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Kaipara Harbour Ecological Monitoring Programme:

Report on data collected between October 2009 and February 2010.

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Kaipara Harbour Ecological Monitoring Programme: Report on data collected between October 2009 and February 2010.

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1 Executive Summary

In October 2009, a monitoring programme was established in Kaipara Harbour to investigate the health of the harbour and establish a monitoring programme that will be able to detect changes associated with development in the catchment. In line with other similar programmes run by the Auckland Regional Council (ARC), the monitoring focuses on intertidal sandflat macrobenthos.

Following consultation with the ARC, six general locations in Kaipara Harbour were selected for study: Tapora Bank (TPB), Kakarai Flats (KKF), Omokoiti Flats near the mouth of Haratahi Creek (HCK), Kaipara Flats (KaiF), near the mouth of Ngapuke Creek (NPC) and Kaipara Bank near the mouth of the Kaipara River (KaiB). These locations are dispersed through the main body of the southern section of the Harbour, near to river and creek inputs. Similar to monitoring in Manukau Harbour, homogeneous sandflat areas were selected for study, although for the Kaipara, the sites were positioned near to mud/sand transitions. This positioning would enhance the ability of the programme to detect spread of muddy areas. Sites were sampled bimonthly after the initial sampling in October 2009. Monitoring methods used were consistent with other established ecological monitoring programmes (i.e., Manukau, Waitemata and Mahurangi Harbours) and will enable future among harbour comparisons.

While all the sites are predominantly fine sand, sites KaiB and KKF have slightly higher mud content. Site NPC also differs slightly with shell hash on the sediment surface. All sites were well below the Threshold Effect Concentration (TEL) guidelines for Polycyclic Aromatic Hydrocarbons (PAH) and heavy metals measured.

The benthic macrofaunal communities at each site are relatively distinct from each other. TPB was dominated by polychaetes on all occasions, while the others were dominated either by a mix of bivalves and polychaetes (KKF, KaiB and NPC) or a mix of amphipods, bivalves and polychaetes (HCK and KaiF). The taxa found is most similar to those found in the Manukau Harbour, and the community compositions were most similar to the Manukau sites CB (Clarks Beach), EB (Elliots Beach) and CH (Cape Horn).

It should be noted that, as monitoring is in its early phases, the full extent of species temporal and spatial variability is unknown. State of the environment indicators were used to determine an initial position of estuarine health, so that relative changes over time can be assessed in future, but robust statements of current estuarine health is not possible with only six months of sampling. Therefore, we recommend that, similar to the other ecological monitoring programmes run by the ARC, monitoring of all sites should continue until five years of data has been collected. Bimonthly monitoring should focus on selected species, although once a year (October sampling) the data should be analysed for all taxa. This cost-effective monitoring will allow application of recently developed State of the Environment (SOE) indicators (the Benthic Health Model and the NIWACOOBII) that require full taxa lists. The species recommended for monitoring include many of those monitored in Manukau Harbour, along with some specific to the Kaipara, and are those that would be expected to show changes in response to increased sediment or contaminant inputs.

2 Introduction

The Kaipara Harbour is the largest natural harbour in the Auckland region, New Zealand and potentially the Southern Hemisphere. A recent review of information pertaining to the Kaipara revealed there to be a lack of detailed knowledge around the spatial and temporal patterns of soft sediment benthic species (Haggitt et al., 2008). In addition, there is mounting concern surrounding the effects of historical and present day land based activities on the ecological functioning and water quality of Kaipara Harbour. In order to address this information gap, the Auckland Regional Council (ARC) commissioned the National Institute of Water and Atmospheric Research (NIWA) to establish a Kaipara Harbour ecological monitoring programme. The monitoring programme will build on the comprehensive survey of southern Kaipara Harbour carried out as part of the Tier II monitoring (Hewitt & Funnell 2005), allowing changes in specific sites to put into the context of the rest of the harbour. The long-term monitoring of Southern Kaipara Harbour will also allow for more regional representation in the monitoring of harbours and estuaries conducted in the Auckland Region.

The methods used to collect and process the samples were to be consistent with the other established monitoring programmes that the ARC undertakes (e.g., Manukau (Hailes & Hewitt 2009), Upper Waitemata (Miller et al., 2008), Central Waitemata (Townsend et al., 2010) and Mahurangi (Halliday & Cummings 2009) Harbours). These methods have proven to be successful and will enable between-Harbour comparisons to be made in the future.

The objectives of this programme were to (a) collect macrofauna samples at six sites every two months and determine any spatial and temporal patterns of soft-sediment infaunal species within and among sites; (b) collect sediment samples at these locations to monitor environmental conditions; and c) describe the physical features at each site. The information gathered is intended to better inform management decisions and practices regarding the health of the Kaipara Harbour and establish a monitoring programme that will track any long term changes in conditions.

This report details the results of the first three sampling occasions (Oct-09, Dec-09 and Feb-10) and includes:

- rationale of site selections;
- physical descriptions of the sites (including sediment grain size, organic matter and chlorophyll *a* content) and surrounding areas;
- comparison of the macrofaunal communities within and among sites;
- comparison of the macrofaunal communities at the Kaipara and Manukau Sites;
- an assessment of health using existing and newly developed indices (related to heavy metal concentrations, mud content and functional group richness); and,
- recommendations for the future monitoring of Kaipara Harbour.

3 Methodology

3.1 Site Selection

Locations for the intertidal monitoring were selected following consultation with the ARC and with reference to the habitat map of Kaipara Harbour completed in 2005 which was initiated by the ARC (Hewitt & Funnell, 2005). The site locations were required to be dispersed through the main body of the southern section of the harbour, be near to river and creek inputs, and to reflect the quality of the water discharge into the harbour off the land. Focus was placed on sandy, homogeneous, un-vegetated habitats, without excessively dense tube-worm mats. Any future variation away from the sandy homogeneous habitats selected (i.e., mud deposition, increased abundance of particular taxa) would be clearly detected. In October 2009, the locations were visited and a 9000 m^2 (x-axis 100 m; y-axis 90 m) site chosen at each location that represented the selected habitat criteria, were at mid-tide and were in close proximity to a mud/sand transition zone. Sites were chosen at Tapora Bank (TPB), Kakarai Flats (KKF), Omokoiti Flats near the mouth of Haratahi Creek (HCK), Kaipara Flats (KaiF), near the mouth of Ngapuke Creek (NPC) and Kaipara Bank near the mouth of the Kaipara River (KaiB) (Figure 1, Table 1). All sites are accessed by boat, launching from the Shelly Beach (southern four sites) and the boat ramp on Hoteo River (northern two sites).

Figure 1:

Map of Kaipara Harbour showing the positions of the monitoring sites, Tapora Bank (TPB); Kakarai Flats (KKF); Haratahi Creek (HCK); Kaipara Flats (KaiF); Ngapuke Creek (NPC) and Kaipara River (KaiB).

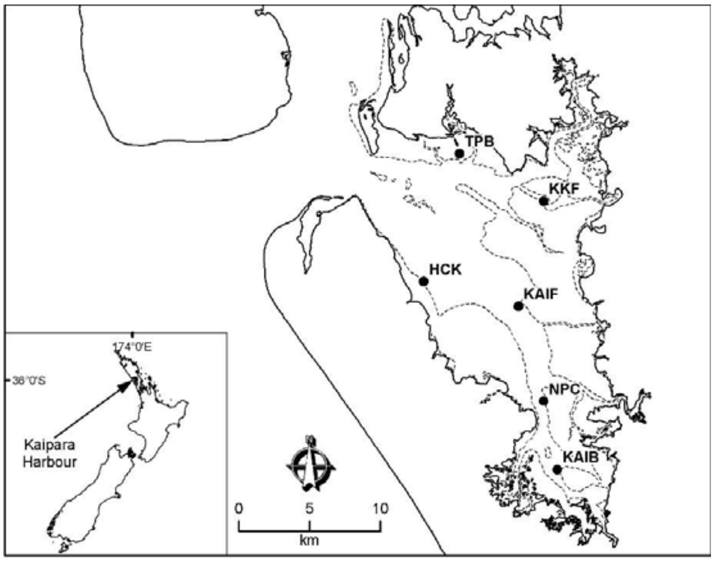


Table 1:

GPS Coordinates of the intertidal monitoring sites in Kaipara Harbour.

	Latitude	Longitude
Tapora Bank (TPB)	36 23.99671	174 18.86232
Kakarai Flats (KKF)	36 25.73292	174 22.91934
Haratahi Creek (HCK)	36 28.90934	174 17.31285
Kaipara Flats (KaiF)	36 29.83540	174 21.82453
Ngapuke Creek (NPC)	36 33.43656	174 23.05691
Kaipara Bank (KaiB)	36 36.04419	174 23.76757

3.2 Sample Collection and Identification

For this and other intertidal monitoring programmes funded by the ARC, samples are collected and processed as follows: each 9,000 m^2 site is divided into 12 equal sectors and one macrofauna core sample (13 cm diameter, 15 cm depth) is taken from a random location within each sector. To limit the influence of spatial autocorrelation, and preclude any localized modification of populations by previous sampling events, core samples are not positioned within a 5 m radius of each other or of any samples collected in the preceding six months. These samples are sieved over a 500 µm mesh, preserved with 70% isopropyl alcohol and then stained with Rose Bengal, prior to processing. The macrofauna are then sorted, and the taxa identified to the lowest practical level, enumerated and stored in 50% isopropyl alcohol.

During each bimonthly field trip, attention is paid to the appearance of each site and the surrounding sandflat. In particular, surface sediment characteristics (i.e., ripples), the presence of ray pits, birds, gastropods and plants are noted.

Sediment characteristics (grain size, organic content and chlorophyll *a*) are assessed at each site on each sampling occasion. At six random locations within the site, two small sediment cores (2 cm deep, 2 cm diameter) are collected, one to determine grain-size and organic content and the other for chlorophyll *a* analysis. Cores from the six locations are pooled and kept frozen in the dark prior to being analysed as described below.

