Central Waitematā Harbour Ecological Monitoring: 2000-2014

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Central Waitematā Harbour Ecological Monitoring: 2000-2014

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1 Executive summary

This report details the results of the State of the Environment monitoring programme for the Central Waitematā Harbour conducted between October 2000 and February 2014. The focus of the programme is to monitor the ecological status of the harbour, and determine any trends in macrobenthic communities and the sediment they live in. The programme consists of six intertidal soft-sediment sites monitored on a rotational basis, four of which are currently monitored. The sites near Hobsonville and Whau, and one site in Shoal Bay have all been monitored since 2000, with a site in Lower Shoal Bay being added in October 2010, to monitor the effect of a predicted increase in sedimentation and metal contamination in this area. The monitoring focuses on 20 taxa which are expected to respond differently to anthropogenic stressors.

This report addresses several questions relevant to State of the Environment monitoring:

- Have there been any changes in the characteristics of each site or the surrounding areas?
- Have there been any changes in the monitored benthic communities of Central Waitematā Harbour and are these of concern?
- Are any changes observed confined to one site or area of the harbour, or do they reflect a harbour-wide change?

The sites near Hobsonville and the Whau Estuary have shown minimal change in site characteristics as sediment composition over the last few years. The site near Hobsonville has shown minor changes in the hydrodynamics, with a tidal drainage channel moving onto a small area of the site. However, this channel has stabilised over recent years. The older site on the western side of Shoal Bay has decreased in tidal height. It is now rarely exposed at low tide and has become muddier.

Most of the temporal variation in community composition observed at the Hobsonville and Whau sites are minor changes relating to seasonality and multi-year patterns in abundance. Larger trends in species abundances associated with increasing mud content have been seen at the older Shoal Bay. The newer site in Lower Shoal Bay has not been monitored long enough for trends to be identified with confidence.

There are no indications of a harbour-wide change; instead changes are limited to the older site in Shoal Bay. Unfortunately it is not possible to determine whether similar changes are occurring across the whole of Shoal Bay. The sediment at the new site in Shoal Bay is mainly fine sand and mud, and as the taxa are those that are relatively tolerant of mud, it is likely that further sedimentation will result in only subtle changes in the monitored populations and the broader macrofaunal community, changes that may be hard to detect. Because of this we recommend that sandier areas within Shoal Bay area are investigated for a potential location to replace the two muddy Shoal Bay sites.

We also recommend that a scientist who is familiar with the sites should be present during two field samplings per year to ensure continuity of sampling while Auckland Council staff changes are occurring.

Sites near Henderson Creek and Meola Reef have not been monitored since April 2010. These sites will be rotated back into the monitoring programme in June 2015.

2 Introduction

In October 2000 a State of the Environment monitoring programme for the Central Waitematā Harbour was developed for the Auckland Regional Council. The programme was designed to be scientifically credible, practical, affordable and to meet the requirements of the Resource Management Act 1991. The focus of this programme is to monitor the ecological status of the harbour, and determine any trends in macrobenthic communities and the sediment they live in.

Hewitt (2000) suggested that the Central Waitematā would be best represented by six intertidal sites; five from soft-sediment habitats and one from a rocky habitat. In 2000, NIWA was commissioned to monitor the soft sediment sites and the University of Auckland was commissioned to monitor the rocky site at Meola Reef. The soft-sediment sites were selected for monitoring in consultation with the Auckland Regional Council, and were chosen to integrate multiple aquatic inputs while remaining at a distance from any industry-specific contaminant sources. A site was placed in each of five sub-regions of the Central Waitematā Harbour, based on hydrodynamics and drainage areas with significant intertidal habitats (Figure 1; Hewitt 2000). Details on site selection are given in the first report (Nicholls et al. 2002). In a continuation of the spatially and temporally nested monitoring design, which has proved cost-effective in the Manukau, two of these sites are not being monitored at present; those near Henderson Creek and Meola Reef (Townsend et al. 2010).

The Lower Shoal Bay (LoS) site was established in October 2010 as predictions of future sediment and contaminant movement within the Waitematā Harbour identified this area as a contaminant depositional area (Green 2008). This is due to the tidal flow dynamics which means that Shoal Bay receives a higher proportion of sediment emerging from Henderson Creek than other intertidal areas.

The monitoring focuses on a selection of 20 species (Table 2, see Nicholls et al. 2002 for selection criteria) that can be expected to respond to changes in their environmental surroundings. This method has proved useful in monitoring both the Manukau and Mahurangi Harbours, and has been further validated in work carried out by NIWA and the University of Auckland on ways of defining benthic community health (Anderson et al. 2002).

This report presents the results from monitoring four soft-sediment sites between October 2000 and February 2014, and details the present status of the benthic communities in the Central Waitematā Harbour. In particular the following questions are addressed:

- Have there been any changes in the characteristics of each site or the surrounding areas?
- Have there been any changes in the monitored benthic communities of Central Waitematā Harbour and are these of concern?
- Are any changes observed confined to one site or area of the harbour, or do they reflect a harbour-wide change?

Figure 1.

Map of the Waitematā Harbour showing the four soft-sediment monitoring sites at Hobsonville (HBV), Whau River (Whau), Shoal Bay (ShB) and Lower Shoal Bay (LoS) (black circle symbols); and the two sentinel sites Henderson Creek (HC) and Te Tokoroa Reef (Reef) that have not been monitored since February 2010 (red square symbols).

3 Methods

During the 2012 – 2014 period, four soft-sediment sites were sampled representing three different drainage sub-regions of the Central Waitematā harbour: Hobsonville (HBV), Whau River (Whau), and Shoal Bay (ShB and LoS) (see Figure 1). Two previously sampled monitoring sites were not sampled between April 2010 and February 2014 (Reef and HC). Sites are located at the mid-tide level, with the exception of LoS (which appears to be lower on the shore; discussed below), and each cover an area of 9000 m^2, with the exception of HBV (which covers 10,800 m^2). Sites are located in areas that are representative of the general character of the surrounding intertidal environment and are as close to channels as practical (to aid access). Sites are marked by wooden stakes and can be located using GPS coordinates (Table 1).

Table 1.

Dimensions and GPS co-ordinates for the Central Waitematā monitored sites in 2012 - 2014. Lower Shoal Bay (LoS), Hobsonville (HBV), Whau River (Whau) and Shoal Bay (ShB). GPS co-ordinates mark the 0,0 point of each site.

Site	Dimensions (m)		GPS coordinates in NZTM	
	X	Y	North	East
LoS	100	90	5924310	1757533
HBV	150	60	5926077	1749644
Whau	100	90	5920785	1748809
ShB	180	50	5923855	1756645

Methods and techniques used for sampling and sample processing are consistent with those used at the established sentinel locations of Mahurangi and Manukau Harbours, and have been detailed in a previous report (Nicholls et al. 2002). Sampling in the Central Waitematā Harbour began in October 2000, and is conducted every two months by Auckland Council staff. The methods used are briefly described below.

3.1 Macrofauna

On each sampling occasion, 12 sediment cores (13 cm diameter, 15 cm deep) are collected from each site. To provide an adequate spread of cores over the site, each site is 'divided' into 12 equal sections and one core is taken from a random location within each section (see Appendix 10.3). To reduce the influence of previous sampling activity and spatial autocorrelation, 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. Samples are then sorted and stored in 50 % isopropyl alcohol. The 20 selected species (see Table 2) are identified, counted and stored in 50 % isopropyl alcohol. Other macrofauna are not discarded; rather they are kept to be processed if other funding becomes available. All taxa collected during the October sampling each year are identified and enumerated for use in regional indicators of benthic health.

Table 2.

The 20 taxa recommended for long-term monitoring in the Waitematā Harbour monitoring programme. Where genera and species names have changed with taxonomic refinement, the names in brackets indicate the previous name. For example, *Nucula* is now called *Linucula*, and *Exosphaeroma chilensis* is now *Exosphaeroma planulum*.

Order	Taxa
Bivalvia	*Arthritica bifurca*
	Austrovenus (Chione) stutchburyi
	Macomona (Tellina) liliana
	Linucula (Nucula) hartvigiana
	Paphies australis
Cnidaria	*Anthopleura aureoradiata*
Cumacea	*Colurostylis lemurum*
Gastropoda	*Diloma subrostrata*
	Haminoea zelandiae
	Notoacmea scapha (helmsi)
	Zeacumantus lutulentus
Isopoda	*Exosphaeroma (chilensis) planulum*
Polychaeta	*Aonides trifida (oxycephala)*
	Prionospio (Aquilaspio) aucklandica
	Aricidea sp.
	Boccardia syrtis
	Euchone sp.
	Glycera americana
	Heteromastus filiformis
	Macroclymenella stewartensis

3.2 Bivalve size-class analysis range

After identification, individual *Austrovenus stutchburyi, Macomona liliana* and *Paphies australis* are measured and placed into size classes. The size classes for *Austrovenus* and *Macomona* are <5 mm, 5 – 10 mm, 10 – 15 mm, 15 – 20 mm and then in 10 mm increments. *Paphies* size-classing is the same initially but, after the 15 - 20 mm, changes to 20 mm increments (20 - 40 mm, 40 – 60 mm, >60 mm). This is consistent with size classes used in the Manukau and Mahurangi monitoring programmes. *Linucula (Nucula) hartvigiana* is not measured as the high densities found at some sites make this economically impractical, and previous size classing in Manukau and Mahurangi have shown high variability due to the small size of this shellfish. Instead, only those bivalve species which grow to be relatively large, and have juveniles which are more sensitive to stress than adults, are measured.

3.3 Site characteristics

During each site visit by Auckland Council staff, attention is paid to the appearance of the site and the surrounding sand flat. In particular, surface sediment characteristics and the presence of birds, plants and epifaunal species are noted. The sites are also inspected by an experienced person from NIWA once a year to examine long-term changes in broader site characteristics. In April 2014, the sites were inspected by Dr Carolyn Lundquist from NIWA, who has undertaken an annual visit to all sites since 2000, with the exception of 2011. Sediment samples are also taken for grain size, organic content and chlorophyll *a.* 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 taken, which is then digested in ~ 9% hydrogen peroxide until frothing ceases. The 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 ≤3.9 μm. All fractions are then dried at 60^oC until a constant weight is achieved (fractions are weighed at ~ 40 hr and then again at 48 hr). 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* is extracted by boiling the sediment in 90% ethanol, and the extract processed using a spectrophotometer. An acidification step is used to separate degradation products from chlorophyll *a*.

Organic content: Approximately 5 g of sediment is placed in a dry, pre-weighed tray. The sample is then dried at 60^oC until a constant weight is achieved (the sample is weighed after ~ 40 hr and then again after 48 hr). The sample is then ashed for 5.5 hr at 400^oC (Mook and Hoskin 1982) and reweighed.

3.4 Statistical analyses

For macrofauna, all analyses were performed on the sum of the twelve cores collected at a site on each sampling occasion. For sediment the analyses were conducted on the grain size and chlorophyll *a* results from each site on each sampling occasion.

Regression analysis was used to investigate the potential for linear trends over time for sediment properties and macrofauna. Auto-correlation was investigated in the trend analysis using chi-square probabilities. Where auto-correlation was indicated, increasing or decreasing trends were investigated by adjusting parameters and significance levels (*AUTOREG* procedure, SAS). Otherwise ordinary least squares regression was carried out. Where a statistically significant trend was observed ($p < 0.05$) residuals were examined and the original time series was assessed to verify that the trend was not driven by cyclic patterns. Regression analysis was linear unless a step trend was indicated or a logarithmic transformation was required.

Rank abundance tables and multivariate ordinations of macrofaunal community data collected in October of each year were used to determine if there had been temporal variations in community composition between years. Rank abundance tables were constructed for the 5 most numerically dominant taxa. Ordination of October raw and 4^{th} root transformed data was performed, using non-metric multidimensional scaling (MDS) of Bray Curtis similarities and correspondence analysis of chi-square distances.

3.5 State of the environment indicators

3.5.1 Traits-Based Index

Organisms can be categorised according to characteristics (traits) that are likely to reflect ecosystem function (i.e., their feeding mode, degree of mobility, position in the sediment column, body size, body shape, capacity to create tubes/pits/mounds, etc.). During 2010 and 2011, an index based on these biological traits was created (van Houte-Howes and Lohrer 2010) and improved (Lohrer and Rodil 2011). The index is based on seven broad trait categories (living position, sediment topography feature created, direction of sediment particle movement, degree of mobility, feeding behaviour, body size, body shape and body hardness). Specifically the richness of taxa exhibiting seven particular traits: living in the top 2 cm of sediment, having an erect structure or tube, moving sediment around within the top 2 cm, being sedentary or only moving within a fixed tube, being a suspension feeder, being of medium size, or being worm shaped. Values of this index range from 0-1, with values close to 0 indicating low levels of functional redundancy and highly degraded sites. Values closest to 1 indicate high levels of functional redundancy, which is indicative of healthy areas (high functional redundancy tends to increase the inherent resistance and resilience in the face of environmental changes, Hewitt et al. (2012)). The index has been refined over the last couple of years (Hewitt et al. 2012) with the SUMmax parameter modified to allow the metric to be applied to a wider range of sites and those sampled with differing numbers of replicates (Lohrer and Rodil 2011).

3.5.2 Benthic health models

The original benthic health model (**BHMmetals**) was developed by Auckland Regional Council, Marti Anderson (then Auckland University) and Simon Thrush and Judi Hewitt (NIWA), to determine the health of macrofaunal communities relative to storm-water contaminants. The model is based on a multivariate analysis of the variation in macrofaunal community composition related to total sediment copper, lead and zinc concentrations, extracted from the 500 µm fraction of the sediment (Anderson et al. 2006).

In 2010-2011, another model was developed, this time to determine health relative to sediment mud content (BHMmud, Hewitt and Ellis 2011). At the time of the development of this model it was determined that, while there was some crossover between community compositions found in response to high mud and high contaminants, the two effects could still be separated.

Both models are based on the community composition observed at 84 intertidal sites in the Auckland Region between 2002 and 2005. The sites are within tidal creeks, estuaries or harbours, but do not include exposed beaches. They cover a range of contaminant concentrations and mud content. The models use Canonical Analysis of Principal Coordinates (CAP, Anderson and Willis 2003) of square root transformed Bray-Curtis dissimilarities to extract variation related to a single environmental variable and produce a score of community composition related to that variable. For the metal model, the concentrations of the three metals have been used in a Principle Component Analysis to create a single axis (PC1) that explains >90% of the variability in contaminant differences between the sites. For the mud model, the % mud content of sediment at the time of sampling is used.

The macrofaunal community composition of sites and sampling times not in the models are compared to model data (using the "*add new samples*" routine in *CAP, PermANOVA addon,* Primer E). The samples are then allotted to five different groups related to health (see Table 3).

3.5.3 Combined indices

Hewitt et al. (2012) recommended the use of the three indices above (TBI index, BHMmud score (CAPmud) and BHMmetals score (CAPmetals)) to provide a complementary assessment of health. Average health values are determined for each site in the following way:

1. If the CAPmud score is ≤ -0.12, the site is allocated to Mud group 1 (Table 3), and the combined Health score is calculated as the average CAPmetals and CAPmud group values. The TBI is not used in the combined score in this case, as it does not work well when mud content is extremely low (Hewitt et al. 2012).
2. If the CAPmetals score is ≥0.10, the site is allocated to group 4 or 5, and the combined Health score is equal to the TBI group value. At this level of contaminants, the TBI score itself fully reflects health.
3. Otherwise, Health is the average of the CAPmetals, CAPmud and TBI group values.

Health scores, “x”, are then translated as x ≤ 0.2 “extremely good”; 0.2 <x≤ 0.4 “good”; 0.4 <x≤ 0.6 “moderate”; 0.6 <x≤ 0.8 “poor” and x > 0.8 “unhealthy with low resilience”. It is important to recognise that the health scores are from particular sites within each estuary, and do not necessarily represent the health status of the estuary as a whole. There may be locations in each estuary that are significantly healthier, or less healthy, than the monitored sites.

Table 3.

Conversion of CAPmetals and CAPmud scores into health groups (1 is least healthy). Cut off point is equal or less than. These groups are then converted (along with TBI scores) into values of similar scale (0-1) that run in the same direction (higher values indicating more degraded conditions), to facilitate their combination into overall health scores.

Group	CAPmetals		CAPmud		TBI	
	Cutoff	value	Cutoff	value	Cutoff	value
1	-0.164	0.2	-0.12	0.2	0.4	0.33
2	-0.0667	0.4	-0.05	0.4	0.3	0.67
3	0.0234	0.6	0.02	0.6		1.0
4	0.10	0.8	0.10	0.8		
5		1.0		1.0		

4 Present status of benthic communities in the Central Waitematā Harbour

This programme was designed to monitor the ecological status and trends of change in macrobenthic communities in the Central Waitematā Harbour. An important process in detecting trends is determining temporal variability, as knowledge of cyclic patterns of recruitment aids in detection of long-term trends (Hewitt et al. 1994). In this section of the report we ask the following questions:

- Have there been any changes in site characteristics?
- At each site, are species exhibiting seasonal patterns or multi-year cycles, or are trends over the monitored period occurring?
- Are species' abundances exhibiting similar patterns at each site?
- Have any changes in species over time led to changes in communities, with sites becoming more or less similar to each other?

4.1 Have there been any changes in site characteristics?

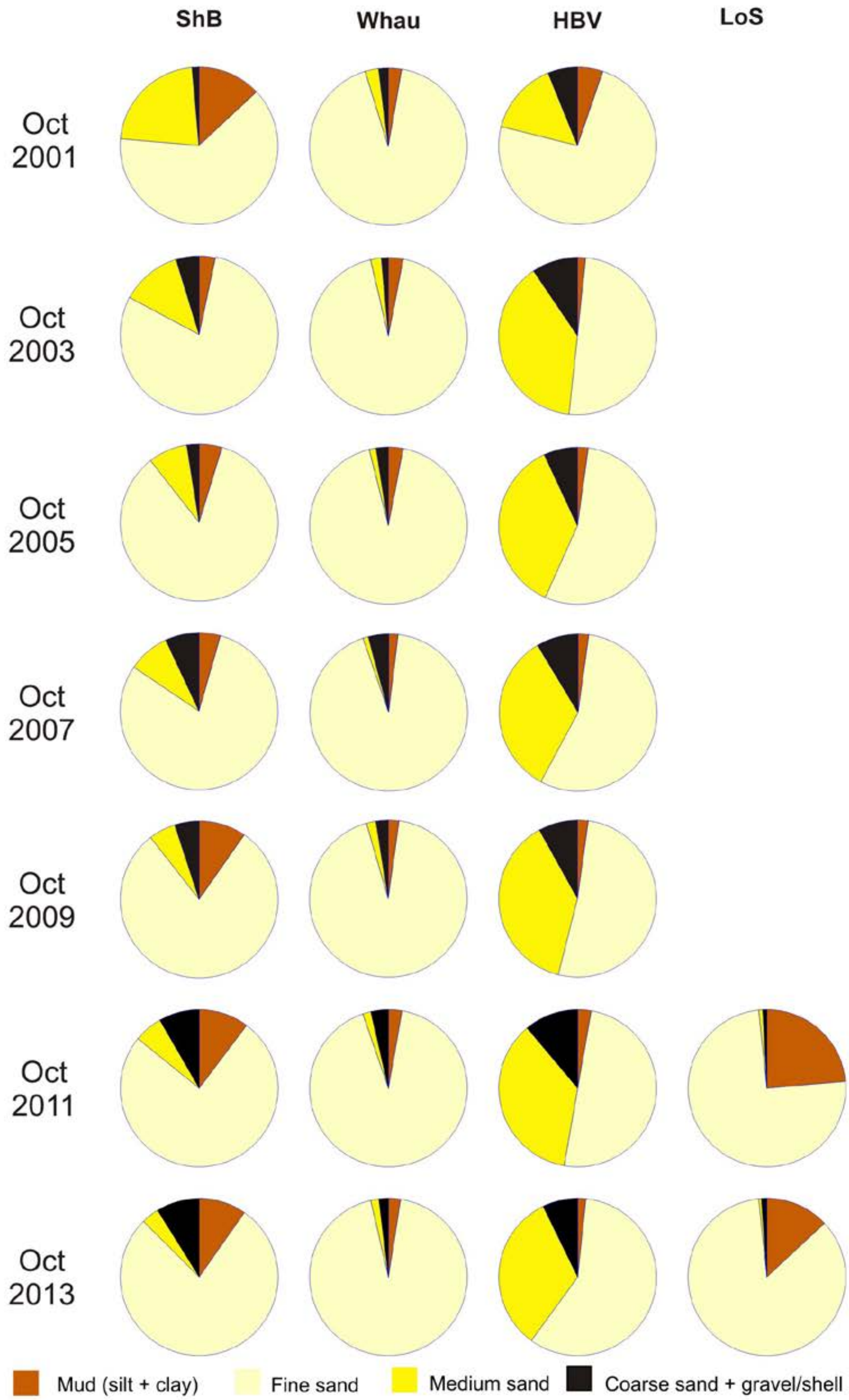
4.1.1 Hobsonville (HBV)

Site HBV is located on the sand flats near the Hobsonville Air Base, close to the deep channel entering the Upper Waitematā Harbour. The sand flat shows characteristics of high tidal flow or wind wave energy, with coarse sediment and ripple features visible on the sediment surface (Plate 1). The majority of the site is still hard-packed sand; few ripples were evident at the April 2014 sampling due to calm conditions. Ray pits are a common feature, with ~30 ray pits throughout the monitoring site, and patches of oyster reef (usually ~10 cm diam.) common throughout the site at densities of approximately 1 patch per 25 m^2. While general features of the site have changed little since monitoring began, increasing muddiness near the 0,0 peg has been observed due to the change in size and position of a tidal drainage channel along the seaward/eastern side of the monitoring site. The tidal channel expanded rapidly between 2008 and 2010, but appears to have stabilised at a distance of approximately 2 m from the 0,0 peg, and just encroaching ~1 m into the site at the other easterly peg of the monitoring site. This site is examined annually to determine if further encroachment has occurred that might impact the site. If this occurs, the site can be moved alongshore 5-10 m from its current position. A second smaller shallow sub-channel is present through the middle of the site, associated with slightly less firm sediments. A large shell bank was noted in May and December 2012, having migrated from the seaward side of the site to within the centre of the site; this shell bank has nearly disappeared though a slight raise in sediment height (20-30 cm maximum, though generally <10 cm) is still evident, associated with high density (90% cover) shell hash. Shell hash throughout the remainder of the site is generally high with 50-75% cover. The sediment is predominantly fine (56%) and medium (32%) sand, with a lesser amount of coarse material (6%) (Figure 2). Chlorophyll *a* content of the sediment ranged between 8.0 and

23.2 µg/g sediment and the organic content has been both low and variable (average 1.4%, range 0.36-6.40) (Appendix 10.1).

