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Ecological Monitoring Programme for Manukau Harbour: Report on data collected up to February 2003

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Ecological Monitoring Programme for Manukau Harbour: Report on data collected up to February 2003

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Executive Summary

This report updates the results of the Manukau Harbour Ecological Monitoring Programme, established in October 1987. 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. Since April 2001, only three of the six original sites have been sampled (Auckland Airport, Clarks Beach and Cape Horn). This report encompasses all data collected at these sites from the start of the programme to February 2003.

In the last report it was noted that three taxa (*Aonides oxycephala*, *Aquilaspio aucklandica* and *Magelona ?dakini*) were exhibiting trends of abundance possibly related to increased sediment silt/clay levels. Further data has revealed that sediment silt/clay levels have reduced to levels seen at the start of the monitoring programme and that the trends of abundance in these species have also all reduced in magnitude.

At the Cape Horn site a number of changes have occurred in the monitored taxa over the last two years. Two previously rare species (*Magelona ?dakini* and *Waitangi brevirostris*) have increased in abundance and two species (*Owenia fusiformis* and *Goniada emerita*) have completely disappeared. The site has also changed from being dominated by the tubeworm *Boccardia syrtis* to being dominated by a mix of polychaetes, cumaceans, bivalves and amphipods. With the decommissioning of the Mangere wastewater treatment plant, it was expected that the water quality would improve and this may have been a contributing factor to the change at this site. However, sediment silt/clay levels are also less than previously observed and the site elevation may have increased.

On evidence from the principle two sites at Auckland Airport and Clarks Beach, we are able to identify a number of greater than annual cycles. Previous reports have shown the high value that these continuous data sets have in enabling us to assess what is happening at the other four sites around the Manukau.

We make the following recommendations.

- Monitoring of the Auckland Airport and Clarks Beach sites continue.

- Monitoring at the Cape Horn site continued to determine whether the changes to the site persist. A visit to Te Tau Bank by NIWA staff to measure elevation of the site and carry out an, at least visual, investigation of the surrounding environment and communities is also recommended.

1. Introduction

In October 1987 the Water Quality Centre (now NIWA) was commissioned to design and conduct a biological monitoring programme for Manukau Harbour. Six sites around the harbour were chosen and monitored in order to document changes in the ecology of the intertidal sandflat communities on a harbour-wide basis and to provide information important for ecosystem management. This was the first harbour-wide ecological monitoring conducted in New Zealand. When monitoring was initiated, it was envisaged that the programme would be maintained for five years. After this time, sufficient data would enable appropriate statistical analyses to be carried out, leading to recommendations on a cost-effective continuation. The recommendations for cost-effective monitoring were to reduce the intensity of monitoring to two sites for five years, and then reinstate the full monitoring programme, in 1998, for a period of two years (Hewitt et al. 1994). Resumption of monitoring the original six sites would provide an update of resource quantity and quality, as well as a valuable check that nothing unexpected had happened at the four unmonitored sites.

After careful consideration, the monitoring programme was reduced to monitoring only the Auckland Airport and Clarks Beach sites. Since December 1996, ARC staff have carried out the sampling at these two sites. Resumption of the full monitoring programme commenced in August 1999, with sampling conducted by both NIWA and ARC staff. The full monitoring programme ran for 2 years, up until April 2001. Since April 2001 the monitoring programme has again been reduced, and now includes the continuously monitored sites at Auckland Airport and Clarks Beach, as well as the Cape Horn site. The Cape Horn site was included as it was decided, in consultation with the ARC, that due to the improvements in water treatment discharging into the Manukau at Mangere, the Cape Horn site might provide interesting changes relating to the expected improved water quality. A previous report (Funnell et al. 1991), which included data from all six sites, clearly indicated the benefits of having the two continuous data sets at Auckland Airport and Clarks Beach. Based on the information gained from these sites, cyclic patterns could be observed in the broken data sets which otherwise might have been seen as increasing or decreasing trends in abundance.

This report presents results of data collected in the last two years (April 2001 to February 2003) of the reduced monitoring programme.

2. Methods

2.1 Sample collection and identification

The sites at Auckland Airport and Clarks Beach (Figure 1) have been sampled every two months between October 1987 and April 2003. Two sampling occasions were missed (October and December 1988) due to lack of continuity of funding. The site at Cape Horn has been sampled for the ARC from October 1987 to February 1993, and again from August 1999 to April 2003. Additional sampling was carried out at Cape Horn by NIWA, without funding by the ARC, from February 1993 to December 1995. This data was collected as part of studies conducted on Te Tau bank, and funded via the Foundation for Research Science and Technology.

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

2.2 Bivalve size class analysis

After identification all bivalves are measured. Bivalves less than 10mm (longest shell dimension) are measured using a digitiser attached to a microscope. Larger bivalves are measured with digital callipers. Individuals are then allotted to particular size classes corresponding to the mesh sizes of the sieves used in previous years (i.e., ≤1mm, >1-2mm, >2-4mm, >4-8mm, >8-11mm, >11-16mm, >16-22mm and >22mm).

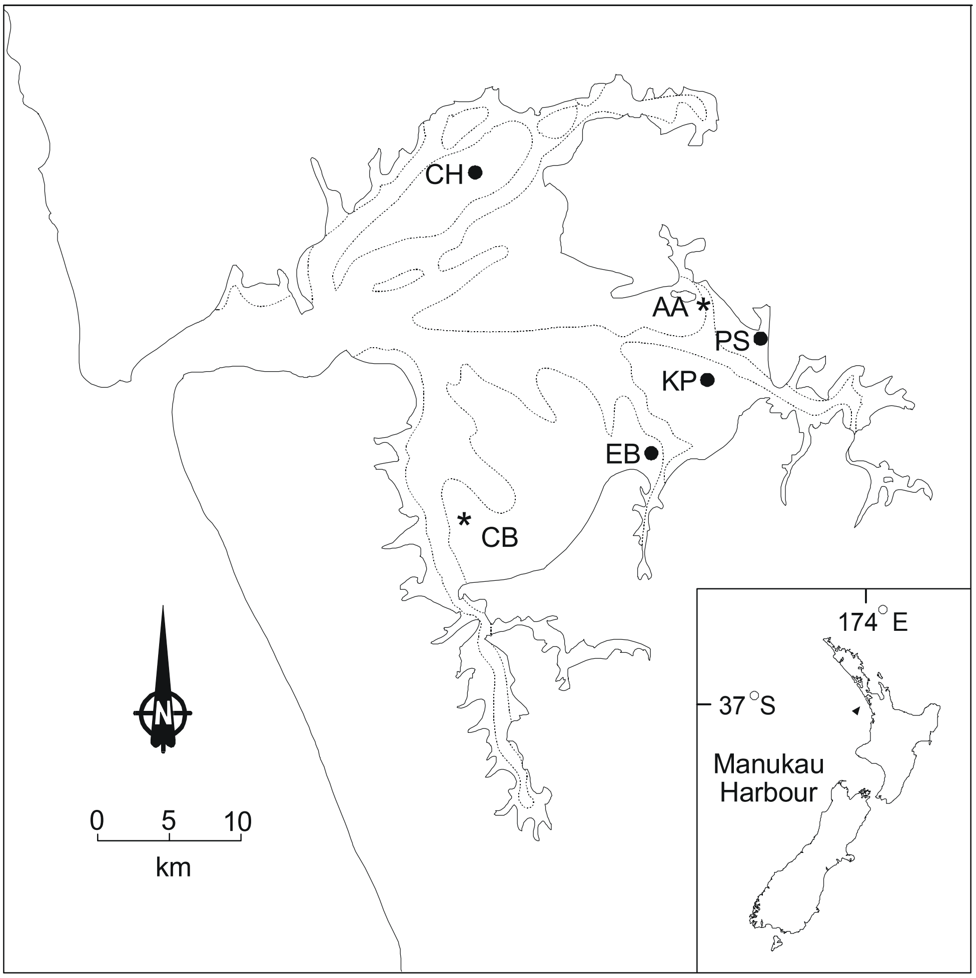
2.3 Site characteristics

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

Between 1995 and 1998, a number of scoops of surface sediment (<2 cm deep) were taken at each site in October for grain size analysis. Since August 1999, scoops have been taken at each site on each sampling occasion. A composite sample is made for each site, and organic matter is removed from the sample by digestion in hydrogen peroxide. Sediment grain size analysis is then carried out by wet sieving into fractions of gravel (particles >2mm), sand (particles 63µm-2mm) and silt/clay (particles <63µm), which are then dried and weighed. This same procedure was used to determine the sediment characteristics for each site in October 1987. To determine the organic content, the remainder of the homogenised sediment sample collected for grain size analysis is dried at 90°C for 48 h, and combusted for 5.5 h at 400°C. Also, on each sampling occasion, 6 core samples (adjacent to every second macrofauna core, 2.5cm diameter and 2cm deep) are collected and bulked for chlorophyll *a* analysis. Chlorophyll *a* (a measure of food supply to benthic animals) is extracted from sediments by boiling in 95%

ethanol, and measured spectrophotometrically. An acidification step was used to separate degradation products from chlorophyll *a* (Sartory 1982).

