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The distribution and abundance of pipis and cockles in the Northland, Auckland, and Bay of Plenty regions, 2010

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EXECUTIVE SUMMARY

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Twelve beaches/harbours in the greater Auckland, Northland, and Bay of Plenty regions were surveyed between February 2010 and July 2010 to estimate the distribution, abundance, and size frequency of pipis (*Paphies australis*) and cockles (*Austrovenus stutchburyi*). As expected, no tuatua were found (none of the areas surveyed in 2009 were open coast beaches).

Before sampling, discussions with appropriate iwi and other interested locals were conducted to define (or refine) each survey area, such that two principal criteria would be met:

(i) 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 estuary/beach/harbour, and

(ii) the area should encompass where the shellfish populations of interest have been in the past and are therefore likely to be found in the future. This decision was made to ensure comparability with future surveys.

The target coefficient of variation (c.v.) of 20% on absolute abundance for cockles and pipi was met for all beaches containing reasonable densities of the target species (i.e. densities greater than 10 individuals per m^2).

Cockles

When comparing the 2010 cockle population at each beach with the previous study, none of the beaches showed strong evidence of a decline. Given the die off of cockles in the summer of 2008, it was somewhat surprising that Whangateau Harbour showed only weak evidence (p = 0.08) of a decline, with 15% fewer cockles than the estimate in 2006. However, Whangateau Harbour did show a marked decrease in the number of large cockles (over 30 mm). There was evidence that the cockle population increased at all other beaches except Little Waihi Estuary (which showed no evidence of a change). Compared to their previous survey estimate, cockle increases appeared significant at Aotea Harbour (a 100% increase), Ohiwa Harbour (493%), Umupuia Beach (429%), and Waiotahi (240%). However, while these specific changes were large, most populations were not unusual when examined in a broader context, i.e., most 2010 population estimates were at levels that had been seen in previous surveys. Only Mill Bay had an unusually high cockle population (relative to its previous population estimates).

Compared to the other beaches surveyed in 2010, Okoromai Bay contained a particularly large proportion of 'harvestable' cockles. This proportion was about four and five times higher than the two beaches with the next highest proportions (Cockle Bay and Whangateau Harbour). Harvestable cockles were far rarer at all of the other beaches (no other beach had harvestable proportions greater than 2.6%). There was evidence of a decline in harvestable cockle density at Mill Bay, Te Haumi, Umupuia, and Whangateau.

Pipis

There was evidence that the pipi population increased at four of the eight beaches containing pipi beds. Pipi increases were particularly large at Mill Bay and Waiotahi Estuary (609% and 136% more pipi than their 2005 survey respectively). In contrast, both Otumoetai and Whangateau Harbours showed evidence of a decline in the pipi population since 2006, falling to 73% and 16% of their respective 2006 survey population estimate.

Significant evidence of decreases in harvestable pipi density was found at Te Haumi beach and Ohiwa harbour. In contrast, Waiotahi Estuary and Raglan Harbour showed evidence of harvestable pipi density increases. Pipis of harvestable size were relatively common only in Raglan Harbour (20%). Ohiwa Harbour pipis had an intermediate proportion of harvestable pipis (8%) although this was smaller than the harvestable proportions found in previous years (26% in 2006 and 74% in 2005). The proportion of harvestable pipis at all other beaches was less than 3% of the total population. Significant evidence of decreases in harvestable pipi density was found at Te Haumi beach and Ohiwa harbour. In contrast, Waiotahi Estuary and Raglan Harbour showed evidence of increases in harvestable pipi density.

1. INTRODUCTION

1.1 General overview

The state of the 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). It is commonly perceived that the amateur harvesting of intertidal shellfish resources has been a major contributor to the decline of 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 main species of concern are pipi (*Paphies australis*), cockles (*Austrovenus stutchburyi*) and tuatua (*Paphies subtriangulata*). Recreational harvesting may have been a major contributor to the decline of shellfish abundance at popular beaches in the region.

The Ministry of Fisheries (MFish) 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, and Mt Maunganui beaches under s 186A of the Fisheries Act 1996. 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 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 & Ford 2006, Pawley et al. unpublished data, Walshe & Akroyd (2002, 2003, 2004), Walshe et al. (2005), Akroyd et al. (2000, 2001), Morrison and Browne (1999), Morrison et al. (1999), O'Shea & Kuipers (1994), Iball (1993), and Cook et al. (1992). The surveyed beaches and dates 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. Throughout the document I also refer to surveys by their AKI project year, e.g. ‘2009 survey’ and ‘2005 survey’ refers to the AKI2009 and AKI2005 surveys respectively (sample dates for specific beaches are shown in Appendix 1, Table A1.2).

2. OVERALL OBJECTIVE

To monitor shellfish populations on selected beaches in the Auckland Fisheries Management Area.

2.1 Specific objectives

1. To design/refine a monitoring programme for pipi and cockle shellfish populations on selected beaches in the Auckland Fishery Management Area to determine population trends to assist the Ministry in determining whether management intervention is required.
2. To undertake a survey of pipi and cockle populations on 12 selected locations within the Auckland Fishery Management Area in 2009/2010 in order to determine population trends to assist the Ministry in determining whether management intervention is required.

The beaches examined in the 2009 survey are shown in Figure 1.

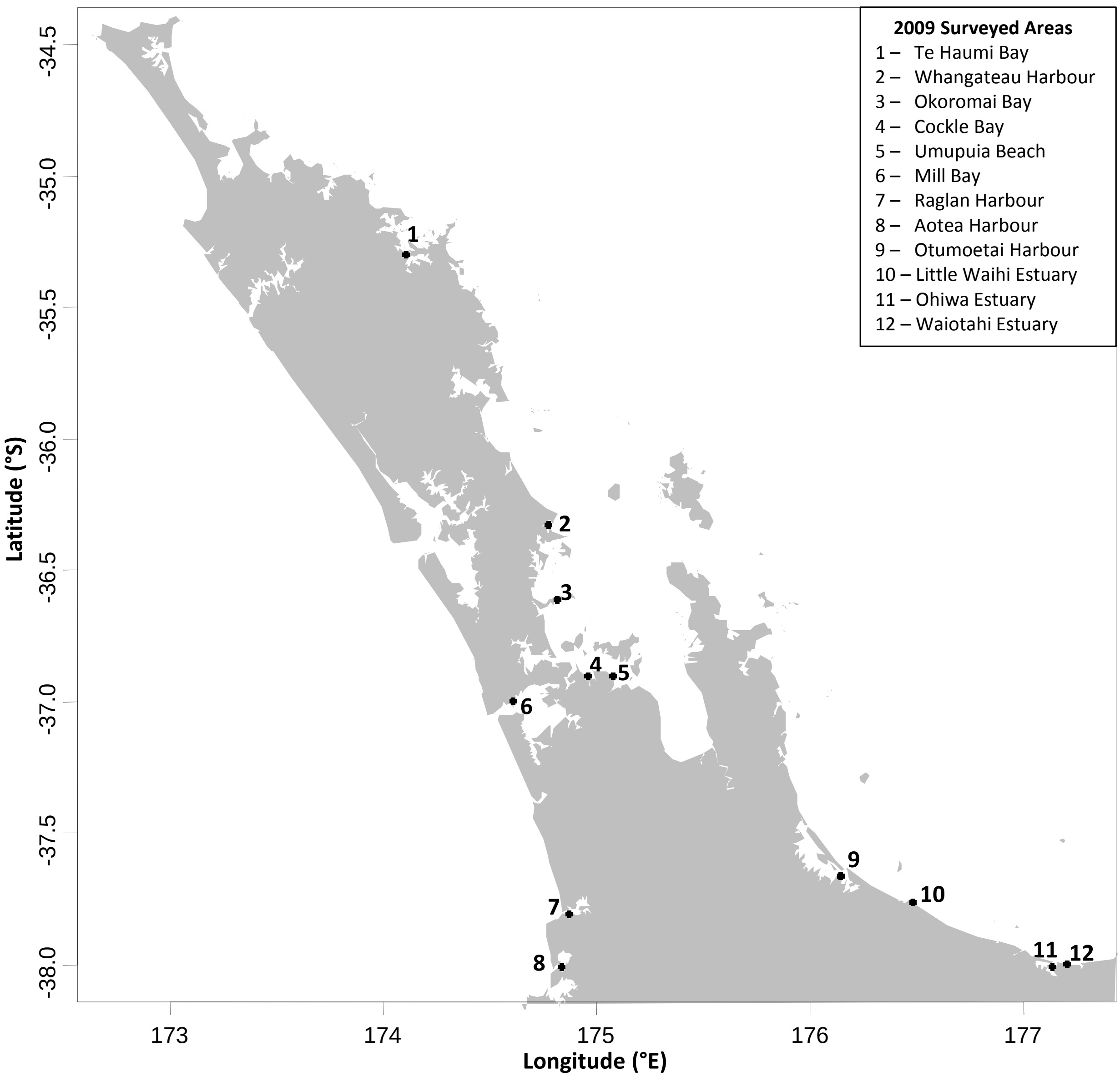

Figure 1: The 12 beaches sampled in the 2009 survey.

3. METHODS

3.1 Refining the sample extent

Before the 2009 survey, the Auckland Intertidal monitoring programme (AKI) focused on (i) population sustainability, (ii) pollution concerns, (iii) the effectiveness of beach closures, and (iv) areas under current high harvest pressure.

Following Pawley & Ford (2006), MFish extended the monitored area (the ‘sample extent’) so that two principal criteria would be met,

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 estuary/beach/harbour.
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.[2]

3.2 Survey methods

Since 1996, the sampling designs have been based on some combination of two techniques: a systematic design (Cochran 1977) and a two phase stratified random design (Francis 1984). The 2009 survey used the same sampling method used in 2006, i.e., a combination of both techniques to maximise power and logistical efficiency.

3.2.1 Site examination

The area under consideration was examined remotely (using Google Earth) and in person to determine the presence of any physical or environmental variables that may influence the spatial distribution of the shellfish populations. Useful environmental variables included: shell/sandbanks, gross topography, streams, sediment size, and conspecific shell abundance. This additional information was considered in order to possibly refine the strata that constitute the total sample extent, e.g., the main channels in Waiotahi and Little Waihi Estuaries have moved over the years. Strata were redefined to consist of the channel (between specific stable landmarks) rather than following a GPS based region. Following discussions with interested parties and local iwi (which indicated localised areas of fishing pressure), prominent features were recorded and spatially referenced (or mapped).

3.2.2 The initial sample (phase 1)

In all previously sampled beaches, the sample density was allocated to each stratum on each beach based on information from its most recent survey. Cockle Bay had not been previously surveyed by MFish, so the initial sample size allocation was determined using data collected by the Chinese Community Education Trust (CCET). 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).

[2]In many instances (particularly with cockle beds that are less likely to move), the previously defined sample extent was an appropriate indicator to determine when to close a beach/harbour.

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).

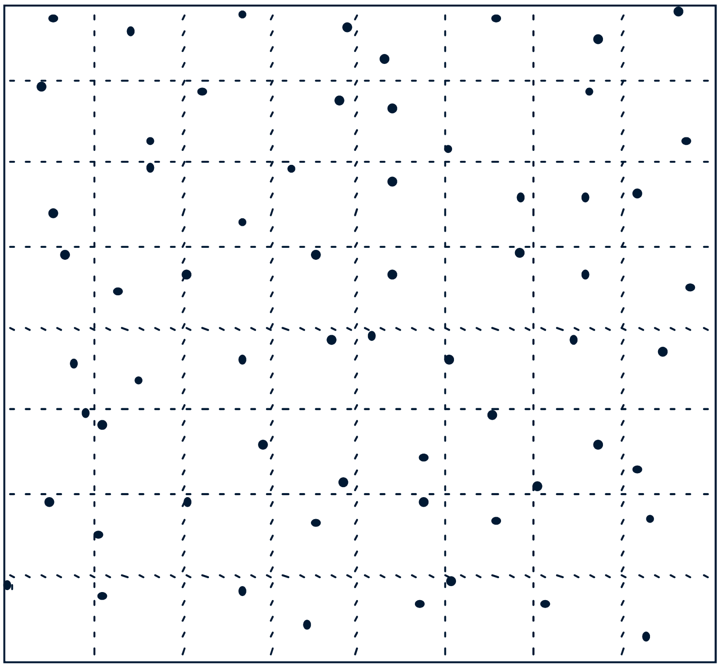

Figure 2: An example of a randomised systematic sample. The sample extent is divided using a grid (dashed lines), whose resolution depends on the sample size (a sample size of n = 8x8 = 64 is shown above). Within each grid section a sample is randomly positioned (circle).

