

Central Waitematā Harbour Ecological Monitoring 2000-2017

Samantha Parkes and Carolyn Lundquist

May 2018

Technical Report 2018/010





Central Waitematā Harbour ecological monitoring: 2000-2017

May 2018

Technical Report 2018/010

Samantha Parkes
Carolyn Lundquist

National Institute of Water and Atmospheric Research Ltd, NIWA

NIWA project: ARC17271
NIWA client report: 2017150HN

Auckland Council
Technical Report 2018/010

ISSN 2230-4525 (Print)
ISSN 2230-4533 (Online)

ISBN 978-0-9951277-0-8 (Print)
ISBN 978-0-9951277-1-5 (PDF)

This report has been peer reviewed by the Peer Review Panel.
Review completed on 3 May 2018 Reviewed by two reviewers
Approved for Auckland Council publication by: Name: Eva McLaren Position: Acting Manager, Research and Evaluation (RIMU)
Name: Jacqueline Anthony Position: Manager, Environmental Monitoring, Research and Evaluation (RIMU)
Date: 3 May 2018

Recommended citation

Parkes, S. M and Lundquist, C. (2018). Central Waitematā Harbour ecological monitoring: 2000-2017. Prepared by the National Institute of Water and Atmospheric Research Ltd, NIWA for Auckland Council. Auckland Council technical report, TR2018/010

© 2018 Auckland Council

This publication is provided strictly subject to Auckland Council's copyright and other intellectual property rights (if any) in the publication. Users of the publication may only access, reproduce and use the publication, in a secure digital medium or hard copy, for responsible genuine non-commercial purposes relating to personal, public service or educational purposes, provided that the publication is only ever accurately reproduced and proper attribution of its source, publication date and authorship is attached to any use or reproduction. This publication must not be used in any way for any commercial purpose without the prior written consent of Auckland Council.

Auckland Council does not give any warranty whatsoever, including without limitation, as to the availability, accuracy, completeness, currency or reliability of the information or data (including third party data) made available via the publication and expressly disclaim (to the maximum extent permitted in law) all liability for any damage or loss resulting from your use of, or reliance on the publication or the information and data provided via the publication. The publication, information, and data contained within it are provided on an "as is" basis.

Executive summary

This report presents the results of the State of the Environment monitoring programme for the Central Waitematā Harbour conducted between October 2000 and February 2017. The programme is a cost-effective, spatially and temporally nested design that focuses on monitoring the ecological status of the harbour. The monitoring focuses on animals living in mud and sand flats as these animals form an important link between sediment and water column processes, are important prey items for birds and fish, sensitive to anthropogenic activities and relatively stationary so good representatives of local conditions. They are also widely used internationally for monitoring impacts on, and health of, ecosystems.

Three intertidal sites, representing the north, north-east and south-west of the harbour have been monitored bimonthly (Hobsonville Point, Whau Estuary and Upper Shoal Bay) since October 2000. Two sites in the south-east and north-west (Meola Reef and Henderson Creek) are monitored with a cycle of five years off, two years on. All five sites were monitored during the 2015-2017 period. The monitoring identifies trends in the abundances of 20 taxa (selected to represent different predicted responses to environmental changes) and sediment characteristics. The health status of the harbour is assessed each year using Auckland Council's Benthic Health Models (BHM) and Traits Based Index (TBI) indicators, derived from October data when all taxa are monitored.

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?

Sediment characteristics (chlorophyll *a* concentrations, grain size and organic matter) have shown minimal change at the sites near Hobsonville Point and the Whau Estuary over the monitoring period. The site near Meola Reef had shown an increase until 2010, but is no longer increasing. However, the site near Henderson Creek continues to show an increasing trend in mud content. A patch of the invasive Asian date mussel has also been observed growing near the site off Henderson Creek. Considering the high variability of the mud content at this site over the course of the monitoring period this is not yet a cause for concern.

- Have there been any changes in the monitored macrofauna of the Central Waitematā Harbour and are these of concern?

No changes in macrofaunal abundances or community composition were observed at the Whau site. At the sites off Hobsonville Point and Henderson Creek there were trends in the abundance of five and four taxa respectively in a direction that would be expected from increased sedimentation or increased fine sediments in the water column. However, approximately 50 per cent of these may be long multi-year cycles. At the site near Meola Reef, changes in abundance were detected for five taxa that could be a response to either increased seagrass cover or sediment mud content. Most of the taxa showing changes are ones that have displayed trends in the past, with the exception of the polychaete *Boccardia syrtis* at Hobsonville and Henderson Creek. None of the observed changes are of concern.

- Are any changes observed confined to one site or area of the harbour, or do they reflect a harbour-wide change?

The changes in macrofauna observed are small and are confined to two areas of the harbour around Meola Reef and Henderson Creek/Hobsonville. They do not reflect a harbour-wide change. Moreover, the present combined health scores, calculated from the Benthic Health Model and Traits Based Index scores, show that all five of the currently monitored sites in the Central Waitematā Harbour are in moderate to good condition. However, additional sites in the upper parts of the Whau, Henderson, Meola and Motions tidal creeks, which are sampled during other Auckland Council monitoring projects (Upper Waitematā Harbour and Regional Discharge Programme) continue to be ranked “poor” or “unhealthy”.

Recommendations for the monitoring programme

We recommend limited monitoring at the sites near Meola Reef and Henderson Creek post June 2017, rather than a full cessation. The site near Meola Reef should have seagrass cover monitored annually by photo quadrats and the site near Henderson Creek should have sediment grain size samples taken and the distance of the date mussel patches to the site estimated.

The Upper Shoal Bay site was introduced in August 2014 to replace the two older Shoal Bay sites (ShB and LoS), as per the recommendation in the last report as monitoring at these sites was no longer considered effective due to the increased muddiness of the sites and the resultant decreases in species abundance. The newer site in Upper Shoal Bay has not been monitored long enough for trends to be identified with confidence. However, analysis of the sediment and community data from the new site has shown that it is very different to the old Shoal Bay sites, containing a variety of species whose abundances would be sensitive to increased mud or contaminant concentrations. Therefore, it should be much more useful as an indicator site for ongoing increases in sedimentation in the bay. The site is also similar enough in community composition to the Hobsonville Point and Whau sites for these sites to provide a template of natural variability and we recommend its continued bimonthly monitoring.

We also recommend continuation of the bimonthly monitoring at the sites off the Whau and Hobsonville Point. The Whau site will be valuable as time series against which to assess any changes observed in the Shoal Bay site. Site Hobsonville Point should be continued to be monitored to determine whether the changes documented in this report continue.

Table of contents

1.0	Background.....	1
2.0	Methods	3
2.1	Macrofauna	3
2.2	Bivalve size-class analysis range.....	4
2.3	Site characteristics	5
2.4	Statistical analyses	5
2.5	State of the environment indicators	7
3.0	Present status of benthic communities in the Central Waitematā Harbour	11
3.1	Have there been any changes in site characteristics?	11
3.2	Are species exhibiting temporal variations?.....	18
3.3	Are species abundances exhibiting similar patterns at all sites?.....	36
3.4	Have any changes over time led to communities, or sites, becoming more or less similar to each other?	37
4.0	State of the environment indicators	41
5.0	Conclusions and recommendations	46
5.1	Have there been any changes in the characteristics of each site or of the surrounding areas?	46
5.2	Have there been any changes in the monitored benthic communities of Central Waitematā Harbour and are these of concern?.....	46
5.3	Are any changes observed confined to one site or area of the harbour, or do they reflect a harbour-wide change?.....	46
5.4	Has the renewed sampling at Reef and Henderson Creek revealed any changes of concern that suggests they need to be monitored more regularly?.....	47
5.5	Recommendations for the monitoring programme.....	47
6.0	Acknowledgements	49
7.0	References.....	50
8.0	Plates	52
9.0	Appendices	58
9.1	Appendix A: Sampling coordinates	58
9.2	Appendix B: Sediment characteristics October 2000-February 2017.....	59
9.3	Benthic invertebrate data collected between April 2014 and February 2017	66

List of figures

Figure 1. Map of the Waitematā Harbour showing the five soft-sediment monitoring sites	2
Figure 2. Summary of sediment characteristics at each site.....	13
Figure 3. Temporal changes in site sediment changes at Reef and HC.. ..	18
Figure 4. Temporal patterns in species abundances at the HBV site.....	21
Figure 5. Trends in abundance of different size classes of the bivalves <i>Austrovenus stutchburyi</i> , <i>Macomona liliiana</i> and <i>Paphies australis</i> found at HBV.	23
Figure 6. Temporal patterns in species abundances at the Whau site.....	26
Figure 7. Trends in abundance of different size classes of the bivalves <i>Austrovenus stutchburyi</i> and <i>Macomona liliiana</i> found at Whau.	27
Figure 8. Temporal patterns in species abundances at the Reef site.	30
Figure 9. Trends in abundance of different size classes of the bivalves <i>Austrovenus stutchburyi</i> and <i>Macomona liliiana</i> found at Reef.....	31
Figure 10. Temporal patterns in species abundances at the HC site.....	34
Figure 11. Trends in abundance of different size classes of the bivalves <i>Austrovenus stutchburyi</i> and <i>Macomona liliiana</i> found at HC.	35
Figure 12. MDS ordination using Bray-Curtis similarity on the raw data of the monitored species from October data 2000-2016	38
Figure 13. MDS ordination using Bray-Curtis similarity on the 4th root transformed data of the monitored species from October data 2000-2016.....	39
Figure 14. Trends in the abundance of <i>Nassarius burchardi</i> at all central Waitematā Harbour monitoring sites.....	40
Figure 15. TBI scores for the five currently monitored sites (HBV, Whau, Reef, HC and UpS) and two previously monitored sites (ShB and LoS) during the monitoring period (October 2000-October 2016).. ..	42
Figure 16. Map of the Waitematā Harbour showing October 2016 combined health scores (TBI and BHM).	45

List of tables

Table 1. Dimensions and GPS co-ordinates (NZTM) for the Central Waitematā monitoring sites....	3
Table 2. The 20 taxa recommended for long-term monitoring in the Central Waitematā Harbour monitoring programme.	4
Table 3. Conversion of TBI scores into health groups	7
Table 4. Conversion of CAPmetals and CAPmud scores into overall health scores.	9
Table 5. Analysis of temporal variability in sediment characteristics at HBV, Whau, HC, Reef.....	17
Table 6. The three most abundant monitored taxa found over time at HBV.....	19
Table 7. Summary of temporal patterns in abundance of selected taxa observed at each site between October 2000 and February 2017	22
Table 8. The three most abundant monitored taxa found over time at Whau.....	24
Table 9. The three most abundant monitored taxa found over time at Reef.	28
Table 10. The three most abundant monitored taxa found over time at HC.....	32
Table 11. The three most abundant monitored taxa found over time at UpS.....	36
Table 12. Benthic Health Model scores for metals and mud (CAPmetal, CAPmud), TBI scores and combined health scores for all monitoring sites in 2000 and 2009-2016.	43

1.0 Background

In October 2000 a State of the Environment monitoring programme for the Central Waitematā Harbour was developed for the Auckland Regional Council (Hewitt 2000). The programme was designed to be scientifically credible, practical, affordable and to meet the requirements of the Resource Management Act 1991. The goal of this programme is to monitor the ecological status of the harbour, and determine any trends in macrobenthic communities and the sediment they live in. The monitoring focuses on benthic macrofauna as these animals form an important link between sediment and water column processes, are important prey items for birds and fish, are relatively stationary yet sensitive to anthropogenic activities, and are widely used internationally for monitoring impacts on and health of ecosystems.

Hewitt (2000) suggested that the Central Waitematā would be best represented by six intertidal sites; five from soft-sediment habitats and one from a rocky habitat. In 2000, NIWA was commissioned to monitor the soft sediment sites and the University of Auckland was commissioned to monitor the rocky site at Meola Reef. The soft-sediment sites were selected for monitoring in consultation with the Auckland Regional Council, and were chosen to integrate multiple aquatic inputs while remaining at a distance from any industry-specific contaminant sources. A site was placed in each of five sub-regions of the Central Waitematā Harbour, based on hydrodynamics and drainage areas with significant intertidal habitats (Figure 1).

Shoal Bay has been identified as a contaminant depositional area (Green 2008) as the tidal flow dynamics mean the bay receives a higher proportion of sediment emerging from Henderson Creek than other intertidal areas. The sediment at the two existing sites in the bay (ShB and LoS) already has a very high mud content, which is reflected by the macrofaunal communities living there. Therefore, it is likely that any further sedimentation will only result in very subtle changes in the monitored populations, and broader macrofaunal community. As a result, the decision was made to replace these two sites with a new much sandier site, where any increases in sediment deposition will most likely result in noticeable community changes. Monitoring at the new upper Shoal Bay site (UpS) began in August 2014. Sampling at the Meola Reef and Henderson Creek sites was suspended between June 2010 and June 2015 as part of the nested sampling monitoring strategy (a cycle of five years off, two years on).

For cost effectiveness, analysis is mainly based on the abundance of 20 taxa (Table 2) selected for their importance to the ecosystem and to provide a range of responses to different anthropogenic impacts and environmental conditions. However, the analysis of all taxa collected in October of each year provides a more complete picture of community composition over time. 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). The complete taxa sampling in October is used to calculate indicators of benthic health that can be compared regionally (and potentially nationally).

This report presents the results from monitoring five soft-sediment sites between October 2000 and February 2017, and details the present status of the benthic communities in the Central Waitematā Harbour. In particular, the following questions are addressed:

- Have there been any changes in the characteristics of each site or the surrounding areas?
- Have there been any changes in the monitored benthic communities of Central Waitematā Harbour and are these of concern?
- Are any changes observed confined to one site or area of the harbour, or do they reflect a harbour-wide change?
- Has the renewed sampling at Reef and HC revealed any changes of concern that suggests they need to be monitored more regularly?

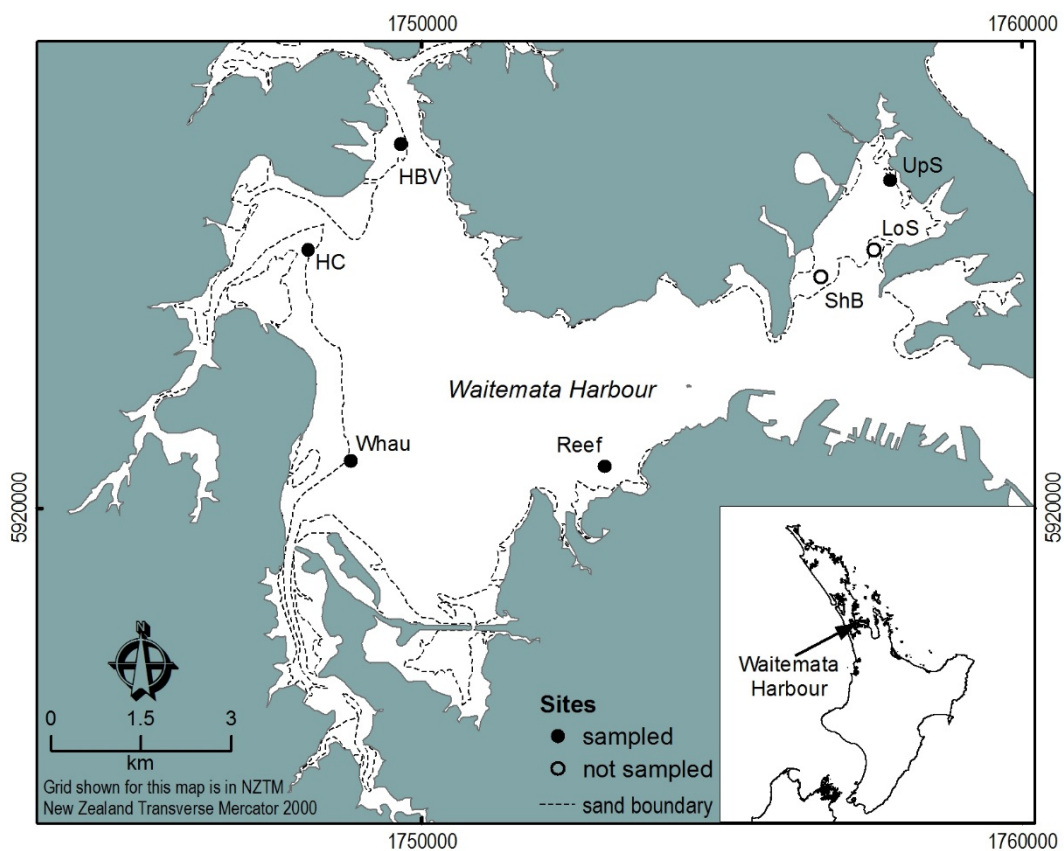


Figure 1. Map of the Waitematā Harbour showing the five soft-sediment monitoring sites at Hobsonville (HBV), Whau River (Whau), Henderson Creek (HC), Meola Reef (Reef) and Upper Shoal Bay (UpS) (solid black circles); and the two discontinued sites in Shoal Bay (ShB and LoS) (white circles).

2.0 Methods

Five soft-sediment sites were sampled, representing five different drainage sub-regions of the Central Waitematā Harbour; Hobsonville (HBV), Whau River (Whau), Upper Shoal Bay (UpS), Henderson Creek (HC) and Meola Reef (Reef) (see Figure 1). Sites HC and Reef were not sampled between April 2010 and June 2015; sampling resumed in August 2015 following the five year rotation policy. In August 2014 the new Shoal Bay site (UpS) replaced ShB and LoS. Sites are located at the mid-tide level, and each cover an area of 9000m², with the exception of HBV (which covers 10,800m²). Sites are located in areas that are representative of the general character of the surrounding intertidal environment and are as close to channels as practical (to aid access). Sites are marked by wooden stakes and can be located using GPS coordinates (Table 1).

Table 1. Dimensions and GPS co-ordinates for the Central Waitematā monitoring sites Hobsonville (HBV), Whau River (Whau), Upper Shoal Bay (UpS), Meola Reef (Reef), Henderson Creek (HC), Shoal Bay (ShB) and Lower Shoal Bay (LoS). GPS co-ordinates mark the 0,0 point of each site.

Site	Dimensions (m)		GPS coordinates in	
	X	Y	North	East
HBV	150	60	5926077	1749644
Whau	100	90	5920785	1748809
UpS	180	50	5925462	1757807
Reef	180	50	5920692	1753048
HC	100	90	5924310	1748104
ShB	180	50	5923855	1756645
LoS	100	90	5924310	1757533

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

2.1 Macrofauna

On each sampling occasion, 12 sediment cores (13cm diameter, 15cm deep) are collected from each site. To provide an adequate spread of cores over the site, each site is 'divided' into 12 equal sections and one core is taken from a random location within each section (Appendix 9.1). To reduce the influence of previous sampling activity and spatial autocorrelation, samples are not placed within a 5m radius of each other or of any samples collected in the previous 12 months. Core samples are sieved through a 500 µm mesh and the residues stained with rose bengal and preserved in 70% isopropyl alcohol. Samples are then sorted and stored in 50% isopropyl alcohol. The 20 selected species (see Table 2) are identified, counted and stored in 50% isopropyl alcohol. Other macrofauna are not discarded; rather they are kept to be processed if other funding

becomes available. All taxa collected during the October sampling each year are identified and enumerated for use in regional indicators of benthic health, changes in which are included in this report.

Table 2 . The 20 taxa recommended for long-term monitoring in the Central Waitematā Harbour monitoring programme. Where genera and species names have changed with taxonomic refinement, the names in brackets indicate the previous name. For example, *Nucula* is now called *Linucula*.

Taxonomic name	Common name or description
<i>Arthritica bifurca</i>	Small shellfish
<i>Austrovenus (Chione) stutchburyi</i>	Cockle
<i>Macomona (Tellina) lilliana</i>	Wedge shell
<i>Linucula (Nucula) hartvigiana</i>	Nut shell
<i>Paphies australis</i>	Pipi
<i>Anthopleura aureoradiata</i>	Anemone
<i>Colurostylis lemurum</i>	Hooded shrimp
<i>Diloma subrostrata</i>	Sea snail
<i>Haminoea zelandiae</i>	Sea snail
<i>Notoacmea scapha (helmsi)</i>	Limpet
<i>Zeacumantus lutulentus</i>	Sea snail
<i>Exosphaeroma spp.</i>	Sea slater
<i>Aonides trifida (oxycephala)</i>	Worm
<i>Prionospio (Aquilaspio) aucklandica</i>	Worm
<i>Aricidea</i>	Worm
<i>Boccardia syrtis</i>	Worm
<i>Euchone</i>	Worm
<i>Glycera americana (ovigera)</i>	Worm
<i>Heteromastus filiformis</i>	Worm
<i>Macroclymenella stewartensis</i>	Worm

2.2 Bivalve size-class analysis range

After identification, individual *Austrovenus stutchburyi*, *Macomona lilliana* and *Paphies australis* are measured and placed into size classes. The size classes for *Austrovenus* and *Macomona* are <5mm, 5-10mm, 10-15mm, 15-20mm and then in 10mm increments. *Paphies* size-classing is the same initially but, after the 15-20mm, changes to 20mm increments (20-40mm, 40-60mm,

>60mm). This is consistent with size classes used in the Manukau and Mahurangi monitoring programmes. *Linucula (Nucula) hartvigiana* is not measured as the high densities found at some sites make this economically impractical, and previous size classing in Manukau and Mahurangi have shown high variability due to the small size of this shellfish. Instead, only those bivalve species that 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 December 2016, the sites were inspected by Dr Carolyn Lundquist from NIWA, who has undertaken an annual visit to all sites since 2000, with the exception of 2011. Sediment samples are also taken for grain size, organic content and chlorophyll *a*. At six random locations within the site, two small sediment cores (2cm deep, 2cm 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 5g of sediment taken, which is then digested in ~ 9% hydrogen peroxide until frothing ceases. The sample is then wet sieved through 2000 μm , 500 μm , 250 μm and 63 μm mesh sieves. Pipette analysis is used to separate the <63 μm fraction into >3.9 μm and \leq 3.9 μm . All fractions are then dried at 60°C until a constant weight is achieved (fractions are weighed at ~ 40 hr and then again at 48 hr). The results of the analysis are presented as percentage weight of gravel/shell hash (>2000 μm), coarse sand (500-2000 μm), medium sand (250-500 μm), fine sand (62.5-250 μm), silt (3.9-62.5 μm) and clay (\leq 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 5g 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 hr and then again after 48 hr). The sample is then ashed for 5.5 hrs at 400°C (Mook and Hoskin 1982) and reweighed.

2.4 Statistical analyses

The analysis of monitoring programmes is strongly dependent on the length of time the data has been collected. Initially, little can be done other than to graphically determine cyclic patterns. As the time series extends past five years, the data may be analysed for trends (long-term increases

or decreases) statistically. However, a trend detected over a time period of less than 10 years may in reality be part of a long-term cyclic pattern. As the time series lengthen, statistical analyses become more likely to detect very small, possibly unimportant, changes, due to increasing degrees of freedom, and it becomes essential to determine that the changes are not part of multi-year cycles and to estimate the magnitude of change relative to natural variability. To investigate ecologically important long-term trends and cycles in environmental and species abundance data at all six sites, we conducted the analyses below. For macrofauna, all analyses were performed on the sum of the 12 cores collected at a site on each sampling occasion. For sediment the analyses were conducted on the grain size and chlorophyll *a* results from each site on each sampling occasion.

2.4.1 Seasonal and multi-year patterns

Plots of total abundance for each monitored population and measured environmental variables were visually examined to identify whether cyclic patterns are occurring, and the types of any potential trends (e.g., step, linear or logarithmic).

2.4.2 Trend analysis

Trend analyses were conducted to formally test the significance of any suggested trends in the abundance of the monitored taxa, or measured environmental variables at the monitored sites. Autocorrelation in each time series was investigated using Durbin-Watson statistics. Step trends were determined based on the significance of Yule-Walker parameter estimates following the Autoreg procedure (SAS 9.3) on time series data points grouped before and after a suspected change (if autocorrelation was present, degrees of freedom were adjusted). Gradual changes were investigated by ordinary least squares regression on raw or log transformed data, unless autocorrelation was present. Where autocorrelation was indicated, increasing or decreasing trends were investigated by adjusting parameters and significance levels (AUTOREG procedure, SAS/ETS). Residuals of statistically significant trends were examined for indications of multi-year cycles; where these indicated significant bias the trend was considered to be a multi-year cycle rather than a trend. For the intermittently monitored sites, the 2013-2015 time series was assessed relative to previous variation and to the time series at the permanently monitored sites.

2.4.3 Community analysis

Rank abundance tables and multivariate ordinations of macrofaunal community data collected in October of each year were used to determine if there had been temporal variations in community composition between years. Rank abundance tables were constructed for the three most numerically dominant taxa. Ordination of October raw and 4th-root transformed data was performed, using non-metric multidimensional scaling (MDS) of Bray Curtis similarities and correspondence analysis of chi-square distances. To test the average similarity across the monitored period, a SIMPER test was done for each site using the monitored taxa (PRIMER; Clarke and Gorley, 2006).

