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TE RAUHITANGA TAIAO

Waitemata Harbour Ecological Monitoring Programme - results from the first year of sampling. Oct 2000 - 2001

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Waitemata Habour Ecological Monitoring Programme – results from the first year of sampling, October 2000 - 2001.

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Prepared for
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Executive Summary

In October 2000, a long-term monitoring programme was established in Waitemata Harbour. The aim of this programme is to monitor the ecological status and trends in marine macrobenthic species representative of the region, and to monitor habitats that have the potential to be affected by sedimentation, pollution and other impacts associated with the urban environment. Waitemata Harbour is the third sentinel location to be established in the Auckland Region.

Following consultations with the ARC and an initial site visit, five permanent intertidal sites were selected within the harbour. These are located at Hobsonville (HBV), Henderson Creek (HC), Whau River (Whau), Te Tokaroa Reef (Reef) and Shoal Bay (ShB). Methods and techniques used for sampling and sample processing were consistent with the two established sentinel sites, Manukau and Mahurangi Harbours. Sites were sampled every second month from October 2000 to October 2001.

The marine benthic communities at each site were quite distinct from each other in October 2000, and this did not change significantly over the sampling period. The site Reef showed the greatest temporal variability, while HC showed the least. The bivalve *Nucula hartvigiana* was by far the most abundant species at all five sites. The cockle *Austrovenus stutchburyi* was abundant at HBV, HC and Whau. The polychaetes *Aonides oxycephala* and *Aquilaspio aucklandica* were common at HBV. The chiton *Notoacmea helmsi* was common at Whau and ShB, and the polychaetes *Euchone* sp. and *Aricidea* sp., at Reef.

Common taxa at all the sites showed a certain amount of temporal variability during the year, and there are suggestions of cyclic patterns and trends in abundance for some taxa. However, more data is required to validate these.

With these results in mind; we recommend:

- A list of twenty species for ongoing monitoring. These are comprised of the most abundant and functionally important taxa over all the sites.

- Continuing to monitor all 5 sites every second month. These sites are representative of the dominant habitats in the central Waitemata

Harbour, and there are differences in the spatial and temporal variation of the benthic communities between these sites.

- Maintaining the sampling methodology described in this report, so that it is consistent with that used in the other two sentinel monitoring sites, Manukau and Mahurangi Harbours. These techniques have proved successful and will enable future between-harbour comparisons to be made.

1. INTRODUCTION

In October 2000, a State of the Environment monitoring programme was developed for the Auckland Regional Council (ARC) (Hewitt, 2000). The programme was designed to be scientifically credible, practical, affordable and to meet the requirements of the Resource Management Act (1991). The focus of the programme was to monitor: (a) the ecological status and trends of change in macrobenthic communities in marine habitats representative of the region; and (b) habitats affected by the ARC's priority issues of sedimentation and pollution, while providing feedback about other issues. A 3-level programme was suggested to comprehensively cover the Auckland region, based on: (1) intensive monitoring of sentinel locations; (2) less frequent monitoring of habitat and ecological community characteristics; and (3) broad-scale habitat monitoring inventories.

The sentinel-location monitoring programme was designed using recommendations and experience from a number of sources (Hewitt, 2000). The programme:

- Focusses mainly on Auckland's sheltered waters (estuaries, harbours and small inlets) which comprise two thirds of the region's coastline and cover a large number of habitats, including those most at environmental risk (Hewitt, 2000).
- Focusses on ecological monitoring of macrobenthos. Ecological monitoring is the most appropriate method of establishing the importance of environmental changes. Monitoring macrobenthos has a number of advantages (Thrush et al., 1989), including practicalities of sampling and restricted mobility of most macrofaunal species.
- Emphasises changes occurring at sites within the sentinel location over time.
- Recommends the use of consistent methodology, where such use does not compromise the ability of the monitoring programme to deliver results.
- Balances cost/sampling effort in space and time with the emphasis on intensive temporal sampling. Sampling must occur frequently enough to prevent temporal variability from compromising detection of change, and to allow detection of ecologically meaningful changes in the temporal pattern of recruitment and survival of

species. These issues are discussed more fully with respect to monitoring in Manukau Harbour by Thrush et al. (1989) and Hewitt et al. (1994) and are confirmed by Cummings et al. (2001) for monitoring in Mahurangi Harbour.

- Focusses on monitoring a selection of species that could be expected to respond to changes in their surroundings in a variety of ways. This method has proved useful in monitoring Manukau and Mahurangi and has been further validated in work carried out by NIWA and Auckland University on ways of defining healthy communities (Anderson et al., in prep).

Four sentinel locations were chosen to represent areas of special interest to the ARC. These locations were chosen and ordered according to greatest; pressure from toxic and sediment inputs; size of area and hydrodynamic regime: Manukau, Mahurangi, Waitemata and Wairoa Harbours. Both Manukau and Mahurangi are already monitored, and Waitemata was selected by the ARC as next sentinel location to be established.

Hewitt (2000) suggested that the central Waitemata would be best represented by 6 intertidal sites, 5 soft sediment and one rocky habitat. NIWA was commissioned to monitor the soft sediments and the University of Auckland was to monitor the rocky site. This report details the results of the first full year of monitoring the soft-sediment sites. It includes:

- Rationale of site selections;
- Detailed descriptions of macrobenthic communities found at each site;
- Between-site comparisons;
- Descriptions of within-site temporal variability observed over the first year.

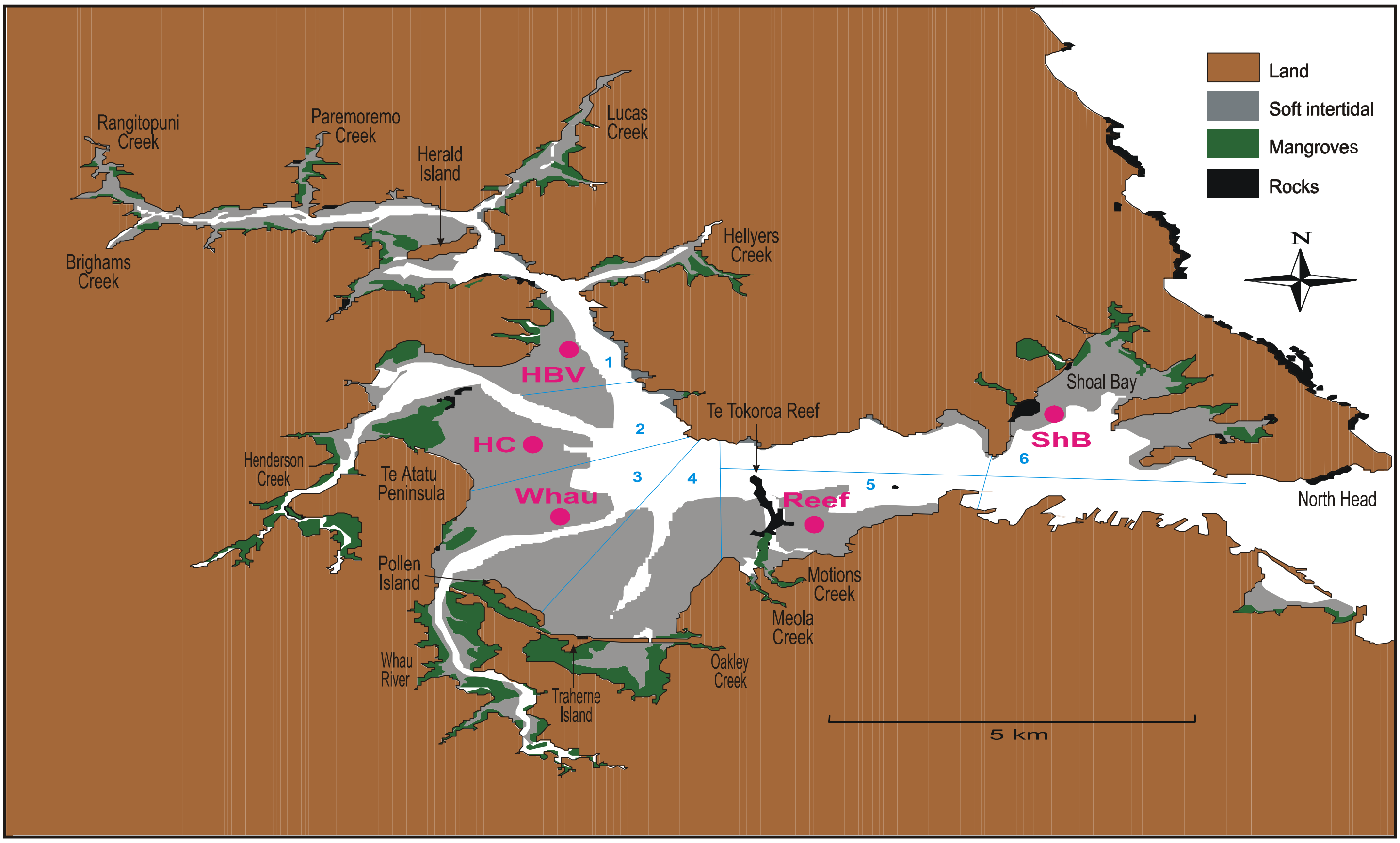


Figure 1. Map of Waitemata Harbour showing the five permanent monitoring sites at Hobsonville (HBV), Henderson Creek (HC), Whau River (Whau), Te Tokaroa Reef (Reef) and Shaol Bay (ShB) (indicated by pink circles). The numbers 1-6 represent the 6 sub-regions of the harbour which contain significant intertidal habitats.

