Ministry for Primary Industries
Manatū Ahu Matua

The distribution and abundance of pipis and cockles in the Northland, Auckland and Bay of Plenty regions, 2012

New Zealand Fisheries Assessment Report 2012/45

M.D. Pawley

ISSN 1179-5352 (online)
ISBN 978-0-478-40440-1 (online)

October 2012

New Zealand Government

Growing and Protecting New Zealand

Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries websites at:
http://www.mpi.govt.nz/news-resources/publications.aspx
http://fs.fish.govt.nz go to Document library/Research reports

EXECUTIVE SUMMARY

Pawley, M.D.M. (2012) The distribution and abundance of pipis and cockles in the Northland, Auckland and Bay of Plenty regions, 2012.

***New Zealand Fisheries Assessment Report 2012/45.* 69 p.**

Twelve beaches and harbours in the greater Auckland, Northland, and Bay of Plenty regions were surveyed between February and June 2011 to estimate the distribution, abundance, and size frequency of pipis (*Paphies australis*) and cockles (*Austrovenus stutchburyi*). No tuatua were found (none of the areas surveyed in 2011 were open coast beaches).

A target coefficient of variation (c.v.) of 20% on absolute abundance for cockles and pipi was met at most beaches containing reasonable densities of the target species (i.e. densities greater than 10 individuals per m^2). The only exception was the Grahams Beach pipi population - pipis were found there in very low density (around 14 per m^2).

Cockles

The cockle population increased at seven of the eleven beaches with cockle beds, compared to previous surveys. Large increases were found at five beaches: the population more than tripled at Bowentown Beach compared to the previous survey (2001), Grahams Beach, Ruakaka Estuary and Whangamata Estuary more than doubled their previous (2006) populations and the cockle population at Ngunguru Estuary had approximately doubled since the previous survey (2001). Umupuia Beach and Cockle Bay showed modest population gains and the Whangateau Estuary cockle population was similar to the previous (2009) survey.

Despite the cockle population increasing at most beaches, there was a concomitant decline in the number and proportion of harvestable cockles (i.e. cockles larger than 30 mm) at most locations. Umupuia Beach, which is closed to harvesting, and Cockle Bay were the only beaches that had a significant increase in the number of harvestable cockles. Significant declines were found at all other beaches except Grahams Beach and Whangateau Harbour. With the exception of Umupuia Beach, the number of harvestable cockles was at, or near, the lowest recorded value of all beaches surveyed more than three times.

Pipis

Nine beaches in the survey had pipi beds. The pipi population at Mangawhai Harbour and Tairua Harbour was more than triple the population compared to the previous survey. Modest changes in the pipi population were found at Whangamata and Whangateau Estuaries. Significant declines were found at Ngunguru and Whangapoua Estuaries – these populations declined to less than half the population recorded in the previous survey.

The intertidal bed of large pipis at Whangateau Harbour meant that it was the only beach that had more harvestable pipis (i.e. pipis at least 50 mm) than in the previous survey. All other beaches except Whangamata Estuary had significant declines in the harvestable pipi population.

1. INTRODUCTION

1.1 General overview

The state of intertidal shellfish resources and the recreational harvesting of these resources are high profile issues in the Auckland region. Such resources are highly prized, not only as a source of subsistence, but for their historical and intrinsic values (Keough & Quinn 2000). Globally, there is concern that heavy human harvesting is pressuring coastal systems and threatening the existence of some harvested species (Kennedy et al. 2002). This concern (specifically that the Auckland shellfish beds have been depleted by harvesting pressure) has been expressed by both the public and the Hauraki Gulf Forum (Grant & Hay 2003).

Dense (and growing) urban populations typically mean that local shellfish populations are particularly susceptible to over-exploitation due to large numbers of potential gatherers (Hartill et al. 2005). The main species of concern are pipi (*Paphies australis*), cockles (*Austrovenus stutchburyi*) and tuatua (*Paphies subtriangulata*). It is commonly perceived that amateur harvesting of intertidal shellfish resources has been a major contributor to the decline in shellfish abundance at popular beaches in the Auckland, Northland, and Bay of Plenty areas, although intertidal shellfish resources are also perceived to be under pressure from other impacts such as environmental degradation (Grant & Hay 2003).

The Ministry of Fisheries (MFish) (now part of Ministry of Primary Industries) developed a management strategy aiming to provide controlled use of shellfish resources to meet the sustainable needs of customary and recreational harvesters using the tools provided by the Fisheries Act 1996. The depletion of some shellfish beds has led to the introduction of temporary closures at Cheltenham, Karekare, Eastern, Coromandel West Coast, Mt Maunganui and (most recently) Umupuia and Whangateau beaches under Section 186A of the Fisheries Act 1996. In addition a seasonal closure of Cockle Bay has been introduced under Notice 2008 (F463). These closures have been in conjunction with local communities on the understanding that scientifically rigorous monitoring of these sites will be carried out.

Baseline monitoring activities are essential to determine which areas may need closure and how shellfish populations respond to closures, and form the basis for deciding when harvesting bans could be removed or what other local controls could be implemented. Intertidal shellfish surveys in the greater Auckland metropolitan area have been undertaken since 1992. Since 1999 the surveys have been extended to cover beaches[1] throughout the MFish Northern region. The data collected also provide longer-term information on intertidal shellfish population dynamics, a research area of importance to sustainable management that has to date received little attention.

Previous surveys of the intertidal populations have been summarised in various reports including Pawley (2011), Pawley & Ford (2006), Walshe & Akroyd (2002, 2003, 2004), Walshe et al. (2005), Akroyd et al. (2000, 2001), Morrison & Browne (1999), Morrison et al. (1999), O'Shea & Kuipers (1994), Iball (1993), and Cook et al. (1992). The surveyed beaches and sampling dates covered in these surveys are shown in Appendix 1.

This report documents the results of the latest in the series of surveys to monitor the abundance and population structure of recreationally harvested shellfish.

[1] For simplicity, the term ‘beach’ is used as an umbrella term to refer to the geographic area under consideration of closure, i.e. beach, harbour, estuaries.

2. OVERALL OBJECTIVE

To determine the distribution, abundance and size frequency of selected intertidal shellfish on 12 selected beaches in the Auckland Fisheries Management Area for each year of this project.

2.1 Specific objectives

1. Using the monitoring programme designed in project AKI2009/01, determine the distribution, abundance and size frequency of pipis (*Paphies australis*), cockles (*Austrovenus stutchburyi*) or any other selected bivalve species at 12 selected beaches, during the 2010/2011 fishing year. The target coefficient of variation (c.v.) of the estimate of absolute abundance is 20%.

2. Report the abundances and trends over time at the surveyed sites, and within the context of all surveyed sites under the Auckland Intertidal monitoring series.

The beaches examined in the 2010 survey[2] are shown in Figure 1.

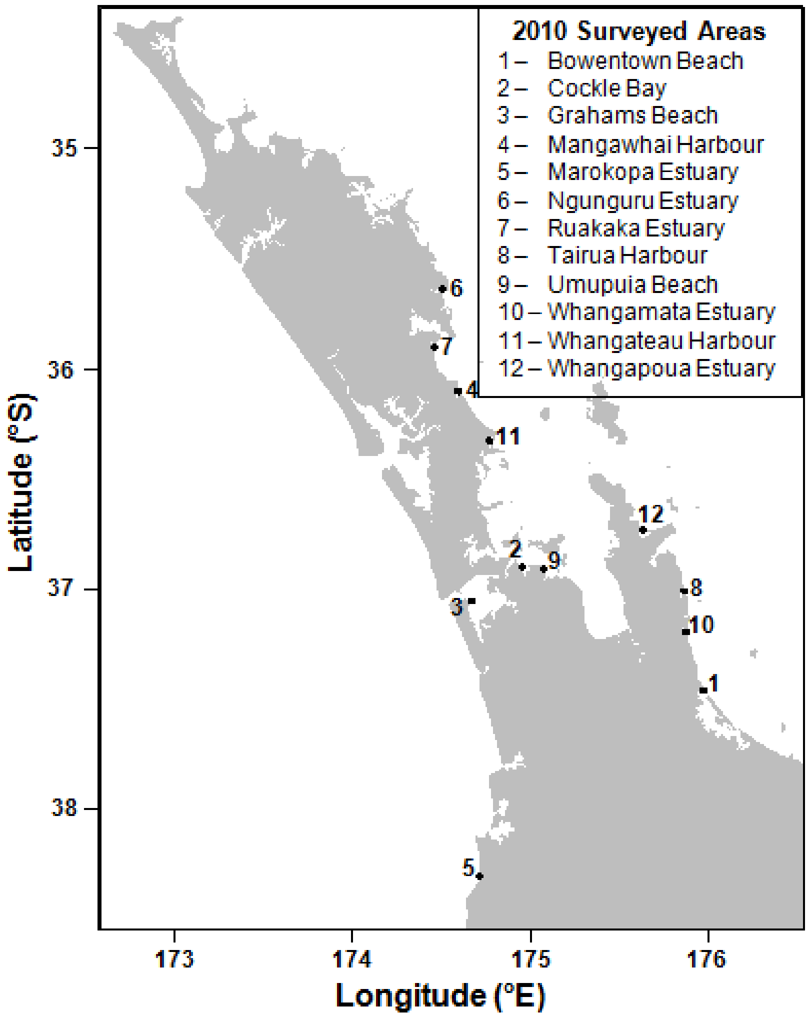

Figure 1: The 12 beaches sampled in the 2010 survey.

[2] Throughout the document surveys are referred to by their AKI project year, e.g.,'2010 survey' and '2005 survey' refers to the AKI2010 and AKI2005 surveys respectively (sample dates for specific beaches are shown in Appendix 1, Table A1.2).

3. METHODS

3.1 Determining the sample extent

In the 2010 survey, Mangawhai Harbour was the only beach that changed the monitored area (‘sample extent’) – in all other beaches the sample extent was established based on previous surveys. In general changes in sample extent are made in order to meet two principal criteria:

1. The area should be defined such that information obtained from it could be considered informative when implementing some kind of closure/restriction to shellfish gathering for the beach.
2. The area should encompass where the shellfish populations of interest have been in the past and are therefore are likely to be found in the future. This decision was made to ensure comparability to future surveys.

3.1.1 Site examination

Each location was examined both remotely (using Google Earth) and in person to determine the presence of any physical or environmental variables that may influence the spatial distribution of shellfish populations. Relevant environmental variables included: shell/sandbanks, gross topography, streams, sediment size, and conspecific shell abundance. Discussions with interested parties and local iwi were also held (which indicated localised areas of fishing pressure), and prominent features were recorded and spatially referenced (or mapped). This additional information was taken into account when defining strata where changes over time have occurred.

3.2 Survey methods

Since 1996, the sampling design has been based on two techniques: a systematic design (Cochran 1977) and a two phase stratified random design (Francis 1984). The 2010 survey used a combination of both techniques to maximise power and logistical efficiency - this sampling method has been used since 2006.

3.2.1 The initial sample (phase 1)

All beaches in the 2010 survey had been previously sampled through the AKI project, so the number of samples taken on each beach was determined using information from the most recent survey. Strata sample sizes were determined by optimal allocation (Cochran 1977), i.e. sample size allocation was determined by the size and population variability within each stratum. For some beaches this necessitated optimising the optimal sample allocation across both cockles and pipi (Manly et al. 2003).

The initial sample density was also adjusted by more pragmatic factors that might influence logistical efficiency (e.g., pipi juveniles are notoriously slow to measure and some areas with extremely large numbers were down-weighted).

Within each stratum the initial sample design was a stratified-random systematic sample. As the name suggests, sample points are independently chosen at random locations within each of the systematic sample strata (Figure 2).

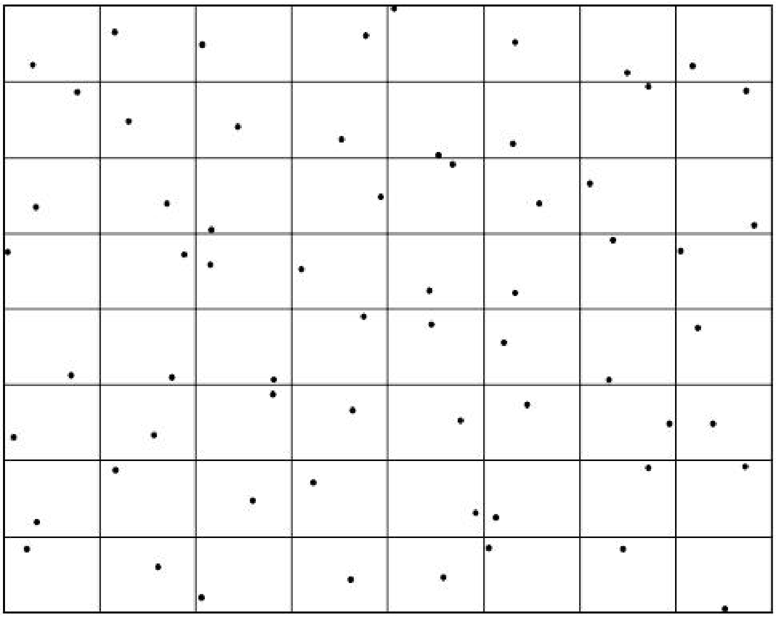

Figure 2: An example of a randomised systematic sample. The sample extent is divided using a grid (dashed lines), whose resolution depends on the sample size (a sample size of n = 8x8 = 64 is shown above). Within each grid section a sample is randomly positioned (filled circle).

3.2.3 The second phase of sampling

Using the two-phase sampling approach, if a coefficient of variation (c.v.) of 20% is not met, then a second phase of samples was allocated to those strata where the highest variation was recorded. The sample placements of the second phase were allocated using a stratified-random systematic design. In the 2010 survey, no second phase samples were required.

3.2.4 The sample unit

The intertidal samples were collected by taking a sample unit consisting of two adjacent, circular cores (with a 15 cm diameter) pushed into the substrate to a depth of 15 cm. The contents from the two cores were aggregated (so each sample unit covered a cross sectional area of 0.0353 m^2) and passed through a 5 mm aperture sieve. All individuals of the target species retained on the sieve were identified and counted. In most instances, all target species individuals were measured across their widest axis to the nearest millimetre, but in strata with very dense populations (more than 2000 per m^2), a random subset of around 50 individuals from each sample unit was measured.

3.3 Statistical analyses

3.3.1 Estimating the population abundance

The sample units were considered to be the pair of adjacent cores (double-core), and the basic unit of datum was the count from the double core. These were standardised by scaling the units up to individual density per square metre. The total count in a stratum was then estimated by multiplying the mean density per square metre by the total area of the stratum.

Standard equations were used for estimation of population sizes (Cochran 1977). The estimate of total population size, $\hat{N}$, was calculated by equation [1].

$$\hat{N} = \sum_{h=1}^{k} A_h \, y_h \qquad [1]$$

where the summation is calculated over k different strata; A_h is the area for the h_{th} stratum and, y_h is the estimated density per square metre for the h^{th} stratum.

The population variance estimator, Var($\hat{N}$), was estimated by treating the stratified-random systematic design as a standard simple random sample (*SRS*) (equation [2]):

$$Var(\hat{N}) = \sum_{h=1}^{k} \frac{A_h^{\,2} s_h^{\,2}}{n_h} \qquad [2]$$

where for the h_{th} stratum, A_h is the area, s_h^2 is the variance of standardised sample units (per square metre), and n_h is the number of sample units.

Using equation [2] instead of a model-based systematic sample variance estimator or post-stratification method is a technique commonly used by ecologists (Dunn & Harrison 1993). It tends to give a conservative estimate of the variance of the population mean (i.e. the estimated population total is likely to be closer than reported) (Cochran 1946). This is because in the presence of a positively autocorrelated population (as commonly occurs in ecological populations), the distribution of systematic sample means is less variable than *SRS* (Ripley 1981). [3]

3.3.2 Calculating the weighted length frequency distribution

A weighted length frequency distribution (LFD) was calculated for each species at each beach. When calculating the LFD, all individual length measurements were weighted to account for:

i. the proportion of samples taken in a stratum relative to its size within the total sample extent ('stratum weight'). This term is equal to the total sample extent divided by the area of the stratum in question.
ii. the total number of shellfish counted divided by the total number of shellfish measured ('sample unit weight').

[3] The size of bias is dependent upon the interplay of a number of factors, including the range and amount of autocorrelation and the sample size. Pawley (2006) simulated biological spatial data with moderate autocorrelation and found that the variance of sample means using *SRS* was between 50% to 700% larger than the variance of the systematic sample means.

These weights were multiplicative in effect. For example, if a stratum was 50% of the sample extent then but only contained 25% of the samples, then individuals in the stratum would receive a stratum weight of 2 (i.e. each individual length was assessed as if it was counted twice). If one of the sample units within that stratum had counted 50 individuals but measured only 20 of them, then each measured individual within that particular sample also got an additional weight of 2.5 (i.e. 50/20). In this example, the total weight applied to those individuals within that quadrat would be 5 (stratum weight times quadrat weight), i.e. each measured individual within that quadrat will be considered as if there were five measured individuals of that length. The final weighted distribution was used to calculate the LFD.

3.3.3 Statistical inferences and calculations made at each beach

At each beach, the populations of each shellfish present were examined and compared to the previous survey. Calculations for each shellfish population typically included:

- a 95% confidence interval (CI) of population abundance,
- a two-sample t-test examining whether there is evidence of a change in population abundance (compared to the previous survey),
- a 95% confidence interval estimating the size of the change in population abundance (from the previous survey),
- the weighted length frequency distribution (LFD) – see Section 3.3.2 for calculation details. Results from each LFD were plotted as a histogram and compared with the LFD from the previous survey,
- calculating the weighted length frequency distribution summary statistics (i.e. mean, mode, median, range (largest to smallest sizes recorded), and inter-quartile range (i.e. the 25^{th} to 75^{th} percentiles of the distribution (IQR))[4],
- a two-sample t-test examining whether there is evidence of any changes in 'harvestable population' abundance (compared to the previous survey).

The Ministry of Primary Industries has used a general guideline (density of 25 per m^2 for cockles 30 mm length and over, and pipi 50 mm length and over) to identify areas which may need management control (Walshe et al. 2005). The same length cut-offs were used to establish the 'harvestable population' estimates.

All analyses and graphs were calculated using Microsoft Excel and the statistical software 'R v2.11.1' (R Development Core Team 2010).

[4] the IQR is used as a reference to 'typical' sized shellfish.

4. RESULTS

4.1 Regional shellfish densities and lengths

The maximum cockle density found in the 2010 survey was around 1800 per m^2, maximum pipi density was around 1500 per m^2 across all 12 locations examined (Figure 3). A kernel density estimate (kde) of shellfish density (individuals per m^2) suggests that shellfish densities from the region are fit relatively well modelled with a unimodal (log-normal) distribution. The density of pipis across the 2010 survey was more variable than cockles and the kde model suggests that the average pipi density was lower (160 pipis per m^2) than cockles (478 cockles per m^2). Note: the same beaches are not sampled every year, so any change in the kde model (kernel) parameters over time should not be interpreted as a regional change in density. It is unknown whether the kde model is robust if data are drawn from different beaches.

