Central Waitemata Harbour Ecological Monitoring: 2000-2012

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Reviewed by	Approved for Auckland Council publication by
Name: Megan Carbines Position: Senior Scientist, Research, Investigations and Monitoring Unit Organisation: Auckland Council Date: June 2012	Name: Grant Barnes Position: Manager; Research Investigations and Monitoring Unit Organisation: Auckland Council

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Central Waitemata Harbour Ecological Monitoring: 2000 - 2012

Jane Halliday
Michael Townsend
Carolyn Lundquist

Prepared for
Auckland Council

National Institute of Water & Atmospheric Research Ltd
Gate 10 Silverdale Road, Hamilton
P O Box 11-115, Hamilton, New Zealand
Phone +64-7-856 7026, Fax +64-7-856 0151
www.niwa.co.nz

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Reviewed by:

Judi Hewitt

Approved for release by:

Drew Lohrer

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Executive Summary

This report details the results of the State of the Environment monitoring programme for the Central Waitemata Harbour conducted between October 2000 and February 2012. The focus of the programme is to monitor the ecological status and determine any trends in macrobenthic communities in the Central Waitemata. The programme consists of 6 intertidal soft-sediment sites, three of which have been monitored since 2000 near the Whau estuary, Hobsonville and Shoal Bay. Two of the sites (located near Henderson Creek and Meola Reef) are not presently monitored, and a new site was added at Lower Shoal Bay in October 2010. 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 Waitemata Harbour and are these of concern?
- Are any changes observed confined to one site or one area of the harbour or do they reflect a harbour-wide change?

The sites near Hobsonville and Whau have shown minimal change in sediment composition over the last few years and small seasonal and multi-year cycles in species abundances. The older site in Shoal Bay has shown increasing trends in the sediment mud content and gravel (which is mostly shell hash) and this is reflected in the Benthic Health model scores of the macrofaunal community and in the abundances of some of the monitored taxa.

The new site in Lower Shoal Bay was established on the eastern shore of Shoal Bay in October 2010 to monitor the effect of a predicted increase in sedimentation and metal contamination in this area. The sediment at this site is mainly fine sand and mud and the taxa present at are those expected to be relatively tolerant of mud. For this reason, the monitoring is only likely to be able to detect large changes, and we recommend the investigation of alternate sandier sites within the Shoal Bay area. If no suitable sites are available, the merits of continued sampling at this muddy site should be re-evaluated.

Reef and HC have not been monitored since February 2010. These sites will be rotated back into the monitoring programme in the future. In the meantime, it is recommended that:

- ShB continues to be monitored due to the large changes occurring in the sediment and community structure at this site. ShB is the only sandy location monitored within Shoal Bay so is likely to be most sensitive to predicted increases in sedimentation to this sub-estuary.
- Whau continues to be monitored. Missing site markers need to be reinstalled to their original positions as soon as possible (i.e., June 2012).
- HBV continues to be monitored due to its proximity to the Upper Waitemata Harbour and because trends in individual species populations and overall community structure have been detected at this site. Consideration may be needed to moving the HBV 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.

- Alternative sandier sites within the Shoal Bay area are investigated for their potential to replace LoS.
    - A scientist who is familiar with the sites should be present during two field sampling occasions per year to ensure continuity of sampling.

1.0 Introduction

In October 2000, a State of the Environment monitoring programme for the Central Waitemata Harbour was developed for the Auckland Council (AC). The programme was designed to be scientifically credible, practical, and affordable and to meet the requirements of the Resource Management Act (1991). The focus of the programme was to monitor the ecological status and trends of change in macrobenthic communities in the Central Waitemata.

Hewitt (2000) suggested that the Central Waitemata would be best represented by 6 intertidal sites; 5 from soft-sediment habitats and 1 rocky habitat. In 2000, NIWA was commissioned to monitor the soft sediments 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 AC, 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 Waitemata 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 presently not being monitored; those near Henderson Creek and Meola Reef (Townsend et al., 2010).

The Lower Shoal Bay (LoS) ecological monitoring site was established in October 2010 as predictions of future sediment and contaminant movement within the Waitemata Harbour identified this area as a contaminant depositional area (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. Modelling has predicted change to this area, with elevated sedimentation and metal contamination probable (Green 2008). Establishing baseline data now will help determine the magnitude of degradation in this bay in the future.

The monitoring focuses on a selection of 20 species (see Nicholls et al. 2002) 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 of soft-sediment sites between October 2000 and February 2012 and details the present status of the benthic communities in the Central Waitemata 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 Waitemata Harbour and are these of concern?
- Are any changes observed confined to one site or one area of the harbour or do they reflect a harbour-wide change?

Figure 1. Map of the Waitemata Harbour showing the three permanent soft-sediment monitoring sites at Hobsonville (HBV), Whau River (Whau), and Shoal Bay (ShB) (black circle symbol); the two sentinel sites Henderson Creek (HC) & Te Tokoroa Reef (Reef) that have not been monitored since Feb 2010 (red square symbol); and Lower Shoal Bay (LoS) which was established in Feb 2011 (black circle symbol).

2.0 Methods

During the 2010 – 2012 period, four soft-sediment sites were sampled representing three different drainage sub-regions of the Central Waitemata: Upper-Waitemata-Hobsonville (HBV), Whau River (Whau), and Shoal Bay (ShB and LoS) (see Figure 1). Two previously sampled monitoring sites were not sampled between Feb 2010 and Feb 2012 (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 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 Waitemata monitored sites in 2010 - 2012. 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 NZMG	
	X	Y	North	East
LoS	100	90	6486007	2667976
HBV	180	60	6487791	2660090
Whau	100	90	6482500	2659244
ShB	180	50	6485554	2667087

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 is conducted every two months by Auckland Council staff, and began in October 2000. The methods used are briefly described below.

2.1 Macrofauna

On each sampling occasion, 12 core samples (each 13 cm diameter, 15 cm deep) are collected from each site. To provide an adequate spread of cores over the site, each site is ‘divided’ into 12 equal sections and one core sample is taken from a random location within each section. To reduce the influence of previous sampling activity and spatial autocorrelation, 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 and processed under other funding when available.

Table 2. The 20 taxa recommended for long-term monitoring in the Waitemata Harbour monitoring programme. Where genera and species names have changed with taxonomic refinement, the names in brackets indicate the previous name.

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

2.2 Bivalve size-class analysis range

After identification, individual *Paphies australis*, *Austrovenus stutchburyi* and *Macomona liliana* are measured and placed into size classes. The size classes for *Austrovenus* and *Macomona* are <1 mm, 1 – 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 10 - 20 mm, changes to 20 mm increments (20 - 40 mm, 40 – 60 mm, >60 mm). *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.

2.3 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 May 2012, the sites were inspected by Dr Carolyn Lundquist from NIWA, who has visited all sites at least annually since 2000, with the exception of 2011.

2.4 Sediment characteristics

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

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

Chlorophyll *a*: Within one month of sampling, the full sample is freeze dried, weighed, then homogenised and a subsample (~0.5 g) taken for analysis. Chlorophyll *a* 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°C until a constant weight is achieved (the sample is weighed after ~ 40 h and then again after 48 h). The sample is then ashed for 5.5 h at 400°C (Mook and Hoskin 1982) and then reweighed.

2.5 Functional Indicators & Benthic Health Model

A functional diversity index, NIWACOOBII, was developed to assess changes in functional attributes for intertidal non-vegetated benthic communities in the Auckland Region (van Houte-Howes and Lohrer 2010). This study assessed 29 functional traits from 7 functional groups, with the final index comprising the most reliable and sensitive traits from each of the 7 groups. This index was developed from Regional Discharge Project and Mahurangi time series data to observe how the index responded to gradients in muddiness and heavy metal contamination (van Houte-Howes and Lohrer 2010). After NIWACOOBII scores were calculated for the 2010 Central Waitemata report (Townsend et. al 2010), the index was refined to make it more applicable to functionally diverse sandy sites (such as ecological monitoring sites) and re-named TBI. The SUMmax value, representing the theoretical maximum score of a pristine site, was increased to 226.39 for a 12 replicate sample. The reasoning for the change in the formula is outlined in Lohrer and Rodil (2011). The new index has been applied to the October data from 2000 and 2011 for the four Central Waitemata sites presently sampled and the results are discussed.

Data from October 2000 and 2011 has also been analysed using the Benthic Health Model (BHM). The BHM is a multivariate model of community structure based on canonical analysis of the principle co-ordinates (Anderson et al. 2002). This has recently been updated to show community changes caused by changing mud content as well as stormwater heavy metal contamination (Hewitt and Ellis 2010).

2.6 Statistical analyses

When the State of the Environment monitoring programme was developed for the AC, the methods to be used in analysing the data were also detailed (Hewitt, 2000). This report recommended that, every 2 years, a graphical analysis of patterns in selected taxa abundances over time at each site should be conducted to identify seasonal patterns, multiyear patterns and trends.

Analyses included:

- Changes in dominant taxa over time to determine whether observed changes in individual monitored taxa led to community changes.
- Multivariate ordination of ecological data collected in October of each year to determine whether community composition at the sites was changing over the monitored period:
  - Ordination of raw data was conducted through non-metric multidimensional scaling based on Bray-Curtis similarities.
  - Canonical analysis of principle co-ordinates (CAP, Anderson and Robinson 2003, Anderson and Willis 2003) to relate Bray-Curtis similarities of raw data to environmental factors.
- Trend analysis- to formally identify any suggested trends in both biotic and abiotic variables, trend analysis was conducted on:
  - Total species abundances – to investigate if there were significant changes in the direction of the populations of the monitored species and if so, whether these changes occurred in the same direction and for the same species across the different sites.
  - Sediment properties - to see if changes in the sediment environment occurred and if so, whether these alterations related to changes in species abundances.
  - Bivalve size classes - to investigate if there were size specific changes occurring and if so, where changes in a size class would underpin changes occurring in the species abundance.

In each trend analysis autocorrelation was investigated using *chi*-square probabilities. Where autocorrelation 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. Only linear trends were analysed for as investigation of residual variability suggested no other responses. Note that all analyses conducted are performed on the sum of the 12 cores collected at each site.

3.0 Present status of benthic communities in the Central Waitemata Harbour

This programme was designed to monitor the ecological status and trends of change in macrobenthic communities in the Central Waitemata 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). Thus, in this report we ask the following questions:

- Have there been any changes in site characteristics?
- At each site, are species exhibiting temporal variations that appear predictable, i.e., trends, seasonal patterns or multi-year cycles?
- 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?

3.1 Have there been any changes in site characteristics?

3.1.1 Hobsonville (HBV)

Site HBV is located on the sandflats near the Hobsonville Air Base, close to the deep channel entering the Upper Waitemata Harbour. The sandflat 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 with distinct ripples 1-3 cm in depth. While general features of the site have changed little since monitoring began, increasing muddiness on the shoreward 1/6 of site near the 0,0 peg has been observed. These changes are associated with the increase in size and proximity of two tidal drainage channels. The first is a large drainage channel on the seaward/eastern side of the site, which is now within ~2 m of the 0,0 peg. The second is a smaller sub-channel, now approximately 3 m in width, 0.3 m deep (first observed in 2008), which branches from the main Hobsonville channel and approaches the site on its seaward side nearest the 0,0 peg. Additional observations from May 2012 indicate that a large shellbank, previously located on the shore side of plot, has migrated inside the monitoring area. The shellbank has dimensions of roughly 10 m across-shore x 50 m alongshore, and is located on the opposite side of the plot from the 0,0 peg. Sediment characteristics have shown little change since 2010 and have been relatively stable since October 2002. The sediment is still predominantly fine and medium sand, with a lesser amount of coarse material (Figure 2). Chlorophyll *a* content of the sediment has ranged between 8.0 and 23.2 µg/g sediment and the organic content has been both low and variable (average 1.5%, range 5.9).

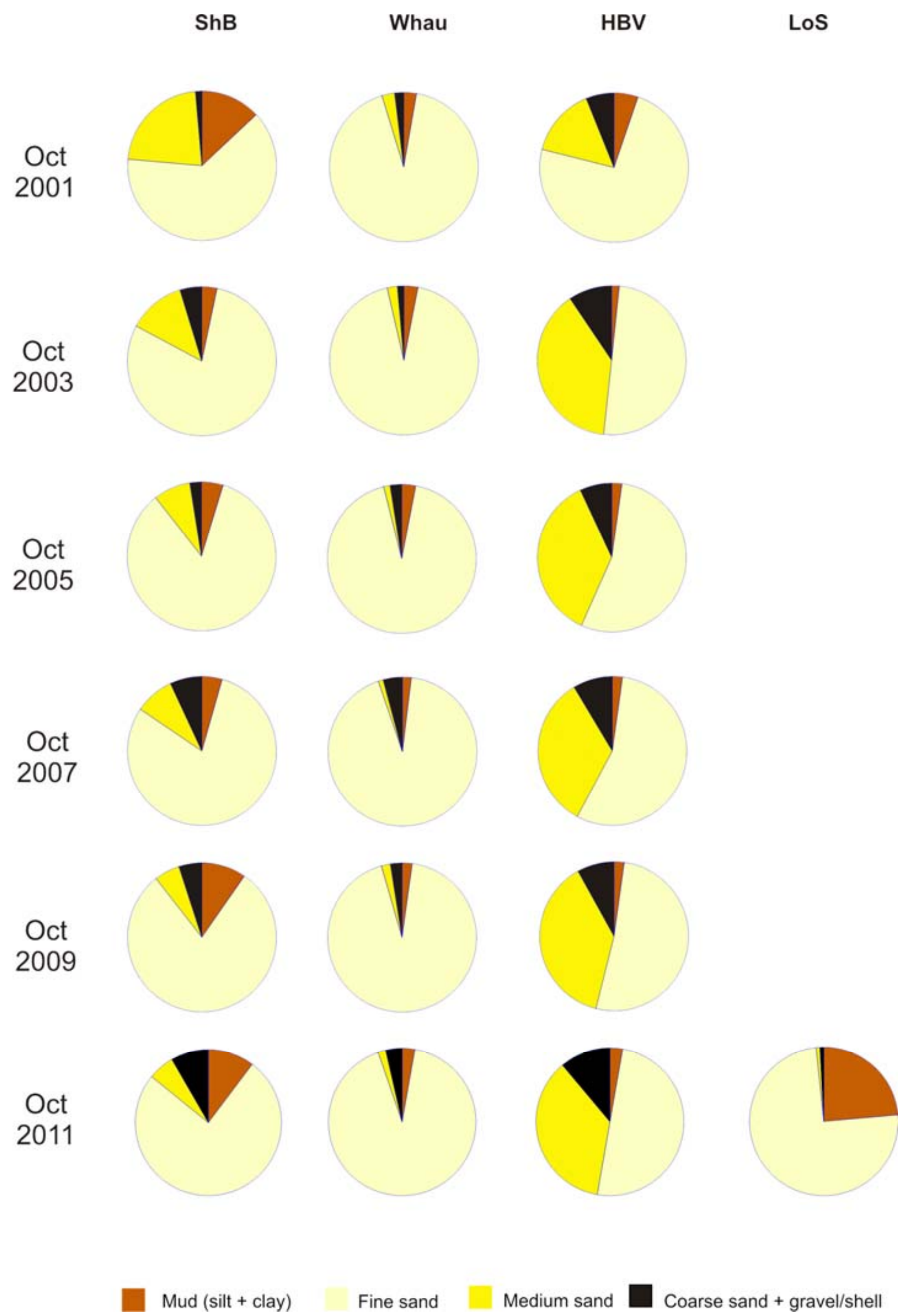

Figure 2. Summary of sediment characteristics at Hobsonville (HBV), Whau River (Whau), Shoal Bay (ShB), and Lower Shoal Bay (LoS) from October 2001 to October 2011. Coarse sand and gravel (>500μm), medium sand (250 – 500 μm), fine sand (62.5 – 250 μm), mud (< 62.5 μm). Full results are given in Appendix 1.

3.1.2 Whau River (Whau)

The Whau site is located on the north-western side of the Whau River (Plate 2). The sand flats here are large, sandy and generally show signs of wind-wave activity (small ripples on the sediment surface). There has been little visual change to this site or the nearby channel over nearly ten years of monitoring, with hard-packed 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. The medium sand fraction was variable prior to February 2004, but showed minimal change from then until October 2008. Since October 2008 this fraction has increased in variability and reached a local maximum of 6.0% in February 2011. The sediment at Whau is predominantly fine sand (> 82%), with an average chlorophyll a content of 11.4 µg/g sediment and a low organic content (generally <1%)(Appendix 1).

During the May 2012 site inspection it was noted that new site markers had mistakenly been placed seaward from the 0,0 peg rather than toward the mouth of the Whau River, effectively moving the site 100 m alongshore on the sandbank toward the subtidal. The area mistakenly sampled was in the same hard packed sand as the original site, although it was lower on the shore and thus not exposed for as long during the low tide period. Auckland council staff believe the new pegs were added in either October or December 2011, affecting data collected since then.

3.1.3 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). The sediment at this site is coarse with a dense shell hash layer over much of the surface and consequently it has the highest gravel-sized sediment of all monitored sites (Appendix 1). The mud content at this site has been increasing but variable since February 2003 (Figure 3). The gravel content of the sediment (which also contains shell hash) is also highly variable but appears to have increased at the same time. The proportion of medium sand has decreased since February 2003 (Figure 3). Overall, across this site there is large spatial variation. A site visit in May 2012 indicates little has changed at the site since the last NIWA visit in 2010, when increased muddiness was observed over 1/3 of the site, 1/3 of the site consisted of fine sand, and 1/3 of site shell hash. Two-thirds of the site is still predominately a hard sand and shell hash dominated community similar to the original sampling. The sediment at ShB is mainly fine (mean 75%, Figure 2) and medium sand (mean 13%, 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 1).