2.5 State of the environment indicators

2.5.1 Traits Based Index

Organisms can be categorised according to characteristics (traits) that are likely to reflect ecosystem function (i.e., their feeding mode, degree of mobility, position in the sediment column, body size, body shape, capacity to create tubes/pits/mounds, etc.). During 2010 and 2011, an index based on these biological traits was created (van Houte-Howes and Lohrer 2010) and improved (Lohrer and Rodil 2011). The index is based on seven broad trait categories (living position, sediment topography feature created, direction of sediment particle movement, degree of mobility, feeding behaviour, body size, body shape and body hardness). Specifically the richness of taxa exhibiting seven particular traits was used to create the index: living in the top 2cm of sediment, having an erect structure or tube, moving sediment around within the top 2cm, being sedentary or only moving within a fixed tube, being a suspension feeder, being of medium size, or being worm shaped. This index ranges from 0-1, with TBI scores <0.3 indicating low levels of functional redundancy and highly degraded sites and scores of 0.3-0.4 indicating intermediate conditions. Scores >0.4 indicate high levels of functional redundancy, which is indicative of healthy areas (high functional redundancy tends to increase the inherent resistance and resilience in the face of environmental changes, Hewitt et al. (2012) (Table 3). The index has been refined over the last couple of years (Hewitt et al. 2012) with the SUMmax parameter modified to allow the metric to be applied to a wider range of sites and those sampled with differing numbers of replicates (Lohrer and Rodil 2011).

Table 3. Conversion of TBI scores into health groups (1 is most healthy). These groups are then converted (along with CAPmetals and CAPmud scores) into values of similar scale (0 to 1) that run in the same direction (higher values indicating more degraded conditions), to facilitate their combination into overall health scores.

Group	TBI	
	Cutoff	Value
1	>0.4	0.33
2	0.3-0.4	0.67
3	<0.3	1.00

2.5.2 Benthic health models

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

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

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

The macrofaunal community composition of sites and sampling times not in the models are compared to model data (using the “*add new samples*” routine in CAP, *PerMANOVA addon*, Primer E). The samples are then allotted to five different groups related to health (see Table 4).

These indices have now been used to assess the health of sites in other regions (e.g., Northland, Waikato and Southland) and the methodology is being explored by a PhD student for use at a national scale.

Table 4. Conversion of CAPmetals and CAPmud scores into health groups (1 is most healthy). Cut off point is equal or less than. These groups are then converted (along with TBI scores) into values of similar scale (0 to 1) that run in the same direction (higher values indicating more degraded conditions), to facilitate their combination into overall health scores.

Health Group	CAPmetals		CAPmud	
	Cutoff	Value	Cutoff	Value
1	-0.1640	0.2	-0.12	0.2
2	-0.0667	0.4	-0.05	0.4
3	0.0234	0.6	0.02	0.6
4	0.1000	0.8	0.10	0.8
5		1.0		1.0

2.5.3 Combined indices

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

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

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

3.0 Present status of benthic communities in the Central Waitematā Harbour

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

- Have there been any changes in site characteristics?
- At each site, are species exhibiting seasonal patterns or multi-year cycles, or are trends over the monitored period occurring?
- Are species' abundances exhibiting similar patterns at each site?
- Have any changes in species over time led to changes in communities, with sites becoming more or less similar to each other?
- Has the renewed sampling at Reef and HC revealed any changes of concern that suggests they need to be sampled more regularly?

3.1 Have there been any changes in site characteristics?

3.1.1 Hobsonville (HBV)

Site HBV is located on the sand flats near the Hobsonville Air Base, close to the deep channel entering the Upper Waitematā Harbour. The sand flat shows characteristics of high tidal flow or wind-wave energy, with coarse sediment and ripple features visible on the sediment surface (Plate 1). The site is predominantly covered by hard-packed sand. Ripples are typically evident, and were observed (1-2cm tall, 5cm wide) on both the April and December 2016 monitoring trips. Ray pits are also a common feature at HBV, though these are seasonal, with pit frequency recorded as 5-10 pits per 25m² in December 2016 (summer), and <10 across the site in winter (April 2016). Patches of oyster reef (usually ~10cm diam.) remain common throughout the site at densities of approximately one patch per 25m². While general features of the site have changed little since monitoring began, increasing muddiness near the 0,0 peg has been observed due to the change in size and position of a tidal drainage channel along the seaward/eastern side of the monitoring site. The tidal channel expanded rapidly between 2008 and 2010, but stabilised at a distance of approximately 2-3m from the 0,0 peg in 2014. Some sediment erosion within this small channel occurred in late 2016, and firmer sediment was observed in December 2016. Previously observed areas of minor encroachment of this small channel near the easterly peg are no longer apparent. A second smaller shallow sub-channel, previously observed bisecting the centre of the site, is no longer

apparent, though an area of finer sediments is present just seaward of the site. A large shell bank has migrated across the site over the last 5-7 years, found seaward of the site prior to 2012, and then observed in the centre of the site in 2012. This high density (>90% cover) shell bank has now mostly dispersed, decreasing from 20-30cm high in 2012 to only ~5cm high in 2016.

Shell hash in the bank is approximately 30% cover, and is composed of roughly 70% *Austrovenus*, 20% *Paphies*, and 10% *Macomona* shells. Shell hash cover throughout the site continues to show a gradual decline, from typical levels of >50% cover recorded in the early 2000s to <5% cover recorded in December 2016. The sediment is predominantly fine (56%) and medium (32%) sand, with a lesser amount of coarse material (6%) (Figure 2). Chlorophyll a content of the sediment ranged between 8.0 and 23.2 µg/g sediment and the organic content has been both low and variable (average 1.4%, range 0.36-6.40) (Appendix 9.2).

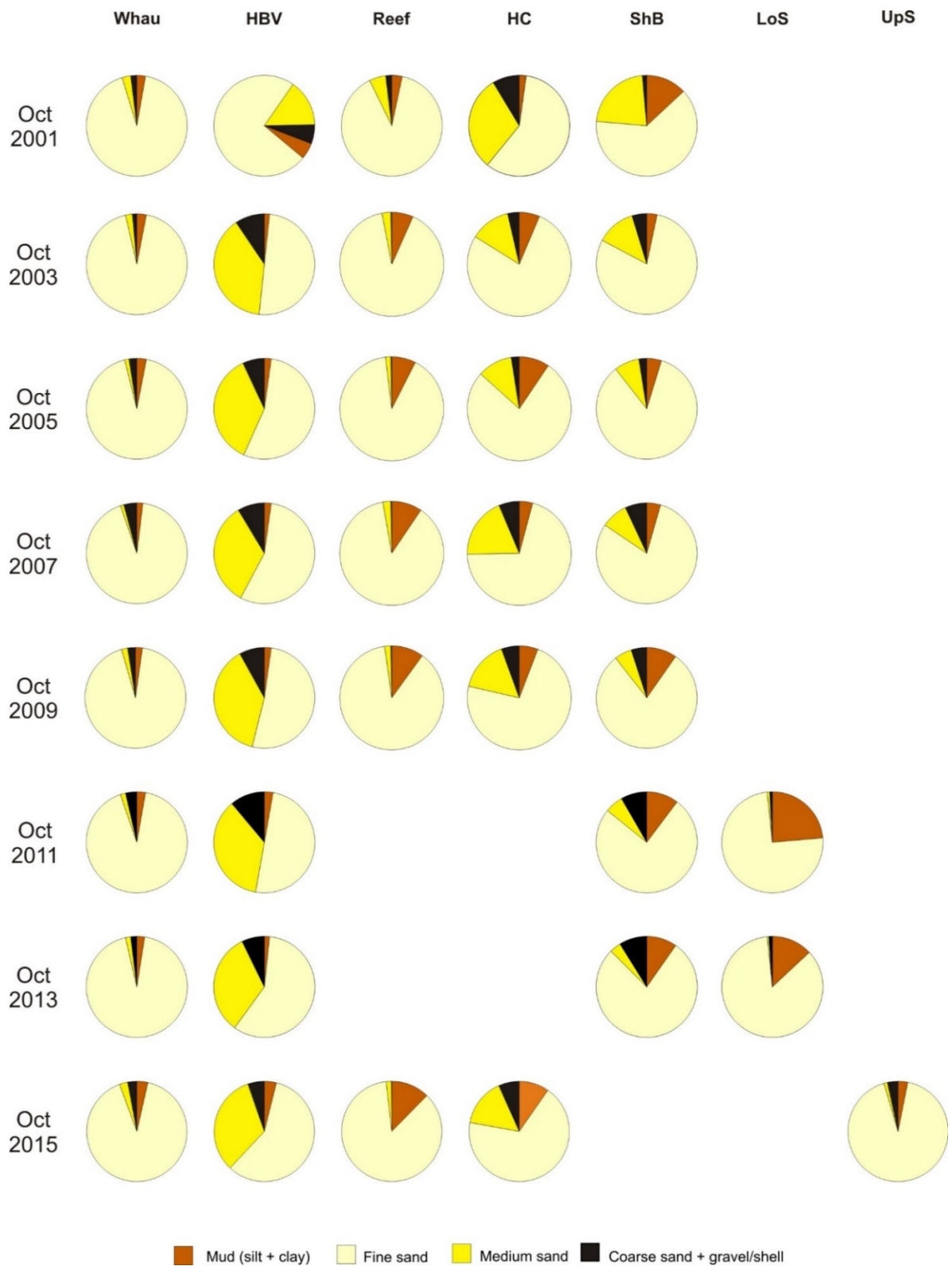


Figure 2. Summary of sediment characteristics at Whau River (Whau), Hobsonville (HBV), Meola Reef (Reef), Henderson Creek (HC) and Shoal Bay (ShB, LoS and UpS) from October 2001 to October 2015. Coarse sand and gravel (>500µm), medium sand (250-500 µm), fine sand (62.5-250 µm), mud (< 62.5 µm). Full results are given in Appendix 9.2.

3.1.2 Whau River (Whau)

The Whau site is located on the north-western side of the Whau River (Plate 2). The site is a mid-intertidal sand bank, located next to a navigation channel consisting of fine, deep muddy sediment. This site has shown the least amount of visual change of all the CWH monitoring sites over the monitoring time series. The intertidal flats here are large, sandy and generally show signs of wind-wave activity. Ripples observed on the December 2016 sampling trip were broad (10-20cm wide) and shallow (1cm depth), whereas more typically shallow ripples at the site are only 2-3cm apart. Sediment at the site consists primarily of hard-packed fine sand and some shell hash (~10% cover) visible on the surface, and abundant grazing gastropods. *Macomona* tracks are common (about five tracks per m²), with occasional small crab burrows. Gastropod densities have varied in recent years, with typical high abundances of 50-100 *Zeacumantus lutulentus* per m² last observed in 2014, and limited recovery in abundance to 5-10 per m² observed in April and December 2016. The decline was possibly associated with an influx of sediment observed on the site in 2015. A short lasting colonisation of tube-forming worms was also observed in April 2016, with abundances of worm tubes as high as 20 per m² in some portions of the site, and densities of ~5 per m² observed throughout the site. However, worm tubes were not observed at high densities in December 2016.

The sediment at Whau is predominantly fine sand (> 90%), with an average chlorophyll a content of 12.1 µg/g sediment and a low organic content (generally <1%) (Figure 2) (Appendix 9.2).

3.1.3 Meola Reef (Reef)

The intertidal flat on the eastern side of Meola Reef is a muddy sandflat located near Meola and Motions Creeks (Plate 3). Sampling at this site was temporarily suspended between June 2010 and June 2015 (5 years) as part of the nested sampling monitoring strategy. Of all the study areas, this has the longest uninterrupted fetch and consequently may be affected by both waves and currents. The site itself is situated a few hundred metres west of scattered patches of rock, and at the end of a shallow-sloping channel. Since December 2004 patches of seagrass (*Zostera muelleri*) have established at the site (Plate 3). Seagrass has been increasing in density since 2008, and now fills the majority of this embayment, extending into the shallow subtidal area. Seagrass cover is near continuous throughout most of the embayment, typically with 50-100% cover, though occasional small patches of sandy hummocks (<10m²) with more consolidated sediments are distributed throughout the seagrass meadow. The seagrass appears healthy and in good condition with long (15-20cm) green blades that are roughly two to three times the typical blade length of New Zealand intertidal seagrass.

Possibly due to the ability of seagrass to trap sediment, there has been a consistent upward trend in the mud fraction of the sediment (Appendix 9.2, Figure 2 and Figure 3) since 2008. However, the sediment at the site is still dominated by fine sand (76-95%) with the percentage of coarse sand at this site being the lowest of all monitored sites (<1%) (Figure 2). The average chlorophyll a content is also the lowest (9.1 µg/g) of all the monitored sites. Average organic content is 1.6%.

3.1.4 Henderson Creek

The HC site is located adjacent to Henderson Creek on a large intertidal flat, which is fringed by mangroves on the upper edge and oyster reef on the western edge. Sampling at this site was temporarily suspended between June 2010 and June 2015 as part of a rotational policy. The sediment surface is generally free from features such as ripples and is covered with a substantial layer of shell-hash (Plate 4). The appearance of the HC site has shown little change since 2010, with dense shell hash over most of the area, and less firm areas of fine sediment found throughout the site. Shell hash is composed of predominantly 80% *Austrovenus*, 5% *Macomona*, and 15% of older bleached, broken shells (most likely *Mactra*). Gastropods are abundant on the site, predominantly *Cominella glandiformis* and *Diloma subrostrata*, observed at densities of ~5 per m² in December 2016. Gastropod densities show temporal variability, with densities of *Cominella*, *Diloma*, and *Zeacumantus* of 50, 10 and 10 per m² observed in April 2016. In December 2016, abundant Asian date mussel, *Arcuatula senhousia*, hummocks were observed between the site and the channel. The mussel area is currently restricted to deeper intertidal areas, but was approaching to within 20m of the site in December 2016. The hummocks are comprised of predominantly small <10mm individual mussels, suggesting this is a recent colonisation event. In future, bimonthly or annual sampling could perform GIS tracking to monitoring the encroachment of this mussel area toward the site, as the transition zone of the mussel hummocks and the shell hash dominated habitat typical of site HC is easily visible (Plate 5).

The sediment is predominantly medium and fine sand (Figure 2). The proportion of fine sand increased at this site rapidly over the first two years of monitoring, accompanied by a decrease in medium sand, but then stabilised around October 2002 (Appendix 10.1). The mud content showed an upward trend during the first four years of sampling (Halliday and Hewitt, 2006), and then exhibited high variation until 2010. Since sampling resumed in 2015 there has been a further upward trend (Figure 3). This site has the highest average chlorophyll a content (25.6 µg/g) out of all the monitoring sites. There is a cyclic pattern of lowest chlorophyll a content in either August or October.

3.1.5 Upper Shoal Bay

The Upper Shoal Bay site (Plate 6) was established in August 2015, replacing the original Shoal Bay location near the Harbour Bridge which had shown substantial changes in sediment and biota over the first 15 years of sampling, and had become unsuitable for sampling. An additional site (Lower Shoal Bay, at the RDP sampling location) was also sampled for four and a half years as an intended replacement for Shoal Bay, but the high mud content and associated benthic communities observed at this site suggested it was unsuitable for detecting change. The Upper Shoal Bay site is located in an area frequented by feeding shorebird species (i.e., NZ dotterel, variable oystercatcher and Caspian tern). The sandflat is adjacent to a shell bank which is seaward of a narrow band of stunted mangroves, and is accessed via a man-made pathway through the mangroves. Sediments are predominantly fine, with a slight gradient across the site from sand-dominated sediments near the 0,0 peg, with some wind-wave generated ripples (approximately 1-2cm high, 3-5cm apart), toward less firm sediments at the far edge of the site, where ripples are less apparent. An area of softer sediment was observed in December 2016 on the seaward edge

of the site; ongoing sampling should examine if this area of muddier sediments encroaches landward onto the site. High gastropod abundance was observed, predominantly *Zeacumantus* at densities of up to 100 per m². *Austrovenus* were present at abundances of ~10 per m², typically 15-20mm in size. Ray pits are typically observed on the site, with frequent ray pits (10 per 25m²) observed in April 2016, but only about 10 observed across the full site in December 2016. A diatom mat was observed across the surface sediment in December 2016.

The sediment at this site is dominated by fine sand (ranging from 81-92%) (Figure 2), and it has the second highest average chlorophyll *a* content (16.8 µg/g) of the five monitoring sites.

3.1.6 Summary of changes in site characteristics

The organic matter content at HBV, Whau, Reef and HC and LoS has remained comparable with previous years of the study, showing minimal change in the level of variation (Table 4B, Townsend et al. 2010, Halliday et al. 2012, Parkes and Lundquist 2015). There has been little variation in chlorophyll *a* content at HBV and HC compared to past years. However, the changes in standard deviation for chlorophyll *a* at Whau and Reef have gone from -0.27 and -0.15 (Parkes and Lundquist 2015, Townsend et al. 2010) to 0.28 and 0.03, indicating a shift towards increased stability. The highest values of organic material and sediment chlorophyll *a* concentration were found at Reef and HC respectively, while the lowest values for both were present at Whau (Appendix 10.1). The five sites can be divided into two groups on the basis of within-year variability in sediment characteristics: Whau, Reef and UpS had lower variability than HBV and HC (Table 4A). Table 4B demonstrates the change in variability over the last three years by comparing the standard deviation of data from October 2000 to February 2014 (shown in the last report) with the data from October 2000 to February 2017. Overall, there has been minimal change in the temporal variability of sediment characteristics at HBV and Whau over the last three years, and at Reef and HC since 2010 (Table 4B). The UpS site shows there has been variation in the mud and fine sand content of the sediment between February 2015-2016 and February 2016-2017, while chlorophyll *a* values have remained very stable (Table 4B).

Table 5. Analysis of temporal variability in sediment characteristics at HBV, Whau, HC, Reef (from October 2000 to February 2017) and UpS (from February 2016 to February 2017).

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), organics and chlorophyll a. Note: gravel fraction (>2000 μm) not included.

B) Changes in the standard deviations compared with results reported in 2012 for HBV and Whau, results reported in 2010 for HC and Reef, and from February 2015-February 2016 for UpS. Negative values indicate larger variability over the last two years, whereas positive values indicate increased stability.

A)

Site	%mud	%fine sand	%medium sand	%coarse sand	%organics	Chl a mg/g
HBV	1.48	7.93	7.56	2.33	0.71	2.78
Whau	1.27	2.71	1.57	0.24	0.32	3.74
HC	2.69	8.17	7.61	1.76	0.65	5.57
Reef	3.89	3.95	1.65	0.20	0.81	3.03
UpS	3.14	3.89	0.25	0.17	0.31	1.98

B)

Site	%mud	%fine sand	%medium sand	%coarse sand	%organics	Chl a mg/g
HBV	0.05	0.42	0.45	0.11	0.06	0.10
Whau	0.01	0.11	0.13	-0.01	0.03	0.28
HC	-0.44	0.64	0.48	0.09	0.03	-0.15
Reef	0.15	0.24	-0.02	0.00	0.06	0.03
Ups	-1.21	-2.59	-0.09	-0.04	-0.07	3.03

Both HBV and Whau display historic trends in several size fractions, however, there have been no substantial changes since April 2002 and December 2003 respectively. There is a statistically significant increasing trend for mud at both Reef and HC (p 0.0002 and p <0.0001 respectively), however the trend at Reef is also one likely driven by historic data. The current values for mud are no higher than they were in 2008-2010 (Figure 3).

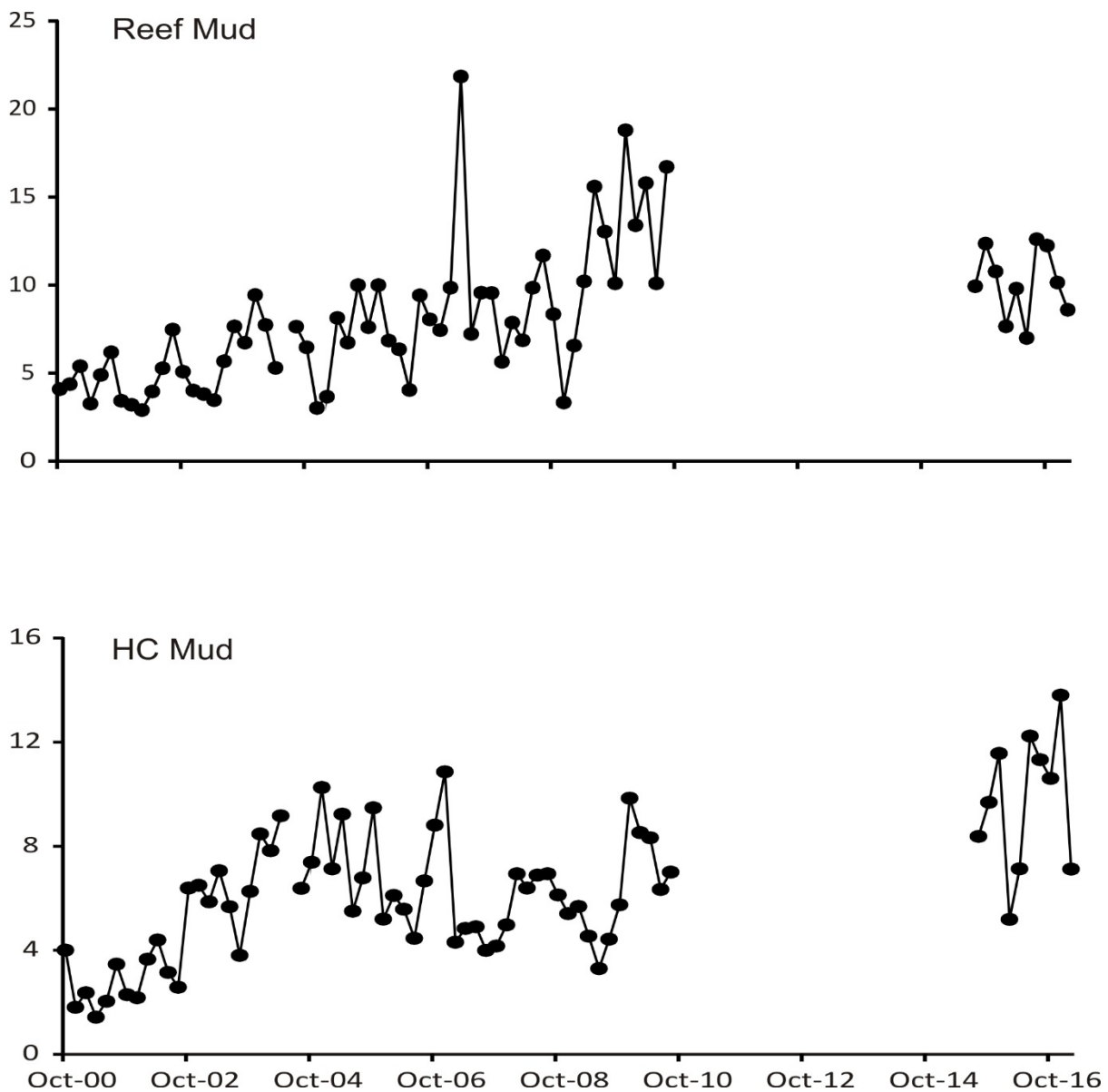


Figure 3. Temporal changes in site sediment changes at Reef and HC. Trends show percent mud to be increasing at both sites.

3.2 Are species exhibiting temporal variations?

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

3.2.1 Hobsonville (HBV)

Between October 2000 and April 2011 the Hobsonville site was consistently dominated, in terms of abundance, by three species: the nut clam *Linucula hartvigiana*, the polychaete *Aonides trifida*, and the venerid bivalve *Austrovenus stutchburyi* (Table 5). The only exceptions to this were eight occasions between August 2001 and August 2008 when the limpet *Notoacmea scapha* was the

third most abundant species. In all instances this peak occurred around June/August, indicating the presence of a multi-year cycle. Prior to February 2007 *Linucula* was consistently the most dominant species; between February 2007 and October 2013 there was a continual fluctuation between *Linucula* and *Aonides*, and then from December 2013 *Aonides* was consistently dominant (with the exception of December 2014). This fluctuation is probably due to a combination of two factors. Firstly, *Aonides* demonstrated increasing abundance between 2005 and 2008, and since then the numbers have remained relatively high and constant. Secondly, abundances of *Linucula* show a greater than annual trend. Their numbers were high and relatively constant during the first six years, declined from 2007-2011, recovered slightly between 2011 and 2013, and since then seem to have settled out at a slightly lower baseline (Figure 4). The remaining monitored fauna were usually low in abundance, although *Prionospio aucklandica*, *Colurostylis lemurum*, *Notoacmea scapha* and *Anthopleura aureoradiata* were among the three most abundant taxa present on multiple sampling dates (Appendix 9.3).

