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Manatū Ahu Matua

The distribution and abundance of pipis and cockles in the Northland, Auckland and Bay of Plenty regions, 2013

New Zealand Fisheries Assessment Report 2014/29

M.D.M. Pawley,
A.N.H. Smith

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Ministry for Primary Industries
PO Box 2526
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Twelve beaches and harbours in the greater Auckland, Northland, and Bay of Plenty regions were surveyed between December 2012 and March 2013 (referred to as the 2012 survey) to estimate the distribution, abundance, and size frequency of pipis (*Paphies australis*) and cockles (*Austrovenus stutchburyi*).

A target coefficient of variation (CV) 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 cockle and pipi populations which were both found in very low density (around 20 per m^2).

Cockles
Ten of the beaches surveyed had cockle beds. The estimated total abundance of cockles increased significantly at Whangateau Harbour (by 52%), Ohiwa Estuary and Bowentown Beach (around 40%). In contrast, Grahams Beach showed a significant decrease, with only around 16% of the previous (2010) cockle population. Other beaches showed no evidence of any change in their total cockle populations.

The estimated number of harvestable cockles at Bowentown Beach remained stable but sparse (densities less than 3 per square meter), and there was no evidence ($p>0.12$) of any change in the harvestable cockle population at Ohiwa Estuary, Raglan Harbour, and Okoromai Bay. However the three beaches which have had a rahui (closure) or restriction implemented by MPI, i.e. Cockle Bay, Umupuia Beach and Whangateau Harbour all had significant increases in the estimated number of large cockles. The 2012 estimate of the harvestable cockle population more than doubled at Cockle Bay and Little Waihi Estuary and approximately quintupled at Umupuia since their previous respective surveys. The estimated number of harvestable cockles at Whangateau Harbour increased in proportion to the increase in the total cockle population. The estimated harvestable cockle population almost doubled at Te Haumi Beach (although the population of harvestable cockles there was much smaller than at those beaches with a rahui).

Pipis
We note that the survey has a maximum depth of 0.5 m below chart datum (CD), so variation in the pipi population estimate may be caused by movement of the pipi bed to deeper (or shallower) positions. Seven of the twelve beaches surveyed in 2012 had pipi beds, and significant subtidal pipi beds are known to exist at Raglan Harbour, Ohiwa Estuary and Whangateau Harbour.

The estimated total pipi population at Marsden Bank declined by around 70% since the previous (2010) survey. The small pipi population at Raglan Harbour approximately tripled in size since the previous (2009) survey, and the total pipi population at Whangateau Harbour roughly doubled since the 2010 survey. Ohiwa Estuary had the largest proportional change in any of the pipi beds, and the northern edge of Motuotu Island (within Ohiwa Estuary) was found to have dense patches of pipis. The total pipi population at Grahams Beach, Little Waihi Estuary and Te Haumi Beach showed no evidence of change ($p>0.12$). The pipi bed at Whitianga Harbour was sampled by this project for the first time and was found to have low density of pipi spread patchily over a relatively wide geographic area.

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 and upper North Island 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 shellfish beds have been depleted by harvesting pressure) has been expressed by both the public, for the upper North Island and the Hauraki Gulf Forum, for that smaller area (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 Primary Industries (MPI (previously 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, Mt Maunganui and (most recently) Umupuia Marsden Bank 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, 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 MPI Northern region. The data collected also provide longer-term information on the dynamics of intertidal shellfish populations, an area of research that is crucial to sustainable management, yet has received little attention.

Previous surveys of the intertidal populations have been summarised in various reports including Pawley (2012), 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

The overall objective of this study was 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 2012/2013 fishing year. The target coefficient of variation (CV) 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 2012 survey[2] are shown in Figure 1.

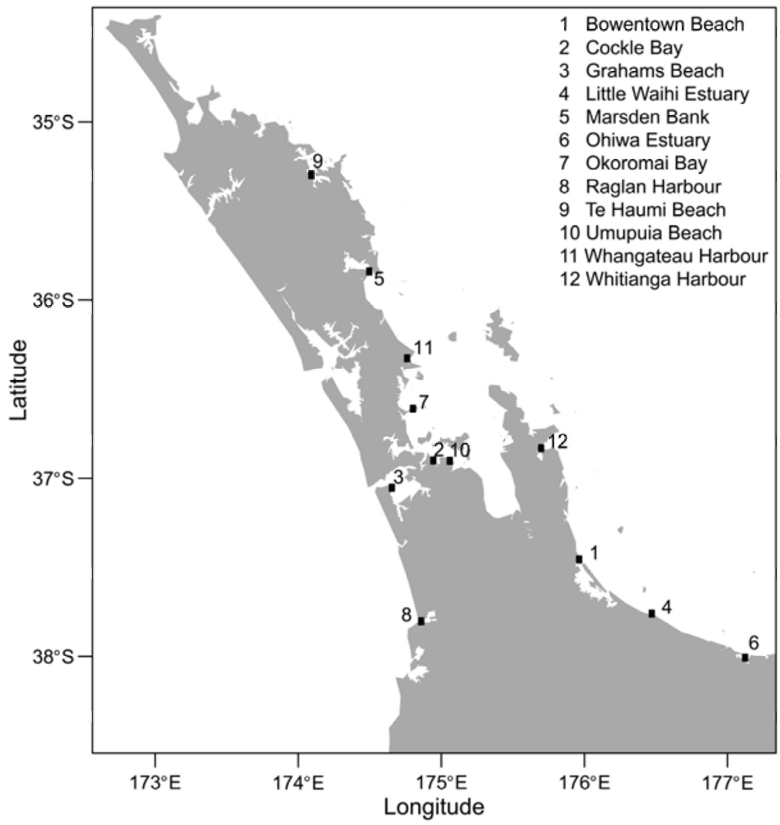

Figure 1: The 12 beaches sampled in the 2012 survey.

In recent years, beaches have been selected by MPI using three criteria:

1. Where information is needed to support proposed closures or re-openings.
2. Where concern is being voiced about local shellfish resources.
3. To achieve a geographic spread throughout Northland, Auckland, Waikato and the Bay of Plenty.

[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 2012 survey, Whitianga Harbour was the only beach that had not been previously sampled by the AKI project. In all other beaches the sample extent was established in previous surveys.

In general, changes in sample extent were made so that two principal criteria were 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 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 in which 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 2012 survey used a combination of both techniques to maximise power and logistical efficiency. This sampling design has been used since 2006.

3.2.1 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. Whitianga Harbour had not been previously surveyed by MPI, so there was some exploratory work determining the historical extent of the pipi bed. The sample size within Whitianga Harbour was based solely on the number of samples that could be taken within the tidal window. At other beaches in the 2012 survey, stratum 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).

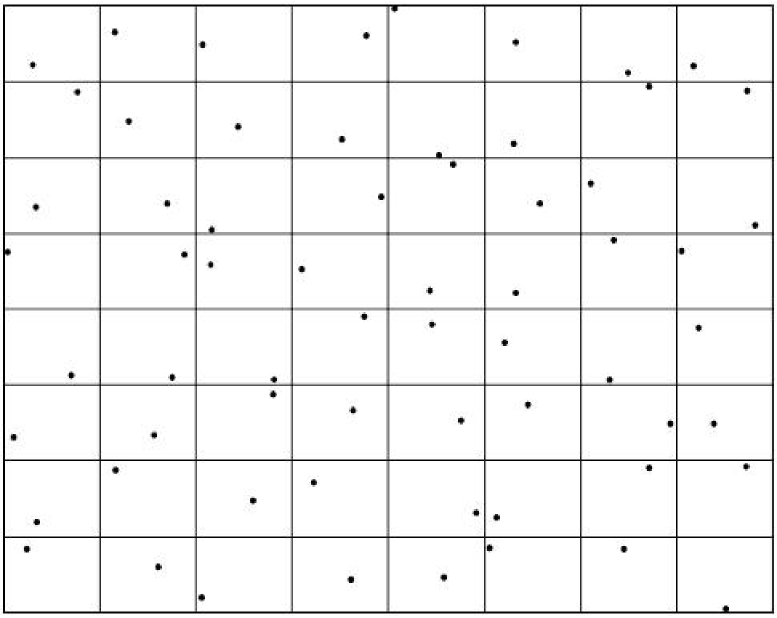

Figure 2: An example of a randomised systematic sample. The sample extent is divided using a grid (dashed lines), whose resolution depends on the sample size (a sample size of n = 8x8 = 64 is shown above). Within each grid section a sample is randomly positioned (filled circle).

3.2.3 The second phase of sampling

Using the two-phase sampling approach, if a coefficient of variation (CV) 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 2012 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 the density of individuals per m^2. 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 the 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 strata; A_h is the area for the h_{th} stratum and, y_h is the estimated density per m^2 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 m^2), 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'). For the i^{th} stratum, the stratum weight (SW_i) is:

$$SW_i = \left(\frac{n_i}{\sum n_i}\right) \Big/ \left(\frac{Area_i}{\sum Area_i}\right) \quad \propto \; n_i / Area_i$$

ii. the number of *counted* shellfish divided by the number of *measured* shellfish ('Sample Unit Weight').

[3] The distribution of sample means is dependent upon the interplay of a number of factors, including the range and degree 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 allocated 50% of all samples but covered only 25% of the sample extent, then 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 samples within that stratum had only measured 20 out of 50 (counted) individuals, then each measured individual within that particular sample also was given 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 × 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).
- Determining 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 25th to 75th 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).

All analyses and graphs were calculated using Microsoft Excel and the statistical software 'R v2.15.1' (R Development Core Team 2012). Errors from previous reports are shown in Appendix 2 – the amended values are used in the appropriate tables and time series graphs.

Harvestable and recruited populations

The Ministry for Primary Industries has historically used a general guideline (density of 25 per m^2 for cockles 30 mm length and over, and pipis 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.

Cockles smaller than 15 mm, and pipis smaller than 18 mm in length were considered to be 'recent recruits' (i.e. shellfish less than one year old). These size limits were determined using assessed growth parameters for each species (Ministry for Primary Industries 2012).

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

4. RESULTS

4.1 Regional shellfish densities and lengths

The maximum average density of cockles found in the 2012 survey was around 1960 per m^2 (Raglan, stratum A), and the maximum density of pipis was around 15856 per m^2 (Ohiwa Bank, stratum G) within all strata across all examined beaches (Figure 3).

A kernel density estimate (kde) of shellfish density (individuals per m^2) suggests that cockle densities from the regions were relatively well modelled with a unimodal (log-normal) distribution. The density of pipis was less symmetric and more variable than cockles, and the kde model suggests that the typical pipi density was higher (733 pipis per m^2) than cockles (315 cockles per m^2).

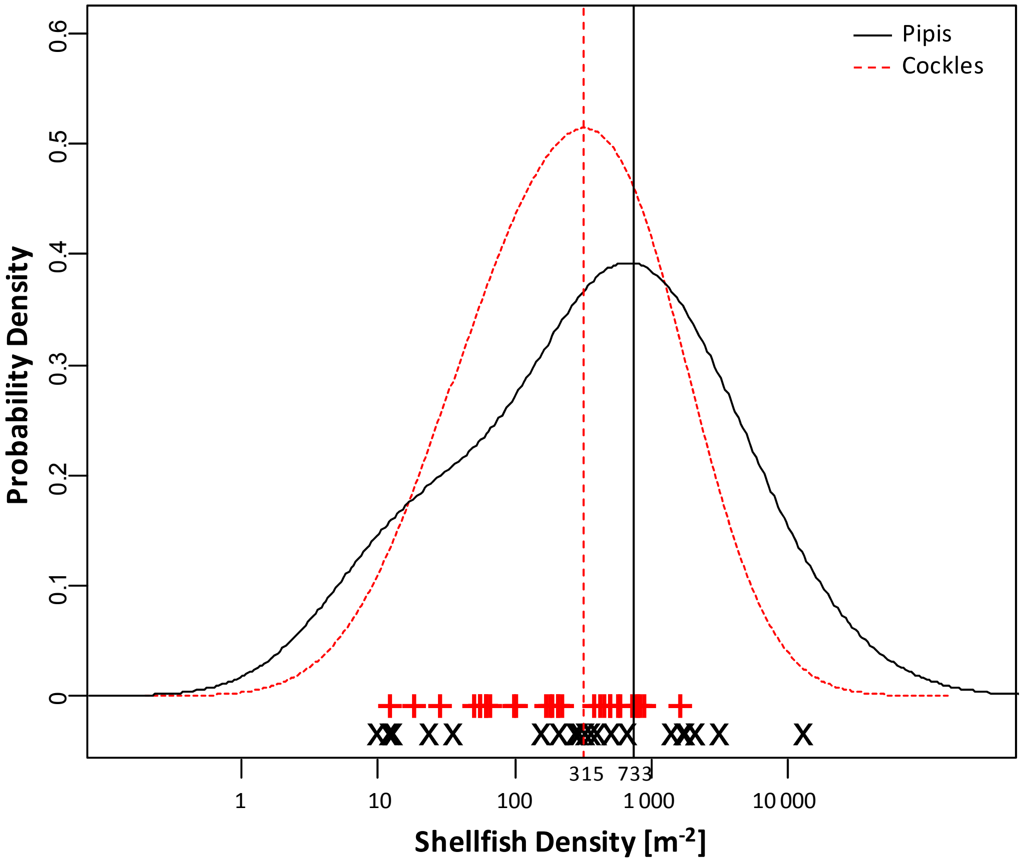

Figure 3: Cockle and pipi density found in all 2012 strata containing beds (i.e. where shellfish density was greater than 10 per m^2). Individual stratum densities are denoted by a '+' (cockles) or 'x' (pipi). Red black lines show the kernel density estimates for the cockle and pipi populations, indicating a model fit to the observed shellfish densities. Vertical lines show the mode of the modelled distributions.

At the 12 beaches examined in 2012, cockle sizes ranged between 2 and 45 mm (Figure 4). The median (and mode) cockle size was around 20 mm and most (75%) cockles found were smaller than 25 mm. The distribution of pipi lengths was bimodal and more variables than cockles. The overall pipi length frequency distribution had two prominent modes around 15 and 41 mm, and sizes ranged between 1 and 68 mm. The median pipi size across all beaches was 31 mm and most (75%) of pipis were smaller than 42 mm.

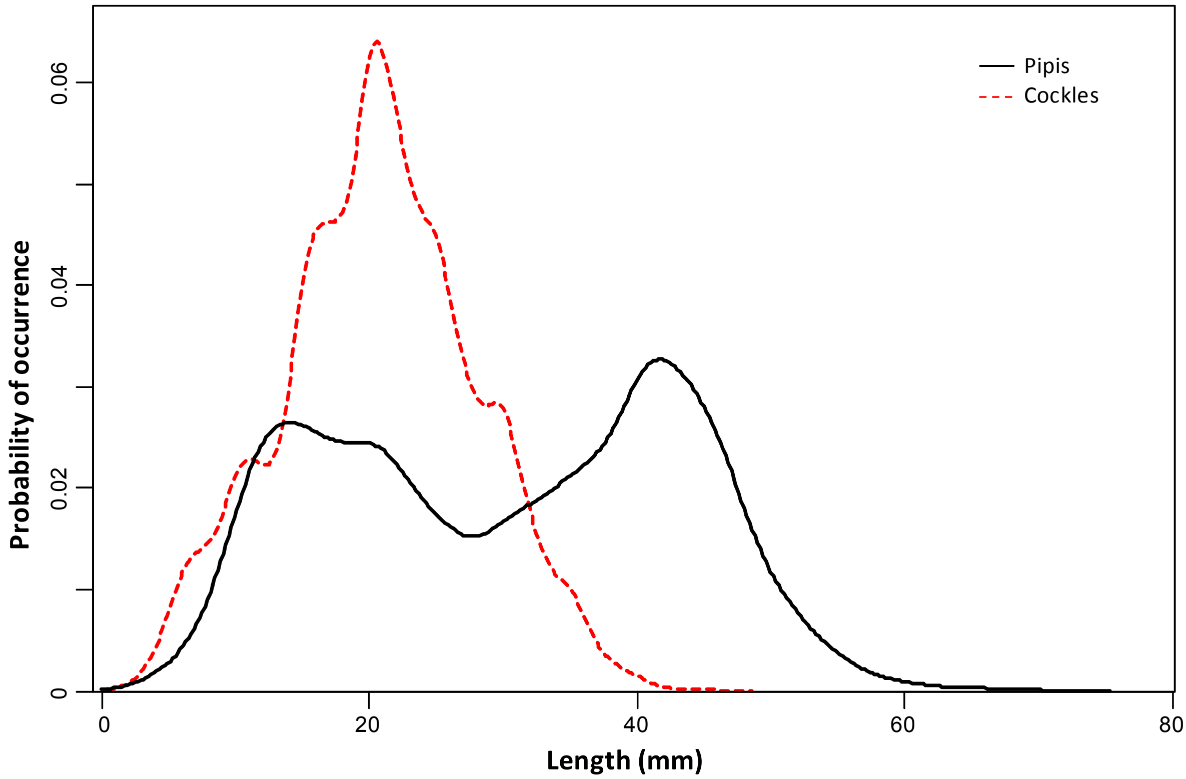

Figure 4: Length frequency distributions for cockles (red) and pipis (black) from all beaches in 2012. Distributions were modelled using kernel density estimates of lengths, frequencies of each stratum of every beach were reweighted by their geographic size and sample number (see Section 3.3.2 for details).

4.2 Analysis of individual beaches[5]

4.2.1 Bowentown Beach

Beach description

The Bowentown Beach sample extent remained unchanged from the previous MPI surveys in 2010 and 2001 (Figure 5). In the 2012 survey, a total of 187 samples were taken from cockle beds in stratum A (20 × 175 m), B (100 × 30 m) and C (175 × 50 m).

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

Bowentown Beach cockles

We estimated (with 95% confidence) that the 2012 sample extent contained 24.81 ± 2.8 million cockles (Table 1). There was strong evidence of a change in the size of the cockle population since the previous (2010) survey (p = 0.0012). In 2012, there were between 2.96 million and 11.36 million more cockles than 2010.

Cockles were typically between 16 and 22 mm, which was, on average, about 3 mm larger than what was found in the 2010 survey (Table 2 and Figure 6). Few cockles of harvestable size were found

[5] Beaches are presented in alphabetical order.

(around 0.2% of the total population). There was no evidence of a difference in the number ($p = 0.44$) or proportion of harvestable cockles compared to the 2010 survey (Table 3).

