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Intertidal shellfish monitoring in the northern North Island region, 2024–25

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PLAIN LANGUAGE SUMMARY

People in New Zealand enjoy the collection of seafood as a recreational and customary activity along the country's coastline. Two important seafood species in coastal areas are cockles and pipi, which occur in intertidal sediments of beaches, estuaries, and large tidal inlets and harbours. In northern New Zealand, cockles and pipi have been regularly monitored for several decades across different sites in Northland, Auckland, Waikato, and Bay of Plenty. This monitoring aims to ensure the persistence of their populations, providing information of the abundance, density, and population size structure of cockles and pipi. Presented here are the survey findings from the summer of 2024–25, with population information for Pataua Estuary (Northland), Cockle Bay, Kawakawa Bay (West), Mill Bay, Ōkahu and Okoromai bays (Auckland and its wider region), Ōhiwa Harbour, Otūmoetai (Tauranga Harbour), and Waiotahe Estuary (Bay of Plenty), and Whangapoua and Whitianga harbours (Waikato). Both cockle and pipi populations across these northern sites were generally large, consisting of millions of individuals. Their densities varied dependent on the site, but were a minimum of over 140 individuals per square metre for cockles, and over 180 individuals per square metre for pipi, except at one site (Pataua Estuary). At several sites, small-sized individuals made up most of the population, highlighting strong recruitment events that preceded the data collection.

EXECUTIVE SUMMARY

Berkenbusch, K.[1]; Hill-Moana, T.[1] (2025). Intertidal shellfish monitoring in the northern North Island region, 2024–25.

***New Zealand Fisheries Assessment Report 2025/27*. 111 p.**

Recreational and customary fisheries in New Zealand target a wide range of marine species, including intertidal bivalves in coastal environments. Two important target species for these non-commercial shellfish collections are cockle (*Austrovenus stutchburyi*) and pipi (*Paphies australis*), which are widely distributed in sedimentary habitats, and often easily accessible. In areas with considerable fishing activites, their populations are vulnerable to overexploitation, in addition to anthropogenic impacts from landuse changes.

In northern North Island, cockle and pipi populations are regularly monitored by Fisheries New Zealand across the Northland, Auckland, Waikato, and Bay of Plenty regions. This monitoring was initiated in the early 1990s, with its subsequent spatial extension and refinement of survey methods providing consistent information of cockles and pipi targeted in non-commercial fisheries across a diverse range of sites and environments. The survey data provide estimates of abundance and density for both species, and information of the population size structure. For most of the survey sites, multiple surveys since the early 2000s have resulted in extensive time-series data, allowing the assessment of population trends over time, and inter-regional comparisons. In addition, the subsequent adoption of sediment sampling in the cockle beds has provided an indication of benthic habitat quality since 2013–14.

Presented here are the survey results from the northern bivalve assessment conduced in the 2024–25 fishing year. The survey focused on 11 sites across northern North Island (in alphabetical order): Cockle Bay, Kawakawa Bay (West), Mill Bay, Ōhiwa Harbour, Ōkahu Bay, Okoromai Bay, Otūmoetai (Tauranga Harbour), Pataua Estuary, Waiotahe Estuary, Whangapoua Harbour, and Whitianga Harbour. Ōkahu Bay in Auckland was surveyed for the first time as part of this monitoring programme.

Cockle populations were present at all of the 2024–25 sites, and their population estimates varied from the smallest population of 10.22 million (coefficient of variation (CV): 17.05%) cockles at Ōhiwa Harbour to the largest population of 292.13 million (CV: 14.29%) individuals at Pataua Estuary. Ōkahu Bay had a relatively small cockle population and was the only site where the CV of the estimates exceeded 20%.

Most sites supported cockle populations at high densities, i.e., of several hundred individuals per square metre. The lowest density of 148 cockles per m^2 (CV: 11.18%) was at Waiotahe Estuary. Both Pataua Estuary and Whitianga Harbour had comparatively high densities at 1031 cockles per m^2 (CV: 14.29%) and 1617 cockles per m^2 (CV: 9.71%), respectively. Regardless of population density, none of the populations included a notable number of large cockles (defined as $\geq$30 mm shell length), and their population estimates had generally high CV values. A number of cockle populations were characterised by strong recruitment, indicated by a relatively high proportion (i.e., over 20% of the total population) of recruits ($\leq$15 mm shell length). These populations were at Kawakawa Bay (West), Ōhiwa Harbour, Ōkahu Bay, Okoromai Bay, Otūmoetai (Tauranga Harbour), Pataua and Waiotahe estuaries, and Whitianga Harbour. At Ōkahu Bay and Whitianga Harbour, over 80% of the population consisted of recruits.

Pipi populations were assessed at six of the northern sites, at Ōhiwa Harbour, Otūmoetai (Tauranga Harbour), Pataua Estuary, Waiotahe Estuary, Whangapoua Harbour, and Whitianga Harbour. The abundance estimates for this species were generally similar across sites. The smallest population was at Whitianga Harbour, with an estimated abundance of 13.93 million (CV: 9.68%) pipi. In comparison, Waiotahe Estuary supported the largest pipi population, with an estimated 95.89 million (CV: 17.99%) individuals. All population estimates had CV values of less than 20%. Pipi densities were generally

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high (i.e., several hundred individuals per square metre), except at Pataua Estuary, where the density estimate was 60 pipi per m^2 (CV: 11.47%). The maximum density estimate was at Ōhiwa Harbour with 1110 pipi per m^2 (CV: 7.62%). Large pipi ($\geq$50 mm shell length) were scarce or absent across all of the sites. Similar to some of the cockle populations, three of the pipi populations had a high proportion of recruits ($\leq$20 mm shell length); at Ōhiwa Harbour, Pataua Estuary, and Waiotahe Estuary, recruits made up between 23 and 50% of the total pipi population.

Sediment sampling in the cockle beds documented a low organic content, which was below 3.4% on average across all sites. At most sites, the sediment granulometry was largely determined by fine sand (grain size $>$125 µm) and either medium or very fine sands ($>$250 and $>$63 µm, respectively). The proportion of sediment fines ($<$63 µm) varied across sites, and was comparatively high (i.e., on average above 7%) at Cockle Bay, Kawakawa Bay (West), Mill Bay, Ōkahu Bay, and Waiotahe Estuary. Individual sediment samples at these sites contained a high proportion of sediment fines, ranging from 19% at Mill Bay and Waiotahe Estuary to 69% at Cockle Bay.

Applying Principal Component Analysis to explore cockle abundance in relation to sediment grain size indicated a general pattern of higher abundances associated with fine sand fractions at several sites.

For sites with multiple assessments, spatial and temporal trends in predicted cockle densities were also assessed through geostatistical modelling. The outcomes of this modelling allowed the tracking of high-density areas (“hotspots”) over time. At Cockle Bay, Ōhiwa Harbour, Okoromai Bay, Pataua Estuary, Waiotahe Estuary, and Whangapoua Harbour, these hotspots of the total population were mostly determined by the predicted densities of large cockles. At two of the sites, Ōhiwa Harbour and Waiotahe Estuary, the hotspots did not persist over time, following the disappearance of large cockles at both sites. Mill Bay, Otūmoetai (Tauranga Harbour), and Whitianga Harbour had extensive high-density areas of all cockles, and large individuals were generally scarce throughout the survey series. At Otūmoetai (Tauranga Harbour), there was a notable reduction in the spatial extent of high-density cockle areas over time. In constrast, the high-density area of total cockles at Whitianga Harbour showed a spatial extension throughout most of the cockle stratum in the current survey. At Kawakawa Bay (West), cockle hotspots were highly localised, and showed a general reduction in spatial extent over time.

1. INTRODUCTION

Recreational and customary fisheries in New Zealand target a number of marine species, including intertidal bivalves across different coastal environments (Heinemann & Gray 2024). Two important bivalve species targeted in these fisheries are cockles/tuangi (*Austrovenus stutchburyi*) and pipi (*Paphies australis*). Both species occur throughout the country, where they are often abundant and easily accessible for handgathering, making them popular targets for shellfish fishing activities.

In addition to fishing, pressures on their populations include land use changes resulting in increased sediment runoff and resuspension, pollution, and physical habitat loss and degradation. In this context, sediment properties such as suspended sediment loads and grain size composition, have been identified as important factors influencing the distribution and abundance of cockles and pipi. For example, previous studies have highlighted declines of both species following increases in sediment mud content (silt and clay, grain size <63 micron). For cockles, highest abundances were in sediments that contained less than 11% mud, whereas pipi had a lower tolerance, requiring sediment that contained less than 3% in this grain size fraction (Thrush et al. 2005, Anderson 2008).

Recognition of the potential impacts of human activities on northern cockle and pipi populations has led to the regular monitoring of their populations by Fisheries New Zealand. Initiated in the early 1990s in the Auckland region, the population surveys have been subsequently extended across the northern North Island area, spanning a variety of sites across Northland, Auckland, Waikato, and Bay of Plenty. Since the late 1990s, the use of largely consistent survey methods has provided extensive time-series data, particularly for cockle beds that are considered to be less ephemeral than some of the pipi beds.

The surveys provide population data for bivalve beds targeted in non-commercial fisheries, including abundance and density estimates, and length-frequency distributions. The population size data are relevant for identifying recruitment events, and also for determining the proportion of mature individuals within each population. For cockles, size at maturity appears to be at a minimum shell length of 18 mm (Larcombe 1971), whereas pipi appear to be mature at 40 mm shell length (Hooker & Creese 1995).

The addition of a sediment sampling regime to the bivalve survey in 2013–14 provides information of sediment organic content and grain size composition, both characteristics that are known to influence bivalve populations. The sediment data represent baseline information of benthic habitat characteristics, with subsequent refinements to the sediment sampling design (in 2015–16) supporting formal analyses of cockle population data in relation to sediment properties (Neubauer et al. 2021). Part of this data analysis has included principal component analysis, assessing cockle densities in relation to different sediment grain size fractions. This data exploration is updated after each survey, following the addition of the most recent survey data.

Previous studies based on the survey data have also included the investigation of alternative approaches to using survey-based estimations for deriving bivalve population estimates (Tremblay-Boyer et al. 2021). This investigation focused on the development of geostatistical estimators to incorporate spatial and temporal aspects in the estimation, while attempting to decrease uncertainty associated with the estimates. Although the population estimates provided here continue to be survey-based, geostatistical modelling was also used to visually assess spatio-temporal patterns of cockle densities at each site.

Provided here are the findings of the most recent cockle and pipi survey across the northern regions, conducted in the 2024–25 fishing year. For this assessment, bivalves were surveyed at 11 northern North Island sites (in alphabetical order): Cockle Bay, Kawakawa Bay (West), Mill Bay, Ōhiwa Harbour, Ōkahu Bay, Okoromai Bay, Otūmoetai (Tauranga Harbour), Pataua Estuary, Waiotahe Estuary, Whangapoua Harbour, and Whitianga Harbour (Figure 1). Ōkahu Bay was surveyed for the first time as part of this monitoring series.

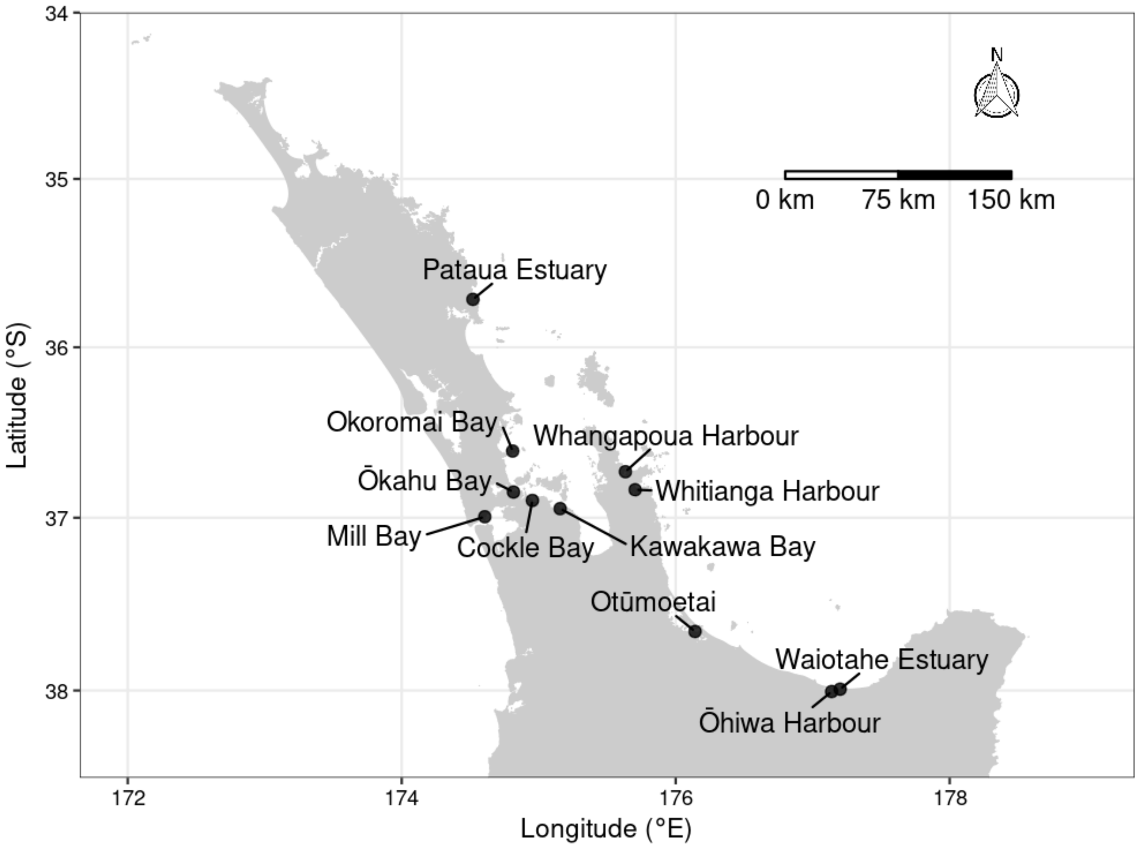

Figure 1: Sites included in the northern North Island intertidal bivalve survey in 2024–25.

2. METHODS

The methods used in the present study were based on previous bivalve assessments that provided temporal comparisons across the northern survey series. Since 1996, the general sampling protocol of the northern North Island bivalve surveys has used a combination of a systematic design and a two-phase stratified random design (Pawley & Ford 2007).

The methods used in recent surveys are described in detail by Berkenbusch & Neubauer (2016, 2017). For completeness, the methods are included here, following updates to reflect the 2024–25 assessment.

2.1 Survey methods

At each site, the intertidal areas sampled were identified based on existing information and input from local communities and stakeholders. This preliminary exploration also included extensive reconnaissance of the sampling areas at each site, with the on-site determination of population boundaries, defined as fewer than 10 individuals per m^2 (see Pawley 2011). Establishing population boundaries included the acquisition of geographical information through the use of global positioning system (GPS). During sampling, GPS units were used to determine the location of each sampling point.

Preliminary analyses of cockle density data from previous surveys (2013–14 to 2016–17) using GPS-referenced samples indicated that the previous stratification at individual sites rarely delimited areas of similar characteristics (e.g., homogenous densities) and, therefore, did not necessarily lead to reductions in variance in the estimation of cockle population sizes and densities. For this reason, the high-resolution spatial data (GPS-referenced samples) from previous surveys were used to re-define cockle strata based on the spatial distribution and variability of previous samples (see Berkenbusch & Neubauer 2016).

The number of sampling points for each bivalve population was determined by the population size and variability within each stratum, informed by data from previous surveys. For each stratum, a regular grid was generated, with the size and shape of the grid cells reflecting the desired sampling density and the orientation of the stratum. For strata with irregular shapes, the number of grid cells did not necessarily reflect the number of desired samples; if there were more grid cells than sampling points, not all cells had sampling points allocated to them. In this case, sampling points were allocated across all cells with a probability proportional to the area of the cells.

The position of the point within a cell was randomly allocated. All sampling points were pre-calculated for two phases before the sampling began. All phase-1 points were sampled, whereas sampling of phase-2 points was only carried out when the coefficient of variation (CV) of the total abundance estimate after first-phase sampling exceeded the target value of 20% for either cockle or pipi. Based on recommendations by the Shellfish Fishery Working Group (at its meeting in November 2021), the number of allocated phase-2 points was limited to about 10% of the overall sampling effort (see also Francis 2006).

Owing to the importance of sediment properties for infaunal bivalves, recent previous surveys included a sediment sampling programme to determine the sediment organic content and grain size at each site (see Berkenbusch et al. 2015, Berkenbusch & Neubauer 2015). The initial sediment sampling provided general baseline information; subsequent improvements to the sediment sampling design in 2015–16 allowed the analysis of spatial patterns in sediment variables and of gradients in cockle abundance in relation to sediment properties (Neubauer et al. 2015, Berkenbusch & Neubauer 2016, Neubauer et al. 2021).

The sediment sampling was restricted to cockles, because pipi populations frequently extend into subtidal waters deeper than 0.5 m, so that only parts of the population are sampled. Following the stratification of sites, a total of 24 sediment sampling points was allocated at each site. The sediment sampling point allocation was based on a subset of sediment sampling points that was randomly allocated within each cockle stratum, corresponding with a randomly-allocated cockle sampling point. Data from the sediment sampling were used to provide baseline information of current sediment properties, and to build a data set that allows spatial and temporal comparisons as data get updated.

The most recent analysis of sediment properties was conducted in 2019–20, based on data from five years of monitoring (Neubauer et al. 2021). This analysis provided a spatial and temporal assessment of the relationship between cockles and sediment grain size properties. It included a principal component analysis, and the modelling of cockle population abundances as a function of different grain size fractions, for all cockles and also for individuals in the large size class (i.e., exceeding 30-mm shell length).

2.2 Field sampling – bivalves

The field survey across the 11 northern North Island sites was conducted in January and February 2025. The survey sampled bivalve populations at each site during periods of low tide (see sampling dates for the present and previous surveys in Appendix A, Tables A-1, A-2).

Bivalves were sampled using the same sampling unit as in previous surveys, consisting of a pair of benthic cores that were 15-cm diameter each; the combined cores sampled a surface area of 0.035 m^2. The cores were sampled to a sediment depth of 15 cm; this sampling depth included the maximum burrowing depths of cockles and pipi, which reside in the top 10 cm of the sediment (i.e., 1–3 cm for cockles, Hewitt & Cummings 2013; and 8–10 cm for pipi, Morton & Miller 1973).

Sampling points within each stratum were located using GPS units. For pipi populations, the intertidal sampling extended to 0.5 m water depth (at low tide) in channels that included pipi populations (following the sampling approach of previous surveys). At each sampling point, the cores were placed directly adjacent to each other and pushed 15 cm into the sediment. The cores were excavated, and all sediment from each core was sieved in the field on 5-mm mesh. All cockles and pipi retained on the sieve were counted and measured (length of the maximum dimension, to the nearest millimetre), before returning them to the benthos.

For strata with population densities exceeding 2000 individuals per m^2, the recording of shell length measurements involved subsampling (see Pawley 2011). The subsampling was only used when the number of individuals in both cores exceeded 70 (equating to 2000 individuals per m^2) and there were at least 50 individuals in the first core. The subsampling consisted of recording shell length measurements for all individuals in the first core, whereas bivalves in the second core were not measured. When there were fewer than 50 individuals in the first core, all bivalves were measured in both cores.

2.3 Field sampling – sediment

The sediment sampling involved the collection of a subset of sediment cores (5-cm diameter, sampled to a depth of 10 cm) that were collected within existing cockle strata. Subsequent analyses included the grain size distribution and organic content of the sediment samples.

The grain size analysis was based on wet sieving to ascertain the proportion of different size classes, ranging from sediment fines (silt and clay, $\leq$63 µm grain size) to different sand fractions of very fine to very coarse sands and gravel (i.e., grain sizes 125 to 2000 µm) (Eleftheriou & McIntyre 2005). Each sample was homogenised before processing through a stack of sieves to determine the proportion in each sediment grain size fraction (i.e., >63, >125, >250, >500, and >2000 µm). Sediment retained on each sieve was subsequently dried to constant weight at 60 °C before weighing it (accuracy ± 0.0001 g).

The sediment organic content of each sample was determined by loss on ignition (4 hours at 500 °C) after drying the sample to constant weight at 60 °C (Eleftheriou & McIntyre 2005).

Descriptive sediment data from these analyses include the percentage organic content and proportions of different sediment grain size fractions for each sample (see detailed information in Appendix B).

2.4 Data analysis – bivalves

2.4.1 Survey-based population estimates

For each survey site and species combination, the data analysis focused on estimating abundance, population density, and the size (length) frequency distribution, both within and across strata. Results from the present survey were compared with previous surveys using the Fisheries New Zealand beach database. Comparisons with previous surveys from 1999–2000 onwards were made for estimates of abundance and population density. Length-frequency distributions from the present survey were compared with the two preceding surveys.

The data analysis followed the previous approach (e.g., Berkenbusch et al. 2015). Consistent with previous surveys, the two cores within each grid cell were considered a single sampling unit. Bivalve abundance within the sampled strata at each site was estimated by extrapolating local density (individuals per m^2), calculated from the number of individuals per sampling unit, to the stratum size:

$$\hat{y}_k = \frac{1}{S_k} \sum_{s=1}^{S} \frac{n_{s,k}}{0.035}, \tag{1a}$$

$$\hat{N} = \sum_{k=1}^{K} A_k \hat{y}_k, \tag{1b}$$

where $n_{s,k}$ is the number of individuals in sample s within stratum k, S_k is the total number of samples processed in stratum k, and $\hat{y}_k$ is the estimated density of bivalves (individuals per m^2) within the stratum. The total number $\hat{N}$ of bivalves at each site is then the sum of total abundance within each stratum, estimated by multiplying the density within each stratum by the stratum area A_k.

The variance $\sigma^2_{\hat{N}}$ of the total abundance was estimated as:

$$\hat{\sigma}^2_N = \sum_{k=1}^{K} \frac{A_k^2 \sigma^2_{\hat{y}_k}}{S_k},$$

where $\sigma^2_{\hat{y}_k}$ is the variance of the estimated density per sample. The corresponding coefficient of variation (CV, in %) is then:

$$CV = 100 \times \frac{\sigma_{\hat{N}}}{\hat{N}}.$$

To estimate the length-frequency distributions at each site, measured individuals were allocated to size classes (millimetre-length). Within each size class l, the number $n^m_{l,s}$ of measured (superscript m) individuals within each sample s was scaled up to the estimated total number at length within the sample ($\hat{n}_{l,s}$) by dividing by the proportion p^m_s of measured individuals within the sample, so that:

$$\hat{n}_{l,s} = \frac{n^m_{l,s}}{p^m_s}.$$

The numbers at length over all strata were then calculated according to equations 1a and 1b for each length class l. The same procedure was used to estimate the abundance of large-size individuals (defined as $\geq$30-mm shell length for cockles, and $\geq$50-mm shell length for pipi) at each site, summing numbers at length of individuals greater than the reference length r for each species:

$$\hat{n}_{l \geq r,s} = \sum_{l=r}^{\max(l)} \hat{N}_l.$$

In addition to large-sized bivalves, the population assessments also considered the proportion of recruits within the bivalve populations at the sites surveyed. Recruits were defined as cockles that were $\leq$15 mm and pipi that were $\leq$20 mm in shell length.

