Manukau Harbour Ecological Monitoring Programme:
Report on data collected up until February 2011

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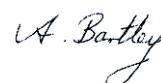
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Executive Summary

This report updates the results of the Manukau Harbour Ecological Monitoring Programme, which was established in October 1987 as an initiative of the Auckland Regional Council (now Auckland Council). The original programme was designed to provide: stocktaking of resources under stewardship; feedback on harbour management activities; and a baseline against which future cause-effect or impact studies could be conducted. The programme is a spatially and temporally nested design with two intertidal sites permanently monitored bimonthly (Auckland Airport and Clarks Beach). Intertidal sites at Elletts Beach, Karaka Point and Puhinui Stream alternate monitored with unmonitored years on a cycle of five years off, two years on. Monitoring of the intertidal site at Cape Horn initially followed this cycle, but monitoring began again prior to the removal of the waste water treatment ponds at Mangere in 2001. Selected macrofaunal taxa are monitored at all sites; carefully selected to provide different responses to environmental changes. Annually in October all macrofaunal taxa are enumerated in order for the sampling to be used in the Auckland Council's Benthic Health Model.

Prior to the last report in 2009, abundances of the majority of the monitored species at the Auckland Airport (AA) and Clarks Beach (CB) sites exhibited multi-year cycles with small and non-significant overall change in community composition. Recently two species (the cockle *Austrovenus* and the limpet *Notoacmea*) from CB have shown larger than previously observed recruitment events; however, these may be part of long-term multi-year cycles. Since 2009, temporal patterns in the abundance of monitored species continue to be similar across all sites (AA, CB and CH).

The most significant changes observed over the whole monitored period occurred at Cape Horn (CH) between 2000 and 2005 as a result of a strong El Niño Southern Oscillation (ENSO) and the decommissioning of the Mangere waste water treatment ponds in May 2001. Little change has occurred since 2005 and a new stable community appears to have evolved. For this reason, a decision was taken in June 2010 to halt continuous monitoring at this site and return to rotational monitoring.

There have been no major changes in the sediment characteristics during the last two years, with sediment chlorophyll *a* concentrations, grain size and percentage organic matter maintaining levels observed in February 2009.

Overall, there is no evidence of detrimental effects on ecosystem health (supported by application of the Benthic Health Model and the NIWACOOBII functional traits index) within the extensive intertidal flats that make up the main body of the Manukau Harbour. We recommend that bimonthly monitoring at Auckland Airport and Clarks Beach continue to maintain the integrity of this data set. This data set is important as it provides a time series against which other sites in the Manukau, as well as sites from the Mahurangi, Kaipara and Waitemata Ecological Monitoring Programs are assessed.

1 Introduction

In October 1987, the Water Quality Centre (now NIWA) was commissioned to design and implement a biological monitoring programme for Manukau Harbour (see Thrush et al. 1988 for details). This was initiated in light of concerns for the harbour, due to changing land developments and potential impacts that anthropogenic catchment practices may have on harbour health. Six intertidal sandflat sites around the harbour were chosen as representative areas, associated with the main inlets to the harbour (Figure 2.1). The sites were monitored in order to document ecological changes in the intertidal sandflat communities on a harbour-wide basis and to provide information relevant for ecosystem management. This was the first harbour-wide ecological monitoring conducted in New Zealand. For cost effectiveness, it was based on the abundance of 23 taxa which were selected for their community importance and to provide a range of responses to different anthropogenic impacts and environmental conditions (Appendix 7.1). This increases the ability of the monitoring programme to detect important community changes.

When monitoring began it was envisaged that six sites would be continuously monitored for five years, and then the cost-effectiveness of this monitoring would be assessed. In 1993, the programme was reduced to continuous monitoring of the Auckland Airport (AA) and Clarks Beach (CB) sites only (based on a spatially and temporally nested design, recommended by Hewitt et al. 1994). A programme of alternating monitoring of all sites and reduced sites has continued since then (refer to Section 2.1 and Table 2.1)

The data obtained from monitoring the intertidal estuarine sediments at Manukau Harbour has been invaluable with respect to enhancing our knowledge of long term trends and multi-year cycles, natural variability in taxa abundances and responses of taxa to both environmental (i.e., El Niño Southern Oscillation patterns; Hailes and Hewitt 2009) and anthropogenic disturbances (i.e., decommissioning of the Mangere wastewater treatment plant; Funnell et al. 2003). Furthermore, the data has been a pivotal resource for exploration of tools to measure the health of estuarine systems in New Zealand (Anderson et al. 2006; Hewitt and Ellis 2010; Lohrer and Rodil 2011; van Houte-Howes and Lohrer 2010).

This report presents the results of data collected from the initial monitoring in October 1987 until February 2011. The report focuses on trends in abundance of the monitored taxa and sediment data at Auckland Airport, Clarks Beach and Cape Horn.

₂ Methods

2.1 Sample collection and identification

Sites Auckland Airport (AA) and Clarks Beach (CB) (Figure 2.1, Table 2.1) have been sampled bimonthly between October 1987 and February 2011. Two sampling occasions were missed (October and December 1988) due to a gap in funding. Sites Cape Horn (CH), Elletts Beach (EB), Karaka Point (KP) and Puhinui Stream (PS) have been sampled for the ARC from October 1987 to February 1993, and again from August 1999 to April 2001. Sampling continued at site CH from April 2001 to monitor the effects of improvements in water quality discharging from Mangere. Additional sampling was carried out at Cape Horn by NIWA, without funding from ARC, between February 1993 and December 1995. This data was collected as part of studies conducted on Te Tau Bank, and funded by the Foundation for Research Science and Technology. Sampling at sites EB, KP and PS commenced again in August 2006 on the recommendation of Funnell and Hewitt (2005) for 2 years until June 2008. Monitoring of Cape Horn ceased in June 2010, whilst Auckland Airport and Clarks Beach have remained ongoing.

Figure 2.1:
Map of Manukau Harbour showing the positions of sites Auckland Airport (AA), Clarks Beach (CB), Cape Horn (CH), Elletts Beach (EB), Karaka Point (KP) and Puhinui Stream (PS). The asterisk denotes the two continuously monitored sites, while the others are monitored intermittently.
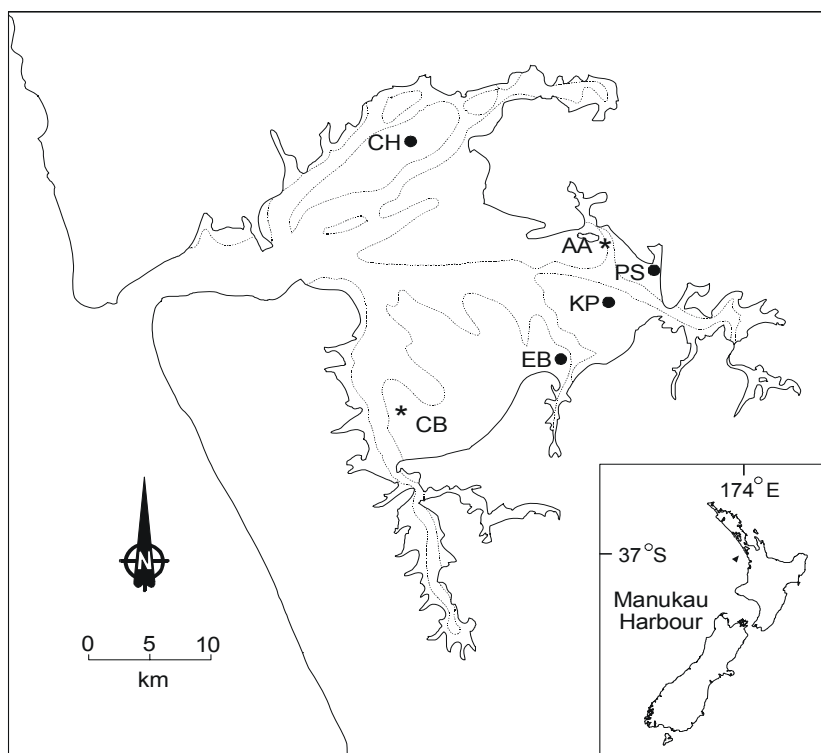
Table 2.1:

Monitoring years (x) of sites AA, CB, CH, EB, KP and PS since the commencement of the Manukau Harbour Ecological Monitoring Programme in October 1987. A grey box denotes no sampling in a specific year, ***** indicates that no sampling was conducted for AA and CB in October and December 1988 due to a gap in funding and ~ denotes additional sampling conducted at site CH.

	AA	CB	CH	EB	KP	PS
1987	x	x	x	x	x	x
1988*	x	x	x	x	x	x
1989	x	x	x	x	x	x
1990	x	x	x	x	x	x
1991	x	x	x	x	x	x
1992	x	x	x	x	x	x
1993~	x	x	x	x	x	x
1994~	x	x	x			
1995~	x	x	x			
1996	x	x				
1997	x	x				
1998	x	x				
1999	x	x	x	x	x	x
2000	x	x	x	x	x	x
2001	x	x	x	x	x	x
2002	x	x	x			
2003	x	x	x			
2004	x	x	x			
2005	x	x	x			
2006	x	x	x	x	x	x
2007	x	x	x	x	x	x
2008	x	x	x	x	x	x
2009	x	x	x			
2010	x	x	x			
2011	x	x				

Samples are collected and processed as follows. Each site (9000 m^2) is divided into 12 equal sectors and one macrofauna core sample (13 cm diameter, 15 cm depth) is collected from a random location within each sector. To limit the influence of spatial autocorrelation (see Thrush et al. 1989) and preclude localised modification of populations by previous sampling events, core samples are not positioned within a 5 m radius of each other or of any samples collected in the preceding six months. After collection, the macrofauna are separated from the sediment by sieving over a 500 µm mesh, preserved with 70% isopropyl alcohol and stained with Rose Bengal. The macrofauna are then sorted, and the 21 monitored taxa are identified (Appendix 7.1), enumerated and stored in 50% isopropyl alcohol.

2.2 Bivalve size class analysis

After identification, bivalve species *Austrovenus stutchburyi*, *Macomona liliana*, and *Soletellina siliqua* are measured (longest shell dimension; mm). Originally a set of nested sieves were used to estimate sizes (1995 – 2001). From 2001 to 2007, monitored bivalves were individually measured (with calipers or digitizing under a stereo microscope) and the results were summarised into the following size classes: <1 mm, 1-2 mm, 2-4 mm, 4-8 mm, 8-11 mm, 11-16 mm, 16-22 mm and >22 mm. However, in consultation with ARC, the methodology and size classes have been modified to enable direct comparison with the Mahurangi and Waitemata ecological monitoring programmes. Individual bivalves are now assigned a size class <5 mm, 5-10 mm, 10-15 mm, 15-20 mm, 20-30 mm, 30-40 mm, 40-50 mm and >50 mm.

2.3 Site and sediment characteristics

During each visit, attention is paid to the appearance of the site and the surrounding sandflat. In particular, any unusual surface sediment characteristics and the presence of ray pits, foraging birds, gastropods and plants are noted.

Between 1995 and 1998, a pooled sample of surface sediment (<2 cm deep) was collected by randomly sampling areas within the site for grain size analysis (October sampling only). Since August 1999, two small sediment cores (2 cm deep, 2 cm diameter) are collected from every second macrofauna core location and pooled into two containers; one to determine grain-size and organic content and the other for chlorophyll *a* analysis.

Organic matter is removed from a sub-sample from the grain-size/organic content sample by digestion in hydrogen peroxide. Sediment grain size analysis is then carried out by wet sieving into fractions of gravel (particles >2 mm), coarse sand (particles 500 µm-2 mm); medium sand (particles 250 µm-500 µm); fine sand (particles 63 µm- 250 µm); and mud (particles <63 µm), which are then dried and weighed. Before drying, the mud fraction is analysed by pipette analysis for proportions of silt and clay. A similar procedure was used to determine the sediment characteristics for each site from October 1987 through until June 2000, although only the gravel, sand and mud fractions were determined.