Figure 2.

Summary of sediment characteristics at Hobsonville (HBV), Whau River (Whau) and Shoal Bay (ShB) from October 2001 to October 2013, and Lower Shoal Bay (LoS) from October 2011 to October 13. Coarse sand and gravel (>500μm), medium sand (250 – 500 μm), fine sand (62.5 – 250 μm), mud (< 62.5 μm). Full results are given in Appendix 10.1.



4.1.2 Whau River (Whau)

The Whau site is located on the north-western side of the Whau River (Plate 2). The site is a mid-intertidal sand bank, located next to a navigation channel. The sand flats here are large, sandy and generally show signs of wind-wave activity (small ripples on the sediment surface). At the April 2014 visit, ripples were shallow, about 1-2 cm in height and 10 cm in width. There has been little visual change to this site or the nearby channel over nearly fourteen years of monitoring. Sediments at the site consist of primarily hard-packed fine sand and some shell hash visible on the surface, and abundant grazing gastropods. The majority of the sediment size fractions have been consistent over time (Figure 2). The sediment at Whau is predominantly fine sand (> 90%), with an average chlorophyll *a* content of 12.1 µg/g sediment and a low organic content (generally <1%) (Appendix 10.1).

4.1.3 Shoal Bay (ShB)

The intertidal flat selected for monitoring in Shoal Bay is adjacent to the Auckland Harbour Bridge and offshore from a large rock platform at the side of the motorway (Plate 3). In 2000, this sand bank consisted of hard-packed fine sands with abundant shell hash. This site has continued to change since previous visits in May and December 2012, and is becoming more difficult to sample due to increasing mud content across at least 1/3 of the site. Previously, difficulties were experienced in sampling the site, as it was often not completely uncovered except at large spring tides and without onshore winds. The April 2014 sampling occurred with spring tides (0.4 m) and calm conditions, resulting in a larger portion of the monitoring site and neighbouring sand flat (at least 20-30 m offshore of the site) uncovering. A cable that once crossed the site diagonally has been moved such that it now runs parallel to the edge of the monitoring site.

Currently, this site has large spatial variation in mud content and shell hash. Highest mud content was observed through the centre of the site (sections 5-8), whereas in the past, the seaward sites closest to the motorway (9 and 12) had experienced the muddiest sediment, and were most difficult to access. Some increase in mud content was observed in seaward sections 1 and 4. Other sections had mostly firmer sediments. In general, the original fine sand/shell hash layer, composed of large shells (primarily *Cyclomactra ovata*), was present across the site, but varied in the amount of finer sediments that had been deposited atop this shell hash layer. Based on observations, it appears that substantial sediment has been deposited in recent years on the seaward edge of this sandbank, changing bed level height and resulting in higher mud content. The deepest mud content was ~30 cm above this shell hash layer; moderate shell hash is present throughout the mud layer.

The sediment at ShB is mainly fine (mean 75%, Figure 2) and medium sand (mean 12%, Figure 2). ShB sediment has a low mean organic content (0.23 – 1.94%), and the chlorophyll *a* content is also frequently low (< 10 µg/g sediment) (Appendix 10.1).

4.1.4 Lower Shoal Bay (LoS)

Ecological monitoring of the intertidal flat at LoS was initiated in October 2010 (Plate 4). The site is now accessed from the sea, anchoring approximately 50 m to the west in a shallow tidal channel. The site and roughly 50 m of adjacent mudflats were uncovered at the April 2014 visit. While not an issue in April 2014, Auckland Council staff note that it is rare to find this site uncovered. This is likely due to its position within the lower intertidal zone, and the prevailing onshore winds. Generally the sediment at this site is relatively homogeneous, and is composed of a mud layer 10-30 cm deep over historical shell hash deposits. The sediment is hummocky with lots of deep pools with tube worms and diatomaceous growth. No ray pits were observed in April 2014 and bivalves were generally rare. The sparse shell hash observed on the sediment surface consisted mainly of fragments of cockles and wedge shells. The sediment at LoS is almost exclusively fine sand (mean 81%, Figure 2) and mud (mean 17%, Figure 2). LoS sediment has a low mean organic matter (1.4%) and chlorophyll *a* content (mean 8.2 µg/g sediment).

4.1.5 Summary of changes in site characteristics

The organic matter content at HBV, ShB, Whau and LoS has remained comparable with previous years of the study, showing minimal change in the level of variation (Table 4B, Townsend et al. 2010, Halliday et al. 2012). There has been little variation in chlorophyll *a* content at HBV, ShB and LoS, with HBV and ShB remaining comparable to past years. Variation in chlorophyll *a* content at Whau has remained relatively high in comparison to the other sites, however it has decreased since 2012 (-0.91 to -0.27) (Table 4B, Halliday et al. 2012). The highest values of organic material and sediment chlorophyll *a* concentration were found at HBV, while the lowest values for both were present at ShB (Appendix 10.1). The four sites can be divided into two groups on the basis of within-year variability in sediment characteristics: Whau and LoS had lower variability than HBV and ShB (Table 4A). Table 4B demonstrates the change in variability over the last two years by comparing the standard deviation of data from October 2000 to February 2012 (shown in the last report) with the data from October 2000 to February 2014. There has been minimal change in the temporal variability of sediment characteristics over the last two years (Table 4B).

Table 4.

Analysis of temporal variability in sediment characteristics at HBV, Whau, ShB and LoS from October 2000 to February 2014: A) Average annual variability (Standard Deviation) of sediment % by weight: coarse sand (500 – 2000 μm), medium sand (250 – 500 μm), fine sand (62.5 – 250 μm), mud (< 62.5 μm) and chlorophyll *a*. Note: gravel faction (>2000 μm) not included. B) Changes in the standard deviations compared with results reported in 2012. Negative values indicate larger variability over the last two years, whereas positive values indicate increased stability.

A)

site	%mud	%fine sand	%medium sand	%coarse sand	%organics	chl*a* mg/g
HBV	1.53	8.35	8.00	2.44	0.78	2.89
Whau	1.28	2.82	1.71	0.23	0.34	4.02
ShB	3.40	7.33	8.11	1.49	0.35	2.47
LoS	4.84	4.64	0.13	0.16	0.57	1.32

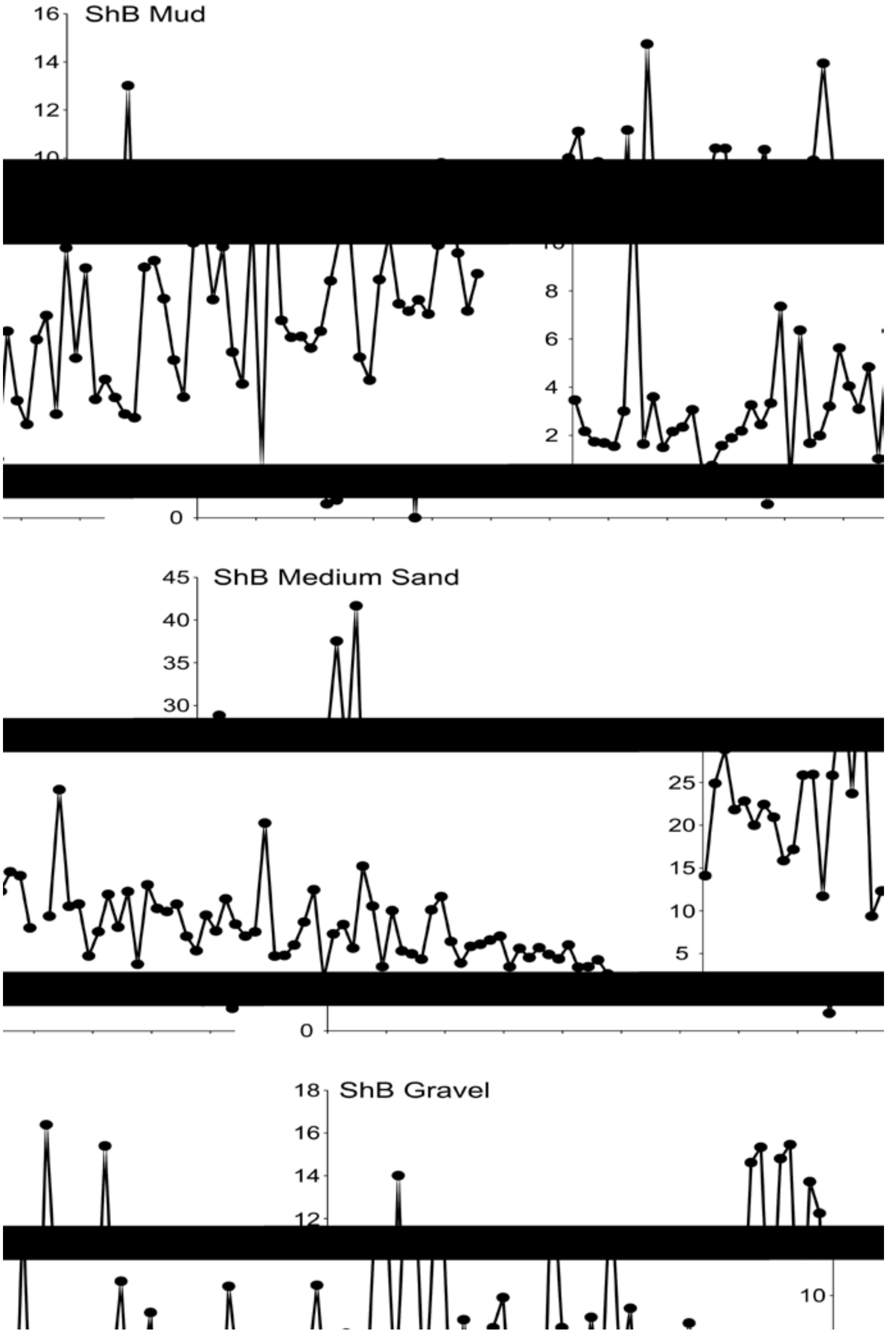
B)

site	%mud	%fine sand	%medium sand	%coarse sand	%organics	chl*a* mg/g
HBV	-0.06	0.35	0.39	0.13	0.03	0.05
Whau	0.08	0.03	0.13	0.00	0.01	-0.27
ShB	-0.10	0.16	0.11	0.07	0.02	-0.05
LoS	0.11	0.02	0.02	-0.01	-0.10	-0.18

Both HBV and Whau display historic trends in several size fractions, however, there have been no substantial changes since April 2002 and December 2003 respectively. It was noted in the 2010 and 2012 reports (Townsend et al. 2010, Halliday et al. 2012) that the mud and gravel fractions displayed an increasing trend at site ShB, whilst the medium fraction was trending downwards. A statistically significant ($p < 0.0001$) increasing trend was still detected for mud and a decreasing trend for medium sand, however, no trend was detected for the gravel fraction (Figure 3).

Figure 3.

Temporal changes in site sediment characteristics at ShB. Trends show percent mud to be increasing, with percent medium sand decreasing. Percent gravel is no longer trending upwards.



4.2 Are species exhibiting temporal variations?

This section describes patterns observed in species abundances at the monitoring sites. Three types of patterns are described: trends, seasonal patterns, and multi-year patterns. The latter are usually variations in the magnitude of seasonal recruitment, although the description also covers species that have multi-year recruitment patterns.

4.2.1 Hobsonville (HBV)

Between October 2000 and April 2011 the Hobsonville site was consistently dominated, in terms of abundance, by three species: the nut clam *Linucula hartvigiana,* the polychaete *Aonides trifida*, and the venerid bivalve *Austrovenus stutchburyi* (Table 5). The only exceptions to this were the eight occasions between August 2001 and August 2008 when the limpet *Notoacmea scapha* was the third most abundant species. In all instances this peak occurred around June/August, indicating the presence of a multi-year cycle. As stated in the last report (Halliday et al. 2012) there was a switch in the most dominant species for this site. Prior to February 2007 *Linucula* was consistently the most dominant species; between February 2007 and February 2010 *Aonides* was more abundant than *Linucula* on six occasions; then in the last report period (April 2010 – February 2012) *Aonides* was consistently the most abundant species. In the latest report period (April 2012 – February 2014), there has been a continual fluctuation between these two species for the dominant position, each occupying the top position for six out of the twelve sampling trips. This is probably due to a combination of two factors. Firstly, *Aonides* was shown to have an increasing abundance between 2005 and 2008, and since then the numbers have remained relatively constant. Secondly, abundances of *Linucula* show a multi-year cycle and numbers appear to be recovering (following a decline from 2007 – 2011). The remaining monitored fauna were usually low in abundance, although *Prionospio aucklandica, Colurostylis lemurum* and *Anthopleura aureoradiata* were among the three most abundant taxa present on multiple sampling dates (Appendix 10.2).

Table 5.

The three most abundant monitored taxa found over time at HBV.

Date	1st	2nd	3rd
Oct-00	*Linucula*	*Aonides*	*Austrovenus*
Oct-01	*Linucula*	*Aonides*	*Austrovenus*
Oct-02	*Linucula*	*Aonides*	*Austrovenus*
Oct-03	*Linucula*	*Aonides*	*Austrovenus*
Oct-04	*Linucula*	*Aonides*	*Austrovenus*
Oct-05	*Linucula*	*Aonides*	*Notoacmea*
Oct-06	*Linucula*	*Aonides*	*Austrovenus*
Oct-07	*Linucula*	*Aonides*	*Austrovenus*
Oct-08	*Linucula*	*Aonides*	*Austrovenus*
Oct-09	*Aonides*	*Linucula*	*Austrovenus*
Oct-10	*Aonides*	*Linucula*	*Austrovenus*
Oct-11	*Aonides*	*Austrovenus*	*Colurostylis*
Oct-12	*Linucula*	*Aonides*	*Austrovenus*
Oct-13	*Linucula*	*Aonides*	*Prionospio*

4.2.1.1 Seasonality and multi-year cycles

Anthopleura, Aonides, Colurostylis, Linucula, Macomona, Macroclymenella, Notoacmea, Prionospio and *Zeacumantus* all demonstrate long multi-year cyclic patterns at HBV. For example, *Prionospio* has cycles in recruitment which occur every five to seven years, with recruitment events in April 2001, February 2008, June 2012 and April 2013 (Figure 4). The multi-year patterns for *Anthopleura, Macomona* and *Macroclymenella* were not identified in the last report (Halliday et al. 2012), but have become apparent with further time-series data. Seasonal patterns were also observed in a number of species at HBV. For example, *Aricidea* and *Boccardia* both displayed peak abundances during winter (August to October and June to August respectively), whilst peak abundances for *Colurostylis* can be seen during April and August. *Austrovenus* displays its peak abundances during the summer months, typically December to February (Figure 4).

4.2.1.2 Statistically significant trends

Trends are evident in five taxa at HBV (Table 6). Two of these trends are driven by historical data and do not appear to be active any longer. Halliday et al. (2012) reported a decreasing trend in the abundance of *Paphies*, however, it appears that this trend only occurred until 2008. Since then the abundance of *Paphies* has remained variable but does not appear to be decreasing further. HBV continues to be the only monitoring location where *Paphies* are observed, occurring predominantly as juvenile (<10mm) and intermediate (10-40mm) sizes (Figure 5). The second historic trend can be seen for *Aonides*, which Halliday et al. (2012) reported to be increasing. It appears that this trend was driven by the lower values in the first four years, however, since 2008 abundance has remained variable with no further increase (Figure 4). In addition to these two trends are an increasing trend in the abundance of *Anthopleura, Aricidea* and *Heteromastus*. The increasing trend in *Heteromastus* abundance has only come about in the last two years (Figure 4, Table 6), and following further data collection may turn out to be part of a multi-year cycle.

The number of *Austrovenus* at HBV has remained relatively high, although there has been a slight decline since the last report (Figure 4, Halliday et al. 2012). Since October 2010 there has been a steady decline in the number of intermediate (5-20mm) sized *Austrovenus*, which has meant they are no longer the dominant size class present at HBV. Instead, HBV is currently dominated by juveniles (<5mm) (Figure 5).

Figure 4.

Temporal patterns in abundances of *Anthopleura aureoradiata, Aonides trifida, Aricidea sp., Austrovenus stutchburyi, Boccardia syrtis, Colurostylis lemurum, Heteromastus filiformis, Linucula hartvigiana, Paphies australis* and *Prionospio aucklandica* at the HBV site.