3.1.4 Lower Shoal Bay (LoS)

Ecological monitoring of the intertidal flat at LoS was initiated in October 2010 (Plates 4 & 5). Generally the sediment at this site is relatively homogeneous, and is composed of mud layers of 10-30 cm depth 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 May 2012 and bivalves were generally rare. No ripples were observed on the surface of the sediment during the May 2012 site inspection, though ripples were clearly visible at all other sites on this occasion given the day's windy conditions. Very little shell hash was observed on the sediment surface, consisting mainly of fragments of cockles and wedge shells. A few *Hemiplax hirtipes* (mud crabs) were observed but not in high densities. Two live *Nassarius* (*Plicarcularia*) *burchardi* (invasive gastropod) were observed at the site but few other gastropods were observed apart from a few *Cominella glandiformis*. The shoreward side (farthest from 0,0 peg) had a high concentration of dead *Musculista senhousia* (non-indigenous date mussel) shells. The LoS site is situated slightly lower on the shore than the other sites and is only likely to be uncovered for short periods during spring tides. The sediment at LoS is almost exclusively fine sand (mean 79%, Figure 2) and mud (mean 20%, Figure 2). LoS sediment has a low mean organic matter (2.0%) and chlorophyll *a* content (mean 7.5 µg/g sediment).

3.1.5 Summary of site characteristics

The organic matter content at each site remained comparable with previous years of the study and showed minimal change in the level of variation (Table 3B, Halliday and Hewitt 2006, Townsend et al. 2008). The chlorophyll *a* content at HBV and ShB also remained comparable with previous years. However, sediment chlorophyll *a* content became more variable at Whau due to several high values between June 2010 and October 2011 (Appendix 1). The highest values of organic material were found at LoS, while the lowest values were present at ShB. Despite the high organic matter content at LoS, this site had the lowest sediment chlorophyll *a* concentration. The highest sediment chlorophyll *a* concentrations were found at HBV (Appendix 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 3A). Table 3B demonstrates the change in variability over the last two years by comparing the standard deviation of data from October 2000 to February 2010 (shown in the last report) with the data from October 2000 to February 2012. There has been minimal change in the temporal variability of sediment characteristics over the last two years (Table 3B).

Table 3. Analysis of temporal variability in sediment characteristics at four sites from October 2000 to February 2012; Hobsonville (HBV), Whau River (Whau), Shoal Bay (ShB) and Lower Shoal Bay (LoS): 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 Chla = chlorophyll a. Note: gravel faction (>2000 μm) not included. B) Changes in the standard deviations compared with results reported in 2010. Negative values indicate larger variability over the last two years, whereas positive values indicate increased stability. Note, monitoring of site LoS only began in October 2010 so no comparison can be made with results reported in the 2010 report.

A)

site	%mud	%fine sand	%medium sand	%coarse Sand	%organics	chl*a* μg/g
HBV	1.47	8.7	8.39	2.57	0.81	2.94
Whau	1.36	2.85	1.84	0.23	0.35	3.75
ShB	3.3	7.49	8.22	1.56	0.37	2.42
LoS	4.95	4.66	0.15	0.15	0.47	1.14

B)

site	%mud	%fine sand	%medium sand	%coarse Sand	%organics	chl*a* μg/g
HBV	0.09	0.11	0.32	0.2	-0.04	0.07
Whau	0.06	-0.17	0.11	0.01	0.02	-0.91
ShB	-0.34	0.25	0.23	0.2	-0.05	-0.02
LoS	.	.	.	.	.	.

The sediment data for HBV have historic trends in several size fractions, but there have been no substantive changes since April 2002. The trends apparent at the Whau site are also driven by the early data, with little change occurring after December 2003 (Figure 3). ShB has shown substantial changes in sediment over time and has recent increases in the mud fraction (Figure 3). ShB shows an increasing trend in gravel and continues to have a decreasing medium fraction which was noted in the 2008 and 2010 reports (Figure 3) (Townsend et al. 2008; Townsend et al. 2010).

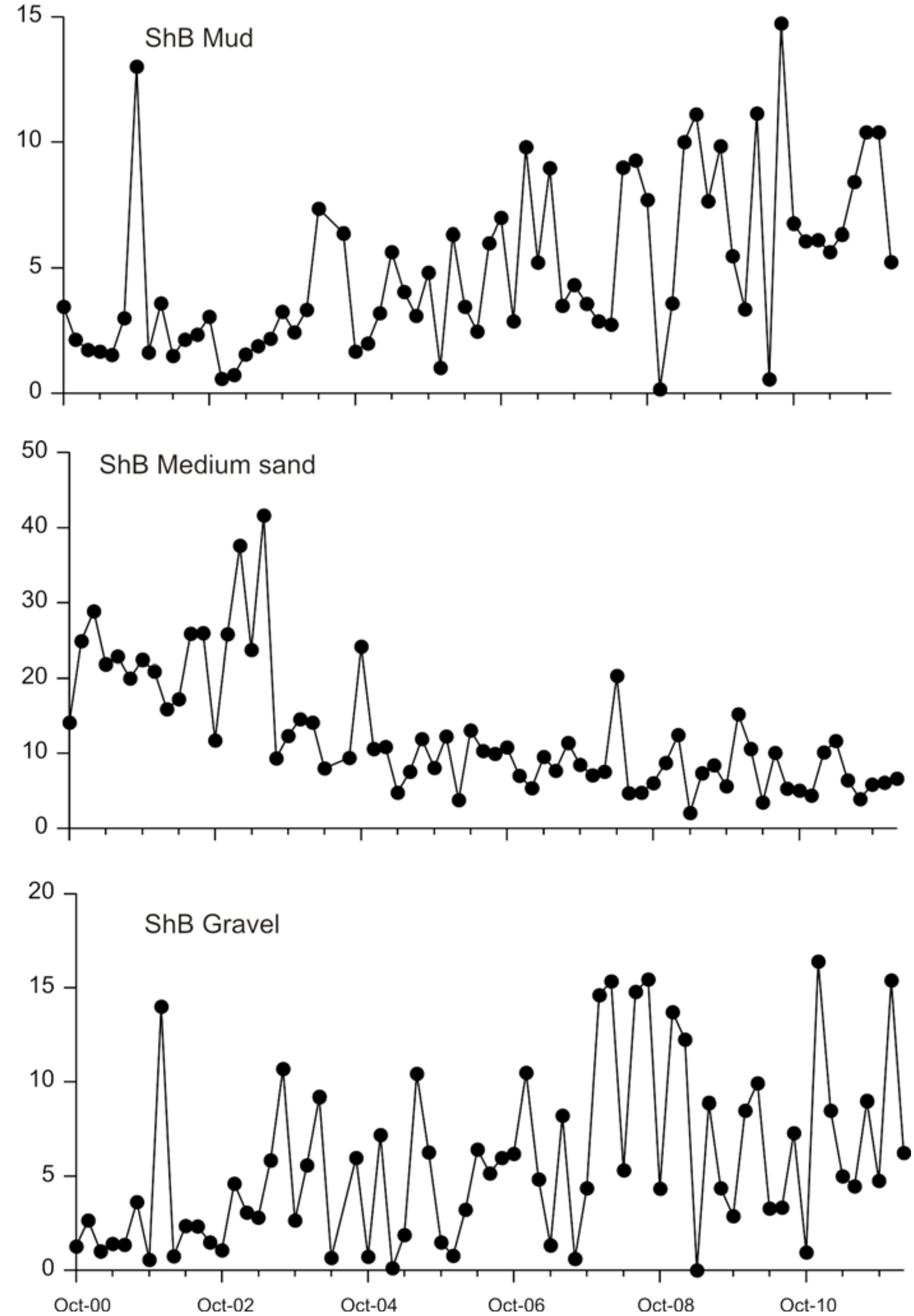

Figure 3. Temporal changes in site sediment characteristics at ShB. Trends show percent mud and gravel to be increasing, with percent medium sand decreasing.

4.0 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 that are similar in timing from year to year; 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.

4.1 Hobsonville (HBV)

In terms of abundance, the Hobsonville site had been dominated by nut clams *Nucula hartvigiana*, the polychaete *Aonides trifida* and the venerid bivalve *Austrovenus stutchburyi* until October 2010 (Table 4). Prior to February 2007 there had been no change in dominance with *Nucula* consistently the most abundant species. Between February 2007 and February 2010, however, *Aonides* was more abundant than *Nucula* on six occasions. In the latest report period (April 2010 – Feb 2012), *Aonides* has consistently been the most abundant species, with *Nucula* ranked second to sixth most abundant. The change in dominance is a combination of two factors. Firstly in the last report, *Aonides* was shown to have increasing abundance and abundances are still high although no longer increasing (Table 5, Figure 4). Secondly, abundances of *Nucula* show a multi-year cycle and declined in abundance over the last four years (Figure 4). With the decline in *Nucula* abundances over the last year, *Austrovenus* has moved from the 3rd dominant species to the 2nd dominant species at the HBV site. The remaining monitored fauna were usually low in abundance, although *Notoacmea scapha*, *Prionospio aucklandica, Anthopleura aureoradiata, Colurostylis lemurum and Paphies australis* were among the abundant taxa on multiple sampling dates (Appendix 10.2).

Table 4.The three most abundant monitored taxa found over time at HBV.

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

Zeacumantus lutulentus shows cyclic behaviour (1-2 years) with a series of peak abundances occurring through the time series (Figure 4). *Prionospio, Aonides, Colurostylis lemurum, Notoacmea and Nucula* all demonstrate long multi-year cyclic patterns at HBV. *Prionospio* has cycles in recruitment which have been seven years apart; with a large recruitment event at the end of summer in 2001 and a more recent event in February 2008 and February 2012 (Figure 4). *Nucula* had an elevation in abundance in 2001, but has been declining ever since and the population is now considerably lower than in October 2000. *Aonides* also shows behaviour of a long term cycle in abundance (Figure 4). Seasonal patterns with peak abundances during the summer occurred for *Austrovenus* (February) and *Exosphaeroma chilensis* (February-April). Both *Boccardia* and *Colurostylis* showed cyclic patterns with peak abundances during June-August, and April and August respectively (Figure 4, Table 5).

Trends are evident in five taxa at HBV, three of which have increasing populations and two declining (Table 5). *Aricidea* sp. shows an upward trend with high numbers since February 2008 with the exception of April 2008 and April 2011 (Figure 4). *Aricidea* also shows seasonal patterns with peak abundances from August to October. Both *Anthopleura* and *Aonides* have increased in abundance since 2004 (Figure 4, Table 5).

In 2010 we reported *Austrovenus* was increasing in abundance at HBV; this trend was mainly driven by the abundance of juveniles <5 mm (Figure 4). Since then number of *Austrovenus* has returned to normal levels with very little recruitment in December 2010 and a moderate peak of recruitment in December 2011 (Figure 4 and 5). The abundance of cockles at this site is high and most similar to the Whau site (Appendix 10.2). *Austrovenus* at the HBV site continues to be dominated by 5-20 mm sized individuals and juveniles are also relatively abundant (<5 mm) (Figures 5 and 6).

Macomona liliana at HBV was dominated by adult individuals in similar densities to those at Whau (Figure 5 and 6, Appendix 10.2). *Macomona* was less abundant in recent years compared to the period prior to February 2004.

The HBV site remains the only monitoring location to consistently support *Paphies;* which are predominantly of juvenile and intermediate sizes (Figures 5 and 6); not surprisingly as adult *Paphies* inhabit high flow area near the spring low tide mark. In the 2008 report, juvenile *Paphies* exhibited a decreasing trend in abundance and the population has remained low since February 2006 (Townsend et al. 2008). A recent increase in juvenile *Paphies* in the past few sampling times (October 2011 and February 2012) may reverse this trend in future years (Figure 5). There is however an indication of decline in intermediate sized individuals which have been low since December 2008 (Figure 5).

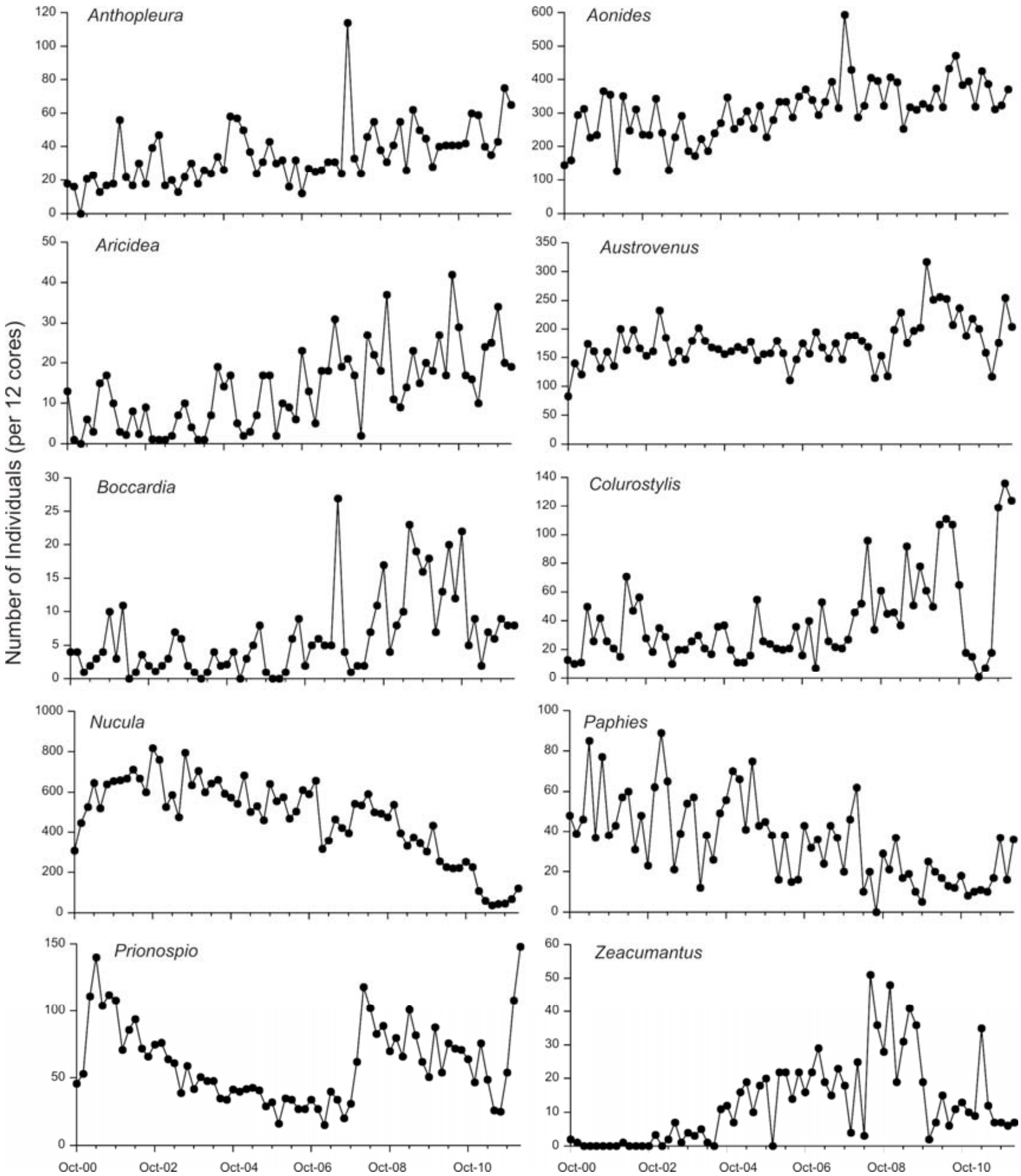

Figure 4. Temporal patterns in abundances of Anthopleura aureoradiata, Aonides trifida, Aricidea sp., Austrovenus stutchburyi, Boccardia syrtis, Colurostylis lemurum, Nucula hartvigiana, Paphies australis, Prionospio aucklandica and Zeacumantus lutulentus at the HBV site.

Table 5. Summary of temporal patterns in abundance of selected taxa observed at each site between October 2000 to February 2012. Hobsonville (HBV), Whau River (Whau) and Shoal Bay (ShB). *temporal pattern suggests trend no longer operating.