2.4.2 Model-based population estimates

Since 2013–14, the field data have included high-resolution spatial data, providing the accurate position of each sampling point. Since 2015–16, these high-resolution spatial data have been used within geostatistical models of cockle densities to determine the optimal shape and location of cockle strata based on the spatial distribution and variability of previous samples (see Berkenbusch & Neubauer 2016). Although the re-stratification has been regularly applied since 2015–16 to determine cockle strata at each site prior to the field sampling, population estimates continue to be derived from sampling-based estimators to ensure comparability of population data throughout the survey series.

At some sites, unpredictable shifts in high-density cockle patches between surveys and resultant high uncertainty in the estimates prompted the exploration of geostatistical models to also derive population estimates (Tremblay-Boyer et al. 2021). Model-based geostatistical estimators interpolate between observations to generate site-wide predictions, while accounting for the correlation between observations as the distance increases between them.

The initial exploration provided a comparison between model-based geostatistical estimates and survey-based estimates for the northern sites included in the 2019–20 survey. It also included a temporal correlation structure, which allowed the inclusion of multiple years of survey data in spatio-temporal models. In general, these spatio-temporal models appeared more robust and provided more precise population estimates than single-year models for most sites (Tremblay-Boyer et al. 2021).

Based on the initial development of geostatistical models, the current analysis continued this modelling approach in parallel with the survey-based estimation, by using the spatio-temporal models with the 2024–25 survey data from the current sites. These models were used to predict total cockle density and the density of large cockles over a spatial scale of one square metre. For each of the current sites with cockle populations and multiple-year survey data, the predicted densities were mapped over time (see Appendix C). In comparison to the survey-based estimates that were derived for individual survey years throughout the monitoring series, the geostatistical estimates allowed examination of spatio-temporal patterns in predicted cockle densities at the northern sites.

2.5 Sediment data

For each site, sediment data from the sample processing provided information of the organic content and grain size composition. Sediment organic content is presented as percentage of the total, in addition to percentages of the individual sediment grain size fractions. These data were also summarised for a comparison across the sites included in the current survey.

Previous analyses have examined the relationship between cockle abundance and sediment characteristics (Neubauer et al. 2015, Neubauer et al. 2021). The most recent assessment used data to 2019–20 in principal component analyses (PCAs) to explore relationships of the total cockle population and of large cockles with sediment grain size (see Neubauer et al. 2021). The principal component analysis was updated here with sediment data from the current field sampling in 2024–25.

3. RESULTS

3.1 Cockle Bay

Cockle Bay/Tūwakamana is one of the metropolitan Auckland sites, on the south-eastern coast of the city. At this beach, restrictions for the collection of shellfish were first introduced in 2008, as a seasonal (summer) closure, with a year-round closure implemented in 2021 (Department of Internal Affairs 2008, 2021). There are no resident pipi at this beach, with a focus on cockle population in regular surveys since 2009–10, with the current survey providing the tenth assessment in the survey series (see Appendix A, Tables A-1, A-2). Throughout the surveys, the sampling extent has been consistent, and the current assessment sampled cockles in 90 sampling points across three strata.

Sediment organic content was generally low, ranging from 1.0 to 5.4% (Figure 2, and see details in Appendix B, Table B-1). The sediment grain size composition was predominantly fine sand (grain size >125-µm) and very fine sand (grain size >63 µm), with varying proportions of sediment fines (grain size ≤63 µm). The latter grain size fraction exceeded 15% in six of the sediment samples, with a maximum proportion of 69.7% of sediment fines; all of these samples were in stratum A, close to the shore.

The distribution of cockles across the Cockle Bay sampling extent was predominantly in the upper to mid-intertidal zone, in stratum A (Figure 3, Table 1). The current estimates for the total population were 76.74 million (CV: 13.65%) cockles, occurring at an estimated density of 487 cockles per m^2 (Table 2). Both estimates were marked increases from the 2022–23 estimates of 32.28 million (CV: 16.54%) cockles and 205 individuals per m^2. The current population included a small number of large cockles (≥30 mm shell length), with an estimated 5.81 million (CV: 22.40%) individuals in this size class. Their density was 37 large individuals per m^2.

The large size class made only a small contribution (7.57%) to the total population in 2024–25, compared with 20.60% of large cockles in 2022–23 (Table 3, Figure 4). At the same time, about a third (28.12%) of the current population consisted of recruits (≤15 mm shell length). This population structure was consistent with the preceding survey, with a strong cohort of medium-sized individuals augmented by recruits; in 2024–25, the continued recruitment and concomitant reduction in large-sized cockles led to a shift from a bimodal to a unimodal population structure. Current mean and modal sizes were 19.61 mm and 20 mm shell length, respectively.

Cockle abundance in relation to sediment grain size fractions showed a relatively consistent pattern of higher abundances of both total and large cockles associated with the finer grain size fractions, compared with gravel (Figure 5).

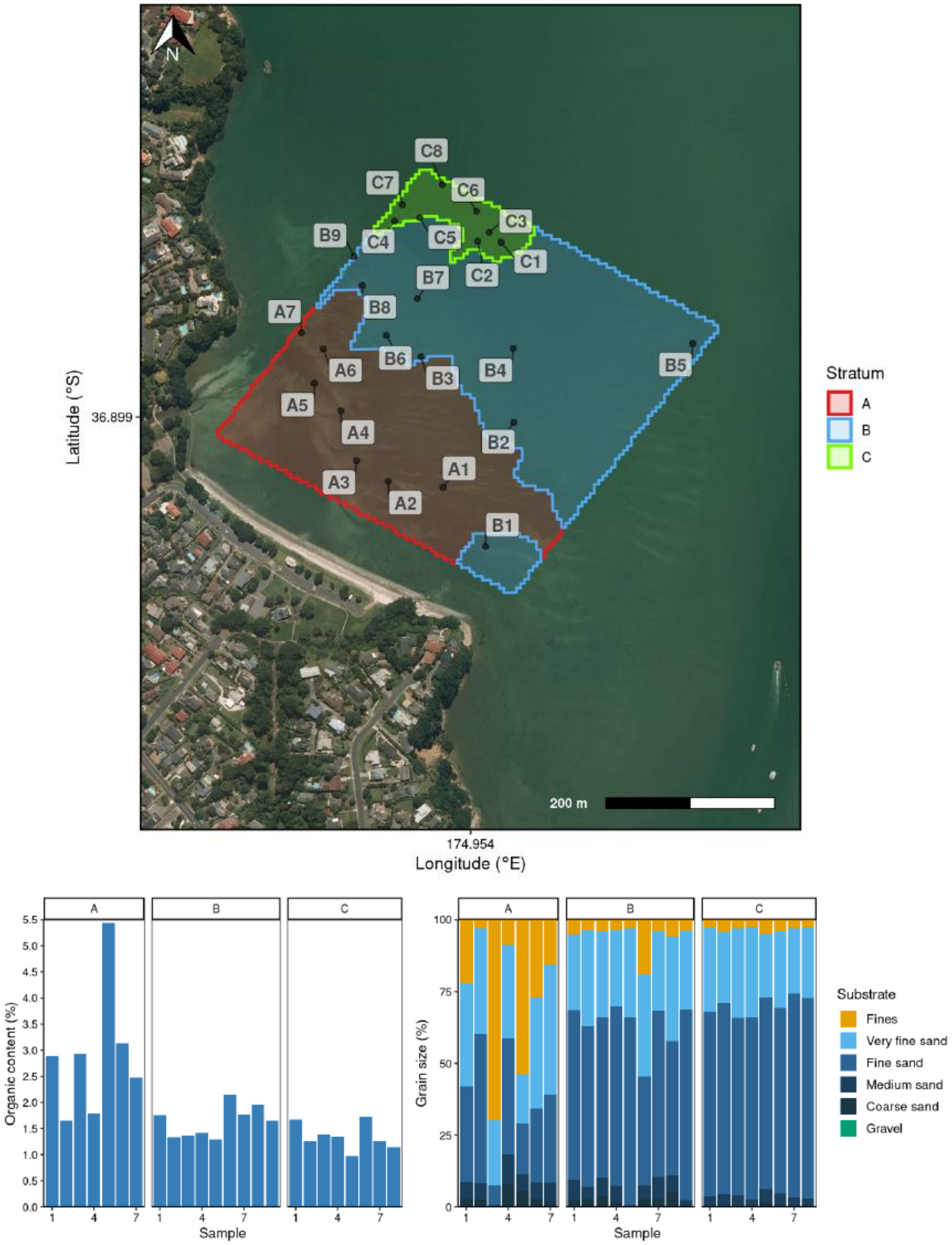

Figure 2: Sediment sample locations and characteristics at Cockle Bay. Labels correspond to stratum and sample number. Graphs show organic content (% dry weight) and cumulative grain size (%). Sediment grain size fractions include fines (silt and clay, ≤63 µm), sands (very fine, >63 µm; fine, >125 µm; medium, >250 µm; coarse, >500 µm), and gravel (>2000 µm) (see details in Table B-1).

3.1.1 Cockles at Cockle Bay

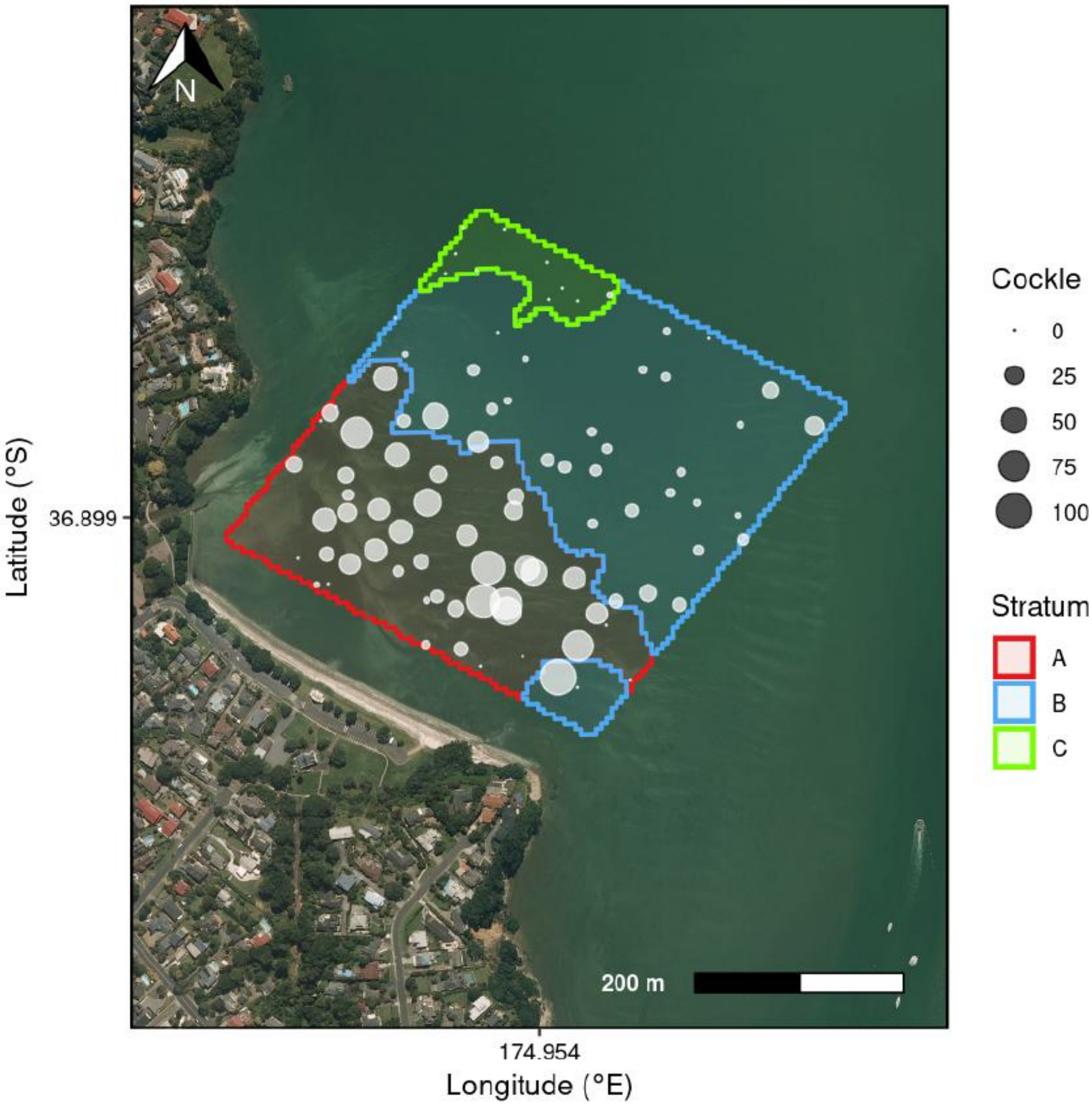

Figure 3: Map of sample strata and individual sample locations for cockles at Cockle Bay, with the size of the circles proportional to the number of cockles (per 0.035 m^2) found at each location. Samples with zero counts are shown as small dots.

Table 1: Estimates of cockle abundance at Cockle Bay, by stratum, for 2024–25. Presented are the area surveyed, the number of points and the number of cockles sampled, the mean total estimate, the mean density, and the coefficient of variation (CV).

Stratum		Sample		Population estimate		
	Area (ha)	Points	Cockle	Total (millions)	Density (m^{-2})	CV (%)
A	6.3	45	1 236	49.52	785	14.08
B	8.6	35	389	27.19	318	28.75
C	0.9	10	1	0.03	3	>100

Table 2: Estimates of cockle abundance at Cockle Bay for all sizes and large size (≥30 mm) cockles. Columns include the mean total estimate, mean density, and coefficient of variation (CV).

Year	Extent (ha)	Population estimate			Population ≥ 30 mm		
		Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
2009–10	16.0	59.54	372	5.60	6.27	39	12.48
2010–11	16.0	72.20	451	5.61	21.29	133	8.15
2012–13	16.0	54.67	342	7.51	36.46	228	8.78
2013–14	15.8	33.68	214	8.14	21.02	133	9.50
2015–16	15.8	21.46	136	8.48	15.37	98	10.77
2017–18	15.8	43.37	275	11.62	17.48	111	13.87
2019–20	15.8	44.41	282	13.84	11.75	75	15.81
2021–22	15.6	34.58	222	14.93	4.99	32	15.57
2022–23	15.8	32.28	205	16.54	6.65	42	45.02
2024–25	15.8	76.74	487	13.65	5.81	37	22.40

Table 3: Summary statistics of the length-frequency (LF) distribution of cockles at Cockle Bay. The LF distributions (in mm) were estimated for all strata in each survey and subsequently summed for the distribution of total LFs. Recruits were defined by a shell length of ≤15 mm and large individuals by a shell length of ≥30 mm.

Year	Mean	Mode	Range	Recruits (%)	Medium (%)	Large (%)
2021–22	22.77	17	7–39	11.13	74.43	14.44
2022–23	22.08	15	6–46	24.15	55.25	20.60
2024–25	19.61	20	6–41	28.12	64.31	7.57

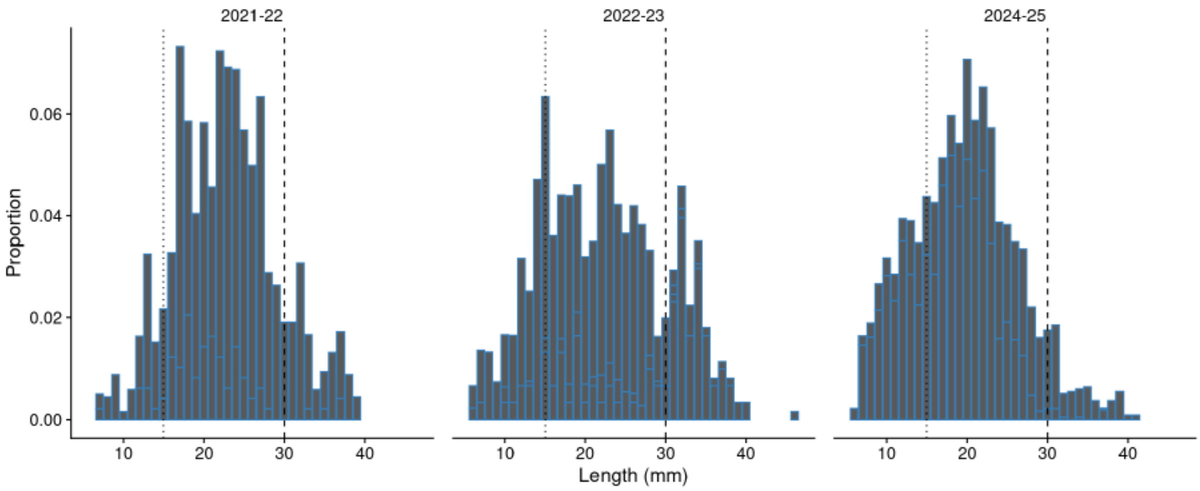

Figure 4: Weighted length-frequency (LF) distribution of cockles for the present and previous surveys at Cockle Bay. Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively.

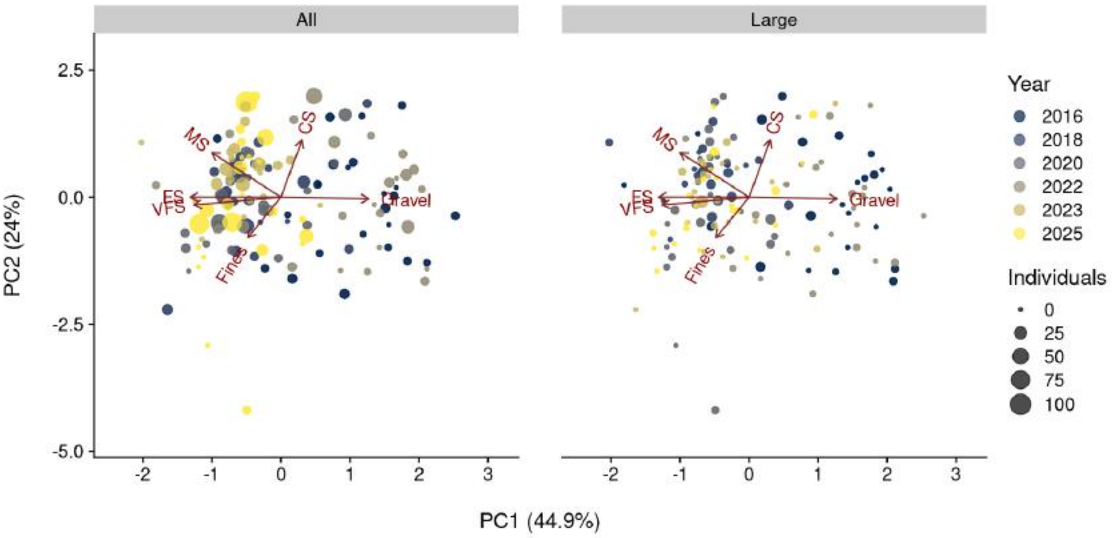

Figure 5: Cockle abundance along two principal components (standardised PCs, including % variance explained) of sediment granulometry for all cockle size classes (all) and large cockles (≥30 mm shell length) at Cockle Bay. Sediment grain size fractions are defined as fines (silt and clay) ≤63 µm, very fine sand (VFS) >63 µm, fine sand (FS) >125 µm, medium sand (MS) >250 µm, coarse sand (CS) >500 µm, and gravel >2000 µm.

3.2 Kawakawa Bay (West)

Kawakawa Bay (West) is in the wider Auckland area and part of Hauraki Gulf. It was first included in the northern survey series in 2004–05, with seven assessments preceding the current survey (see Appendix A, Tables A-1, A-2). Across surveys, the sampling extent has remained the same, covering the entire bay. There are no pipi beds in the bay, so that the survey is focused on cockles only. In the 2024–25 survey, cockles were sampled across three strata, based on a total of 108 sampling points.

The sediment sampling documented a low organic content (i.e., less than 4.0%), with the grain size composition in most samples dominated by very fine and fine sands (grain sizes >63 µm and >125 µm) (Figure 6, and see details in Appendix B, Table B-1). The proportion of sediment fines (grain size ≤ 63 µm) was variable, exceeding 10% in seven samples, with up to 24.4% in this grain size fraction.

The cockle population was distributed across the bay, excepting the northern area, stratum C (Figure 7, Table 4). The current population estimates of 205.04 million (CV: 16.60%) cockles and 337 individuals per m^2 signified increases from the preceding abundance and density estimates of 156.07 million (CV: 14.29%) individuals and 256 individuals per m^2 (Table 5). Similarly, there was an increase in the population of large cockles (≥ 30 mm shell length), with an estimated 20.22 million individuals and an estimated density of 33 large individuals per m^2; however, there was considerable uncertainty with these estimates (CV: 70.46%).

The proportion of large cockles remained consistent in recent surveys, reaching about 10% of the population in 2022–23 and 2024–25 (Table 6, Figure 8). In comparison, recruits (≤ 15 mm shell length) contributed a signficant proportion of the population in recent surveys, with over 40% of individuals in this size class; in 2024–25, their proportion was 54.89% of the total population. Their prevalence determined the largely unimodal population structure, which was defined by mean and modal shell lengths of 16.71 mm and 12 mm, respectively. This population size structure remained similar across the three most recent surveys, documenting a cockle population largely consisting of recruits and small individuals in the medium size class.

Considering the abundance of cockles in relation to sediment grain size, the proportions of gravel and of the finer grain size fractions explained 59.4% of the variance (along PC1), particularly in previous surveys (Figure 9).