3.2.3 The second phase of sampling

Using the two-phase sampling approach, 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 2009, second phase samples were required only at Whangateau Harbour (17 out of 108 samples in stratum A were second phase).

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 cross sectional area covered 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, but on strata with very dense populations (more than 1000 per m^2), only a random subset of 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 estimated count from the double core. These were standardised by scaling the units up to individual density per m^2. The total count in a stratum was then estimated by multiplying the mean density per m^2 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*), i.e.:

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

where for the h_{th} stratum, A_h is the area, s_h^2 is the variance of standardized 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 cockles counted divided by the total number of cockles measured ('sample unit weight').

These weights were multiplicative in effect. For example, if a stratum was 50% of the sample extent then regardless of the number of samples allocated to this stratum, all individuals would receive a stratum weight of 2 (i.e., each individual length was assessed as if it was counted twice). If one of the

[3] The size of estimation varies 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% times larger than the variance of the systematic sample means.

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 (= 50/20). In this example, the total weight applied to those individuals within that quadrat would be 5 (stratum weight x 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 made at each beach

At each beach, the populations of cockles, or cockles and pipis, 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).
- determining the weighted length frequency distribution (LFD) – see Section 3.3.2 for calculation details. Results from each LFD was plotted as a histogram (shown in Section 4.2).
- calculating the weighted length frequency distribution summary statistics (i.e., mean, mode, median, range, and inter-quartile range (IQR)).
- 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 Fisheries has been using 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 v2.11.0’ (R Development Core Team 2009).

4. RESULTS

4.1 Analysis of individual harbours[4]

4.1.1 Aotea Harbour

Beach description

A total of 160 samples was taken from Aotea Harbour across three distinct areas within the harbour; including:

(1) a cockle bed southeast of town (strata A and D, each covering an area of 400 x 200 m),

(2) a narrow subtidal strip (stratum B – a 1.8 km strip sampled to a depth of about 0.5 m below chart datum (CD) along the bank (averaging 20 m wide). The only easily accessible way to reach stratum B was by boat as there is no direct road access.

(3) a sand bank directly north of the township (stratum C, 8.5 ha). Anecdotal evidence from local iwi and residents suggest that the sand bank in front of Aotea town (stratum C) once contained high densities of pipi and we were asked to survey this area. The bank contained no trace of the pipi population and sample cores contained no pipi shells.

Strata C and D were sampled for the first time in the 2009 survey (Figure 3). Aotea Harbour was previously sampled in 2005.

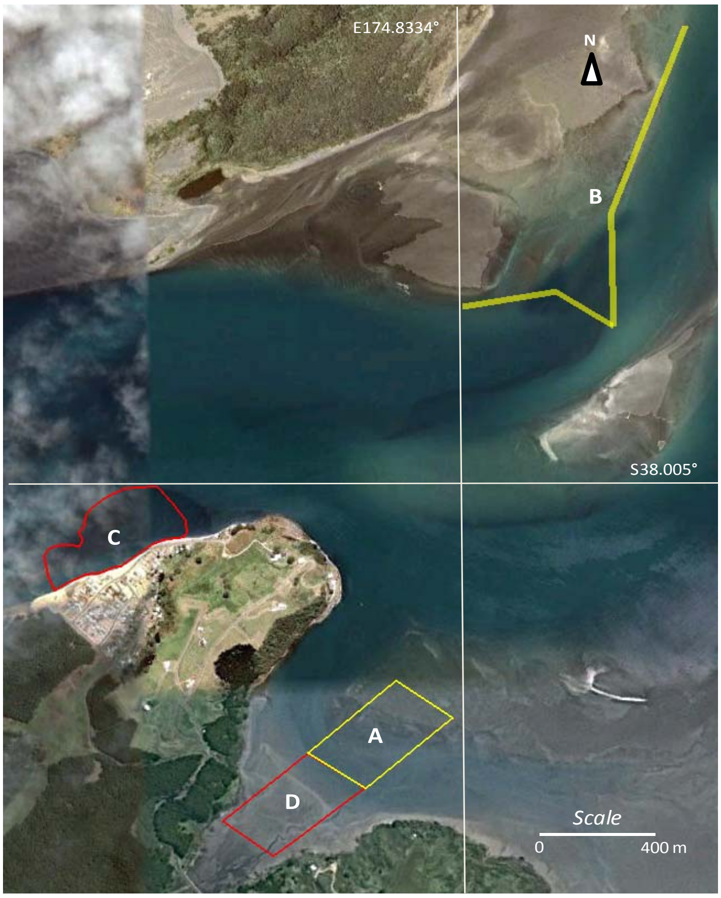

Figure 3: Aotea Harbour – the sample extent (depicted by polygon) consisted of 3 distinct areas (A–D); new strata (strata C and D) are denoted by red polygons).

[4] Beaches are presented in alphabetical order.

Aotea Harbour cockles

Strata A, B, and D each contained high densities of cockles (relative to other beaches in the survey), the average density of the strata was about 750, 900, and 250 cockles per m^2 respectively. No cockles were found in stratum C.

I estimate (with 95% confidence) that the entire 2009 sample extent contained 140.83 ± 29.6 million cockles (Table 1). Strata A and B (i.e., the sample extent in 2005) contained 72.35 ± 16.9 (95% CI) million cockles, i.e., between 24.8 million and 59.1 million more cockles than 2005.

Cockles were, on average, smaller than those found in the previous survey (Table 2), and there was no evidence of a difference in the number of harvestable cockles compared to the 2005 survey ($p = 0.17$, Table 3).

Table 1: Aotea cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2009 (All strata)	140.83	14.80	10.5	718.5
2009 (Strata A & B)	72.35	8.40	11.7	822.6
2009 (Stratum A only)	70.25	11.88	16.9	878.1
2005	30.42	2.18	7.2	345.9

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

Survey	Mean	Mode	Range	Median	IQR
2009	17.7	17	3–37	17	15–21
2005	21.7	22	6–36	22	19–25

Table 3: Aotea cockles ≥ 30 mm length.

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2009	2.1	0.6	10.8	1.5
2005	1.2	0.3	1.2	3.9

Aotea Harbour pipis

Only three pipis were found within the sample extent at Aotea Harbour (all in stratum B). No further analyses on Aotea Harbour pipis were completed.

Discussion – Aotea Harbour

The majority of cockles in the 2009 survey were found in the mudflat to the southeast of town (strata A and D). The 2005 survey found cockles solely in stratum A, The population there more than doubled since 2005. However, cockle size has not increased over this time (the average length has, if anything, decreased).

Stratum D was added in the 2009 survey because the area is more easily accessible than A (it is adjacent to the main road and does not require a spring tide to cross the channel), and is therefore likely to come under future harvesting pressure. The cockle population characteristics (density, LFD) in stratum D were similar to A. Cockles were patchily distributed in stratum B and individuals were about 5 mm smaller than those in strata A and D.

4.1.2 Cockle Bay

Beach description

Cockle Bay had not been previously sampled by an MFish funded project, but between 2005 and 2007 data were collected by the Chinese Community Education Trust (CCET) by sampling a pair of transects (sample points of the transects are shown as circles in Figure 4). Based on the CCET data, the MFish sample extent for Cockle Bay was split into two strata (reflecting different cockle densities) that covered the intertidal area directly in front of the main beach (Figure 4). A total of 289 samples was taken within the sample extent (Appendix 1, Table A1.3).

Figure 4: The Cockle Bay survey extent consisted of two strata (yellow polygons) based on information from the Chinese Community Education Trust (CCET) sample extent. Circles in the figure indicate the CCET sample positions.

Cockle Bay cockles

I estimate (with 95% confidence) that the 2009 sample extent for Cockle Bay contained 119.2 ± 13.1 million cockles (Table 4).

Cockle density within the sample extent was moderately high relative to other sampled beaches (372 cockles per m^2) with about 10% of the cockle population being of harvestable size. Cockles were typically between 19 and 25 mm in length (Table 5 and Table 6).

The 2009 survey results are shown in conjunction with the CCET survey results in Figure 5. The 2009 survey results show a relatively high density of cockles and a relatively high confidence in this density relative to the CCET results.

Table 4: Cockle Bay cockles – population estimate.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2009	119.2	6.6	5.5	372.6

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

Survey	Mean	Mode	Range	Median	IQR
2009	22	20	5–51	21	19–25

Table 6: Cockle Bay cockles ≥ 30 mm length.

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2009	11.8	1.2	36.5	9.8

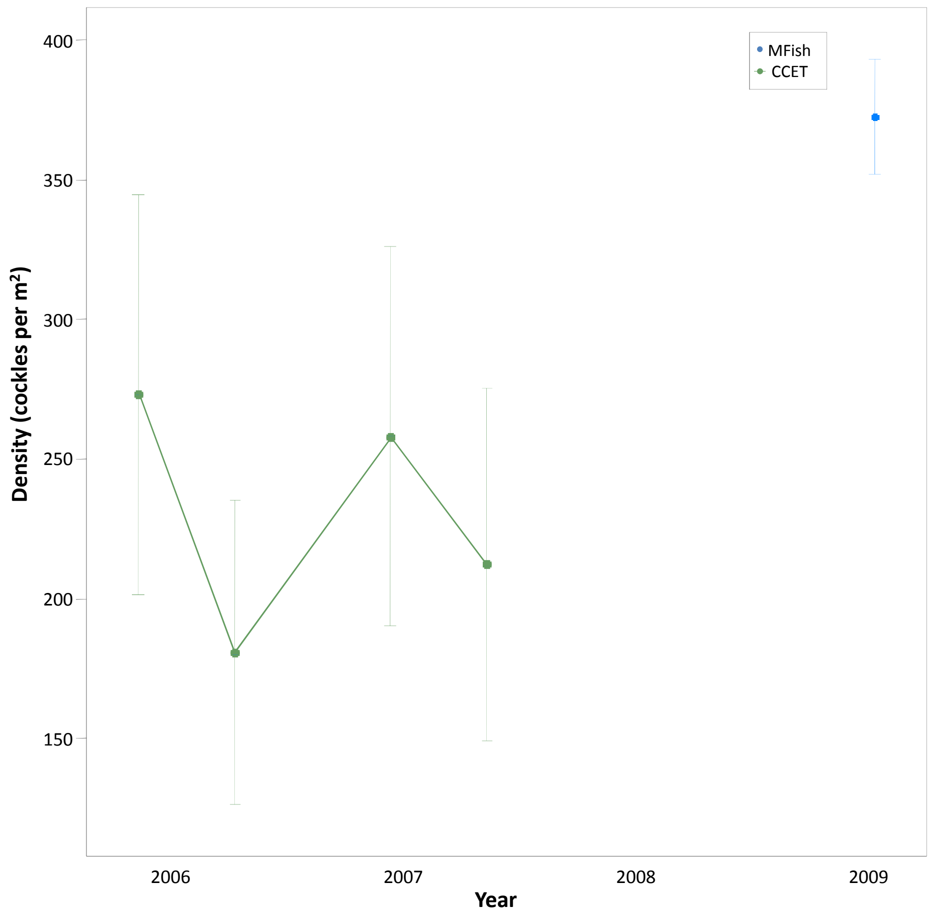

Figure 5: Mean cockle density (with standard error bars) at Cockle Bay, as estimated by CCET (2005–07) and MFish (AKI2009). Direct comparisons between surveys are not feasible since the MFish survey had a broader survey extent (see Figure 4).

Cockle Bay pipis

Only seven pipis were found within the sample extent at Cockle Bay (no analyses were done).

Discussion – Cockle Bay

The sample extent within Cockle Bay contained a moderate density of cockles. The proportion of harvestable cockles (10%) was high compared to most other beaches surveyed in 2009.
Although different survey extents meant that the CCET and MFish survey results are not directly comparable, the CCET survey results suggest that the cockle population is likely to be highly variable across years (e.g., the population almost halved between 2005 and 2006).

