Coastal and Estuarine Benthic Macrofauna Monitoring Report 2010

Prepared by Stephen Park, Environmental Scientist

Bay of Plenty Regional Council
Environmental Publication 2012/03

5 Quay Street
P O Box 364
Whakatane
NEW ZEALAND

ISSN: 1175 9372 (Print)
ISSN: 1175 9471 (Online)

Working with our communities for a better environment
E mahi ngatahi e pai ake ai te taiao

Bay of Plenty REGIONAL COUNCIL

Coastal and Estuarine Benthic Macrofauna Monitoring Report 2010

Environmental Publication 2012/03
ISSN: 1175 9372 (Print)
ISSN: 1179 9471 (Online)

February 2011

Bay of Plenty Regional Council
5 Quay Street
PO Box 364
Whakatane 3158
NEW ZEALAND

Prepared by Stephen Park, Environmental Scientist

Cover Photo:
Royal Spoonbill feeding in Maketu Estuary, May 2008.

Acknowledgements

The assistance of numerous summer students that have worked on this monitoring program over the years is gratefully acknowledged. The staff of the Regional Council laboratory (past and present) are also thanked for their support and analysis or handling of many samples over the years.

Executive summary

Bay of Plenty Regional Council initiated a coastal and estuarine monitoring programme in 1990 that set out to monitor the benthic macrofauna at 15 exposed and 33 sheltered soft-shore sites to address its responsibilities to monitor the state of the environment as directed by the Resource Management Act (1991). In 1995 and 2000 reviews of the programme resulted in a number of sites being suspended from current monitoring. At this point four exposed open coast and 17 sheltered soft-shore sites are monitored with results and a review of the programme presented in this report.

Results for the monitoring of the benthic macrofauna communities at seven sites in Tauranga Harbour have shown all sites have no significant and consistent decrease in species diversity. Some minor changes in species composition or sediment parameters have occurred but appear to be natural fluctuations. The reduction of mud and increase in cockles recorded at the Otumoetai and Town Reach sites coincides with loss of seagrass cover due to swan grazing, hence not considered a positive trend. Waimapu Estuary site shows a small but significant increase in mud and total organic carbon (TOC) and increased dominance by polychaete worms which is considered to be a detrimental change in response to catchment impact.

Ōhiwa Harbour shows similar results with no change in species diversity at the four sites but two of those sites recording significant increases in mud. Site 1 has changes in species composition and the overall changes are considered detrimental. Maketū Estuary sites (4) have all shown marked changes in species and sediment parameters in response to highly dynamic changes in sand erosion, deposition and migration as the estuary continues to infill. These changes mask ability to detect catchment related water quality issues. Waihī and Waiotahi Estuary sites also show no change in species diversity. Waiotahi Estuary site recording more variability due to river influences.

Exposed soft-shore coastal sites show very low species diversity and numbers of animals due to the harsh physical nature of the habitat. The four sites that are currently monitored show variation in species diversity consistent with changes in the sediment which occur during the different climatic conditions. The exposed soft-shore sites have poor ability to detect water quality changes.

Reviewing Council's benthic macrofauna monitoring programme with consideration of the objectives, value obtained from the data to date and how to optimise it in context of other components of environmental monitoring undertaken, the following changes are recommended;

- Continue monitoring the current sites (7) in Tauranga Harbour.
- Continue monitoring the current sites (4) in Ohiwa Harbour.
- Suspend monitoring current sites in Maketū Estuary and investigate suitable location of a new site.
- Continue monitoring of the Waihī Estuary site and suspend the Waiotahi Estuary site.
- Suspend monitoring of the exposed soft-shore sites.
- Monitor a range of sediment parameters at additional high risk sites.

Overall it is apparent from this monitoring programme and other components of Council's holistic environmental monitoring, that harbours and estuaries in the region are still facing pressure from catchment development and use.

Contents

Figures

Part 1: Introduction

1.1 Scope

As a component of Bay of Plenty Regional Council's Regional Monitoring Programme, surveys of intertidal benthic macrofauna are conducted at sites throughout the enclosed and open waters of the Bay of Plenty. The objectives of this programme are the provision of data to:

- Provide reliable baseline data on benthic habitat and species.
- Assess changes over time in terms of species richness and abundance.
- Provide a means of assessing cumulative impacts on the environment.
- Address Bay of Plenty Regional Council's responsibilities under the Resource Management Act (RMA).
- Review the monitoring programme.

This report provides an update on the state of those sites regularly monitored up until the summer of 2010/11.

1.2 Background

Worldwide shallow inshore waters such as those of the Bay of Plenty are recognised for their high productivity. They are generally important for both natural ecosystems and the economies of countries with these resources. However shallow coastal waters are also highly susceptible to a range of water quality issues. There is a growing recognition of the ways in which pollutants are transported to and possibly accumulated in marine environments. For example, it has been estimated that more than 95% of nitrogen delivered by river to the coast accumulates there. The particle reactivity of most pollutants results in the coastal margin, not the deep ocean, being the ultimate sink for all contaminants.

Eutrophication (nutrient enrichment) and bioaccumulation of toxic substances can affect ecosystems in a number of different ways leading to subtle changes in community composition, productivity and energy flows. It is impossible to monitor all the chemicals, which may be present in the marine environment and determine what possible impacts they may have. Information on the persistence, bioaccumulation and toxicity of many contaminants is still poorly known. In addition to this, evaluation of whether chemicals of identical or dissimilar toxic action are additive in their action at all concentrations and possible synergistic or antagonistic actions are rarely determined (GESAMP 1989). In many cases, the degradation products of a chemical compound exhibit high toxicity. This makes it even more difficult to predict effects on marine communities.

In theory, the use of biological systems to monitor the health of ecosystems should be more reliable as chemical monitoring of all possible pollutants and their toxic effects on all species of a community is not possible. In the past, many studies using statistical analyses of community structure have successfully distinguished fine gradients in pollution effects.

The studies of the Bay of Plenty coastal waters presented in this report will help improve the holistic approach to resource management taken by Bay of Plenty Regional Council. It addresses Bay of Plenty Regional Council's responsibilities under the Resource Management Act (1991) in relation to the sustainable management principals set out in Part II (section5) and directives to monitor the state of the environment as set out Part IV (section 35; 1 and 2a, section 30; 1a). It will also provide data that can be used to monitor the effectiveness of the coastal plan and land plans, particularly in the long-term, and provide a better understanding of terrestrial and anthropogenic influences and cumulative impacts when reviewing these plans.

Part 2: Methods

2.1 Soft-shore survey methods

Ecological monitoring of benthic communities on soft-shores (sandy) has been identified as the most appropriate type of monitoring to establish the importance of environmental changes over large geographic areas (DSIR 1988). Similar sampling methods and sites within the intertidal zone were employed for both enclosed and open coastal waters.

Selections of all aspects of the CEE monitoring programme were based on consideration of the objectives and the most cost-effective methods.

2.1.1 Sample size and numbers

The size and number of benthic samples collected for processing influences the reliability of results and ability to determine significant differences of species numbers over time. A larger sized sampling unit is more likely to include a higher proportion of the total species pool present, but limits the number of samples which can be processed. In a more variable habitat, this could limit the accuracy with which the community is described. It may also reduce the ability to detect significant variations. Comparison of species richness or abundance is also difficult between studies utilising different sample sizes.

To sample the benthic macrofauna a stainless steel corer with an internal diameter of 13 cm was used to collect sediment to a depth of 15 cm for enclosed waters and 25 cm depth for open coastal waters. This standardises the size of the sampling unit with that used by the Auckland Regional Council for baseline monitoring of sandflat communities in the Manukau Harbour. It also allows direct comparison of species numbers for the larger taxa between these two studies. More importantly, an evaluation of sample numbers required to include all species present for this sized sampling unit has been conducted by Pridmore *et.al* (1990).

Results from Pridmore *et.al* (1990) showed that for each site, few new taxa were likely to be found in each additional core after 16-24 cores had been analysed. From this evaluation, a soft-shore sample replication number of 30 were initially chosen for the CEE monitoring programme. A review of sampling requirements based on five years of monitoring data showed that sample replication of 24 for enclosed waters was optimal for detecting change. This assessment took into account the measured amount of inter-annual variation of species richness at sites in Tauranga Harbour.

2.1.2 Selection of sieve size

The size of sieve mesh used for processing benthic samples is also an important variable determining the numbers and type of fauna recovered from the sediments. Benthic organisms range in size from bacteria and single celled algae up to large bivalve molluscs and crustaceans. The selection of a mesh size is an arbitrary decision with little taxonomic or ecological relevance. Most factors determining mesh size are related to the practicalities of sorting and counting samples.

The lower size limit of macrofauna is usually regarded as 0.5 or 1 mm and depends upon the objectives of the study. Many countries such as those in the Baltics have now standardised the mesh used in their studies at 1 mm (Eleftheriou and Holme 1984). Hartley et al (1987) also quote a number of studies which show the use of 1 mm mesh has been vindicated by the detection of pollution effects in a number of areas. For monitoring purposes it is regarded as the most cost-effective compromise between ease of sorting and information gained.

An initial trial processing of benthic samples from several sites in Tauranga Harbour showed retention of large quantities of sediment on the 0.5 mm mesh resulted in greatly increased handling times. Sample sorting was significantly quicker using 1 mm mesh which means a greater numbers of samples can be processed. This translates directly into an increased ability to detect changes or monitor more sites for the same effort. Consequently this mesh was selected to process all soft-shore monitoring samples.

2.1.3 Positioning and collection of samples

At each harbour or estuarine monitoring site, 24 benthic sediment core samples were collected and labelled so that six samples came from each of four blocks on the shore. For open coastal sites, 30 samples are taken from five blocks. This design was used to allow analysis of the data using Nested Analysis of Variance to look at changes over time.

To position the sampling blocks on the shore, a permanent starting point was located at low tide level for each monitoring site. From this point, a 100 m tape measure was laid out parallel to the shore. Each of the blocks from which the six samples were collected measured 5 x 5 m and were located at the 0, 15, 30, 45, and 60 m marks along the tape. The six replicate samples within each block were positioned using randomly derived Cartesian co-ordinates.

Sampling frequency is annual with samples being collected in summer each year to minimise seasonal variability in species numbers. In the case of the open coastal sites, no sampling is conducted within fourteen days of any significant on-shore storm.

The mean low tide level was selected for positioning of the sampling transects as species diversity and sensitivity to pollutants generally increases down the shore. This is also true for open coastal beaches where species diversity reaches a maximum on the lower shore and then decreases markedly in the shallow sub-tidal surf zone before increasing once again with increasing water depth (Brown and McLachlan 1990).

The sampling design is also intended to minimise the variance of species numbers introduced by tidal height while covering any spatial variability along the shore within each site. McArdle and Blackwell (1989) studied the spatial variability of the dominant bivalve, the cockle, (*Austrovenus stutchburyi*) in Ohiwa Harbour. Results showed that densities were correlated up and down the shore for distances of up to 10 m, and along the shore for distances up to 15 m.

2.1.4 Processing of samples

The individual sediment core samples were placed in plastic bags and labelled for separation of benthic macrofauna back in the laboratory by sieving (1.0 mm mesh). The sorted animals were then preserved with 70% alcohol and counts later made of all species to the lowest possible taxonomic level using a stereo microscope. The majority of macrofauna are recorded at the species level.

2.1.5 Data analysis

All survey data is gained using random sampling techniques. Before performing any statistical tests on the data, checks are made for homogeneity of variance and normality, and then transformed if necessary. To investigate changes in species richness or individual species abundance over time, Nested Analysis of Variance is used. This analysis uses a blocked sampling design and can show whether differences between blocks at each site are more significant than differences over time.

Future reports will also make use of non-parametric data analysis techniques in cases of non-normal data for comparative purposes. When appropriate, multivariate methods are also used to identify important variables in the data sets.

2.2 Location and description of sampling sites

Monitoring sites were located throughout the major estuaries and the open coastal margin of the Bay of Plenty to provide both regional coverage and to reflect the highly valued ecosystems at selected sites. A full list of site locations is provided in Appendix 10.

2.2.1 Exposed soft-shore site locations

Initially, fifteen monitoring sites were established on the open coastal sandy beaches of the Bay of Plenty and these are shown in Figure 2. The Bay of Plenty has a moderate swell environment, as it is sheltered from the prevailing westerly winds and associated high-energy seas. The beaches range from relatively steep reflective, type beaches (e.g. Otamarakau - Walkers road) with coarse sediments to low gradient dissipative beaches with fine sediments (e.g. Te Rangihara Bay). Following a review of the monitoring program the number of sites for ongoing monitoring was cut right back to 4. Even with just a moderate swell environment the species communities tend to be low diversity with high inter-annual variation dominated by physical processes.

2.2.2 Estuarine site locations

The monitoring sites throughout the estuaries of the Bay of Plenty were selected to minimise sediment variability, hence increasing comparability between sites should changes occur over time. Sandy substrates with moderate exposure were targeted and muddy, unstable or gravel/shellbank habitats were avoided. In Tauranga and Ohiwa Harbours where sea grass (*Zostera*) beds cover a major portion of the intertidal zone, monitoring sites were also positioned in these habitats.

In total there have been 18 sites monitored in Tauranga Harbour over various periods of time. Many of the sites were located at locations where descriptive parameters of the sediments including sediment grain size, sorting, skewness, TOC etc. were already available. A number of the monitoring sites are also in the close vicinity of water quality sites monitored as part of Bay of Plenty Regional Council's regional monitoring network. Currently 7 are being monitored.

Figure 1 *Benthic ecology sites currently monitored in Tauranga Harbour.*

Maketu Estuary has four monitoring sites and these are shown in Figure 2. Waihi Estuary has three sites (Figure 2) with only one being currently monitored.

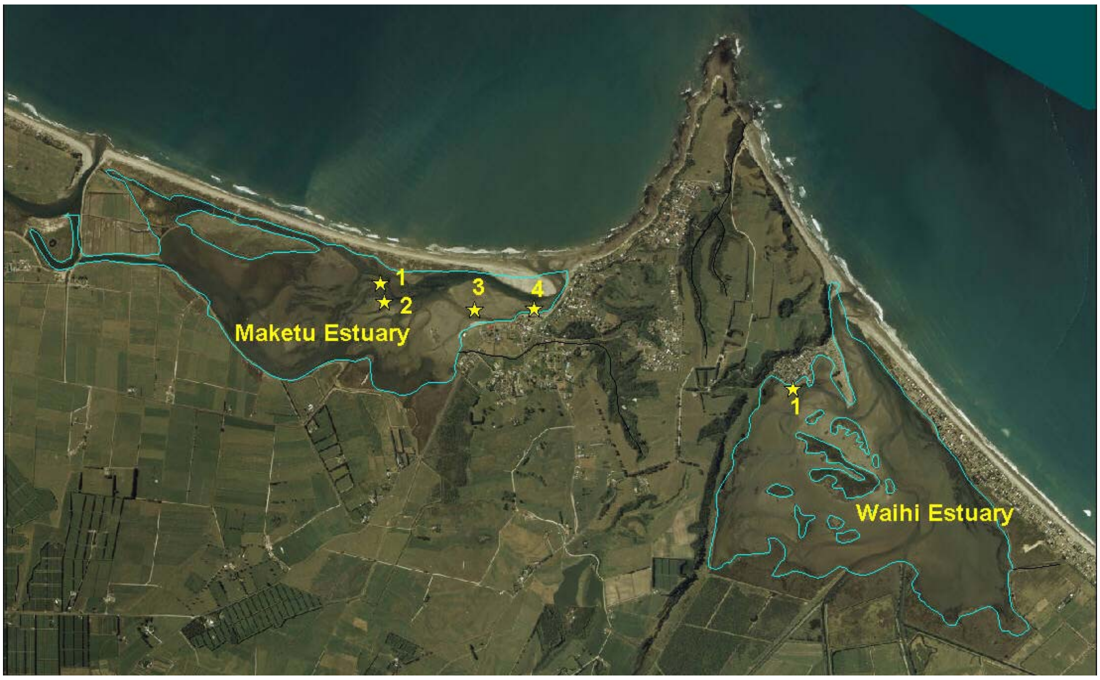

Figure 2 *Benthic ecology sites currently monitored in Maketu and Waihi Estuaries.*

Figure 3 Benthic ecology sites currently monitored in Ohiwa Harbour and Waiotahi Estuary.