Table 1: Bowentown Beach cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	24.81	1.39	5.6	1570
2010	17.65	1.60	9.1	1117

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

Survey	Mean	Mode	Range	Median	IQR
2012	19.1	20	3–29	20	16–22
2010	16.7	20	333	17	13–20

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

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2012	0.066	0.028	4.19	0.3
2010	0.076	0.02	4.14	0.4

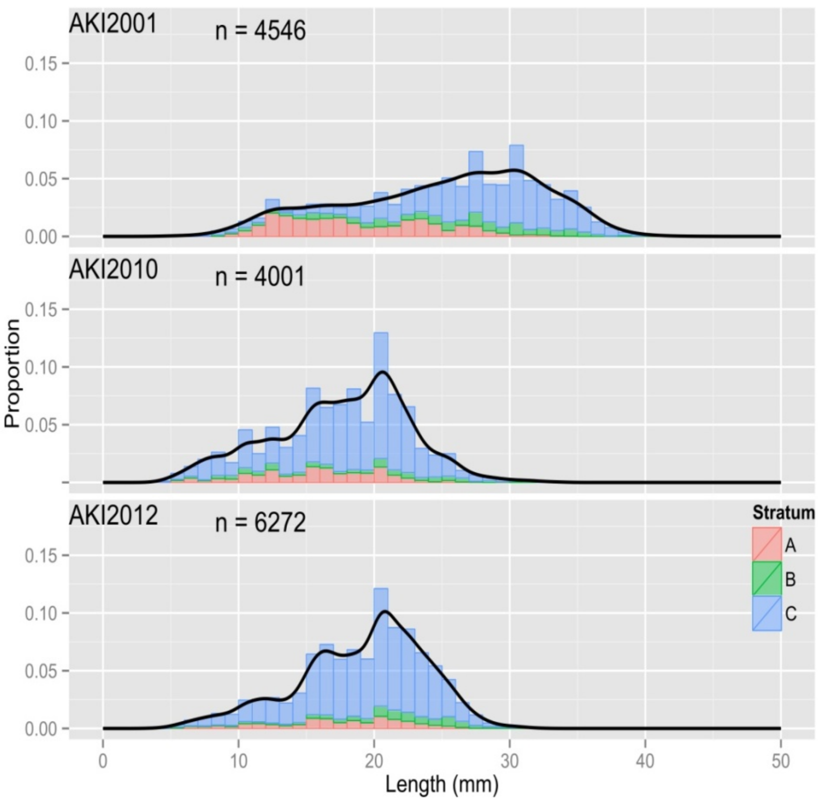

Figure 6: The weighted length frequency distributions of cockles at Bowentown Beach. Stratum contributions are represented by different colours and smoothed estimates of the length frequency distributions are also shown (black lines).

Bowentown Beach pipis

The average density of pipis was less than 20 per m^2 in all Bowentown Beach strata and only 81 pipis in total were found (in the 2010 and 2001 surveys, 26 and 18 pipis were found). Due to this low density of pipis no population estimate was generated.

Discussion – Bowentown Beach

Strata A and B contained moderate densities of cockles relative to other beaches in the survey, with the average density of the strata estimated to be around 729 and 872 cockles per m^2, respectively (Figure 3 shows the distribution of shellfish densities found in the entire 2012 survey). Stratum C contained a dense bed of cockles (1076 cockles per m^2).

The length distribution of cockles remained relatively stable since the 2010 survey, with a minor increase in average size over this period. In the 2012 survey, there were almost no cockles of harvestable size and around half of the population were smaller than 20 mm. Cockle sizes were lower than in 2001 when about a quarter of the population were larger than 30 mm in length (and around two thirds were larger than 20 mm).

4.2.2 Cockle Bay

Beach description

The sample extent for Cockle Bay encompasses most of the intertidal region of the bay. Cockle Bay was previously sampled in the 2009 and 2010 MPI surveys. 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 2012 survey, 121 samples were taken within the sample extent. Since October 2008, MPI has implemented a seasonal closure for Cockle Bay banning shellfish harvesting over the summer period.

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

Cockle Bay cockles

We estimated (with 95% confidence) that the 2012 sample extent for Cockle Bay contained 54.1 ± 8.1 million cockles (Table 4). There was strong evidence of a decrease in the cockle population since the previous (2010) survey (p=0.003). In the 2012 survey, there were between 5.9 million and 28.7 million fewer cockles than the 2010 survey.

The mean and median cockle sizes were approximately 6 mm longer than found in the previous (2010) survey. Typical cockle size was between 28 and 34 mm (Table 5, Figure 8). There was strong evidence of an increase in the number (p<0.001) and proportion (p<0.001) of harvestable cockles. We estimated (with 95% confidence) that there were between 7.8 million and 22.1 million more harvestable cockles than in 2010 (Table 6).

Table 4: Cockle Bay cockles – population estimate.

Survey	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	54.1	4.1	7.5	338.4
2010	71.5	4.0	5.6	446.9
2009	59.0	3.3	5.6	368.5

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

Survey	Mean	Mode	Range	Median	IQR
2012	30.9	32	6–44	31	28–34
2010	25.2	25	3–45	25	21–29
2009	22.0	20	5–51	21	19–25

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

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2012	36.1	3.2	225.6	66.7
2010	21.1	1.7	130.7	17.0
2009	5.8	0.61	36.5	13.0

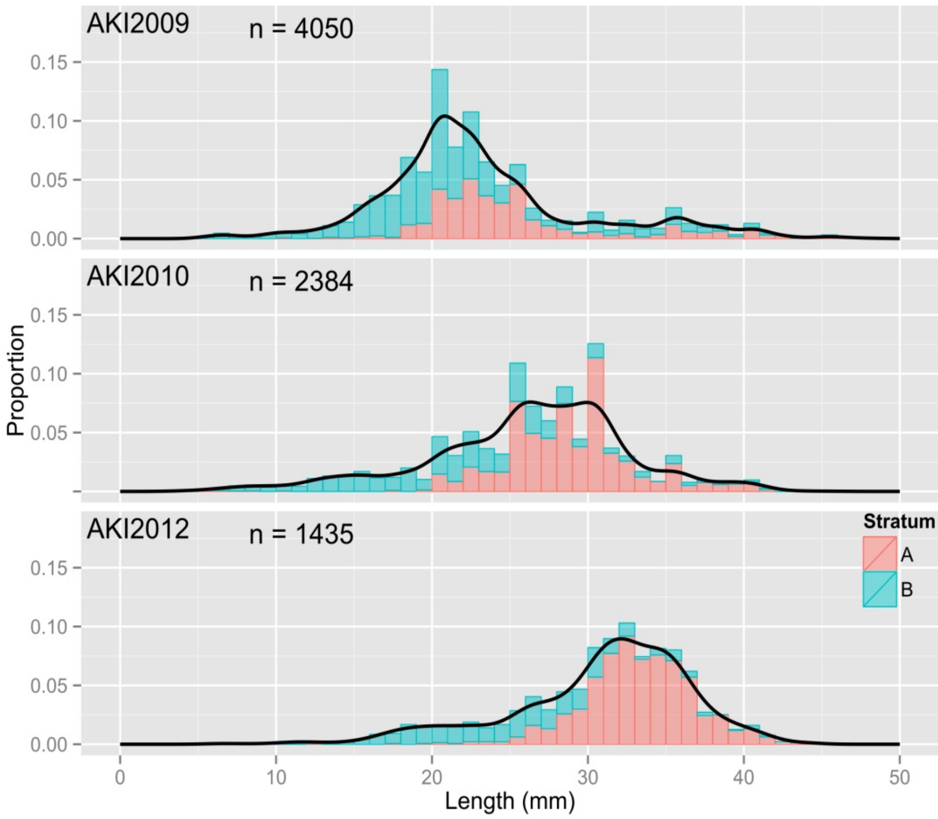

Figure 8: The weighted length frequency distributions of cockles at Cockle Bay. Stratum contributions are represented by different colours and smoothed estimates of the length frequency distribution are also shown (black lines).

Cockle Bay pipis

Only nine pipis were found within the sample extent at Cockle Bay (eight were found in 2010). Due to this low density of pipis no population estimate was generated.

Discussion – Cockle Bay

Cockle density within the Cockle Bay sample extent (467 and 207 cockles per m^2 for strata A and B respectively) was moderate compared to other beaches in the 2012 survey.

The cockle population declined to levels similar to those found in the 2009 survey. However, there was a large increase in the average size of cockles (found primarily in Stratum A) at Cockle Bay. Both the number and proportion (relative to the total population) of harvestable cockles have increased substantially since the previous (2010) survey. The increase in cockle size is even more apparent when examined over a longer period. Although the 2009 survey had similar numbers of cockles as 2012, only around 13% were of harvestable size.

In October 2008, MPI implemented a seasonal closure for Cockle Bay over the summer periods from 1st October to 30th April. This closure may be a reason why the cohort of large cockles has become available at this beach. However, there is not enough data in the time series to identify how the total population fluctuates over time, nor is there much information prior to the closure to see the levels of cockle numbers that were naturally sustained at the beach.

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 9). A total of 137 samples were taken from the sample extent. Grahams Beach was previously surveyed in 2006 and 2010.

Figure 9: The sample extent for Grahams Beach.

Grahams Beach cockles

We estimated (with 95% confidence) that the 2012 Grahams Beach sample extent contained 4.0 ± 1.7 million cockles. There was strong evidence of a decrease in cockle numbers since the previous (2010) survey ($p<0.001$) (Table 7). We estimated that the 2012 survey had between 10.6 million and 31.1 million fewer cockles than in 2010.

Cockle sizes in 2012 were, on average, larger than those found in the 2010 survey. At 21 mm, the median cockle size was almost double the 2010 median size, and typical cockles ranged between 13 and 23 mm (Table 8). However, no cockles larger than 30 mm were found in 2012 (Table 9 and Figure 10).

Table 7: Grahams Beach cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	4.02	0.87	21.6	20.03
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
2012	18.9	23	6–28	21	13–23
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 (≥ 30 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2012	0	0	0	0
2010	0.019	0.019	0.366	0.07
2006	0	0	0	0

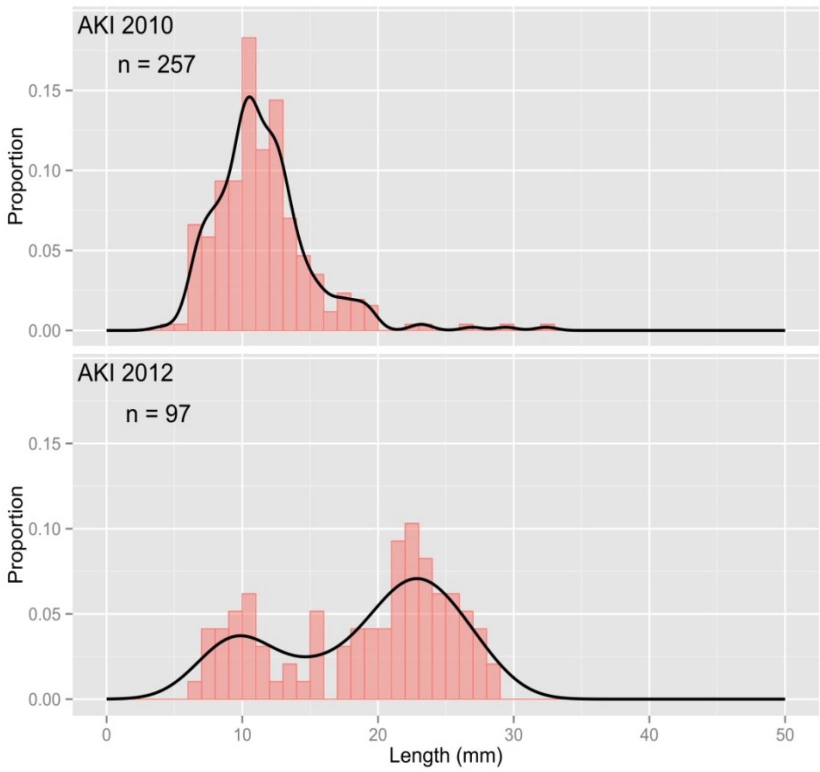

Figure 10: Histogram of the weighted length frequency distributions of cockles at Grahams Beach with a smoothed estimate of the length frequency distribution (black lines).

Grahams Beach pipis

We estimated (with 95% confidence) that the 2012 Grahams Beach sample extent contained 2.9 ± 2.0 million pipis. There was no evidence of a change in the size of the pipi population since the previous (2010) survey (p = 0.58) (Table 10). We estimated that the 2012 survey had between 3.6 million fewer and 2.0 million more pipis than in 2010.

The average pipi size has increased by around 5 mm since the previous (2010) survey. However, typical pipi size was still relatively small (12 to 25 mm) and none were of harvestable size (Table 11 and Figure 11).

Table 10: Grahams Beach pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	2.9	1.01	35.0	14.5
2010	2.6	0.73	28.2	11.8

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

Survey	Mean	Mode	Range	Median	IQR
2012	18.6	14	10–35	15	12–25
2010	13	12	6–32	11.5	10–14

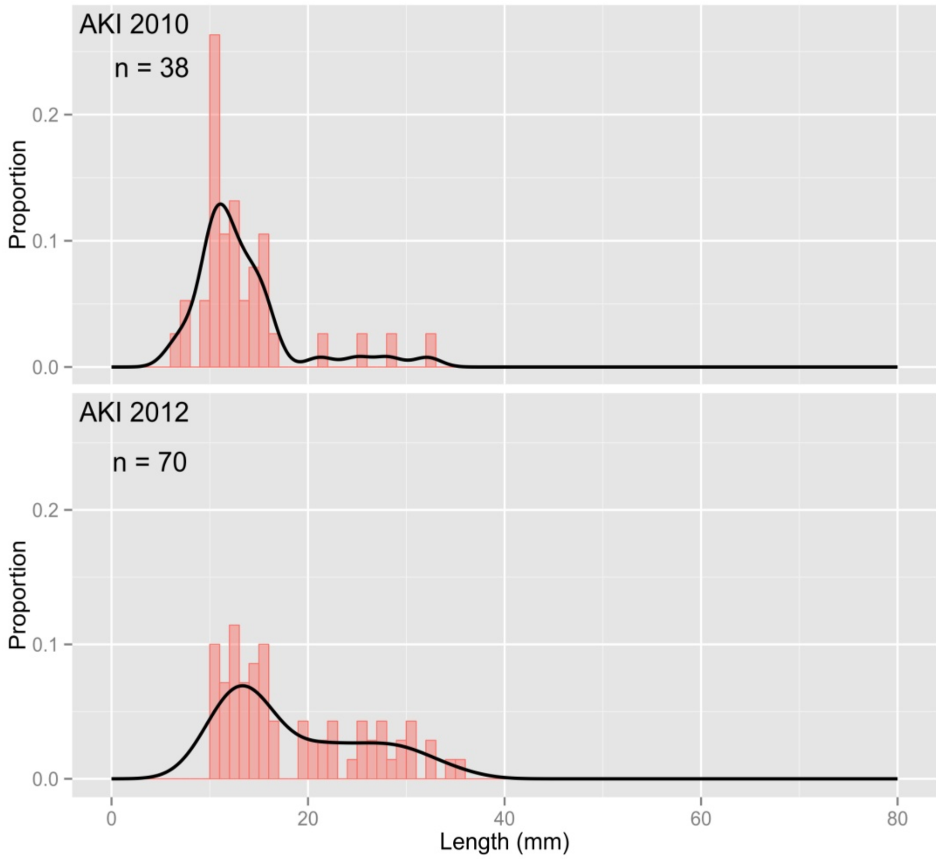

Figure 11: Histogram of the weighted length frequency distributions of pipis at Grahams Beach with a smoothed estimate of the length frequency distribution (black lines).

Discussion – Grahams Beach

Grahams Beach showed a marked decrease in the relative numbers of cockles, estimated at only around 16% of the previous (2010) population. The density and number of cockles at Grahams Beach has always been extremely low compared to other beaches (only around 100 cockles were found in total), and with such small numbers, large proportional changes are likely to occur over time. The typical size of cockles has increased by an average of around 5 mm since 2010, but no cockles of harvestable size were found.

The pipi density at Grahams Beach was extremely low, with fewer than 20 pipis per m^2. A total of 70 pipis were found at Grahams Beach; none of which were of harvestable size. This is a similar density to the 2010 survey.

4.2.4 Little Waihi Estuary

Beach description

The sample extent for Little Waihi Estuary has always been near its mouth – approximately adjacent to the campervan park (western side of Figure 12). Previous surveys have found shifts in the geomorphology of the area. To that end, the survey extent was redefined in 2009 and previous surveys had their strata rescaled for comparative purposes. A total of 175 samples was taken in 2012. Little Waihi estuary has been previously surveyed in 2000, 2002–04, 2006 and 2009.

Figure 12: The sample extent for Little Waihi Estuary (yellow polygons). The area was divided into two strata (A and B - equating to the areas covered by the main channel and the western bank). The red polygon denotes a region where the water level was too deep and the current was too swift to sample (or harvest) – this area was excluded from the sample extent.

Little Waihi cockles

We estimated (with 95% confidence) that the 2012 sample extent contained 17.6 ± 6.5 million cockles (Table 12). There was no evidence of a change in the size of the cockle population since the previous survey conducted in 2009 (p = 0.55). We estimated that 2012 had between 12.2 million fewer and 6.6 million more cockles than in 2009 (Table 12).

Cockle size was more variable than in 2009. Cockles were typically between 10 and 20 mm, with evidence of two cohorts centred on 8 and 21 mm in length (Table 13 and Figure 13). There was a modest increase in the number and proportion of harvestable cockles compared to 2009 (Table 14).