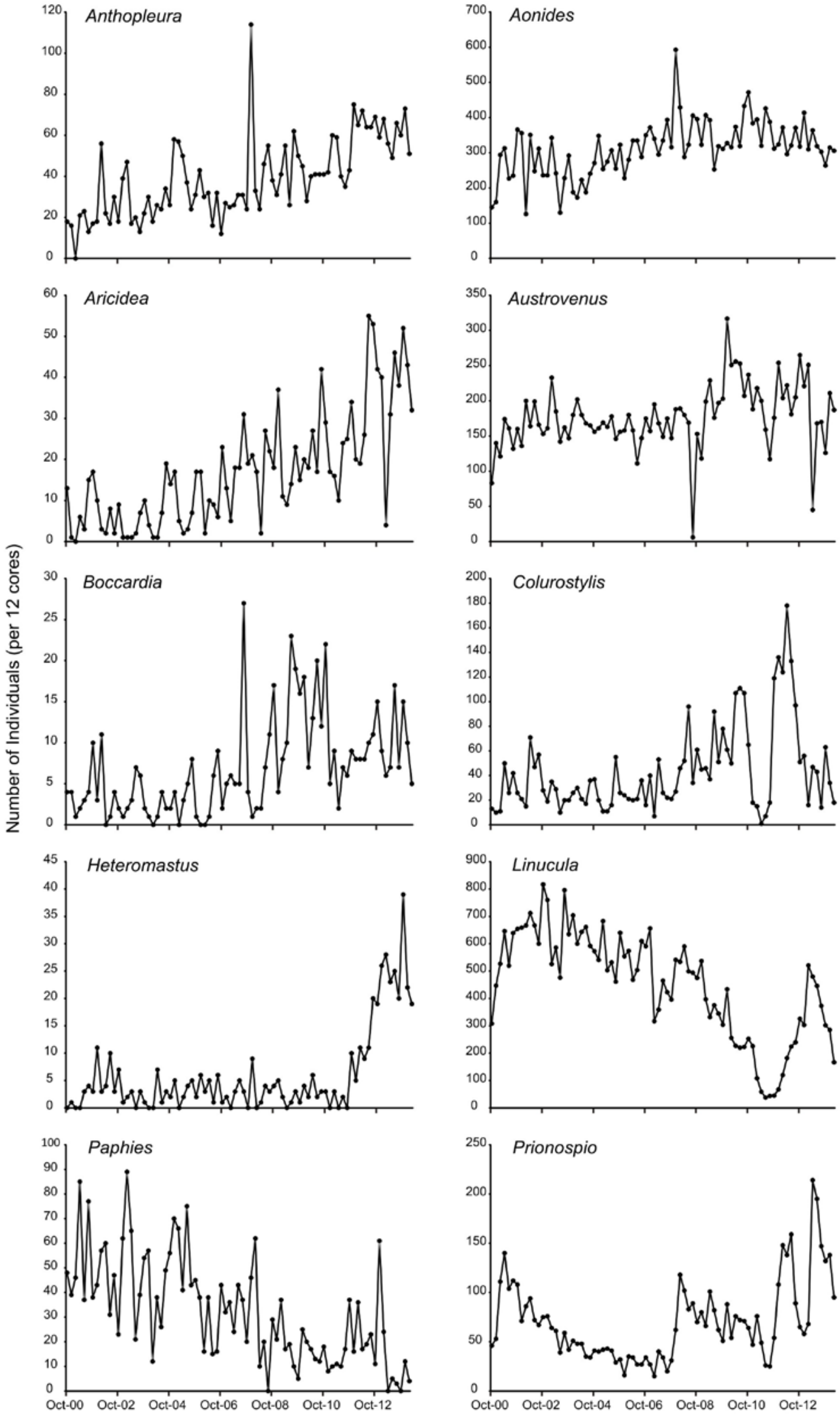


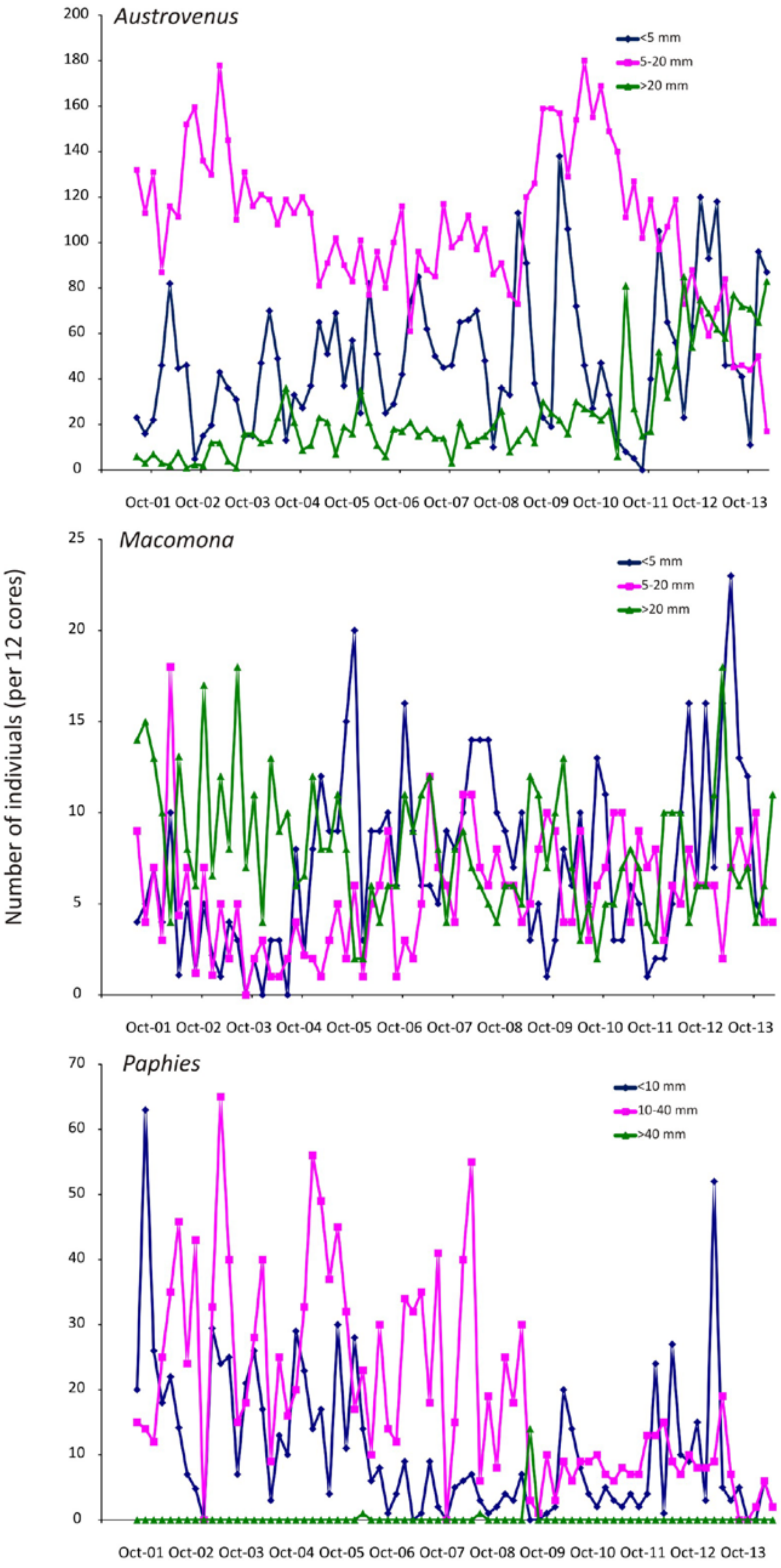
Table 6.

Summary of temporal patterns in abundance of selected taxa observed at each site between October 2000 and February 2014. Hobsonville (HBV), Whau River (Whau) and Shoal Bay (ShB). Lower Shoal Bay (LoS) has not been monitored long enough for patterns and trends to be identified. *temporal pattern suggests trend no longer operating. Size of change in predicted change in total abundance of 12 cores over the monitored period of just over 13 years.

Site	Seasonal cycles	Multi-year cycles	Trends	Trend direction	Size of change	p-value
HBV	*Aricidea* *Austrovenus* *Boccardia* *Colurostylis* *Exosphaeroma* *Macomona*	*Anthopleura* *Aonides* *Colurostylis* *Linucula* *Macomona* *Macroclymenella* *Notoacmea* *Prionospio* *Zeacumantus*	*Aonides* *Paphies* *Anthopleura* *Aricidea* *Heteromastus*	Increase* Decrease* Increase Increase Increase	134.0 -48.3 45.0 35.1 15.0	<0.0001 <0.0001 <0.0001 <0.0001 <0.0001
Whau	*Austrovenus* *Colurostylis* *Notoacmea*	*Anthopleura* *Arthritica* *Austrovenus* *Boccardia* *Colurostylis* *Euchone* *Glycera* *Macomona* *Macroclymenella* *Notoacmea* *Zeacumantus*	*Aricidea* *Linucula* *Prionospio*	Decrease* Decrease* Decrease*	-119.5 -477.3 -28.1	0.0239 <0.0001 <0.0001
ShB	*Austrovenus* *Colurostylis* *Glycera* *Linucula* *Notoacmea*	*Anthopleura* *Aonides* *Aricidea* *Arthritica* *Austrovenus* *Boccardia* *Colurostylis* *Euchone* *Glycera* *Macroclymenella* *Prionospio*	*Aricidea* *Heteromastus* *Linucula* *Notoacmea* *Prionospio* *Macomona*	Increase Increase Decrease Decrease Increase Decrease*	33.0 105.7 -312.8 -95.4 36.3 -13.2	<0.0001 <0.0001 <0.0001 <0.0001 <0.0001 <0.0001

Figure 5.

Trends in abundance of different size classes of the bivalves *Austrovenus stutchburyi, Macomona liliana* and *Paphies australis* found at site HBV.



4.2.2 Whau River (Whau)

Linucula is typically the most abundant species at this site, although there has been some variation in its ranking from year to year (Table 7). Other species of moderate to high abundance at this site include *Aricidea*, *Austrovenus*, *Colurostylis*, *Notoacmea, Macomona* and *Macroclymenella* (Appendix 10.2).

Table 7.

The three most abundant monitored taxa found over time at Whau.

Date	1st	2nd	3rd
Oct-00	*Linucula*	*Aricidea*	*Austrovenus*
Oct-01	*Linucula*	*Aricidea*	*Austrovenus*
Oct-02	*Linucula*	*Aricidea*	*Austrovenus*
Oct-03	*Linucula*	*Austrovenus*	*Aricidea*
Oct-04	*Aricidea*	*Linucula*	*Macroclymenella*
Oct-05	*Linucula*	*Aricidea*	*Macroclymenella*
Oct-06	*Linucula*	*Aricidea*	*Macroclymenella*
Oct-07	*Linucula*	*Aricidea*	*Austrovenus*
Oct-08	*Austrovenus*	*Linucula*	*Aricidea*
Oct-09	*Austrovenus*	*Linucula*	*Aricidea*
Oct-10	*Linucula*	*Aricidea*	*Austrovenus*
Oct-11	*Austrovenus*	*Aricidea*	*Linucula*
Oct-12	*Aricidea*	*Linucula*	*Austrovenus*
Oct-13	*Aricidea*	*Linucula*	*Austrovenus*

4.2.2.1 Seasonality and multi-year cycles

The same seasonal patterns witnessed at HBV can be seen in the *Austrovenus* population at Whau, with peaks in abundance between December and February (Figures 4 and 6). *Colurostylis* also displays seasonal patterns, with peak abundance typically in April to June. Halliday et al. (2012) questioned whether the unusually high abundance in February 2012 was a result of the temporary accidental relocation of the site (see Halliday et al. 2012), or part of a natural cycle. Since this peak the abundance of this species has returned to normal levels. At this stage the answer to this question is still unclear, although there are a couple of factors suggesting this is part of a natural cycle. This species does exhibit multi-year cycles, and the abundance of *Colurostylis* was also high at HBV at this time (Figures 4 and 6). Seasonal patterns can also be seen in *Notoacmea,* with peaks in abundance usually occurring in December (Figure 6). Variable recruitment in *Notoacmea* has also resulted in multi-year patterns in abundance (Table 6). The number of species reported this year to be displaying multi-year patterns has increased from the last report (Halliday et al. 20012). This is a result of increases in the time-series data allowing us to identify new patterns. Species with newly identified multi-year cycles include: *Arthritica, Austrovenus, Boccardia, Euchone and Glycera.*

Bivalve populations have been variable over time at Whau. Both *Austrovenus* and *Macomona* are dominated by juveniles (<5 mm), with large and variable recruitment events (Figure 7).

4.2.2.2 Statistically significant trends

As noted by Halliday et al. (2012), the trends presented in the 2010 report (Townsend et al. 2010) of decreasing *Aricidea, Linucula* and *Prionospio* are no longer operating. These trends were driven by high values prior to 2004, with the abundance of all three species remaining relatively unchanged after this point (Figure 6). Halliday et al. (2012) reported an increasing trend in the number of *Zeacumantus* at Whau. It is now evident that this increase was actually part of a multi-year cycle, which is also seen in the *Zeacumantus* population at HBV (Table 6). The previously reported increasing trend in the abundance of *Anthopleura* (Halliday et al. 2012) is also part of a multi-year cycle.

Figure 6.

Temporal patterns in abundances of *Anthopleura aureoradiata, Aricidea sp., Austrovenus stutchburyi, Colurostylis lemurum, Heteromastus filiformis, Linucula hartvigiana, Macroclymenella stewartensis, Notoacmea scapha, Prionospio aucklandica* and *Zeacumantus lutulentus* at the Whau site.

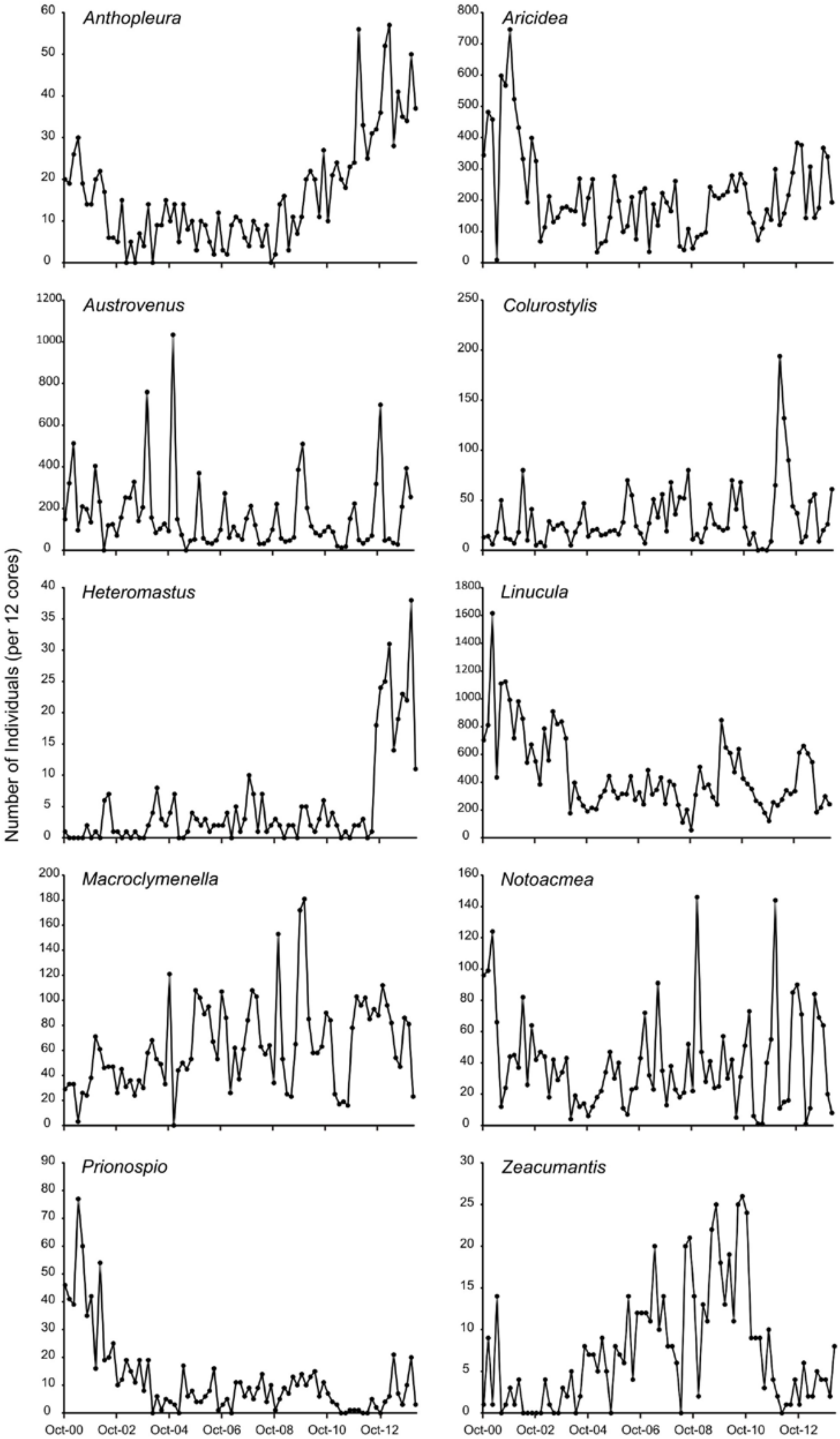
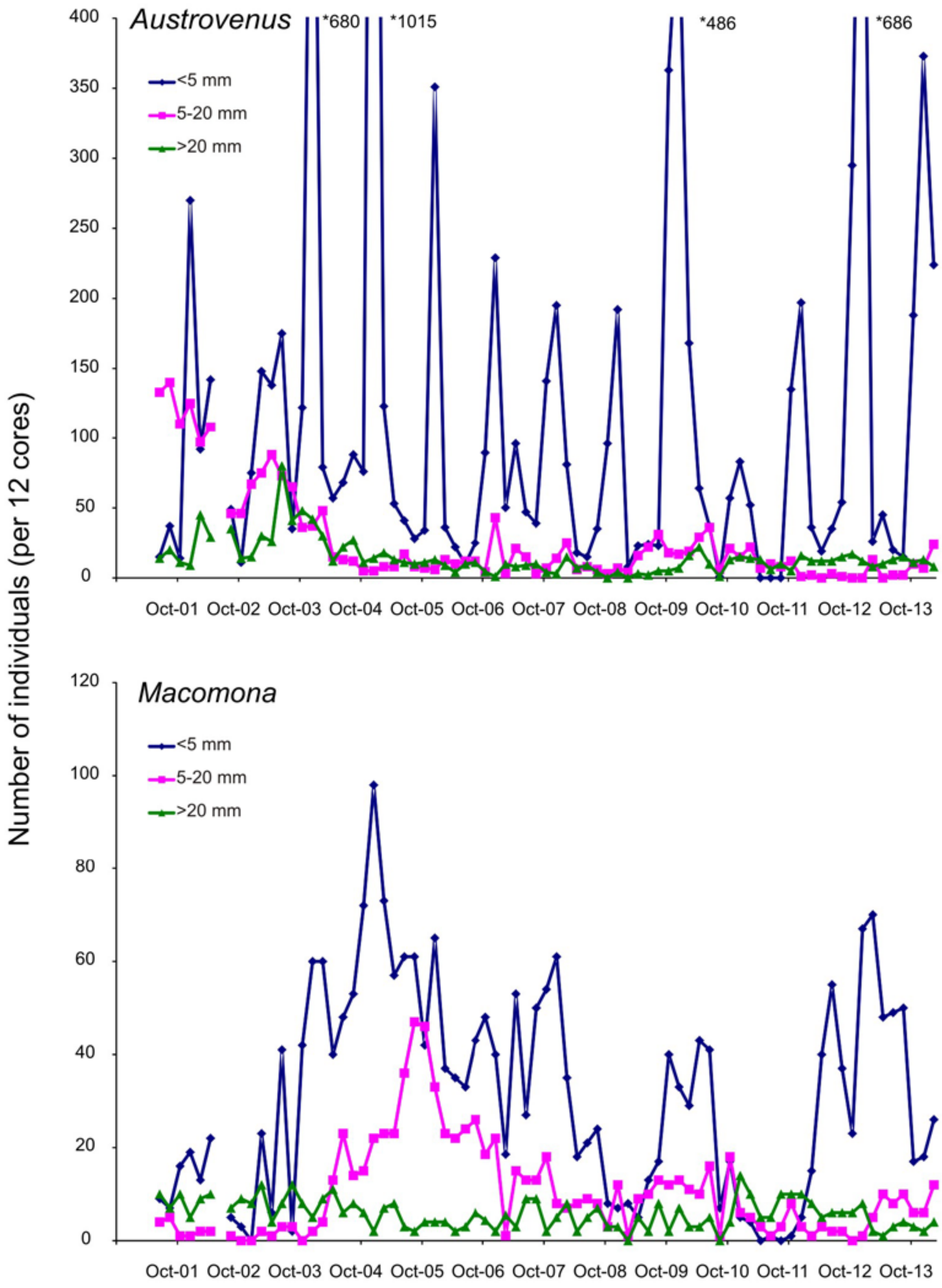


Figure 7.

Trends in abundance of different size classes of the bivalves *Austrovenus stutchburyi* and *Macomona liliana* found at Whau. No *Paphies australis* were present at Whau.



4.2.3 Shoal Bay (ShB)

Species dominance at ShB has remained variable, even with the inclusion of data from the latest reporting period (Table 8). Prior to April 2004 *Linucula* was consistently the most abundant species found at the ShB site, although the steady decline of this species due to low recruitment has meant that it hasn't appeared in the top three most dominant species since April 2011. *Boccardia* was the highest or second highest ranked species on every sampling occasion from February 2009 to October 2011. However since then, the top ranked position has been filled by *Heteromastus*, with *Boccardia* only appearing twice as the third most highly ranked species. Other common species at this site include *Aricidea, Colurostylis, Notoacmea* and *Prionospio*.

Table 8.

The three most abundant monitored taxa found over time at ShB.

Date	1st	2nd	3rd
`Oct-00	*Linucula*	*Notoacmea*	*Boccardia*
Oct-01	*Linucula*	*Notoacmea*	*Aricidea*
Oct-02	*Linucula*	*Notoacmea*	*Aricidea*
Oct-03	*Linucula*	*Notoacmea*	*Aricidea*
Oct-04	*Linucula*	*Notoacmea*	*Euchone*
Oct-05	*Notoacmea*	*Boccardia*	*Euchone*
Oct-06	*Linucula*	*Notoacmea*	*Boccardia*
Oct-07	*Notoacmea*	*Boccardia*	*Euchone*
Oct-08	*Aricidea*	*Boccardia*	*Heteromastus*
Oct-09	*Boccardia*	*Aricidea*	*Heteromastus*
Oct-10	*Boccardia*	*Heteromastus*	*Aricidea/Euchone*
Oct-11	*Heteromastus*	*Boccardia*	*Aricidea*
Oct-12	*Heteromastus*	*Aricidea*	*Boccardia*
Oct-13	*Heteromastus*	*Prionospio*	*Aricidea*

4.2.3.1 Seasonality and multi-year cycles

Seasonal patterns have been identified for a number of species at this site (Table 6). *Austrovenus, Colurostylis* and *Glycera* all had peak abundances in summer, *Linucula* in autumn, and *Diloma* and *Notoacmea* in winter. A large number of species at ShB exhibited multi-year cycles (Table 6), including *Aricidea, Anthopleura* and *Austrovenus,* primarily reflecting variation in recruitment success from year to year. The density of tube worms (*Macroclymenella* and *Boccardia*) has stabilised, following the high peak in late 2009 (Figure 8). *Austrovenus* are present in much smaller numbers than at HBV and Whau, although the same variable recruitment peaks are evident (Figure 9).