There are six monitoring sites in Ohiwa Harbour with Site 3 located in a sea grass bed. Four of the sites still have current monitoring (Figure 3), although in the last few years Ohiwa Harbour sites were not monitored due to logistic issues.

In Whakatane and Opotiki Estuaries two sites were established and monitored in each estuary for a period of five years. All these sites have a high riverine influence which is strongly reflected by the species present and the low diversity compared to other sites. Waiotahi Estuary is another highly riverine estuary and has one site that was established in 1993 which is currently monitored.

Part 3: Results

3.1 Tauranga Harbour

3.1.1 Pio's Beach (Site 1)

The Pio's beach site is located northwest of the boat ramp at the mean low tide level. The site has a low gradient and appears to be reasonably stable with only a small shallow channel nearby. Surveys of this site cover the period from 1991 through to 2011. Species diversity (Fig 4) both in numbers of species (richness) and evenness (Shannon-Weiner index) is one of the highest recorded amongst the Tauranga Harbour sites. The species diversity and evenness show a moderate degree of stability with no change over time.

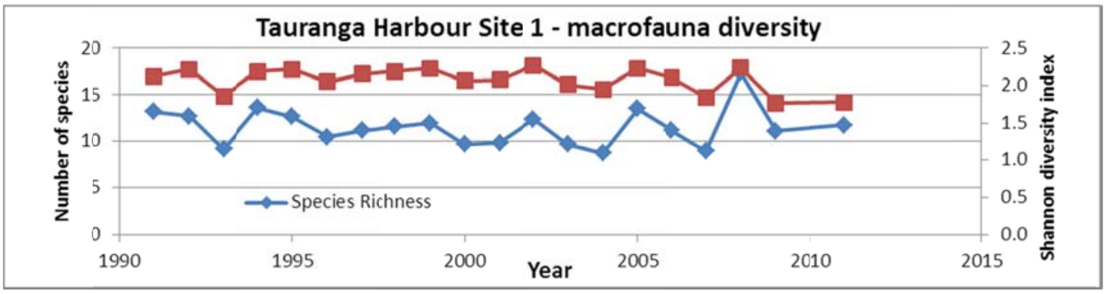

Figure 4 *Mean species richness and Shannon-Weiner diversity index recorded over time at Pio's Beach (n=24).*

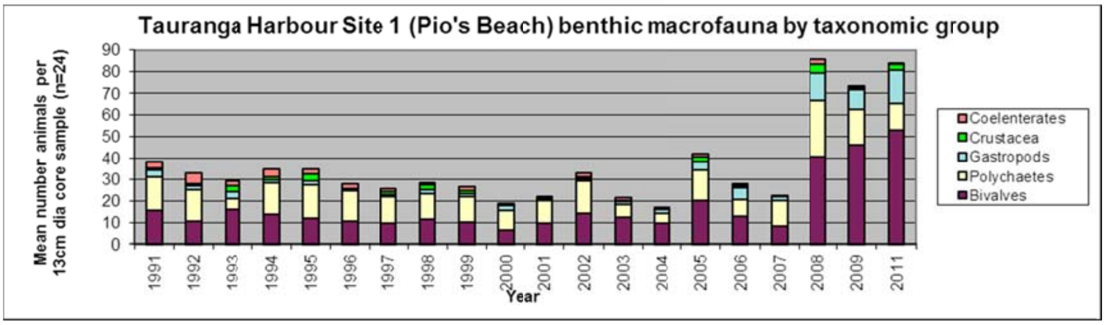

Figure 5 *Mean number of individuals by taxonomic group recorded at the Pio's Beach site over time.*

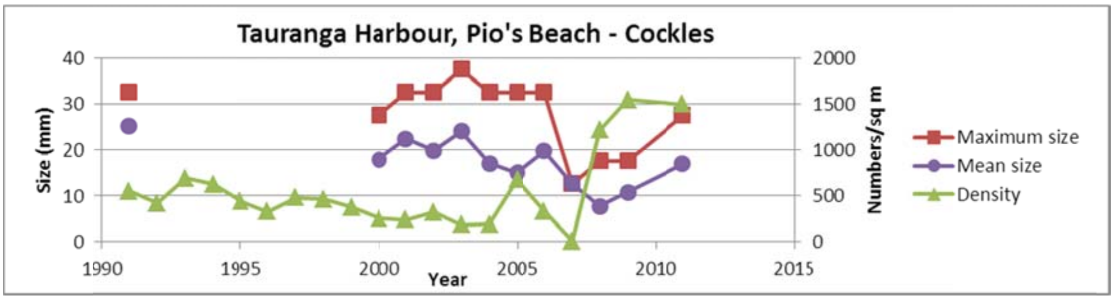

Figure 6 *Mean density, size and maximum size of cockles recorded at the Pio's Beach site over time.*

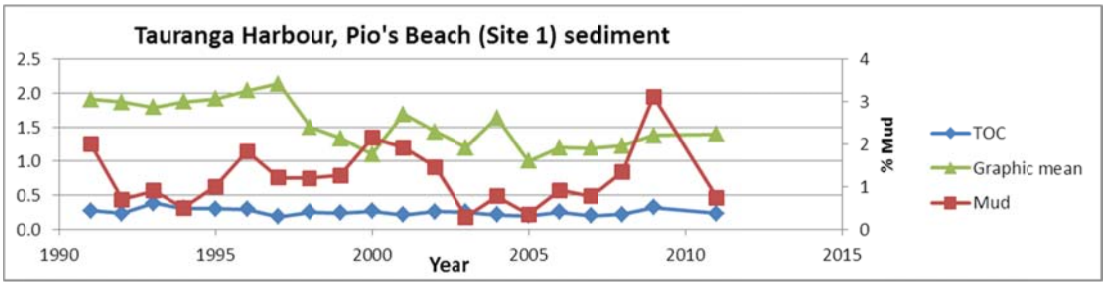

Figure 7 *TOC, mud (silt + clay) and graphic mean of particle size measured in the surficial sediment at the Pio's Beach site over time.*

Numbers of bivalves increased from 2009 relative to the proportions of other macrofaunal groups as shown in Figure 5. Figure 6 shows that numbers of cockles present at the site increased at the same time and accounts for the change. The change may just be natural fluctuation in recruitment as the sediment parameters shown in Figure 7 have not shown any consistent change over time for TOC and mud content but there has been a significant change in the graphic mean of sediment particle size (regression p=0.000). This change took place between 1997 and 1998 prior to the cockle increase and has since been relatively stable.

3.1.2 **Katikati boat ramp (site 4)**

The site at Katikati boat ramp is moderately exposed with clean sandy sediment, a wide low gradient shore profile and located around the neap low tide mark. Species diversity at this site has remained stable over the period of monitoring (Figure 8). The macrofaunal groups at this site (Figure 9) show a relatively stable number of bivalves present while the number of polychaetes is variable and in most years the dominant group present. Density of cockles at this site is very low and absent in some years (Figure 10). There has been a small but significant change in the graphic mean of particle size (p=0.003) but no change in the mud content over time (Figure 11). Overall the site appears relatively stable with no changes over time (from 1991 – 2011) in the key biological and sediment parameters analysed at the site.

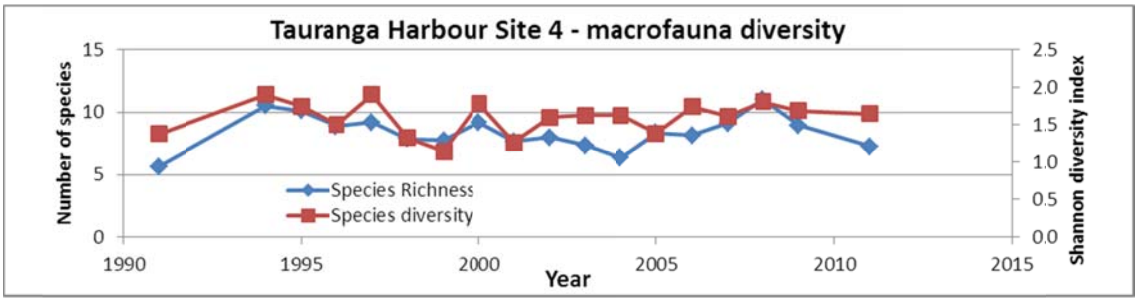

Figure 8 *Mean species richness and Shannon-Weiner diversity index recorded over time at Katikati beach (n=24).*

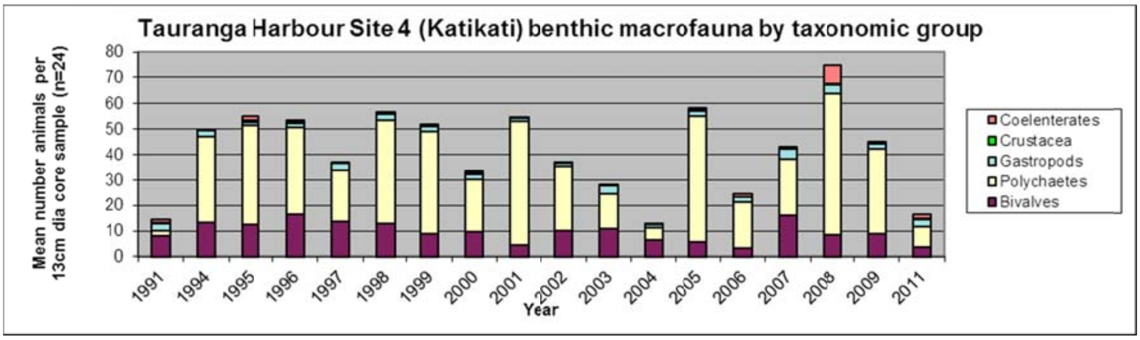

Figure 9 *Mean number of individuals by taxonomic group recorded at the Katikati Beach site over time.*

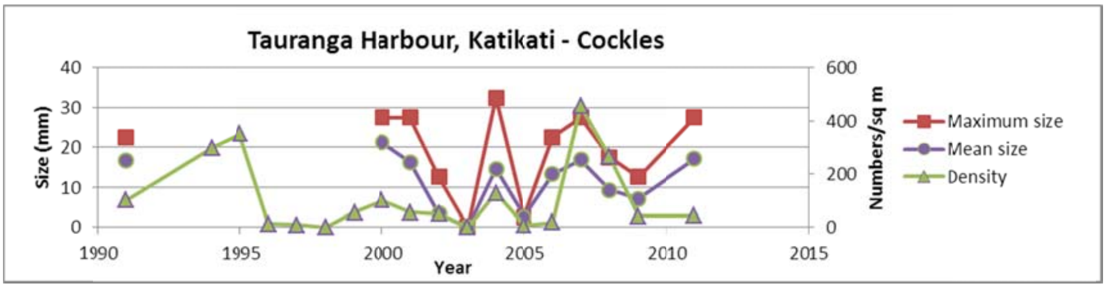

Figure 10 *Mean density, size and maximum size of cockles recorded at the Katikati Beach site over time.*

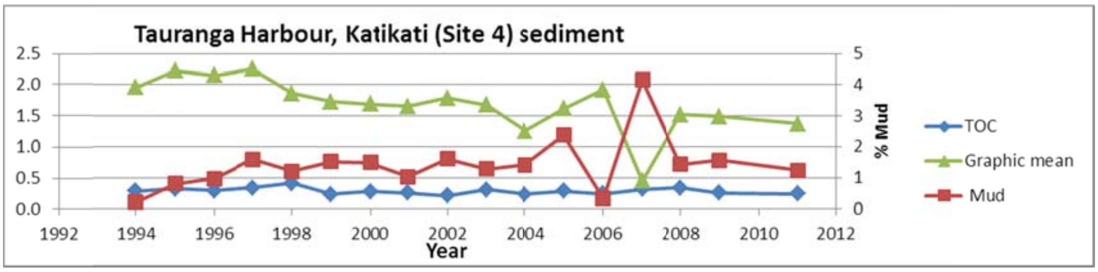

Figure 11 *TOC, mud (silt + clay) and graphic mean of particle size measured in the surficial sediment at the Katikati Beach site over time.*

3.1.3 Te Puna Estuary (Site 9)

The Te Puna Estuary site is a sheltered site that has higher influence from catchment runoff a corresponding increase in the amount of mud in the sediment. The site is located around the neap low tide mark on the flats near the channel margin. Species diversity at this site has been variable but stable with no change between 1991 and 2011 (Figure 12). The number of individual animals has been variable over time with bivalves and polychaete worms being the dominant groups. Cockle density and size is generally low at this site and show no marked change over time. Sediment particle size has shown moderate variability but no consistent change over time (Figure 15).

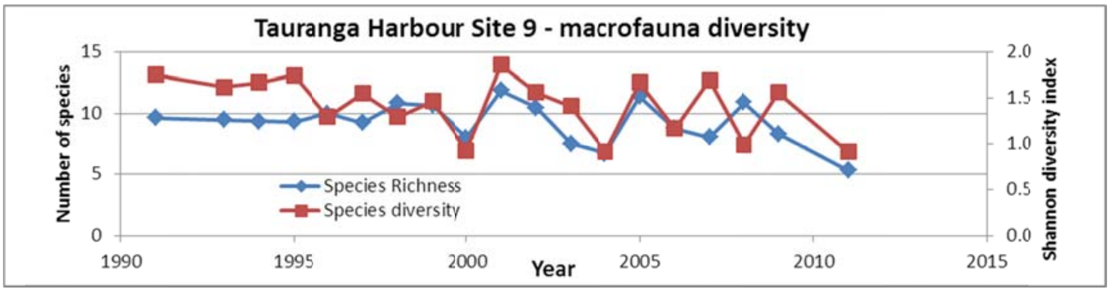

Figure 12 Mean species richness and Shannon-Weiner diversity index recorded over time at Te Puna Estuary (n=24).

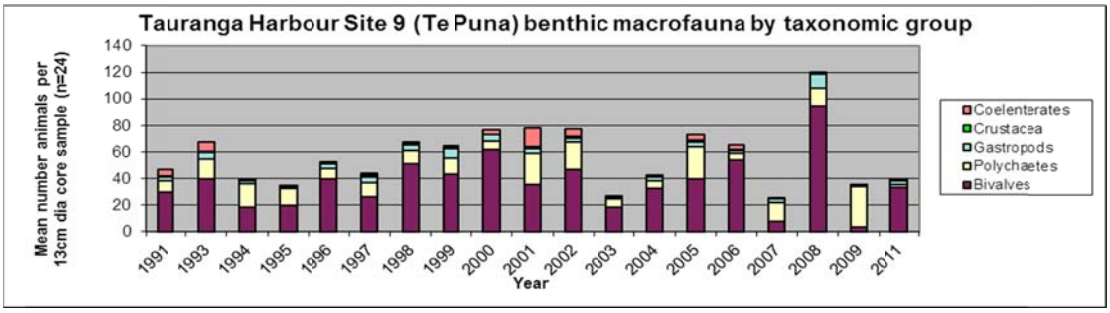

Figure 13 Mean number of individuals by taxonomic group recorded at the Te Puna Estuary site over time.