4.1.3 Little Waihi Estuary

Beach description

The sample extent for Little Waihi Estuary has always been near its mouth – approximately adjacent to the campervan park (left side of Figure 6). The 2009 survey found a considerable shift in the geomorphology of the area. The eastern sand bank at the mouth of the estuary had extended further west since the previous survey in 2006 and the entire main channel was able to be sampled during a spring tide (i.e., the entire channel within the sample extent was shallower than 0.5 m below chart datum). The sample extent was divided into four strata (A, mouth of estuary (rocky substrate); B, main channel; C, western bank (with juvenile pipis); and D, cockle bank) (Figure 6). The satellite image of this area from 2003 (Appendix 2) shows the change in bank morphology. The Little Waihi estuary has been previously surveyed in 2000, 2002–04, and 2006.

Figure 6: The sample extent for Little Waihi Estuary covered pipi and cockle populations found at the mouth of the estuary (yellow polygons indicate strata A–D that subdivide the sample extent).The eastern bank and the mouth of the channel have moved west since the 2006 survey. Previous sample strata are denoted by the black polygons but were not indicative of pipi or cockle beds in the 2009 survey.

To compensate for future changes in bank morphology, the sample extent was extended and defined as the entire area east of the campervan peninsula, including the sand bank west of the main channel that is uncovered at 0.5 m below CD. Since this was a wider area than in previous years, the population estimates were scaled up proportionately to the size of the new sample extent (see next section). A total of 174 samples was taken within the sample extent.

Rescaling previous population estimates in Little Waihi

The 2006 population estimates were calculated by rescaling two areas.

i. The population total from strata A–D (which covered 2.66 ha and lay within the channel) was rescaled to the sample extent area in the 2009 survey (9.87 ha); i.e., the population from these strata was multiplied by 3.71.
ii. The size of stratum E in previous surveys (0.5 ha) was rescaled to the size of the cockle bank survey area in the 2009 survey (5 ha).

Little Waihi Estuary cockles

I estimate (with 95% confidence) that the 2009 Little Waihi sample extent contained 20.4 ± 6.7 million cockles. There was no evidence of a change in the cockle population since 2006 (p = 0.28) (Table 7). Assuming that the average cockle population density in the previous survey (2006) was consistent over the new sample extent, I estimate that the 2009 survey had between 4.1 million fewer and 14.3 million more cockles than in 2006.

Cockle sizes were, on average, around 4 mm larger than the 2006 population, with typical cockles ranging between 15 and 21 mm (Table 8). However, there was little change in the population of harvestable cockles between 2009 and the previous survey (2006) (Table 9).

Table 7: Little Waihi cockles – population estimates. The 2006 population estimate was scaled (by a factor of 10) to compensate for the increase in stratum area in the 2009 survey.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2009	20.4	3.4	16.6	146.2
2006	15.3[5]	3.2	20.6	109.7

Table 8: Little Waihi cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2009	17.3	15	5–31	17	15–21
2006	13.5	13	5–31	13	10–16

Table 9: Little Waihi cockles ≥ 30 mm length.

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2009	0.10	0.052	0.44	0.3
2006	0.06	0.005	0.44	0.4

[5] See section on rescaling the population.

Little Waihi Estuary pipis

Little Waihi Estuary had a very high density of pipis (averaging 2075 per m^2). I estimate (with 95% confidence) that the 2009 Little Waihi sample extent contained 288.9 ± 69 million pipis (Table 10). Assuming that the average pipi population density in the previous survey (2006) was consistent over the new sample extent, then I estimate that the 2009 survey had between 48.5 million and 195.1 million more pipis than in 2006 (Table 10), i.e. there was strong evidence of an increase in the pipi population ($p<0.01$).

The 2009 pipi LFD for Little Waihi was bimodal, with modes around 17 and 36 mm. The typical pipi size was between 25 and 41 mm – little different from the 2006 population (Table 11). There was no evidence of a difference between the 2009 and 2006 survey population estimates for harvestable pipis ($p > 0.12$) (Table 12).

Table 10: Little Waihi pipis – population estimates

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2009	288.9	34.9	12.1	2075
2006	167.1	12.5	7.5	1200

Table 11: Little Waihi pipis – weighted length frequency distribution summary statistics (mm)

Survey	Mean	Mode	Range	Median	IQR
2009	32.7	17, 36	7–55	35	25–41
2006	31.6	34	5–65	32	23–40

Table 12: Little Waihi pipis ≥ 50 mm length

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2009	6.8	1.3	56.0	2.7
2006	6.6	0.7	54.0	4.5

Discussion – Little Waihi

To compare between surveys, it was necessary to make some assumptions about the population in previous surveys – namely that the population characteristics (density, length frequency distribution etc) were consistent in the unsampled areas on the bank and main channel. All comparisons between years are reliant upon this caveat.

In the 2009 survey, the entire bank west of the main channel was sampled (Figure 6), although most cockles were found near the edges of the bank. Assuming the caveats mentioned above, the cockle population appears relatively unchanged. The proportion of cockles that were of harvestable size remains relatively small (under 1% in 2009 and 2006) compared to the 2004 survey (about 4.5%).

The pipi population appears to have markedly increased since 2006. This increase was mainly due to an influx of juvenile pipi (less than 20 mm) found on the western bank of the estuary. The density of pipis in this area averaged 5118 per m^2 – a very high density relative to other strata (and other surveyed beaches). In contrast, the pipi density within the main channel of the estuary was relatively stable in the 2009 and 2006 surveys (3560 and 3572 pipis per m^2 respectively).

4.1.4 Mill Bay

Beach description

The sample extent for Mill Bay covers most (4.95 ha) of the intertidal area (Figure 7). A total of 118 samples was taken from the sample extent. Mill Bay was previously sampled 1999–2001 and 2003–05.

Figure 7: The sample extent for Mill Bay (yellow polygon).

Mill Bay cockles

I estimate (with 95% confidence) that the 2009 sample extent contained 11.2 ± 2.0 million cockles (Table 13). There was strong evidence of an increase in the cockle population since the previous survey (p<0.01). I estimate that 2009 had between 2 million and 6.9 million more cockles than in 2005 (Table 13).

The typical (median) cockle size was 11 mm smaller than those found in 2005 (Table 14). Despite the increase in total population size, there were fewer cockles of harvestable size than in 2005 (p<0.01) (Table 15).

Table 13: Mill Bay cockles – population estimates

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2009	11.2	1.0	8.9	226.4
2005	6.7	0.7	10.9	135.8

Table 14: Mill Bay cockles – weighted length frequency distribution summary statistics (mm)

Survey	Mean	Mode	Range	Median	IQR
2009	13.9	9	3–33	11	9–19
2005	21	27	6–35	22	16–27

Table 15: Mill Bay cockles ≥ 30 mm length

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2009	0.08	0.02	1.6	0.7
2005	0.51	0.07	103.2	7.6

Mill Bay pipis

Mill Bay contained a low density of pipis (relative to other beaches), averaging about 113 pipis per m^2). I estimate (with 95% confidence) that the 2009 sample extent contained 5.6 ± 1.9 million pipis (Table 16). There was strong evidence of an increase in the pipi population since the previous survey (p<0.01). I estimate that 2009 had between 2.9 million and 6.7 million more pipis than in 2005 (Table 16).

The mean and median size of Mill Bay pipis in the 2009 survey were respectively 4 and 5 mm smaller than those found in 2005 (Table 17). No pipis of harvestable size (over 50 mm) were found.

Table 16: Mill Bay pipis – population estimates

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2009	5.6	0.97	17.4	112.9
2005	0.8	0.15	19.4	15.9

Table 17: Mill Bay pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2009	17	11	5–49	15	11–21
2005	21	19	6–52	20	16–23

Discussion – Mill Bay

The Mill Bay cockle total population increased significantly since 2005. However, cockle size has decreased and harvestable cockle density has dropped from 103.2 per m^2 (2005) to 1.5 per m^2. Less than one per cent of the cockles sampled were of harvestable size.

The pipi population has increased markedly since 2005. The lack of large pipis was unsurprising; very few pipis over 50 mm have been found historically (only one was found in 2005).

4.1.5 Ohiwa Estuary

Beach description

The sample extent for Ohiwa Estuary is split into four strata A, B, C, and E (with respective sizes 0.6, 0.3, 0.3, and 0.9 ha) lying near the channel on the northern and eastern banks of Motuotu Island. These strata are easily accessible only by boat (Figure 8). The 2009 survey found the survey area on the northwestern corner of Motuotu Island to be covered by coarse, lightly-packed sand. Ngati Awa and Whakatohea iwi representatives expressed surprise at the change of the bank shape and substrate; the banks were steeper and the shelly substrate had disappeared since the 2006 survey. However, despite the changes in geomorphology, the pipi beds were still found in about the same positions as in previous surveys. The subtidal area (down to about 0.5 m below CD) on the northern end of the island was surveyed. The sample extent covered while searching for the pipi beds is denoted by a red line in Figure 8.

A total of 161 samples were taken within the sample extent. Before the 2009 survey, Ohiwa Estuary was sampled in 2001, 2005 and 2006.

Figure 8: The Ohiwa Estuary sample extent is spread around Motuotu Island (yellow polygons depict the sampled strata). The red line denotes the low tide contour line around the northern end of island that was searched for pipi beds. Strata A and B lie along the western edge of the main channel.

Ohiwa Estuary cockles

I estimate (with 95% confidence) that the 2009 sample extent for Ohiwa Estuary contained 6.4 ± 1.1 million cockles. There was strong evidence of an increase in the cockle population since the previous survey (p<0.01). I estimate that 2009 had between 4.2 million and 6.5 million more cockles than in 2006 (Table 18).

Cockles were of similar size to those found in 2006, typically falling between 13 and 19 mm (Table 19). The population of harvestable cockles was also unchanged in the 2009 survey, with a smaller proportion of cockles being of harvestable size (Table 20).

Table 18: Ohiwa cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2009	6.4	0.6	8.8	304.7
2006	1.1	0.1	12.3	51.4
2005	3.7	0.4	10.8	175.7

Table 19: Ohiwa cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2009	16.6	16	5–35	17	13–19
2006	17.0	18	3–44	17	12–21
2005	22.2	24	8–38	22	19–25

Table 20: Ohiwa cockles ≥ 30 mm length.

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2009	0.015	0.01	0.61	0.2
2006	0.015	0.01	0.77	1.5
2005	0.17	0.03	8.01	4.6

Ohiwa Estuary pipis

I estimate (with 95% confidence) that the 2009 sample extent for Ohiwa Estuary contained 14.7 ± 4.1 million pipis. There was strong evidence of an increase in the pipi population since the previous survey ($p<0.01$). I estimate that 2009 had between 2.1 million and 10.7 million more pipis than in 2006 (Table 21).

Pipis were, on average, 4 mm smaller than the 2006 survey and about 13 mm smaller than those found in the 2005 survey. The typical length was between 35 and 45 mm (Table 22).

There was strong evidence of a decrease in the number and proportion of harvestable pipis ($p < 0.001$) (Table 23).

Table 21: Ohiwa pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2009	14.7	2.0	13.9	698.4
2006	8.3	0.87	10.5	394.3
2005	3.4	0.4	11.8	161.5

Table 22: Ohiwa pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2009	39.4	42	11–57	41	35–45
2006	43.2	44	4–68	44	40–48
2005	51.4	56	18–69	54	45–58

Table 23: Ohiwa pipis ≥ 50 mm length.

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2009	1.15	0.15	54.5	7.8
2006	2.14	0.22	102.1	25.9
2005	2.52	0.19	119.5	74.0

Discussion – Ohiwa harbour

The changes in the beach substrate and morphology make it difficult to assess whether the apparent increase in pipi population is due to a geographical shift in the population to more accessible (i.e., shallower) areas or an increase in the population. Regardless of the reason, there is strong evidence that the current accessible population of pipis on the northern end of Motuotu Island is considerably larger than was found in previous studies. The cockle population in strata A and B (on the eastern side of the island) also increased (almost six-fold) since 2006. However, the number and density of harvestable cockles were similar to what was found in 2006. Harvestable cockles in 2005 were found in greater numbers and density than either of the most recent surveys.

Despite the increase in pipi numbers, the numbers of harvestable pipis has dropped since 2006. The proportion of pipis that were of harvestable size has dropped sharply since the 2005 and 2006 surveys.

4.1.6 Okoromai Bay

Beach description

The sample extent for Okoromai Bay is split into two strata (A and B, of 8 and 12 ha respectively) encompassing most of the suitable area for cockles (Figure 9). Most of the substrate in A was covered by the sea-grass *Zostera*. Strata A and B both have rocky substrate on each side and contain moderate cockle density relative to other sampled beaches (about 60 and 280 cockles per m^2 respectively). A total of 223 samples was taken within the sample extent.