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

Date	1 st	2 nd	3 rd
Oct-00	<i>Linucula</i>	<i>Aonides</i>	<i>Austrovenus</i>
Oct-01	<i>Linucula</i>	<i>Aonides</i>	<i>Austrovenus</i>
Oct-02	<i>Linucula</i>	<i>Aonides</i>	<i>Austrovenus</i>
Oct-03	<i>Linucula</i>	<i>Aonides</i>	<i>Austrovenus</i>
Oct-04	<i>Linucula</i>	<i>Aonides</i>	<i>Austrovenus</i>
Oct-05	<i>Linucula</i>	<i>Aonides</i>	<i>Notoacmea</i>
Oct-06	<i>Linucula</i>	<i>Aonides</i>	<i>Austrovenus</i>
Oct-07	<i>Linucula</i>	<i>Aonides</i>	<i>Austrovenus</i>
Oct-08	<i>Linucula</i>	<i>Aonides</i>	<i>Austrovenus</i>
Oct-09	<i>Aonides</i>	<i>Linucula</i>	<i>Austrovenus</i>
Oct-10	<i>Aonides</i>	<i>Linucula</i>	<i>Austrovenus</i>
Oct-11	<i>Aonides</i>	<i>Austrovenus</i>	<i>Colurostylis</i>
Oct-12	<i>Linucula</i>	<i>Aonides</i>	<i>Austrovenus</i>
Oct-13	<i>Linucula</i>	<i>Aonides</i>	<i>Prionospio</i>
Oct-14	<i>Aonides</i>	<i>Linucula</i>	<i>Austrovenus</i>
Oct-15	<i>Aonides</i>	<i>Linucula</i>	<i>Austrovenus</i>
Oct-16	<i>Aonides</i>	<i>Linucula</i>	<i>Austrovenus</i>

3.2.1.1 Seasonality and multi-year cycles

Anthopleura, *Boccardia*, *Colurostylis*, *Heteromastus*, *Macomona*, *Macroclymenella*, *Notoacmea*, *Prionospio* and *Zeacumantus* all demonstrate long multi-year cyclic patterns at HBV. For example, *Prionospio* has cycles in recruitment which occur every five to seven years, with high recruitment events in April 2001, February 2008, June 2012 and April 2013 (Figure 4). The multi-year patterns for *Boccardia* and *Heteromastus* were not identified in the last report (Parkes and Lundquist 2015), but have become apparent with further time-series data. Seasonal patterns were also observed in

a number of species at HBV. For example, *Aricidea* and *Boccardia* both displayed peak abundances during winter (August to October and June to August, respectively), while peak abundances for *Colurostylis* can be seen during April and August. *Anthopleura* and *Austrovenus* display peak abundances during the summer months, typically December to February (Figure 4).

3.2.1.2 Statistically significant trends

Trends are evident in eight taxa at HBV (Table 6). Two of these trends are driven by historical data and do not appear to be active any longer. The decreasing trend in *Paphies* (Halliday et al. 2012) only occurred until 2008, since then the abundance of *Paphies* has remained variable but does not appear to be decreasing further. HBV continues to be the only monitoring location where *Paphies* is observed, occurring predominantly as juvenile (<10mm) and intermediate (10-40mm) sizes (Figure 5). The second historic trend can be seen for *Aonides*, which was reported to be increasing (Halliday et al. 2012). It appears that this trend was driven by the lower values in the first four years, however, since 2008 abundance has remained variable with no further increase (Figure 4). In addition to these two historic trends are increasing trends in the abundance of *Anthopleura*, *Aricidea*, *Arthritica*, *Boccardia* and *Heteromastus* and decreasing trends in *Linucula* (Table 6). The increasing trends in *Arthritica* and *Boccardia* abundances have only been observed in the last three years (Figure 4, Table 6), and are possibly being driven by high recruitment in the last five and two years respectively. In the last report it was suggested that the increasing trend in *Heteromastus* abundance was actually just part of a multi-year pattern. Following further collection it appears this is true, although a statistically significant trend ($p < 0.0001$) is also still present.

The number of *Austrovenus* at HBV has remained relatively high. In the last report we noted a decline in the number intermediate (5-20mm) sized *Austrovenus*; these have since increased in number again (Figure 5). In addition to this, the numbers of juvenile (<5mm) bivalves recorded in February 2015 and 2016 exceed any previous records and there is a statistically significant increasing trend ($p < 0.0001$) in the number of adults (>20mm) (Figure 5).

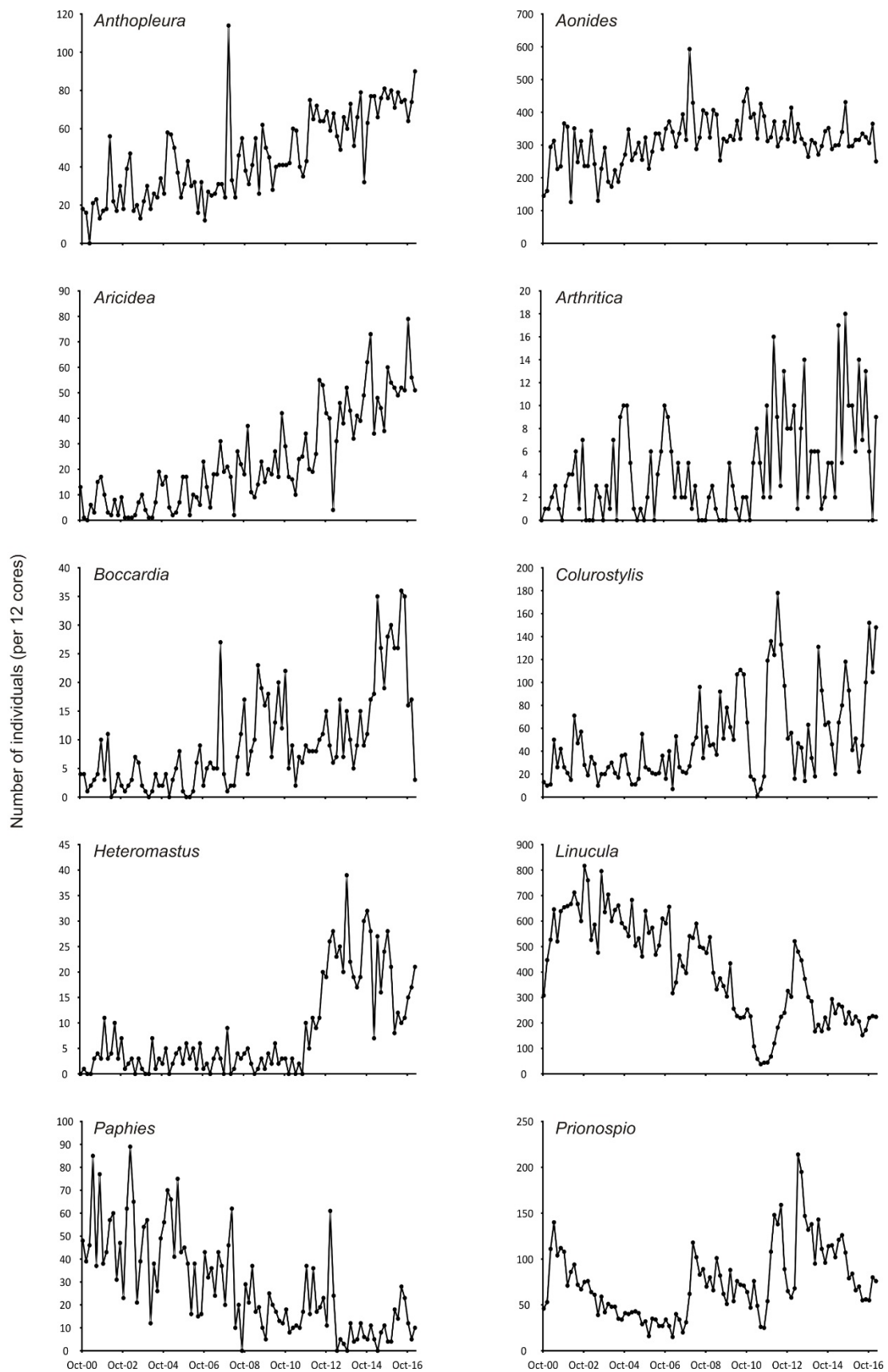


Figure 4. Temporal patterns in abundances of *Anthopleura aureoradiata*, *Aonides*, *Aricidea*, *Arthritica bifurca*, *Bocardia syrtis*, *Colurostylis lemurum*, *Heteromastus filiformis*, *Linucula hartvigiana*, *Paphies australis* and *Prionospio aucklandica* at the HBV site.

Table 7. Summary of temporal patterns in abundance of selected taxa observed at each site between October 2000 and February 2017. Hobsonville (HBV), Whau River (Whau), Meola Reef (Reef) and Henderson Creek (HC). Reef and HC were not sampled between August 2010 and August 2015 as part of a rotational resting. Upper Shoal Bay (UpS) has not been monitored long enough for patterns and trends to be identified. *temporal pattern suggests trend no longer operating. Size of change predicted for total abundance (based on 12 cores) over the monitored period of just over 16 years.

Site	Seasonal cycles	Multi-year cycles	Trends	Trend direction	Size of change	p-value
HBV	<i>Anthopleura</i> <i>Aricidea</i> <i>Austrovenus</i> <i>Boccardia</i> <i>Colurostylis</i> <i>Exosphaeroma</i> <i>Glyceria</i>	<i>Anthopleura</i>	<i>Aonides</i>	Increase*	95.4	0.0028
		<i>Boccardia</i>	<i>Paphies</i>	Decrease*	-51.7	<0.0001
		<i>Colurostylis</i>	<i>Anthopleura</i>	Increase	60.4	<0.0001
		<i>Heteromastus</i>	<i>Aricidea</i>	Increase	54.8	<0.0001
		<i>Macomona</i>	<i>Arthritica</i>	Increase	6.5	0.0023
		<i>Macroclymenella</i>	<i>Boccardia</i>	Increase	19.7	<0.0001
		<i>Notoacmea</i>	<i>Heteromastus</i>	Increase	21.5	<0.0001
		<i>Prionospio</i> <i>Zeacumantus</i>	<i>Linucula</i>	Decrease	-537.2	<0.0001
Whau	<i>Anthopleura</i> <i>Austrovenus</i> <i>Colurostylis</i> <i>Linucula</i> <i>Notoacmea</i>	<i>Anthopleura</i>	<i>Linucula</i> <i>Prionospio</i>	Decrease* Decrease*	-506.4 -16.8	0.0002 0.0363
		<i>Aricidea</i>				
		<i>Austrovenus</i>				
		<i>Boccardia</i>				
		<i>Colurostylis</i>				
		<i>Euchone</i>				
		<i>Glyceria</i>				
		<i>Heteromastus</i> <i>Macomona</i> <i>Macroclymenella</i> <i>Notoacmea</i> <i>Zeacumantus</i>				
Reef	<i>Aricidea</i> <i>Arthritica</i> <i>Austrovenus</i> <i>Euchone</i> <i>Glyceria</i> <i>Haminoea</i>	<i>Arthritica</i>	<i>Aricidea</i> <i>Heteromastus</i> <i>Macomona</i> <i>Notoacmea</i> <i>Prionospio</i>	Increase Increase Decrease Increase Increase	751.3 861.7 -15.2 42.9 118.6	<0.0001 <0.0001 0.0375 <0.0001 <0.0001
		<i>Austrovenus</i>				
		<i>Boccardia</i>				
		<i>Colurostylis</i>				
		<i>Glyceria</i>				
		<i>Haminoea</i>				
		<i>Heteromastus</i> <i>Macomona</i> <i>Macroclymenella</i> <i>Prionospio</i> <i>Zeacumantus</i>				
		HC				
<i>Arthritica</i>						
<i>Austrovenus</i>						
<i>Boccardia</i>						
<i>Colurostylis</i>						
<i>Diloma</i>						
<i>Exosphaeroma</i> <i>Macroclymenella</i> <i>Notoacmea</i> <i>Prionospio</i> <i>Zeacumantus</i>						

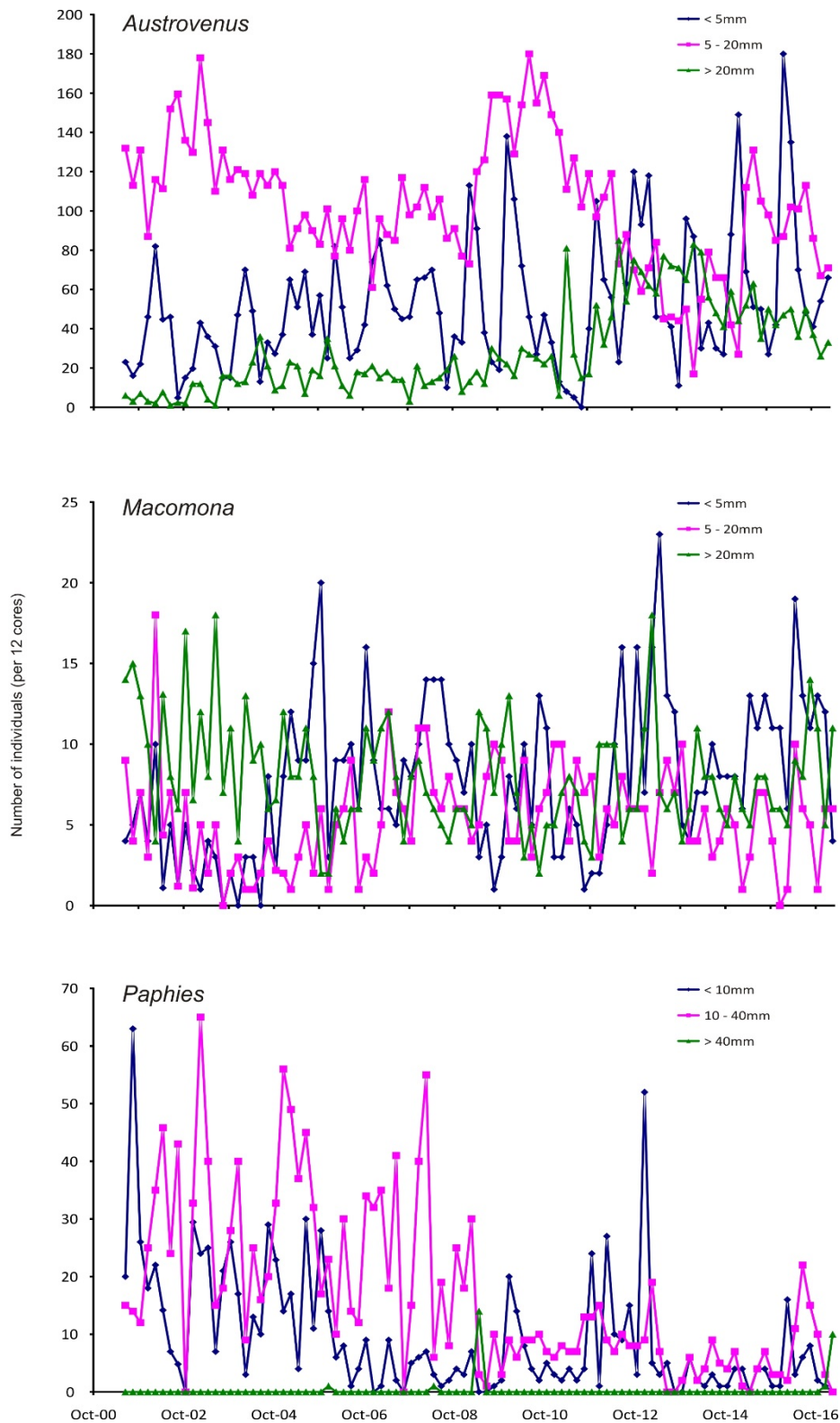


Figure 5. Trends in abundance of different size classes of the bivalves *Austrovenus stutchburyi*, *Macomona liliiana* and *Paphies australis* found at site HBV.

3.2.2 Whau River (Whau)

Until February 2014 *Linucula* was typically the most abundant species at this site, occasionally being replaced by either *Austrovenus* or *Aricidea* (Table 7). However, since April 2014 *Aricidea* has consistently been the top ranking species found at Whau. Other species of moderate to high abundance at this site include *Colurostylis*, *Notoacmea*, *Boccardia*, *Macomona* and *Macroclymenella* (Appendix 9.3).

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

Date	1 st	2 nd	3 rd
Oct-00	<i>Linucula</i>	<i>Aricidea</i>	<i>Austrovenus</i>
Oct-01	<i>Linucula</i>	<i>Aricidea</i>	<i>Austrovenus</i>
Oct-02	<i>Linucula</i>	<i>Aricidea</i>	<i>Austrovenus</i>
Oct-03	<i>Linucula</i>	<i>Austrovenus</i>	<i>Aricidea</i>
Oct-04	<i>Aricidea</i>	<i>Linucula</i>	<i>Macroclymenella</i>
Oct-05	<i>Linucula</i>	<i>Aricidea</i>	<i>Macroclymenella</i>
Oct-06	<i>Linucula</i>	<i>Aricidea</i>	<i>Macroclymenella</i>
Oct-07	<i>Linucula</i>	<i>Aricidea</i>	<i>Austrovenus</i>
Oct-08	<i>Austrovenus</i>	<i>Linucula</i>	<i>Aricidea</i>
Oct-09	<i>Austrovenus</i>	<i>Linucula</i>	<i>Aricidea</i>
Oct-10	<i>Linucula</i>	<i>Aricidea</i>	<i>Austrovenus</i>
Oct-11	<i>Austrovenus</i>	<i>Aricidea</i>	<i>Linucula</i>
Oct-12	<i>Aricidea</i>	<i>Linucula</i>	<i>Austrovenus</i>
Oct-13	<i>Aricidea</i>	<i>Linucula</i>	<i>Austrovenus</i>
Oct-14	<i>Aricidea</i>	<i>Austrovenus</i>	<i>Linucula</i>
Oct-15	<i>Aricidea</i>	<i>Linucula</i>	<i>Notoacmea</i>
Oct-16	<i>Aricidea</i>	<i>Linucula</i>	<i>Colurostylis</i>

3.2.2.1 Seasonality and multi-year cycles

Bivalve populations have been variable over time at Whau. Both *Austrovenus* and *Macomona* are dominated by juveniles (<5mm), with large and variable recruitment events (Figure 7). The same seasonal patterns witnessed at HBV can be seen in the *Austrovenus* population at Whau, with peaks in abundance between December and February (Figure 5, Figure 6). *Colurostylis* also displays seasonal patterns, with peak abundance typically in April to June. Halliday et al. (2012) questioned whether the unusually high abundance in February 2012 was a result of the temporary accidental relocation of the site (see Halliday et al. 2012), or part of a natural cycle. This species does exhibit multi-year cycles, and the abundance of *Colurostylis* was also high at HBV at this time (Figures 4 and 6). A second unusually high recruitment peak in October 2016 also suggests this was just part of a natural cycle. Seasonal patterns can also be seen in *Notoacmea*, with peaks in abundance usually occurring in October / December (Figure 6). Variable recruitment in *Notoacmea*

has also resulted in multi-year patterns in abundance (Table 6). Following the collection of additional data a seasonal pattern is now apparent for *Anthopleura*, which is consistent with patterns seen at HBV and HC (Figure 4, Figure 6, and Figure 10). Multi-year patterns are displayed by twelve of the twenty monitored species at Whau (Table 6). The increase in time-series data has allowed us to identify two new multi-year patterns that were not evident when the last report (Parkes and Lundquist 2015) was published. The first of these is for *Aricidea*, which appears to have high recruitment for two years, followed by ten to eleven years of much lower recruitment. Secondly, *Heteromastus* had a large recruitment event from late 2012-late 2014, and since then abundance levels appear to be returning to normal (Figure 6).

3.2.2.2 Statistically significant trends

Two of the monitored species at Whau (*Linucula* and *Prionospio*) display historic trends, driven by high values prior to 2004. However, none of the species at this site are exhibiting current trends.

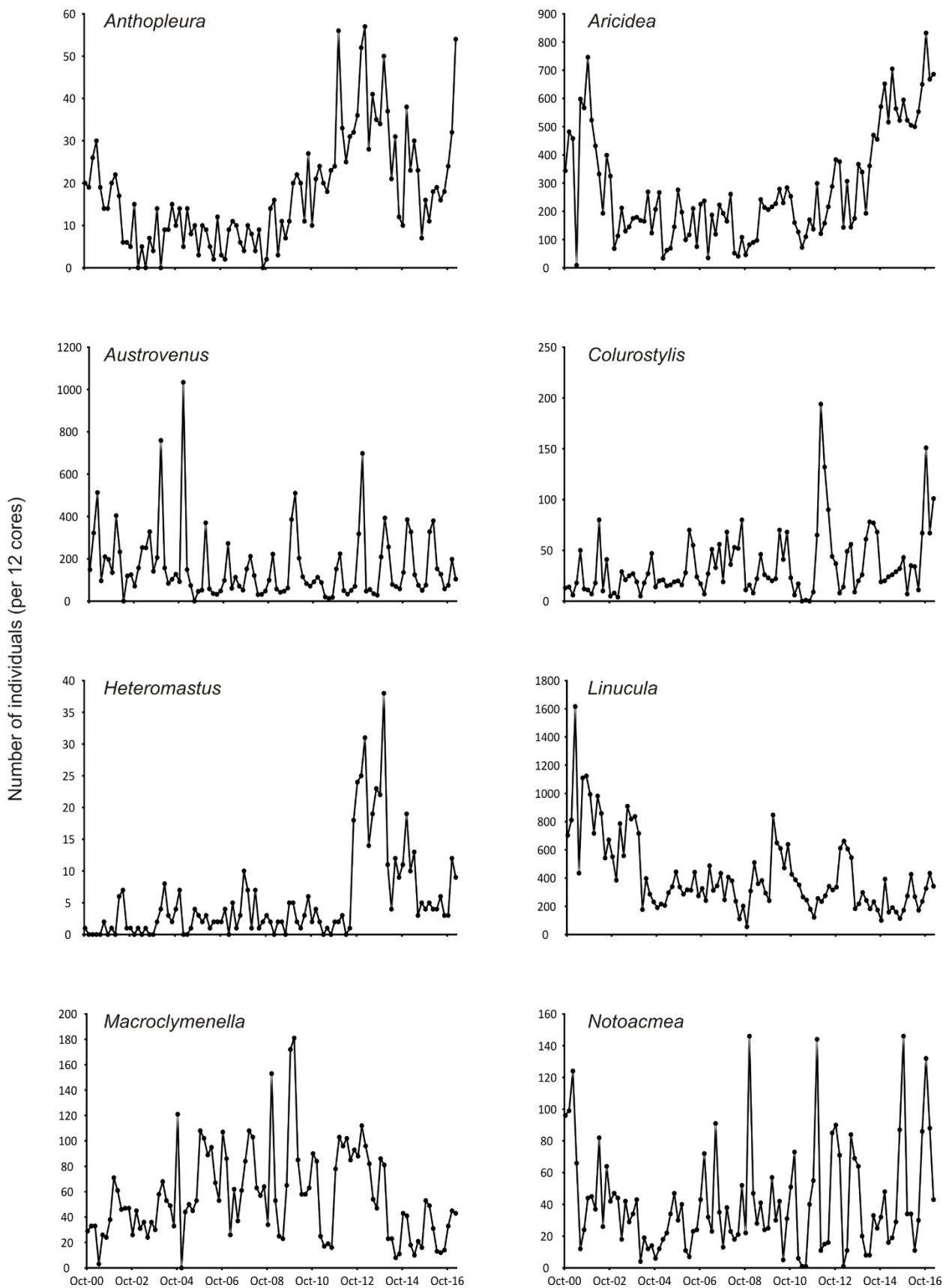


Figure 6. Temporal patterns in abundances of *Anthopleura aureoradiata*, *Aricidea*, *Austrovenus stutchburyi*, *Colurostylis lemurum*, *Heteromastus filiformis*, *Linucula hartvigiana*, *Macroclymenella stewartensis*, and *Notoacmea scapha* at the Whau site.

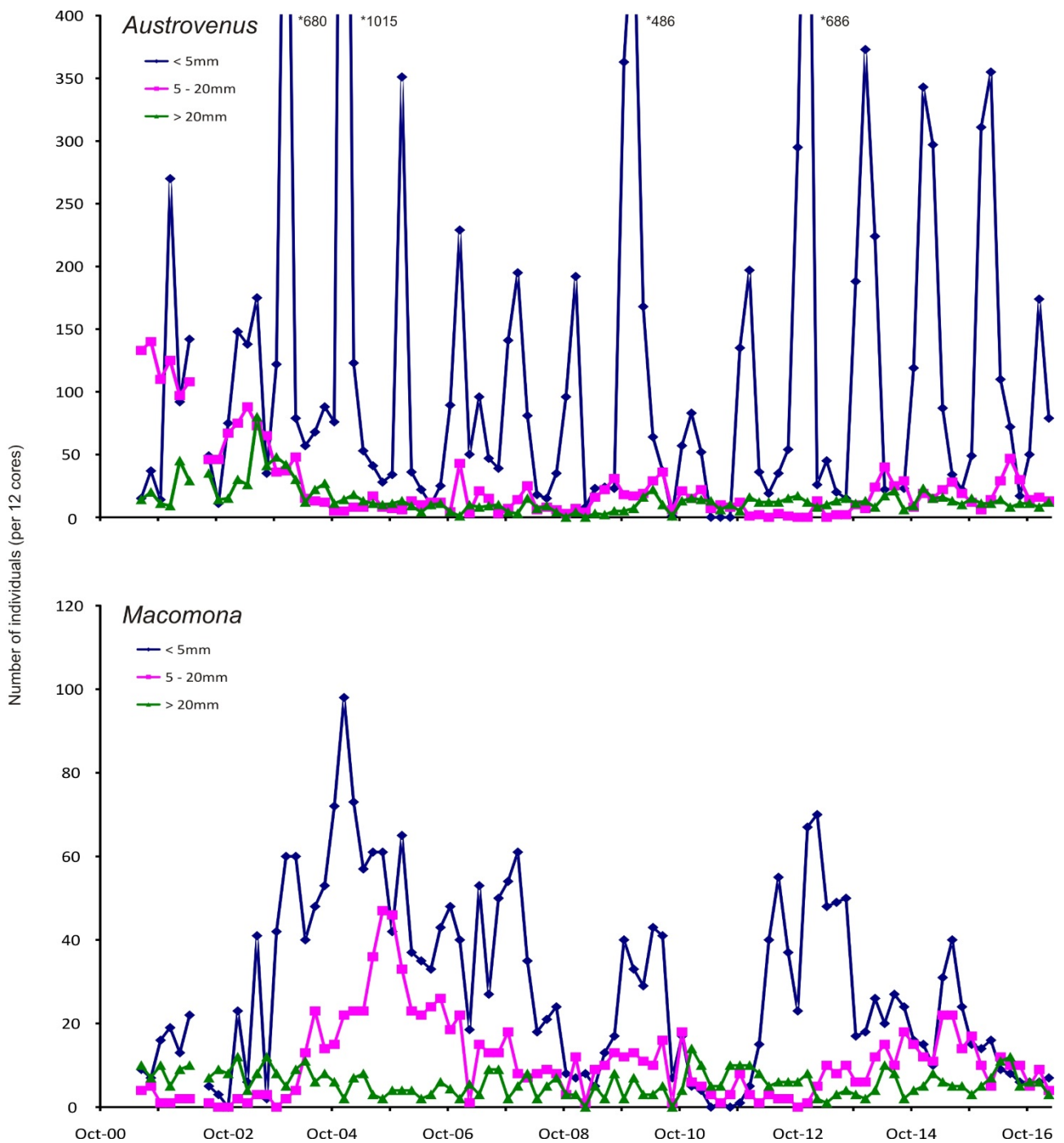


Figure 7. Trends in abundance of different size classes of the bivalves *Austrovenus stutchburyi* and *Macomona liliانا* found at Whau. No *Paphies australis* were present at Whau.