Site selection

Sites were selected for monitoring in consultation with the ARC, and were largely based on recommendations made in Hewitt (2000). The sites were chosen to integrate over as many aquatic inputs as possible, while being distanced from any industry specific source. The central Waitemata can be 'divided' into 8 sub-regions, based on hydrodynmaics and drainage areas, 6 of which have significant intertidal habitats (Figure 1; Hewitt, 2000). The 6 sub-regions are downstream of the following major drainage areas:

1. Upper Waitemata.
2. Henderson Creek.
3. Whau River.
4. Traherne Island/Oakley Creek
5. Motions and Meola Creek, near Te Tokaroa Reef.
6. Shoal Bay

One site was placed in each sub-region of the harbour except for the Traherne Island/Oakley Creek region. The decision to exclude this sub-region was based on the desire to locate more sites in the south-eastern side of the harbour; the site in the Te Tokaroa Reef area is still down stream of this sub-region.

Site positions had to be located in areas that were representative of the general character of the surrounding intertidal area and as close to channels as practical. While site locations were suggested in Hewitt (2000), an initial site visit with Dominic McCarthy (ARC) found many of these positions were unsatisfactory due to access difficulties, such as low tidal height, and very high mud content.

The five intertidal monitoring sites chosen during the initial site visit in October 2000 were: Hobsonville (HBV), Henderson Creek (HC), Whau River (Whau), Te Tokaroa Reef (Reef) and Shoal Bay (ShB) (see Figure 1 and Table 1). All sites were located at the mid-tide level and each covered an area of 9000 m^2.

Hobsonville (HBV)

Site HBV is located on the sandflats near the Hobsonville Air Base, close to the deep channel entering the Upper Waitemata Harbour. The Upper Waitemata has 5 contributing creeks: Lucas, Hellyers, Brighams, Paremoremo and Rangitopuni. In the past, this catchment area has been predominantly rural, however this is slowly changing to accommodate residential lifestyle blocks. The sandflat at HBV exhibits many of the characteristics of areas subject to high flow (coarse sediment, hollows in the sediment surface). Large fragments of old logs are often found buried below the sediment surface, and there is a thick shell layer approximately 15 cm below the surface.

Henderson Creek (HC)

Site HC is located adjacent to Henderson Creek. The catchment surrounding the upper reaches of this creek is largely industrial and residential. HC is on a large intertidal flat which is fringed by mangroves on the upper edge and supports patches of Pacific oysters. The sediment is muddy and generally free of surface features, such as ripples.

Whau River (Whau)

Site Whau is located on the north-western side of the Whau river. The flats here are large, sandy and they generally show signs of wind-wave activity (small ripples on the sediment surface). On the south-eastern side, there is a large intertidal flat, adjacent to the Pollen Island Marine Reserve. The reserve had been recommended as a potential site (Hewitt, 2000), however on the initial visit, it was unanimously decided that these flats were too muddy. There is a large amount of boat activity past the chosen site and there are often discarded tyres, wood and plastic observed in the area when sampling.

Te Tokaroa Reef (Reef)

The intertidal flat on the eastern side of Te Tokoroa Reef is a muddy sandflat with a small channel dissecting it. It is probably the most sheltered of the five sites. The site itself is situated next to scattered patches of rock, well away from the channel, and is mainly soft muddy-sand, with high numbers of gastropods. Both Meola Creek to the south-west, and Motions Creek to the south-east, drain past the site.

Shoal Bay (ShB)

Shoal Bay contains a number of intertidal flats. Many of those furtherest into the bay are near point sources associated with commercial and industrial businesses, and there is large marina on the eastern side. The intertidal flat selected for the monitoring site is adjacent to the Auckland Harbour bridge, and near a large rock platform. The sediment in the area is coarse with ripples on the sediment surface - both characteristics of an exposed site. A buried pipeline running perpendicular to the shore intersects the site. Broken bottles and discarded plastic were often observed on this sandflat during sampling.

On the first sampling occasion (October 2000) the corners of each site were marked with wooden stakes. The '0,0' or start position was recorded using a hand-held Garmin GPS to aid site relocation (See Table 1).

Table 1. Dimensions and GPS co-ordinates for the monitored sites in the Waitemata Harbour.

Site	Dimensions (m)		GPS coordinates	
	X	Y	Southing	Easting
HBV	150	60	36° 47. 959	174° 40. 643
HC	100	90	36° 48. 821	174° 39. 639
Whau	100	90	36° 50. 828	174° 40. 143
Reef	180	50	36° 50. 730	174° 43. 008
ShB	180	50	36° 49. 093	174° 45. 377

2. METHODS

Methods and techniques used for sampling and sample processing are consistent with those used at the established sentinel locations of Mahurangi and Manukau Harbours.

Macrofauna

Every second month, 12 core samples (each 13 cm diameter, 15 cm deep) are collected from each site. To provide an adequate spread of cores over the site, a site is 'divided' into 12 equal sections and one core sample is taken from a random location within each section. To reduce the influence of previous sampling activity and spatial autocorrelation (Hewitt et al., 1994; Pridmore et al., 1990; Thrush et al., 1988, 1994), samples are not placed within a 5 m radius of each other or of any samples collected in the previous 12 months. Core samples are sieved through a 500 μm mesh and the residues stained with rose bengal and preserved in 70 % isopropyl alcohol in seawater. Samples are then sorted, identified to the lowest possible/practical taxonomic level, counted and stored in 50 % isopropyl alcohol.

Sediment characteristics

Sediment characteristics (i.e. grain size, organic content and chlorophyll *a*) are also 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. The six cores are pooled, homogenised, sub-sampled and analysed as described below.

Grain size

A sub-sample (~ 6 g) of the homogenised sediment is digested in 6% hydrogen peroxide (H_2O_2) for 48 h to remove organic matter, dispersed using calgon, and wet sieved through a stack of 4 sieves of decreasing mesh size. The results of the grain size analyses are presented as percentage composition of gravel/shell hash (>2 mm), coarse sand (between 2 mm and 500 μm), medium sand (between 500 and 250 μm), fine sand (between 250 and 63 μm) and mud (<63 μm).

Chlorophyll *a*

All samples are kept chilled and in the dark upon collection, frozen as soon as possible, and then freeze-dried prior to analysis. Chlorophyll *a* is extracted by boiling the freeze-dried sediment in 95 % ethanol (C_2H_5OH), and the extract is then processed using a spectrophotometer. An acidification step is used to separate degradation products from chlorophyll *a* (Sartory, 1982).

Organic content

A sub-sample (~ 6 g) of the homogenised sediment is dried at 60 °C for 48 h and then combusted for 5.5 h at 400 °C. Organic content is calculated as a percentage of dry weight.

Statistical analyses

When the State of the Environment monitoring programme was developed for the ARC, the methods to be used in analysing the data were also detailed (Hewitt, 2000). Following these recommendations, the following analyses were conducted for this report:

- Rank abundance plots were used to compare community structure found at each site on the first sampling occasion.

- Differences between sites in the abundance of common taxa, number of individuals and number of taxa were examined, for the first sampling occasion, using generalized linear models (McCullagh and Nelder, 1989).

- Similarities in community composition over the monitoring period were examined by ordination of raw, square-root transformed and presence/absence data, using both correspondence analysis (CANOCO; Ter Braak, 1986) and nonmetric multidimensional scaling (MDS) based on Bray Curtis similarities (PRIMER; Clarke, 1993).

- Spatial variability was determined using detection limits for a number of the common taxa (those with a mean greater than 1 individual per core at more than 3 sites) on the first sampling date, using the methods described in Ward et al. (1990).

- Ability to detect trends was predicted for the monitored taxa using the methods described in Ward et al. (1990).