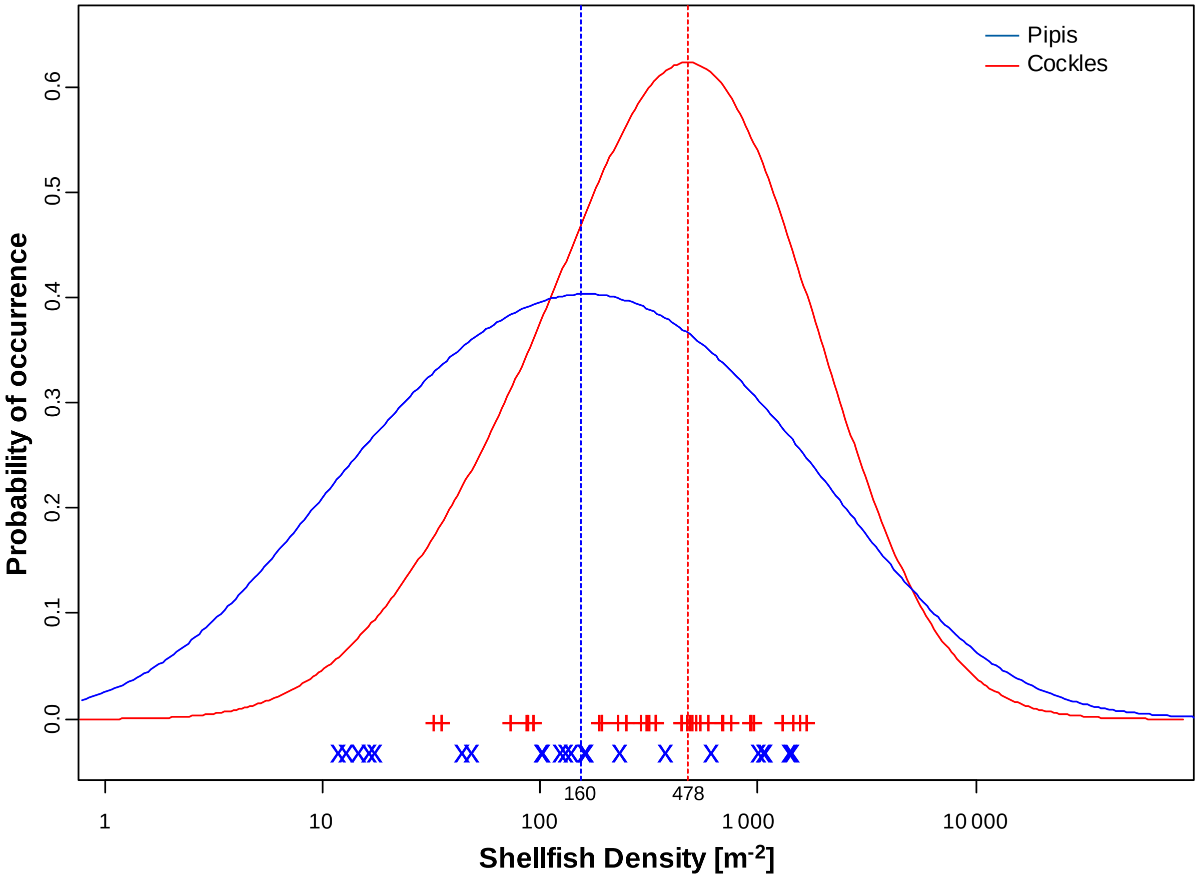

Figure 3: Cockle and pipi density found in all 2010 strata containing beds (i.e. where shellfish density greater than 10 per m^2). Individual stratum densities are denoted by a '+' (cockles) or 'x' (pipi). Red and blue solid lines show the kernel density estimate for the cockle and pipi populations indicating a model fit to the observed shellfish densities. Dashed red and blue lines show the mean of the modelled distributions for cockle and pipi distributions, respectively.

At the 12 beaches examined in 2010, cockle sizes ranged between 2 and 50 mm (Figure 4). The median (and mode) cockle size was 18 mm and most (75%) cockles found were smaller than 22 mm. The distribution of pipi lengths varied more between beaches than cockles. The overall pipi length frequency distribution had two prominent modes around 30 and 50 mm and sizes ranged between 4 and 74 mm. The median pipi size across all beaches was 29 mm and most (75%) of pipis were smaller than 39 mm.

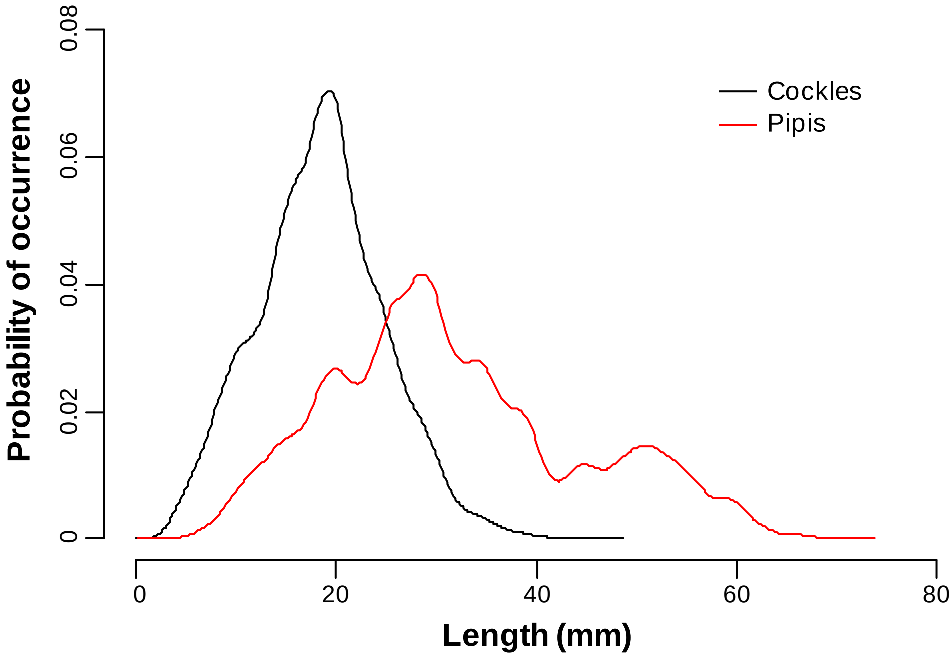

Figure 4: Length frequency distributions for cockles (black) and pipis (red) from all beaches in 2010. Distributions were modelled using kernel density estimates of lengths, frequencies of each stratum of every beach were reweighted by their geographic size and sample number (see section 3.3.2 for details).

4.2 Analysis of individual beaches[5]

4.2.1 Bowentown Beach

Beach description

The Bowentown Beach sample extent remained unchanged from the only previous (2001) MPI survey. In the 2010 survey, a total of 135 samples were taken from cockle beds in stratum A (20 x 175 m), B (100 x 30 m) and C (175 x 50 m) (Figure 5).

Figure 5: Bowentown Beach – the sample extent (depicted by polygon) consisted of 3 distinct areas (A–C).

Bowentown Beach cockles

I estimate (with 95% confidence) that the 2010 sample extent contained 17.7 ± 3.2 million cockles (Table 1). There was strong evidence of an increase in the cockle population since the previous (2001) population ($p<0.001$). In 2010 there were between 8.7 million and 15.4 million more cockles than 2001.

[5] Beaches are presented in alphabetical order.

Cockles were typically between 13 and 20 mm – this was, on average, almost 13 mm smaller than those found in the 2001 survey (Table 2, Figure 6). Few cockles of harvestable size (i.e. cockles 30 mm) were found; the proportion of harvestable cockles decreased since 2001 from around 25% to around 0.3% in 2010 (Table 3).

Table 1: Bowentown Beach cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	17.65	1.60	9.1	1117
2001	5.59	0.60	10.7	354

Table 2: Bowentown Beach cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	16.7	18	3–33	17	13–20
2001	30	29	544	26.2	20–30

Table 3: Bowentown Beach – harvestable cockles (at least 30 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2010	0.079	0.03	4.14	0.4
2001	1.38	NA[6]	86.6	24.7

[6] NA (not applicable) – denotes when data is unavailable in previous reports or datasets.

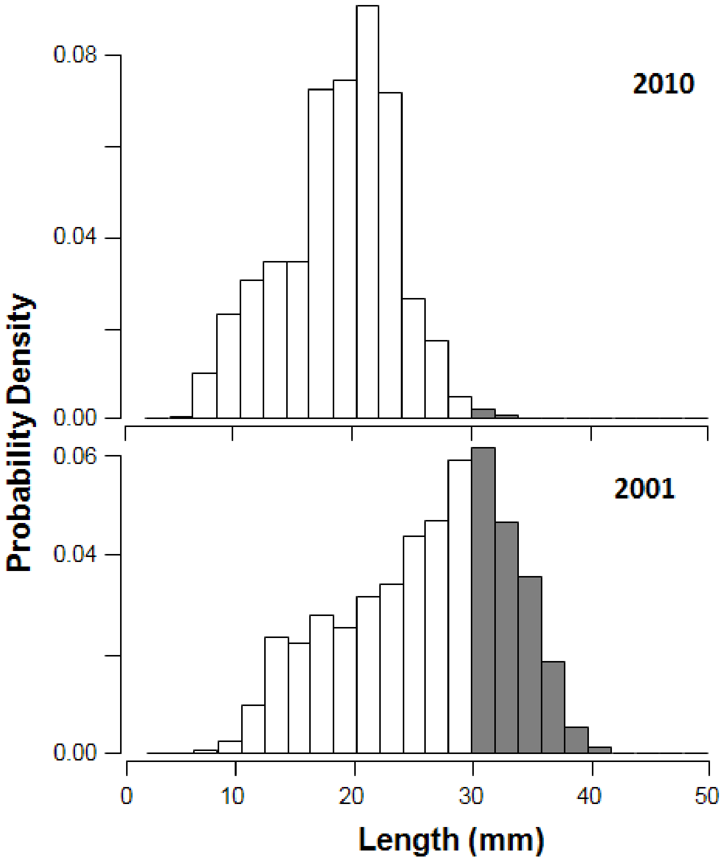

Figure 6: Weighted length frequency distribution of cockles at Bowentown Beach. Dark bars indicate shellfish considered to be of 'harvestable size'.

Bowentown Beach pipis

Average pipi density was less than 1 per m^2 in all strata (only 45 individuals were sampled), so no further analyses were done on pipis. In the 2001 survey only 18 pipis were found within the sample extent at Bowentown Beach.

Discussion – Bowentown Beach

Strata A and B contained moderate densities of cockles relative to other beaches in the survey - the average density of the strata was around 572 and 517 cockles per m^2 respectively (Figure 3 shows the distribution of shellfish densities found in the 2010 survey). Stratum C contained a dense bed of cockles (1430 cockles per m^2).

There has been a large increase in cockle density in all strata between 2001 and 2010. Cockle density at stratum C almost quintupled between the 2001 (293 cockles per m^2) and 2010 surveys (1430 cockles per m^2). However, cockle size has decreased over this period. In the 2010 survey, there were almost no cockles of harvestable size and around 80% of cockles were smaller than 20 mm. This is a marked change from 2001 when about a quarter of the cockles were larger than 30 mm in length (and around two thirds were larger than 20 mm).

4.2.2 Cockle Bay

Beach description

Since 2008, Cockle Bay has had a shellfish seasonal closure between 1 October and 30 April in the following year (Fisheries Notice 2008 (F463)). Cockle Bay was previously sampled in the 2009 MPI survey. Between 2005 and 2007, data were also collected by the Chinese Community Education Trust (CCET) by sampling a pair of transects (sample points along the transects are shown as circles in Figure 7). In the 2010 survey 150 samples were taken within the sample extent.

Figure 7: The Cockle Bay survey extent was divided into two strata (yellow polygons). Circles in the figure indicate sites samples by the CCET between 2005 and 2007.

Cockle Bay cockles

I estimate (with 95% confidence) that the 2010 sample extent for Cockle Bay contained 71.5 ± 7.9 million cockles (Table 4). There was strong evidence of an increase in the cockle population since the previous (2009) population (p<0.001). In the 2010 survey there were between 2.2 million and 22.8 million more cockles than the 2009 survey.

The mean and median cockle size was around 3 or 4 mm longer than found in the previous survey. Typical cockle size was between 21 and 29 mm (Table 5, Figure 8). There was strong evidence of an increase in the number of harvestable cockles (p<0.001) (Table 6).

Table 4: Cockle Bay cockles – population estimate.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m²)
2010	71.5	4.0	5.6	446.9
2009	59.0[7]	3.3	5.6	368.5

Table 5: Cockle Bay cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	25.2	25	3–45	25	21–29
2009	22.0	20	5–51	21	19–25

Table 6: Cockle Bay harvestable cockles (at least 30 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m²)	Proportion of total population (%)
2010	21.1	1.7	130.7	29.5
2009	6.2	0.65	38.8	10.5

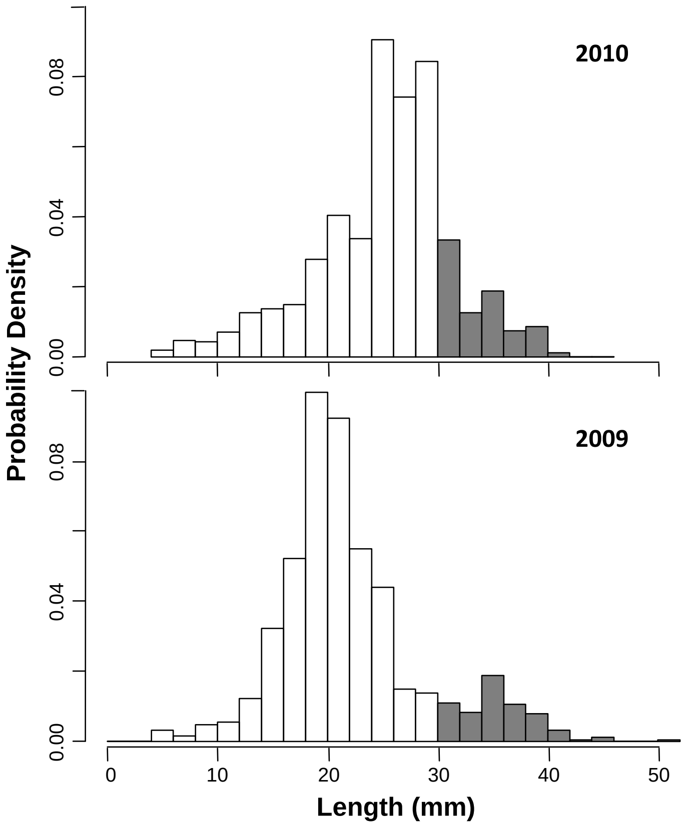

Figure 8: Weighted length frequency distribution of cockles at Cockle Bay. Dark bars indicate shellfish considered to be of 'harvestable size'.

[7] Note: The AKI2009 FAR erroneously reported double the actual population and standard error.

The MPI survey results are shown in conjunction with the CCET survey results in Figure 9. The MPI survey results show a relatively high density of cockles compared to the CCET results. Although there is a paucity of time series data, both surveys show population fluctuations of 20–30% between years.

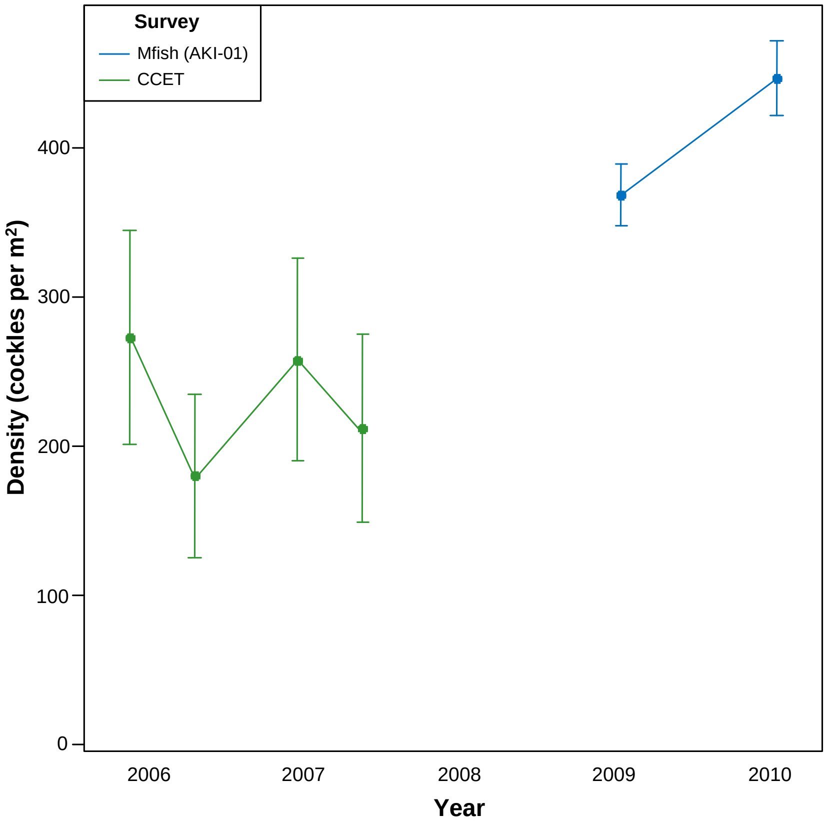

Figure 9: Mean cockle density (with standard error bars) at Cockle Bay, as estimated by CCET (2005–07) and MPI (2009 and 2010). Direct comparisons between surveys are not feasible since the MPI survey had a broader survey extent (see Figure 7).

Cockle Bay pipis

Only eight pipis were found within the sample extent at Cockle Bay (seven were found in 2009). No further analyses were done on pipis.

Discussion – Cockle Bay

Cockle density (372 cockles per m^2) within the Cockle Bay sample extent was moderate compared to other beaches in the 2010 survey.

The cockle population has increased around 20% since the previous survey (Pawley, 2011). The population contained the highest proportion of harvestable cockles (29.5%) compared to other cockle beds in the current survey. The proportion and the number of harvestable cockles have more than tripled since the 2009 survey.

4.2.3 Grahams Beach

Beach description

The sample extent for Grahams Beach covers the entire intertidal area in front of the town (approximately 1.7 km in length and covering around 24.75 ha) (Figure 10). In 2010, 93 samples were taken from the sample extent. Grahams Beach was previously surveyed in 2006.

Figure 10: The sample extent for Grahams Beach.

Grahams Beach cockles

I estimate (with 95% confidence) that the 2010 Grahams Beach sample extent contained 24.9 ± 10.1 million cockles. There was a strong evidence of an increase in the cockle population since the previous (2006) survey (p = 0.005) (Table 7). I estimate that the 2010 survey had between 5.0 million and 27.8 million more cockles than in 2006.

Cockle sizes in 2010 were similar to those found in the 2006 survey. Typical cockles ranged between nine and 12 mm (Table 8). There was only one cockle greater than or equal to 30 mm found in the 2010, and none were found in 2006 (Table 9 and Figure 11).

Table 7: Grahams Beach cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	24.9	5.09	20.4	99.3
2006	8.5	2.7	31.7	33.8

Table 8: Grahams Beach cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	11.1	10	4–32	10	9–12
2006	11.7	11	4–27	11	10–13.5

Table 9: Grahams Beach harvestable cockles (at least 30 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2010	0.019	0.019	0.366	0.07
2006	0	0	0	0

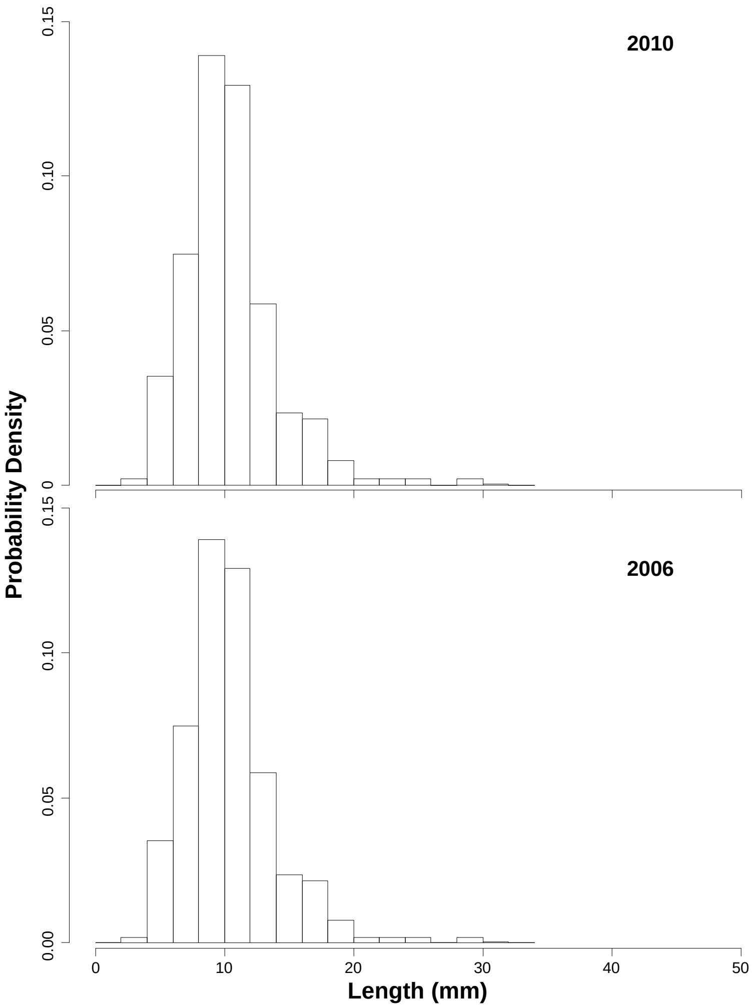

Figure 11: Weighted length frequency distribution for cockles from Grahams Beach.

Grahams Beach pipis

I estimate (with 95% confidence) that the 2010 Grahams Beach sample extent contained 3.7 ± 2.0 million pipis. During the 2006 MPI survey no pipis were found on Grahams Beach (Table 10).

Typical pipi size was small (10 to 14 mm) and none were of harvestable size (Table 11 and Figure 12).