3.2.3 Meola Reef (Reef)

The species dominance at the Reef site has changed multiple times since monitoring began (Table 8). Initially *Linucula hartvigiana* was the dominant species, but its abundance declined dramatically, and was replaced by *Euchone* in June 2003. Between June 2003 and August 2007 there was a continual fluctuation between *Euchone* and *Heteromastus*. From October 2007 until sampling was put on hold in August 2010 *Heteromastus* took over as the most dominant species at this site. Since monitoring at this site was re-introduced in August 2015 *Heteromastus* has remained dominant, with the exception of August and October 2015 when it was overtaken by *Aricidea* (Table 8). Other species that are relatively common at this site include *Boccardia*, *Prionospio* and *Colurostylis* (Appendix 9.3).

Table 9. The three most abundant monitored taxa found over time at the reef.

Date	1 st	2 nd	3 rd
Oct-00	<i>Linucula</i>	<i>Euchone</i>	<i>Aricidea</i>
Oct-01	<i>Linucula</i>	<i>Euchone</i>	<i>Aricidea</i>
Oct-02	<i>Linucula</i>	<i>Euchone</i>	<i>Aricidea</i>
Oct-03	<i>Euchone</i>	<i>Austrovenus</i>	<i>Linucula</i>
Oct-04	<i>Euchone</i>	<i>Heteromastus</i>	<i>Aricidea</i>
Oct-05	<i>Heteromastus</i>	<i>Euchone</i>	<i>Boccardia</i>
Oct-06	<i>Heteromastus</i>	<i>Euchone</i>	<i>Aricidea</i>
Oct-07	<i>Heteromastus</i>	<i>Euchone</i>	<i>Aricidea</i>
Oct-08	<i>Heteromastus</i>	<i>Euchone</i>	<i>Boccardia</i>
Oct-09	<i>Heteromastus</i>	<i>Boccardia</i>	<i>Aricidea</i>
Oct-15	<i>Aricidea</i>	<i>Heteromastus</i>	<i>Boccardia</i>
Oct-16	<i>Heteromastus</i>	<i>Aricidea</i>	<i>Boccardia</i>

3.2.3.1 Seasonality and multi-year cycles

Arthritica, *Austrovenus*, *Boccardia*, *Colurostylis*, *Glycera*, *Haminoea*, *Heteromastus*, *Macomona*, *Macroclymenella*, *Prionospio* and *Zeacumantus* all show multi-year abundance patterns (Figure 8, Appendix 9.3). In 2010 Townsend et al. reported an increasing trend in abundances for *Boccardia* and *Macroclymenella*. Following the collection of further time-series data it is evident these were just part of a multi-year cycle, which is consistent with patterns seen at both HBV and Whau (Table 6). Seasonal cycles in abundance are evident for *Austrovenus*, *Haminoea*, *Macroclymenella* and *Arthritica bifurca*; which all peaked during the summer months, usually between December and February (Table 6, Figure 8). *Aricidea* also demonstrated a seasonal pattern, with winter peaks in abundances and lowest numbers during summer (Figure 8).

Austrovenus abundances at Reef are the lowest of all the Central Waitematā Harbour monitoring sites. Abundances are predominantly comprised of juveniles which exhibit cyclic patterns in recruitment, with adults absent and intermediate individuals rare across the whole time series (Figure 9). All *Macomona* size-classes are found at Reef and, prior to sampling being suspended in

April 2010, densities were typical of those of the other monitoring sites. Since monitoring resumed in August 2015 the juvenile size-class (<5mm) remains dominant. However, *Macomona* abundances are noticeably lower than prior to 2010 (Figure 8, Figure 9).

3.2.3.2 Statistically significant trends

Four of the monitored species at Reef (*Aricidea*, *Heteromastus*, *Notoacmea* and *Prionospio*) exhibit strong ($p < 0.0001$) statistically significant increasing trends across the time series (Table 6). The decreasing trend for *Macomona* is much weaker ($p = 0.038$) and, due to the gap in the data, it is hard to say if this is an actual decreasing trend in abundance, potentially brought about by the increasing extent of seagrass cover, or if it is just at a low point of a multi-year trend. *Macomona* at HBV and Whau exhibit multi-year patterns so the latter is likely. An initial increase in the abundance of both *Notoacmea* and *Prionospio* would be expected with increasing density or cover of seagrass.

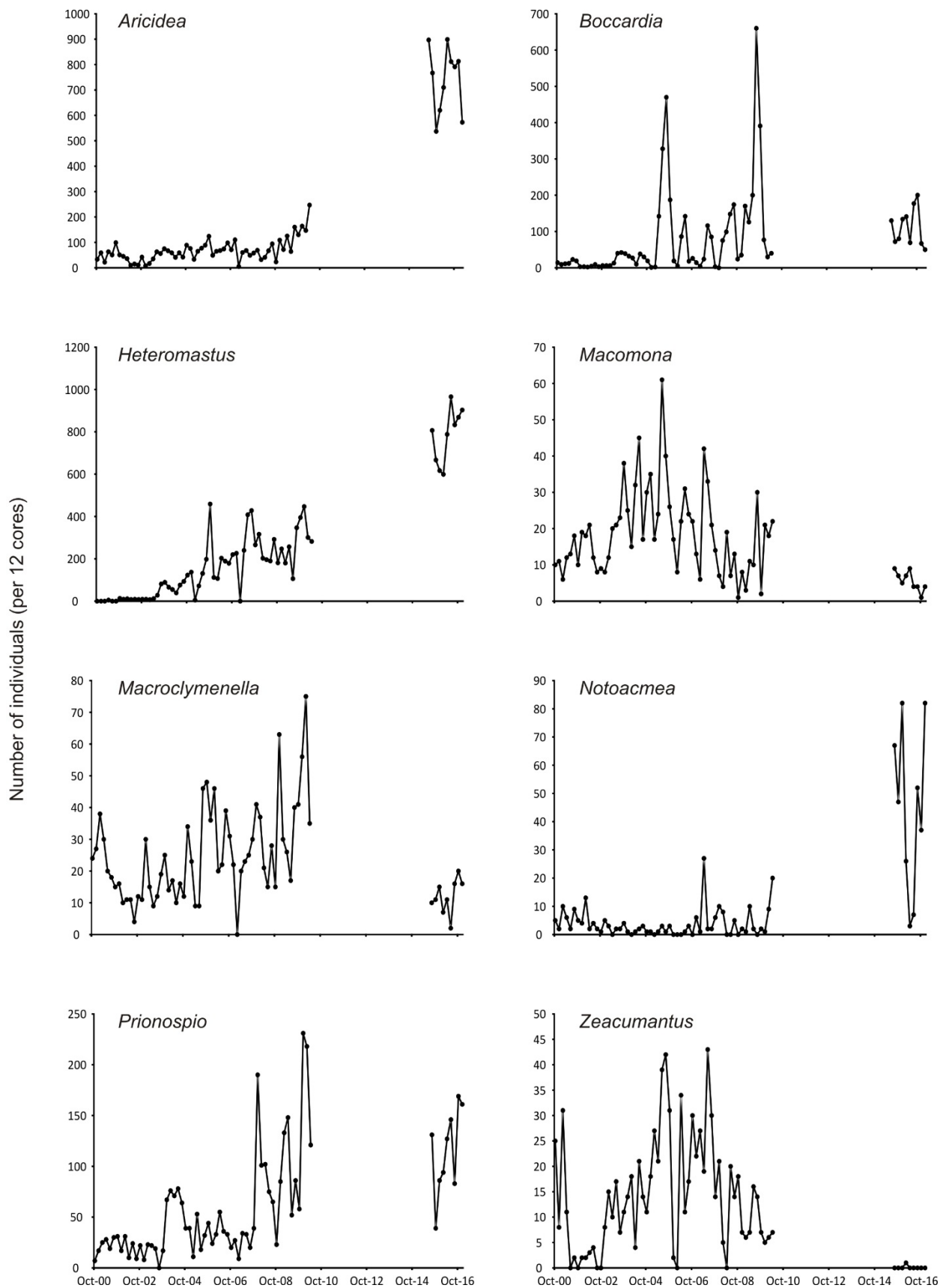


Figure 8. Temporal patterns in abundances of *Aricidea*, *Bocardia syrtis*, *Heteromastus filiformis*, *Macomona liliiana*, *Macroclymenella stewartensis*, *Notoacmea scapha*, *Prionospio aucklandica* and *Zeacumantus lutulentus* at the Reef site.

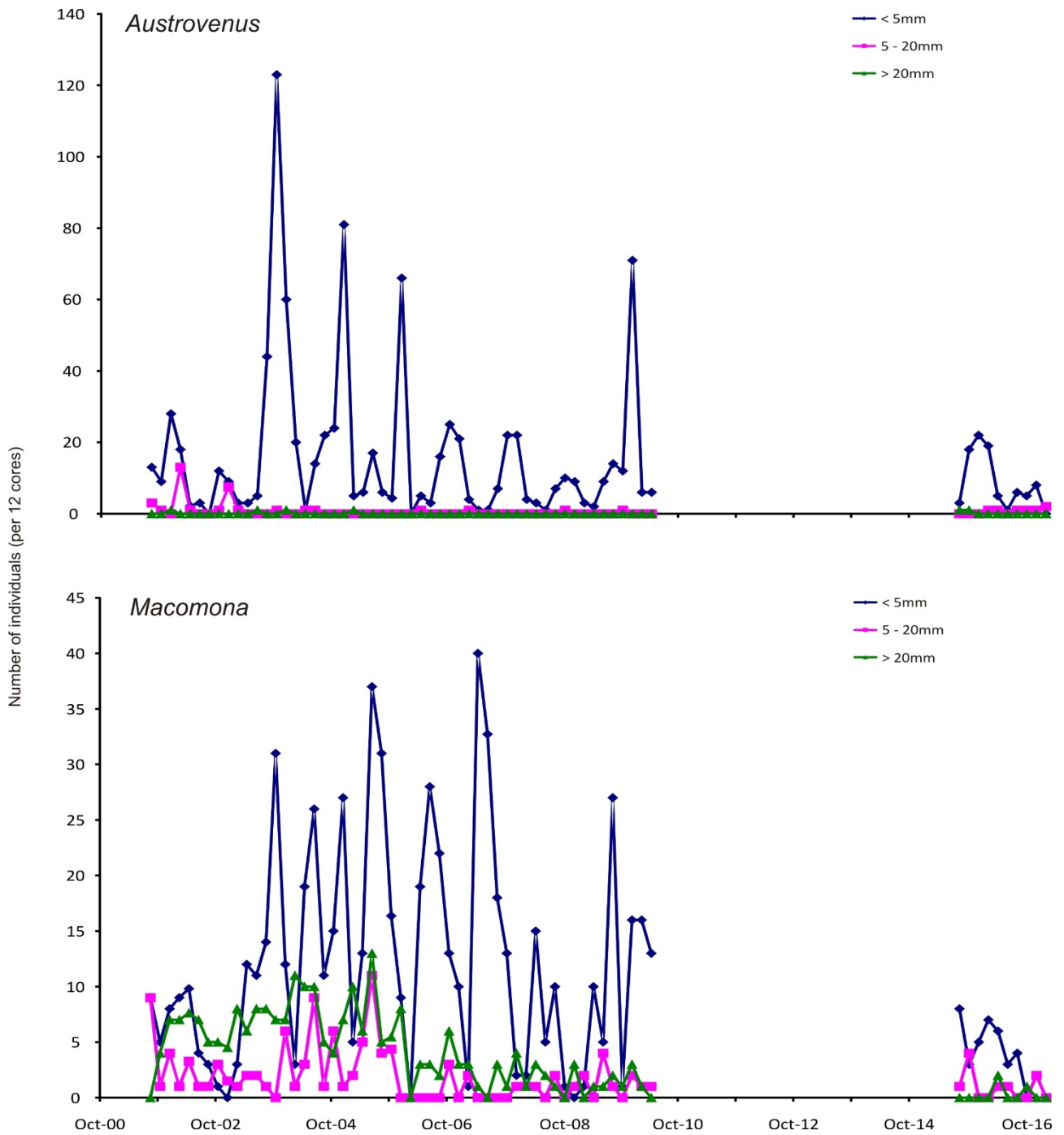


Figure 9. Trends in abundance of different size classes of the bivalves *Austrovenus stutchburyi* and *Macomona liliانا* found at Reef. No *Paphies australis* were present at Reef.

3.2.4 Henderson Creek (HC)

Since October 2000 *Linucula hartvigiana* has been the dominant species at this site, with only a single exception (*Austrovenus* dominated briefly in April 2016) (Table 9). The second most dominant species has fluctuated between *Austrovenus* and *Aricidea*. Other common species included *Notoacmea scapha*, *Prionospio aucklandica* and *Anthopleura aureoradiata* (Appendix 9.3).

Table 10. The three most abundant monitored taxa found over time at HC.

Date	1 st	2 nd	3 rd
Oct-00	<i>Linucula</i>	<i>Austrovenus</i>	<i>Notoacmea</i>
Oct-01	<i>Linucula</i>	<i>Austrovenus</i>	<i>Aricidea</i>
Oct-02	<i>Linucula</i>	<i>Austrovenus</i>	<i>Aricidea</i>
Oct-03	<i>Linucula</i>	<i>Austrovenus</i>	<i>Notoacmea</i>
Oct-04	<i>Linucula</i>	<i>Austrovenus</i>	<i>Notoacmea</i>
Oct-05	<i>Linucula</i>	<i>Austrovenus</i>	<i>Aricidea</i>
Oct-06	<i>Linucula</i>	<i>Aricidea</i>	<i>Austrovenus</i>
Oct-07	<i>Linucula</i>	<i>Aricidea</i>	<i>Austrovenus</i>
Oct-08	<i>Linucula</i>	<i>Aricidea</i>	<i>Austrovenus</i>
Oct-09	<i>Linucula</i>	<i>Aricidea</i>	<i>Austrovenus</i>
Oct-15	<i>Linucula</i>	<i>Aricidea</i>	<i>Austrovenus</i>
Oct-16	<i>Linucula</i>	<i>Aricidea</i>	<i>Austrovenus</i>

3.2.4.1 Seasonality and multi-year cycles

Multi-year patterns are displayed by eleven of the monitored species at HC (Table 6). For example, *Exosphaeroma* has also shown a multi-year behaviour with abundance patterns showing three-year cyclic patterns (Figure 10). Greater than annual patterns were seen in *Austrovenus*, *Notoacmea* and *Diloma subrostrata* which showed variation in peak size and differential recruitment success from year to year. Peaks in *Diloma* abundance occurred every 10 to 15 months. Seasonal cycles can be seen in *Anthopleura*, *Austrovenus*, *Exosphaeroma* and *Macroclymenella* populations, all of which exhibit peak abundances during the summer (December-February) (Table 6, Figure 10). All size classes of *Austrovenus* show multi-year cycles in abundance with the peaks in juvenile (<5mm) abundance being high since December 2005 (Figure 11). Dominance in size classes fluctuates between juveniles (<5mm) and intermediates (5-20mm).

3.2.4.2 Statistically significant trends

Three of the monitored species at HC (*Aricidea*, *Colurostylis* and *Macomona*) exhibit increasing step trends, which occurred in April 2007 (Figure 10, Table 6). *Anthopleura*, *Boccardia* and *Heteromastus* all exhibit increasing trends in their abundance, whereas *Linucula* exhibits a

decreasing trend. *Macomona liliiana* has lower abundance at the HC site compared to all other monitoring sites. The juvenile size-class (<mm) has high variability similar to that observed in the Manukau Harbour. Townsend et al. (2010) reported an increasing trend in abundance of juveniles that is still occurring, although no trends were apparent in the intermediate (5-20mm) or adult (>20mm) size classes.

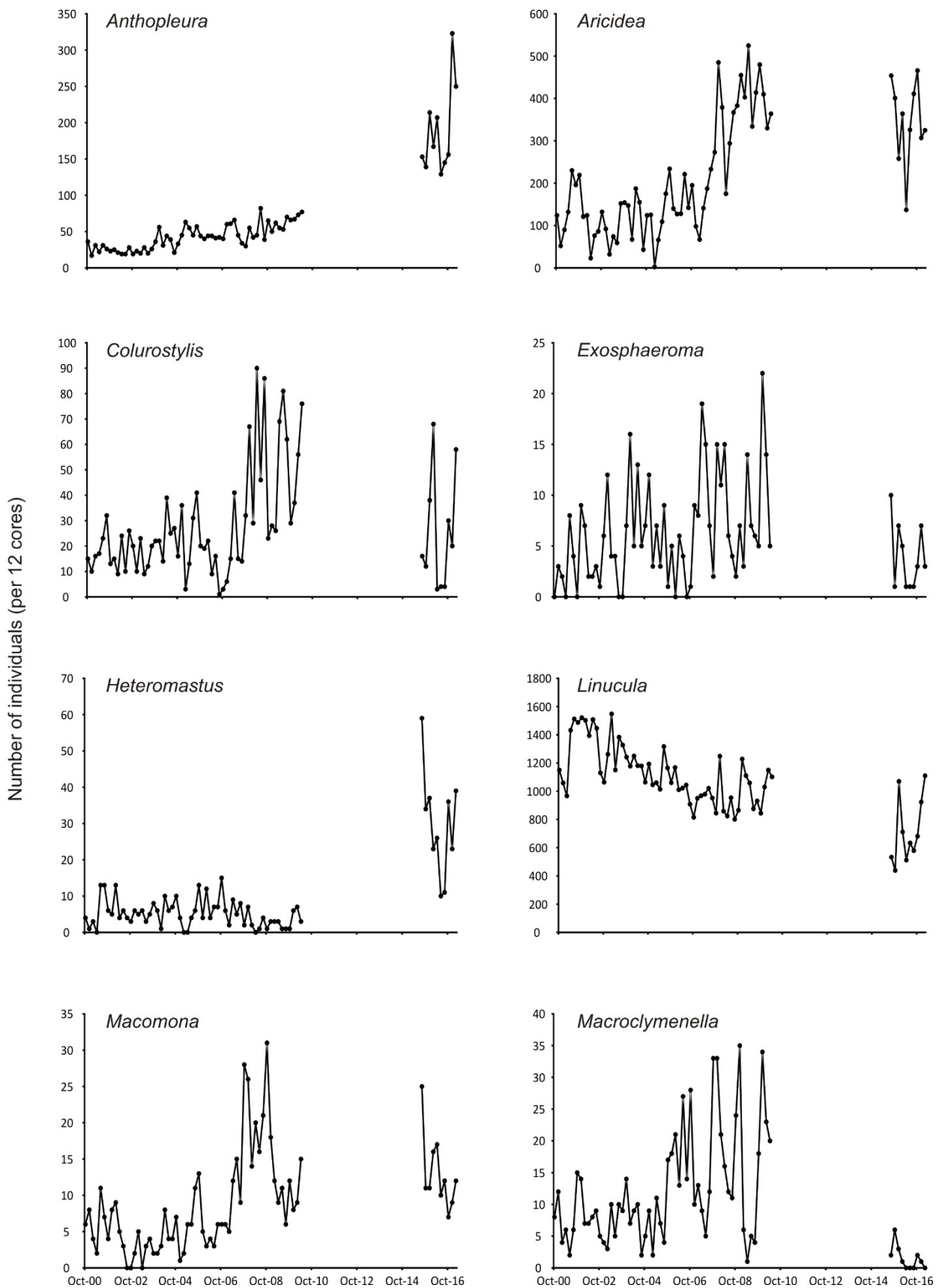


Figure 10. Temporal patterns in abundances of *Anthopleura aureoradiata*, *Aricidea*, *Colurostylis lemurum*, *Exosphaeroma* spp., *Heteromastus filiformis*, *Linucula hartvigiana*, *Macomona liliana* and *Macroclymenella stewartensis* at the HC site.

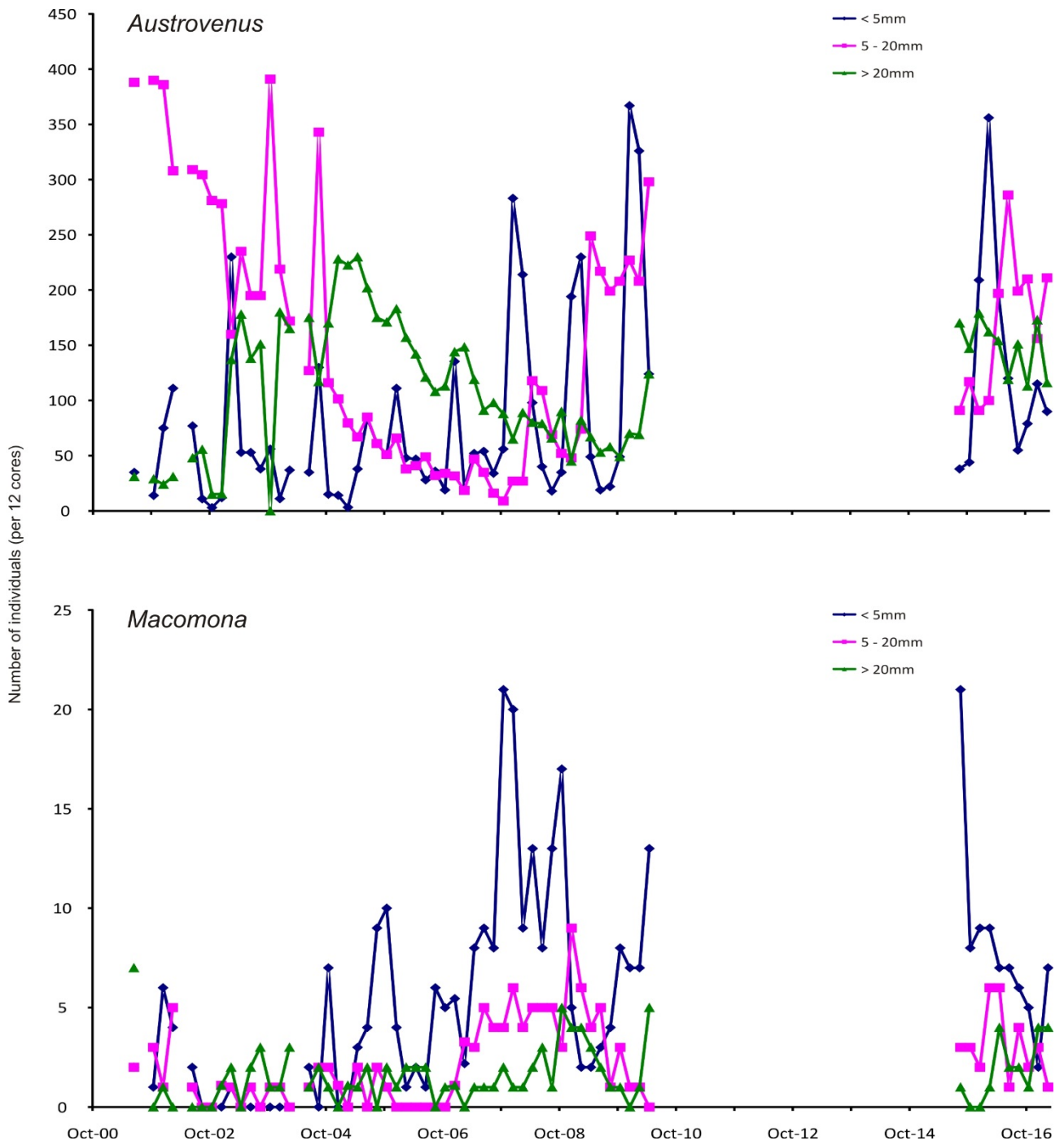


Figure 11. Trends in abundance of different size classes of the bivalves *Austrovenus stutchburyi* and *Macomona liliana* found at HC. No *Paphies australis* were present at HC.

3.2.5 Upper Shoal Bay (UpS)

Since monitoring at UpS began in August 2014 *Austrovenus* has been the most dominant species during every monitoring event. *Linucula* was the second most common species until February 2016, after which it was replaced by *Zeacumantus*. This is consistent with a large decline in the abundance of *Linucula* between December 2015 and February 2016. Other common species include *Prionospio* and *Aricidea*. After only two and a half years of monitoring it is too early to detect trends or changes in the monitored taxa over time.

Table 11. The three most abundant monitored taxa found over time at UpS.

Date	1 st	2 nd	3 rd
Oct-14	<i>Austrovenus</i>	<i>Linucula</i>	<i>Aricidea</i>
Oct-15	<i>Austrovenus</i>	<i>Linucula</i>	<i>Zeacumantus</i>
Oct-16	<i>Austrovenus</i>	<i>Zeacumantus</i>	<i>Aricidea</i>

3.3 Are species abundances exhibiting similar patterns at all sites?

There were some consistent trends in the abundance and types of species across the monitoring sites in the Central Waitematā Harbour.