Table 12: Little Waihi Estuary cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	17.6	3.3	18.6	114.1
2009	20.4	3.4	16.6	146.2

Table 13: Little Waihi Estuary cockles – weighted length frequency distribution summary statistics (mm)

Survey	Mean	Mode	Range	Median	IQR
2012	16.2	8, 21	2–45	16	10–20
2009	17.3	15	5–31	17	15–21

Table 14: Little Waihi Estuary harvestable cockles (≥ 30 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2012	0.20	0.075	1.3	1.1
2009	0.08	0.041	0.44	0.3

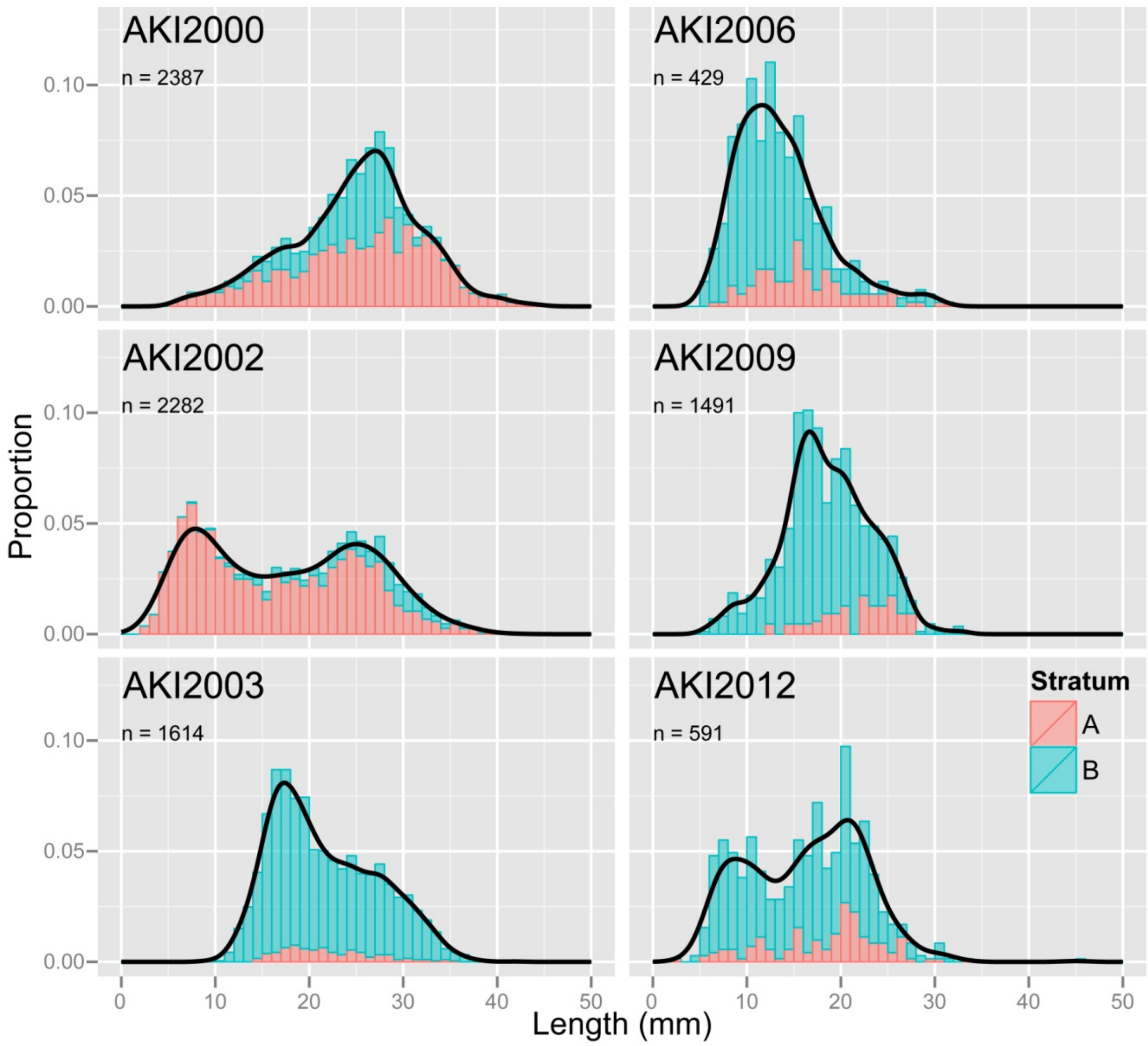

Figure 13: The weighted length frequency distribution of cockles at Little Waihi Estuary. Stratum contributions are represented by different colours and smoothed estimates of the length frequency distributions are also shown (black lines).

Little Waihi Estuary pipis

We estimated (with 95% confidence) that the 2012 sample extent contained 217.3 ± 33.7 million pipis (Table 15). There was weak evidence of a decrease in the pipi population since the 2009 survey (p = 0.069). We estimated that 2012 had between 148.7 million fewer and 5.5 million more pipis than in 2009.

The distribution of pipi sizes was similar in 2012 and 2009 (Table 16 and Figure 14), with pipi sizes typically between 25 and 42 mm. There was no evidence of a change in the number (p = 0.9) or the proportion (p = 0.3) of harvestable pipis since the 2009 survey (Table 17).

Table 15: Little Waihi Estuary pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	217.3	17.1	7.9	1409
2009	269.3	31.1	12.1	2075

Table 16: Little Waihi Estuary pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2012	33.7	43	5–59	34	25–42
2009	32.7	17, 36	7–55	35	25–41

Table 17: Little Waihi Estuary harvestable pipis (≥ 50 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2012	10.2	1.8	65.8	4.7
2009	10.0	2.0	56.0	2.7

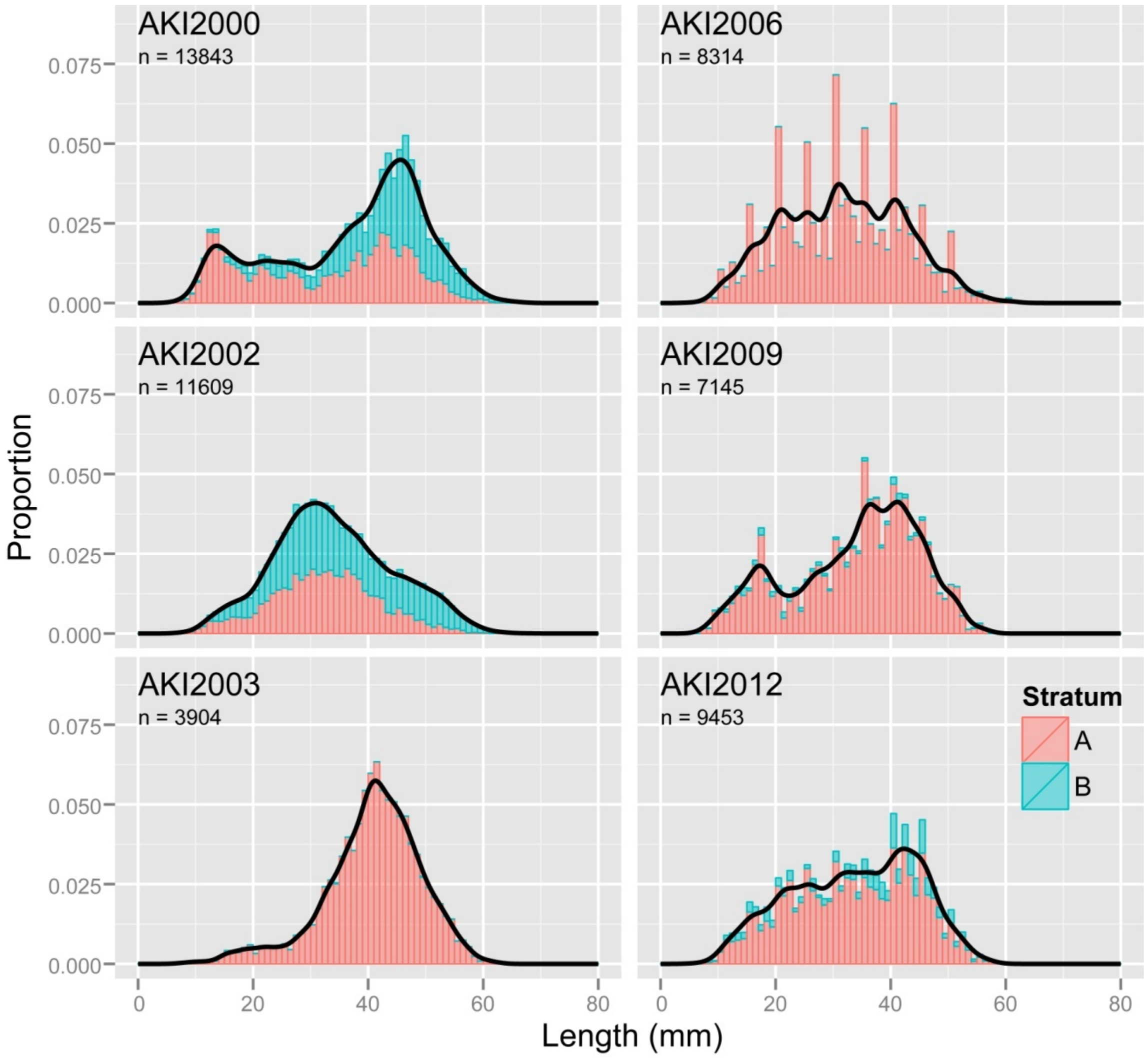

Figure 14: The weighted length frequency distribution of pipis at Little Waihi Estuary. Stratum contributions are represented by different colours and smoothed estimates of the length frequency distributions are also shown (black lines).

Discussion – Little Waihi Estuary

The average cockle density at Little Waihi remained moderately low (114 per m^2). Only around one percent of cockles there were of harvestable size, and this has not changed since the previous (2009) survey.

The average pipi density at Little Waihi was very high. The main channel had a density of around 2000 pipis per m^2. The total population of pipis appeared to have dropped since the 2009 survey, but the number of harvestable-sized pipis had not changed over this period.

4.2.5 Marsden Bank

Beach description

The sample extent of the Marsden Bank pipi bed was split into three strata that extend from the east bank to a depth of around 0.5 m below chart datum (Figure 15). In 2012, 168 samples were taken within the sample extent. Marsden Bank was previously sampled on one occasion in 2010 for the MPI IPA2010-12 project and in May 2012 by NIWA – the results of these projects were used as a comparison with this December survey.

Figure 15: The Marsden Bank sample extent (yellow polygon) extended south and west of the bank itself. The pipi bed (red polygon) was divided into high (A) and lower (B) density strata.

Marsden Bank cockles

No cockles were found at Marsden Bank in this (or any previous) survey.

Marsden Bank pipis

We estimated (with 95% confidence) that the 2012 sample extent for Marsden Bank contained 60.0 ± 23 million pipis (Table 18). There was strong evidence of a change in the pipi population since the previous surveys ($p<0.01$). We estimated that 2012 had between 61 million and 235 million fewer pipis than in the 2009 survey.

The average pipi size was almost 4 mm larger than in 2009. The typical length was between 17 and 23 mm (Table 19). However, in contrast with the 2009 survey, no pipis of harvestable size were found in 2012 (Table 20 and Figure 16).

Table 18: Marsden Bank pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	60.0	11.87	19.8	950
2012b[6]	9.0	1.92	21.4	103.7
2010	208.8	42.3	20.3	1815

Table 19: Marsden Bank pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2012	21.1	20	1–48	20	17–23
2012b	19.9	17	8–43	19	15–23
2010	18.5	13	3–78	15	12–19

Table 20: Marsden Bank harvestable pipis (≥ 50 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2012	0	0	0	0
2012b	0	0	0	0
2010	10.0	7.9	2.6	3.8

[6] The results of surveys: MDN2012 (conducted in May 2012), and IPA2009 (done in March 2010) are included for comparison. The AKI2012 survey was conducted in December 2012.

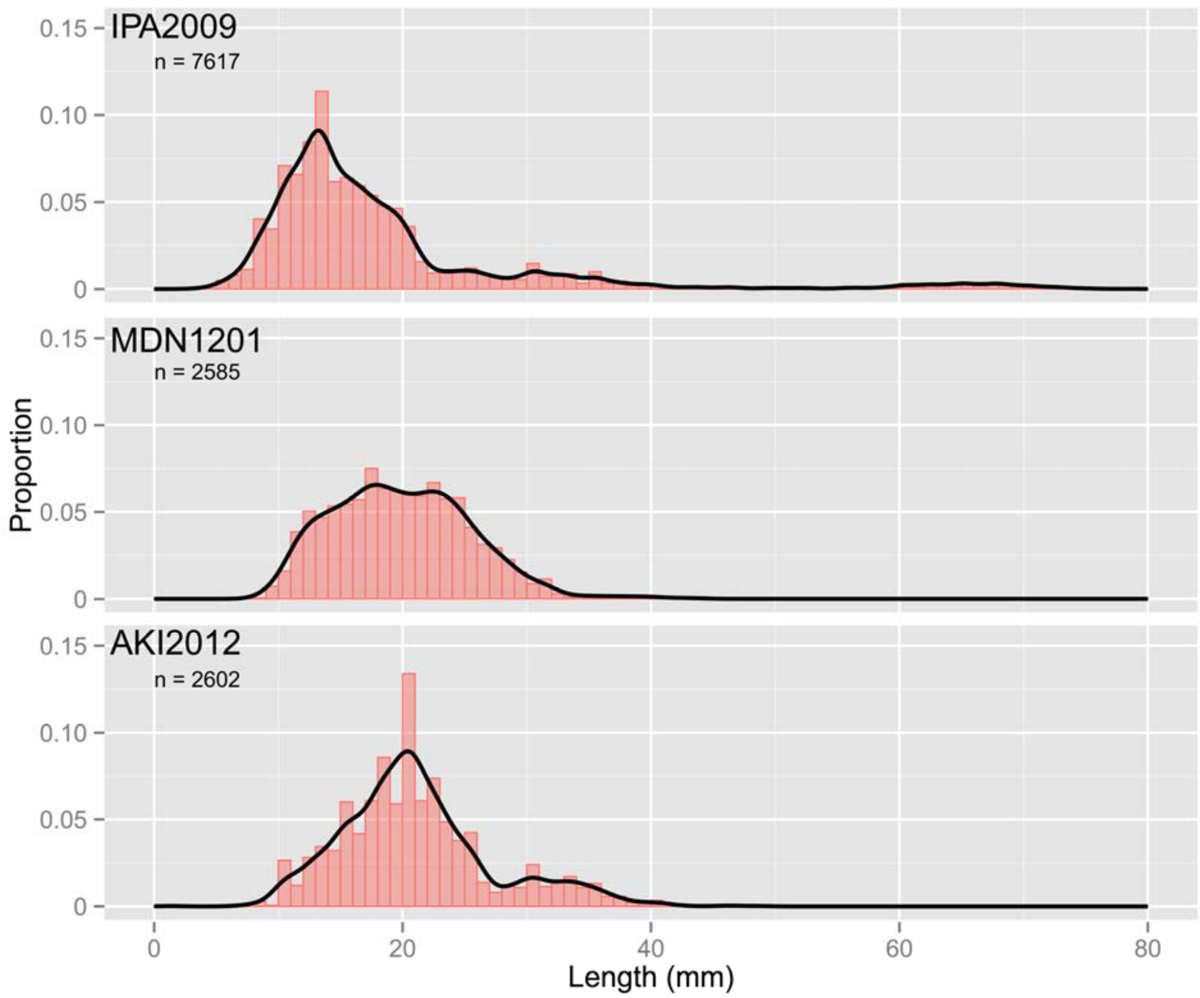

Figure 16: The weighted length frequency distribution of pipis at Marsden Bank. Smoothed estimates of the length frequency distributions as black lines.

Discussion – Marsden Bank

As was found with previous surveys, Marsden Bank had an extremely high density of small pipis. The bed location had an average density of around 2500 pipis per m^2) and this bed appeared to have extended south since 2009. However, the total pipi population declined overall, and was less than half the estimated population from the previous (2009) survey. The large pipis that was previously found around the northern edge of Marsden bank in the 2009 survey were not found in 2012.

4.2.6 Ohiwa Estuary

Beach description

The sample extent for Ohiwa Estuary all lay on Motuotu Island and were easily accessible only by boat (Figure 17). The sample extent was split into two disparate areas: strata A and B (with respective sizes 0.6 and 0.3 ha) were on the south-eastern bank of the island, and Stratum C and E were pipi beds on the northern edge of the island. The bank morphology changed since 2009 and the co-ordinates that defined stratum C were further ashore and unlikely to be comparable to previous years. The subtidal area (down to about 0.5 m below CD) on the northern end of the island was surveyed. The 2012 sample extent covered while searching for the northern pipi beds is denoted by a yellow line, with the 2009 survey depicted with a red line for comparative purposes (Figure 17).

In 2012, a total of 198 samples were taken within the sample extent. Prior to the 2012 survey, Ohiwa Estuary was sampled in 2001, 2005 and 2006 and 2009.

Figure 17: The Ohiwa Estuary sample extent and sampled strata around Motuotu Island (yellow polygons). The orange line denotes the low tide contour line around the northern end of island that was searched for pipis in 2012, and the red line denotes the analogous contour line from the 2009 survey. A small but very dense pipi bed (new stratum G, green polygon, Figure 20) was found west of stratum E, and most of the NW contour had pipis (new stratum F).

Ohiwa Estuary cockles

We estimated (with 95% confidence) that the Ohiwa Estuary 2012 sample extent contained 9.0 ± 1.86 million cockles (Table 21). There was very strong evidence of an increase in the number of cockles since the previous (2009) survey ($p<0.02$). We estimated there was between 0.34 million and 4.8 million more cockles than in the 2009 survey.

Cockles were, on average, around 4 mm smaller than in the previous (2009) survey. Typical cockle size was between 14 and 19 mm (Table 22). Less than 1% of the total population was of harvestable size (Table 23, Figure 18), and there was no evidence of a change in the number of harvestable cockles ($p = 0.36$).