Figure 1: Map of Manukau Harbour showing the position of the two continuously monitored intertidal sandflat sites (marked with an asterisk), together with the position of the other four partially monitored sites. Sites: AA (Auckland Airport), CB (Clarks Beach), CH (Cape Horn), PS (Puhinui Stream), KP (Karaka Point) and EB (Elletts Beach).



2.4 Statistical analyses[1]

Statistical analyses were performed to identify significant linear trends, step trends or changes in temporal cycles. Methods for analysing temporal variations are given in detail in the fifth year summary report (Hewitt et al. 1994) and are briefly described below.

- For all monitored populations at a site, graphs of abundance vs. time are drawn and temporal autocorrelation analyses are carried out.
- The time series of each population is tested to determine whether the variation in the temporal series contains a cyclic component.
- Trend analyses are conducted on:
  1. the original time series data
  2. the residuals if a cyclic model can be fitted
  3. the basal population where a basal period can be detected.
- When a dataset exhibits significant temporal autocorrelation, adjustments are made to the calculation of standard errors and significance values.
- For all populations in which a trend in abundance is detected, the fit of the trend to the observed data is examined by analysis of the residuals.

In addition, ordinations of the monitored species at each site were conducted using correspondence analysis (ter Braak, 1986). This procedure is consistent with that used in the Mahurangi Monitoring Programme (Cummings et al., 2001). This technique summarizes the changes occurring in all monitored taxa, however, since the analysis only uses data for the relatively few monitored species, patterns do not necessarily mirror community dynamics. Due to the large number of data points since the start of the programme only the October sampling times were analysed. October sampling times should not be largely influenced by the recruitment peaks that occur for some of the monitored species.

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1 Analyses presented are based on the total numbers of individuals found in the 12 core samples collected on each sampling occasion.

3. Present status of the benthic communities of Manukau Harbour[2]

This monitoring programme was designed to address the following questions:

"Are populations at the monitored sites generally exhibiting similar patterns?"

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

In order to answer these two general questions a series of more specific questions can be posed:

1. Have there been any changes in the general appearance of the sites or the areas nearby?

a) General site descriptions

Auckland Airport – The appearance of this site largely changes due to the presence or absence of ray pits. During summer large numbers of pits can cause a major change in surface topography, creating a mottled appearance with shell hash surrounding the pits. In winter the incidence of ray pits is low and the site is largely flat with relatively little shell hash. The sediment surface is normally covered in sand ripples.

Clarks Beach – This site generally has few surface features other than minor sand ripples. The site's appearance is largely determined by the presence or absence of a surficial mud and/or diatom layer. At times deep muddy hummocks have covered the site. For example, in October 1999 the site had an obviously muddy surface with 2-3 cm deep hummocks.

Cape Horn – The appearance of Cape Horn changes due to the presence/absence of the polychaete *Boccardia syrtis*. At times during the year dense mats of *Boccardia syrtis* tubes create large patches of soft mud several centimetres thick. Areas not covered by this mud/*Boccardia* layer tend to have sand ripples, and a few ray pits. Since the monitoring programme began the elevation of this site has changed, resulting in the need to move the site up shore by 50m in 1999 to keep the area sampled in the intertidal zone.

[2] Summary statistics of the monitored populations are presented in Appendix 1.

b) Sediment characteristics

Silt/clay levels at Auckland Airport in the past 2 years have not changed much compared to previous years (Funnell et al. 2001), and remain similar to the levels recorded at the start of the monitoring programme in 1987 (Table 1). At Clarks Beach in October 2001 the silt/clay level recorded was ~5 times higher than that recorded in 1987. Site descriptions for October 2001 indicate the presence of a surface mud layer. However, after a number of years where the silt levels were considerably higher than at the start of the programme, the levels observed in October 2002 are close to those originally found in 1987 (Table 1). The sediment silt levels for Cape Horn in October of the last three years have been lower than those found at the beginning of the monitoring programme. Results for the more intensive sampling carried out over the last two years of monitoring (i.e., sediment collected at each sampling time for each site), show that the silt levels tend to be quite variable, as might be expected in a harbour with extensive intertidal areas and strong, variable wind patterns. Levels have ranged from 0.5-16.5% at the Auckland Airport site, from 1.4-15.8% at the Clarks Beach site and from 0.4-14.7% at the Cape Horn site over the last two years (full grain size results are given in Appendix 2).

Chlorophyll *a* results show that levels were variable between sites and times of the year. They ranged from 8.5 to 17.0µg Chlorophyll *a* per gram of sediment. A table of Chlorophyll *a* results are given in Appendix 3.

Organic content varies slightly throughout the year, with higher values from April to August (Appendix 4). A very high value found in October 2002 at the Cape Horn site was probably due to the presence of a dead large worm in the sample.

Table 1: Sediment grain size (percent composition) at the Auckland Airport and Clarks Beach sites for the whole period of sediment sampling, and at Cape Horn for the initial sampling time and since the reinstatement of the full programme (October sampling times only). Gravel particles >2mm, Sand particles 63µm-2mm, Silt/clay particles <63µm.

Site		1987	1995	1996	1997	1998	1999	2000	2001	2002
AA	%gravel	1.6	0.6	0.4	0.02	0.3	1.3	0.0	0.0	0.2
	% sand	96.7	99.1	99.3	99.5	96.7	97.5	98.9	98.1	99.0
	%silt/clay	1.7	0.3	0.3	0.51	3.0	1.2	1.1	1.9	0.8
CB	%gravel	6.1	4.3	3.9	5.15	1.31	0.5	2.1	1.5	5.2
	% sand	91.1	93.2	94.3	84.2	90.3	56.9	90.9	82.7	91.8
	%silt/clay	2.8	2.5	1.8	10.7	8.4	42.6	7.0	15.8	3.0
CH	%gravel	2.5					0.1	0.0	0.0	0.0
	% sand	93.3					95.6	98.7	97.8	99.6
	%silt/clay	4.2					4.3	1.3	2.2	0.4

2. Are annual cycles in abundance being maintained?

All cyclic patterns in the abundance of populations identified in previous reports are still present at the Auckland Airport and Clarks Beach sites. With 15 years of uninterrupted data, 5 - 7 yearly cycles for some populations are apparent (for example, *Magelona ?dakini*, Figure 2).

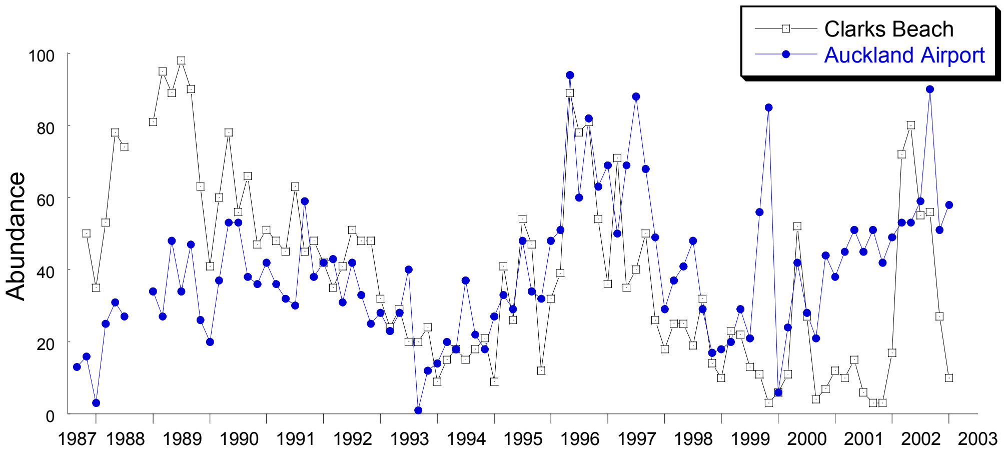


Figure 2: Greater than annual cycles are apparent for some monitored populations, for example *Magelona ?dakini* at Clarks Beach and Auckland Airport.

