The northern-western end of the channel towards the harbour mouth, where additional sites have been sampled, is comprised of sand (Figure 4). The sampling of addition of subtidal sites at the southern end of the channel also shows the sediment there to be largely comprised of sand (Figure 4). It is of note that the constructions of the groyne structures on the Mangatawhiri Spit in the 1970's may be partially responsible for habitat stability, as historically material in the inlet was much more mobile (Titchener 1993).

Epifauna was dominated by the starfish *Patiriella regularis* and *Coscinasterias calamaria*. *Patiriella* was found throughout the harbour, although in low densities. *Coscinasterias* was also found in low numbers but was more common further north, closer to the mouth. High density patches of pipis were identified in several areas, particularly close to the entrance to the harbour. Patches of a larger bivalve, likely to be *Gari stangeri,* were also observed in the channel mouth and the deeper areas of the outer channel. Species identification could not be confirmed from video analysis and direct quantitative sampling was beyond the scope of the project.

Figure 4:

The updated subtidal section of the Whangateau Harbour habitat map (2010).



4.2 Intertidal

The updated habitat map indicates that there have not been substantive changes in habitat types since 2000 (Figure 5). However, a number of the previously mapped habitats (Hartill et al., 2000) have shown some change in distribution which is evident from comparing Figures 1 and 5 (Figure 6). The most numerous and greatest changes are in the southern section of the harbour to the south of the Causeway; with the expansion of mangrove and change in seagrass (*Zostera muelleri*) habitats. Overall Whangateau Harbour has a medium to low likelihood of large-scale mangrove expansion (Swales et al., 2009), but some smaller areas have expanded and other patches have increased in tree-density. The main features and changes of note are summarised below (South to North):

- At the southern tip of the harbour, in the 'V' shape between the areas of sandbank and saltmarsh (Figure 1), the sand flat has been colonised with a low to moderate density of mangroves. These occur on both sides of the narrow channel (Figure 6 item 1, Figure 7).
- The area of mangroves to the east of Jones Road Creek has increased in density. The patch of sand, previously between two patches of mangroves, has now been covered by scattered mangroves (Figure 6 item 2, Figure 7).
- The large patch of seagrass to the east of Jones Road Creek has changed in shape, although covers an approximately similar area. The south-western end of this seagrass patch has reduced in extent and has fragmented into a few smaller patches. Conversely, the north-eastern tip has slightly increased in size and has connected with a previously separate patch (Figure 6 item 3).
- The area of sand on the eastern flank of the largest seagrass patch in the harbour now contains scattered mangroves. Mangroves are more numerous within this patch of seagrass than previously described (Figure 6 item 4).
- The saltmarsh habitat which runs south down Mangatawhiri Spit, from the causeway, is now fringed with a low density of mangroves (for approximately 1 km) particularly where the creek joins Waikokopu Channel. The saltmarsh has not reduced in extent, rather the sand flat has been colonised by mangroves (Figure 6 item 5, Figure 8).
- As noted in Kelly (2009), immediately south of the bridge, predominantly single mangroves line the transition between the causeway and the sand flat (Figure 7 in Kelly 2009) (Figure 6 item 6, Figure 8).
- The *Spartina alterniflora* habitat that was present on the eastern side just south of the Causeway is no longer present (Figure 6 item 7, Figure 9).
- There is now a small patch of seagrass just to the north of the causeway on the western side (Figure 6 item 8, Figure 9).
- The patch of saltmarsh on the western side of the harbour to the north of the causeway is lined with scattered mangroves. This mangrove patch has increased in size (Figure 6 item 9).

Figure 5:

The updated intertidal habitat map of Whangateau Harbour (2009).

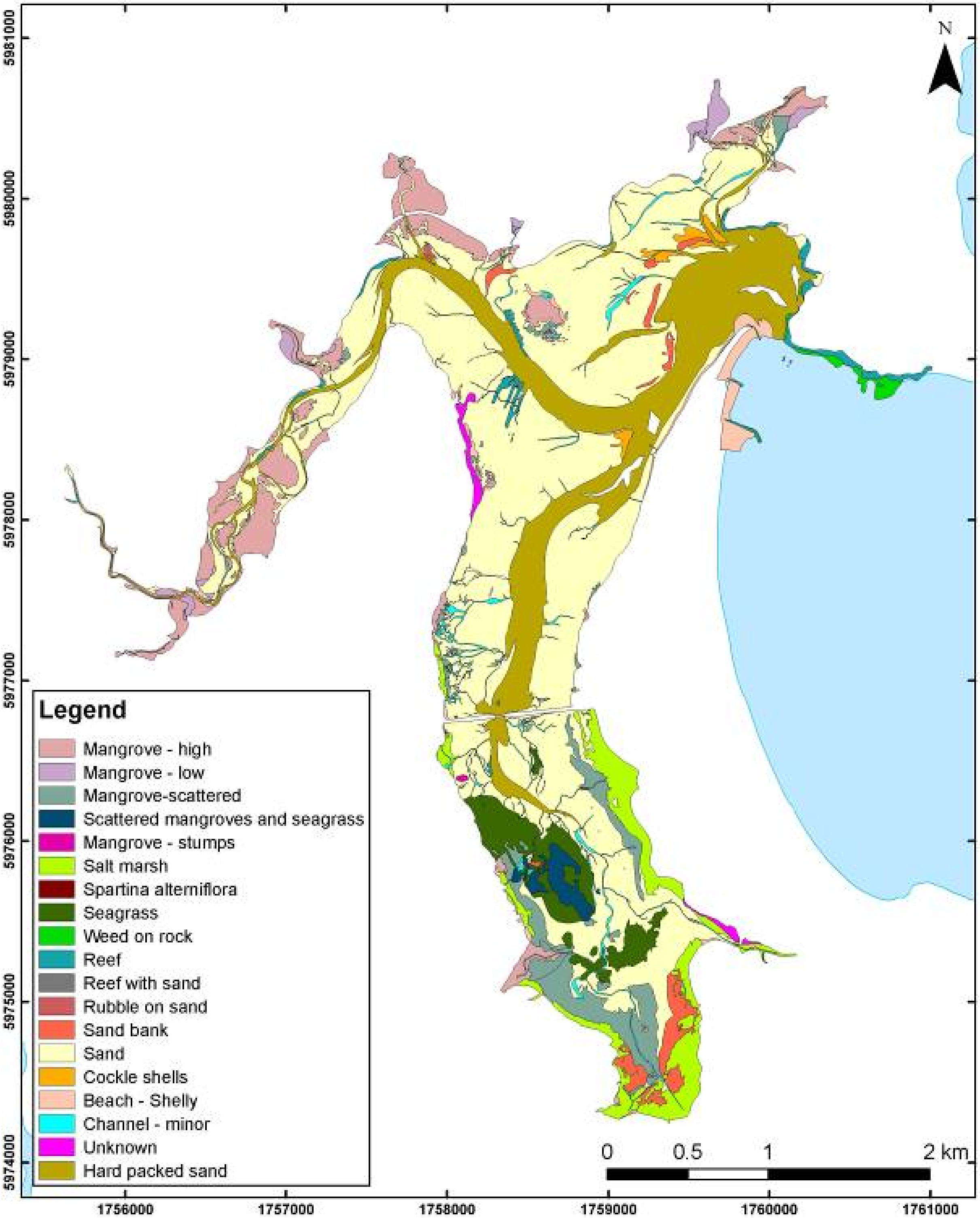


Figure 6:

Locations where changes in habitat type or extent have been found (numbers referenced in text).