4.2.3.2 Statistically significant trends

The increasing trends in *Aricidea, Heteromastus,* and *Prionospio* are still apparent at ShB (Townsend et al. 2010, Halliday et al. 2012). There is also a decreasing trend in the abundance of *Linucula* and *Notoacmea*. The number of *Macomona* at this site remains low, although the decreasing trend reported in 2012 (Halliday et al. 2012) appears to be driven by a high point in early 2001, and is no longer operating (Figure 8). Halliday et al. (2012) reported a decreasing trend in the abundance of *Diloma* at this site. This trend was most likely driven by large recruitment peaks in the first 5 years. Since then the abundance of this species has remained consistently low and variable (an average of <1 per core).

Figure 8.

Trends in abundance of *Aricidea sp., Boccardia syrtis, Heteromastus filiformis, Macomona liliana, Macroclymenella stewartensis, Notoacmea scapha, Linucula hartvigiana* and *Prionospio aucklandica* at the ShB site.

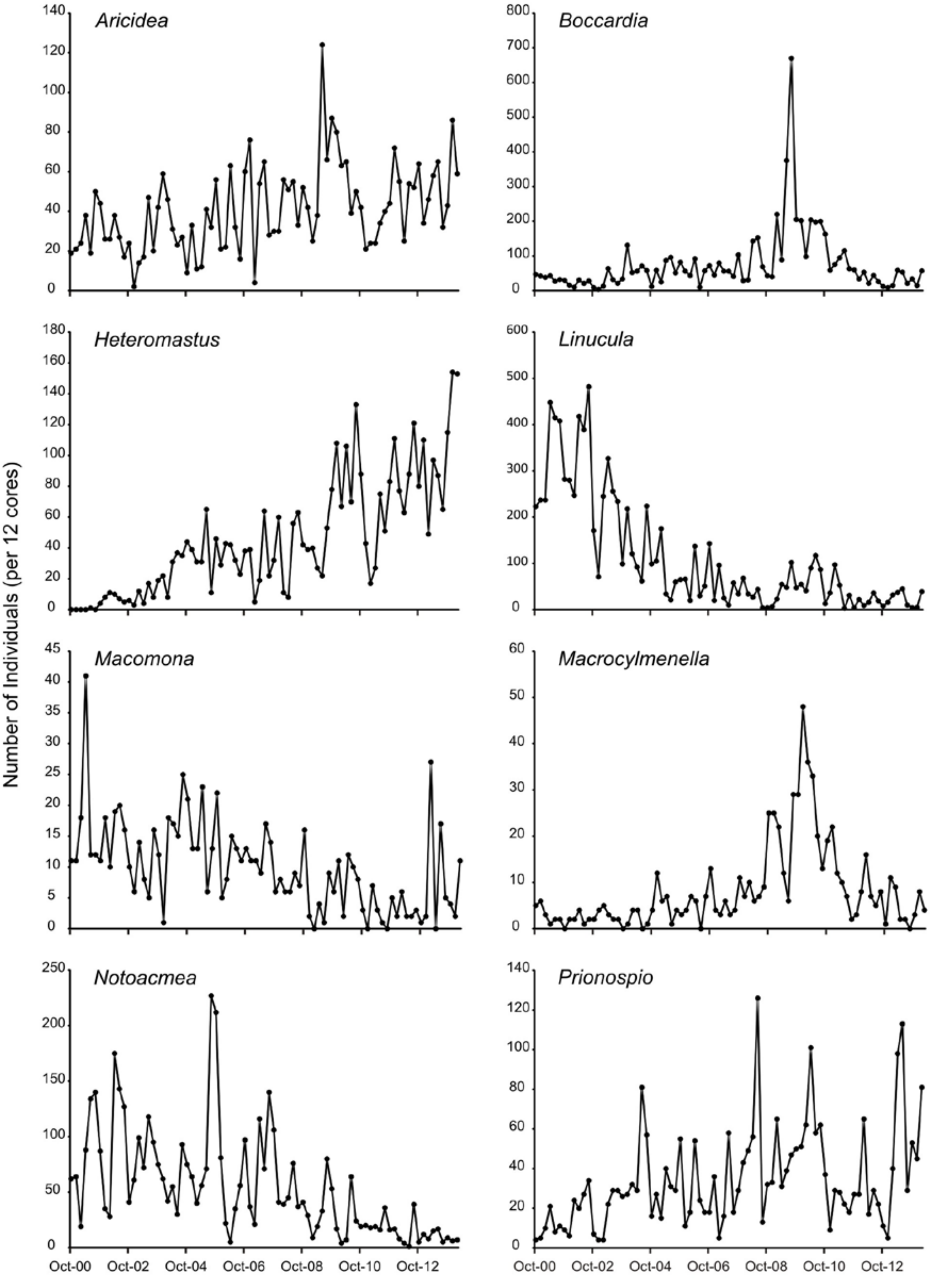
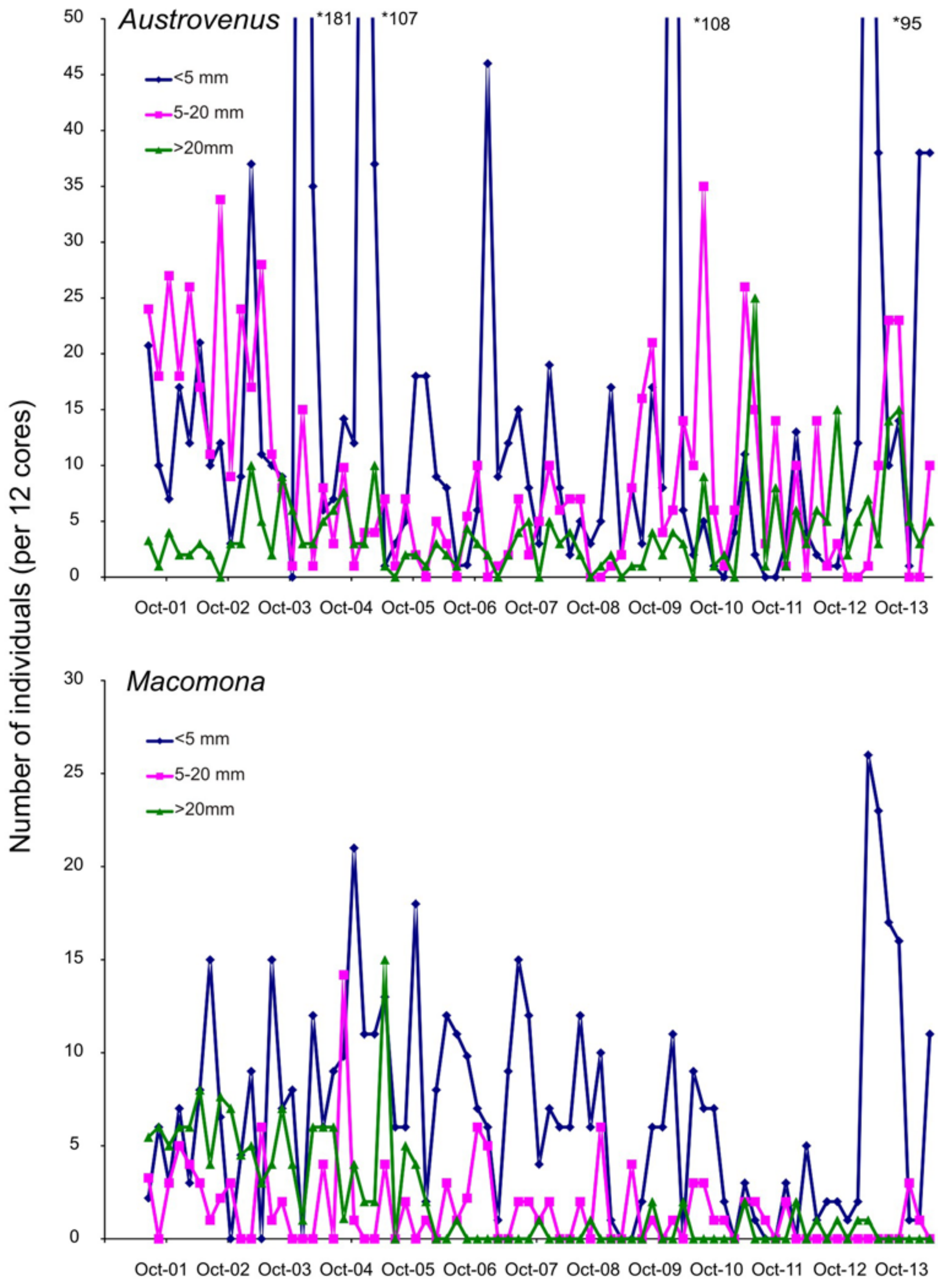


Figure 9.

Trends in abundance of different size classes of the bivalves *Austrovenus stutchburyi* and *Macomona liliana* found over time at ShB. No *Paphies australis* were present at ShB.



4.2.4 Lower Shoal Bay (LoS)

The two most abundant monitored taxa at LoS were *Boccardia* and *Heteromastus* (Table 9). *Prionospio, Linucula* and *Euchone* were also common at this site, ranking second or third most abundant on several occasions. *Austrovenus* and *Macomona* were rare at this site (averaging one and two individuals per 12 replicates, respectively) and *Paphies* appears to be absent (no *Paphies* recorded at this site to date). After only four years of monitoring it is too early to detect trends or changes in the monitored taxa over time. A high proportion of non-monitored taxa were common (ranked in the top five in abundance) during the sampling period, including the polychaetes Cirratulidae, *Cossura consimilis* and *Paradoneis lyra*, the amphipod *Torridoharpinia hurleyi* and nemerteans.

Table 9.

The three most abundant monitored taxa found over time at LoS.

Date	1st	2nd	3rd
Oct-10	*Boccardia*	*Heteromastus*	*Linucula*
Oct-11	*Heteromastus*	*Boccardia*	*Linucula*
Oct-12	*Aricidea*	*Heteromastus*	*Prionospio*
Dec-12	*Heteromastus*	*Boccardia*	*Arthritica*
Feb-13	*Heteromastus*	*Macomona*	*Boccardia*
Apr-13	*Heteromastus*	*Arthritica*	*Prionospio*
Jun-13	*Euchone*	*Boccardia*	*Arthritica*
Aug-13	*Boccardia*	*Heteromastus*	*Euchone*
Oct-13	*Heteromastus*	*Boccardia*	*Euchone*
Dec-13	*Heteromastus*	*Arthritica*	*Boccardia*
Feb-14	*Heteromastus*	*Arthritica*	*Prionospio*

4.3 Are species abundances exhibiting similar patterns at all sites?

There were some consistent trends in the abundance and types of species across the monitoring sites in the Central Waitematā Harbour. There has been an increasing trend in the abundance of anemones, *Anthopleura*, at HBV and their numbers have also remained high at Whau following successful recruitment during their multi-year cycle. Both HBV and Whau have a considerable amount of shell hash (Plates 1 and 2), and HBV also has a large number of adult *Austrovenus* present. Therefore these high abundances are likely to be facilitated by the availability of suitable attachment substrate. Increasing trends were also detected in silt-tolerant polychaetes at HBV (*Aricidea* and *Heteromastus*) and ShB (*Aricidea, Heteromastus* and *Prionospio*). These trends were more noticeable at ShB, which has shown increases in mud content. In terms of sensitivity to sedimentation, all three of these species have been assessed as having a broad tolerance for sediments with a high silt content, though *Aricidea* is assessed as preferring sandier substrates, and *Heteromastus* and *Prionospio* as preferring intermediate substrates with some but not high percentages of mud (Gibbs and Hewitt 2004). Although there is no overall increase in mud content at HBV, there are patches of increased muddiness associated with the two tidal drainage channels at the site, which may be supporting these polychaetes over others with lower mud tolerance. The increase of polychaetes at ShB may also be due to the low number of bivalves, with low numbers of adult *Austrovenus* and *Macomona*, the absence of *Paphies*, and a declining abundance of *Linucula*. For example, Whitlatch et al. (1997) experimentally demonstrated that *Austrovenus* density negatively impacts a polychaete species (*Microspio maori*) whilst simultaneously promoting other species. Gadd et al. (2009) found that *Aricidea* and *Heteromastus* were both common in non-cockle communities. Lower bivalve populations may also reduce the biogenic disturbance and thus facilitate an increased abundance of these polychaetes.

4.4 Have any changes over time led to communities, or sites, becoming more or less similar to each other?

4.4.1 Changes in site characteristics

Recently there has been a noticeable trend of increasing mud content at ShB (Figure 3). This increase is likely to influence the biotic component, but may also have been simultaneously mediated by it. Shoal Bay is a region predicted to have high sedimentation in the future (Green 2008). This is due to the tidal flow dynamics which mean that Shoal Bay receives a higher proportion of sediment emerging from Henderson Creek than other intertidal areas.

4.4.2 Changes in communities

In the last report (Halliday et al. 2012) the multivariate analysis showed community composition was very distinct at each of the sites. However, this is no longer true for ShB and LoS. Whilst the HBV and Whau sites still remain distinct, the other two sites are becoming much more similar (Figure 10). HBV shows the lowest variability over time, almost returning to the same state it was in during October 2000, with intermediate variability at Whau and high variability at ShB (Figure 10). The variability at ShB was primarily driven by decreases in the bivalve species *Linucula* and the gastropod species *Notoacmea*, and increases in the polychaete species *Aricidea, Heteromastus* and *Prionospio*. The changes in community composition at ShB are due to changes in species abundances rather than presence or absence of particular monitored species. This is evident in the 4th root ordination, which reduces the effect of extreme abundances (Figure 11).The 4th root ordination also shows ShB continuing to track away from HBV and Whau towards the other Shoal Bay site LoS (Figure 11, Halliday et al. 2012). The community composition of LoS is closest to that of ShB (Figures 10 and 11).

Figure 10.

MDS ordination using Bray-Curtis similarity on the raw data of the monitored species from October data 2000-2013 at the four sites (HBV, Whau, ShB and LoS). MDS stress value of 0.10 indicates that this is a good two dimensional representation of the data.

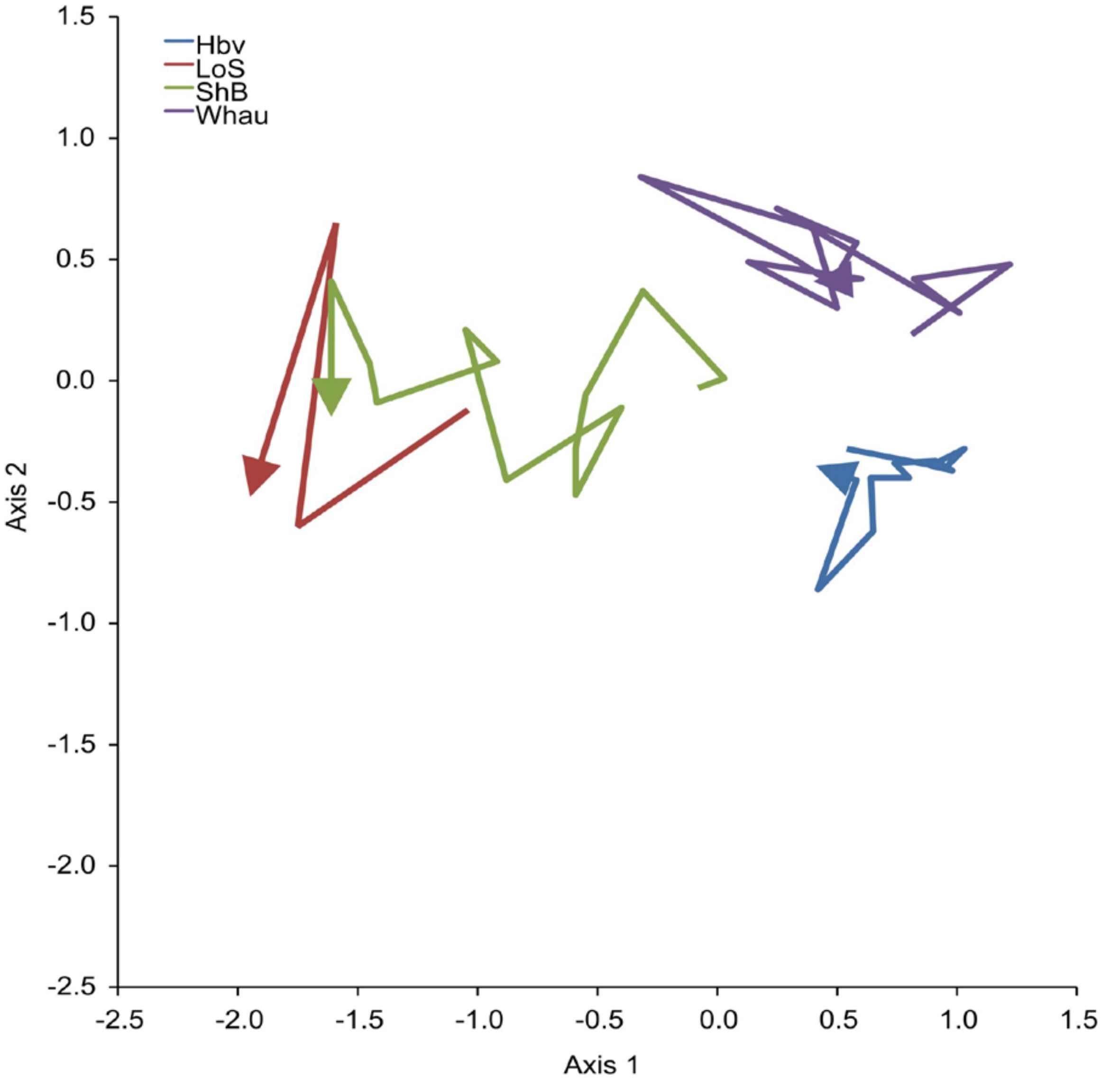
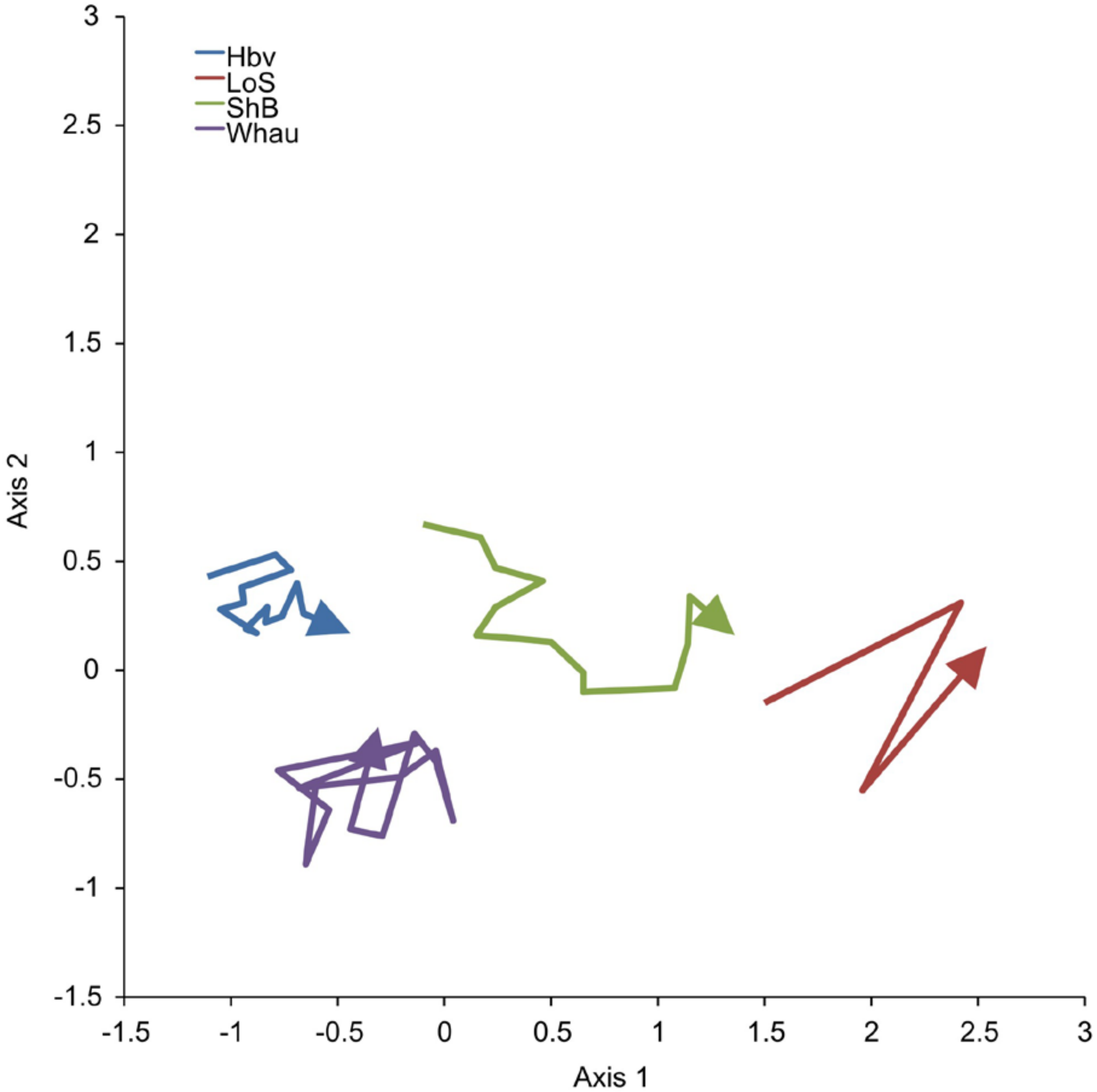


Figure 11.