Figure 3 shows how recruitment of *Macomona liliana* can be variable and not consistent from year to year. However, this variability in recruitment does not significantly impact on the abundances of adults greater than 16mm in size. As mentioned in previous reports it is likely that for the bivalve species monitored, the low variable recruitment with occasional high peaks is the norm.

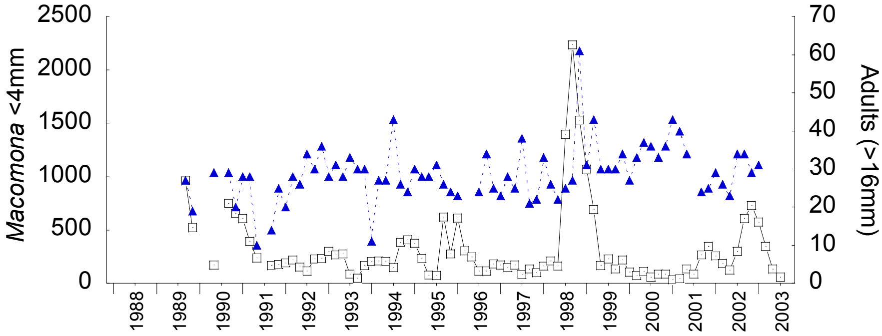


Figure 3: Abundances of *Macomona liliana* sized <4mm (squares) and *Macomona liliana* adults sized >16mm (triangles) at the Auckland Airport site.

3. Are trends in abundance being maintained?

As the length of the monitored period increases, some trends prove to be part of longer term cycles. In the data collected up to February 2001, we detected eleven trends in abundance at Auckland Airport and Clarks Beach (Table 2). We also conducted trend analysis for the reduced data set at Cape Horn, which detected an increasing trend in *Hiatula siliqua*.

Table 2: Statistically significant trends in abundance detected at Auckland Airport and Clarks Beach over the whole monitoring period. Direction (increase '+' or decrease '-') and magnitude[3] of the trend are presented.

Taxa	October 1987 to February 1994	October 1987 to February 1999	October 1987 to February 2001	October 1987 to February 2003
a) Auckland Airport site				
Anthopleura aureoradiata	-3.43	-3.8	-3.2	
Aonides oxycephala	-29.8	-34.5	-26.9	-23.6
Aquilaspio aucklandica			+1.7	+1.6
Magelona ?dakini				+19.8
Nucula hartvigiana			-24.9	-27.9
b) Clarks Beach site				
Anthopleura aureoradiata				+6.5
Aonides oxycephala		-7.2	-6.0	-5.6
Aquilaspio aucklandica			+19.0	+10.8
Boccardia syrtis				-57.5
Exosphaeroma spp.	+3.7	-5.61	-5.3	+0.9
Hiatula siliqua	-29.9	-9.52	-8.2	-7.7
Magelona ?dakini	-56.9	-20.3	-24.3	-20.5
Orbinia papillosa		-1.3	-1.2	-1.0
Torridoharpinia hurleyi			+18.6	
Trochodota dendyi				-3.3
c) Cape Horn				
Goniada emerita				-11.0
Magelona ?dakini				+33.0
Owenia fusiformis				-7.5
Hiatula siliqua			+3.5	+4.9
Trochodota dendyi				+0.3
Waitangi brevirostris				+1.8

[3] Magnitude refers to the change in number of individuals in 12 cores, compared to the initial sampling occasion in 1987 (after any cyclic component has been removed).

Auckland Airport

Three of the four trends detected in the previous report are still present and after another two years of data, one new trend has been identified. The magnitude of the trend for both *Aquilaspio aucklandica* and *Aonides oxycephala* has reduced slightly, although the magnitude of the trend in *Aonides oxycephala* is still greater than that of *Aquilaspio aucklandica*. For *Aonides oxycephala* the decrease in magnitude relates to the slight increase in abundances over the last four years (Figure 4a). The decrease in magnitude for *Aquilaspio aucklandica* can be attributed to the very low numbers of this species found at this site since 1992 (Figure 4b). There has been a slight increase in the magnitude of the negative trends for *Nucula hartvigiana*. The abundances for *Nucula hartvigiana* have been consistently lower over the last seven years compared to the first six years of monitoring. The trend for *Anthopleura aureoradiata* is no longer reported on as this species has been absent from this site since August 1991.

Magelona ?dakini has exhibited an increase in numbers over the course of the monitoring programme. It is clear that, at both Clarks Beach and Auckland Airport, *Magelona ?dakini* exhibits a greater than annual cycle of abundance (Figure 2). Interestingly, while *Magelona ?dakini* has decreased at Clarks Beach over the course of the whole monitored period, it has increased at Auckland Airport.

Clarks Beach

Of the seven species for which trends were reported in the last report, five continue to exhibit trends in the same direction, one trend has changed from a decrease to an increase in abundance, and the other is no longer significant. Three new trends have also been detected.

For all the species exhibiting the same type of trend as the previous report, the magnitude of change has decreased (i.e., *Aonides* oxycephala, *Aquilaspio aucklandica*, *Hiatula siliqua*, *Magelona ?dakini* and *Orbinia papillosa*). The slight decrease in magnitude for *Aonides oxycephala*, *Hiatula siliqua* and *Orbinia papillosa* is due to the continually low abundances of these species at this site. As mentioned earlier, *Magelona ?dakini* is exhibiting a greater than annual cycle of abundance (Figure 2). However, taking into account the cyclic nature of *Magelona ?dakini* abundance, there is still a detectable decrease over the course of the entire monitoring programme. Over the last two years this decrease has reduced in magnitude indicating an increased abundance at this site over the last two years. *Aquilaspio aucklandica* exhibits a cyclic pattern where times of low abundance are interspersed with occasional times of high abundance (Figure 4b). As predicted in Funnell et al. (2001), a decrease in the abundances of *Aquilaspio aucklandica* over the last two years compared to the previous 4 years has caused the decrease in magnitude for this species. The trend for *Exosphaeroma* spp. has reversed over the last two years, however this is likely due to the generally low numbers and periods of high variability.

This year a trend in the abundance of *Trochodota dendyi* was detected. This species was present in higher numbers at the start of the monitoring programme (pre-June 1992), and has generally exhibited low, but decreasing, abundances since. *Boccardia syrtis* also exhibits a decreasing trend of abundance. Analysis of the base population (i.e., the data set with the periods of recruitment removed) indicates that the level of recruitment has not changed but the base population has decreased. *Anthopleura aureoradiata* is exhibiting an increase in abundance.

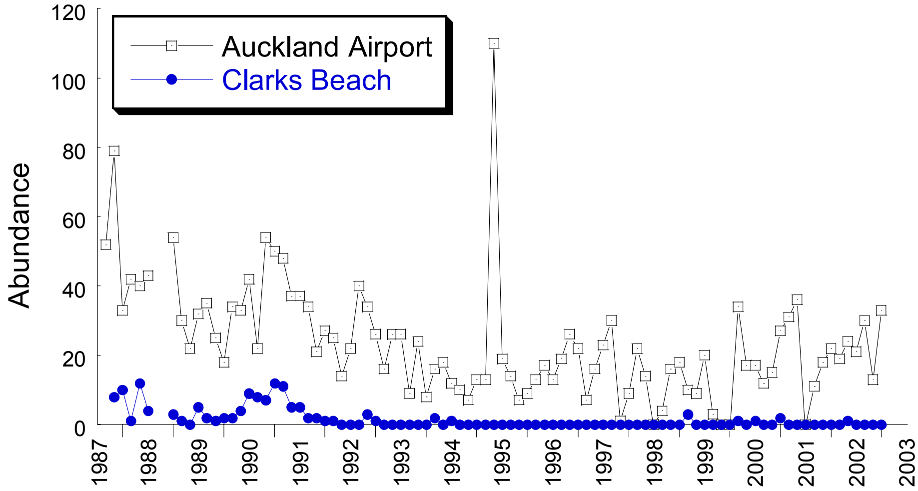
Cape Horn

Cape Horn has not been monitored continuously like the sites at Clarks Beach and Auckland Airport. Therefore, trends for certain species may be identified in the Cape Horn data set that have been identified as belonging to greater than annual cycles of abundance in the complete data set at Clarks Beach and Auckland Airport.