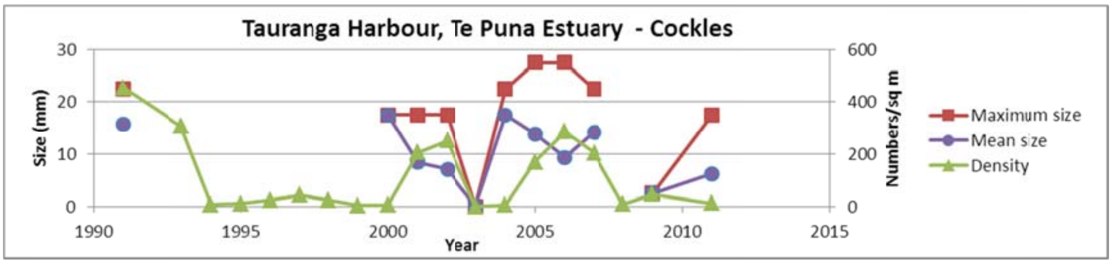

Figure 14 Mean density, size and maximum size of cockles recorded at the Te Puna Estuary site over time.

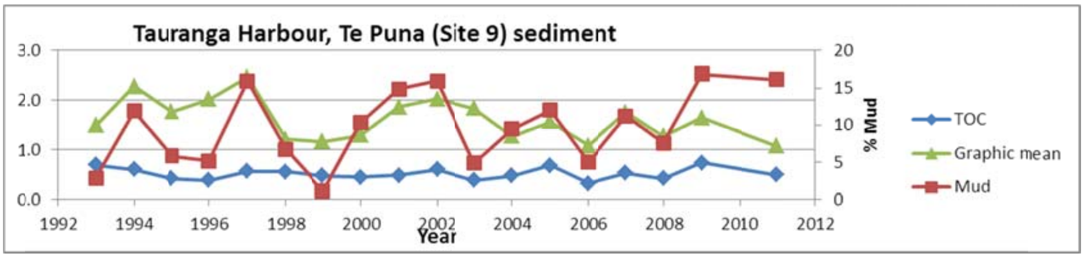

Figure 15 TOC, mud (silt + clay) and graphic mean of particle size measured in the surficial sediment at the Te Puna Estuary site over time.

3.1.4 **Otumoetai (Site 11)**

The Otumoetai site is moderately exposed and located near the Wairoa River inflow which influences the site at times. It is positioned around the neap low tide level and was initially in lush seagrass. However, intensive grazing by swans has reduced the amount of seagrass markedly. Species diversity at the site has shown some variability but remained stable with no change over time (Figure 16). Bivalves tend to be the dominant group present and total numbers of all animals have been relatively stable over time some change (Figure 17). Cockle density (Figure 18) has been variable but shows a significant increase (p=0.003) over time. The mud content measured in the sediment has also shown a marginal (p=0.011) decline overtime.

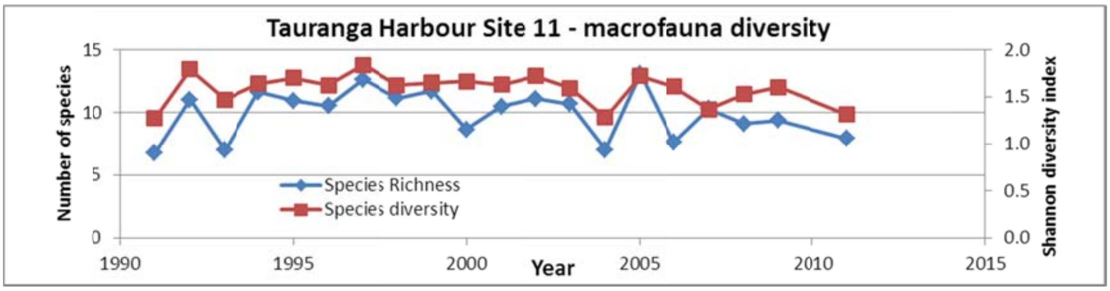

Figure 16 *Mean species richness and Shannon-Weiner diversity index recorded over time at Otumoetai (n=24).*

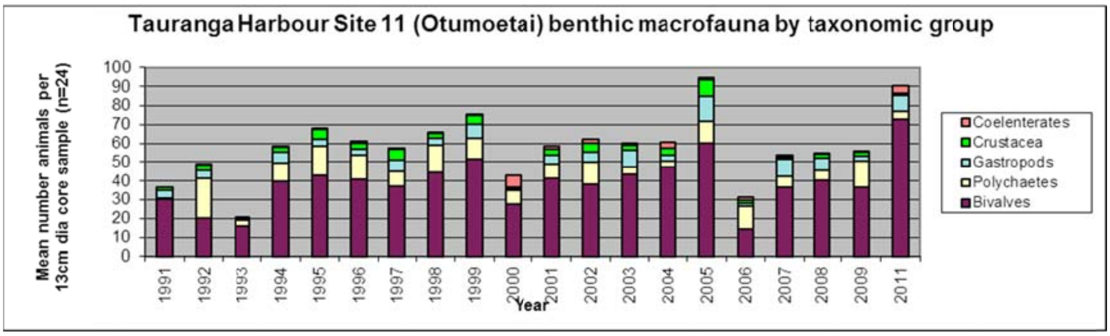

Figure 17 *Mean number of individuals by taxonomic group recorded at the Otumoetai site over time.*

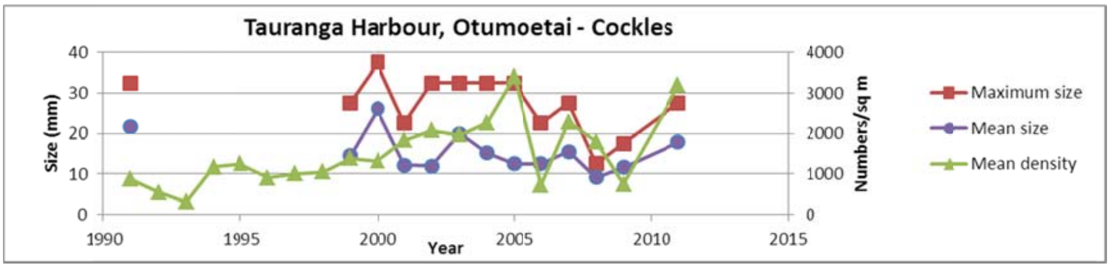

Figure 18 *Mean density, size and maximum size of cockles recorded at the Otumoetai site over time.*

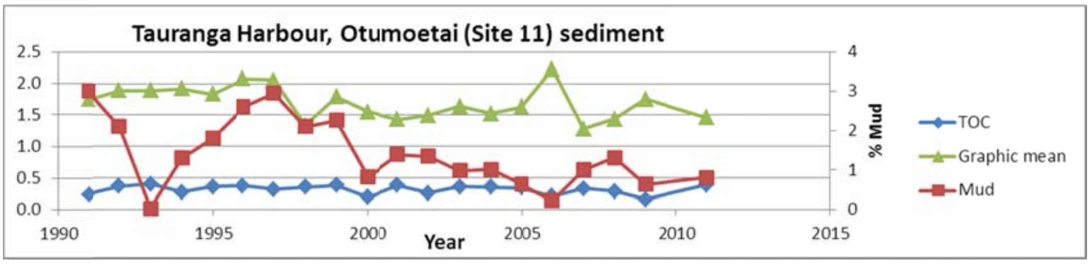

Figure 19 *TOC, mud (silt + clay) and graphic mean of particle size measured in the surficial sediment at the Otumoetai site over time.*

3.1.5 Town Reach (Site 13)

The Town Reach site is also located in sparse seagrass around the mean low tide level with low exposure. The density of seagrass at this site has also declined over time with some swan grazing taking place. The sediments have a moderate amount of mud present.

Species diversity (Figure 20) has shown some variability but no change over time. Polychaete worms and bivalves are the most numerous groups present (Figure 21). Cockle density (Figure 22) is low and shows a small but consistent increase over recent years. The graphic mean of sediment particle size and mud content (Figure 23) have shown significant declines over time (p=0.000 & 0.005 respectively).

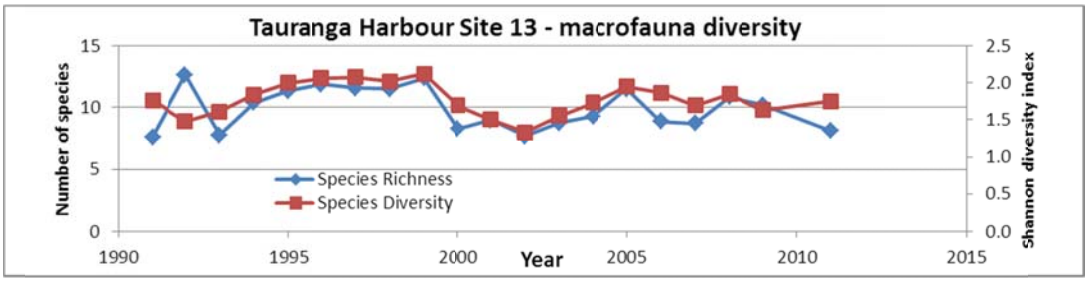

Figure 20 *Mean species richness and Shannon-Weiner diversity index recorded over time at Town Reach (n=24).*

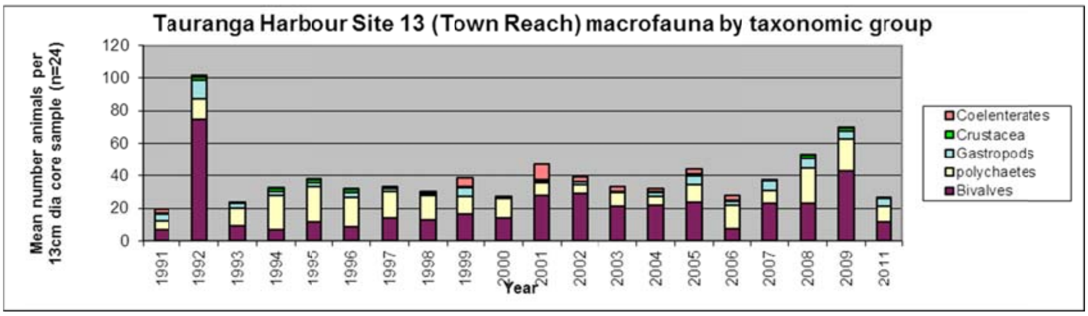

Figure 21 *Mean number of individuals by taxonomic group recorded at the Town Reach site over time.*

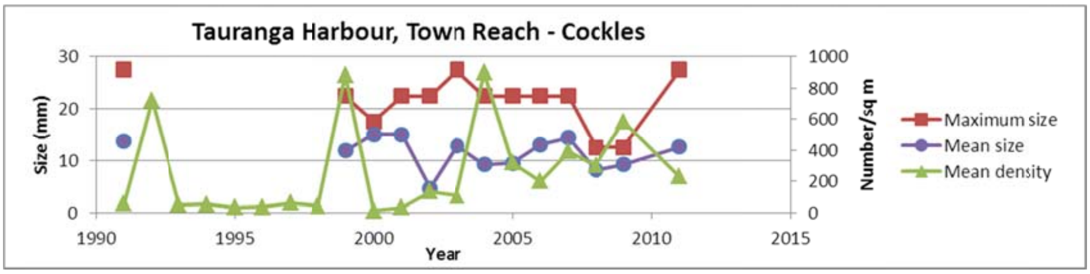

Figure 22 *Mean density, size and maximum size of cockles recorded at the Town Reach site over time.*

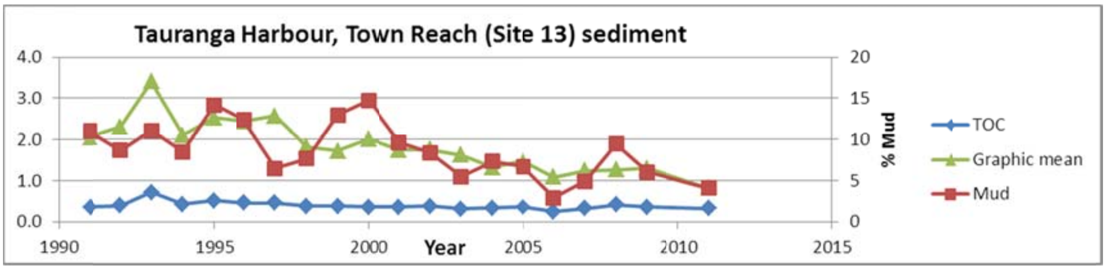

Figure 23 *TOC, mud (silt + clay) and graphic mean of particle size measured in the surficial sediment at the Otumoetai site over time.*

3.1.6 Waimapu Estuary (Site 17)

The Waimapu Estuary site has low exposure being very sheltered from the prevailing westerly winds. The site is located on the flats adjacent to the channel around the neap low tide level. Sediments contain a moderate amount of mud due to influence of the Waimapu River.

Species diversity (Figure 24) has shown some variation over time but has not changed. The most numerous group of animals at this site (Figure 25) is polychaete worms and numbers appear to have increased since 2008. Cockle density is moderate with shellfish of small maximum and average size with no consistent changes over time. The amount of TOC and mud recorded over time in the sediment has shown a significant increase (p=0.007 & 0.003 respectively).

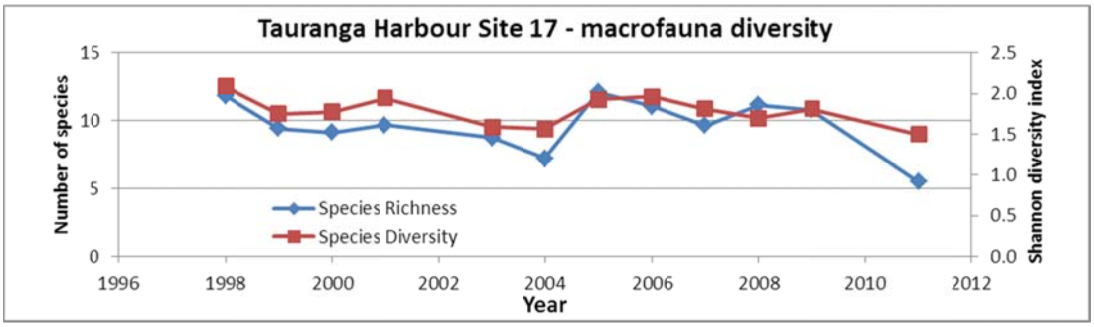

Figure 24 *Mean species richness and Shannon-Weiner diversity index recorded over time at Waimapu Estuary (n=24).*

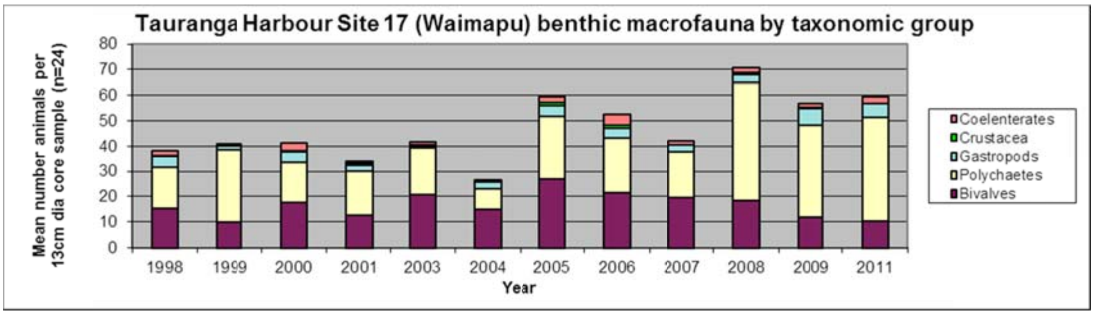

Figure 25 *Mean number of individuals by taxonomic group recorded at the Waimapu Estuary site over time.*

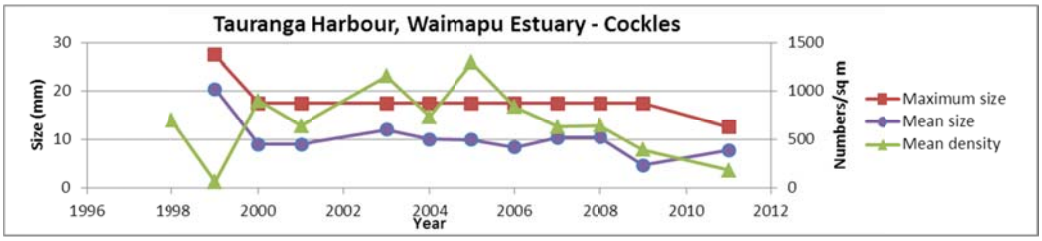

Figure 26 Mean density, size and maximum size of cockles recorded at the Waimapu Estuary site over time.