MDS ordination using Bray-Curtis similarity on the 4th root transformed data (reduces the effect of extreme abundances) of the monitored species from October data 2000-2011 of the four sites (HBV, Whau, ShB and LoS). MDS stress value of 0.13 indicates that this is a reasonably good two dimensional representation of the data.

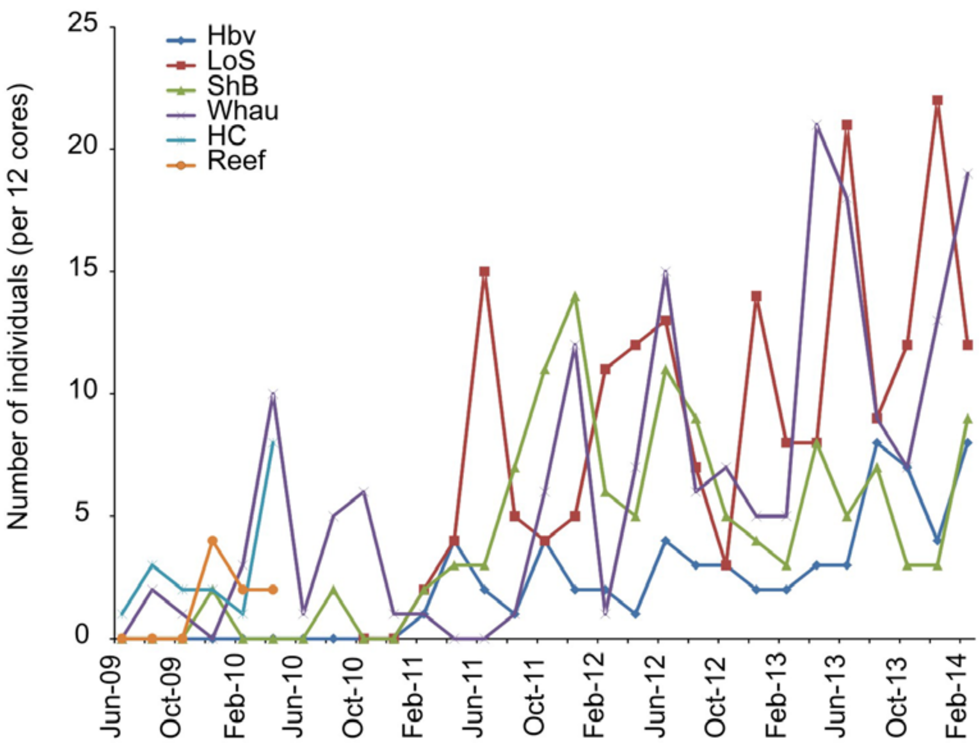


4.4.3 *Nassarius burchardi*

The Australian dog whelk, *Nassarius (Plicarcularia) burchardi* (Dunker in Philippi, 1849) continues to be found in the Waitematā Harbour (Townsend et al. 2010, Townsend 2010, Halliday et al. 2012). Concerns over the impact of *Nassarius* stem from its opportunistic and predatory feeding behaviour on *Austrovenus* and *Paphies*. While abundances have increased at the monitoring sites (with the exception of ShB), impacts of *Nassarius* on benthic communities in the Waitematā Harbour have not yet been observed.

Figure 12.

Trends in the abundance of *Nassarius burchardi* at all central Waitematā Harbour monitoring sites (HBV, HC, Reef, Whau, ShB and LoS) since it was first observed in June 2009. Note sampling at HC and Reef was temporarily suspended in April 2010. Sampling at LoS began in October 2010.

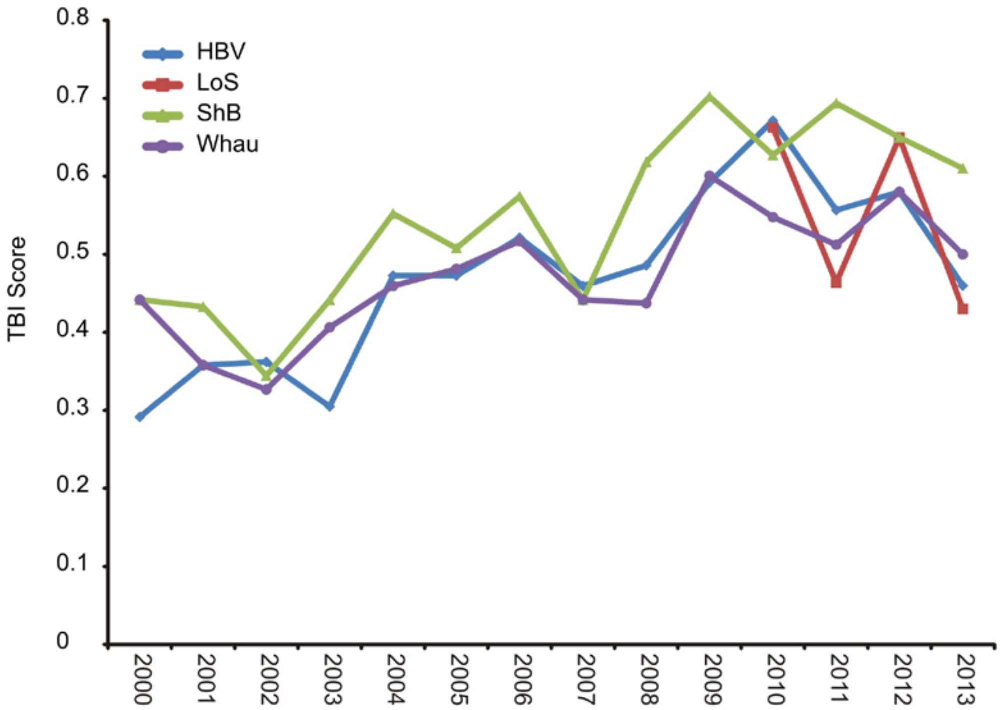


5 State of the environment indicators

Here, Traits-Based Index (TBI) scores have been calculated using the latest TBI formula (Lohrer and Rodil 2011) and October data from each site. TBI scores for the four currently monitored sites ranged from 0.29 at HBV (October 2000) to 0.69 at ShB (October 2009) (Figure 13, Table 10). Interestingly, the values for the four monitored sites were quite similar to one another and increased and decreased together over time, suggesting that the various resident species at the sites are responding in concert to broad scale change (e.g., ENSO, storms, larval settlement, factors affecting productivity). In October 2011 (Halliday et al. 2012) the TBI scores were on average higher than in 2000 and appeared to be trending upwards. Since then the score for ShB has decreased slightly, while the scores for HBV, Whau and LoS all increased from October 2011 to 2012, and then decreased in 2013 (Figure 13). The analysis of TBI scores in other locations within the Auckland area demonstrates that there can be natural variability in TBI scores over long timescales (Hewitt et al. 2012). Fluctuations in scores that are already >0.4 are generally of no concern; downward trends in TBI scores to values <0.3 are slightly more concerning, as this likely indicates a negative response to mud or metals (or both).

Figure 13.

TBI score for the four monitoring sites (HBV, LoS, ShB and Whau) during the monitoring period (October 2000 – October 2013). TBI scores are calculated from the entire macrobenthic fauna, not just the monitored taxa, found at each site during the October sampling.



Benthic health model scores for both mud and metals were also calculated (Table 10). Of all the sites LoS has the highest scores for both metals and mud (i.e., lower health), although the scores are around the middle of the model range for both metals and mud, indicating moderate health. No consistent changes in direction were apparent for CAPmetal scores at any of the sites. However, an increase in CAPmud scores was apparent for ShB. A comparison of the combined health scores (TBI and BHM) of the Central Waitematā monitored sites to sites that are part of other monitoring programs shows they are in relatively good condition (Figure 14).

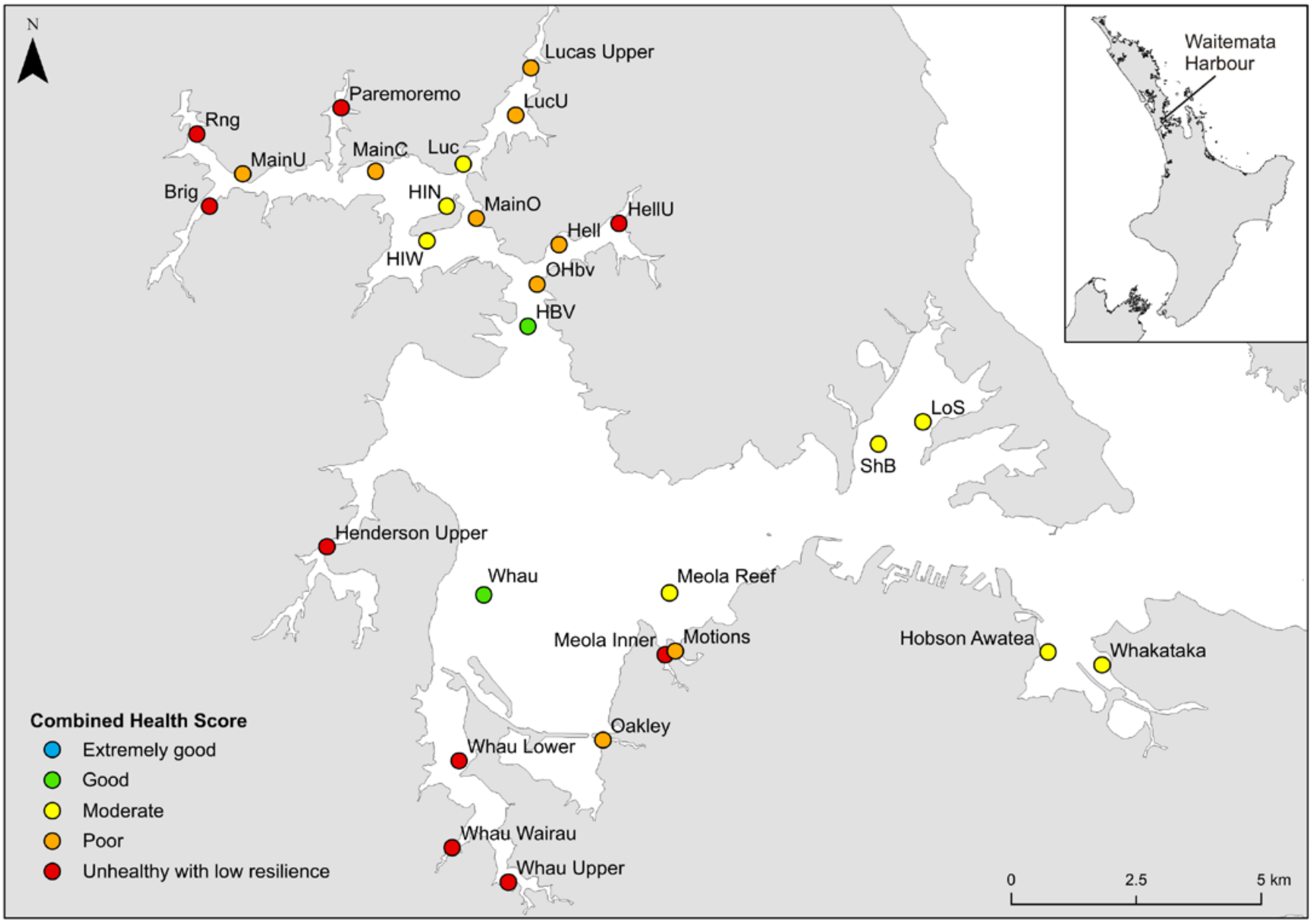
Table 10.

Benthic Health Model scores for metals and mud (CAPmetal, CAPmud), TBI scores and combined health scores for the presently monitored sites in 2000, 2009, 2010, 2011, 2012 and 2013. Health scores, “x”, are translated as: x ≤ 0.2 “extremely good”; 0.2 <x≤ 0.4 “good”; 0.4 <x≤ 0.6 “moderate”; 0.6 <x≤ 0.8 “poor” and x > 0.8 “unhealthy with low resilience”. Note: monitoring at LoS did not begin until 2010.

Site	Year	CAPmetal	CAPmud	TBI	Combined health score
Hbv	2000	-0.116	-0.161	0.29	
	2009	-0.095	-0.137	0.59	
	2010	-0.117	-0.141	0.67	
	2011	-0.156	-0.148	0.56	
	2012	-0.111	-0.125	0.58	
	2013	-0.099	-0.127	0.46	0.30
LoS	2010	-0.028	-0.014	0.66	
	2011	-0.043	0.011	0.46	
	2012	-0.019	-0.013	0.65	
	2013	-0.018	0.025	0.43	0.58
ShB	2000	-0.080	-0.127	0.44	
	2009	-0.082	-0.077	0.70	
	2010	-0.081	-0.055	0.63	
	2011	-0.100	-0.073	0.69	
	2012	-0.086	-0.063	0.65	
	2013	-0.081	-0.046	0.61	0.44
Whau	2000	-0.075	-0.125	0.44	
	2009	-0.123	-0.122	0.60	
	2010	-0.093	-0.127	0.55	
	2011	-0.115	-0.130	0.51	
	2012	-0.088	-0.102	0.58	
	2013	-0.105	-0.123	0.50	0.30

Figure 14.

Map of the Waitematā Harbour showing October 2013 combined health scores (TBI and BHM) for all of the monitored Central Waitematā sites (HBV, Whau, ShB and LoS) as well as those sampled during other AC monitoring projects in the area (Upper Waitematā Harbour and Regional Discharge Programme).



6 Conclusions and recommendations

This report set out to determine changes in site characteristics and benthic macrofaunal species. Any changes detected then have to be assessed to determine whether they are either of concern already or may lead to concerns about the health either of the whole harbour or a section of it. At present, the combined health scores, calculated from the Benthic Health Model and Traits-Based Index scores, show that all four of the currently monitored sites in the Central Waitematā Harbour are in relatively good condition.

There has been minimal change in the temporal variability of sediment characteristics over the last two years at the Hobsonville (HBV), Whau (Whau) and Lower Shoal Bay (LoS) sites. However, there has been a noticeable trend of increasing mud content at the other site in Shoal Bay (ShB). This change looks to be anthropogenic in origin, associated with higher sedimentation in this embayment. Future monitoring is necessary to determine the potential for further changes (as predicted by Green 2008) and if future community changes relate to environmental parameters.

The general patterns in macrofaunal species abundances and community composition occurring in the Central Waitematā are: (1) relatively minor change occurring at HBV and Whau relating to seasonality and multi-year patterns in abundances and (2) larger change at ShB in species abundances associated with increasing mud content at this site. There is not enough time series data to draw any conclusions on changes over the whole of the Shoal Bay area as sampling at the secondary site did not begin until October 2010.

The changes recorded at Shoal Bay have some implications for the design of the monitoring. Continuing to monitor the older Shoal Bay site (ShB) is no longer very effective due to the increased muddiness of the site and the change in species abundance detected as a result. The newer Shoal Bay site (LoS) was established to monitor the effect of predicted increases in sedimentation and metal contamination in the intertidal areas of Shoal Bay (Green 2008). However, LoS is already considerably muddier than ShB and the other monitoring sites and the fauna reflects this. Observations of the site also suggest that it is lower down the shore than the other sites, meaning that it will be exposed less frequently. This is backed up by the presence of subtidal mysid shrimps in many of the samples. As the taxa at LoS appear to be relatively tolerant of mud, it is likely that further sedimentation will result in only subtle changes in the monitored populations and the broader macrofaunal community, changes that may be hard to detect. Therefore, as previously suggested, we recommend the investigation of alternative sandier sites within the Shoal Bay area, for a single replacement for both LoS and ShB. We do, however, suggest that visual monitoring of the current ShB site is maintained to see if sediment is still being deposited, or if it is eroding again.

Another recommendation related to the monitoring programme relates to the tidal drainage channel next to HBV and another smaller channel that have been slowly expanding over time and are causing increased muddiness in a small section of the site nearest the 0,0 peg (Lundquist pers obs). We recommend that the extent of the muddy area at the site is noted on each sampling occasion and that the macrofaunal samples collected within this area are indicated. This will allow us to assess the potential effects of these channels. We also recommend collecting two separate grainsize samples at this site, one from the muddier area near the 0,0 peg and one composite sample from the rest of the site. The effect of the channel expansion will have to be continually monitored and consideration should be given on a yearly basis to moving the site 10 m alongshore to the north to ensure that changing sediment conditions are a result of anthropogenic impacts and not changing hydrodynamics at the site.

We also have been notified by Auckland Council of a change in the person who will be running this monitoring programme. Therefore, we recommend that a scientist who is familiar with the sites should be present during two of the six sampling trips per year. This would allow scientific input into the monitoring of site changes such as the channel encroachment at HBV. Scientific input would also ensure the consistency of field sampling methods, which is absolutely critical to the interpretation and utility of long-term environmental data upon which the AC relies for resource management and State of the Environment reporting.

Finally, sampling at the Reef and HC sites was suspended in April 2010. Following a five year rotation policy, sampling of these sites should resume in June 2015.

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9 Plates

Plate 1.

The Hobsonville area (top), with a close-up of sediment from within the HBV site (bottom). Photos taken in April 2014.

Plate 2.

The sandflat near Whau River (top), with a close-up of sediment from within the Whau site (bottom). Photos taken in April 2014.

Plate 3.

The sand flat on the western side of Shoal Bay (ShB) with the 0,0 marker (top), and a close-up of sediment from within the ShB site (bottom). Photos taken in April 2014.

Plate 4.

The sand flat on the eastern side of Shoal Bay (LoS) with the 0,0 marker (top), and a close-up of sediment from within the LoS site (bottom). Photos taken in April 2014.