Site	Seasonal cycles	Greater than annual patterns	Trends	Trend direction
HBV	*Aricidea*	*Colurostylis*	Aricidea	Increase
	Austrovenus	*Notoacmea*	Anthopleura	Increase
	Macomona	*Prionospio*	Aonides	Increase
	Boccardia	*Zeacumantus*	*Nucula*	Decrease
	Colurostylis	*Nucula*	*Paphies*	Decrease
	Exphaeroma	*Aonides*		
		Prionospio		
Whau	*Austrovenus*	*Macroclymenella*	*Aricidea*	Decrease*
	Colurostylis	*Notoacmea*	*Nucula*	Decrease*
	Notoacmea	*Colurostylis*	*Prionospio*	Decrease*
		Macomona	*Zeacumantus*	Increase
			Anthopleura	Increase
ShB	*Austrovenus*	*Anthopleura*	*Heteromastus*	Increase
	Colurostylis	*Aricidea*	*Aricidea*	Increase
	Glycera	*Austrovenus*	*Prionospio*	Increase
	Notoacmea	*Euchone*	*Notoacmea*	Decrease
	Nucula	*Boccardia*	*Diloma*	Decrease
		Macroclymenella	*Macomona*	Decrease
		Prionospio	*Nucula*	Decrease*

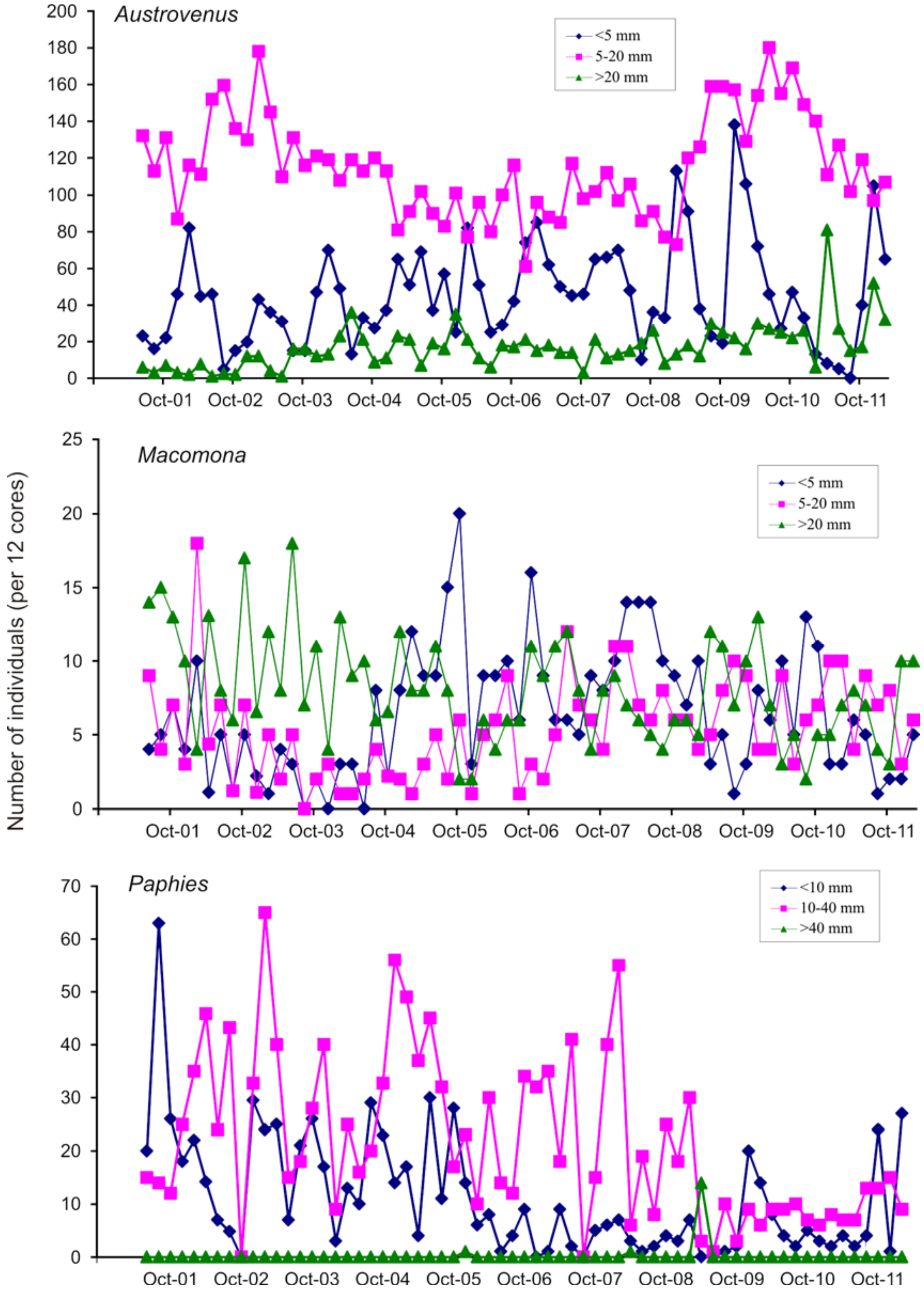

Figure 5. Trends in abundance of different size classes of the bivalves *Austrovenus stutchburyi, Macomona liliana* and *Paphies australis* found at site HBV.

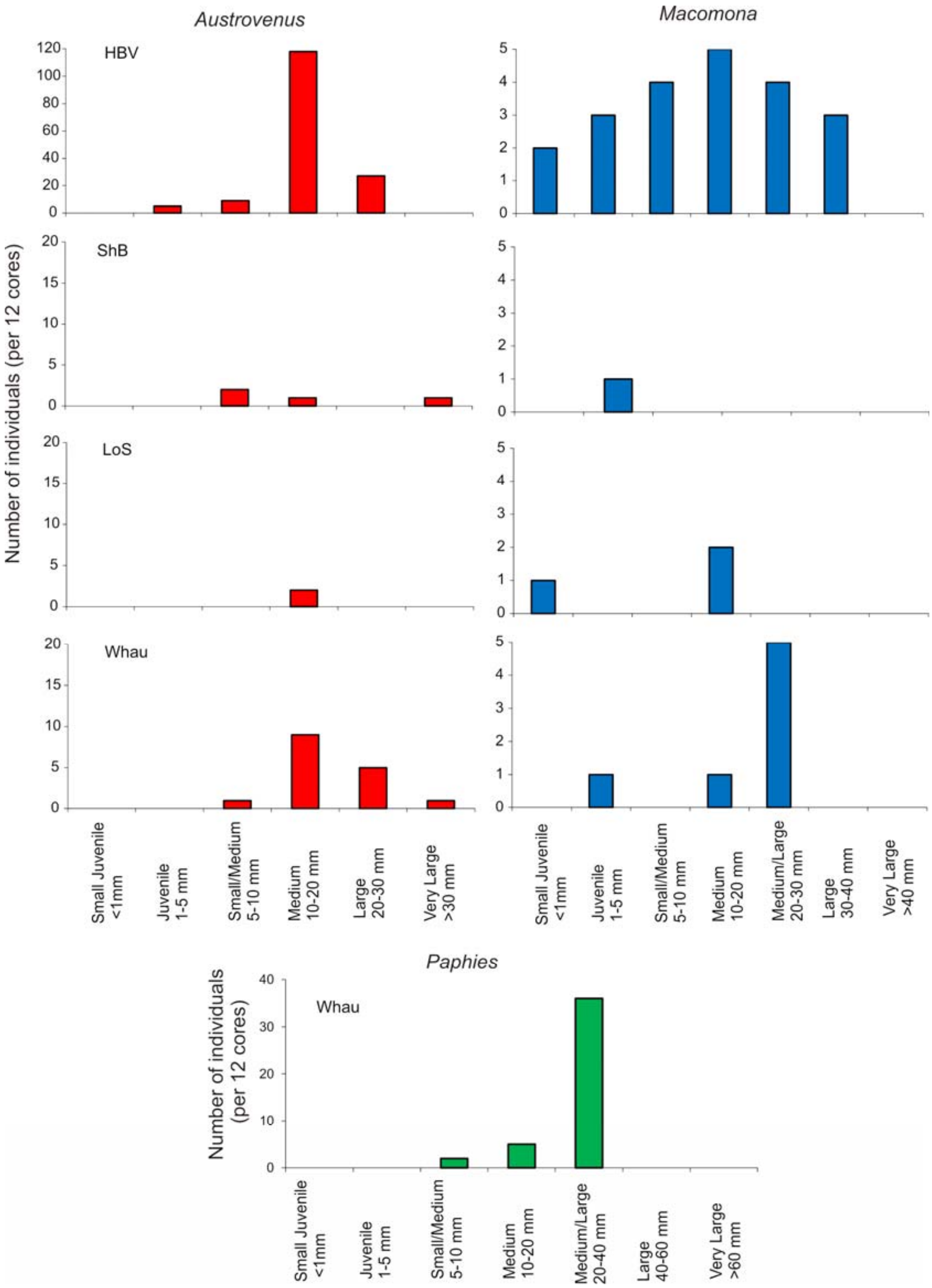

Figure 6**. Size class distributions of cockles (*Austrovenus stutchburyi)* (red), wedge shells (*Macomona liliana*) (blue) and *Paphies australis* (green) measured as maximum shell width, at each site in June 2011. Population structures during recruitment periods are generally dominated by juveniles. Size class distributions of *Paphies* are only shown for the Hobsonville site as HBV is the only site to consistently support this species. To give a more general representation of population structure, this graph is based on June, typically a month when juvenile recruitment is low or absent.**

4.2 Whau River (Whau)

Nucula continues to be abundant at the Whau site, although its ranking varies with year (Table 6) and season (frequently being the numerical dominant from December to August). *Aricidea* sp. has also consistently been abundant at this site. Other species of moderate to high abundance at this site include *Austrovenus*, *Colurostylis*, *Notoacmea, Macomona and Macroclymenella stewartensis.* (Appendix 10.2).

Table 6. The three most abundant monitored taxa found over time at Whau.

Date	1^{st}	2^{nd}	3^{rd}
Oct-00	*Nucula*	*Aricidea*	*Austrovenus*
Oct-01	*Nucula*	*Aricidea*	*Austrovenus*
Oct-02	*Nucula*	*Aricidea*	*Austrovenus*
Oct-03	*Nucula*	*Austrovenus*	*Aricidea*
Oct-04	*Aricidea*	*Nucula*	*Macroclymenella*
Oct-05	*Nucula*	*Aricidea*	*Macroclymenella*
Oct-06	*Nucula*	*Aricidea*	*Macroclymenella*
Oct-07	*Nucula*	*Aricidea*	*Austrovenus*
Oct-08	*Austrovenus*	*Nucula*	*Aricidea*
Oct-09	*Austrovenus*	*Nucula*	*Aricidea*
Oct-10	*Nucula*	*Aricidea*	*Austrovenus*
Oct-11	*Austrovenus*	*Aricidea*	*Nucula*

Trends of decreasing *Aricidea, Prionospio,* and *Nucula* abundances at Whau reported in 2010 continue to be evident (Townsend et al. 2010). However, these declines are historic, driven by high values prior to February 2004, with all species remaining relatively unchanged in abundance after this point. An increase in the number of *Zeacumantus* at Whau was first reported in 2010 (Townsend et al. 2010). Low values since October 2010 may indicate the end of this trend (Figure 7).

Seasonal patterns can be seen for *Colurostylis,* which normally has a peak in abundance in June. However, *Colurostylis* was unusually abundant in February 2012. It is possible this was a result of the accidental relocation of the site, or it could be a part of a natural cycle, as *Colurostylis* was also common at HBV at this time (Figures 4 and 7). Seasonal patterns are also still evident in *Austrovenus*, which peaks between December and February (Figure 7 and 8, Table 5). *Notoacmea* shows peaks in abundance each December, with the abundance peaks being more obvious over the last few years (Figure 7, Table 5). Variable recruitment of *Notoacmea* leads to greater than annual cycles in it abundance as well. Greater than annual cycles were also evident in *Macroclymenella, Colurostylis* and *Macomona* populations at Whau. *Macroclymenella* shows a cyclic pattern of abundance (1-2 year cycle) and an increase trend in abundance peaks.

Bivalve populations have been variable over time at the Whau site. The total *Austrovenus* population does not show an overall trend in abundance over the monitored time series due to the juvenile size class (<5 mm), which exhibits large and variable annual recruitment. However, both the intermediate (5-20 mm) and adult (>20 mm) size classes showed significant trends of declining abundance in the first 4 years of monitoring and have remained low since this time. *Macomona* exhibits multi-year cycles in the abundance of juveniles (<5 mm) and intermediates (5-20 mm), yet consistently shows low adult densities.

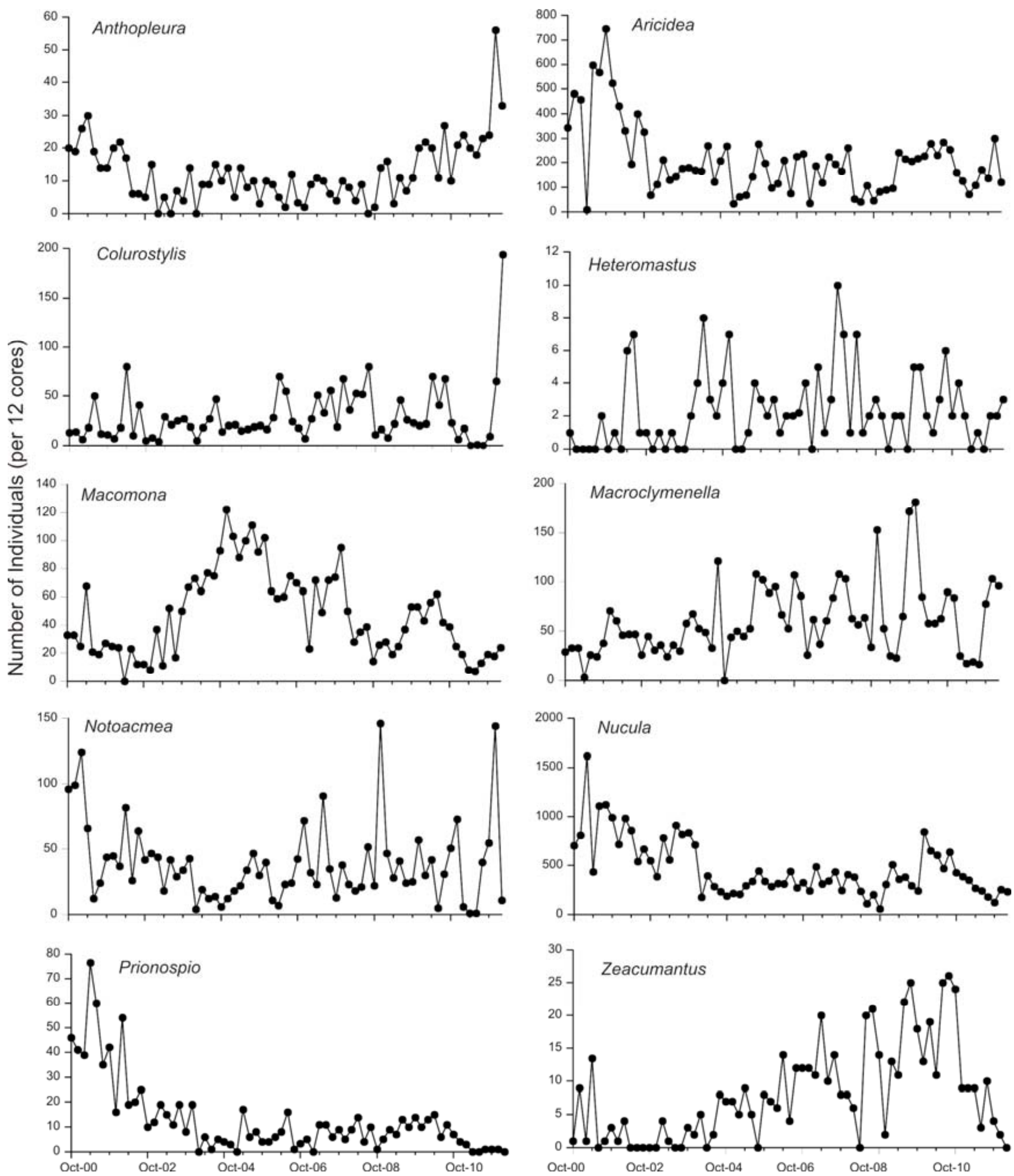

Figure 7. Temporal patterns in abundances of Anthopleura aureoradiata, Aricidea sp., Colurostylis lemurum, Heteromastus filiformis, Macomona liliana, Macroclymenella stewartensis, Notoacmea scapha, Nucula hartvigiana, Prionospio aucklandica and Zeacumantus lutulentus at the Whau site.

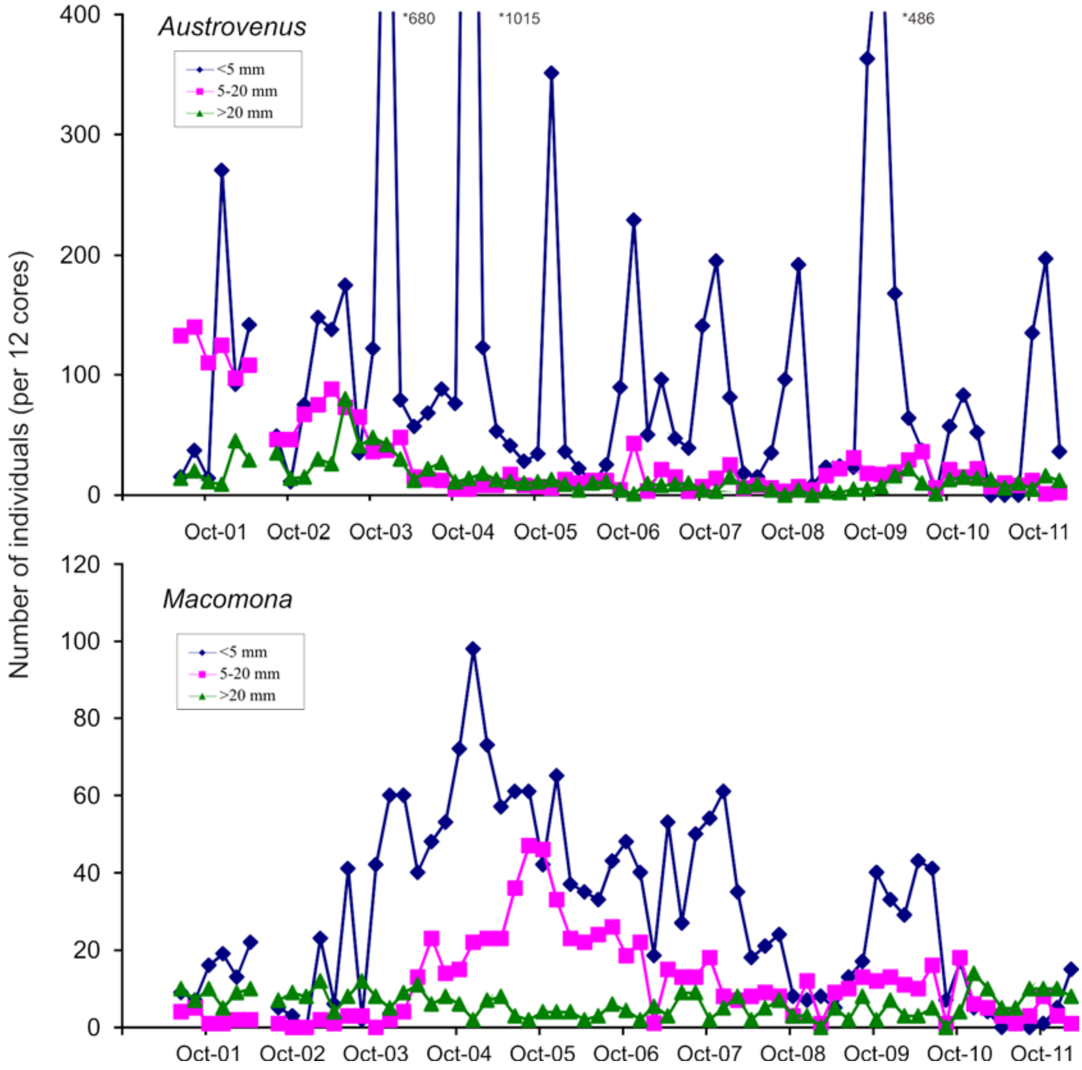

Figure 8. Trends in abundance of different size classes of the bivalves *Austrovenus stutchburyi* and *Macomona liliana* found at Whau. No *Paphies australis* were present at Whau.