Before the 2009 survey, Okoromai Bay was previously sampled in 1996–99, 2001–04 and 2006.

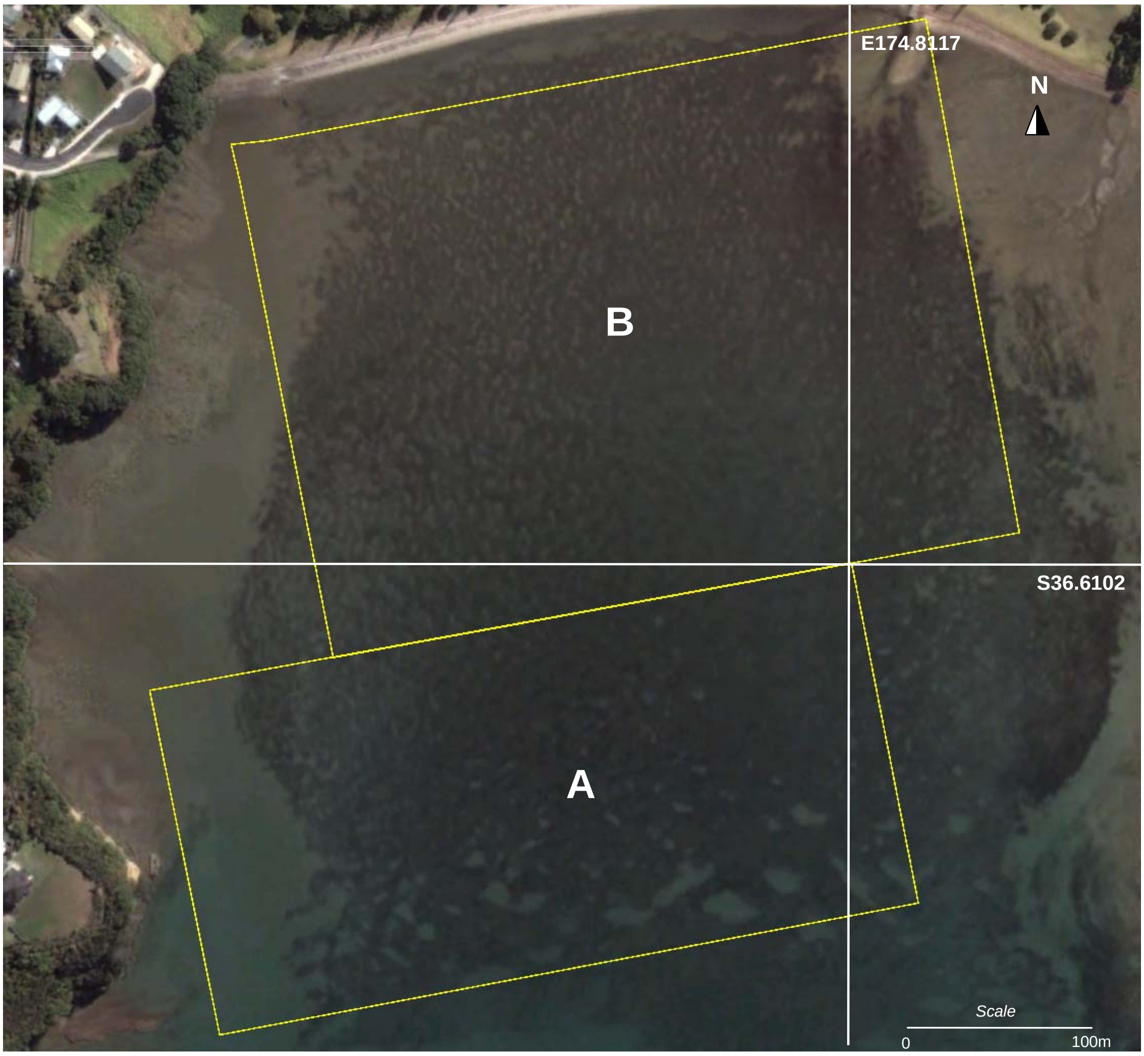

Figure 9: Okoromai Bay – sample extent consists of two strata (yellow polygons) covering cockle beds.

Okoromai Bay cockles

I estimate (with 95% confidence) that the Okoromai Bay 2009 sample extent contained 29.3 ± 5.6 million cockles. There was very strong evidence of an increase in the number of cockles since the previous survey (p<0.01). I estimate there was between 3.1 million and 16.3 million more cockles than in the 2006 survey (Table 24).

Cockles were similar in size to those in 2006. Typical sizes were between 23 and 31 mm (Table 25), with 90 percent of all individuals 18 mm or larger.

There was no evidence of a change in the population or proportion of harvestable cockles between the 2006 and 2009 surveys (p = 0.1) (Table 26).

Table 24: Okoromai cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2009	29.3	2.8	9.6	146.7
2006	19.6	1.8	9.3	98.0
2004	34.5	3.6	10.4	172.9

Table 25. Okoromai Bay cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2009	26.8	29	5–47	29	23–31
2006	27.3	30	5–44	29	24–32
2004	29.0	31	8–42	27	22–31

Table 26: Okoromai cockles ≥ 30 mm length.

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2009	10.6	0.89	53.0	36.1
2006	8.48	0.90	42.4	43.3
2004	13.8	0.89	69.0	40.0

Okoromai Bay pipis

No analysis was made of the pipi population – only two pipis have been found in the last three surveys.

Discussion – Okoromai Bay

Although the 50% increase in cockle numbers since 2006 appears to be a dramatic change, it falls well within the inter-annual variation seen in cockle numbers since 1999. The most recent increase simply reverses the population decline found between the 2004 and 2006 surveys (i.e., the population almost halved between those years).

Harvestable cockles still make up more than a third of all cockles sampled at Okoromai Bay – a high proportion relative to other beaches in the survey. The estimated density of harvestable cockles in the 2009 survey sits between the 2004 and 2006 estimates.

4.1.7 Otumoetai Harbour

Beach description

The sample extent of Otumoetai Harbour covers a large subtidal pipi bed on the edge of the main channel (strata A and B, each 1.8 ha). The sample extent also encompassed a cockle bed located several kilometres towards the southwest (strata C and D, each 1 ha). At the request of Ngai Te Rangi kai tiaki, an intertidal area between the pipi beds and cockle beds was also examined (Figure 10). Neither pipis nor cockles were found in this area (no further analyses were done on this area). A total of 203 samples was taken within the sample extent that was standard in previous years (i.e., strata A–D). Otumoetai was previously sampled in 2000, 2002, 2005, and 2006.

Figure 10: Otumoetai Harbour with previously sampled strata depicted by yellow polygons. The western strata (A and B) lie on the edge of a channel, and primarily consist of a pipi bed (with some cockles). The eastern strata (C and D) cover a cockle bed near the shore. At the request of Ngai Te Rangi representatives, the 2009 survey also examined an intertidal area to the west of strata C and D (depicted by the red polygon).

Otumoetai Harbour cockles

I estimate (with 95% confidence) that the 2009 Otumoetai Harbour sample extent had 14.6 ± 3.1 million cockles. There was no evidence of a change in the cockle population (p = 0.4) since the previous survey. I estimate that 2009 had between 4.1 million fewer to 3.8 million more cockles than 2006 (Table 27).

Cockle size in the 2009 survey was little different from 2006; typical cockle size was between 13 and 19 mm (Table 28). There is weak evidence that the harvestable population was bigger than that found in 2006 (p = 0.07), but harvestable cockle density was low (fewer than 4 cockles per m^2) (Table 29).

Table 27: Otumoetai cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2009	14.6	1.58	10.9	260.5
2006	14.8	1.2	8.3	263.4
2005	3.8	0.7	18.4	67.6

Table 28: Otumoetai cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2009	15.8	15	3–39	15	13–19
2006	16.3	18	4–32	17	13–20
2005	17.6	16	6–33	17	14–21

Table 29: Otumoetai cockles ≥ 30 mm length.

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2009	0.21	0.09	3.6	1.4
2006	0.041	0.02	1.1	0.4
2005	0.03	0.02	0.5	0.8

Otumoetai Harbour pipis

I estimate (with 95% confidence) that the Otumoetai Harbour 2009 sample extent had 17.2 ± 2.5 million pipis. There was evidence of a decrease in the pipi population since the previous survey (p<0.01). I estimate that 2009 had between 2.6 million and 10.2 million fewer pipi than 2006 (Table 30).

On average, the 2009 survey pipi sizes were 7 to 10 mm larger than 2006. Typical pipi size was 35 to 45 mm (Table 31). Only 4% of the population was estimated to be larger than 50 mm. There was no evidence of a decline in the harvestable pipi population since 2006 (p > 0.15) (Table 32).

Table 30: Otumoetai pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2009	17.2	1.2	7.2	306.8
2006	23.6	1.5	6.4	422.1
2005	34.3	1.5	4.3	611.1

Table 31: Otumoetai pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2009	39.2	42	11–75	41	35–45
2006	32.5	29	9–61	31	29–35
2005	34.3	32	13–81	33	29–39

Table 32: Otumoetai pipis ≥ 50 mm length.

Survey	Population estimate (millions)	Population SE (millions)	Average density (per m^2)	Proportion of total population (%)
2009	0.68	0.15	12.3	4.0
2006	1.01	0.17	18.2	4.3
2005	1.62	0.14	28.7	4.7

Discussion – Otumoetai

The number of cockles within the Otumoetai Harbour sample extent was not significantly different from that in the previous survey (AKI2006). Very few cockles of harvestable size were found, a result consistent with previous surveys. In contrast, the total pipi population has sequentially decreased by about 30% in surveys since 2005 and the number and proportion of harvestable pipis remains low relative to 2005.

4.1.8 Raglan Harbour

Beach description

The sample extent for Raglan Harbour encompassed two distinct areas:

(1) an area alongside Wainui Road (strata A and C, between the bridges). These strata covered 5 and 0.24 ha respectively.

(2) a mudflat lying north of town (stratum D, covering 3 ha) (Figure 11).

A total of 180 samples was taken within the sample extent. Raglan Harbour was previously sampled in 1999, 2000, 2002, and 2003.

Figure 11: Raglan Harbour – the sample extent (yellow polygons) covered two different areas. The initial sample extent for Stratum C extended the subtidal strip to cover almost the entire area between the bridges (down to 0.5 m below CD – red polygon); however, the pipi bed was found in the same area as the previous survey (2003).

Raglan Harbour cockles

The Raglan Harbour sample extent contained very high densities of cockles relative to other beaches in the survey (averaging about 1500 per m^2). I estimate (with 95% confidence) that the Raglan Harbour 2009 sample extent had 124.4 ± 12.9 million cockles (Table 33). There was strong evidence of an increase in the cockle population since the previous survey ($p < 0.001$). I estimate that the 2009 population had between 18.8 million and 50.3 million more cockles than 2003.

The median cockle size in the 2009 survey was 2 mm smaller than the previous (2003) survey, with typical cockles ranging between 17 and 23 mm (Table 34). There was no evidence of a change in the number of harvestable cockles since the previous survey ($p = 0.5$) (Table 35).

Table 33: Raglan cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2009	124.4	6.5	5.2	1509
2003	89.8	4.6	5.1	1090

Table 34: Raglan cockles — weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2009	19.4	19	5–45	19	17–23
2003	–	23	6–39	22	19–25

Table 35: Raglan cockles population estimates ≥ 30 mm length.

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2009	3.2	0.77	39.2	2.6
2003	3.8	0.44	45.8	4.2

Raglan Harbour pipis

Most pipis were found within the channel between the bridges (Stratum C). I estimate (with 95% confidence) that the 2009 Raglan Harbour sample extent had 0.59 ± 0.2 million pipis (Table 36). There was no evidence of a change in the pipi population since the previous survey (p = 0.25). I estimate that the 2009 population had between 0.12 million fewer and 0.41 million more pipis than in 2003.

The 2009 LFD was bimodal, with peaks around 19 and 51 mm. Pipis were of similar size to the previous survey, with typical pipi lengths from the 2009 survey ranging between 21 and 49 mm (Table 37). There was evidence of increases in the population total (p < 0.01) and the proportion of harvestable pipis (p < 0.01) compared with the previous survey (Table 38).