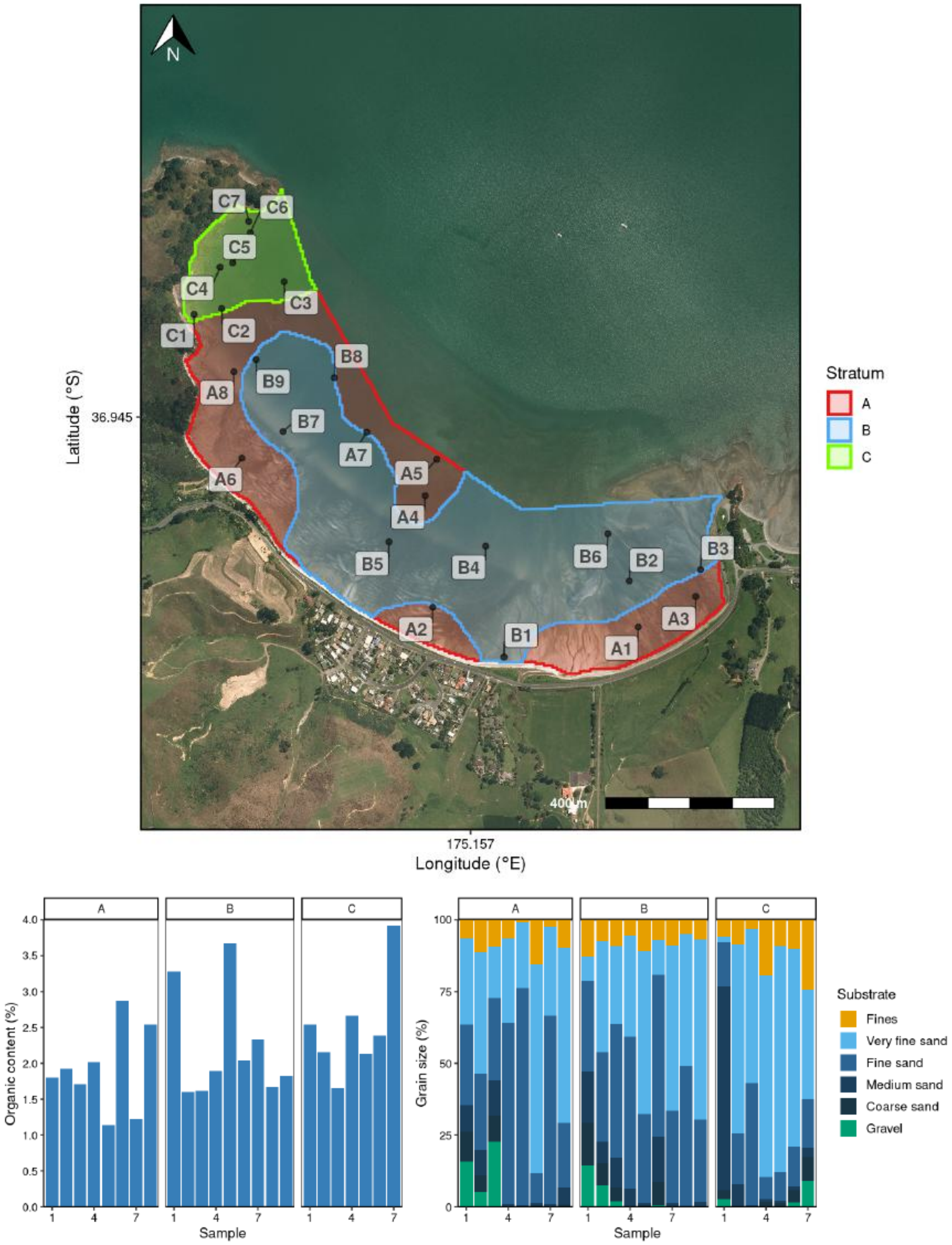

Figure 6: Sediment sample locations and characteristics at Kawakawa Bay (West). Labels correspond to stratum and sample number. Graphs show organic content (% dry weight) and cumulative grain size (%). Sediment grain size fractions include fines (silt and clay, ≤63 µm), sands (very fine, >63 µm; fine, >125 µm; medium, >250 µm; coarse, >500 µm), and gravel (>2000 µm) (see details in Table B-1).

3.2.1 Cockles at Kawakawa Bay (West)

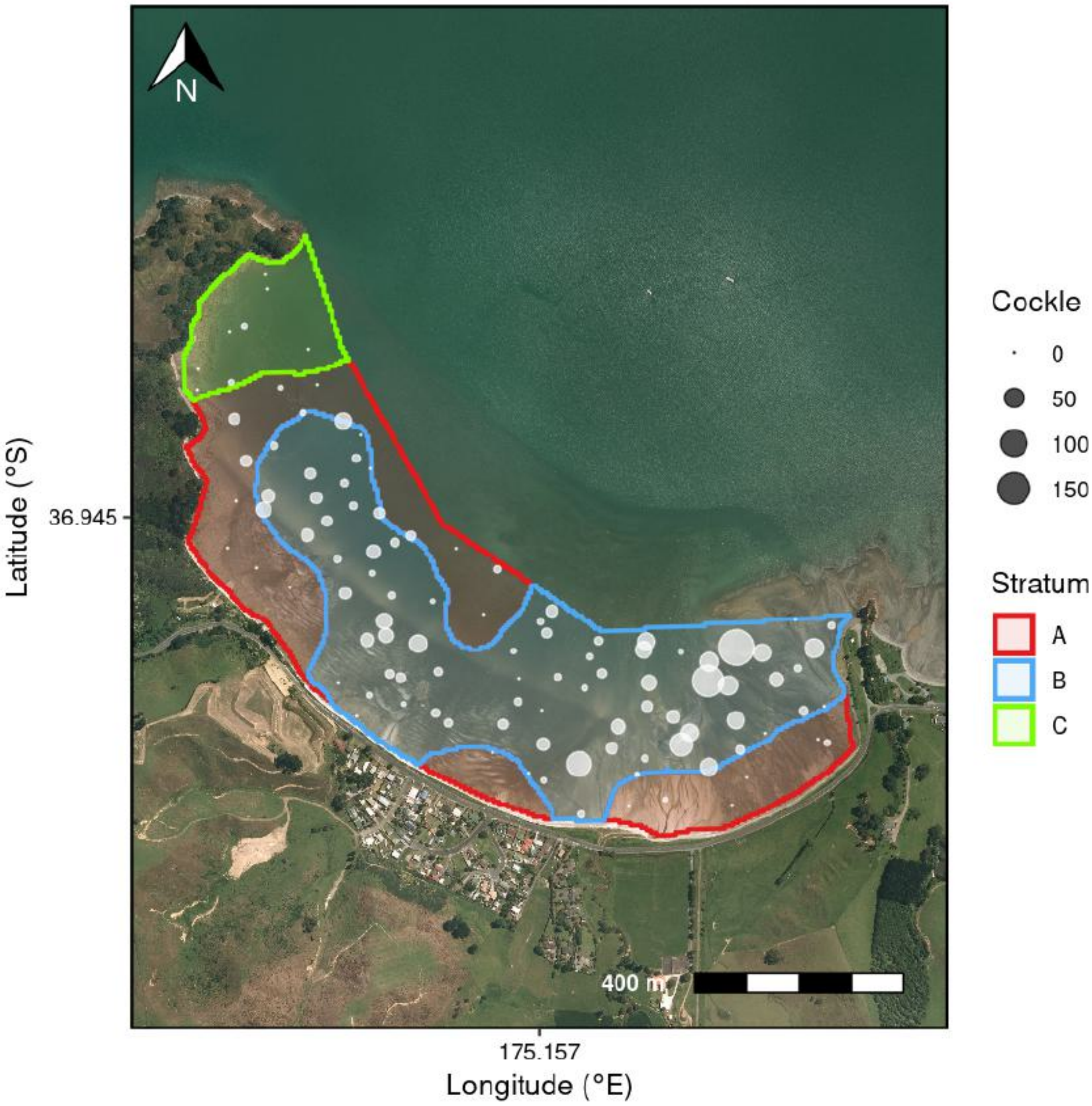

Figure 7: Map of sample strata and individual sample locations for cockles at Kawakawa Bay (West), with the size of the circles proportional to the number of cockles (per 0.035 m^2) found at each location. Samples with zero counts are shown as small dots.

Table 4: Estimates of cockle abundance at Kawakawa Bay, by stratum, for 2024–25. Presented are the area surveyed, the number of points and the number of cockles sampled, the mean total estimate, the mean density, and the coefficient of variation (CV).

Stratum		Sample		Population estimate		
	Area (ha)	Points	Cockle	Total (millions)	Density (m^{-2})	CV (%)
A	20.7	20	77	22.73	110	46.17
B	34.4	80	1 478	181.47	528	17.84
C	5.9	8	4	0.84	14	65.47

Table 5: Estimates of cockle abundance at Kawakawa Bay (West) for all sizes and large size (≥30 mm) cockles. Columns include the mean total estimate, mean density, and coefficient of variation (CV).

Year	Extent (ha)	Population estimate			Population ≥ 30 mm		
		Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
2004–05	60.4	87.68	145	9.19	13.28	22	17.55
2006–07	62.9	86.39	137	10.54	21.23	34	22.75
2014–15	60.9	74.44	122	9.69	19.80	33	15.80
2016–17	60.9	261.21	429	13.84	18.33	30	36.42
2018–19	60.9	222.41	365	17.52	9.34	15	28.81
2020–21	60.9	200.93	330	12.01	10.91	18	27.20
2022–23	60.9	156.07	256	14.29	15.33	25	36.15
2024–25	60.9	205.04	337	16.60	20.22	33	70.46

Table 6: Summary statistics of the length-frequency (LF) distribution of cockles at Kawakawa Bay. The LF distributions (in mm) were estimated for all strata in each survey and subsequently summed for the distribution of total LFs. Recruits were defined by a shell length of ≤15 mm and large individuals by a shell length of ≥30 mm.

Year	Mean	Mode	Range	Recruits (%)	Medium (%)	Large (%)
2020–21	18.01	15	5–40	40.80	53.76	5.43
2022–23	17.46	12	4–40	48.26	41.91	9.82
2024–25	16.71	12	6–40	54.89	35.24	9.86

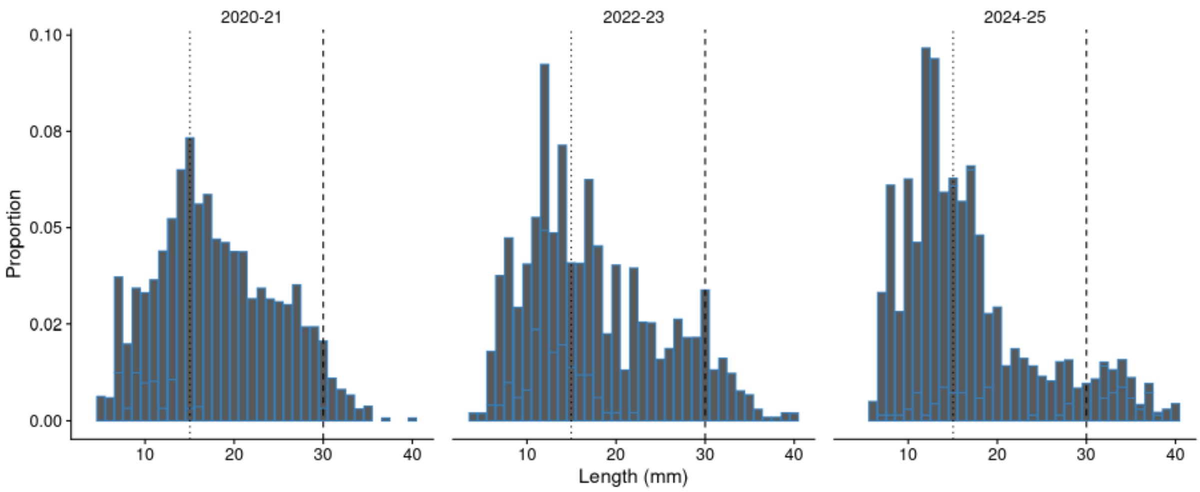

Figure 8: Weighted length-frequency (LF) distribution of cockles for the present and previous surveys at Kawakawa Bay (West). Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively.

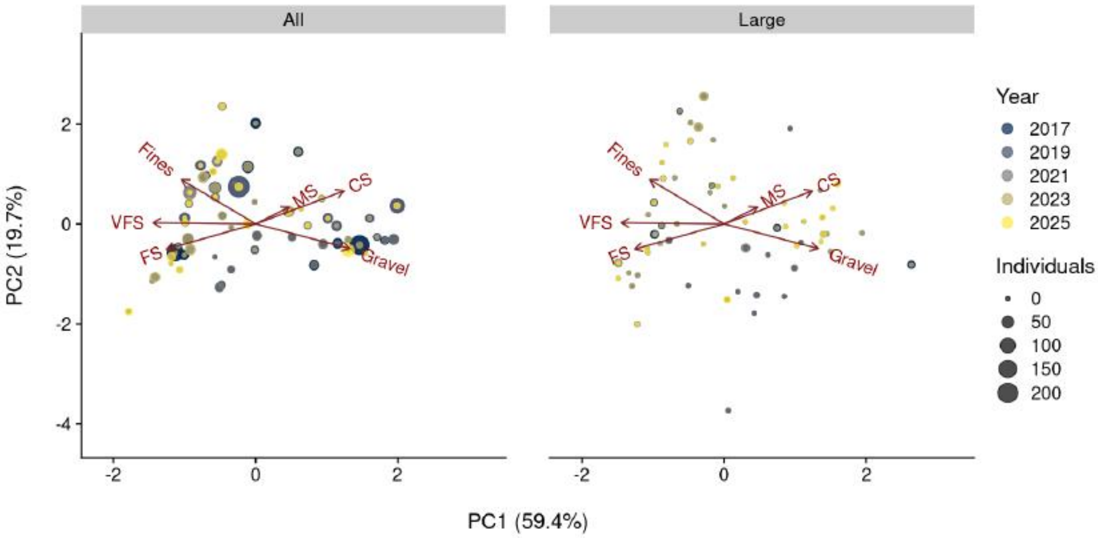

Figure 9: Cockle abundance along two principal components (standardised PCs, including % variance explained) of sediment granulometry for all cockle size classes (all) and large cockles (≥30 mm shell length) at Kawakawa Bay (West). Sediment grain size fractions are defined as fines (silt and clay) ≤63 µm, very fine sand (VFS) >63 µm, fine sand (FS) >125 µm, medium sand (MS) >250 µm, coarse sand (CS) >500 µm, and gravel >2000 µm.

3.3 Mill Bay

Mill Bay is on the northern side of Manukau Harbour, close to the entrance. It has been part of the bivalve monitoring since 1999–2000, with the survey in 2021–22 immediately preceding the present survey (see Appendix A, Tables A-1, A-2). The sampling extent has remained the same throughout the survey series, spanning the intertidal zone across the bay. The sampling effort in 2024–25 enocompassed three strata with a total of 90 sampling points.

The sediment in the bay had a low organic content of less than 3.8%, with varying proportions of sediment fines (grain size ≤63 µm); this grain size fraction varied between 2.6% and 20.1%, with ten samples exceeding 10% in sediment fines (Figure 10, and see details in Appendix B, Table B-1). Fine and medium sands (grain sizes >250-µm and >500-µm) were the prevalent grain size fractions across samples, with relatively large proportions (up to 14.5%) of gravel (>2000-µm) in some samples, particularly in stratum C.

The cockle population was distributed across the intertidal range of the sampling extent, with a comparatively high abundance in the mid-intertidal zone (Figure 11, Table 7). The current population estimates were 25.51 million (CV: 14.25%) cockles with a mean density of 523 cockles per m^2 (Table 8). Both these estimates were marked decreases from relatively high values in 2021–22, when cockle abundance and density estimates were 46.68 million (CV: 12.00%) individuals and 964 individuals per m^2. Within the population, large cockles (≥30 mm shell length) were scarce, and their population estimates had high uncertainty (i.e., a CV of 38.73%).

The scarcity of large cockles at Mill Bay was in contrast to the significant proportion of recruits (≤15 mm shell length), which largely influenced the population in the three most recent surveys; in 2024–25, 49.15% of the population consisted of recruits (Table 9, Figure 12). Over this time, fluctuations in their proportion were reflected in the overall population estimates, and also in the population size structure. The recent reduction in the proportion of recruits led to a slight shift in mean and modal sizes towards the medium-size class in 2024–25. Nevertheless, these shell lengths remained around the upper cut-off length of 15 mm for the recruits size class at 16.23 mm and 15 mm, respectively.

Some of the variation in total cockle abundance was explained by the sediment grain size composition, with higher estimates associated with the finer sand fractions, compared with coarse sand and gravel (Figure 13).

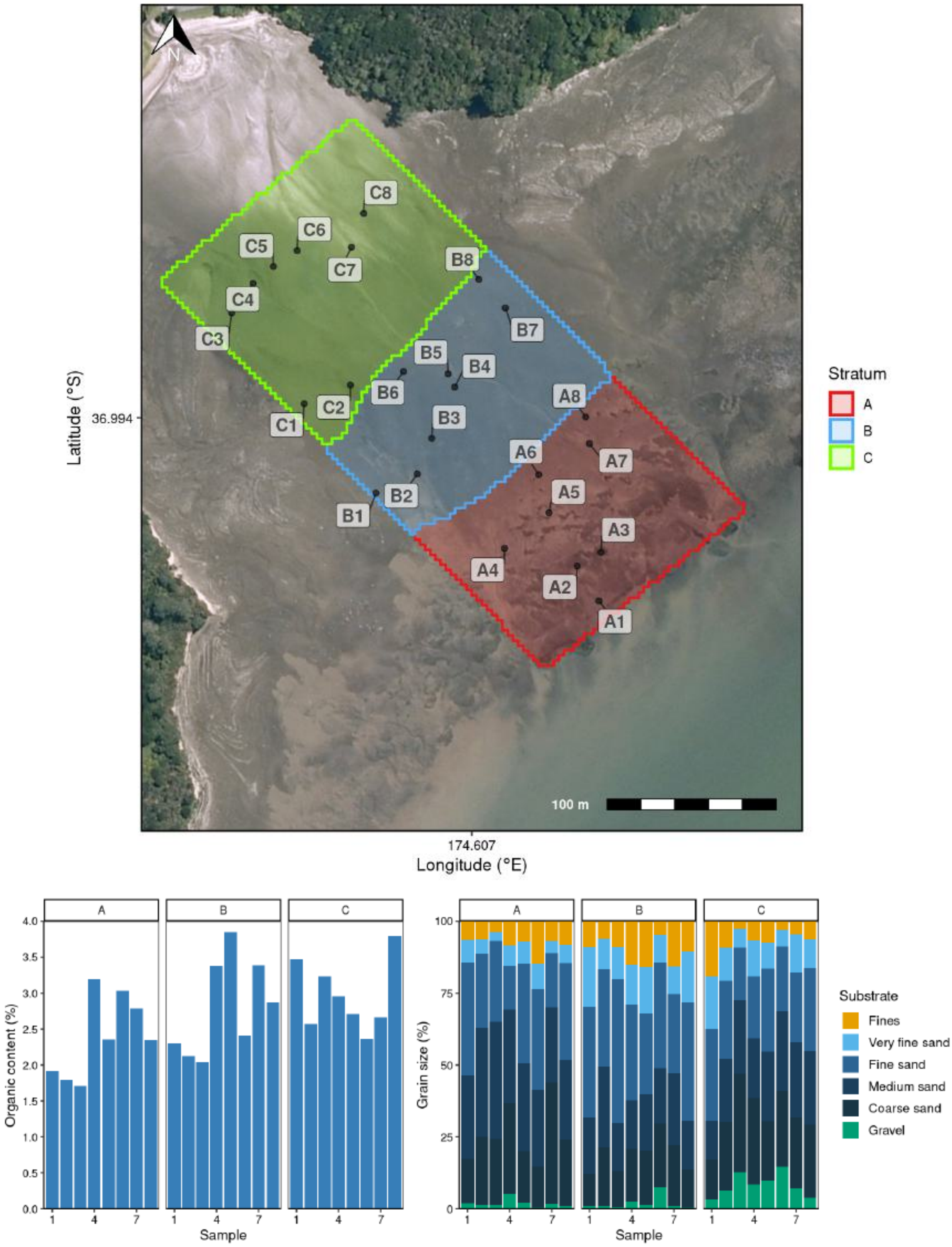

Figure 10: Sediment sample locations and characteristics at Mill Bay. Labels correspond to stratum and sample number. Graphs show organic content (% dry weight) and cumulative grain size (%). Sediment grain size fractions include fines (silt and clay, ≤63 µm), sands (very fine, >63 µm; fine, >125 µm; medium, >250 µm; coarse, >500 µm), and gravel (>2000 µm) (see details in Table B-1).

3.3.1 Cockles at Mill Bay

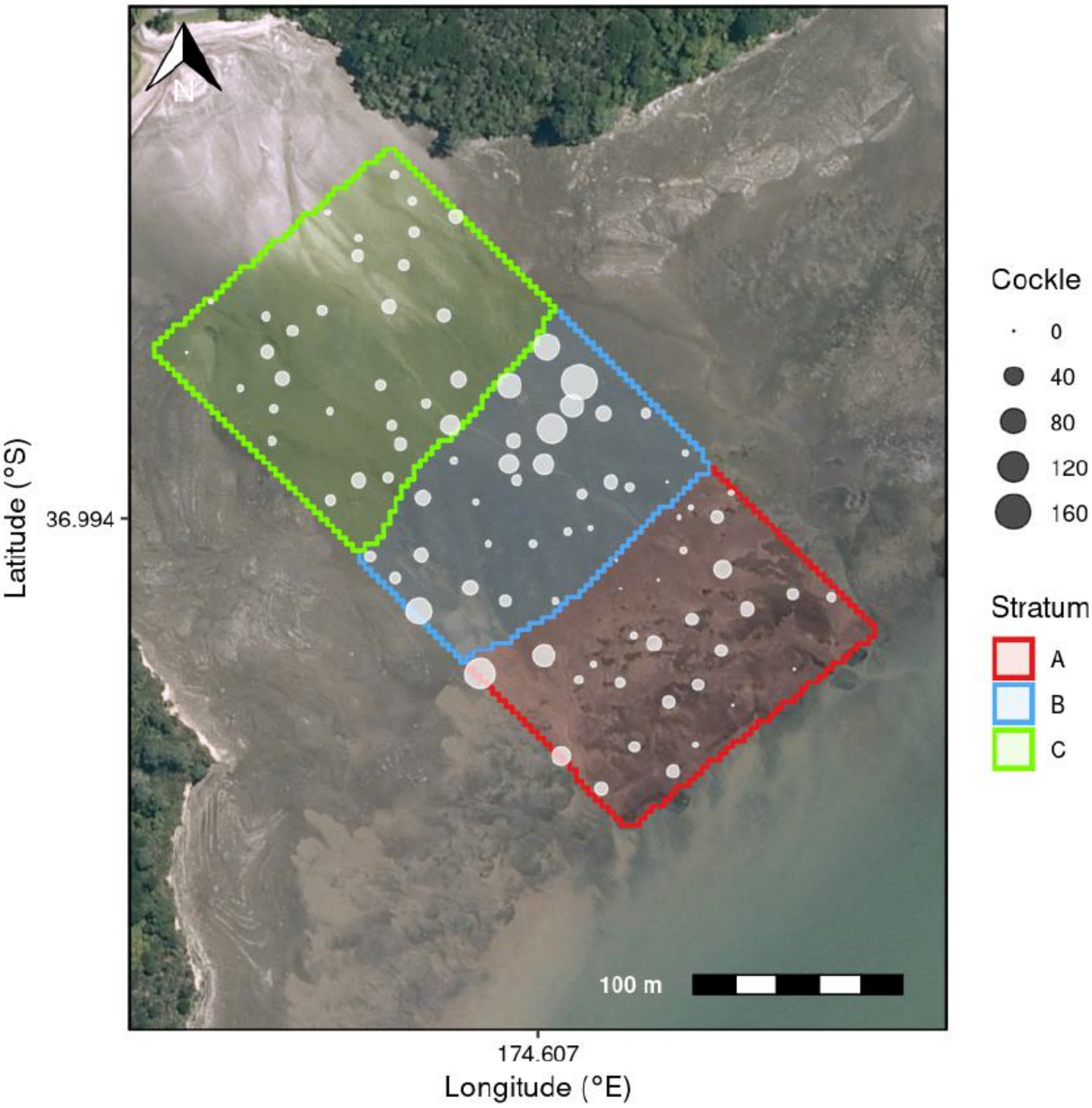

Figure 11: Map of sample strata and individual sample locations for cockles at Mill Bay, with the size of the circles proportional to the number of cockles (per 0.035 m^2) found at each location. Samples with zero counts are shown as small dots.