The only trend detected in the previous report at Cape Horn was for the bivalve *Hiatula siliqua,* which had a slight increase in abundance. With another two years of data the magnitude of the trend for this bivalve has increased slightly. However, this species tends to exhibit cyclic patterns of abundance at other sites and therefore this increase maybe part of a greater than annual cycle.

Five other trends have now been identified at this site. Four of these are driven by what appears to be a change over the last year of monitoring. Two of these (*Owenia fusiformis* and *Goniada emerita*) are due to their complete absence from this site since August 2001 and April 2002, respectively. Both species were relatively common prior to 1996 when sampling at this site was interrupted. The other two species (*Magelona ?dakini* and *Waitangi brevirostris*) have increased in abundance. *Magelona ?dakini*, in particular, exhibited a large increase in abundance over the last year. As described at other sites, *Magelona ?dakini* has a cyclic pattern to its abundance and it is likely that the numbers will reduce over the next couple of years. However, the increase over the last year is nearly double the abundances found at any other time during the monitored period, and such a large increase is not mirrored at the other two sites. *Waitangi brevirostris* was virtually absent from the site prior to 1996, but over the last year it has become less rare, although the numbers are still low (<10 per sampling time). *Trochodota dendyi* is mostly absent from this site and is only ever found in very low numbers (<2 per sampling time).

a)



b)

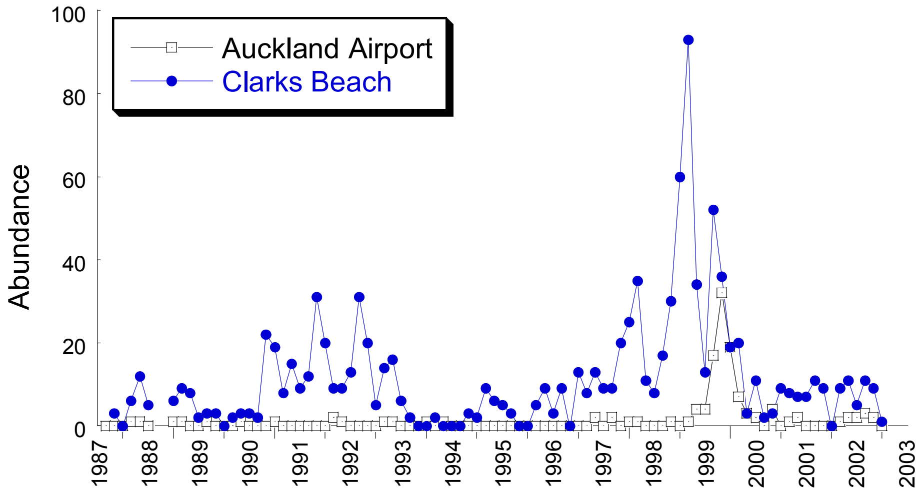


Figure 4: a) *Aonides oxycephala* over the last two years has increased slightly in abundance at both the Auckland Airport and Clarks Beach sites. b) *Aquilaspio aucklandica* has shown a decrease in abundance over the last two years at both sites, probably as part of 8 year cycle.

4. Are dominant species consistent over time?

Table 3 shows the changes in the three most dominant species in February of each year at all sites. At the Auckland Airport site, the dominant species present has consistently been *Macomona liliana*, with changes in the second and third most abundant species reflecting long-term trends and cycles in abundance (Table 3a). The decrease in *Aonides oxycephala* at this site is reflected in the absence of this species from the dominant taxa after 1991. The Clarks

Beach site exhibits more change in the most dominant species, again reflecting long-term cycles in abundance (Table 3b). For example, the appearance of *Boccardia syrtis* amongst the dominant taxa from 1991 to 1994 reflects the five to seven year cycle common for this species around the Manukau. Since 1989, *Magelona ?dakini* has not been a dominant species, reflecting a trend of decreasing abundance. In the past, Cape Horn tended to be dominated by the polychaete *Boccardia syrtis,* which can occur at abundances of greater than 7000 individuals per sampling time at this site (i.e., an average of 583 individuals per core, or 132cm^2 of sediment surface). However, over the last 2 years, *Boccardia syrtis* has not been dominant. Instead *Magelona ?dakini* was the most numerically dominant species over the last 2 years. The cumacean *Colurostylis lemurum*, the bivalve *Hiatula siliqua* and the amphipod *Methalimedon* sp. all became dominant for the first time in the last 2 years (Table 3c). It appears that most changes in the dominant taxa are due to long term trends and cycles of abundance, and therefore many are driven by recruitment.

Table 3: The three most abundant species found in February each year at the monitored sites [4].

a) Auckland Airport

Year	Auckland Airport		
1988	*Macomona liliana*	*Austrovenus stutchburyi*	*Aonides oxycephala*
1989	*Macomona liliana*	*Austrovenus stutchburyi*	*Orbinia papillosa*
1990	*Macomona liliana*	*Austrovenus stutchburyi*	*Exosphaeroma* spp.
1991	*Macomona liliana*	*Nucula hartvigiana*	*Aonides oxycephala*
1992	*Macomona liliana*	*Nucula hartvigiana*	*Magelona ?dakini*
1993	*Macomona liliana*	*Travisia olens*	*Orbinia papillosa*
1994	*Macomona liliana*	*Austrovenus stutchburyi*	*Travisia olens*
1995	*Macomona liliana*	*Austrovenus stutchburyi*	*Nucula hartvigiana*
1996	*Macomona liliana*	*Magelona ?dakini*	*Travisia olens*
1997	*Macomona liliana*	*Magelona ?dakini*	*Orbinia papillosa*
1998	*Macomona liliana*	*Austrovenus stutchburyi*	*Magelona ?dakini*
1999	*Macomona liliana*	*Hiatula siliqua*	*Orbinia papillosa*
2000	*Macomona liliana*	*Mactra ovata*	*Hiatula siliqua*
2001	*Macomona liliana*	*Waitangi brevirostris*	*Magelona ?dakini*
2002	*Macomona liliana*	*Orbinia papillosa*	*Magelona ?dakini*
2003	*Macomona liliana*	*Magelona ?dakini*	*Orbinia papillosa*

[4] *Macroclymenella stewartensis,* for convenience, is referred to by genus only in this table.

b) Clarks Beach

Year	Clarks Beach		
1988	*Nucula hartvigiana*	*Macomona liliana*	*Magelona ?dakini*
1989	*Magelona ?dakini*	*Nucula hartvigiana*	*Macomona liliana*
1990	*Nucula hartvigiana*	*Magelona ?dakini*	*Macomona liliana*
1991	*Boccardia syrtis*	*Macroclymenella*	*Nucula hartvigiana*
1992	*Boccardia syrtis*	*Macroclymenella*	*Macomona liliana*
1993	*Boccardia syrtis*	*Macroclymenella*	*Nucula hartvigiana*
1994	*Boccardia syrtis*	*Macomona liliana*	*Nucula hartvigiana*
1995	*Macroclymenella*	*Nucula hartvigiana*	*Macomona liliana*
1996	*Nucula hartvigiana*	*Boccardia syrtis*	*Macomona liliana*
1997	*Macroclymenella*	*Nucula hartvigiana*	*Macomona liliana*
1998	*Boccardia syrtis*	*Macomona liliana*	*Austrovenus stutchburyi*
1999	*Nucula hartvigiana*	*Macomona liliana*	*Aquilaspio aucklandica*
2000	*Torridoharpinia hurleyi*	*Macroclymenella*	*Macomona liliana*
2001	*Boccardia syrtis*	*Nucula hartvigiana*	*Macomona liliana*
2002	*Nucula hartvigiana*	*Macomona liliana*	*Macroclymenella*
2003	*Macomona liliana*	*Nucula hartvigiana*	*Macroclymenella*

c) Cape Horn

Year	Cape Horn		
1988	*Boccardia syrtis*	*Goniada emerita*	*Magelona ?dakini*
1989	*Boccardia syrtis*	*Magelona ?dakini*	*Macomona liliana*
1990	*Boccardia syrtis*	*Magelona ?dakini*	*Macroclymenella*
1991	*Boccardia syrtis*	*Goniada emerita*	*Torridoharpinia hurleyi*
1992	*Boccardia syrtis*	*Goniada emerita*	*Macroclymenella*
1993	*Macroclymenella*	*Magelona ?dakini*	*Boccardia syrtis*
:			
2000	*Magelona ?dakini*	*Macroclymenella*	*Torridoharpinia hurleyi*
2001	*Boccardia syrtis*	*Torridoharpinia hurleyi*	*Magelona ?dakini*
2002	*Magelona ?dakini*	*Colurostylis lemurum*	*Macroclymenella*
2003	*Magelona ?dakini*	*Hiatula siliqua*	*Methalimedon* sp.