To determine the organic content, the remainder of the homogenised sediment sample is dried at 60°C to a constant weight and combusted for 5.5 hours at 400 °C. Organic content is determined by the difference in weight of the sample prior to and after combustion.

The other sediment sample collected is analysed for chlorophyll *a*. Chlorophyll *a* (a proxy of microalgae abundance and food supply to benthic animals) is extracted by freeze-drying then homogenising the sediment, boiling in 90% ethanol and reading the extract on a spectrophotometer (measured in µg/g sediment). An acidification step is used to separate degradation products from chlorophyll *a* (Sartory, 1982).

2.4 Statistical analysis

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, statistical analysis of trends becomes more important. However, as the time series increases further, it becomes possible to detect very small changes statisticalyl and even changes that are obviously part of longer-term cycles. To investigate long-term trends and cycles in environmental and species abundance data we conducted the following analyses.

Seasonal and multiyear patterns

Plots of total abundance for each monitored population and measured environmental variables were visually examined to identify repeatable cyclic patterns. We also consider the density of each species at each site in light of our knowledge of the natural history of each species, to ensure that our statistical analyses are interpreted in a biologically meaningful fashion.

Trend analysis

To formally identify any suggested trends in the abundance of the monitored taxa, or measured environmental variables, at the monitored sites, trend analyses were conducted. Autocorrelation in each time series was investigated using Chi-square probabilities (SAS/ETS). Step trends were investigated using Wilcoxon rank tests and, if autocorrelation was present, adjusting the degrees of freedom. Gradual changes were investigated by ordinary least squares regression unless autocorrelation was present. Where autocorrelation was indicated, increasing or decreasing trends were investigated by adjusting parameters and significance levels (AUTOREG procedure, SAS/ETS). Only linear trends and step trends were assessed as investigation of residual variability suggested no other responses. Changes that are obviously part of longer-term cycles are identified by obvious patterns in plots of residuals.

Community Analysis

To make an overall assessment of community stability of sites over time, we performed non-metric multidimensional scaling based on Bray-Curtis percentage dissimilarities of log-transformed data) using monitored taxa only (October abundances) (PRIMER; Clarke and Gorley, 2006).

To determine the relative functional health of each site, community compositions, including monitored and non-monitored taxa, from AA, CB and CH in October 2009 were analysed using the NIWACOOBII index (Lohrer & Rodil, 2011; van Houte-Howes and Lohrer 2010). The NIWACOOBII index was developed for the Auckland Council by NIWA to provide an understandable and scientifically defensible indicator of the ecological integrity of its estuarine and coastal areas. The index is based upon the richness of macrofaunal taxa in each of seven functional trait groups (e.g., organism size, mobility, feeding mode, position in the sediment, etc.). The index value ranges from 0 to 1, with 0 indicating highly degraded sites and 1 indicating the opposite. Declines in NIWACOOBII scores with increases in mud and heavy metal concentrations are interpreted as losses of functional redundancy. Communities with high functional redundancy (i.e., many species present in each functional trait group) will tend to have higher inherent resistance and resilience in the face of environmental

changes, as the higher numbers of species per functional group provide "insurance" for stochastic or stress-induced losses of particular species.

The list of taxa found in a particular set of samples (i.e., the 12 replicates from a specific site in October 2010) was matched to the functional traits database and a score was assigned. The scores were added together (SUMactual) and used in the formula below:

$$1 - (SUM_{max} - SUM_{actual})/SUM_{max}$$

The SUM_{max} used was 226.39, which is the maximum SUM score for 12 replicates calculated in Lohrer & Rodil (2011).

The Benthic Health Model (BHM) was then used to assess the influence of mud content and contamination by copper, lead and zinc only, on monitored and non-monitored taxa from October 2009 and 2010 benthic communities (Anderson et. al 2006, Hewitt & Ellis 2010). The BHM was developed by the Auckland Council to provide a tool for classifying sites within the region according to categories of relative ecosystem health, based on community compositions and predicted responses to storm-water contamination, and later extended to assess the influence of sediment mud content. The model is based on canonical ordination of Principle Coordinates (CAP) using Bray-Curtis dissimilarities.

3 Present Status of Benthic Communities in Manukau Harbour

The Manukau Harbour Ecological Programme was designed to answer the following questions over a long term scale:

1. Are populations at the monitored sites generally exhibiting similar patterns?

2. Do any of the observed patterns in population abundances indicate important changes in the benthic communities?

Through site observations and sediment and community analysis it will be possible to assess these broad questions.

3.1 General site descriptions

Site characteristics such as appearance and sediment features, can provide a context against which changes in macrofauna can be described. Changes to site characteristics over time, such as expansion of seagrass beds into the monitored area or disturbance by eagle rays may help explain variability (i.e., Townsend 2010). Changes to surface sediment at the site (e.g., fine sediment deposited by storms) or changes associated with human use (presence of nets etc.) may also affect macrofauna. For this reason, a brief description of site appearance and sediment characteristics is given here.

Auckland Airport (AA)

The appearance of this site has remained similar over the entire monitoring period (since 1987) with minimal changes over the last two years. The sediment is firm sand and the topography is usually dominated by ripples (1-2 cm wave height, 3-6 cm period), dense *Macomona liliana* feeding tracks (Figure 3.1) and an abundance of excavated ray pits. In June and August 2005, small sparse patches of seagrass were observed at the site. Between April 2010 and February 2011, gastropods (i.e., *Zeacumantus lutulentus* and *Cominella glandiformis*) were notably common and worm tubes were observed in April and June 2010. *Gracilaria* sp. was also observed occasionally (June and October 2009 and December 2010).

The surrounding area is largely similar to that observed within the monitored area, however the presence of shell hash and whole shells (primarily *Austrovenus stutchburyi* and *Macomona*) on the sediment surface has become increasingly common since August 2010 and green mossy algae and *Gracilaria* sp. (that has taken root) has been observed.

Figure 3.1:
Photographs of site AA a) monitored area and b) sediment surface.

a)

b)
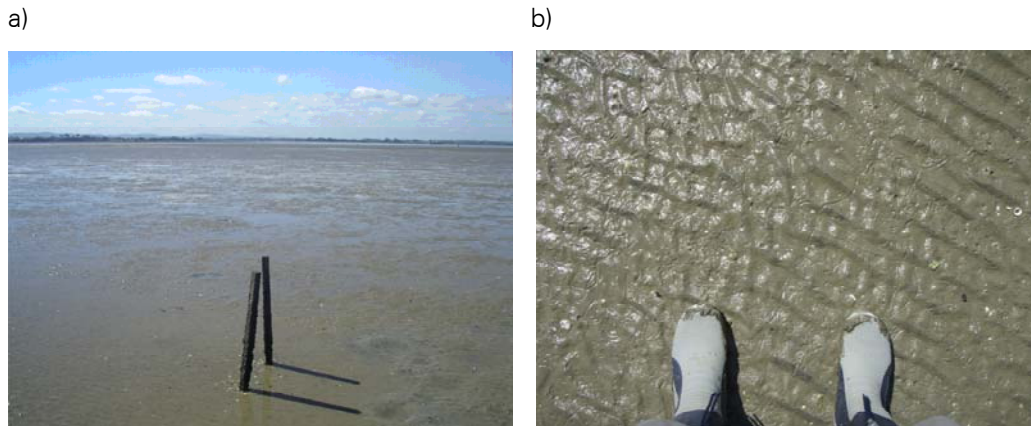
Clarks Beach (CB)

The appearance of this site is more temporally variable compared to AA; however there have been no unusual features observed in the February 2009 – February 2011 period. The site topography changes between being dominated by ripples (1 cm wave height, 1 cm period) and a mosaic of ripples, flat sediment, hillocks and *Zostera muelleri* (Figures 3.2a-c). Whole shells on the surface, shell hash (dense coverage, primarily *Austrovenus* and *Macomona*), worm tubes and gastropods are usually common or abundant throughout much of the year. Furthermore, a surficial mud layer and the presence of *Gracilaria* sp. on the surface are also common throughout most of the year (Figures 3.2d). Patches of *Zostera* are still common within the monitored area (first described by Funnell et al. 1999); and its distribution has varied between 2-30 m^{-2} since February 2009. In February 2011, two macrofaunal cores were taken within *Zostera* (replicates 4 and 11), however, the number of species and individuals collected from these cores were similar to those collected from elsewhere within the monitoring site. In the winter months, it is common to observe a diatom mat covering the sediment surface and in June 2009 and August 2010, *Lyngbya* was observed in small clumps across the monitored site and surrounding area. The surrounding area has remained comparable to the monitored area over the past two years.

Figure 3.2:
Photographs taken at CB of a) the typical appearance of the site, b) and sediment surface, c) a dense *Zostera muelleri* patch and d) the sediment surface when *Gracilaria* sp. is abundant.

a)

b)

c)

d)

Cape Horn (CH)

Between February 2009 and June 2010 the sediment was largely unchanged from that reported by Hailes and Hewitt (2009), although dense patches of *Gracilaria* sp. have not been observed since February 2009. The site has firm sand with ripples (2 cm wave height, 6-15 cm period) and often *Macomona* feeding tracks and tube worms are present on the sediment surface (Figure 3.3). Ray pits were common in October 2009 and February 2010 and in June and August 2009 a diatom mat and a surficial mud layer was observed. The surrounding area was much the same as the monitored area; however, *Gracilaria* sp. was abundant on most sampling occasions.

Figure 3.3:
Photographs of CH a) monitored area and b) sediment surface.

a)

b)
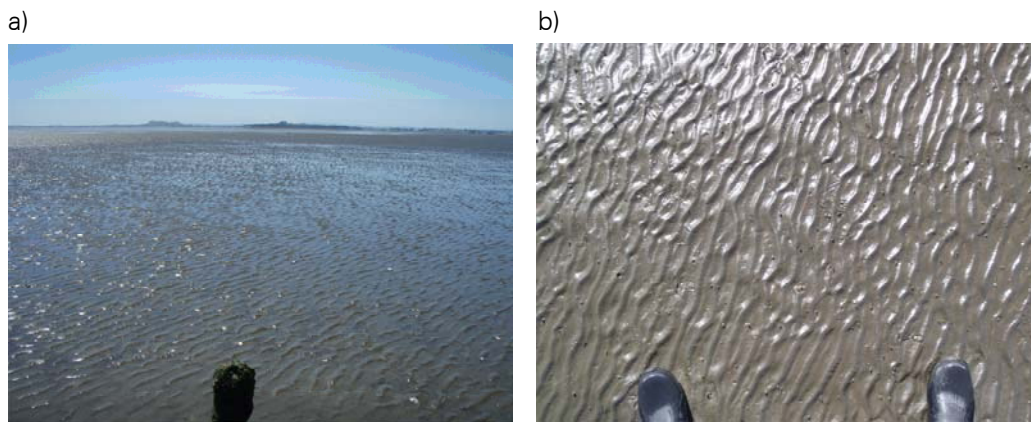
3.2 Sediment characteristics

The bimonthly results for sediment grain size, chlorophyll *a* and organic content for each of the monitoring sites (AA, CB and CH) are given in Appendix 7.2. No significant trends, with the exception of those at CH reported on by Hailes and Hewitt (2009) in response to the decommissioning of the waste water treatment plant, have been observed. A summary of the results is presented below.

Grain size

Between February 2009 and February 2011, there have been no marked changes in the sediment grain size composition at sites AA, CB and CH (Figures 3.4 and 3.5). The percent mud content at site CB continues to be variable and has ranged between 2.84 – 15.93% within the last two years. Seasonal peaks of high mud content are particularly noticeable at site CB with the highest percent mud typically observed during the winter months. Site AA continues to have the lowest percent mud content, followed by CH and CB, with an average percent mud content over the last two years of 0.7, 0.72 and 12 %, respectively. The gravel and sand fractions of the sediment at each of the sites are also consistent with that reported in February 2009 (Figure 3.5).