Table 7: Estimates of cockle abundance at Mill Bay, by stratum, for 2024–25. Presented are the area surveyed, the number of points and the number of cockles sampled, the mean total estimate, the mean density, and the coefficient of variation (CV).

Stratum		Sample		Population estimate		
	Area (ha)	Points	Cockle	Total (millions)	Density (m^{-2})	CV (%)
A	1.6	30	457	7.02	435	28.50
B	1.4	30	909	12.18	866	23.65
C	1.9	30	356	6.31	339	15.11

Table 8: Estimates of cockle abundance at Mill Bay for all sizes and large size (≥30 mm) cockles. Columns include the mean total estimate, mean density, and coefficient of variation (CV).

Year	Extent (ha)	Population estimate			Population ≥ 30 mm		
		Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
1999–00	4.6	4.91	107	7.87	0.74	16	12.06
2000–01	4.8	10.24	213	6.32	1.23	26	9.50
2001–02	4.5	5.21	116	6.89	0.38	8	13.26
2003–04	4.5	5.33	118	7.69	0.32	7	14.64
2004–05	4.5	4.23	94	7.30	0.30	7	14.45
2005–06	4.5	6.72	149	6.66	0.39	9	11.89
2009–10	5.0	11.31	229	8.92	0.18	4	31.80
2014–15	4.9	16.66	342	9.56	0.07	1	42.43
2017–18	4.9	7.78	160	25.18	0.21	4	41.00
2018–19	4.9	23.04	475	14.68	0.67	14	20.30
2021–22	4.8	46.68	964	12.00	0.29	6	37.80
2024–25	4.9	25.51	523	14.25	0.15	3	38.73

Table 9: Summary statistics of the length-frequency (LF) distribution of cockles at Mill Bay. The LF distributions (in mm) were estimated for all strata in each survey and subsequently summed for the distribution of total LFs. Recruits were defined by a shell length of ≤15 mm and large individuals by a shell length of ≥30 mm.

Year	Mean	Mode	Range	Recruits (%)	Medium (%)	Large (%)
2018–19	17.37	14	5–35	43.80	53.30	2.90
2021–22	14.14	13	5–32	64.00	35.38	0.62
2024–25	16.23	15	5–32	49.15	50.25	0.60

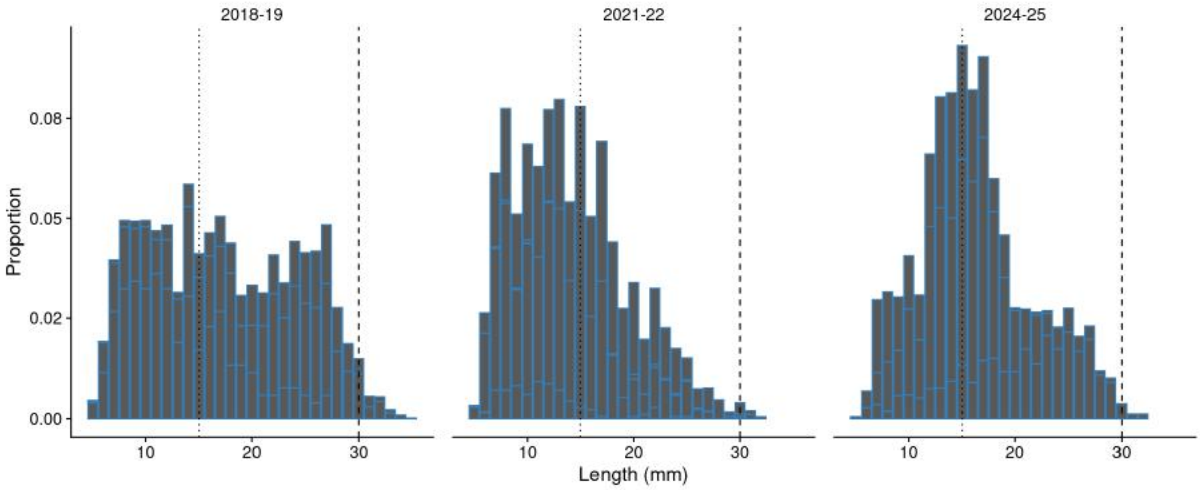

Figure 12: Weighted length-frequency (LF) distribution of cockles for the present and previous surveys at Mill Bay. Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively.

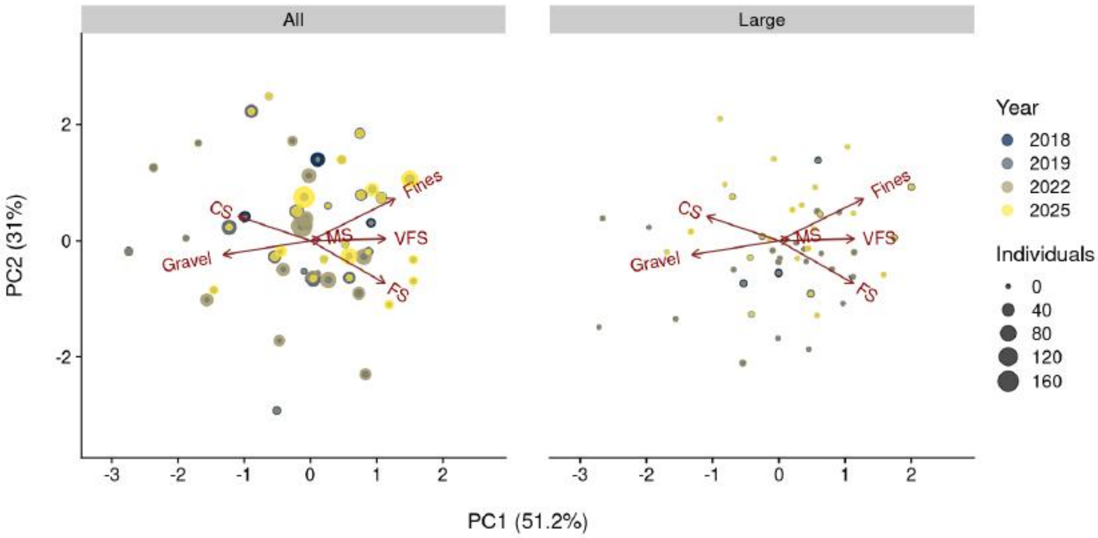

Figure 13: Cockle abundance along two principal components (standardised PCs, including % variance explained) of sediment granulometry for all cockle size classes (all) and large cockles (≥30 mm shell length) at Mill Bay. Sediment grain size fractions are defined as fines (silt and clay) ≤63 µm, very fine sand (VFS) >63 µm, fine sand (FS) >125 µm, medium sand (MS) >250 µm, coarse sand (CS) >500 µm, and gravel >2000 µm.

3.4 Ōhiwa Harbour

Ōhiwa Harbour is a large harbour in eastern Bay of Plenty. Cockles and pipi in the harbour have been surveyed in ten assessments since 2001–02, including the current study (see Appendix A, Tables A-1, A-2). The sampling extent encompasses disjunct cockle and pipi strata, with changes in pipi beds resulting in changes to the sampling extent over time. These changes have included significant sand movement in the main harbour channel and its entrance, particularly following severe tropical cyclone Gabrielle in 2023. In 2024–25, the sampling focused on four strata, two each for cockles and pipi, with a total of 150 sampling points.

Sediment samples in the two cockle strata were characterised by a low organic content of less than 4% and a varying proportion of sediment fines (≤63 µm), ranging from 1.2 to 14.3% (Figure 14, and see details in Appendix B, Table B-1). Most of the sediment consisted of fine sand (grain size >125 µm) with only small proportions of the samples at other grain sizes.

Cockles were present in all strata, but at comparatively low numbers in the pipi beds, strata C and D (Figure 15, Table 10). Acros the entire sampling extent, their estimated population size was 10.22 million (CV: 17.05%) cockles, doubling the previous population estimate of 5.04 million (CV: 14.23%) cockles (Table 11). There was also a marked increase in the population density from 269 cockles per m^2 in 2022–23 to 469 cockles per m^2 in 2024–25. There were few large cockles (≥30 mm shell length) within the total population, and this size class consisted of an estimated 0.20 million (24.47%) large individuals, with their density estimated at nine large cockles per m^2.

The proportion of large cockles was consistently minor in the three most recent surveys (i.e., less than 3.5%), in contrast to notable proportions of recruits (≤15 mm shell length) (Table 12). In 2024–25, recruits contributed 26.03% of all individuals, continuing to augment a single, strong cohort, mostly consisting of medium-sized cockles (Figure 16). The consistency in the population size composition was also evident in mean and modal sizes, which remained similar in recent surveys, with current shell lengths at a mean of 18.89 mm and a mode of 17 mm.

Considering the PCA of cockle abundance in relation to sediment grain sizes, there were generally higher abundances of all cockles associated with the finer sediment grain fractions, but less so with sediment fines (Figure 17).

There were two pipi beds surveyed in 2024–25, with one bed in the western part of the main channel (stratum C) and the other bed in a side channel (stratum D) (Figure 18, Table 13). The latter bed was buried in sediment and inaccessible in the preceding survey, but pipi re-colonised this area prior to the current survey. Across the entire sampling extent, the total pipi population was estimated at a total of 24.17 million (CV: 7.62%) pipi, with a corresponding mean density of 1110 pipi per m^2 (Table 14). These population estimates marked a notable reversal of the continued population decline since 2018–19, with a similar density estimate to the relatively high estimate in 2015–16. At the same time, the population continued to contain only a small number of large pipi (≥50 mm shell length) (i.e., 0.06 million individuals), and the uncertainty associated with their population estimates also remained high (CV: 30.66%).

The increases in the total population estimates in 2024–25 were accompanied by a notable increase in the proportion of recruits (≤20 mm shell length) from 3.91% in 2020–21 to 48.84% in 2024–25 (Table 15, Figure 19). This considerable recruitment led to a decrease in the proportion of medium-sized pipi, which previously determined over 80% of the population. The shift towards small-sized recruits was also evident in the reduction of mean and modal sizes; for example, the latter shell length decreased from 40 and 42 mm in the two preceding surveys to 18 mm shell length in 2024–25. These changes led to a shift of the previously bimodal population to a unimodal size structure, with a single cohort around the recruit size class cut-off at 20 mm.

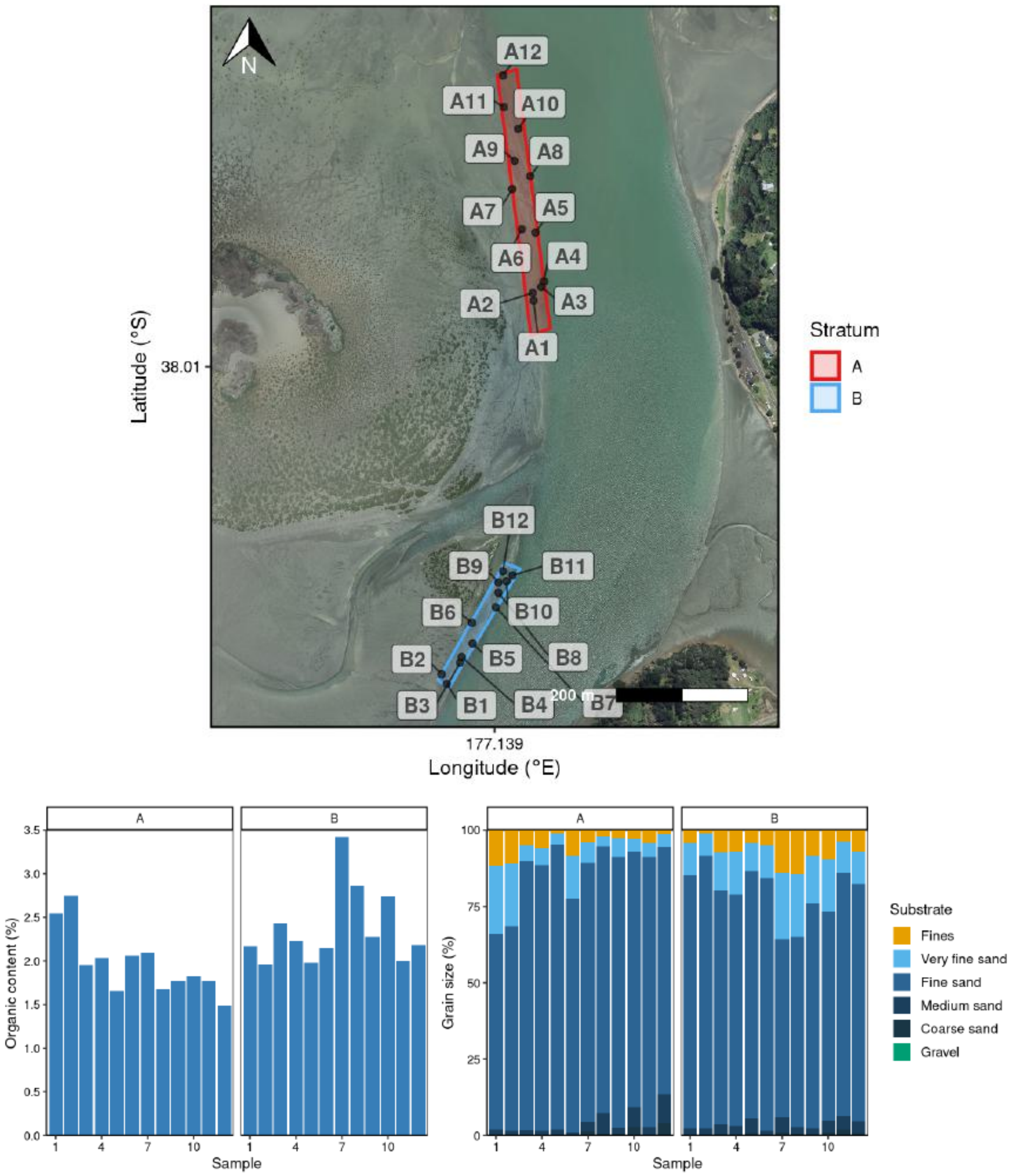

Figure 14: Sediment sample locations and characteristics at Ōhiwa Harbour. Labels correspond to stratum and sample number. Graphs show organic content (% dry weight) and cumulative grain size (%). Sediment grain size fractions include fines (silt and clay, ≤63 µm), sands (very fine, >63 µm; fine, >125 µm; medium, >250 µm; coarse, >500 µm), and gravel (>2000 µm) (see details in Table B-1).

3.4.1 Cockles at Ōhiwa Harbour

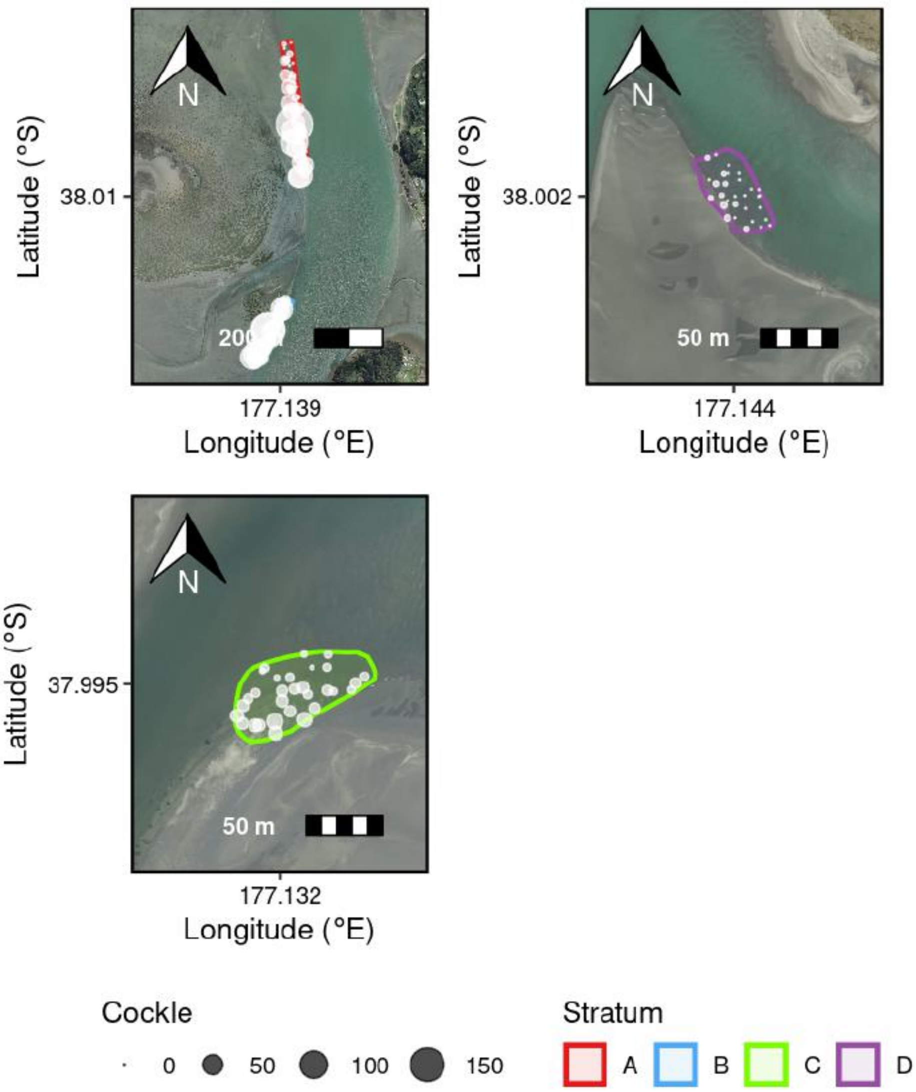

Figure 15: Map of sample strata and individual sample locations for cockles at Ōhiwa Harbour, with the size of the circles proportional to the number of cockles (per 0.035 m^2) found at each location. Samples with zero counts are shown as small dots.

Table 10: Estimates of cockle abundance at Ōhiwa Harbour, by stratum, for 2024–25. Presented are the area surveyed, the number of points and the number of cockles sampled, the mean total estimate, the mean density, and the coefficient of variation (CV).

Stratum		Sample		Population estimate		
	Area (ha)	Points	Cockle	Total (millions)	Density (m^{-2})	CV (%)
A	1.2	45	797	6.11	506	26.43
B	0.5	45	1 038	3.06	659	21.03
C	0.3	30	316	1.03	301	11.53
D	0.2	30	15	0.02	14	31.44

Table 11: Estimates of cockle abundance at Ōhiwa Harbour for all sizes and large size (≥30 mm) cockles. Columns include the mean total estimate, mean density, and coefficient of variation (CV).

Year	Extent (ha)	Population estimate			Population ≥ 30 mm		
		Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
2001–02	2.2	4.53	201	7.82	0.16	7	22.37
2005–06	2.7	3.69	137	7.07	0.17	6	15.69
2006–07	5.7	17.48	307	10.59	1.12	20	14.47
2009–10	2.1	6.47	308	8.79	0.03	1	51.49
2012–13	2.6	9.05	344	10.49	0.05	2	36.42
2015–16	3.4	11.27	334	13.38	0.08	2	99.96
2018–19	2.5	5.57	219	13.38	0.82	32	39.04
2020–21	2.6	12.61	476	19.44	0.42	16	20.71
2022–23	1.9	5.04	269	14.23	0.08	4	58.31
2024–25	2.2	10.22	469	17.05	0.20	9	24.47

Table 12: Summary statistics of the length-frequency (LF) distribution of cockles at Ōhiwa Harbour. The LF distributions (in mm) were estimated for all strata in each survey and subsequently summed for the distribution of total LFs. Recruits were defined by a shell length of ≤15 mm and large individuals by a shell length of ≥30 mm.

Year	Mean	Mode	Range	Recruits (%)	Medium (%)	Large (%)
2020–21	20.20	20	7–36	15.15	81.50	3.35
2022–23	17.93	17	6–35	33.03	65.34	1.63
2024–25	18.89	17	6–36	26.03	72.02	1.95

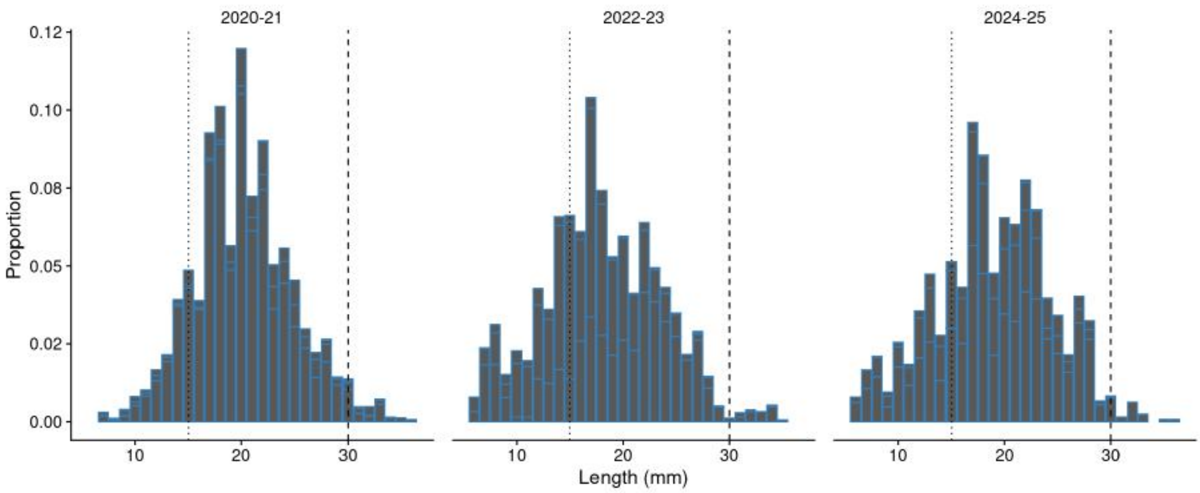

Figure 16: Weighted length-frequency (LF) distribution of cockles for the present and previous surveys at Ōhiwa Harbour. Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively.