Grain size: The samples are homogenised and a subsample of approximately 5 g of sediment is placed in ~ 9% hydrogen peroxide for organic matter digestion until bubbling ceases. The sediment sample is then wet sieved through 2000 µm, 500 µm, 250 µm and 63 µm mesh sieves. Pipette analysis is used to separate the <63 µm fraction into >3.9 µm and $\leq$3.9 µm. All fractions are then dried at 60°C until a constant weight is achieved (fractions are weighed at ~ 40 h and then again at 48 h). The results of the analysis are presented as percentage weight of gravel/shell hash (>2000 µm), coarse sand (500 – 2000 µm), medium sand (250 – 500 µm), fine sand (62.5 – 250 μm), silt (3.9 – 62.5 μm), and clay (≤3.9 μm). Mud content is calculated as the sum of the silt and clay content.

Chlorophyll *a*: Within one month of sampling, the full sample is freeze dried, weighed, then homogenised and a subsample (~0.5 g) taken for analysis. Chlorophyll *a* and its degradation product are extracted by boiling the sediment in 90% ethanol. An acidification step is used to remove the degradation product (Phaeophytin) before reading the extract on a spectrophotometer (measured in µg/g sediment).

Organic matter content: Approximately 5 g of sediment is placed in a dry, pre-weighed tray. The sample is then dried at 60°C until a constant weight is achieved (the sample is weighed after ~ 40 h and then again after 48 h). The sample is then combusted for 5.5 h at 400°C and then reweighed.

Chemical analyses: On the first visit, 3 sets of 2 cm deep samples of the sediment were also taken, from each site, and stored frozen for analysis of contaminants. Analyses for heavy metal and organic (PAH) contaminants were performed by R J Hill Laboratories Ltd (Hamilton) using standard ARC methods and protocols as outlined in Mills and Williamson (2008).

Total sediments were analysed for total organic carbon (g/100g dry wt); polycyclic aromatic hydrocarbons (PAHs) (mg/kg dry wt); and total recoverable iron, manganese, arsenic, copper, lead and zinc (mg/kg dry wt).

Fine fractions were analysed for weak acid (2M HCl) extractable copper, lead, and zinc (mg/kg dry weight). PAH analysis separated total PAH into components of: acenaphthene, acenaphthylene, anthracene, benzo[a]anthracene, benzo[a]pyrene (BAP), benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, bhrysene, dibenzo[a,h]anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, naphthalene, phenanthrene, and pyrene (mg/kg dry wt).

3.3 Bivalve Size Class Analysis

After identification, the most common bivalve species (*Austrovenus stutchburyi* and *Macomona liliana*) were measured (longest shell dimension (mm)) and placed into size classes to enable direct comparison with other long-term monitoring locations (i.e., Manukau, Waitemata and Mahurangi Monitoring Programmes). Individual bivalves were allotted into size classes of <5 mm; 5-10 mm; 10-20 mm; 20-30 mm; 30-40 mm and >40 mm.

3.4 Statistical Analysis

Sediment data collected in October 2009 was analysed by Principle Component Analysis (PCA) on normalized data to determine similarities between sites.

Macrofauna data collected in October and December 2009 and February 2010 was analysed for community composition. The five most dominant taxa were calculated, ordinations (non-metric multidimensional scaling) were conducted, and within and between-site similarities were determined. Both the ordinations and the similarity analyses were conducted using Bray-Curtis similarities from $\log_e(x+1)$ transformed data.

Macrofauna data was also assessed using three recently developed State of the Environment (SOE) indicators:

- The Benthic Health Model is a multivariate model of community health relative to storm water contamination represented by concentrations of total extractable copper, lead and zinc (Anderson et al., 2006).
- A similar model has recently been developed to model health relative to changing mud content (Hewitt & Ellis i2010).
- A functional diversity index, NIWACOOBII, has been developed to track the health status of intertidal non-vegetated benthic communities in the Auckland Region (van Houte-Howes & Lohrer 2010). Index values range between 0 and 1, and indicate the richness of taxa that are sensitive to heavy metal contaminants and sediment mud content (and thus the degree of functional redundancy present in the benthic communities). Note that the index was developed based on 10 replicate samples per site, so a random subset of 10 samples was taken from the 12 replicates available here.

4 Environmental Characteristics

4.1 General Site Descriptions

Site characteristics, including appearance and sediment characteristics, can provide a context against which changes in macrofauna can be described. Changes to the site characteristics over time, such as the expansion of seagrass into a monitored area and the disturbance of eagle rays, may help explain natural variability (i.e., Townsend 2010). For this reason, a brief description of site appearance and sediment characteristics are given here.

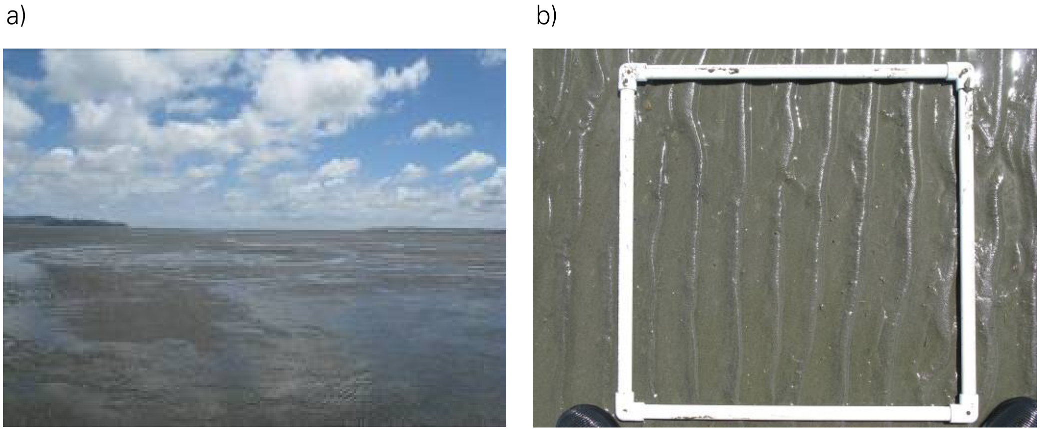
4.1.1 Tapora Bank (TPB)

Site TPB is located at the top of the southern section of the Kaipara Harbour on the Tapora Bank sandflat (Figure 1; Table 1). The site is situated east of Gum Store Creek and south west of Te Ngaio Point. Approximately 400 m to the south of the TPB lies the Tauhoa Channel which drains the Tauhoa, Opatu, Papakanui, Hoteo, and Omaumau Rivers. The site is located adjacent to a raised bank (20-30 cm high) which divides the intertidal area into two shelves; with the monitored area located on the lower shelf section. The monitored area is firm sand (Figure 2a) with prominent ripples on the surface (5-10 cm wave length, 1 cm wave height) (Figure 2b). Epifauna are evident at this site, notably the whelk *Cominella adspera*, and cushion star *Patiriella regularis* and there is also a low density of ray feeding pits. Worm tubes (*Macroclymenella stewartensis*) are also evident on the sediment surface. Between the site and the Tauhao Channel there are numerous mounds formed by the invasive date mussel, *Musculista senhousia*. These mounds are between 1-4 m in diameter and up to 30 cm in height. North of the monitored area on the upper shelf section the sediment is finer, although still firm underfoot. This section contains low density patches of seagrass and evidence of historic patches of *Musculista* with raised patches of fine sediment, shell hash and byssus threads. The upper section of the intertidal area is expansive and is approximately 1 km long to the high water mark.

Between October 2009 and February 2010, there were no noticeable changes in the site and surrounding area apart from the fluctuation of the frequency of ray pits and gastropods on the sediment surface.

Figure 2:

Photographs of site TPB: a) the intertidal monitored area looking SW and b) the sediment surface.


a)
b)

4.1.2 Kakarai Flats (KKF)

Site KKF is located on the north-eastern side of southern Kaipara Harbour, on the Kakarai Flats. The site is south-east of Orongo Point and south-west of Moturemu Island where the Hoteo River channel joins the Tauhoa channel (Figure 1; Table 1). The sediment at KKF is firm sand (Figure 3a,b) which shows strong but variable ripple features (5-10 cm wave length, 1-2 cm wave height) with thin clay deposits in the ripple troughs (Figure 3b). *Macomona liliana* siphon tracks and *Austrovenus stutchburyi* can be seen on the sediment surface, with the whelk, *Cominella glandiformis*, also present in low densities. The site is an un-vegetated firm sandy area surrounded by thick meadows of *Zostera muelleri* and finer softer/muddier sediments and large rills and sub-channels (directly to the east of the site). Within the site, seagrass detritus (single blades) are noticeable on the sediment surface; however these are not rooted and are sparse. There is also evidence of past *Musculista senhousia* populations around this site with raised patches of finer sediment, shell hash and byssus threads.

Between October 2009 and February 2010, there has been little change at this site, except for fluctuations in the density of shell hash, whole shells and gastropod species (i.e., *Cominella glandiformis*, *Cominella adspersa* and *Zeacumantus lutulentus*) visible on the sediment surface. Black swans, *Cygnus atratus*, have been observed feeding at this site on two out of three sampling occasions.

Figure 3:
Photographs of site KKF: a) the intertidal monitored area looking SW and b) the sediment surface.

a)

b)

4.1.3 Haratahi Creek (HCK)

The HCK site is located on the north-western side of southern Kaipara Harbour, on the northern tip of the Omokoiti sandflat, near where the Haratahi Creek meets the main harbour channel (Figure 1; Table 1). The monitored area is adjacent to the main harbour channel, which shelves sharply. The site has characteristics of a high energy environment with firm, coarse sand (Figure 4a) and strong ripple features (10 cm wave length, 2-3 cm wave height) (Figure 4b). Except for the physical characteristics, the surface sediment was relatively featureless with minimal evidence of shells or shell hash, gastropods or tubeworms. Approximately 20 m away (inshore and west) from the monitored plot is a large raised patch of muddy-sand (sinking to ankle depth) that has formerly been inhabited by *Musculista senhousia.* The sediment surface is covered with a dense *Musculista* shell hash layer and pooled water is also evident (Figure 4c).

Between October 2009 and February 2010, there have been no noticeable changes to the site or surrounding area, except for the differences in the wave length and height of the ripples on the sediment surface.