Figure 3.4:
Sediment mud (silt and clay) content (% weight) at the monitored sites between October 1989 and February 2011.
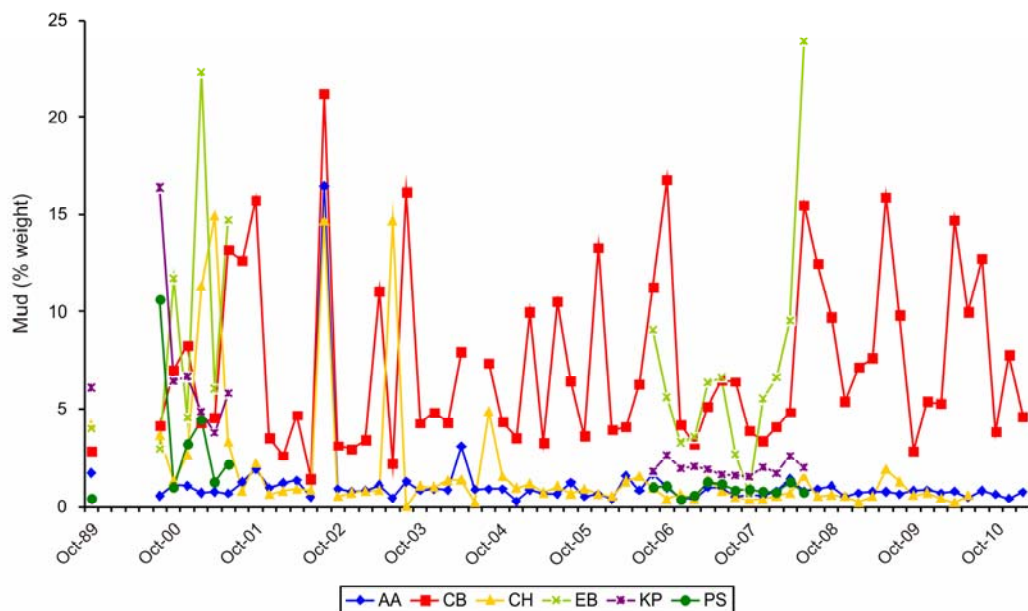
Figure 3.5:

Changes in the proportions of gravel/shell (>2 mm), sand (coarse <2 mm to fine >63 um) and silt/clay (i.e., mud <63 um) at each of the monitored sites (Auckland Airport, Clarks Beach, Cape Horn, Elletts Beach, Karaka Point and Puhinui Stream) over the entire monitoring period (October months only).
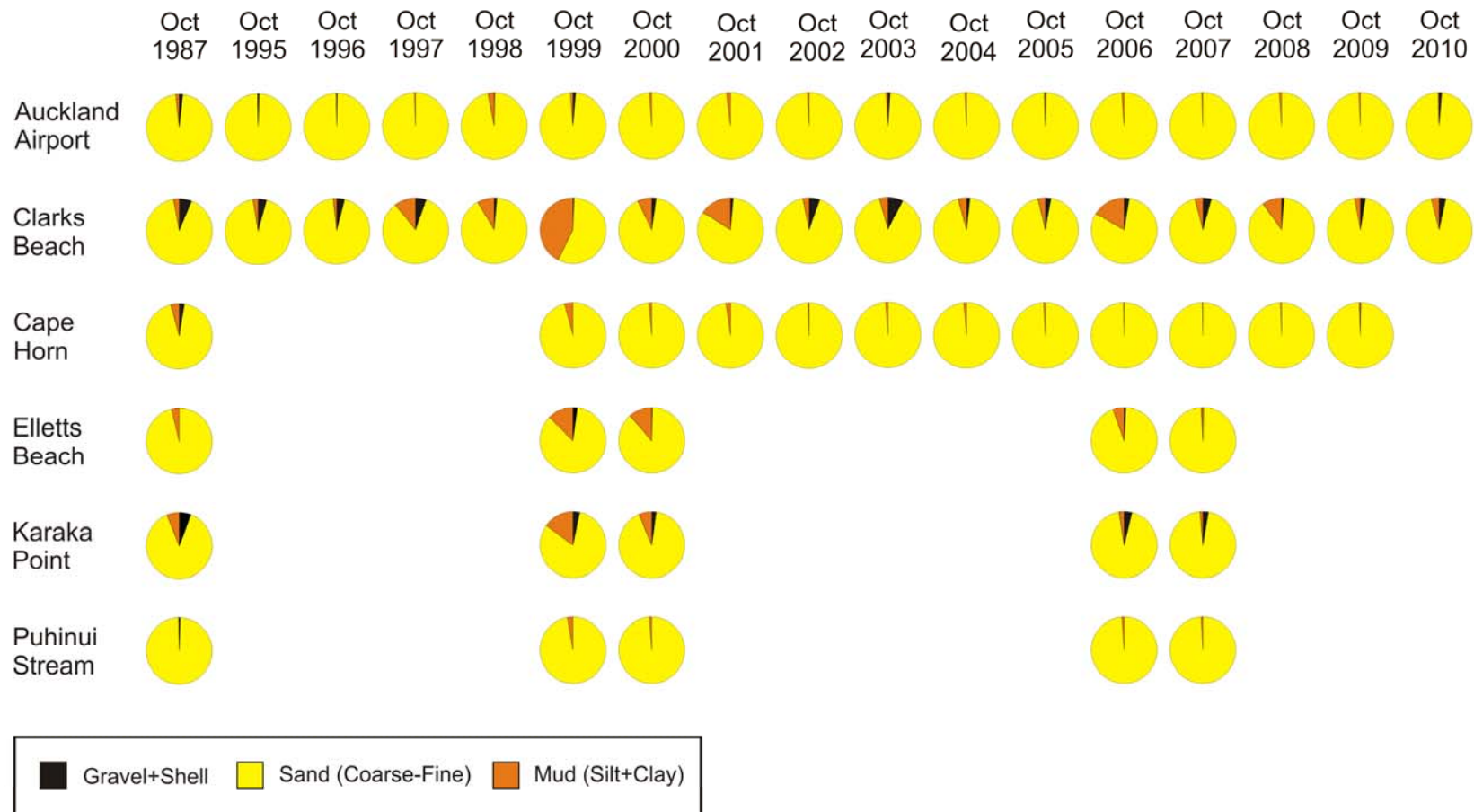
Chlorophyll *a*

The chlorophyll *a* values at sites AA and CH have remained similar and consistent over the past two years (Figure 3.6). Although chlorophyll *a* levels at site CB decreased between February 2009 and 2010, these levels were similar to those observed in other years at this site. Chlorophyll *a* levels at AA, CB and CH over the last two years have ranged between 7.91-12.04, 8.73-13.64 and 7.34-11.92 µm/g sediment, respectively.

Figure 3.6:

Chlorophyll *a* levels (µm/g sediment) of sediment collected from monitoring sites between August 2000 and February 2011.
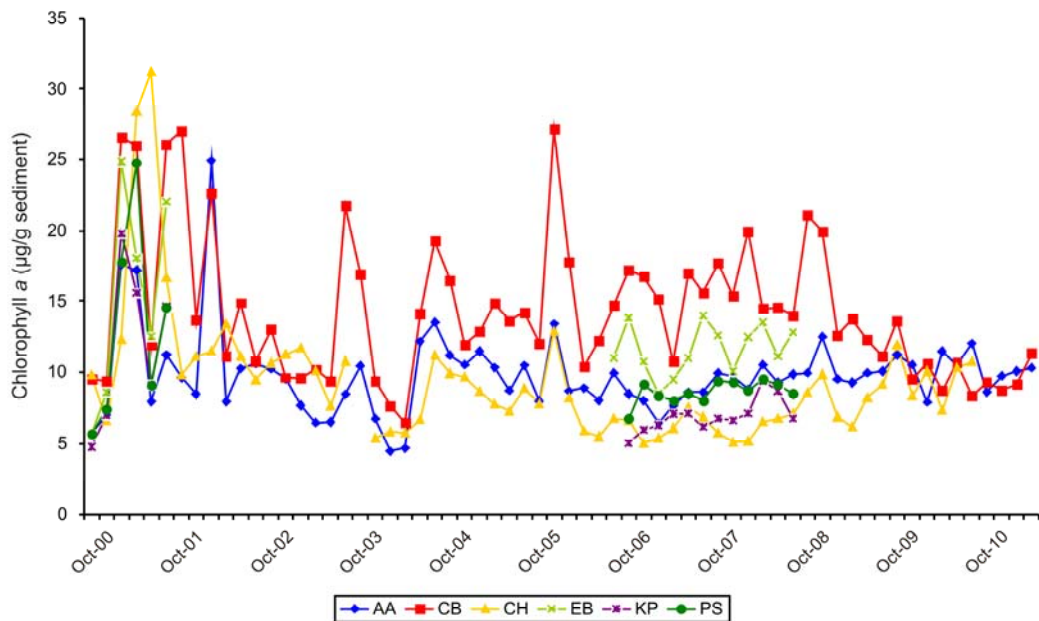
Organic content

Sediment organic content at the AA, CB and CH sites, have remained low and variable since February 2009 (Figure 3.7). Temporal variability both within and between sites implies some differences in food resources available for benthic organisms, but as all values are low there is no indication of any enrichment or eutrophication problems. All sites show seasonal peaks during winter months and lower percentages during the warmer summer months. The sediment organic content at sites AA and CH appear to follow a similar pattern (except for a peak at CH in August 2009), however, site CB is slightly higher. Average organic content AA, CB and CH over the last two years has been 0.57, 1.38 and 0.72%, respectively.

Figure 3.7:
Percentage organic content of sediment collected from monitoring sites between October 2000 and February 2011.
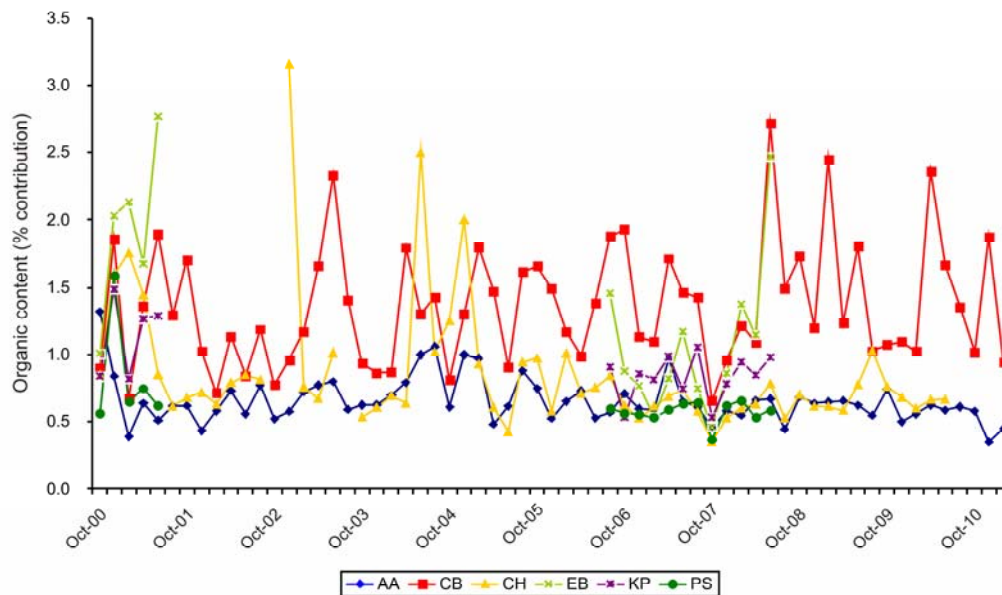
3.3 Are trends in abundance being maintained?

In 2009, trend analysis identified a step change in *Aonides trifida* from AA and a gradual change in *Anthopleura aueoradiata* at CB from 2004.

Over the last 2 years there is still an indication that abundances of *Aonides* at AA may be trending upwards (Figure 3.8), however, this observed increase over the last two years was not statistically significant (p>0.05).