Table 10: Grahams Beach pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	3.7	1.02	27.6	14.8
2006	0	0	0	0

Table 11: Grahams Beach pipis – weighted length frequency distribution summary statistics (mm)

Survey	Mean	Mode	Range	Median	IQR
2010	13	10	6–32	11.5	10–14

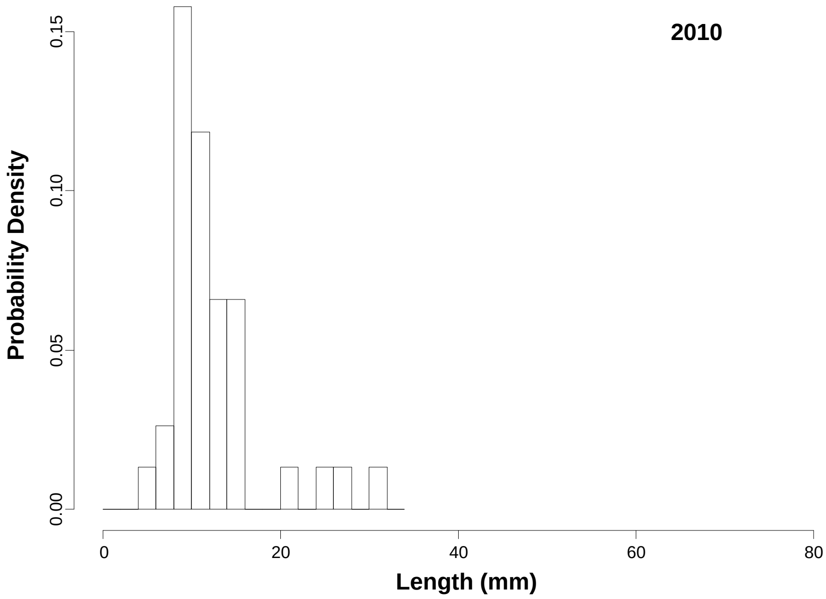

Figure 12: Weighted length frequency distribution of pipis from Grahams Beach.

Discussion – Grahams Beach

Cockle density at Grahams Beach was low in the 2010 survey - only around 300 cockles were found in total. However, this still equates to almost triple the density of the previous (2006) survey. The size of cockles has remained consistent over this period, with almost no cockles found of harvestable size.

Only 38 pipis were found at Grahams beach; none of which were of harvestable size. This is, however, the first time pipis have been sampled there (i.e. no pipis were found in the 2006 survey). Anecdotal evidence was that there were ‘abundant’ pipi beds at Grahams beach in previous decades (pers. comm. George Flavell).

4.2.4 Mangawhai Harbour

Beach description

The sample extent for Mangawhai Harbour covers three distinct areas - strata A, B and C (2.25, 1 and 1 ha respectively) covering the intertidal area (to a depth of around 0.5 m below chart datum) in front of the parks at the mouth of the estuary (Figure 13). Stratum D (2.8 ha) covers a cockle bed further south and stratum E (0.75 ha) is a pipi bed on a bank in the south east side of the harbour.

The size of stratum E was increased (from 0.4 ha) when it was recognized that pipi density was still substantial to the west of the former boundary. A total of 179 samples were taken from the sample extent. Mangawhai Harbour was previously sampled in 1999 and 2001–03.

Figure 13: The sample extent for Mangawhai Harbour (yellow polygons). The red polygon depicts the sample extent for stratum E in the previous (2003) survey.

Mangawhai Harbour cockles

I estimate (with 95% confidence) that the 2010 sample extent contained 61.2 ± 5.6 million cockles (Table 12). There was no evidence of a change in the cockle population since the previous survey conducted in 2003 (p<0.75). I estimate that 2010 had between 13.9 million fewer and 10.1 million more cockles than in 2003 (Table 12).

The typical (median) cockle size was typically 7 mm smaller than those found in 2003 (Table 13) – cockles were typically between 16 and 25 mm. Despite the increase in total population size, there were fewer cockles of harvestable size than in 2003 (p<0.01) (Table 14 and Figure 14).

Table 12: Mangawhai Harbour cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	61.2	5.6	9.1	679.7
2003	50.8	4.1	8.2	681.9

Table 13: Mangawhai Harbour cockles – weighted length frequency distribution summary statistics (mm)

Survey	Mean	Mode	Range	Median	IQR
2010	21.1	21	5–39	21	16–25
2003	25.2	28	544	27	2231

Table 14: Mangawhai Harbour harvestable cockles (at least 30 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2010	8.2	1.45	92.0	13.5
2003	17.4	1.91	234.0	34.3

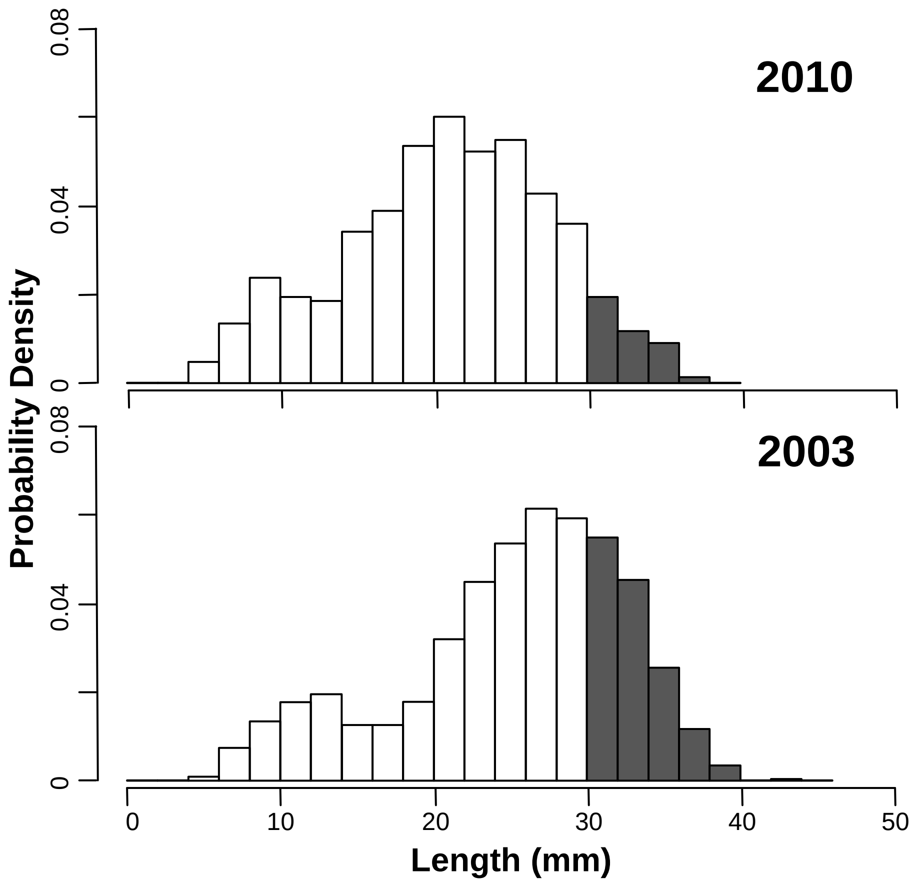

Figure 14: Weighted length frequency distribution of cockles from Mangawhai Harbour. Dark bars denote 'harvestable cockles' (i.e. at least 30 mm).

Mangawhai Harbour pipis

I estimate (with 95% confidence) that the 2010 sample extent contained 4.2 ± 1.6 million pipis (Table 15). There was strong evidence of an increase in the pipi population since the 2003 survey (p<0.001). I estimate that 2010 had between 1.3 million and 4.6 million more pipis than in 2003 - this assumes that in the 2003 survey there were few pipis outside the sampling extent. When comparing only those pipis found within the 2003 sample extent, the 2010 population estimate is smaller (3.6 ± 1.6 million pipis) but still significantly larger than the 2003 pipi population.

The median pipi length was similar in 2010 and 2003, but the mean pipi in the 2010 survey was around 10 mm smaller than in 2003 (Table 16) because the 2003 pipi population had a bimodal length distribution (Figure 15A). There was a decline in the number and proportion of pipis of harvestable size in 2010 (p<0.01) (Table 17).

Table 15: Mangawhai Harbour pipis – population estimates. The 2010 population is estimated within the 2010 and the smaller 2003 sample extents.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010 (2010 stratum E sample extent)	4.2	0.81	19.6	46.3
2010 (2003 stratum E sample extent)	3.6	0.80	22.2	42.0
2003	1.2	0.22	18.4	15.8

Table 16: Mangawhai Harbour pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	25.7	10	6–57	25	14–35
2003	34.8	18, 58[8]	9–71	24	54–62

Table 17: Mangawhai Harbour harvestable pipis (at least 50 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2010	0.076	0.021	0.9	1.8
2003	0.44	0.080	5.9	36.7

[8] If two numbers are presented, then a bimodal distribution was evident (e.g., see Figure 15).

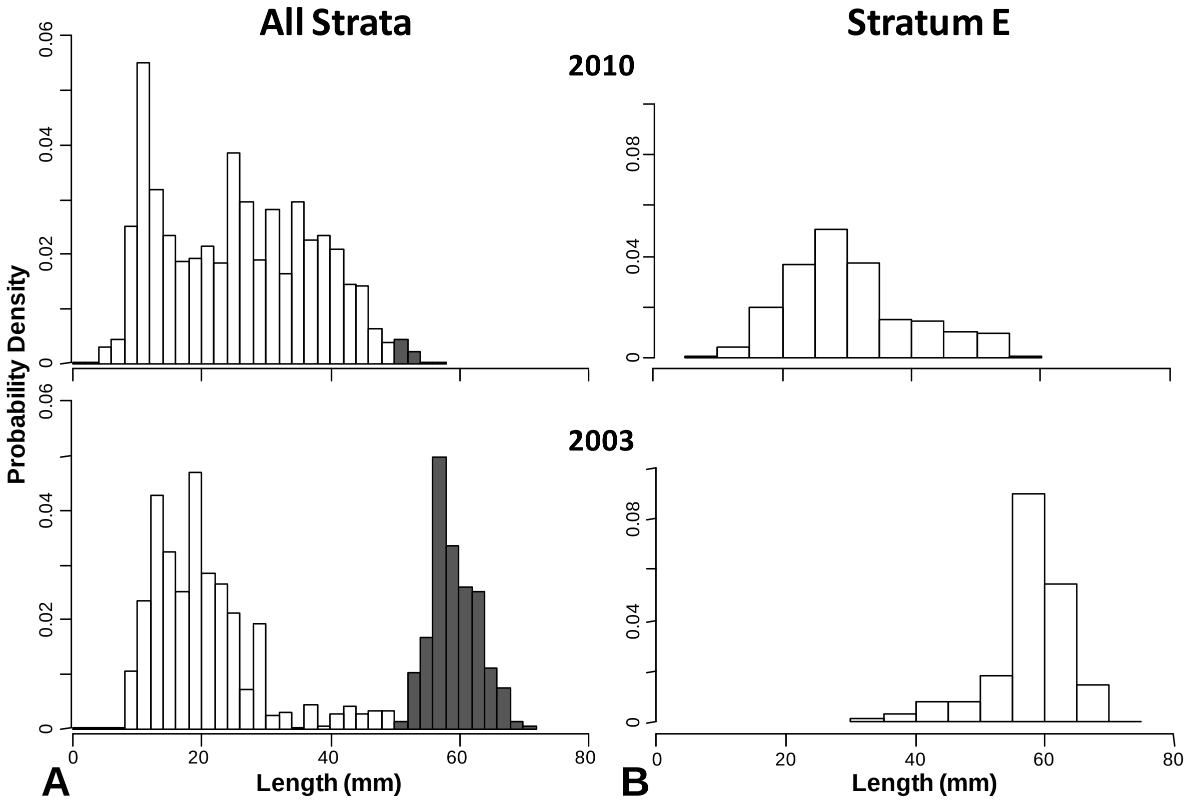

Figure 15: (A) Weighted length frequency distribution of pipis from all strata in Mangawhai Harbour and (B) from stratum E in 2010 and 2003. Dark bars indicate shellfish considered to be of 'harvestable size'.

Discussion – Mangawhai Harbour

Although the average density of cockles in the 2010 Mangawhai Harbour survey was relatively high (around 680 cockles per m^2), this varied considerably depending on the stratum. Strata A and D contained high densities (around 760 and 1022 cockles per m^2 respectively), strata B and E contained low densities (254 and 80 cockles per m^2), and stratum C contained only around 1 cockle per m^2. The total cockle population estimate was similar to what was found in the previous (2003) survey, however fewer large cockles were found. In 2003 almost 34% of cockles were of harvestable size, in 2010 this proportion had dropped to around 14%.

Mangawhai Harbour contained a low density of pipis (relative to other beaches), averaging around 46 pipis per m^2.The highest density of pipis were found in strata B and E (which had 256 and 152 pipis per m^2 respectively) The total pipi population has more than tripled since 2003 – primarily due to increases in pipi density at stratum B. Stratum E contained 70% of all pipis in 2003 – the majority of which were of harvestable size and contributed to a second mode around 60 mm in the LFD (see Figure 15B). In contrast, few harvestable pipis were found in any stratum (only around 2%) in the current survey.

4.2.5 Marokopa Estuary

Beach description

The sample extent for Marokopa Estuary is split into three strata that extend from the east bank to a depth of around 0.5 m below chart datum (Figure 16). In 2010, 168 samples were taken within the sample extent. Marokopa Estuary was previously sampled on only one occasion in 2005.

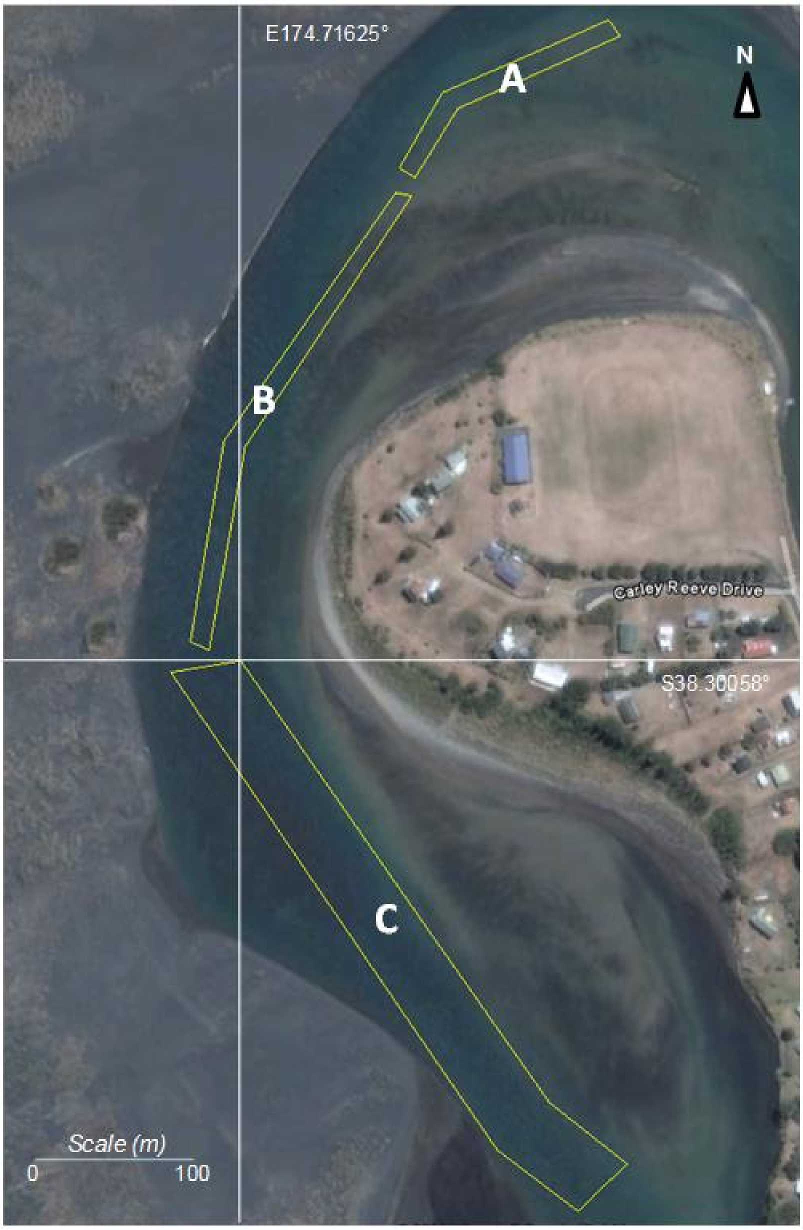

Figure 16: The Marokopa Estuary sample extent (yellow polygons).

Marokopa Estuary cockles

No cockles were found within Marokopa Estuary in the current survey. This is consistent with the previous survey (2005) in which no cockles were found.

Marokopa Estuary pipis

I estimate (with 95% confidence) that the 2010 sample extent for Marokopa Estuary contained 3.0 ± 0.9 million pipis (Table 18). There was no evidence of a change in the pipi population since the previous (2005) survey (p<0.75). I estimate that 2010 had between 0.9 million fewer and 1.3 million more pipis than in 2005.

The average pipi size was almost 4 mm smaller than in 2005. The typical length was between 17 and 35 mm and the LFD suggests a bimodal distribution with modes around 12 and 36 mm (Table 19 and Figure 17). No harvestable pipis were found in 2010, which is consistent with the 2005 survey.

Table 18: Marokopa Estuary pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	3.0	0.450	15.0	127.9
2005	2.82	0.33	11.5	120.2

Table 19: Marokopa Estuary pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	26.9	12, 36	747	29	17–35
2005	30.6	30	10–45	31	28–33

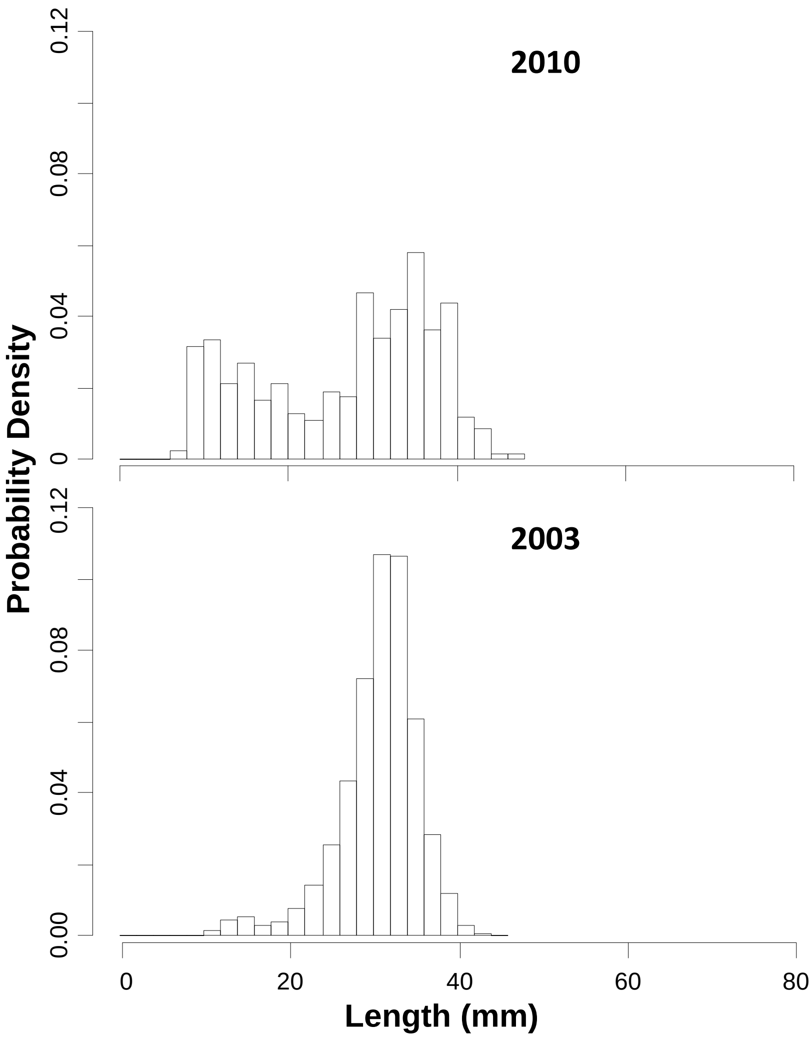

Figure 17: Weighted length frequency distribution of pipi from Marokopa Estuary.

Discussion – Marokopa Estuary

The Marokopa Estuary pipi population has remained relatively constant since the previous (2005) survey. The LFD showed evidence of a new cohort of juveniles which were around 12 mm in size.