Figure 4:

Photographs of site HCK: a) the intertidal monitored area looking NW b) the sediment surface and c) raised, muddy remnant *Musculista senhousia* patches up from the 0,90 m corner of the site.

a)

b)

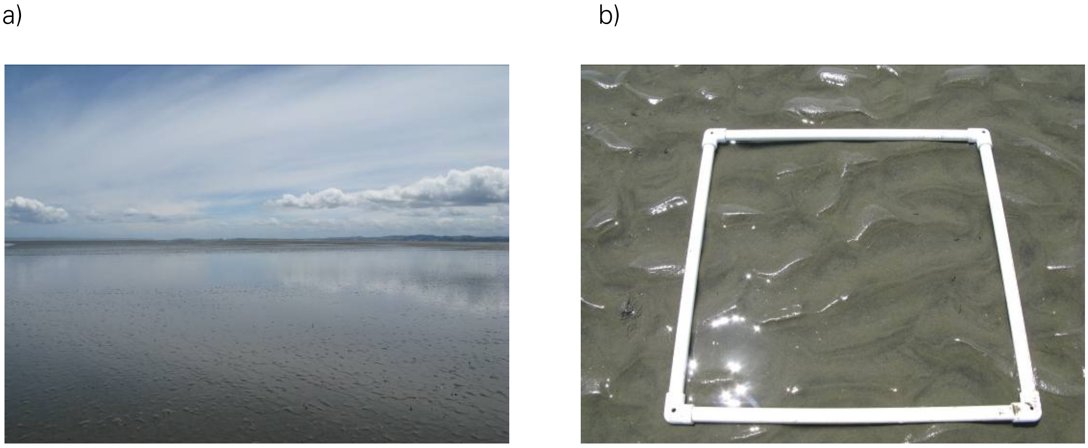
c)

4.1.4 Kaipara Flats (KaiF)

Site KaiF is located on the eastern side of the southern Kaipara Harbour on the Kaipara Flats (the largest sandflat in Kaipara Harbour). KaiF is south-west of the flat and is close to the point where the Araparera River joins the main harbour channel (Figure 1; Table 1). The monitored area is on a tapered section of sandflat and is surrounded by water on three of its sides. The main harbour channel has a steep bank and is adjacent to the site, with Mataia Creek flanking the site to the south-east and north-east. Beyond the north-western side of the monitored area there are sparse patches of low to medium density seagrass in raised muddy clumps. The monitored site is firm and sandy (Figure 5a) and shows strong ripple features (15 cm wave length, 2 cm wave height) (Figure 5b) with sparse *Musculista senhousia* shell hash. There is an intermediate density of ray feeding pits and a low density of worm faecal mounds on the surface. Gastropods (i.e., *Cominella adspersa*, *Cominella glandiformis* and *Zeacumantus lutulentus*) were evident on the sediment surface, as was hermit crab activity.

Between October 2009 and February 2010, there have been fluctuations in the amount of worm tubes (ranging from low density/sparse to several high density patches), shell hash and whole shells on the surface. On occasion foraging birds have been seen within and around the site.

Figure 5:
Photographs of site KaiF: a) the intertidal monitored area looking E and b) the sediment surface.


a)
b)

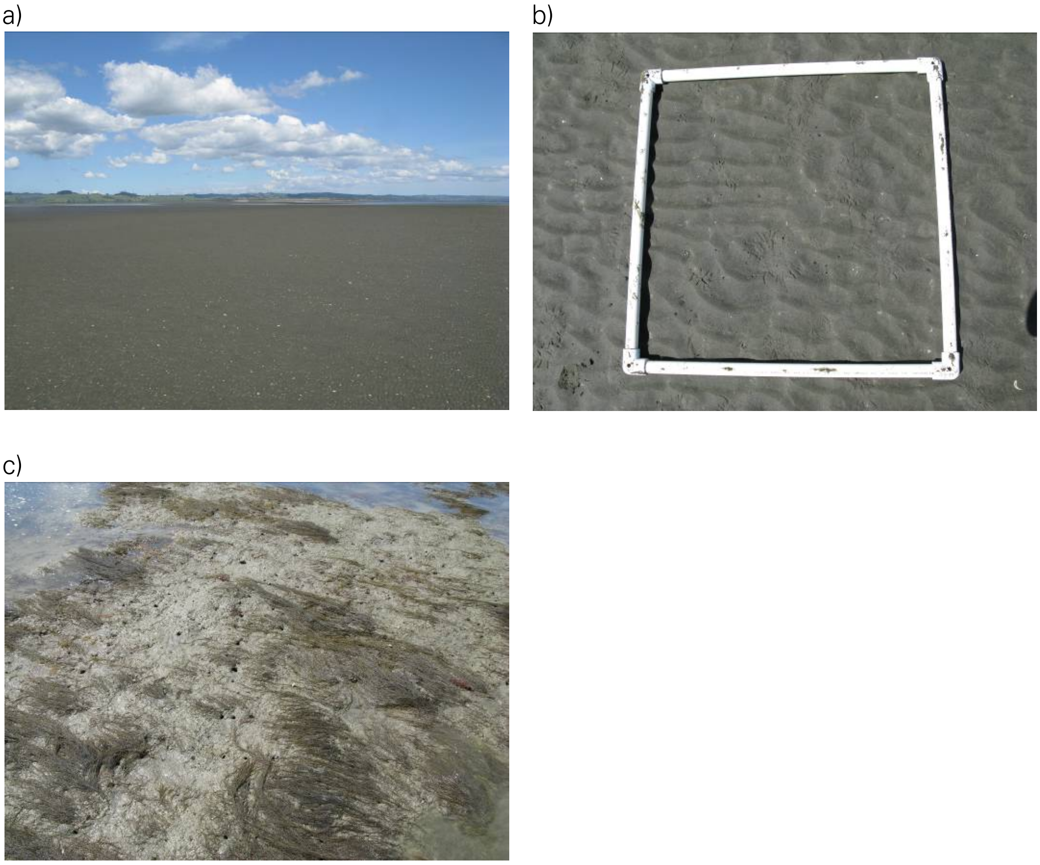
4.1.5 Ngapuke Creek (NPC)

Site NPC is located towards the bottom end of the southern Kaipara Harbour, on the sandflat adjacent to Ngapuke Creek (Figure 1; Table 1). The main harbour channel has a steep bank and runs parallel to the east of the monitored area. To the north of the site, the Ngapuke Creek and Makarua River join the main harbour channel. The site is firm and sandy (Figure 6a) and has small ripples (4 cm wave length, 1 cm wave height) with surficial mud occurring in the troughs between them (Figure 6b). The sediment surface is marked with a high density of conspicuous *Macomona liliana* siphon tracks and a low density of shell hash. The shell hash content is higher in the southern half of the monitored area. Low densities of worm faecal mounds are also evident on the sediment surface. Approximately 20 m north of the monitored area, a large raised patch of red algae has been observed (Figure 6c) The algae is likely to be *Gracilaria* sp., however future collection and identification will confirm this. The sediment in this patch is uneven and muddy (sinking to above ankle depth). It contains a high density of crab burrows and a low density of *Cominella glandiformis*.

Between October 2009 and February 2010 site NPC has remained consistent. Over the sampling occasions, ray pit density has remained low; there has been minimal surficial sediment in troughs between ripples and a low density of gastropods (including *Cominella glandiformis* and *Zeacumantus lutulentus*) has been noted.

Figure 6:

Photographs of site NPC: a) the intertidal monitored area looking SE, b) the sediment surface and c) *Gracilaria* sp. to the north of the site.



4.1.6 Kaipara River (KaiB)

Site KaiB is located at the bottom end of the southern Kaipara Harbour on the sandflats where the Kaipara River joins the main body of the harbour (Figure 1; Table 1). This section of the Harbour has multiple inputs, notably the Puharakeke and Parekawa Creeks, and the Kaipara and Kaukapakapa Rivers. Beyond the north-western side of the monitored area there is a large raised muddy patch (sinking 30-50 cm to knee depth) with extremely high crab and gastropod density. This area also has a patchy red algae covering (*Gracilaria* sp.). The monitored area is firm and sandy (Figure 7a) and has small ripples over the surface (2 cm wave length, 0.5 cm wave height) with thin surficial mud deposits in wave troughs (Figure 7b). The sediment at this site is a sandy mud (sinking 1-2 cm) with a low density of *Macomona liliana* and *Austrovenus stutchburyi* shell hash. Similarly to the other southern sites, this area has a low density of worm faecal mounds on the surface. There is a high density of the crab *Hemiplax hirtipes* on the western channel side of the site, with burrow structures and pseudofaeces evident on the sediment surface. The site also has a high density of gastropods, notably *Cominella glandiformis* and *Zeacumantus lutulentus*. Bird foraging is common over the entire sandflat (within and beyond the monitoring area).

Between October 2009 and February 2010, site KaiB has been the most varied of the monitored sites. The surficial mud layer, although minimal (and really only in troughs between ripples) in October 2009, was thicker in December 2009 and February 2010 (approx. 2-4 cm).

Figure 7:
Photographs of site KaiB: a) the intertidal monitored area looking SE and b) the sediment surface.

4.2 Sediment Characteristics

The bimonthly results of the sediment grain size, percent organic and chlorophyll *a* content for each of the monitored sites are provided in Table 2.

Generally, all sites are similar in terms of grain size with the fine sand (range: 89-99.5%) consistently the dominant sediment fraction (Table 2). Site KaiB (the southern-most site) has the highest percentage of mud (7-11%) with site KKF also reasonably high (2-4%). Across the first three sampling periods, the silt fraction at site KaiB has increased slightly, which is consistent with the thicker surficial mud layer seen over the site during field trips. Site NPC has notably high shell hash on the sediment surface which is reflected in the coarse grain size fraction (% gravel).

The percent organic content of sites TPB, HCK, KaiF and NPC are all similar and low (<1%, Table 2). The percent organic content at site KKF is a little higher, possibly as a result of the seagrass detritus at this site. During the processing of macrofaunal cores we found that the site may be located over a historical seagrass bed as there was a significant amount of detritus in the sediment around 10-15 cm depth. Higher organic contents were also observed at site KaiB, possibly related to the higher silt content.