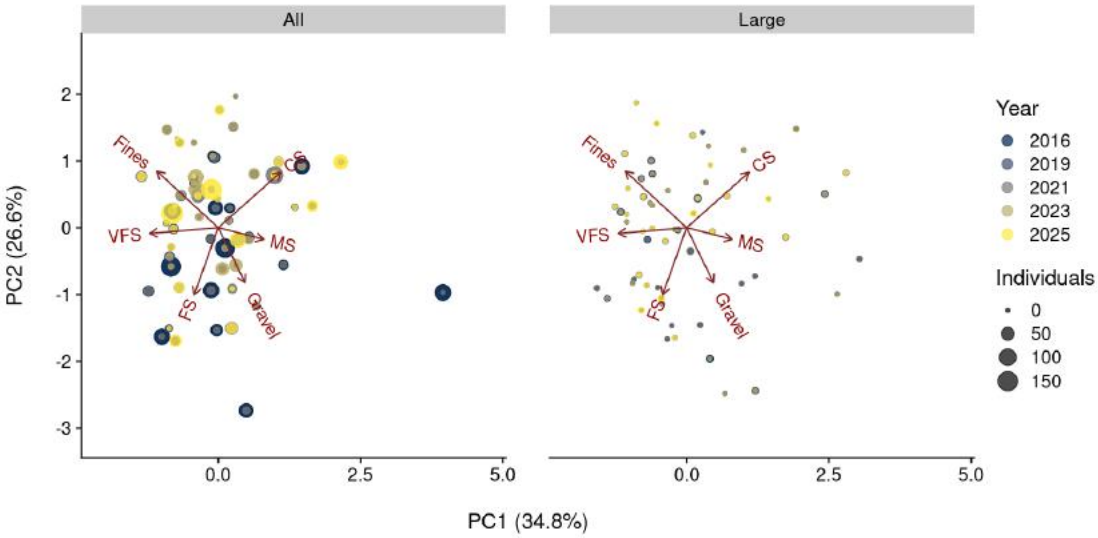

Figure 17: Cockle abundance along two principal components (standardised PCs, including % variance explained) of sediment granulometry for all cockle size classes (all) and large cockles (≥30 mm shell length) at Ōhiwa Harbour. Sediment grain size fractions are defined as fines (silt and clay) ≤63 µm, very fine sand (VFS) >63 µm, fine sand (FS) >125 µm, medium sand (MS) >250 µm, coarse sand (CS) >500 µm, and gravel >2000 µm.

3.4.2 Pipi at Ōhiwa Harbour

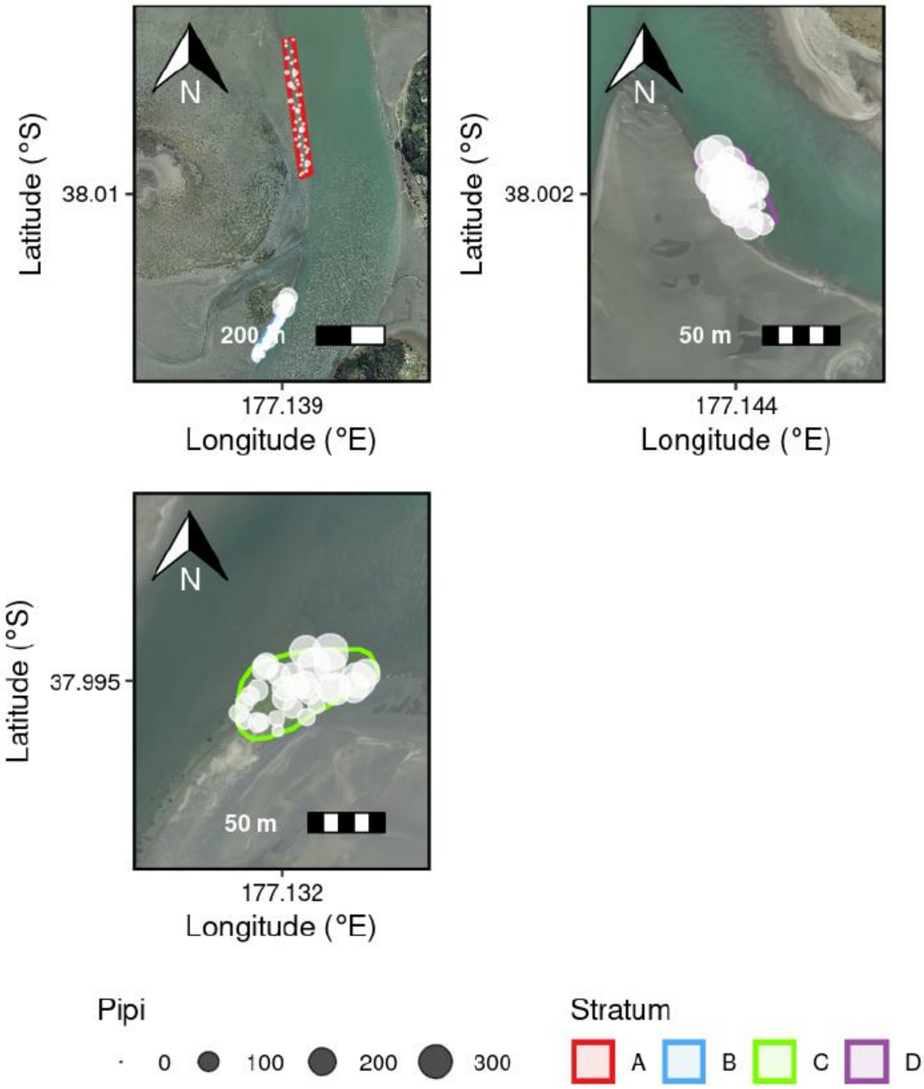

Figure 18: Map of sample strata and individual sample locations for pipi at Ōhiwa Harbour, with the size of the circles proportional to the number of pipi (per 0.035 m^2) found at each location. Samples with zero counts are shown as small dots.

Table 13: Estimates of pipi abundance at Ōhiwa Harbour, by stratum, for 2024–25. Presented are the area surveyed, the number of points and the number of pipi sampled, the mean total estimate, the mean density, and the coefficient of variation (CV).

Stratum		Sample		Population estimate		
	Area (ha)	Points	Pipi	Total (millions)	Density (m^{-2})	CV (%)
A	1.2	45	12	0.09	8	36.54
B	0.5	45	530	1.56	337	29.53
C	0.3	30	4 562	14.86	4 345	10.33
D	0.2	30	4 893	7.65	4 660	11.86

Table 14: Estimates of pipi abundance at Ōhiwa Harbour for all sizes and large size (≥50 mm) pipi. Columns include the mean total estimate, mean density, and coefficient of variation (CV).

Year	Extent (ha)	Population estimate			Population ≥ 50 mm		
		Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
2001–02	2.2	5.67	252	6.88	2.14	95	7.46
2005–06	2.7	3.40	126	7.27	2.52	93	6.36
2006–07	5.7	8.27	145	10.52	2.14	38	13.78
2009–10	2.1	15.25	726	14.46	1.63	78	18.77
2012–13	2.6	41.59	1 581	14.39	1.03	39	31.52
2015–16	3.4	41.24	1 221	12.10	3.70	109	18.37
2018–19	2.5	13.05	514	13.00	1.24	49	19.69
2020–21	2.6	7.15	270	10.26	0.86	33	21.48
2022–23	1.9	1.47	78	10.61	0.03	2	32.65
2024–25	2.2	24.17	1 110	7.62	0.06	3	30.66

Table 15: Summary statistics of the length-frequency (LF) distribution of pipi at Ōhiwa Harbour. The LF distributions (in mm) were estimated for all strata in each survey and subsequently summed for the distribution of total LFs. Recruits were defined by a shell length of ≤20 mm and large individuals by a shell length of ≥50 mm.

Year	Mean	Mode	Range	Recruits (%)	Medium (%)	Large (%)
2020–21	39.55	40	9–64	3.91	84.01	12.09
2022–23	37.45	42	8–60	11.49	86.30	2.21
2024–25	22.56	18	9–58	48.84	50.92	0.24

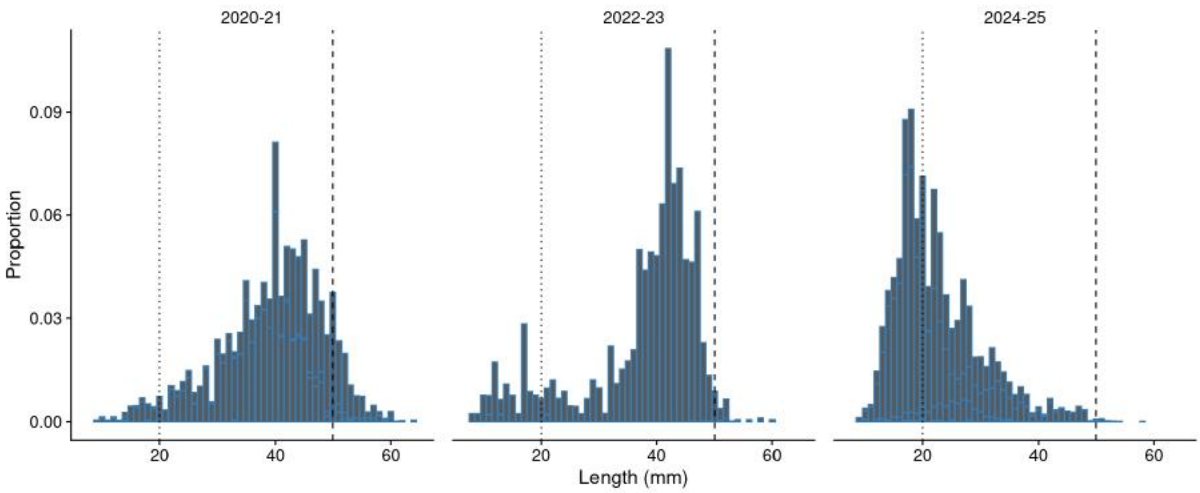

Figure 19: Weighted length-frequency (LF) distribution of pipi for the present and previous surveys at Ōhiwa Harbour. Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively.

3.5 Ōkahu Bay

Ōkahu Bay is in metropolitan Auckland, at the entrance of Waitematā Harbour in Hauraki Gulf. It is a relatively small, sheltered bay, close to Port of Auckland. The bay is of cultural importance to Ngāti Whātua Ōrākei, with considerable efforts towards restoring the bay following severe degradation, including studies of resident bivalve populations (e.g., see Kahui-McConnell 2012, Kainamu & Hikuroa 2012, Freilich 2018). Benthic sampling of the bay has also been conducted by Auckland Council at a limited number of points (Auckland Council 2021, unpubl. data).

The present study represents the first survey of bivalves at this site as part of the northern survey series (see Appendix A, Tables A-1, A-2). The sampling extent covered the intertidal area of the bay, representing relatively homogenous intertidal mudflat habitat, including a seagrass (*Zostera muelleri*) bed. The sampling extent included areas previously surveyed (Kainamu & Hikuroa 2012, Freilich 2018), and also benthic sampling points from Auckland Council (Auckland Council 2021, unpubl. data). The present assessment was based on a single stratum, with a survey effort of 88 points in phase-1 and phase-2 sampling.

Sediment organic content in the samples varied between 1.4 and 4.9 %, and most of the sediment generally consisted of fine sand (grain size >125 µm) and very fine sand (grain size >63 µm) (Figure 20, and see details in Appendix B, Table B-1). The proportion of sediment fines (grain size <63 µm) varied dependent on the sample, with 3.8 to 28.1 % of sediment in this grain size fraction. Five samples contained over 10% of fines.

The field sampling only recorded cockles, and their distribution was localised in the north-eastern corner of the sampling extent (Figure 21, Table 16). The current population estimates were 15.48 million cockles, and 257 cockles per m^2, with a CV value of 30.77% exceeding the target CV of 20% (Table 17). There were few large cockles ($\geq$30 mm shell length) in the bay, and the low number of large cockles sampled led to unreliable estimates (i.e., a CV $>$100%) for this size class.

In addition to the highly-localised distribution of cockles, the population consisted predominantly of recruits ($\leq$15 mm shell length); this size class constituted 81.45% of the current population (Table 18). Most of the remainder of the population (18.42%) consisted of medium-sized individuals. The influence of recruits was also evident in the population size structure, with a single cohort largely formed by these small-sized individuals (Figure 22). Mean and modal sizes were below the 15-mm cut off for this size class, at 12.31 mm and 12 mm shell length, respectively.

Overall, these findings highlighted a significant recruitment event prior to the sampling, augmenting a small population of medium-sized cockles. The patchiness of the cockle population, and the relatively high number of sampling points without cockles explained the variation in the estimates. Future surveys may stratify the sampling extent based on the current information, potentially improving the population estimates by reducing uncertainty (i.e., the CV). Nevertheless, future stratification may not encompass the potentially unpredictable location of recruits.

Previous surveys at this site also sampled cockles, and similar to the present assessment, documented a high proportion of small-sized individuals (i.e., less than 15 mm shell length) (Kainamu & Hikuroa 2012). The previous study was transect-based, and also included a small number of pipi in one of the transects. A subsequent transect survey also recorded small numbers of pipi across the bay (Freilich 2018). A few pipi individuals were also recorded in the benthic sampling by Auckland Council (Auckland Council 2021 unpubl. data). The intertidal mudflat habitat of Ōkahu Bay seems uncharacteristic for pipi (this species generally prefers clean sands and tidal water flow), and it is likely that the previously-recorded individuals failed to become established in the current habitat conditions.

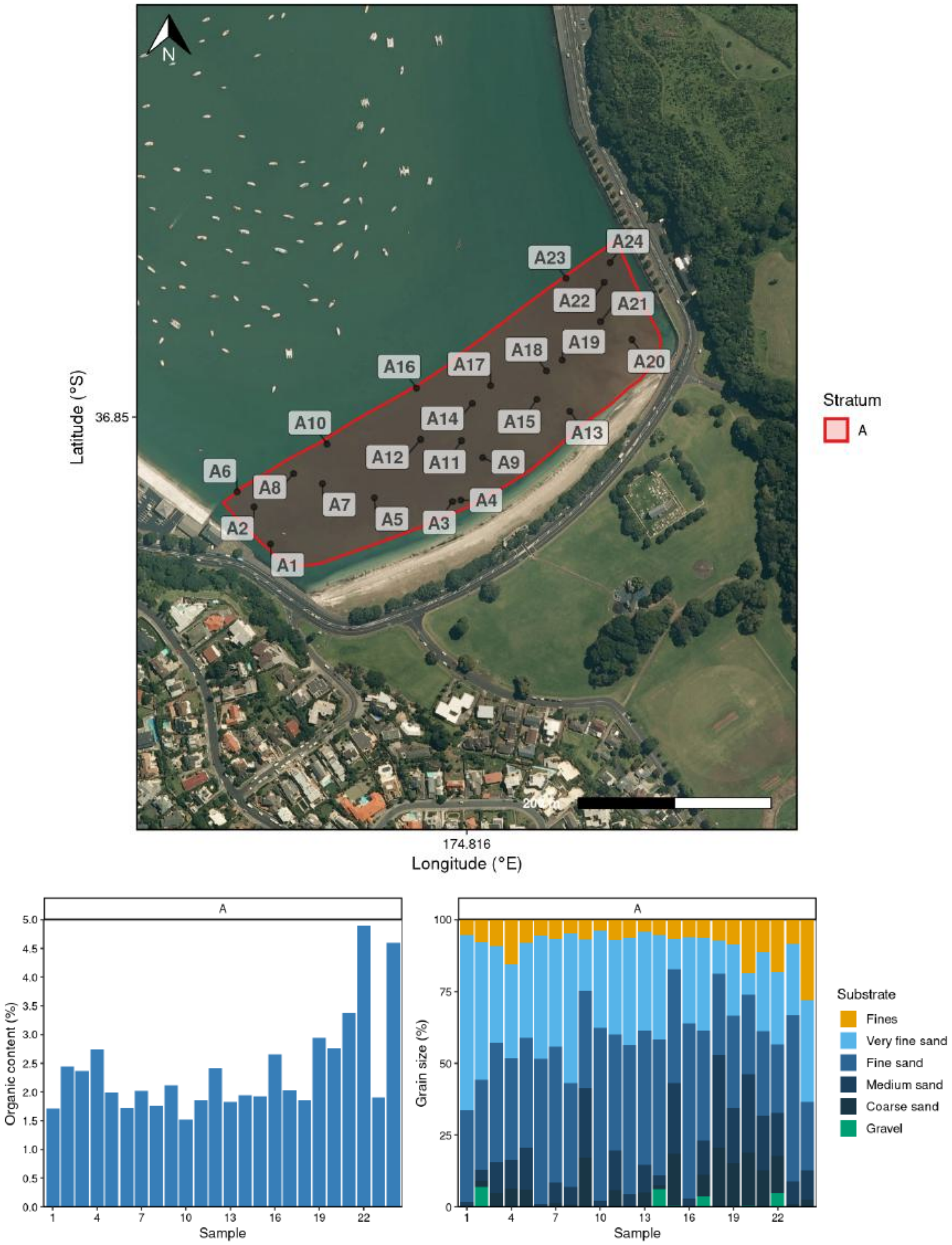

Figure 20: Sediment sample locations and characteristics at Ōkahu Bay. Labels correspond to stratum and sample number. Graphs show organic content (% dry weight) and cumulative grain size (%). Sediment grain size fractions include fines (silt and clay, ≤63 µm), sands (very fine, >63 µm; fine, >125 µm; medium, >250 µm; coarse, >500 µm), and gravel (>2000 µm) (see details in Table B-1).

3.5.1 Cockles at Ōkahu Bay

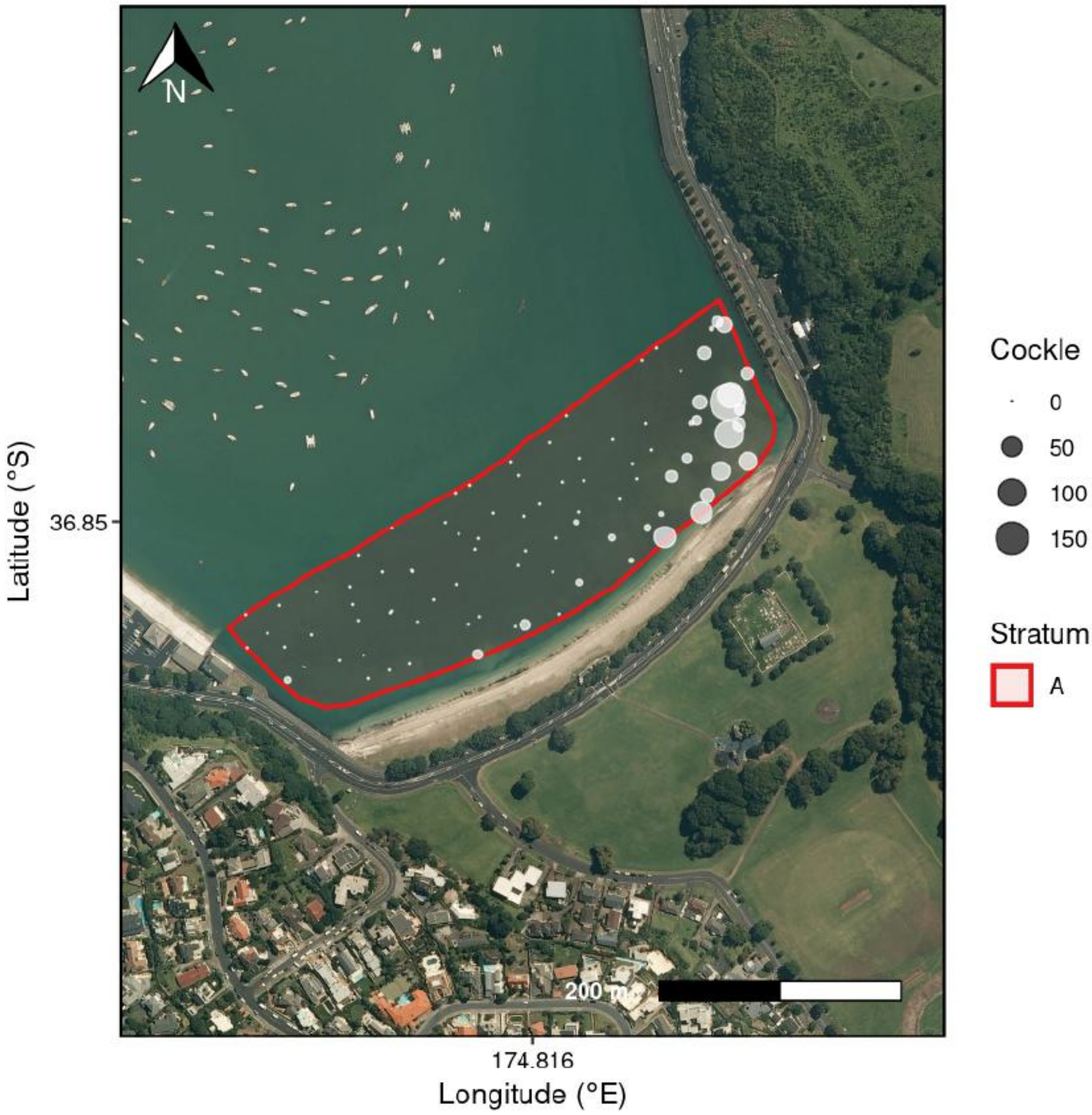

Figure 21: Map of sample strata and individual sample locations for cockles at Ōkahu Bay, with the size of the circles proportional to the number of cockles (per 0.035 m^2) found at each location. Samples with zero counts are shown as small dots.

Table 16: Estimates of cockle abundance at Ōkahu Bay, by stratum, for 2024–25. Presented are the area surveyed, the number of points and the number of cockles sampled, the mean total estimate, the mean density, and the coefficient of variation (CV).

Stratum		Sample		Population estimate		
	Area (ha)	Points	Cockle	Total (millions)	Density (m^{-2})	CV (%)
A	6.0	88	793	15.48	257	30.77

Table 17: Estimates of cockle abundance at Ōkahu Bay for all sizes and large size (≥30 mm) cockles. Columns include the mean total estimate, mean density, and coefficient of variation (CV).

Year	Extent (ha)	Population estimate			Population ≥ 30 mm		
		Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
2024–25	6.0	15.48	257	30.77	0.02	<1	>100

Table 18: Summary statistics of the length-frequency (LF) distribution of cockles at Ōkahu Bay. The LF distributions (in mm) were estimated for all strata in each survey and subsequently summed for the distribution of total LFs. Recruits were defined by a shell length of ≤15 mm and large individuals by a shell length of ≥30 mm.