There has been an increasing trend in the abundance of anemones, *Anthopleura*, at HBV and HC. Both HBV and HC have a considerable amount of shell hash (Plates 1 and 4), as well as large numbers of intermediate and adult sized *Austrovenus* present. Therefore these high abundances are likely to be facilitated by the availability of suitable attachment substrate.

Increasing trends were detected in silt-tolerant polychaetes at Reef (*Aricidea*, *Heteromastus* and *Prionospio*), HC (*Aricidea*, *Boccardia* and *Heteromastus*) and HBV (*Aricidea*, *Boccardia* and *Heteromastus*). All of these species have been assessed as preferring to live in muddy sands (Gibbs and Hewitt 2004). *Aricidea*, *Heteromastus* and *Prionospio* have a broad tolerance for sediments with a high silt content (Robertson and Stevens 2012), although *Prionospio* also is found in increased abundances in seagrass (Hewitt pers. comm.). Both Reef and HC have displayed increasing trends in mud content and, although there is no overall increase in mud content at HBV, there are patches of increased muddiness associated with the tidal drainage channel at the site. However, the abundances of *Heteromastus* and *Boccardia* at Whau show long multi-year cycles and the trend in abundance at HBV also shows signs of being a multiyear cycle. With both these sites showing long term multiyear cycles, the increases observed at the intermittently sampled Reef and HC may also be cycles rather than trends.

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

3.4.1 Changes in site characteristics

The changes in site characteristics of the Central Waitematā monitoring sites have been minimal. The only noticeable trends are the increasing mud content at Reef and HC (Figure 3). This increase at Reef is most likely due to the increasing coverage of seagrass and its ability to trap fine sediment. An increase in mud content at HC may be the result of more fine sediment being trapped either by the mangroves that fringe the site, or by the encroaching *Arcuatula*.

3.4.2 Changes in communities

In the last report (Parkes and Lundquist 2015) the multivariate analysis showed community composition at HBV and Whau was very distinct, while ShB and LoS exhibited high similarity. The sites at HBV and Whau, which have been monitored continuously since October 2000 still exhibit low variability (Figure 12). The site at HC, where sampling was suspended for five years as part of the temporal nesting monitoring strategy also exhibits very low variability. There was a slight shift between October 2009 and October 2015, but then by October 2016 this shift was reversed (Figure 12). In contrast to this, the site at Reef exhibits very high variability. Both Figure 12 and Figure 13 show how the site continues to track further away from its original state in October 2000. The variability at Reef was primarily driven by (1) increases in the polychaete species *Aricidea* and *Heteromastus* and the gastropod species *Notoacmea* (2) decreases in the bivalve species *Austrovenus* and *Linucula*, and the polychaete species *Euchone*. The changes in community composition at Reef are due to changes in species abundances rather than presence or absence of particular monitored species. This is evident in the 4th root ordination, which reduces the effect of extreme abundances (Figure 13). The 4th root ordination also shows Reef continuing to track away from all the other sites (Figure 13). The community composition of UpS is closest to that of Whau and HBV (Figure 12, Figure 13).

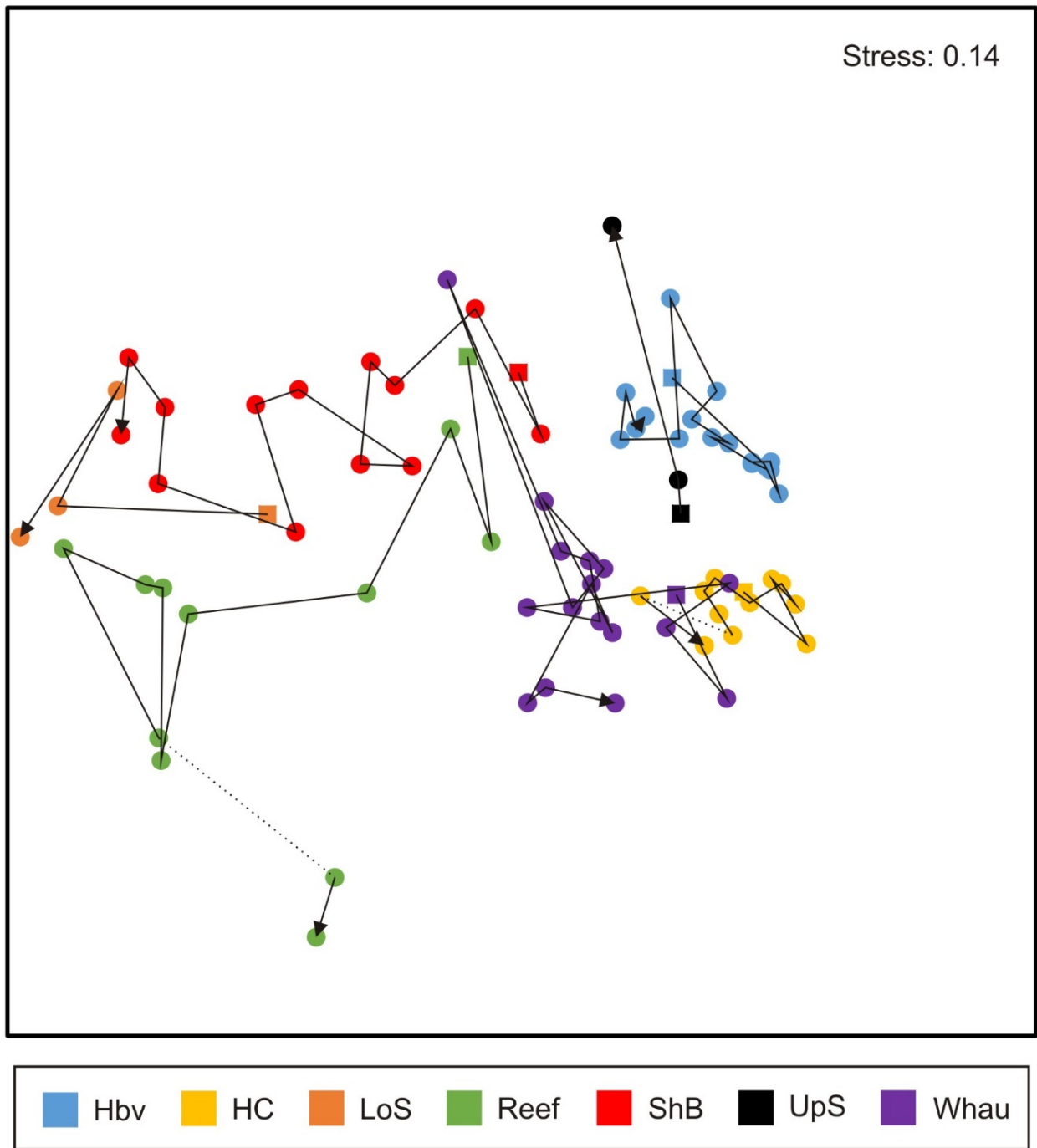


Figure 12. MDS ordination using Bray-Curtis similarity on the raw data of the monitored species from October data 2000-2016 at the seven sites (HBV, Whau, Reef, HC, UpS, ShB and LoS). The dotted line (....) indicates the five year period where sampling at Reef and HC was temporarily suspended. In 2014 sampling stopped at ShB and LoS, and started at UpS. MDS stress value of 0.14 indicates that this is a good two dimensional representation of the data.

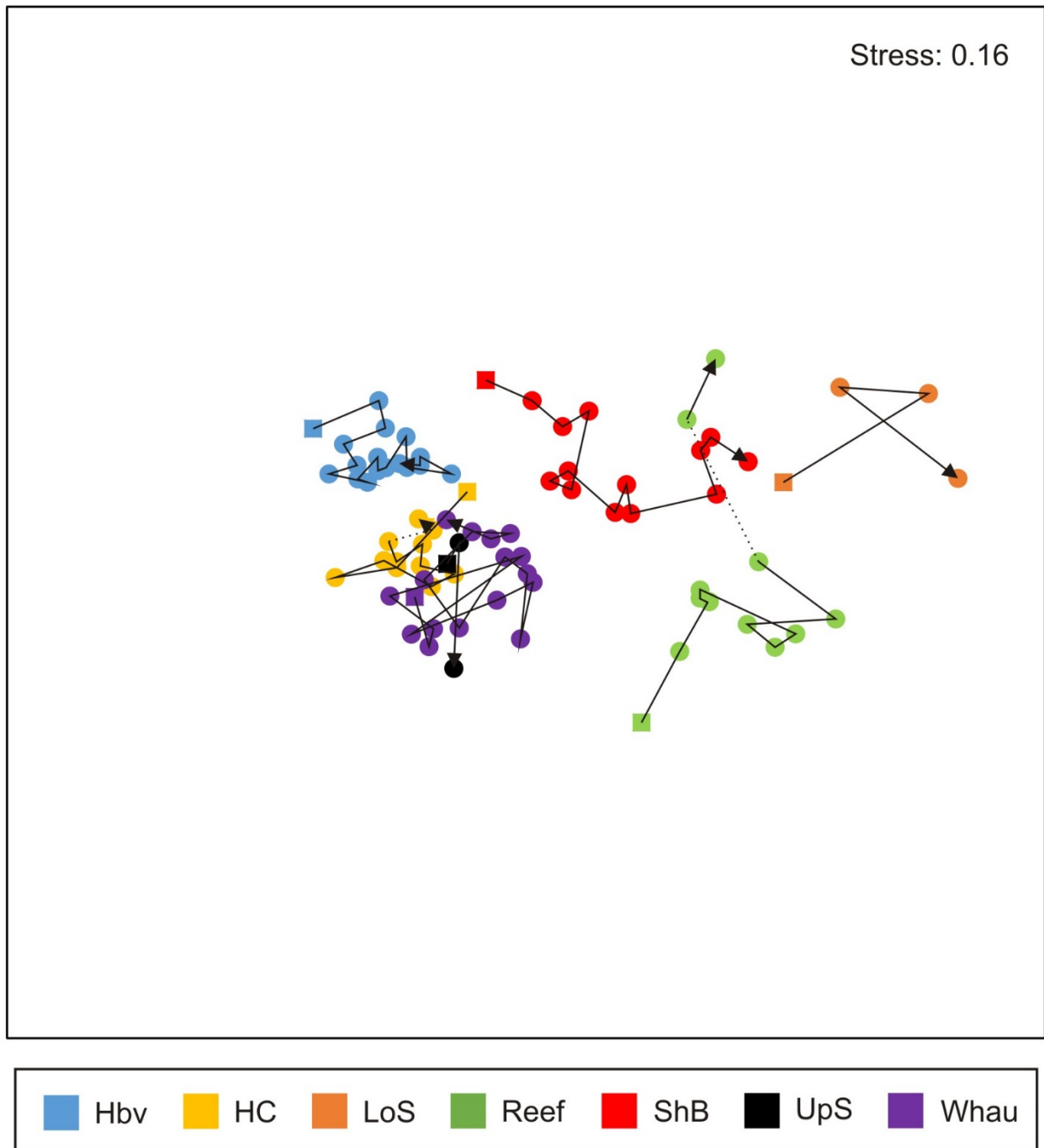


Figure 13. MDS ordination using Bray-Curtis similarity on the 4th root transformed data (reduces the effect of extreme abundances) of the monitored species from October data 2000-2016 of the seven sites (HBV, Whau, Reef, HC, UpS, ShB and LoS). The dotted line (...) indicates the five year period where sampling at Reef and HC was temporarily suspended. In 2014 sampling stopped at ShB and LoS, and started at UpS. MDS stress value of 0.16 indicates that this is a reasonably good two dimensional representation of the data.

3.4.3 *Nassarius burchardi*

The Australian dog whelk, *Nassarius (Plicarcularia) burchardi* (Dunker in Philippi, 1849) continues to be found throughout the Central Waitematā Harbour (Townsend et al. 2010, Townsend 2010, Halliday et al. 2012, Parkes & Lundquist 2015). Concerns over the impact of *Nassarius* stem from its opportunistic and predatory feeding behaviour on *Austrovenus* and *Paphies*. While abundances have increased at all the monitoring sites (especially Reef and HC) impacts of *Nassarius* on benthic communities in the Waitematā Harbour have not yet been observed.

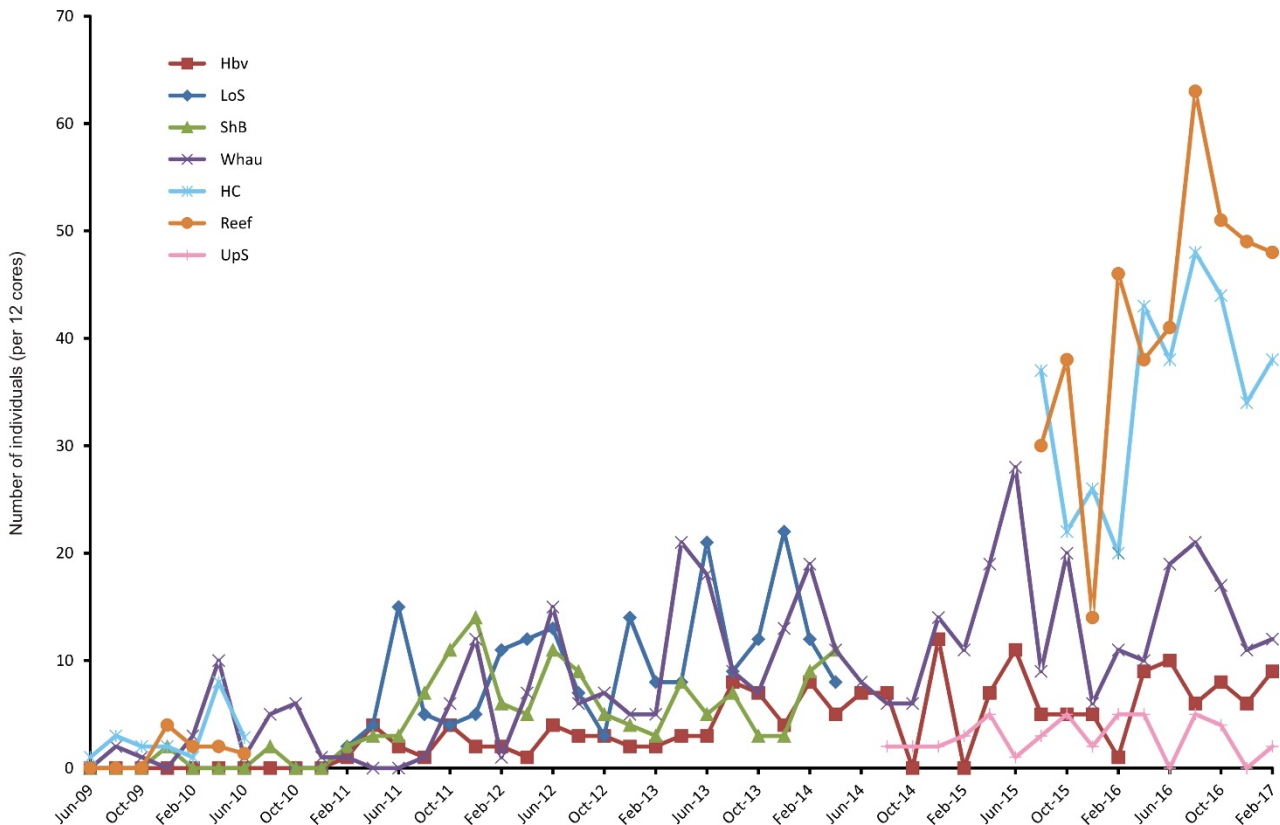


Figure 14. Trends in the abundance of *Nassarius burchardi* at all central Waitematā Harbour monitoring sites (HBV, HC, Reef, Whau, UpS, ShB and LoS) since it was first observed in June 2009. Note sampling at HC and Reef was temporarily suspended in April 2010 and then began again in August 2015. Sampling at the old Shoal Bay sites (ShB and LoS) stopped in June 2015, and the new site (UpS) started in August 2015.

4.0 State of the environment indicators

Organisms can be categorised according to characteristics (traits) that are likely to reflect ecosystem function (i.e., their feeding mode, degree of mobility, position in the sediment column, body size, body shape, capacity to create tubes/pits/mounds, etc.). During 2010 and 2011, an index based on these biological traits was created (van Houte-Howes and Lohrer 2010) and improved (Lohrer and Rodil 2011). Values of this index range from 0-1, with values close to 0 indicating low levels of functional redundancy and highly degraded sites. Values closest to 1 indicate high levels of functional redundancy, which is indicative of healthy areas (high functional redundancy tends to increase the inherent resistance and resilience in the face of environmental changes, Hewitt et al. (2012)).

Traits Based Index (TBI) scores have been calculated using the latest TBI formula (Lohrer and Rodil 2011) and October data from each site. In October 2000 the TBI scores for the monitored sites ranged from 0.29 at HBV to 0.44 at Whau. TBI scores for the five currently monitored sites range from 0.41 at UpS to 0.69 at Reef (Figure 15, Table 11). Interestingly, the values for the five monitored sites are typically quite similar to one another and tend to increase and decrease 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). The analysis of TBI scores in other locations within the Auckland area demonstrates that there can be natural variability in TBI scores over long timescales (Hewitt et al. 2012). Fluctuations in scores that are already >0.4 are generally of no concern; downward trends in TBI scores to values <0.3 would be concerning, indicating a strong reduction in functional redundancy.

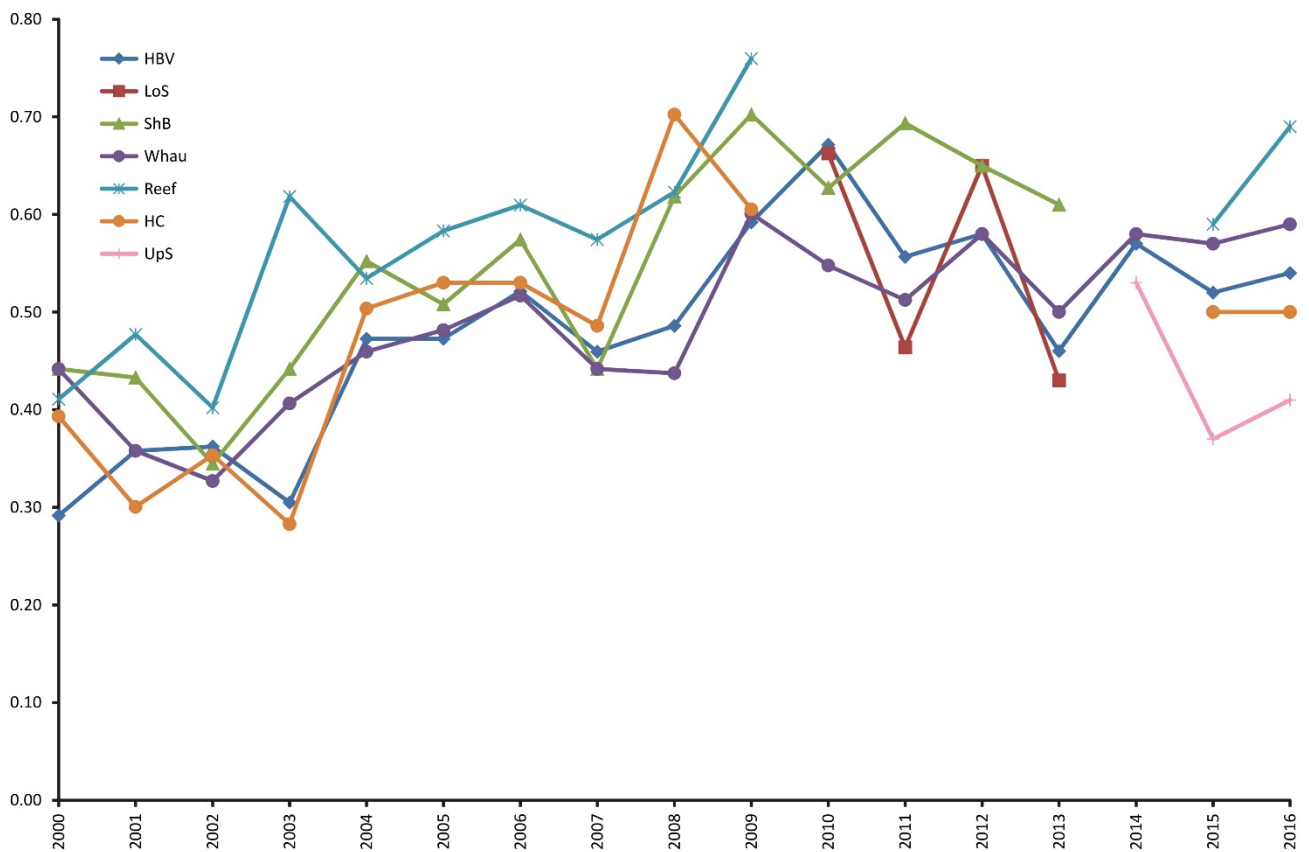


Figure 15. TBI scores for the five currently monitored sites (HBV, Whau, Reef, HC and UpS) and two previously monitored sites (ShB and LoS) during the monitoring period (October 2000-October 2016). Sampling at Reef and HC was suspended between 2010 and 2015, and sampling began at UpS in 2015. TBI scores are calculated from the entire macrobenthic fauna, not just the monitored taxa, found at each site during the October sampling.

Benthic health model scores for both mud and metals were also calculated (Table 11). Of all the currently monitored sites Reef has the highest scores for both metals and mud (i.e., lower health), although the scores are around the middle of the model range for both metals and mud, indicating moderate health. No consistent changes in direction were apparent for CAPmetal scores at any of the sites. However, an increase in CAPmud scores (decreasing health) was apparent for Reef suggesting the community is responding to the increases in mud content also observed. A comparison of the combined health scores (TBI and BHM) of the Central Waitematā monitored sites to sites that are part of other monitoring programs shows they are in relatively good condition (Figure 16).

Table 12. Benthic Health Model scores for metals and mud (CAPmetal, CAPmud), TBI scores and combined health scores for all monitoring sites in 2000 and 2009-2016. Health scores, “x”, are translated as: $x \leq 0.2$ “extremely good” (blue); $0.2 < x \leq 0.4$ “good” (green); $0.4 < x \leq 0.6$ “moderate” (yellow); $0.6 < x \leq 0.8$ “poor” (orange) and $x > 0.8$ “unhealthy with low resilience” (red). TBI scores in grey do not factor into the combined health score because CAPmud is < -0.12 (Group 1, blue; see Section 2.5.3). (Note: monitoring at ShB and LoS was stopped in 2014, monitoring at Reef and HC was suspended between 2010 and 2015, and monitoring at UpS did not begin until 2014.