The chlorophyll *a* (Chl *a*) and phaeophytin content of the top 2 cm of sediment at each site is relatively low and is consistent with most coarse intertidal sandy sediment (Table 2). Over time both Chl *a* and phaeophytin levels at each site have remained similar. For example at site TPB 4.24 and 5.04 µg/g sediment was recorded and at site HCK 9.28 and 8.48 µg/g sediment was recorded in October 2009 and February 2010, respectively.

A principle component analysis (PCA) of the sediment characteristics from the six sites revealed the dissimilarities between sites based on sediment grain size, organic content, and chlorophyll *a* properties. The first and second axes explained 41.8% and 28.7% of the variation (total of 69.8% of variation explained), respectively (Figure 8). There are no obvious groupings of sites; however, the dissimilarity between sites is mainly due to the percent of mud and fine sand and sediment Chl*a* content.

Figure 8:

Principle Component Analysis (PCA) of sediment properties (Gravel (GRAVEL); Fine Sand (FS); Medium Sand (MS); Coarse Sand (CS); Silt+Clay (MUD); Chlorophyll *a* (CHLA) and Organic Content (OC)) in October 2009 displaying the dissimilarity between sites. Dissimilar sites are spaced distantly from each other compared to sites that are more similar.

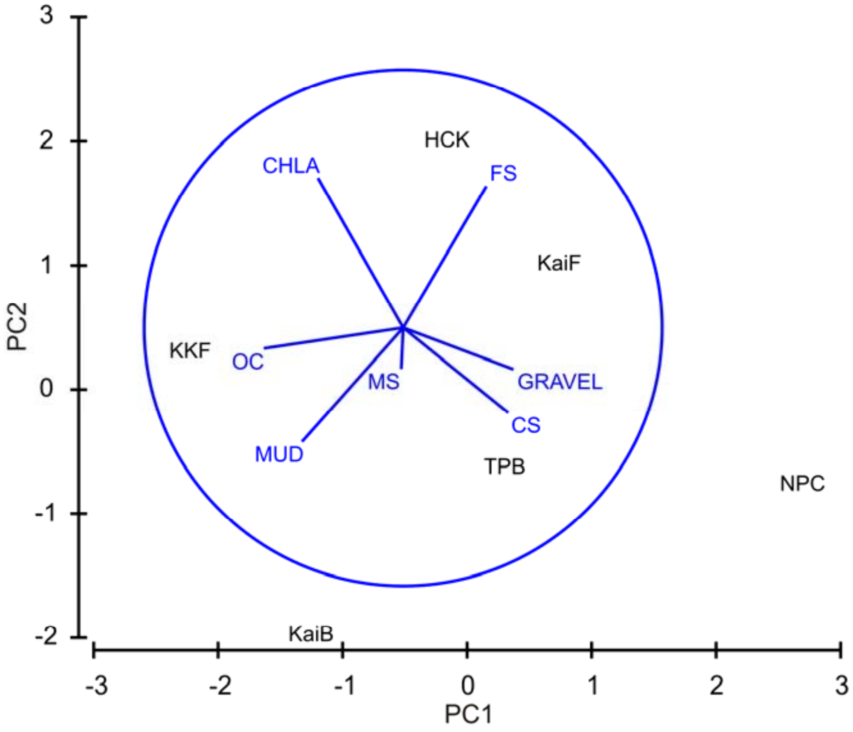


Table 2:

Grain size, organic content, Chlorophyll *a* and phaeophytin results.

		% Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Mud	% Organic Content	Chlorophyll a (µg/g sediment)	Phaeophytin (µg/g sediment)
TPB	Oct-09	0.00	0.08	5.59	93.84	0.49	0.58	5.50	1.00
	Dec-09	0.03	0.10	6.68	92.70	0.48	0.58	3.32	2.34
	Feb-10	0.33	0.08	7.09	91.98	0.53	0.54	5.04	1.56
KKF	Oct-09	0.07	0.03	0.74	94.78	4.39	1.24	8.59	2.06
	Dec-09	0.08	0.07	0.31	97.10	2.44	1.02	4.81	2.79
	Feb-10	0.00	0.08	0.44	96.66	2.83	1.07	8.25	1.69
HCK	Oct-09	0.04	0.06	0.15	99.43	0.32	0.78	9.28	1.79
	Dec-09	0.00	0.03	0.20	99.43	0.34	0.72	6.53	3.34
	Feb-10	0.23	0.06	0.56	98.26	0.88	0.95	8.48	1.25
KaiF	Oct-09	0.00	0.13	0.17	99.28	0.42	0.72	7.57	1.09
	Dec-09	0.00	0.11	0.16	99.50	0.22	0.60	8.94	1.88
	Feb-10	0.00	0.08	1.63	98.06	0.22	0.70	6.88	0.89
NPC	Oct-09	0.71	0.15	0.08	98.05	1.02	0.52	4.24	0.81
	Dec-09	1.41	0.06	0.00	97.66	0.86	0.68	4.47	1.64
	Feb-10	4.34	0.16	0.11	94.49	0.90	0.67	5.62	1.19
KaiB	Oct-09	0.01	0.13	0.34	92.69	6.82	1.10	5.50	2.12
	Dec-09	0.04	0.12	0.36	89.00	10.48	1.28	5.96	1.93
	Feb-10	0.00	0.05	0.41	90.43	9.11	1.23	8.14	3.19

4.3 Chemical Characteristics

All sites had low and similar levels of all PAH components, although site HCK, displayed higher levels (mg/kg dry wt.) of Benzo[a]anthracene (0.012; other sites mean 0.0028) , Benzo[g,h,i]perylene (0.011; other sites mean 0.003), Chrysene (0.013; other sites mean 0.003), Dibenzo[a,h]anthracene (0.011; other sites mean 0.0032), Fluoranthene (0.013; other sites mean 0.0026), Indeno(1,2,3-c,d)pyrene (0.012; other sites mean 0.0028) and Pyrene (0.016; other sites mean 0.0026) (Table 3).

Values of copper, lead and zinc found in the weak acid extracted <63 µm fraction of sediment were all very low across sites (Table 4). They did not exceed Threshold Effect Concentrations (TEL) (McDonald et al., 1996) and were well within the green contaminant concentration category of the environmental response criteria developed by the ARC (Williamson & Kelly 2003). Total recoverable (<500 µm fraction) Cu, Pb and Zn values were similar to or lower than the <63 µm fraction values.

Table 3:

Total Polyaromatic Hydrocarbons (PAH) for all sites. All PAH values have been normalised to 1% total organic carbon (TOC).

	TPB	KKF	HCK	KaiF	KaiB	NPC
Acenaphthene	0.003	0.003	0.002	0.002	0.003	0.002
Acenaphthylene	0.003	0.003	0.002	0.002	0.003	0.002
Anthracene	0.003	0.003	0.002	0.002	0.003	0.002
Benzo[a]anthracene	0.003	0.003	0.012	0.003	0.003	0.002
Benzo[a]pyrene (BAP)	0.003	0.003	0.007	0.002	0.003	0.002
Benzo[b]fluoranthene + Benzo[j]fluoranthene	0.003	0.003	0.010	0.003	0.003	0.002
Benzo[g,h,i]perylene	0.003	0.003	0.011	0.004	0.003	0.002
Benzo[k]fluoranthene	0.003	0.003	0.010	0.004	0.003	0.002
Chrysene	0.003	0.003	0.013	0.004	0.003	0.002
Dibenzo[a,h]anthracene	0.003	0.003	0.011	0.005	0.003	0.002
Fluoranthene	0.003	0.003	0.013	0.002	0.003	0.002
Fluorene	0.003	0.003	0.002	0.002	0.003	0.002
Indeno(1,2,3-c,d)pyrene	0.003	0.003	0.012	0.003	0.003	0.002
Naphthalene	0.011	0.011	0.010	0.010	0.011	0.010
Phenanthrene	0.003	0.003	0.003	0.002	0.003	0.002
Pyrene	0.003	0.003	0.016	0.002	0.003	0.002

Table 4:

Mean concentration (mg/kg dry wt.) of PAH's (adjusted to 1% carbon) and metals in the top 2 cm of sediment collected in October 2009 from the six monitoring sites in Kaipara Harbour. The available Threshold Effect Concentrations (TEL) for total recoverable metals are displayed along the bottom (MacDonald et al., 1996).

			< 63 µm metals			Total Recoverable Metals									
Site	TOC	Total PAH	Cu	Pb	Zn	Fe	Mn	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
TPB	< 0.13	0.00	9.0	4.8	30	5,600	158	3.90	< 0.01	6.9	1.8	1.3	0.02	4.9	13
KKF	0.17	0.00	8.8	5.1	34	11,250	255	5.55	0.01	12.3	3.1	2.6	0.06	9.3	29
HCK	0.16	0.12	10.8	5.9	32	12,050	315	6.10	0.01	11.3	3.2	2.5	0.03	10.5	26
KaiF	< 0.13	0.03	8.9	3.2	19	9,150	184	4.90	0.01	8.9	2.1	1.7	0.02	6.0	20
NPC	< 0.13	0.00	22.0	5.9	36	10,600	225	5.35	0.01	10.9	3.9	2.2	0.04	12.9	25
KaiB	0.24	0.00	16.0	4.6	29	15,400	410	6.80	0.02	12.9	5.4	3.5	0.06	13.1	34
TEL		1.7						7.24	0.68	52.3	18.7	30.2		15.9	124

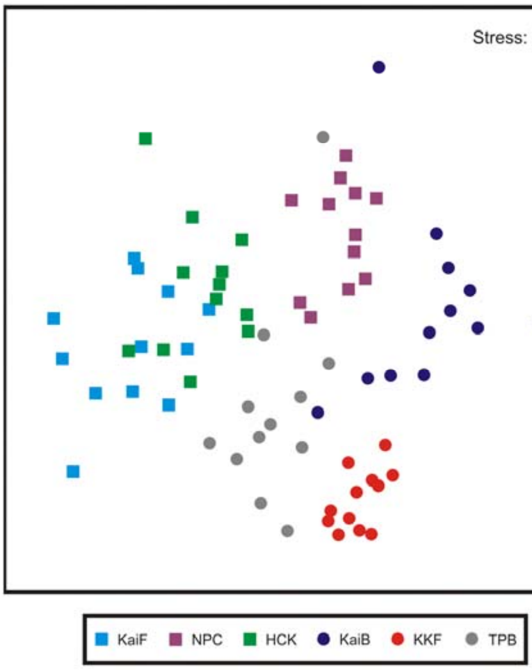
5 Benthic Communities of Southern Kaipara Harbour

5.1 Site descriptions

The macrofaunal communities sampled at each site were relatively rich, with an average of 34 taxa found across all sites in October 2009. Within site variability ranged between 52 and 60% across sites and, in general, the replicates within sites clustered together in distinct groups (Figure 8). The replicates collected at sites KKF and TPB were the most tightly clustered and had similarities of 62.72 and 60.72%, respectively.