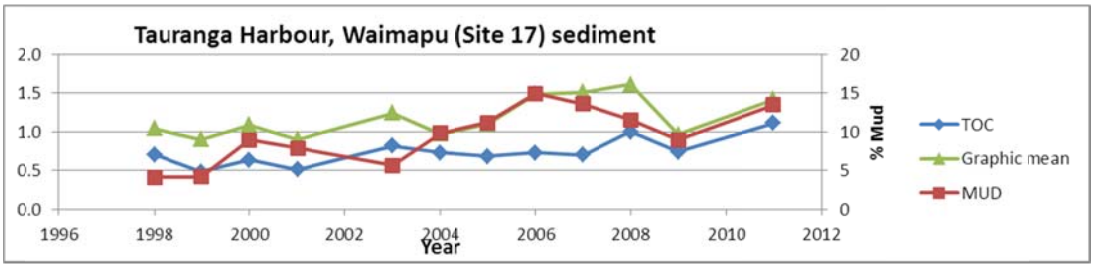

Figure 27 TOC, mud (silt + clay) and graphic mean of particle size measured in the surficial sediment at the Waimapu Estuary site over time.

3.1.7 Welcome Bay (Site 18)

The Welcome Bay site has moderate exposure and is located above the neap low tide level on the flats well away from the channel edge. Species diversity (Figure 28) is moderately variable but shows no change over time (2001 - 2011). The most numerous group of animals (Fig 29) is bivalves with coelenterates, specifically the common shore anemone being the next most abundant animal. Cockles are abundant at this site (Figure 30) although average size is small and they are the dominant bivalve present. Cockle density shows no consistent change over time. There is also no change is sediment parameters over time (Figure 31).

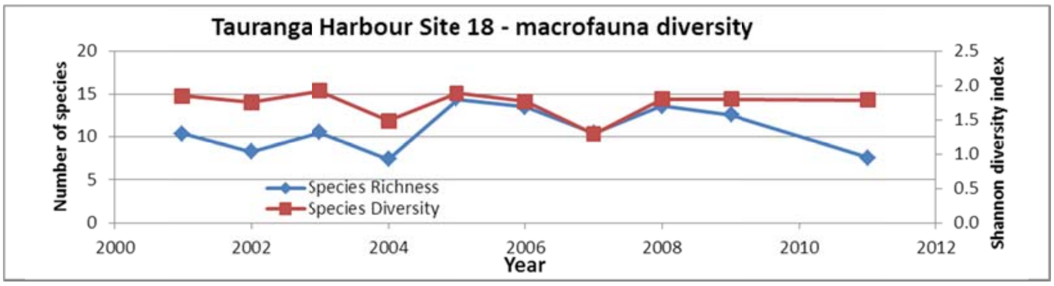

Figure 28 Mean species richness and Shannon-Weiner diversity index recorded over time at Welcome Bay (n=24).

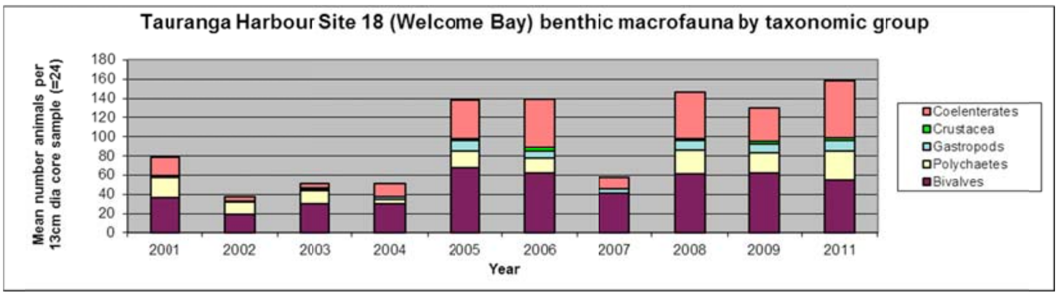

Figure 29 Mean number of individuals by taxonomic group recorded at the Welcome Bay site over time.

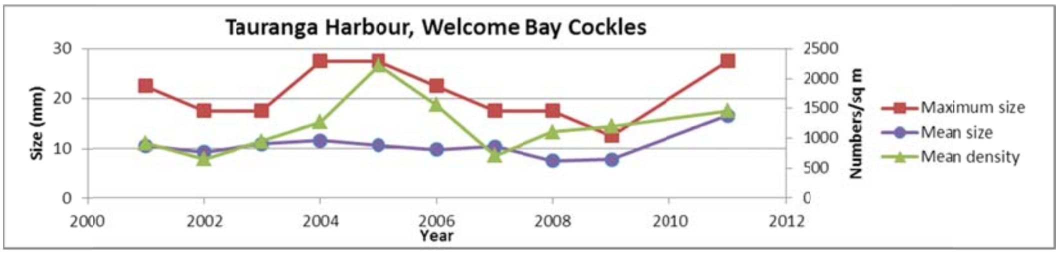

Figure 30 *Mean density, size and maximum size of cockles recorded at the Welcome Bay site over time.*

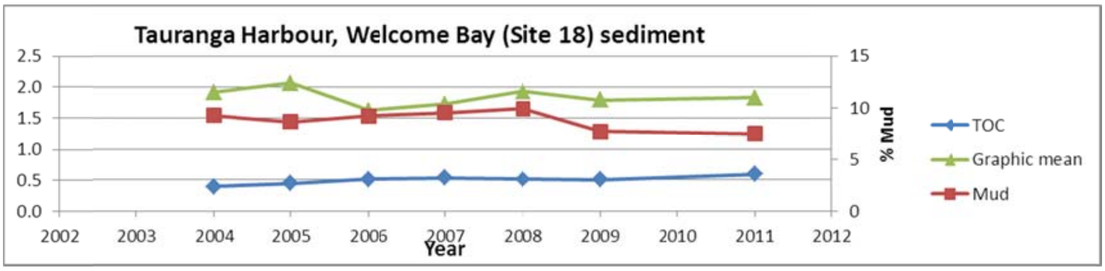

Figure 31 *TOC, mud (silt + clay) and graphic mean of particle size measured in the surficial sediment at the Welcome Bay site over time.*

3.2 Ohiwa Harbour

3.2.1 Ōhiwa Site 1

Site 1 is located off the eastern end of Ohakana Island around low tide level. Species diversity (Figure 32) shows some variability but no change over time. Numbers of individual macrofauna vary markedly between years (Figure 33) with the bivalve, polychaete and coelenterates the most common groups. The common shore anemone (coelenterate) has become more common at this site since 2001. Cockles generally show low to moderate density (Figure 34) but in 1995 a recruitment pulse resulted in high densities being present. Mud content of the sediment (Figure 35) shows a marginally significant increase over time ($p=0.035$).

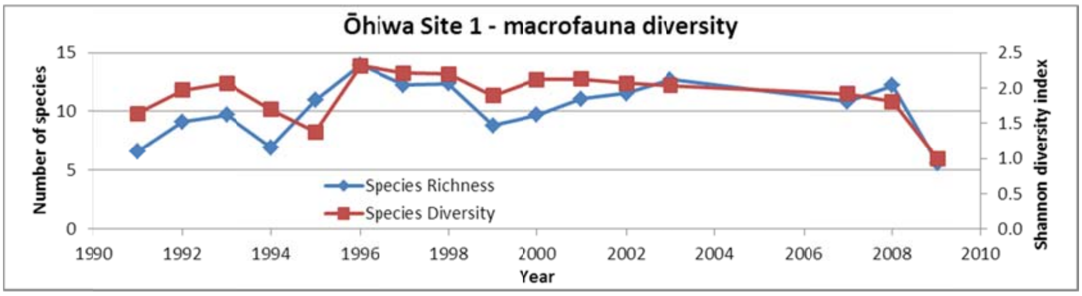

Figure 32 *Mean species richness and Shannon-Weiner diversity index recorded over time at Ōhiwa Site 1 (n=24).*

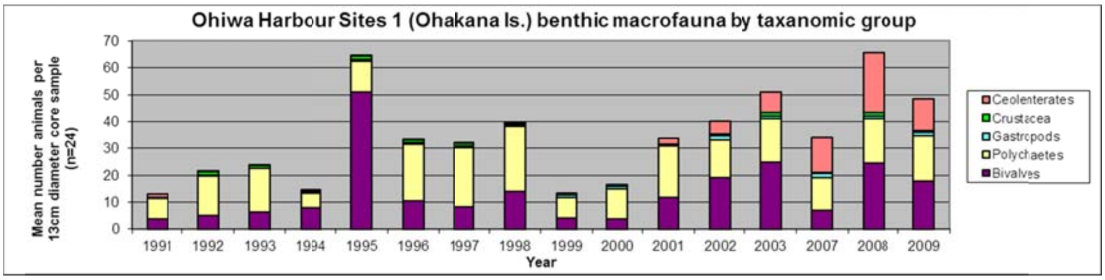

Figure 33 Mean number of individuals by taxonomic group recorded at Ōhiwa Site 1 over time.

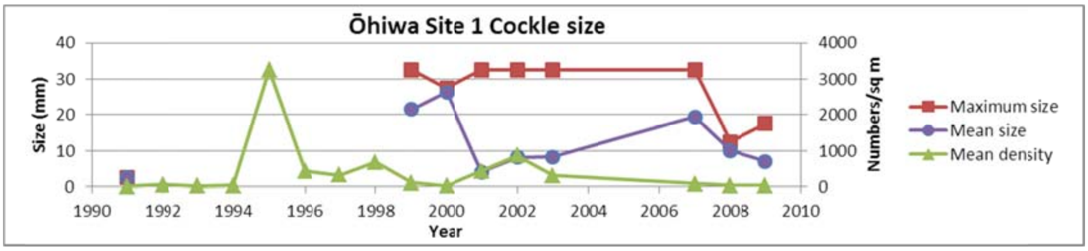

Figure 34 Mean density, size and maximum size of cockles recorded at Ōhiwa Site 1 over time.

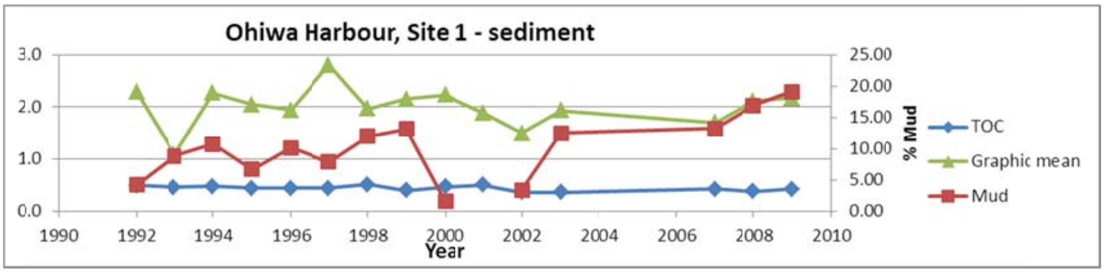

Figure 35 TOC, mud (silt + clay) and graphic mean of particle size measured in the surficial sediment at Ohiwa Site 1 over time.

3.2.2 Ōhiwa Site 2

Ōhiwa Site 2 is located to the east of Paparoa Point on the flat adjacent to the channel around the neap low tide level. Species diversity (Figure 36) shows variability but has not consistently changed over time. The most numerous groups of macrofauna are the Coelenterates due to the high abundance of the common shore anemone (Figure 37). Cockle density (Figure 38) is generally low but shows a possible increase from 2002 onwards. The sediment parameters shown in Figure 39 show no consistent change over time.

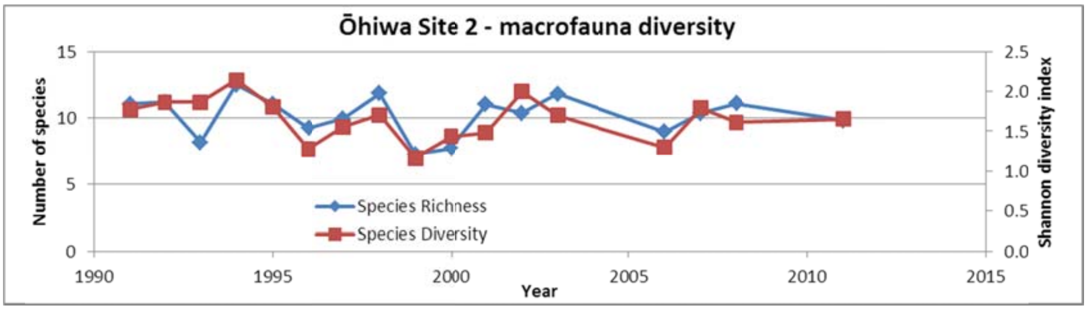

Figure 36 Mean species richness and Shannon-Weiner diversity index recorded over time at Ōhiwa Site 2 (n=24).

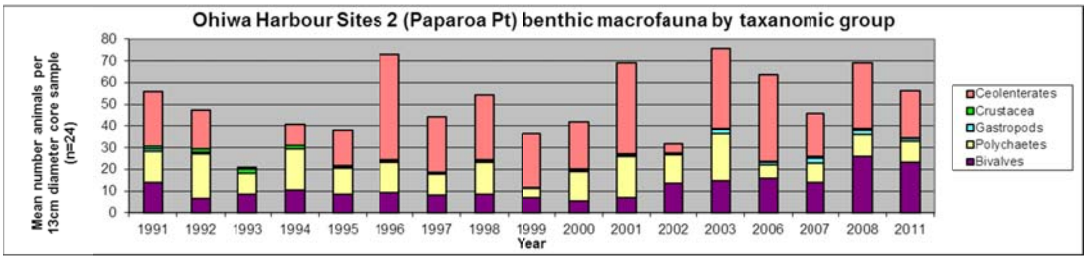

Figure 37 Mean number of individuals by taxonomic group recorded at Ōhiwa Site 2 over time.

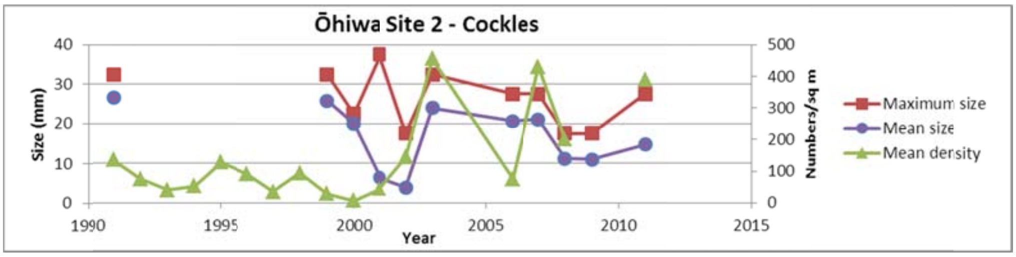

Figure 38 Mean density, size and maximum size of cockles recorded at Ōhiwa Site 2 over time.