4.2.6 Ngunguru Estuary

Beach description

The sample extent for Ngunguru Estuary is split into three strata (Figure 18). Stratum A (400 x 20 m) encompasses a cockle bed on the west bank, strata B (approximately 400 x 10 m) and C (400 x 15 m) were pipi and cockle beds respectively. Access to strata B and C requires crossing the channel (by swimming or boating). Stratum B was sampled to a depth of around 0.5 m below chart datum. A total of 118 samples were taken within the sample extent. Ngunguru Estuary was previously sampled in 2003 and 2004.

Figure 18: Ngunguru Estuary – sample extent consists of two strata (yellow polygons) covering cockle beds.

Ngunguru Estuary cockles

I estimate (with 95% confidence) that the Ngunguru Estuary 2010 sample extent contained 19.1 ± 4 million cockles (Table 20). There was very strong evidence of an increase in the number of cockles since the previous (2004) survey (p<0.01). I estimate there was between 4.4 million and 14.2 million more cockles than in the 2004 survey.

Cockles were, on average, around 4 mm smaller than in the previous (2004) survey. Typical cockle size was between 14 and 19 mm (Table 21). Fewer than 1% of the total population were of harvestable size (Table 22, Figure 19).

Table 20: Ngunguru Estuary cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	19.1	2.1	10.9	1063.0
2004	9.8	1.3	12.8	545.4

Table 21: Ngunguru Estuary cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	17.0	21	5–32	17	14–19
2004	20.8	23	5–41	21	17–24

Table 22: Ngunguru Estuary harvestable cockles (at least 30 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2010	0.064	0.022	3.6	0.33
2004	0.34	0.1	19.0	3.50

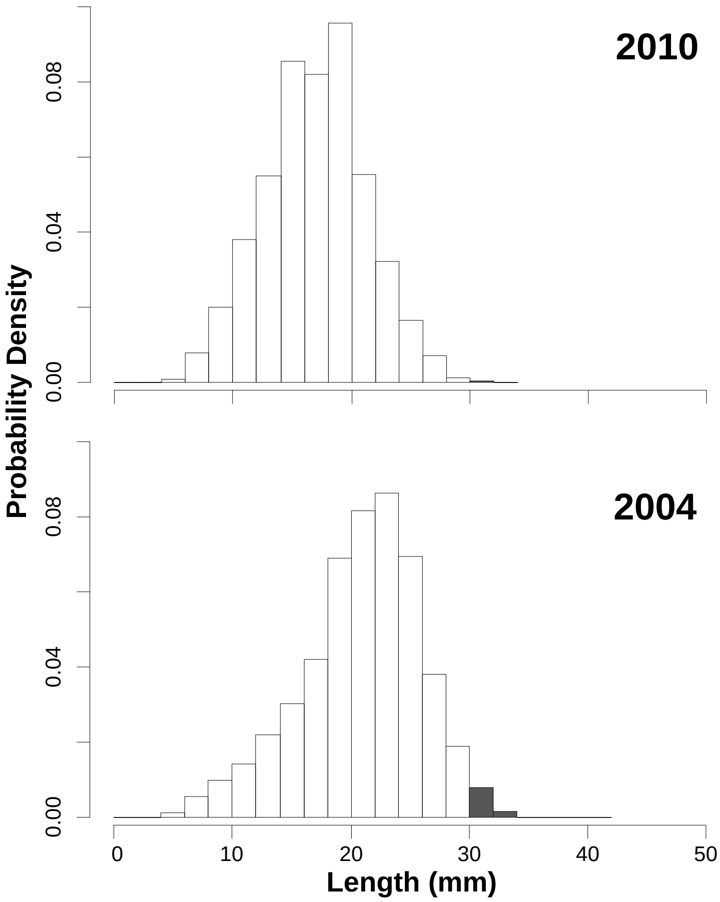

Figure 19: Weighted length frequency distribution of cockles from Ngunguru Estuary. Dark bars denote 'harvestable cockles' (i.e. at least 30 mm).

Ngunguru Estuary pipis

I estimate (with 95% confidence) that the 2010 sample extent for Ngunguru Estuary contained 0.72 ± 0.23 million pipis (Table 23). There was strong evidence of a decrease in the pipi population since the previous (2004) survey (p<0.01). I estimate that 2010 had between 1 million and 1.9 million fewer pipis than 2004.

The average pipi size was almost 6 mm smaller than in 2004. The typical length was between 33 and 51 mm (Table 24 and Figure 20). The population of pipis of harvestable size has declined since 2004 (Table 25).

Table 23: Ngunguru Estuary pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	0.72	0.12	17	40.0
2004	2.23	0.18	7.9	123.9

Table 24: Ngunguru Estuary pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	41.6	50	7–67	44	33–51
2004	47.3	43	1068	47	42–53

Table 25: Ngunguru Estuary harvestable pipis (at least 50 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2010	0.25	0.05	13.8	34.4
2004	0.95	0.13	53.1	42.6

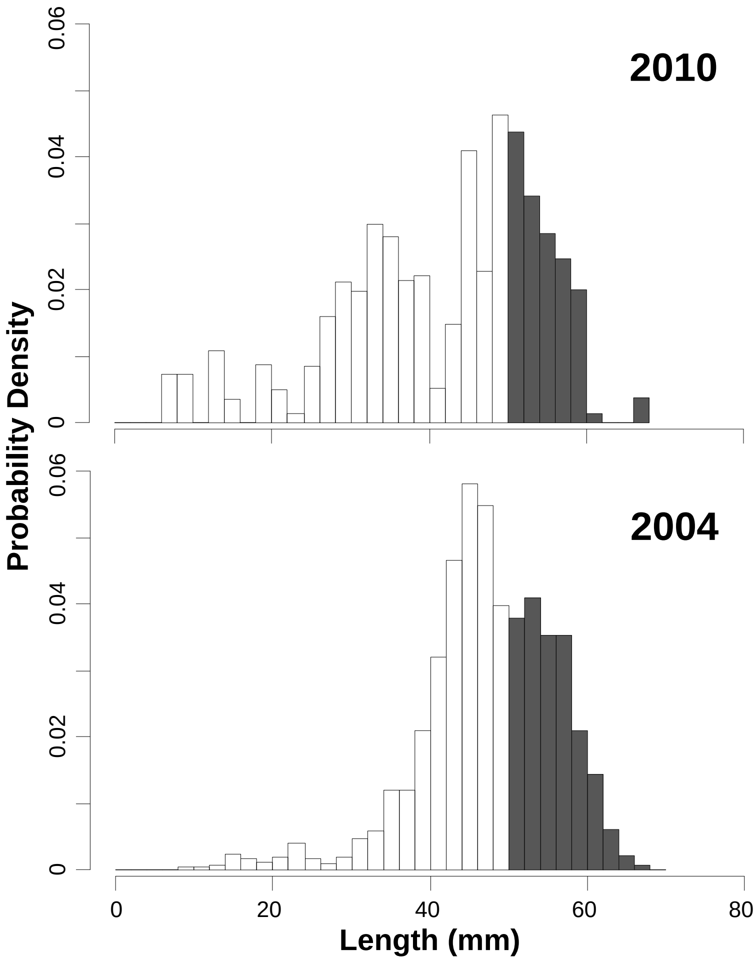

Figure 20: Weighted length frequency distribution of pipis from Ngunguru Estuary. Dark bars denote 'harvestable pipis' (i.e. at least 50 mm).

Discussion – Ngunguru Estuary

The cockle population in Ngunguru Estuary has almost doubled since the previous survey conducted in 2004. The average cockle size was slightly smaller and there were fewer large harvestable cockles (i.e. at least 30 mm) in the current survey, compared to 2004.

Pipi numbers have decreased since the 2004 survey. The number and proportion of harvestable pipis have also decreased over this period. The pipi bank (stratum B) is found mid-channel, so the estimated pipi population (accessible to harvesters) is likely to change if the bank morphology is variable.

4.2.7 Ruakaka Estuary

Beach description

The position of the main channel in Ruakaka Estuary has moved over the years. As with the previous survey specific strata within the sample extent were defined using landmarks instead of GPS waypoints. The main channel of Ruakaka Estuary winds through the south side of the estuary (Figure 21) and contains pipis. Cockles are found more sparsely on the banks of the channel. Ruakaka Estuary was previously sampled in 2006.

Figure 21: Ruakaka Estuary with the sample extent depicted by a red polygon.

Ruakaka Estuary cockles

I estimate (with 95% confidence) that the 2010 Ruakaka Estuary sample extent had 3.6 ± 1.4 million cockles (Table 26). There was strong evidence of an increase in the cockle population since the previous (2006) survey (p = 0.003). I estimate that 2010 had between 0.8 million to 3.7 million more cockles than 2006.

Average cockle size in the 2010 survey was around 8 mm smaller than 2006, with typical cockle size between 11 and 19 mm (Table 27, Figure 22). There is strong evidence that the number of harvestable cockles had decreased compared to the previous (2006) survey (p = 0.002), but harvestable cockle density was low in both surveys (densities lower than one cockle per square metre) (Table 28).

Table 26: Ruakaka Estuary cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	3.6	0.7	19.3	32.5
2006	1.37	0.23	16.7	12.4

Table 27: Ruakaka Estuary cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	15.8	19	2–35	15	11–19
2006	23.9	23	7–38	24	20–27

Table 28: Ruakaka Estuary harvestable cockles (at least 30 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2010	0.04	0.021	0.4	1.1
2006	0.27	0.07	0.7	19.4

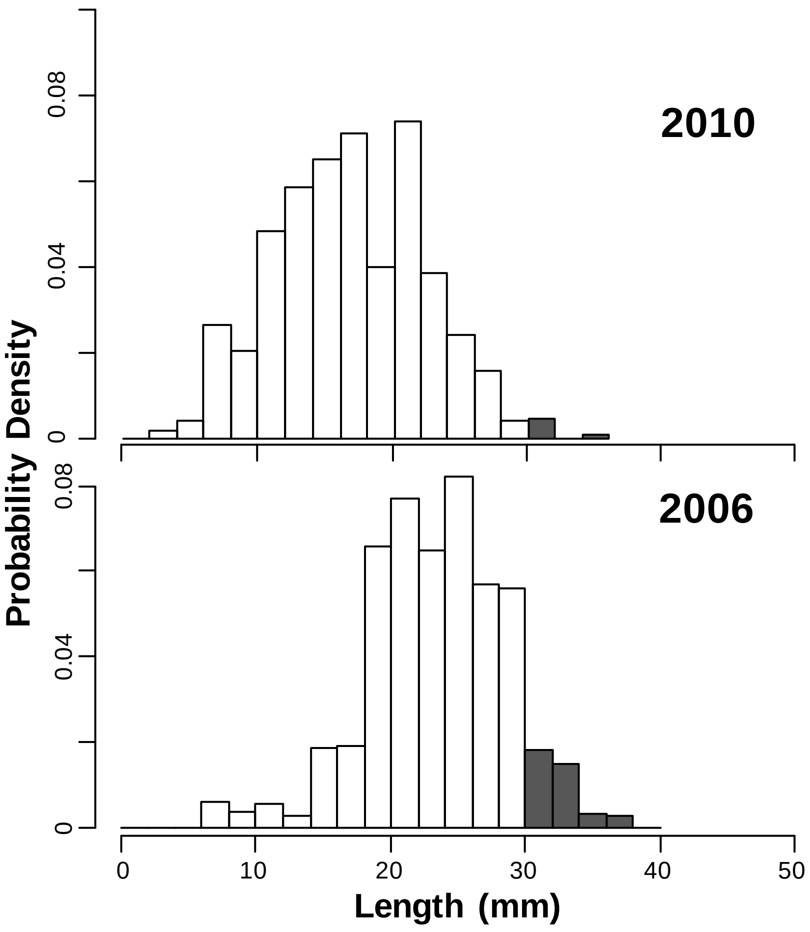

Figure 22: Weighted length frequency distribution of cockles from Ruakaka Estuary. Dark bars denote 'harvestable cockles (i.e. at least 30 mm).

Ruakaka Estuary pipis

I estimate (with 95% confidence) that the Ruakaka Estuary 2010 sample extent had 39.6 ± 16.0 million pipis (Table 29). There was no evidence of a change in the abundance of pipis since the 2006 survey (p = 0.57). I estimate that there were between 13.2 million fewer and 23.4 million more pipis in 2010 compared to 2006.

The average and median pipi size was, respectively, 2 and 6 mm larger in the 2010 survey compared to 2006. Typical pipi size was 20 to 31 mm (Table 30 and Figure 23). There was strong evidence of a decrease in the number of harvestable pipis since 2006 (p<0.01) (Table 31).

Table 29: Ruakaka Estuary pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	39.6	8.1	20.4	359.5
2006	34.4	4.5	13.0	272.5

Table 30: Ruakaka Estuary pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	26.7	31	7–55	26	20–31
2006	24.7	36	5–65	20	14–24

Table 31: Ruakaka Estuary harvestable pipis (at least 50 mm length).

Survey	Population estimate (millions)	Population SE (millions)	Average density (per m^2)	Proportion of total population (%)
2010	0.12	0.12	1.1	0.3
2006	1.5	0.31	12.9	4.3

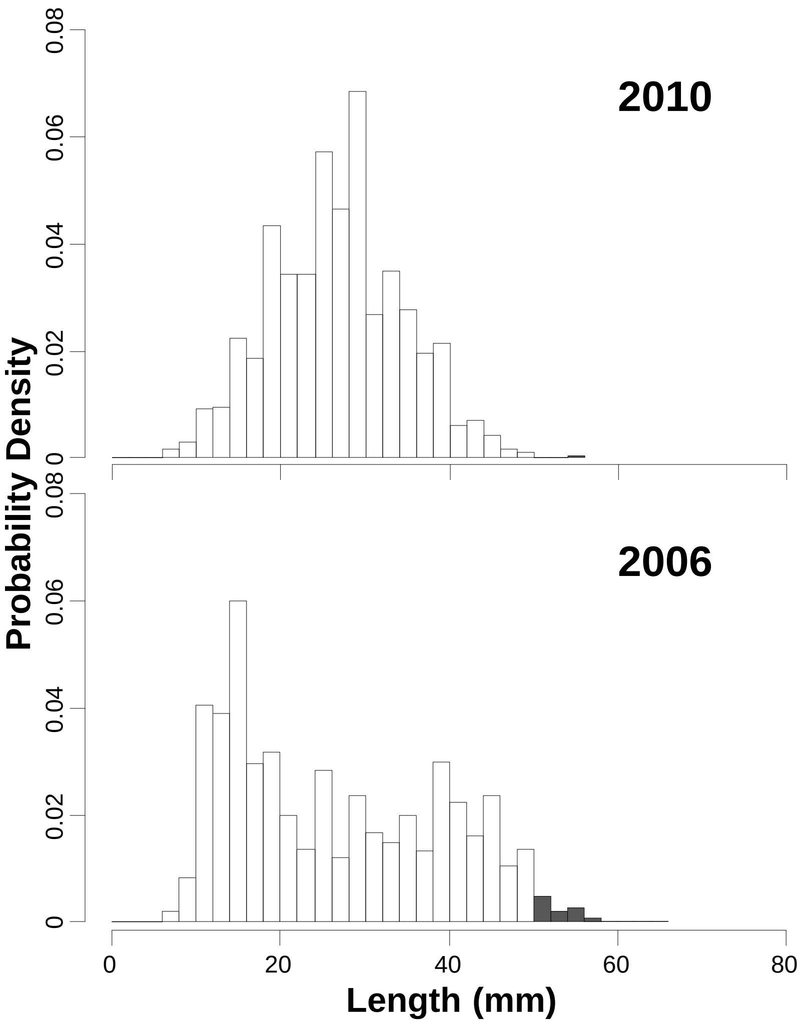

Figure 23: Weighted length frequency distribution of pipis from Ruakaka Estuary. Dark bars denote ‘harvestable pipis’ (i.e. at least 50 mm).

Discussion – Ruakaka Estuary

The average density of cockles was low (only around 32 per m^2) within the 2010 Ruakaka Estuary survey. However, the cockle population had more than doubled since the previous (2006) survey. Cockles found in 2010 were considerably smaller than those found in 2006 – only around 1% of them were of harvestable size (at least 30 mm), compared to around 19% in 2006.

The pipi population total has remained relatively unchanged since the 2006 survey. At the time of the 2010 sample the main channel travelled from the left of the figure east and then north-north-east for around 200 m (see Figure 21). Satellite images suggests that the estuary channel in 2010 travelled around 400–500 m further in a north-north-west direction, then looped around a narrow sand peninsula before heading south to the open coast (see Appendix 2). Changes in the channel morphology appear to happen relatively regularly at Ruakaka Estuary and may affect the pipi population. The channel’s former path was observable – it contained pools of water with many dead and rotting pipis (these were not sampled due to health concerns). The pipi deaths may be due to anoxic conditions resulting from the stagnant nature of the pools.

4.2.8 Tairua Harbour

Beach description

The sample extent for Tairua Harbour encompassed two distinct areas:

(1) the southern side of Tairua Harbour, near the mouth of the estuary contains two pipi beds (strata C and D).

(2) a mudflat lying north of town (strata B and E) and two pipi beds (strata A and F) on the northern edge of the main channel (Figure 24).

A total of 291 samples were taken within the sample extent. Tairua Harbour was previously sampled each year from 1999 to 2002, and in 2005 and 2006.

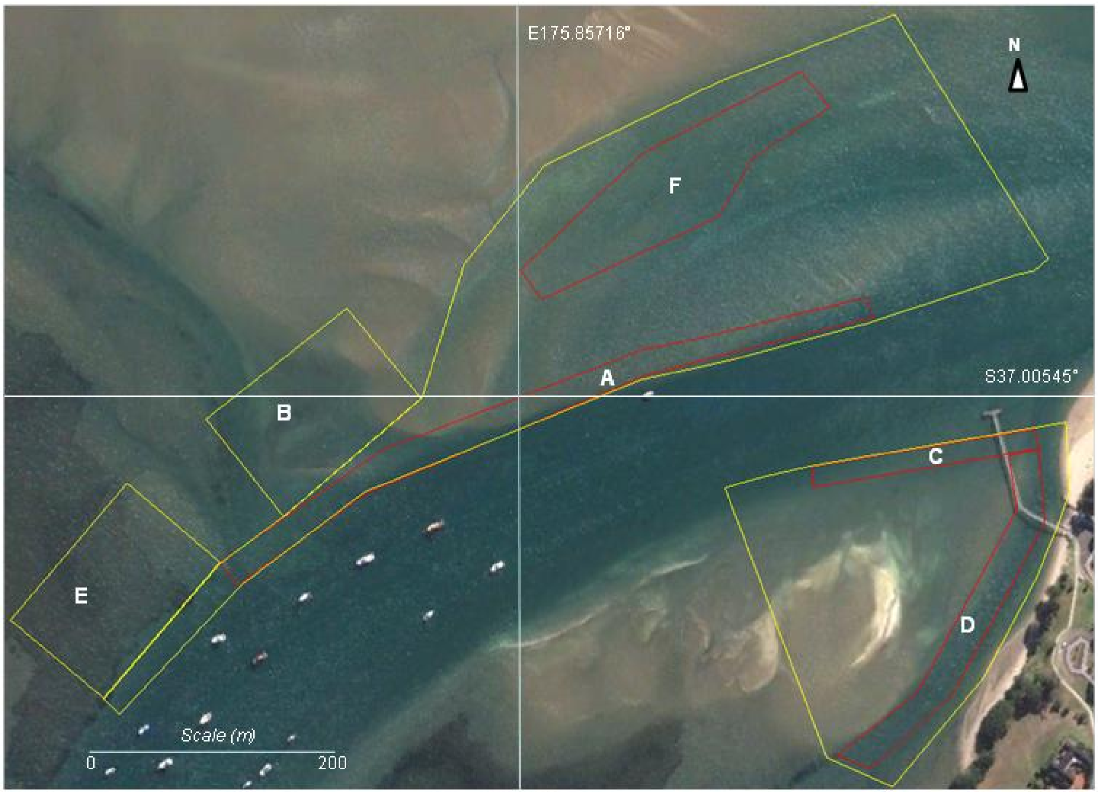

Figure 24: Tairua Harbour – the sample extent (yellow polygons) covered areas on both sides of the main channel. The position and size of pipi beds found in 2010 is denoted by the red polygons.

Tairua Harbour cockles

The Tairua Harbour sample extent contained moderate densities of cockles relative to other beaches in the survey (averaging about 450 per m^2). I estimate (with 95% confidence) that the Tairua Harbour 2010 sample extent had 24.1 ± 5.1 million cockles (Table 32). There was evidence of a decrease in the cockle population since the previous (2006) survey (p<0.012). I estimate that the 2010 population had between 2.0 million and 15.2 million fewer cockles than 2006.