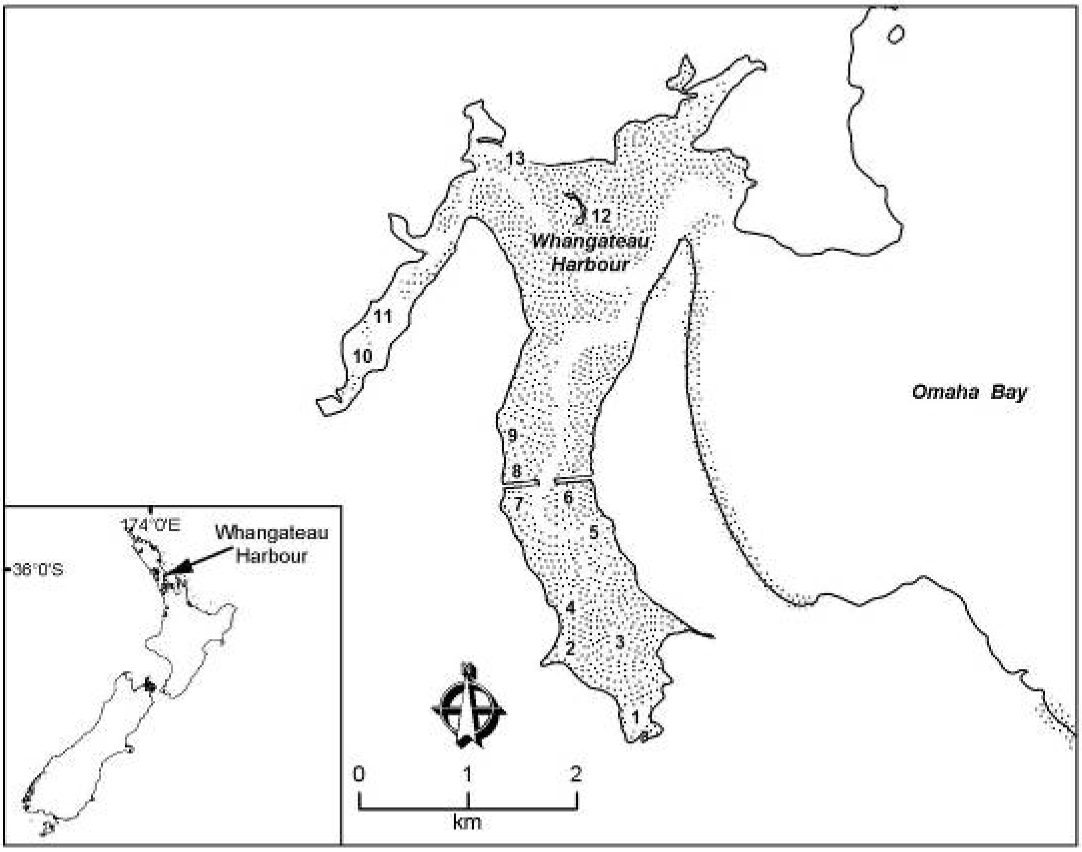


Figure 7:
The southern section of Whangateau Harbour (east of Tokanui Point). Red areas indicate area which were previously classified as 'sand – dark', but now showing signs of scattered mangroves.

Figure 8:
The southern section of Whangateau Harbour, immediately south of the Causeway. Red line indicates mangroves, which now line the Causeway and extend south to Tokanui Point in scattered to low density (higher density at the drainage creek). This area had not previously been classified as containing mangroves.

- At the southern tip of Omaha River, the area previously classified as 'sand-dark' habitat is now covered with mangroves. Mangroves are most evident on the fringe of this sandy area and at lowest density in the centre (Figure 6 item 10, Figure 10).
- Throughout the mangrove sections of Omaha River arm of the harbour, the previous classification included areas of 'low density mangroves'. The majority of these mangroves have increased in density and can now be considered medium-high density (Figure 6 item 11, Figure 10).
- There are localised patches of mud associated with the mangroves in Omaha River which are of too small a scale to be incorporated in the habitat map.
- Large patches of the fucoid algae Neptune's necklace (*Hormosira banksii*) were observed attached to large areas of the sand flats on the western side of the harbour north of the causeway (map not updated due to likely non-permanency of this habitat).

Figure 9:
Changes in habitat type by the causeway. A small patch of seagrass is now present to the north (top circled in red). The *Spartina alterniflora* habitat which was present in 2000 has disappeared (bottom red circle).

Figure 10:

An area previously mapped as 'sand - dark' showing evidence that it is being recruited by mangroves (lower red line), most prominently at the edges. The mangrove patch to the north of this (upper red line) is now more uniform and of high density.

- There has been a slight increase in mangrove coverage on the southern and eastern side of Horseshoe Island (Figure 6 item 12).
- The area previously classified as scattered mangroves south of the inlet where Birdsall Stream enters the harbour, should be classified as 'low-medium density mangroves' (Figure 6 item 13).
- Mangrove densities and habitat extent between Ti Point and Coxhead Creek inlets are relatively unchanged, compared with Hartill et al. (2000).

4.2.1 Intertidal habitat summary

The intertidal habitats have remained relatively stable over the ten years since the last survey. There have been proportionally fewer changes north of the causeway, relative to the south. The greatest changes have been expansion of vegetative habitats, with mangroves increasing in distribution and density. However, these changes are still relatively small compared with the total habitat area. Mangrove distribution has been predicted to increase (Swales et al., 2009) and observations have found fine sediment accumulation south of the causeway (Kelly 2009), which may accelerate this process. Muddier sediment was also observed towards the southernmost extent of the Harbour (M Townsend *pers. obs*.) which may be related to the change in habitat type, as both seagrass and mangroves can increase the trapping of fine material.

Both the original and updated habitat maps are based on the surficial habitat characteristics. For the large areas of sand on the western shore, from Point Wells south to the large seagrass patch below the causeway, the soft sediment appears in many places to be underlain by mudstone ranging in depth from a few centimeters to much deeper (>30 cm). Over this area, the patches listed as 'Reef' habitat are predominantly the places where the mudstone protrudes from the surface of the soft sediment. Comprehensively measuring the sediment depth was beyond the scope of the current study. However, this information may be useful for assessing the risk of habitat change (i.e., varying risk of mangrove establishment in different soft sediment depths).