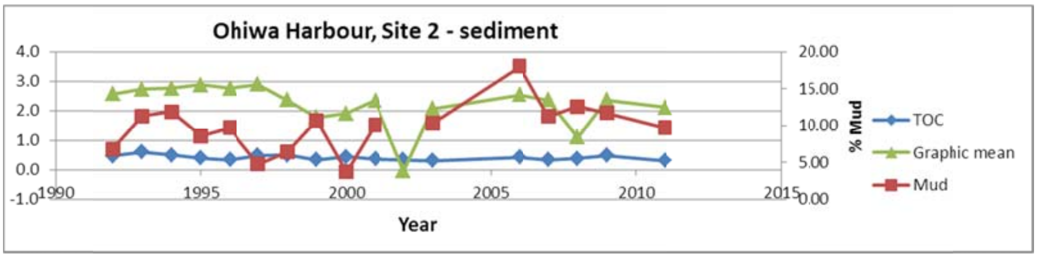

Figure 39 TOC, mud (silt + clay) and graphic mean of particle size measured in the surficial sediment at Ohiwa Site 2 over time.

3.2.3 Ōhiwa Site 3

Ōhiwa Site 3 is located west of Uretara Island on the flat around neap low tide level in a seagrass bed. Species diversity (Figure 40) shows a small amount of variability between years but no consistent change over the period of monitoring. The most numerous group of macrofauna are the polychaete worms (Figure 41) and between years the numbers of all macrofauna has been variable. Density of cockles at this site is generally low but the mean and maximum size is reasonably large (Figure 42). Sediment TOC values have been stable over the monitoring period (Figure 43) but the mud content shows a significant increase overtime (p=0.002).

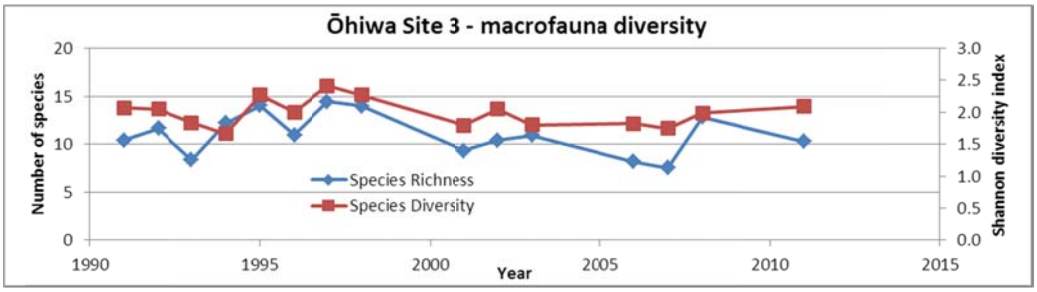

Figure 40 *Mean species richness and Shannon-Weiner diversity index recorded over time at Ōhiwa Site 3 (n=24).*

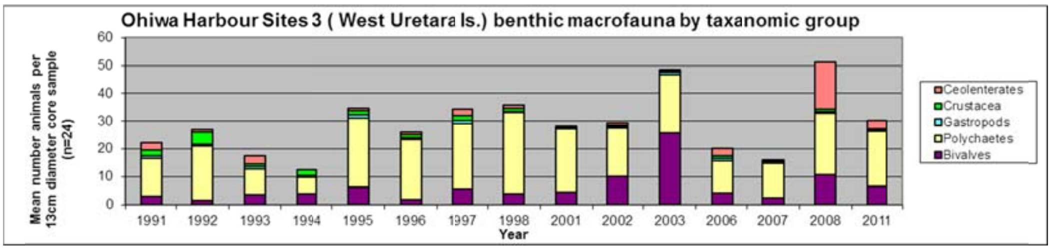

Figure 41 *Mean number of individuals by taxonomic group recorded at Ōhiwa Site 3 over time.*

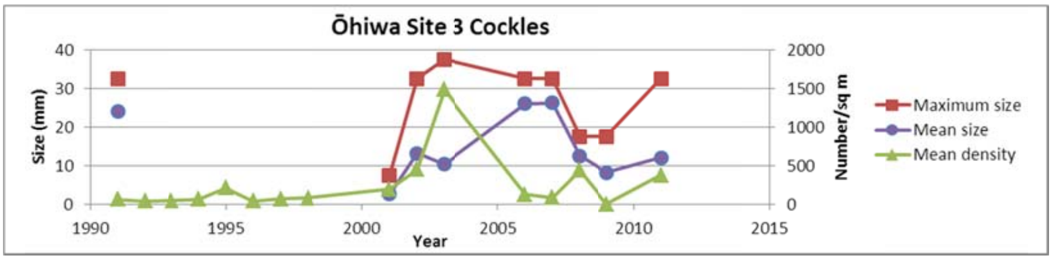

Figure 42 *Mean density, size and maximum size of cockles recorded at Ōhiwa Site 3 over time.*

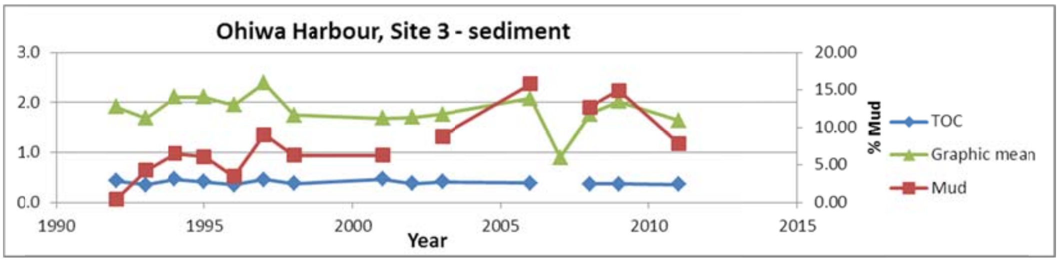

Figure 43 *TOC, mud (silt + clay) and graphic mean of particle size measured in the surficial sediment at Ohiwa Site 3 over time.*

3.2.4 Ōhiwa Site 6

Ōhiwa Site 6 is located north of Hokianga Island on the channel bank around mean low tide level. Species diversity has shown no consistent change over the monitoring period (Figure 44). The most numerous group of macrofauna is generally polychaete worms although coelenterates and bivalves are also common and total numbers of all macrofauna vary from year to year. Cockle density is moderate most years (Figure 45) and size is generally large. Sediment parameters (Figure 46) show some variability but no consistent change over the period of monitoring.

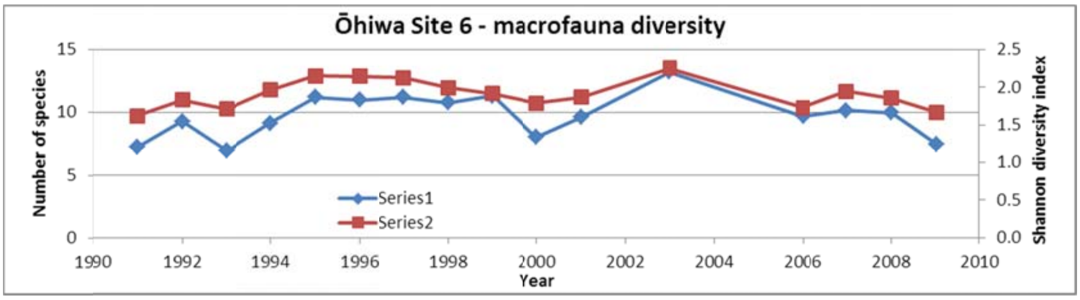

Figure 44 *Mean species richness and Shannon-Weiner diversity index recorded over time at Ōhiwa Site 6 (n=24).*

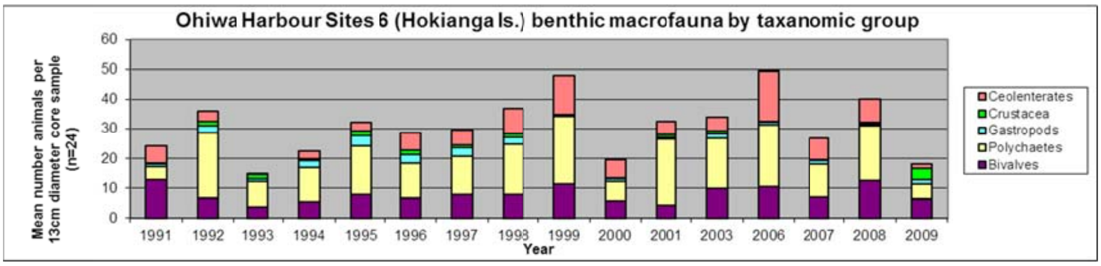

Figure 45 *Mean number of individuals by taxonomic group recorded at Ōhiwa Site 6 over time.*

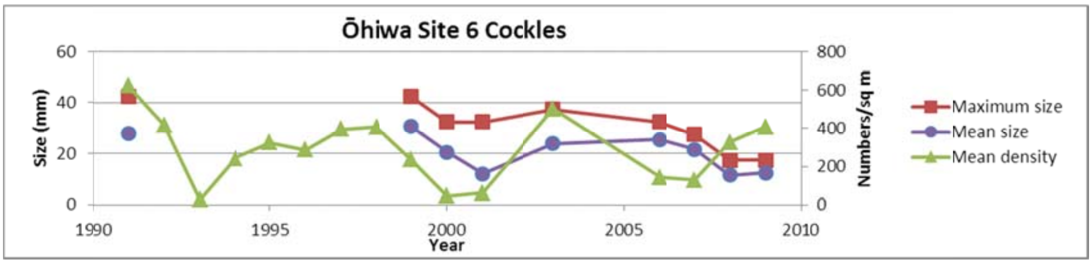

Figure 46 *Mean density, size and maximum size of cockles recorded at Ōhiwa Site 6 over time.*

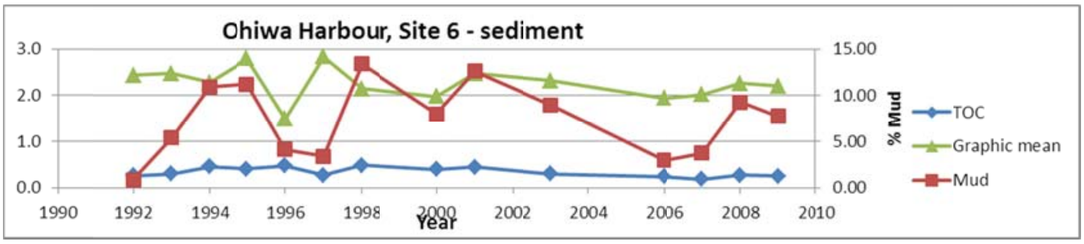

Figure 47 *TOC, mud (silt + clay) and graphic mean of particle size measured in the surficial sediment at Ohiwa Site 6 over time.*

3.3 Maketu Estuary

3.3.1 Maketū Site 1

Site 1 in Maketū Estuary is located in the central area of the estuary as shown in Figure 2. Located adjacent to a meandering channel has resulted in the site being eroded and changed over the years. This is reflected in the variable species diversity results (Figure 48) and decline in the number of macrofauna found (Figure 49) over the period of monitoring. Cockle densities also reflect the impact of the channel eroding the site with shellfish numbers and size reducing from 2003 to

2008. Sediment parameters (Figure 50) have also been variable with a trend towards lower TOC and mud content as the site has eroded with the current.

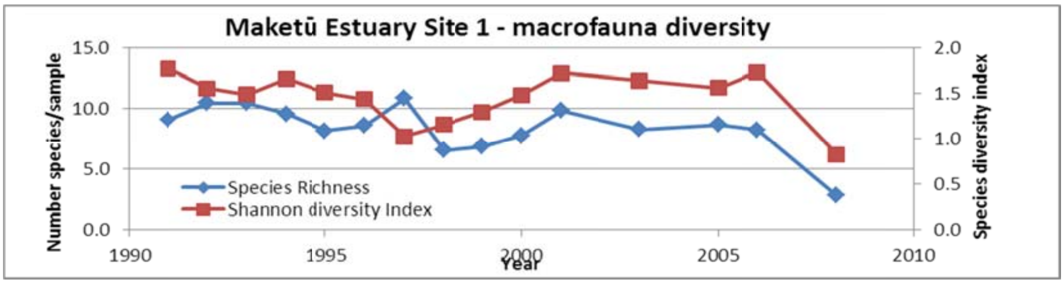

Figure 48 Mean species richness and Shannon-Weiner diversity index recorded over time at Maketu Site 1 (n=24).

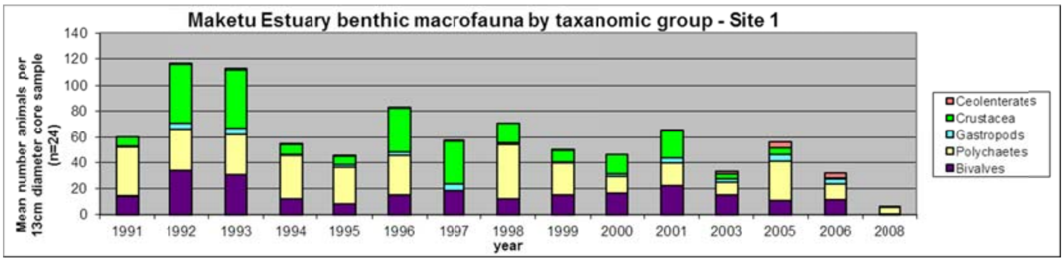

Figure 49 Mean number of individuals by taxonomic group recorded at Maketū Site 1 over time.

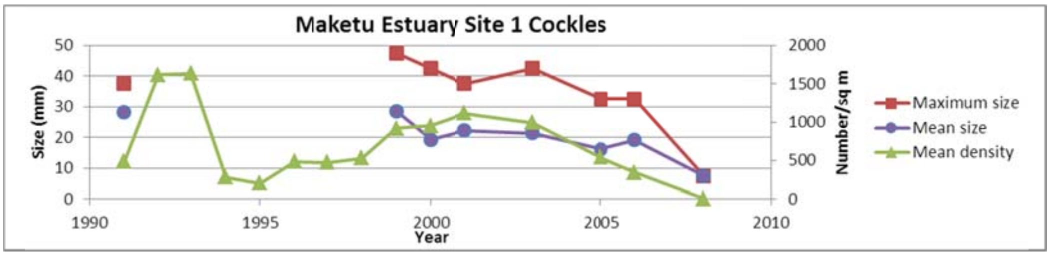

Figure 50 Mean density, size and maximum size of cockles recorded at Maketu Site 1 over time.

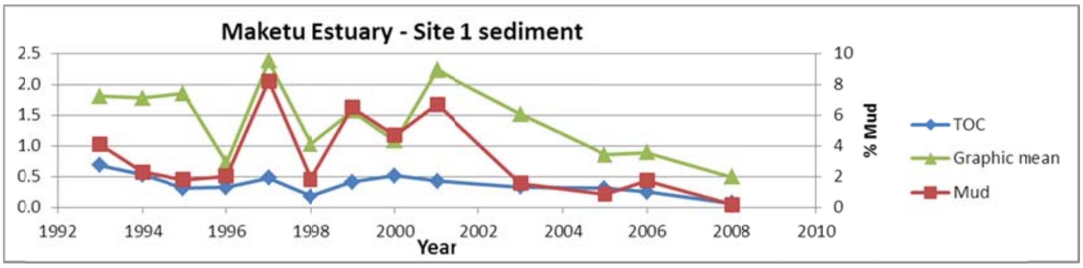

Figure 51 TOC, mud (silt + clay) and graphic mean of particle size measured in the surficial sediment at Maketu Site 1 over time.