Year	Mean	Mode	Range	Recruits (%)	Medium (%)	Large (%)
2024–25	12.31	12	5–35	81.45	18.42	0.13

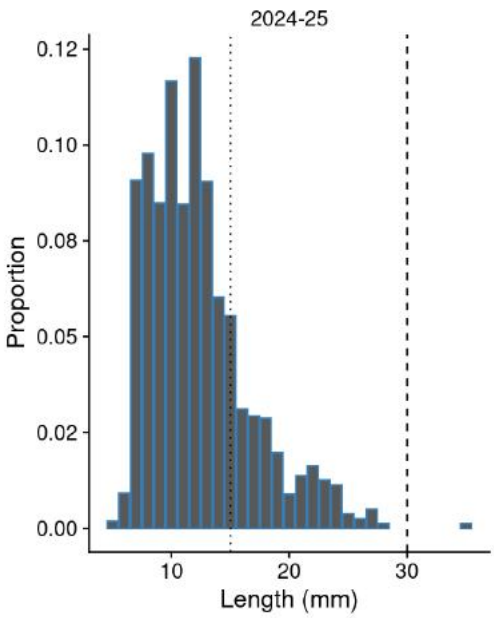

Figure 22: Weighted length-frequency (LF) distribution of cockles for the present survey at Ōkahu Bay. Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively.

3.6 Okoromai Bay

Okoromai Bay is a sheltered bay in Hauraki Gulf, north of Auckland. It was first surveyed in 1999–2000, with a total of 14 assessments since then, including the current survey (see Appendix A, Tables A-1, A-2). The sampling extent has remained consistent throughout the monitoring, extending across the intertidal zone. The assessments only include cockles, because there are no resident pipi beds in the bay. In 2024–25, the cockle survey had a sampling effort of 90 sampling points, divided across three strata.

The sediment sampling documented sediments with a low organic content of less than 3%, with a generally small proportion of sediment fines (≤63 µm) (Figure 23, and see details in Appendix B, Table B-1). Most of the sediment was very fine and fine sands (grain sizes >65 µm and >125 µm).

Cockles were mostly distributed throughout the mid- and low-intertidal zones (Figure 24, Table 19). Their current abundance and density estimates signified increases in the total population size, from 43.62 million (CV: 14.32%) cockles at an estimated mean density of 220 cockles per m^2 in 2022–23 to 55.16 million (CV: 9.47%) cockles and a mean density of 278 cockles per m^2 in 2024–25 (Table 20). The total population included a small number of large cockles (≥30 mm shell length), with an estimated 4.46 million large individuals, occurring at an estimated mean density of 22 cockles per m^2, but the estimates had a relatively high CV of 25.79%.

The cockle population was largely determined by medium-sized cockles and a notable proportion of recruits (≤15 mm shell length); the latter size class contributed 31.35% of individuals to the current population (Table 21). This population size structure was similar in the two preceding surveys, although the current assessment revealed a stronger influx of recruits in 2024–25 than in the two previous surveys. The influx of recruits explained the recent increase in the total population, and also led to a change from a previously distinctly unimodal poulation to a bimodal population size structure in 2024–25 (Figure 25).

Exploring cockle abundances in relation to sediment grain size composition via PCA illustrated higher abundances with finer sand fractions and fines, compared with coarse sand and gravel (Figure 26).

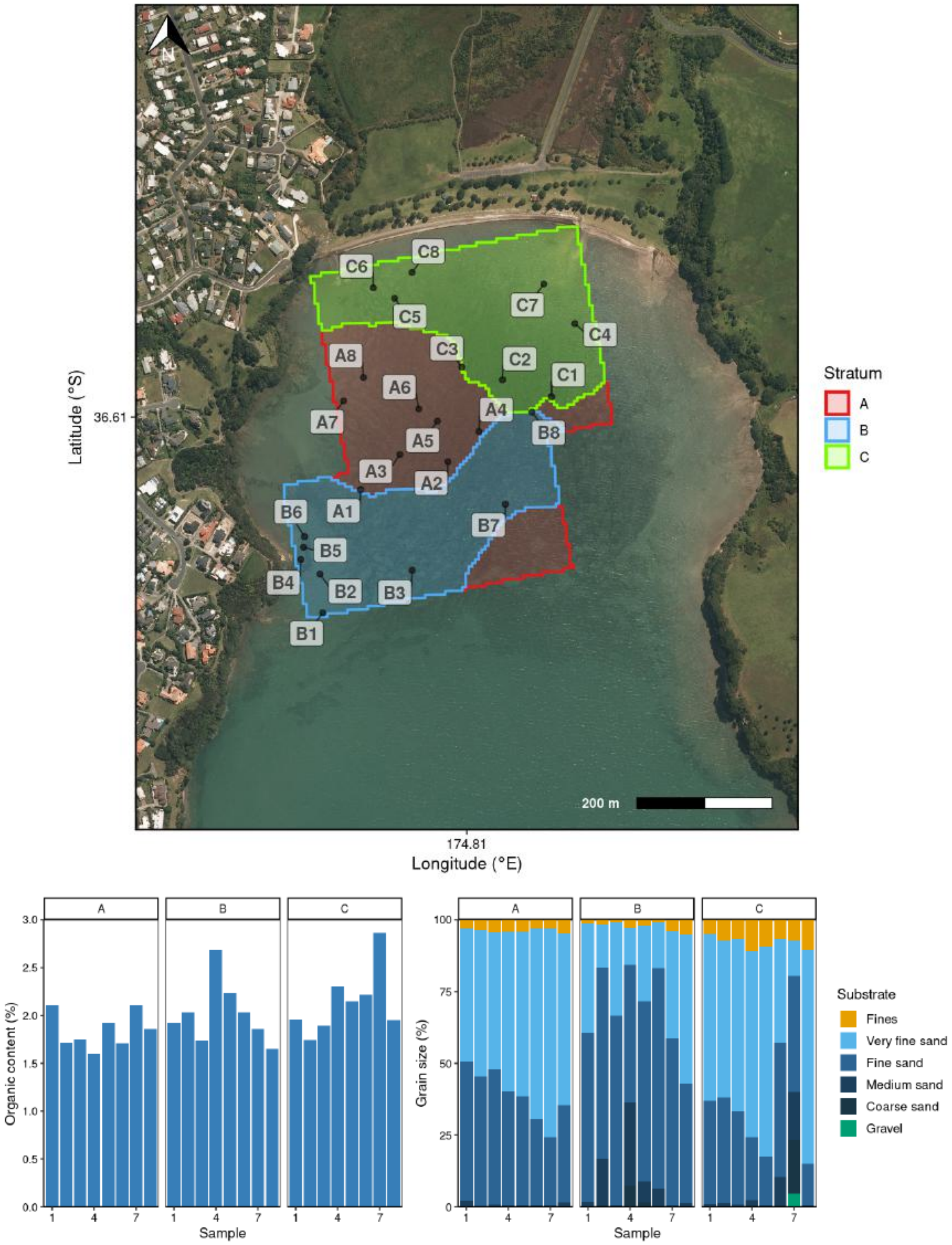

Figure 23: Sediment sample locations and characteristics at Okoromai Bay. Labels correspond to stratum and sample number. Graphs show organic content (% dry weight) and cumulative grain size (%). Sediment grain size fractions include fines (silt and clay, ≤63 µm), sands (very fine, >63 µm; fine, >125 µm; medium, >250 µm; coarse, >500 µm), and gravel (>2000 µm) (see details in Table B-1).

3.6.1 Cockles at Okoromai Bay

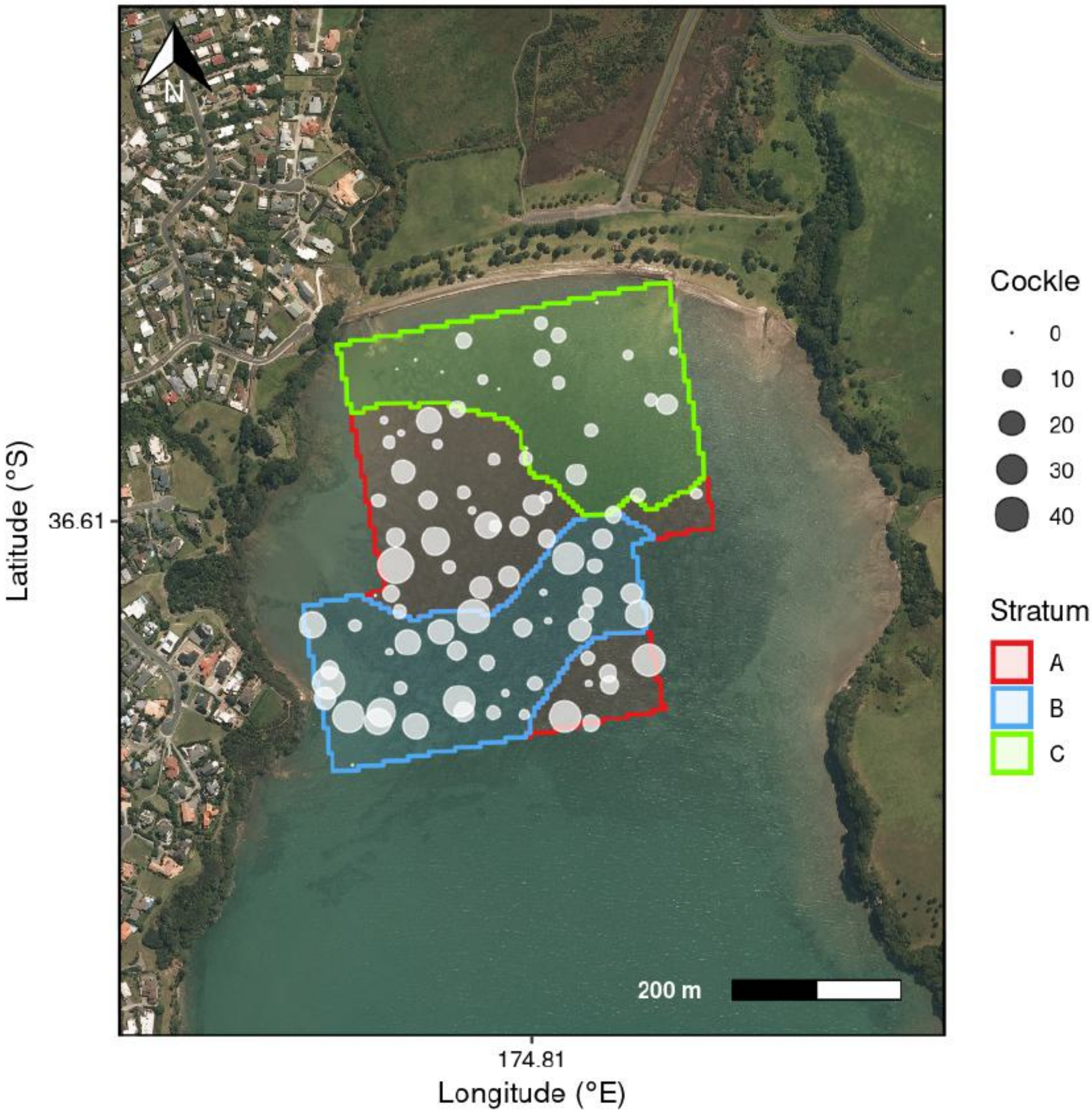

Figure 24: Map of sample strata and individual sample locations for cockles at Okoromai Bay, with the size of the circles proportional to the number of cockles (per 0.035 m^2) found at each location. Samples with zero counts are shown as small dots.

Table 19: Estimates of cockle abundance at Okoromai Bay, by stratum, for 2024–25. Presented are the area surveyed, the number of points and the number of cockles sampled, the mean total estimate, the mean density, and the coefficient of variation (CV).

Stratum		Sample		Population estimate		
	Area (ha)	Points	Cockle	Total (millions)	Density (m^{-2})	CV (%)
A	6.5	35	383	20.44	313	16.60
B	6.5	35	506	26.72	413	13.29
C	6.8	20	82	8.01	117	22.23

Table 20: Estimates of cockle abundance at Okoromai Bay for all sizes and large size (≥30 mm) cockles. Columns include the mean total estimate, mean density, and coefficient of variation (CV).

Year	Extent (ha)	Population estimate			Population ≥ 30 mm		
		Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
1999–00	20.0	90.05	450	4.26	24.38	122	5.30
2001–02	24.0	27.26	114	7.78	8.66	36	8.31
2002–03	20.0	26.86	134	5.10	7.05	35	6.56
2003–04	20.0	27.96	140	11.48	12.01	60	10.62
2004–05	20.0	34.50	172	7.44	13.80	69	4.37
2006–07	20.0	17.39	87	9.08	7.03	35	12.18
2009–10	20.0	29.62	148	9.60	13.07	65	10.84
2012–13	20.0	28.50	142	10.61	13.61	68	11.92
2013–14	19.8	28.14	142	12.69	4.48	23	19.47
2015–16	19.8	34.78	175	19.45	8.48	43	19.44
2017–18	19.8	52.25	263	15.24	4.29	22	19.79
2020–21	19.8	64.37	325	15.53	6.10	31	24.50
2022–23	19.8	43.62	220	14.32	3.52	18	27.08
2024–25	19.8	55.16	278	9.47	4.46	22	25.79

Table 21: Summary statistics of the length-frequency (LF) distribution of cockles at Okoromai Bay. The LF distributions (in mm) were estimated for all strata in each survey and subsequently summed for the distribution of total LFs. Recruits were defined by a shell length of ≤15 mm and large individuals by a shell length of ≥30 mm.

Year	Mean	Mode	Range	Recruits (%)	Medium (%)	Large (%)
2020–21	22.55	24	5–39	12.51	78.02	9.48
2022–23	22.03	25	6–38	14.61	77.32	8.07
2024–25	19.80	27	5–39	31.35	60.57	8.08

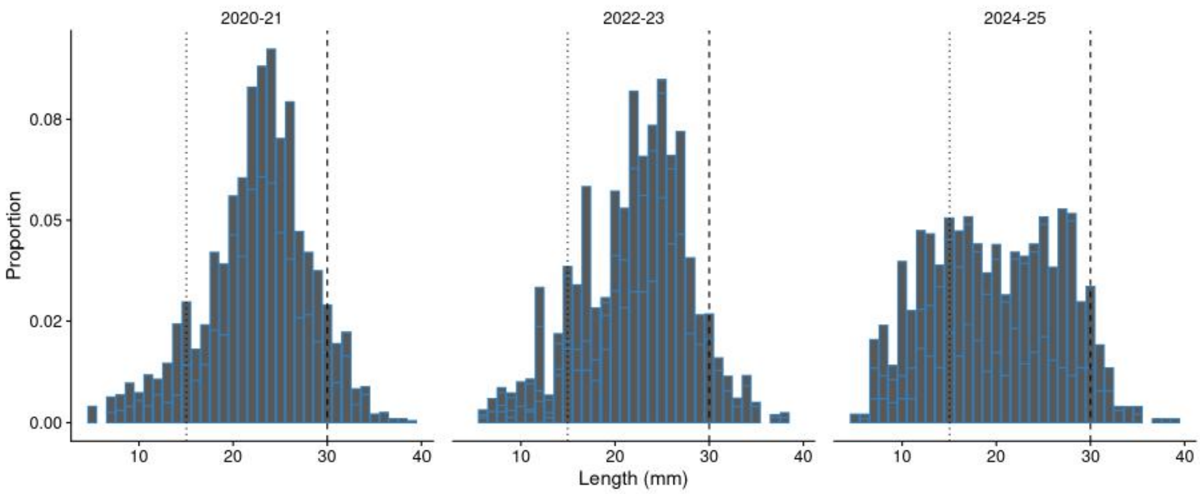

Figure 25: Weighted length-frequency (LF) distribution of cockles for the present and previous surveys at Okoromai Bay. Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively.

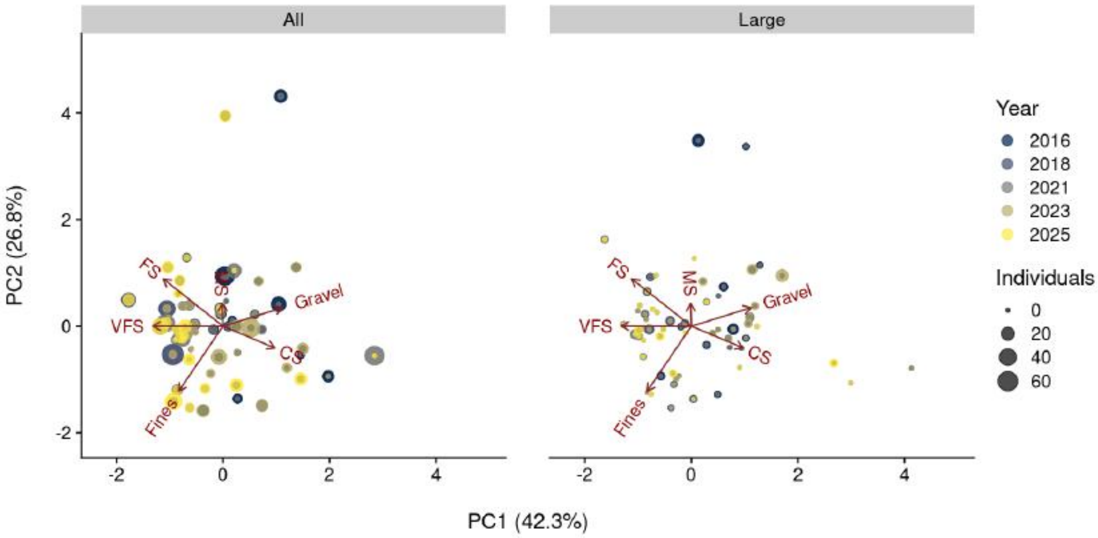

Figure 26: Cockle abundance along two principal components (standardised PCs, including % variance explained) of sediment granulometry for all cockle size classes (all) and large cockles (≥30 mm shell length) at Okoromai Bay. Sediment grain size fractions are defined as fines (silt and clay) ≤63 µm, very fine sand (VFS) >63 µm, fine sand (FS) >125 µm, medium sand (MS) >250 µm, coarse sand (CS) >500 µm, and gravel >2000 µm.

3.7 Otūmoetai (Tauranga Harbour)

Otūmoetai is within Tauranga Harbour, and one of the Bay of Plenty sites. It was first included in the survey series in 2000–01, with 11 regular assessments, including the current survey in 2024–25 (see Appendix A, Tables A-1, A-2). The sampling extent consists of separate cockle and pipi beds, with some changes in the location and spatial extent of the pipi bed leading to some variation in the sampling extent over time. The survey in 2024–25 sampled 87 points across three strata (Table 22).

Sediment in the cockle strata was characterised by a low organic content between 1 and 2%, and most of the sediment consisted of fine sand (grain size >125 µm) (Figure 27, and see details in Appendix B, Table B-1). Other grain size frations had notable smaller proportions, including sediment fines (grain size ≤63 µm), with most samples containing less than 2.0% of sediment fines.

Cockles showed a distinct distribution by being largely restricted to one of the designated cockle strata (stratum A) and throughout most of the pipi bed (stratum C) (Figure 28, Table 22). The current abundance estimate was a total of 17.83 million (CV: 12.15%) cockles, and the density estimate was 398 cockles per m^2 (Table 23). These estimates were similar to values in the preceding 2022–23 survey. Large cockles were generally absent from the population, and population estimates for this size class had high uncertainy, i.e., a CV of over 60%, which was consistently high throughout most of the survey series.

Length-frequency data highlighted the lack of large individuals in a population comprising of recruits (≤15 mm shell length) and medium-sized cockles (Table 24, Figure 29). This population size structure was generally consistent with the size compositions in the two preceding surveys, but there was a marked increase in recruits in 2024–25. This increase led to 48.00% of individuals in this size class, compared with 26.84% in 2022–23. The recent influx of recruits resulted in a second cohort of these small-sized cockles, compared with the single cohort of recruits and medium-sized individuals that characterised the population size structure previously. Both mean and modal sizes remained similar in 2024–25, just above the 15-mm medium size class cut-off, at 15.46 mm and 18 mm shell length, respectively.

The PCA documented comparatively higher total cockle abundance associated with finer sand fractions in recent assessments compared with earlier surveys, when coarse sand and gravel appeared to mostly influence this population measure (Figure 30).

Pipi at Otūmoetai were confined to the pipi bed, with their distribution extending throughout this stratum (Figure 31, Table 25). Total pipi abundance was estimated at 27.31 million (CV: 5.48%) individuals, with their mean density estimated at 609 pipi per m^2 (Table 26). These estimates reflected marked increases in the population size, reversing the declining population trend that was evident from 2016–17 onwards, including particularly low estimates in the preceding survey. For example, the population density in 2022–23 was 263 pipi per m^2.

The pipi population at this site was characterised by a lack of large pipi (≥50 mm shell length), and this size class was scarce throughout the time series. The proportion of recruits (≤20 mm shell length) was also small (2.18%), and this finding was consistent with the two previous surveys (Table 27, Figure 32). Instead of different size classes constituting the population, medium-sized pipi formed a single cohort. The modal shell length in 2024–25 was 42 mm, increasing from 37 mm shell length in 2022–23. These increases in shell length reflected some growth of medium-sized pipi towards larger sizes.