Figure 3.8:

Abundance of *Aonides trifida* at Auckland Airport from October 1987 until February 2011.
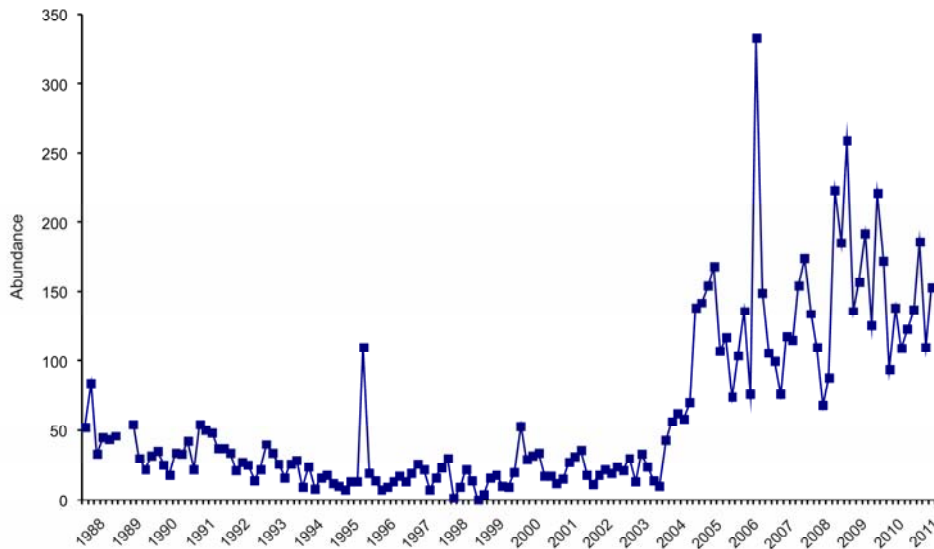
At site CB, a significant (p>0.05) increasing trend of the abundance of *Anthopleura* (Figure 3.9), was recorded by Hailes and Hewitt (2009). With two more years of data this is still apparent.

Figure 3.9:

Abundance of *Anthopleura aueoradiata* at Clarks Beach from October 1987 until February 2011.
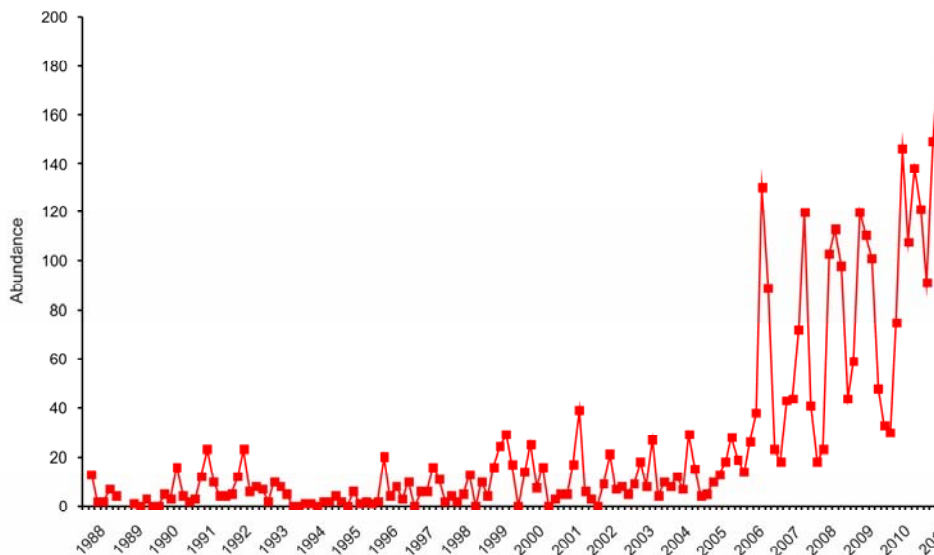
In 2001 the waste water plant at Mangere was decommissioned and although there were immediate changes in the abundance of some monitored taxa at site CH, approximately 7 km away, since 2005 the abundances of most monitored species have

exhibited little change. The abundances of some species decreased or increased post 2001 e.g., *Glycinde trifida* (Figure 3.10), while others (e.g., *Macroclymenella stewartensis*) showed an initial decline but then returned to pre-2001 abundances (Figure 3.11).

Figure 3.10:

Abundance of *Glycinde trifida* at Cape Horn from October 1987 until February 2011.
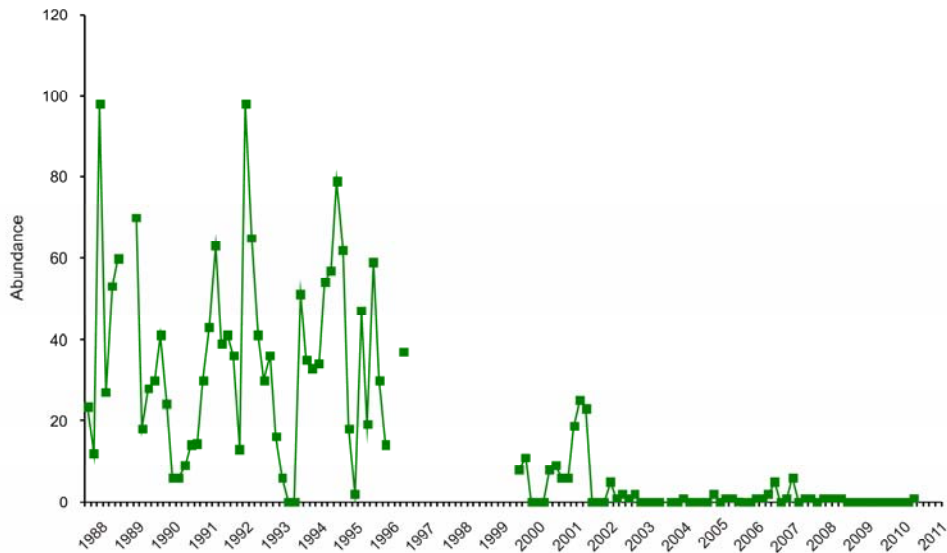
Figure 3.11:

Abundance of *Macroclymenella stewartensis* at Cape Horn from October 1987 until February 2011.
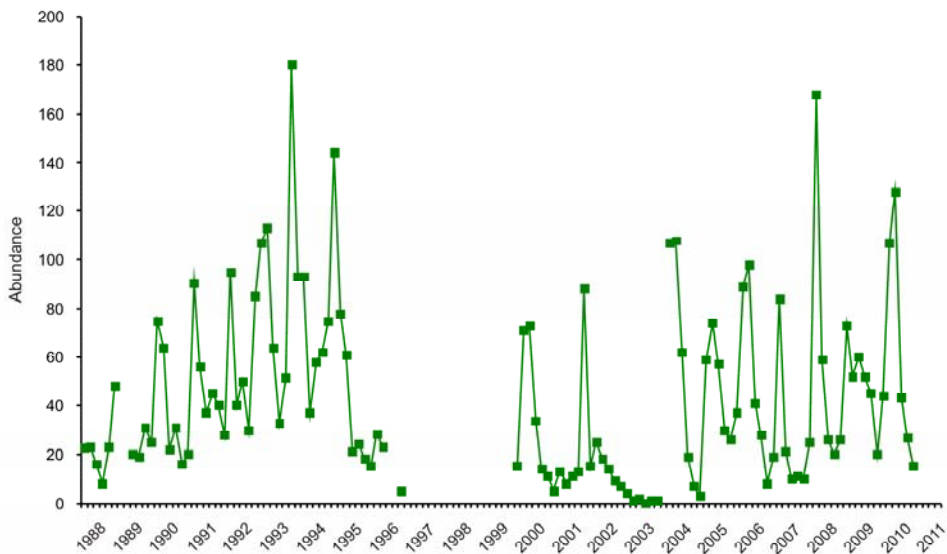
3.4 Are cyclic patterns in macrofaunal abundance being maintained?

Throughout the monitored period, a number of the monitored taxa have exhibited seasonality in abundance with definite recruitment peaks, although these vary in timing and magnitude. Some species i.e., *Macomona* from CH, that were previously reported to be exhibiting seasonal cycles are now also exhibiting larger than annual multi-year cycles in abundance (Table 3.1). As reported by Hailes & Hewitt (2009) and Hewitt & Thrush (2009), long term population dynamics can be correlated with environmental variables including El Niño Southern Oscillation cycles and local changes in wind and water temperature and management activities. Abundances of many species were reported to correlate well with the El Niño Southern Oscillation cycles, although not necessarily at all sites. Such cycles will continue to affect species abundances in the Manukau to varying extents. For example, the abundance of *Magelona* at all sites is still maintaining this greater than annual cycle (6-8 years) detectable over the entire monitoring period (Figure 3.12).

Soletellina siliqua displays a multi-year cycle of 7-9 years in its abundance which was also reported by Hailes & Hewitt (2009) to be correlated with the El Niño Southern Oscillation cycle. After two more years of data, this cycle continues to be obvious both at site CH and site AA (Figure 3.13). Furthermore, at site CH, six of the monitored species (including *Magelona* and *Soletellina*) are still displaying the multi-year cycles in abundance reported by Hailes & Hewitt (2009) (Table 3.1). At AA, 14 of the monitored taxa are displaying obvious multi-year cycles in abundance, including *Colorostylis lemurum*, *Glycinde trifida* and *Orbinia papillosa* (Table 3.1). At site CB, 15 of the monitored species are displaying greater than annual cycles in abundances (Table 3.1), e.g., *Prionospio aucklandica* (Figure 3.14). Finally, some species have abundances which are consistently low including *Aglaophamus macroura* (AA and CB), *Anthopleura aueoradiata* and *Methalimedon* sp. (AA), *Aonides trifida* and *Trochodota dendyi* (CB) and *Macomona liliana* (CH).

Table 3.1:

Monitored species and whether they are exhibiting multi-year cycles of abundance, seasonal patterns or no detectable pattern (-); usually due to low numbers.

	AA	CB	CH
Anthopleura aueoradiata	Seasonal cycle	Seasonal cycle	Multi-year cycle: 6-7 years
Prionospio aucklandica	Seasonal cycle	Multi-year cycle: 4-6 years	-
Aglaophamus macroura	-	-	Multi-year cycle: 7-9 years
Aonides trifida	Seasonal cycle	-	-
Boccardia syrtis	-	Multi-year cycle: 5-7 years	-
Colorostylis lemurum	Multi-year cycle: 2-3 years	Multi-year cycle: 2-4 years	Seasonal cycle
Austrovenus stutchburyi	Multi-year cycle: 7-9 years	Multi-year cycle: 2 year	-
Exosphaeroma sp.	Multi-year cycle: 2-3 years	Multi-year cycle: 2-4 years	-
Glycinde trifida	Multi-year cycle: 6-9 years	Multi-year cycle: 3-6 years	-
Magelona dakini	Multi-year cycle: 6-8 years	Multi-year cycle: 6-8 years	Multi-year cycle: 6-8 years
Methalminedon sp.	-	Multi-year cycle: 2-5 years	Multi-year cycle: 2-5 years
Macroclymenella stewartensis	-	Multi-year cycle: 3-5 years	Multi-year cycle: 7-9 years
Nucula hartvigiana	Multi-year cycle: 6-7 years	Multi-year cycle: 3-6 years	-
Notoacema scapha	Multi-year cycle: 2-3 years	Multi-year cycle: 5-6 years	-
Owenia petersonae[1]	-	Multi-year cycle: 8-10 years	-
Orbinia papillosa	Multi-year cycle: 2-4 years	-	-
Torridoharpinia hurylei	Multi-year cycle: 6-8 years	Multi-year cycle: 6-8 years	-
Soletellina siliqua	Multi-year cycle: 7-9 years	Multi-year cycle: 7-9 years	Multi-year cycle: 7-9 years
Trochodota dendyi	Multi-year cycle: 5-7 years	-	-
Macmona liliana	Multi-year cycle: 6-8 years	Multi year cycle: 7-9 years	-
Travisia olens	Multi-year cycle: 5-6 years	-	-
Waitangi brevirostris	Multi-year cycle: 4-6 years	-	-