5. Do any of the sites exhibit differences in time over all monitored species?

Variability in the composition of the monitored taxa assemblages over time was examined for each site using Correspondence Analysis. The closer together points are in the ordination space the more similar the communities are. Conversely, the larger the area taken up by points, the more the communities are changing over time. Figure 5 shows how the three currently monitored sites have changed since the start of the monitoring programme (October sampling dates only). Note that both the Auckland airport and Clarks Beach sites show very little variation in community composition over time. The Cape Horn site shows a couple of periods where community composition has deviated from the community observed at the start of the monitoring. Normally during October, densities of *Boccardia syrtis* are very low, however at times large peaks do occur and the changes seen in the plot relate to these periods of high abundance. Over the last four years, however, the community composition has been similar to that at the start of the monitored period. Note that for 3 years between 1995 and 1999 the site at Cape Horn was not monitored (marked on the Figure 5 by the dashed line).

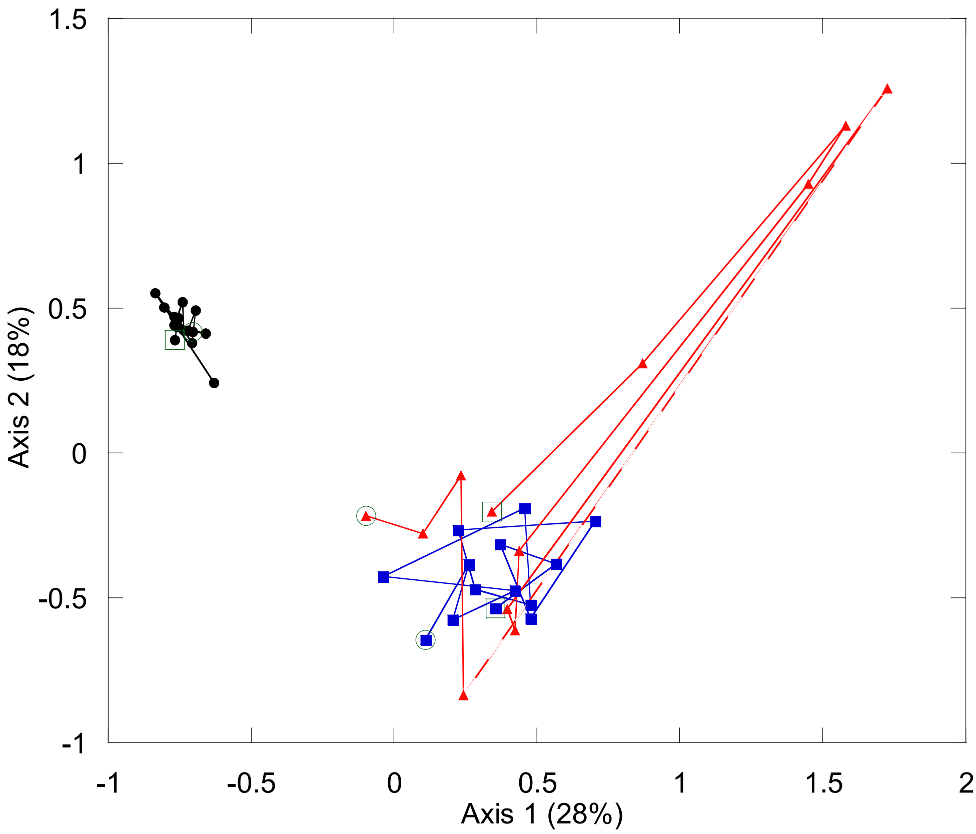


Figure 5: Correspondence Analysis ordination plots of the monitored community composition for October sampling times since the start of the monitoring programme. Auckland Airport, Clarks Beach and Cape Horn sites are marked by circles, squares and triangles respectively. The earliest sampling occasion is marked by open squares, and the most recent sampling time by open circles. The dashed line on the Cape Horn plot indicates the period in which no monitoring took place.

4. Conclusions

"Are populations at the three sites generally exhibiting similar patterns?"

The cyclic abundance patterns observed for Auckland Airport and Clarks Beach in the previous report are still present, and some similar patterns are emerging at the Cape Horn site (e.g., for Magelona ?dakini and Aonides oxycephala). Thus we can conclude that the same populations are generally exhibiting similar patterns at the three monitored sites.

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

The individual monitored taxa should respond in particular ways to environmental change. In the previous report we recorded our concern at the decrease, over the last few years, in the abundance of the polychaete Aonides oxycephala at a number of sites. This polychaete worm prefers wave exposed, sandy conditions, and a decline in its abundance may indicate a greater amount of fine sediments present either in the water or on the sediment surface. The latest results show that, while this species is now rarely found at Clarks Beach, it has increased slightly in abundance at the Auckland Airport site (although it is still less abundant than at the start of the monitoring programme).

Magelona ?dakini is also expected to respond negatively to an increase in silt/clay. It was reported (Funnell et al. 2001) that there had been a decrease in abundance of this species at the Clarks Beach site, and the negative trend was persisting. With the last two years of data, the abundance of Magelona ?dakini has increased slightly at Clarks Beach, as well as at both the Auckland Airport and Cape Horn sites. Aquilaspio aucklandica, a species that has been found in very high numbers in areas with silt/clay levels up to 65-75% (Norkko et al. 2001), has decreased in abundance at the Auckland Airport and Clarks Beach sites over the last 2 years.

Funnell et al. (2001) suggested that the previously observed increases in Aquilaspio oxycephala and decreases in Magelona ?dakini and Aonides oxycephala could be related to observed increases in sediment silt levels. With another two years of data we have found that the sediment silt/clay levels for all three sites have reduced to those found near the beginning of the monitoring period, or even below those original levels. The concurrent reversing of trends for the three species provide encouraging results and relate well to the reduced silt/clay levels found over the last year.

There are no clear and consistent patterns that can account for the changes seen at the monitored sites. It is possible climatic variation may be a factor, for example, a change in wind direction and/or strength may change wave exposure, creating conditions that favour certain species. There are no signs to date that sediment loading into the estuary is impacting the sand flat assemblages at the monitored sites.

At Cape Horn there have been a number of changes in the benthic populations that may relate to a change at the site as a whole. Namely the presence of two species that were very rare early in the monitoring period (Magelona ?dakini and Waitangi brevirostris), and the absence of another two species that were originally present (Owenia fusiformis and Goniada emerita). All of these changes have occurred over the last year or two. Another change can be seen in the dominant species table (Table 3c), where over the last two years three species have appeared for the first time (Colurostylis lemurum, Hiatula siliqua and Methalimedon sp.). In addition, on the last 2 sampling occasions (December 2002 and February 2003), the bivalve Divaricella huttoniana has been found at this site for the first time. The multivariate analysis, examining the monitored assemblage, does not show any substantial change in the community from the start of the programme. However this analysis may be influenced by the relatively few taxa being monitored, as is indicated by the changes seen when densities of Boccardia syrtis caused a large change in the ordination diagram (Figure 5). The sediment silt/clay levels are also lower than normal, however, these levels are generally variable due to the shallow, windy nature of Manukau harbour. This site was relocated earlier in the programme by 50m, to a higher location, when the site started becoming subtidal. It is possible that the movement of the sandbank has caused the changes in the benthic community that we have seen over the last two years. However, none of these species should be sensitive to changes in tidal height from low to mid tide, and the site has not been recorded as becoming high intertidal by the ARC staff sampling it. Another possibility is the improvement in water quality that was anticipated to accompany the decommissioning of the Mangere wastewater treatment plant. Further sampling of this site, in particular of the environment and the communities surrounding the site, is necessary to provide evidence on what might be causing the observed community changes.