- Sampling precision versus effort curves were developed for all abundant taxa (mean greater than 1 individual per core) for October 2000, using a bootstrapped version of the randomisation technique described in Hewitt et al. (1993). Random draws of different sample sizes were made from the data and standard errors calculated for each draw. The 90 percentile standard error (precision) was then calculated for each sample size and plotted against sample size (effort). The rate of decrease in precision was used, along with the standard error and the spatial detection limit obtained from all 12 samples, to determine whether the initial sample size of 12 was adequate.

3. RESULTS

Site Descriptions

The macrofauna common at each site are shown in Table 2 and sediment characteristics are detailed in Tables 3, 4 and 5. A brief description of each site is given below. In all cases, numbers of individuals of each taxa refers to the total number of collected in the 12 cores.

Table 2. Rank abundances of the five most abundant taxa for Hobsonville (HBV), Henderson Creek (HC), Whau River (Whau), Te Tokaroa Reef (Reef) and Shoal Bay (ShB) over time, from October 2000 to October 2001.

	Date	Most abundant	⇨	⇨	⇨	Least abundant
HBV	Oct 00	*Nucula*	*Aonides*	*Austrovenus*	*Paphies*	*Aquilaspio*
	Dec 00	*Nucula*	*Aonides*	*Austrovenus*	*Aquilaspio*	Phoxocephalidae
	Feb 01	*Nucula*	*Aonides*	*Austrovenus*	*Aquilaspio*	Exogonidae
	Apr 01	*Nucula*	*Aonides*	*Austrovenus*	*Notoacmea*	*Aquilaspio*
	June 01	*Nucula*	*Aonides*	*Austrovenus*	*Notoacmea*	*Aquilaspio*
	Aug 01	*Nucula*	*Aonides*	*Notoacmea*	*Austrovenus*	*Aquilaspio*
	Oct 01	*Nucula*	*Aonides*	*Austrovenus*	*Aquilaspio*	*Notoacmea*
HC	Oct 00	*Nucula*	*Austrovenus*	*Notoacmea*	*Aricidea*	*Boccardia*
	Dec 00	*Nucula*	*Austrovenus*	*Aricidea*	*Notoacmea*	*Aquilaspio*
	Feb 01	*Nucula*	*Austrovenus*	*Aricidea*	*Aquilaspio*	Phoxocephalidae
	Apr 01	*Nucula*	*Austrovenus*	*Aricidea*	*Aquilaspio*	*Notoacmea*
	June 01	*Nucula*	*Austrovenus*	*Aricidea*	*Notoacmea*	Phoxocephalidae
	Aug 01	*Nucula*	*Notoacmea*	*Aricidea*	*Aquilaspio*	Phoxocephalidae
	Oct 01	*Nucula*	*Austrovenus*	*Aricidea*	*Notoacmea*	*Diloma*
Whau	Oct 00	*Nucula*	*Aricidea*	*Austrovenus*	*Notoacmea*	*Elminius*
	Dec 00	*Nucula*	*Aricidea*	*Austrovenus*	*Notoacmea*	*Elminius*
	Feb 01	*Nucula*	*Austrovenus*	*Aricidea*	*Notoacmea*	Phoxocephalidae
	Apr 01	*Nucula*	*Austrovenus*	*Macomona*	*Notoacmea*	*Aquilaspio*
	June 01	*Nucula*	*Aricidea*	*Austrovenus*	Phoxocephalidae	*Aquilaspio*
	Aug 01	*Nucula*	*Aricidea*	*Austrovenus*	Phoxocephalidae	*Aquilaspio*
	Oct 01	*Nucula*	*Aricidea*	*Austrovenus*	*Notoacmea*	*Aquilaspio*
Reef	Oct 00	*Nucula*	*Euchone*	*Aricidea*	*Zeacumantus*	*Macroclymenella*
	Dec 00	*Nucula*	*Austrovenus*	*Euchone*	Exogonidae	*Aricidea*
	Feb 01	*Nucula*	Exogonidae	*Euchone*	*Austrovenus*	*Macroclymenella*
	Apr 01	*Nucula*	*Euchone*	*Colurostylis*	*Aricidea*	Exogonidae
	June 01	*Nucula*	*Euchone*	*Colurostylis*	Phoxocephalidae	Exogonidae
	Aug 01	*Euchone*	*Nucula*	*Aricidea*	Exogonidae	Phoxocephalidae
	Oct 01	*Nucula*	*Euchone*	*Aricidea*	Exogonidae	Oligochaetes
ShB	Oct 00	*Nucula*	*Notoacmea*	Paracolliopidae	*Boccardia*	Phoxocephalidae
	Dec 00	*Nucula*	*Notoacmea*	Paracolliopidae	*Boccardia*	Phoxocephalidae
	Feb 01	*Nucula*	*Austrovenus*	Phoxocephalidae	unid. gastropod	*Elminius*
	Apr 01	*Nucula*	*Elminius*	*Notoacmea*	*Austrovenus*	Exogonidae
	June 01	*Nucula*	*Notoacmea*	Phoxocephalidae	Paracolliopidae	*Austrovenus*
	Aug 01	*Nucula*	*Notoacmea*	Paracolliopidae	Phoxocephalidae	*Aricidea*
	Oct 01	*Nucula*	*Notoacmea*	*Aricidea*	Tanaid	*Austrovenus*

Hobsonville (HBV)

Sediment at HBV was predominantly medium and fine sand, with a small amount of shell hash/gravel and coarse sand (See Table 3). Chlorophyll *a* content of the sediments ranged between 10.26 and 18.79 µg/g sediment (See Table 4). Organic content of the sediment was low, and ranged from 0.81 to 1.29 % (See Table 5).

The small deposit-feeding bivalve *Nucula hartvigiana* was by far the most abundant species at HBV throughout the sampling period (308 - 654 individuals), followed by the polychaete, *Aonides oxycephala* (145 – 366 individuals; See Table 2). The cockle *Austrovenus stutchburyi*, the limpet *Notoacmea helmsi*, and the polychaete *Aquilaspio aucklandica* were also common at this site. The pipi *Paphies australis*, exogonid polychaetes and phoxocephalid amphipods were also amongst the dominant taxa on some sampling dates (See Table 2). Throughout, between 26 - 34 different taxa were collected from HBV, from October 2000 to October 2001.

Henderson Creek (HC)

HC sediments were dominated by fine sands (66.93 – 78.45 %), and they also contained a reasonable proportion of mud (3.97 - 8.13 %) and shell hash/gravel (1.43 – 4.75 %) (See Table 3). Chlorophyll *a* content ranged from 9.53 – 29.61 µg/g sediment (See Table 4). Organic content was low (1.46 and 2.66 %; See Table 5).

Like HBV, *Nucula* was by far the most abundant species monitored (357 – 1521 individuals). *Nucula* were more abundant at HC, than at any other monitored site in the central Waitemata. *Austrovenus*, *Notoacmea*, the polychaetes *Aricidea* sp. and *Aquilaspio,* and phoxocephlid amphipods, were also common. *Boccardia syrtis* and the gastropod, *Diloma subrostrata* were ranked amongst the top 5 species on one sampling occasion, with a total of 98 and 43 individuals, respectively (See Table 2). Throughout, between 27 - 38 different taxa were collected from HC, from October 2000 to October 2001.

Whau River (Whau)

Sediment from Whau was dominated by fine sand (82.15 – 94.48 %) and had low levels of mud (2.22 – 3.19 %; See Table 3). Over the sampling period, chlorophyll *a* content of the sediment ranged from 8.35 – 20.74 µg/g (See Table 4) and organic content from 0.76 – 1.42 % (See Table 5).

Nucula was again the most abundant taxa at Whau, with 344 – 1616 individuals (See Table 3). *Aricidea*, *Austrovenus, Notoacmea, Aquilaspio,* phoxocephlid amphipods, the barnacle *Elminius modestus* and wedge shell *Macomona* featured amongst the dominant taxa on at least one sampling occasion (See Table 2). The polychaete *Macroclymenella stewartensis* and the gastropod *Haminoea zelandiae* were found here in greater total abundances than at any other monitored site (2 - 38 and 0 – 7 individuals respectively). As others, 31 –

45 different taxa were collected from Whau, from October 2000 to October 2001.

Te Tokaroa Reef (Reef)

Sediment at Reef was dominated by fine sand (87.22 – 93.12 %) and had the lowest proportion of gravel/shell hash (0.43 – 1.67 %) of all the monitored sites (See Table 3). Chlorophyll *a* content ranged from 7.28 to 15.02 µg/g sediment, while organic content ranged between 0.74 and 1.26 % (See Table 4 and 5).