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[1] Note this species name has now been confirmed as petersonae rather than fusiformis

Figure 3.12:
Abundance of *Magelona dakini* at Auckland Airport, Clarks Beach and Cape Horn from October
1987 until February 2011.
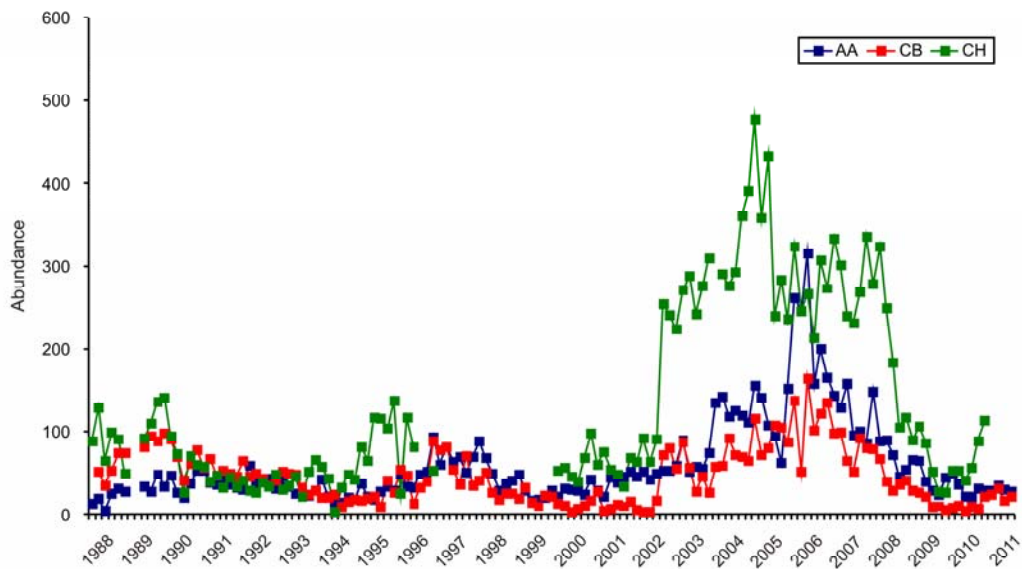
Figure 3.13:
Abundance of *Soletellina siliqua* at Auckland Airport and Cape Horn from October 1987 until
February 2011.
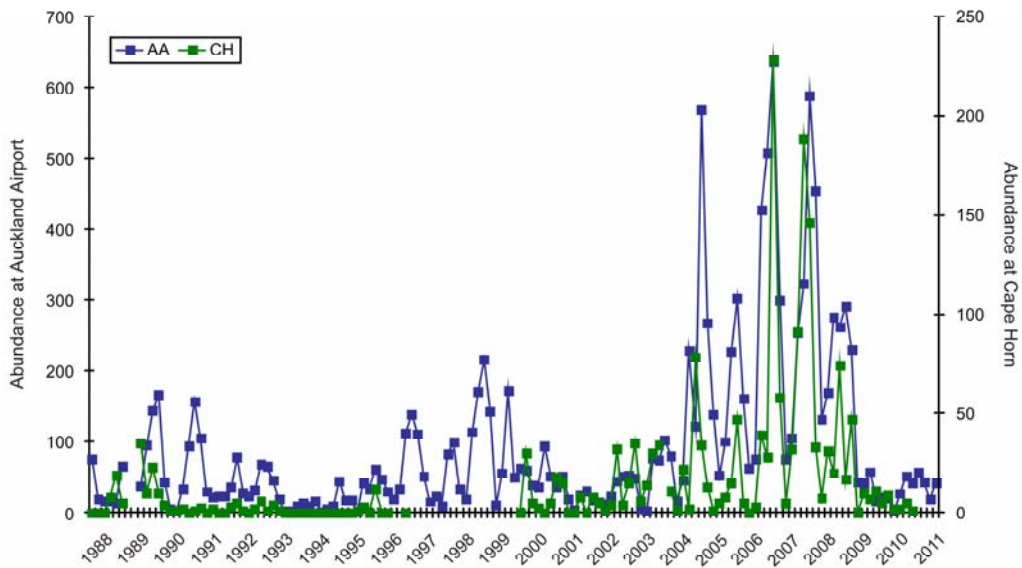
Abundance of *Prionospio aucklandica* at Clarks Beach from October 1987 until February 2011.
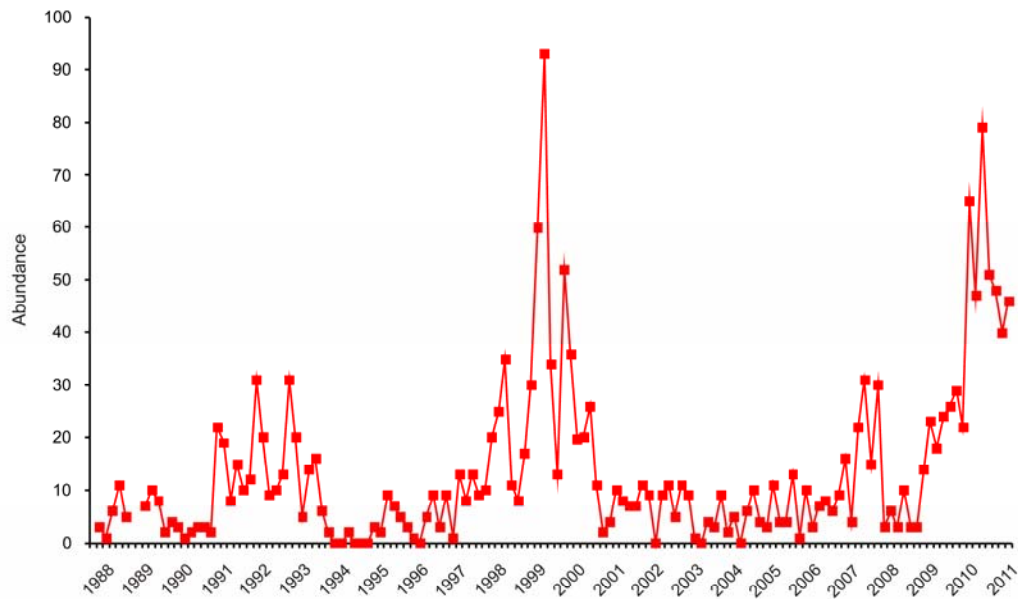
Although abundances of *Owenia petersonae* at CB continue to show multi-year cycles, there is evidence, (due to the sustained larger than normal recruitment in recent times) that the length of the multi-year cycle has been extended (Figure 3.15). As yet, abundances are not greater than those previously observed in 1997-1998.

Figure 3.15:
Abundance of *Owenia petersonae* at Clarks Beach from October 1987 until February 2011.
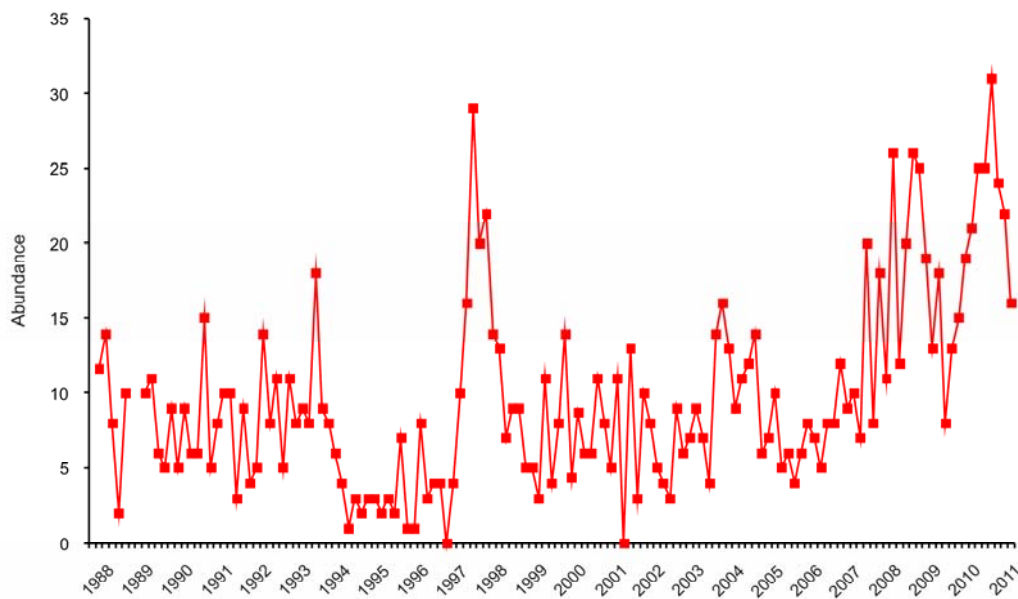
Abundances of *Nucula hartvigiana* at site CB continue to be highly variable with a recent large recruitment of 1080 individuals (total per 12 replicate cores) (Figure 3.16). Other species that have recently had a large recruitment peak at this site include *Austrovenus* (123 individuals in 12 replicate cores, in December 2010; Figure 3.18) and *Notoacmea scapha* (108 individuals in 12 replicate cores, in February 2011).

Figure 3.16:
Abundance of *Nucula hartvigiana* at Clarks Beach from October 1987 until February 2011.
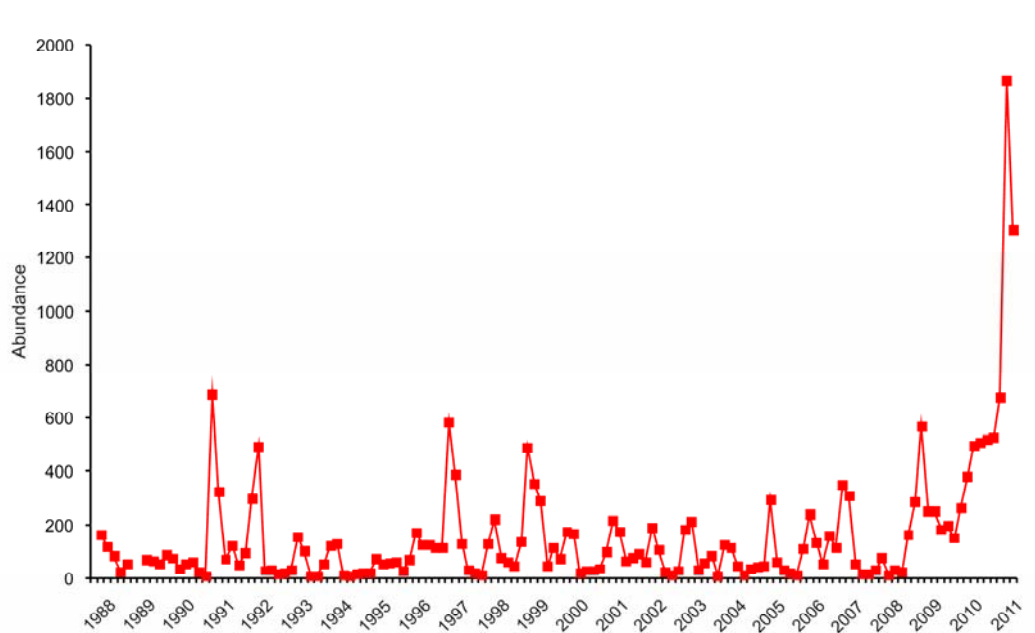
A large recruitment of juvenile *Macomona* also occurred at site AA in April 2010, which may result in an increase in the abundance of adults at this site in the future, as has happened at site CB and in the past at AA (Figure 3.17).