Figure 8:

Non-metric multidimensional scaling ordination plot (MDS) of the community structure sampled in each of the 12 replicate cores collected per site at Kaipara Sites (TPB, KKF, HCK, KaiF, NPC and KaiB) in October 2009. The stress of the plot is 0.22 and sites that are closest together are most similar. The macrofaunal data was log transformed.



Sites HCK and KaiF were mainly dominated by the polychaetes *Aricidea* sp. and *Magelona dakini* (Table 5). Both species were consistently abundant at both sites between Oct-09 to Feb-10. A similar total number of taxa were observed in October 2009 (23 and 29 taxa respectively) at these two sites. Sites KKF, NPC and TPB were dominated by a mixture of polychaetes; *Magelona dakini*, *Euchone* sp., *Heteromastus filiformis* and *Aricidea* sp. and bivalves *Macomona liliana, Nucula hartivigiana* and *Soletellina siliqua* (Table 5). Site KKF had the highest number of taxa and individuals across all sites in October 2009 (49 and 886 respectively), while sites NPC and TPB had lower numbers of taxa (33 and 37 taxa respectively).

While the most dominant species were generally consistent over time, lower ranked dominants showed greater variability (Table 5). The exception was at site KaiB where all the dominant species changed over time. *Macomona liliana* and *Austrovenus stutchburyi* were the dominant bivalve species at most sites, namely, TPB, KKF, NPC and KaiB (Figure 9). At site TPB, the abundance of *Macomona* was greater than *Austrovenus* and there was a high abundance of juveniles (<5 mm) and adults (>20 mm). Site KKF had the highest abundance of *Macomona* in October 2009, with approximately six times more juveniles than intermediates (5-20 mm) and adults (approximately 10 individuals each). *Austrovenus* was also relatively abundant at site KKF, but most were juveniles. Sites HCK and KaiF both had a low abundance of *Macomona* (less than 10 juveniles at each site and less than 10 adults at Site HCK) and no *Austrovenus*. *Macomona* and *Austrovenus* were both present at sites NPC and KaiB. Abundances of *Austrovenus* at both sites were relatively similar across all size classes; however, abundances were higher at site KaiB. The abundance of *Austrovenus* was relatively low at site NPC, with only two individuals found in the juvenile and intermediate size classes. At site KaiB, *Austrovenus* was more abundant, with all size classes represented.

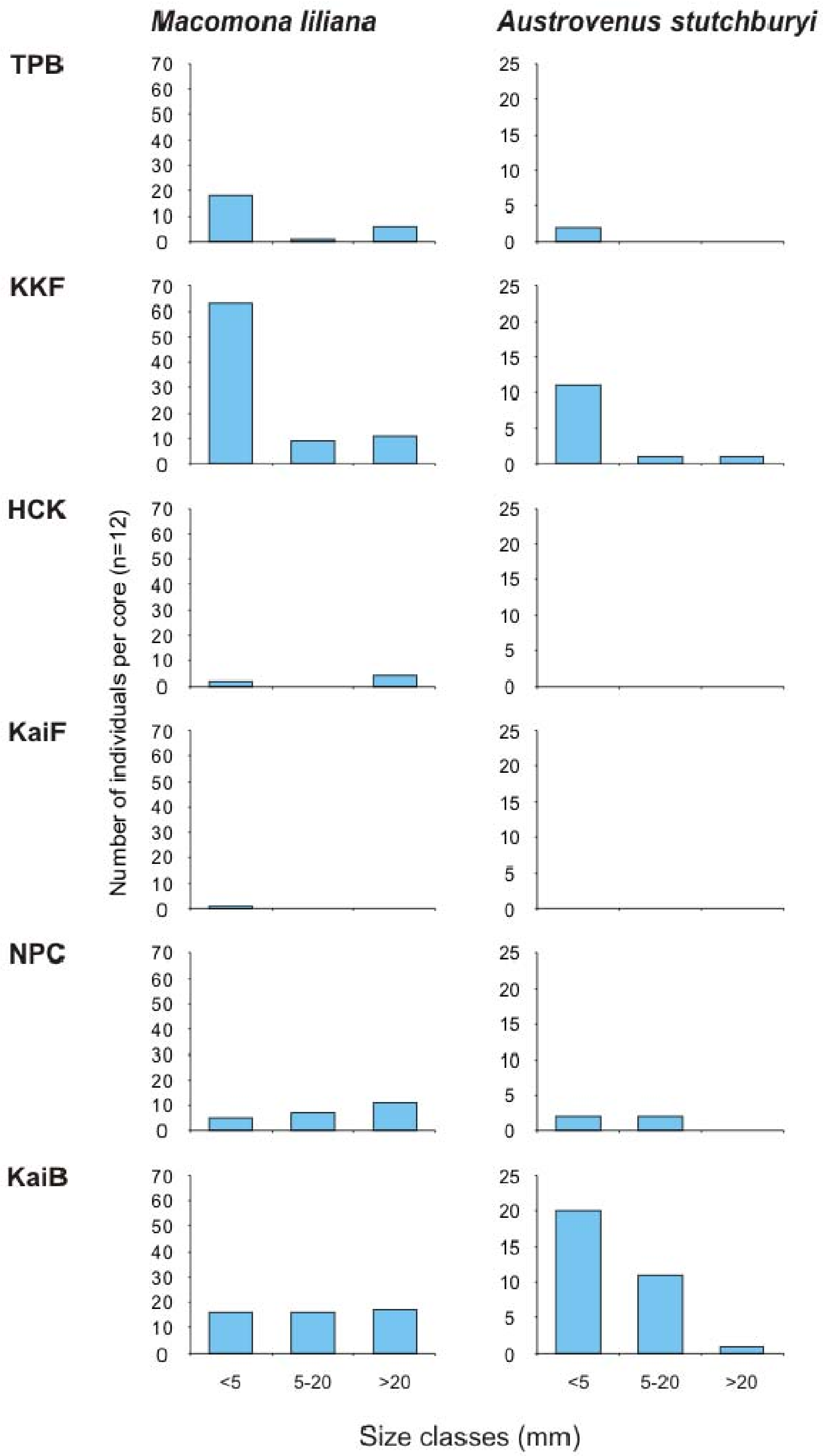
Table 5:

Rank abundances of the five most abundant taxa (sum; n=12) for Tapora Bank (TPB), Kakarai Flats (KKF), Haratahi Creek (HCK), Kaipara Flats (KaiF), Ngapuke Creek (NPC) and Kaipara Bank (KaiB) over time (October 2009 to February 2010).

	Date	Most abundant →				Least abundant
TPB	Oct-09	*Euchone* sp. (367)	*Magelona dakini* (141)	*Aricidea* sp. (49)	*Heteromastus filiformis* (38)	Syllidae (Bumpy cirri) (33)
	Dec-09	*Euchone* sp. (327)	*Magelona dakini* (133)	*Heteromastus filiformis* (31)	*Aricidea* sp. (28)	*Trochodota dendyi* (23)
	Feb-10	*Euchone* sp. (289)	*Magelona dakini* (207)	*Heteromastus filiformis* (71)	*Aricidea* sp. (40)	*Phoronis* sp. (38)
KKF	Oct-09	*Heteromastus filiformis* (208)	*Macomona liliana* (83)	*Aricidea* sp. (81)	*Magelona dakini* (71)	*Owenia fusiformis* (49)
	Dec-09	*Heteromastus filiformis* (232)	*Aricidea* sp. (110)	*Nucula hartvigiana* (50)	*Macomona liliana* (39)	*Owenia fusiformis* (37)
	Feb-10	*Heteromastus filiformis* (121)	*Macomona liliana* (70)	*Aricidea* sp. (68)	*Nucula hartvigiana* (63)	Nemertea (58)
HCK	Oct-09	*Aricidea* sp. (145)	*Magelona dakini* (44)	*Heteromastus filiformis* (20)	*Coluorostylis lemurum* (15)	Nemertea (13)
	Dec-09	*Aricidea* sp. (101)	*Magelona dakini* (43)	*Heteromastus filiformis* (24)	Urothrodae (21)	Nemertea (21)
	Feb-10	*Aricidea* sp. (125)	*Magelona dakini* (52)	*Sotetellina siliqua* (33)	*Heteromastus filiformis* (25)	Nemertea (14)
KaiF	Oct-09	*Aricidea* sp. (189)	*Methalimedon* sp. (23)	*Magelona dakini* (18)	*Waitangi brevirostris* (17)	*Aglaophamus macoura* (16)
	Dec-09	*Aricidea* sp. (155)	*Magelona dakini* (19)	Nemertea (13)	*Scoloplos cylindrifer* (11)	*Waitangi brevirostris* (10)
	Feb-10	*Aricidea* sp. (112)	*Levinsinia gracilis* (36)	*Magelona dakini* (23)	Hessionidae (22)	*Aglaophamus macoura* (12)
NPC	Oct-09	*Magelona dakini* (208)	*Heteromastus filiformis* (50)	*Soletellina siliqua* (30)	*Anthropleura aueoradiata* (26)	*Macomona liliana* (23)
	Dec-09	*Magelona dakini* (202)	*Heteromastus filiformis* (66)	*Soletellina siliqua* (31)	*Anthropleura aueoradiata* (20)	*Paracalliope* sp. (15)
	Feb-10	*Magelona dakini* (202)	*Heteromastus filiformis* (68)	*Soletellina siliqua* (66)	*Anthropleura aueoradiata* (26)	*Macomona liliana* (25)
KaiB	Oct-09	*Magelona dakini* (95)	*Macomona liliana* (47)	*Austrovenus stutchburyi* (32)	*Cossura consimilis* (26)	*Nemertea (21)*
	Dec-09	*Macomona liliana* (91)	*Magelona dakini* (74)	*Heteromastus filiformis* (24)	*Aricidea* sp. (22)	*Austrovenus stutchburyi* (22)
	Feb-10	*Magelona dakini (94)*	*Heteromastus filiformis* (54)	*Macomona liliana* (50)	*Nicon aestuarensis* (42)	*Austrovenus stutchburyi* (20)

Figure 9:

Size class structure of dominant bivalves, *Macomona liliana* and *Austrovenus stutchburyi,* at sites Tapora Bank (TPB), Kakarai Flats (KKF), Haratahi Creek (HCK), Kaipara Flats (KaiF), Ngapuke Creek (NPC) and Kaipara Bank (KaiB) in October 2009.