The average cockle size in the 2010 survey was around 3 mm smaller than the previous survey, with typical cockles ranging between 13 and 21 mm (Table 33 and Figure 25). There was strong evidence of a decrease in the number of harvestable cockles since the previous (2006) survey (p<0.001) (Table 34).

Table 32: Tairua cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	24.1	2.6	10.8	416.1
2006	32.7	2.1	6.3	523.2
2005	30.7	2.1	6.8	491.2

Table 33: Tairua cockles — weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	17.7	19	5–50	17	13–21
2006	20.8	19	360	21	15–26
2005	25	26	744	26	21–29

Table 34: Tairua harvestable cockles (at least 30 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2010	1.2	0.34	20.8	4.9
2006	2.8	0.3	44.9	8.6
2005	4.66	0.44	74.7	15.2

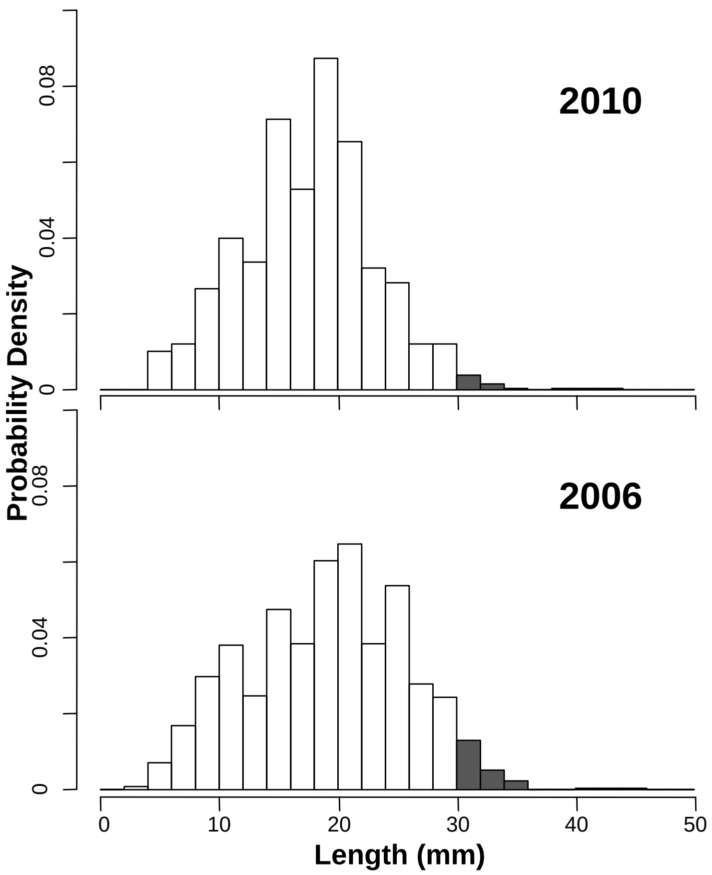

Figure 25: Weighted length frequency distribution of cockles from Tairua Harbour. Dark bars denote 'harvestable cockles' (i.e. at least 30 mm).

Tairua Harbour pipis

Most pipis were found on the edge of the bank in the southern strata, within the main channel and within an intertidal area north of the main channel (stratum F). Stratum F was not examined in previous surveys (the bank morphology in this area appears to be quite variable - so it may have been too deep). Including stratum F, there was strong evidence of an increase in pipi abundance since the previous (2006) survey (p<0.001) I estimate (with 95% confidence) that the 2010 Tairua Harbour sample extent had 25.5 ± 5.7 million pipis (Table 35) – this is between 11.2 million and 23 million more pipis than in 2006.

If we exclude stratum F, I estimate that there were 8.2 ± 1.4 million pipis and there was no evidence of a change in the pipi population since the previous survey (p = 0.8). Excluding stratum F, I estimate that the 2010 population had between 2.0 million fewer and 1.6 million more pipis than in 2006.

The median pipi size was 16 mm smaller than the previous (2006) survey (Table 36). There was strong evidence of a decrease in the number and proportion of large harvestable pipi since the previous survey (p<0.001) (Table 37).

Table 35: Tairua pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	25.5	2.9	11.3	438.9
2010 (without stratum F)	8.2	0.69	8.4	174.4
2006	8.4	0.55	6.5%	165.6
2005	3.89	0.64	16.5%	76.7

Table 36: Tairua pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	30.3	27	8–68	29	24–35
2010 (without stratum F)	33.4	32	8–65	34	27–40
2006	43.2	48	4–80	45	35–52
2005	44	45	6–72	44	36–54

Table 37: Tairua harvestable pipis (at least 50 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2010	0.82	0.2	14.1	3.2
2010 (without stratum F)	0.35	0.05	7.6	2.8
2006	2.64	0.21	52.8	31.6
2005	0.76	0.18	15.2	19.6

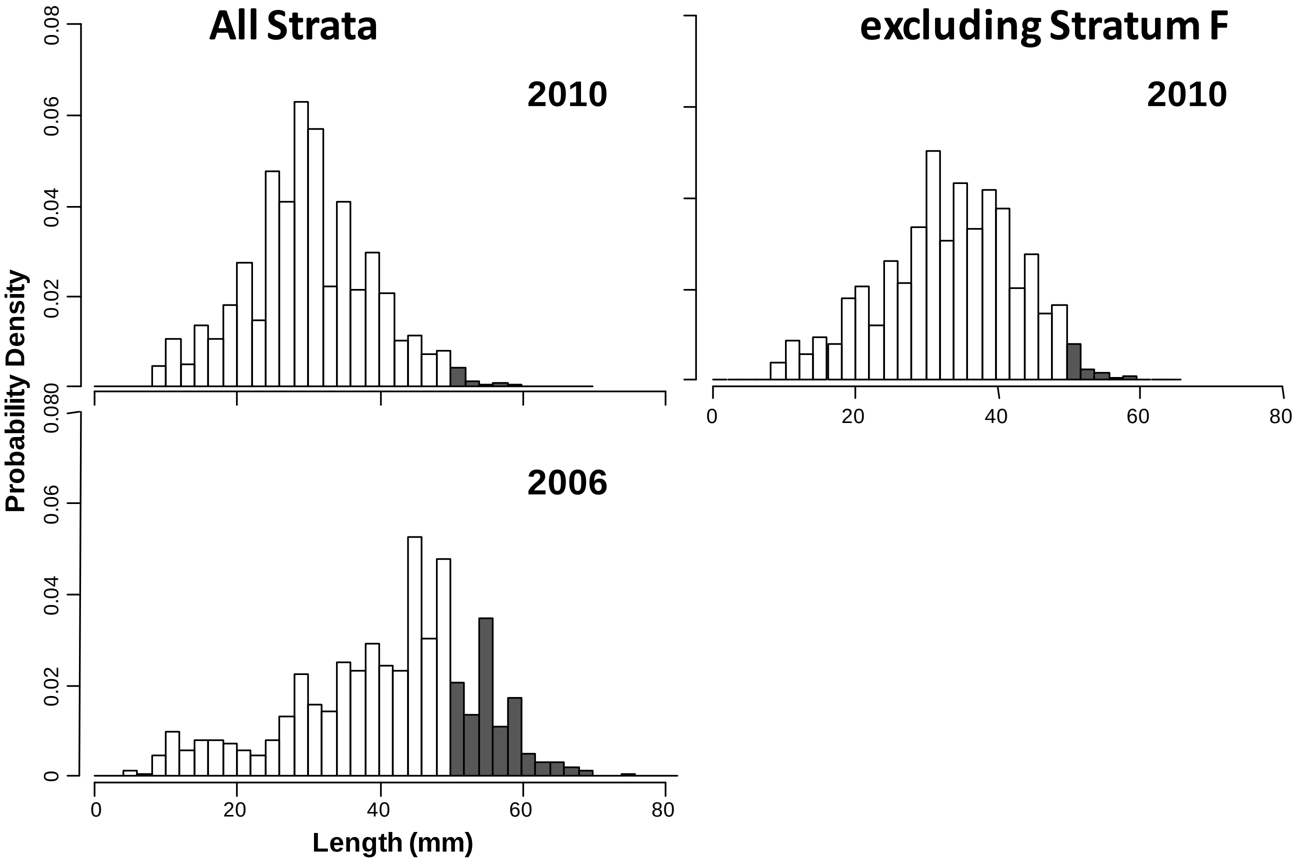

Figure 26: Weighted length frequency distribution of pipis from Tairua Harbour including pipi from stratum F (the length frequency distribution. Dark bars denote ‘harvestable pipis (i.e. at least 50 mm).

Discussion – Tairua Harbour

Cockle numbers in Tairua Harbour have declined around 25% since the previous (2006) survey. Cockles have also decreased in size; the number of harvestable cockles is less than a quarter of the 2006 population.

Pipis were found on the edge of the bank in the southern strata, within the main channel. A dense bed of pipis was also found in a side channel in the harbour (stratum F). Stratum F was not examined in previous surveys (the bank morphology in this area appears to be quite variable - so it may have been too deep). Pipis found in this bed almost tripled the size of the pipi population in the intertidal area. Excluding the new bed, pipi numbers were similar to 2006, although there was a decrease in the number of harvestable pipis since the last survey.

4.2.9 Umupuia Beach

Beach description

The Umupuia sample extent was split into four strata, covering the majority of the beach intertidal area (strata A and B each encompassed 6 ha, strata C and D each covered 12 ha) (Figure 27). Before the 2010 survey, Umupuia was surveyed 1997–2006 and 2009.
Umupuia beach has been closed to recreational harvesting since October 2008.

Figure 27: Umupuia beach – the sample extent was split into four strata covering the majority of the intertidal zone of the beach.

Umupuia Beach cockles

I estimate (with 95% confidence) that the 2010 Umupuia Beach sample extent contained 102.1 ± 20.1 million cockles (Table 38). There was strong evidence of an increase in the cockle population since the 2009 survey ($p<0.001$). I estimate that there were between 16.7 million and 65.5 million more cockles in 2010 compared to 2009.

Cockle sizes were similar to those found in 2009 – typical cockle length was 20 to 26 mm. Surveys done in 2005 and 2006 had cockles that were, on average, around 6 mm larger than in 2009 or 2010 (Figure 28 and Table 39).

There was a large increase in the number of harvestable cockles since 2009. The proportion of harvestable cockles (relative to the total population size) also increased compared with the 2009 survey (Table 40).

Table 38: Umupuia cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	102.1	10.2	10.0	283.5
2009	61.0	6.9	11.3	169.4
2006	11.6	1.6	13.8	31.9
2005	26.9	3.9	14.5	74.2

Table 39: Umupuia cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	22.1	20	3–47	22	20–26
2009	21.8	21	5–45	23	19–25
2006	28.0	36	3–48	30	21–35
2005	27.6	31	4–46	30	19–34

Table 40: Umupuia harvestable cockles (at least 30 mm length).

Survey	Population Estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2010	9.23	1.40	25.6	9.0
2009	1.35	0.23	3.8	2.2
2006	5.05	0.86	13.9	43.6
2005	14.52	2.89	40.1	54.0

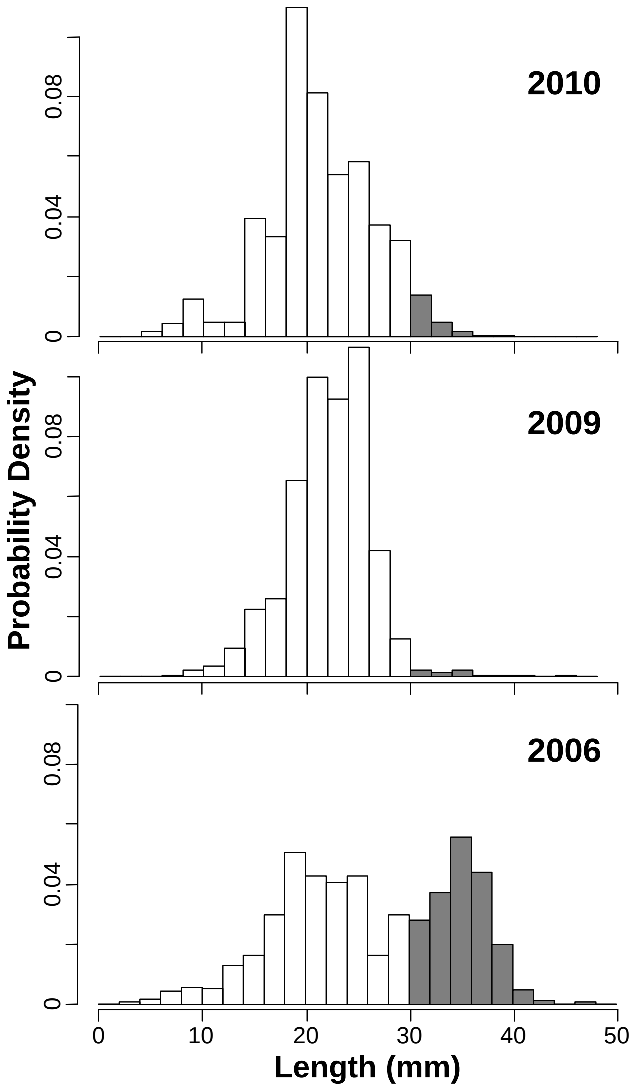

Figure 28: Weighted length frequency distribution of cockles from Umupuia Beach. Dark bars denote 'harvestable cockles' (i.e. at least 30 mm).

Umupuia Beach pipis

Population estimates were not calculated for pipi at Umupuia as no pipis were found during the 2010 survey.

Discussion – Umupuia beach

There was a consistent decline in the Umupuia Beach cockle population between 2000 and 2006 that led to a Section 186A[9] closure of the beach. The previous (2009) survey was the first survey after the closure (October 2008) – it found a marked increase in the cockle population. The 2010 survey showed that cockle numbers have further increased since the 2009 survey. Moreover the number and proportion of harvestable cockles have substantially increased since 2009; however, the harvestable cockle proportion is still small relative to early survey results from the 2006 and earlier surveys.

[9] Section 186A of the Fisheries Act 1996 allows the Minister of Fisheries to temporarily close an area to fishing, or to restrict a method of fishing, in order to provide for the use and management practices of tangata whenua in the exercise of their non-commercial fishing rights.

4.2.10 Whangamata Estuary

Beach description

The sample extent at Whangamata Estuary is split into three strata (two within A, and C) (Figure 29). Stratum E was also sampled, but the results have been excluded from population estimates because although it had been sampled in the previous survey (2006), it was not included in earlier sampling. Stratum B (4 ha) is west of the marina channel and extends into the main river to 0.5 m below chart datum. Within stratum A, cockles and pipis were found in distinct beds (of size 0.45 and 0.2 ha respectively). These strata cover most of the intertidal area to the east of the dredged marina channel.

Prior to the 2010 survey, Whangamata Estuary was sampled each year from 1998 to 2004 and in 2006.

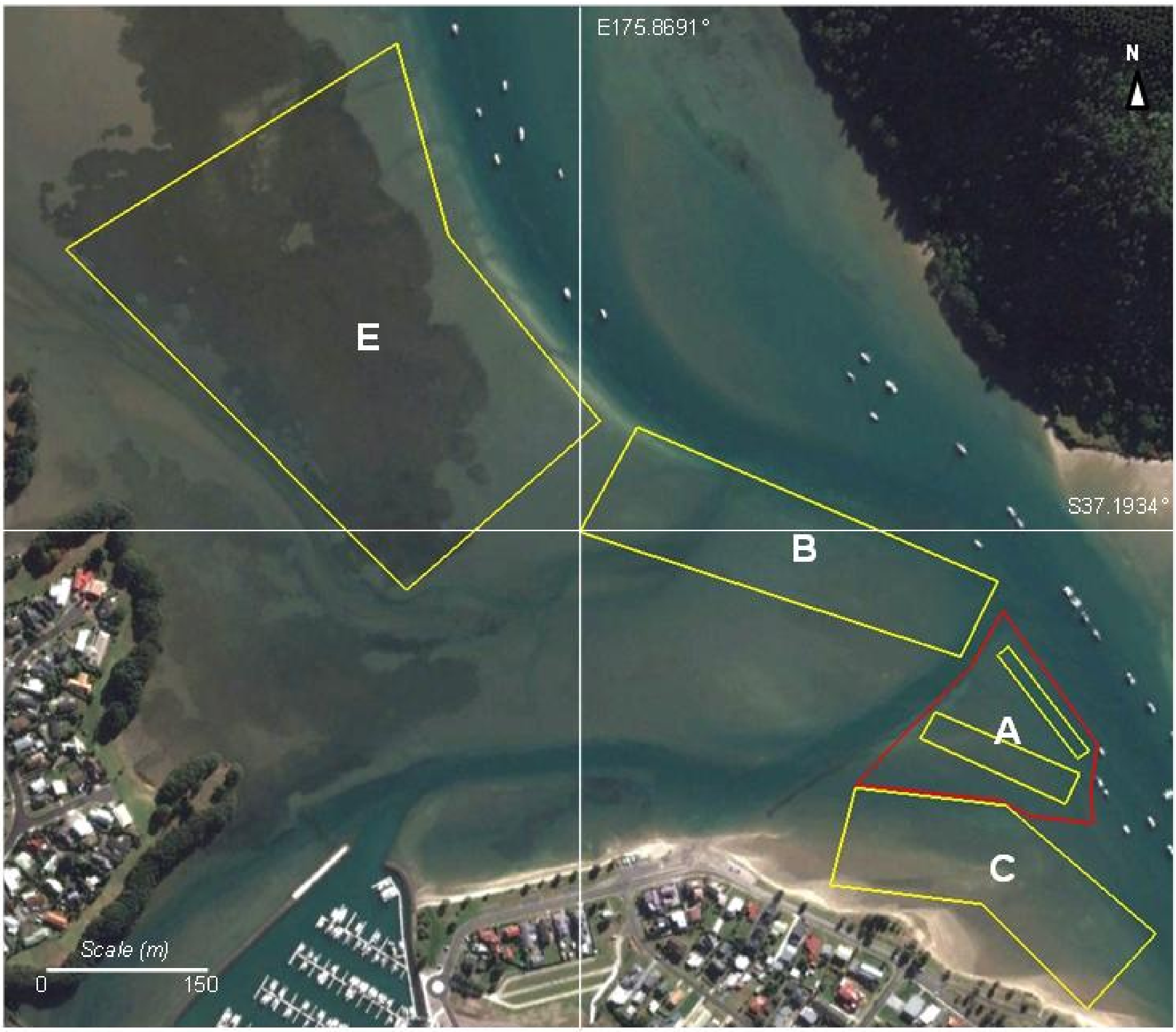

Figure 29: The Whangamata Estuary sample extent consisted of two pipi beds (stratum B and the edges of A) and two cockle beds (central A and C). To maintain historical consistency, stratum E was not included in total population estimates. Yellow polygons depict the bed positions. The red polygon shows the area examined when looking for pipi beds in stratum A.

Whangamata Estuary cockles

I estimate (with 95% confidence) that in 2010 the Whangamata Estuary sample extent contained 84.0 ± 28.4 million cockles (Table 41). There was strong evidence of an increase in the cockle population in this area since the previous (2006) survey ($p<0.001$). I estimate that there were between 22.5 million and 80.3 million more cockles than in 2006.

The median cockle size in the 2010 survey was around 1 mm smaller than in 2006 (Figure 30 and Table 42). There was no evidence of a change in the number of harvestable cockles since 2006 ($p=0.21$) (Table 43).

Table 41: Whangamata Estuary cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	84.0	14.34	17.1	1427
2006	32.6	2.46	7.5	537
2004	40.5	3.37	8.3	667

Table 42: Whangamata Estuary cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	17.0	19	4–40	17	13–20
2006	18.5	18	3–45	18	13–23
2004	25.2	28	543	26	21–29

Table 43: Whangamata Estuary harvestable cockles (at least 30 mm length).