4.3 Shoal Bay (ShB)

Since October 2005, the species dominance at the Shoal Bay site has been variable (Table 7). The site was dominated by *Nucula* prior to 2005, although this species has declined in numbers and now remains in low abundance. Recently *Boccardia* has become abundant and was the highest or second highest ranked species on every sampling occasion from April 2010 to October 2011. *Heteromastus filiformis* was also common, ranking in the top three in abundance on 10 of the 12 most recent sampling occasions. Other species have been variable in abundance, with six different species ranking second or third most abundant in the past year (*Prionospio, Nucula, Aricidea, Austrovenus, Euchone* and *Colurostylis*) (Appendix 10.2). Other common species include *Aonides*, *Notoacmea* and *Macroclymenella* at this site (Appendix 10.2).

Table 7. The three most abundant monitored taxa found over time at ShB.

Date	1st	2nd	3rd
Oct-00	*Nucula*	*Notoacmea*	*Boccardia*
Oct-01	*Nucula*	*Notoacmea*	*Aricidea*
Oct-02	*Nucula*	*Notoacmea*	*Aricidea*
Oct-03	*Nucula*	*Notoacmea*	*Aricidea*
Oct-04	*Nucula*	*Notoacmea*	*Euchone*
Oct-05	*Notoacmea*	*Boccardia*	*Euchone*
Oct-06	*Nucula*	*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*

Notoacmea, *Nucula*, *Colurostylis*, *Glycera* spp. and *Austrovenus* all continue to show seasonal patterns in abundances at ShB (Figure 9, Table 5). The peak abundances occurred in winter for *Notoacmea* (August) and in autumn for *Nucula (*April). *Glycera, Colurostylis*, *Austrovenus* all had peak abundances in summer. Greater than annual cycles were seen in *Aricidea*, *Anthopleura*, *Euchone, Prionospio* and *Austrovenus* primarily reflecting variation in recruitment success from year to year or less frequent recruitment (Table 5). *Macroclymenella, Boccardia* and *Aricidea* also show cyclic peaks in abundance but with an unusually high peak in abundance in late 2009 (Figure 9). The density of tube worms (*Macroclymenella* and *Boccardia*) has decreased since their peak in late 2009, but densities are still generally higher than in the first two years of monitoring. The increase in the population of *Heteromastus* is still apparent at the ShB site (Townsend et al. 2010). The decreasing trend in *Nucula* is also still noticeable with this species found in lower densities since around October 2004. The density of *Austrovenus* is relatively low at ShB site (Figure 10) and adults are rare. The juvenile size-class (<5 mm) displays the characteristic pattern of large annual peak in recruitment, but no overall trend. There are signs of a multi-year cycle in the intermediate size-class. Adult *Macomona* continue to show a decreasing trend in abundance at ShB, due to higher abundance prior to June 06 and rarity since. A similar pattern is seen for the intermediate size category although this is less pronounced. Overall *Macomona* has a decreasing trend in total abundance.

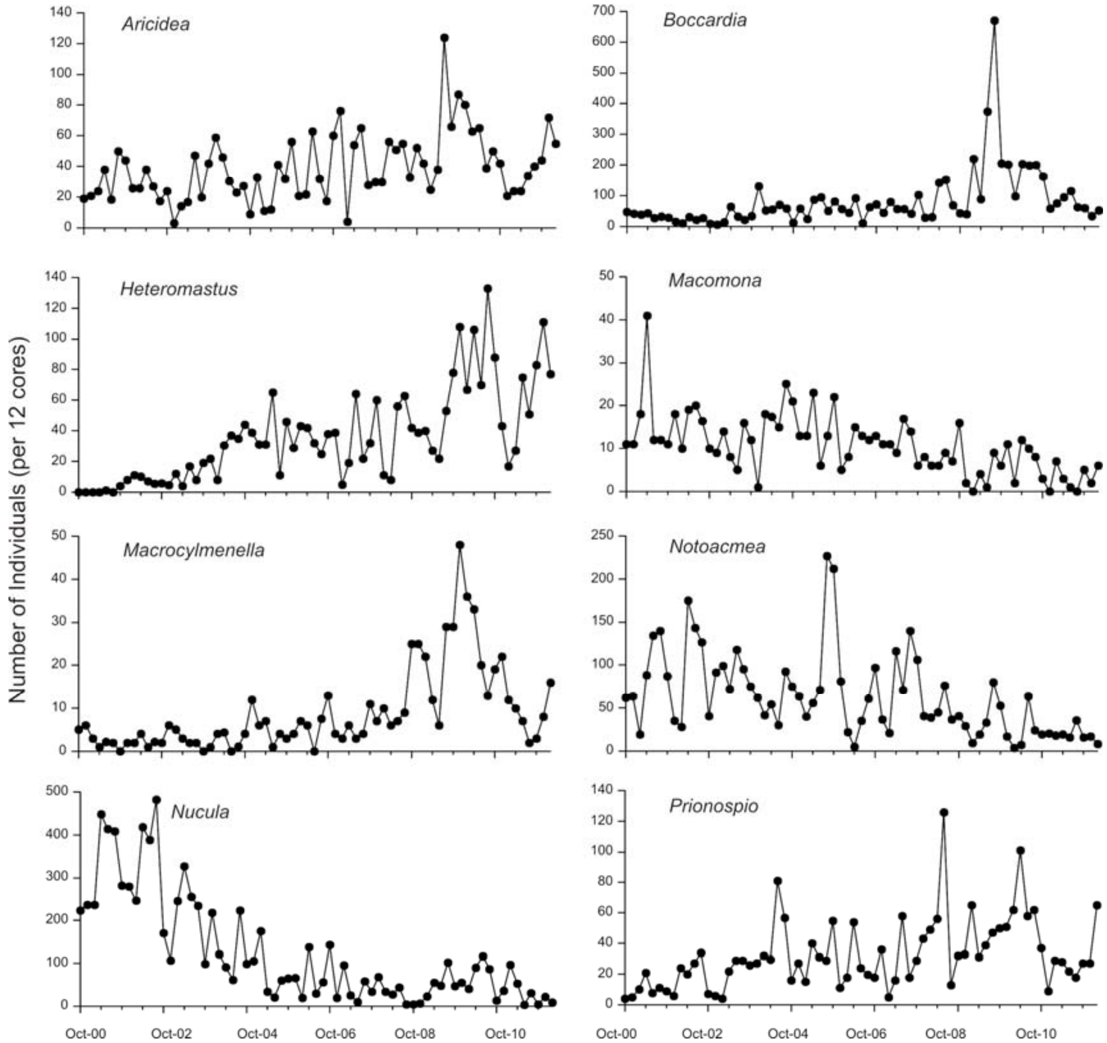

Figure 9. Trends in abundance of Aricidea sp., Boccardia syrtis, Heteromastus filiformis, Macomona liliana, Macroclymenella stewartensis, Notoacmea scapha, Nucula hartvigiana and Prionospio aucklandica at the ShB site.

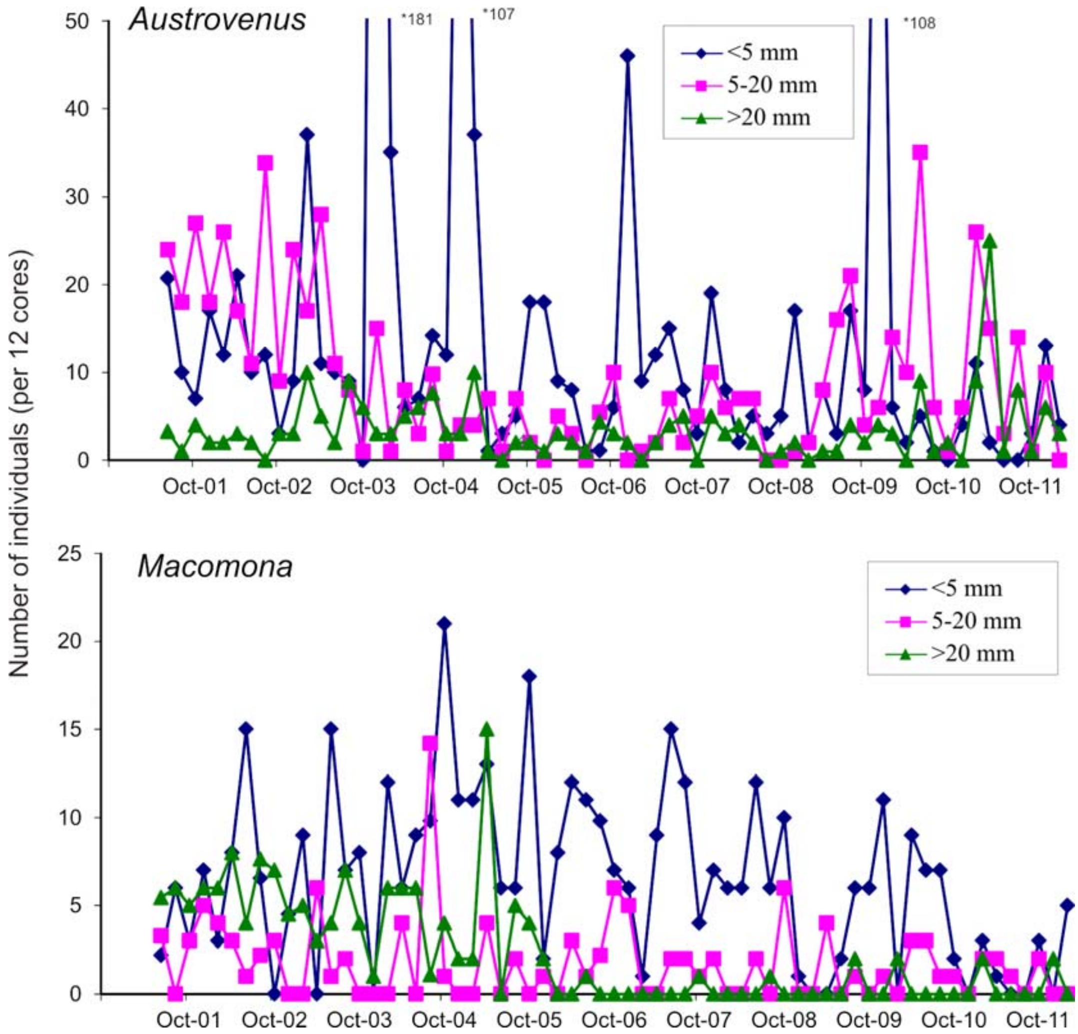

Figure 10. Trends in abundance of different size classes of the bivalves *Austrovenus stutchburyi* and *Macomona liliana* found over time at ShB. No *Paphies australis* were present at ShB.

4.4 Lower Shoal Bay (LoS)

The two most abundant monitored taxa at LoS were *Boccardia* and *Heteromastus* (Table 8). *Prionospio* and *Nucula* were also common at this site, ranking 2nd or 3rd most abundant on several occasions. *Austrovenus* and *Macomona* were rare at this site (averaging 3 and 4 individuals per 12 replicates, respectively) and *Paphies* appears to be absent (no *Paphies* recorded in nine sampling occasions between October 2010 and February 2012). After fewer than two 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 polychates Cirratulidae, *Cossura consimilis* and *Paradoneis lyra*, the amphipod *Paracalliope novizealandiae* and nemerteans.

Table 8. The three most abundant monitored taxa found over time at LoS.

Date	1st	2nd	3rd
Oct-10	*Boccardia*	*Heteromastus*	*Nucula*
Dec-10	*Boccardia*	*Prionospio*	*Heteromastus /Nucula*
Feb-11	*Boccardia*	*Heteromastus*	*Prionospio*
Apr-11	*Boccardia*	*Heteromastus*	*Nucula*
Jun-11	*Heteromastus*	*Boccardia*	*Prionospio*
Aug-11	*Heteromastus*	*Boccardia*	*Prionospio*
Oct-11	*Heteromastus*	*Boccardia*	*Nucula*
Dec-11	*Heteromastus*	*Prionospio*	*Arthritica*
Feb-12	*Heteromastus*	*Nucula*	*Prionospio*

4.5 Are species abundances exhibiting similar patterns at all sites?

There were some consistent trends in the abundance of species, and types of species, across multiple sites in the Waitemata Harbour. There was a noticeable decline in bivalve populations with *Nucula* decreasing at HBV and ShB (and historically at Whau), *Paphies* decreasing at HBV and *Macomona* decreasing at ShB. There was also an increase in silt-tolerant polychaetes, most noticeably at the ShB site, which also has shown increases in mud content. *Heteromastus, Prionospio* and *Aricidea* are all increasing in abundance at ShB. In terms of sensitivity to sedimentation, these species have all been ranked as having a preference for silty sediment with a tolerance for higher suspended sediment concentration (Gibbs and Hewitt 2004). *Aricidea* was found to be increasing in abundance both at ShB and HBV. The increase in the populations of polychaetes, particularly at ShB, may have been facilitated by the low number of bivalves. For example, Whitlatch et al. (1997) experimentally demonstrated that *Austrovenus* density negatively affects a polychaete species (*Microspio maori*) although simultaneously promoting other species. Also *Macomona* has been shown to have a negative impact on community members (Thrush 1994, 2000). Gadd et al. (2009) found that both *Aricidea* and *Heteromastus* were common species in non-cockle communities. Lower *Nucula* and *Macomona* populations and reductions in adult *Austrovenus* may reduce the level of biogenic sediment disturbance and thus facilitate these polychaetes. High abundances of anemones, *Anthopleura*, were recorded at HBV and Whau in December 2011. The density of anemones is potentially being limited by recruitment success and by the abundance of suitable attachment surfaces. In these sandy sites attachment surfaces are usually live cockles or shell hash. HBV has a large quantity of attachment substrate, intermediate sized *Austrovenus* have been increasing since early 2009 and the shell hash ridge has recently migrated into the sampling site (*pers. obs*.). Additionally, the declining adult and intermediate *Paphies* population may actually facilitate *Anthopleura*, if the decline results in more *Paphies* shell hash for attachment. Whau has less adult *Austrovenus* than HBV and no *Paphies*, but empty bivalve shells are common on the surface of the sediment (Plate 2), so attachment surfaces are unlikely to be a limiting factor in *Anthopleura* density at this site.

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

4.6.1 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 them. 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.

4.6.2 Changes in communities

The multivariate analysis of the sites shows that community composition is distinct at each of the sites (Figure 11). HBV shows the lowest variability over time, Whau intermediate and ShB the highest variability over time (Figure 11). The variability at ShB was primarily driven by decreases in some bivalve (*Macomona* and *Nucula*) and gastropod species (*Diloma* and *Notoacmea*) and increases in some polychaete species (*Heteromastus*, *Aricidea* and *Prionospio*). The community composition of HBV has changed more over the last two years of sampling than in the previous eight (Figure 14). The changes were due to a decline in *Nucula* and unusually high abundances of *Austrovenus* and *Notoacmea* in October 2010 and *Colurostylis* in October 2011.The changes in community composition at HBV over the last two years are due to changes in species abundances rather than presence or absence of particular monitored species. This is evident in the 4^{th} root ordination, which reduces the effect of extreme abundances (Figure 12). The 4^{th} root ordination also shows ShB continuing to track away from the other sites (Figure 12). The community composition of the new site LoS is closest to the other Shoal Bay site, ShB (Figure 11 and 12).

Differences in community composition at the sites relate to the sediment mud content (Figure 13). This analysis found a strong correlation (r = 0.85) between community composition and percentage mud content, with the values for the new site LoS being the most distinct, with high sediment mud content and CAPmud values. Values for ShB were lower in 2010 and 2011 than previously recorded indicating the community composition is becoming more like LoS and less like the other monitored sites (Figure 13).