5 Estuarine monitoring

5.1 Site Descriptions

Routine assessment of the visual and sediment characteristics of each site can provide information a context against which changes in macrofauna can be evaluated. A brief description of site appearance and sediment characteristics are given here.

5.1.1 Site 1

Located in the southern arm of Whangateau Harbour (Table 1), Site 1 is positioned alongside upper Waikokopu Creek and north-west of Tokanui Point (Figures 3 & 11). Waikokopu Creek branches and runs parallel to both sides of the plot which runs north to south (the left hand side channel is approx 20 m away from the west side of the plot). A small oyster bed and a small stand of mangroves are located approximately 15 m away from the south-western corner of the monitored area. The monitored area is homogeneous firm sand with little evidence of surface features, such as large ripples at the time of sampling; however there is evidence of a relatively strong current, as the sediment surface appears scoured. *Macomona liliana* and *Austrovenus stutchburyi* shells litter the sediment surface but there is little evidence of epifauna at this site. Fresh seagrass detritus (single blades) were seen on the sediment surface.

5.1.2 Site 2

Site 2 is located to the north-west of Site 1 and is positioned approximately 10 m away from the eastern side of the main channel (Figure 3). The site runs north-west to south-east and is adjacent to a large lone mangrove on the east side (Figure 12a, Table 1). The monitored area is firm, sandy and similar in appearance to the substrate at Site 1. Surface ripples are prominent at this site and have a wave length and height of approximately 15 cm and 1 cm, respectively (Figure 12b). The occurrence of epifauna on the surface is uncommon, however, *Austrovenus stutchburyi* and *Macomona liliana* shell hash is present on the surface.

Figure 11:

Photographs of Site 1. a) Looking south from the northern end of the site (stand of mangroves near the south western corner are visible); b) sediment at Site 1 with low density *Austrovenus stutchburyi* and *Macomona liliana* shells.

a)

b)

Figure 12:

Photographs taken at Site 2. a) Looking to the east of the monitored area, b) the sediment surface displaying the surface ripples and scattered *Austrovenus stutchburyi* and *Macomona liliana* shells.

a)

b)

5.1.3 Site 3

Site 3 is located on the western intertidal area of the main channel and runs from north to south (Waikokopu Creek) and is approximately 20 m south of the Causeway (Figure 3) (Table 1, Figure 13a-c). Of all the monitoring sites established, Site 3 is the closest in proximity to the mangrove removal site of May 2010 (Figure 13a). Rills and sub-channels surround the site with associated muddy patches (sink approximately 5-10 cm). The sediment surface of the monitoring area is a homogeneous, firm sandy sediment. However, at times a thin (<1 cm) layer of overlying muddy sediment was observed (Figure 13b). The sediment at this site has more shell hash (including *Austrovenus stutchburyi* and *Macomona liliana*) on the sediment surface and feels much grittier than Sites 1 and 2, with a larger proportion of coarse sand. Three epifaunal species: *Cominella glandiformis*, *Zeacumantus lutulentus* and *Diloma subrostrata* are abundant (collectively, approximately 10 individuals per 0.5 m^2).

5.1.4 Site 4

Site 4 is located on the western bank of the main channel, running in a north-east to south west direction, and is approximately 10 m away from the channel prior to it sharply bending east prior to the locations of the permanent moorings (Table 1, Figure 3, Figure 14a). From approximately 10 m north of the monitored site, a number of deep rills cut the sandflat and extend from the channel towards the western bank. The monitored site is a homogeneous sandy area and has a number of different surface features including: a) a slightly undulating appearance where depressions remain filled with water at low tide; b) a substantial amount of *Austrovenus stutchburyi* and *Macomona liliana* shell hash; c) *Macomona* feeding tracks (~ density of 15 m^{-2}); d) sparse small maldanid tubes; and e) epifauna (*Diloma subrostrata* and *Cominella glandiformis*) (Figure 14b).

5.1.5 Site 5

Site 5 is located along the western arm of Whangateau Harbour on the tidal section of Omaha River (Table 1, Figure 3). The monitored site has been established on the eastern side of the channel located 5 m away from the channel edge and ~ 20 m away from the start of the stands of mangroves and muddy habitats to the south (Figure 15a). A rill lined with mangrove saplings boarders the north and east sides of the monitored area. In October 2009, the sediment was homogeneous firm rippled sand with a wave length and height of approximately 10 cm and 1 cm, respectively. The surface of the sediment was littered with both *Austrovenus stutchburyi* and *Macomona liliana* shell hash and *Macomona* feeding tracks were dense and often quite large. *Cominella glandiformis* were also common. However, when the site was visited in April 2010, a thin layer (approximately 2 cm deep) of muddy sediment blanketed the site (Figure 15b). On this occasion, low densities of *Diloma subrostrata* were observed on the sediment surface and the presence of shell hash was minimal and sparse.

Figure 13:

Photographs taken at Site 3: a) from the south of the site in the direction of the mangrove removals; b) the sediment surface displaying notable epifauna and shell hash and c) the proximity of the monitoring site to the causeway.

Figure 14:
Photographs taken at Site 4: a) looking south from the northern end of the monitored area, and b) the sediment surface displaying the surface features including shell hash, tube worms and *Macomona liliana* feeding tracks.

a)

b)

Figure 15:

Photographs taken at Site 5. a) Looking in a south-westerly direction across the rippled sediment surface of the monitored area (October 2009), towards where the mangroves and muddier habitats are located, and b) the sediment surface photographed in April 2010, displaying a notable change in surface sediment (muddy layer overlying the firm sandy sediment).

a)

b)

5.1.6 Site 6

Site 6 was established in the northern-most arm of Whangateau Harbour which drains Coxhead Creek and is south of a forested area and Leigh Racecourse (Figures 3 &16a, Table 1). The site is to the north of cockle beds which experienced the mass-mortality event in January-February 2009, and is flanked by a small marked channel to the east and a sub-channel and rill to the west (Figure 16a, b). The site is located approximately 350 m south of the edge of the dense mangroves situated in the upper portion of this arm. Of all the monitoring sites, Site 6 is the muddiest (Figure 16c). The sediment surface is relatively void of surface features such as ripples and epifauna, however, there is a small amount of terrestrial woody debris and shell hash. This site is the closest in proximity to the old landfill sites which have previously been a source of contamination (Kelly 2009).