Reef had lower overall abundances compared to the other monitored sites. Reef was dominated by *Nucula* (240 – 880 individuals), except in August 2001, when the polychaete *Euchone* sp. was more abundant (648 individuals; See Table 2). Exogonids and *Aricidea* were also dominant taxa on more than 2 sampling occasions. The cumacean *Colurostylis lemurum, Macomona,* phoxocephalid amphipods and the turret shell *Zeacumantus lutulentus* were common on 1 or 2 sampling occasions only*.* Reef was the only site where *Zeacumantus* was present in reasonable numbers (0 – 31 individuals). As others, 34 - 42 different taxa were collected from Reef, from October 2000 to October 2001.

Shoal Bay (ShB)

Sediment at ShB was dominated by fine (63.30 – 78.71 %) and medium sand (14.11 – 28.84 %; See Table 3). ShB sediments had the lowest chlorophyll *a* content (4.87 – 10.72 µg/g sediment) and organic content (0.27 – 0.91 %) of all the monitored sites (See Tables 4 and 5).

Nucula was by far the most abundant species, with 223 to 448 individuals. *Notoacmea*, phoxocephalid and colliopid amphipods and *Austrovenus* were dominant taxa on more than 2 occasions. *Elminius, Boccardia, Aricidea*, a tanaid crustacean, and exogonid polychaetes were all dominant on 1 or 2 sampling occasions. Overall, 33 - 42 different taxa were collected from ShB, from October 2000 to October 2001.

Grain size, chlorophyll *a* and organic content

Values for organic content and chlorophyll *a* are comparable to the other sentinel sites in the Manukau and Mahurangi Harbours (Funnell et al., 2001, Cummings et al., 2001). Chlorophyll *a* was generally quite similar between sites, although levels tended to be relatively lower at ShB and higher at HC (See Table

4). Organic content was low at all sites (i.e. <3%) and, as noted for chlorophyll *a* , was lowest at ShB. (See Table 5).

Table 3. Grain size of sediments at Hobsonville (HBV), Henderson Creek (HC), Whau River (Whau), Te Tokaroa Reef (Reef), Shoal Bay (ShB), from October 2000 to October 2001.

% Sediment composition	Date	HBV	HC	Whau	Reef	ShB
Gravel/ Shell hash	Oct 00	7.64	1.50	1.00	0.06	1.26
	Dec 00	1.59	3.26	1.53	0.43	2.65
	Feb 01	0.85	2.09	2.19	0.85	1.01
	Apr 01	10.90	3.20	0.16	1.20	1.41
	June 01	0.74	4.75	4.84	0.68	1.35
	Aug 01	1.20	1.43	0.36	1.43	3.64
	Oct 01	1.08	2.09	1.59	1.67	0.56
Coarse sand	Oct 00	9.36	4.01	0.80	0.28	2.46
	Dec 00	7.77	2.33	0.82	0.29	1.96
	Feb 01	8.05	2.88	0.69	0.18	0.87
	Apr 01	5.08	4.97	0.26	0.23	0.64
	June 01	7.96	5.19	0.64	0.19	1.31
	Aug 01	5.19	2.66	0.65	0.14	1.57
	Oct 01	7.43	4.02	0.47	0.26	0.70
Medium sand	Oct 00	23.92	12.20	1.79	3.77	14.11
	Dec 00	40.02	10.74	3.04	1.79	24.91
	Feb 01	37.74	14.43	2.40	2.78	28.84
	Apr 01	26.83	18.26	14.23	3.24	21.83
	June 01	31.22	18.27	3.37	2.78	22.83
	Aug 01	22.95	12.67	1.81	5.02	20.01
	Oct 01	30.63	14.90	2.78	5.21	22.43
Fine sand	Oct 00	55.08	74.16	93.64	91.80	78.71
	Dec 00	48.81	78.45	92.38	93.12	68.32
	Feb 01	50.99	75.11	91.90	90.81	67.55
	Apr 01	55.75	66.93	82.15	92.07	74.45
	June 01	58.03	67.83	88.91	91.43	72.98
	Aug 01	67.19	77.59	94.48	87.22	71.78
	Oct 01	58.56	73.67	92.42	89.44	63.30
Mud	Oct 00	4.00	8.13	2.77	4.09	3.46
	Dec 00	1.81	5.22	2.22	4.37	2.16
	Feb 01	2.37	5.49	2.81	5.39	1.73
	Apr 01	1.43	6.64	3.19	3.26	1.68
	June 01	2.04	3.97	2.24	4.91	1.54
	Aug 01	3.46	5.66	2.69	6.19	3.01
	Oct 01	2.29	5.32	2.75	3.43	13.01

Table 4. Chlorophyll *a* content of sediments collected from the monitored sites on each sampling occasion, from October 2000 to October 2001.

µg/g sediment	HBV	HC	Whau	Reef	ShB
Oct 00	10.26	9.53	8.35	7.28	5.25
Dec00	13.36	19.89	10.20	11.12	8.78
Feb 01	13.62	17.99	12.17	10.51	4.87
Apr 01	17.77	26.12	12.82	12.74	7.04
Jun 01	18.79	29.61	20.74	15.02	10.29
Aug 01	17.51	18.89	16.08	10.94	7.03
Oct 01	16.50	21.67	15.57	10.54	10.72

Table 5. Organic content of sediments collected from the monitored sites on each sampling occasion, from October 2000 to October 2001.

% dry weight	HBV	HC	Whau	Reef	ShB
Oct 00	0.95	1.61	0.76	0.90	0.63
Dec00	1.05	1.89	0.77	0.92	0.64
Feb 01	1.16	1.75	0.86	1.09	0.27
Apr 01	1.29	2.66	1.42	1.13	0.91
Jun 01	1.18	2.65	1.02	1.26	0.49
Aug 01	1.15	1.50	0.90	1.16	0.54
Oct 01	0.81	1.46	0.86	0.74	0.48

Rank abundance

Figure 2 shows rank abundance plots of numbers of individuals in each taxa collected at each monitored site in October 2000. These graphs show the spread of abundance among the species. None of the plots indicate a highly stressed community with few rare species and high numerical dominance by one or 2 species. At sites HC, Reef and ShB, the steep slope at the top of the curves is caused by a very high abundance of *Nucula*. The site Reef is showing some indications of stress.

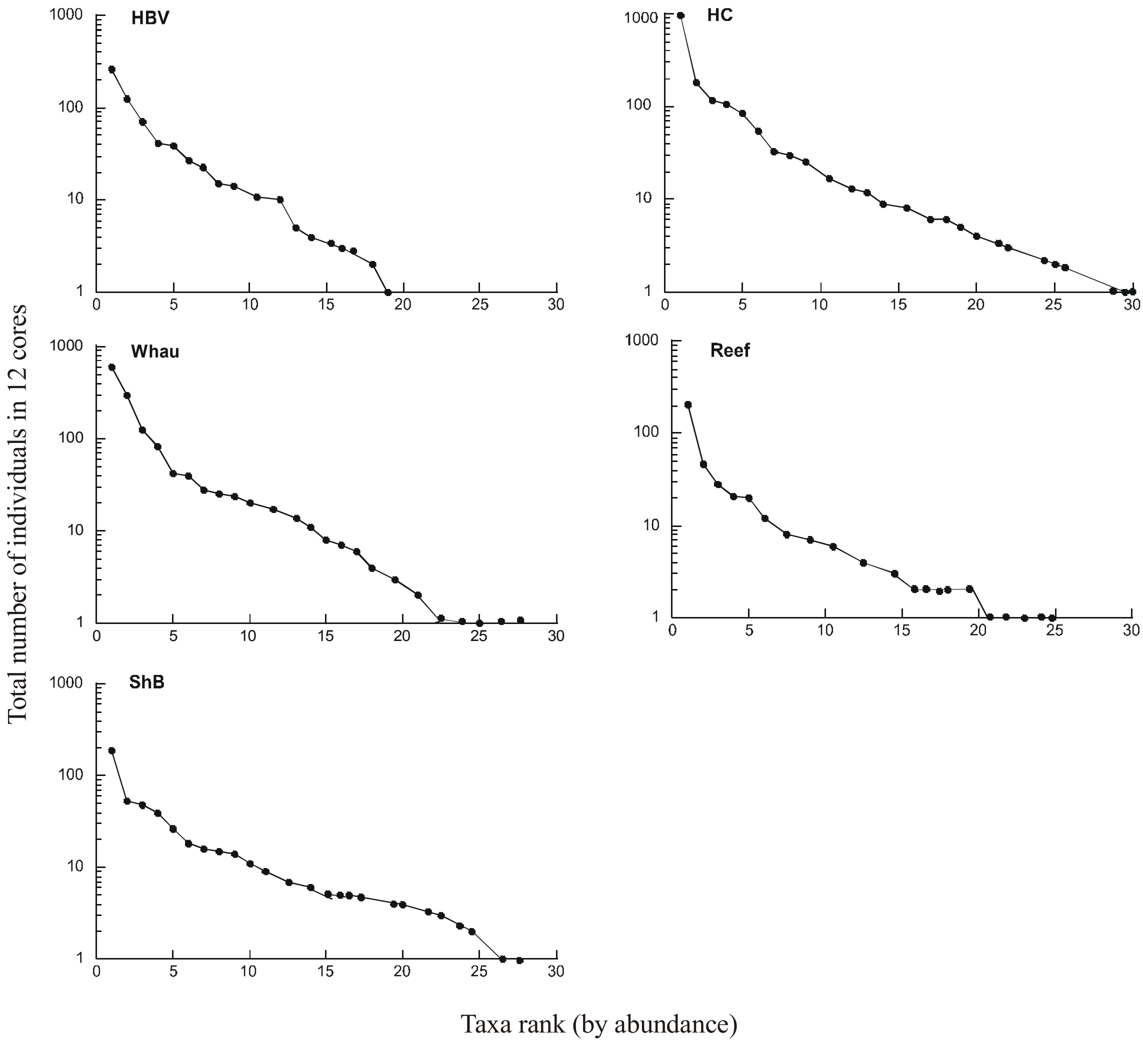


Figure 2. Distribution of individuals amongst taxa, on the first sampling occasion, October 2000.