Table 36: Raglan pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2009	0.59	0.11	19.1	7.2
2003	0.44	0.07	15.2	5.4

Table 37: Raglan pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2009	35.9	19, 51	9–59	39	21–49
2003	-	38	13–59	40	34–45

Table 38: Raglan pipis population estimates ≥ 50 mm length.

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2009	0.12	0.02	1.41	19.6
2003	0.02	0	0.24	4.5

Discussion – Raglan Harbour

In the six years since the previous survey, the cockle density within the Raglan Harbour sample extent has increased by almost 50%. Cockle size has remained relatively low; less than 3% of the sampled cockles were of harvestable size.

The pipi density has remained relatively static since 2003. However, the number and proportion of harvestable pipis has increased significantly and substantially – almost 20% of pipis found were larger than 50 mm, compared with less than 5% in the same size fraction in 2003.

4.1.9 Te Haumi Bay

Beach description

The sample extent at Te Haumi Bay consists of two strata (A and B, covering 3 and 6 ha respectively) that cover most of the main beach with an additional pipi bank (stratum C – 0.8075 ha) in the estuary (on the western side of the main road –Figure 12).

The large 'L'-shaped shell/sand bank that was used to subdivide stratum B in the 2006 survey was still evident in the 2009 survey. This bank appears to shelter the southern side of the stratum which generally contained finer sediment substrate and more cockles. A total of 257 samples was taken from the sample extent. Additional samples were taken from stratum D, an area south of strata A and B on the main beach. This stratum covered the river to a depth of about 0.5 m below CD.

Before the 2009 survey, Te Haumi Bay was sampled in 1999–2002 and 2006.

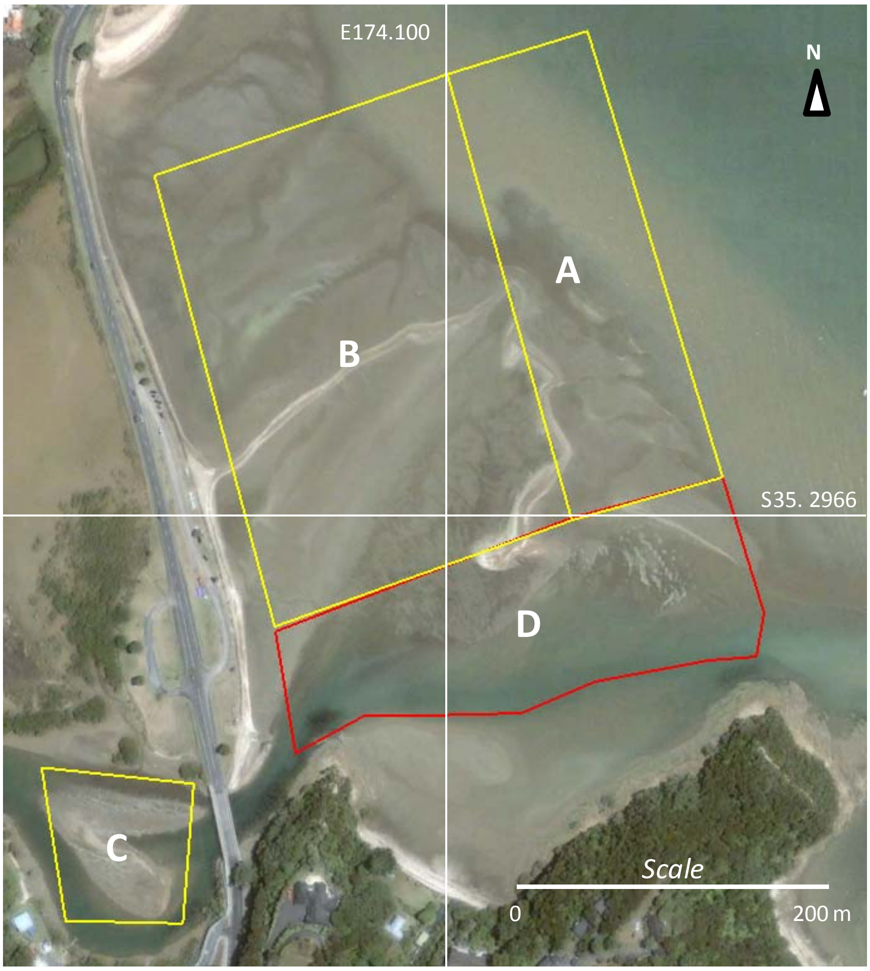

Figure 12: Te Haumi Bay sample extent consisted of two distinct areas – the intertidal area of the main beach (strata A and B) and a small pipi bed on the inner estuary (stratum C). Stratum B exhibited a shell/sand bank that roughly split it into two parts (visible in the figure). Stratum D (adjacent to the river to the south of the main beach) was sampled, but not included in population calculations.

Te Haumi Bay cockles

Within strata A, B, and C (i.e., those areas consistent with previous surveys), I estimate (with 95% confidence) that the Te Haumi Bay sample extent contained 30.3 ± 5.5 million cockles. There was strong evidence of an increase in the cockle population in this area since the previous survey (p<0.001). I estimate that there were between 4.9 million and 17.9 million more cockles than in 2006 (Table 39).

Population estimates of cockles and harvestable cockles that include stratum D are shown in Table 39 and Table 40.

The mean and median cockle sizes in the 2009 survey were respectively 4 and 5 mm smaller than in 2006 (Table 40). There was strong evidence of a decrease in the number of harvestable cockles since 2006 (p<0.001). I estimate that there were between 0.9 million and 2.1 million fewer harvestable cockles than in 2006. The number of harvestable cockles in 2009 (in strata A - C) was less than the previous survey (p < 0.01) (Table 41).

Table 39: Te Haumi cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2009 (Strata A–C)	30.26	2.75	9.1	308.5
2009 (Strata A–D)	34.65	3.34	9.7	287.4
2006 (Strata A–C)	18.85	1.8	9.6	192.5

Table 40: Te Haumi cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2009	18.6	20	5–47	19	13–21
2006	22.3	28	4–42	25	14–29

Table 41: Te Haumi cockle population estimates ≥ 30 mm length.

Survey	Population Estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2009 (Strata A–C)	0.57	0.16	5.6	1.8
2009 (Strata A–D)	1.74	0.45	14.4	5.0
2006 (Strata A–C)	2.1	0.25	21.4	11.1

Te Haumi Bay pipis

I estimate (with 95% confidence) that the 2009 Te Haumi Bay sample extent contained between 43.5 ± 10.8 million pipis. No pipis were found in stratum D. There was weak evidence of an increase in the pipi population since the previous survey (p = 0.08). I estimate that the 2009 survey had between 1.4 million fewer and 24.8 million more pipis than in 2006 (Table 42).

Mean and median pipi lengths in the 2009 survey were respectively 9 and 11 mm less than in 2006; typical pipi size in 2009 ranged between 13 and 27 mm (Table 43). Despite the increase in the total population, there was strong evidence of a decrease in the number of harvestable pipis since the previous survey (p<0.001); a change reflected by the marked drop in the proportion of harvestable pipis (Table 44).

Table 42: Te Haumi pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2009	43.5	5.5	9.1	443.6
2006	31.8	3.7	11.7	324.3

Table 43: Te Haumi pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2009	20.8	17	3–55	19	13–27
2006	30	18	3.5–60	30	19–41

Table 44: Te Haumi pipi population estimates ≥ 50 mm length.

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2009	0.13	0.03	1.3	0.3
2006	1.19	0.18	11.9	3.7

Discussion – Te Haumi Bay

The cockle population increased by around 61% since the last survey (2006). Samples from the new area (stratum D) found no pipis but had a similar cockle density to the other strata on the main beach (A and B). About 20% of cockles in stratum D were of harvestable size, a far higher proportion than was found within the main beach. However, excluding stratum D, the population and proportion of harvestable cockles appears to have declined since 2006.

The changes in the pipi population were similar to those found with cockles. That is, the total 2009 population was significantly greater than in 2006, but with a marked decrease in the number and proportion of harvestable pipis.

4.1. 10 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 13). Before the 2009 survey, Umupuia was surveyed 1997–2006.

Figure 13: 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 2009 Umupuia Beach sample extent contained between 61.0 ± 13.6 million cockles. There was strong evidence of a change in the cockle population since 2006 (p<0.001). I estimate that 2009 had between 35.8 million and 63.8 million more cockles than in 2006 (Table 45).

Cockle sizes were, on average, about 6 to 7 mm smaller than in previous surveys. Typical cockle length was 19 to 25 mm (Table 46).

There was evidence of a decrease in the number of harvestable cockles since 2006 (p = 0.04). The number and proportion of harvestable cockles (relative to the total population size) was markedly lower than the previous surveys (Table 47).

Table 45: Umupuia cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
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 46: Umupuia cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
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 47: Umupuia cockle population estimates ≥ 30 mm length.

Survey	Population Estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
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

Umupuia Beach pipis

Population estimates were not calculated for pipi at Umupuia (no pipi were found during the 2009 survey).

Discussion – Umupuia beach

There was a consistent decline in the Umupuia Beach cockle population between 2000 and 2006 that led to a 186A[6] closure of the beach. The 2009 survey found a marked increase in the cockle population (similar to the population that was found in 2000 or 2001). The increase in cockles was due to an influx of smaller individuals (less than 30 mm). Despite the increase in the total cockle population, the number (and proportion) of harvestable cockles still appeared to be in decline.

[6] 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.

4.1.11 Waiotahi Estuary

Beach description

The sample extent for Waiotahi Estuary covered the area that started at the western end of a sand bank in the river (Figure 14) and extended to the mouth of the estuary. The additional area to the north and west of stratum A contained no cockles or pipis in the 2009 survey. The entire estuary channel was sampled within this extent, i.e., the limits of previously defined strata B, C, and E approximately defined the new strata positions. A total of 195 samples was taken from the sample extent. The areas encompassed by strata A–E were: 3, 3, 1, 1.5, and 1 ha respectively. Before the 2009 survey, Waiotahi Estuary was previously surveyed in 2000 and 2002–05.[7]

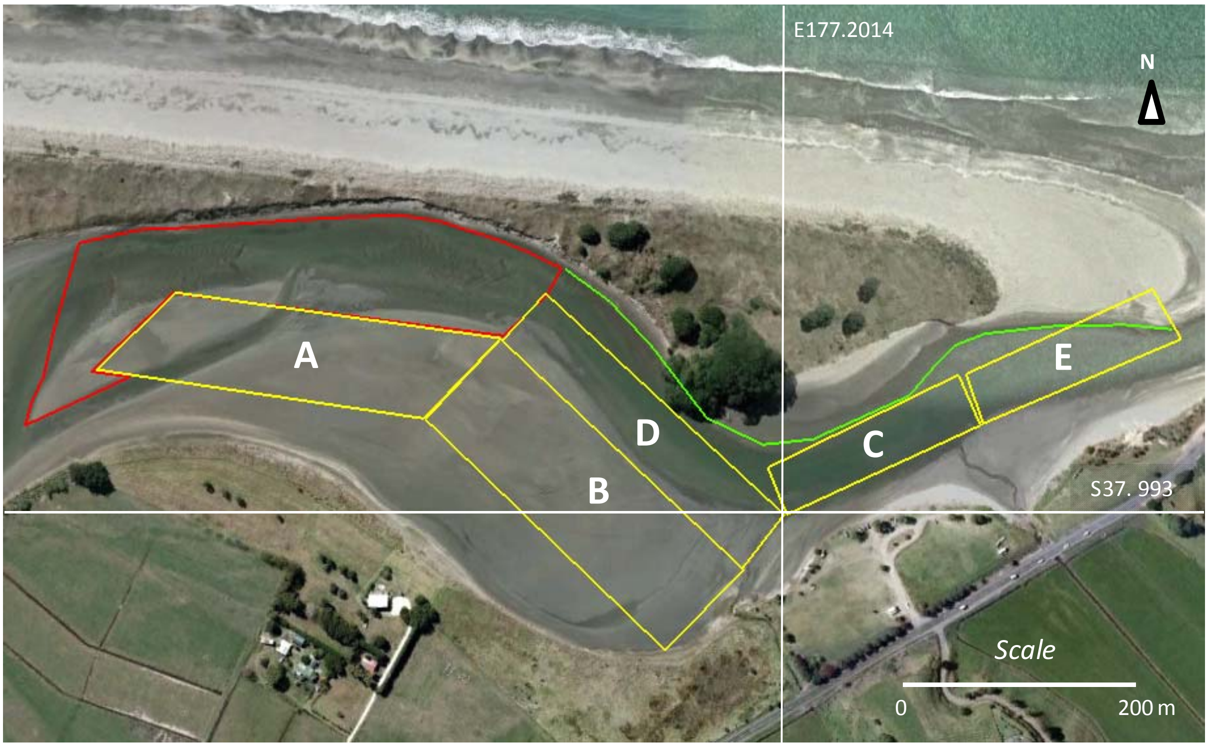

Figure 14: Waiotahi Estuary –the sample extent was historically split into five strata, A–E, (yellow polygons). The green line shows the 2009 survey boundary for strata D, C and E (which followed the low tide mark of the northern side of the estuary). The red polygon indicates an extended sample extent compared to previous surveys (although) no cockles or pipi were found within this area.