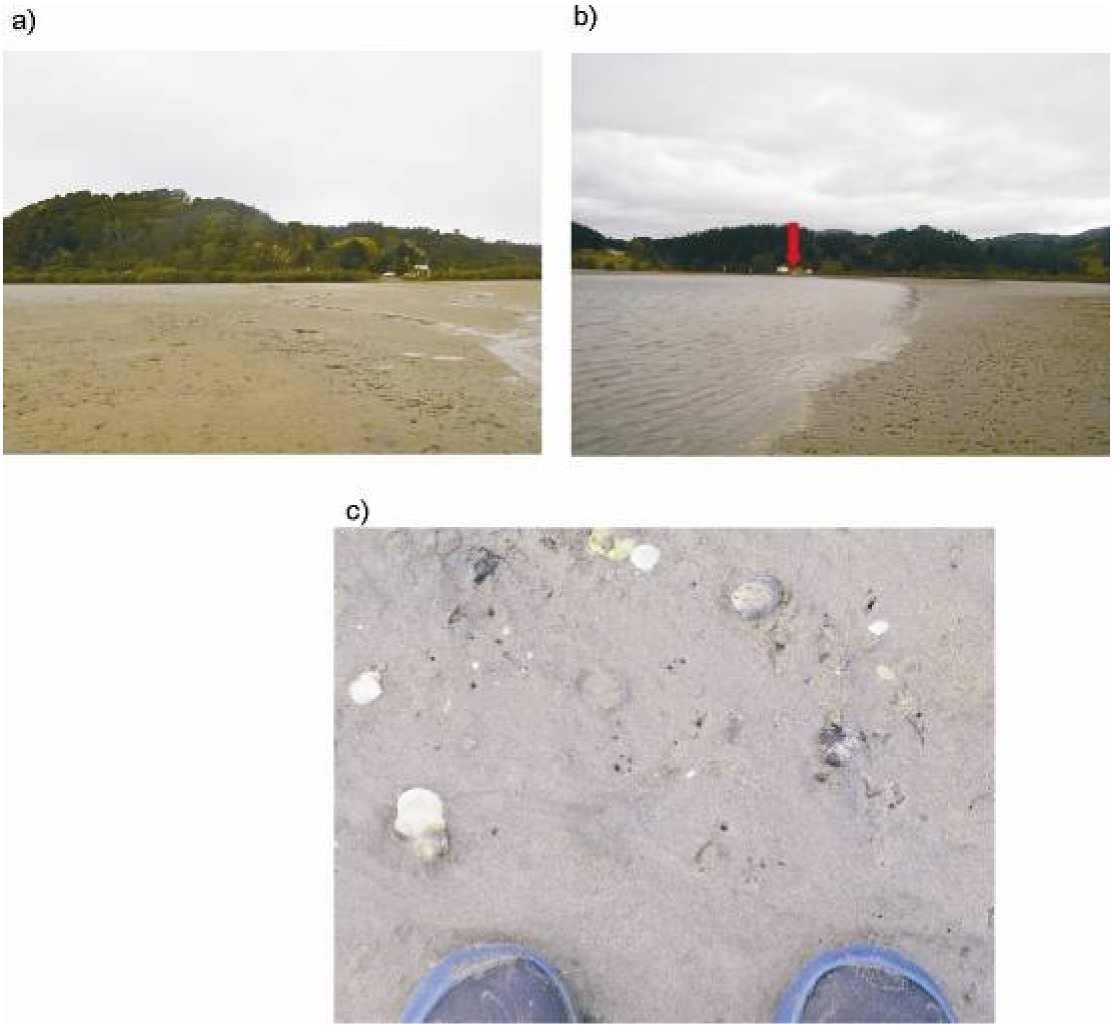
5.1.7 Site 7

Site 7 was established on the intertidal sandflat adjacent to the old wharf off Leigh Road and approximately 200 m west of Whangateau Holiday Park (Figure 17). The monitored site is located parallel to the main channel, approximately 10 m away from the water when the tide is low, running in a south-east to north-west direction. The upper intertidal is lined with a dense stand of mangroves, which extends from Big Omaha Wharf along to the Whangateau Holiday Park. The monitored area and surrounding intertidal area was homogeneous firm sandy, rippled sediment (approximate wave length and height of 5 and 1 cm, respectively) with scattered shall hash (*Austrovenus stutchburyi* and *Macomona liliana* shells). Epifauna (*Cominella glandiformis*, *Diloma subrostrata* and *Zeacumatus lutulentus)* were common on the sediment surface.

Figure 16:

Photographs taken at Site 6. a) looking south-east across the monitored area and showing the proximity of the site to the dense shell hash from the mass mortality event (red arrow), and c) the sediment surface indicating the muddiness of the site and lack of surface features.

Figure 17:
Photographs taken at Site 7. a) looking north along the length of the monitored area, b) looking west showing the proximity of the site to Old Omaha Wharf (red arrow) and c) the sediment surface displaying the epifauna and shell hash.



5.2 Sediment Characteristics

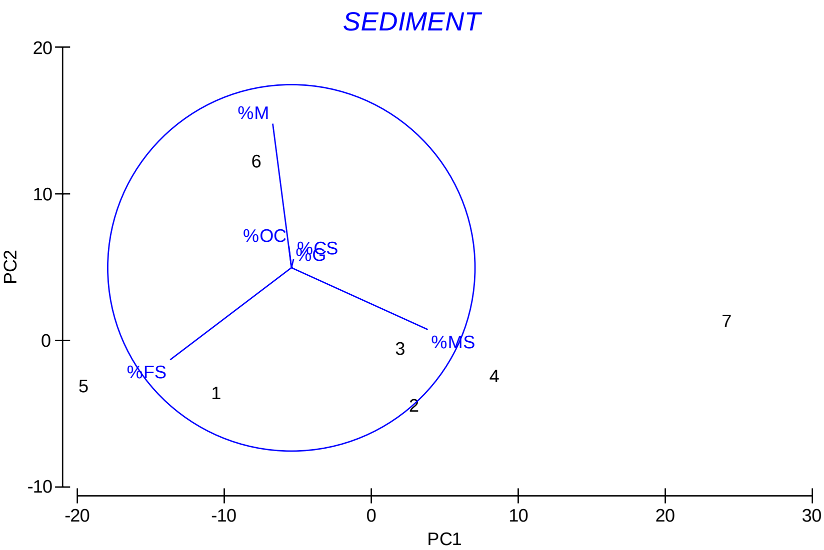
All sites except Site 6 had low levels of mud (<5%; Table 2). Site 6 was reasonably muddy with a mud content of ~14%. Sites 3 and 5 were the next muddiest with around 3% mud, while Sites 2 and 4 had <1% mud. Sites 1 and 5 were predominantly fine sand (>80%), while Site 7 could more readily be classified as medium sand (~41%). Sites 2 – 4 also had reasonable quantities of medium sand (>20%). The percentage of sediment organic matter was low at all sites (<3%), with highest values found at Site 6 (2.7%). A principle component analysis of the sediment characteristics shows Site 6 well separated from the others along the second axis (representing mud content), while the other sites form an increasing gradient in coarseness of sediment from Site 5 to Site 7 (Figure 18). Sites 2 and 3 are the most similar.

Table 2:

Sediment grain size and organic content observed at the sites.