4.1 Recommendations for future monitoring

We recommend that at a minimum, monitoring continue at both the Auckland Airport and Clarks Beach sites. The value of this uninterrupted data set for drawing conclusions on harbour-wide trends and levels of natural variability has been clearly demonstrated by Funnell et al. (2001). The unusual results found at the Cape Horn site also suggests that the continued monitoring at this site would be highly useful in determining what is happening in this area of the Manukau. A site visit that looks not just at the site, but at the surrounding environment and communities is also recommended. We also suggest that it would be useful to carry out an elevation survey of the site. Then, if any movement of the sandbank was suspected in the future, resurveying the area would provide valuable evidence of this.

5. Acknowledgements

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Thrush, S.F.; Hewitt, J.E.; Pridmore, R.D. (1989). Patterns in the spatial arrangement of polychaetes and bivalves in intertidal sandflats. *Marine Biology 102*: 529-535.

Appendix 1

Summary of temporal data[5] collected every 2 months at the Auckland Airport (AA), Clarks Beach (CB) and Cape Horn (CH) sites, between April 2001 (Series 82) and February 2003 (Series 93).

		AA		CB		CH	
	Series	Total	Mean	Total	Mean	Total	Mean
Aglaophamus macroura	82	0.08	1	0.00	0	0.75	9
Aglaophamus macroura	83	0.08	1	0.00	0	0.00	0
Aglaophamus macroura	84	0.17	2	0.00	0	0.17	2
Aglaophamus macroura	85	0.08	1	0.00	0	0.83	10
Aglaophamus macroura	86	0.83	10	0.00	0	1.58	19
Aglaophamus macroura	87	0.25	3	0.00	0	0.33	4
Aglaophamus macroura	88	0.33	4	0.00	0	0.58	7
Aglaophamus macroura	89	0.33	4	0.00	0	0.50	6
Aglaophamus macroura	90	0.50	6	0.00	0	0.25	3
Aglaophamus macroura	91	0.33	4	0.00	0	0.67	8
Aglaophamus macroura	92	0.08	1	0.00	0	0.42	5
Aglaophamus macroura	93	0.00	0	0.00	0	0.33	4
Anthopleura aureoradiata	82	0.00	0	3.25	39	0.00	0
Anthopleura aureoradiata	83	0.08	1	0.50	6	0.08	1
Anthopleura aureoradiata	84	0.00	0	0.25	3	0.00	0
Anthopleura aureoradiata	85	0.00	0	0.00	0	0.00	0
Anthopleura aureoradiata	86	0.00	0	0.75	9	0.00	0
Anthopleura aureoradiata	87	0.00	0	1.75	21	0.00	0
Anthopleura aureoradiata	88	0.00	0	0.58	7	0.00	0
Anthopleura aureoradiata	89	0.00	0	0.67	8	0.00	0
Anthopleura aureoradiata	90	0.00	0	0.42	5	0.00	0
Anthopleura aureoradiata	91	0.00	0	0.75	9	0.00	0
Anthopleura aureoradiata	92	0.00	0	1.50	18	0.00	0
Anthopleura aureoradiata	93	0.00	0	0.67	8	0.00	0
Aonides oxycephala	82	2.58	31	0.00	0	0.00	0
Aonides oxycephala	83	3.00	36	0.00	0	0.00	0
Aonides oxycephala	84	0.00	0	0.00	0	0.08	1
Aonides oxycephala	85	0.92	11	0.00	0	0.00	0
Aonides oxycephala	86	1.50	18	0.00	0	0.00	0
Aonides oxycephala	87	1.83	22	0.00	0	0.00	0

[5] Data is only given if, during the first 2 years of the monitoring programme, the taxa occurred at that site on each sampling time, or if its abundance on at least one sampling time per year was greater than 5.

Aonides oxycephala	88	1.58	19	0.00	0	0.00	0
Aonides oxycephala	89	2.00	24	0.08	1	0.00	0
Aonides oxycephala	90	1.75	21	0.00	0	0.00	0
Aonides oxycephala	91	2.50	30	0.00	0	0.00	0
Aonides oxycephala	92	1.08	13	0.00	0	0.00	0
Aonides oxycephala	93	2.75	33	0.00	0	0.33	4
Aquilaspio aucklandica	82	0.08	1	0.67	8	0.08	1
Aquilaspio aucklandica	83	0.17	2	0.58	7	0.00	0
Aquilaspio aucklandica	84	0.00	0	0.58	7	0.00	0
Aquilaspio aucklandica	85	0.00	0	0.92	11	0.00	0
Aquilaspio aucklandica	86	0.00	0	0.75	9	0.00	0
Aquilaspio aucklandica	87	0.00	0	0.00	0	0.00	0
Aquilaspio aucklandica	88	0.08	1	0.75	9	0.00	0
Aquilaspio aucklandica	89	0.17	2	0.92	11	0.00	0
Aquilaspio aucklandica	90	0.17	2	0.42	5	0.00	0
Aquilaspio aucklandica	91	0.25	3	0.92	11	0.08	1
Aquilaspio aucklandica	92	0.17	2	0.75	9	0.00	0
Aquilaspio aucklandica	93	0.00	0	0.08	1	0.00	0
Austrovenus stutchburyi	82	3.83	46	0.00	0	0.50	6
Austrovenus stutchburyi	83	1.17	14	0.08	1	0.17	2
Austrovenus stutchburyi	84	1.58	19	0.08	1	0.00	0
Austrovenus stutchburyi	85	1.17	14	0.83	10	0.00	0
Austrovenus stutchburyi	86	2.08	25	0.75	9	0.00	0
Austrovenus stutchburyi	87	1.17	14	1.92	23	0.00	0
Austrovenus stutchburyi	88	3.67	44	0.00	0	0.00	0
Austrovenus stutchburyi	89	5.92	71	0.08	1	0.00	0
Austrovenus stutchburyi	90	2.92	35	0.08	1	0.00	0
Austrovenus stutchburyi	91	4.58	55	0.00	0	0.00	0
Austrovenus stutchburyi	92	1.67	20	0.50	6	0.17	2
Austrovenus stutchburyi	93	1.67	20	0.00	0	0.00	0
Boccardia syrtis	82	0.25	3	20.50	246	140.25	1683
Boccardia syrtis	83	0.00	0	31.00	372	79.17	950
Boccardia syrtis	84	0.00	0	8.25	99	1.75	21
Boccardia syrtis	85	0.17	2	1.42	17	0.25	3
Boccardia syrtis	86	0.00	0	0.08	1	0.00	0
Boccardia syrtis	87	0.25	3	0.33	4	0.00	0
Boccardia syrtis	88	0.00	0	0.67	8	0.00	0
Boccardia syrtis	89	0.00	0	0.75	9	0.00	0
Boccardia syrtis	90	0.00	0	0.08	1	0.00	0