Spatial variability

With-in site variability

Collecting 12 samples from each site on each sampling occasion resulted in sufficiently high precision (standard errors < 3.0 individuals per core) for most common taxa (See Table 6). Only the very abundant *Nucula*, at all sites, and *Aricidea*, at Whau, had standard errors larger than this. Curves of standard errors versus sample size constructed for the common species at all sites showed that most gains in precision (i.e., decreased standard errors) had been achieved with a sample size of 12 (e.g. Figure 3).

Table 6. Spatial variability of the monitored sites in October 2000. Values are presented as standard errors. '-' indicates an insufficient number of individuals to calculate an error.

	HBV	HC	Whau	Reef	ShB
Anthopleura	0.4	0.5	0.7	-	0.4
Arthritica	-	0.5	-	-	-
Aonides	0.1	2.2	0.1	0.1	0.4
Aquilaspio	1.2	0.9	1.3	0.2	0.1
Austrovenus	2.5	0.8	1.8	0.2	0.5
Aricidea	2.8	0.4	6.1	0.6	0.6
Boccardia	2.9	0.1	0.8	0.4	1.1
Colurostylis	0.3	0.4	0.3	0.2	0.4
Diloma	-	0.3	-	-	-
Exosphaeroma	0.1	0.1	-	-	-
Glyceridae	0.1	-	-	0.3	0.3
Haminoea	-	-	0.3	-	-
Heteromastus	0.1	-	0.1	0.2	0.1
Macomona	0.1	0.3	0.4	0.2	0.1
Nucula	11.7	4.4	8.5	2.9	3.5
Paphies	0.9	-	-	-	-
Zeacumantus	-	-	0.3	-	-

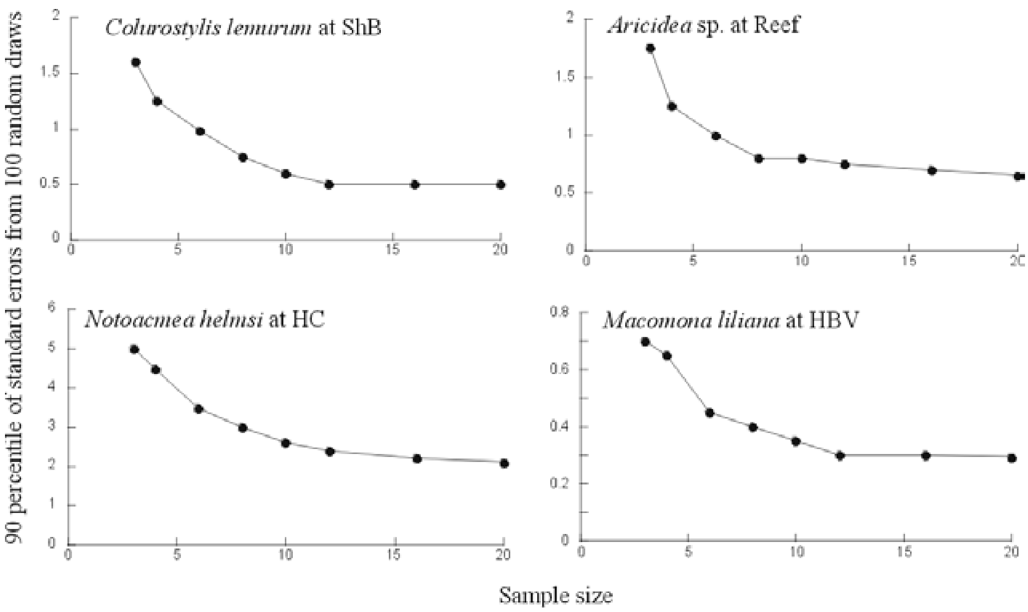


Figure 3. Examples of sampling precision versus effort curves for selected abundant taxa at selected sites, in October 2000. The 90 percentile standard error (i.e., the inverse of precision) drops sharply at first as the sample size increases, then the rate of drop decreases. (Sample size = number of cores)

Between-site variability

Significant differences in mean abundances between sites were found for all common taxa except *Colurostylis,* Glyceridae and *Heteromastus* (See Table 7).

Table 7. Differences in abundances of common taxa in October 2000. Sites that are significantly different from the others are separated by a '>' symbol. ns = not significant = p-value > 0.05 (using a generalised linear model, using either normal or poisson errors and a canonical link function).

	Result of multiple contrasts
Anthopleura	HC > HBV Whau ShB
Aonides	HBV > ShB Whau HC Reef
Aquilaspio	HC HBV Whau > Reef ShB
Austrovenus	HC Whau > HBV ShB Reef
Aricidea	Whau HC > Reef ShB HBV
Boccardia	HC ShB > Whau Reef HBV
Colurostylis	ns
Glyceridae	ns
Heteromastus	ns
Macomona	Whau > ShB HBV Reef HC
Nucula	HC > Whau > HBV Reef ShB

Temporal variability

Temporal variability in some of the more dominant species at each site is discussed below. There are some suggestions of trends and cycles in abundance, however as the monitoring data from Manukau and Mahurangi demonstrates, more data are needed to confirm these patterns. Figure 4a clearly shows the site-dependent nature of the differences in density and variation in temporal patterns for common macrofaunal species.

Hobsonville (HBV)

The total abundance of *Nucula* and *Austrovenus* increased over the monitored period (See Figure 4a). A peak in *Austrovenus* abundance was observed in April 2001, when 174 individuals were collected. The polychaete, *Aonides* also increased in abundance over the sampling period, from 145 individuals in October 2000 to 366 individuals in October 2001. The abundance of *Notoacmea* appeared to follow a cyclic pattern over time with a peak in June 2001 of 150 individuals. There were peaks in total abundance for *Anthopleura* and *Diloma* in June 2001 of 23 and 10 individuals respectively (See Figure 4a).

Henderson Creek (HC)

The abundance of *Nucula* and *Austrovenus* increased over the monitoring period (See Figure 4a). HC had the greatest number of *Notoacmea* at any of the sites, and their abundance appears to follow a cyclic pattern with a peak of 245 individuals in August 2001 (See Figure 4a). The abundance of *Diloma* increased markedly on the last sampling occasion (October 2001) to 43 individuals.

Whau River (Whau)

Nucula and *Austrovenus* both exhibited peaks in abundance in February 2001 and lowest numbers in April 2001. The abundance of *Notoacmea* and *Anthopleura* both decreased slowly over time following peaks in February 2001; however there is some suggestion of a cyclic abundance pattern for *Notoacmea*. Numbers of *Aonides* were generally low at this site, but had a peak in abundance in April 2001 (47 individuals; See Figure 4a).