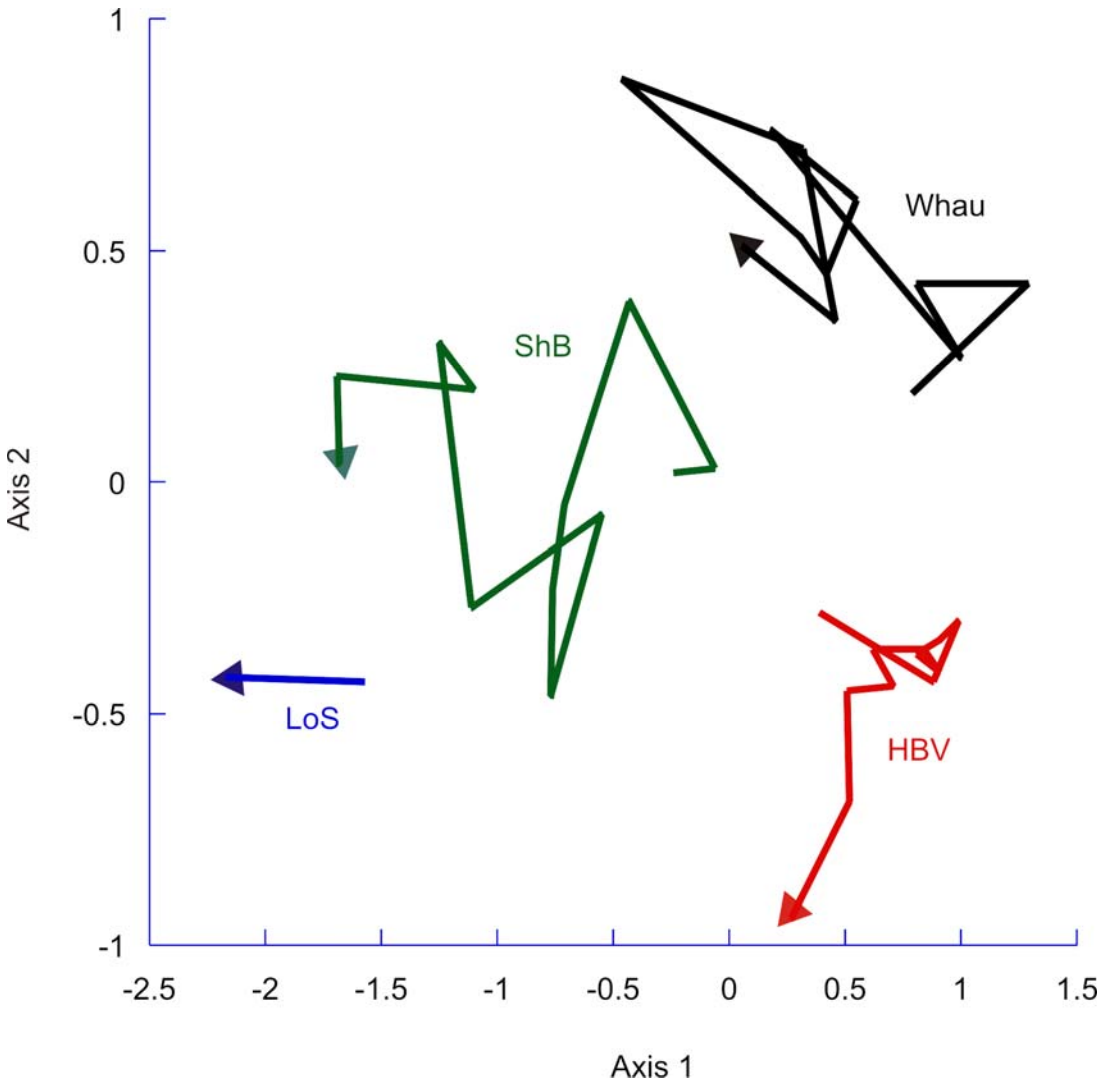

Figure 11. MDS ordination using Bray-Curtis similarity on the raw data of the monitored species from October data 2000-2011 at the four sites (HBV, LoS, Whau and ShB). MDS stress value of 0.09 indicates that this is a good two dimensional representation of the data.

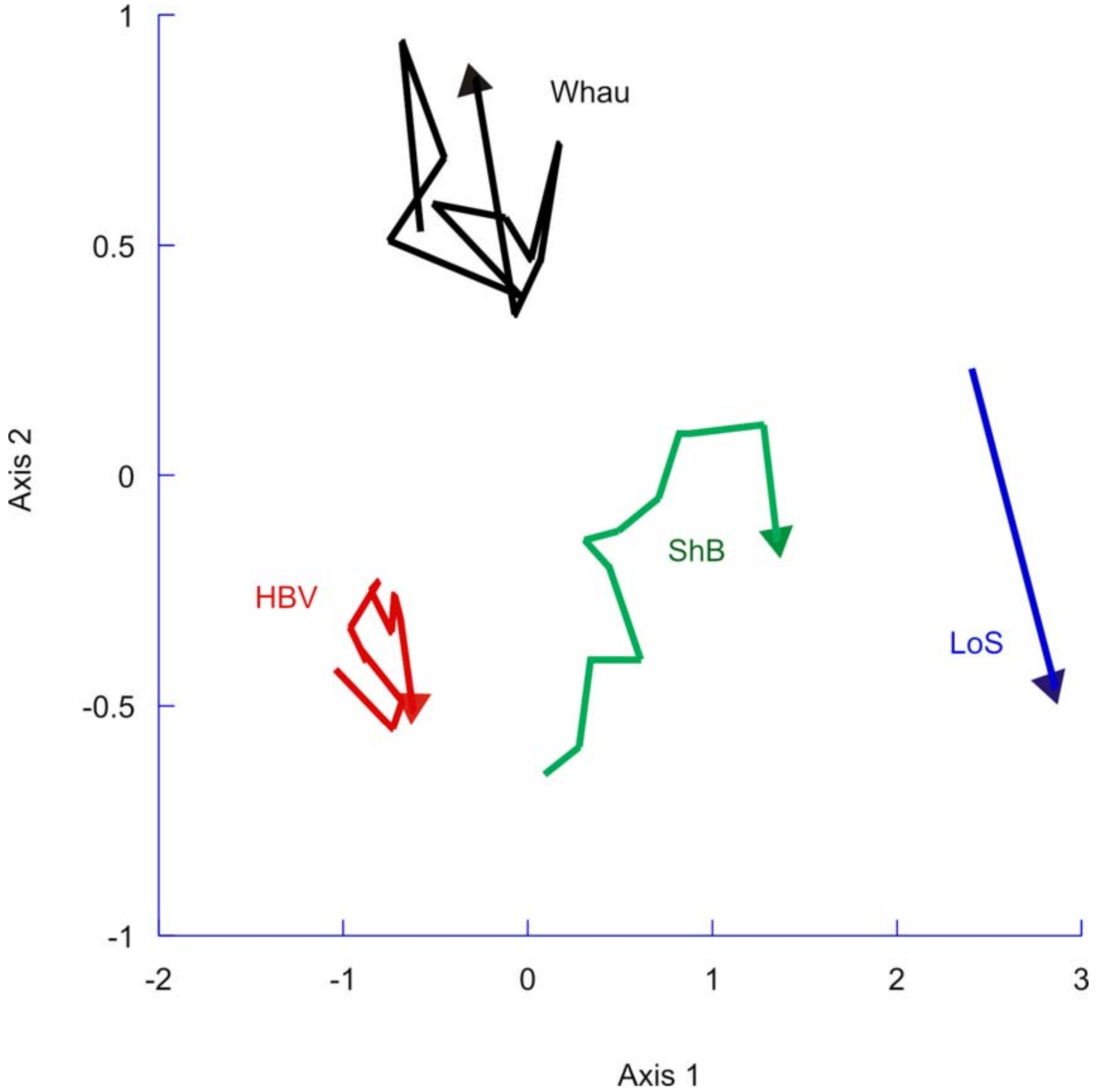

Figure 12. MDS ordination using Bray-Curtis similarity on the 4th root transformed data of the monitored species from October data 2000-2011 of the four sites (HBV, LoS, Whau and ShB). MDS stress value of 0.13 indicates that this is a reasonably good two dimensional representation of the data.

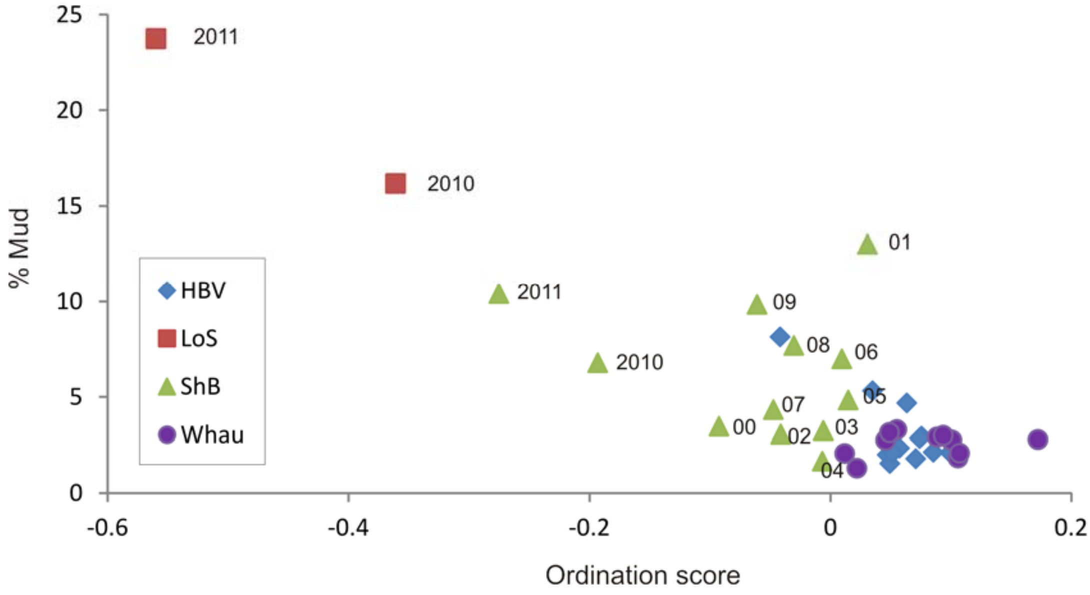

Figure 13. Canonical ordination scores related to mud, produced by DISTLM, for each site-time from October data 2000-2011. Dates shown for LoS and ShB data points only.

4.6.3 Nassarius burchardi

Since its arrival in June 2009, the Australian dog whelk, *Nassarius (Plicarcularia) burchardi* (Dunker in Philippi, 1849) continues to be found in the Waitemata Harbour (Townsend et al. 2010, Townsend 2010). *Nassarius* has now been recorded at all monitoring sites, initially being found at HC in June 2009, followed by Whau in August 2009 and then Reef and ShB in December 2009. In October 2010 sampling began at LoS and in February 2011 *Nassarius* was found at this site and also at HBV for the first time. Thus, since February 2011, with the exception of April and June 2011 at Whau, *Nassarius* has been consistently present in moderate abundance (Figure 14). The nature of this multi-site invasion, including increased abundances and occurrences over two years of monitoring, suggests that *Nassarius* should be considered an established species in the Waitemata Harbour rather than simply a temporary colonist. Interestingly this species has increased its distributional range in New Zealand, having now been discovered in Whangarei Harbour in high abundances (>400 ind/m^{-2}) (M. Gibbs, M. Morley pers. com.). Individuals in Whangarei Harbour are typically smaller than those observed in Waitemata Harbour, which may relate to environmental conditions, food supply, or the earlier stage of the invasion in Whangarei. 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, impacts of *Nassarius* on benthic communities in the Waitemata Harbour are not yet readily observable.

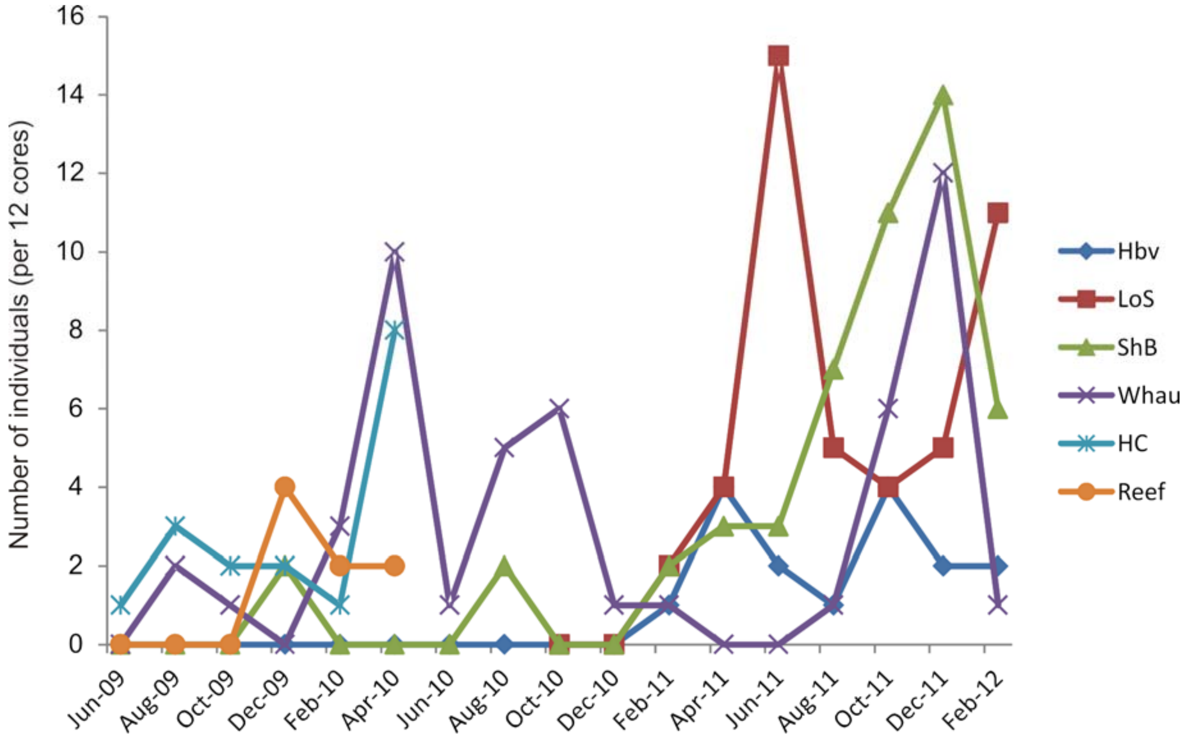

Figure 14.Trends in the abundance of *Nassarius burchardi* at all central Waitemata Harbour monitoring sites (HBV, HC, Reef, Whau, ShB and LoS) since it was first observed in June 2009. Note sampling at HC and Reef was temporarily suspended in April 2010. Sampling at LoS began in October 2010.

4.6.4 State of the Environment Indicators

Here, TBI scores have been calculated using the latest TBI formula (Lohrer and Rodil 2012) and October data from each site. Note that the values quoted in this report will not be directly comparable to NIWACOOBII results presented by Townsend et al. (2010); the new values should supersede the old ones.

TBI scores for the four monitored sites reported on here ranged from 0.29 at HBV (October 2000) to 0.69 at ShB (October 2011) (Figure 15). 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). TBI October scores were on average higher in 2012 than in 2000 and appear to be trending upwards. However, 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. (in review)). 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).

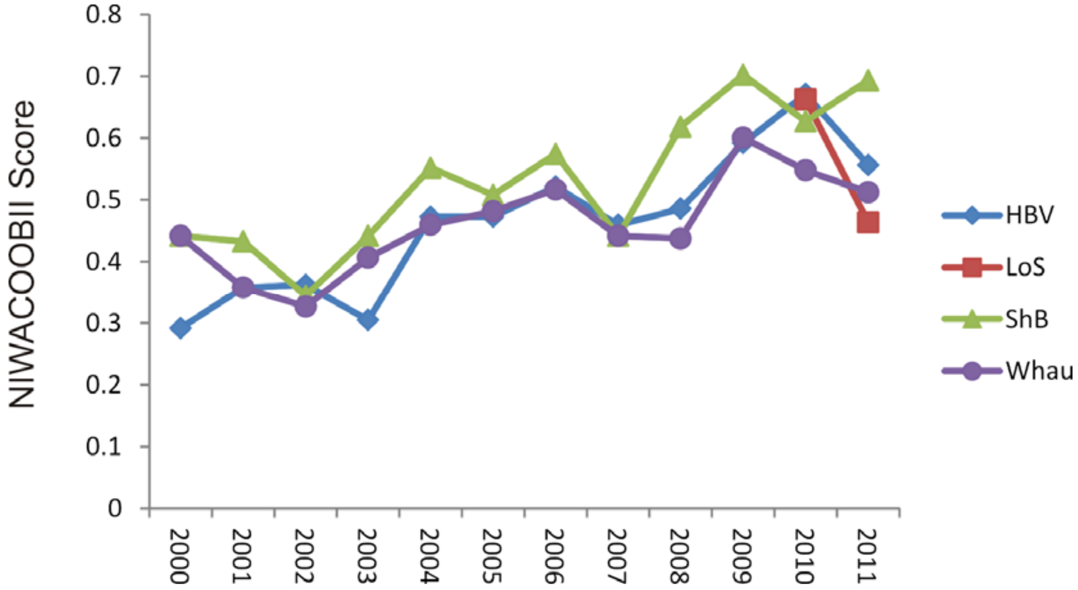

Figure 15. TBI score for the four monitoring sites (HBV, LoS, ShB and Whau) during the monitoring period (October 2000 – October 2011). TBI scores are calculated from the entire macrobenthic fauna, not just the monitored taxa, found at each site each October.

Benthic health model scores for both mud and metals were also calculated (Table 8). 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. 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.

Table 8. Benthic Health Model scores for metals and mud (CAPmetal, CAOmud) for the presently monitored sites in 2000, 2009, 2010 and 2011. Note that the scores differ slightly from those plotted in the previous report as those scores were rescaled to have a lowest value of 0.

Site	Year	CAPmetal	CAPmud
Hbv	2000	-0.116	-0.161
	2009	-0.095	-0.137
	2010	-0.117	-0.141
	2011	-0.156	-0.148
LoS	2010	-0.028	-0.014
LoS	2011	-0.043	0.011
ShB	2000	-0.080	-0.127
	2009	-0.082	-0.077
	2010	-0.081	-0.055
	2011	-0.100	-0.073
Whau	2000	-0.075	-0.125
Whau	2009	-0.123	-0.122
Whau	2010	-0.093	-0.127
Whau	2011	-0.115	-0.130

5.0 Conclusions and recommendations

The general patterns in community composition occurring in the Central Waitemata are: (1) moderate change occurring at HBV and Whau relating to variability and cyclic patterns in abundances and (2) changes occurring at ShB and potential for further changes (as predicted by Green 2008). Changes at ShB look to be anthropogenic in origin through the increasing mud content associated with higher sedimentation in this embayment. Future monitoring is necessary to determine whether these changes continue and if future community changes relate to environmental parameters.