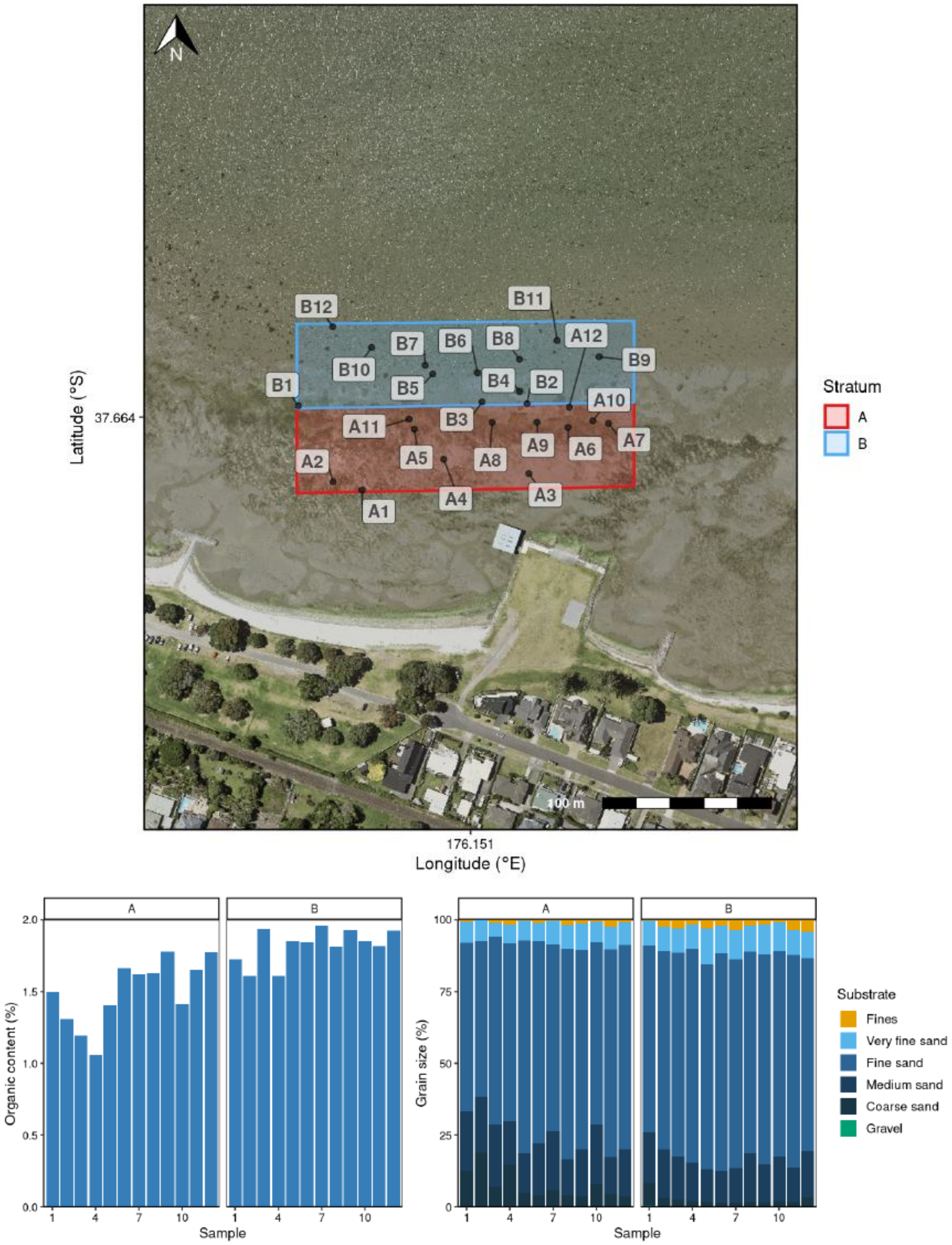

Figure 27: Sediment sample locations and characteristics at Otūmoetai (Tauranga Harbour). Labels correspond to stratum and sample number. Graphs show organic content (% dry weight) and cumulative grain size (%). Sediment grain size fractions include fines (silt and clay, ≤63 µm), sands (very fine, >63 µm; fine, >125 µm; medium, >250 µm; coarse, >500 µm), and gravel (>2000 µm) (see details in Table B-1).

3.7.1 Cockles at Otūmoetai (Tauranga Harbour)

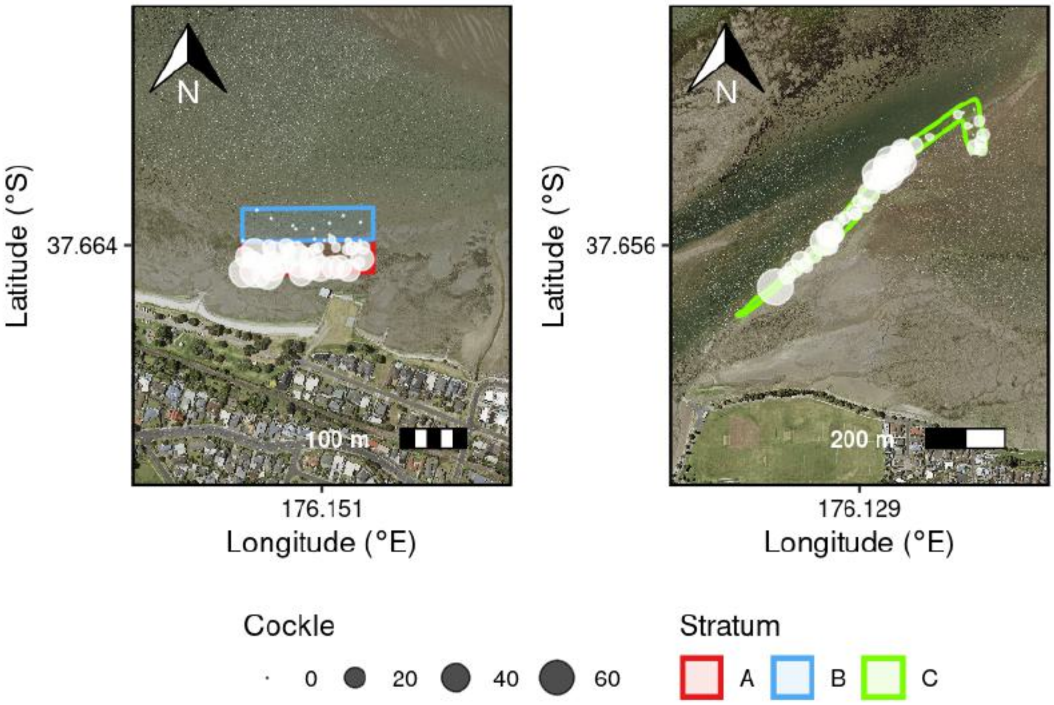

Figure 28: Map of sample strata and individual sample locations for cockles at Otūmoetai (Tauranga Harbour), with the size of the circles proportional to the number of cockles (per 0.035 m^2) found at each location. Samples with zero counts are shown as small dots.

Table 22: Estimates of cockle abundance at Otūmoetai, by stratum, for 2024–25. Presented are the area surveyed, the number of points and the number of cockles sampled, the mean total estimate, the mean density, and the coefficient of variation (CV).

Stratum		Sample		Population estimate		
	Area (ha)	Points	Cockle	Total (millions)	Density (m^{-2})	CV (%)
A	1.0	35	651	5.31	531	14.31
B	1.0	12	2	0.05	5	>100
C	2.5	40	698	12.47	499	16.26

Table 23: Estimates of cockle abundance at Otūmoetai (Tauranga Harbour) for all sizes and large size (≥30 mm) cockles. Columns include the mean total estimate, mean density, and coefficient of variation (CV).

Year	Extent (ha)	Population estimate			Population ≥ 30 mm		
		Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
2000–01	5.6	5.62	100	9.04	0.54	10	12.88
2002–03	5.6	11.25	201	5.71	0.03	<1	35.73
2005–06	4.6	2.21	48	10.27	0.02	<1	79.03
2006–07	4.6	10.67	232	10.13	0.04	<1	54.78
2009–10	5.6	14.73	263	10.85	0.20	4	80.85
2014–15	7.7	37.28	486	7.20	0.02	<1	>100
2016–17	8.1	40.11	496	14.56	0.34	4	>100
2018–19	8.1	21.95	272	10.48	0.01	<1	100
2020–21	6.5	22.43	344	10.78	0.00	0	
2022–23	4.4	15.51	349	12.32	0.01	<1	>100
2024–25	4.5	17.83	398	12.15	0.04	<1	62.88

Table 24: Summary statistics of the length-frequency (LF) distribution of cockles at Otūmoetai. The LF distributions (in mm) were estimated for all strata in each survey and subsequently summed for the distribution of total LFs. Recruits were defined by a shell length of ≤15 mm and large individuals by a shell length of ≥30 mm.

Year	Mean	Mode	Range	Recruits (%)	Medium (%)	Large (%)
2020–21	16.73	17	5–29	38.56	61.44	0.00
2022–23	17.72	17	6–30	26.84	73.11	0.05
2024–25	15.46	18	5–34	48.00	51.75	0.25

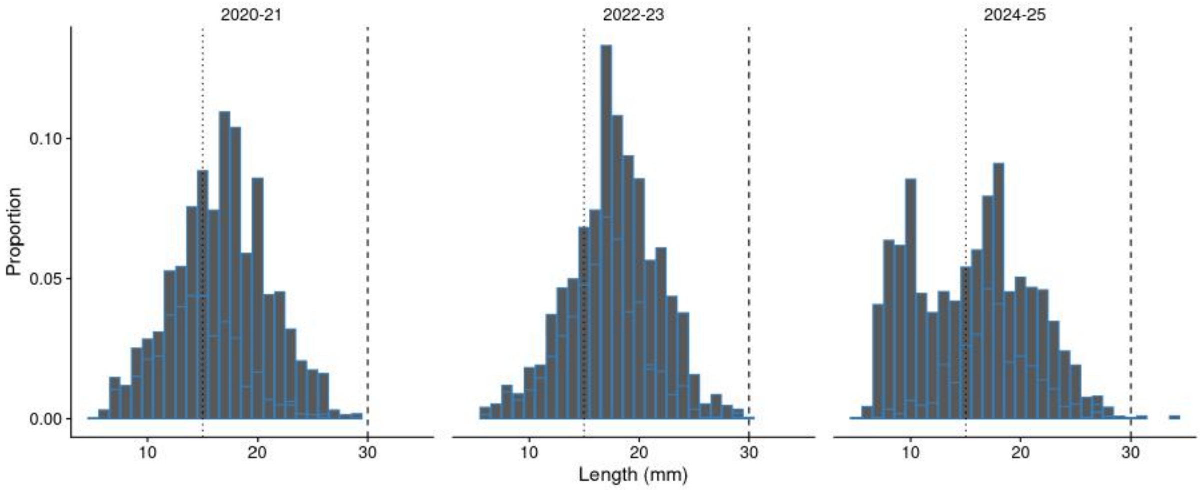

Figure 29: Weighted length-frequency (LF) distribution of cockles for the present and previous surveys at Otūmoetai (Tauranga Harbour). Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively.

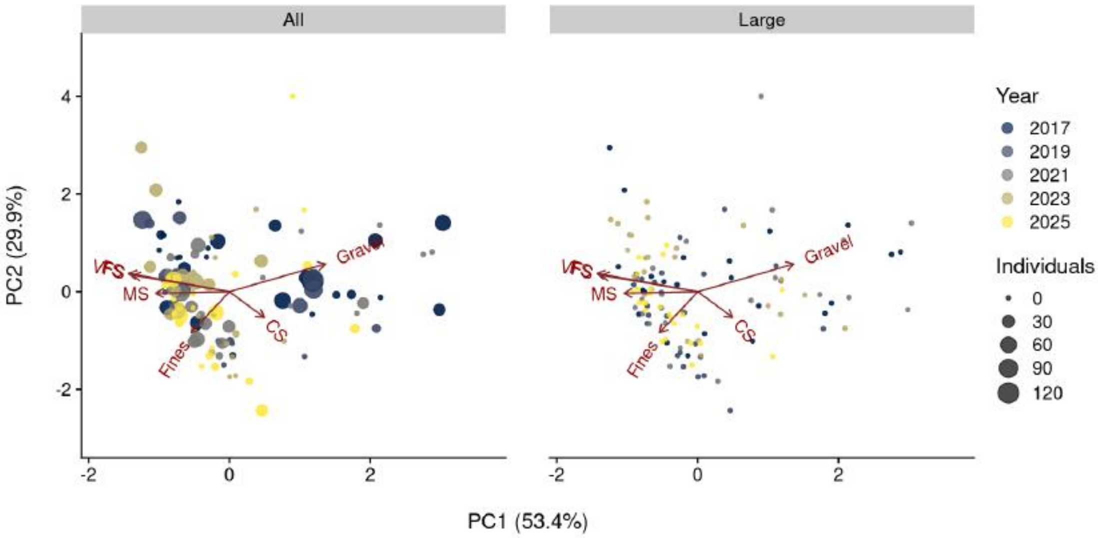

Figure 30: Cockle abundance along two principal components (standardised PCs, including % variance explained) of sediment granulometry for all cockle size classes (all) and large cockles (≥30 mm shell length) at Otūmoetai (Tauranga Harbour). Sediment grain size fractions are defined as fines (silt and clay) ≤63 µm, very fine sand (VFS) >63 µm, fine sand (FS) >125 µm, medium sand (MS) >250 µm, coarse sand (CS) >500 µm, and gravel >2000 µm.

3.7.2 Pipi at Otūmoetai (Tauranga Harbour)

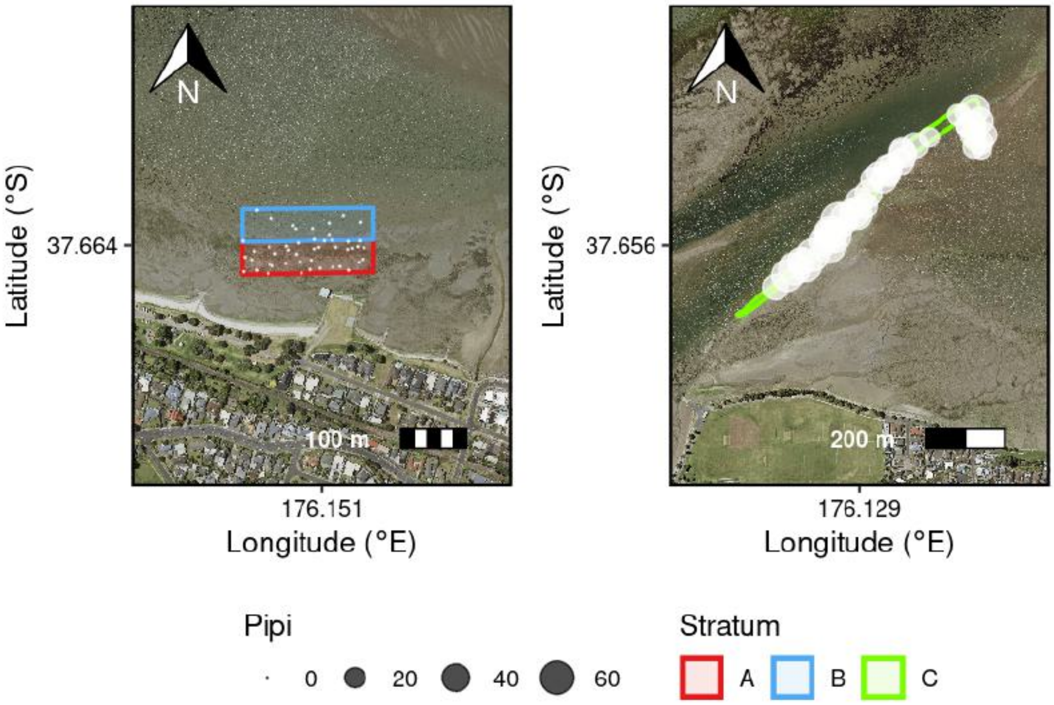

Figure 31: Map of sample strata and individual sample locations for pipi at Otūmoetai (Tauranga Harbour), with the size of the circles proportional to the number of pipi (per 0.035 m^2) found at each location. Samples with zero counts are shown as small dots.

Table 25: Estimates of pipi abundance at Otūmoetai, by stratum, for 2024–25. Presented are the area surveyed, the number of points and the number of pipi sampled, the mean total estimate, the mean density, and the coefficient of variation (CV).

Stratum		Sample		Population estimate		
	Area (ha)	Points	Pipi	Total (millions)	Density (m^{-2})	CV (%)
A	1.0	35	0	0.00	0	
B	1.0	12	0	0.00	0	
C	2.5	40	1 529	27.31	1 092	5.48

Table 26: Estimates of pipi abundance at Otūmoetai (Tauranga Harbour) for all sizes and large size (≥50 mm) pipi. Columns include the mean total estimate, mean density, and coefficient of variation (CV).

Year	Extent (ha)	Population estimate			Population ≥ 50 mm		
		Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
2000–01	5.6	24.76	442	3.30	9.17	164	3.56
2002–03	5.6	20.37	364	3.63	2.06	37	7.56
2005–06	4.6	34.26	745	2.76	1.62	35	7.11
2006–07	4.6	23.63	514	6.61	1.02	22	17.46
2009–10	5.6	17.35	310	7.23	0.63	11	27.44
2014–15	7.7	92.59	1 207	5.59	0.47	6	29.21
2016–17	8.1	71.90	889	11.16	0.13	2	56.94
2018–19	8.1	58.86	731	10.94	0.30	4	40.75
2020–21	6.5	49.01	752	7.34	0.13	2	48.62
2022–23	4.4	11.68	263	11.81	0.11	2	39.84
2024–25	4.5	27.31	609	5.48	0.09	2	51.06

Table 27: Summary statistics of the length-frequency (LF) distribution of pipi at Otūmoetai. The LF distributions (in mm) were estimated for all strata in each survey and subsequently summed for the distribution of total LFs. Recruits were defined by a shell length of ≤20 mm and large individuals by a shell length of ≥50 mm.

Year	Mean	Mode	Range	Recruits (%)	Medium (%)	Large (%)
2020–21	32.71	32	12–53	2.83	96.90	0.27
2022–23	38.81	37	10–52	0.90	98.20	0.90
2024–25	37.83	42	7–53	2.18	97.49	0.33

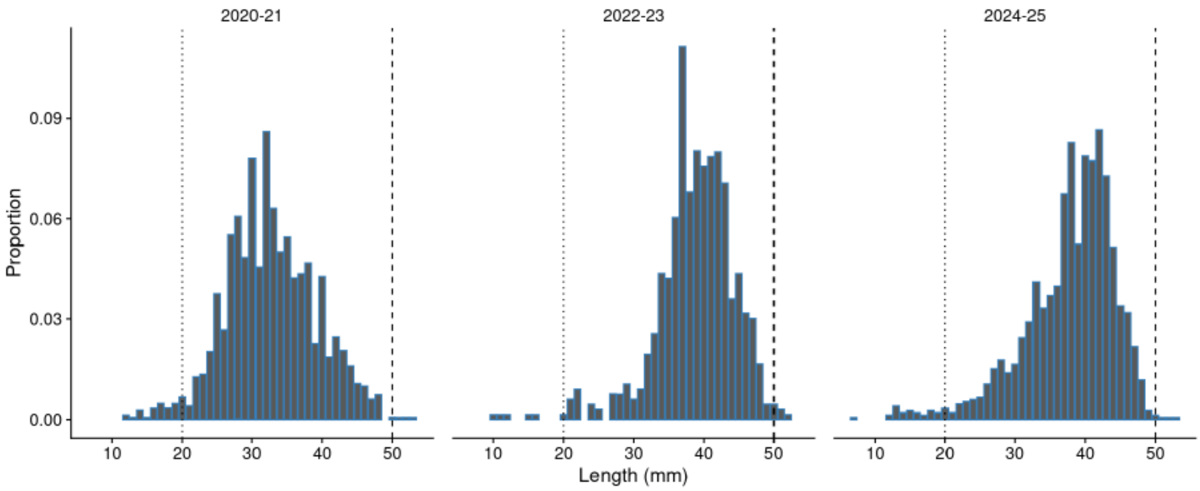

Figure 32: Weighted length-frequency (LF) distribution of pipi for the present and previous surveys at Otūmoetai (Tauranga Harbour). Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively.

3.8 Pataua Estuary

Pataua Estuary is on the east coast of Northland, north of Whangārei. Since 2002–03, the estuary has been part of a total of ten surveys, including the current study (see Appendix A, Tables A-1, A-2). The preceding assessment in 2022–23 was prompted by a reported pipi mass mortality event in July 2022, leading to the inclusion of an additional pipi bed in a sheltered side channel of the lower estuary. Across surveys, the sampling extent has remained similar since 2013–14, covering an extensive intertidal sandflat inhabited by cockles in the upper estuary, and separate pipi beds in the lower estuary area, along the main channel and close to the entrance. The current survey effort covered five strata, with a total of 119 sampling points.

Sediment in the cockle strata had a low organic content (maximum of 2.9%) and mostly consisted of fine sand (grain size >125 μm), with varying proportions of other sediment grain size fractions (Figure 33, and see details in Appendix B, Table B-1). The proportion of sediment fines (grain size ≤63 μm) was less than 5.7% across all samples. Similarly, the proportion of gravel (grain size >2000 μm) was generally low, but exceeded 10% in three of the samples.

Within the estuary, cockles were distributed across the intertidal sandflat, with the main channel dividing strata A and B (Figure 34, Table 28). The current population estimates were similar to the preceding abundance and density estimates, at 292.13 million (CV: 14.29%) cockles and 1031 cockles per m^2, respectively (Table 29). The population supported a small number of large cockles (≥30 mm shell length), but their population estimates had high uncertainty (CV: 45.25%); there were an estimated 5.52 million individuals in this size class, at an average density of 19 large cockles per m^2. This size class made up a small part of the total population throughout the survey series.

In constrast to the small proportion of large individuals, recruits (≤15 mm shell length) made up between a quarter and a third of all individuals in recent surveys (i.e., 23.84% in 2024–25) (Table 30, Figure 35). This consistent recruitment regularly augmented the strong cohort of medium-sized cockles that characterised the population size structure. Recent growth (i.e., since 2022–23) within this latter size class led to an increase in mean and modal sizes. For example, modal shell length increased from 18 mm to 20 mm in 2024–25, leading to a change from the previously unimodal to a bimodal population of recruits and medium-sized individuals.

There were no discernible patterns between cockle abundances and sediment grain size fractions evident in the PCA (Figure 36).

Pipi in the estuary were evenly distributed throughout the pipi strata, associated with the main channel (strata C and D) and with a side channel close to the entrance (stratum E) (Figure 37, Table 31). For 2024–25, the total pipi population was estimated at 16.93 million (CV: 11.47%) individuals, occurring at an average density of 60 pipi per m^2 (Table 32). These estimates reflected a substantial increase in the pipi population; when compared across surveys with a similar-sized sampling extent, the estimates signified the largest population since 2013–14. At the same time, large pipi (≥50 mm shell length) were scarce, following a decline from the previous estimate, although this size class was consistently small with few individuals throughout the survey series (frequently with estimates that had high uncertainty, i.e., CV values exceeding 20%).

The recent decrease in large pipi diminished their proportion within the total population to 0.80%, compared with 18.43% in 2022–23 (Table 33, Figure 38). In contrast, the proportion of recruits (≤20 mm shell length) more than doubled over the same period, from 11.83% in 2022–23 to 25.58% in 2024–25. The increase in recruits was also evident in the marked reduction in mean and modal sizes; for example, the modal shell length declined from 47 mm in 2022–23 to 25 mm shell length in 2024–25. Although the population continued to have a bimodal structure, the influence of this recent recruitment (and likely strong recruitment in the preceding year) led to a shift towards smaller sizes in the population overall, particularly within the medium size class.