Te Tokaroa Reef (Reef)

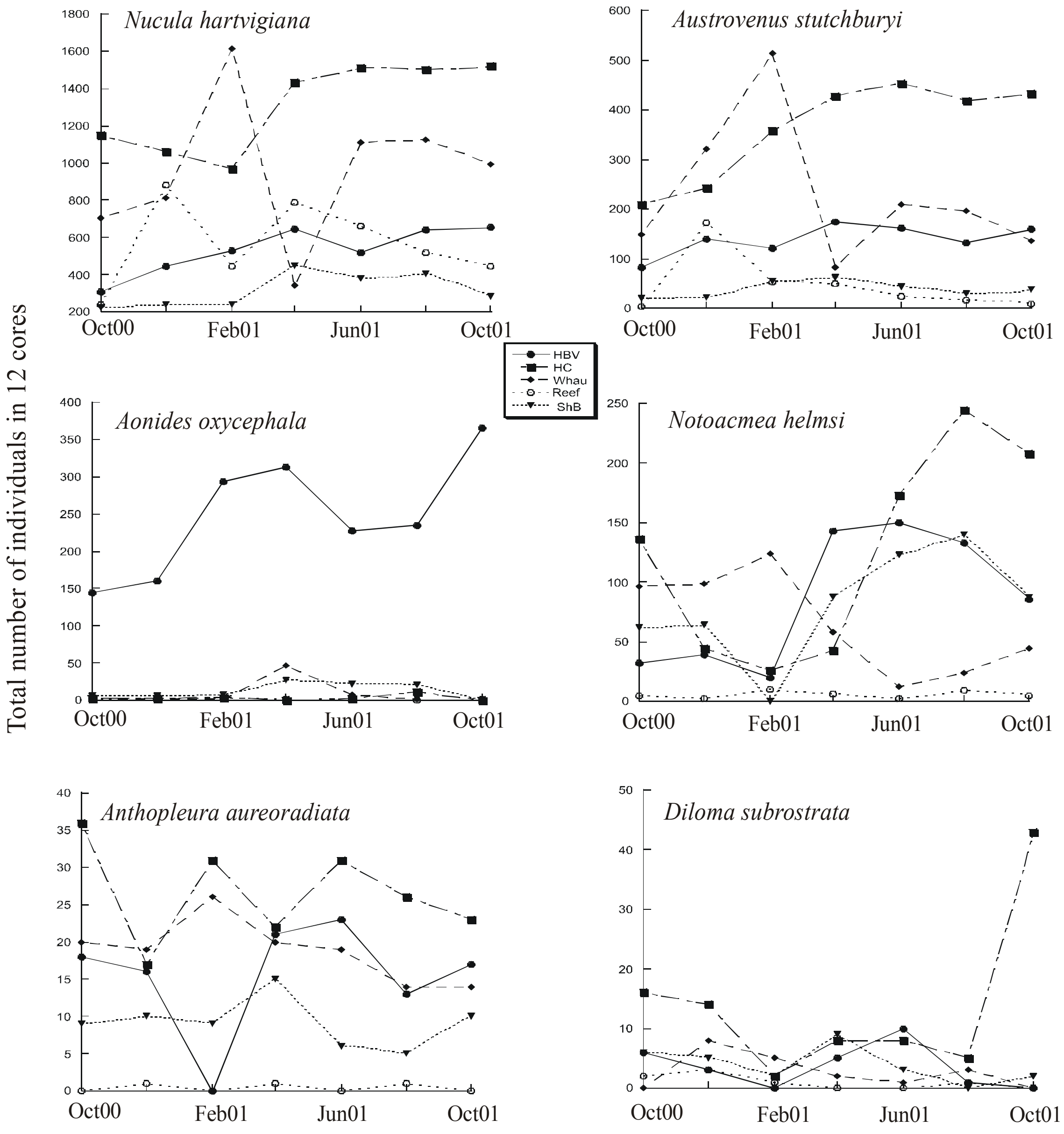
The abundance of *Nucula* at Reef was variable over the sampling period and peaks of 880 and 789 individuals were observed in December 2000 and in April 2001, respectively. *Austrovenus* had a peak in abundance in December 2000 (173 individuals), but otherwise numbers remained low at this site. The abundance of *Macroclymenella* decreased slightly over the monitoring period with highest numbers in February 2001 (38 individuals). The abundance of

Arthritica showed suggestions of a cyclic pattern, with a peak of 15 individuals in April 2001 (See Figure 4b). The abundance of *Colurostylis* had a huge pulse with 218 individuals, in June 2001 (See Figure 4b).

Shoal Bay (ShB)

Nucula exhibited consistent numbers at ShB, with 223 - 448 individuals. *Austrovenus* at ShB had a peak in abundance in April 2001. Like HC, *Notoacmea* abundance at ShB peaked in August 2001 (See Figure 4a).

Figure 4a. **Total number of individuals for selected species collected on each sampling occasion, from October 2000 to October 2001, at each of the monitored sites. On each occasion all individuals from the 12 cores were pooled.**



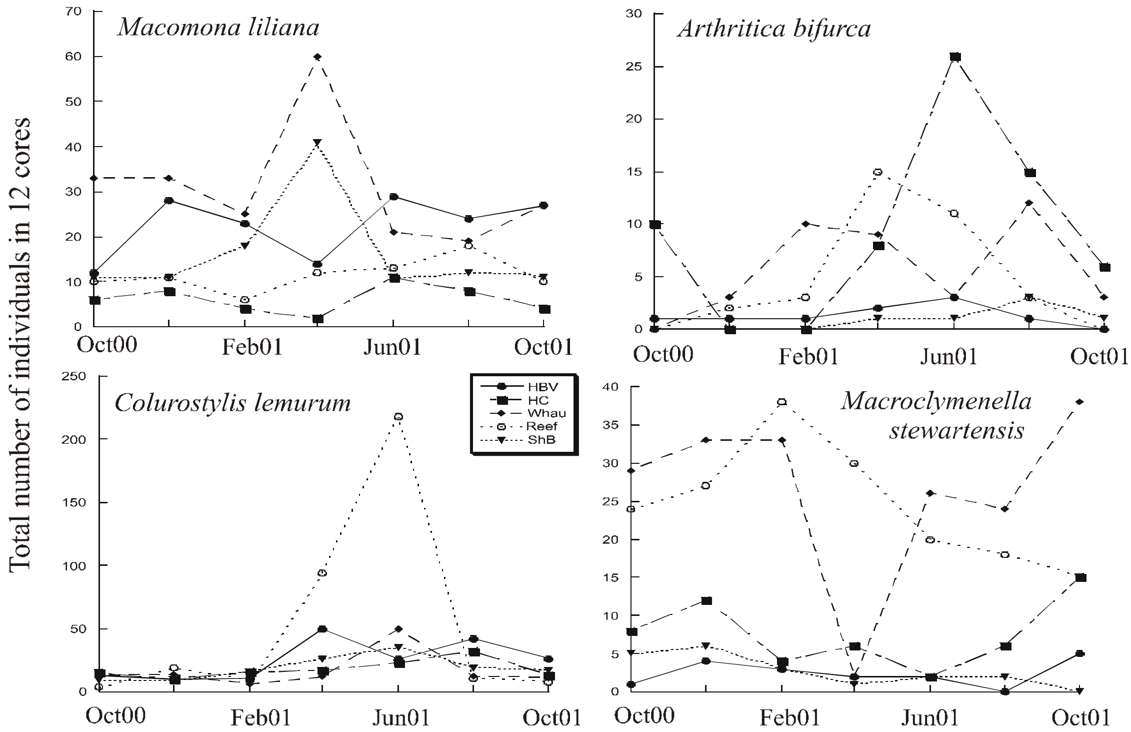


Figure 4b. Total number of individuals for selected species collected on each sampling occasion, from October 2000 to October 2001, at each of the monitored sites. On each occasion all individuals from the 12 cores were pooled.

Grain size, chlorophyll *a* and organic content

Generally there was little change in the sediments overall grain size, at each site, over the sampling period (October 2000 to October 2001), except for the high proportion of mud observed at ShB in October 2001 (13.01 %) (See Table 3). In general chlorophyll *a* levels were highest in June 2001, with the exception of ShB, which had its maximum (10.72 µg/g sediment) in October 2001 (See Table 4). Organic content did not vary significantly over the sampling period, however peaks in organic content were observed in April 2001 at all sites, except Reef (See Table 5).

Community patterns

Figure 5 shows an ordination reflecting the relative composition of all taxa from the monitored sites and the temporal changes in these communities over the sampling period. In October 2000, the benthic community at each of the monitored sites was distinctly different. Benthic communities at HBV were the most distinct from the other sites, followed by Reef, while communities at ShB, HC and Whau were more similar.

Benthic communities at HBV, HC and ShB did not change significantly over the sampling period. The benthic community at Reef showed the largest temporal variation. The communities at HBV, Reef and ShB each remained distinctly different to at all other sites. Benthic communities at Whau made one major shift in April 2001. This was possibly a reaction to a short-term disturbance, because on the next sampling occasion the benthic community had reverted, so that it was similar to that previously observed. In December 2000, February and April 2001, the communities at Reef became more similar to that of ShB; however later in the year, the composition differed considerably.