Site	Year	CAPmetal	CAPmud	TBI	Combined health score
Hbv	2000	-0.116	-0.161	0.29	0.30
	2009	-0.095	-0.137	0.59	0.30
	2010	-0.117	-0.141	0.67	0.30
	2011	-0.156	-0.148	0.56	0.30
	2012	-0.111	-0.125	0.58	0.30
	2013	-0.099	-0.127	0.46	0.30
	2014	-0.093	-0.119	0.57	0.38
	2015	-0.087	-0.119	0.52	0.38
	2016	-0.096	-0.119	0.54	0.38
Whau	2000	-0.075	-0.125	0.44	0.30
	2009	-0.123	-0.122	0.60	0.30
	2010	-0.093	-0.127	0.55	0.30
	2011	-0.115	-0.130	0.51	0.30
	2012	-0.088	-0.102	0.58	0.38
	2013	-0.105	-0.123	0.50	0.30
	2014	-0.112	-0.111	0.58	0.38
	2015	-0.060	-0.094	0.57	0.44
	2016	-0.074	-0.113	0.59	0.38
HC	2000	-0.047	-0.114	0.41	0.44
	2009	-0.068	-0.110	0.60	0.38
	2015	-0.067	-0.096	0.50	0.38
	2016	-0.084	-0.106	0.50	0.38
Reef	2000	-0.103	-0.121	0.43	0.30
	2009	-0.048	-0.018	0.81	0.51

Site	Year	CAPmetal	CAPmud	TBI	Combined health score
	2015	-0.031	-0.008	0.59	0.51
	2016	-0.031	0.013	0.69	0.51
UpS	2014	-0.083	-0.120	0.53	0.38
	2015	-0.093	-0.138	0.37	0.30
	2016	-0.078	-0.095	0.41	0.38
ShB	2000	-0.080	-0.127	0.44	0.30
	2009	-0.082	-0.077	0.70	0.38
	2010	-0.081	-0.055	0.63	0.38
	2011	-0.100	-0.073	0.69	0.38
	2012	-0.086	-0.063	0.65	0.38
	2013	-0.081	-0.046	0.61	0.44
LoS	2010	-0.028	-0.014	0.66	0.51
	2011	-0.043	0.011	0.46	0.51
	2012	-0.019	-0.013	0.65	0.51
	2013	-0.018	0.025	0.43	0.58

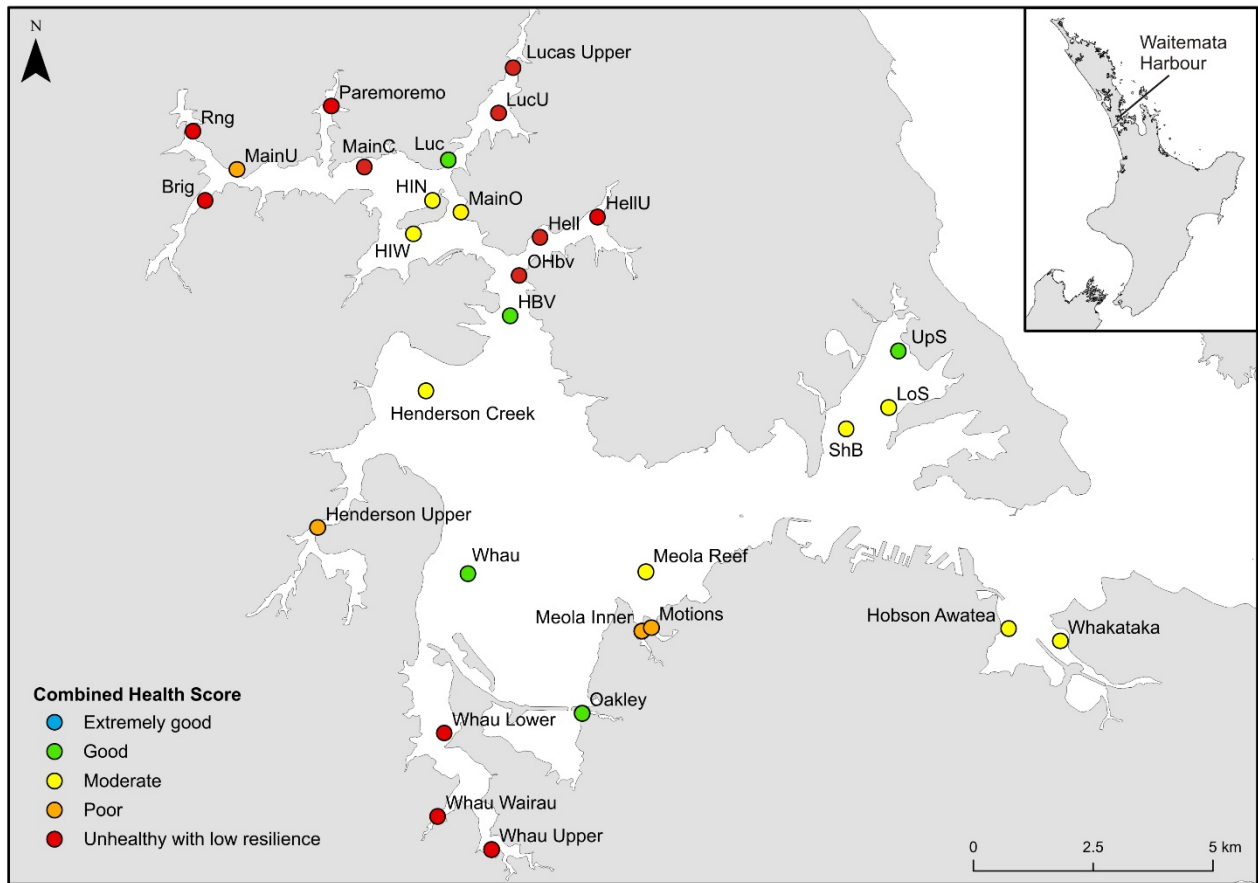


Figure 16. Map of the Waitematā Harbour showing October 2016 combined health scores (TBI and BHM) for all of the Central Waitematā sites (HBV, Whau, Reef, HC, UpS, ShB and LoS) as well as those sampled during other Auckland Council monitoring projects in the area (Upper Waitematā Harbour and Regional Discharge Programme).

5.0 Conclusions and recommendations

This report set out to determine changes in site characteristics and benthic macrofaunal species. Any changes detected then have to be assessed to determine whether they are either of concern already or may lead to concerns about the health either of the whole harbour or a section of it.

5.1 Have there been any changes in the characteristics of each site or of the surrounding areas?

There has been minimal change in the temporal variability of sediment characteristics at the Hobsonville (HBV) and Whau River (Whau) sites. There has, however, been a noticeable trend of increasing mud content at the Meola Reef (Reef) and Henderson Creek (HC) sites. At Reef this is most likely due to the increasing coverage of seagrass and its ability to trap fine sediment, and at HC this is possibly due to fine sediment being trapped either by the mangroves that fringe the site or by the encroaching patches of *Arcuatula*.

5.2 Have there been any changes in the monitored benthic communities of Central Waitematā Harbour and are these of concern?

The general patterns in macrofaunal species abundance and community composition occurring in the Central Waitematā Harbour are: (1) relatively minor changes at HBV, Whau and HC driven by seasonality and multi-year patterns in abundances and (2) slightly larger changes at Reef. The only trends in abundance observed in the Whau site are historic. At HBV there were trends in the abundance of five taxa in a direction that would be expected from increased sedimentation or increased fine sediments in the water column, although three of these may be long multi-year cycles. At HC there were trends in the abundance of four taxa in a direction that would be expected from increased sedimentation or increased fine sediments in the water column, with two of these potentially being long multi-year cycles. At the Reef site, changes in abundance were detected for five taxa that could either be a direct response to increased seagrass cover or mud content or in the case of *Heteromastus*, a potential multiyear cycle.

In earlier years it was suggested that the invasive species *Nassarius* may impact on bivalve populations. As *Nassarius* continues to increase at some sites an analysis was conducted comparing total abundances of *Austrovenus* and *Paphies* to abundances of *Nassarius*. No significant trends were detected at any of the sites, indicating that at the moment *Nassarius* is not having any noticeable impact on bivalve populations.

5.3 Are any changes observed confined to one site or area of the harbour, or do they reflect a harbour-wide change?

The changes observed are small and are confined to two areas of the harbour around Meola Reef and Henderson Creek/Hobsonville. They do not reflect a harbour-wide change. Moreover the present combined health scores, calculated from the Benthic Health Model and Traits Based Index scores, show that all five of the currently monitored sites in the Central Waitematā Harbour are in

moderate to good condition. However, sites in the upper parts of the Whau, Henderson, Meola and Motions tidal creeks continue to be ranked “poor” or “unhealthy”.

5.4 Has the renewed sampling at Reef and HC revealed any changes of concern that suggests they need to be monitored more regularly?

Sampling at the Reef and HC sites was resumed in August 2015, following the temporally nested sampling strategy of five years of no monitoring and two years of monitoring; the sampling of these sites ceases in August 2017. The rotational concept of sampling sites appears to be working well for the Central Waitematā Harbour monitoring programme and there were no marked changes that were unexpected. The data collected at Reef and HC from August 2015-February 2017 was not always consistent with the data previously observed for these sites (October 2000-April 2010) therefore, in many instances, the time signals were fitted against the permanently monitored sites (HBV and Whau) in order to obtain conclusive patterns and trends.

Changes observed in sediment mud content, the abundances of some monitored taxa and the macrofaunal community, consistent with increasing coverage of seagrass at Reef suggest the need for ongoing monitoring of seagrass cover at this site.

Increases in sediment mud content and the abundances of a few species together with the expanding patches of the invasive Asian date mussel near the HC site also suggest the need for ongoing monitoring of sediment mud content and the distance of date mussel patches from the site.

5.5 Recommendations for the monitoring programme

We recommend limited monitoring at Reef and HC post June 2017, rather than a full cessation. Reef should have seagrass cover monitored annually in October by photo quadrats and HC should have sediment grain size samples taken and the distance of the date mussel patches to the site estimated.

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. Monitoring at the old Shoal Bay sites (ShB and LoS) was stopped in 2014 and it was no longer considered effective due to the increased muddiness of the sites and the change in species abundance detected as a result. Analysis of the sediment and community data from the new site (UpS) that was introduced in August 2014 has shown that it is very different to the old Shoal Bay sites. The community composition of UpS is closest to that of Whau and HBV and contains a variety of species whose abundances would be sensitive to increased mud or contaminant concentrations. Therefore, it will be much more useful as an indicator site for increased sedimentation in the bay and we recommend its continued bimonthly monitoring.

We also recommend continuation of the bimonthly monitoring at Whau and HBV. The Whau site will be valuable as a time series against which to assess any changes observed in the Shoal Bay site. Site HBV should be continued to be monitored to determine whether the changes documented in this report continue.

6.0 Acknowledgements

Thanks to:

Luke Stanley, Ebrahim Hussain, and others from the Auckland Council team for assisting with the programme and conducting fieldwork.

Sarah Hailes, Lisa McCartain, Mike Meredyth-Young, Kit Squires, Barry Greenfield and Kelly Carter from NIWA for laboratory analysis.

7.0 References

- Anderson M J, Hewitt J E, Thrush S F (2002). Using a multivariate statistical model to define community health. Prepared by NIWA (ARC02221) for Auckland Regional Council. Auckland Regional Council technical publication, TP184.
- Anderson M J, Robinson J (2003). Generalized discriminant analysis based on distances. *Australian & New Zealand Journal of Statistics*, 45, 301-318.
- Anderson M J, Willis T J (2003). Canonical analysis of principal coordinates: a useful method of constrained ordination for ecology. *Ecology*, 84, 511-525.
- Anderson M J, Hewitt J E, Ford R B, Thrush S F (2006). Regional models of benthic ecosystem health: predicting pollution gradients from biological data. In: Auckland Regional Council technical publication, TP317.
- Gadd J, Coco G, Hewitt J (2009). Interactions between heavy metals, sedimentation and cockle feeding and movement Part 3. Auckland Regional Council Report. technical report, TR2010/023.
- Gibbs M, Hewitt J E (2004). Effects of sedimentation on macrofaunal communities: a synthesis of research studies for ARC. Prepared by NIWA for Auckland Regional Council. Auckland Regional Council technical publication, TP264.
- Green M (2008). Central Waitematā Harbour Contaminant Study. Predictions of Sediment, Zinc and Copper Accumulation under future Development Scenario 1. Prepared for Auckland Regional Council.
- Halliday J, Townsend M, Lundquist C (2012). Central Waitematā Harbour Ecological Monitoring: 2000-2012. Prepared by NIWA for Auckland Council. Auckland Council technical report, TR2012/027.
- Hewitt J E (2000). Design of a State of the Environment monitoring programme for the Auckland Marine Region. Report prepared by NIWA (ARC00205) for Auckland Regional Council. Auckland Regional Council technical publication, TP271.
- Hewitt J E, Thrush S F, Pridmore R D, Cummings V J (1994) Ecological monitoring programme for Manukau Harbour: Analysis and interpretation of data collected October 1987-February 1993. Prepared by NIWA for Auckland Regional Council. Auckland Regional Council technical publication, TP271.
- Hewitt J E, Ellis J (2010). Assessment of the benthic health model. Prepared by NIWA for Auckland Regional Council. Auckland Council technical report, TR2010/034.
- Hewitt J E, Lohrer A M, Townsend M (2012). Health of Estuarine Soft-sediment Habitats: continued testing and refinement of State of the Environment indicators. Prepared by Organisation for Auckland Council. Auckland Council technical report, TR2012/012.

Lohrer A M, Rodil I F (2011). Suitability of a new functional traits index as a state of the environment indicator. Prepared by NIWA for Auckland Council. Auckland Council technical report, TR2011/041.

Mook D H, Hoskin C M (1982). Organic determination by ignition: caution advised. *Estuarine Coastal and Shelf Science*, 15, 697-699.

Nicholls P, Hewitt J E, Hatton S (2002). Waitematā Harbour Ecological Monitoring Programme –results from the first year of sampling, October 2000-2001. Prepared by NIWA (ARC01271) for Auckland Regional Council. Auckland Regional Council, technical publication, TP225.

Parkes S M, Lundquist C (2015). Central Waitematā Harbour Ecological Monitoring: 2000-2014. Prepared by NIWA for Auckland Regional Council Auckland. Auckland Council technical report, TR2015/006.

Robertson B, Stevens L (2012). New River Estuary – Fine scale monitoring of highly eutrophic arms 2011/2012. Prepared by Wriggle Limited for Environment Southland.

Townsend M, Marshall B A, Greenfield B L (2010). First Records of the Australian dog whelk, *Nassarius (Plicarcularia) burchardi* (Dunker in Philippi, 1849) (Mollusca: Gastropoda) from New Zealand. *New Zealand Journal Marine and Freshwater Research*, 44: 343-348.

Townsend M, Lundquist C, Halliday J. (2008). Central Waitematā Harbour Ecological Monitoring: 2000-2008. Prepared by NIWA for Auckland Regional Council Auckland. Regional Council technical report, TR2008/017.

Townsend M, Lundquist C, Hewitt J (2010). Central Waitematā Harbour Ecological Monitoring 2000-2010. Prepared by NIWA for Auckland Regional Council. Auckland Regional Council technical report, TR2010/060.

van Houte-Howes K, Lohrer D (2010). State of Environment Indicators for Intertidal habitats in the Auckland Region. Prepared by NIWA for Auckland Regional Council. Auckland Regional Council technical report, TR2010/035.

Whitlatch R, Hines A, Thrush S, Hewitt J, Cummings V (1997). Benthic faunal responses to variations in patch density and patch size of a suspension-feeding bivalve inhabiting a New Zealand intertidal sand flat. *Journal of Experimental Marine Biology*, 216: 171-189.

8.0 Plates

Plate 1: The intertidal flat at the Hobsonville site (top), with a close-up of sediment from within the HBV site (bottom). Photos taken in December 2016.



Plate 2: The intertidal flat at the Whau River site (top), with a close-up of sediment from within the Whau site (bottom). Photos taken in December 2016.



Plate 3: The intertidal flat at the Meola Reef site (top), with a close-up of sediment from within the Reef site (bottom). Photos taken in December 2016.

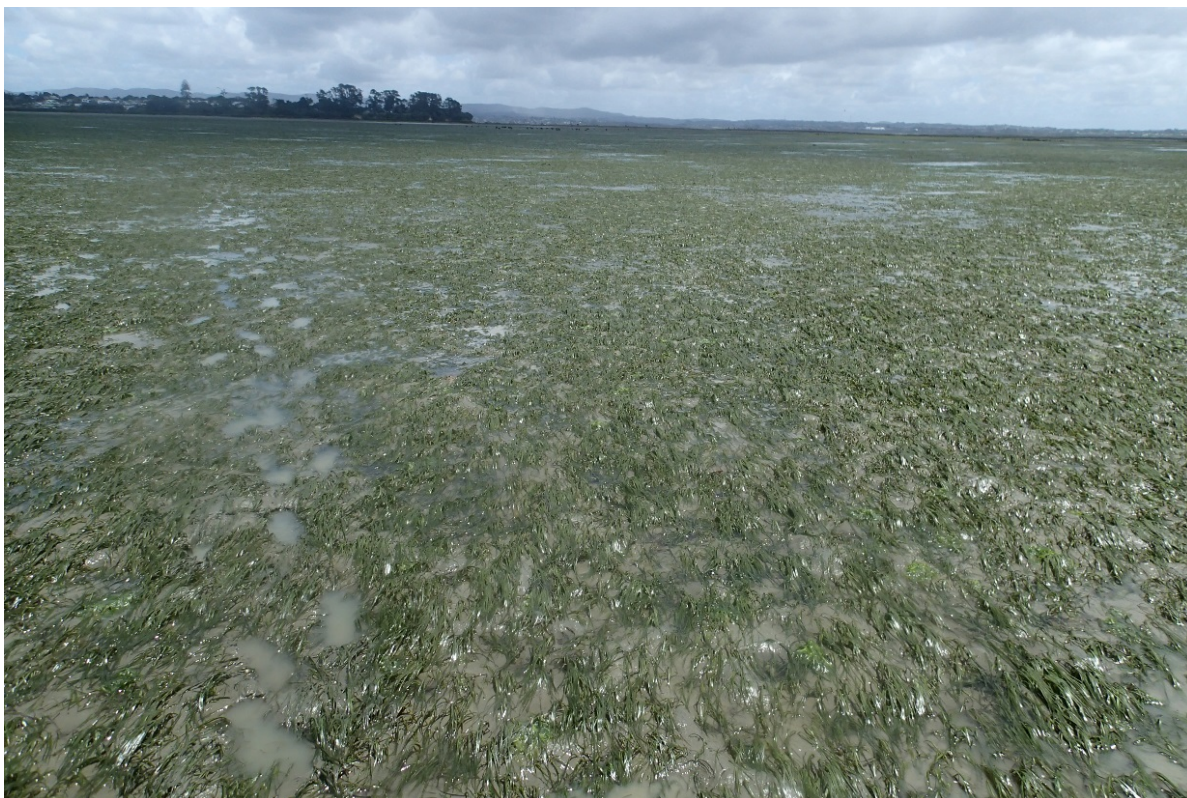


Plate 4: The intertidal flat at the Henderson Creek site (top), with a close-up of sediment from within the HC site (bottom). Photos taken in December 2016.



Plate 5: The transition zone between the shell hash dominant habitat and *Arcuatula* hummocks at the Henderson Creek site (top), with a close-up of the mussel hummocks (bottom). Photos taken in December 2016.



Plate 6: The intertidal flat at the Upper Shoal Bay site (top), with a close-up of sediment from within the UpS site (bottom). Photos taken in December 2016.



9.0 Appendices

9.1 Appendix A: Sampling coordinates

Site maps displaying the 12 macrofaunal coring positions in February 2017. Each site is divided into 12 sectors where one core is randomly collected from each and is not positioned within 5m from another core collected in the preceding six sampling occasions. Paces along the x and y axis of the site originate from a stake marking the lower left corner of the site (0,0 m).

x-coord	y-coord	#	paces x	paces y	x-coord	y-coord	#	paces-x	paces-y	x-coord	y-coord	#	paces-x	paces-y
16	20	1	16	20	15	23	1	15	23	2	9	1	2	9
16	58	2	0	38	17	46	2	2	23	13	53	2	11	44
5	81	3	-11	23	33	41	3	16	-5	44	30	3	31	-23
31	78	4	26	-3	37	17	4	4	-24	27	23	4	-17	-7
46	55	5	15	-23	80	18	5	43	1	65	16	5	38	-7
31	4	6	-15	-51	83	40	6	3	22	68	51	6	3	35
58	4	7	27	0	115	30	7	32	-10	90	52	7	22	1
73	49	8	15	45	91	3	8	-24	-27	85	2	8	-5	-50
64	82	9	-9	33	137	16	9	46	13	114	15	9	29	13
98	89	10	34	7	128	38	10	-9	22	122	54	10	8	39
91	53	11	-7	-36	154	37	11	26	-1	127	33	11	5	-21
88	30	12	-3	-23	171	12	12	17	-25	143	2	12	16	-31

	time= Whau HC LoS Feb-17
	time= Reef ShB Feb-17
	time= HBV Feb-17

9.2 Appendix B: Sediment characteristics October 2000-February 2017

Sediment characteristics including particle size as gravimetric %, % organics calculated from loss on ignition, and chlorophyll a (chl_a). June 2004 samples were lost prior to analysis. Sampling at sites Reef and HC was temporarily suspended between August 2010 and August 2015. Sampling at UpS did not start until August 2014.

Site	Date	%clay	%silt	%mud	%fine sand	%med sand	%coarse sand	% gravel	% organics	Chl a □g/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
	Dec-07	1.50	3.00	4.51	58.93	25.96	8.82	1.79	1.89	12.50
	Feb-08	2.46	0.82	3.28	56.54	32.59	7.19	0.40	1.54	13.64
	Apr-08	3.29	3.29	6.58	52.95	33.90	4.88	1.68	1.85	12.73
	Jun-08	1.72	1.15	2.87	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	Chl a \square /g/g
	Aug-08	0.13	2.71	2.83	54.06	37.27	4.91	0.93	1.15	16.27
	Oct-08	2.35	0.00	2.35	65.64	26.23	4.11	1.67	1.25	15.59
	Dec-08	2.39	2.05	4.43	48.40	33.48	11.14	2.55	1.98	12.49
	Feb-09	1.21	0.35	1.56	43.41	34.61	18.45	1.97	1.49	13.53
	Apr-09	2.78	0.28	3.05	58.39	32.80	4.79	0.96	0.91	17.19
	Jun-09	1.47	0.49	1.96	52.58	38.08	6.24	1.14	1.21	14.91
	Aug-09	1.21	1.81	3.02	53.79	33.33	7.65	2.22	1.57	14.67
	Oct-09	1.06	1.06	2.12	51.79	38.05	7.43	0.61	1.15	12.84
	Dec-09	2.61	1.45	4.07	37.53	47.49	9.88	1.03	1.47	12.61
	Feb-10	1.99	2.32	4.32	58.02	31.03	5.58	1.04	0.98	10.89
	Apr-10	1.91	1.53	3.44	51.92	36.15	5.19	3.30	1.33	10.77
	Jun-10	1.30	0.37	1.68	45.94	41.62	8.08	2.69	1.41	14.22
	Aug-10	1.74	0.87	2.61	53.86	34.77	6.97	1.78	1.43	10.66
	Oct-10	2.34	2.34	4.68	56.49	32.61	4.88	1.34	1.65	14.33
	Dec-10	0.87	2.02	2.89	43.18	41.87	8.50	3.56	1.62	15.48
	Feb-11	3.87	0.00	3.87	50.60	38.05	4.62	2.87	1.57	16.51
	Apr-11	2.76	1.38	4.15	44.92	39.78	6.27	4.89	1.36	18.00
	Jun-11	1.61	2.58	4.19	45.92	39.35	5.90	4.64	1.54	16.05
	Aug-11	4.00	1.00	5.00	46.24	39.54	5.59	3.63	2.18	16.16
	Oct-11	1.85	0.98	2.84	49.91	36.12	5.58	5.55	1.18	23.15
	Dec-11	1.97	2.18	4.15	53.38	31.77	5.05	5.65	1.64	14.10
	Feb-12	1.93	1.29	3.22	48.95	37.34	6.58	3.92	1.64	16.63
	Apr-12	0.80	0.60	1.39	40.43	47.10	6.73	4.35	1.32	16.85
	Jun-12	2.88	2.62	5.50	50.06	34.49	6.25	3.70	1.07	16.50
	Aug-12	4.55	1.88	6.43	54.53	31.52	5.76	1.75	0.99	16.05
	Oct-12	2.58	2.58	5.15	55.55	29.71	7.22	2.37	1.40	17.65
	Dec-12	2.00	1.33	3.33	52.81	37.69	4.96	1.21	0.74	17.20
	Feb-13	1.88	0.94	2.82	61.60	26.65	5.12	3.81	0.36	12.38
	Apr-13	3.99	2.18	6.17	55.40	31.32	5.09	2.01	0.91	17.88
	Jun-13	1.53	0.92	2.45	60.93	29.66	4.99	1.97	0.89	15.02
	Aug-13	3.04	2.78	5.82	56.49	29.91	5.85	1.93	1.20	17.78
	Oct-13	1.14	0.46	1.60	58.27	32.84	4.26	3.03	1.11	15.08
	Dec-13	2.83	1.41	4.24	53.22	36.11	5.45	0.99	0.96	15.22
	Feb-14	0.78	1.81	2.59	64.70	27.84	3.32	1.56	0.85	17.92
	Apr-14	2.35	1.04	3.39	63.95	26.20	3.21	3.25	0.98	13.84
	Jun-14	2.72	3.10	5.82	57.78	27.86	3.95	4.59	1.31	12.97
	Aug-14	1.46	0.29	1.76	67.18	24.45	4.48	2.13	0.86	11.92
	Oct-14	2.65	0.38	3.03	56.00	32.44	4.85	3.67	1.21	13.25
	Dec-14	1.95	0.98	2.93	56.67	29.60	4.51	6.30	1.29	13.18
	Feb-15	1.41	1.41	2.82	62.67	27.58	5.66	1.26	1.02	10.23
	Apr-15	2.61	1.74	4.34	68.25	22.49	3.85	1.06	1.15	13.74
	Jun-15	1.92	0.64	2.56	62.69	28.43	5.02	1.30	0.89	17.07
	Aug-15	2.58	1.72	4.30	55.87	27.50	6.79	5.55	1.19	15.00
	Oct-15	2.86	1.04	3.90	58.08	32.71	4.08	1.22	1.10	13.75
	Dec-15	2.20	0.82	3.02	58.48	31.70	5.93	0.87	1.08	11.40
	Feb-16	3.64	2.91	6.55	65.24	20.41	3.85	3.95	1.57	9.12
	Apr-16	3.17	1.32	4.49	59.83	25.44	4.82	5.41	1.08	11.83
	Jun-16	2.81	2.11	4.92	55.33	30.69	6.07	2.99	1.41	14.76
	Aug-16	2.43	0.81	3.24	53.71	35.26	5.94	1.85	0.73	13.63
	Oct-16	1.84	0.61	2.45	50.76	38.90	5.49	2.39	1.31	15.24
	Dec-16	1.83	1.05	2.88	51.80	31.08	5.15	9.11	1.75	16.70
	Feb-17	1.59	0.99	2.59	58.54	30.79	3.34	4.74	1.40	11.45
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