10 Appendices

10.1 Appendix 1: Sediment characteristics October 2000 – February 2014

Sediment characteristics including particle size as gravimetric %, % organics calculated from loss on ignition, and chlorophyll *a* (chla). June 2004 samples were lost prior to analysis.

site	date	%clay	%silt	%mud	%fine sand	%med sand	%coarse sand	% gravel	% organics	chla υg/g
HBV	Oct-00	0.48	7.65	8.13	74.16	12.20	4.01	1.50	0.95	10.26
	Dec-00	0.05	5.17	5.22	78.45	10.74	2.33	3.26	1.05	13.36
	Feb-01	1.08	4.41	5.49	75.11	14.43	2.88	2.09	1.16	13.62
	Apr-01	1.80	4.84	6.64	66.93	18.26	4.97	3.20	1.29	17.77
	Jun-01	1.38	2.59	3.97	67.83	18.27	5.19	4.75	1.18	18.79
	Aug-01	1.20	4.46	5.66	77.59	12.67	2.66	1.43	1.15	17.51
	Oct-01	1.49	3.83	5.32	73.67	14.90	4.02	2.09	0.81	16.50
	Dec-01	1.60	4.42	6.02	71.49	15.98	2.73	3.78	0.80	12.38
	Feb-02	1.80	3.24	5.03	71.49	13.79	4.96	4.72	1.67	11.21
	Apr-02	0.85	1.02	1.88	46.32	45.28	5.92	0.60	1.14	17.18
	Jun-02	0.69	0.69	1.38	48.61	42.09	5.58	2.34	1.17	18.09
	Aug-02	0.32	0.49	0.81	46.19	40.48	9.45	3.07	2.43	15.80
	Oct-02	0.50	1.49	1.99	54.79	31.31	8.15	3.75	3.73	13.98
	Dec-02	1.60	0.27	1.86	58.28	32.23	4.65	2.97	1.25	12.58
	Feb-03	1.70	1.06	2.76	53.54	31.54	8.33	3.82	1.12	12.20
	Apr-03	0.00	2.05	2.05	55.95	33.42	7.65	0.92	1.39	17.75
	Jun-03	1.05	1.05	2.10	56.44	24.44	13.32	3.69	1.17	10.76
	Aug-03	0.00	1.29	1.29	60.15	31.61	6.09	0.86	0.78	11.24
	Oct-03	0.78	0.78	1.55	50.07	39.00	7.84	1.53	0.78	7.97
	Dec-03	0.00	1.50	1.50	47.68	43.56	7.09	0.17	0.83	14.11
	Feb-04	0.00	1.85	1.85	59.54	31.24	5.70	1.67	1.11	12.83
	Apr-04	0.00	2.67	2.67	49.60	32.00	5.75	9.98	3.38	11.23
	Jun-04									7.98
	Aug-04	2.32	1.55	3.87	56.69	33.33	6.10	0.00	0.52	18.04
	Oct-04	1.97	0.98	2.95	52.05	25.78	5.87	13.36	1.75	10.78
	Dec-04	2.40	0.00	2.40	48.99	39.52	8.70	0.38	2.19	15.36
	Feb-05	2.55	1.28	3.83	56.71	32.41	6.53	0.52	6.40	10.39
	Apr-05	1.30	2.59	3.89	49.48	33.58	7.08	5.97	1.07	12.66
	Jun-05	2.25	2.25	4.50	54.52	33.01	7.30	0.67	1.29	16.24
	Aug-05	2.46	0.99	3.45	56.32	34.15	5.67	0.41	1.12	15.32
	Oct-05	1.65	0.47	2.12	54.51	36.31	6.86	0.20	1.53	17.55
	Dec-05	0.98	0.00	0.98	44.21	42.33	10.71	1.76	1.75	10.68
	Feb-06	1.61	1.61	3.22	63.63	36.18	6.78	0.18	1.87	11.00
	Apr-06	1.67	2.01	3.68	57.92	30.86	6.47	1.07	0.78	10.99
	Jun-06	0.96	1.43	2.39	57.51	32.08	6.94	1.09	1.48	9.51
	Aug-06	2.85	0.36	3.21	56.96	32.09	5.10	2.64	1.46	19.72
	Oct-06	1.20	0.60	1.80	52.08	36.62	7.92	1.58	1.39	15.81
	Dec-06	2.29	0.76	3.05	58.52	32.22	4.77	1.44	1.21	11.70
	Feb-07	1.66	2.07	3.72	55.41	34.87	4.95	1.04	2.22	14.55
	Apr-07	3.23	0.40	3.63	50.80	36.13	7.76	1.68	1.43	13.87
	Jun-07	2.06	1.85	3.91	65.45	24.73	4.25	1.66	1.40	16.27
	Aug-07	0.00	3.87	3.87	58.35	23.11	12.43	2.25	1.92	16.39
	Oct-07	1.86	0.27	2.13	55.62	33.52	7.67	1.07	1.13	12.15
HBV	Dec-07	1.50	3.00	4.51	58.93	25.96	8.82	1.79	1.89	12.50
	Feb-08	2.46	0.82	3.28	56.54	32.59	7.19	0.40	1.54	13.64
	Apr-08	3.29	3.29	6.58	52.95	33.90	4.88	1.68	1.85	12.73

site	date	%clay	%silt	%mud	%fine sand	%med sand	%coarse sand	% gravel	% organics	chla υg/g
	Jun-08	1.72	1.15	2.87	60.36	28.98	6.51	1.28	1.64	11.70
	Aug-08	0.13	2.71	2.83	54.06	37.27	4.91	0.93	1.15	16.27
	Oct-08	2.35	0.00	2.35	65.64	26.23	4.11	1.67	1.25	15.59
	Dec-08	2.39	2.05	4.43	48.40	33.48	11.14	2.55	1.98	12.49
	Feb-09	1.21	0.35	1.56	43.41	34.61	18.45	1.97	1.49	13.53
	Apr-09	2.78	0.28	3.05	58.39	32.80	4.79	0.96	0.91	17.19
	Jun-09	1.47	0.49	1.96	52.58	38.08	6.24	1.14	1.21	14.91
	Aug-09	1.21	1.81	3.02	53.79	33.33	7.65	2.22	1.57	14.67
	Oct-09	1.06	1.06	2.12	51.79	38.05	7.43	0.61	1.15	12.84
	Dec-09	2.61	1.45	4.07	37.53	47.49	9.88	1.03	1.47	12.61
	Feb-10	1.99	2.32	4.32	58.02	31.03	5.58	1.04	0.98	10.89
	Apr-10	1.91	1.53	3.44	51.92	36.15	5.19	3.30	1.33	10.77
	Jun-10	1.30	0.37	1.68	45.94	41.62	8.08	2.69	1.41	14.22
	Aug-10	1.74	0.87	2.61	53.86	34.77	6.97	1.78	1.43	10.66
	Oct-10	2.34	2.34	4.68	56.49	32.61	4.88	1.34	1.65	14.33
	Dec-10	0.87	2.02	2.89	43.18	41.87	8.50	3.56	1.62	15.48
	Feb-11	3.87	0.00	3.87	50.60	38.05	4.62	2.87	1.57	16.51
	Apr-11	2.76	1.38	4.15	44.92	39.78	6.27	4.89	1.36	18.00
	Jun-11	1.61	2.58	4.19	45.92	39.35	5.90	4.64	1.54	16.05
	Aug-11	4.00	1.00	5.00	46.24	39.54	5.59	3.63	2.18	16.16
	Oct-11	1.85	0.98	2.84	49.91	36.12	5.58	5.55	1.18	23.15
	Dec-11	1.97	2.18	4.15	53.38	31.77	5.05	5.65	1.64	14.10
	Feb-12	1.93	1.29	3.22	48.95	37.34	6.58	3.92	1.64	16.63
	Apr-12	0.80	0.60	1.39	40.43	47.10	6.73	4.35	1.32	16.85
	Jun-12	2.88	2.62	5.50	50.06	34.49	6.25	3.70	1.07	16.50
	Aug-12	4.55	1.88	6.43	54.53	31.52	5.76	1.75	0.99	16.05
	Oct-12	2.58	2.58	5.15	55.55	29.71	7.22	2.37	1.40	17.65
	Dec-12	2.00	1.33	3.33	52.81	37.69	4.96	1.21	0.74	17.20
	Feb-13	1.88	0.94	2.82	61.60	26.65	5.12	3.81	0.36	12.38
	Apr-13	3.99	2.18	6.17	55.40	31.32	5.09	2.01	0.91	17.88
	Jun-13	1.53	0.92	2.45	60.93	29.66	4.99	1.97	0.89	15.02
	Aug-13	3.04	2.78	5.82	56.49	29.91	5.85	1.93	1.20	17.78
	Oct-13	1.14	0.46	1.60	58.27	32.84	4.26	3.03	1.11	15.08
	Dec-13	2.83	1.41	4.24	53.22	36.11	5.45	0.99	0.96	15.22
	Feb-14	0.78	1.81	2.59	64.70	27.84	3.32	1.56	0.85	17.92
ShB	Oct-00	0.13	3.33	3.46	78.71	14.11	2.46	1.26	0.63	5.23
	Dec-00	0.42	1.74	2.16	68.32	24.91	1.96	2.65	0.64	8.78
	Feb-01	0.46	1.27	1.73	67.55	28.84	0.87	1.01	0.27	4.87
	Apr-01	0.09	1.59	1.68	74.45	21.83	0.64	1.41	0.91	7.04
	Jun-01	0.37	1.17	1.54	72.98	22.83	1.31	1.35	0.49	10.29
	Aug-01	0.77	2.24	3.00	71.78	20.01	1.57	3.64	0.54	7.03
	Oct-01	12.36	0.65	13.01	63.30	22.43	0.70	0.56	0.48	10.72
	Dec-01	0.96	0.67	1.63	62.87	20.93	0.55	14.01	1.05	11.10
	Feb-02	0.68	2.91	3.59	78.72	15.86	1.08	0.76	0.76	10.53
	Apr-02	0.19	1.31	1.49	77.08	17.17	1.90	2.36	0.62	10.03
	Jun-02	0.50	1.66	2.15	67.64	25.86	2.01	2.34	0.73	8.19
	Aug-02	2.34	0.00	2.34	67.51	25.94	2.72	1.50	0.69	10.67
	Oct-02	2.80	0.25	3.06	80.84	11.70	3.33	1.07	0.81	7.79
	Dec-02	0.47	0.10	0.58	60.27	25.83	8.71	4.61	0.84	8.48
	Feb-03	0.18	0.55	0.74	53.62	37.54	5.03	3.07	0.23	6.45
	Apr-03	0.00	1.56	1.56	69.27	23.72	2.63	2.82	0.51	6.63
	Jun-03	0.00	1.89	1.89	48.92	41.65	1.68	5.86	0.70	8.38
	Aug-03	1.36	0.82	2.18	76.41	9.37	1.37	10.68	0.59	6.37
	Oct-03	0.36	2.89	3.25	79.66	12.31	2.13	2.65	0.70	6.87
	Dec-03	0.00	2.44	2.44	75.61	14.59	1.76	5.59	0.57	5.62
	Feb-04	0.00	3.33	3.33	69.35	14.13	3.97	9.21	0.91	5.05

site	date	%clay	%silt	%mud	%fine sand	%med sand	%coarse sand	% gravel	% organics	chla υg/g
	Apr-04	0.00	7.35	7.35	83.55	8.02	0.41	0.66	0.42	2.77
	Jun-04									13.56
	Aug-04	3.18	3.18	6.37	73.68	9.39	4.58	5.98	0.54	8.08
	Oct-04	0.83	0.83	1.67	72.67	24.18	0.77	0.71	0.87	8.37
	Dec-04	1.98	0.00	1.98	77.59	10.56	2.69	7.19	1.36	6.53
	Feb-05	0.00	3.20	3.20	85.28	10.82	0.59	0.12	1.94	7.99
	Apr-05	3.08	2.55	5.63	87.08	4.75	0.66	1.88	1.23	6.75
	Jun-05	2.69	1.35	4.04	75.08	7.57	2.87	10.44	0.96	5.04
	Aug-05	2.65	0.44	3.09	74.20	11.95	4.48	6.28	0.78	6.81
	Oct-05	2.23	2.60	4.83	84.69	8.11	0.87	1.50	1.01	14.32
	Dec-05	1.02	0.00	1.02	85.13	12.27	0.80	0.78	0.68	6.64
	Feb-06	5.85	0.49	6.33	86.11	3.79	0.53	3.23	0.71	4.23
	Apr-06	0.86	2.59	3.45	73.95	13.06	3.12	6.42	0.54	6.53
	Jun-06	0.96	1.50	2.46	78.57	10.29	3.51	5.17	1.48	8.36
	Aug-06	2.60	3.38	5.99	76.75	9.94	1.33	5.99	0.87	7.68
	Oct-06	3.84	3.14	6.98	74.17	10.81	1.84	6.19	0.88	9.40
	Dec-06	2.16	0.72	2.88	77.40	7.04	2.19	10.49	0.76	4.36
	Feb-07	3.56	6.24	9.80	78.43	5.36	1.57	4.84	0.70	7.11
	Apr-07	3.29	1.92	5.22	82.41	9.51	1.54	1.33	0.91	6.76
	Jun-07	3.39	5.57	8.96	71.75	7.67	3.39	8.23	1.15	2.75
	Aug-07	0.50	3.00	3.50	83.17	11.42	1.28	0.62	0.91	10.66
	Oct-07	2.70	1.62	4.33	80.22	8.47	2.61	4.37	1.23	6.88
	Dec-07	1.49	2.09	3.58	72.77	7.07	1.97	14.62	1.11	6.54
	Feb-08	1.31	1.58	2.89	72.32	7.57	1.88	15.34	1.02	5.62
	Apr-08	2.39	0.34	2.74	69.24	20.29	2.41	5.32	0.88	8.37
	Jun-08	4.00	4.99	8.99	70.79	4.73	0.68	14.80	1.31	9.86
	Aug-08	4.39	4.88	9.27	67.93	4.81	2.54	15.46	1.33	13.30
	Oct-08	4.76	2.93	7.69	78.64	6.04	3.28	4.36	1.13	11.00
	Dec-08	2.25	2.89	5.14	71.39	8.71	1.04	13.72	0.88	8.14
	Feb-09	2.16	1.44	3.60	68.63	12.48	3.05	12.24	1.02	7.91
	Apr-09	5.27	4.74	10.01	87.79	2.05	0.14	0.00	1.46	6.94
	Jun-09	5.79	5.31	11.11	70.52	7.33	2.17	8.88	1.11	8.14
	Aug-09	2.98	4.68	7.65	75.92	8.41	3.63	4.38	1.17	8.14
	Oct-09	2.87	6.97	9.84	79.50	5.67	2.11	2.89	1.01	7.79
	Dec-09	4.01	1.46	5.47	68.29	15.24	2.49	8.51	0.91	7.22
	Feb-10	3.18	0.95	4.14	69.20	10.58	6.16	9.92	1.16	4.76
	Apr-10	4.92	6.24	11.16	80.87	3.49	1.18	3.30	1.91	9.17
	Jun-10	0.29	0.27	0.56	84.20	10.04	1.85	3.35	1.26	8.83
	Aug-10	5.90	8.84	14.74	70.72	5.33	1.92	7.29	1.84	7.11
	Oct-10	2.97	3.82	6.78	86.61	5.01	0.62	0.97	1.05	8.25
	Dec-10	2.64	3.44	6.08	71.49	4.37	1.67	16.40	1.28	8.48
	Feb-11	3.40	2.72	6.11	72.32	10.12	2.93	8.51	1.04	8.83
	Apr-11	3.17	2.47	5.63	73.88	11.68	3.80	5.01	0.85	7.11
	Jun-11	3.90	2.44	6.34	82.30	6.44	0.45	4.48	0.98	12.15
	Aug-11	4.82	3.61	8.43	76.94	3.93	1.71	8.99	1.63	9.86
	Oct-11	4.50	5.90	10.40	75.49	5.86	3.46	4.78	1.20	14.22
	Dec-11	4.16	6.24	10.40	65.83	6.12	2.23	15.41	1.54	8.42
	Feb-12	2.33	2.92	5.25	72.27	6.60	6.63	6.25	0.78	10.78
	Apr-12	1.79	2.51	4.30	74.75	7.06	4.48	9.41	0.86	8.60
	Jun-12	3.56	4.93	8.48	85.50	3.48	0.98	1.56	1.01	12.15
	Aug-12	5.29	5.06	10.35	79.56	5.63	1.30	3.17	0.92	12.61
	Oct-12	4.08	3.40	7.47	81.63	4.56	1.92	4.42	0.90	7.91
	Dec-12	3.91	3.26	7.17	77.39	5.70	3.43	6.31	0.68	8.94
	Feb-13	4.42	3.22	7.64	79.59	4.93	2.70	5.14	0.35	6.65
	Apr-13	4.03	3.02	7.05	78.03	4.41	1.80	8.72	0.51	7.68
	Jun-13	4.46	5.45	9.91	79.39	6.03	2.35	2.32	0.78	11.92
	Aug-13	4.53	9.41	13.94	80.81	3.42	1.24	0.58	0.83	12.61
	Oct-13	3.19	6.39	9.58	78.05	3.48	2.44	6.45	1.06	11.17

site	date	%clay	%silt	%mud	%fine sand	%med sand	%coarse sand	% gravel	% organics	chla υg/g
	Dec-13	3.22	3.96	7.18	84.44	4.28	1.35	2.75	0.74	10.17
	Feb-14	2.65	6.07	8.72	85.89	2.66	0.84	1.89	0.65	9.99
Whau	Oct-00	0.02	2.75	2.77	93.64	1.79	0.80	1.00	0.76	5.23
	Dec-00	0.26	1.96	2.22	92.38	3.04	0.82	1.53	0.77	8.78
	Feb-01	0.70	2.11	2.81	91.90	2.40	0.69	2.19	0.86	4.87
	Apr-01	0.02	3.17	3.19	82.15	14.23	0.26	0.16	1.42	7.04
	Jun-01	0.57	1.67	2.24	88.91	3.37	0.64	4.84	1.02	10.29
	Aug-01	0.85	1.84	2.69	94.48	1.81	0.65	0.36	0.90	7.03
	Oct-01	0.85	1.90	2.75	92.42	2.78	0.47	1.59	0.86	10.72
	Dec-01	0.53	1.38	1.91	91.65	1.10	0.34	5.00	2.86	11.10
	Feb-02	0.41	2.00	2.41	90.94	4.59	0.81	1.24	1.03	10.53
	Apr-02	1.06	1.06	2.12	95.48	1.29	0.43	0.68	0.93	10.03
	Jun-02	0.00	1.81	1.81	91.37	5.18	0.75	0.89	1.09	8.19
	Aug-02	0.00	1.81	1.81	92.44	2.49	0.54	2.72	1.07	10.67
	Oct-02	0.99	2.31	3.30	91.71	3.79	0.56	0.64	0.75	7.79
	Dec-02	1.70	0.57	2.26	94.94	1.57	0.49	0.73	0.58	8.48
	Feb-03	2.50	1.59	4.10	88.20	4.67	0.91	2.12	0.76	6.45
	Apr-03	0.80	2.41	3.21	92.25	2.19	0.52	1.83	0.80	6.63
	Jun-03	1.76	1.76	3.52	92.20	3.16	0.65	0.47	0.85	8.38
	Aug-03	1.91	0.00	1.91	95.10	1.98	0.59	0.42	0.80	6.37
	Oct-03	1.46	1.46	2.92	93.55	2.24	0.66	0.64	0.92	6.87
	Dec-03	0.80	4.01	4.81	91.87	2.09	0.35	0.89	0.87	5.62
	Feb-04	0.86	4.30	5.16	92.29	1.20	0.50	0.85	0.84	5.05
	Apr-04	0.00	5.10	5.10	93.48	0.97	0.45	0.00	0.58	8.72
	Jun-04									10.02
	Aug-04	2.00	1.33	3.33	94.22	1.51	0.88	0.05	0.16	13.28
	Oct-04	1.47	0.59	2.06	93.08	1.07	0.39	3.40	1.17	11.22
	Dec-04	1.33	2.65	3.98	93.68	1.55	0.80	0.00	2.03	11.79
	Feb-05	0.00	1.62	1.62	93.95	1.22	0.73	2.48	1.58	10.13
	Apr-05	1.94	3.23	5.16	88.73	1.26	0.60	4.24	1.28	7.36
	Jun-05	3.52	0.59	4.10	93.07	0.89	0.58	1.35	1.02	9.77
	Aug-05	2.74	2.19	4.93	91.40	1.37	0.71	1.59	0.63	12.94
	Oct-05	1.05	2.10	3.15	92.89	1.40	0.90	1.67	1.01	12.41
	Dec-05	1.54	0.00	1.54	96.07	1.22	0.42	0.75	1.19	7.19
	Feb-06	1.10	0.74	1.84	95.69	0.83	0.54	1.09	0.84	10.60
	Apr-06	1.96	1.96	3.92	92.11	1.29	0.76	1.93	0.48	11.44
	Jun-06	2.39	0.95	3.34	92.73	1.43	0.65	1.85	1.28	12.37
	Aug-06	1.46	2.29	3.75	93.08	1.45	0.68	1.04	1.25	14.44
	Oct-06	1.00	1.75	2.75	93.43	1.55	1.50	0.77	0.84	16.74
	Dec-06	2.32	0.58	2.90	93.74	1.72	0.96	0.68	0.98	13.87
	Feb-07	2.83	0.00	2.83	93.19	2.00	0.57	1.40	1.12	13.29
	Apr-07	2.09	1.77	3.86	91.61	1.56	0.80	2.17	0.85	11.47
	Jun-07	1.78	1.60	3.38	92.71	1.86	1.00	1.04	1.16	11.93
	Aug-07	0.27	1.09	1.37	94.93	1.41	0.56	1.74	0.99	14.67
	Oct-07	0.78	1.05	1.83	92.89	1.23	0.83	3.22	0.85	12.39
	Dec-07	2.03	0.00	2.03	91.51	1.53	0.86	4.06	1.02	12.73
	Feb-08	1.63	0.65	2.29	90.91	2.15	1.26	3.39	1.14	10.20
	Apr-08	2.15	0.00	2.15	92.77	1.62	0.72	2.74	0.98	9.86
	Jun-08	1.42	1.42	2.85	94.06	1.35	0.72	1.03	1.09	12.38
	Aug-08	3.04	1.75	4.79	89.12	1.83	0.96	3.30	0.95	15.59
	Oct-08	1.04	1.04	2.08	89.35	1.35	0.88	6.34	0.84	10.89
	Dec-08	3.64	2.43	6.06	91.83	1.97	0.13	0.00	0.95	7.97
	Feb-09	2.20	1.20	3.41	81.95	3.37	1.01	10.27	1.24	8.71
	Apr-09	1.33	0.95	2.29	90.33	5.61	0.69	1.08	1.00	11.47
	Jun-09	7.02	1.91	8.93	87.64	1.35	0.79	1.29	1.10	13.30
	Aug-09	1.04	0.35	1.39	94.18	1.63	0.83	1.97	0.92	13.30
	Oct-09	0.87	0.43	1.30	93.40	1.99	0.77	1.67	0.88	13.76