Figure 3.17:

Abundance of juvenile (<5 mm; red line) and adult (>16 mm; black line) *Macomona liliana* from sites Auckland Airport and Clarks Beach from April 2001 until February 2011.
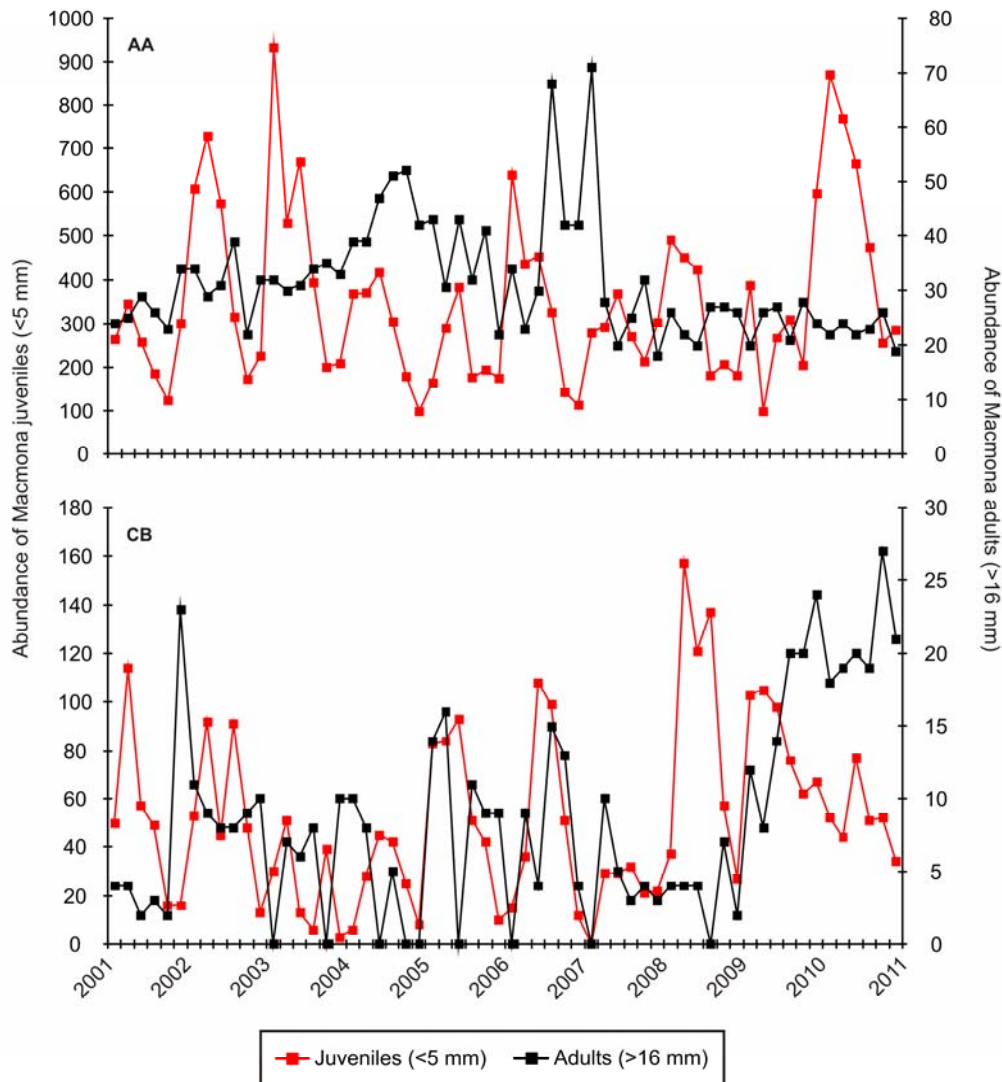
Although the abundance of adult *Austrovenus* at site AA is usually low across the entire monitoring period, the abundance of juveniles is much greater (Figure 3.18), implying a high post-settlement dispersal rate (Cummings et al. 1995; Lundquist et al. 2004) or mortality rate. At site AA, there is a multi-year cycle of approximately 3-4 years for the abundance of juvenile *Austrovenus*. At CB, *Austrovenus* (juveniles and adults) are usually low or absent; however, there was a large recruitment in December 2010 that was significantly greater than previously observed over the entire monitoring period. Further monitoring will elucidate whether they settle or undergo post-settlement transport to another more suitable location.

Figure 3.18:

Abundance of juvenile (<5 mm) *Austrovenus stutchburyi* from sites Auckland Airport and Clarks Beach from April 2001 until February 2011.
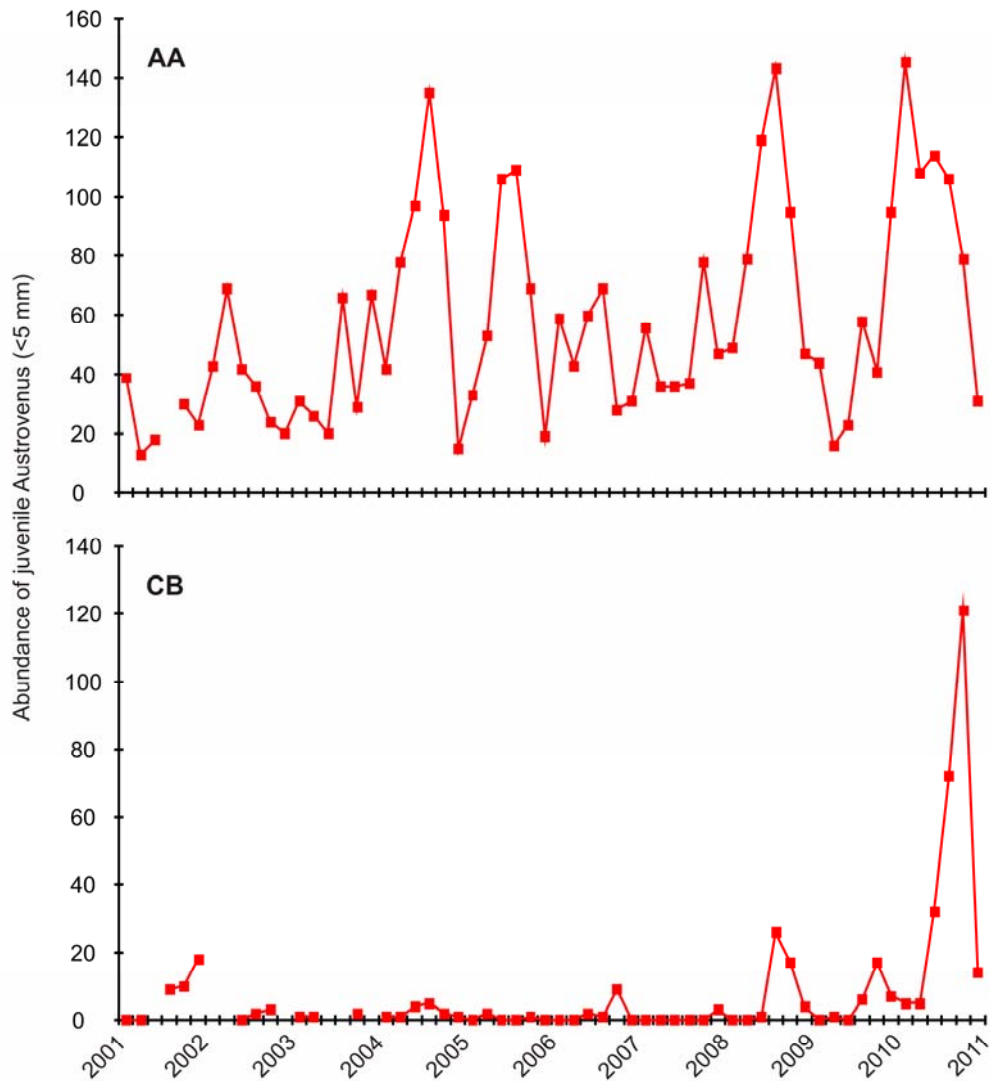
The abundance patterns of juvenile *Soletellina* at sites AA and CH follow the same long-term cycle with peaks and declines in abundance at similar times (Figure 3.19). Abundances observed over the past 2 years are similar to those observed in 2001-2003.

Figure 3.19:

Abundance of juvenile (<5 mm) *Soletellina siliqua* from sites Auckland Airport and Cape Horn from April 2001 until February 2011.

3.5 Have any of the sites exhibited differences in community composition over time?

Variation in community composition based on the monitored taxa in October, provides an indication of whether communities are changing over time and how similar communities from each site are to each other.

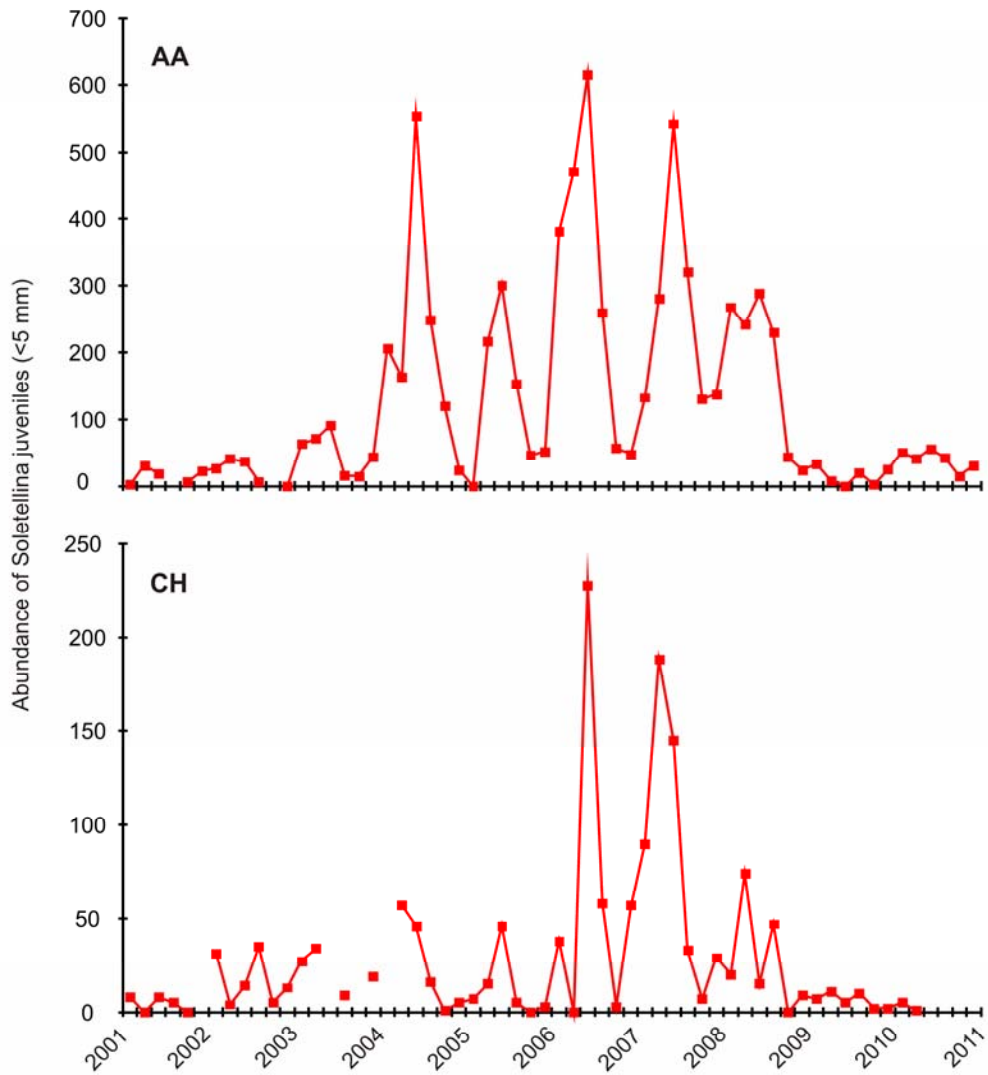At site AA, the community is almost always dominated by bivalves *Macomona liliana*, *Soletellina siliqua* and *Austrovenus stutchburyi*. These bivalve species contribute most to the similarity of the communities at AA over time. The most abundant polychaete is *Aonides trifida,* with the cumacean *Colorostylis lemurum* also numerically dominant (Appendix 7.3). The community composition of AA has been the most stable over the duration of the monitoring period (communities exhibited 82% similarity in community composition (based on Bray-Curtis index) between October 1987 and October 2011) and it remains the site most distinct from the others (Figure 3.20).