Waiotahi Estuary cockles

I estimate (with 95% confidence) that the 2009 sample extent had 20.0 ± 6.1 million cockles (Table 48). There was strong evidence of an increase in the cockle population since the previous survey (p<0.001). I estimate that 2009 had between 7.6 million and 20.6 million more cockles than in 2006 (Table 48).

The median cockle size in 2009 was 5 mm larger than in 2006 (Table 49), with typical cockle sizes ranging between 15 and 21 mm. There was no evidence of a change in the number of harvestable cockles since 2006 (p = 0.23). However, the proportion of harvestable cockles in 2009 appeared to be smaller than the previous survey (Table 50).

[7] Stratum E was added in 2005.

Table 48: Waiotahi cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2009	20.0	3.1	15.5	210.2
2005	5.9	1.0	16.3	61.8

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

Survey	Mean	Mode	Range	Median	IQR
2009	18	19	5–35	19	15–21
2005	15	12	7–39	14	11–18

Table 50: Waiotahi cockle population estimates ≥ 30 mm length.

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2009	0.02	0.01	0.2	0.1
2005	0.09	0.05	2.2	1.5

Waiotahi Estuary pipis

I estimate (with 95% confidence) that the Waiotahi Estuary 2009 survey had 95.8 ± 23.6 million pipis (Table 51). There was strong evidence of an increase in the pipi population since the previous survey (p<0.001). I estimate that the 2009 survey had between 28.2 million and 82.1 million more pipis than in 2006 (Table 51).

Waiotahi Estuary pipis in the 2009 survey were, on average, 5 mm smaller than in 2006, with typical pipis ranging between 19 and 39 mm (Table 52). There was evidence of an increase in the number of harvestable pipis since 2006 (p = 0.04). However, the proportion of harvestable cockles was similar to that in 2006 (Table 53).

Table 51: Waiotahi pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
2009	95.8	11.9	12.5	1008.2
2005	40.6	6.4	15.7	427.2

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

Survey	Mean	Mode	Range	Median	IQR
2009	29.1	21, 40	3–63	29	19–39
2005	33.9	37	7–61	36	30–41

Table 53: Waiotahi pipi population estimates ≥ 50 mm length.

Survey	Population Estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2009	2.4	0.4	25.3	2.5
2005	1.2	0.4	13.1	3.1

Discussion – Waiotahi Estuary

Both pipi and cockle numbers have more than doubled since the 2005 survey. Although cockles were, on average, slightly larger there were very few individuals of harvestable size (fewer than in 2005).

The numbers of harvestable pipis almost doubled since 2005 (which was approximately proportional to the increase in the total pipi population). The pipi LFD showed cohorts (centred around 20 and 40 mm) which may be the reason for the large increase in population (see Section 4.2.2).

4.1.12 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 CD) (see Figure 15). The pipi bed was located in a similar area to 2006, but extended further north (and was less dense) than in 2006. A total of 197 samples was taken from the sample extent – 10 samples in stratum A were second phase samples. Before the 2009 survey, Whangateau harbour was sampled in 2001, 2003, 2004 and 2006.

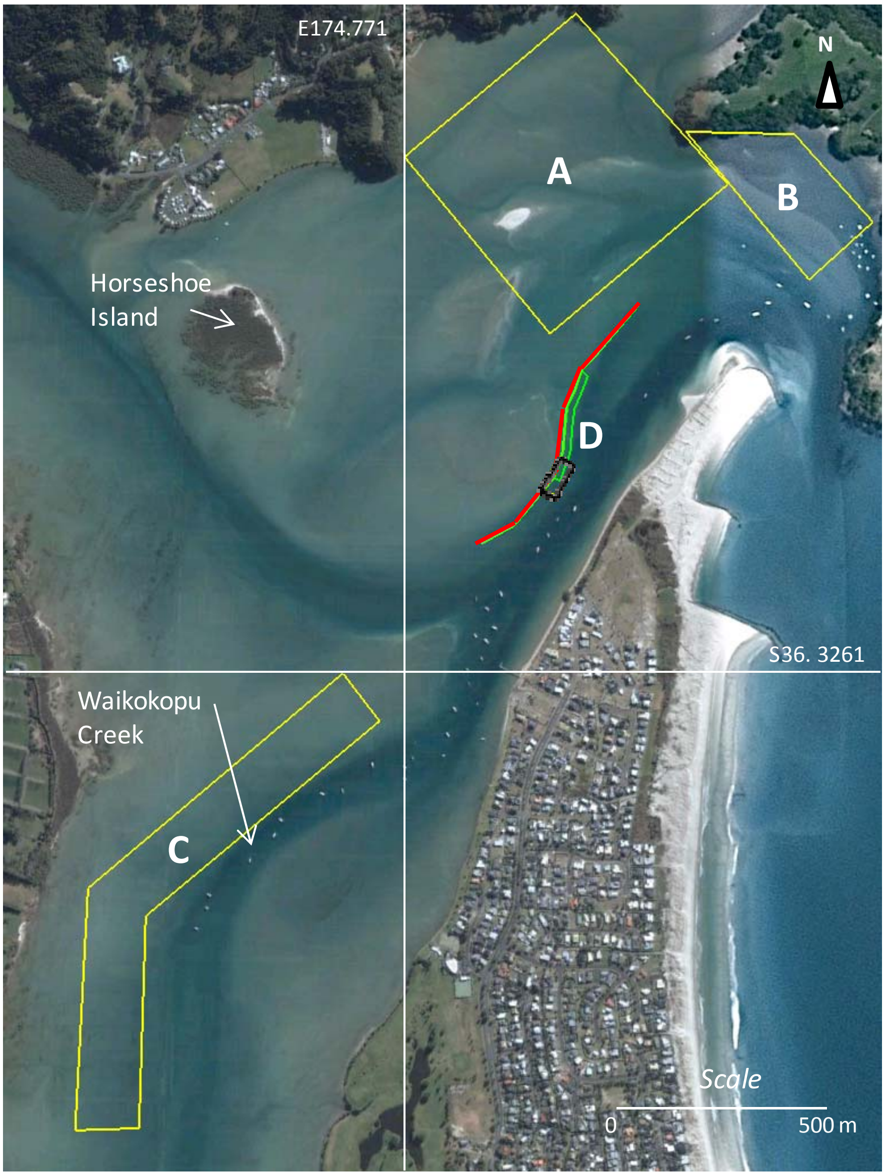

Figure 15: The Whangateau Harbour sample extent was divided into four strata (yellow polygons). The red line denotes the sample extent looking for the pipi bed in Stratum D. The pipi bed locations in 2009 (green polygon) and 2006 (black polygon) are shown.

Whangateau Harbour cockles

I estimate (with 95% confidence) that the Whangateau Harbour sample extent in the 2009 survey had between 239.9 ± 34.1 million cockles (Table 54). There was weak evidence of a change in the cockle population since the previous survey (p = 0. 08). I estimate that 2009 had between 107.3 million fewer and 7.0 million more cockles than in 2006.

Cockles in the 2009 survey were, on average, around 2 mm smaller than those found in 2006, with typical cockles ranging between 17 and 25 mm (Table 55). There was strong evidence of a decrease in the number of harvestable cockles since 2006 ($p < 0.001$) and a corresponding decrease in the proportion of harvestable cockles (relative to the total population) since 2006 (Table 56).

Table 54: Whangateau cockles – population estimates.

Year	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
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

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

Survey	Mean	Mode	Range	Median	IQR
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 cockles ≥ 30 mm length.

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
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

Whangateau Harbour pipis

I estimate (with 95% confidence) that the Whangateau Harbour sample extent in 2009 had between 15.2 ± 4.9 million pipis (Table 57). There was no evidence of a change in the pipi population since the previous survey (p = 0.29). I estimate that 2009 had between 3.1 million fewer and 10.5 million more pipis than 2006 (Table 57).

The mean and median lengths of Whangateau Harbour pipis in the 2009 survey were, respectively, 12 and 16 mm less than in 2006, with typical pipis ranging between 11 and 27 mm (Table 58). There was no evidence of a change in the number of harvestable pipis since 2006 (p = 0.24), and the proportion of harvestable pipis was relatively stable since 2006 (but was markedly higher in 2004) (Table 59).

Table 57: Whangateau pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	c.v. (%)	Average density (per m^2)
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
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 pipis ≥ 50 mm length.

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
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

Discussion – Whangateau Estuary

In the summer of 2008, locals noted numerous rotting cockles on the surface of the Whangateau Harbour. This event was attributable to multiple causes, predominantly a coccidian parasite and a mycobacterium (K. Tricklebank, University of Auckland, pers. comm.). On 25 March 2010, the Minister of Fisheries approved a three-year closure of Whangateau Harbour to the harvest of cockles and pipis and has erected signage to ensure that the public is aware of the closure. However, within the MFish sample extent, the cockle population appears to have somewhat recovered, with only weak evidence of a decline since 2006. This survey shows a decline in the cockle population of around 17% (although the confidence interval shows a decline up to 37% is plausible) since 2006.

Monitoring the pipi population with Whangateau Harbour has always been relatively tricky. Although stratum D which extends into the main channel is considered the primary pipi bed, its relatively small size and low density in recent years means that it actually has had little influence on the pipi population estimate (it accounts for less than 1% of the estimated number of pipis in the survey). The pipi population estimate in this MFish survey is dominated by a cohort of juvenile pipis (less than 20 mm in length) found intertidally in stratum A. This population shows an approximately three-fold increase since 2006. This is not to say that the event did not affect pipis – but simply that we have no evidence of a decline in the population since the 2006 survey (we note that both current total pipi and harvestable pipi numbers are below what have been recorded in previous surveys). The number and proportion of harvestable pipis in the 2009 survey was similar to that in 2006, and remains considerably smaller than the estimated population in 2004. However, pipis found were, on average, considerably smaller than in previous years.

4.2 Summary results

4.2.1 Cockles

A summary of cockle population estimates, number of individuals measured, standard errors, and coefficients of variation (c.v.), for each beach are given in Table 60. A comparison with the previous survey is shown in Table 61, with the time series of all surveys shown in Figure 16. The LFD for each beach is shown in Figure 17.

Table 60: The 2009 survey cockle population estimates (including the number of cockles counted).

Beach	Estimated population (millions)	SE (millions)	c.v. (%)	Harvestable Proportion (%)	Cockles counted
Aotea Harbour	140.83	14.8	10.5	1.5	2044
Cockle Bay	119.2	6.6	5.5	10.0	4051
Little Waihi Estuary	20.4	3.4	16.6	0.3	1491
Mill Bay	11.2	1.0	8.9	0.7	944
Ohiwa Harbour	6.4	0.6	8.8	0.2	3194
Okoromai Bay	29.3	2.8	9.6	36.1	1409
Otumoetai Beach	14.6	1.6	10.9	1.4	1759
Raglan Harbour	124.4	6.5	5.2	2.6	7767
Te Haumi Beach	30.3	2.8	9.1	1.8	1977
Umupuia Beach	61.4	6.9	11.3	2.2	1563
Waiotahi Estuary	20.0	3.1	15.5	0.1	1247
Whangateau Harbour	247.1	17.9	7.2	7.4	2354

Table 61: Comparing the 2009 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). An asterisk indicates standardisation and an assumption that the population structure is invariant are required due to changes of survey.[8] 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	
Aotea Harbour	2005	**24.8**	**59.1**	**200**
Little Waihi Estuary*	2006	-4.1	14.3	133
Mill Bay	2005	**2**	**6.9**	**167**
Ohiwa Estuary	2006	**4.2**	**6.5**	**593**
Okoromai Bay	2006	**3.1**	**16.3**	**150**
Otumoetai Harbour	2005	**0.3**	**7.6**	**137**
Raglan Harbour	2003	**18.8**	**50.3**	**139**
Te Haumi Beach	2006	**4.9**	**17.9**	**161**
Umupuia Beach	2006	**35.8**	**63.8**	**529**
Waiotahi Estuary	2005	**7.6**	**20.6**	**340**
Whangateau Harbour	2006	-100.8	15.0	85

[8] When required, the sample extent for each was standardised between years. Further details can be found in the beach description sections.