Site	% Shell hash	%Coarse Sand	% Medium Sand	% Fine Sand	% Mud	% Organic Content
1	0.00	0.07	16.42	81.15	2.36	0.89
2	0.00	0.13	26.75	72.77	0.35	0.59
3	1.08	0.51	24.33	71.08	3.00	1.37
4	0.82	0.82	29.72	67.80	0.84	0.81
5	0.05	0.13	9.47	86.81	3.54	1.21
6	0.27	0.96	13.04	71.39	14.34	2.73
7	0.17	0.67	40.59	55.85	2.72	1.05

Figure 18:
Principle component analysis of sediment characteristics of the seven sites. FS (fine sand), MS (medium sand) and M (mud) drive the ordination, with OC (organic content, CS (coarse sand) and G (shell hash) having little effect. Sites closest together are most similar.



5.3 Chemical Characteristics

Concentrations of all chemicals measured were low at all sites (Table 3) and well below the available Threshold Effect Level (TEL) guidelines. In fact, all but Site 6 copper concentrations were below the field-derived levels of effect for total copper, lead and zinc based on 50% drops in abundance of 5% of common taxa reported by Hewitt et al. (2009) (5.3-6.5, 10.4 -18.5, and 113-114 mg· kg-1 for copper, lead, and zinc, respectively.

Table 3:

Mean concentration (mg/kg dry wt.) of PAHs (adjusted to 1% carbon) and metals in the top 2 cm of sediment collected in October 2009 from the seven monitoring sites in Whangateau Harbour. Copper, lead and zinc values are given for both the <63 µm and <500 µm fractions. TOC, total organic carbon, is given as g/100 g. The Threshold Effect Concentrations (TEL) and the field derived levels (Hewitt et al., 2009) are given where available.

		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	TEL	Field derived levels of effects
<500µm	TOC	0.2	0.1	0.5	0.2	0.3	0.6	0.3		
	PAH	0.000	0.000	0.000	0.000	0.000	0.028	0.000	1.68	
	Iron	3133	2143	4067	2900	7967	15767	5933		
	Manganese	26.0	21.7	30.3	26.3	75.0	116.7	66.3		
	Arsenic	1.6	1.5	2.5	1.6	2.9	5.5	2.8	7.24	
	Cadmium	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.68	
	Chromium	5.6	4.3	7.5	5.8	11.0	18.2	9.3	52.3	
	Mercury	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.1	< 0.01		
	Nickel	1.9	1.4	2.8	2.1	4.3	8.0	3.8	15.9	
	Copper	0.9	0.4	1.6	0.8	2.8	7.2	2.2	18.7	5.3 – 6.5
	Lead	0.8	0.6	1.2	0.7	2.0	4.5	1.3	30.2	10.4 – 18.5
	Zinc	8.3	5.9	10.9	7.3	20.2	33.0	14.5	124	113 - 114
<63µm	Copper	9.4	4.7	10.4	7.9	9.1	10.3	8.6		
	Lead	5.7	1.3	7.5	5.6	6.3	7.4	5.7		
	Zinc	35.0	8.3	42.0	30.7	43.0	37.7	32.7		

5.4 Macrofauna

5.4.1 Site Descriptions

5.4.1.1 Site 1

Site 1 was dominated in October by a mix of bivalves and crustaceans (Table 4). The bivalves *Nucula hartvigiana* and *Macomona liliana* were most dominant with the amphipods of the Lyssianassidae and Phoxocephalidae families and the polychaete *Prionospio aucklandica* also present in high numbers. *Austrovenus stutchburyi* juveniles and adults were rare, although medium sized individuals occurred more frequently (Figure 19). *Macomona* of all size classes were found, although juveniles were most common. An average of 15.7 taxa per replicate core were observed (Table 5) with 25 taxa in total observed at the site, the samples from the site form a tight cluster in ordination space (Figure 20). The number of individuals in each core was relatively low in comparison with the other sites at 60 individuals, with a high evenness value indicating individuals were evenly spread across the taxa.

Table 4:

The five most dominant taxa observed at each site in October 2009.

S1	S2	S3	S4	S5	S6	S7
Nucula	Urothidae	*Nucula*	*Nucula*	*Scolelepis*	*Prionospio*	*Colurostylis*
Macomona	*Nucula*	*Prionospio*	*Eatoniella*	*Ceratonereis*	*Colurostylis*	*Nucula*
Lyssianassidae	*Colurostylis*	Phoxocephalidae	Phoxocephalidae	*Colurostylis*	*Boccardia*	*Prionospio*
Prionospio	*Macomona*	Oligochaete	*Prionospio*	*Nucula*	Phoxocephalidae	*Macomona*
Phoxocephalidae	*Exosphaeroma*	*Austrovenus*	*Austrovenus*	*Macomona*	*Ceratonereis*	*Austrovenus*

Figure 19:

Sizes of *Austrovenus stutchburyi* and *Macomona liliana* observed at the sites in October 2009.