Survey	Population Estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2010	1.78	0.78	30.2	2.1
2006	2.86	0.35	47.1	8.8
2004	10.35	0.82	170.5	25.5

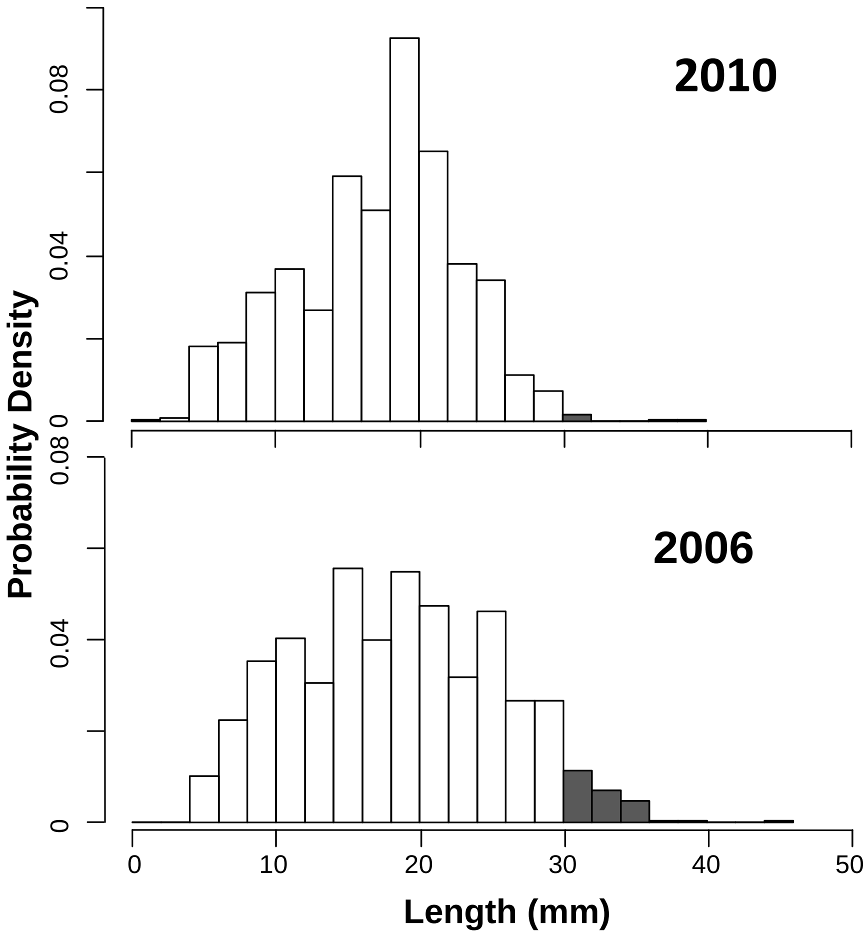

Figure 30: Weighted length frequency distribution of cockles from Whangamata Estuary. Dark bars denote 'harvestable cockles' (i.e. at least 30 mm).

Supplementary sampling (Stratum E)

In the 2006 survey, a large, relatively dense cockle bed was found to the east of the standard survey strata (see Figure 29). Its relatively close proximity to areas currently popular for harvesting suggest that in the future, it might be an area that could come under harvesting pressure. The cockle density estimates from the 2010 and 2006 surveys are shown in Table 44.

Table 44: Cockle density from the supplementary sampling (stratum E).

Survey	Cockle density (per m^2)	SE (density)
2010	1379	112
2006	2350	397.5

Whangamata Estuary pipis

I estimate (with 95% confidence) that the 2010 Whangamata Estuary sample extent contained between 5.5 ± 2.1 million pipis. There was evidence of an increase in the pipi population since the previous (2006) survey (p = 0.049) (Table 45). I estimate that the 2010 survey had between 0.2 million and 4.4 million more pipis than in 2006.

Mean and median pipi lengths in the 2010 survey were around 9 mm less than in 2006; typical pipi size in 2010 ranged between 22 and 51 mm (Table 46). There was no evidence of a change in the number of harvestable pipis since the previous survey (p<0.84). The proportion of harvestable pipis declined by around 20% since 2006 (Table 47 and Figure 31).

Table 45: Whangamata Estuary pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	5.5	1.07	19.6	95.1
2006	3.30	0.25	7.4	57.5
2004	2.45	0.44	18.2	42.7

Table 46: Whangamata Estuary pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	38.3	14, 50	5–73	41	22–51
2006	47.6	58	4–76	50	39–58
2004	44.79	51	8–69	48	39–53

Table 47: Whangamata Estuary harvestable pipis (at least 50 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2010	1.52	0.44	26.0	27.8
2006	1.5	0.10	24.6	45.7
2004	1.31	0.29	21.5	53.4

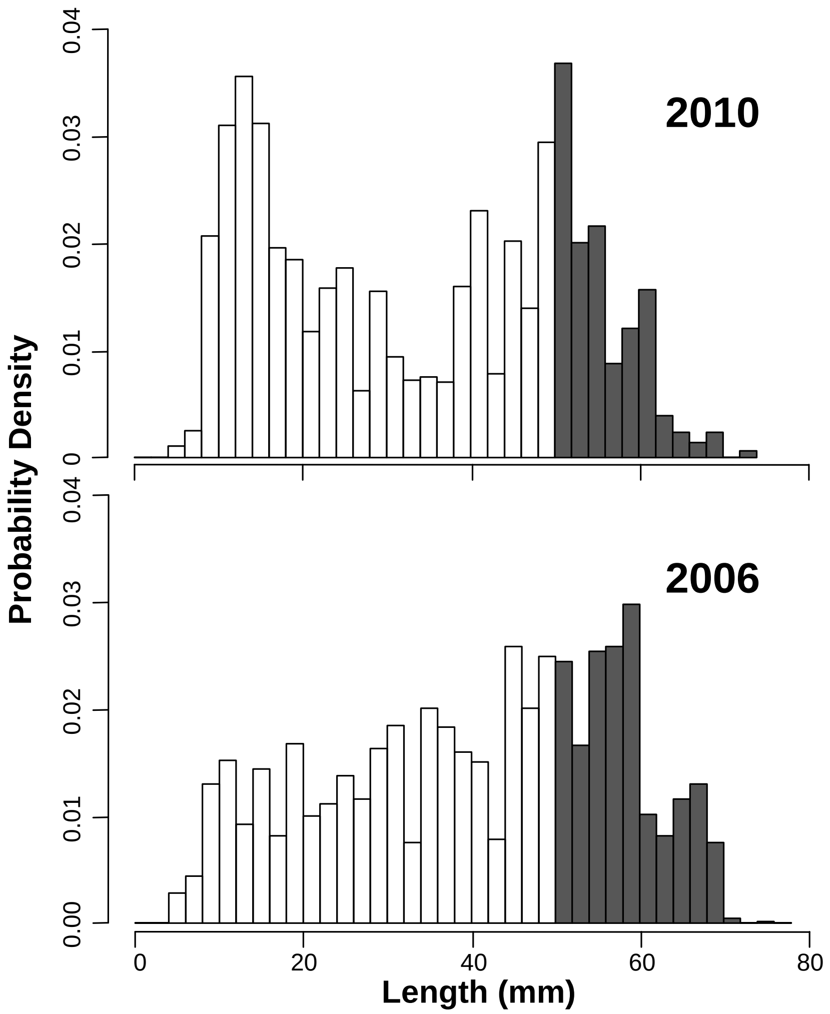

Figure 31: Weighted length frequency distribution of pipis from Whangamata Estuary. Dark bars denote 'harvestable pipis' (i.e. at least 50 mm).

Discussion – Whangamata Estuary

The density of cockles in Whangamata Estuary has more than doubled since the previous (2006) survey. Cockle beds in strata A and C both increased in density, but the largest density change was at stratum B which increased by more than an order of magnitude (from 92 cockles per m^2 (2006) to 1483 cockles per m^2 (2010). Average cockle size over this period has remained similar since 2006. Pipi numbers have also increased since 2006. The change was due to an increase in stratum B. Density at that stratum increased from 0.5 to around 6 pipi per m^2. The abundance of pipis in other beds (where access was unaffected by the marina channel) has slightly declined since the 2006 survey.

The strength of shellfish populations in stratum B may be due to changes in access to the site following the construction of the marina in 2008–2009. Recreational fishers now either need to swim across a newly dredged channel or walk a much greater distance to reach stratum B. Ironically, this construction was opposed partially on the grounds of its potential damage to intertidal shellfish populations.

4.2.11 Whangapoua Estuary

Beach description

The sample extent for Whangapoua Estuary covered both sides of the estuary. The eastern sampling extent covered two cockle beds (strata A and B) that were easily accessible from the Matarangi township, while the western sampling extent contained a pipi bed (stratum D) and a cockle bed (stratum C) (Figure 32). Whangapoua Estuary was previously sampled in surveys from 2002 to 2005.

Figure 32: The sample extent for Whangapoua Estuary is shown by yellow polygons.

Whangapoua Estuary cockles

I estimate (with 95% confidence) that the 2010 sample extent had 31.8 ± 6.1 million cockles (Table 48). There was no evidence of a change in the cockle population since the previous (2005) survey (p<0.51) (Table 48). I estimate that 2010 had between 10.0 million fewer and 5.0 million more cockles than in 2005.

The median cockle size in 2010 was 6 mm smaller than in 2005 (Table 49), with typical cockle sizes ranging between 16 and 24 mm. There was strong evidence of a decrease in the number of harvestable cockles since 2005 (p<0.001). The proportion of harvestable cockles in 2010 was smaller than the previous survey (Table 50, Figure 33).

Table 48: Whangapoua Estuary cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	31.8	3.1	9.8	610.5
2005	34.3	2.2	6.3	658.5

Table 49: Whangapoua Estuary cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	20.3	19	2–45	20	16–24
2005	26	26	5–44	26	23–29

Table 50: Whangapoua Estuary harvestable cockles (at least 30 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2010	2.8	0.51	53.9	8.8
2005	8.13	1.27	156.8	23.7

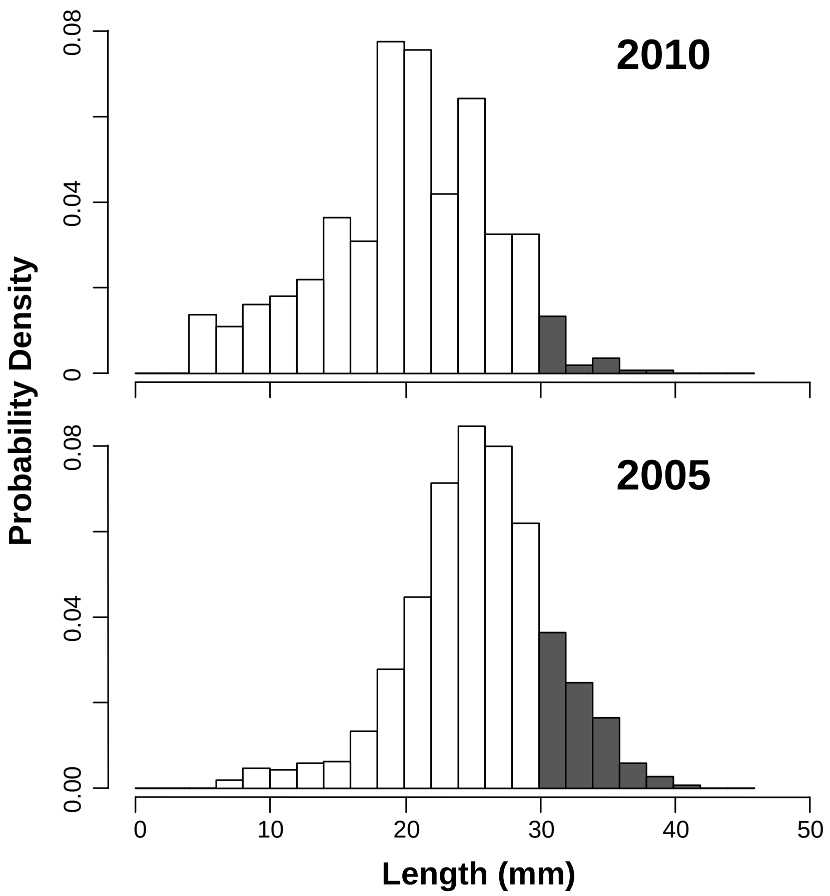

Figure 33: Weighted length frequency distribution of cockles from Whangapoua Estuary. Dark bars denote cockles of 'harvestable size' (i.e. at least 30 mm).

Whangapoua Estuary pipis

I estimate (with 95% confidence) that the Whangapoua Estuary 2010 survey had 2.7 ± 1.0 million pipis (Table 51). There was strong evidence of a decrease in the abundance of pipis since the previous (2005) survey (p<0.001) (Table 51). I estimate that the 2010 survey had between 2.1 million and 4.2 million fewer pipis than the previous survey.

The median pipi size in 2010 was 3 mm smaller than in 2005, with typical pipis ranging between 37 and 54 mm (Table 52). There was strong evidence of a decrease in the number and proportion of harvestable pipis since 2005 (p<0.001) (Table 53, Figure 34).

Table 51: Whangapoua Estuary pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	2.7	0.51	18.8	52.2
2005	6.2	0.49	8.0	119.1

Table 52: Whangapoua Estuary pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	45.1	39	11–72	45	37–54
2005	47	51	8–76	48	41–54

Table 53: Whangapoua Estuary harvestable pipis (at least 50 mm length).

Survey	Population Estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2010	1.17	0.25	22.5	43.1
2005	2.82	0.1	54.3	45.7

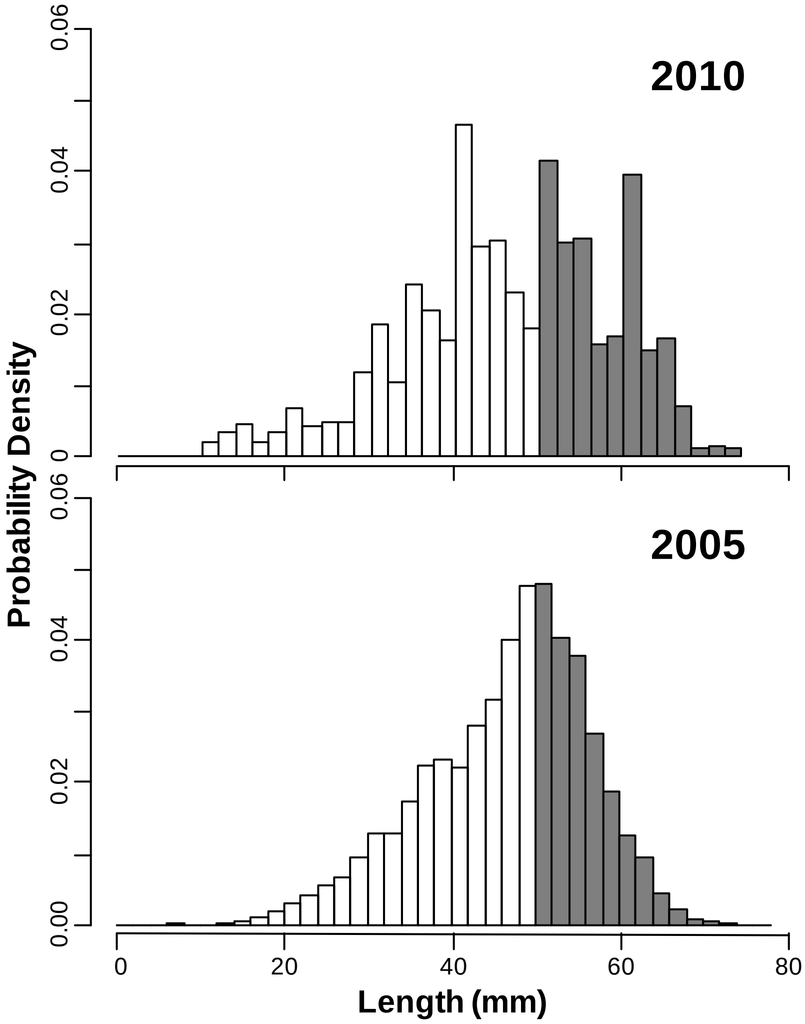

Figure 34: Weighted length frequency distribution of pipis from Whangapoua Estuary. Dark bars denote pipis of 'harvestable size' (i.e. at least 50 mm).

Discussion – Whangapoua Estuary

There has been little change in the numbers of cockles at Whangapoua Estuary since the previous (2005) survey. However, the average size of cockles has decreased and the numbers and proportion of harvestable cockles are only around a quarter of what was found in the 2005 survey.

Pipi numbers have declined to less than half the 2005 population. The average pipi and the proportion of harvestable pipis remained relatively stable since 2005.

4.2.12 Whangateau Harbour

Beach description

The sample extent in Whangateau consists of four separate areas. Strata A and B encompass two intertidal areas lying in Lew's Bay and northwest of Ti Point Wharf respectively (36 and 9.2 ha). Stratum C is another intertidal site to the west of Waikokopu Creek, and stratum D is a narrow subtidal strip bordering the west side of the main channel that covers a pipi bed (sampled to 0.5 m below chart datum) (see Figure 35). A total of 197 samples were taken from the sample extent. Before the 2010 survey, Whangateau harbour was sampled in 2001, 2003, 2004, 2006 and 2009.

The Whangateau Harbour was closed for recreational harvesting of all shellfish on 25 March 2010 for at least a 3 year period.

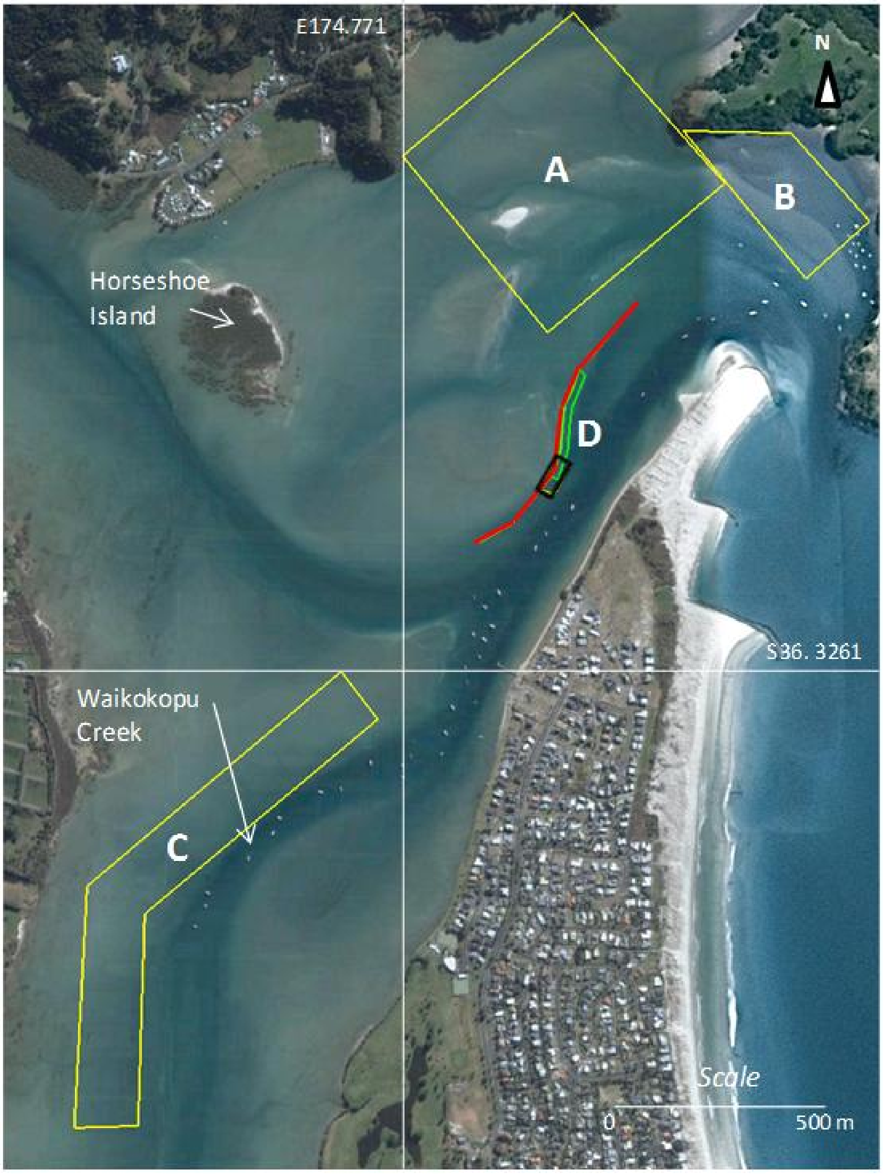

Figure 35: The Whangateau Harbour sample extent was divided into four strata. Yellow polygons denote the sample extent covering cockle beds and the red line (stratum D) denotes the sample extent along the channel bank examined for pipis. The pipi bed locations in 2009 (green polygon) and 2010 (black polygon) are shown.

Whangateau Harbour cockles

I estimate (with 95% confidence) that the 2010 Whangateau Harbour sample extent had 237.0 ± 23.7 million cockles (Table 54). There was no evidence of a change in the cockle population since the previous (2009) survey (p = 0.9). I estimate that the 2010 survey had between 44.6 million fewer and 39.0 million more cockles than the 2009 survey.

The average cockle size in the 2010 survey was around 1 mm smaller than in 2009, with typical cockles ranging between 14 and 23 mm in size (Table 55, Figure 36). There was no evidence of a change in the number or proportion of harvestable cockles since 2009 (p = 0.69) (Table 56).

Table 54: Whangateau cockles – population estimates.