Boccardia syrtis	91	0.00	0	0.33	4	0.08	1
Boccardia syrtis	92	0.08	1	0.17	2	0.00	0
Boccardia syrtis	93	0.00	0	0.67	8	0.00	0
Colurostylis lemurum	82	0.00	0	0.00	0	8.17	98
Colurostylis lemurum	83	0.83	10	0.00	0	0.67	8
Colurostylis lemurum	84	1.08	13	0.00	0	3.42	41
Colurostylis lemurum	85	1.33	16	0.17	2	1.92	23
Colurostylis lemurum	86	1.25	15	0.58	7	0.58	7
Colurostylis lemurum	87	0.33	4	0.17	2	2.75	33
Colurostylis lemurum	88	0.33	4	0.50	6	3.58	43
Colurostylis lemurum	89	2.00	24	1.42	17	1.25	15
Colurostylis lemurum	90	1.08	13	4.92	59	3.42	41
Colurostylis lemurum	91	3.00	36	1.00	12	5.17	62
Colurostylis lemurum	92	0.92	11	0.83	10	5.33	64
Colurostylis lemurum	93	0.42	5	0.25	3	0.92	11
Exosphaeroma spp.	82	9.25	111	0.00	0	0.00	0
Exosphaeroma spp	83	0.42	5	0.00	0	0.08	1
Exosphaeroma spp	84	0.67	8	0.00	0	0.00	0
Exosphaeroma spp	85	0.67	8	0.00	0	0.00	0
Exosphaeroma spp.	86	2.67	32	0.08	1	0.00	0
Exosphaeroma spp.	87	2.67	32	0.00	0	0.00	0
Exosphaeroma spp.	88	2.58	31	0.00	0	0.00	0
Exosphaeroma spp.	89	0.25	3	0.00	0	0.00	0
Exosphaeroma spp.	90	0.33	4	0.00	0	0.00	0
Exosphaeroma spp.	91	0.17	2	0.67	8	0.00	0
Exosphaeroma spp.	92	0.00	0	0.83	10	0.00	0
Exosphaeroma spp.	93	0.00	0	0.00	0	0.00	0
Goniada emerita	82	0.00	0	0.75	9	2.08	25
Goniada emerita	83	0.17	2	1.00	12	1.92	23
Goniada emerita	84	0.00	0	1.00	12	0.00	0
Goniada emerita	85	0.58	7	0.58	7	0.00	0
Goniada emerita	86	0.00	0	0.67	8	0.00	0
Goniada emerita	87	0.25	3	0.75	9	0.42	5
Goniada emerita	88	0.17	2	0.92	11	0.08	1
Goniada emerita	89	0.50	6	0.58	7	0.17	2
Goniada emerita	90	0.58	7	1.08	13	0.08	1
Goniada emerita	91	0.92	11	0.67	8	0.17	2
Goniada emerita	92	0.08	1	0.58	7	0.00	0
Goniada emerita	93	0.00	0	0.00	0	0.00	0

Hiatula siliqua	82	2.08	25	0.33	4	0.67	8
Hiatula siliqua	83	2.58	31	0.00	0	0.00	0
Hiatula siliqua	84	1.50	18	0.08	1	0.67	8
Hiatula siliqua	85	1.25	15	0.08	1	0.42	5
Hiatula siliqua	86	1.00	12	0.08	1	0.08	1
Hiatula siliqua	87	2.00	24	0.17	2	0.33	4
Hiatula siliqua	88	3.75	45	0.00	0	2.67	32
Hiatula siliqua	89	4.25	51	0.17	2	0.33	4
Hiatula siliqua	90	4.42	53	0.00	0	1.25	15
Hiatula siliqua	91	4.08	49	0.42	5	2.92	35
Hiatula siliqua	92	0.42	5	0.42	5	0.50	6
Hiatula siliqua	93	0.25	3	0.00	0	1.17	14
Macomona liliana	82	32.42	389	10.08	121	4.67	56
Macomona liliana	83	36.67	440	15.33	184	1.42	17
Macomona liliana	84	28.42	341	0.00	0	0.25	3
Macomona liliana	85	24.50	294	5.58	67	0.25	3
Macomona liliana	86	17.33	208	3.67	44	0.08	1
Macomona liliana	87	34.50	414	8.33	100	0.00	0
Macomona liliana	88	64.67	776	6.50	78	0.75	9
Macomona liliana	89	76.75	921	4.83	58	0.17	2
Macomona liliana	90	57.75	693	5.25	63	0.75	9
Macomona liliana	91	38.58	463	10.50	126	0.08	1
Macomona liliana	92	16.58	199	7.00	84	0.08	1
Macomona liliana	93	13.75	165	3.25	39	0.17	2
Macroclymenella stewartensis	82	0.00	0	7.67	92	1.08	13
Macroclymenella stewartensis	83	0.00	0	7.83	94	7.33	88
Macroclymenella stewartensis	84	0.00	0	6.58	79	1.25	15
Macroclymenella stewartensis	85	0.08	1	4.33	52	2.08	25
Macroclymenella stewartensis	86	0.00	0	6.00	72	1.50	18
Macroclymenella stewartensis	87	0.00	0	2.00	24	1.17	14
Macroclymenella stewartensis	88	0.00	0	0.58	7	0.75	9
Macroclymenella stewartensis	89	0.00	0	1.25	15	0.58	7
Macroclymenella stewartensis	90	0.00	0	0.50	6	0.33	4
Macroclymenella stewartensis	91	0.17	2	5.17	62	0.08	1
Macroclymenella stewartensis	92	0.00	0	7.50	90	0.17	2
Macroclymenella stewartensis	93	0.00	0	2.50	30	0.00	0
Magelona ?dakini	82	3.75	45	0.83	10	2.75	33
Magelona ?dakini	83	4.25	51	1.25	15	5.67	68
Magelona ?dakini	84	3.75	45	0.50	6	5.25	63

Magelona ?dakini	85	4.25	51	0.25	3	7.67	92
Magelona ?dakini	86	3.50	42	0.25	3	5.25	63
Magelona ?dakini	87	4.08	49	1.42	17	7.58	91
Magelona ?dakini	88	4.42	53	6.00	72	21.25	255
Magelona ?dakini	89	4.42	53	6.67	80	20.08	241
Magelona ?dakini	90	4.92	59	4.58	55	18.67	224
Magelona ?dakini	91	7.50	90	7.25	87	22.58	271
Magelona ?dakini	92	4.25	51	4.67	56	24.00	288
Magelona ?dakini	93	4.83	58	2.25	27	20.25	243
Methalimedon sp.	82	0.08	1	0.00	0	0.00	0
Methalimedon sp.	83	0.08	1	0.00	0	1.00	12
Methalimedon sp.	84	0.00	0	0.00	0	0.42	5
Methalimedon sp.	85	0.00	0	0.00	0	0.25	3
Methalimedon sp.	86	0.08	1	0.00	0	0.00	0
Methalimedon sp.	87	0.00	0	0.00	0	0.00	0
Methalimedon sp.	88	0.00	0	0.00	0	0.17	2
Methalimedon sp.	89	0.33	4	0.50	6	0.08	1
Methalimedon sp.	90	0.33	4	0.33	4	0.00	0
Methalimedon sp.	91	0.17	2	0.42	5	1.33	16
Methalimedon sp.	92	0.00	0	1.42	17	0.75	9
Methalimedon sp.	93	0.00	0	0.00	0	1.08	13
Notoacmea helmsi	82	0.00	0	0.33	4	0.00	0
Notoacmea helmsi	83	0.08	1	0.17	2	0.00	0
Notoacmea helmsi	84	0.00	0	0.00	0	0.00	0
Notoacmea helmsi	85	0.00	0	0.00	0	0.00	0
Notoacmea helmsi	86	0.08	1	0.00	0	0.00	0
Notoacmea helmsi	87	0.08	1	0.00	0	0.00	0
Notoacmea helmsi	88	0.08	1	0.00	0	0.00	0
Notoacmea helmsi	89	0.00	0	0.00	0	0.00	0
Notoacmea helmsi	90	0.00	0	0.00	0	0.00	0
Notoacmea helmsi	91	0.33	4	0.00	0	0.00	0
Notoacmea helmsi	92	0.17	2	0.25	3	0.00	0
Notoacmea helmsi	93	0.17	2	0.25	3	0.00	0
Nucula hartvigiana	82	1.25	15	5.42	65	0.50	6
Nucula hartvigiana	83	1.00	12	6.42	77	0.00	0
Nucula hartvigiana	84	0.58	7	7.42	89	0.08	1
Nucula hartvigiana	85	0.50	6	5.17	62	0.00	0
Nucula hartvigiana	86	1.08	13	15.83	190	0.08	1
Nucula hartvigiana	87	0.75	9	8.75	105	0.00	0