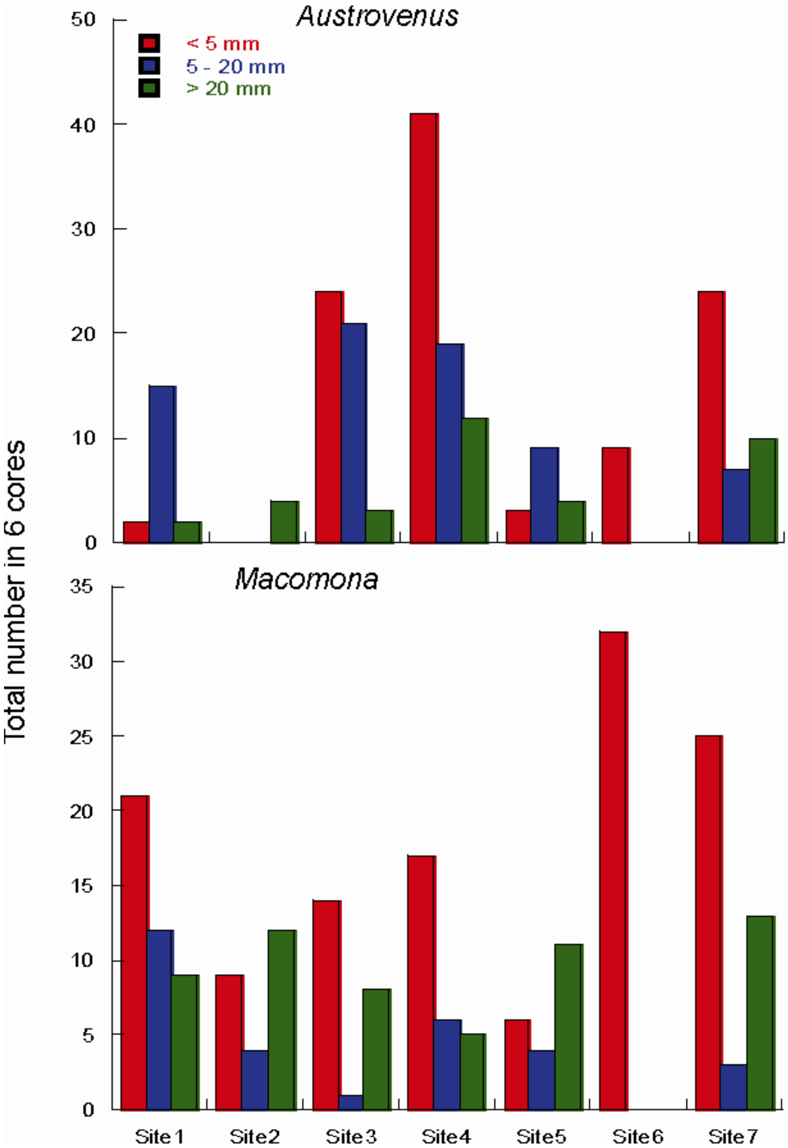


Figure 20:

Non-metric multidimensional scaling ordination of community composition in October 2009. The ordination is based on Bray-Curtis similarities of log (x+1) transformed data. Points that are closest together are most similar.

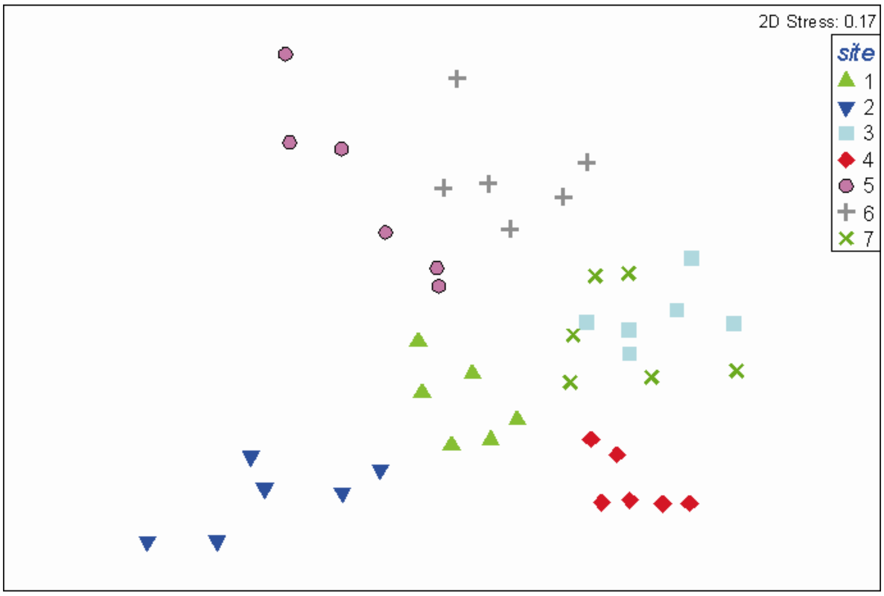


Table 5:

Diversity statistics at each site in October 2009. Numbers in brackets are standard errors.

	Average # taxa	Total # taxa	Average # individuals	Average Pielou's evenness
Site 1	15.7 (1.1)	25	60.0 (12.3)	0.884 (0.025)
Site 2	9.8 (1.0)	20	44.8 (3.9)	0.745 (0.060)
Site 3	15.5 (0.9)	30	123.7 (15.7)	0.761 (0.018)
Site 4	20.8 (1.3)	32	192.8 (29.5)	0.756 (0.018)
Site 5	13.0 (0.8)	28	53.7 (6.2)	0.884 (0.015)
Site 6	15.3 (1.2)	31	110.8 (20.2)	0.785 (0.032)
Site 7	21.8 (1.2)	42	106.2 (13.8)	0.813 (0.019)

5.4.1.2 Site 2

Site 2 was also dominated in October 2009 by a mix of bivalves and crustaceans (Table 4). Amphipods of the Urothidae family and *Nucula harvigiana* were the two most dominant taxa and the cumacean, *Colurostylis lemurum*, the bivalve *Macomona liliana* and the isopod *Exosphaeroma falcatum* were also present in high numbers. Occasional *Austrovenus stutchburyi* adults were observed (Figure 19). *Macomona* of all size classes were found, although adults were most common. While the average number of taxa observed was low (9.8; Table 5), in total 20 different taxa were observed across the site. The average number of individuals in each core was also low at 45 individuals, with a moderately high evenness value (0.745). As a result the samples from this site form a diffuse cluster in ordination space (Figure 20).

5.4.1.3 Site 3

In contrast to the first two sites, Site 3 was dominated in October by a mix of bivalves and polychaetes (Table 4). *Nucula hartvigiana* and *Prionospsio aucklandica* were the two most dominant species and phoxocephalid amphipods, oligochaetes and the bivalve *Austrovenus stutchburyi* were also present in high numbers. *Austrovenus* sized to 20 mm were common (Figure 19) as were both *Macomona liliana* adults and juveniles. An average of 15.5 taxa per replicate was observed and 30 taxa in total across the site (Table 5). The number of individuals in each core was higher that in the previous two sites at ~124 individuals, with a moderately high evenness value (0.761), and samples formed a relatively tight cluster in ordination space (Figure 20).

5.4.1.4 Site 4

Site 4 was dominated in October by a mix of molluscs and crustaceans (Table 4). *Nucula hartvigiana* and the gastropod *Eatoniella* spp. were most dominant and phoxocephalid amphipods, *Prionospio aucklandica* and *Austrovenus stutchburyi* were also present in high numbers. For both *Austrovenus* and *Macomona liliana,* all size classes were found but juveniles predominated (Figure 19). An average of 20.8 taxa were observed (Table 5) and, in total, 32 different taxa across the site. The number of individuals in each core was high at ~193 individuals, with a moderately high evenness value (0.756). Due to the small difference between the average and total number of taxa observed at the site, samples formed a relatively tight cluster in ordination space (Figure 20).

5.4.1.5 Site 5

Site 5 was dominated in October by a mix of polychaetes, bivalves and crustaceans (Table 4). The polychaetes, *Scolelepis* sp. and *Ceratonereis* sp., were the two most dominant species and *Colurostylis lemurum, Nucula hartivigiana* and *Macomona liliana* were also present in high numbers. *Austrovenus stutchburyi* juveniles and adults were rare, although medium sized individuals occurred more frequently (Figure 19). *Macomona* of all size classes were found, although adults were most common. On average 13 taxa were observed (Table 5) although 30 taxa in total were found across the site. Number of individuals in each core was relatively low at ~54 individuals, with a high evenness value. The relatively large difference between average and total number of taxa is reflected in a diffuse cluster in ordination space (Figure 20).