Table 21: Ohiwa Estuary cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	9.0	0.94	10.5	340.6
2009	6.4	0.56	8.8	304.7

Table 22. Ohiwa Estuary cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2012	17.9	16	5–35	17	13–19
2009	16.6	16	5–35	17	13–19

Table 23: Ohiwa Estuary harvestable cockles (≥ 30 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2012	0.05	0.018	1.9	0.5
2009	0.03	0.012	1.4	0.4

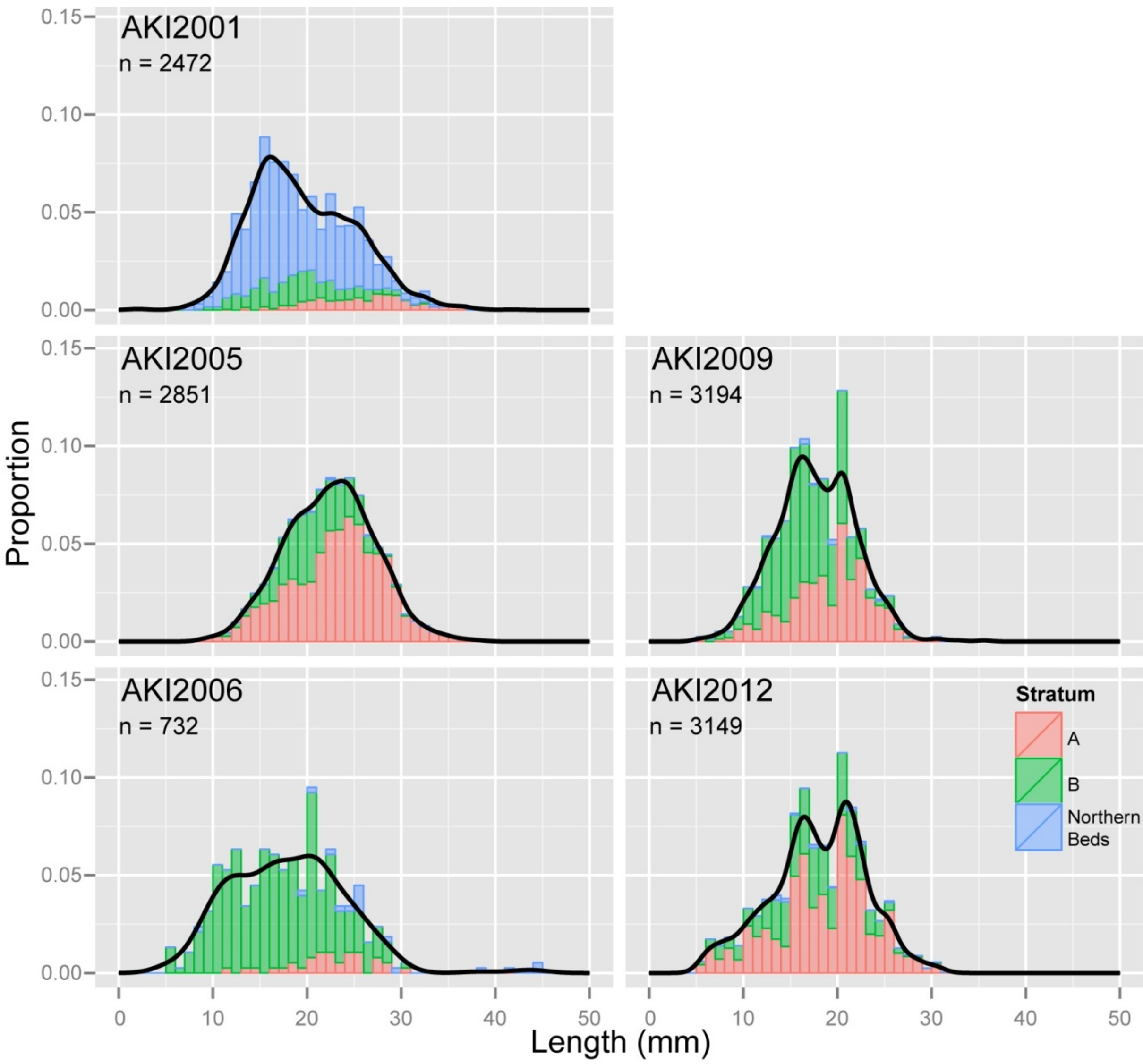

Figure 18: The weighted length frequency distribution of cockles at Ohiwa Estuary. Stratum contributions are represented by different colours and smoothed estimates of the length frequency distributions are also shown (black lines).

Ohiwa Estuary pipis

We estimated (with 95% confidence) that the 2012 sample extent for Ohiwa Estuary contained 43.7 ± 11.9 million pipis (Table 24). There was strong evidence of an increase in the pipi population since the previous (2009) survey ($p<0.001$). We estimated that 2012 had between 16.5 million and 41.5 million more pipis than in 2009.

There were two cohorts in pipi lengths at Ohiwa Estuary: a cohort of recruits centred around 12 mm and another cohort of larger pipis centred around 42 mm. The cohort of small pipis dropped the average pipi size from 39 mm (in 2009) to 27 mm (in 2012) (Table 25 and Figure 19). There was no evidence of change in the number of harvestable pipis (relative to the total population, Table 26) ($p<0.289$), but there was a clear decrease in the proportion of harvestable pipis ($p = 0.002$) (due to the large increase in juvenile pipis found in 2012).

Table 24: Ohiwa Estuary pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	43.7	6.0	13.7	1659.3
2009	14.7	2.0	13.9	698.4

Table 25: Ohiwa Estuary pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2012	27.3	12, 42	3–56	20	13–42
2009	39.4	42	11–57	41	35–45

Table 26: Ohiwa Estuary harvestable pipis (≥ 50 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2012	1.13	0.32	43.2	2.6
2009	1.57	0.26	75.0	10.7

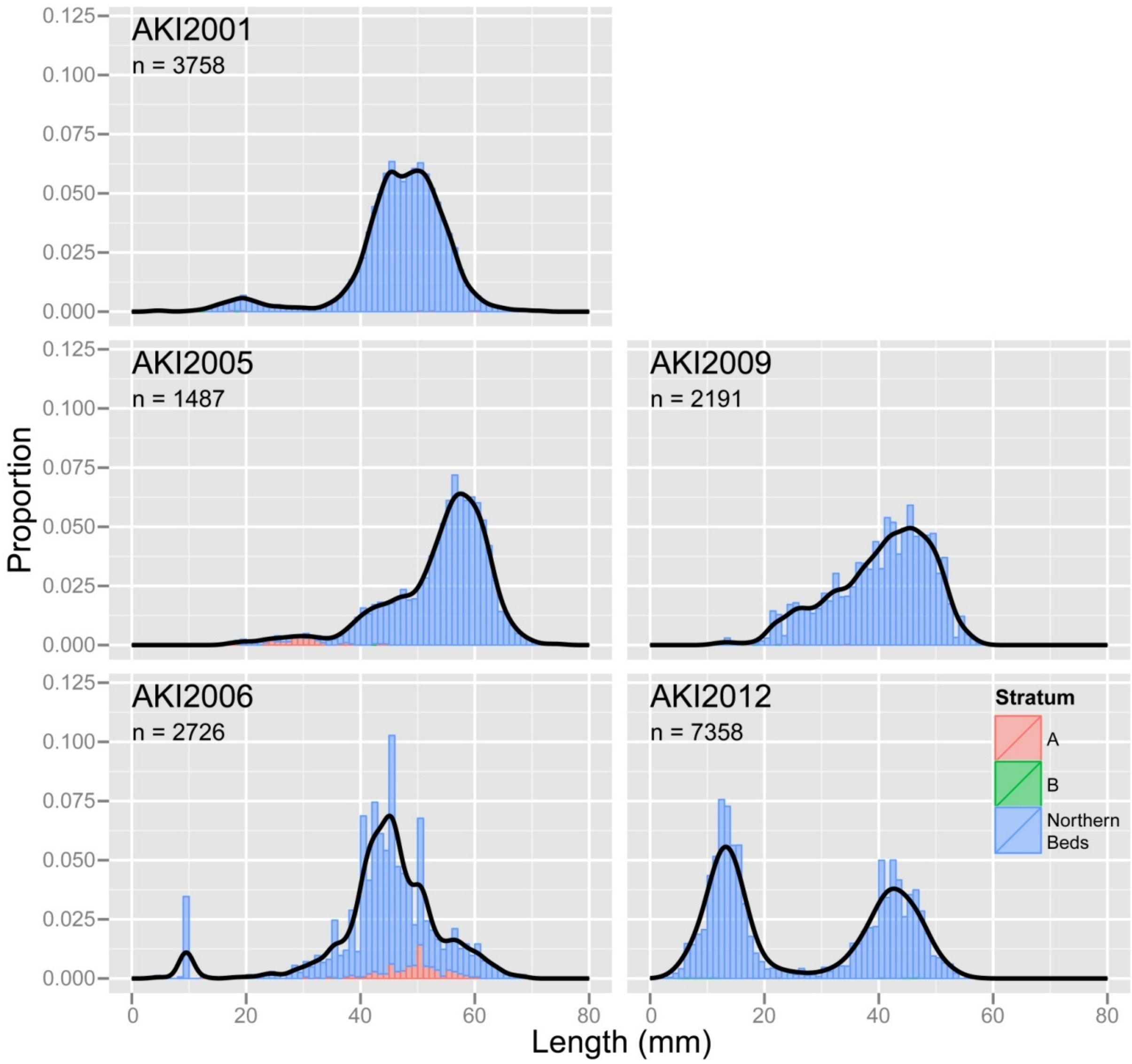

Figure 19: The weighted length frequency distribution of pipis at Ohiwa Estuary. Stratum contributions are represented by different colours and smoothed estimates of the length frequency distributions are also shown (black lines).

Figure 20: A newly discovered pipi bed at Ohiwa Estuary (Stratum G). The bed was relatively small (only 300 m^2), but had an extremely dense population of adult pipis and was up to 30 cm thick on top of the substratum.

Discussion – Ohiwa Estuary

The cockle population at Ohiwa Estuary had remained stable since the previous survey. Most cockles were found on the Western bank of Motuotu Island where the physical structure of the bank has been relatively stable. In contrast, the changes in the beach morphology at the northern end of Motuotu Island made it difficult to assess the temporal changes in the pipi population located there. The previous study made a point of recording the area canvassed while looking for pipi beds. This same general area was examined in 2012, although the bank appeared to extend further north than in the 2009 survey. In 2012, the GPS co-ordinates of stratum C lay on an intertidal flat on the island, almost 100 m from the bank edge. The area was still surveyed and found a dense numbers (around 2000 m^2) of small pipis (less than 20 mm in length). At the north-eastern edge of the Motuotu Island, where stratum C used to lie, there was another relative large patch of pipis. This new stratum was labelled 'Stratum F' and had dense numbers of pipis (around 4000 per m^2) between five and 55 mm in length (Figure 19). Stratum G was another new bed on the edge of the Northern edge of Motuotu Island that was not found in 2009. Although it was a small bed (around 300 m^2) it was highly visible because the density of adult pipis (around 15,000 per m^2) meant that it lay up to 30 cm higher than the substratum (Figure 20). The depth of the bed made it difficult to sample accurately because our corers were not deep enough.

4.2.7 Okoromai Bay

Beach description

The sample extent for Okoromai Bay was split into two strata (A and B, of 8 and 12 ha respectively) encompassing most of the suitable area for cockles (Figure 21). Most of the substratum in stratum A was covered by the sea-grass *Zostera*. Strata A and B both have rocky substratum on each side and contained moderate to low cockle density relative to other sampled beaches (about 240 and 68 cockles per m^2 respectively). A total of 122 samples was taken within the sample extent.

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

Figure 21: The sample extent for Okoromai Bay is split into two strata (yellow polygons).

Okoromai Bay cockles

We estimated (with 95% confidence) that the Okoromai Bay 2012 sample extent contained 28.2 ± 5.6 million cockles. There was no evidence of a change in the number of cockles since the previous survey (p = 0.78). We estimated there was between 9.2 million fewer and 7.0 million more cockles than in the 2009 survey (Table 27).

Cockles were similar in size to those found in 2009. Typical sizes were between 24 and 32 mm (Table 28 and Figure 22), and most cockles were larger than 20 mm.

There was no evidence of a change in the population or proportion of harvestable cockles between the 2012 and 2009 surveys (p = 0.77) (Table 29).

Table 27: Okoromai cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	28.2	3.0	10.6	141.1
2009	29.3	2.8	9.6	146.7

Table 28. Okoromai Bay cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2012	28.3	30	5–45	29	24–32
2009	26.8	29	5–47	29	23–31

Table 29: Okoromai cockles ≥ 30 mm length.

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2012	13.5	1.6	67.4	47.8
2009	12.9	1.4	64.7	44.1

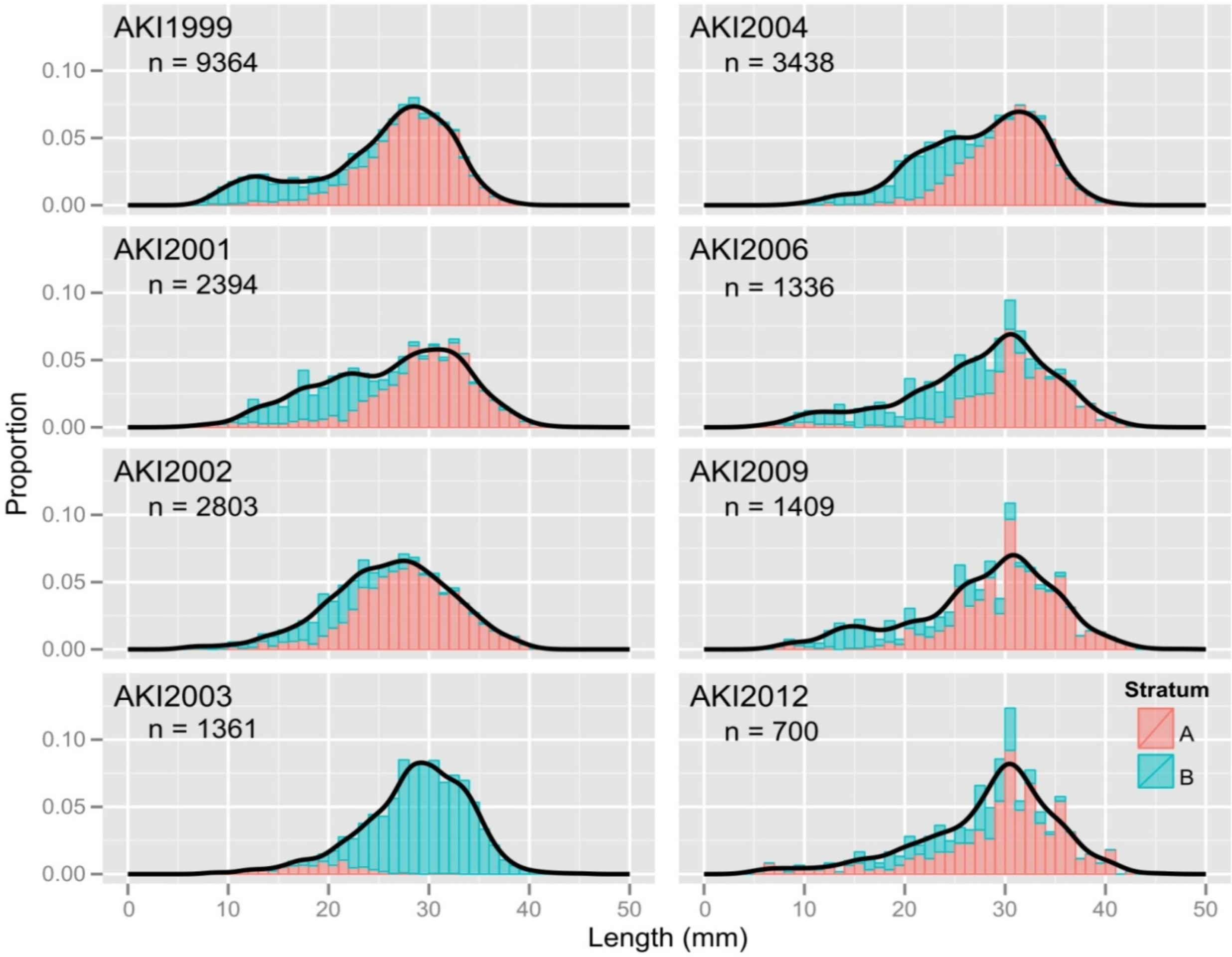

Figure 22: The weighted length frequency distribution of cockles at Okoromai Bay. Stratum contributions are represented by different colours and smoothed estimates of the length frequency distributions are also shown (black lines).

Okoromai Bay pipis

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

Discussion – Okoromai Bay

The cockle population at Okoromai Bay remained relatively static since 2009. Although the average density of cockles was only moderate (around 140 cockles per m^2), almost half of the cockles were of harvestable size, which is a high proportion relative to other beaches in the survey (Figure 3). The number and proportion of harvestable cockles also remained stable at Okoromai Bay.

4.2.8 Raglan Harbour

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 23).

A total of 180 samples was taken within the sample extent. Raglan Harbour was previously sampled in 1999, 2000, 2002, 2003 and 2009.

Figure 23: Raglan Harbour – the sample extent (yellow polygons) covered two different areas. The initial sample extent for Stratum C covered most of the area between the bridges (down to 0.5 m below CD). The pipi bed (red polygon) was found in the same area as the previous surveys (2003 and 2009).

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). We estimated (with 95% confidence) that the Raglan Harbour 2012 sample extent had 127.8 ± 17.2 million cockles (Table 30). There was no evidence of a change in the cockle population since the previous survey (p = 0.76). We estimated that the 2012 population had between 18.1 million fewer and 24.9 million more cockles than 2009.

The median cockle size in the 2012 survey was around 3 mm larger than the previous (2009) survey, and typical cockles ranged between 18 and 25 mm (Table 31 and Figure 24). There was no evidence of a change in the number (p = 0.9) or proportion of harvestable cockles since the previous survey (Table 32).

Table 30: Raglan cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	127.8	8.7	6.8	1550
2009	124.4	6.5	5.2	1509

Table 31: Raglan cockles — weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2012	21.9	21, 26	4–45	22	18–25
2009	19.4	19	5–45	19	17–23

Table 32: Raglan cockles population estimates ≥ 30 mm length.