3.3.2 Maketū Site 2

Maketū Site 2 is located in the central area of the estuary and has over time experienced some erosion due to shifting channels and sediment deposition. The changes in the habitat are reflected in the highly variable species diversity recorded over the monitoring period (Figure 52). The total number of macrofauna has been low in many years and variable, peaking in 2001 with crustacean and polychaete worms being the dominant groups (Figure 53). The density of cockles (Figure 54) was low up to 1999 and has since increased as the habitat conditions changed. Sediment particle size (graphic mean & mud % - Figure 55) has been variable in response to the erosion and deposition of sand at the site.

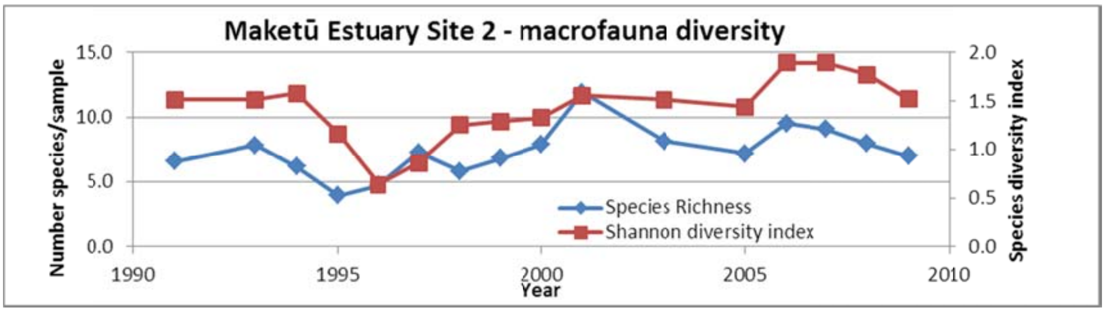

Figure 52 *Mean species richness and Shannon-Weiner diversity index recorded over time at Maketu Site 2 (n=24).*

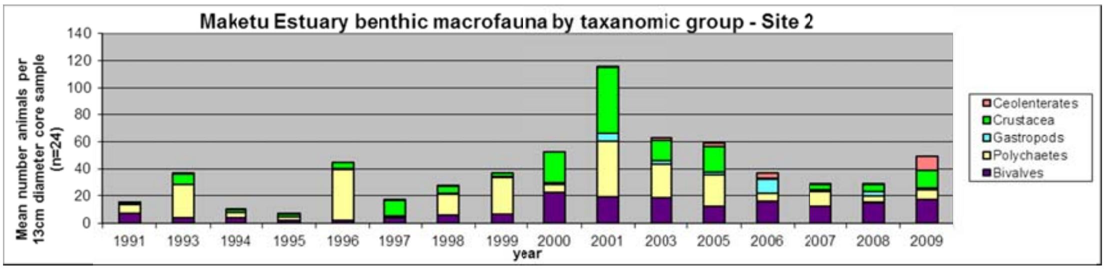

Figure 53 *Mean number of individuals by taxonomic group recorded at Maketū Site 2 over time.*

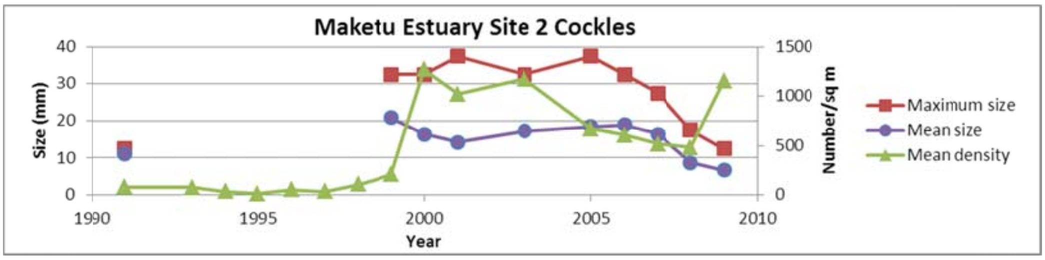

Figure 54 *Mean density, size and maximum size of cockles recorded at Maketu Site 2 over time.*

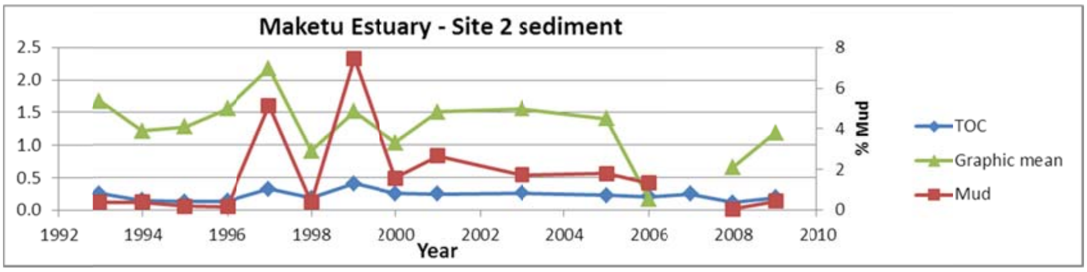

Figure 55 *TOC, mud (silt + clay) and graphic mean of particle size measured in the surficial sediment at Maketu Site 2 over time.*

3.3.3 Maketū Site 3

Site 3 in Maketū Estuary is on the flats away from the main channel but nearer the entrance in an area where sand migration and deposition has been occurring over the period of monitoring. Species diversity has been low and variable (Figure 56) as a result of the physical changes that have occurred with the sand deposition and movement. The total numbers of macrofauna present at this site have been low even in the first few years and then very low from 1995 to 2007 (Figure 57). Cockle density (Figure 58) shows a similar trend to the total numbers of all macrofauna present. Average and maximum shellfish size is very small. The sand deposition at this site has caused very high variability in the graphic mean of particle size (Figure 59). The sand migration and deposition has been very clean sediment from the open coast so that mud content has remained low over the period of monitoring.

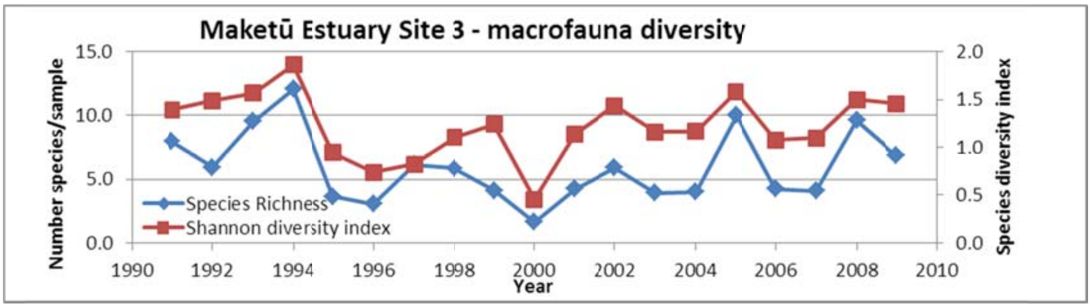

Figure 56 Mean species richness and Shannon-Weiner diversity index recorded over time at Maketu Site 3 (n=24).

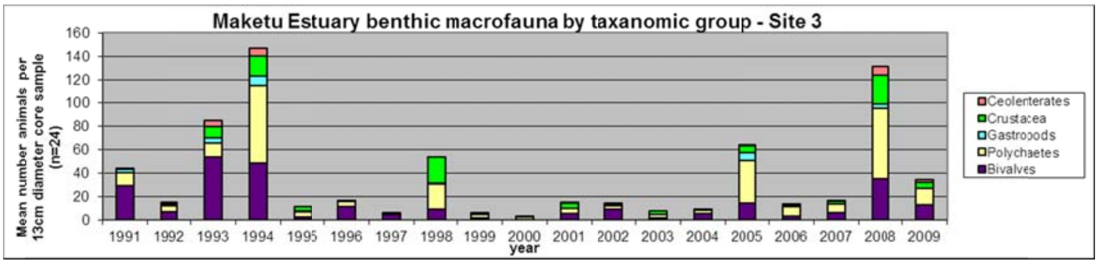

Figure 57 Mean number of individuals by taxonomic group recorded at Maketū Site 3 over time.

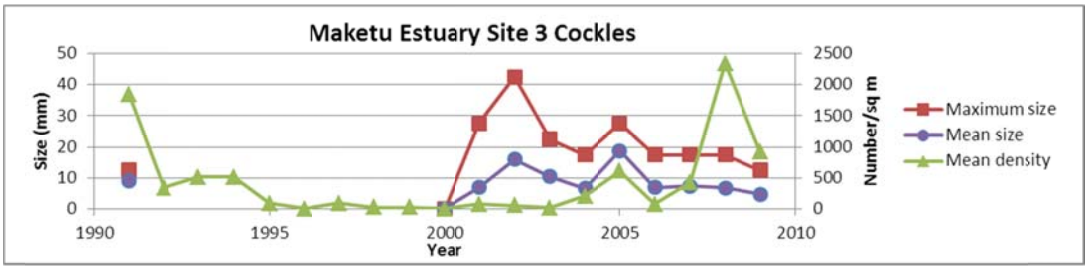

Figure 58 Mean density, size and maximum size of cockles recorded at Maketu Site 3 over time.

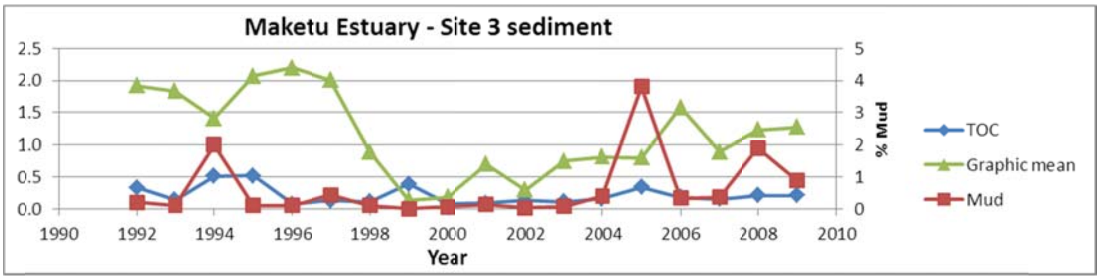

Figure 59 TOC, mud (silt + clay) and graphic mean of particle size measured in the surficial sediment at Maketu Site 3 over time.

3.3.4 Maketū Site 4

Site 4 in Maketū Estuary is closest to the entrance and very dynamic with large episodes of erosion and sand deposition as the channel has shifted and the spit breached in 199? Species diversity has been variable and very low at times (Figure 60) and the total number of macrofauna present (Figure 61) shows the same pattern. Cockles have either been totally absent or present at low density (Figure 62). Sediment particle size parameters have been variable reflecting the physical changes that have occurred (Figure 63).

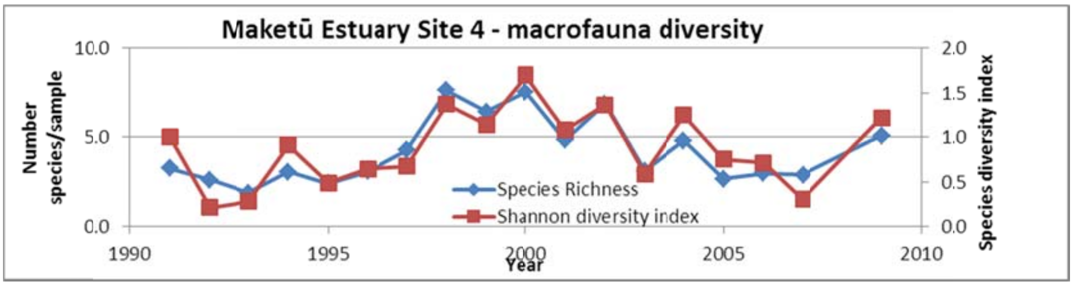

Figure 60 *Mean species richness and Shannon-Weiner diversity index recorded over time at Maketu Site 4 (n=24).*

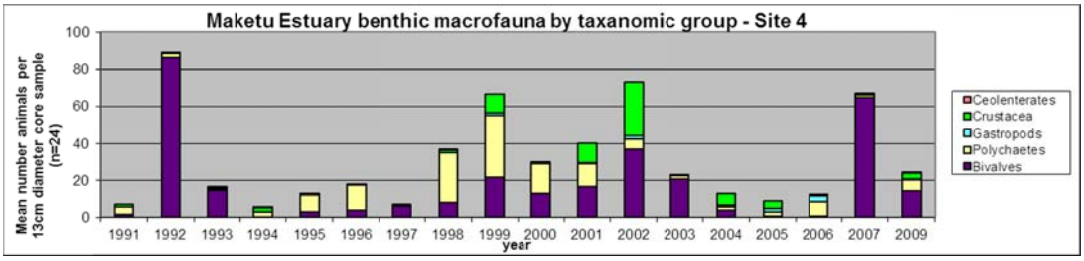

Figure 61 *Mean number of individuals by taxonomic group recorded at Maketū Site 4 over time.*

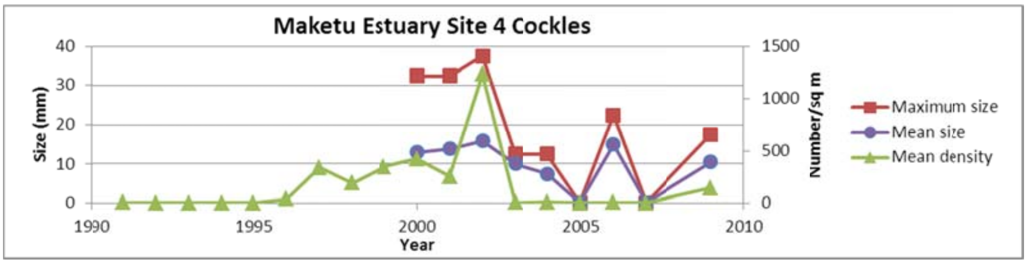

Figure 62 *Mean density, size and maximum size of cockles recorded at Maketu Site 4 over time.*

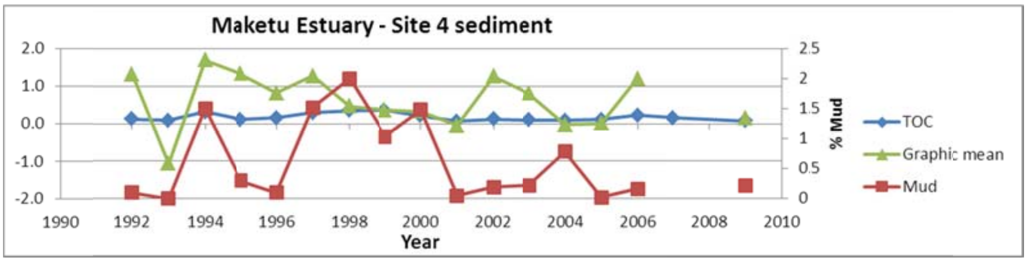

Figure 63 *TOC, mud (silt + clay) and graphic mean of particle size measured in the surficial sediment at Maketu Site 4 over time.*

3.4 Waihi Estuary

Site 3 in Waihī Estuary is located in a more stable area on the western side. It is around neap low tide level on the flat adjacent to a small channel. Species diversity has shown some variation but remained relatively stable with no consistent trends over time (Figure 64). Numbers of macrofauna present has declined over the period of monitoring and bivalves and polychaetes are generally dominant (Figure 65). Cockle densities show some variation (Figure 66) but no consistent trends over the monitoring period. Sediment particle size parameters (graphic mean & mud %) show no change over time (Figure 67) but TOC shows a small decrease (p=0.001).