A tidal drainage channel next to HBV and another smaller channel have been expanding over time and are now causing increased muddiness in 1/6 of the site nearest the 0,0 peg (Lundquist pers obs). We recommended 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, so that the effect of the expanding channel areas can be assessed. 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.

In the 2008 report it was highlighted that the ShB site needed to be surveyed on a low tide of 0.7 m or lower. As this site is now sampled from shore, this decreases the likelihood of sampling of this site whilst underwater. If the sampling crew is still having difficulty finding this site out of water, they should take note of the tidal height upon sampling, as adequate sampling may require a lower tide, e.g., of 0.5 m or lower.

During the site inspection by NIWA in May 2012 it was noted that new marker pegs had been placed at Whau in the wrong locations. The area defined by the new pegs was lower on the shore than the site should have been, but in similar firm packed sand. Peter Williams from Auckland Council believes the new pegs were added in either October or December 2011. It is critical to interpretation of long term monitoring data that sites remain in the same location unless there are important reasons to move them. Before the next sampling occasion the incorrectly sited pegs must be removed, the location of the old pegs must be verified using GPS, and new site marker pegs need to be added.

LoS was established as a baseline site 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 suggests that it is lower down the shore than the other sites, meaning that it will be exposed less frequently. This observation 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. We therefore recommend the investigation of alternative sandier sites within the Shoal Bay area. If no suitable sites are available, the merits of continued sampling at LoS should be re-evaluated. Continued sampling at ShB will assist in detecting any adverse effects from the predicted increase in sedimentation and sediment contaminant in this sub-estuary.

We also recommend that a scientist who is familiar with the sites should be present during two of the six sampling trips per year (preferably in April and October each 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.

6.0 Acknowledgements

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8.0 Plates

Plate 1.

The Hobsonville area (top), with a close-up of sediment from within the HBV site (bottom). Photos taken in May 2012.

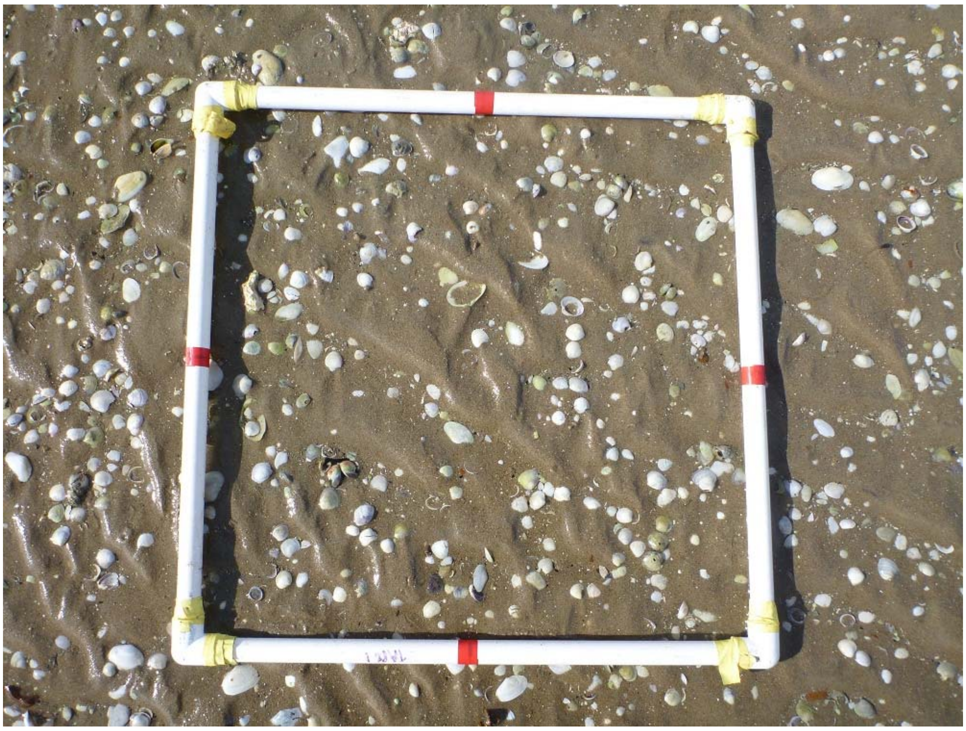


Plate 2.

The sandflat near Whau River (top), with a close-up of sediment from within the Whau site (bottom). Photos taken in May 2012.

Plate 3.

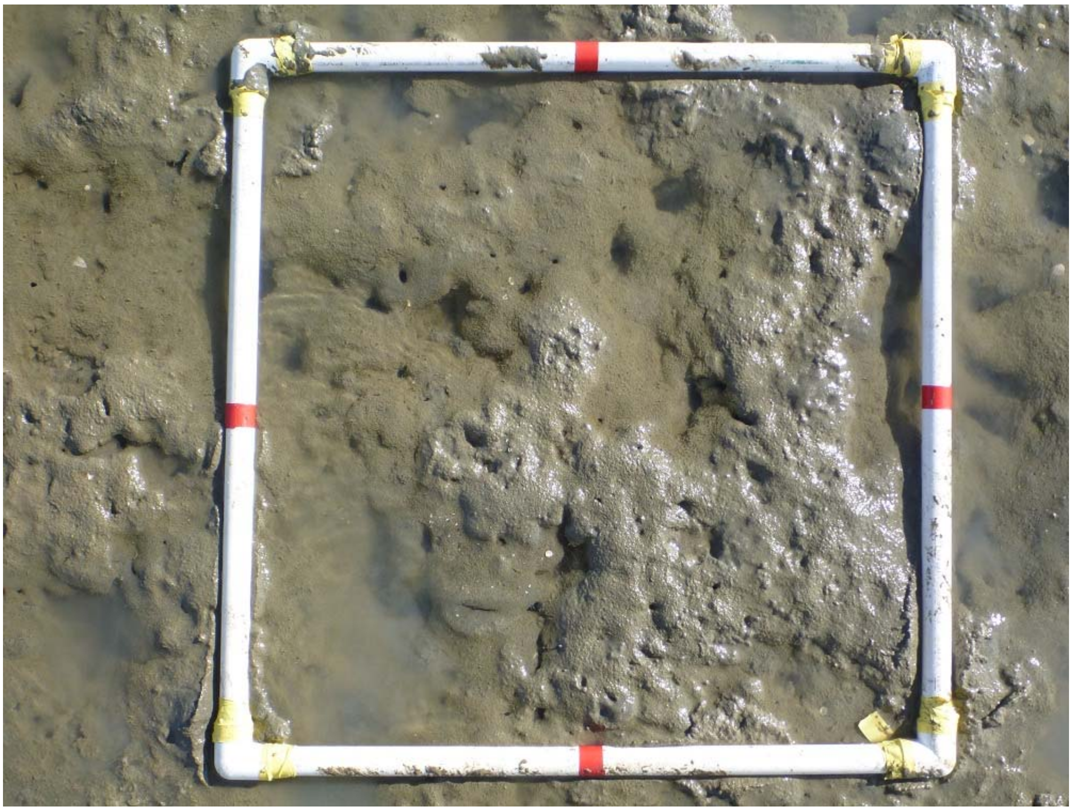
The sandflat on the western side of Shoal Bay with the 0,0 marker (top), and a close-up of sediment from within the ShB site (bottom). Photos taken in May 2012.

Plate 4.

The sandflat on the eastern side of Shoal Bay (LoS) x-axis parallel to shore (top), y-axis at right-angles to shore (bottom), Photos taken in May 2012.

Plate 5.

Close-up of sediment from LoS (top) and foot prints showing penetration depth into soft-sediment (bottom). Photos taken in May 2012.



9.0 Appendices

9.1 Appendix 1: Sediment characteristics October 2000 – February 2012

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	17.64	56.54	32.59	7.19	0.40	1.54	13.64
	Apr-08	3.29	3.29	17.87	52.95	33.90	4.88	1.68	1.85	12.73
	Jun-08	1.72	1.15	15.05	60.36	28.98	6.51	1.28	1.64	11.70

site	date	%clay	%silt	%mud	%fine sand	%med sand	%coarse sand	% gravel	% organics	chla υg/g
	Aug-08	0.13	2.71	17.55	54.06	37.27	4.91	0.93	1.15	16.27
	Oct-08	2.35	0.00	19.19	65.64	26.23	4.11	1.67	1.25	15.59
	Dec-08	2.39	2.05	16.85	48.40	33.48	11.14	2.55	1.98	12.49
	Feb-09	1.21	0.35	16.23	43.41	34.61	18.45	1.97	1.49	13.53
	Apr-09	2.78	0.28	20.88	58.39	32.80	4.79	0.96	0.91	17.19
	Jun-09	1.47	0.49	17.59	52.58	38.08	6.24	1.14	1.21	14.91
	Aug-09	1.21	1.81	17.45	53.79	33.33	7.65	2.22	1.57	14.67
	Oct-09	1.06	1.06	15.05	51.79	38.05	7.43	0.61	1.15	12.84
	Dec-09	2.61	1.45	16.70	37.53	47.49	9.88	1.03	1.47	12.61
	Feb-10	1.99	2.32	13.87	58.02	31.03	5.58	1.04	0.98	10.89
	Apr-10	1.91	1.53	14.01	51.92	36.15	5.19	3.30	1.33	10.77
	Jun-10	1.30	0.37	16.93	45.94	41.62	8.08	2.69	1.41	14.22
	Aug-10	1.74	0.87	13.83	53.86	34.77	6.97	1.78	1.43	10.66
	Oct-10	2.34	2.34	18.32	56.49	32.61	4.88	1.34	1.65	14.33
	Dec-10	0.87	2.02	17.96	43.18	41.87	8.50	3.56	1.62	15.48
	Feb-11	3.87	0.00	21.95	50.60	38.05	4.62	2.87	1.57	16.51
	Apr-11	2.76	1.38	22.12	44.92	39.78	6.27	4.89	1.36	18.00
	Jun-11	1.61	2.58	19.20	45.92	39.35	5.90	4.64	1.54	16.05
	Aug-11	4.00	1.00	22.34	46.24	39.54	5.59	3.63	2.18	16.16
	Oct-11	1.85	0.98	26.19	49.91	36.12	5.58	5.55	1.18	23.15
	Dec-11	1.97	2.18	17.70	53.38	31.77	5.05	5.65	1.64	14.10
	Feb-12	1.93	1.29	20.20	48.95	37.34	6.58	3.92	1.64	16.63
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
	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
ShB	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

site	date	%clay	%silt	%mud	%fine sand	%med sand	%coarse sand	% gravel	% organics	chla υg/g
	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	11.64	69.24	20.29	2.41	5.32	0.88	8.37
	Jun-08	4.00	4.99	15.17	70.79	4.73	0.68	14.80	1.31	9.86
	Aug-08	4.39	4.88	19.01	67.93	4.81	2.54	15.46	1.33	13.30
	Oct-08	4.76	2.93	16.89	78.64	6.04	3.28	4.36	1.13	11.00
	Dec-08	2.25	2.89	11.27	71.39	8.71	1.04	13.72	0.88	8.14
	Feb-09	2.16	1.44	11.09	68.63	12.48	3.05	12.24	1.02	7.91
	Apr-09	5.27	4.74	13.66	87.79	2.05	0.14	0.00	1.46	6.94
	Jun-09	5.79	5.31	15.05	70.52	7.33	2.17	8.88	1.11	8.14
	Aug-09	2.98	4.68	12.28	75.92	8.41	3.63	4.38	1.17	8.14
	Oct-09	2.87	6.97	11.68	79.50	5.67	2.11	2.89	1.01	7.79
	Dec-09	4.01	1.46	12.15	68.29	15.24	2.49	8.51	0.91	7.22
	Feb-10	3.18	0.95	9.10	69.20	10.58	6.16	9.92	1.16	4.76
	Apr-10	4.92	6.24	16.00	80.87	3.49	1.18	3.30	1.91	9.17
	Jun-10	0.29	0.27	10.38	84.20	10.04	1.85	3.35	1.26	8.83
	Aug-10	5.90	8.84	14.84	70.72	5.33	1.92	7.29	1.84	7.11
	Oct-10	2.97	3.82	12.28	86.61	5.01	0.62	0.97	1.05	8.25
	Dec-10	2.64	3.44	12.40	71.49	4.37	1.67	16.40	1.28	8.48
	Feb-11	3.40	2.72	13.27	72.32	10.12	2.93	8.51	1.04	8.83
	Apr-11	3.17	2.47	11.13	73.88	11.68	3.80	5.01	0.85	7.11
	Jun-11	3.90	2.44	17.03	82.30	6.44	0.45	4.48	0.98	12.15
	Aug-11	4.82	3.61	16.30	76.94	3.93	1.71	8.99	1.63	9.86
	Oct-11	4.50	5.90	19.92	75.49	5.86	3.46	4.78	1.20	14.22
	Dec-11	4.16	6.24	14.13	65.83	6.12	2.23	15.41	1.54	8.42
	Feb-12	2.33	2.92	13.89	72.27	6.60	6.63	6.25	0.78	10.78
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
Whau	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

site	date	%clay	%silt	%mud	%fine sand	%med sand	%coarse sand	% gravel	% organics	chla υg/g
	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	13.00	92.77	1.62	0.72	2.74	0.98	9.86
	Jun-08	1.42	1.42	14.90	94.06	1.35	0.72	1.03	1.09	12.38
	Aug-08	3.04	1.75	19.58	89.12	1.83	0.96	3.30	0.95	15.59
	Oct-08	1.04	1.04	12.77	89.35	1.35	0.88	6.34	0.84	10.89
	Dec-08	3.64	2.43	12.55	91.83	1.97	0.13	0.00	0.95	7.97
	Feb-09	2.20	1.20	12.16	81.95	3.37	1.01	10.27	1.24	8.71
	Apr-09	1.33	0.95	13.80	90.33	5.61	0.69	1.08	1.00	11.47
	Jun-09	7.02	1.91	21.41	87.64	1.35	0.79	1.29	1.10	13.30
	Aug-09	1.04	0.35	15.26	94.18	1.63	0.83	1.97	0.92	13.30
	Oct-09	0.87	0.43	15.50	93.40	1.99	0.77	1.67	0.88	13.76
	Dec-09	4.05	1.45	18.44	91.22	1.99	0.35	0.94	1.10	13.29
	Feb-10	1.04	0.52	14.24	93.41	3.72	0.93	0.37	0.70	12.50
	Apr-10	2.76	0.23	18.72	93.33	2.64	0.55	0.49	1.06	14.90
	Jun-10	0.18	0.03	22.74	92.98	4.00	1.16	1.65	1.00	21.56
	Aug-10	2.07	0.69	15.55	93.24	2.30	0.68	1.03	1.10	12.38
	Oct-10	1.00	1.99	15.46	93.60	1.90	0.60	0.91	1.16	13.30
	Dec-10	1.96	0.98	15.84	92.30	2.56	0.78	1.42	1.28	12.61
	Feb-11	0.72	0.48	23.70	86.15	5.99	0.72	5.93	1.20	21.78
	Apr-11	1.70	0.73	22.19	93.36	2.70	0.74	0.77	1.23	19.26
	Jun-11	1.22	1.22	18.87	90.82	2.29	0.91	3.55	1.14	16.51
	Aug-11	1.64	0.70	21.89	84.90	2.18	1.10	9.48	1.22	19.03
	Oct-11	1.46	1.32	20.10	91.81	1.79	0.85	2.77	0.98	17.65
	Dec-11	1.63	1.08	17.74	88.26	2.86	0.76	5.41	0.99	15.13
	Feb-12	1.60	0.46	16.80	85.61	2.48	0.68	9.17	1.49	15.02
LoS	Oct-10	5.20	10.97	14.07	81.93	0.65	0.24	1.02	2.11	6.76
	Dec-10	3.33	7.90	12.49	87.15	0.88	0.04	0.71	1.37	7.79
	Feb-11	5.96	15.65	15.57	77.37	0.69	0.19	0.14	1.92	7.68
	Apr-11	4.29	22.22	15.36	72.58	0.59	0.29	0.04	2.25	8.83
	Jun-11	3.62	21.19	14.49	74.36	0.58	0.12	0.13	2.16	8.71
	Aug-11	5.08	14.10	13.56	80.30	0.45	0.06	0.00	2.18	6.31
	Oct-11	5.41	18.33	14.71	74.56	0.92	0.41	0.38	1.96	7.34
LoS	Dec-11	4.67	11.67	12.98	80.44	0.83	0.48	1.92	1.78	6.53
	Feb-12	5.52	11.37	18.11	82.10	0.66	0.17	0.18	1.65	9.63

9.2 Appendix 2: Benthic Invertebrate data collected between April 2010 and February 2011

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	58	40	3.5	8	3.3
Hbv	59	41	2.5	10	3.4
Hbv	60	41	3.5	11	3.4
Hbv	61	41	2	8	3.4
Hbv	62	42	3	9	3.5
Hbv	63	60	5	6	5.0
Hbv	64	59	5	12	4.9
Hbv	65	40	2	7	3.3
Hbv	66	35	3.5	5	2.9
Hbv	67	43	2	10	3.6
Hbv	68	75	6	9	6.3
Hbv	69	65	6	12	5.4
LoS	63	1	0	1	0.1
LoS	64	0	0	0	0.0
LoS	65	0	0	0	0.0
LoS	66	1	0	1	0.1
LoS	67	0	0	0	0.0
LoS	68	0	0	0	0.0
LoS	69	0	0	0	0.0
ShB	58	9	0	6	0.8
ShB	59	12	0	5	1.0
ShB	60	9	0	5	0.8
ShB	61	1	0	1	0.1
ShB	62	13	0.5	4	1.1
ShB	63	8	0	3	0.7
ShB	64	14	1	4	1.2
ShB	65	7	0	4	0.6
ShB	66	11	0.5	4	0.9
ShB	67	18	0	7	1.5
ShB	68	14	1	5	1.2
ShB	69	13	0	8	1.1
Whau	58	20	1	5	1.7
Whau	59	11	0	5	0.9
Whau	60	27	1.5	9	2.3
Whau	61	10	1	3	0.8
Whau	62	21	1.5	4	1.8
Whau	63	24	1	7	2.0
Whau	64	20	1	6	1.7
Whau	65	18	1	7	1.5
Whau	66	23	2.5	5	1.9
Whau	67	24	2	5	2.0
Whau	68	56	4	9	4.7
Whau	69	33	3	10	2.8