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2012	6.0	1.2	73.0	4.7
2009	5.8	1.1	70.9	4.7

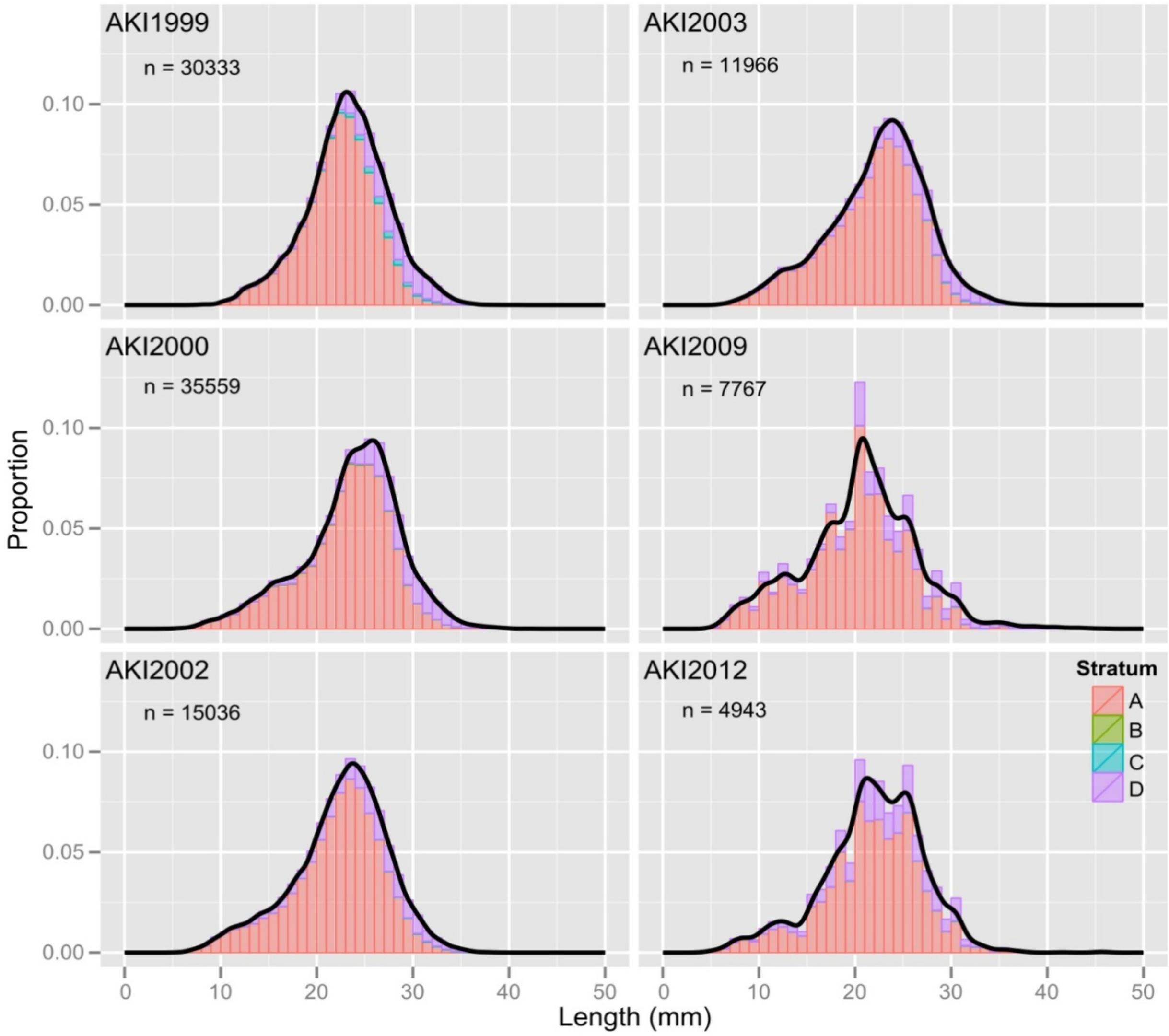

Figure 24: The weighted length frequency distribution of cockles at Raglan Harbour. Stratum contributions are represented by different colours and smoothed estimates of the length frequency distributions are also shown (black lines).

Raglan Harbour pipis

Most pipis were found within the channel between the bridges (Stratum C). We estimated (with 95% confidence) that the 2012 Raglan Harbour sample extent had 1.76 ± 0.5 million pipis (Table 33). There was strong evidence of an increase in the pipi population since the previous survey (p<0.001). We estimated that the 2012 population had between 0.6 million and 1.7 million more pipis than in 2009.

The average pipi size was slightly smaller than in 2009. The typical length was between 33 and 51 mm (Table 34 and Figure 25). There was no evidence of a change in the number of harvestable pipis (p = 0.29), but a decline in the proportion of harvestable pipis (relative to the total population) (p<0.001).

Table 33: Raglan pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	1.76	0.26	14.5	21.4
2009	0.59	0.11	19.1	7.2

Table 34: Raglan pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2012	33.9	36	3–61	35	26–40
2009	35.9	19, 51	9–59	39	21–49

Table 35: Raglan harvestable pipis (≥ 50 mm length)..

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2012	0.13	0.03	1.59	7.5
2009	0.15	0.02	1.76	24.3

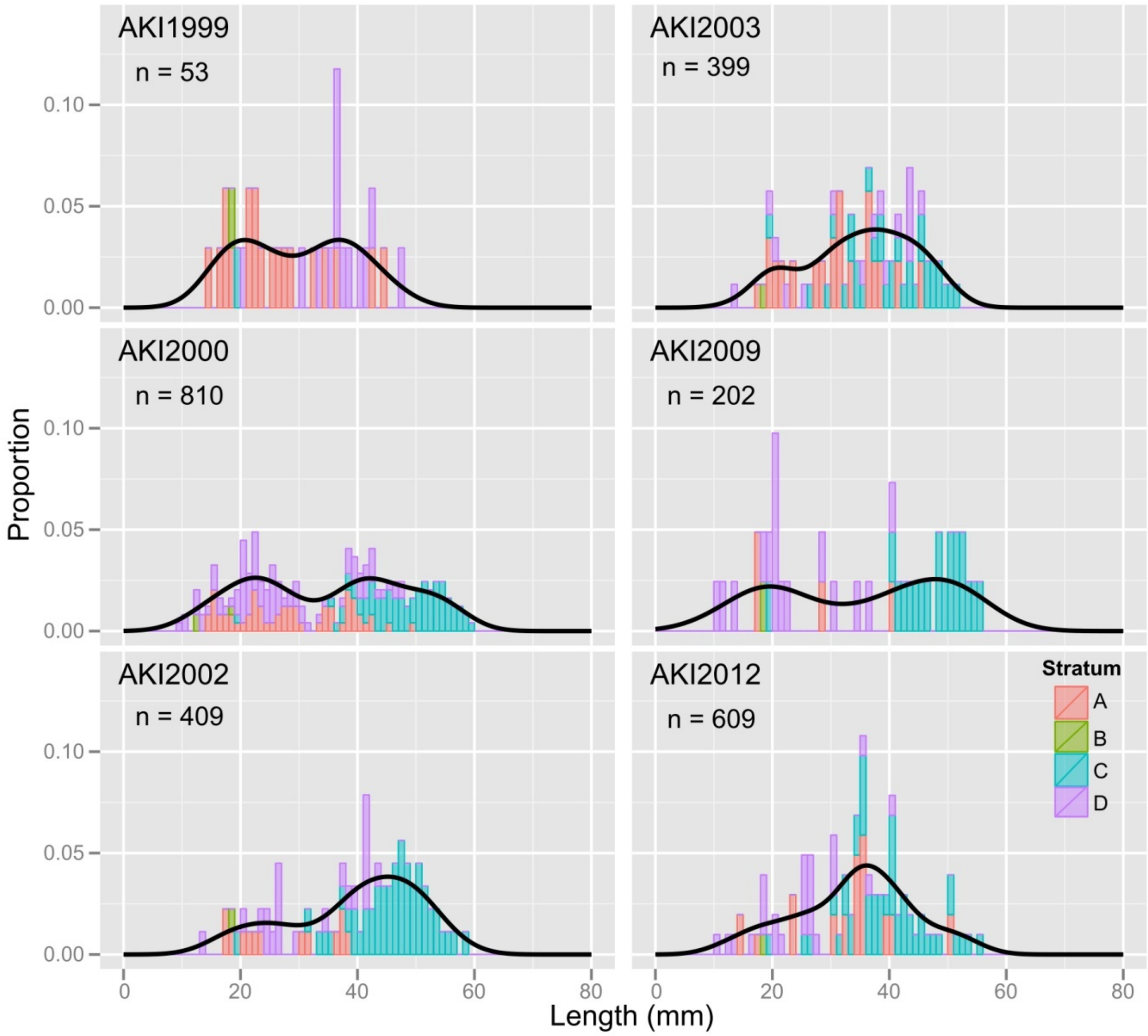

Figure 25: The weighted length frequency distribution of pipis at Raglan Harbour. Stratum contributions are represented by different colours and smoothed estimates of the length frequency distributions are also shown (black lines).

Discussion – Raglan Harbour

The cockle density at Raglan harbour was extremely high (around 1500 cockles per m^2). The cockle population within the Raglan Harbour sample extent has not changed since the previous (2009) survey. Cockle size has increased slightly, although the typical length remained relatively low; around 5% of the sampled cockles were of harvestable size.

The 2012 survey found the first increase in the total number of pipis since 2000. The total pipi population almost trebled, however most of the pipis found were relatively small. This has led to a corresponding decrease in the proportion of harvestable pipis (although the total number of harvestable pipis was relatively unchanged since 2009).

4.2.9 Te Haumi Beach

Beach description

The sample extent at Te Haumi Bay consists of two strata (A and B, covering 3 and 6 ha respectively) which 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, see Figure 26).

The large 'L'-shaped shell/sand bank that was used to subdivide stratum B in the 2006 and 2009 surveys was not evident in the 2012 survey. A total of 142 samples were 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 chart datum.

Before the 2012 survey, Te Haumi Beach was sampled in 1999–2002, 2006 and 2009.

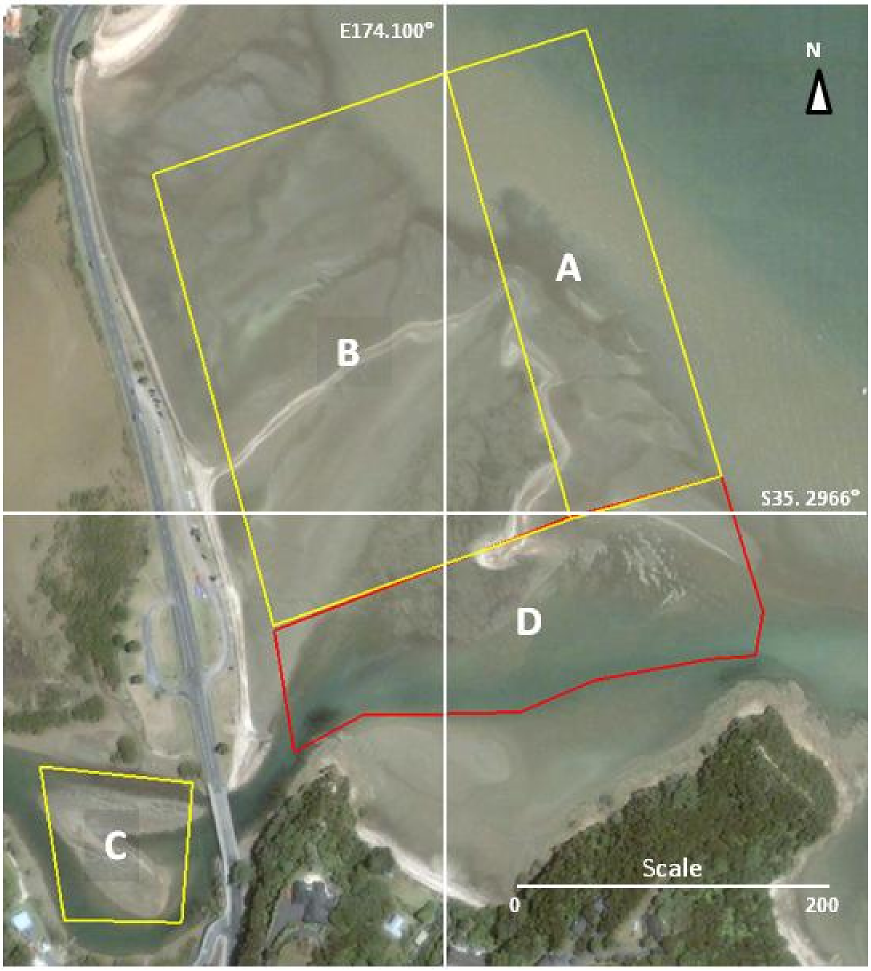

Figure 26: Te Haumi Bay sample extent consisted of two distinct areas – the intertidal area of the main beach (strata A and B) and a small pipi bed on the inner estuary (stratum C). Stratum B exhibited a shell/sand bank that roughly split it into two parts (visible in the figure). Stratum D (adjacent to the river to the south of the main beach) was sampled, but not included in population calculations.

Te Haumi Beach cockles

Excluding stratum D, we estimated (with 95% confidence) that in 2012 the Te Haumi Beach sample extent contained 41.5 ± 10.5 million cockles (Table 36). There was weak evidence of an increase in the cockle population in this area since the previous (2009) survey (p = 0.065). We estimated that there were between 0.65 million fewer and 23.0 million more cockles than in 2009.

Cockle size in the 2012 survey was similar to the length distribution found in 2009 (Table 37). There was strong evidence of an increase in the number of harvestable cockles since 2009 (p<0.001) (Table 38). We estimated (with 95% confidence) that there were between 0.76 million and 2.2 million more harvestable cockles than in 2009.

Table 36: Te Haumi Beach cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	41.5	5.3	12.7	422.9
2009	30.4	3.1	10.2	310.1

Table 37: Te Haumi Beach cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2012	18.7	15	5–42	18	13–24
2009	18.6	20	5–47	19	13–21

Table 38: Te Haumi Beach harvestable cockles (≥ 30 mm length).

Survey	Population Estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2012	2.0	0.33	20.1	4.7
2009 (Strata A–C)	0.9	0.25	9.2	2.9

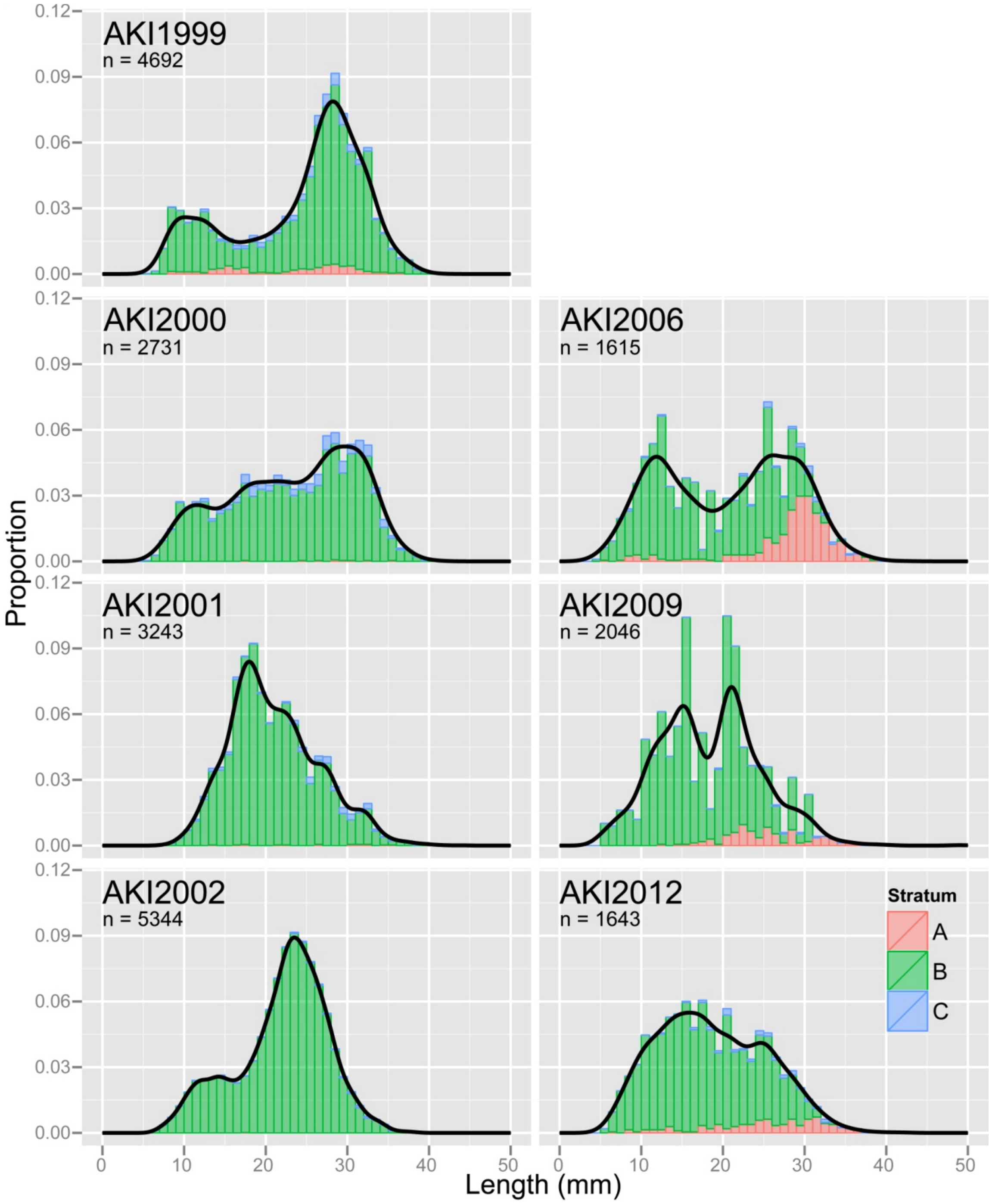

Figure 27: The weighted length frequency distribution of cockles at Te Haumi Beach. Stratum contributions are represented by different colours and smoothed estimates of the length frequency distributions are also shown (black lines). In 2009, stratum B was split into separate strata (B_1 and B_2).

Te Haumi Beach pipis

We estimated (with 95% confidence) that the 2012 Te Haumi Beach sample extent contained between 66.2 ± 25.1 million pipis. There was little evidence of a change in the total pipi population since the previous (2009) survey (p = 0.106) (Table 39). We estimated that the 2012 survey had between 4.8 million fewer and 50.2 million more pipis than in 2009.

Pipi size was similar to the 2009 survey; typical pipi size in 2012 ranged between 15 and 26 mm (Table 40). There were very few pipis of harvestable size, and there was no evidence of a change from the 2009 harvestable population (p = 0.4). Indeed, less than one percent of all pipis found were larger than 50 mm. The length frequency distribution does suggest a larger proportion of pipis between 15 and 30 mm in length (Table 41, Figure 28).