5.4.1.6 Site 6

Site 6 was dominated in October by a mix of polychaetes and crustaceans (Table 4). *Prionospio aucklandica* and *Colurostylis lemurum* were the two most dominant species and Phoxocephalid amphipods and the polychaetes *Boccardia syrtis* and *Ceratonereis* sp. were also present in high numbers. For the common bivalves, only juveniles of *Austrovenus stutchburyi* and *Macomona liliana* were found (Figure 19). An average of 13 taxa were observed (Table 5) and, in total, 28 taxa across the site. Number of individuals in each core was low at ~54 individuals, with a high evenness value (0.884), and samples formed a diffuse cluster in ordination space (Figure 20).

5.4.1.7 Site 7

For Site 7, *Colurostylis lemurum* and *Nucula hartvigiana* were the two most dominant species (Table 4) with *Prionospio aucklandica, Macomona liliana* and *Austrovenus stutchburyi* also present in high numbers. All size classes of *Austrovenus* were observed although juveniles were most common (Figure 19). For *Macomona*, both juveniles and adults were common. An average of 21.8 taxa per replicate were observed (Table 5) and, in total, 42 taxa across the site. The number of individuals in each core was ~106 individuals, with a high evenness value (0.813). In the ordination space there is considerable overlap with samples from Site 3 (Figure 20).

5.4.2 Between Site Comparisons

Between site comparisons revealed that most of the sites differed in community composition (Global R=0.891, p = 0.001; Figure 20). Only Site 3 and 7 were not significantly different (p < 0.05 cf p > 0.05 for all other comparisons. Site 3 and Site 7 were only 47% dissimilar to one another, with all the other sites being greater than 50 % and up to 71% dissimilar (Table 6

Table 6:

Between site comparisons of community composition as % Bray-Curtis dissimilarity.

	Site1	Site2	Site3	Site4	Site5	Site6
Site2	55					
Site3	55	69				
Site4	51	71	51			
Site5	57	66	65	67		
Site6	55	71	53	62	51	
Site7	51	68	47	53	63	55

The lowest number of taxa and individuals were observed at Site 2, while Site 7 had the highest number of taxa and Site 4 the highest number of individuals.

5.4.3 State of the Environment Indicators

All the Whangateau sites fit well within the Benthic Health Model created for mud (BHMmud; Figure 21). However, the same is not true for the contaminant related BHM (Figure 22), known as BHMcont for the purpose of this report. Here, with the exception of Site 6, which has higher concentrations of copper, the community composition of all sites plot well above where we would expect them to lie (Figure 22). This is probably a result of two factors. Firstly, the majority of the sites are below the range of contaminants observed in the sites used to create the initial model. Only three sites are within the model range of contaminant values for copper, only two for zinc and only one for lead. Secondly, the ratios of the metal concentrations differ markedly for copper to lead and lead to zinc with those of the original data used for model development. The average copper to lead ratio in the Whangateau samples is higher than the 90th percentile value found for the model sites and the average lead to zinc ratio is below the 10th percentile value. Hewitt et al., (2009) suggested that the model would be critically affected by changes in the ratio of one metal to the others, as this is based on a single principle component axis derived from the three metals. They raised this as a concern about the ability of the model to continue to assess health as lead values in the environment decline. Whangateau may, therefore, serve a useful role in adapting the BHMcont to changes in contaminant ratios.

Figure 21:

Plot of the relationship between % mud content of the sediment and community composition related to mud (CAPmud). Sites used to derive the initial BHMmud are black, Whangateau sites are red.

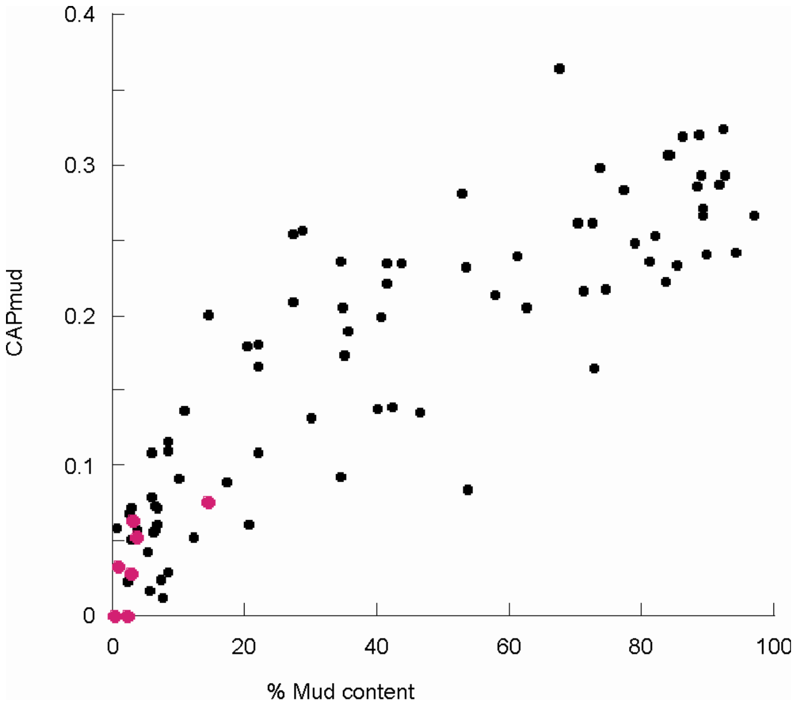
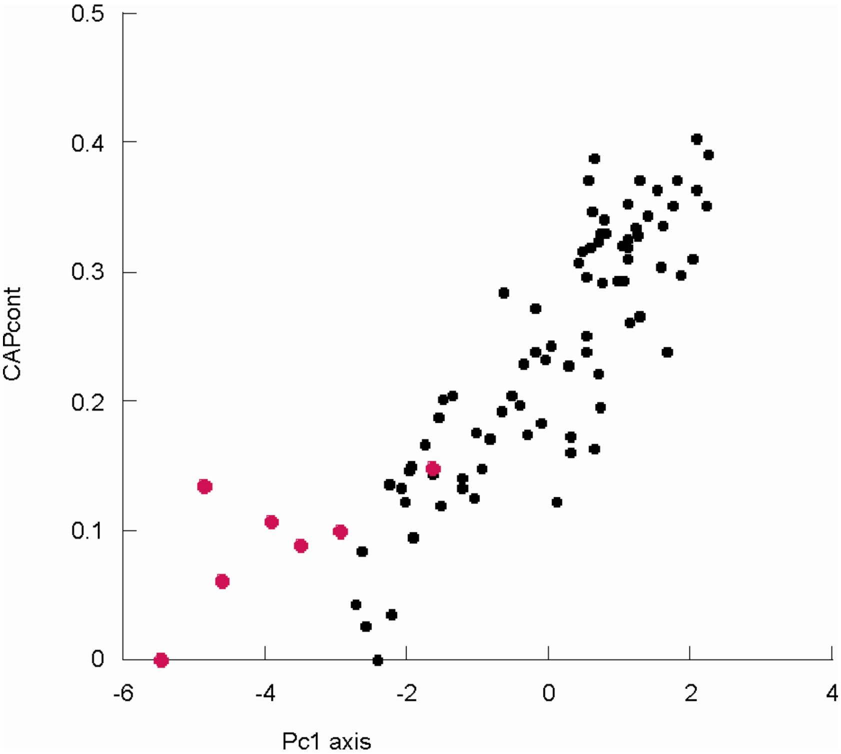


Figure 22:

Plot of the relationship between the principle component axis (Pc1) related to copper, lead and zinc concentrations in the sediment and community composition related to them (CAPcont). Sites used to derive the initial BHMmud are black, Whangateau sites are red.