Species: Aonides trifida

Site	Series	Total	Median	Range	Mean
Hbv	58	374	26	36	31.2
Hbv	59	319	24	40	26.6
Hbv	60	433	32	63	36.1
Hbv	61	472	38.5	47	39.3
Hbv	62	384	29	33	32.0
Hbv	63	395	32	42	32.9
Hbv	64	320	26	38	26.7
Hbv	65	426	33.5	64	35.5
Hbv	66	388	30	38	32.3
Hbv	67	312	26	32	26.0
Hbv	68	324	27.5	29	27.0
Hbv	69	372	33.5	28	31.0
LoS	63	0	0	0	0.0
LoS	64	1	0	1	0.1
LoS	65	0	0	0	0.0
LoS	66	3	0	2	0.3
LoS	67	0	0	0	0.0
LoS	68	0	0	0	0.0
LoS	69	0	0	0	0.0
ShB	58	1	0	1	0.1
ShB	59	10	0	5	0.8
ShB	60	1	0	1	0.1
ShB	61	3	0	3	0.3
ShB	62	1	0	1	0.1
ShB	63	20	0.5	11	1.7
ShB	64	5	0	3	0.4
ShB	65	0	0	0	0.0
ShB	66	11	0	9	0.9
ShB	67	0	0	0	0.0
ShB	68	5	0	4	0.4
ShB	69	4	0	2	0.3
Whau	58	7	0	2	0.6
Whau	59	2	0	2	0.2
Whau	60	8	0	7	0.7
Whau	61	5	0	3	0.4
Whau	62	3	0	1	0.3
Whau	63	5	0	2	0.4
Whau	64	0	0	0	0.0
Whau	65	4	0	1	0.3
Whau	66	2	0	1	0.2
Whau	67	0	0	0	0.0
Whau	68	0	0	0	0.0
Whau	69	1	0	1	0.1

Species: *Aricidea* sp.

Site	Series	Total	Median	Range	Mean
Hbv	58	27	2	6	2.3
Hbv	59	17	1	5	1.4
Hbv	60	42	2	11	3.5
Hbv	61	29	2	6	2.4
Hbv	62	17	0	6	1.4
Hbv	63	16	0.5	8	1.3
Hbv	64	10	0	5	0.8
Hbv	65	24	0.5	11	2.0
Hbv	66	25	1	13	2.1
Hbv	67	34	0.5	12	2.8
Hbv	68	20	1	6	1.7
Hbv	69	19	0	10	1.6
LoS	63	7	0.3	2	0.5
LoS	64	29	1	10	2.4
LoS	65	12	0	4	1.0
LoS	66	20	1	6	1.7
LoS	67	9	1	3	0.8
LoS	68	23	1.5	6	1.9
LoS	69	11	1	2	0.9
ShB	58	65	4.5	16	5.4
ShB	59	39	3	7	3.3
ShB	60	50	3	11	4.2
ShB	61	42	1.5	13	3.5
ShB	62	21	1	7	1.8
ShB	63	24	0.5	11	2.0
ShB	64	24	1	8	2.0
ShB	65	34	1	9	2.8
ShB	66	40	3	11	3.3
ShB	67	44	2.5	18	3.7
ShB	68	72	3.5	26	6.0
ShB	69	55	2	17	4.6
Whau	58	279	21	63	23.3
Whau	59	230	10.5	80	19.2
Whau	60	284	21.5	44	23.7
Whau	61	253	14.5	59	21.1
Whau	62	160	8.5	41	13.3
Whau	63	127	6.5	37	10.6
Whau	64	72	2.5	24	6.0
Whau	65	110	4	26	9.2
Whau	66	170	12.5	42	14.2
Whau	67	137	6.5	30	11.4
Whau	68	299	17	70	24.9
Whau	69	121	7	21	10.1

Species: Arthritica bifurca

Site	Series	Total	Median	Range	Mean
Hbv	58	1	0	1	0.1
Hbv	59	0	0	0	0.0
Hbv	60	2	0	2	0.2
Hbv	61	2	0	1	0.2
Hbv	62	0	0	0	0.0
Hbv	63	5	0	3	0.4
Hbv	64	8	0.5	2	0.7
Hbv	65	5	0	4	0.4
Hbv	66	2	0	2	0.2
Hbv	67	10	0	3	0.8
Hbv	68	2	0	1	0.2
Hbv	69	16	0	10	1.3
LoS	63	20	0.5	9	1.6
LoS	64	22	1	5	1.8
LoS	65	13	0	4	1.1
LoS	66	4	0	1	0.3
LoS	67	23	1.5	6	1.9
LoS	68	46	2.5	10	3.8
LoS	69	23	1	10	1.9
ShB	58	9	0	3	0.8
ShB	59	3	0	1	0.3
ShB	60	1	0	1	0.1
ShB	61	1	0	1	0.1
ShB	62	0	0	0	0.0
ShB	63	1	0	1	0.1
ShB	64	4	0	4	0.3
ShB	65	5	0	4	0.4
ShB	66	1	0	1	0.1
ShB	67	7	0	5	0.6
ShB	68	8	0	4	0.7
ShB	69	5	0	3	0.4
Whau	58	3	0	2	0.3
Whau	59	1	0	1	0.1
Whau	60	6	0	4	0.5
Whau	61	4	0	3	0.3
Whau	62	0	0	0	0.0
Whau	63	0	0	0	0.0
Whau	64	0	0	0	0.0
Whau	65	16	1	3	1.3
Whau	66	2	0	2	0.2
Whau	67	3	0	2	0.3
Whau	68	2	0	1	0.2
Whau	69	4	0	3	0.3

Species: Austrovenus stutchburyi

Site	Series	Total	Median	Range	Mean
Hbv	58	256	22	16	21.3
Hbv	59	253	21	30	21.1
Hbv	60	207	17	27	17.3
Hbv	61	237	18	23	19.8
Hbv	62	188	16	30	15.7
Hbv	63	218	17.5	22	18.2
Hbv	64	200	16	14	16.7
Hbv	65	159	13	18	13.3
Hbv	66	117	11	18	9.8
Hbv	67	176	12.5	28	14.7
Hbv	68	254	18	30	21.2
Hbv	69	204	15.5	16	17.0
LoS	63	0	0	0	0.0
LoS	64	0	0	0	0.0
LoS	65	2	0	2	0.2
LoS	66	0	0	0	0.0
LoS	67	4	0	2	0.3
LoS	68	8	0	2	0.7
LoS	69	8	0	3	0.7
ShB	58	12	0	12	1.0
ShB	59	49	0	14	4.1
ShB	60	8	0	3	0.7
ShB	61	3	0	3	0.3
ShB	62	10	0	6	0.8
ShB	63	67	2	26	5.6
ShB	64	42	0.5	11	3.5
ShB	65	4	0	1	0.3
ShB	66	22	0.5	10	1.8
ShB	67	5	0	2	0.4
ShB	68	29	0	17	2.4
ShB	69	2	0	1	0.2
Whau	58	115	8.5	13	9.6
Whau	59	83	7.5	11	6.9
Whau	60	71	6	9	5.9
Whau	61	91	6	26	7.6
Whau	62	113	7	20	9.4
Whau	63	88	6.5	13	7.3
Whau	64	20	2	4	1.7
Whau	65	13	1	3	1.1
Whau	66	18	1	7	1.5
Whau	67	152	8	40	12.7
Whau	68	224	15.5	26	18.7
Whau	69	50	3	11	4.2

Species: Boccardia syrtis

Site	Series	Total	Median	Range	Mean
Hbv	58	13	1	5	1.1
Hbv	59	20	1	11	1.7
Hbv	60	12	0	4	1.0
Hbv	61	22	2	6	1.8
Hbv	62	5	0	2	0.4
Hbv	63	9	0	5	0.8
Hbv	64	2	0	1	0.2
Hbv	65	7	0	2	0.6
Hbv	66	6	0.5	1	0.5
Hbv	67	9	0.5	2	0.8
Hbv	68	8	0	5	0.7
Hbv	69	8	0	4	0.7
LoS	63	183	12.5	44	15.3
LoS	64	248	22	31	20.7
LoS	65	124	9	13	10.3
LoS	66	88	5.5	14	7.3
LoS	67	48	3	12	4.0
LoS	68	34	2	8	2.8
LoS	69	21	2	4	1.8
ShB	58	204	11.5	41	17.0
ShB	59	198	14	38	16.5
ShB	60	200	16	37	16.7
ShB	61	163	8	38	13.6
ShB	62	59	4.5	9	4.9
ShB	63	76	3	27	6.3
ShB	64	95	2.5	24	7.9
ShB	65	115	6	29	9.6
ShB	66	63	3	16	5.3
ShB	67	60	4.5	21	5.0
ShB	68	34	3	8	2.8
ShB	69	53	2	20	4.4
Whau	58	73	4.5	21	6.1
Whau	59	23	2	4	1.9
Whau	60	69	3.5	17	5.8
Whau	61	30	1	11	2.5
Whau	62	10	0	7	0.8
Whau	63	8	0	5	0.7
Whau	64	9	0.5	3	0.8
Whau	65	2	0	1	0.2
Whau	66	51	2.5	15	4.3
Whau	67	12	0	8	1.0
Whau	68	19	1	4	1.6
Whau	69	11	1	2	0.9

Species: Colurostylis lemurum

Site	Series	Total	Median	Range	Mean
Hbv	58	107	8	20	8.9
Hbv	59	111	7	21	9.3
Hbv	60	107	7.5	17	8.9
Hbv	61	65	5.5	12	5.4
Hbv	62	18	2	3	1.5
Hbv	63	15	0.5	6	1.3
Hbv	64	1	0	1	0.1
Hbv	65	7	0	3	0.6
Hbv	66	18	0.5	5	1.5
Hbv	67	119	10.5	14	9.9
Hbv	68	136	13.5	21	11.3
Hbv	69	124	8.5	26	10.3
LoS	63	0	0	0	0.0
LoS	64	0	0	0	0.0
LoS	65	0	0	0	0.0
LoS	66	0	0	0	0.0
LoS	67	0	0	0	0.0
LoS	68	1	0	1	0.1
LoS	69	1	0	1	0.1
ShB	58	49	2.5	14	4.1
ShB	59	38	1.5	11	3.2
ShB	60	5	0	3	0.4
ShB	61	17	1	9	1.4
ShB	62	2	0	2	0.2
ShB	63	10	0	4	0.8
ShB	64	0	0	0	0.0
ShB	65	1	0	1	0.1
ShB	66	8	0	4	0.7
ShB	67	22	1	8	1.8
ShB	68	37	1	14	3.1
ShB	69	0	0	0	0.0
Whau	58	70	5.5	10	5.8
Whau	59	41	3	6	3.4
Whau	60	68	4	13	5.7
Whau	61	23	1.5	4	1.9
Whau	62	6	0	2	0.5
Whau	63	17	1.5	4	1.4
Whau	64	0	0	0	0.0
Whau	65	1	0	1	0.1
Whau	66	0	0	0	0.0
Whau	67	9	0.5	2	0.8
Whau	68	65	4	14	5.4
Whau	69	194	14	27	16.2

Species: Diloma subrostrata

Site	Series	Total	Median	Range	Mean
Hbv	58	2	0	2	0.2
Hbv	59	6	0	2	0.5
Hbv	60	5	0	2	0.4
Hbv	61	9	0.5	4	0.8
Hbv	62	2	0	2	0.2
Hbv	63	4	0	1	0.3
Hbv	64	10	0.5	2	0.8
Hbv	65	4	0	1	0.3
Hbv	66	8	0.5	2	0.7
Hbv	67	8	0.5	2	0.7
Hbv	68	3	0	1	0.3
Hbv	69	7	0	2	0.6
LoS	63	0	0	0	0.0
LoS	64	0	0	0	0.0
LoS	65	0	0	0	0.0
LoS	66	0	0	0	0.0
LoS	67	0	0	0	0.0
LoS	68	0	0	0	0.0
LoS	69	0	0	0	0.0
ShB	58	0	0	0	0.0
ShB	59	4	0	2	0.3
ShB	60	2	0	2	0.2
ShB	61	0	0	0	0.0
ShB	62	0	0	0	0.0
ShB	63	3	0	2	0.3
ShB	64	1	0	1	0.1
ShB	65	1	0	1	0.1
ShB	66	4	0	2	0.3
ShB	67	0	0	0	0.0
ShB	68	1	0	1	0.1
ShB	69	0	0	0	0.0
Whau	58	0	0	0	0.0
Whau	59	3	0	2	0.3
Whau	60	6	0	2	0.5
Whau	61	4	0	2	0.3
Whau	62	1	0	1	0.1
Whau	63	3	0	1	0.3
Whau	64	0	0	0	0.0
Whau	65	1	0	1	0.1
Whau	66	4	0	2	0.3
Whau	67	1	0	1	0.1
Whau	68	2	0	1	0.2
Whau	69	0	0	0	0.0

Species: *Euchone* sp.

Site	Series	Total	Median	Range	Mean
Hbv	58	0	0	0	0.0
Hbv	59	1	0	1	0.1
Hbv	60	0	0	0	0.0
Hbv	61	0	0	0	0.0
Hbv	62	0	0	0	0.0
Hbv	63	1	0	1	0.1
Hbv	64	0	0	0	0.0
Hbv	65	0	0	0	0.0
Hbv	66	0	0	0	0.0
Hbv	67	0	0	0	0.0
Hbv	68	0	0	0	0.0
Hbv	69	0	0	0	0.0
LoS	63	1	0	1	0.1
LoS	64	0	0	0	0.0
LoS	65	3	0	1	0.3
LoS	66	1	0	1	0.1
LoS	67	1	0	1	0.1
LoS	68	0	0	0	0.0
LoS	69	2	0	1	0.2
ShB	58	43	2.5	15	3.6
ShB	59	50	2	24	4.2
ShB	60	42	3	11	3.5
ShB	61	42	1.5	13	3.5
ShB	62	12	0	6	1.0
ShB	63	5	0	1	0.4
ShB	64	2	0	2	0.2
ShB	65	3	0	3	0.3
ShB	66	8	0	5	0.7
ShB	67	3	0	1	0.3
ShB	68	2	0	1	0.2
ShB	69	17	1	7	1.4
Whau	58	1	0	1	0.1
Whau	59	6	0	2	0.5
Whau	60	25	1.5	8	2.1
Whau	61	15	1	3	1.3
Whau	62	9	0	3	0.8
Whau	63	0	0	0	0.0
Whau	64	0	0	0	0.0
Whau	65	0	0	0	0.0
Whau	66	0	0	0	0.0
Whau	67	0	0	0	0.0
Whau	68	0	0	0	0.0
Whau	69	0	0	0	0.0

Species: Exosphaeroma chilensis

Site	Series	Total	Median	Range	Mean
Hbv	58	3	0	2	0.3
Hbv	59	2	0	2	0.2
Hbv	60	2	0	2	0.2
Hbv	61	5	0	2	0.4
Hbv	62	0	0	0	0.0
Hbv	63	0	0	0	0.0
Hbv	64	0	0	0	0.0
Hbv	65	1	0	1	0.1
Hbv	66	0	0	0	0.0
Hbv	67	4	0	2	0.3
Hbv	68	0	0	0	0.0
Hbv	69	0	0	0	0.0
LoS	63	0	0	0	0.0
LoS	64	0	0	0	0.0
LoS	65	0	0	0	0.0
LoS	66	0	0	0	0.0
LoS	67	0	0	0	0.0
LoS	68	0	0	0	0.0
LoS	69	0	0	0	0.0
ShB	58	0	0	0	0.0
ShB	59	0	0	0	0.0
ShB	60	0	0	0	0.0
ShB	61	0	0	0	0.0
ShB	62	0	0	0	0.0
ShB	63	0	0	0	0.0
ShB	64	1	0	1	0.1
ShB	65	0	0	0	0.0
ShB	66	0	0	0	0.0
ShB	67	0	0	0	0.0
ShB	68	0	0	0	0.0
ShB	69	0	0	0	0.0
Whau	58	2	0	1	0.2
Whau	59	4	0	3	0.3
Whau	60	3	0	1	0.3
Whau	61	0	0	0	0.0
Whau	62	0	0	0	0.0
Whau	63	0	0	0	0.0
Whau	64	0	0	0	0.0
Whau	65	0	0	0	0.0
Whau	66	0	0	0	0.0
Whau	67	0	0	0	0.0
Whau	68	2	0	1	0.2
Whau	69	0	0	0	0.0

Species: *Glycerid* spp.