Table 39: Te Haumi Beach pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	66.2	12.7	19.2	674.6
2009	43.5	5.5	9.1	443.6

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

Survey	Mean	Mode	Range	Median	IQR
2012	22.4	15	6–54	20	15–26
2009	20.8	17	3–55	19	13–27

Table 41: Te Haumi Beach harvestable pipis (≥ 50 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2012	0.28	0.09	2.9	0.4
2009	0.20	0.04	2.0	0.5

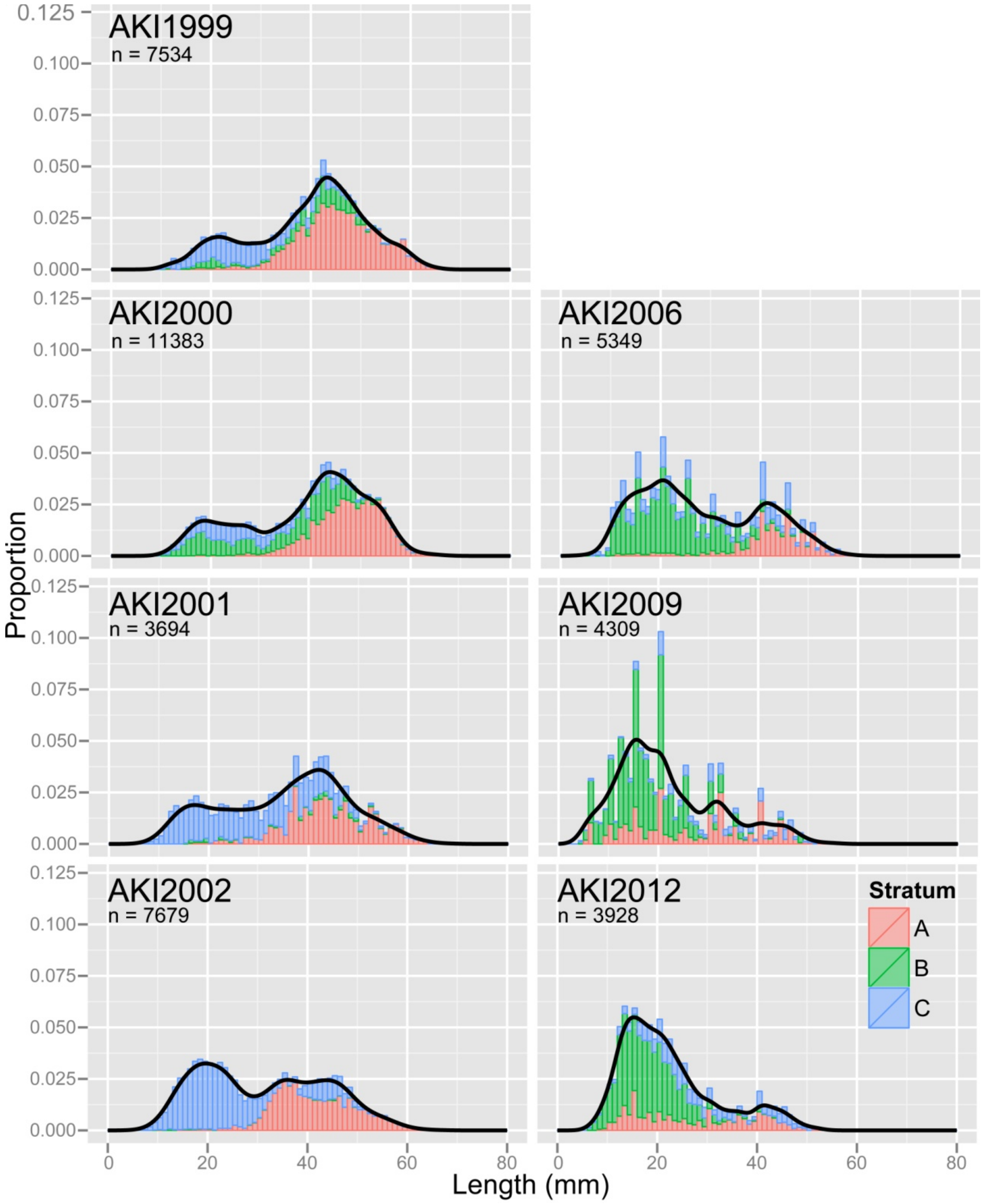

Figure 28: The weighted length frequency distribution of pipis at Te Haumi Beach. Stratum contributions are represented by different colours and smoothed estimates of the length frequency distributions are also shown (black lines).

Discussion – Te Haumi Beach

Most cockles at Te Haumi Beach were found in stratum B, and the average density of cockles (422 per m^2) was moderately high compared to other surveyed beaches. Cockle size has remained relatively unchanged since the previous survey. Although there was evidence of an increase in the number of harvestable cockles, this proportion was still considerably lower than what was found between 1999 and 2002 (Figure 27).

Pipis at Te Haumi Beach were primarily found in stratum B (juveniles) and stratum C (adults and juveniles). The two distinct size class structures within these strata meant that the length frequency distribution at Te Haumi often showed evidence of bimodality. Pipi numbers also remained relatively unchanged since 2009, but the density of small pipis in stratum B increased from around 411 per m^2 (2009) to around 613 per m^2 (2012).

4.2.10 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 29).

A total of 190 samples were taken from the sample extent. Before the 2012 survey, Umupuia was surveyed 1997–2006 and 2009. Umupuia beach was closed to recreational harvesting in October 2008.

Figure 29: Umupuia beach – the sample extent was split into four strata covering the majority of the intertidal zone of the beach.

Umupuia Beach cockles

We estimated (with 95% confidence) that the 2012 Umupuia Beach sample extent contained 124.0 ± 33.8 million cockles (Table 42). There was no evidence of a change in the cockle population since the 2010 survey (p = 0.31). We estimated that there were between 19.2 million fewer and 59.8 million more cockles in 2012 compared to 2010.

Cockle size increased since the previous (2010) survey. Typical cockle length was 24 to 31 mm although the distribution was bimodal, with peaks occurring at six and 31 mm lengths (Table 43).

There was strong evidence of an increase in the number (p<0.001) and proportion (relative to the total population size) (p<0.001) of harvestable cockles since 2010 (Table 44). In 2012, harvestable cockles made up nearly 40% of the population. We estimated (with 95% confidence) that there were between 25.7 million and 50.9 million more harvestable cockles than in 2010.

Table 42: Umupuia cockles – population estimates.

Survey	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	124.0	17.6	13.2	344.1
2010	102.1	10.2	10.0	283.5

Table 43: Umupuia cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2012	25.4	6,31	2–40	28	24–31
2010	22.1	20	3–47	22	20–26

Table 44: Umupuia harvestable cockles (≥ 30 mm length).

Survey	Population Estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2012	47.5	6.2	132.1	38.3
2010	9.2	1.4	25.7	9.0

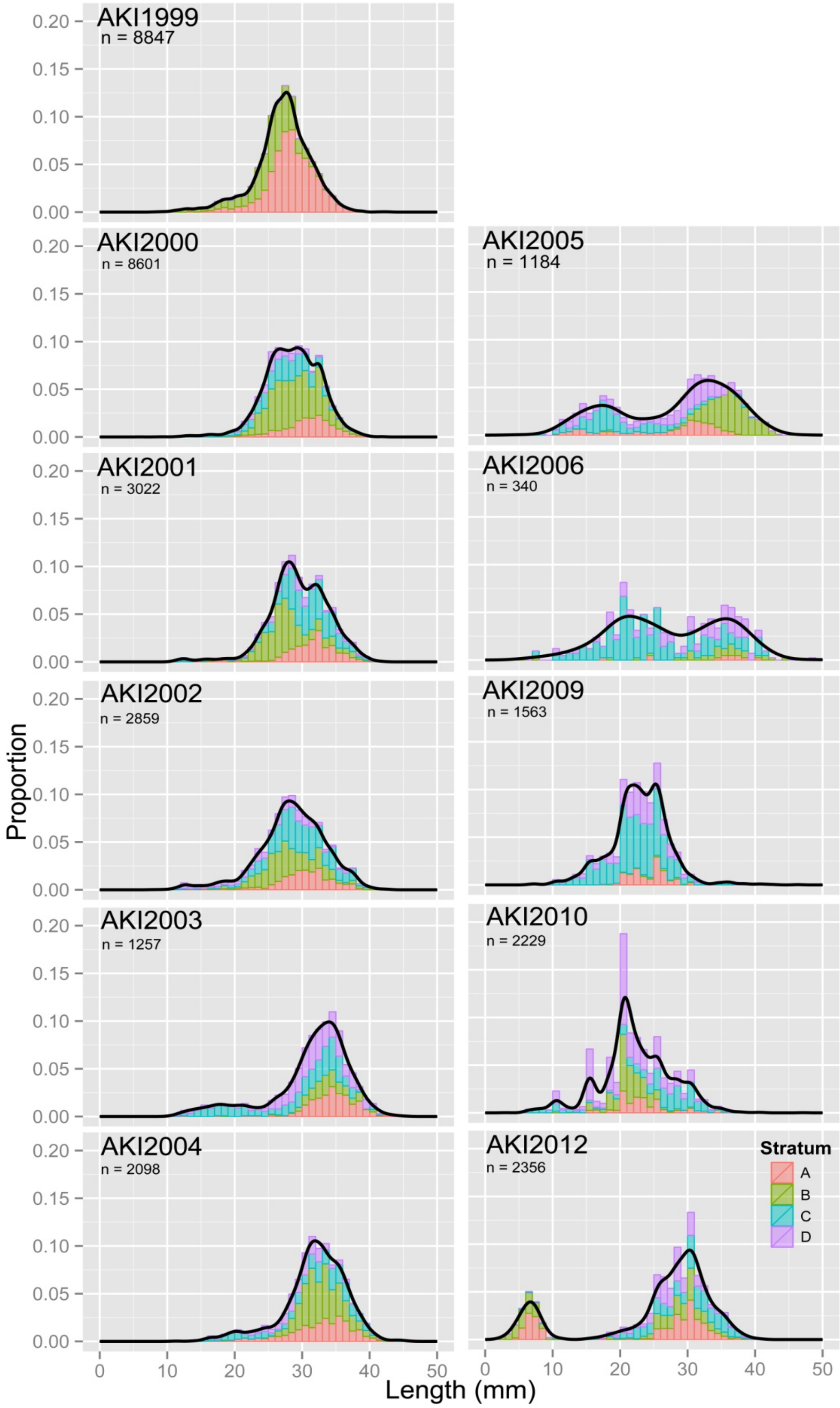

Figure 30: The weighted length frequency distribution of cockles at Umupuia Beach. Stratum contributions are represented by different colours and smoothed estimates of the length frequency distributions are also shown (black lines).

Umupuia Beach pipis

Population estimates were not calculated for pipi at Umupuia because no pipis were found during the 2012 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[7] closure of the beach. However, since the closure, the cockle population has shown a marked increase, although there was no evidence of a change between 2010 and 2012.

The number and proportion of harvestable cockles have substantially increased since 2010, and the proportion of harvestable cockles at Umupuia Beach is now relatively large compared to most beaches. Umupuia Beach appears to have had strong recruitment over the last year. This was indicated by a cohort of small cockles (centred at around 6 mm) found in the strata near the low-tide mark (strata A and B).

[7] 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.

4.2.11 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 small pipi bed bordering the west side of the main channel that covers a pipi bed (sampled to 0.5 m below chart datum) (see Figure 31). A total of 230 samples were taken from the sample extent. Before the 2012 survey, Whangateau harbour was surveyed in 2001, 2003, 2004, 2006, 2009 and 2010. The Whangateau Harbour was closed for recreational harvesting of all shellfish on 25 March 2010 for at least a three-year period.

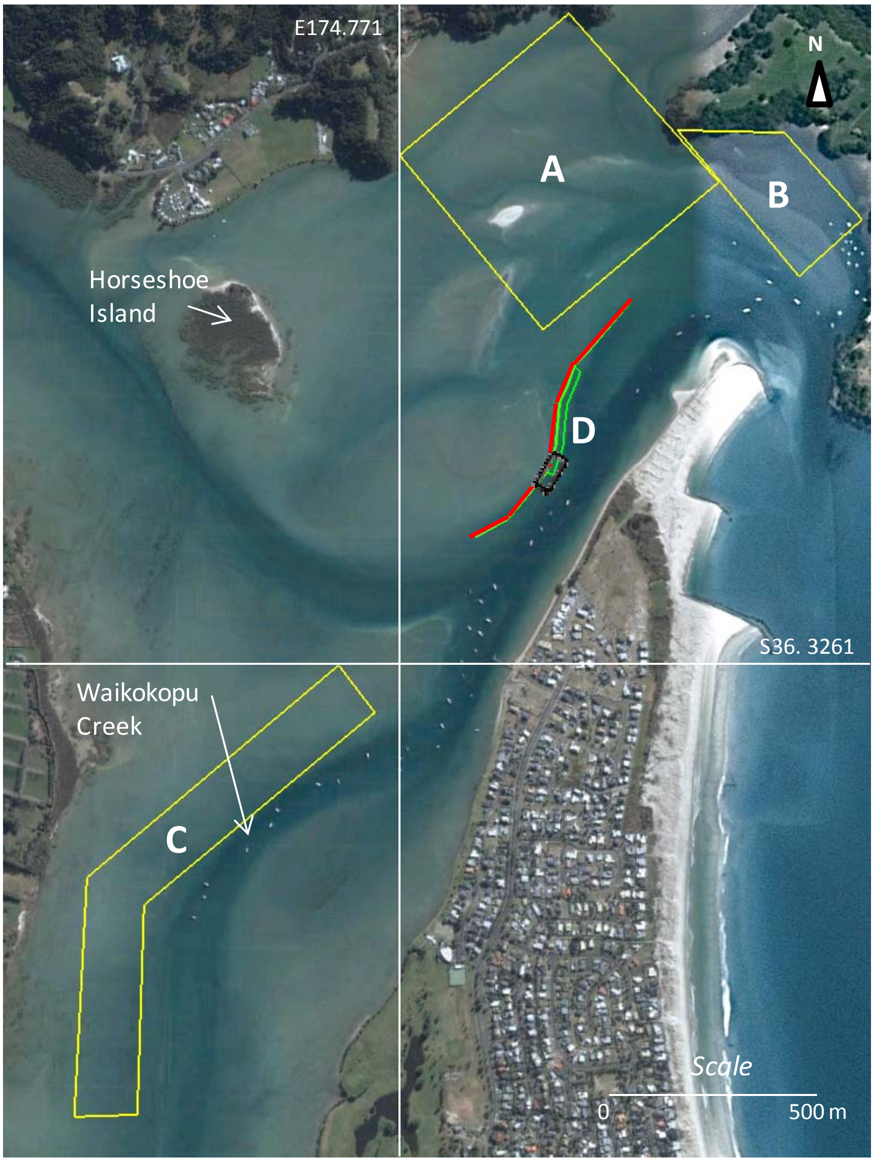

Figure 31: The Whangateau Harbour sample extent was divided into four strata. Yellow polygons denote the sample extent covering cockle beds and the red line (stratum D) denotes the sample extent along the channel bank examined for pipis. The pipi bed locations in 2012 (green polygon) and 2010 (black polygon) are shown.

Whangateau Harbour cockles

We estimated (with 95% confidence) that the 2012 Whangateau Harbour sample extent had 360.0 ± 41.7 million cockles (Table 45). There was strong evidence of an increase in the cockle population since the previous (2010) survey ($p<0.001$). We estimated that the 2012 survey had between 75.0 million and 171.4 million more cockles than the 2010 survey.

The average cockle size in the 2012 survey was similar to 2010, with typical cockles ranging between 16 and 25 mm in size (Table 46, Figure 32). There was strong evidence of an increase in the number of harvestable cockles since 2010 ($p = 0.69$) (Table 47). We estimated (with 95% confidence) that there were between 1.0 million and 20.8 million more harvestable cockles than in 2010.

Table 45: Whangateau cockles – population estimates.

Year	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	360.2	21.1	5.8	561.0
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 46: Whangateau cockles – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2012	20.8	21	3–39	20	16–25
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 47: Whangateau harvestable cockles (≥ 30 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2012	30.5	4.1	47.6	8.5
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

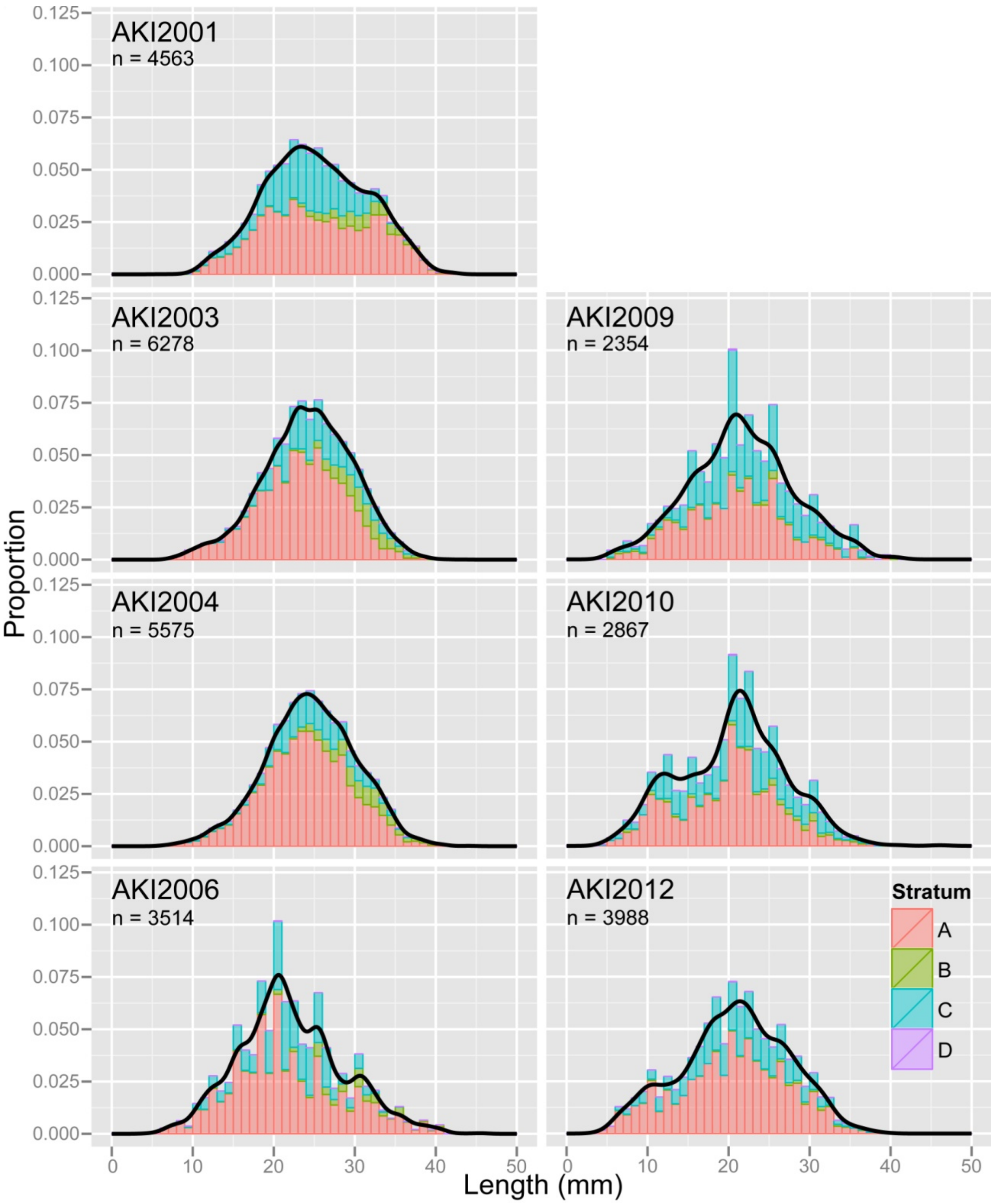

Figure 32: The weighted length frequency distribution of cockles at Whangateau Estuary. Stratum contributions are represented by different colours and smoothed estimates of the length frequency distributions are also shown (black lines).