Site CB is dominated by a mixture of bivalves (i.e., *Nucula hartvigiana* and *Macmona*), polychaetes (i.e., *Macroclymenella stewartensis* and *Magelona dakini*) and the amphipod *Torridoharpinia hurylei* (Appendix 7.3). Although this site exhibits variability in abundances, it is less variable than CH (communities exhibited 77% similarity in community composition (based on Bray-Curtis index) between October 1987 and October 2011). The latest community structure observed (October 2010) is similar to that observed in October 1999 (Figure 3.20).

The community composition at site CH changed markedly in October 2001 related to some extent to the Mangere waste water treatment plant upgrade (Hailes and Hewitt 2009). During the last two years, the community has changed little (Figure 3.20) and the site is mainly dominated by polychaete species *Macroclymenella* and *Magelona* and the cumacean *Colorostylis* (Appendix 7.3).

Figure 3.20:

Multi-dimensional Scaling (MDS) plot of the dissimilarity in macrofaunal communities over time (October 1987-October 2010) (Log transformed data). The earliest sampling occasion is denoted by a closed square and the most recent is denoted by an open square. Coloured ovals represent the total area of community movement over time at Auckland Airport (blue), Clarks Beach (red) and Cape Horn (yellow). The further away the points are in the ordination space, the more dissimilar the community composition is.
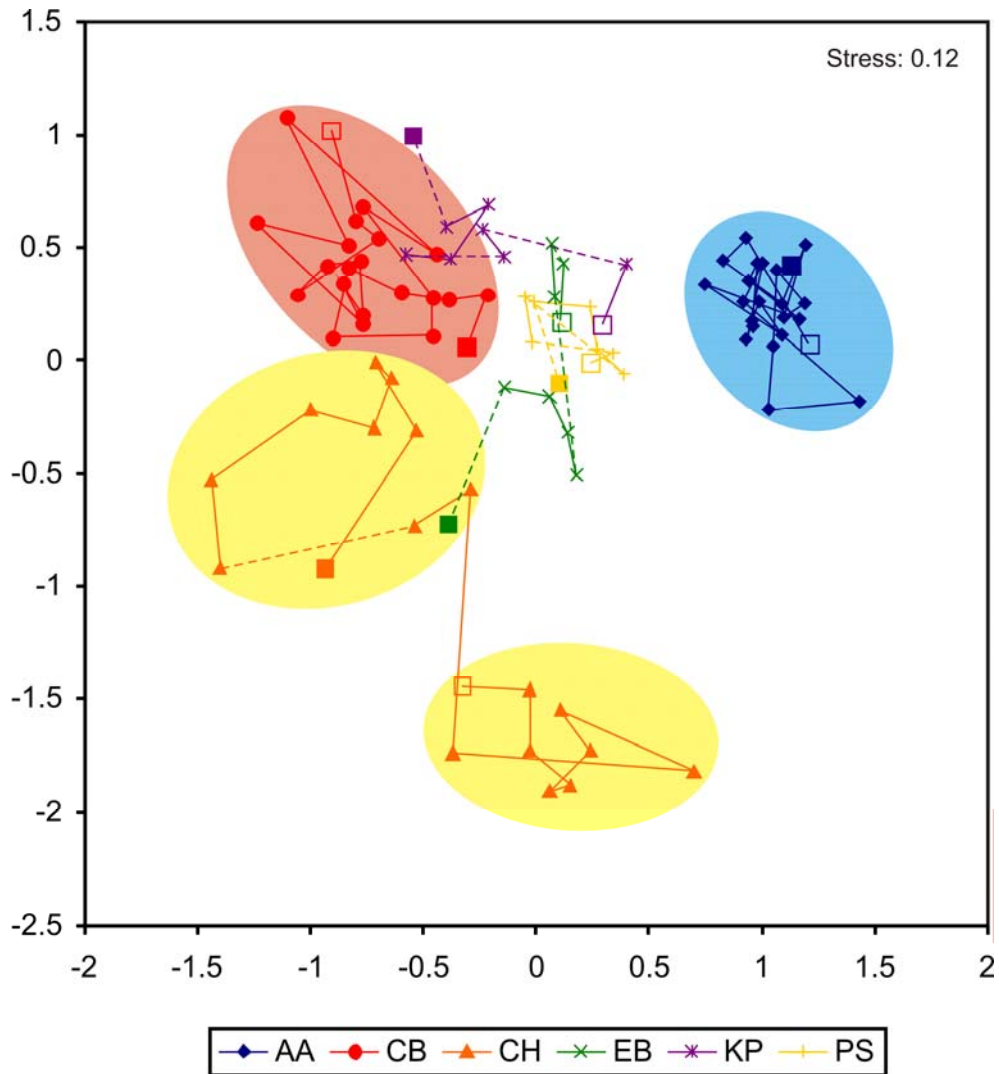
₄ Conclusions

4.1 Are populations at sites generally exhibiting similar patterns?

Most of the monitored taxa exhibit seasonal and multi-year cycles in abundance across all sites, often correlated with environmental variables including local temperature and the El Niño Southern Oscillation cycle (Hailes and Hewitt, 2009). Long-term trends in abundance are still being maintained for *Aondies* at site AA and *Anthopleura* at site CB.

4.2 Do any of the observed patterns in population abundances indicate important changes in benthic communities?

During the last two years, there has been no evidence to suggest there have been detrimental effects on communities at sites in the main body of Manukau Harbour. Abundances of monitored species have remained similar to those described in 2009 and long multi-year cycles are still maintained. Community compositions at the sites generally exhibit little variation, and none of the changes observed are consistent with responses to anthropogenic activity.

Using the Benthic Health Model (Anderson et al. 2006; Hewitt and Ellis, 2010), the health of the Manukau sites (October 2009 and October 2010) can be assessed relative to sediment copper, zinc and lead concentrations (CAPcont) and sediment muddiness (CAPmud). The Manukau sites are situated towards the bottom left of both of the CAPcont and CAPmud plots (Figures 4.1 and 4.2), indicating that the communities remain healthy and the sediment remains largely sandy.

The newly developed index (NIWACOOBII) to assess the functional redundancy of benthic communities as an indicator of resilience was also applied to the Manukau data (van Houte-Howes and Lohrer, 2010; Lohrer and Rodil, 2011). NIWACOOBII was calculated for AA, CB and CH using data from October 2009 and was based on the number of taxa in seven functional groups. Values closer to 0 indicate low functionality (and possibly an indication of degradation) and values near 1 indicate high ecosystem functionality. Communities with a high functionality (i.e., many species present in each functional trait group) tend to have a higher inherent resistance and resilience in the face of environmental change (Lohrer and Rodil, 2011). The values generated for AA, CB and CH are average NIWACOOBII values and were 0.48, 0.65 and 0.40, respectively. The higher value for CB indicates that the community at this site has a higher ecological functionality compared to the communities at AA and CH, however, the values calculated for all sites are typical of sandy areas.

Figure 4.1:

Plot of the relationship between a) the principle component axis related to copper, lead and zinc concentrations in the sediment and community composition related to them (CAPcont) and b) the percent mud content of the sediment and community composition related to mud (CAPmud). Sites used to derive the initial BHM are black and the Manukau sites AA, CB and CH are blue, red and green, respectively. Data from 2002, 2009 and 2010 is denoted by an open circle, a closed circle and a closed square, respectively.
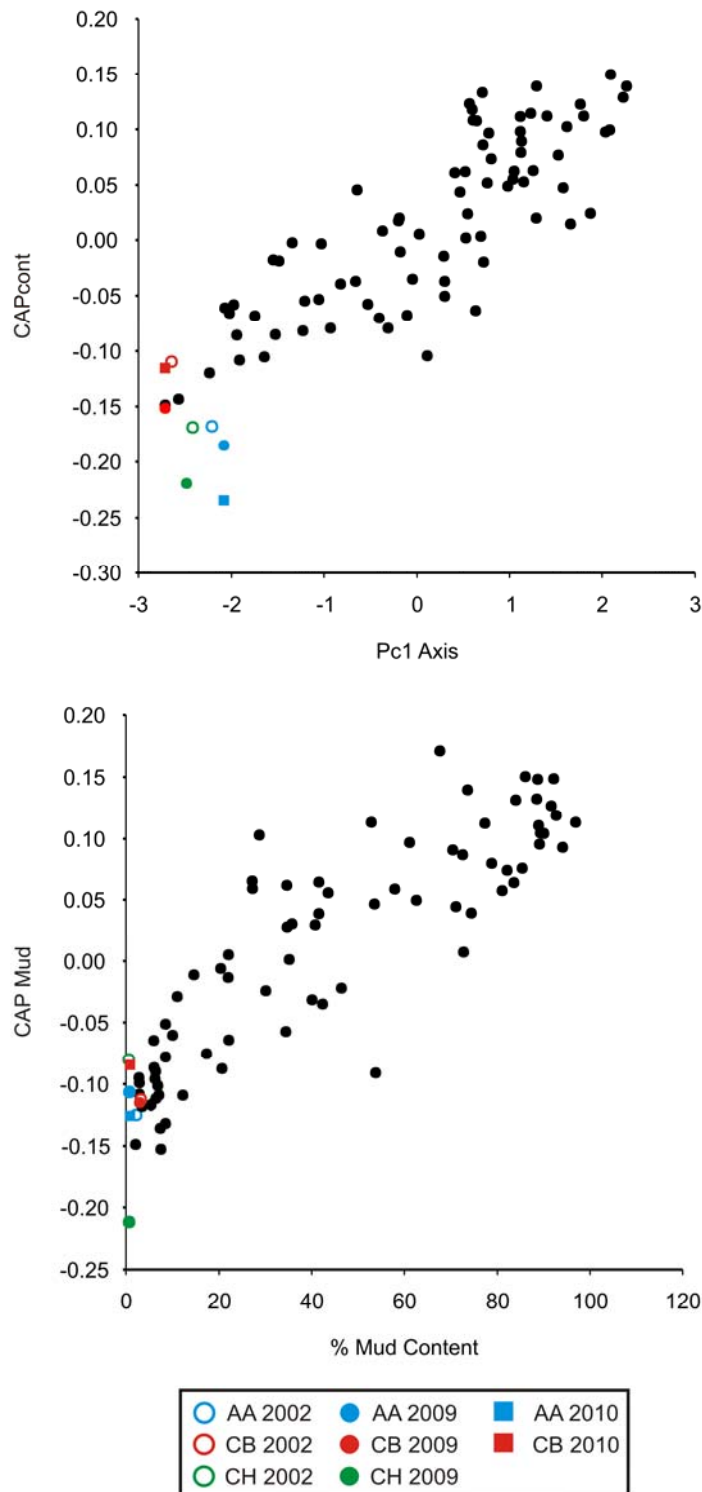
4.3 Summary and recommendations

The ecological monitoring of Manukau Harbour over the last 23 years has allowed the Auckland Council to state with authority that despite ongoing urbanisation and industralisation in catchments adjacent to Manukau Harbour, the extensive sandflats within the main body are not becoming degraded. The continuation of bimonthly monitoring at sites AA and CB is recommended and is important, as this data provide template patterns of species abundance against which the other sites are assessed. Furthermore, the data and information gathered from this extensive data set is used as a reference for other monitoring conducted by the Auckland Council (e.g., Mahurangi, Kaipara and Waitemata ecological monitoring programmes).

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7 Appendices

7.1 Monitored species for Manukau Harbour and their known sensitivity to mud and contaminants

The species recommended for monitoring are those that would be expected to show different types of changes in response to increased sediment or contaminant inputs and/or are likely to play key roles in influencing the composition of other taxa.

Arthropoda: Amphipoda

- *Methalimedon* sp.

Methalimedon sp. belongs to the amphipod family Exoedicerotidae. It is relatively common in estuarine sediments and is commonly found at monitoring sites in Manukau Harbour. It is most likely to be a deposit feeder, however, little is known about the genus.