Site	Series	Total	Median	Range	Mean
Hbv	58	3	0	1	0.3
Hbv	59	1	0	1	0.1
Hbv	60	3	0	1	0.3
Hbv	61	3	0	2	0.3
Hbv	62	8	0.5	2	0.7
Hbv	63	1	0	1	0.1
Hbv	64	1	0	1	0.1
Hbv	65	1	0	1	0.1
Hbv	66	2	0	1	0.2
Hbv	67	8	0.5	2	0.7
Hbv	68	11	1	2	0.9
Hbv	69	15	1	3	1.3
LoS	63	2	0	1	0.2
LoS	64	1	0	1	0.1
LoS	65	0	0	0	0.0
LoS	66	1	0	1	0.1
LoS	67	3	0	1	0.3
LoS	68	3	0	1	0.3
LoS	69	2	0	1	0.2
ShB	58	4	0	1	0.3
ShB	59	7	0.5	2	0.6
ShB	60	5	0	2	0.4
ShB	61	3	0	1	0.3
ShB	62	3	0	1	0.3
ShB	63	1	0	1	0.1
ShB	64	1	0	1	0.1
ShB	65	3	0	1	0.3
ShB	66	0	0	0	0.0
ShB	67	3	0	1	0.3
ShB	68	8	0	3	0.7
ShB	69	6	0	3	0.5
Whau	58	4	0	1	0.3
Whau	59	4	0	1	0.3
Whau	60	0	0	0	0.0
Whau	61	1	0	1	0.1
Whau	62	0	0	0	0.0
Whau	63	0	0	0	0.0
Whau	64	0	0	0	0.0
Whau	65	0	0	0	0.0
Whau	66	0	0	0	0.0
Whau	67	0	0	0	0.0
Whau	68	23	1.5	4	1.9
Whau	69	7	0.5	2	0.6

Species: Haminoea zelandiae

Site	Series	Total	Median	Range	Mean
Hbv	58	0	0	0	0.0
Hbv	59	0	0	0	0.0
Hbv	60	0	0	0	0.0
Hbv	61	0	0	0	0.0
Hbv	62	0	0	0	0.0
Hbv	63	0	0	0	0.0
Hbv	64	0	0	0	0.0
Hbv	65	0	0	0	0.0
Hbv	66	0	0	0	0.0
Hbv	67	0	0	0	0.0
Hbv	68	0	0	0	0.0
Hbv	69	0	0	0	0.0
LoS	63	1	0	1	0.1
LoS	64	0	0	0	0.0
LoS	65	0	0	0	0.0
LoS	66	0	0	0	0.0
LoS	67	0	0	0	0.0
LoS	68	0	0	0	0.0
LoS	69	0	0	0	0.0
ShB	58	1	0	1	0.1
ShB	59	0	0	0	0.0
ShB	60	1	0	1	0.1
ShB	61	0	0	0	0.0
ShB	62	0	0	0	0.0
ShB	63	0	0	0	0.0
ShB	64	0	0	0	0.0
ShB	65	0	0	0	0.0
ShB	66	0	0	0	0.0
ShB	67	0	0	0	0.0
ShB	68	0	0	0	0.0
ShB	69	0	0	0	0.0
Whau	58	1	0	1	0.1
Whau	59	1	0	1	0.1
Whau	60	1	0	1	0.1
Whau	61	0	0	0	0.0
Whau	62	0	0	0	0.0
Whau	63	0	0	0	0.0
Whau	64	0	0	0	0.0
Whau	65	0	0	0	0.0
Whau	66	0	0	0	0.0
Whau	67	0	0	0	0.0
Whau	68	0	0	0	0.0
Whau	69	0	0	0	0.0

Species: Heteromastus filiformis

Site	Series	Total	Median	Range	Mean
Hbv	58	6	0	2	0.5
Hbv	59	2	0	2	0.2
Hbv	60	3	0	1	0.3
Hbv	61	3	0	1	0.3
Hbv	62	0	0	0	0.0
Hbv	63	3	0	1	0.3
Hbv	64	0	0	0	0.0
Hbv	65	2	0	2	0.2
Hbv	66	0	0	0	0.0
Hbv	67	10	0.5	3	0.8
Hbv	68	5	0	2	0.4
Hbv	69	11	1	3	0.9
LoS	63	92	7.3	11	7.6
LoS	64	117	8.5	14	9.8
LoS	65	206	16.5	19	17.2
LoS	66	234	21.5	20	19.5
LoS	67	222	17	28	18.5
LoS	68	207	17.5	18	17.3
LoS	69	136	10.5	18	11.3
ShB	58	106	6	23	8.8
ShB	59	70	5	15	5.8
ShB	60	133	9.5	24	11.1
ShB	61	88	7	18	7.3
ShB	62	43	3.5	12	3.6
ShB	63	17	1	5	1.4
ShB	64	27	2	9	2.3
ShB	65	75	4.5	16	6.3
ShB	66	51	2	13	4.3
ShB	67	83	6	21	6.9
ShB	68	111	3	31	9.3
ShB	69	77	5	16	6.4
Whau	58	1	0	1	0.1
Whau	59	3	0	1	0.3
Whau	60	6	0	2	0.5
Whau	61	2	0	1	0.2
Whau	62	4	0	1	0.3
Whau	63	2	0	2	0.2
Whau	64	0	0	0	0.0
Whau	65	1	0	1	0.1
Whau	66	0	0	0	0.0
Whau	67	2	0	1	0.2
Whau	68	2	0	1	0.2
Whau	69	3	0	2	0.3

Species: Macomona liliana

Site	Series	Total	Median	Range	Mean
Hbv	58	22	2	4	1.8
Hbv	59	14	1	3	1.2
Hbv	60	21	1.5	4	1.8
Hbv	61	23	2	3	1.9
Hbv	62	16	1	4	1.3
Hbv	63	20	2	4	1.7
Hbv	64	18	1	5	1.5
Hbv	65	21	1	4	1.8
Hbv	66	12	1	3	1.0
Hbv	67	13	1	3	1.1
Hbv	68	15	1	3	1.3
Hbv	69	21	2	3	1.8
LoS	63	7	0	3	0.5
LoS	64	4	0	1	0.3
LoS	65	4	0	1	0.3
LoS	66	5	0	2	0.4
LoS	67	0	0	0	0.0
LoS	68	3	0	1	0.3
LoS	69	5	0	2	0.4
ShB	58	12	0	6	1.0
ShB	59	10	0	5	0.8
ShB	60	8	0	5	0.7
ShB	61	3	0	1	0.3
ShB	62	0	0	0	0.0
ShB	63	7	0	2	0.6
ShB	64	3	0	1	0.3
ShB	65	1	0	1	0.1
ShB	66	0	0	0	0.0
ShB	67	5	0	1	0.4
ShB	68	2	0	1	0.2
ShB	69	6	0.5	1	0.5
Whau	58	56	4.5	9	4.7
Whau	59	62	5	10	5.2
Whau	60	42	3	7	3.5
Whau	61	39	3.5	5	3.3
Whau	62	25	2	4	2.1
Whau	63	19	1	4	1.6
Whau	64	8	0	3	0.7
Whau	65	7	0.5	2	0.6
Whau	66	13	1	3	1.1
Whau	67	19	1	4	1.6
Whau	68	18	1	5	1.5
Whau	69	24	2	5	2.0

Species: Macroclymenella stewartensis

Site	Series	Total	Median	Range	Mean
Hbv	58	5	0	2	0.4
Hbv	59	6	0	3	0.5
Hbv	60	9	0.5	2	0.8
Hbv	61	6	0	3	0.5
Hbv	62	13	0.5	5	1.1
Hbv	63	1	0	1	0.1
Hbv	64	1	0	1	0.1
Hbv	65	1	0	1	0.1
Hbv	66	4	0	1	0.3
Hbv	67	3	0	2	0.3
Hbv	68	6	0	2	0.5
Hbv	69	5	0	2	0.4
LoS	63	8	0.8	2	0.6
LoS	64	7	0	3	0.6
LoS	65	2	0	1	0.2
LoS	66	4	0	2	0.3
LoS	67	5	0	1	0.4
LoS	68	6	0	2	0.5
LoS	69	5	0	2	0.4
ShB	58	33	2.5	5	2.8
ShB	59	20	1	4	1.7
ShB	60	13	1	4	1.1
ShB	61	19	1	5	1.6
ShB	62	22	1	5	1.8
ShB	63	12	0	3	1.0
ShB	64	10	0.5	3	0.8
ShB	65	7	0	3	0.6
ShB	66	2	0	2	0.2
ShB	67	3	0	1	0.3
ShB	68	8	0.5	2	0.7
ShB	69	16	1.5	4	1.3
Whau	58	58	3.5	12	4.8
Whau	59	58	5	11	4.8
Whau	60	63	4.5	10	5.3
Whau	61	90	8	11	7.5
Whau	62	84	7.5	8	7.0
Whau	63	25	2	6	2.1
Whau	64	17	1	4	1.4
Whau	65	19	1.5	4	1.6
Whau	66	16	1	4	1.3
Whau	67	78	6	8	6.5
Whau	68	103	7.5	15	8.6
Whau	69	96	8.5	9	8.0

Species: Notoacmea scapha

Site	Series	Total	Median	Range	Mean
Hbv	58	36	2.5	10	3.0
Hbv	59	37	2.5	8	3.1
Hbv	60	134	12	10	11.2
Hbv	61	231	13.5	39	19.3
Hbv	62	65	5.5	9	5.4
Hbv	63	17	0.5	8	1.4
Hbv	64	11	0	3	0.9
Hbv	65	7	0	3	0.6
Hbv	66	43	3	9	3.6
Hbv	67	66	5	11	5.5
Hbv	68	48	4	8	4.0
Hbv	69	29	2	6	2.4
LoS	63	0	0	0	0.0
LoS	64	0	0	0	0.0
LoS	65	0	0	0	0.0
LoS	66	0	0	0	0.0
LoS	67	0	0	0	0.0
LoS	68	11	0	11	0.9
LoS	69	0	0	0	0.0
ShB	58	7	0	7	0.6
ShB	59	64	3.5	27	5.3
ShB	60	24	0	16	2.0
ShB	61	19	0	13	1.6
ShB	62	20	1	5	1.7
ShB	63	18	1	4	1.5
ShB	64	19	0	8	1.6
ShB	65	16	0	6	1.3
ShB	66	36	0.5	10	3.0
ShB	67	16	0	5	1.3
ShB	68	17	0.5	10	1.4
ShB	69	8	0	4	0.7
Whau	58	42	0.5	15	3.5
Whau	59	5	0	3	0.4
Whau	60	31	2	6	2.6
Whau	61	51	1	19	4.3
Whau	62	73	3.5	18	6.1
Whau	63	6	0	3	0.5
Whau	64	1	0	1	0.1
Whau	65	1	0	1	0.1
Whau	66	40	1	11	3.3
Whau	67	55	3	17	4.6
Whau	68	144	11	33	12.0
Whau	69	11	1	3	0.9

Species: Nucula hartvigiana

Site	Series	Total	Median	Range	Mean
Hbv	58	227	18	37	18.9
Hbv	59	220	17	43	18.3
Hbv	60	223	16.5	38	18.6
Hbv	61	253	21	35	21.1
Hbv	62	226	16	35	18.8
Hbv	63	108	6.5	16	9.0
Hbv	64	59	2.5	17	4.9
Hbv	65	38	2	11	3.2
Hbv	66	44	2.5	15	3.7
Hbv	67	45	2.5	18	3.8
Hbv	68	68	4	25	5.7
Hbv	69	120	7.5	25	10.0
LoS	63	36	3	7	3.0
LoS	64	53	3.5	10	4.4
LoS	65	30	2.5	8	2.5
LoS	66	26	1.5	8	2.2
LoS	67	42	3.5	7	3.5
LoS	68	22	1.5	5	1.8
LoS	69	59	4	13	4.9
ShB	58	90	1	42	7.5
ShB	59	117	4.5	36	9.8
ShB	60	87	1.5	50	7.3
ShB	61	13	0	5	1.1
ShB	62	36	0	18	3.0
ShB	63	97	2	40	8.1
ShB	64	53	0	22	4.4
ShB	65	3	0	1	0.3
ShB	66	31	0	24	2.6
ShB	67	4	0	3	0.3
ShB	68	22	0	12	1.8
ShB	69	9	0	9	0.8
Whau	58	610	26	116	50.8
Whau	59	472	38.5	84	39.3
Whau	60	639	66	78	53.3
Whau	61	427	18.5	95	35.6
Whau	62	388	19	81	32.3
Whau	63	351	20	76	29.3
Whau	64	266	9.5	59	22.2
Whau	65	244	13.5	55	20.3
Whau	66	179	7	40	14.9
Whau	67	122	6.5	25	10.2
Whau	68	256	19	57	21.3
Whau	69	234	19	36	19.5

Species: Paphies australis

Site	Series	Total	Median	Range	Mean
Hbv	58	17	0	11	1.4
Hbv	59	13	1	5	1.1
Hbv	60	12	1	4	1.0
Hbv	61	18	1	8	1.5
Hbv	62	8	0	4	0.7
Hbv	63	10	0	6	0.8
Hbv	64	11	0	7	0.9
Hbv	65	10	0	7	0.8
Hbv	66	17	0.5	7	1.4
Hbv	67	37	1	15	3.1
Hbv	68	16	0.5	5	1.3
Hbv	69	36	0	21	3.0
LoS	63	0	0	0	0.0
LoS	64	0	0	0	0.0
LoS	65	0	0	0	0.0
LoS	66	0	0	0	0.0
LoS	67	0	0	0	0.0
LoS	68	0	0	0	0.0
LoS	69	0	0	0	0.0
ShB	58	0	0	0	0.0
ShB	59	0	0	0	0.0
ShB	60	0	0	0	0.0
ShB	61	0	0	0	0.0
ShB	62	2	0	2	0.2
ShB	63	0	0	0	0.0
ShB	64	0	0	0	0.0
ShB	65	0	0	0	0.0
ShB	66	0	0	0	0.0
ShB	67	0	0	0	0.0
ShB	68	0	0	0	0.0
ShB	69	0	0	0	0.0
Whau	58	0	0	0	0.0
Whau	59	0	0	0	0.0
Whau	60	0	0	0	0.0
Whau	61	0	0	0	0.0
Whau	62	0	0	0	0.0
Whau	63	0	0	0	0.0
Whau	64	0	0	0	0.0
Whau	65	0	0	0	0.0
Whau	66	0	0	0	0.0
Whau	67	0	0	0	0.0
Whau	68	0	0	0	0.0
Whau	69	0	0	0	0.0

Species: Prionospio aucklandica

Site	Series	Total	Median	Range	Mean
Hbv	58	76	7	12	6.3
Hbv	59	72	5.5	16	6.0
Hbv	60	71	5	10	5.9
Hbv	61	64	4.5	9	5.3
Hbv	62	47	2.5	10	3.9
Hbv	63	76	5.5	11	6.3
Hbv	64	49	4	8	4.1
Hbv	65	26	2	6	2.2
Hbv	66	25	1	8	2.1
Hbv	67	54	4	10	4.5
Hbv	68	108	8	19	9.0
Hbv	69	148	12.5	16	12.3
LoS	63	60	5	14	5.0
LoS	64	38	2	20	3.2
LoS	65	42	3.5	7	3.5
LoS	66	54	3.5	12	4.5
LoS	67	28	2	6	2.3
LoS	68	62	5	12	5.2
LoS	69	55	3.5	11	4.6
ShB	58	101	6	26	8.4
ShB	59	58	2	17	4.8
ShB	60	62	3.5	11	5.2
ShB	61	37	3	6	3.1
ShB	62	9	0	4	0.8
ShB	63	29	2	8	2.4
ShB	64	28	2	7	2.3
ShB	65	22	0.5	9	1.8
ShB	66	18	1	5	1.5
ShB	67	27	1	10	2.3
ShB	68	27	1	9	2.3
ShB	69	65	3.5	19	5.4
Whau	58	15	1	5	1.3
Whau	59	6	0	2	0.5
Whau	60	11	0.5	2	0.9
Whau	61	7	0	2	0.6
Whau	62	4	0	1	0.3
Whau	63	3	0	1	0.3
Whau	64	0	0	0	0.0
Whau	65	0	0	0	0.0
Whau	66	1	0	1	0.1
Whau	67	1	0	1	0.1
Whau	68	1	0	1	0.1
Whau	69	0	0	0	0.0

Species: Zeacumantus lutulentus

Site	Series	Total	Median	Range	Mean
Hbv	58	15	1	4	1.3
Hbv	59	6	0	2	0.5
Hbv	60	11	1	3	0.9
Hbv	61	13	1	4	1.1
Hbv	62	10	0	3	0.8
Hbv	63	9	1	3	0.8
Hbv	64	35	3	7	2.9
Hbv	65	12	1	4	1.0
Hbv	66	7	0.5	2	0.6
Hbv	67	7	0	2	0.6
Hbv	68	6	0	2	0.5
Hbv	69	7	0	3	0.6
LoS	63	0	0	0	0.0
LoS	64	0	0	0	0.0
LoS	65	0	0	0	0.0
LoS	66	0	0	0	0.0
LoS	67	0	0	0	0.0
LoS	68	0	0	0	0.0
LoS	69	0	0	0	0.0
ShB	58	0	0	0	0.0
ShB	59	1	0	1	0.1
ShB	60	0	0	0	0.0
ShB	61	0	0	0	0.0
ShB	62	0	0	0	0.0
ShB	63	0	0	0	0.0
ShB	64	0	0	0	0.0
ShB	65	0	0	0	0.0
ShB	66	0	0	0	0.0
ShB	67	0	0	0	0.0
ShB	68	0	0	0	0.0
ShB	69	0	0	0	0.0
Whau	58	11	0.5	4	0.9
Whau	59	25	2	3	2.1
Whau	60	26	1.5	5	2.2
Whau	61	24	2	5	2.0
Whau	62	9	0.5	3	0.8
Whau	63	9	0	4	0.8
Whau	64	9	1	3	0.8
Whau	65	3	0	2	0.3
Whau	66	10	0.5	3	0.8
Whau	67	4	0	2	0.3
Whau	68	2	0	1	0.2
Whau	69	0	0	0	0.0