Whangateau Harbour pipis

We estimated (with 95% confidence) that the 2012 Whangateau Harbour sample extent had 19.4 ± 6.5 million pipis (Table 48). There was strong evidence of an increase in the pipi population since the previous (2010) survey (p = 0.006). We estimated that 2012 had between 2.9 million and 17.5 million more pipis than 2010.

The mean and median lengths of Whangateau Harbour pipis in the 2012 survey were, respectively, 8 and 6 mm less than in 2010, with typical pipis ranging between 13 and 24 mm (Table 49, Figure 33). There was strong evidence of a decrease in the number and proportion of harvestable pipis since the 2009 survey (p<0.001) (Table 50). We estimated (with 95% confidence) that there were between 0.4 million and 1.6 million fewer harvestable pipis than in 2010.

Table 48: Whangateau pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	19.4	3.3	16.9	30.2
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 49: Whangateau pipis – weighted length frequency distribution summary statistics (mm).

Survey	Mean	Mode	Range	Median	IQR
2012	20.4	17	7–67	18	13–24
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 50: Whangateau harvestable pipis (≥ 50 mm length).

Survey	Population estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2012	0.59	0.22	0.92	3.0
2010	1.6	0.22	2.40	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

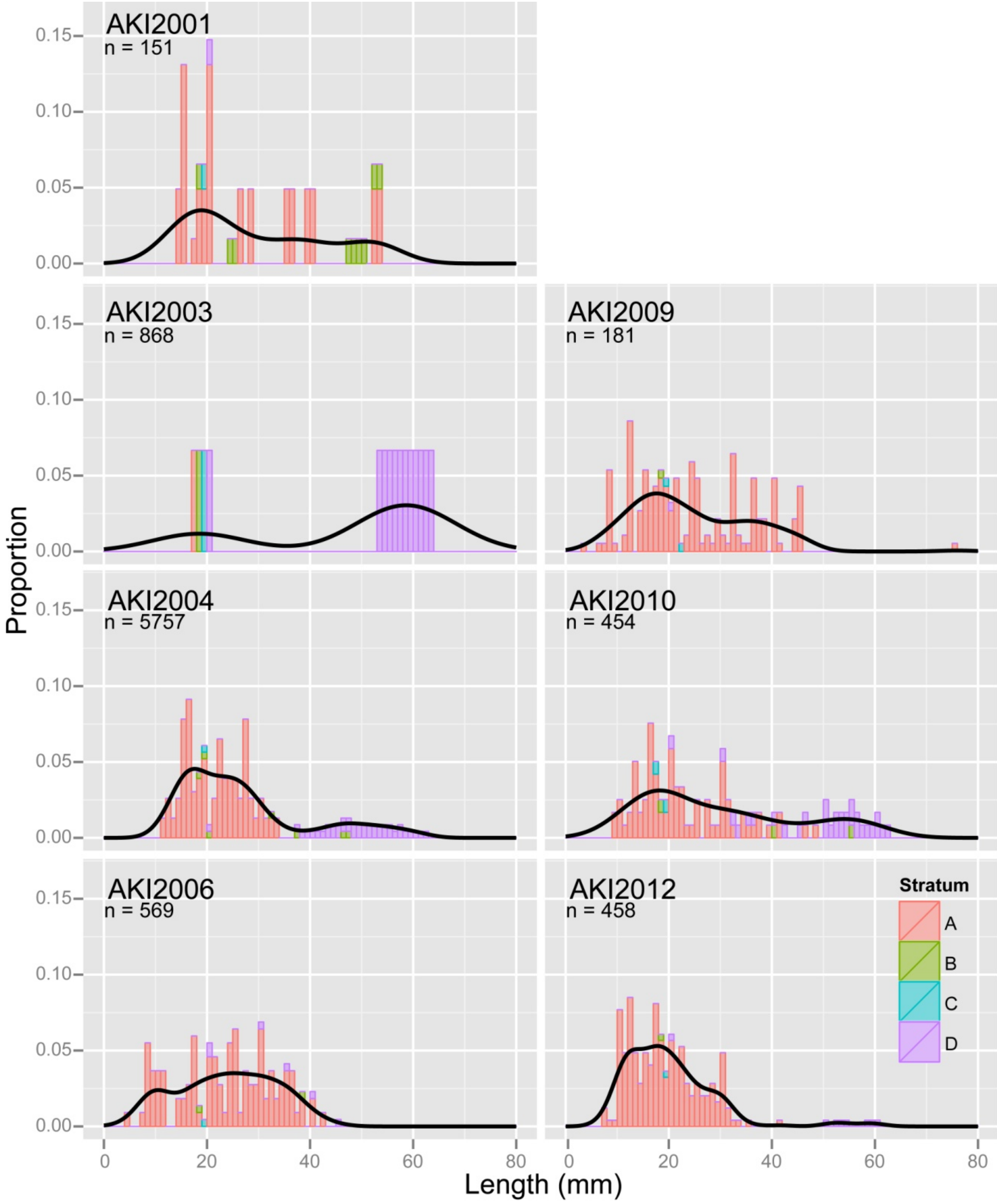

Figure 33: The weighted length frequency distribution of pipis at Whangateau Estuary. Stratum contributions are represented by different colours and smoothed estimates of the length frequency distribution are also shown (black lines).

Discussion – Whangateau Estuary

In the summer of 2008/2009, locals noted numerous rotting cockles on the surface of the Whangateau Harbour. Biosecurity New Zealand (MAFBNZ) attributed the epizootic to a number of coinciding factors. The role of heat and very low tides is not clear but may have made the cockles more susceptible to infection by two separate pathogens –a coccidian parasite infecting their gills and a mycobacterium (Bingham 2009). In response to the die-off, on 25 March 2010, the Ministry of Fisheries approved a three-year closure of Whangateau Harbour to the harvest of cockles and pipis and erected signage to ensure that the public was aware of the closure.

The cockle population within the Whangateau Estuary increased since the previous (2010) survey, and was the second highest since the AKI project started monitoring this beach in 2001. Although there hasn't been a shift in the distribution of length frequencies, the number of harvestable cockles at Whangateau Harbour has changed in proportion to the increase in the total cockle population. As a consequence, the number of large cockles at Whangateau has rebounded to population levels seen around 2006. However, we note that the harbour still contains only half the number of large cockles that were seen in earlier surveys (between 2001 and 2004 the number of harvestable cockles was consistently around 60 million).

There was a marked decrease in the average length of pipis at Whangateau Harbour in the 2012 survey; the length frequency distribution was similar to that found in 2009. The primary reason for this change was an increase in the number of pipis found intertidally in Stratum A. The pipis in this stratum are exclusively less than 20 mm in length and dominate the total population in the beach (see Figure 33). In contrast, nearly all harvestable pipis within Whangateau Harbour are gathered at stratum D (a small pipi bed lying on the channel). Stratum D often moves between years, and in 2012 the population of pipis found there was only around 38% of what was found in 2010. However, we note that the number of harvestable pipis in the 2010 survey was unusually high, and, despite the decline, the estimated number of harvestable pipis this year was the second highest on record (since 2001).

4.2.12 Whitianga Harbour

Beach description

Whitianga Harbour was surveyed for the first time for this project, and the sample extent was determined after consulting representatives from the Auckland City Council, Waikato Regional Council, Ngati Hei and the local community.

A total of 131 samples were taken from the sample extent. This is the first time that Whitianga Harbour has been sampled for the AKI-01 project.

Figure 34: The sample extent for Whitianga Harbour is shown by yellow polygons.

Whitianga Harbour cockles

No cockles were found within the sample extent at Whitianga Harbour.

Whitianga Harbour pipis

We estimated (with 95% confidence) that the Whitianga Harbour 2012 survey had 18.5 ± 6.6 million pipis (Table 51).

The Whitianga Harbour pipi distribution was bimodal with peaks at 13 and 39 mm. Pipis typically ranged between 29 and 43 mm (Table 52, Figure 35). More than 10% of the pipi population was of harvestable size (Table 53).

Table 51: Whitianga Harbour pipis – population estimates.

Survey	Population estimate (millions)	SE (millions)	CV (%)	Average density (per m^2)
2012	18.5	3.39	18.4	260.9

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

Survey	Mean	Mode	Range	Median	IQR
2012	34.8	13, 39	3–68	37	29–43

Table 53: Whitianga Harbour harvestable pipis (≥ 50 mm length).

Survey	Population Estimate (millions)	SE (millions)	Average density (per m^2)	Proportion of total population (%)
2012	1.97	0.36	27.8	10.7

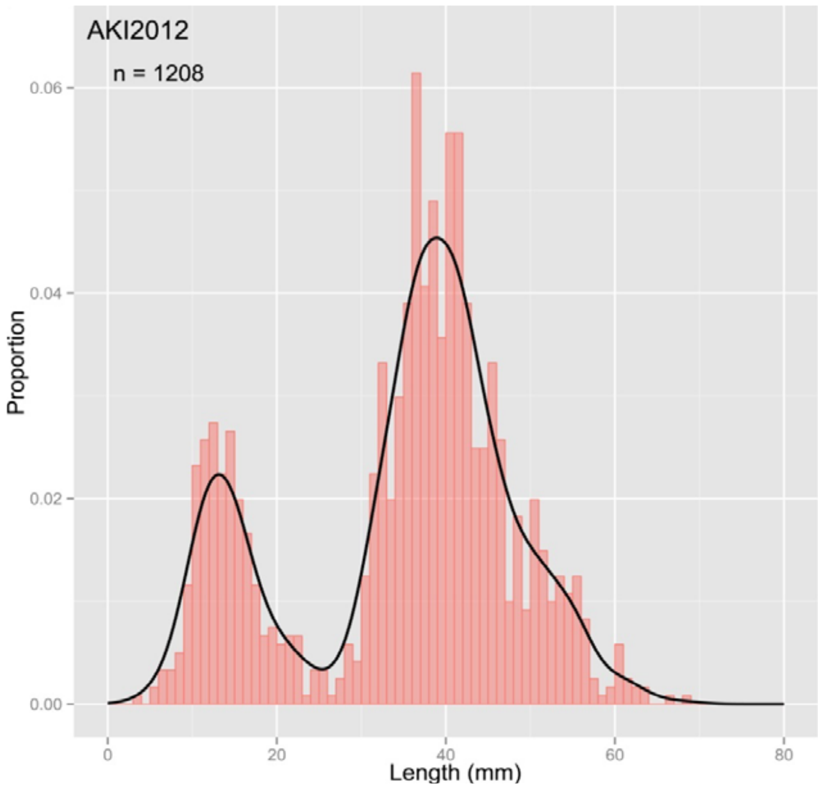

Figure 35: The weighted length frequency distribution of pipis at Whitianga Harbour and a smoothed estimate of the length frequency distribution is also shown (black line).

Discussion – Whitianga Harbour

The Whitianga Harbour pipi bed was found to be patchy over a relatively large area (around 70 800 m^2) with a relatively low density (260 m^2) of pipis (Table 51). The beach showed strong recruitment in the previous year, as evidenced by a distinct cohort of juveniles centred around 13 mm in length. A comparatively large cohort of harvestable-sized pipis was also found at the beach.

4.3 Summary results

4.3.1 Cockles

Table 54 provides a summary of cockle populations for each beach, including estimates, standard errors, coefficients of variation (CV), the proportion of the 'harvestable' cockle population (i.e. at least 30 mm), and the number of individuals counted. Comparisons with the previous survey are made for the total population (Table 55) and the harvestable population (Table 56). The changes in total, recently recruited and harvestable cockle populations for all recorded surveys (at all beaches surveyed in 2012) are shown in Figure 36 and Figure 37.

Table 54: The 2012 cockle population estimates (including the number of cockles counted).

Beach	Estimated population (millions)	SE (millions)	CV (%)	Harvestable Proportion (%)	Cockles counted
Bowentown Beach	24.81	1.39	5.6	0.3	6272
Cockle Bay	54.1	4.1	7.5	66.7	1435
Grahams Beach	4.02	0.87	21.6	0	97
Little Waihi Estuary	17.6	3.3	18.6	1.1	591
Marsden Bank	0	0	0	0	0
Ohiwa Estuary	8.9	0.94	10.6	0.5	3149
Okoromai Bay	28.2	3.0	10.6	47.8	700
Raglan Harbour	127.8	8.7	6.8	4.7	4943
Te Haumi Beach	41.5	5.3	12.7	4.7	1643
Umupuia Beach	124	17.6	13.2	38.3	2356
Whangateau Harbour	360.2	21.1	5.8	8.5	3988
Whitianga Harbour	0	0	0	0	0

Table 55: Comparing the 2012 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	2010	**3.0**	**11.4**	**140.6**
Cockle Bay	2010	**-6.2**	**-29**	**75.4**
Grahams Beach	2010	**-10.6**	**-31.1**	**16.1**
Little Waihi Estuary	2009	-12.2	6.6	86.3
Ohiwa Estuary	2009	**0.4**	**4.8**	**140**
Okoromai Bay	2009	-9.2	7.0	96.2
Raglan Harbour	2009	-18.1	24.9	102.7
Te Haumi Beach	2009	-1.1	23.3	136.5
Umupuia Beach	2010	-18.5	62.3	121.4
Whangateau Harbour	2010	**75.0**	**171.0**	**152.0**

Table 56: Comparing the 2012 harvestable cockle populations with the previous survey. Colour scheme follows that used in Table 55.

Beach	Previous survey	Harvestable population (millions)	Previous harvestable Population (millions)	Proportion of previous survey (%)
Bowentown Beach	2010	0.046	0.066	69.7
Cockle Bay	2010	**36.0**	**21.1**	**170**
Grahams Beach	2010	**0**	**0.02**	**0**
Little Waihi Estuary	2009	**0.2**	**0.08**	**250.0%**
Ohiwa Estuary	2009	0.05	0.03	166.7%
Okoromai Bay	2009	13.5	12.9	104.7%
Raglan Harbour	2009	6	5.8	103.4%
Te Haumi Beach	2009	**2**	**0.9**	**222.2%**
Umupuia Beach	2010	**47.5**	**9.2**	**516.3%**
Whangateau Harbour	2010	**30.5**	**19.6**	**155.6%**

Figure 36: Changes over time in total (red), harvestable (≥30 mm) (green), and recently recruited (<15 mm) cockle populations for beaches sampled in the 2012 survey. For ease of interpretation, the y-axes are displayed on the log-scale.[8] Error bars indicate the 95% confidence intervals around the population totals.

[8] A caveat: the log-scale of the y-axes 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).

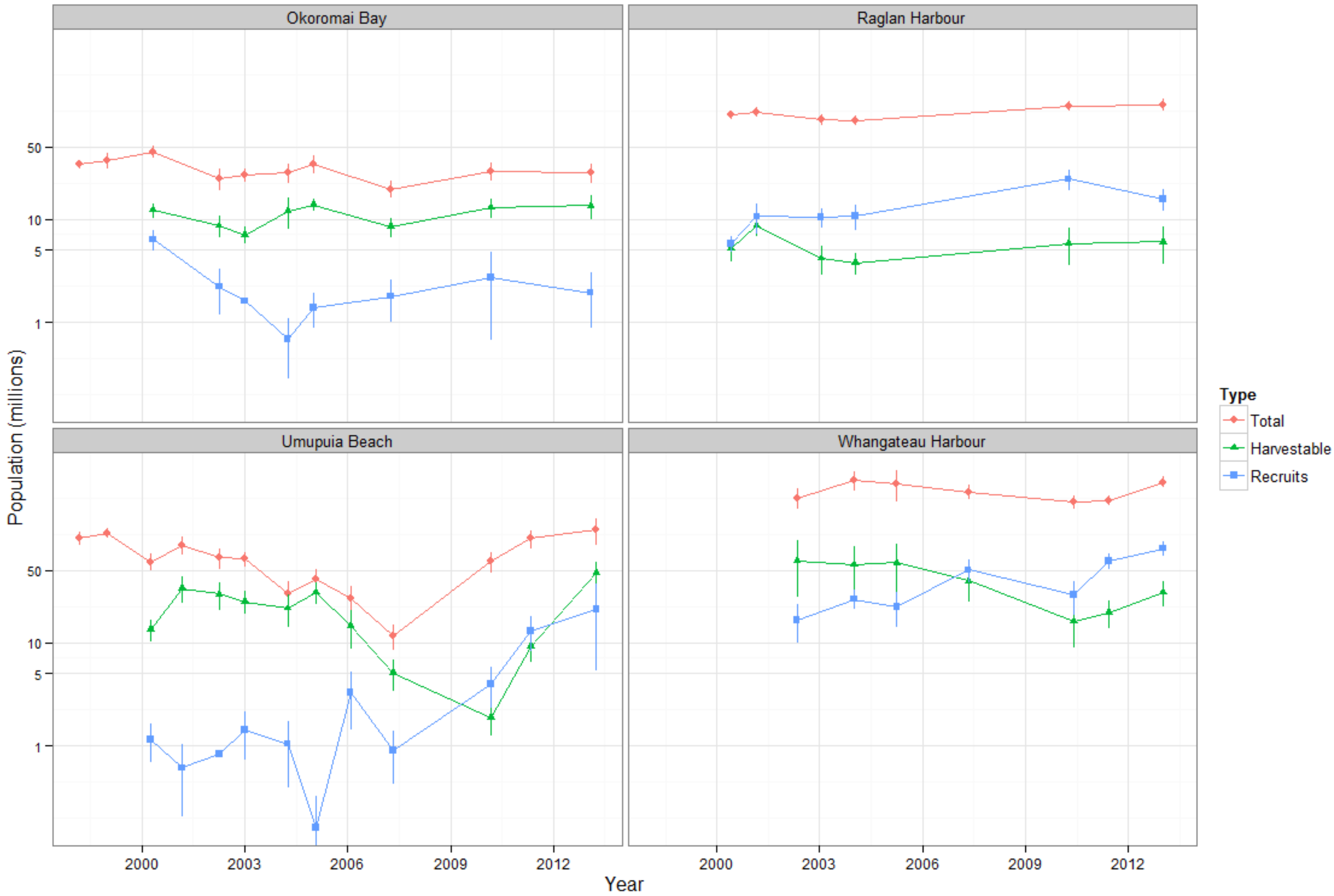

Figure 37: Changes over time in total (red), harvestable (≥30 mm) (green), and recently recruited (<15 mm) cockle populations for beaches sampled in the 2012 survey. The four beaches with the largest cockle populations are shown. For ease of interpretation, the y-axes are displayed on the log-scale. Error bars indicate the 95% confidence intervals around the population totals.