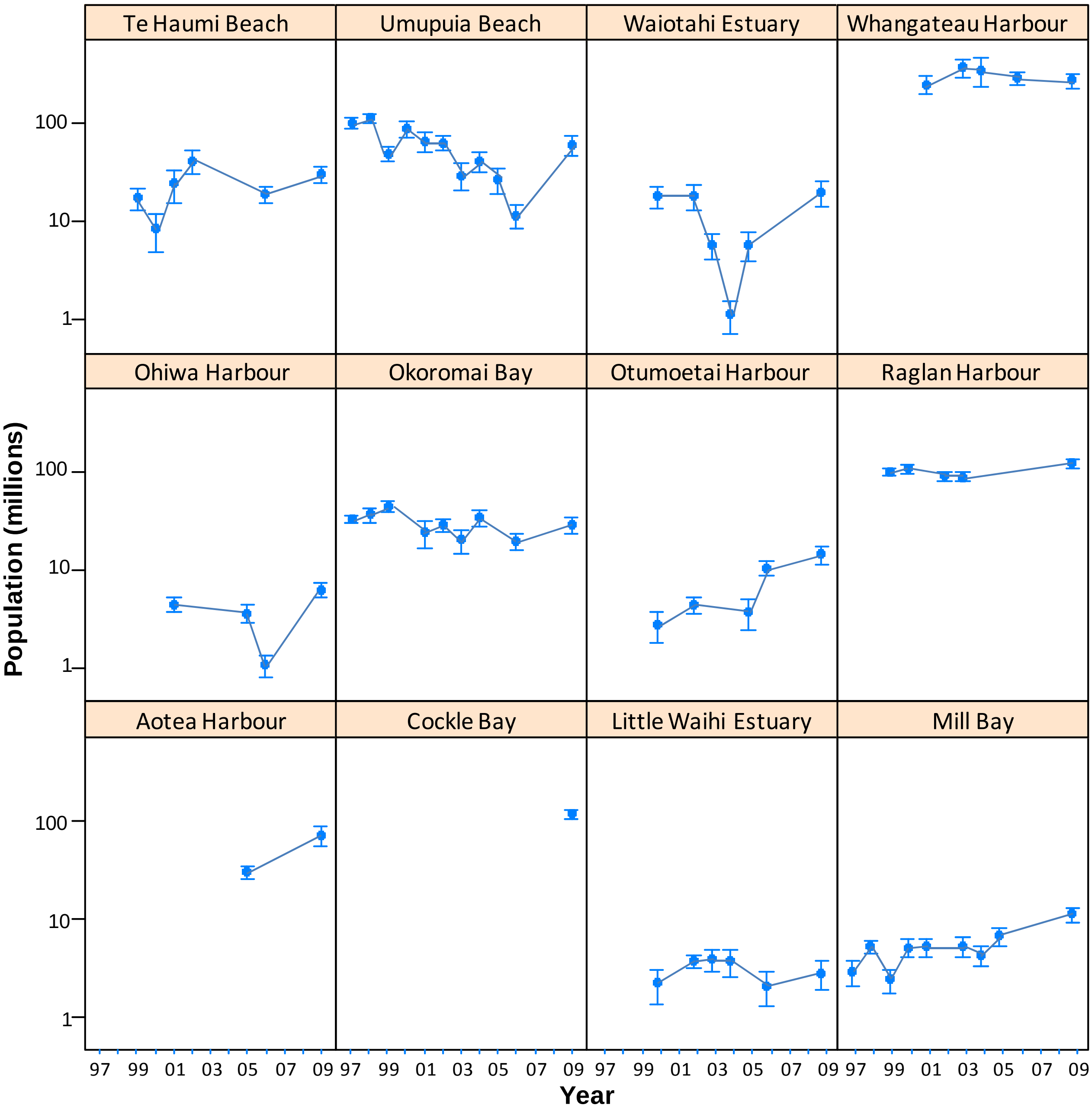

Figure 16: Changes over time in cockle populations for those beaches selected for survey in the 2009 survey. For interpretability, the y-axis is displayed on the log-scale.[9] Error bars indicate the standard error around the population total.

[9] 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).

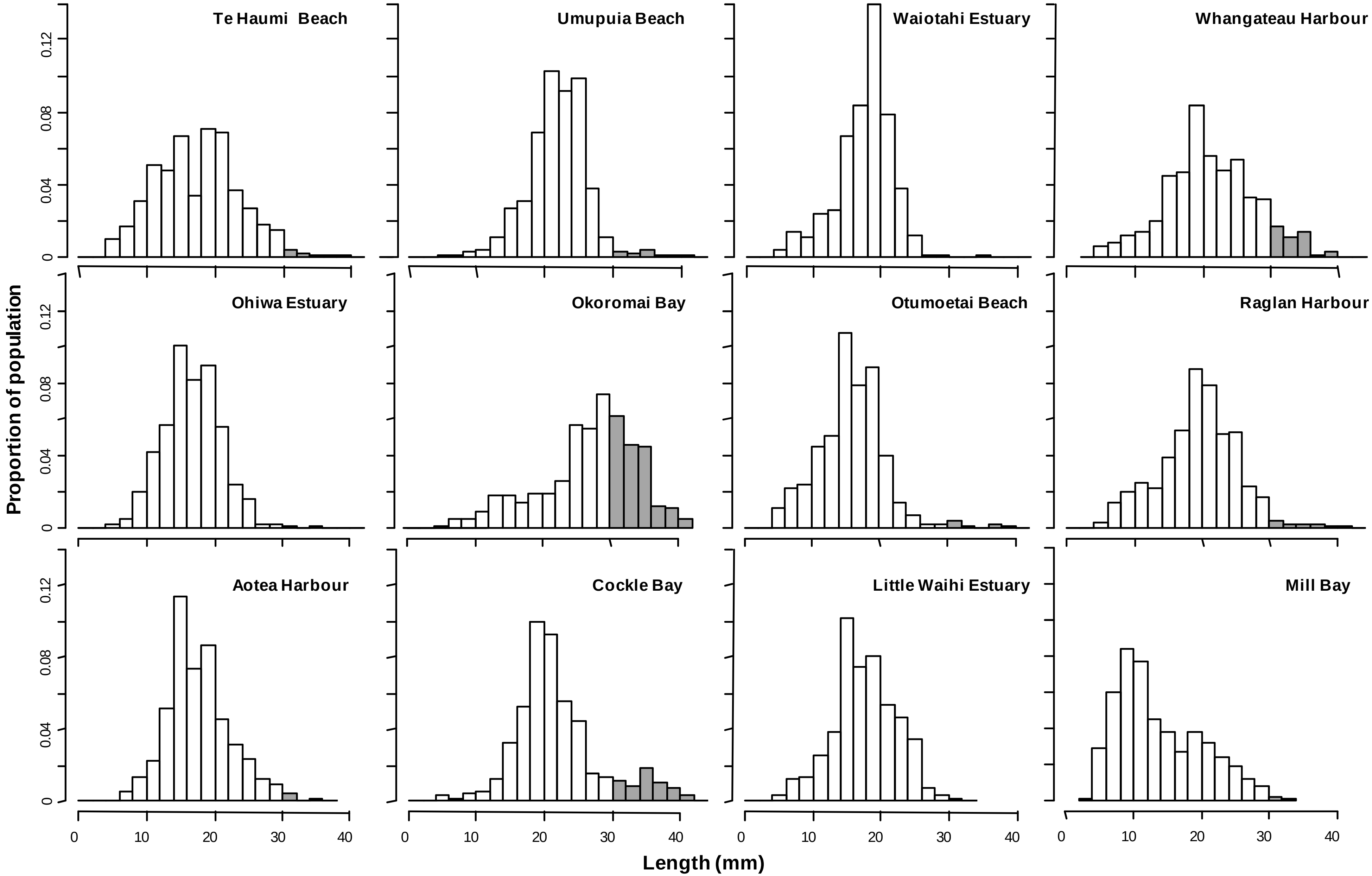

Figure 17: Cockle weighted length frequency distributions. Cockles of 'harvestable size' (i.e., longer than 30 mm) are denoted by dark bars.

4.2.2 Pipis

A summary of pipi population estimates, number of individuals measured, standard errors, and coefficients of variation (c.v.), for each beach are given in Table 62. A comparison to the previous survey is shown in Table 63, with the time series of all surveys shown in Figure 18. The LFD for each beach is shown in Figure 19.

Table 62: The 2009 survey pipi population estimates (including the number of pipis counted). *NA*, not applicable due to low sampled numbers.

Beach	Population estimate (millions)	SE (millions)	C.V. (%)	Harvestable Proportion (%)	Pipis counted
Aotea Harbour	*NA*				4
Cockle Bay	*NA*				7
Little Waihi Estuary	288.9	34.9	12.1	2.7	7495
Mill Bay	5.6	1.0	17.4	0.0	471
Ohiwa Harbour	14.7	2.0	13.0	7.8	2191
Okoromai Bay	*NA*				1
Otumoetai Beach	17.2	1.2	7.2	4	2035
Raglan Harbour	0.6	0.1	19.1	19.6	202
Te Haumi Bay	43.5	5.5	9.1	0.3	4309
Umupuia Beach	*NA*				0
Waiotahi Estuary	95.8	11.9	12.5	2.5	8882
Whangateau Harbour	15.5	2.5	16.3	1.0	181

Table 63: Comparing the 2009 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). An asterisk indicates standardisation and an assumption that the population structure is invariant are required due to changes of survey.[10] 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	
Little Waihi Estuary*	2006	**42.1**	**165.5**	**173**
Mill Bay	2005	**2.9**	**6.7**	**709**
Ohiwa Estuary	2006	**2.1**	**10.7**	**177**
Otumoetai Harbour	2006	**-2.6**	**-10.3**	**73**
Raglan Harbour	2003	-0.1	0.4	134
Te Haumi Bay	2006	-1.4	24.8	137
Waiotahi Estuary	2005	**28.2**	**82.1**	**236**
Whangateau Harbour	2006	-3.1	10.5	131

[10] When required, the sample extent for each was standardised between years. Further details can be found in the beach description sections.