Year	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	237.0	12.0	5.1	369.4
2009	239.8	17.3	7.2	371.8
2006	290.0	23.2	8.0	452.0
2004	349.0	57.9	16.6	544.1

W.mn min max Median LQR UQR

Table 55: Whangateau cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	19.6	21	4–46	19	14–23
2009	20.5	19	5–39	21	17–25
2006	22.4	18	4–48	22	18–27
2004	24	24	5–44	24	20–27

Table 56: Whangateau harvestable cockles (at least 30 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2010	19.6	2.9	30.5	8.3
2009	17.7	3.7	27.4	7.4
2006	39.6	7.6	61.7	13.7
2004	56.9	14.8	88.7	16.3

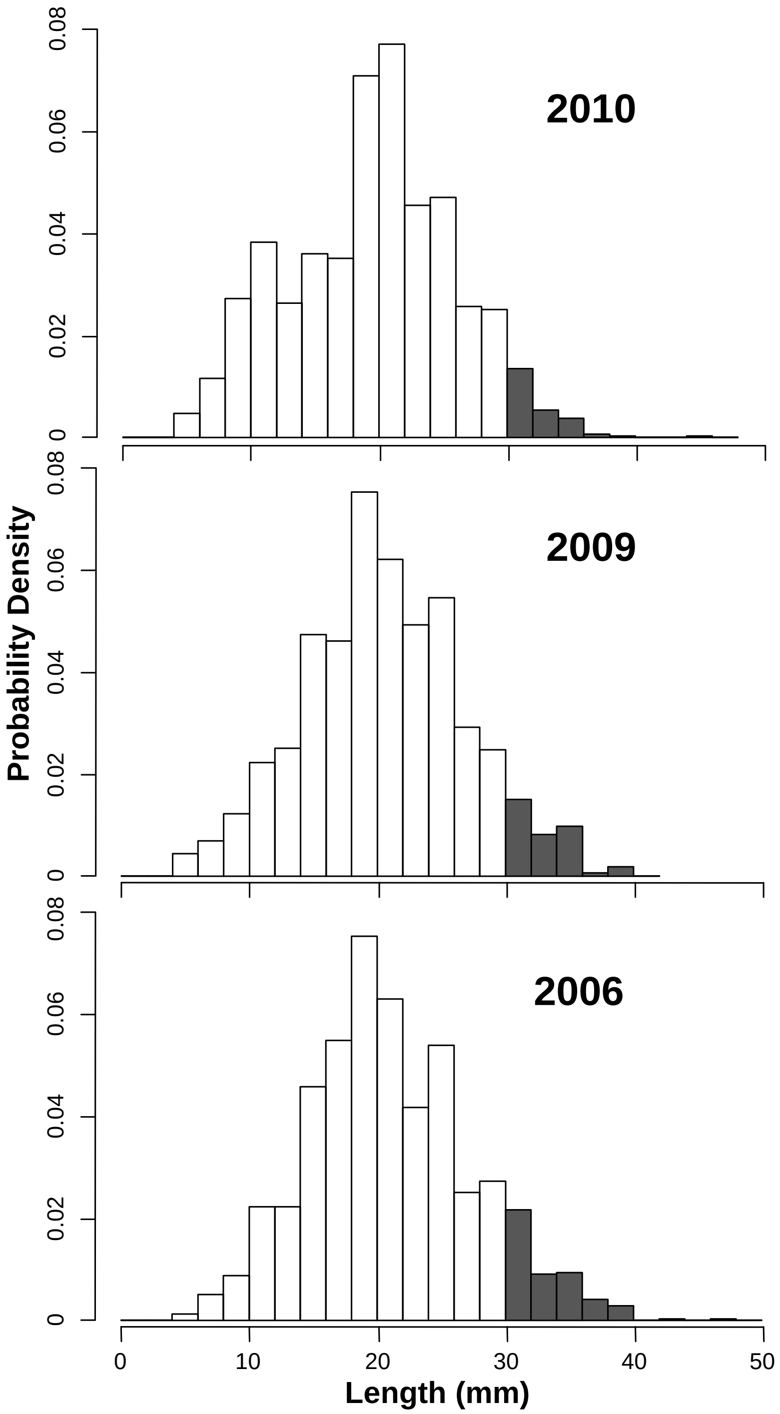

Figure 36: Weighted length frequency distribution for cockles from Whangateau Harbour. Dark bars denote cockles of 'harvestable size' (i.e. at least 30 mm).

Whangateau Harbour pipis

I estimate (with 95% confidence) that the 2010 Whangateau Harbour sample extent had 9.2 ± 3.2 million pipis (Table 57). There was evidence of a decrease in the pipi population since the previous (2009) survey (p = 0.04). I estimate that 2010 had between 0.2 million and 11.8 million fewer pipis than 2009.

The mean and median lengths of Whangateau Harbour pipis in the 2010 survey were, respectively, 9 and 7 mm more than in 2009, with typical pipis ranging between 16 and 39 mm (Table 58, Figure 37). There was strong evidence of an increase in the number and proportion of harvestable pipis since the 2009 survey (p<0.001) (Table 59).

Table 57: Whangateau pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2010	9.2	1.6	17.7	14.4
2009	15.2	2.45	16.2	23.5
2006	11.8	2.37	20.1	18.5
2004	1.5	0.22	15.5	2.3

Table 58: Whangateau pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2010	28.9	15	9–70	24	16–39
2009	19.7	10	3–75	17	11–27
2006	32.2	36	4–59	33	24–40
2004	49.0	45	11–77	49	44–54

Table 59: Whangateau harvestable pipis (at least 50 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2010	1.6	0.22	2.4	16.9
2009	0.15	0.14	0.23	1.0
2006	0.05	0.03	0.08	0.4
2004	0.58	0.10	0.89	38.7

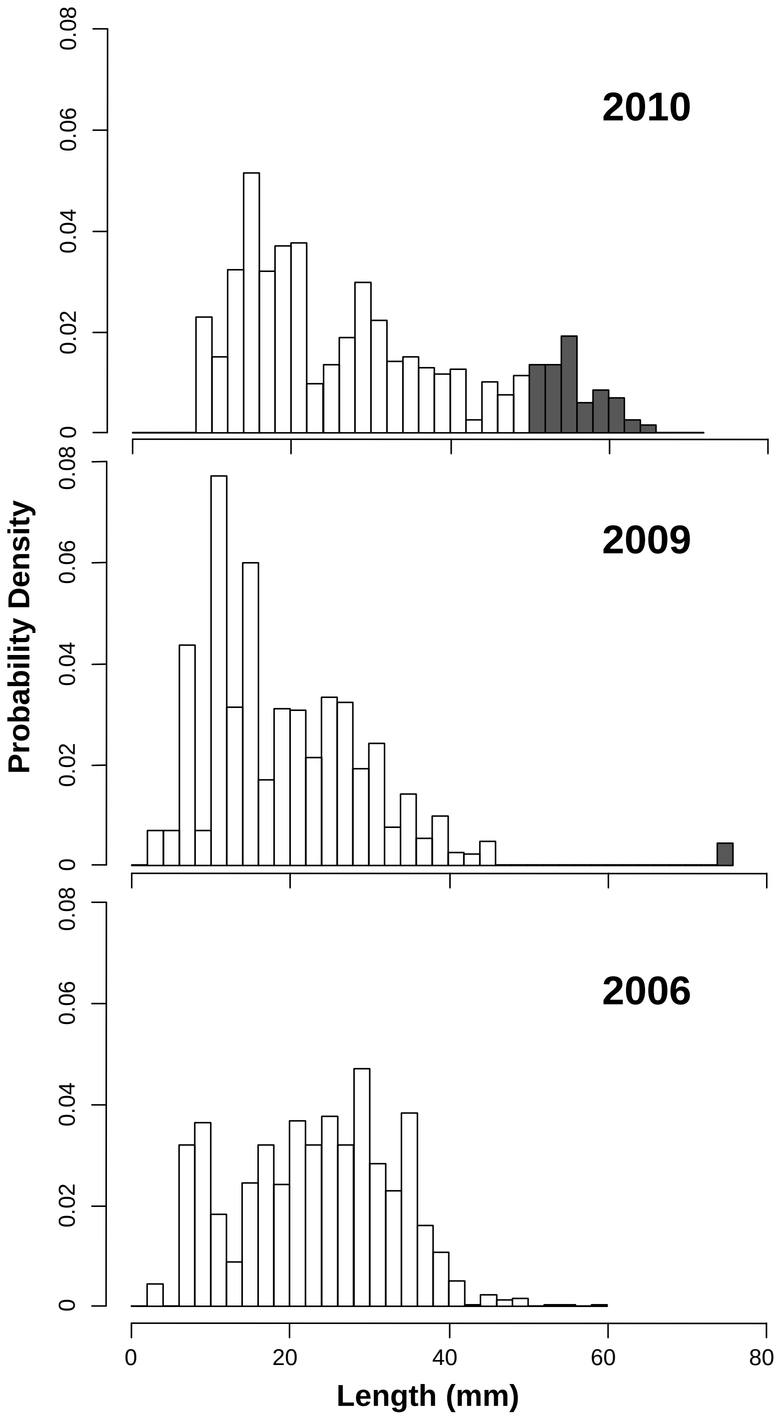

Figure 37: Weighted length frequency distribution of pipis from Whangateau Harbour. Dark bars denote pipis of 'harvestable size' (i.e. at least 50 mm).

Discussion – Whangateau Estuary

The cockle population within the Whangateau Estuary was similar to the previous (2009) survey in terms of both densities and LFD. However the cockle population remained around 20–30% lower than the 2006 and 2004 surveys. The decrease in cockle numbers shown in the 2009 survey was likely to be due to an event during January to April 2009 when a coccidian parasite and a mycobacterium appeared to cause massive mortality in the beds (K. Tricklebank, University of Auckland, pers. comm., Bingham 2009). The Whangateau Harbour is closed to recreational fishers for a period of 3 years from 25 March 2010 following the mortality.

For the last two years, the pipi population estimate has been dominated by a cohort of juvenile pipis (less than 20 mm in length) found intertidally in stratum A. These recruits were less abundant in 2010, and the overall abundance of pipis had declined by around 30% compared to 2009 (but was still relatively large compared to 2004). During the 2010 survey a bed of large-sized pipis was found in stratum D at depths shallower than 0.5 m below chart datum. Because of the small geographic size of this bed it had little influence on total population numbers. However the bed strongly influenced the length frequency distribution – which shows a distinct cohort of pipis around 60 mm in length (all from stratum D), that was not present in 2006 or 2009. This bed meant that the number and proportion of harvestable pipis (at least 50 mm) in 2010 was around an order of magnitude larger compared to 2006 or 2009, and was triple the estimated 2004 population.

4.3 Summary results

4.3.1 Cockles

A summary of cockle population estimates, standard errors, coefficients of variation (c.v.), the proportion of the 'harvestable' cockle population (i.e. ≥ 30 mm) and the number of individuals counted for each beach are given in Table 60. A comparison with the previous survey is shown in Table 61. The change in total and harvestable cockle populations for all recorded surveys (at all beaches surveyed in 2010) is shown in Figure 38.

Table 60: The 2010 survey cockle population estimates (including the number of cockles counted).

Beach	Estimated population (millions)	SE (millions)	c.v. (%)	Harvestable Proportion (%)	Cockles counted
Bowentown Beach	17.65	1.60	9.0	0.4	3 994
Cockle Bay	71.5	4.0	5.6	29.5	2 384
Grahams Beach	24.9	5.1	20.5	0.07	257
Mangawhai Harbour	61.2	5.6	9.1	13.5	2 475
Marokopa Estuary	0	0	0	0	0
Ngunguru Estuary	19.1	2.1	10.9	0.33	4 277
Ruakaka Estuary	3.6	0.7	19.3	1.1	456
Tairua Harbour	24.1	2.6	10.8	4.9	3 254
Umupuia Beach	102.1	10.2	10.0	9.0	2 229
Whangamata Estuary	84.0	14.3	7.1	2.1	7 522
Whangapoua Estuary	31.8	3.1	9.8	8.8	3 213
Whangateau Harbour	237.0	12.0	5.1	8.3	2 867

Table 61: Comparing the 2010 survey cockle populations with the previous survey. The scale of the change is shown by the 95% CI of the change and the proportion of the previous survey's point estimates (<100% indicate a decrease, >100% indicate an increase in the previous survey). Statistically significant (*p*<0.05) changes are bolded = decreases in red, increases in green.

Beach	Previous survey	Change (in millions)		Proportion of previous survey (%)
		Lower Limit	Upper Limit	
Bowentown Beach	2001	**8.7**	**15.4**	**315**
Cockle Bay	2009	**5.0**	**27.8**	**121**
Grahams Beach	2006	**4.2**	**26.2**	**279**
Mangawhai Harbour	2003	-13.9	10.1	121
Ngunguru Estuary	2004	**4.4**	**14.2**	**195**
Ruakaka Estuary	2006	**0.8**	**3.7**	**263**
Tairua Harbour	2006	**2.0**	**15.2**	**74**
Umupuia Beach	2009	**16.7**	**65.5**	**167**
Whangamata Estuary	2006	**22.5**	**80.3**	**258**
Whangapoua Estuary	2005	-10.0	5.0	93
Whangateau Estuary	2009	-44.6	39	99

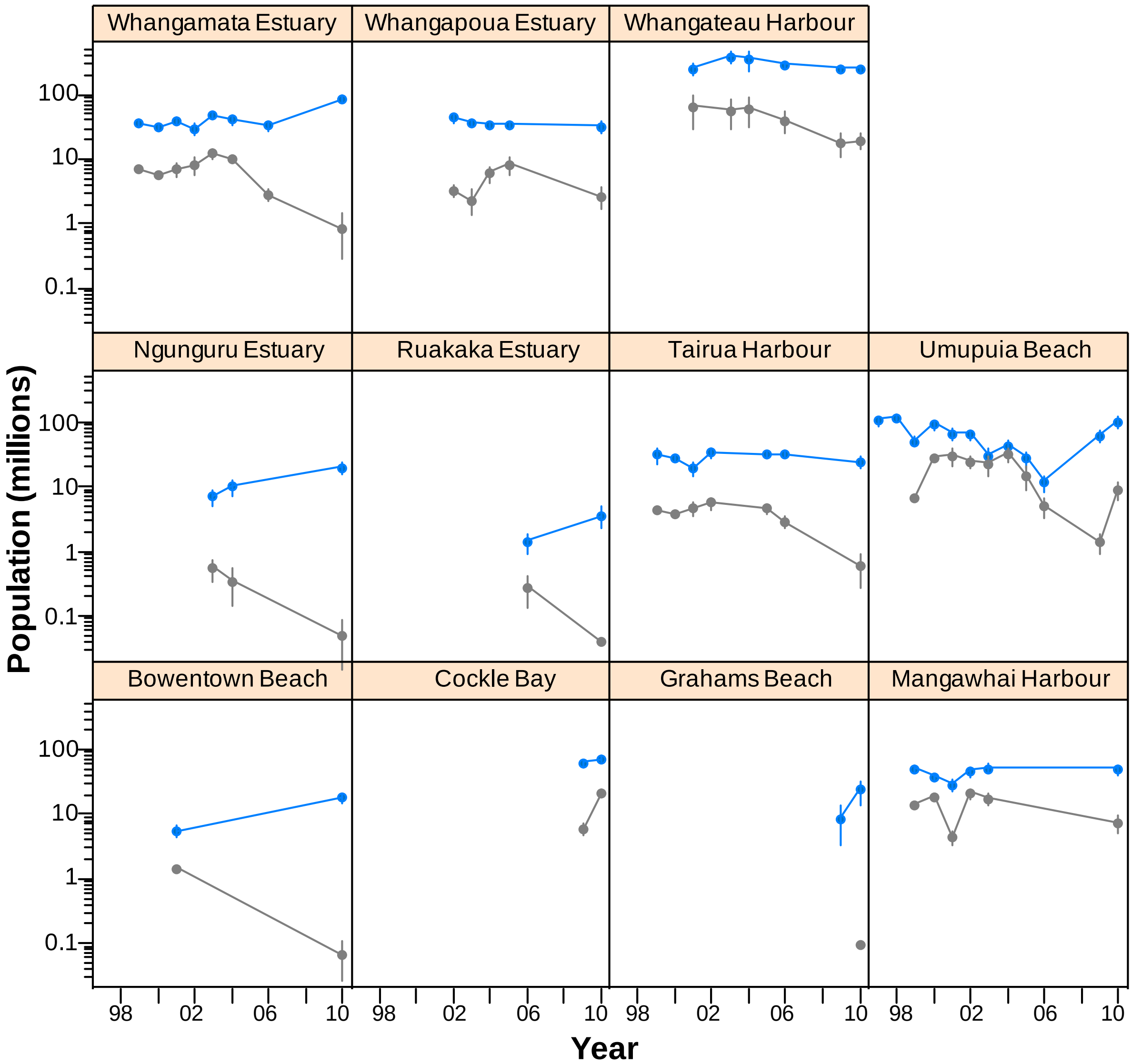

Figure 38: Changes over time in total cockle (blue) and harvestable cockle (grey) populations for those beaches selected in the 2010 survey. The y-axis is displayed on the log-scale.[10] Error bars indicate the 95% confidence interval around the population total.

[10] A caveat: the log-scale makes proportional changes linear (e.g., a 10-fold increase is the same amount whether the change is from 1 to 10, or from 100 to 1000). However, this may mask the size of some large *absolute* changes when the plotted points are large (relative to other points).

4.3.2 Pipis

A summary of pipi population estimates, standard errors, coefficients of variation (c.v.), the proportion of the 'harvestable' population (i.e. at least 50 mm) considered 'harvestable' and the number of individuals measured, for each beach are given in Table 62. A comparison to the previous survey is shown in Table 63. The change in total and harvestable pipi populations for all recorded surveys (at all beaches surveyed in 2010) is shown in Figure 39.

Table 62: The 2010 survey pipi population estimates (including the number of pipis counted). NA indicates beaches that were 'not applicable' due to low sample numbers.

Beach	Population estimate (millions)	SE (millions)	c.v. (%)	Harvestable Proportion (%)	Pipis counted
Bowentown Beach	*NA*				0
Cockle Bay	*NA*				0
Grahams Beach	3.7	1.02	27.9	0	38
Mangawhai Harbour	4.2	0.81	19.6	1.8	614
Marokopa Estuary	3.0	0.45	15.0	0	618
Ngunguru Estuary	0.72	0.12	17.0	34.4	303
Ruakaka Estuary	39.6	8.10	20.4	0.3	1 744
Tairua Harbour	25.5	2.9	11.3	3.2	5 347
Umupuia Beach	*NA*				0
Whangamata Estuary	5.5	1.07	19.6	27.8	609
Whangapoua Estuary	2.7	0.51	18.8	43.1	976
Whangateau Harbour	9.2	1.60	17.7	16.9	454

Table 63: Comparing the 2010 survey pipi populations with the previous survey. The scale of the change is shown by the 95% CI of the change and the proportion of the previous survey's point estimates (<100% indicate a decrease, >100% indicate an increase in the previous survey). Statistically significant (*p*<0.05) changes are bolded, decreases in red, increases in green. NA – not applicable – indicates that no pipis were found in the previous survey.