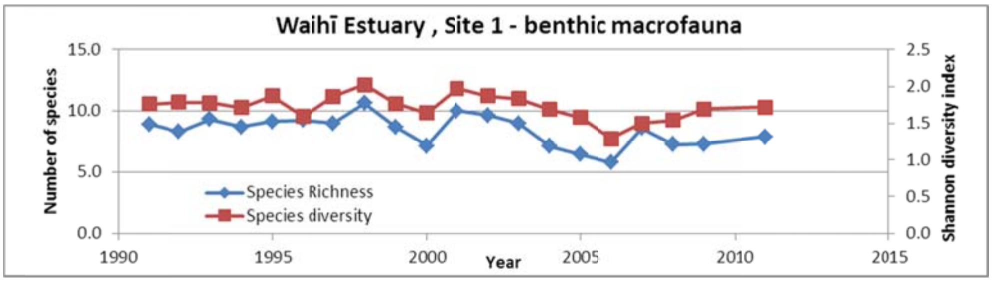

Figure 64 Mean species richness and Shannon-Weiner diversity index recorded over time at Waihi Estuary Site 1 (n=24).

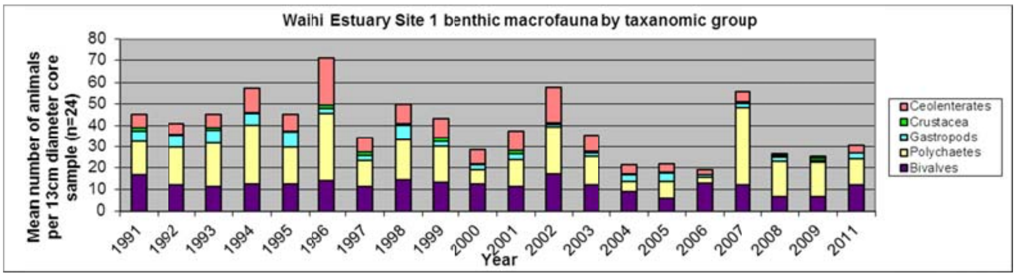

Figure 65 Mean number of individuals by taxonomic group recorded at Waihī Estuary Site 1 over time.

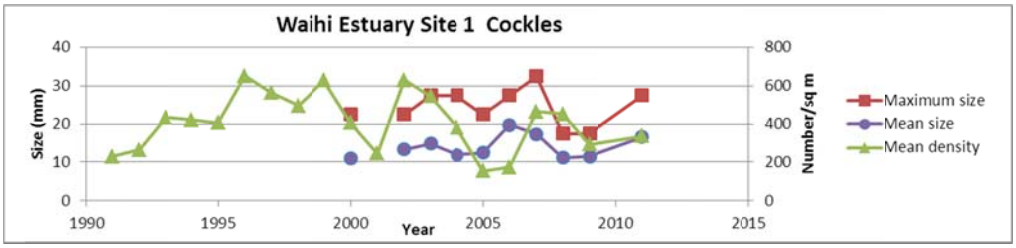

Figure 66 Mean density, size and maximum size of cockles recorded at Waihi Estuary Site 1 over time.

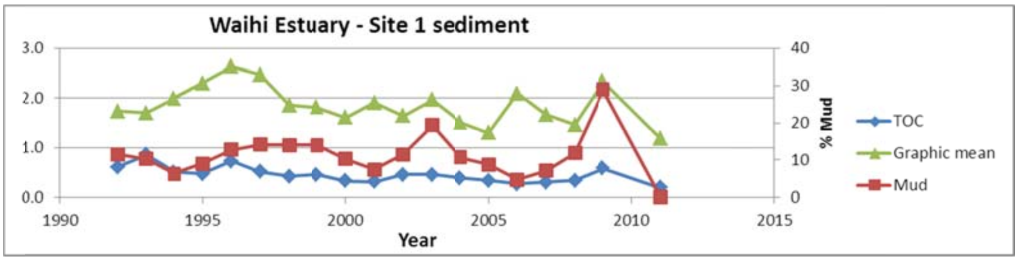

Figure 67 TOC, mud (silt + clay) and graphic mean of particle size measured in the surficial sediment at Waihī Estuary Site 1 over time.

3.5 Waiotahi Estuary

Waiotahi Estuary site is located around the mean low tide mark on a low gradient sand flat close to the main channel. The site shows a moderate amount of variability in terms of the sediments shifting due to the influence of the river. Species diversity is moderately low and variable but shows no consistent trends over time (Figure 68). Total numbers of macrofauna vary between years as does the dominant group which is usually bivalves, polychaete worms or crustacean (Figure 69). Cockle densities are low in most years (Figure 70) and of small size. Sediment parameters show no consistent change over time and mud content is the most variable.

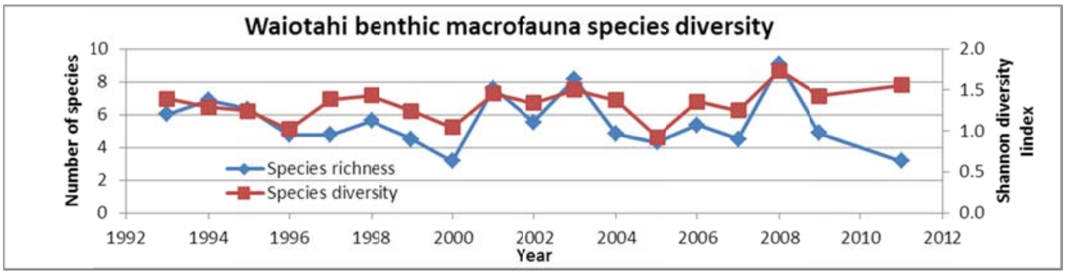

Figure 68 Mean species richness and Shannon-Weiner diversity index recorded over time at Waiotahi Estuary (n=24).

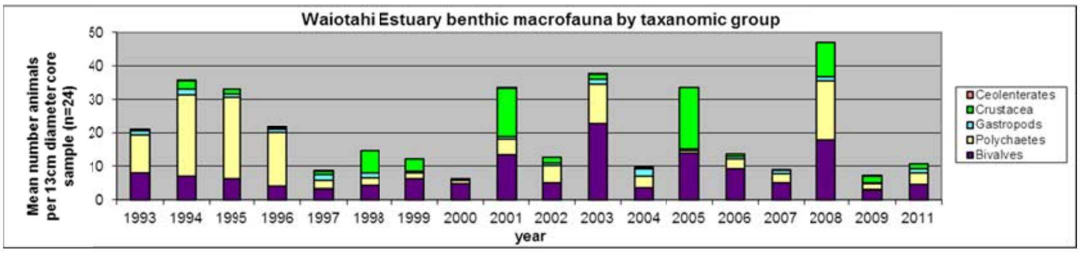

Figure 69 Mean number of individuals by taxonomic group recorded at Waiotahī Estuary over time.

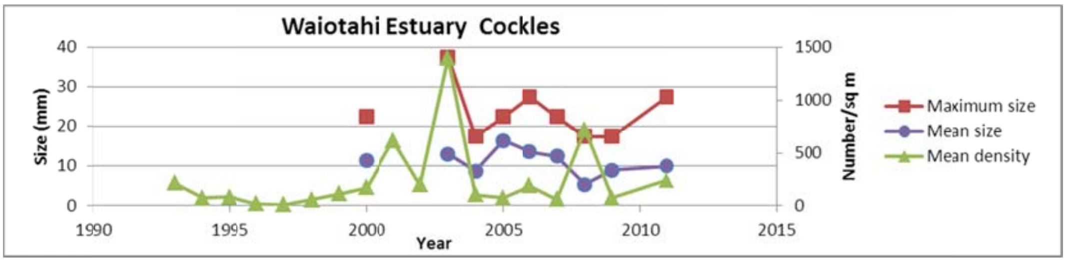

Figure 70 Mean density, size and maximum size of cockles recorded at Waiotahi Estuary over time.

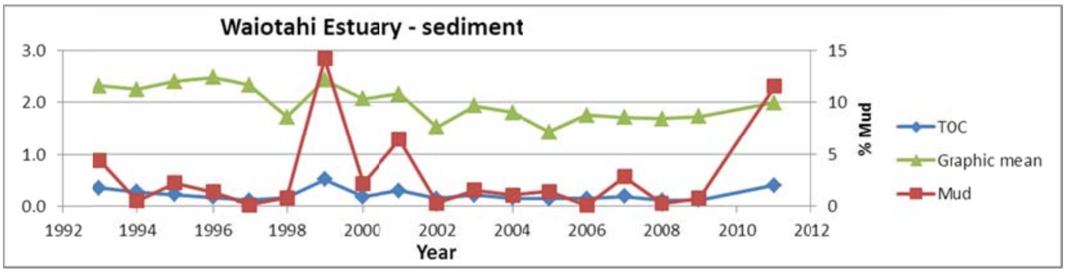

Figure 71 TOC, mud (silt + clay) and graphic mean of particle size measured in the surficial sediment at Waiotahī Estuary over time.

3.6 Open coast sandy shore sites

The open coast sandy shore sites are all located on the open Bay of Plenty coast with exposure to the north-westerly to southerly wind and wave climate of the Pacific Ocean. The macrofauna at these sites are adapted to the harsh physical conditions in which they live and numbers of species are much lower than more sheltered estuarine sites.

3.6.1 Pāpāmoa Beach

Pāpāmoa Beach is a low gradient dissipative beach with medium to fine well sorted sand. Species richness is low and variable (Figure 72) with crustacea (amphipods and isopods) the dominant group in most years (Figure 73). Sediment particle size variation over the period of monitoring (Figure 74) is similar to the pattern of variation seen in species diversity.

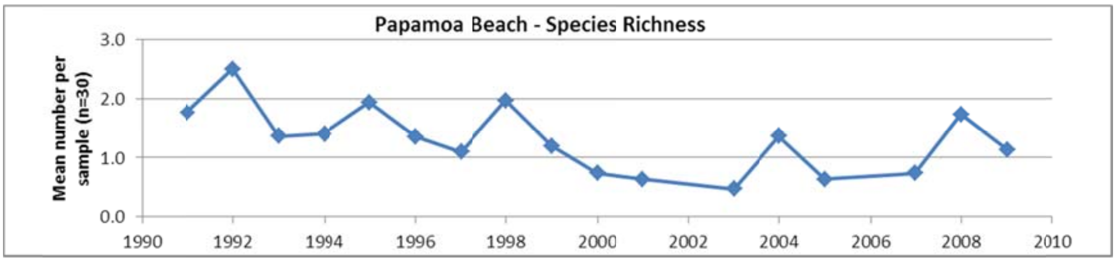

Figure 72 Mean species richness recorded over time at Pāpāmoa Beach.

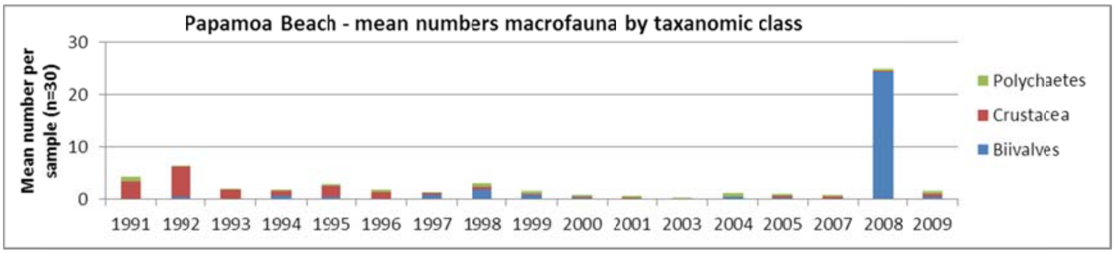

Figure 73 Mean number of individuals by taxonomic group recorded over time at Pāpāmoa Beach.

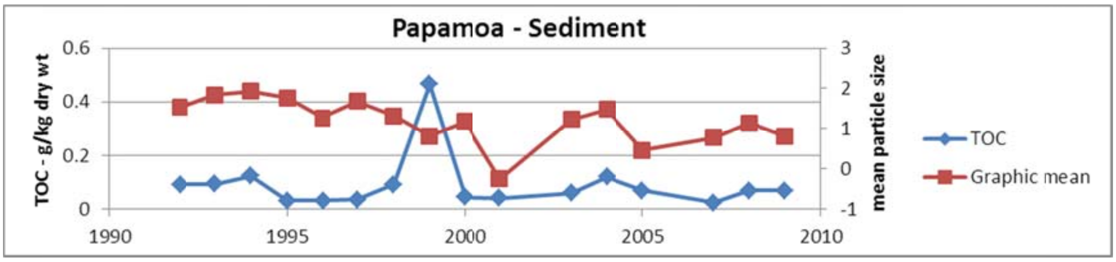

Figure 74 TOC and graphic mean of particle size measured in the surficial sediment at Papamoa Beach over time.

3.6.2 Matatā Beach

Matatā Beach is a reflective beach with moderate gradient and coarse sand. Species richness is very low as is number of macrofauna found in each sample (Figure 76). Graphic mean of particle size is variable over time with values reflecting the coarse sands/fine gravels present.

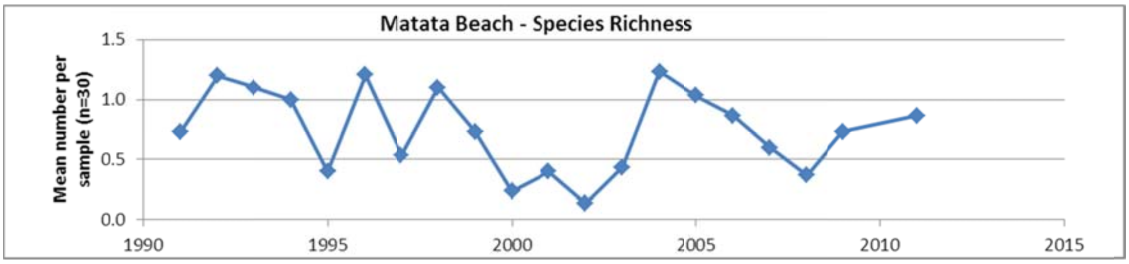

Figure 75 Mean species richness recorded over time at Matata Beach.

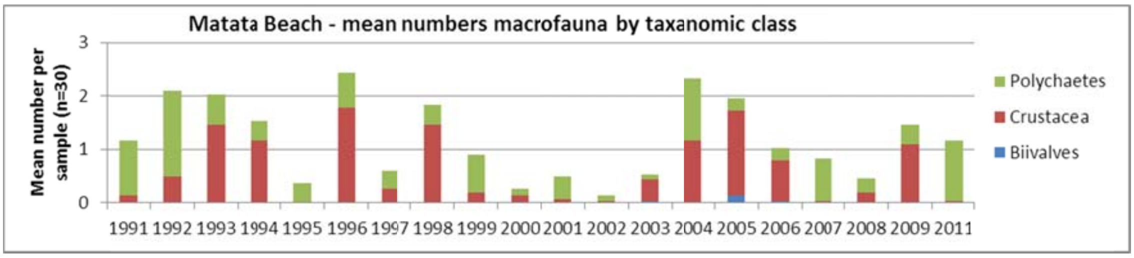

Figure 76 Mean number of individuals by taxonomic group recorded over time at Matata Beach.

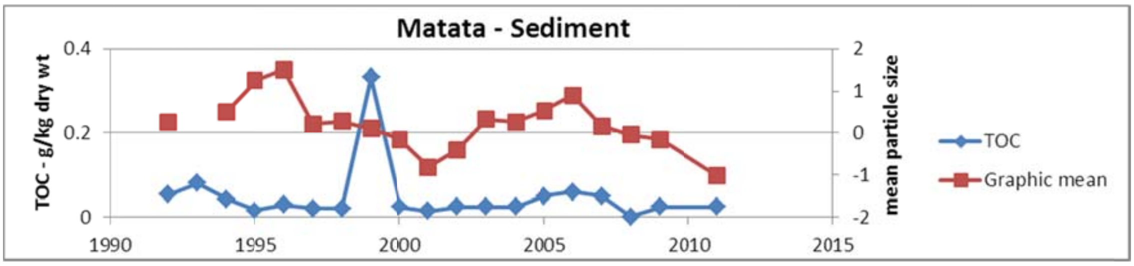

Figure 77 TOC and graphic mean of particle size measured in the surficial sediment at Matata Beach over time.