site	date	%clay	%silt	%mud	%fine sand	%med sand	%coarse sand	% gravel	% organics	chla υg/g
	Dec-09	4.05	1.45	5.49	91.22	1.99	0.35	0.94	1.10	13.29
	Feb-10	1.04	0.52	1.56	93.41	3.72	0.93	0.37	0.70	12.50
	Apr-10	2.76	0.23	2.99	93.33	2.64	0.55	0.49	1.06	14.90
	Jun-10	0.18	0.03	0.21	92.98	4.00	1.16	1.65	1.00	21.56
	Aug-10	2.07	0.69	2.76	93.24	2.30	0.68	1.03	1.10	12.38
	Oct-10	1.00	1.99	2.99	93.60	1.90	0.60	0.91	1.16	13.30
	Dec-10	1.96	0.98	2.93	92.30	2.56	0.78	1.42	1.28	12.61
	Feb-11	0.72	0.48	1.20	86.15	5.99	0.72	5.93	1.20	21.78
	Apr-11	1.70	0.73	2.43	93.36	2.70	0.74	0.77	1.23	19.26
	Jun-11	1.22	1.22	2.43	90.82	2.29	0.91	3.55	1.14	16.51
	Aug-11	1.64	0.70	2.35	84.90	2.18	1.10	9.48	1.22	19.03
	Oct-11	1.46	1.32	2.78	91.81	1.79	0.85	2.77	0.98	17.65
	Dec-11	1.63	1.08	2.71	88.26	2.86	0.76	5.41	0.99	15.13
	Feb-12	1.60	0.46	2.06	85.61	2.48	0.68	9.17	1.49	15.02
	Apr-12	0.68	0.68	1.36	92.74	2.37	0.77	2.76	1.04	20.41
	Jun-12	1.87	0.62	2.49	94.61	1.54	0.50	0.87	1.00	21.32
	Aug-12	2.24	0.56	2.80	91.18	2.10	1.11	2.81	0.64	16.28
	Oct-12	1.92	0.96	2.39	91.78	2.61	0.81	1.92	0.71	16.97
	Dec-12	2.44	1.36	3.80	90.95	1.89	0.76	2.60	0.75	13.30
	Feb-13	1.61	0.64	2.26	92.50	1.75	0.74	2.75	0.36	10.89
	Apr-13	2.70	0.68	3.38	88.37	2.10	0.81	5.35	0.65	10.55
	Jun-13	1.66	1.33	2.99	94.49	1.49	0.51	0.52	0.67	15.36
	Aug-13	2.12	0.27	2.39	89.34	1.87	0.84	5.56	0.79	16.04
	Oct-13	1.73	0.86	2.59	93.83	1.77	0.95	0.86	0.87	15.63
	Dec-13	1.56	1.17	2.73	87.29	2.17	0.82	6.97	0.73	16.58
	Feb-14	1.02	1.28	2.30	86.70	1.61	0.44	8.95	0.72	18.77
LoS	Oct-10	5.20	10.97	16.17	81.93	0.65	0.24	1.02	2.11	6.76
	Dec-10	3.33	7.90	11.22	87.15	0.88	0.04	0.71	1.37	7.79
	Feb-11	5.96	15.65	21.61	77.37	0.69	0.19	0.14	1.92	7.68
	Apr-11	4.29	22.22	26.51	72.58	0.59	0.29	0.04	2.25	8.83
	Jun-11	3.62	21.19	24.81	74.36	0.58	0.12	0.13	2.16	8.71
	Aug-11	5.08	14.10	19.18	80.30	0.45	0.06	0.00	2.18	6.31
	Oct-11	5.41	18.33	23.73	74.56	0.92	0.41	0.38	1.96	7.34
	Dec-11	4.67	11.67	16.34	80.44	0.83	0.48	1.92	1.78	6.53
	Feb-12	5.52	11.37	16.89	82.10	0.66	0.17	0.18	1.65	9.63
	Apr-12	3.56	10.04	13.61	82.26	0.55	0.30	3.29	1.44	6.76
	Jun-12	6.25	9.69	15.94	80.89	0.80	0.26	2.11	1.06	7.45
	Aug-12	7.82	10.16	17.98	80.82	0.55	0.16	0.49	1.43	8.03
	Oct-12	7.09	10.40	17.49	77.21	3.16	0.64	1.50	1.41	8.48
	Dec-12	5.92	6.91	12.83	85.53	0.64	0.61	0.40	0.75	8.49
	Feb-13	6.32	7.50	13.82	85.06	0.63	0.30	0.19	0.34	6.77
	Apr-13	6.33	6.75	13.08	85.98	0.60	0.17	0.17	0.81	8.49
	Jun-13	7.35	18.65	26.00	72.93	0.58	0.15	0.34	1.60	12.15
	Aug-13	5.17	11.44	16.61	81.73	0.55	0.30	0.81	1.03	8.48
	Oct-13	3.57	9.37	12.94	85.37	0.51	0.36	0.82	1.04	8.40
	Dec-13	5.58	7.98	13.56	83.94	0.51	0.35	1.64	0.97	8.77
	Feb-14	3.93	6.29	10.22	87.95	0.51	0.28	1.04	0.71	9.35

10.2 Appendix 2: Benthic Invertebrate data collected between April 2012 and February 2014

Total, median, mean number of individuals found in 12 cores. Range= 90th percentile – 5th percentile.

Species: Anthopleura aureoradiata

Site	Series	Total	Median	Range	Mean
Hbv	70	72	4	19	6
Hbv	71	64	5	18	5
Hbv	72	64	4	13	5
Hbv	73	69	5	12	6
Hbv	74	59	6	12	5
Hbv	75	68	5	12	6
Hbv	76	56	4	10	5
Hbv	77	49	4	12	4
Hbv	78	66	4	23	6
Hbv	79	60	3	14	5
Hbv	80	73	4	27	6
Hbv	81	51	3	12	4
LoS	70	0	0	0	0
LoS	71	0	0	0	0
LoS	72	2	0	1	0
LoS	73	0	0	0	0
LoS	74	2	0	2	0
LoS	75	2	0	1	0
LoS	76	2	0	1	0
LoS	77	0	0	0	0
LoS	78	1	0	1	0
LoS	79	0	0	0	0
LoS	80	1	0	1	0
LoS	81	0	0	0	0
ShB	70	12	1	4	1
ShB	71	13	1	8	1
ShB	72	8	0	2	1
ShB	73	9	0	4	1
ShB	74	11	1	5	1
ShB	75	14	1	5	1
ShB	76	13	1	5	1
ShB	77	16	1	5	1
ShB	78	9	0	4	1
ShB	79	6	0	2	1
ShB	80	12	0	7	1
ShB	81	11	0	3	1
Whau	70	25	2	6	2
Whau	71	31	2	7	3
Whau	72	32	3	9	3
Whau	73	36	3	15	3
Whau	74	52	4	6	4
Whau	75	57	6	9	5
Whau	76	28	2	6	2
Whau	77	41	4	6	3
Whau	78	35	2	11	3
Whau	79	34	2	8	3
Whau	80	50	3	9	4
Whau	81	37	3	7	3

Species: Aonides trifida

Site	Series	Total	Median	Range	Mean
Hbv	70	296	24	57	25
Hbv	71	321	24	46	27
Hbv	72	371	29	54	31
Hbv	73	318	23	47	27
Hbv	74	414	37	45	35
Hbv	75	310	25	44	26
Hbv	76	364	32	58	30
Hbv	77	319	26	34	27
Hbv	78	303	24	36	25
Hbv	79	264	23	15	22
Hbv	80	315	24	49	26
Hbv	81	306	25	30	26
LoS	70	0	0	0	0
LoS	71	1	0	1	0
LoS	72	0	0	0	0
LoS	73	0	0	0	0
LoS	74	2	0	1	0
LoS	75	1	0	1	0
LoS	76	0	0	0	0
LoS	77	0	0	0	0
LoS	78	3	0	2	0
LoS	79	0	0	0	0
LoS	80	0	0	0	0
LoS	81	3	0	2	0
ShB	70	7	0	2	1
ShB	71	2	0	1	0
ShB	72	7	0	7	1
ShB	73	0	0	0	0
ShB	74	2	0	1	0
ShB	75	13	0	13	1
ShB	76	2	0	2	0
ShB	77	0	0	0	0
ShB	78	2	0	1	0
ShB	79	0	0	0	0
ShB	80	0	0	0	0
ShB	81	1	0	1	0
Whau	70	4	0	1	0
Whau	71	3	0	1	0
Whau	72	1	0	1	0
Whau	73	2	0	2	0
Whau	74	1	0	1	0
Whau	75	2	0	2	0
Whau	76	1	0	1	0
Whau	77	2	0	2	0
Whau	78	2	0	1	0
Whau	79	6	0	2	1
Whau	80	0	0	0	0
Whau	81	8	0	8	1

Species: *Aricidea* sp.

Site	Series	Total	Median	Range	Mean
Hbv	70	26	1	9	2
Hbv	71	55	3	18	5
Hbv	72	53	2	13	4
Hbv	73	42	3	12	4
Hbv	74	40	2	10	3
Hbv	75	4	0	2	0
Hbv	76	31	2	10	3
Hbv	77	46	4	9	4
Hbv	78	38	2	13	3
Hbv	79	52	4	14	4
Hbv	80	43	2	13	4
Hbv	81	32	1	13	3
LoS	70	36	2	10	3
LoS	71	8	1	2	1
LoS	72	8	0	3	1
LoS	73	94	8	13	8
LoS	74	12	0	4	1
LoS	75	7	0	3	1
LoS	76	16	1	3	1
LoS	77	18	1	5	2
LoS	78	12	1	4	1
LoS	79	8	0	3	1
LoS	80	9	1	2	1
LoS	81	20	0	8	2
ShB	70	25	2	7	2
ShB	71	54	5	15	5
ShB	72	52	3	14	4
ShB	73	64	4	16	5
ShB	74	34	2	10	3
ShB	75	46	1	15	4
ShB	76	58	3	18	5
ShB	77	65	5	11	5
ShB	78	32	1	20	3
ShB	79	43	3	9	4
ShB	80	86	6	35	7
ShB	81	59	6	9	5
Whau	70	158	9	41	13
Whau	71	216	12	49	18
Whau	72	288	21	47	24
Whau	73	383	29	57	32
Whau	74	376	31	63	31
Whau	75	143	7	36	12
Whau	76	307	17	81	26
Whau	77	144	12	28	12
Whau	78	175	13	37	15
Whau	79	367	20	83	31
Whau	80	339	26	61	28
Whau	81	193	12	57	16

Species: Arthritica bifurca

Site	Series	Total	Median	Range	Mean
Hbv	70	9	0	5	1
Hbv	71	3	0	1	0
Hbv	72	13	1	2	1
Hbv	73	8	1	2	1
Hbv	74	8	0	3	1
Hbv	75	10	1	5	1
Hbv	76	1	0	1	0
Hbv	77	8	0	4	1
Hbv	78	14	0	8	1
Hbv	79	2	0	1	0
Hbv	80	6	0	2	1
Hbv	81	6	0	2	1
LoS	70	17	1	6	1
LoS	71	43	3	9	4
LoS	72	34	2	12	3
LoS	73	2	0	1	0
LoS	74	17	0	6	1
LoS	75	30	1	7	3
LoS	76	80	7	22	7
LoS	77	106	8	21	9
LoS	78	65	5	13	5
LoS	79	34	2	10	3
LoS	80	49	3	10	4
LoS	81	59	3	24	5
ShB	70	13	1	3	1
ShB	71	12	1	4	1
ShB	72	3	0	1	0
ShB	73	9	0	5	1
ShB	74	18	0	7	2
ShB	75	17	0	13	1
ShB	76	19	1	6	2
ShB	77	6	0	2	1
ShB	78	2	0	1	0
ShB	79	23	0	18	2
ShB	80	13	0	6	1
ShB	81	8	0	6	1
Whau	70	5	0	4	0
Whau	71	2	0	1	0
Whau	72	1	0	1	0
Whau	73	13	0	9	1
Whau	74	31	1	15	3
Whau	75	10	0	5	1
Whau	76	2	0	1	0
Whau	77	8	0	5	1
Whau	78	8	0	5	1
Whau	79	10	1	3	1
Whau	80	8	0	4	1
Whau	81	18	1	8	2

Species: Austrovenus stutchburyi

Site	Series	Total	Median	Range	Mean
Hbv	70	222	20	27	19
Hbv	71	181	14	28	15
Hbv	72	205	17	13	17
Hbv	73	265	22	28	22
Hbv	74	221	19	28	18
Hbv	75	251	21	29	21
Hbv	76	45	0	22	4
Hbv	77	168	14	11	14
Hbv	78	170	13	21	14
Hbv	79	126	10	14	11
Hbv	80	211	16	33	18
Hbv	81	187	16	17	16
LoS	70	2	0	2	0
LoS	71	8	1	1	1
LoS	72	0	0	0	0
LoS	73	4	0	1	0
LoS	74	5	0	2	0
LoS	75	11	1	3	1
LoS	76	18	1	4	2
LoS	77	7	1	1	1
LoS	78	3	0	1	0
LoS	79	3	0	1	0
LoS	80	3	0	1	0
LoS	81	14	1	3	1
ShB	70	22	0	14	2
ShB	71	10	0	9	1
ShB	72	19	0	17	2
ShB	73	8	0	3	1
ShB	74	14	0	5	1
ShB	75	103	6	38	9
ShB	76	0	0	0	0
ShB	77	47	1	30	4
ShB	78	23	0	16	2
ShB	79	6	0	4	1
ShB	80	41	2	21	3
ShB	81	53	2	18	4
Whau	70	33	2	6	3
Whau	71	51	4	7	4
Whau	72	70	5	10	6
Whau	73	318	20	67	27
Whau	74	698	50	87	58
Whau	75	47	3	11	4
Whau	76	55	4	11	5
Whau	77	35	3	7	3
Whau	78	28	2	9	2
Whau	79	209	18	28	17
Whau	80	393	28	64	33
Whau	81	256	22	30	21

Species: Boccardia syrtis

Site	Series	Total	Median	Range	Mean
Hbv	70	8	1	2	1
Hbv	71	10	1	3	1
Hbv	72	11	1	3	1
Hbv	73	15	1	3	1
Hbv	74	9	1	3	1
Hbv	75	6	0	2	1
Hbv	76	7	0	3	1
Hbv	77	17	2	4	1
Hbv	78	7	0	2	1
Hbv	79	15	1	4	1
Hbv	80	10	0	4	1
Hbv	81	5	0	2	0
LoS	70	15	1	4	1
LoS	71	37	3	7	3
LoS	72	36	3	7	3
LoS	73	11	1	3	1
LoS	74	17	1	4	1
LoS	75	35	2	9	3
LoS	76	46	2	10	4
LoS	77	114	9	21	10
LoS	78	121	8	22	10
LoS	79	92	8	18	8
LoS	80	48	3	11	4
LoS	81	43	3	8	4
ShB	70	21	1	5	2
ShB	71	44	4	12	4
ShB	72	26	3	5	2
ShB	73	12	1	4	1
ShB	74	9	0	4	1
ShB	75	15	1	4	1
ShB	76	59	2	34	5
ShB	77	53	4	11	4
ShB	78	21	0	6	2
ShB	79	34	2	8	3
ShB	80	15	1	4	1
ShB	81	57	4	16	5
Whau	70	9	1	3	1
Whau	71	191	11	78	16
Whau	72	214	21	21	18
Whau	73	241	16	44	20
Whau	74	37	2	11	3
Whau	75	19	1	9	2
Whau	76	19	2	4	2
Whau	77	39	2	13	3
Whau	78	7	0	3	1
Whau	79	13	1	5	1
Whau	80	11	0	5	1
Whau	81	19	1	5	2

Species: Colurostylis lemurum

Site	Series	Total	Median	Range	Mean
Hbv	70	178	11	23	15
Hbv	71	133	6	45	11
Hbv	72	97	8	13	8
Hbv	73	51	5	8	4
Hbv	74	56	4	19	5
Hbv	75	16	1	4	1
Hbv	76	47	3	11	4
Hbv	77	43	4	8	4
Hbv	78	14	1	3	1
Hbv	79	63	5	10	5
Hbv	80	34	2	12	3
Hbv	81	18	1	8	2
LoS	70	0	0	0	0
LoS	71	0	0	0	0
LoS	72	0	0	0	0
LoS	73	2	0	1	0
LoS	74	0	0	0	0
LoS	75	0	0	0	0
LoS	76	1	0	1	0
LoS	77	0	0	0	0
LoS	78	0	0	0	0
LoS	79	0	0	0	0
LoS	80	0	0	0	0
LoS	81	6	0	3	1
ShB	70	2	0	1	0
ShB	71	4	0	2	0
ShB	72	1	0	1	0
ShB	73	4	0	2	0
ShB	74	22	0	12	2
ShB	75	12	1	7	1
ShB	76	7	0	4	1
ShB	77	7	0	3	1
ShB	78	4	0	1	0
ShB	79	3	0	1	0
ShB	80	15	2	2	1
ShB	81	22	2	5	2
Whau	70	132	9	22	11
Whau	71	90	7	8	8
Whau	72	44	3	8	4
Whau	73	37	3	7	3
Whau	74	8	0	3	1
Whau	75	14	1	5	1
Whau	76	49	4	7	4
Whau	77	56	5	11	5
Whau	78	9	0	3	1
Whau	79	20	1	6	2
Whau	80	26	2	4	2
Whau	81	61	5	8	5

Species: Diloma subrostrata

Site	Series	Total	Median	Range	Mean
Hbv	70	0	0	0	0
Hbv	71	5	0	1	0
Hbv	72	1	0	1	0
Hbv	73	8	1	2	1
Hbv	74	3	0	1	0
Hbv	75	4	0	2	0
Hbv	76	3	0	1	0
Hbv	77	7	0	2	1
Hbv	78	6	1	1	1
Hbv	79	7	0	3	1
Hbv	80	8	1	3	1
Hbv	81	9	1	2	1
LoS	70	0	0	0	0
LoS	71	0	0	0	0
LoS	72	0	0	0	0
LoS	73	0	0	0	0
LoS	74	0	0	0	0
LoS	75	0	0	0	0
LoS	76	0	0	0	0
LoS	77	0	0	0	0
LoS	78	0	0	0	0
LoS	79	0	0	0	0
LoS	80	0	0	0	0
LoS	81	0	0	0	0
ShB	70	0	0	0	0
ShB	71	0	0	0	0
ShB	72	3	0	2	0
ShB	73	1	0	1	0
ShB	74	1	0	1	0
ShB	75	0	0	0	0
ShB	76	2	0	1	0
ShB	77	0	0	0	0
ShB	78	4	0	2	0
ShB	79	0	0	0	0
ShB	80	0	0	0	0
ShB	81	0	0	0	0
Whau	70	3	0	2	0
Whau	71	2	0	1	0
Whau	72	1	0	1	0
Whau	73	5	0	2	0
Whau	74	3	0	1	0
Whau	75	4	0	2	0
Whau	76	5	0	1	0
Whau	77	3	0	1	0
Whau	78	3	0	1	0
Whau	79	9	0	7	1
Whau	80	4	0	3	0
Whau	81	2	0	1	0

Species: *Euchone* sp.