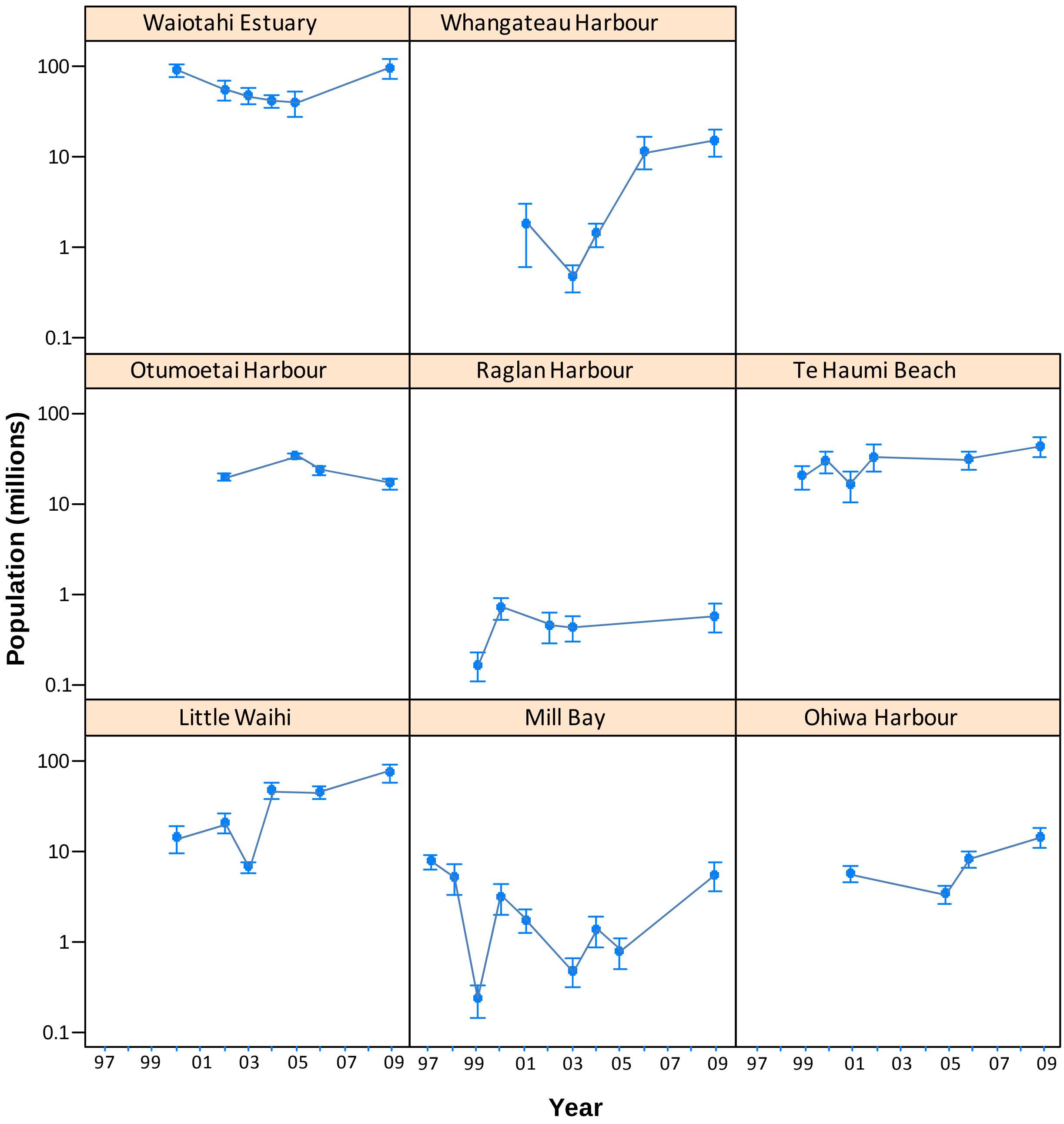

Figure 18: Changes over time in pipi populations for those beaches selected for survey in the 2009 survey. For ease of interpretation, the y-axis is displayed on the log-scale. The Little Waihi Estuary 2009 estimate was rescaled to reflect the areas surveyed in previous years. Error bars indicate the standard error around the population total.

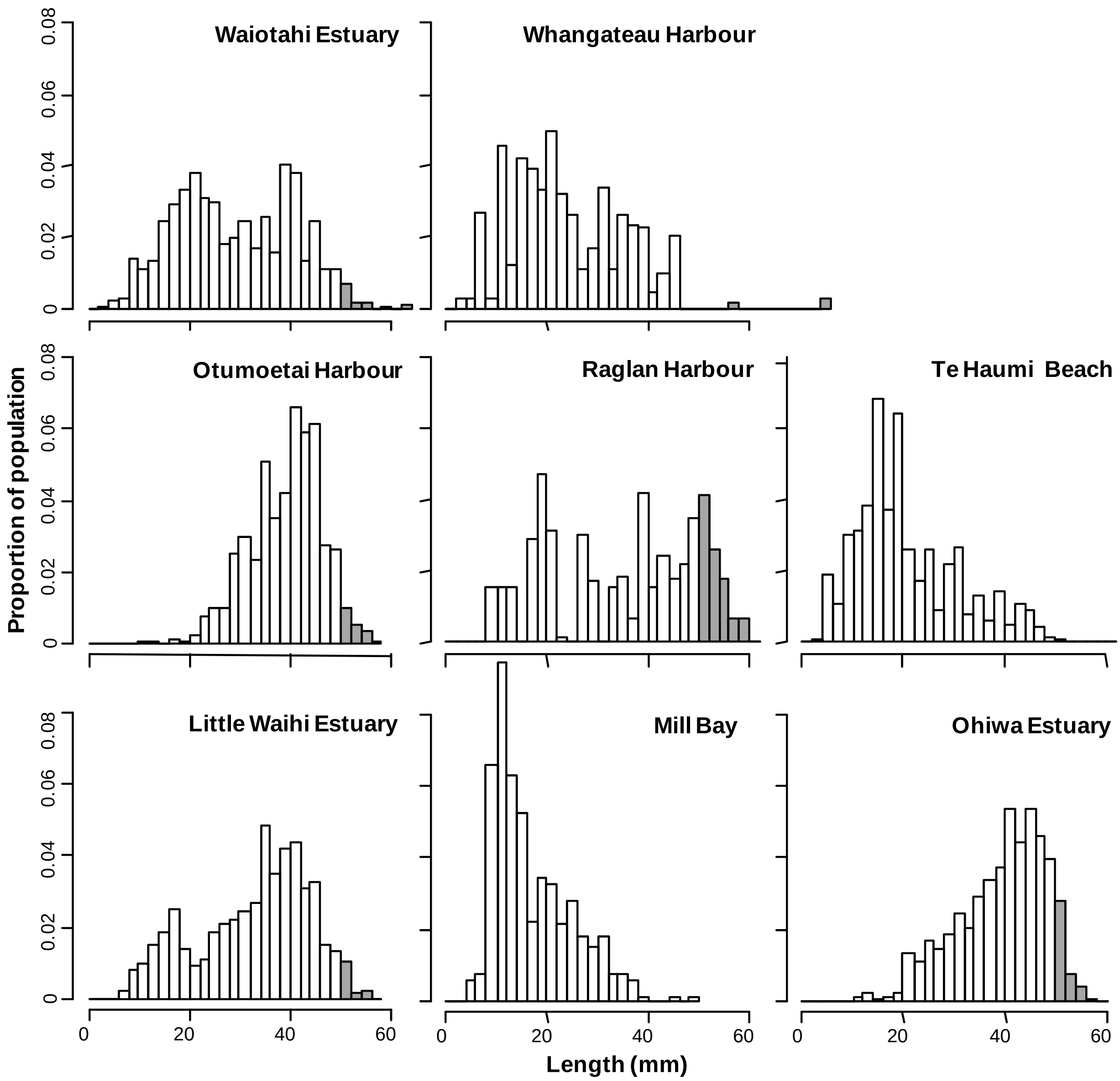

Figure 19: Pipi weighted length frequency distributions (beaches with more than 100 sampled pipis are shown). Pipis of 'harvestable size' (i.e. longer than 50 mm) are denoted by dark bars.

5. DISCUSSION

5.1 Cockles

The change in cockle population (relative to the previous survey) was large at four beaches: Aotea Harbour more than doubled the 2005 cockle population estimate, Waiotahi Estuary more than tripled the 2005 estimate and Umupuia Beach and Ohiwa Estuary increased to 529% and 593% of their 2006 estimate (see Table 61). Little Waihi Estuary was the only surveyed beach which showed no evidence (at the 5% level) of a change in cockle population compared to the previous survey. Despite the recorded cockle mortality in the summer of 2008, Whangateau Harbour showed only weak evidence of a decrease in the cockle population compared to 2006.

The paucity of prior population estimates at Aotea Harbour and Cockle Bay makes it difficult to put their population changes in a longer context. However, the remaining 10 beaches examined in the 2009 survey had previously been surveyed in several years (see Figure 16). When examining population changes over a longer term, the 2009 population fell within the range of previous surveys at five of the beaches: Te Haumi Beach, Waiotahi Estuary, Okoromai Bay, Umupuia and Raglan Harbour all had similar cockle populations in previous surveys.[11] However, Little Waihi Estuary, Mill Bay and Otumoetai Harbour all showed unusually high population estimates compared to previous surveys.

Compared to the other 2009 beaches, Okoromai Bay contained a particularly large proportion of 'harvestable' cockles (some 36% were larger than 30 mm). This proportion was about four and five times higher than the two beaches with the next highest proportions (harvestable cockles at Cockle Bay and Whangateau Harbour were 10% and 7.4% of the total cockle population). Harvestable cockles were far rarer at all of the other beaches (no other beach had harvestable proportions greater than 2.6%). There was evidence of a decline in harvestable cockle density at Mill Bay, Te Haumi, Umupuia, and Whangateau.

5.2 Pipis

Eight beaches surveyed in 2009 had pipi beds. All these beaches had been surveyed multiple times in previous years (see Figure 18). Raglan Harbour was the only surveyed beach which showed no evidence (at the 5% level) of a change in pipi population compared to the previous survey. Otumoetai and Whangateau Harbours showed a decline in pipi numbers – I estimated that the latter beach had only 16% of the 2006 survey population. All other beaches showed evidence of an increase from the previously surveyed population. The population change (relative to the previous survey) was significant at four beaches: Little Waihi Estuary and Otumoetai Harbour were both around 75% higher than their respective 2006 pipi population estimates, Waiotahi Estuary more than doubled the 2005 estimate, and Mill Bay increased to 709% of its 2005 estimate (see Table 63). However, when examining population changes over a longer term (see Figure 18), the 2009 pipi population for all beaches fell within the range of population estimates seen in previous years.

Pipis of harvestable size were relatively common only in Raglan Harbour (19.6% of pipis were larger than 50 mm). Ohiwa Harbour had an intermediate proportion of harvestable pipis (around 8% of the total population); however this was far smaller than the harvestable proportions found in previous years (26% of all pipis in 2006 and 74% in 2005 were of harvestable size). The proportion of harvestable pipis at all other beaches was less than 3% of the total population. Significant evidence of

[11] Although the 2009 Umupuia Beach cockle population rose five-fold relative to its previous survey (reversing a systematic decline since 2000), its 2009 population was similar to levels found before 2001).

decreases in harvestable pipi density was found at Te Haumi beach and Ohiwa harbour. In contrast, Waiotahi Estuary and Raglan Harbour showed evidence of harvestable pipi density increases.

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

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

Table A1.1: Grey cells indicate the beach was surveyed for the AKI project that year. 2009 beaches (blue highlights) are colour-coded: red/green cells indicate significant 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	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	09
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																																
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.

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
Beach **Year**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2010**
Aotea Harbour									17-18Jan		27Mar-13Jul
Beachlands	10-27Mar	9Dec98-29Jan99									
Bowentown					26Apr-25May						
Cheltenham Beach	7Jan-9Feb	12-Jan									
Clarks Beach								3-24Feb			
Cockle Bay											16-Feb
Cornwallis Beach					26-Mar						
Eastern Beach	22Jan-13Mar	12-27Jan	15May-30Jun		14Mar-16Apr						
Grahams Beach										20-Apr	
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				
Marokopa									18-20Feb		
Mill Bay	16Jan-1Apr	9-24Dec98	4Mar-30Jun	20-23Feb	20Mar-22Apr		26-28Jan	24Dec04-24Jan05	20-24Jan		13-May
Ngunguru							6-7Mar	6-7Feb			
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	
Tairua Harbour			1Apr-1May	15-16Feb	23-24May	23Feb-28Mar			14-15Jan	3May-1Aug	
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
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	
Whangapoua Beach						30Mar-6Apr	1-3Feb	8-10Mar	8-10Mar		
Whangateau Harbour					7Apr-22May		17Dec03-2Mar04	2-26Mar		19Mar-2May	18Mar-15Jul

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
Aotea Harbour									9.6		15.6
Beachlands	*	*									
Bowentown Beach					1.58						
Cheltenham Beach	*	*									
Clarks Beach								144.71			
Cockle Bay											32
Cornwallis Beach	*	*			2.65						
Eastern Beach	*	*	48		43.38						
Grahams Beach										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									2.35		
Marokopa Beach											
Mill Bay	4.8	*	4.6	4.8	4.5		4.5	4.5	4.5		4.95
Ngunguru Estuary							1.7	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	
Tairua Harbour			3.7	3.9	3.9	3.9			3.9	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
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	
Whangapoua Beach						1.66	5.2	5.2	5.2		
Whangateau Harbour					64.19		64.15	64.15		64.15	64.51

APPENDIX 2: Satellite images of Waihi Harbour in 2003.

Figure A2.1: A satellite image of Little Waihi Estuary in 2003. The dark lines indicate the strata used to sample the area in 2003. The yellow lines denote the strata boundaries that make up the sample extent for 2009 survey. Comparisons of the 2009 and 2006 strata indicate how the channel morphology near the mouth of the estuary has changed over time.