4.3.2 Pipis

Table 57 provides a summary of pipi populations for estimates for each beach, including estimates, standard errors, coefficients of variation (CV), the proportion of the 'harvestable' population (i.e. at least 50 mm) considered 'harvestable', and the number of individuals measured. Comparisons with the previous survey are made for the total population (Table 58) and the harvestable population (Table 59). The changes in total, recently recruited and harvestable pipi populations for all recorded surveys (at all beaches surveyed in 2012) are shown in Figure 38.

Table 57: The 2012 pipi population estimates (including the number of pipis counted).

Beach	Population estimate (millions)	SE (millions)	CV (%)	Harvestable Proportion (%)	Pipis counted
Bowentown Beach					81
Cockle Bay					9
Grahams Beach	2.9	1.01	35.0	0	70
Little Waihi Estuary	217.3	17.1	7.9	4.7	9453
Marsden Bank	60.0	11.87	19.8	0	2602
Ohiwa Estuary	43.7	6.0	13.7	2.6	7358
Okoromai Bay					2
Raglan Harbour	1.76	0.26	14.5	7.5	609
Te Haumi Beach	66.2	12.7	19.2	0.4	3928
Umupuia Beach					0
Whangateau Harbour	19.4	3.3	16.9	3.0	458
Whitianga Harbour	18.5	3.39	18.4	10.7	1208

Table 58: Comparing the 2012 survey pipi populations with the previous survey. Colour scheme follows that used in Table 55.

Beach	Previous survey	Change (in millions)		Proportion of previous survey (%)
		Lower Limit	Upper Limit	
Grahams Beach	2010	-3.6	2.0	112.0
Little Waihi Estuary	2009	-148.7	5.5	80.7
Marsden Bank	2010	**-61.0**	**-235.0**	**28.8**
Ohiwa Estuary	2009	**16.5**	**41.5**	**297.3**
Raglan Harbour	2009	**0.6**	**1.7**	**298.3**
Te Haumi Beach	2009	-4.8	50.2	152.2
Whangateau Harbour	2010	**2.9**	**17.5**	**210.0**
Whitianga Harbour	*None*			

Table 59: Comparing the 2012 harvestable pipi populations with the previous survey. Colour scheme follows that used in Table 55

Beach	Previous survey	Harvestable population (millions)	Previous harvestable population (millions)	Proportion of previous survey (%)
Grahams Beach	2010	0	0	0
Little Waihi Estuary	2009	10.2	10	102.0%
Marsden Bank	2010	**0**	**10**	**0**
Ohiwa Estuary	2009	1.13	1.57	72.0%
Raglan Harbour	2009	0.13	0.15	86.7%
Te Haumi Beach	2009	0.28	0.2	140.0%
Whangateau Harbour	2010	**0.59**	**1.6**	**36.9%**
Whitianga Harbour	*None*	1.97	*NA*	*NA*

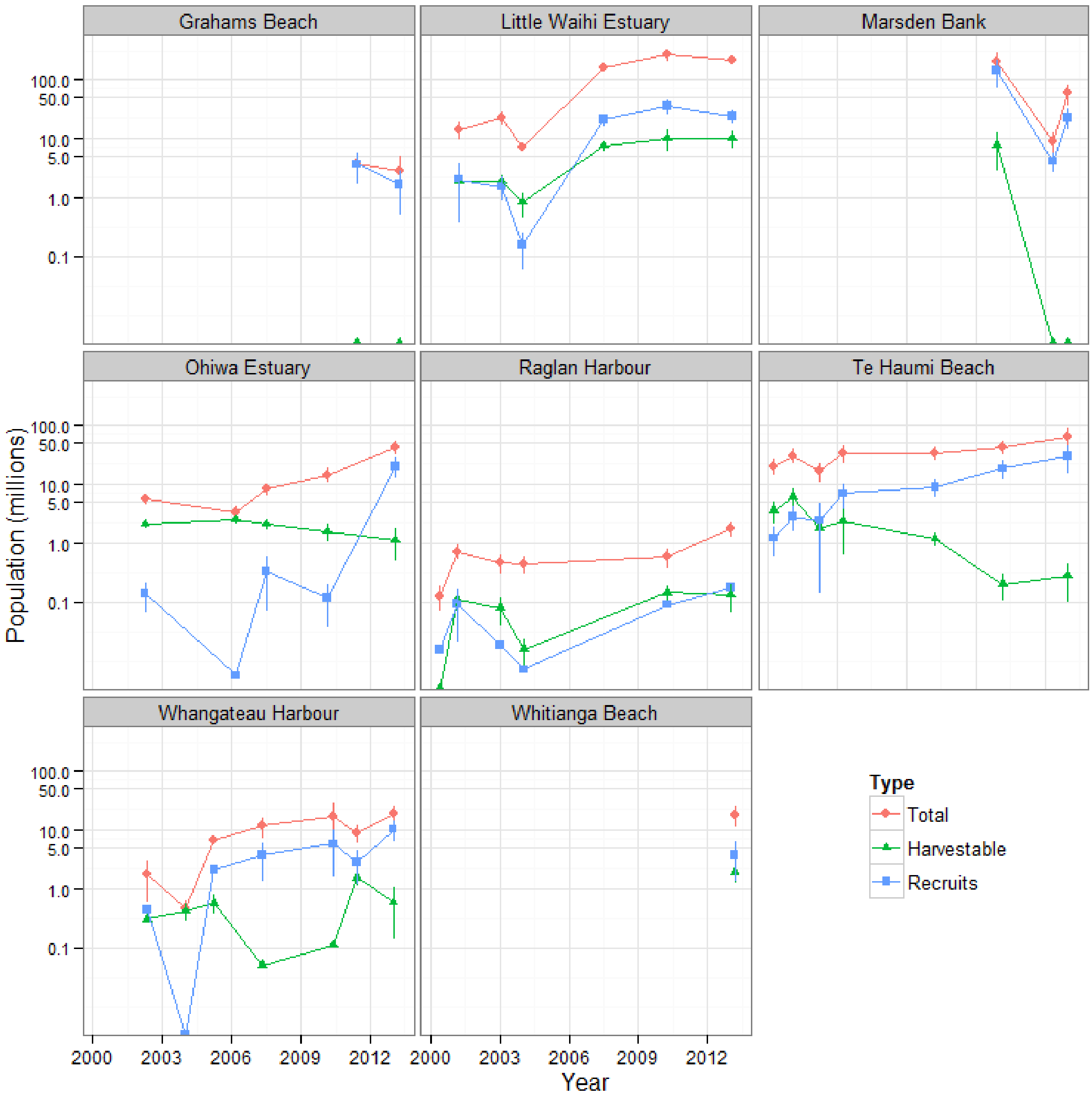

Figure 38: Changes over time in total (red), harvestable (≥50 mm) (green) and recently recruited (<18 mm) pipi (blue) populations for beaches sampled in the 2012 survey. For ease of interpretation, the y-axis is displayed on the log-scale. Error bars indicate the 95% confidence interval around the population total.

5. DISCUSSION

5.1 Cockles

Ten of the twelve beaches in the 2012 survey had cockle beds. The total abundance of cockles increased at Whangateau Harbour, Bowentown Beach and Ohiwa Estuary. The largest change was found in Whangateau Harbour which increased by around 52% of the previous (2010) population, and the population (at an estimated 360 million cockles) is the second largest recorded by this project (exceeded only by the 2003 survey that estimated 376 million cockles). The cockle populations at Ohiwa Estuary and Bowentown Beach both increased by around 40% from their previous populations (2009 and 2010 respectively). In contrast, Grahams Beach showed a marked decrease in the number of cockles since its previous (2010) survey. The density of cockles at Grahams Beach has always been relatively low compared to other beaches with cockle beds, and the density of cockles declined further by around 85% compared to 2010. Other beaches (Okoromai Bay, Raglan Harbour, Te Haumi and Umupuia Beach) did not show any evidence of a change in the total cockle population.

A recovery in the proportion of large (harvestable) cockles correlates with rahui
The previous (2010) survey found evidence of a long-term decline in the number and proportion of 'harvestable' cockles (i.e. cockles larger than 30 mm) at most of the 12 beaches surveyed that year. Five of the beaches surveyed in 2010 were re-surveyed in 2012, and of those beaches, the harvestable cockles at Bowentown Beach and Grahams Beach remained sparse. However Cockle Bay, Umupuia Beach and Whangateau Harbour all had marked increases in the number and proportion of large cockles. All three of these beaches have had a rahui (closure) or restriction implemented by MPI. Closures at Cockle Bay and Umupuia came into effect on October 16, 2008, and Whangateau Harbour has been closed to cockle and pipi harvesting since 25 March, 2010.

Ngai Tai Umupuia Te Waka Totara Trust, on behalf of Ngai Tai and Umupuia Marae, applied for the temporary closure due to concern amongst tangata whenua and the wider community because of the large degree of harvesting and the steady decline in the cockle population. Umupuia had a two-year temporary rahui which was renewed in 2010. Recreational harvesting also led to the seasonal closure at Cockle Bay over summer and autumn (1st October to 30th April). Whangateau Harbour has been closed to recreational fishers after coccidian parasite and a mycobacterium caused massive mortality in the beds.

Harvestable cockles more than doubled at Cockle Bay and around two-thirds of all cockles there were larger than 30 mm. The change at Umupuia was even more marked – the population approximately quintupled, and we estimated that around 38% of cockles there are of harvestable size (the 2010 survey estimated less than 10% of the cockles were harvestable). The number of harvestable cockles at Whangateau Harbour increased proportionally with the increase in the total cockle population. The number of large cockles at Whangateau has rebounded to population levels seen around 2006, but we note that it still only half the level seen in earlier surveys (between 2001 and 2004 the number of harvestable cockles was consistently around 60 million).

Both Umupuia and Cockle Bay have been actively monitored by local communities which are able to keep a close eye on the beach, and this policing may have helped the increase in large cockles. Umupuia is also monitored, but covers a larger area and is more remote to the viewing public.

The harvestable cockle population remained unchanged at Ohiwa Estuary (less than 1% of the total population), Raglan Harbour (around 5%), and Okoromai Bay (a slight increase from 44.1% to 47.8%). The harvestable cockle numbers at Te Haumi Beach doubled, but the proportion was still only around 5%.

Recruitment
Recruitment of cockles appeared to be relatively stable at Bowentown Beach, Little Waihi, Okoromai Bay and Raglan Harbour, but there was a decline in recent recruits at Cockle Bay and Grahams Beach. In contrast, Ohiwa Harbour, Umupuia Beach, Whangateau Harbour and Te Haumi all showed large increases in the number of recent recruits.

5.2 Pipis

Seven of the twelve beaches surveyed in 2012 had pipi beds. The pipi population at Marsden Bank appears to have dropped by around 70% since the previous (2010) survey. In the previous survey, the vast majority of pipis on Marsden Bank were juveniles (smaller than 20 mm), but the north and eastern bank edge used to have larger pipis. The 2012 distribution was still dominated by small pipis, but the centre of the distribution was around 5 mm larger than in 2010 and large pipis were not found on the bank edge. It is possible that the drop in the number of pipis at Marsden Bank is correlated with the pipi numbers at neighbouring Mair Bank - a survey of the latter is planned for the Austral summer of 2013–2014.

Of the remaining six beaches with pipi beds, the total pipi population at Grahams Beach, Little Waihi Estuary and Te Haumi Beach did not show any evidence of change, although Te Haumi did have a much larger number of juvenile pipis on the main beach than in previous surveys. The total number of pipis at Whangateau Harbour roughly doubled since the 2010 survey, and both Raglan Harbour and Ohiwa Estuary tripled in size since their previous respectively surveys. The pipi bed at Whitianga Harbour was sampled by this project for the first time and was found to have low density of pipi spread patchily over a relatively wide geographic area.

Large pipis
Neither Grahams Beach nor Marsden Bank had any harvestable sized pipis in their beds. The large pipis that were previously around the northern edge of Marsden bank (in the 2010 survey) were not found in 2012. The proportion of harvestable pipis at Little Waihi Estuary increased by almost 75%, but this is associated with a decrease in the total number of large pipis. As a consequence, the number of large pipis there has remained relatively constant. Nearly all harvestable pipis within Whangateau Harbour are gathered at stratum D (a small pipi bed lying on the channel) and the numbers of large pipis at that bed was only 37% of the previous (2010) survey.

Recruitment
Recruitment of pipis at Grahams Beach was slightly lower than the previous (2010) survey (the 2006 survey of Grahams beach found almost no pipis). A decline in pipi recruitment was also found at Marsden Bank compared to the 2010 survey (the NIWA survey (MDN1201) done earlier in 2012 also found a marked decline in recruitment). Recruitment was relatively stable at Little Waihi, but Ohiwa Harbour, Raglan Harbour, Te Haumi Beach and Whangateau Harbour all showed large increases.

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APPENDIX 1: Location and dates of AKI project sites 1992–2012

Table A1.1: Grey cells indicate the beach was surveyed for the AKI project that year. 2012 beaches 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

Beach / AKI Project	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	09	10	12
Aotea Harbour																		
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*	
Marsden Bank																		*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																		
Waikawau Bay																		
Waiotahi Estuary																		
Wenderholm Beach																		
Whangamata harbour																		
Whangapoua Beach																		
Whangateau Harbour																		
Whitianga Harbour																		

Pipis

Beach / AKI Project	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	09	10	12
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																		
Marsden Bank																		
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																		
Whitianga 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	AKI 2012-01
Beach **Year**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2010**	**2011**	**2013**
Aotea Harbour									17-18Jan		27Mar-13Jul		
Beachlands	10-27Mar	Dec98-29Jan99											
Bowentown Beach					26Apr-25May							18-Apr	8-Feb
Cheltenham Beach	7Jan-9Feb	12-Jan											
Clarks Beach								3-24Feb					
Cockle Bay											16-Feb	5-May	31-Jan
Cornwallis Beach					26-Mar								
Eastern Beach	22Jan-13Mar	12-27Jan	15May-30Jun		14Mar-16Apr								
Grahams Beach										20-Apr		17-May	11-Mar
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		10-Feb
Mangawhai Estuary			20Mar-30Jun	29-31Jan	15Mar-14Apr	1-31Jan	1-31Jan					24Mar-15Apr	
Marokopa									18-20Feb			16-May	
Marsden Bank												19-20Oct	12-Dec(2012)
Mill Bay	16Jan-1Apr	9-24Dec98	4Mar-30Jun	20-23Feb	20Mar-22Apr		26-28Jan	Dec04-24Jan	20-24Jan		13-May		
Ngunguru							6-7Mar	6-7Feb				23-Mar	
Ohiwa Estuary					9-11Apr				25-26Feb	13-29Jun	3-Mar		9-Feb
Okoromai Bay	16Jan-24Mar	14-22Dec98	19-24Apr		8-12Apr	26-29Dec02	17-20Mar	15-16Jan		20-Mar	17-Feb		30-Jan
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		11-Jan
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		13Dec-11Jun
Umupuia Beach	20Jan-26Mar	Dec98-12Jan	1-12Apr	15-16Feb	28Mar-12Apr	3Dec02-2Jan(	25-28Mar	22-23Jan	28-29Jan	3Mar-1Aug	15-Feb	4-May	13-Mar
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		17Dec03-2Mar(	2-26Mar		19Mar-2May	18Mar-15Jul	20-20May	14Dec-17Dec
Whitianga Harbour													7-Feb

Table A1.3: Size (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	AKI2012
Aotea Harbour									9.6		15.6		
Beachlands	*	*											
Bowentown Beach					1.58							1.58	1.58
Cheltenham Beach	*	*											
Clarks Beach								144.71					
Cockle Bay											16	16	16
Cornwallis Beach	*	*			2.65								
Eastern Beach	*	*	48		43.38								
Grahams Beach										24.75		24.75	20.06
Howick Beach	*	*							6.9				
Kauri Bay								60.37		62.94			
Kawakawa Bay				3		3	3.13	3.75		3.16			
Little Waihi Estuary			9.4	8.4	8.4	8.4	8.4				13.92		15.42
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		2.63
Okoromai Bay	*	*	20		24	20	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		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		9.81
Umupuia Beach	*	*	25	36	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	64.2
Whitianga Harbour													7.08

APPENDIX 2: *Errata*[9]

Bowentown Beach
AKI 2001
Total pipi population recorded as 5.59 million. Data suggests 4.79 million.

Okoromai Bay
AKI2003
Total cockle population reported at 20 million. Data suggests 27.96 million.
Harvestable cockle population reported at 8 million. Data suggests 12 million.

Pataua Beach
AKI2003
Harvestable cockle population reported at 8 million. Data suggests 13.56 million.
Table 49 harvestable pipi population is reported 123.4 million. This is incorrect (the total cockle population appears to have been accidently recorded) - the correct harvestable pipi population is 0.43 million.

Raglan Harbour
AKI1999
Harvestable cockle population reported at 3.07 million. Data suggests 5.15 million.

AKI2009
Harvestable cockle population reported at 5.84 million. Data suggests 3.2 million.

Te Haumi Beach
AKI1999
Harvestable cockle population reported at 3.2 million. Data suggests 4.18 million.
Harvestable pipi population reported at 3.12 million. Data suggests 3.64 million.

AKI2006
Total cockles incorrectly reported at 18.85 million in main text (correctly reported in the summary tables at 15.92 million).

Umupuia Beach
AKI1999
Total area reported at 300 000 m^2 and database records area at 250 000.
Coordinate suggests the area is 360 000 m- [this latter area is consistent and approximately correct for later years]. Population totals were scaled by 360/250 to compensate.

Whangateau Harbour
AKI2004
Total pipi population reported at 1.45 million. Data suggests 6.85 million.

AKI2009
Total cockle population reported at 239.8 million. Data suggests 228.3 million.
Harvestable cockle population reported at 17.7 million. Data suggests 16 million.
Total pipi population reported at 15.2 million. Data suggests 17.4 million.
Harvestable cockle population reported at 17.7 million. Data suggests 16 million.

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[9] Report of original error given – these errors may have been reported in documents published later.