Site	Date	%clay	%silt	%mud	%fine sand	%med sand	%coarse sand	% gravel	% organics	Chl a \square /g
	Apr-01	0.02	3.17	3.19	82.15	14.23	0.26	0.16	1.42	7.04
	Jun-01	0.57	1.67	2.24	88.91	3.37	0.64	4.84	1.02	10.29
	Aug-01	0.85	1.84	2.69	94.48	1.81	0.65	0.36	0.90	7.03
	Oct-01	0.85	1.90	2.75	92.42	2.78	0.47	1.59	0.86	10.72
	Dec-01	0.53	1.38	1.91	91.65	1.10	0.34	5.00	2.86	11.10
	Feb-02	0.41	2.00	2.41	90.94	4.59	0.81	1.24	1.03	10.53
	Apr-02	1.06	1.06	2.12	95.48	1.29	0.43	0.68	0.93	10.03
	Jun-02	0.00	1.81	1.81	91.37	5.18	0.75	0.89	1.09	8.19
	Aug-02	0.00	1.81	1.81	92.44	2.49	0.54	2.72	1.07	10.67
	Oct-02	0.99	2.31	3.30	91.71	3.79	0.56	0.64	0.75	7.79
	Dec-02	1.70	0.57	2.26	94.94	1.57	0.49	0.73	0.58	8.48
	Feb-03	2.50	1.59	4.10	88.20	4.67	0.91	2.12	0.76	6.45
	Apr-03	0.80	2.41	3.21	92.25	2.19	0.52	1.83	0.80	6.63
	Jun-03	1.76	1.76	3.52	92.20	3.16	0.65	0.47	0.85	8.38
	Aug-03	1.91	0.00	1.91	95.10	1.98	0.59	0.42	0.80	6.37
	Oct-03	1.46	1.46	2.92	93.55	2.24	0.66	0.64	0.92	6.87
	Dec-03	0.80	4.01	4.81	91.87	2.09	0.35	0.89	0.87	5.62
	Feb-04	0.86	4.30	5.16	92.29	1.20	0.50	0.85	0.84	5.05
	Apr-04	0.00	5.10	5.10	93.48	0.97	0.45	0.00	0.58	8.72
	Jun-04									10.02
	Aug-04	2.00	1.33	3.33	94.22	1.51	0.88	0.05	0.16	13.28
	Oct-04	1.47	0.59	2.06	93.08	1.07	0.39	3.40	1.17	11.22
	Dec-04	1.33	2.65	3.98	93.68	1.55	0.80	0.00	2.03	11.79
	Feb-05	0.00	1.62	1.62	93.95	1.22	0.73	2.48	1.58	10.13
	Apr-05	1.94	3.23	5.16	88.73	1.26	0.60	4.24	1.28	7.36
	Jun-05	3.52	0.59	4.10	93.07	0.89	0.58	1.35	1.02	9.77
	Aug-05	2.74	2.19	4.93	91.40	1.37	0.71	1.59	0.63	12.94
	Oct-05	1.05	2.10	3.15	92.89	1.40	0.90	1.67	1.01	12.41
	Dec-05	1.54	0.00	1.54	96.07	1.22	0.42	0.75	1.19	7.19
	Feb-06	1.10	0.74	1.84	95.69	0.83	0.54	1.09	0.84	10.60
	Apr-06	1.96	1.96	3.92	92.11	1.29	0.76	1.93	0.48	11.44
	Jun-06	2.39	0.95	3.34	92.73	1.43	0.65	1.85	1.28	12.37
	Aug-06	1.46	2.29	3.75	93.08	1.45	0.68	1.04	1.25	14.44
	Oct-06	1.00	1.75	2.75	93.43	1.55	1.50	0.77	0.84	16.74
	Dec-06	2.32	0.58	2.90	93.74	1.72	0.96	0.68	0.98	13.87
	Feb-07	2.83	0.00	2.83	93.19	2.00	0.57	1.40	1.12	13.29
	Apr-07	2.09	1.77	3.86	91.61	1.56	0.80	2.17	0.85	11.47
	Jun-07	1.78	1.60	3.38	92.71	1.86	1.00	1.04	1.16	11.93
	Aug-07	0.27	1.09	1.37	94.93	1.41	0.56	1.74	0.99	14.67
	Oct-07	0.78	1.05	1.83	92.89	1.23	0.83	3.22	0.85	12.39
	Dec-07	2.03	0.00	2.03	91.51	1.53	0.86	4.06	1.02	12.73
	Feb-08	1.63	0.65	2.29	90.91	2.15	1.26	3.39	1.14	10.20
	Apr-08	2.15	0.00	2.15	92.77	1.62	0.72	2.74	0.98	9.86
	Jun-08	1.42	1.42	2.85	94.06	1.35	0.72	1.03	1.09	12.38
	Aug-08	3.04	1.75	4.79	89.12	1.83	0.96	3.30	0.95	15.59
	Oct-08	1.04	1.04	2.08	89.35	1.35	0.88	6.34	0.84	10.89
	Dec-08	3.64	2.43	6.06	91.83	1.97	0.13	0.00	0.95	7.97
	Feb-09	2.20	1.20	3.41	81.95	3.37	1.01	10.27	1.24	8.71
	Apr-09	1.33	0.95	2.29	90.33	5.61	0.69	1.08	1.00	11.47
	Jun-09	7.02	1.91	8.93	87.64	1.35	0.79	1.29	1.10	13.30
	Aug-09	1.04	0.35	1.39	94.18	1.63	0.83	1.97	0.92	13.30
	Oct-09	0.87	0.43	1.30	93.40	1.99	0.77	1.67	0.88	13.76
	Dec-09	4.05	1.45	5.49	91.22	1.99	0.35	0.94	1.10	13.29
	Feb-10	1.04	0.52	1.56	93.41	3.72	0.93	0.37	0.70	12.50
	Apr-10	2.76	0.23	2.99	93.33	2.64	0.55	0.49	1.06	14.90
	Jun-10	0.18	0.03	0.21	92.98	4.00	1.16	1.65	1.00	21.56

Site	Date	%clay	%silt	%mud	%fine sand	%med sand	%coarse sand	% gravel	% organics	Chl a \square g/g
	Aug-10	2.07	0.69	2.76	93.24	2.30	0.68	1.03	1.10	12.38
	Oct-10	1.00	1.99	2.99	93.60	1.90	0.60	0.91	1.16	13.30
	Dec-10	1.96	0.98	2.93	92.30	2.56	0.78	1.42	1.28	12.61
	Feb-11	0.72	0.48	1.20	86.15	5.99	0.72	5.93	1.20	21.78
	Apr-11	1.70	0.73	2.43	93.36	2.70	0.74	0.77	1.23	19.26
	Jun-11	1.22	1.22	2.43	90.82	2.29	0.91	3.55	1.14	16.51
	Aug-11	1.64	0.70	2.35	84.90	2.18	1.10	9.48	1.22	19.03
	Oct-11	1.46	1.32	2.78	91.81	1.79	0.85	2.77	0.98	17.65
	Dec-11	1.63	1.08	2.71	88.26	2.86	0.76	5.41	0.99	15.13
	Feb-12	1.60	0.46	2.06	85.61	2.48	0.68	9.17	1.49	15.02
	Apr-12	0.68	0.68	1.36	92.74	2.37	0.77	2.76	1.04	20.41
	Jun-12	1.87	0.62	2.49	94.61	1.54	0.50	0.87	1.00	21.32
	Aug-12	2.24	0.56	2.80	91.18	2.10	1.11	2.81	0.64	16.28
	Oct-12	1.92	0.96	2.39	91.78	2.61	0.81	1.92	0.71	16.97
	Dec-12	2.44	1.36	3.80	90.95	1.89	0.76	2.60	0.75	13.30
	Feb-13	1.61	0.64	2.26	92.50	1.75	0.74	2.75	0.36	10.89
	Apr-13	2.70	0.68	3.38	88.37	2.10	0.81	5.35	0.65	10.55
	Jun-13	1.66	1.33	2.99	94.49	1.49	0.51	0.52	0.67	15.36
	Aug-13	2.12	0.27	2.39	89.34	1.87	0.84	5.56	0.79	16.04
	Oct-13	1.73	0.86	2.59	93.83	1.77	0.95	0.86	0.87	15.63
	Dec-13	1.56	1.17	2.73	87.29	2.17	0.82	6.97	0.73	16.58
	Feb-14	1.02	1.28	2.30	86.70	1.61	0.44	8.95	0.72	18.77
	Apr-14	1.85	0.82	2.67	94.03	2.09	0.58	0.63	0.55	13.51
	Jun-14	0.97	0.32	1.29	92.67	4.62	1.20	0.22	0.92	12.05
	Aug-14	1.80	0.30	2.10	89.50	2.32	0.82	5.25	0.92	13.40
	Oct-14	1.76	0.59	2.35	90.39	1.72	0.61	4.93	0.88	14.43
	Dec-14	4.41	2.41	6.82	89.24	2.39	0.37	1.18	0.96	12.47
	Feb-15	1.39	1.74	3.13	90.27	1.75	0.67	4.19	0.95	8.94
	Apr-15	2.44	1.05	3.49	92.49	2.82	0.77	0.43	0.84	10.44
	Jun-15	2.10	0.90	3.01	91.42	2.10	1.14	2.32	0.93	13.25
	Aug-15	2.68	0.45	3.12	91.83	2.02	0.55	2.48	0.87	12.00
	Oct-15	2.89	0.64	3.54	90.87	2.67	1.44	1.49	0.84	12.31
	Dec-15	0.00	5.06	5.06	86.82	1.79	0.61	5.72	0.98	9.94
	Feb-16	2.04	0.76	2.80	88.54	3.09	1.04	4.52	0.98	9.04
	Apr-16	1.61	0.61	2.22	90.32	3.13	1.04	3.29	0.76	10.22
	Jun-16	2.21	1.23	3.43	91.60	2.69	0.80	1.47	1.13	11.77
	Aug-16	1.85	0.46	2.31	86.46	3.48	0.76	6.99	0.66	16.74
	Oct-16	1.68	0.75	2.42	91.33	2.09	0.65	3.50	1.05	14.79
	Dec-16	2.77	0.76	3.53	91.27	1.99	0.57	2.64	1.13	10.66
	Feb-17	2.24	1.12	3.36	92.55	2.54	0.77	0.78	0.79	9.39
Reef	Oct-00	0.59	3.50	4.09	91.80	3.77	0.28	0.06	0.90	7.28
	Dec-00	1.12	3.25	4.37	93.12	1.79	0.29	0.43	0.92	11.12
	Feb-01	1.17	4.22	5.39	90.81	2.78	0.18	0.85	1.09	10.51
	Apr-01	0.24	3.02	3.26	92.07	3.24	0.23	1.20	1.13	12.74
	Jun-01	1.04	3.87	4.91	91.43	2.78	0.19	0.68	1.26	15.02
	Aug-01	0.91	5.28	6.19	87.22	5.02	0.14	1.43	1.16	10.94
	Oct-01	0.67	2.76	3.43	89.44	5.21	0.26	1.67	0.74	10.54
	Dec-01	1.39	1.81	3.20	93.76	2.87	0.11	0.06	1.35	6.29
	Feb-02	0.32	2.58	2.90	87.20	8.37	0.92	0.62	1.02	19.31
	Apr-02	2.13	1.83	3.96	92.37	3.25	0.17	0.25	1.52	17.64
	Jun-02	1.98	3.30	5.27	91.51	3.11	0.10	0.00	1.14	12.65
	Aug-02	3.11	4.36	7.47	89.26	3.00	0.23	0.04	1.62	15.64
	Oct-02	3.63	1.45	5.08	92.25	1.67	0.11	0.89	1.04	10.46
	Dec-02	1.85	2.16	4.01	93.73	1.27	0.24	0.75	2.01	10.03
	Feb-03	1.91	1.91	3.82	93.32	2.56	0.19	0.12	1.13	7.24

Site	Date	%clay	%silt	%mud	%fine sand	%med sand	%coarse sand	% gravel	% organics	Chl a \square /g
	Apr-03	1.86	1.60	3.46	91.96	3.72	0.36	0.50	1.00	9.60
	Jun-03	0.94	4.72	5.67	87.22	7.11	0.00	0.00	2.00	11.92
	Aug-03	7.65	0.00	7.65	89.41	2.59	0.27	0.07	0.99	8.47
	Oct-03	2.70	4.04	6.74	90.29	2.59	0.27	0.12	1.08	6.42
	Dec-03	0.79	8.65	9.44	88.41	2.08	0.07	0.00	1.09	6.52
	Feb-04	1.55	6.19	7.74	89.12	2.97	0.11	0.06	1.24	6.74
	Apr-04	2.12	3.18	5.30	90.98	3.36	0.19	0.16	7.22	7.37
	Jun-04									8.69
	Aug-04	6.12	1.53	7.65	86.56	2.84	0.55	2.40	0.50	9.90
	Oct-04	4.85	1.62	6.47	91.82	1.67	0.04	0.00	1.20	5.36
	Dec-04	2.59	0.43	3.02	94.55	2.26	0.06	0.12	2.16	10.99
	Feb-05	3.67	0.00	3.67	94.85	1.15	0.29	0.04	1.78	7.91
	Apr-05	3.56	4.57	8.13	89.85	1.90	0.00	0.13	1.68	7.83
	Jun-05	4.04	2.69	6.74	87.26	3.93	0.27	1.81	1.28	6.76
	Aug-05	4.45	5.56	10.01	87.09	2.53	0.28	0.10	1.48	10.39
	Oct-05	2.65	4.97	7.61	90.31	1.90	0.11	0.07	1.64	18.45
	Dec-05	3.60	6.40	10.00	87.81	2.03	0.11	0.06	1.93	6.40
	Feb-06	3.00	3.85	6.85	91.58	1.32	0.23	0.02	1.43	7.93
	Apr-06	1.82	4.54	6.35	90.92	2.59	0.12	0.02	0.76	8.83
	Jun-06	2.70	1.35	4.04	93.16	2.24	0.19	0.36	1.86	10.43
	Aug-06	3.92	5.49	9.42	87.42	2.85	0.20	0.11	1.51	7.80
	Oct-06	3.83	4.22	8.05	88.68	3.05	0.22	0.00	1.73	7.80
	Dec-06	4.79	2.66	7.45	90.52	1.94	0.09	0.00	0.65	11.92
	Feb-07	3.63	6.22	9.85	88.31	1.74	0.09	0.00	1.78	12.49
	Apr-07	10.66	11.19	21.85	76.06	1.97	0.12	0.00	1.47	9.63
	Jun-07	3.21	4.01	7.22	89.86	2.60	0.13	0.19	1.47	8.94
	Aug-07	3.19	6.38	9.57	88.26	1.98	0.12	0.07	1.87	10.54
	Oct-07	4.46	5.09	9.55	87.57	2.52	0.30	0.06	1.41	11.92
	Dec-07	4.10	1.54	5.64	91.56	2.50	0.18	0.13	2.60	9.97
	Feb-08	4.24	3.63	7.87	90.18	1.76	0.18	0.01	1.65	10.78
	Apr-08	3.00	3.86	6.86	85.44	3.14	0.25	4.31	1.51	7.56
	Jun-08	4.93	4.93	9.85	88.48	1.55	0.10	0.02	1.63	8.71
	Aug-08	8.03	3.65	11.68	86.17	1.76	0.23	0.16	1.96	12.61
	Oct-08	3.71	4.64	8.36	86.09	2.22	0.07	3.26	1.48	6.42
	Dec-08	2.66	0.67	3.33	81.56	2.01	1.10	12.00	1.47	7.45
	Feb-09	5.56	1.01	6.57	80.68	7.53	0.37	4.85	1.52	8.36
	Apr-09	5.10	5.10	10.21	81.33	7.48	0.68	0.31	0.89	7.22
	Jun-09	7.15	8.45	15.59	81.80	2.26	0.14	0.20	1.92	7.57
	Aug-09	4.35	8.69	13.04	84.70	2.03	0.23	0.00	2.31	9.17
	Oct-09	5.35	4.76	10.11	87.66	1.93	0.20	0.10	1.87	8.02
	Dec-09	2.94	15.87	18.80	79.35	1.71	0.11	0.02	2.21	7.11
	Feb-10	6.35	7.05	13.40	78.61	6.31	0.51	1.17	1.81	6.07
	Apr-10	5.13	10.66	15.80	82.60	1.39	0.13	0.08	2.14	6.42
	Jun-10	3.49	6.60	10.09	88.20	1.53	0.14	0.04	1.52	7.45
	Aug-10	5.93	10.78	16.71	81.98	1.01	0.13	0.17	2.07	6.76
	Aug-15	5.26	4.68	9.94	88.19	1.80	0.07	0.00	1.48	6.46
	Oct-15	5.68	6.69	12.37	85.84	1.68	0.08	0.03	1.41	7.06
	Dec-15	4.12	6.66	10.78	86.65	2.40	0.16	0.00	1.48	6.93
	Feb-16	6.12	1.53	7.65	89.06	3.12	0.16	0.00	1.46	6.35
	Apr-16	5.28	4.52	9.80	87.70	2.29	0.21	0.00	1.29	6.42
	Jun-16	3.94	3.06	7.00	84.20	7.83	0.81	0.16	1.29	6.08
	Aug-16	4.96	7.66	12.61	85.26	2.03	0.09	0.00	1.30	6.07
	Oct-16	5.91	6.34	12.25	85.63	2.07	0.04	0.01	2.10	6.08
	Dec-16	5.07	5.07	10.14	88.12	1.67	0.07	0.00	1.72	7.91
	Feb-17	4.77	3.82	8.59	89.18	2.06	0.11	0.05	1.28	6.07

Site	Date	%clay	%silt	%mud	%fine sand	%med sand	%coarse sand	% gravel	% organics	Chl a \square /g/g
HC	Oct-00	0.43	3.57	4.00	55.08	23.92	9.36	7.64	1.61	9.53
	Dec-00	0.50	1.31	1.81	48.81	40.02	7.77	1.59	1.89	19.89
	Feb-01	0.45	1.92	2.37	50.99	37.74	8.05	0.85	1.75	17.99
	Apr-01	0.17	1.26	1.43	55.75	26.83	5.08	10.90	2.66	26.12
	Jun-01	0.57	1.47	2.04	58.03	31.22	7.96	0.74	2.65	29.61
	Aug-01	0.49	2.97	3.46	67.19	22.95	5.19	1.20	1.50	18.89
	Oct-01	0.53	1.76	2.30	58.56	30.63	7.43	1.08	1.46	21.67
	Dec-01	0.37	1.80	2.17	47.88	35.95	7.65	6.34	1.10	23.60
	Feb-02	0.13	3.53	3.66	52.76	25.84	11.42	6.33	2.55	16.58
	Apr-02	0.00	4.40	4.40	75.51	13.56	5.00	1.53	2.11	29.57
	Jun-02	3.15	0.00	3.15	74.86	15.05	3.82	3.12	2.08	26.77
	Aug-02	0.48	2.09	2.57	66.94	23.80	4.61	2.09	2.32	22.11
	Oct-02	3.73	2.66	6.39	75.07	13.30	3.24	2.00	2.04	22.49
	Dec-02	3.25	3.25	6.49	64.35	12.43	2.39	14.33	1.80	26.04
	Feb-03	2.51	3.35	5.86	72.52	13.85	4.06	3.70	1.77	29.99
	Apr-03	4.23	2.82	7.05	69.26	15.36	3.74	4.58	0.85	23.38
	Jun-03	3.78	1.89	5.67	35.11	52.55	3.16	3.50	1.19	31.70
	Aug-03	2.85	0.95	3.81	75.80	15.16	4.10	1.13	1.47	27.98
	Oct-03	0.83	5.42	6.26	77.57	12.42	2.70	1.05	1.90	20.34
	Dec-03	4.62	3.85	8.47	74.10	13.75	2.24	1.44	1.81	16.53
	Feb-04	3.13	4.70	7.83	74.91	12.75	3.05	1.46	1.92	23.81
	Apr-04	3.67	5.50	9.17	74.96	12.51	1.97	1.39	0.89	27.98
	Jun-04									18.80
	Aug-04	5.11	1.28	6.38	73.89	12.39	5.31	2.02	0.34	24.09
	Oct-04	4.62	2.77	7.39	71.92	17.67	3.03	0.00	2.85	19.92
	Dec-04	8.98	1.28	10.26	72.81	12.12	3.44	1.38	3.62	38.62
	Feb-05	2.67	4.46	7.13	75.56	12.19	2.51	2.60	4.74	37.79
	Apr-05	3.96	5.28	9.23	74.70	12.55	2.84	0.67	3.00	31.27
	Jun-05	3.93	1.57	5.50	77.36	13.39	3.25	0.50	2.37	25.63
	Aug-05	5.65	1.13	6.78	72.12	13.48	5.20	2.42	2.21	32.94
	Oct-05	5.21	4.26	9.47	77.16	10.86	2.01	0.49	2.24	18.41
	Dec-05	4.46	0.74	5.20	77.40	11.77	3.55	2.07	3.34	27.47
	Feb-06	0.47	5.64	6.11	76.45	14.29	2.44	0.72	2.18	16.28
	Apr-06	3.72	1.86	5.58	74.30	13.14	4.83	2.16	1.35	21.76
	Jun-06	1.98	2.47	4.45	77.34	13.99	3.63	0.59	2.36	23.40
	Aug-06	4.07	2.59	6.66	77.15	12.27	2.95	0.97	2.72	14.55
	Oct-06	6.29	2.52	8.81	73.85	11.48	2.52	3.34	2.51	25.22
	Dec-06	7.84	3.02	10.86	66.22	17.04	4.28	1.61	2.27	28.22
	Feb-07	1.01	3.30	4.31	77.09	12.63	3.65	2.32	1.41	28.20
	Apr-07	4.84	0.00	4.84	70.34	21.99	2.83	0.00	2.13	24.76
	Jun-07	2.58	2.32	4.90	72.27	14.71	4.75	3.37	2.27	27.50
	Aug-07	1.71	2.28	4.00	72.83	17.16	3.97	2.04	2.45	20.86
	Oct-07	1.89	2.27	4.16	70.60	18.99	4.89	1.36	1.77	23.60
	Dec-07	3.73	1.24	4.98	73.02	16.42	4.35	1.24	2.68	22.23
	Feb-08	3.74	3.20	6.94	72.28	14.68	3.87	2.23	2.28	22.93
	Apr-08	3.99	2.39	6.39	69.28	17.28	3.27	3.77	2.38	21.09
	Jun-08	3.67	3.21	6.88	72.98	14.32	3.88	1.95	2.21	23.15
	Aug-08	1.45	5.48	6.93	71.33	16.26	3.12	2.36	2.14	25.22
	Oct-08	2.83	3.30	6.12	71.97	15.04	3.05	3.81	2.18	25.91
	Dec-08	2.70	2.70	5.41	70.46	16.89	4.48	2.76	2.36	22.23
	Feb-09	2.27	3.41	5.68	60.80	27.44	5.41	0.67	2.14	27.50
	Apr-09	2.56	1.99	4.54	64.80	23.06	3.57	4.02	1.46	30.49
	Jun-09	2.75	0.55	3.30	76.57	16.95	2.83	0.36	1.74	32.56
	Aug-09	2.41	2.01	4.43	64.98	21.05	4.81	4.72	2.41	28.43
	Oct-09	3.13	2.61	5.74	72.95	15.72	4.44	1.15	2.31	33.02
	Dec-09	6.56	3.28	9.84	66.49	18.97	3.69	1.00	2.40	26.14

Site	Date	%clay	%silt	%mud	%fine sand	%med sand	%coarse sand	% gravel	% organics	Chl a □g/g
	Feb-10	5.86	2.66	8.52	67.90	17.09	3.63	2.86	2.18	25.23
	Apr-10	4.64	3.68	8.32	69.69	16.31	4.09	1.59	2.83	24.07
	Jun-10	4.47	1.86	6.33	72.51	16.35	3.84	0.97	2.31	28.20
	Aug-10	4.67	2.33	7.00	70.61	15.48	4.29	2.63	2.40	19.94
	Aug-15	4.79	3.59	8.38	71.86	13.56	3.08	3.13	2.01	28.78
	Oct-15	5.22	4.47	9.69	68.17	15.46	3.75	2.92	1.75	24.94
	Dec-15	7.50	4.06	11.57	68.50	14.84	3.81	1.28	2.04	28.11
	Feb-16	3.30	1.89	5.18	72.01	16.93	4.81	1.07	2.01	30.94
	Apr-16	3.57	3.57	7.13	66.75	17.39	6.19	2.54	1.66	32.80
	Jun-16	6.55	5.68	12.23	70.42	13.05	2.92	1.38	2.23	35.31
	Aug-16	5.87	5.45	11.32	68.22	13.47	3.50	3.48	1.18	33.72
	Oct-16	6.28	4.32	10.60	67.76	13.94	3.31	4.39	2.58	31.60
	Dec-16	7.82	5.98	13.81	65.68	13.23	5.04	2.24	2.58	33.44
	Feb-17	4.74	2.37	7.11	69.09	15.00	5.72	3.08	2.33	26.36
UpS	Aug-14	2.84	2.13	4.97	90.96	1.84	0.21	2.03	1.00	15.79
	Oct-14	3.61	3.21	6.82	90.32	1.50	0.44	0.93	1.21	19.01
	Dec-14	3.11	1.56	4.67	91.58	1.28	0.56	1.91	1.14	20.29
	Feb-15	2.75	3.09	5.84	92.32	0.80	0.40	0.65	0.74	12.17
	Apr-15	4.46	4.01	8.47	89.15	1.26	0.50	0.62	1.20	23.00
	Jun-15	3.64	2.55	6.20	92.04	1.04	0.46	0.26	0.79	24.92
	Aug-15	3.38	2.42	5.80	91.48	1.09	0.24	1.39	1.02	24.94
	Oct-15	2.09	1.04	3.13	92.33	1.12	0.54	2.88	0.99	21.28
	Dec-15	2.52	1.08	3.60	89.70	0.95	0.58	5.17	0.95	22.39
	Feb-16	4.41	3.15	7.56	90.46	0.83	0.65	0.50	1.44	14.92
	Apr-16	6.65	7.44	14.09	81.02	0.95	0.34	3.60	1.43	12.03
	Jun-16	5.11	4.25	9.36	88.22	1.41	0.16	0.84	1.36	10.20
	Aug-16	3.33	3.61	6.95	90.42	1.36	0.46	0.82	0.71	12.84
	Oct-16	3.43	2.18	5.61	82.45	0.79	0.55	10.60	1.37	11.34
	Dec-16	3.56	2.27	5.83	85.53	0.89	0.38	7.38	1.15	13.75
	Feb-17	3.00	2.00	5.00	83.01	0.94	0.25	10.79	0.78	9.27

9.3 Benthic invertebrate data collected between April 2014 and February 2017

Total and average abundances (n = 12 replicate macrofauna core samples) of monitored taxa at each site since the last monitoring report. A “-” symbol denotes no sample collected as sampling at the site was temporarily suspended (Reef and HC) or had not yet begun (UpS).