Beach	Previous survey	Change (in millions)		Proportion of previous survey (%)
		Lower Limit	Upper Limit	
Grahams Beach	2006	**1.6**	**5.4**	***NA***
Mangawhai Harbour	2003	**1.3**	**4.6**	**356**
Marokopa Estuary	2005	-0.9	1.3	106
Ngunguru Estuary	2004	**-1**	**-1.9**	**33**
Ruakaka Estuary	2006	-13.2	23.4	115
Tairua Harbour	2006	**11.2**	**23**	**304**
Whangamata Estuary	2006	**0.2**	**4.4**	**167**
Whangapoua Estuary	2005	**-2.1**	**-4.2**	**44**
Whangateau Harbour	2009	**-0.2**	**-11.8**	**61**

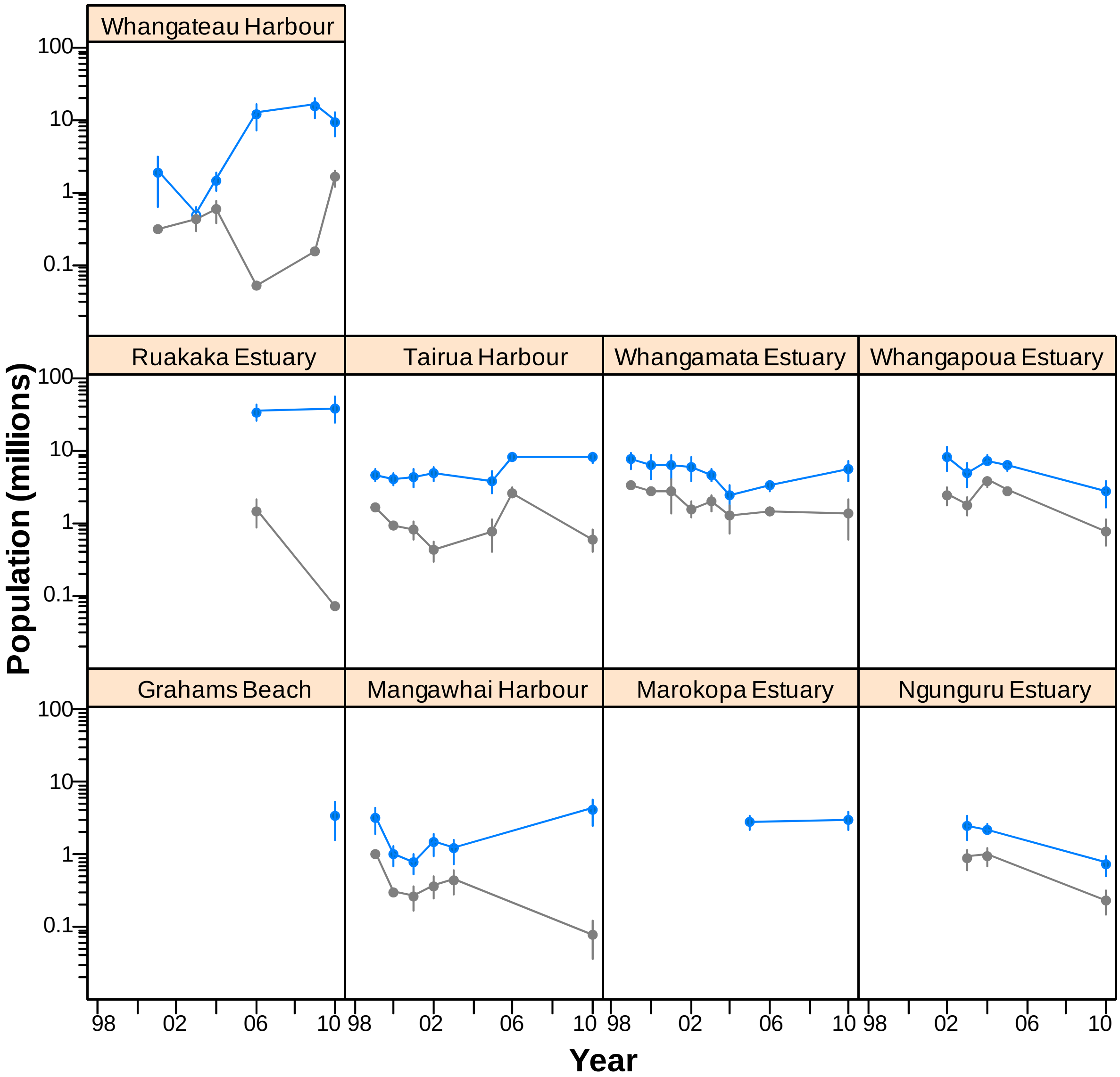

Figure 39: Changes over time in total pipi (blue) and harvestable (at least 50 mm) pipi (grey) populations for those beaches sampled in the 2010 survey. For ease of interpretation, the y-axis is displayed on the log-scale. Error bars indicate the 95% confidence interval around the population total.

5. DISCUSSION

5.1 Cockles

In the 2010 survey, the overall abundance of cockles increased at seven of the eleven beaches with cockle beds. Large increases (i.e. double or more the previous survey's population) were found at five beaches. The cockle population at Bowentown Beach was more than triple the previous population (2001), cockle populations at Grahams Beach, Ruakaka Estuary and Whangamata Estuary more than doubled in abundance since the previous survey (2006) and cockles at Ngunguru Estuary had approximately doubled in number since the 2001 survey. Umupuia Beach and Cockle Bay showed more modest population gains in cockle numbers (increases of 67% and 21% respectively since the 2009 survey) (see Table 61).

The cockle population in Whangateau Estuary has remained relatively stable since the 2009 mortality event. From a longer term perspective, the cockle population at this site was around 40% below the highest estimated population (2003), but was similar to the 2001 population. As only three (or fewer) surveys have been conducted at Ngunguru and Ruakaka Estuaries, Cockle Bay and Grahams Beach it is difficult to put their population changes in a longer-term perspective. Cockle populations at most other beaches in the 2010 survey were not unusual compared to previous surveys. One exception was Whangamata Harbour which showed a large increase in the abundance of cockles, numbers were almost 70% higher than the previous highest values recorded in 2003.

A decline in the number of large cockles

There has been a concomitant decline in the number and proportion of large, 'harvestable' cockles (i.e. cockles larger than 30 mm) at most beaches, despite an increase in total cockle abundance. Umupuia Beach, which was closed to recreational fishing after the 2006 survey, and Cockle Bay (which is subject to a seasonal closure) are the only beaches that have shown a significant increase in the number of large harvestable cockles over this period. With the exception of these two beaches, the number of harvestable cockles is at, or near, the lowest recorded value of all beaches with a reasonable time series (more than three sampling occasions) [11]. Significant declines in the numbers of large cockles were seen at all other beaches except Grahams Beach (which has very low cockle density) and Whangateau Harbour (closed to harvesting since March 2010 following the 2009 mortality event).

5.2 Pipis

Nine of the twelve beaches surveyed in 2010 had pipi beds. The pipi population at Mangawhai Harbour and Tairua Harbour more than tripled since their previous surveys (in 2003 and 2006 respectively) (see Table 63). Modest changes in the pipi population were found at Whangamata Estuary (a decrease of around 40%) and Whangateau Estuary (an increase of around 70%). Significant declines were found at Ngunguru and Whangapoua Estuaries – these populations declined to less than half the population compared to their previous surveyed (in 2004 and 2005 respectively).

A decline in the number of large pipis

[11] Both beaches closed to recreational fishing at the time of the 2010 survey had putative increases in the harvestable cockle population (although the change in the Whangateau Harbour population was relatively small).

The number of large 'harvestable' pipis (at least 50 mm), showed significant declines at most beaches. However the number of 'harvestable' pipis has increased at Whangateau Harbour since the previous survey – due to the inclusion of a small intertidal stratum containing a dense bed of large pipis.

6. ACKNOWLEDGMENTS

There are many people to thank for their help on this project. Firstly, I'd like to thank Maori Trust Boards, kai tiaki and interested locals for their assistance – I appreciate your desire to protect your beaches so that our mokopuna also have the chance to view and treasure their taonga.

Many thanks to the Ministry of Fisheries for their funding (under project AKI2010-01). Thanks also to the MPI pou honunga, Karen Tricklebank and Richard Ford for their assistance and guidance with the project.

I'm very grateful to the Massey University IIMS department, with particular thanks to Lyn, Freda, and Annette who helped with logistics and guided me through a maze of paperwork.

Finally, I'd like to thank the many members of the Shellfish Abundance Squad (SAS) who worked long days on this project.

7. REFERENCES

Akroyd, J.M.; Manly, B.F.J.; Walshe, K.A.R. (2000) Distribution, abundance and size frequency of pipi (*Paphies australis*), cockles (*Austrovenus stutchburyi*) and tuatua (*Paphies subtriangulata*) at eleven beaches during the 1999/2000 fishing year. Final Report to the Ministry of Fisheries, project AKI 1999/01. (Unpublished report held by Ministry for Primary Industries, Wellington).

Akroyd, J.M.; Manly, B.F.J.; Walshe, K.A.R. (2001). Distribution, abundance and size frequency of pipis (*Paphies australis*), cockles (*Austrovenus stutchburyi*) and tuatua (*Paphies subtriangulata*) at twelve beaches during the 2000/2001 fishing year, project AKI2000. (Unpublished report held by Ministry for Primary Industries, Wellington).

Bingham, P. (2009) Quarterly report of investigations of suspected exotic diseases. *Surveillance* 36(4):26–27.

Cochran, W.G. (1946). Relative accuracy of systematic and random samples for a certain class populations. *Annals of Mathematical Statistics* 17:164–177.

Cochran, W.G. (1977). Sampling techniques, 3rd edition. Wiley, New York. 428 p.

Cook, S.; Doorman, P., Drey, R.; Stevens, L.; Turbott, C.; Cryer, M.N. (1992). A pilot study of the intertidal resources of the Auckland metropolitan region – 1992. (Unpublished report held by Ministry for Primary Industries, Wellington).

Dunn, R.; Harrison, A.R. (1993). Two-dimensional systematic sampling of land use. A*pplied Statistics* 42:585–601.

Francis, R.I.C.C. (1984). An adaptive strategy for stratified random trawl surveys. *New Zealand Fisheries Data Report No. 58*. 85 p.

Grant, C.M.; Hay, B.E. (2003). A review of issues related to depletion of populations of selected infaunal bivalve species in the Hauraki Gulf Marine Park. A report prepared for the Hauraki Gulf Forum. Aquabio Consultants Ltd.
URL
http://www.arc.govt.nz/albany/fms/main/Documents/Environment/Coastal%20and%20marine/Hauraki%20Gulf%20Forum%20Shellfish%20Report%20Pgs%201%20-%2087.pdf and at http://www.arc.govt.nz/albany/fms/main/Documents/Environment/Coastal%20and%20marine/Hauraki%20Gulf%20Forum%20Shellfish%20Report%20Pgs%2088%20-%20171.pdf

Hartill, B.W.; Cryer, M.; Morrison, M.A. (2005). Estimates of biomass, sustainable yield, and harvest: neither necessary nor sufficient for the management of non-commercial urban intertidal shellfish fisheries. *Fisheries Research*, 71: 209–222.

Iball, S. (1993). Auckland intertidal shellfish survey, 1993. Unpublished draft report held by the Ministry for Primary Industries, Auckland.

Kennedy, V.S.; Twilley, R.R.; Kleypas, J.A.; Cowan Jr., J.H.; Hore, S.R. (2002). Coastal and marine ecosystems & global climate change. Potential Effects on U.S. Resources. Prepared for the PEW Centre on Global Climate Change. 52p.

Keough, M.J.; Quinn, G.P. (2000). Legislative vs. practical protection of an intertidal shoreline in Southeastern Australia. *Ecological Applications* 10: 871–881.

Manly, B.F.J.; Akroyd, J.M.; Walshe, K.A.R. (2003). Two-phase stratified random surveys on multiple populations at multiple locations. *NZ Journal of Marine and Freshwater Research* 36:581–591.

Morrison, M.A.; Browne, G.N. (1999). Intertidal surveys of shellfish populations in the Auckland region 1998–99 and associated yield estimates. New Zealand Fisheries Assessment Research Document 99/43. 21 p. (Unpublished report held by NIWA library, Wellington).

Morrison, M.A.; Pawley, M.D.M.; Browne, .G.N. (1999). Intertidal surveys of shellfish populations in the Auckland region 1997–98 and associated yield estimates. New Zealand Fisheries Assessment Research Document 99/25. 25 p. (Unpublished report held by NIWA library, Wellington).

O'Shea, S.; Kuipers, B. (1994). Auckland intertidal shellfish survey – 1994. Unpublished report held by the Ministry for Primary Industries, Auckland.

Pawley, M.D.M. (2006). Systematic sampling in ecology. Unpublished PhD thesis, University of Auckland. 317 p.

Pawley, M.D.M. (2011). The distribution and abundance of pipis and cockles in the Northland, Auckland, and Bay of Plenty regions, 2010. *New Zealand Fisheries Assessment Report 2011/24.*

Pawley, M.D.M.; Ford, R. (2006). Distribution and abundance of pipis and cockles in the Northland, Auckland and Bay of Plenty regions, 2006. Final Report to the Ministry of Fisheries, project AKI 2006/01 (Unpublished report held by Ministry for Primary Industries, Wellington.).

R Development Core Team (2010). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Ripley, B.D. (1981). Spatial statistics. Wiley, New York.

Walshe, K.A.R.; Akroyd; J.M. (2002). AKI 2001/01 Intertidal shellfish monitoring in the Auckland fisheries management area. Final Report to the Ministry of Fisheries, project AKI2001/01. (Unpublished report held by Ministry for Primary Industries, Wellington).

Walshe, K.A.R.; Akroyd. J.M. (2003). AKI 2002/01 Intertidal shellfish monitoring in the Auckland fisheries management area. Final Report to the Ministry of Fisheries, project AKI2002/01. (Unpublished report held by Ministry for Primary Industries, Wellington).

Walshe, K.A.R.; Akroyd. J.M. (2004). AKI 2003/01 Intertidal shellfish monitoring in the Auckland fisheries management area. Final Report to the Ministry of Fisheries, project AKI2003/01. (Unpublished report held by Ministry for Primary Industries, Wellington).

Walshe, K.A.R.; Akroyd, J.M.; Manly, B.F.J. (2005). Intertidal shellfish monitoring in the Auckland Fisheries Management Area AKI2005. Final Report to the Ministry of Fisheries, project AKI2005/01. (Unpublished report held by Ministry for Primary Industries, Wellington).

APPENDIX 1: Location and dates of AKI project sites 1992–2009

Table A1.1: Grey cells indicate that the beach was surveyed for the AKI project that year. 2010 beach names have blue background. Red/green cells indicate evidence ($p<0.05$) of a decrease/increase compared to the prior survey. Yellow cells indicate a database discrepancy. *NA* indicates no sizeable population * indicates change in the stratum location.

	Cockles																	Pipis																
Beach / AKI Project	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	09	10	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	09	10
Aotea Harbour																																	*NA*	
Beachlands																																		
Bowentown Beach																																		
Bucklands Beach																																		
Cheltenham Beach																																		
Clarks Beach																																		
Cockle Bay																																		
Cornwallis Beach																																		
Eastern Beach																																		
Grahams Beach																																		
Howick Beach																																		
Kauri Bay																																		
Kawakawa Bay																																		
Little Waihi Estuary																*																	*	
Long Bay																																		
Mangawhai Estuary																																		
Maraetai Beach																																		
Marokopa Beach																	*NA*																	
Mill Bay																																		
Ngunguru Estuary																																		
Ohiwa Estuary																																		
Okoromai Bay																																		
Omana																																		
Otumoetai Harbour																																		
Papamoa Beach																																		
Pataua Beach																																		
Raglan Harbour																																		
Ruakaka Estuary																																		
St Heliers beach																																		
Tairua Harbour																																		
Te Haruhi Bay																																		
Te Haumi Beach																																		
Umupuia Beach																																	*NA*	
Waikawau Bay																																		
Waiotahi Estuary																																		
Wenderholm Beach																																		
Whangamata harbour																																		
Whangapoua Beach																																		
Whangateau Harbour																																		

Table A1.2: Sampling dates for the AKI project. Dates shown indicate the first and last day of sampling.

Project	AKI 1997-01	AKI 1998-01	AKI 1999-01	AKI 2000-01	AKI 2001-01	AKI 2002-01	AKI 2003-01	AKI 2004-01	AKI 2005-01	AKI 2006-01	AKI 2009-01	AKI 2010-01
Beach **Yea**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2010**	**2011**
Aotea Harbour									17-18Jan		27Mar-13Jul	
Beachlands	10-27Mar	9Dec98-29Jan99										
Bowentown Beach					26Apr-25May							18-Apr
Cheltenham Beach	7Jan-9Feb	12-Jan										
Clarks Beach								3-24Feb				
Cockle Bay											16-Feb	5-May
Cornwallis Beach					26-Mar							
Eastern Beach	22Jan-13Mar	12-27Jan	15May-30Jun		14Mar-16Apr							
Grahams Beach										20-Apr		17-May
Howick Beach	27-28Jan	12-27Jan							23Dec05-24Jan06			
Kauri Bay												
Kawakawa Bay								5Feb-8Apr		19-Apr		
Little Waihi Estuary				21-31Mar		30Jan-1Feb	7-19Jan	14-15Jan		15-28Jun	2-Mar	
Mangawhai Estuary			20Mar-30Jun	29-31Jan	15Mar-14Apr	1-31Jan	1-31Jan					24Mar-15Apr
Marokopa Estuary									18-20Feb			16-May
Mill Bay	16Jan-1Apr	9-24Dec98	4Mar-30Jun	20-23Feb	20Mar-22Apr		26-28Jan	24Dec04-24Jan05	20-24Jan		13-May	
Ngunguru Estuary							6-7Mar	6-7Feb				23-Mar
Ohiwa Estuary					9-11Apr				25-26Feb	13-29Jun	3-Mar	
Okoromai Bay	16Jan-24Mar	14-22Dec98	19-24Apr		8-12Apr	26-29Dec02	17-20Mar	15-16Jan		20-Mar	17-Feb	
Otumoetai Harbour				27Mar-2Apr		3-5Mar			15-18Feb	13-14Jun	1-Mar	
Papamoa Beach			1-3May									
Pataua						4-28Mar	14-16Feb		14-16Feb			
Raglan Harbour			26May-30Jun	13Feb-10Mar		13-16Jan	14-16Jan				26-Mar	
Ruakaka Estuary										21-Mar		22-Mar
Tairua Harbour			1Apr-1May	15-16Feb	23-24May	23Feb-28Mar			14-15Jan	3May-1Aug		20-Apr
Te Haruhi Bay				12-Mar								
Te Haumi Beach			7-30Mar	15-26Jan	15Mar-15Apr	21Jan-22Apr				22-Mar	18-Feb	
Umupuia Beach	20Jan-26Mar	16Dec98-12Jan99	1-12Apr	15-16Feb	28Mar-12Apr	28Dec02-2Jan03	25-28Mar	22-23Jan	28-29Jan	3Mar-1Aug	15-Feb	4-May
Waikawau Bay			20May-30Jun	24Feb-15May				18Jan-10Mar	15-27Feb			
Waiotahi Estuary				7-10Feb		7-10Feb	21-24Jan	22-25Jan	10-12Feb		4-Mar	
Whangamata Harbour			20-29May	15-16Feb	9-26May	9-28Mar	1-31Jan	6-8Feb		2May-2Aug		19-Apr
Whangapoua Beach						30Mar-6Apr	1-3Feb	8-10Mar	8-10Mar			21-Apr
Whangateau Harbour					7Apr-22May		17Dec03-2Mar04	2-26Mar		19Mar-2May	18Mar-15Jul	19-20 May

Table A1.3: Size (in ha) of the sample extent for surveyed beaches. * indicates no information on the sample size extent is available.

Beach Project	AKI1997	AKI1998	AKI1999	AKI2000	AKI2001	AKI2002	AKI2003	AKI2004	AKI2005	AKI2006	AKI2009	AKI2010
Aotea Harbour									9.6		15.6	
Beachlands	*	*										
Bowentown Beach					1.58							1.58
Cheltenham Beach	*	*										
Clarks Beach								144.71				
Cockle Bay											16	16
Cornwallis Beach	*	*			2.65							
Eastern Beach	*	*	48		43.38							
Grahams Beach										24.75		24.75
Howick Beach	*	*							6.9			
Kauri Bay								60.37		62.94		
Kawakawa Bay				3		3	3.13	3.75		3.16	13.92	
Little Waihi Estuary			9.4	8.4	8.4	8.4	8.4					
Mangawhai Estuary									8.4			9
Marokopa Estuary									2.35			2.35
Mill Bay	4.8	*	4.6	4.8	4.5		4.5	4.5	4.5		4.95	
Ngunguru Estuary							1.7	1.8				1.8
Ohiwa Estuary					2.25				2.7	5.7	1.8	
Okoromai Bay	*	*	20		24	20	20	20		20	20	
Otumoetai Harbour				5.6		5.6			4.6	4.6	5.6	
Papamoa Beach			2									
Pataua Beach						10.65	10.45		10.45			
Raglan Harbour			10.1	10.04		8.24	8.24				8.24	
Ruakaka Estuary										7		7
Tairua Harbour			3.7	3.9	3.9	3.9			3.9	4.8		4.8
Te Haruhi Bay				13.53								
Te Haumi Beach			10	9.9	9.9	9.9				9.81	9.81	
Umupuia Beach	*	*	25	36	36	36	36	36	36	36	36	36
Waikawau Bay			2.9	2.7				3.1	3.1			
Waiotahi Estuary				8.5		8.5	8.5	9.5	9.5		9.5	
Whangamata Harbour			5.48	5.48	5.48	5.48	5.48	5.48		24.61		24.61
Whangapoua Beach						1.66	5.2	5.2	5.2			5.2
Whangateau Harbour					64.19		64.15	64.15		64.15	64.51	64.51

APPENDIX 2: Satellite images of Ruakaka Harbour in 2010.

Figure A2.1: A satellite image of Ruakaka Estuary taken on 25 May 2010. Note how the channel morphology near the mouth of the estuary has changed over time (compare with Figure 21).