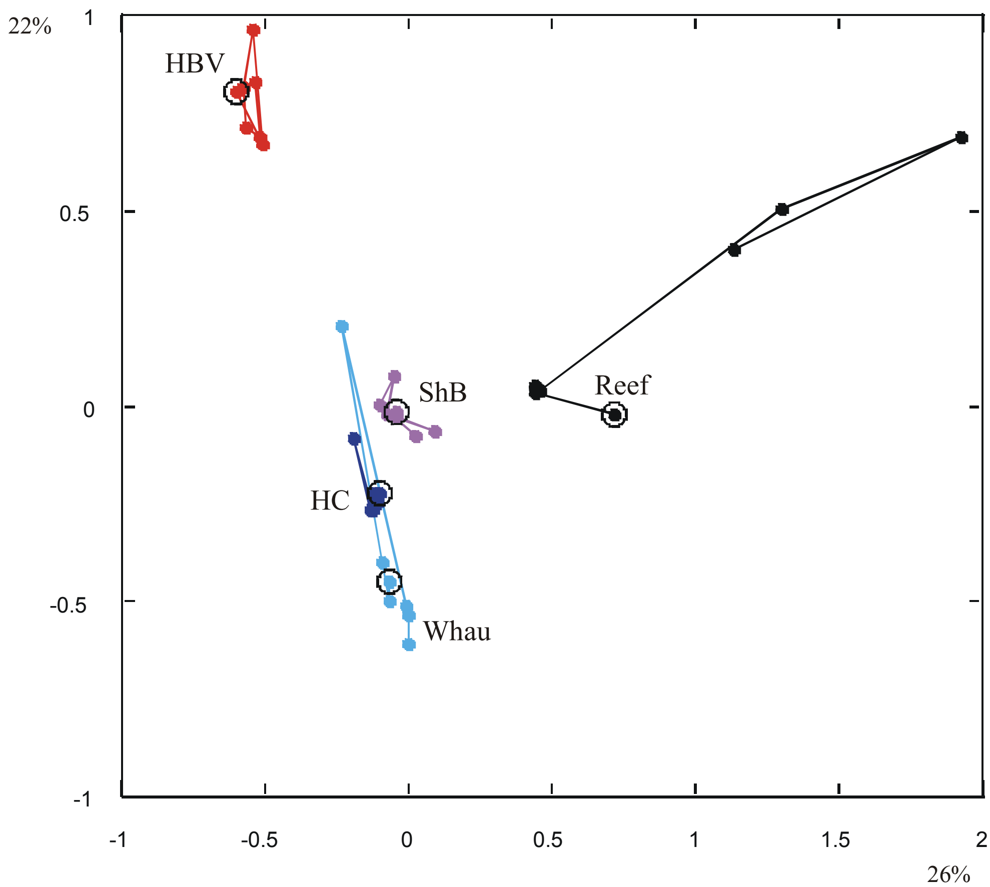


Figure 5. Correspondence analysis showing temporal variation in macrobenthic community composition at each of the five monitored sites, from October 2000 to October 2001. The start position is marked with a black, open circle. (26% of the variation in community composition is explained by the x axis, 22% is explained by the y axis.)

Taxa selected for monitoring

Twenty taxa are recommended for monitoring (See Table 8).

Table 8. List of twenty taxa recommended for ongoing monitoring in the Waitemata Habour long-term monitoring programme. Information on whether a taxon is monitored at the other sentinel sites, Manukau and Mahurangi, is also given.

Order	Taxa	Currently monitored	
		Manukau	Mahurangi
Isopoda	*Exospheroma* sp.	✓	✗
Bivalvia	*Arthritica bifurca*	✗	✓
	Austrovenus stutchburyi	✓	✓
	Macomona liliana	✓	✓
	Nucula hartvigiana	✓	✓
	Paphies australis	✗	✗
Cnidaria	*Anthopleura aureoradiata*	✓	✗
Cumacea	*Colurostylis lemurum*	✓	✗
Gastropoda	*Diloma subrostrata*	✗	✗
	Haminoea zelandiae	✗	✗
	Notoacmea sp.	✓	✓
	Zeacumantus lutulentus	✗	✗
Polychaeta	*Aonides oxycephala*	✓	✓
	Aquilaspio aucklandica	✓	✓
	Aricidea sp.	✗	✓
	Boccardia syrtis	✓	✗
	Euchone sp.	✗	✗
	Glyceridae	✓	✗
	Heteromastus filiformis	✗	✓
	Macroclymenella stewartensis	✓	✗

Taxa were selected using the following criteria:

- Taxa abundance

Taxa that are abundant at one or more sites should be monitored. For example, differences in patterns or trends in abundance of a particular taxa between sites may indicate site specific disturbances.

- Potential key species

Taxa which due to their size, abundance or activities, modify community structure and function. For example, *Boccardia* make and live in fine tubes forming 'mats' that stabilise sediments and affect hydrodynamic flows at the sediment-water interface.

- A variety of niches

Taxa from a variety of niches react to disturbances differently. For example, surface dwellers may be more affected by some types of disturbances than sub-surface dwellers; suspension feeders will be more affected by increased suspended sediment levels in water than deposit feeders.

- Prey species

All the macroinvertebrates chosen are an important food source for fish, birds and in some cases other macrofauna. Examples include *Colurostylis,* which is a prey source for fish and birds.

- Response to disturbance

Taxa that respond in a characteristic manner to disturbance or are sensitive to pollution should be monitored. Studies on the response of invertebrates to increased clay/silt sediments has identified both sensitive and tolerant species (Norkko et al., 2001, Nicholls et al., 2000).

- Practical aspects

Time and financial constraints dictate that monitored taxa should be easy to identify. This does not just exclude rare taxa, as some frequently collected species take more time to identify.

- Taxa currently monitored at other sentinel locations

Consideration for inclusion in the monitored list was also given to species which are currently monitored as part of long-term monitoring programmes in Manukau and Mahurangi Harbours, thus enabling between-harbour comparisons to be made in the future.

Taxa Descriptions

Isopoda

In general isopods are an important food source for birds and fish.

The isopod, *Exospheroma* spp. is a scavenger/ predator that lives and burrows in the top 2 cm of the sediment, and rarely grows more than 5 mm in length. Potentially, 3-4 species of *Exospheroma* are present within the Waitemata. *Exospheroma* were observed in low numbers at all the monitored sites, except ShB.

Bivalvia

In general, bivalves are an important food source for birds, fish, polychaetes, shrimp, gastropods, and humans.

Arthritica bifurca is a small deposit-feeding bivalve that prefers living in muddy-sand habitats, but is sensitive to increasing amounts of mud. These bivalves do not grow more than 5 mm in size. *Arthritica* were found at all the monitored sites. Highest numbers of *Arthritica* were observed at HC and the lowest at ShB.

Austrovenus stutchburyi (cockle) is one of the most common intertidal bivalves. *Austrovenus* is a surface suspension-feeder and is highly mobile both as juveniles and adults. They are found in a range of sediment types, from sand to mud. In the North Island individuals of 35 mm shell length are considered large. *Austrovenus* are found in the top 5 cm of sediment, and often have algae, worm tubes, anemones or barnacles attached to their shell. *Austrovenus* are an important food source for birds, fish, and humans and their presence has the potential to affect the distribution of predator species. Recent research has shown that adult *Austrovenus* respond positively to relatively high levels of suspended sediment concentrations over short periods, although they react negatively to high concentations of recently suspended terrigenous clay and silt (Hewitt et al., 2001). *Austrovenus* was abundant at all the monitored sites.

Macomona liliana (wedge shell) is a common surface deposit-feeder, which prefers sandy to muddy-sand habitats. Adults generally grow to approximately 5 cm in length and are relatively sedentary. Juveniles are highly mobile moving both with the sediment bedload and by drifting in the water column. High densities of adult *Macomona* of all sizes can have a strong effect on many other macrofaunal species living near-by and. they are also very important prey items for fish and birds. For both these reasons, *Macomona* can have an important effect on macroinvertebrate community structure. *Macomona* was common at HBV, Whau, ShB, and Reef. It was present at HC, but only in low numbers.

Nucula hartvigiana (nut shell) is a deposit-feeder, which prefers to live in the top 2 cm of muddy-sand to sandy-mud habitats. *Nucula* are rarely found larger than 8 mm in length, however they are highly mobile and are probably capable of rapid, small-scale colonisation. *Nucula* are moderately sensitive to terrestrial silt/clay deposits (Norkko et al., 2000). *Nucula* was abundant at all the monitored sites, especially HC and Whau.

Paphies australis (pipi) is a suspension feeder that lives in the top 10 cm of the sediment. Juveniles are frequently found in fine sand and sandy-mud habitats, while adults prefer coarser sand and fast currents. Individuals can reach up to approximately 10 cm in shell length and frequently occur in very dense patches. *Paphies* are highly mobile as both adults and juveniles. *Paphies* are an important food source for birds and humans. Recent research has shown *Paphies* are sensitive to elevated suspended sediment levels and to increasing mud content of the sediment (Hewitt et al., 2001). *Paphies* was common at HBV and occurred in low numbers at Whau, Reef and ShB.