3.6.3 Ōhope West End Beach

Ōhope West End Beach is a low gradient dissipative beach with medium to fine well sorted sand. Species richness (Figure 78) is low and variable over the monitoring period. Numbers of macrofauna are usually low with bivalve and crustacean groups dominant (Figure 79). Graphic mean of particle size (Figure 80) reflects the finer particle size and is relatively stable over the monitoring period.

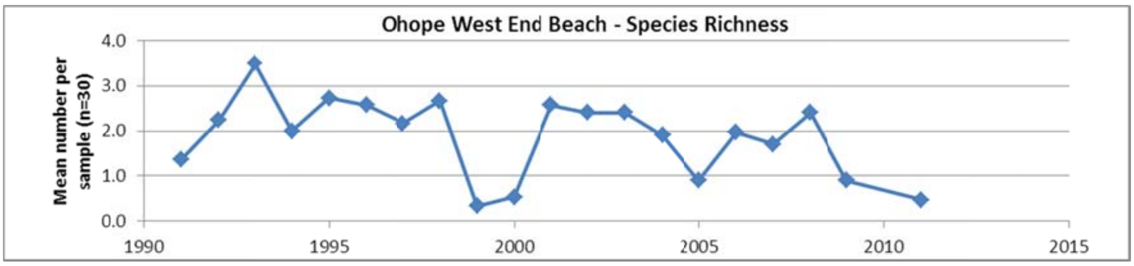

Figure 78 Mean species richness recorded over time at Ōhope West End Beach.

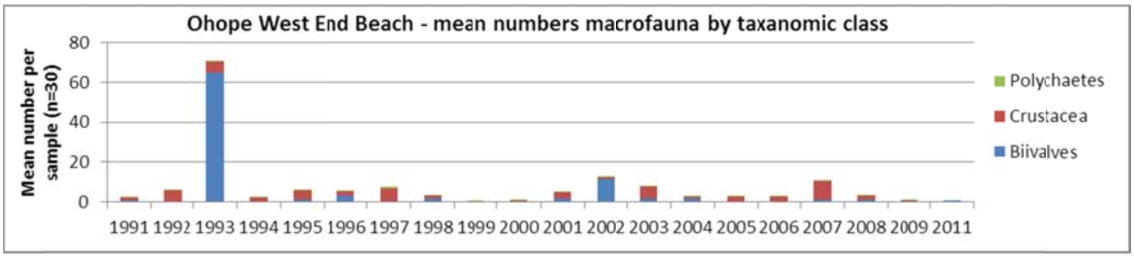

Figure 79 *Mean number of individuals by taxonomic group recorded over time at Ōhope West End Beach.*

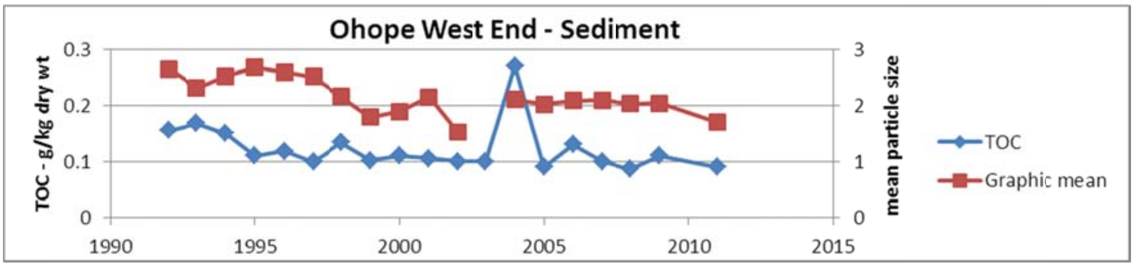

Figure 80 *TOC and graphic mean of particle size measured in the surficial sediment at Ōhope West End Beach over time.*

3.6.4 **Opāpe Beach**

Ōpape Beach is a low gradient dissipative beach with medium to fine well sorted sand located to the east of Opotiki. Species richness (Figure 81) is low and variable but shows no consistent trend over the monitoring period. Numbers of macrofauna are low to moderate and vary from year to year (Figure 82). Crustacea (amphipods and isopods) are usually the dominant taxonomic group present. Graphic mean of particle size (Figure 80) reflects the finer particle size and a trend towards slightly coarser sand over the monitoring period.

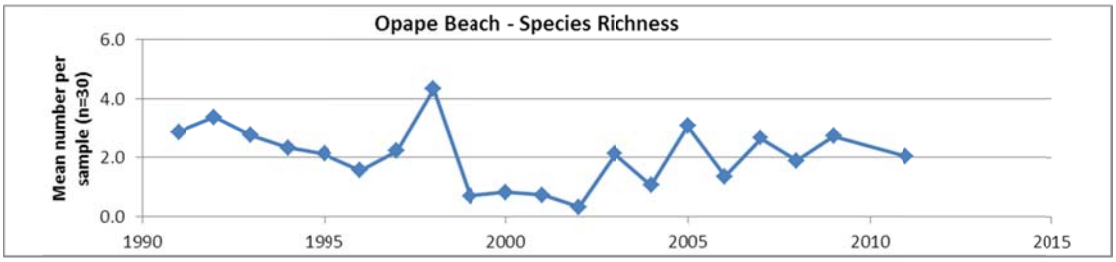

Figure 81 *Mean species richness recorded over time at Ōpape Beach.*

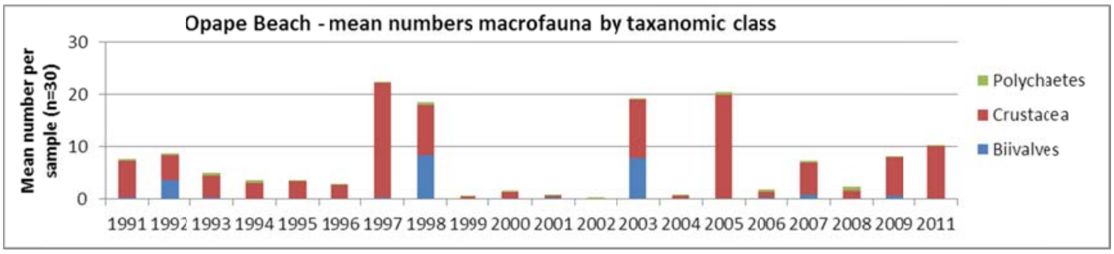

Figure 82 *Mean number of individuals by taxonomic group recorded over time at Ōpape Beach.*

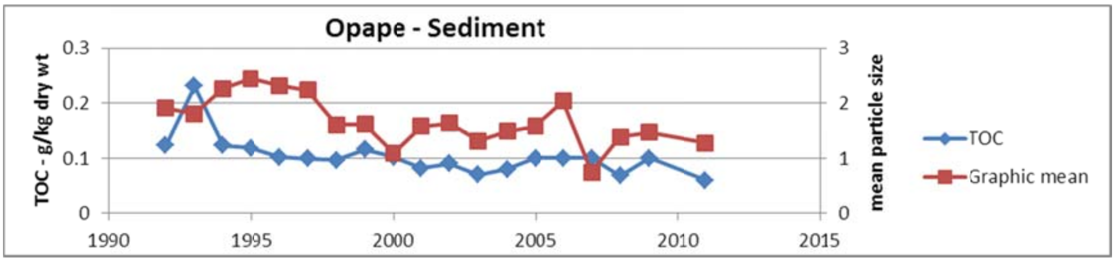

Figure 83 TOC and graphic mean of particle size measured in the surficial sediment at Ōpape Beach over time.

Part 4: Summary and review

4.1 Summary of monitoring results

4.1.1 Tauranga Harbour sites

Of the seven sites currently being monitored in Tauranga Harbour none have shown any significant increase or decrease in species diversity as measured by species numbers (richness) and evenness (Shannon-Weiner index) over the period of monitoring. Most sites show some variability in the total numbers of macrofauna present each year and the dominant taxonomic group. At some of the sites there were also changes in the sediment parameters.

The Pio's Beach site had a slight change in the sediment particle size and cockle numbers. However, these changes do not coincide or appear to be linked and ecologically detrimental. Katikati site shows a similar minor change in sediment particle size.

In the southern end of the harbour both the Otumoetai and Town Reach sites have shown a decrease in the mud content and an increase in the number of cockles. Both these sites were initially set up in seagrass beds which have since become very patchy and sparse in coverage due to swan grazing. The Otumoetai site in particular has increased sediment mobility. The loss of seagrass cover at these two sites probably accounts for the decrease in mud content and the increase in cockle numbers hence overall these changes do not appear to be positive.

The Waimapu Estuary site shows an increase in the dominance of polychaete worms and significant increases in both the TOC and mud content measured in the sediment over the period of monitoring. This is a detrimental change to the habitat and ecology at this site and probably links back to impacts from the Waimapu River catchment.

4.1.2 Ohiwa Harbour sites

Four sites are currently monitored in Ohiwa Harbour and up to this point none have shown any consistent change in species diversity. However some changes have occurred. At Site 1 patches of benthic sponge used to be present but have now totally disappeared while the common shore anemone (*Anthopleura aureoradiata*) has increased. The mud content has also shown a small but significant increase between 1991 and 2009. These changes appear to be detrimental and probably link back to sediment loss from the catchment. Site 3 also shows a detrimental increase in mud content of the sediments but this has not yet resulted in any obvious changes to the benthic macrofauna measured at the site.

4.1.3 Maketu Estuary sites

All four of the sites in Maketu Estuary have shown changes in species diversity and sediment parameters as a result of the highly dynamic habitat caused by shifting channels and sand migration into the estuary. These physical changes are swamping any chance of detecting changes in the benthic macrofauna resulting from water quality issues.

4.1.4 Waihi Estuary

Currently only Site 1 is monitored in Waihi Estuary as the other two both showed a high degree of physical variation from shifting channels and sand movement. Over the period of monitoring (1991 – 2011) there have been a decrease in the total number of macrofauna and a small but significant decline in sediment TOC. The numbers of macrofauna now present are still relatively abundant and within the range seen at many of the other sites, so the change up to this point is not considered detrimental.

4.1.5 Waiotahi Estuary

The Waiotahi Estuary site shows some variability in species diversity and sediment parameters but no consistent change over time. The influence of the river and resultant physical changes appear to be the main driver of the variability. Species diversity is also low due to the fluctuating salinity levels.

4.1.6 Open coastal sites

All four of the currently monitored open coast sandy shore sites show variability in species diversity and sediment parameters but no consistent change. Species diversity is very low at all sites and varies according to the type of beach and energy it receives. The lowest diversity associated with the steep beach at Matata and increasing with flatter beaches with finer sediment. Some change in species diversity at the sites seems to correlate to the physical variation at each site.

4.2 Review of monitoring programme

4.2.1 Sheltered harbour and estuary sites

The first review of the 48 soft-shore benthic macrofauna monitoring sites in 1995 (Park 1995) assessed both the statistical design and objectives, resulting in reduced sample replication and suspension of 8 open coastal sites and 3 estuarine sites. A later review (Park 2000) then suspended a further 16 sites as adequate baselines of benthic communities had been established which could serve as future benchmarks. In addition the Welcome Bay and Waimapu Estuary sites were moved to more stable locations to allow better sensitivity to detect subtle changes in the surrounding harbour flats. All these changes have been driven by the need for the programme to be achievable with limited resources and be able to detect changes in the environment of concern. This includes impacts from sedimentation, reduced water quality and contaminants resulting from activities in the surrounding catchments. To help achieve those objectives other components have also been added to the programme which include seagrass and mangrove mapping and contaminant monitoring. The mapping of indicator species such as seagrass adds an important broad spatial coverage aspect to the programme for assessing environmental trends.

Current sites

The current Tauranga Harbour sites (7) are physically stable and show the ability to detect subtle change in the benthic macrofaunal community over time. It is recommended that these sites continue to be monitored on an annual basis. The 4 sites currently monitored in Ohiwa Harbour and one in Waihi Estuary are physically stable and suitable; hence it is recommended that monitoring continue.

In Maketu Estuary all sites are heavily impacted by sand erosion or deposition masking their ability to be used for the detection of the water quality issues of concern. Monitoring of the sites had been persevered with in part to provide additional information on the effects of the partial re-diversion of the Kaituna River back to the estuary. The re-diversion has not been large enough to stop sand infilling the estuary and the resultant physical effects swamp any possible water quality issues. It is recommended that monitoring of the sites is suspended. The establishment of a site higher in the tidal range in a stable area of the estuary should be investigated.

The Waiotahi Estuary site now has a well-established baseline which is suitable for assessing future change. However it will not be highly sensitive to subtle change due to the periodic impact of river floods and the high fresh water influence resulting in high variability but low species diversity. The catchment has only agricultural development with less development pressure than that occurring around other parts of the coast. Given these factors it is recommended that this site is suspended from current monitoring.

Additional monitoring options

For the size of Tauranga Harbour the seven sites currently being monitored give broad coverage with some weighting towards the southern harbour where water quality and development pressures are highest. However each site is limited in the area that the results will represent hence there are large areas of the harbour for which no information is available. It is now clear from a great deal of recent research in New Zealand that one of the main issues is sedimentation and in highly developed catchments heavy metals, organic pollutants and nutrients. Hence one option may be to monitor the sediments for change in key parameters and contaminants at a number of additional locations.

4.2.2 Open coastal sites

Initially there were fifteen open coast sandy shore sites monitored around the Bay of Plenty and this was dropped back to four following an earlier review. Monitoring of the remaining four sites continued in part to gain a better indication of the natural variation that occurs in the open coast habitats. This has now been established with monitoring over a period of twenty years which included a wide range of the expected climatic variation. Hence it is recommended that monitoring at the open coastal sites is suspended. This can be supported by the fact that the most sensitive habitats to change in the sheltered environments continue to be monitored and other information on water quality of catchment runoff is being collected throughout the Bay of Plenty and regularly assessed for change.

Part 5: References

Brown, A.C. and McLachlan, A. 1990: Ecology of Sandy Shores. Edited by A. C. Brown and A. McLachlan. Published by Elsevier Press.

DSIR Water Quality Centre 1988: Design of an ecological monitoring programme for the Manukau Harbour. Manukau Harbour Action Plan. Report prepared for the Auckland Regional Water Board, Auckland, NZ.

Eleftheriou, A. and Holme, N.A. 1984: Macrofauna techniques (In: Methods for the study of marine Benthos), pp 140-216. Edited by Holme and McIntyre. 2nd edition, Blackwell Scientific Publications.

GESAMP 1989: Report of the meeting of the GESAMP steering group on scientifically based strategies for marine environmental protection and management. Challes-les-Eaux, France 28-31 August 1989.

Hartley, J.P., Dicks, B. and Wolf, W.J. 1987: Processing macrofauna samples. In; Biological surveys of estuaries and coasts. Estuarine and brackish-water sciences association handbook. Edited by J.M. Baker and W.J. Wolff. Published by Cambridge University Press, pp 131-139.

McArdle, B.H. and Blackwell, R.G. 1989: Measurement of density variability in the bivalve Chiione stutchburyi using spatial autocorrelation. Marine Ecology Progress Series, 52: 245-252.

Park, S.G. 1995: Coastal and estuarine ecology monitoring programme – 1994/95. Bay of Plenty Regional Council. Environmental Report 95/20.

Park, S.G. 2000: Benthic macrofauna monitoring. Bay of Plenty Regional Council. Environmental Report 2000/15.

Pridmore, R.D., Thrush, S.F., Hewitt, J.E. and Roper D.S. 1990: Macrobenthic community composition of six intertidal sandflats in Manukau Harbour, New Zealand. New Zealand Journal of Marine and Freshwater Research, 24: 81-96.