5.2 Between Site Comparisons

Overall, the sites were relatively distinct. Three loose clusters can be seen in Figure 8; however, some caution is needed when interpreting this MDS. The ordination stress values are moderately high indicating difficultly in compressing this into two dimensions for display. Levels of dissimilarity are relatively high: Sites HCK and KaiF cluster together and are 51% dissimilar. Sites KKF, NPC and TPB cluster together and are on average 61% dissimilar to each other. Site KaiB is the most distinct, forms its own cluster, and is on average 69% dissimilar to all other sites. KaiB displays the greatest amount of within site variability, with some points relatively dispersed in comparison with other sites.

5.3 State of the Environment Indicators

The ARC is at present developing a suite of State of Environment (SOE) indicators. A recent review of indicators used overseas (van Houte-Howes & Lohrer 2010) demonstrated that these do not work well in New Zealand, possibly as they are developed to demonstrate problems associated with organic over-enrichment and/or eutrophication. van Houte-Howes & Lohrer (2010) demonstrated a new functional indicator that may be of more use (NIWACOOBII), developed with ARC and FRST funding. The ARC also has a Benthic Health Model (Anderson et al., 2006), created to assign ecological health values to intertidal areas of the region based on storm water contaminant levels. The model has recently been extended to assigning health based on mud content of the sediment (Benthic Health Model mud – BHMmud) (Hewitt & Ellis 2010). These three methods were used, not so much to investigate present health, but to create an initial position from which relative changes over time can be assessed against.

Placing the Kaipara sites into the present BHM was problematic as the levels of total copper, lead and zinc in the <500 µm fraction were much lower than those used to develop the model. All the sites thus plot down the extreme bottom of the model (Figure 10) and are assigned to the healthy category. Three of the sites (KaiB, HCK & KKF) do overlap with sites used to develop the model, but the other three sites are extrapolations of the present model. Due to this, small changes in the health of these sites will probably be difficult to observe. Placing the Kaipara sites into the new BHMmud was much easier, as several sites used to develop the model have similar sediment characteristics (Figure 11). The communities at these sites match the sandiness of the sediment at the sites.

Figure 10:

Plot of the relationship between the principle component axis 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, Kaipara sites are red.

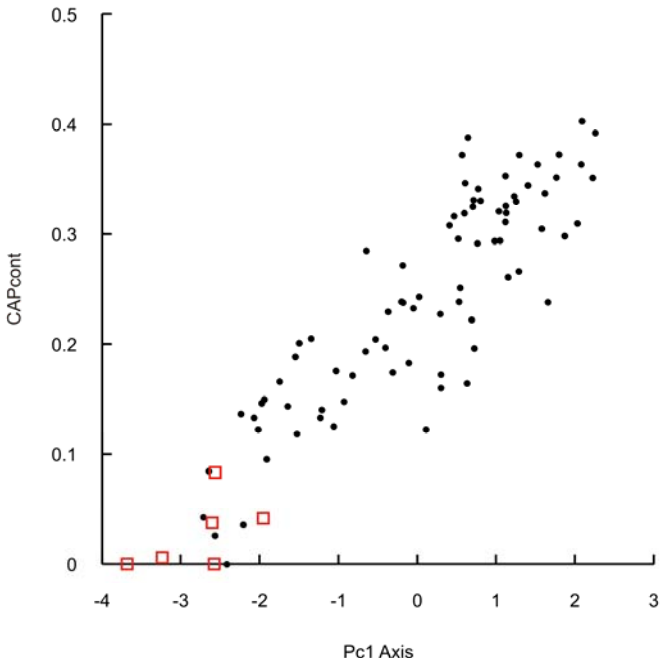
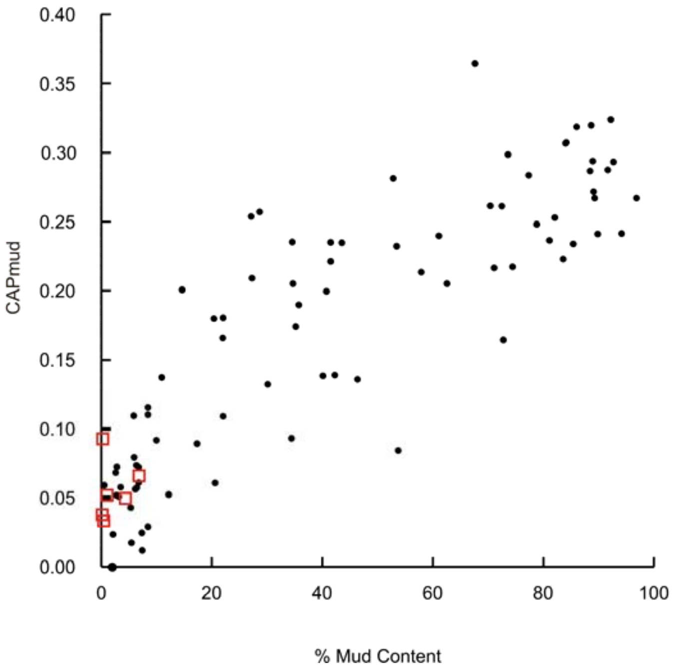


Figure 11:

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, Kaipara sites are red.

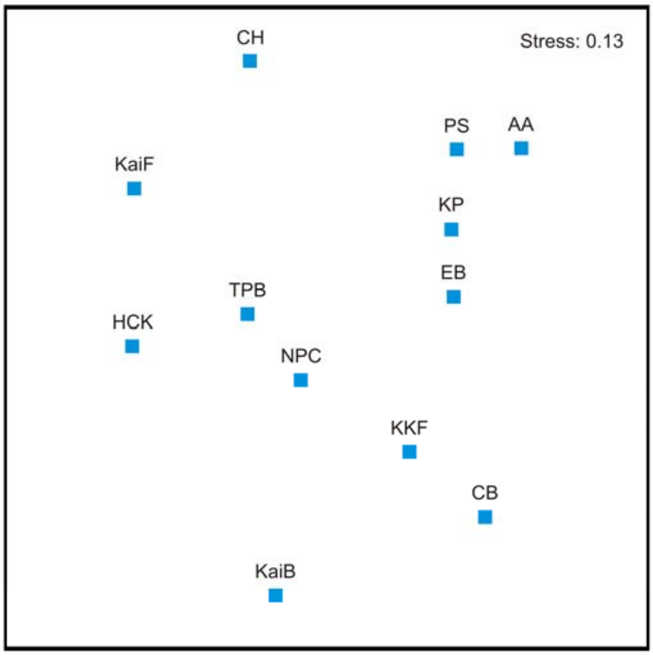


NIWACOOBII was calculated for the six sites based on the number of taxa in seven functional groups. The functional formulae of the NIWACOOBII was designed using the Mahurangi and Regional Discharge Programme community data so that index values fell between 0 and 1; with values near to 0 indicating low functionality and values near 1 indicating high ecosystem functionality. Index values from the Kaipara Harbour sites in October 2009 ranged from a relatively low value at HCK of 0.31 to high values at KKF (0.87) and TBP (0.74). In October, Site HCK had relatively high TOC and arsenic values and the highest total PAH and chlorophyll *a* concentrations, factors which could have potentially altered taxonomic richness and thus produced lower NIWACOOBII values. Sites KaiB, KaiF and NPC exhibited average NIWACOOBII values (0.53, 0.52 and 0.63 respectively).

5.4 Comparison with Manukau Monitoring Sites

The taxa found at sites in southern Kaipara Harbour are also commonly found in a number of other Auckland Harbours and are most similar to those found in Manukau Harbour (See Table 5 in Recommendations Section). Based on macrofauna abundances, no distinct clustering of sites was apparent and, on average, the Kaipara sites were more than 55% dissimilar to Manukau sites (Figure 12).

Figure 12:
Non-metric multidimensional scaling ordination plot (MDS) of the community structure at Kaipara Sites (TPB, KKF, HCK, KaiF, NPC and KaiB) and Manukau Sites (AA, CB, CH, EB, KP and PS) in October 2009. The stress of the plot is 0.13 and sites that are closest together in distance are most similar.



6 Recommendations

We recommend that, similar to the other ecological monitoring programmes run by the ARC, monitoring of all sites should continue until five years of data has been collected. Bimonthly monitoring should focus on selected species (Table 5), with the exception of the October data, which should be analysed for all taxa. This will provide cost-effective monitoring while allowing application of recently developed SOE indicators (the Benthic Health Model and the NIWACOOBII) that require full taxa lists. The species recommended for monitoring include many of those monitored in Manukau Harbour, along with some specific to Kaipara Harbour (*Nicon aestuarensis*, *Euchone* sp., *Scoloplos cylindrifer*, *Cossura consimilis*, *Aricidea* sp., *Asychis* sp. and *Musculista senhousia*), and are those that would be expected to show different types of changes in response to increased sediment or contaminant inputs and/or are likely to play key roles in influencing the composition of other taxa.