Site	Series	Total	Median	Range	Mean
Hbv	70	0	0	0	0
Hbv	71	0	0	0	0
Hbv	72	0	0	0	0
Hbv	73	0	0	0	0
Hbv	74	0	0	0	0
Hbv	75	0	0	0	0
Hbv	76	0	0	0	0
Hbv	77	0	0	0	0
Hbv	78	0	0	0	0
Hbv	79	0	0	0	0
Hbv	80	2	0	1	0
Hbv	81	0	0	0	0
LoS	70	2	0	2	0
LoS	71	5	0	2	0
LoS	72	18	1	7	2
LoS	73	0	0	0	0
LoS	74	1	0	1	0
LoS	75	13	1	4	1
LoS	76	46	2	12	4
LoS	77	144	8	38	12
LoS	78	86	6	16	7
LoS	79	35	2	8	3
LoS	80	25	2	5	2
LoS	81	29	2	8	2
ShB	70	14	0	10	1
ShB	71	92	1	60	8
ShB	72	10	0	4	1
ShB	73	10	0	5	1
ShB	74	5	0	2	0
ShB	75	10	0	3	1
ShB	76	35	2	9	3
ShB	77	59	0	30	5
ShB	78	12	0	7	1
ShB	79	14	1	7	1
ShB	80	26	2	6	2
ShB	81	27	1	11	2
Whau	70	0	0	0	0
Whau	71	0	0	0	0
Whau	72	0	0	0	0
Whau	73	0	0	0	0
Whau	74	0	0	0	0
Whau	75	0	0	0	0
Whau	76	0	0	0	0
Whau	77	0	0	0	0
Whau	78	0	0	0	0
Whau	79	0	0	0	0
Whau	80	0	0	0	0
Whau	81	1	0	1	0

Species: Exosphaeroma planulum

Site	Series	Total	Median	Range	Mean
Hbv	70	0	0	0	0
Hbv	71	0	0	0	0
Hbv	72	1	0	1	0
Hbv	73	4	0	1	0
Hbv	74	2	0	1	0
Hbv	75	2	0	1	0
Hbv	76	0	0	0	0
Hbv	77	0	0	0	0
Hbv	78	2	0	1	0
Hbv	79	0	0	0	0
Hbv	80	0	0	0	0
Hbv	81	0	0	0	0
LoS	70	0	0	0	0
LoS	71	0	0	0	0
LoS	72	0	0	0	0
LoS	73	0	0	0	0
LoS	74	0	0	0	0
LoS	75	0	0	0	0
LoS	76	0	0	0	0
LoS	77	0	0	0	0
LoS	78	0	0	0	0
LoS	79	0	0	0	0
LoS	80	0	0	0	0
LoS	81	0	0	0	0
ShB	70	0	0	0	0
ShB	71	0	0	0	0
ShB	72	0	0	0	0
ShB	73	0	0	0	0
ShB	74	0	0	0	0
ShB	75	1	0	1	0
ShB	76	0	0	0	0
ShB	77	0	0	0	0
ShB	78	0	0	0	0
ShB	79	0	0	0	0
ShB	80	0	0	0	0
ShB	81	0	0	0	0
Whau	70	0	0	0	0
Whau	71	0	0	0	0
Whau	72	0	0	0	0
Whau	73	3	0	2	0
Whau	74	0	0	0	0
Whau	75	0	0	0	0
Whau	76	0	0	0	0
Whau	77	0	0	0	0
Whau	78	0	0	0	0
Whau	79	0	0	0	0
Whau	80	0	0	0	0
Whau	81	0	0	0	0

Species: Glycera americana

Site	Series	Total	Median	Range	Mean
Hbv	70	15	1	3	1
Hbv	71	17	1	3	1
Hbv	72	11	1	2	1
Hbv	73	7	1	2	1
Hbv	74	6	1	1	1
Hbv	75	9	0	4	1
Hbv	76	2	0	1	0
Hbv	77	3	0	1	0
Hbv	78	6	0	2	1
Hbv	79	7	1	2	1
Hbv	80	5	0	2	0
Hbv	81	3	0	1	0
LoS	70	2	0	1	0
LoS	71	4	0	1	0
LoS	72	0	0	0	0
LoS	73	1	0	1	0
LoS	74	1	0	1	0
LoS	75	0	0	0	0
LoS	76	0	0	0	0
LoS	77	1	0	1	0
LoS	78	0	0	0	0
LoS	79	0	0	0	0
LoS	80	3	0	1	0
LoS	81	1	0	1	0
ShB	70	4	0	2	0
ShB	71	3	0	1	0
ShB	72	3	0	1	0
ShB	73	2	0	1	0
ShB	74	3	0	1	0
ShB	75	4	0	2	0
ShB	76	5	0	2	0
ShB	77	5	0	1	0
ShB	78	5	0	2	0
ShB	79	4	0	1	0
ShB	80	15	1	4	1
ShB	81	9	1	2	1
Whau	70	6	0	3	1
Whau	71	4	0	2	0
Whau	72	0	0	0	0
Whau	73	3	0	1	0
Whau	74	1	0	1	0
Whau	75	4	0	1	0
Whau	76	0	0	0	0
Whau	77	1	0	1	0
Whau	78	2	0	1	0
Whau	79	3	0	1	0
Whau	80	12	1	3	1
Whau	81	4	0	1	0

Species: Haminoea zelandiae

Site	Series	Total	Median	Range	Mean
Hbv	70	0	0	0	0
Hbv	71	0	0	0	0
Hbv	72	0	0	0	0
Hbv	73	0	0	0	0
Hbv	74	0	0	0	0
Hbv	75	0	0	0	0
Hbv	76	0	0	0	0
Hbv	77	0	0	0	0
Hbv	78	0	0	0	0
Hbv	79	0	0	0	0
Hbv	80	4	0	2	0
Hbv	81	1	0	1	0
LoS	70	0	0	0	0
LoS	71	0	0	0	0
LoS	72	0	0	0	0
LoS	73	0	0	0	0
LoS	74	0	0	0	0
LoS	75	1	0	1	0
LoS	76	0	0	0	0
LoS	77	0	0	0	0
LoS	78	0	0	0	0
LoS	79	0	0	0	0
LoS	80	0	0	0	0
LoS	81	0	0	0	0
ShB	70	0	0	0	0
ShB	71	0	0	0	0
ShB	72	0	0	0	0
ShB	73	0	0	0	0
ShB	74	0	0	0	0
ShB	75	0	0	0	0
ShB	76	0	0	0	0
ShB	77	0	0	0	0
ShB	78	0	0	0	0
ShB	79	0	0	0	0
ShB	80	0	0	0	0
ShB	81	0	0	0	0
Whau	70	0	0	0	0
Whau	71	0	0	0	0
Whau	72	0	0	0	0
Whau	73	0	0	0	0
Whau	74	0	0	0	0
Whau	75	1	0	1	0
Whau	76	0	0	0	0
Whau	77	0	0	0	0
Whau	78	0	0	0	0
Whau	79	0	0	0	0
Whau	80	0	0	0	0
Whau	81	1	0	1	0

Species: Heteromastus filiformis

Site	Series	Total	Median	Range	Mean
Hbv	70	9	0	3	1
Hbv	71	11	1	4	1
Hbv	72	20	1	7	2
Hbv	73	19	2	3	2
Hbv	74	26	2	5	2
Hbv	75	28	2	12	2
Hbv	76	23	2	6	2
Hbv	77	25	2	6	2
Hbv	78	20	2	4	2
Hbv	79	39	3	10	3
Hbv	80	22	2	5	2
Hbv	81	19	1	6	2
LoS	70	101	8	15	8
LoS	71	149	11	14	12
LoS	72	192	16	15	16
LoS	73	74	5	18	6
LoS	74	95	7	14	8
LoS	75	104	10	15	9
LoS	76	137	13	24	11
LoS	77	99	9	13	8
LoS	78	101	7	18	8
LoS	79	185	14	27	15
LoS	80	179	13	18	15
LoS	81	168	15	15	14
ShB	70	63	5	12	5
ShB	71	88	7	20	7
ShB	72	121	10	32	10
ShB	73	80	5	22	7
ShB	74	110	8	17	9
ShB	75	49	4	11	4
ShB	76	97	7	16	8
ShB	77	87	7	14	7
ShB	78	65	5	18	5
ShB	79	115	9	19	10
ShB	80	154	13	20	13
ShB	81	153	13	17	13
Whau	70	0	0	0	0
Whau	71	1	0	1	0
Whau	72	18	2	3	2
Whau	73	24	2	6	2
Whau	74	25	3	5	2
Whau	75	31	2	5	3
Whau	76	14	1	3	1
Whau	77	19	1	4	2
Whau	78	23	2	5	2
Whau	79	22	2	3	2
Whau	80	38	3	8	3
Whau	81	11	0	4	1

Species: Macomona liliana

Site	Series	Total	Median	Range	Mean
Hbv	70	25	2	5	2
Hbv	71	27	3	4	2
Hbv	72	18	1	4	2
Hbv	73	28	3	5	2
Hbv	74	24	2	4	2
Hbv	75	36	2	13	3
Hbv	76	16	0	8	1
Hbv	77	28	2	3	2
Hbv	78	25	2	4	2
Hbv	79	19	2	3	2
Hbv	80	14	1	3	1
Hbv	81	19	2	3	2
LoS	70	13	1	7	1
LoS	71	5	0	2	0
LoS	72	10	0	2	1
LoS	73	1	0	1	0
LoS	74	10	1	2	1
LoS	75	38	3	7	3
LoS	76	46	3	10	4
LoS	77	27	2	9	2
LoS	78	16	1	2	1
LoS	79	10	1	3	1
LoS	80	15	1	3	1
LoS	81	33	2	14	3
ShB	70	2	0	1	0
ShB	71	2	0	1	0
ShB	72	3	0	1	0
ShB	73	1	0	1	0
ShB	74	2	0	2	0
ShB	75	27	1	12	2
ShB	76	0	0	0	0
ShB	77	17	0	7	1
ShB	78	5	0	3	0
ShB	79	4	0	2	0
ShB	80	2	0	1	0
ShB	81	11	0	5	1
Whau	70	48	5	7	4
Whau	71	63	4	9	5
Whau	72	45	4	8	4
Whau	73	29	2	6	2
Whau	74	76	2	39	6
Whau	75	77	7	9	6
Whau	76	59	4	12	5
Whau	77	60	5	11	5
Whau	78	28	2	3	2
Whau	79	26	2	5	2
Whau	80	26	2	6	2
Whau	81	42	4	8	4

Species: Macroclymenella stewartensis

Site	Series	Total	Median	Range	Mean
Hbv	70	1	0	1	0
Hbv	71	2	0	1	0
Hbv	72	3	0	1	0
Hbv	73	3	0	1	0
Hbv	74	4	0	2	0
Hbv	75	1	0	1	0
Hbv	76	2	0	1	0
Hbv	77	2	0	1	0
Hbv	78	7	1	2	1
Hbv	79	14	1	3	1
Hbv	80	14	1	3	1
Hbv	81	6	0	2	1
LoS	70	7	1	2	1
LoS	71	3	0	2	0
LoS	72	1	0	1	0
LoS	73	1	0	1	0
LoS	74	1	0	1	0
LoS	75	4	0	1	0
LoS	76	1	0	1	0
LoS	77	5	0	4	0
LoS	78	9	1	2	1
LoS	79	6	1	1	1
LoS	80	7	0	2	1
LoS	81	4	0	1	0
ShB	70	7	1	1	1
ShB	71	5	0	2	0
ShB	72	8	1	2	1
ShB	73	1	0	1	0
ShB	74	11	1	3	1
ShB	75	9	1	2	1
ShB	76	2	0	1	0
ShB	77	2	0	1	0
ShB	78	0	0	0	0
ShB	79	3	0	2	0
ShB	80	8	1	2	1
ShB	81	4	0	2	0
Whau	70	102	9	11	9
Whau	71	85	8	10	7
Whau	72	93	7	11	8
Whau	73	88	8	10	7
Whau	74	112	10	10	9
Whau	75	96	8	11	8
Whau	76	82	7	7	7
Whau	77	54	5	8	5
Whau	78	47	3	7	4
Whau	79	86	7	9	7
Whau	80	81	7	8	7
Whau	81	23	2	5	2

Species: Notoacmea scapha

Site	Series	Total	Median	Range	Mean
Hbv	70	21	1	5	2
Hbv	71	14	0	6	1
Hbv	72	56	4	9	5
Hbv	73	122	10	16	10
Hbv	74	99	9	13	8
Hbv	75	10	0	3	1
Hbv	76	20	2	5	2
Hbv	77	86	8	14	7
Hbv	78	69	6	11	6
Hbv	79	84	6	17	7
Hbv	80	116	11	19	10
Hbv	81	72	6	12	6
LoS	70	0	0	0	0
LoS	71	0	0	0	0
LoS	72	0	0	0	0
LoS	73	0	0	0	0
LoS	74	0	0	0	0
LoS	75	0	0	0	0
LoS	76	1	0	1	0
LoS	77	0	0	0	0
LoS	78	0	0	0	0
LoS	79	0	0	0	0
LoS	80	0	0	0	0
LoS	81	0	0	0	0
ShB	70	4	0	2	0
ShB	71	1	0	1	0
ShB	72	39	0	14	3
ShB	73	5	0	1	0
ShB	74	12	1	4	1
ShB	75	8	1	1	1
ShB	76	15	0	9	1
ShB	77	17	1	5	1
ShB	78	5	0	2	0
ShB	79	9	0	6	1
ShB	80	6	0	4	1
ShB	81	7	0	3	1
Whau	70	15	1	3	1
Whau	71	16	0	8	1
Whau	72	85	8	14	7
Whau	73	90	5	22	8
Whau	74	71	6	12	6
Whau	75	1	0	1	0
Whau	76	11	1	3	1
Whau	77	84	6	24	7
Whau	78	69	4	16	6
Whau	79	64	2	22	5
Whau	80	20	2	5	2
Whau	81	8	0	3	1

Species: Linucula hartvigiana

Site	Series	Total	Median	Range	Mean
Hbv	70	182	14	35	15
Hbv	71	224	17	29	19
Hbv	72	240	22	36	20
Hbv	73	326	24	46	27
Hbv	74	303	24	37	25
Hbv	75	521	50	62	43
Hbv	76	480	35	59	40
Hbv	77	446	39	63	37
Hbv	78	373	34	46	31
Hbv	79	302	19	52	25
Hbv	80	285	21	57	24
Hbv	81	167	11	35	14
LoS	70	44	2	20	4
LoS	71	54	5	9	5
LoS	72	16	2	4	1
LoS	73	16	1	4	1
LoS	74	5	0	3	0
LoS	75	7	0	2	1
LoS	76	9	0	4	1
LoS	77	24	2	5	2
LoS	78	18	1	4	2
LoS	79	2	0	1	0
LoS	80	1	0	1	0
LoS	81	8	0	3	1
ShB	70	16	1	8	1
ShB	71	36	0	30	3
ShB	72	19	0	13	2
ShB	73	8	0	4	1
ShB	74	16	1	10	1
ShB	75	32	2	13	3
ShB	76	37	1	16	3
ShB	77	45	2	15	4
ShB	78	10	0	8	1
ShB	79	4	0	2	0
ShB	80	5	0	4	0
ShB	81	39	1	17	3
Whau	70	275	18	68	23
Whau	71	342	29	58	29
Whau	72	316	20	56	26
Whau	73	336	21	78	28
Whau	74	612	56	107	51
Whau	75	662	47	148	55
Whau	76	606	42	108	51
Whau	77	545	46	86	45
Whau	78	183	5	45	15
Whau	79	218	3	62	18
Whau	80	298	14	66	25
Whau	81	242	20	48	20

Species: Paphies australis

Site	Series	Total	Median	Range	Mean
Hbv	70	17	0	7	1
Hbv	71	19	1	11	2
Hbv	72	23	1	8	2
Hbv	73	11	0	8	1
Hbv	74	61	0	40	5
Hbv	75	24	0	14	2
Hbv	76	0	0	0	0
Hbv	77	5	0	5	0
Hbv	78	3	0	2	0
Hbv	79	0	0	0	0
Hbv	80	12	0	6	1
Hbv	81	4	0	3	0
LoS	70	0	0	0	0
LoS	71	0	0	0	0
LoS	72	0	0	0	0
LoS	73	0	0	0	0
LoS	74	0	0	0	0
LoS	75	0	0	0	0
LoS	76	0	0	0	0
LoS	77	0	0	0	0
LoS	78	0	0	0	0
LoS	79	0	0	0	0
LoS	80	0	0	0	0
LoS	81	0	0	0	0
ShB	70	1	0	1	0
ShB	71	0	0	0	0
ShB	72	0	0	0	0
ShB	73	1	0	1	0
ShB	74	0	0	0	0
ShB	75	0	0	0	0
ShB	76	0	0	0	0
ShB	77	0	0	0	0
ShB	78	0	0	0	0
ShB	79	0	0	0	0
ShB	80	0	0	0	0
ShB	81	0	0	0	0
Whau	70	0	0	0	0
Whau	71	1	0	1	0
Whau	72	0	0	0	0
Whau	73	0	0	0	0
Whau	74	3	0	2	0
Whau	75	2	0	1	0
Whau	76	0	0	0	0
Whau	77	0	0	0	0
Whau	78	0	0	0	0
Whau	79	0	0	0	0
Whau	80	0	0	0	0
Whau	81	0	0	0	0

Species: Prionospio aucklandica

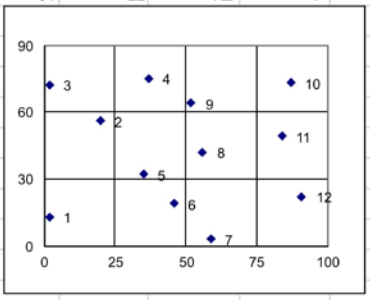
Site	Series	Total	Median	Range	Mean
Hbv	70	138	11	17	12
Hbv	71	159	16	21	13
Hbv	72	89	7	15	7
Hbv	73	65	3	16	5
Hbv	74	58	5	10	5
Hbv	75	68	5	15	6
Hbv	76	214	19	18	18
Hbv	77	195	16	22	16
Hbv	78	147	13	13	12
Hbv	79	132	12	13	11
Hbv	80	138	13	21	12
Hbv	81	95	9	19	8
LoS	70	41	4	8	3
LoS	71	48	4	9	4
LoS	72	57	4	10	5
LoS	73	22	2	5	2
LoS	74	7	0	3	1
LoS	75	29	2	6	2
LoS	76	71	4	13	6
LoS	77	58	5	10	5
LoS	78	50	5	6	4
LoS	79	34	3	7	3
LoS	80	35	3	8	3
LoS	81	45	4	8	4
ShB	70	17	1	8	1
ShB	71	29	2	8	2
ShB	72	22	1	6	2
ShB	73	11	1	3	1
ShB	74	5	0	2	0
ShB	75	40	1	13	3
ShB	76	98	7	21	8
ShB	77	113	8	18	9
ShB	78	29	1	17	2
ShB	79	53	3	14	4
ShB	80	45	3	12	4
ShB	81	81	5	22	7
Whau	70	0	0	0	0
Whau	71	5	0	4	0
Whau	72	2	0	1	0
Whau	73	0	0	0	0
Whau	74	4	0	3	0
Whau	75	6	0	2	1
Whau	76	21	2	5	2
Whau	77	7	0	3	1
Whau	78	3	0	1	0
Whau	79	10	1	4	1
Whau	80	20	1	7	2
Whau	81	3	0	1	0

Species: Zeacumantus lutulentus

Site	Series	Total	Median	Range	Mean
Hbv	70	0	0	0	0
Hbv	71	0	0	0	0
Hbv	72	7	0	7	1
Hbv	73	3	0	3	0
Hbv	74	7	0	7	1
Hbv	75	11	0	11	2
Hbv	76	8	1	8	1
Hbv	77	5	0	5	1
Hbv	78	2	0	2	0
Hbv	79	4	0	4	1
Hbv	80	3	0	3	0
Hbv	81	5	0	5	1
LoS	70	0	0	0	0
LoS	71	0	0	0	0
LoS	72	0	0	0	0
LoS	73	0	0	0	0
LoS	74	0	0	0	0
LoS	75	0	0	0	0
LoS	76	0	0	0	0
LoS	77	0	0	0	0
LoS	78	0	0	0	0
LoS	79	0	0	0	0
LoS	80	0	0	0	0
LoS	81	0	0	0	0
ShB	70	0	0	0	0
ShB	71	0	0	0	0
ShB	72	1	0	1	0
ShB	73	0	0	0	0
ShB	74	0	0	0	0
ShB	75	0	0	0	0
ShB	76	0	0	0	0
ShB	77	0	0	0	0
ShB	78	0	0	0	0
ShB	79	0	0	0	0
ShB	80	0	0	0	0
ShB	81	0	0	0	0
Whau	70	1	0	1	0
Whau	71	1	0	1	0
Whau	72	4	0	4	1
Whau	73	1	0	1	0
Whau	74	6	0	6	1
Whau	75	2	0	2	0
Whau	76	2	0	2	0
Whau	77	5	0	5	1
Whau	78	4	0	4	1
Whau	79	4	0	4	1
Whau	80	2	0	2	0
Whau	81	8	0	8	1

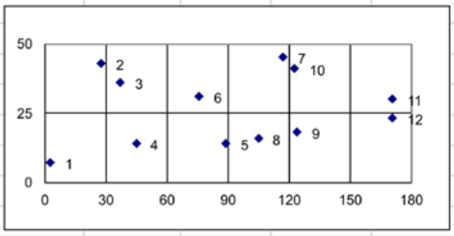
10.3 Appendix 3: Monitoring maps from February 2014

x-coord	y-coord	#	paces x	paces y
2	13	1	2	13
20	56	2	18	43
2	72	3	-18	16
37	75	4	35	3
35	32	5	-2	-43
46	19	6	11	-13
59	3	7	13	-16
56	42	8	-3	39
52	64	9	-4	22
87	73	10	35	9
84	49	11	-3	-24
91	22	12	7	-27



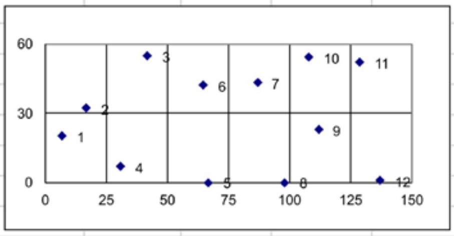
Time = LoS, Whau, HC Feb-14

x-coord	y-coord	#	paces-x	paces-y
3	7	1	3	7
28	43	2	25	36
37	36	3	9	-7
45	14	4	8	-22
89	14	5	44	0
76	31	6	-13	17
117	45	7	41	14
105	16	8	-12	-29
124	18	9	19	2
123	41	10	-1	23
171	30	11	48	-11
171	23	12	0	-7



Time = Reef ShB Feb-14

x-coord	y-coord	#	paces-x	paces-y
7	20	1	7	20
17	32	2	10	12
42	55	3	25	23
31	7	4	-11	-48
67	0	5	36	-7
65	42	6	-2	42
87	43	7	22	1
98	0	8	11	-43
112	23	9	14	23
108	54	10	-4	31
129	52	11	21	-2
137	1	12	8	-51



Time = HBV Feb-14