Cnidaria

Anthopleura aureoradiata is a small predatory anemone, which is often found on the sediment surface attached to shells (particularly *Austrovenus*) or pieces of wood. This species can grow up to 10 mm in diameter and is intolerant of low-salinity, high-turbidity and increasing silt/clay sediment content (Norkko et al. 2001). Laboratory tests have shown that *Anthopleura* are very tolerant to a range of Polycyclic Aromatic Hydrocarbons (PAH's). *Anthopleura* are also tolerant to UV light, because they have mycosporine-like amino acids in their tissue which acts like biological sunscreen (Dr M. Ahrens, *pers. com.* NIWA). *Anthopleura* occurred at all of the monitored sites except HC.

Cumacea

Colurostylis lemurum is a detritus feeder. *Colurostylis* is semi-pelagic and lives in the surface sediments and in the benthic boundary layer. *Colurostylis* are prey for birds and fish. They have been reported to be sensitive to various forms of pollution, including increasing silt/clay content of the sediment (Agg et al., 1978). *Colurostylis* occurred at all the monitored sites in low-medium abundances.

Gastropoda

In general, gastropods are an important food source for birds.

Diloma subrostrata is a grazer, often found around stones and on shells. *Diloma* are highly mobile at the sediment surface and are very sensitive to increasing silt/clay content of the sediment (Norkko et al., 2001). *Diloma* occurred at all the monitored sites and was common at HC.

Haminoea zelandiae (bubble shell) is a predator. It is highly mobile and is common on mudflats and amongst sea grass. *Haminoea* occurred at all monitored sites except for HBV. In general, it's abundance was low.

Notoacmea helmsi is the most common soft-sediment limpet in North Island estuaries. It is usually associated with stones or dead shells on intertidal sand and muddy-sand flats. *Notoacmea* varies widely in shape and colouring. Limpets in general have been found to be sensitive to sewage pollution, and *Notoacmea* is also highly sensitive to fine sediments. *Notoacmea* was common, although not abundant, at all monitored sites. It's greatest abundance was observed at HC.

Zeacumantus lutulentus is a common turret shell. *Zeacumantus* is a highly mobile deposit-feeder that prefers to live just beneath the sediment surface in muddy areas with floating debris. Not only are *Zeacumantus* grazers, but they are scavengers and possibly predators as well (Morton and Miller 1973). *Zeacumantus* was present at all sites except for ShB. It was generally observed in low numbers, except for Reef, where it was common.

Polychaeta

Aonides oxycephala, a spionid, is a small surface deposit-feeding polychaete that lives throughout the sediment to a depth of 10 cm. Although *Aonides* is free-living, it is not very mobile and prefers to live in fine sands. *Aonides* is very sensitive to changes in the terrigenous silt/clay content of the sediment. In general, polychaetes are important prey items for fish and birds (Norkko et al. 2001). *Aonides* was present at all monitored sites. It was abundant at HBV.

Aquilaspio aucklandica is another surface deposit-feeding spionid. It is slightly larger than *Aonides* and prefers living in muddy sands. Despite this, like *Aonides*, *Aquilaspio* is very sensitive to changes in the level of terrestrial silt/clay in the sediment and to terrestrial sediment depositions (Nicholls et al., 2000, Norkko et al., 2001). *Aquilaspio* was present at all monitored sites, and was abundant at HBV.

Aricidea sp., a paraonid, is a small sub-surface, deposit-feeding worm found in muddy-sands. These occur throughout the sediment down to a depth of 15 cm and appear to be sensitive to changes in the mud content of the sediment. Some species of *Aricidea* are associated with sediments with high organic content (Lim and Hong, 1997) *Aricidea* was present at all monitored sites in low numbers, and was abundant at Whau.

Boccardia sp. is a small surface deposit-feeding spionid. *Boccardia* lives in a range of habitats from exposed fine sand to sheltered sandy-mud. It lives in flexible tubes constructed of fine sediment grains, and can form dense mats on the sediment surface. *Boccardia* can play a key role in maintaining community structure because it's mats stabilize the sediment surface (Hewitt, 2000) *Boccardia* was present at all monitored sites except for Whau.

Euchone sp. (fan worm) is a small filter-feeding sabellid. It is frequently found encased in a sandy tube which protrudes above the sediment surface. *Euchone* was abundant at Reef, only present in low numbers at HC and ShB, and was absent from HBV and Whau.

Glyceridae (blood worms) are predators and scavengers. They are typically large, and are highly mobile throughout the sediment down to depths of 15 cm. They are distinguished by having 4 jaws on a long eversible pharynx. Glyceridae were present in low numbers at all monitored sites.

Heteromastus filiformis is a sub-surface, deposit-feeder that lives throughout the sediment to depths of 15 cm, and prefers a muddy-sand substrate. Despite being a capitellid, *Heteromastus* is not opportunistic and does not show a preference for areas of high organic enrichment as other members of this polychaete group do (Hewitt, 2001). *Heteromastus* was present at all the monitored sites in low numbers.

Macroclymenella stewartensis, a maldanid, is a sub-surface, deposit-feeder that is usually found in tubes of fine sand or mud. This species is found throughout the sediment to depths of 15 cm and potentially has a key role in re-working and turn-over of sediment. This worm may modify the sediment conditions, making it more suitable for other species (Thrush et al., 1988). *Macroclymenella* was present at all sites and was common at Whau and Reef.

Amphipoda

Amphipods were not included in the monitored species list because, in general, they were found in low numbers (except for ShB). Amphipods can be difficult and time-consuming to identify and, more importantly, their abundances are extremely variable both spatially and temporally, making it difficult to detect meaningful changes in their abundance.

Trend detection

For each monitored taxa, the trend that would be able to be detected after five years of bimonthly monitoring was predicted, assuming that temporal variability would not change over this time period. The magnitude of the detectable trend varied from 1.7 to 40.2 individuals per core (See Table 9), with taxa that occurred in higher abundances needing larger changes in abundance before trends could be detected. Given the number of these taxa that, after one year of monitoring, display seasonal cycles, we can anticipate that time series analysis will enable us to detect trends of smaller magnitude than those in Table 9.

Table 9. Predicted magnitude of the trend (number of individuals per core) predicted to be able to be detected after 5 years of monitoring. Trends were predicted using methods described in Ward et al. (1990). '-' indicates insufficient numbers of individuals to make a prediction.

Monitored taxa	HBV	HC	Whau	Reef	ShB
Anthopleura	1.8	2.4	1.9	-	1.7
Aonides	14.4	-	4.0	-	2.9
Aquilaspio	6.0	6.2	2.7	2.8	2.2
Aricidea	2.4	7.6	14.4	4.7	3.4
Arthritica	-	-	-	2.7	-
Austrovenus	5.2	30.0	26.6	11.0	3.8
Boccardia	-	5.2	2.5	14.1	2.6
Colurostylis	3.7	2.5	3.6	8.4	2.9
Diloma	-	3.5	-	-	-
Euchone	-	-	-	40.2	-
Exosphaeroma	2.3	-	-	-	-
Glyceridae	-	1.9	-	-	-
Haminoea	-	-	-	2.4	-
Heteromastus	-	2.1	-	1.8	-
Macomona	2.4	-	3.6	1.9	3.1
Macrocylmenella	-	-	3.2	2.6	-
Notoacmea	7.0	15.6	6.1	-	6.0
Nucula	22.4	72.9	77.8	41.6	16.5
Paphies	4.2	-	-	-	-
Zeacumantus	-	-	-	3.3	-

4. Conclusions and Recommendations

Results from the first year of sampling indicate that physical and biological conditions such as sediment grain-size, organic content, chlorophyll *a* content and wind-wave exposure are quite different at some of the monitored sites. Each site is representative of a distinct habitat within the harbour and, as illustrated by the correpondence analysis, the community compositions at each site are also distinctly different. Therefore it is important to continue sampling at each of the five monitored sites.

All sites exhibit temporal variability in their communities and sediment characteristics, caused by natural fluctuations related to recruitment events and storm disturbances. In order to isolate these natural trends and identify those changes due to human impacts we recommend ongoing monitoring every second month. Regular, relatively frequent, sampling throughout the year means that our analyses will be more powerful, and the results more ecologically meaningful.

The relative abundances of taxa at the monitored sites in central Waitemata are similar to those found in the Manukau and Mahurangi Harbours, although Waitemata has greater numbers of *Nucula*. It will be useful, in the future, to compare patterns and trends in abundance from these other sentinel locations with those observed in Waitemata. Therefore we recommend keeping all of the methods for sampling and processing the same.

Twenty taxa are recommended for ongoing monitoring, all of which are identified to the species or genus level.

5. Acknowledgements

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