Nucula hartvigiana	88	0.92	11	1.75	21	0.00	0
Nucula hartvigiana	89	0.83	10	0.92	11	0.08	1
Nucula hartvigiana	90	1.67	20	2.33	28	0.08	1
Nucula hartvigiana	91	1.92	23	15.00	180	0.00	0
Nucula hartvigiana	92	0.00	0	17.67	212	0.08	1
Nucula hartvigiana	93	1.08	13	2.58	31	0.00	0
Orbinia papillosa	82	1.33	24	0.08	1	0.17	2
Orbinia papillosa	83	2.00	11	0.00	0	0.83	10
Orbinia papillosa	84	0.92	8	0.00	0	0.42	5
Orbinia papillosa	85	0.67	3	0.42	5	0.92	11
Orbinia papillosa	86	0.25	64	0.00	0	0.17	2
Orbinia papillosa	87	5.33	58	0.00	0	0.58	7
Orbinia papillosa	88	4.83	29	0.00	0	0.42	5
Orbinia papillosa	89	2.42	30	0.17	2	0.08	1
Orbinia papillosa	90	2.50	16	0.00	0	0.00	0
Orbinia papillosa	91	1.33	27	0.00	0	0.50	6
Orbinia papillosa	92	2.25	46	0.00	0	0.08	1
Orbinia papillosa	93	3.83	24	0.08	1	0.17	2
Owenia fusiformis	82	0.00	0	0.00	0	0.00	0
Owenia fusiformis	83	0.00	0	1.08	13	0.33	4
Owenia fusiformis	84	0.00	0	0.25	3	0.08	1
Owenia fusiformis	85	0.00	0	0.83	10	0.00	0
Owenia fusiformis	86	0.00	0	0.67	8	0.00	0
Owenia fusiformis	87	0.00	0	0.42	5	0.00	0
Owenia fusiformis	88	0.00	0	0.33	4	0.00	0
Owenia fusiformis	89	0.08	1	0.25	3	0.00	0
Owenia fusiformis	90	0.00	0	0.75	9	0.00	0
Owenia fusiformis	91	0.00	0	0.50	6	0.00	0
Owenia fusiformis	92	0.00	0	0.58	7	0.00	0
Owenia fusiformis	93	0.00	0	0.75	9	0.00	0
Torridoharpinia hurleyi	82	0.42	5	1.25	15	1.25	15
Torridoharpinia hurleyi	83	0.00	0	1.42	17	2.00	24
Torridoharpinia hurleyi	84	0.42	5	0.67	8	0.00	0
Torridoharpinia hurleyi	85	0.00	0	0.58	7	0.08	1
Torridoharpinia hurleyi	86	0.00	0	2.92	35	0.00	0
Torridoharpinia hurleyi	87	0.08	1	0.17	2	0.00	0
Torridoharpinia hurleyi	88	0.08	1	2.67	32	0.00	0
Torridoharpinia hurleyi	89	0.08	1	7.92	95	0.00	0
Torridoharpinia hurleyi	90	0.33	4	7.50	90	0.00	0

Torridoharpinia hurleyi	91	0.00	0	6.75	81	0.00	0
Torridoharpinia hurleyi	92	0.50	6	5.50	66	0.00	0
Torridoharpinia hurleyi	93	0.92	11	2.17	26	0.25	3
Travisia olens	82	0.00	0	0.00	0	0.00	0
Travisia olens	83	0.00	0	0.00	0	0.00	0
Travisia olens	84	0.08	1	0.00	0	0.00	0
Travisia olens	85	0.00	0	0.00	0	0.00	0
Travisia olens	86	0.25	3	0.00	0	0.00	0
Travisia olens	87	0.25	3	0.00	0	0.00	0
Travisia olens	88	0.00	0	0.00	0	0.00	0
Travisia olens	89	0.17	2	0.00	0	0.00	0
Travisia olens	90	0.17	2	0.00	0	0.00	0
Travisia olens	91	0.92	11	0.00	0	0.00	0
Travisia olens	92	1.50	18	0.00	0	0.00	0
Travisia olens	93	1.00	12	0.00	0	0.00	0
Trochodota dendyi	82	1.75	21	0.08	1	0.00	0
Trochodota dendyi	83	3.50	42	0.17	2	0.00	0
Trochodota dendyi	84	1.08	13	0.25	3	0.00	0
Trochodota dendyi	85	2.25	27	0.00	0	0.00	0
Trochodota dendyi	86	1.67	20	0.00	0	0.00	0
Trochodota dendyi	87	1.17	14	0.08	1	0.08	1
Trochodota dendyi	88	0.58	7	0.17	2	0.08	1
Trochodota dendyi	89	0.67	8	0.00	0	0.08	1
Trochodota dendyi	90	1.25	15	0.00	0	0.00	0
Trochodota dendyi	91	6.33	76	0.00	0	0.00	0
Trochodota dendyi	92	1.17	14	0.08	1	0.08	1
Trochodota dendyi	93	1.08	13	0.08	1	0.17	2
Waitangi brevirostris	82	2.75	33	0.00	0	0.00	0
Waitangi brevirostris	83	1.50	18	0.00	0	0.33	4
Waitangi brevirostris	84	1.17	14	0.00	0	0.00	0
Waitangi brevirostris	85	1.25	15	0.00	0	0.00	0
Waitangi brevirostris	86	1.75	21	0.00	0	0.00	0
Waitangi brevirostris	87	3.08	37	0.00	0	0.25	3
Waitangi brevirostris	88	1.75	21	0.00	0	0.08	1
Waitangi brevirostris	89	1.42	17	0.00	0	0.17	2
Waitangi brevirostris	90	2.58	31	0.00	0	0.50	6
Waitangi brevirostris	91	2.58	31	0.00	0	0.75	9
Waitangi brevirostris	92	0.00	0	0.00	0	0.50	6
Waitangi brevirostris	93	0.00	0	0.00	0	0.00	0

Appendix 2

Sediment grain size (% composition) on each sampling date since June 2001. Percent composition of initial samples (October 1987) are also given for comparison. Grain size factions given are: Gravel (particles >2mm), Sand (particles 63µm-2mm), Silt/clay (particles <63µm).

		October 1987	June 2001	August 2001	October 2001	December 2001	February 2002	April 2002	June 2002	August 2002	October 2002	December 2002	February 2003
Auckland	% gravel	1.6	0.1	0.3	0.0	1.6	0.1	0.0	0.2	0.2	0.2	0.1	0.5
Airport	% sand	96.7	99.3	98.4	98.1	97.4	98.7	98.7	99.4	83.4	99.0	99.1	98.7
	% silt/clay	1.7	0.7	1.2	1.9	1.0	1.2	1.3	0.5	16.5	0.8	0.8	0.8
Clarks	% gravel	6.1	0.6	2.7	1.5	0.5	1.5	0.8	2.2	0.2	5.2	2.9	2.3
Beach	% sand	91.1	86.2	84.8	82.7	96.0	95.9	94.5	96.3	78.6	91.8	94.2	94.3
	% silt/clay	2.8	13.2	12.6	15.8	3.5	2.6	4.7	1.4	21.2	3.0	2.9	3.4
Cape	% gravel	2.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.9	0.0
Horn	% sand	93.3	96.6	99.2	97.8	99.4	99.2	99.1	99.2	84.6	99.6	98.4	99.2
	% silt/clay	4.2	3.3	0.8	2.2	0.6	0.8	0.9	0.8	14.7	0.4	0.7	0.8

Appendix 3

Sediment chlorophyll *a* levels (µg /g sediment) at each site for the period June 2001 to February 2003.

	Auckland Airport	Clarks Beach	Cape Horn
June 2001	11.2	26.1	16.7
August 2001	9.6	27.0	9.8
October 2001	8.5	13.7	11.1
December 2001	24.9	22.7	11.5
February 2002	7.9	11.2	13.4
April 2002	10.3	14.9	11.1
June 2002	10.6	10.8	9.5
August 2002	10.3	13.0	10.7
October 2002	9.6	9.6	11.3
December 2002	15.4	19.2	23.5
February 2003	13.0	20.4	20.2

Appendix 4

Percent organic content at each site for the period June 2001 to February 2003.

	Auckland Airport	Clarks Beach	Cape Horn
June 2001	0.5	1.9	0.9
August 2001	0.5	1.3	0.6
October 2001	0.6	1.7	0.7
December 2001	0.4	1.0	0.7
February 2002	0.6	0.7	0.6
April 2002	0.7	1.1	0.8
June 2002	0.6	0.8	0.8
August 2002	0.8	1.2	0.8
October 2002	0.5	0.8	10.6
December 2002	0.7	1.2	0.8
February 2003	0.7	1.7	0.7