Amphipoda

Torridoharpinia hurleyi (previously *Proharpinia*) is a large phoxocephalid amphipod often common in intertidal estuarine sediments (Figure 13). It is most likely to feed on detritus and microscopic organisms, although some phoxocephalid species have been shown to be predators. In addition, this amphipod contributes significantly to sediment turnover through its burrowing activities and is an important prey item for birds and small fish (Thrush et al 1988). Amphipods have been shown to be sensitive to toxic contamination of sediments (Swartz et al 1982) and there is evidence that *Torridoharpinia* may also be sensitive to pollution (Roper et al 1988; Fox et al 1988).

Figure 13:
Photograph of *Torridoharpina hurleyi* taken under a dissection microscope (Paavo 2008).

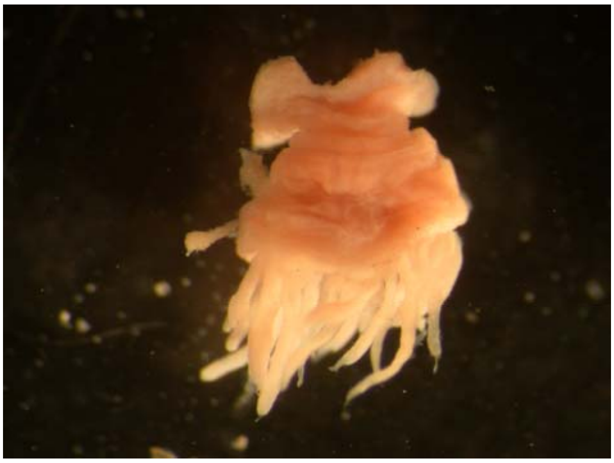
Waitangi brevirostris is another large phoxocephalid amphipod and is likely to play an important role in sediment reworking (Figure 14). Similar to other amphipods, it is probably an important prey item for birds and fish. It is sensitive to lead (Hewitt et al 2009) and to sediment mud content, preferring <5% mud (Gibbs & Hewitt 2004).

Figure 14:
Photograph of *Waitangi brevirostris* taken under a dissection microscope (Greenfield 2009).

Anthozoa

Anthopleura aureoradiata is a predatory sea anemone, living attached to live *Austrovenus*, or broken shells (Figure 15). It is intolerant of high turbidity and requires salinities higher than 20 ppt (Jones 1983). It is sensitive to sediment mud content, preferring <5% (Norkko et al 2001, Anderson et al 2007), and very sensitive to copper (Hewitt et al 2009).

Figure 15:
Photograph of *Anthopleura aureoradiata* taken under a dissection microscope (Greenfield 2009).



Bivalvia

Austrovenus stutchburyi (previously *Chione*) is a large surface living, suspension-feeding bivalve, common throughout much of New Zealand's estuaries intertidal areas (Figure 16). *Austrovenus* is one of the more studied species in New Zealand, potentially growing up to 60 mm and living for more than 3 years. Individuals live 0-5 cm below the sediment surface when the tide is out, moving up to feed at the surface when the tide comes in. They are highly mobile, both as adults on the surface of the sediment, and as juveniles, moving with bedload on in the water column. They provide an important recreational and cultural food source for humans, and are also an important prey item for birds (e.g., oyster catchers), rays and other fish. While their filtration rates are not as high as those of oysters and mussels, Pawson (2004) suggested that feeding by cockles controlled the availability of food in the water column (as algal biomass) in Papanui Inlet on the Otago peninsula. Effects of *Austrovenus* on the accumulation of contaminants (Gadd et al in review), the release of nutrients from the seafloor (Sandwell 2006, Thrush et al., 2006) and sediment destabilisation (Sandwell 2006) have been documented. Importantly, this species is sensitive to terrestrial sedimentation (Norkko et al 2002, Thrush et al 2005), increases in suspended sediment (Hewitt & Norkko 2007) and stormwater contaminants (Hewitt et al 2009).

Figure 16:
Photograph of *Austrovenus stutchburyi* (NIWA 2006).

Macomona liliana (previously *Tellina*) is a reasonably large deposit feeding bivalve (Figure 17). As an adult it lives well below the sediment surface (~10 cm) and feeds on the sediment surface using a long siphon. As a juvenile it is highly mobile, moving with bedload and in the water column. While it is mainly a deposit feeder it can also suspension feed by lifting its siphon into the water column. It lives both intertidally and subtidally, can grow up to 70 mm, and can live for more than 5 years. Similar to *Austrovenus*, the species is an important prey item for birds (e.g., oyster catchers), rays and other fish and has been demonstrated to affect seafloor productivity and nutrient recycling (Thrush et al 2006). It is also sensitive to terrestrial sedimentation

(Norkko et al 2002, Thrush et al 2005), increases in suspended sediment (Nicholls et al 2003) and stormwater contaminants (Hewitt et al 2009).

Figure 17:
Photograph of *Macomona liliana* (NIWA 2006).

Musculista senhousia is an invasive bivalve that can form dense mounds on the sediment surface, trapping sediment and excluding many other taxa (Figure 18). Bivalves have been shown to be most affected as the sediment under the mats becomes muddier and eventually anoxic (Creese et al., 1997). So far in New Zealand, beds appear short lived and are dominated by a one-aged cohort (Sim 1999: Masters Thesis).

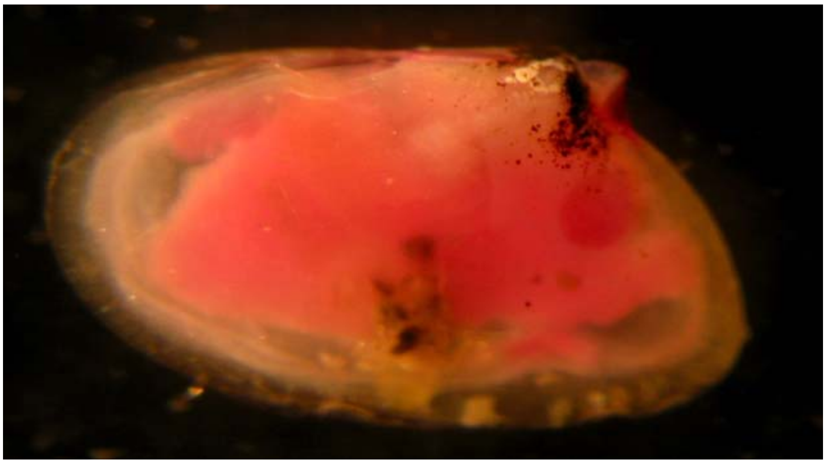
Figure 18:
Photograph of *Musculista senhousia* (Paavo 2008).

Nucula hartvigiana is a small (generally <10 mm) deposit-feeding bivalve that lives near the sediment surface (Figure 19). It is a highly mobile species and is probably capable of rapid small scale recolonisation (Thrush et al 1988). These bivalves are frequently found in the 'undisturbed' zones of an organic pollution gradient (Pearson & Rosenberg 1978). It is somewhat sensitive to sediment mud content (optimum 0–12, Thrush et al 2003, Anderson et al 2007) and copper (Hewitt et al 2009).

Figure 19:
Photograph of *Nucula hartvigiana* (Lundquist 2006).

Soletellina siliqua (previously *Hiatula siliquens*) is a deposit-feeding bivalve, common in the Manukau and Kaipara, of which little is known (Figure 20).

Figure 20:
Photograph of *Soletellina siliqua* taken under a dissection microscope (Paavo 2008).



Cumacean

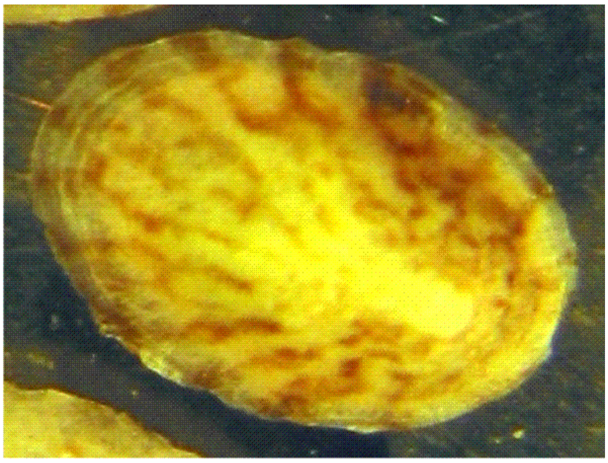
Colorostylis lemurum feeds on detritus and small organisms, making small feeding pits in the sediment surface and spending much of its time in the water column (Figure 21). It has been reported as sensitive to lead (Hewitt et al 2009) and to prefer low sediment mud content (<5% Anderson et al 2007).

Figure 21:
Photograph of *Colorostylis lemurum* taken under a dissection microscope (Greenfield 2009).

Gastropoda

Notocmea scapha (previously *N. helmsi*) is a grazing limpet found associated with gravel and cockle shells (Figure 22). Some limpets have been shown to be sensitive to sewage pollution (Smyth 1968). It prefers low amounts of sediment mud content <5% Gibbs & Hewitt, 2004).

Figure 22:
Photograph of *Notocmea scapha* taken under a dissection microscope (Paavo 2008).



Holuthurian

Trochodota dendyi is a small sea cucumber and a detrital-feeder that has not been well studied (Figure 23). Echinoderms are generally very sensitive to any form of pollution (Agg et al 1978) and New Zealand holothurian species that have been studied, certainly fit into this pattern (Roper et al 1989). Furthermore, it is likely to be responsible for considerable sediment turnover (Thrush et al 1988).

Figure 23:
Photograph of *Trochodota dendyi* taken under a dissection microscope (Funnell 2005).

Isopoda

Little is known about the *Exosphaeroma* genera, although it is one of the more common isopods of our estuaries, with a number of different species. *E. chilensis* (Figure 24) is the most common, followed by *E. falcatum* (Figure 25) and the recently discovered *E. waitematensis.* Isopods are known to be prey for birds and fish.

Figure 24:
Photograph of *Exosphaeroma chilensis* taken under a dissection microscope (Paavo 2008).