Anthopleura aureoradiata

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	66	6	21	2	-	-	-	-	-	-
83	Jun-14	79	7	31	3	-	-	-	-	-	-
84	Aug-14	32	3	12	1	-	-	-	-	7	1
85	Oct-14	63	5	10	1	-	-	-	-	9	1
86	Dec-14	77	6	38	3	-	-	-	-	5	0
87	Feb-15	77	6	23	2	-	-	-	-	9	1
88	Apr-15	66	6	30	3	-	-	-	-	8	1
89	Jun-15	76	6	23	2	-	-	-	-	8	1
90	Aug-15	81	7	7	1	0	0	153	13	10	1
91	Oct-15	76	6	16	1	0	0	139	12	7	1
92	Dec-15	80	7	11	1	1	0	214	18	12	1
93	Feb-16	71	6	18	2	2	0	167	14	14	1
94	Apr-16	79	7	19	2	4	0	207	17	16	1
95	Jun-16	74	6	16	1	1	0	129	11	5	0
96	Aug-16	75	6	18	2	0	0	145	12	4	0
97	Oct-16	64	5	24	2	1	0	156	13	7	1
98	Dec-16	74	6	32	3	2	0	323	27	12	1
99	Feb-17	90	8	54	5	6	1	250	21	13	1

Aonides trifida

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	271	23	2	0	-	-	-	-	-	-
83	Jun-14	297	25	3	0	-	-	-	-	-	-
84	Aug-14	342	29	4	0	-	-	-	-	2	0
85	Oct-14	352	29	3	0	-	-	-	-	0	0
86	Dec-14	288	24	4	0	-	-	-	-	3	0
87	Feb-15	299	25	1	0	-	-	-	-	0	0
88	Apr-15	300	25	4	0	-	-	-	-	0	0
89	Jun-15	340	28	2	0	-	-	-	-	1	0
90	Aug-15	431	36	7	1	0	0	2	0	0	0
91	Oct-15	296	25	0	0	2	0	3	0	0	0
92	Dec-15	297	25	2	0	1	0	7	1	1	0
93	Feb-16	316	26	2	0	2	0	12	1	0	0
94	Apr-16	316	26	3	0	1	0	5	0	1	0
95	Jun-16	335	28	4	0	0	0	7	1	0	0
96	Aug-16	324	27	1	0	1	0	5	0	2	0
97	Oct-16	306	26	3	0	2	0	4	0	0	0
98	Dec-16	365	30	3	0	1	0	5	0	2	0
99	Feb-17	250	21	4	0	0	0	2	0	1	0

Aricidea

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	41	3	361	30	-	-	-	-	-	-
83	Jun-14	39	3	470	39	-	-	-	-	-	-
84	Aug-14	49	4	455	38	-	-	-	-	60	5
85	Oct-14	62	5	571	48	-	-	-	-	69	6
86	Dec-14	73	6	652	54	-	-	-	-	37	3
87	Feb-15	34	3	516	43	-	-	-	-	25	2
88	Apr-15	48	4	705	59	-	-	-	-	32	3
89	Jun-15	44	4	564	47	-	-	-	-	6	1
90	Aug-15	35	3	522	44	897	75	454	38	49	4
91	Oct-15	60	5	595	50	767	64	401	33	28	2
92	Dec-15	54	5	523	44	537	45	258	22	21	2
93	Feb-16	52	4	505	42	620	52	364	30	31	3
94	Apr-16	49	4	500	42	710	59	137	11	11	1
95	Jun-16	52	4	553	46	899	75	326	27	26	2
96	Aug-16	51	4	650	54	812	68	411	34	32	3
97	Oct-16	79	7	832	69	791	66	466	39	32	3
98	Dec-16	56	5	668	56	813	68	307	26	23	2
99	Feb-17	51	4	686	57	573	48	325	27	28	2

Arthritica bifurca

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	6	1	3	0	-	-	-	-	-	-
83	Jun-14	1	0	7	1	-	-	-	-	-	-
84	Aug-14	2	0	6	1	-	-	-	-	13	1
85	Oct-14	5	0	6	1	-	-	-	-	13	1
86	Dec-14	5	0	4	0	-	-	-	-	2	0
87	Feb-15	2	0	10	1	-	-	-	-	0	0
88	Apr-15	17	1	8	1	-	-	-	-	2	0
89	Jun-15	5	0	13	1	-	-	-	-	4	0
90	Aug-15	18	2	11	1	14	1	17	1	5	0
91	Oct-15	10	1	7	1	18	2	20	2	5	0
92	Dec-15	10	1	5	0	41	3	39	3	6	1
93	Feb-16	6	1	13	1	28	2	32	3	2	0
94	Apr-16	14	1	23	2	5	0	14	1	4	0
95	Jun-16	7	1	18	2	3	0	35	3	9	1
96	Aug-16	13	1	11	1	6	1	1	0	23	2
97	Oct-16	6	1	1	0	5	0	15	1	18	2
98	Dec-16	0	0	3	0	3	0	27	2	16	1
99	Feb-17	9	1	4	0	1	0	22	2	6	1

Austrovenus stutchburyi

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	165	14	79	7	-	-	-	-	-	-
83	Jun-14	178	15	69	6	-	-	-	-	-	-
84	Aug-14	144	12	58	5	-	-	-	-	473	39
85	Oct-14	134	11	136	11	-	-	-	-	472	39
86	Dec-14	189	16	385	32	-	-	-	-	430	36
87	Feb-15	220	18	327	27	-	-	-	-	436	36
88	Apr-15	233	19	125	10	-	-	-	-	526	44
89	Jun-15	245	20	75	6	-	-	-	-	388	32
90	Aug-15	190	16	51	4	4	0	299	25	528	44
91	Oct-15	175	15	76	6	19	2	308	26	442	37
92	Dec-15	169	14	328	27	22	2	479	40	427	36
93	Feb-16	314	26	380	32	20	2	618	52	438	37
94	Apr-16	287	24	153	13	6	1	548	46	327	27
95	Jun-16	207	17	127	11	1	0	525	44	347	29
96	Aug-16	211	18	58	5	7	1	405	34	387	32
97	Oct-16	164	14	75	6	6	1	402	34	374	31
98	Dec-16	147	12	198	17	9	1	444	37	357	30
99	Feb-17	170	14	104	9	2	0	417	35	412	34

Boccardia syrtis

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	9	1	44	4	-	-	-	-	-	-
83	Jun-14	15	1	35	3	-	-	-	-	-	-
84	Aug-14	9	1	65	5	-	-	-	-	4	0
85	Oct-14	11	1	35	3	-	-	-	-	9	1
86	Dec-14	17	1	83	7	-	-	-	-	3	0
87	Feb-15	18	2	220	18	-	-	-	-	7	1
88	Apr-15	35	3	271	23	-	-	-	-	8	1
89	Jun-15	26	2	138	12	-	-	-	-	2	0
90	Aug-15	19	2	145	12	130	11	60	5	2	0
91	Oct-15	28	2	112	9	72	6	48	4	7	1
92	Dec-15	30	3	93	8	80	7	75	6	7	1
93	Feb-16	26	2	128	11	134	11	63	5	21	2
94	Apr-16	26	2	92	8	141	12	71	6	10	1
95	Jun-16	36	3	88	7	69	6	68	6	16	1
96	Aug-16	35	3	60	5	177	15	81	7	5	0
97	Oct-16	16	1	61	5	200	17	39	3	9	1
98	Dec-16	17	1	217	18	67	6	17	1	7	1
99	Feb-17	3	0	209	17	50	4	33	3	7	1

Colurostylis lemurum

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	131	11	78	7	-	-	-	-	-	-
83	Jun-14	93	8	77	6	-	-	-	-	-	-
84	Aug-14	63	5	68	6	-	-	-	-	17	1
85	Oct-14	65	5	19	2	-	-	-	-	5	0
86	Dec-14	46	4	20	2	-	-	-	-	9	1
87	Feb-15	20	2	24	2	-	-	-	-	6	1
88	Apr-15	65	5	26	2	-	-	-	-	4	0
89	Jun-15	80	7	29	2	-	-	-	-	8	1
90	Aug-15	118	10	32	3	2	0	16	1	6	1
91	Oct-15	93	8	43	4	44	4	12	1	11	1
92	Dec-15	41	3	7	1	1	0	38	3	1	0
93	Feb-16	51	4	35	3	2	0	68	6	1	0
94	Apr-16	22	2	34	3	1	0	3	0	0	0
95	Jun-16	45	4	11	1	0	0	4	0	1	0
96	Aug-16	100	8	67	6	9	1	4	0	11	1
97	Oct-16	152	13	151	13	7	1	30	3	6	1
98	Dec-16	109	9	67	6	2	0	20	2	4	0
99	Feb-17	148	12	101	8	0	0	58	5	18	2

Diloma subrostrata

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	8	1	3	0	-	-	-	-	-	-
83	Jun-14	10	1	0	0	-	-	-	-	-	-
84	Aug-14	7	1	2	0	-	-	-	-	6	1
85	Oct-14	13	1	1	0	-	-	-	-	4	0
86	Dec-14	11	1	3	0	-	-	-	-	5	0
87	Feb-15	5	0	3	0	-	-	-	-	4	0
88	Apr-15	14	1	9	1	-	-	-	-	6	1
89	Jun-15	14	1	6	1	-	-	-	-	3	0
90	Aug-15	11	1	4	0	0	0	23	2	8	1
91	Oct-15	7	1	3	0	1	0	10	1	5	0
92	Dec-15	3	0	4	0	0	0	9	1	4	0
93	Feb-16	22	2	2	0	0	0	19	2	7	1
94	Apr-16	22	2	11	1	0	0	11	1	8	1
95	Jun-16	13	1	4	0	0	0	6	1	3	0
96	Aug-16	11	1	5	0	0	0	15	1	6	1
97	Oct-16	9	1	10	1	0	0	22	2	3	0
98	Dec-16	13	1	2	0	0	0	26	2	2	0
99	Feb-17	7	1	7	1	0	0	11	1	5	0

Euchone

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	0	0	0	0	-	-	-	-	-	-
83	Jun-14	0	0	0	0	-	-	-	-	-	-
84	Aug-14	0	0	0	0	-	-	-	-	0	0
85	Oct-14	0	0	0	0	-	-	-	-	0	0
86	Dec-14	0	0	0	0	-	-	-	-	0	0
87	Feb-15	0	0	0	0	-	-	-	-	0	0
88	Apr-15	0	0	0	0	-	-	-	-	0	0
89	Jun-15	0	0	0	0	-	-	-	-	0	0
90	Aug-15	0	0	0	0	1	0	0	0	0	0
91	Oct-15	0	0	0	0	2	0	0	0	0	0
92	Dec-15	0	0	0	0	0	0	0	0	0	0
93	Feb-16	1	0	0	0	0	0	0	0	0	0
94	Apr-16	0	0	0	0	0	0	0	0	0	0
95	Jun-16	0	0	0	0	0	0	0	0	0	0
96	Aug-16	0	0	0	0	0	0	0	0	0	0
97	Oct-16	0	0	0	0	0	0	0	0	0	0
98	Dec-16	0	0	0	0	0	0	0	0	0	0
99	Feb-17	0	0	0	0	0	0	0	0	0	0

Exosphaeroma spp.

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	2	0	0	0	-	-	-	-	-	-
83	Jun-14	1	0	0	0	-	-	-	-	-	-
84	Aug-14	9	1	0	0	-	-	-	-	1	0
85	Oct-14	9	1	0	0	-	-	-	-	5	0
86	Dec-14	18	2	2	0	-	-	-	-	1	0
87	Feb-15	16	1	0	0	-	-	-	-	4	0
88	Apr-15	13	1	2	0	-	-	-	-	3	0
89	Jun-15	8	1	2	0	-	-	-	-	2	0
90	Aug-15	13	1	0	0	0	0	10	1	2	0
91	Oct-15	8	1	0	0	0	0	1	0	0	0
92	Dec-15	20	2	2	1	0	0	7	1	2	0
93	Feb-16	38	3	0	1	0	0	5	0	1	0
94	Apr-16	4	0	2	1	0	0	1	0	1	0
95	Jun-16	5	0	0	1	0	0	1	0	1	0
96	Aug-16	1	0	0	1	0	0	1	0	0	0
97	Oct-16	9	1	1	1	0	0	3	0	3	0
98	Dec-16	18	2	4	1	0	0	7	1	0	0
99	Feb-17	26	2	1	1	1	0	3	0	0	0

Glycera americana

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	5	0	6	1	-	-	-	-	-	-
83	Jun-14	3	0	6	1	-	-	-	-	-	-
84	Aug-14	2	0	1	0	-	-	-	-	1	0
85	Oct-14	8	1	5	0	-	-	-	-	1	0
86	Dec-14	4	0	6	1	-	-	-	-	1	0
87	Feb-15	1	0	3	0	-	-	-	-	1	0
88	Apr-15	3	0	4	0	-	-	-	-	1	0
89	Jun-15	2	0	3	0	-	-	-	-	2	0
90	Aug-15	0	0	2	0	1	0	3	0	1	0
91	Oct-15	2	0	1	0	1	0	0	0	2	0
92	Dec-15	2	0	2	0	5	0	1	0	2	0
93	Feb-16	3	0	4	0	11	1	5	0	0	0
94	Apr-16	3	0	5	0	11	1	7	1	0	0
95	Jun-16	1	0	1	0	11	1	3	0	0	0
96	Aug-16	1	0	3	0	3	0	0	0	0	0
97	Oct-16	1	0	1	0	4	0	3	0	0	0
98	Dec-16	2	0	4	0	8	1	5	0	1	0
99	Feb-17	0	0	5	0	5	0	9	1	0	0

Haminoea zelandiae

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	0	0	0	0	-	-	-	-	-	-
83	Jun-14	0	0	0	0	-	-	-	-	-	-
84	Aug-14	0	0	0	0	-	-	-	-	0	0
85	Oct-14	0	0	0	0	-	-	-	-	1	0
86	Dec-14	0	0	3	0	-	-	-	-	0	0
87	Feb-15	0	0	0	0	-	-	-	-	3	0
88	Apr-15	0	0	0	0	-	-	-	-	1	0
89	Jun-15	0	0	2	0	-	-	-	-	0	0
90	Aug-15	1	0	0	0	0	0	0	0	0	0
91	Oct-15	0	0	1	0	0	0	0	0	0	0
92	Dec-15	0	0	0	0	0	0	0	0	2	0
93	Feb-16	0	0	0	0	0	0	0	0	0	0
94	Apr-16	0	0	0	0	0	0	0	0	0	0
95	Jun-16	0	0	0	0	0	0	0	0	0	0
96	Aug-16	0	0	0	0	7	1	0	0	0	0
97	Oct-16	0	0	0	0	0	0	0	0	0	0
98	Dec-16	0	0	0	0	0	0	0	0	0	0
99	Feb-17	0	0	2	0	0	0	0	0	0	0

Heteromastus filiformis

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	17	1	4	0	-	-	-	-	-	-
83	Jun-14	19	2	12	1	-	-	-	-	-	-
84	Aug-14	30	3	9	1	-	-	-	-	10	1
85	Oct-14	32	3	11	1	-	-	-	-	6	1
86	Dec-14	28	2	19	2	-	-	-	-	4	0
87	Feb-15	7	1	10	1	-	-	-	-	4	0
88	Apr-15	27	2	13	1	-	-	-	-	2	0
89	Jun-15	16	1	3	0	-	-	-	-	7	1
90	Aug-15	24	2	5	0	807	67	59	5	5	0
91	Oct-15	28	2	4	0	667	56	34	3	7	1
92	Dec-15	21	2	5	0	617	51	37	3	1	0
93	Feb-16	8	1	4	0	599	50	23	2	0	0
94	Apr-16	12	1	4	0	788	66	26	2	7	1
95	Jun-16	10	1	6	1	966	81	10	1	0	0
96	Aug-16	11	1	3	0	833	69	11	1	5	0
97	Oct-16	15	1	3	0	869	72	36	3	10	1
98	Dec-16	17	1	12	1	903	75	23	2	8	1
99	Feb-17	21	2	9	1	702	59	39	3	6	1

Macomona liliana

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	21	2	45	4	-	-	-	-	-	-
83	Jun-14	21	2	45	4	-	-	-	-	-	-
84	Aug-14	18	2	44	4	-	-	-	-	30	3
85	Oct-14	19	2	35	3	-	-	-	-	22	2
86	Dec-14	21	2	32	3	-	-	-	-	30	3
87	Feb-15	13	1	29	2	-	-	-	-	29	2
88	Apr-15	21	2	55	5	-	-	-	-	33	3
89	Jun-15	26	2	67	6	-	-	-	-	27	2
90	Aug-15	28	2	43	4	9	1	25	2	25	2
91	Oct-15	21	2	35	3	7	1	11	1	34	3
92	Dec-15	17	1	29	2	5	0	11	1	21	2
93	Feb-16	12	1	28	2	7	1	16	1	27	2
94	Apr-16	38	3	32	3	9	1	17	1	17	1
95	Jun-16	27	2	30	3	4	0	10	1	22	2
96	Aug-16	30	3	21	2	4	0	12	1	16	1
97	Oct-16	25	2	17	1	1	0	7	1	28	2
98	Dec-16	23	2	21	2	4	0	9	1	21	2
99	Feb-17	21	2	14	1	0	0	12	1	24	2

Macroclymenella stewartensis

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	5	0	23	2	-	-	-	-	-	-
83	Jun-14	9	1	8	1	-	-	-	-	-	-
84	Aug-14	2	0	11	1	-	-	-	-	11	1
85	Oct-14	5	0	43	4	-	-	-	-	13	1
86	Dec-14	6	1	41	3	-	-	-	-	7	1
87	Feb-15	3	0	18	2	-	-	-	-	1	0
88	Apr-15	1	0	10	1	-	-	-	-	0	0
89	Jun-15	3	0	21	2	-	-	-	-	2	0
90	Aug-15	0	0	16	1	10	1	2	0	6	1
91	Oct-15	4	0	53	4	11	1	6	1	4	0
92	Dec-15	2	0	49	4	15	1	3	0	9	1
93	Feb-16	0	0	31	3	7	1	1	0	0	0
94	Apr-16	2	0	13	1	11	1	0	0	0	0
95	Jun-16	2	0	12	1	2	0	0	0	0	0
96	Aug-16	1	0	14	1	16	1	0	0	1	0
97	Oct-16	1	0	33	3	20	2	2	0	3	0
98	Dec-16	7	1	45	4	16	1	1	0	1	0
99	Feb-17	3	0	43	4	7	1	0	0	6	1

Notoacmea scapha

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	85	7	8	1	-	-	-	-	-	-
83	Jun-14	132	11	33	3	-	-	-	-	-	-
84	Aug-14	117	10	25	2	-	-	-	-	53	4
85	Oct-14	107	9	32	3	-	-	-	-	54	5
86	Dec-14	102	9	48	4	-	-	-	-	54	5
87	Feb-15	106	9	16	1	-	-	-	-	19	2
88	Apr-15	68	6	19	2	-	-	-	-	13	1
89	Jun-15	72	6	29	2	-	-	-	-	16	1
90	Aug-15	58	5	87	7	67	6	161	13	16	1
91	Oct-15	142	12	146	12	47	4	88	7	40	3
92	Dec-15	109	9	34	3	82	7	102	9	22	2
93	Feb-16	127	11	34	3	26	2	49	4	9	1
94	Apr-16	60	5	11	1	3	0	38	3	2	0
95	Jun-16	86	7	30	3	7	1	40	3	7	1
96	Aug-16	92	8	86	7	52	4	154	13	30	3
97	Oct-16	92	8	132	11	37	3	236	20	29	2
98	Dec-16	90	8	88	7	82	7	285	24	19	2
99	Feb-17	52	4	43	4	39	3	143	12	15	1

Linucula hartvigiana

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	193	16	182	15	-	-	-	-	-	-
83	Jun-14	168	14	232	19	-	-	-	-	-	-
84	Aug-14	221	18	174	15	-	-	-	-	440	37
85	Oct-14	178	15	100	8	-	-	-	-	469	39
86	Dec-14	294	25	393	33	-	-	-	-	500	42
87	Feb-15	238	20	158	13	-	-	-	-	376	31
88	Apr-15	272	23	191	16	-	-	-	-	347	29
89	Jun-15	264	22	159	13	-	-	-	-	342	29
90	Aug-15	198	17	114	10	8	1	533	44	470	39
91	Oct-15	242	20	172	14	6	1	439	37	341	28
92	Dec-15	197	16	273	23	7	1	1070	89	386	32
93	Feb-16	225	19	427	36	8	1	711	59	5	0
94	Apr-16	206	17	268	22	30	3	512	43	25	2
95	Jun-16	152	13	172	14	12	1	633	53	5	1
96	Aug-16	172	14	235	20	17	1	579	48	20	3
97	Oct-16	220	18	326	27	6	1	681	57	31	3
98	Dec-16	227	19	434	36	3	0	924	77	19	2
99	Feb-17	224	19	342	29	2	0	1110	93	51	4

Paphies australis

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	5	0	0	0	-	-	-	-	-	-
83	Jun-14	12	1	0	0	-	-	-	-	-	-
84	Aug-14	6	1	0	0	-	-	-	-	0	0
85	Oct-14	5	0	0	0	-	-	-	-	0	0
86	Dec-14	11	1	0	0	-	-	-	-	0	0
87	Feb-15	5	0	0	0	-	-	-	-	0	0
88	Apr-15	0	0	0	0	-	-	-	-	0	0
89	Jun-15	8	1	0	0	-	-	-	-	0	0
90	Aug-15	11	1	0	0	0	0	1	0	0	0
91	Oct-15	4	0	1	0	0	0	0	0	0	0
92	Dec-15	4	0	0	0	0	0	0	0	0	0
93	Feb-16	18	2	2	0	0	0	0	0	0	0
94	Apr-16	14	1	0	0	10	1	0	0	0	0
95	Jun-16	28	2	0	0	0	0	0	0	0	0
96	Aug-16	23	2	0	0	1	0	0	0	0	0
97	Oct-16	12	1	0	0	0	0	0	0	0	0
98	Dec-16	5	0	0	0	0	0	0	0	0	0
99	Feb-17	10	1	0	0	0	0	2	0	0	0

Prionospio aucklandica

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	143	12	16	1	-	-	-	-	-	-
83	Jun-14	111	9	20	2	-	-	-	-	-	-
84	Aug-14	96	8	9	1	-	-	-	-	97	8
85	Oct-14	114	10	15	1	-	-	-	-	37	3
86	Dec-14	115	10	12	1	-	-	-	-	36	3
87	Feb-15	102	9	13	1	-	-	-	-	60	5
88	Apr-15	121	10	14	1	-	-	-	-	38	3
89	Jun-15	126	11	16	1	-	-	-	-	47	4
90	Aug-15	107	9	5	0	131	11	36	3	22	2
91	Oct-15	79	7	14	1	39	3	34	3	29	2
92	Dec-15	84	7	7	1	86	7	38	3	25	2
93	Feb-16	66	6	9	1	94	8	42	4	4	0
94	Apr-16	70	6	14	1	127	11	47	4	15	1
95	Jun-16	55	5	10	1	146	12	51	4	1	0
96	Aug-16	56	5	17	1	83	7	42	4	9	1
97	Oct-16	55	5	26	2	169	14	50	4	8	1
98	Dec-16	80	7	20	2	161	13	72	6	3	0
99	Feb-17	76	6	18	2	69	6	114	10	17	1

Zeacumantus lutulentus

Series	Date	HBV		Whau		Reef		HC		UpS	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean
82	Apr-14	4	0	4	0	-	-	-	-	-	-
83	Jun-14	11	1	1	0	-	-	-	-	-	-
84	Aug-14	11	1	7	1	-	-	-	-	38	3
85	Oct-14	5	0	2	0	-	-	-	-	17	1
86	Dec-14	8	1	4	0	-	-	-	-	26	2
87	Feb-15	12	1	0	0	-	-	-	-	30	3
88	Apr-15	7	1	3	0	-	-	-	-	33	3
89	Jun-15	11	1	3	0	-	-	-	-	36	3
90	Aug-15	9	1	5	0	0	0	18	2	40	3
91	Oct-15	7	1	1	0	0	0	10	1	49	4
92	Dec-15	12	1	4	0	0	0	12	1	38	3
93	Feb-16	9	1	5	0	1	0	27	2	49	4
94	Apr-16	28	2	4	0	0	0	4	0	45	4
95	Jun-16	11	1	3	0	0	0	21	2	43	4
96	Aug-16	18	2	5	0	0	0	17	1	52	4
97	Oct-16	27	2	3	0	0	0	16	1	62	5
98	Dec-16	13	1	3	0	0	0	28	2	35	3
99	Feb-17	26	2	5	0	0	0	27	2	37	3

Find out more: phone 09 301 0101, email rimu@aucklandcouncil.govt.nz or visit aucklandcouncil.govt.nz and knowledgeauckland.org.nz