- *Torridoharpinia hurleyi*

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

- *Waitangi brevirostris*

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

Cnidaria: Anthozoa

- *Anthopleura aureoradiata*

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

Mollusca: Bivalvia

- *Austrovenus stutchburyi*

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

- *Macomona liliana*

Macomona liliana (previously *Tellina liliana*) is a large deposit feeding bivalve. As an adult it lives well below the sediment surface (~10 cm) and feeds on the sediment surface using a long siphon. As a juvenile it is highly mobile, moving with bedload and in the water column. While it is mainly a deposit feeder, it can also suspension feed by lifting its siphon into the water column. It lives both intertidally and subtidally, can grow up to 70 mm, and can live for more than 5 years. Similar to *Austrovenus*, the species is an important prey item for birds (e.g., oyster catchers), rays and other fish and has been demonstrated to affect seafloor productivity and nutrient recycling (Thrush et al. 2006). It is also sensitive to terrestrial sedimentation (Norkko et al. 2002, Thrush et al. 2005), increases in suspended sediment (Nicholls et al. 2003) and stormwater contaminants (Hewitt et al. 2009).

- *Nucula hartvigiana*

Nucula hartvigiana is a small (generally <10 mm) deposit-feeding bivalve that lives near the sediment surface. It is a highly mobile species and is probably capable of rapid small scale recolonisation (Thrush et al. 1988, Lohrer et al. 2011). These bivalves are frequently found in the 'undisturbed' zones of an organic pollution gradient (Pearson & Rosenberg 1978). It is somewhat sensitive to sediment mud content (optimum 0–12, Thrush et al. 2003, Anderson et al. 2007) and copper (Hewitt et al. 2009).

- *Soletellina siliqua*

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

Arthropoda: Cumacea

- *Colorostylis lemurum*

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

Mollusca: Gastropoda

- *Notoacmea scapha*

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

Echinodermata: Holothuroidea

- *Trochodota dendyi*

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

Arthropoda: Isopoda

- *Exosphaeroma chilensis* and *Exosphaeroma falcatum*

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

Annelida: Polychaeta

- *Aglaophamus macroura*

Aglaophamus macroura is the common large predatory nephtyid found intertidally in New Zealand. Little is known about it, but another New Zealand species of similar size is slow growing and lives for at least five years. Nephtyids generally have been shown to be an important intermediate predator, living off smaller invertebrates (Hailes 2006) and providing an important food source for birds and small fish.

- *Aonides trifida*

Aonides trifida (previously *A. oxycephala*) is a small infaunal deposit feeder, living in a wide range of sediments but preferring those of low mud content (5 – 10%, Thrush et

al. 2003, Anderson et al. 2007). It is sensitive to copper contamination (Hewitt et al. 2009).

- *Boccardia syrtis*

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

- *Glycinde trifida*

Glycinde trifida (previously *Goniada emerita*, then *Glycinde dorsalis*) is a Goniadidae polychaete and has been found at all monitored sites in Manukau Harbour. It is moderately sized predator, often exhibiting 2 yearly recruitment patterns.

- *Macroclymenella stewartensis*

Macroclymenella stewartensis is a maldanid tube worm and is an important bioturbator (feeding on subsurface deposits and ejecting material on to the sediment surface. Its tubes can help stabilize surface sediments. It is sensitive to copper (Hewitt et al. 2009) and prefers sediment mud content between 10 and 15 % mud (Gibbs & Hewitt 2004).

- *Magelona dakini*

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

- *Orbinia papillosa*

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

- *Owenia petersonae*

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

- *Prionospio aucklandica*

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

- *Travisia olens* var. NZ

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

7.2 Sediment characteristics results since April 2009. Grain size fractions (% weight) are gravel (>2 mm), sand (2 mm-63 μm) and silt/clay (<63 μm); organic content (OC; %) and chlorophyll *a* (Chl*a*; μm/g sediment).

	Auckland Airport (AA)					Clarks Beach (CB)					Cape Horn (CH)				
	Gravel	Sand	Silt/Clay	OC	Chl*a*	Gravel	Sand	Silt/Clay	OC	Chl*a*	Gravel	Sand	Silt/Clay	OC	Chl*a*
Apr-09	0.03	99.21	0.77	0.66	9.98	0.51	91.85	7.64	1.23	12.27	0.00	99.50	0.50	0.58	8.25
Jun-09	1.37	97.86	0.77	0.62	10.09	0.64	83.43	15.93	1.81	11.12	0.06	98.06	1.88	0.78	9.17
Aug-09	0.36	99.01	0.64	0.55	11.23	0.05	90.11	9.84	1.03	13.64	0.00	98.73	1.27	1.03	11.92
Oct-09	0.11	99.07	0.82	0.74	10.54	2.61	94.55	2.84	1.08	9.51	0.30	99.13	0.57	0.76	8.37
Dec-09	0.55	98.61	0.84	0.50	7.91	0.91	93.69	5.39	1.10	10.66	0.00	99.29	0.71	0.68	10.09
Feb-10	0.00	99.31	0.69	0.56	11.46	4.84	89.89	5.27	1.02	8.71	0.00	99.59	0.41	0.60	7.34
Apr-10	0.00	99.23	0.77	0.62	10.54	0.38	84.89	14.73	2.36	10.66	0.00	99.79	0.21	0.66	10.31
Jun-10	0.12	99.43	0.45	0.59	12.04	1.29	88.73	9.98	1.67	8.37	0.00	99.43	0.57	0.67	10.77
Aug-10	0.10	99.08	0.82	0.61	8.60	1.16	86.14	12.69	1.36	9.28					
Oct-10	1.27	98.11	0.62	0.58	9.74	3.30	92.90	3.80	1.02	8.77					
Dec-10	0.00	99.59	0.41	0.35	10.09	1.97	90.25	7.78	1.88	9.17					
Feb-11	1.41	97.85	0.74	0.45	10.32	8.77	86.62	4.61	0.94	11.35					

7.3 The three most abundant species found in October each year at monitored sites a) AA, b) CB and c) CH.

A) AA			
Year			
1987	*Macomona liliana*	*Soletellina siliqua*	*Austrovenus stutchburyi*
1989	*Macomona liliana*	*Austrovenus stutchburyi*	*Magelona dakini*
1990	*Macomona liliana*	*Soletellina siliqua*	*Austrovenus stutchburyi*
1991	*Macomona liliana*	*Austrovenus stutchburyi*	*Nucula hartvigiana*
1992	*Macomona liliana*	*Travisia olens*	*Austrovenus stutchburyi*
1993	*Macomona liliana*	*Austrovenus stutchburyi*	*Travisia olens*
1994	*Macomona liliana*	*Austrovenus stutchburyi*	*Travisia olens*
1995	*Macomona liliana*	*Austrovenus stutchburyi*	*Soletellina siliqua*
1996	*Macomona liliana*	*Soletellina siliqua*	*Magelona dakini*
1997	*Macomona liliana*	*Soletellina siliqua*	*Austrovenus stutchburyi*
1998	*Macomona liliana*	*Soletellina siliqua*	*Austrovenus stutchburyi*
1999	*Macomona liliana*	*Orbinia papillosa*	*Soletellina siliqua*
2000	*Macomona liliana*	*Soletellina siliqua*	*Orbinia papillosa*
2001	*Macomona liliana*	*Magelona dakini*	*Trochodota dendyi*
2002	*Macomona liliana*	*Magelona dakini*	*Trochodota dendyi*
2003	*Macomona liliana*	*Magelona dakini*	*Nucula hartvigiana*
2004	*Macomona liliana*	*Soletellina siliqua*	*Aonides trifida*
2005	*Macomona liliana*	*Magelona dakini*	*Soletellina siliqua*
2006	*Macomona liliana*	*Soletellina siliqua*	*Colurostylis lemurum*
2007	*Soletellina siliqua*	*Macomona liliana*	*Aonides trifida*
2008	*Aonides trifida*	*Macomona liliana*	*Soletellina siliqua*
2009	*Macomona liliana*	*Aonides trifida*	*Travisia olens*
2010	*Macomona liliana*	*Aonides trifida*	*Colurostylis lemurum*

b) CB

Year			
1989	*Macroclymenella*	*Macomona liliana*	*Torridoharpinia hurleyi*
1990	*Nucula hartvigiana*	*Boccardia syrtis*	*Macroclymenella*
1991	*Nucula hartvigiana*	*Macomona liliana*	*Macroclymenella*
1992	*Macroclymenella*	*Macomona liliana*	*Torridoharpinia hurleyi*
1993	*Macroclymenella*	*Boccardia syrtis*	*Nucula hartvigiana*
1994	*Macomona liliana*	*Macroclymenella*	*Torridoharpinia hurleyi*
1995	*Nucula hartvigiana*	*Magelona dakini*	*Macroclymenella*
1996	*Nucula hartvigiana*	*Boccardia syrtis*	*Torridoharpinia hurleyi*
1997	*Nucula hartvigiana*	*Boccardia syrtis*	*Macomona liliana*
1998	*Nucula hartvigiana*	*Macomona liliana*	*Torridoharpinia hurleyi*
1999	*Macroclymenella*	*Nucula hartvigiana*	*Macomona liliana*
2000	*Nucula hartvigiana*	*Macomona liliana*	*Macroclymenella*
2001	*Macomona liliana*	*Nucula hartvigiana*	*Macroclymenella*
2002	*Nucula hartvigiana*	*Macomona liliana*	*Magelona dakini*
2003	*Macroclymenella*	*Nucula hartvigiana*	*Macomona liliana*
2004	*Macroclymenella*	*Magelona dakini*	*Macomona liliana*
2005	*Macroclymenella*	*Nucula hartvigiana*	*Torridoharpinia hurleyi*
2006	*Nucula hartvigiana*	*Macroclymenella*	*Macomona liliana*
2007	*Macroclymenella*	*Torridoharpinia hurleyi*	*Nucula hartvigiana*
2008	*Nucula hartvigiana*	*Macroclymenella*	*Macomona liliana*
2009	*Nucula hartvigiana*	*Macroclymenella*	*Macomona liliana*
2010	*Nucula hartvigiana*	*Macroclymenella*	*Macomona liliana*

c) CH

Year			
1987	*Magelona dakini*	*Glycinde trifida*	*Macroclymenella*
1989	*Boccardia syrtis*	*Magelona dakini*	*Macroclymenella*
1990	*Boccardia syrtis*	*Macomona liliana*	*Macroclymenella*
1991	*Boccardia syrtis*	*Macroclymenella*	*Macomona liliana*
1992	*Macroclymenella*	*Colurostylis lemurum*	*Torridoharpinia hurleyi*
1993	*Macroclymenella*	*Torridoharpinia hurleyi*	*Magelona dakini*
1994	*Macroclymenella*	*Magelona dakini*	*Glycinde trifida*
1995	*Boccardia syrtis*	*Magelona dakini*	*Glycinde trifida*
:			
1999	*Torridoharpinia hurleyi*	*Macroclymenella*	*Magelona dakini*
2000	*Magelona dakini*	*Boccardia syrtis*	*Colurostylis lemurum*
2001	*Magelona dakini*	*Macroclymenella*	*Colurostylis lemurum*
2002	*Magelona dakini*	*Colurostylis lemurum*	*Soletellina siliqua*
2003	*Magelona dakini*	*Macroclymenella*	*Colurostylis lemurum*
2004	*Magelona dakini*	*Macroclymenella*	*Colurostylis lemurum*
2005	*Magelona dakini*	*Macroclymenella*	*Waitangi brevirostris*
2006	*Magelona dakini*	*Macroclymenella*	*Soletellina siliqua*
2007	*Magelona dakini*	*Macroclymenella*	*Colurostylis lemurum*
2008	*Colurostylis lemurum*	*Magelona dakini*	*Macroclymenella*
2009	*Macroclymenella*	*Magelona dakini*	*Colurostylis lemurum*
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