Figure 25:
Photograph of *Exosphaeroma falcatum* taken under a dissection microscope (Greenfield 2009).

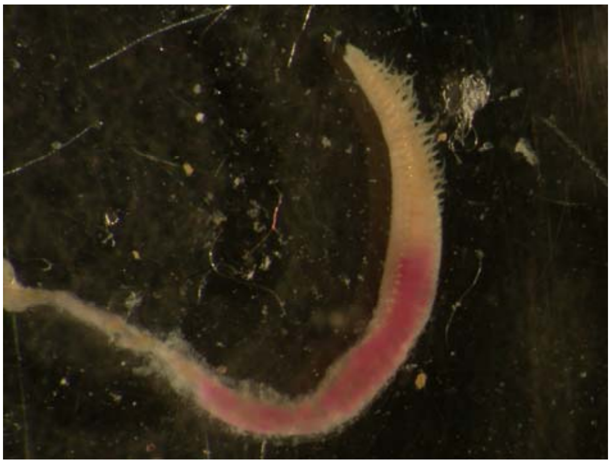
Polychaeta

Aglaophamus macoura is the common large predatory nephtyid found intertidally in New Zealand (Figure 26). Little is known about it, but another New Zealand species of similar size is slow growing and lives for at least five years. Nephtyids generally have been shown to be an important intermediate predator, living off smaller invertebrates and providing an important food source for birds and small fish.

Figure 26:
Photograph of *Aglaophamus macoura* taken under a dissection microscope (Greenfield 2009).

Aonides trifida (previously *A oxycephala*) is a small infaunal deposit feeder, living in a wide range of sediments but preferring those of low mud content (5 – 10%, Thrush et al 2003, Anderson et al 2007) (Figure 27). It is sensitive to copper contamination (Hewitt et al 2009).

Figure 27:
Photograph of *Aonides trifida* taken under a dissection microscope (Greenfield 2009).

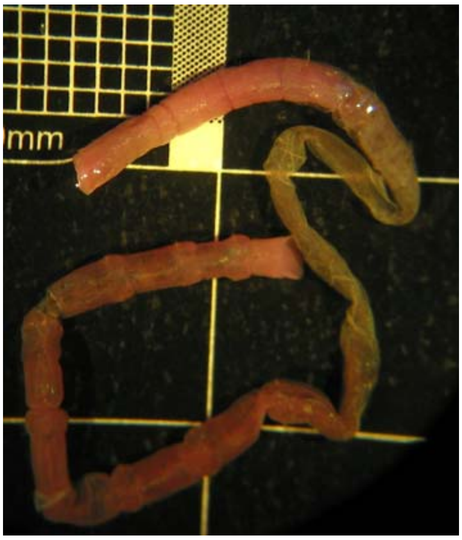


Aricidea sp. is a small sub-surface deposit feeder which has demonstrated sensitivity to lead and zinc, at concentrations near the TEL guidelines (Hewitt et al., 2009) (Figure 28).

Figure 28:
Photograph of *Aricidea* sp. taken under a dissection microscope (Greenfield 2009).

Asychis sp. is a large maldanid tube-worm which deposit feeds below the sediment surface (Figure 29). It therefore is both a bioturbator and a species which can stabilise sediment. It is also likely to be an important prey species for birds and fish. Tube worms have also been show to generally support high macrofaunal biodiversity (Hewitt et al 2009b).

Figure 29:
Photograph of *Asychis* sp. taken under a dissection microscope (Paavo 2008).



Boccardia syrtis is a small polydorid tube worm which forms dense mats capable of stabilising the sediment in energetic environments and trapping small animals moving in the water column (Cummings et al 1996, Thrush et al 1996) (Figure 30). It is generally a surface deposit feeder but can also suspension feed. It is common in muddier sediments (15-30 % mud, Thrush et al 2003) and polydorids have been shown to be sensitive to lead (Hewitt et al 2009).

Figure 30:
Photograph of *Boccardia syrtis* taken under a dissection microscope (Greenfield 2009).

Cossura consimilis is a small deposit-feeding polychaete which has demonstrated sensitivity to copper at concentrations just above the TEL guideline, and a preference for muddy, low oxygen sediment (Gibbs and Hewitt 2004; Hewitt et al., 2009) (Figure 31).

Figure 31:
Photograph of *Cossura consimilis* taken under a dissection microscope (Greenfield 2009).

Euchone sp. is a small suspension-feeding tube worm which has demonstrated sensitivity to copper, at concentrations near the TEL guideline and to zinc, at concentrations below the TEL guideline (Hewitt et al., 2009) (Figure 32).

Figure 32:
Photograph of *Euchone* sp. taken under a dissection microscope (Greenfield 2009).

Macroclymenella stewartensis is a maldanid tube worm, somewhat smaller than *Asychis* (Figure 33). It is similarly an important bioturbator and sediment stabiliser. Is sensitive to copper (Hewitt et al 2009) and prefers sediment mud content between 10 and 15 % mud (Gibbs & Hewitt 2004).

Figure 33:
Photograph of *Macroclymenella stewartensis* taken under a dissection microscope (Greenfield 2009).

Magelona dakini is a small subsurface deposit feeder, living mainly greater than 2 cm below the sediment surface (Figure 34). It is highly sensitive to lead concentrations (Hewitt et al 2009). Little is more known about the species, even its true species name is in doubt.

Figure 34:
Photograph of *Magelona dakini* taken under a dissection microscope (Greenfield 2009).

Nicon aestuarensis is a large nereid predator that has shown preference for contaminated and/or muddy sediments (Thrush et al., 2005, Hewitt et al., 2009) (Figure 35).

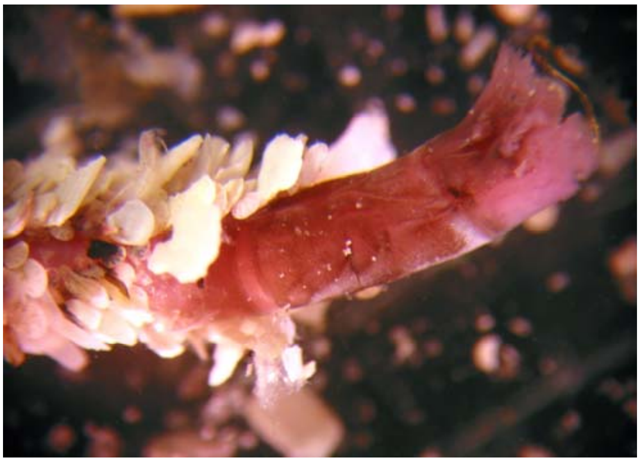
Figure 35:
Photograph of *Nicon aestuarensis* taken under a dissection microscope (Greenfield 2009).

Orbinia papillosa is a large subsurface deposit feeder, preferring slightly silty sediment (5 – 10% mud, Gibbs & Hewitt 2004) (Figure 36). It is a bioturbator and a prey item for birds and fish. Orbinids have been found to be somewhat sensitive to zinc at concentrations slightly below the TEL guideline (Hewitt et al., 2009).

Figure 36:
Photograph of *Orbinia papillosa* taken under a dissection microscope (Paavo 2008).

Owenia fusiformis (possibly *petersonae*) is a cosmopolitan species frequently abundant in sandflats (Figure 37). The worm builds large tubes from heavy sand grains. Their tube structures may influence larval settlement (including providing an attachment surface for *Musculista senhousia*) and provide refuges from epibenthic predators. *Owenia* are principally suspension-feeding animals but may also deposit-feed and they are classified as an intermediate stage species along organic enrichment gradients by Pearson and Rosenberg (1978).

Figure 37:
Photograph of *Owenia fusiformis* taken under a dissection microscope (Paavo 2008).



Prionospio aucklandica (previously *Aquilaspio*) is another small deposit feeder, similar to *Aonides* (Figure 38). However, it generally lives deeper in the sediment and prefers slightly more mud (25 – 30% mud content, Thrush et al 2003). Similarly, while still sensitive to copper, it is less sensitive than *Aonides* (Hewitt et al 2009).

Figure 38:
Photograph of *Prionospio aucklandica* taken under a dissection microscope (Greenfield 2009).

Scoloplos cylindrifer is a subsurface deposit feeder of the same genus as *Orbinia*. It generally fulfils a similar ecosystem role as *Orbinia*, but prefers less mud (0-5% mud content Gibbs & Hewitt 2004) (Figure 39).

Figure 39:
Photograph of *Scoloplos cylindrifer* taken under a dissection microscope (Greenfield 2009).

Travisia olens is a large deposit-feeding ophellid, often seen lying on the sediment surface (Figure 40). It is slightly mobile, crawling over and through sandy sediment (Gibbs & Hewitt 2004).

Figure 40:
Photograph of *Travisia olens* taken under a dissection microscope (Greenfield 2009).

Table 5

Monitored species list for Kaipara Harbour. The list is essentially the monitored species for the Manukau Harbour Ecological Programme; however a few additions (shaded in grey) have been made based on data collected between October 2009 and February 2010.

Phyllum: Class	
Arthropoda: Amphipoda	*Torridoharpinia hurleyi*
	Waitangi brevirostris
Cnidaria: Anthozoa	*Anthopleura aureoradiata*
Mollusca: Bivalvia	*Austrovenus stutchburyi*
	Macomona liliana
	Musculista senhousia
	Nucula hartvigiana
	Soletellina siliqua
Arthropoda: Cumacea	*Colorostylis lemurum*
Mollusca: Gastropoda	*Notoacmea scarpha*
Echinodermata: Holothuroidea	*Trochodota dendyi*
Arthropoda: Isopoda	*Exosphaeroma cilensis*
	Exosphaeroma falcatum
Annelida: Polychaeta	*Aglaophamus macoura*
	Aonides trifida
	Aricidea sp.
	Asychis sp.
	Boccardia syrtis
	Cossura consimilis
	Euchone sp.
	Macroclymenella stewartensis
	Magelona dakini
	Nicon aestuariensis
	Orbinia papillosa
	Owenia fusiformis
	Prionospio aucklandica
	Scoloplos cylindrifer
	Travisia olens var. NZ

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