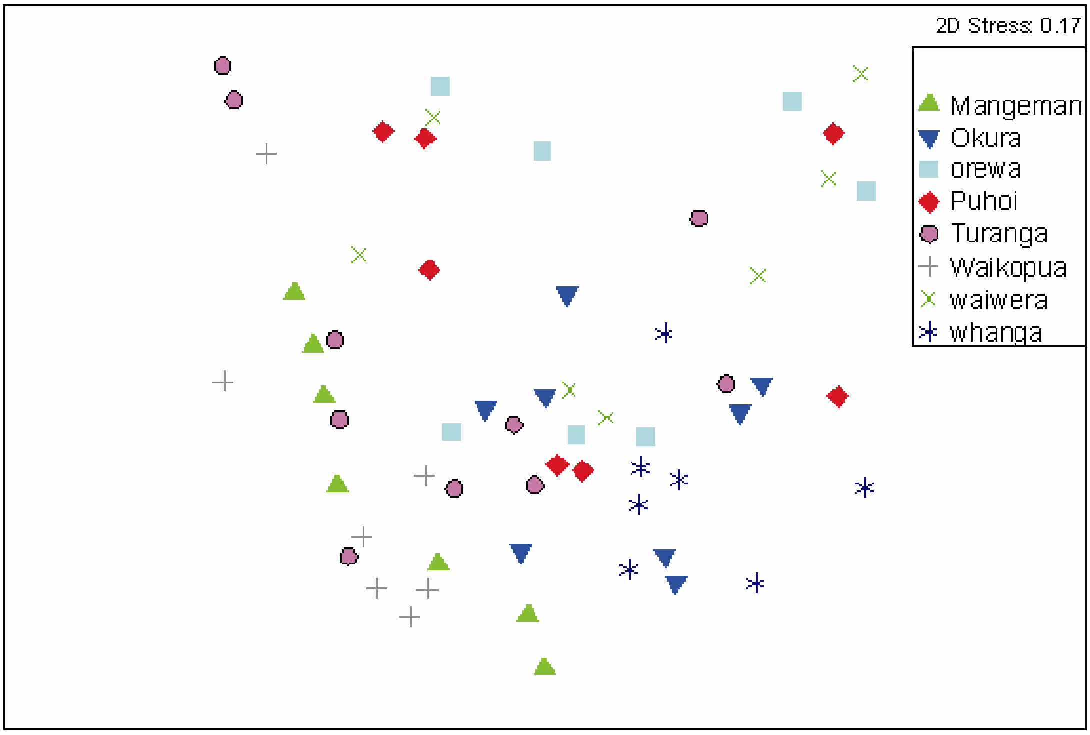
NIWACOOBII was calculated for the six sites based on the number of taxa in seven functional groups (van Houte-Howes & Lohrer, 2010). The functional formulae of the NIWACOOBII was designed using the Mahurangi and RDP community data so that index values fell between 0 and 1; with values near to 0 indicating low functionality and values near 1 indicating high ecosystem functionality. Index values from the Whangateau Harbour sites in October 2009 ranged from a relatively low value at Site 2 of 0.32, to a relatively high value of 0.68 at Site 7. Sites 1 and 5 were also relatively low (0.4) and Sites 3, 4 and 6 exhibited average values (0.48, 0.49 and 0.49 respectively). The low values observed here are likely to be due to the analysis being conducted on data from six replicates per site, compared to the 10 replicates per site that the indicator was developed from. The relative differences between the sites are however suggestive: Site 2 has the lowest organic content of all the sites and lowest NIWACOOBII score. The higher value at Site 7 is consistent with other data demonstrating higher number of taxa and functions in coarser sediments.

5.4.4 Comparison with Estuarine Monitoring Sites

Macrofaunal community composition in Whangateau in October 2009 was similar to that observed in other Auckland east coast estuaries in September 2009 (Figure 23). The greatest similarity was observed with sites in Okura, then with Orewa and Puhoi. Least similarities were observed with the most southern estuaries sampled (those entering the Whitford Embayment). Monitoring in Whangateau Harbour will, therefore, easily be integrated into the Estuarine monitoring framework and analysis already conducted by the ARC.

Figure 23:

Non-metric multidimensional scaling ordination of community composition in Whangateau in October 2009 and other east coast estuaries in September 2009. The ordination is based on Bray-Curtis similarities of log (x+1) transformed data, and points that are closest together are most similar.



6 Conclusions

The intertidal areas of Whangateau Harbour are still relatively pristine, with only low amounts of contaminants present, although slightly higher levels were observed in the muddiest site (Site 6) which is closest to the historic landfills. The ecological communities found are very similar to those found in many other east coast estuaries of the Auckland region, especially those of Orewa, Puhoi and Okura. Monitoring in Whangateau will, therefore, easily be integrated into the Estuarine monitoring framework and analysis already conducted by the ARC.

All the Whangateau sites fit well within the Benthic Health Model created for mud. However, with the exception of Site 6, they do not fit well within the contaminant related model. Here, the community composition of all sites plots well above where we would expect them to lie (Figure 22). This is probably due to the range of contaminants observed in the sites being very different to those used to create the initial model. Not only are the values generally lower but the ratios of the metal concentrations differ markedly for copper to lead and lead to zinc. Hewitt et al. (2009) suggested that the model would be critically affected by changes in the ratio of one metal to the others, and raised this as a concern about the ability of the model to continue to assess health as lead values in the environment decline. Whangateau may, therefore, serve a useful role in adapting the BHMcont to changes in contaminant ratios.

Intertidal habitats have shown some changes in type and distribution across the harbour with the expansion of several vegetative habitats, although the majority have remained stable over the last ten years. Changes have been most commonly seen for mangroves and most prevalently in the southern section of the harbour. Increases may have been caused by a combination of disruption to flow patterns from the causeway, increased sedimentation within the harbour section and favorable conditions for recruitment.

The subtidal habitats determined by Hartill et al. (2000) are very similar to those found in this survey. However, these habitats were basic (Sand, Pipi Shells). Subtidally, we have extended these physically based habitats to represent the proportion of material and now identify three major habitats: 'Sand', 'Sand+Shell hash' and 'Shell hash'.

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