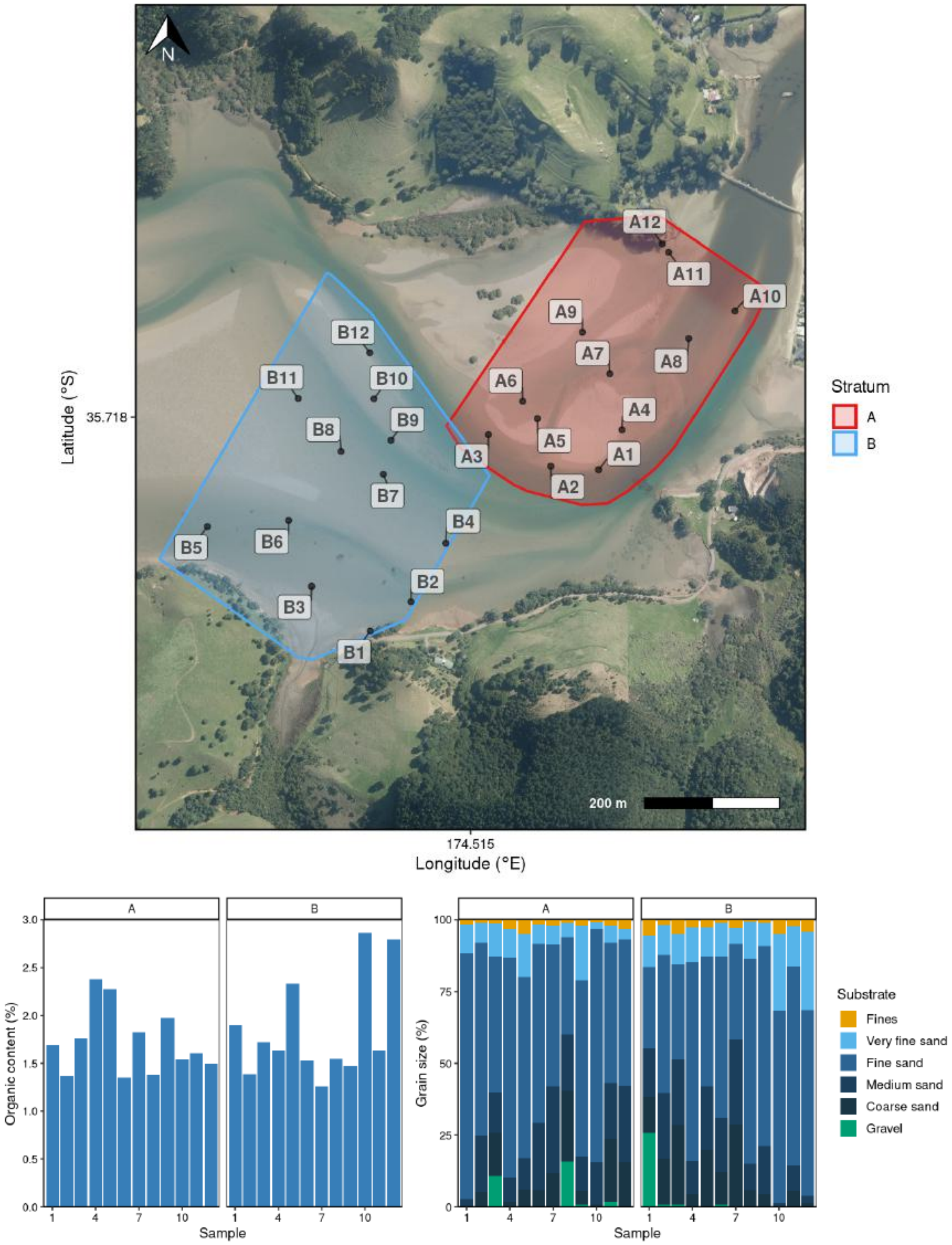

Figure 33: Sediment sample locations and characteristics at Pataua Estuary. Labels correspond to stratum and sample number. Graphs show organic content (% dry weight) and cumulative grain size (%). Sediment grain size fractions include fines (silt and clay, ≤63 µm), sands (very fine, >63 µm; fine, >125 µm; medium, >250 µm; coarse, >500 µm), and gravel (>2000 µm) (see details in Table B-1).

3.8.1 Cockles at Pataua Estuary

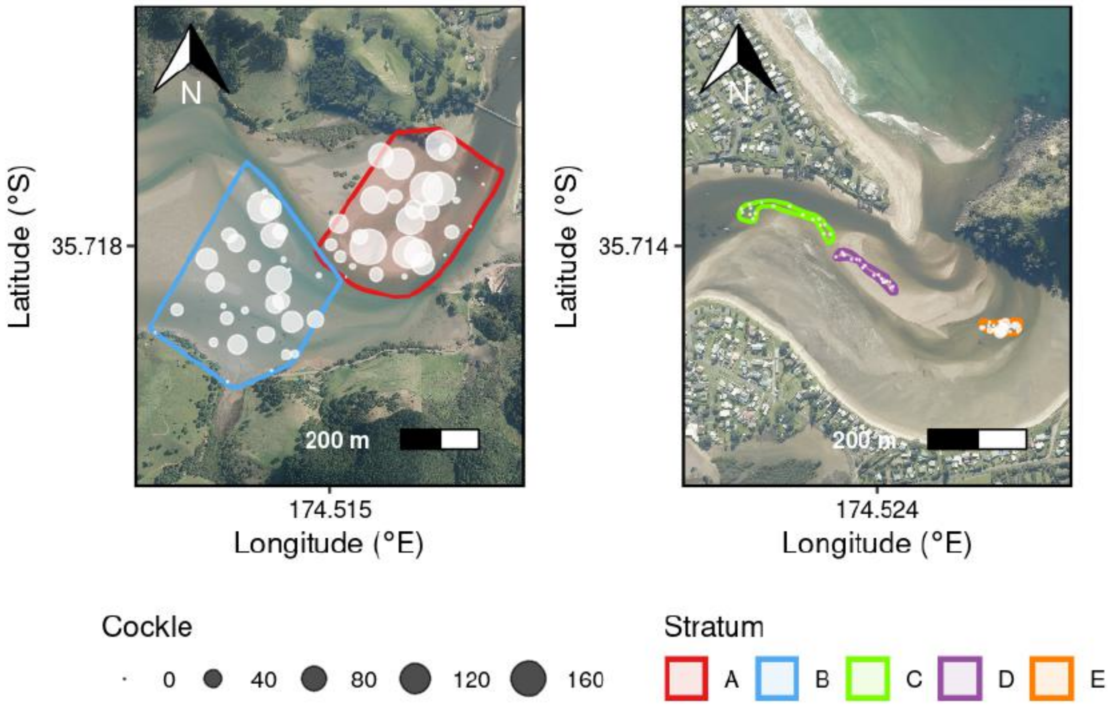

Figure 34: Map of sample strata and individual sample locations for cockles at Pataua Estuary, with the size of the circles proportional to the number of cockles (per 0.035 m^2) found at each location. Samples with zero counts are shown as small dots.

Table 28: Estimates of cockle abundance at Pataua Estuary, by stratum, for 2024–25. Presented are the area surveyed, the number of points and the number of cockles sampled, the mean total estimate, the mean density, and the coefficient of variation (CV).

Stratum		Sample		Population estimate		
	Area (ha)	Points	Cockle	Total (millions)	Density (m^{-2})	CV (%)
A	12.3	30	1 503	175.65	1 431	19.74
B	15.3	30	797	116.37	759	19.96
C	0.3	17	0	0.00	0	
D	0.2	17	0	0.00	0	
E	0.2	25	45	0.10	51	39.41

Table 29: Estimates of cockle abundance at Pataua Estuary for all sizes and large size (≥30 mm) cockles. Columns include the mean total estimate, mean density, and coefficient of variation (CV).

Year	Extent (ha)	Population estimate			Population ≥ 30 mm		
		Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
2002–03	10.7	88.64	832	4.45	21.63	203	6.94
2003–04	10.4	123.54	1 182	3.02	13.56	130	8.90
2005–06	10.4	108.08	1 034	5.18	19.87	190	7.57
2013–14	26.3	410.54	1 561	5.30	6.54	25	15.94
2015–16	27.8	380.13	1 368	7.58	4.89	18	29.68
2017–18	27.7	406.39	1 467	11.78	4.54	16	44.37
2019–20	27.9	362.52	1 299	12.71	3.96	14	44.65
2021–22	27.9	356.31	1 278	12.83	2.25	8	50.01
2022–23	28.2	303.16	1 076	11.48	3.44	12	42.79
2024–25	28.3	292.13	1 031	14.29	5.52	19	45.25

Table 30: Summary statistics of the length-frequency (LF) distribution of cockles at Pataua Estuary. The LF distributions (in mm) were estimated for all strata in each survey and subsequently summed for the distribution of total LFs. Recruits were defined by a shell length of ≤15 mm and large individuals by a shell length of ≥30 mm.

Year	Mean	Mode	Range	Recruits (%)	Medium (%)	Large (%)
2021–22	18.07	17	5–38	31.59	67.77	0.63
2022–23	18.85	18	5–36	25.60	73.27	1.13
2024–25	19.13	20	5–35	23.84	74.27	1.89

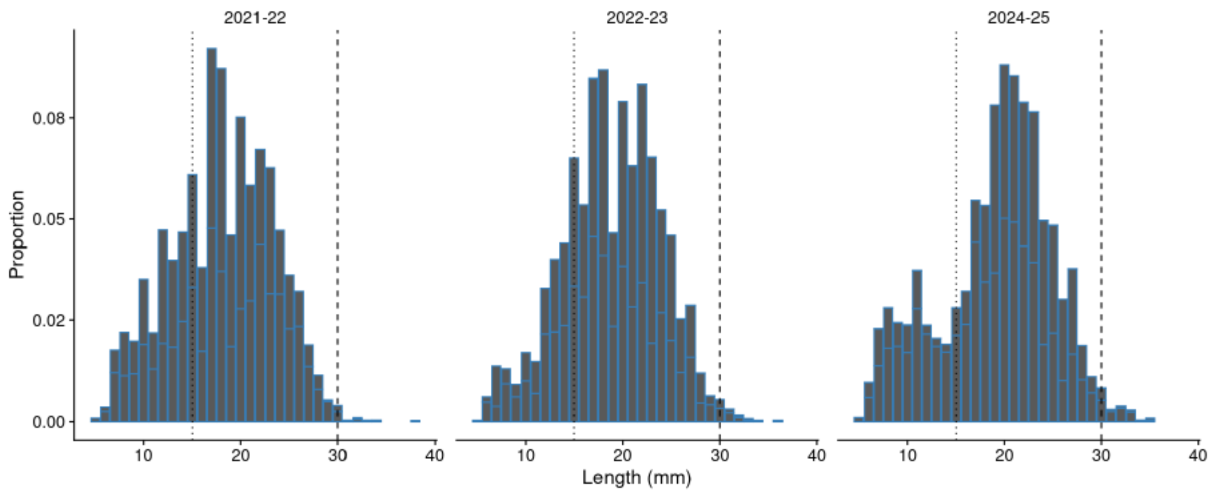

Figure 35: Weighted length-frequency (LF) distribution of cockles for the present and previous surveys at Pataua Estuary. Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively.

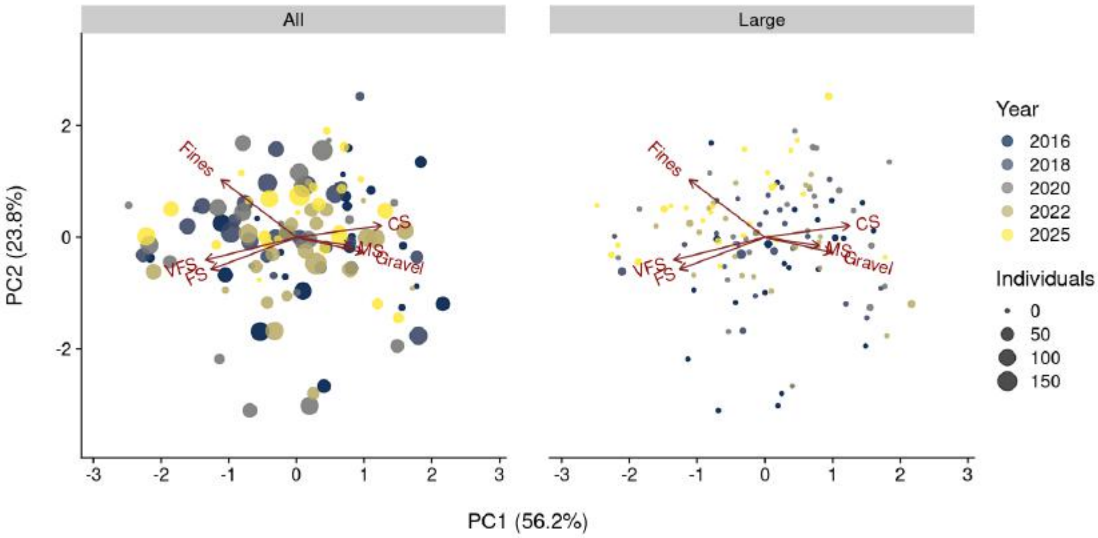

Figure 36: Cockle abundance along two principal components (standardised PCs, including % variance explained) of sediment granulometry for all cockle size classes (all) and large cockles (≥30 mm shell length) at Pataua Estuary. Sediment grain size fractions are defined as fines (silt and clay) ≤63 µm, very fine sand (VFS) >63 µm, fine sand (FS) >125 µm, medium sand (MS) >250 µm, coarse sand (CS) >500 µm, and gravel >2000 µm.

3.8.2 Pipi at Pataua Estuary

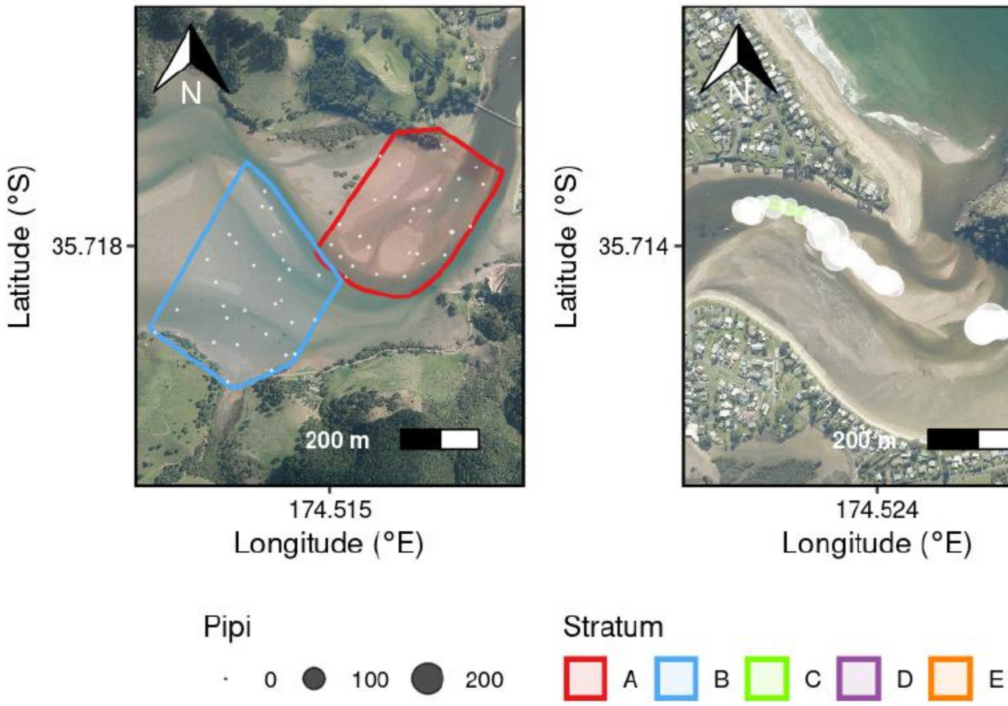

Figure 37: Map of sample strata and individual sample locations for pipi at Pataua Estuary, with the size of the circles proportional to the number of pipi (per 0.035 m^2) found at each location. Samples with zero counts are shown as small dots.

Table 31: Estimates of pipi abundance at Pataua Estuary, by stratum, for 2024–25. Presented are the area surveyed, the number of points and the number of pipi sampled, the mean total estimate, the mean density, and the coefficient of variation (CV).

Stratum		Sample		Population estimate		
	Area (ha)	Points	Pipi	Total (millions)	Density (m^{-2})	CV (%)
A	12.3	30	1	0.12	<1	>100
B	15.3	30	0	0.00	0	
C	0.3	17	1 320	7.39	2218	21.26
D	0.2	17	1 507	5.22	2533	11.81
E	0.2	25	1 818	4.21	2078	22.71

Table 32: Estimates of pipi abundance at Pataua Estuary for all sizes and large size (≥50 mm) pipi. Columns include the mean total estimate, mean density, and coefficient of variation (CV).

Year	Extent (ha)	Population estimate			Population ≥ 50 mm		
		Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
2002–03	10.7	16.58	156	14.00	0.02	<1	>100
2003–04	10.4	2.21	21	11.72	0.43	4	7.94
2005–06	10.4	1.18	11	9.73	0.45	4	32.47
2013–14	26.3	7.52	29	17.28	0.47	2	60.35
2015–16	27.8	6.45	23	14.67	0.19	<1	79.86
2017–18	27.7	2.04	7	35.38	0.19	<1	>100
2019–20	27.9	9.45	34	18.50	0.05	<1	52.35
2021–22	27.9	3.53	13	23.14	0.23	<1	35.33
2022–23	28.2	2.57	9	19.64	0.47	2	22.03
2024–25	28.3	16.93	60	11.47	0.13	<1	25.08

Table 33: Summary statistics of the length-frequency (LF) distribution of pipi at Pataua Estuary. The LF distributions (in mm) were estimated for all strata in each survey and subsequently summed for the distribution of total LFs. Recruits were defined by a shell length of ≤20 mm and large individuals by a shell length of ≥50 mm.

Year	Mean	Mode	Range	Recruits (%)	Medium (%)	Large (%)
2021–22	33.20	37	8–58	24.56	68.99	6.44
2022–23	39.37	47	9–58	11.83	69.74	18.43
2024–25	25.82	25	6–58	25.58	73.63	0.80

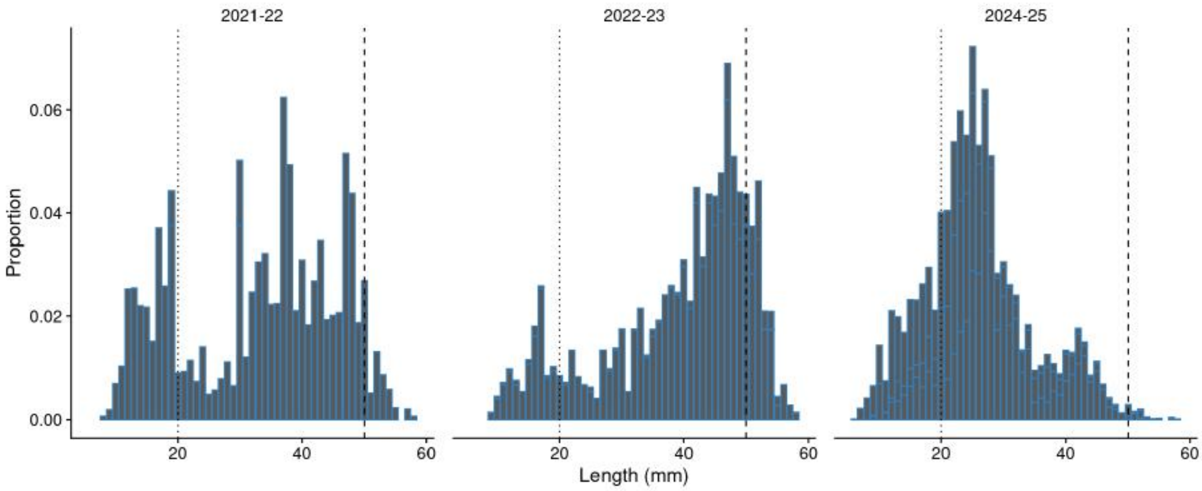

Figure 38: Weighted length-frequency (LF) distribution of pipi for the present and previous surveys at Pataua Estuary. Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively.

3.9 Waiotahe Estuary

Waiotahe Estuary is in eastern Bay of Plenty. Bivalves at this site have been surveyed since 2002–03, in a total of ten surveys, including the immediately preceding assessment in 2022–23 (see Appendix A, Tables A-1, A-2). The sampling extent at this site has been consistent since 2013–14, centred on the lower estuary including the pipi bed in the main channel. In 2024–25, the sampling extent was divided into four strata, and bivalves were sampled in a total of 140 points.

Sediment sampling across the cockle strata revealed a low organic content of less than 3.1%, with the bulk of the sediment consisting of fine sand (grain size >125 µm)(Figure 39, and see details in Appendix B, Table B-1). There were varying proportions of medium sand (grain size >250 µm), and also of sediment fines (grain size ≤63 µm). The latter grain size fraction exceeded 10% in nine of the samples.

The distribution of cockles was relatively even throughout the intertidal sandflat in the southern part of the upper estuary, mainly strata A and B (Figure 40, Table 34). The current population estimates documented recent increases in cockle abundance from 11.69 million (CV: 15.91%) cockles in 2022–23 to 17.42 million (CV: 11.18%) cockles in the present study (Table 35). There was a concomitant increase in cockle density, from 98 to 148 cockles per m^2 in 2024–25. There were no large cockles (≥30 mm shell length) within the population, and this size class was generally absent throughout most of the survey series.

There were similar proportions of recruits (≤15 mm shell length) and of medium-sized cockles in the present population, with 50.82% of individuals in the former size class (Table 36). This size structure was similar in the two preceding surveys, when recruits made up over 45% of the population. In 2022–23, their contribution exceeded 60%, resulting in a decrease in mean and modal sizes; however, both size measures increased in 2024–25, with the current modal length of 18 mm exceeding the 15-mm size class cut-off. The strong influence of recruits, and the lack of medium-sized individuals growing to larger sizes were evident in the length-frequency distributions, with the two most recent surveys consisting of a single cohort around the recruits size class threshold (Figure 41).

Exploring the relationship between total cockle abundance and sediment composition, the PCA indicated a closer association of cockles with fine to coarse grain size fractions, compared with sediment fines and gravel (Figure 42).

Pipi occurred throughout stratum C and in part of stratum D, mostly in the main estuary channel (Figure 43, Table 37). There were an estimated 95.89 million (CV: 17.99%) pipi in 2024–25, and the population density was estimated at 816 pipi per m^2 (Table 38). Following significant and continued declines in previous surveys (i.e., since 2016–17), the present population estimates documented a notable increase in the pipi population. In comparison, the smallest population size in the survey series was in the preceding survey in 2022–23, with an estimated total of 27.90 million (CV: 25.01%) pipi and an estimated 233 pipi per m^2. The current population did not contain any large pipi (≥50 mm shell length).

In contrast, recruits (≤20 mm shell length) made up about a quarter (26.55%) of the current population, following their increase from 17.80% in 2022–23 (Table 39). Nevertheless, medium-sized pipi continued to dominate the population, and their influence on the population size structure was reflected in mean and modal sizes of 26.75 mm and 28 mm shell length (Table 39, Figure 44). The single cohort of pipi was structured around this modal size, with recruits contributing small-sized individuals to this cohort.

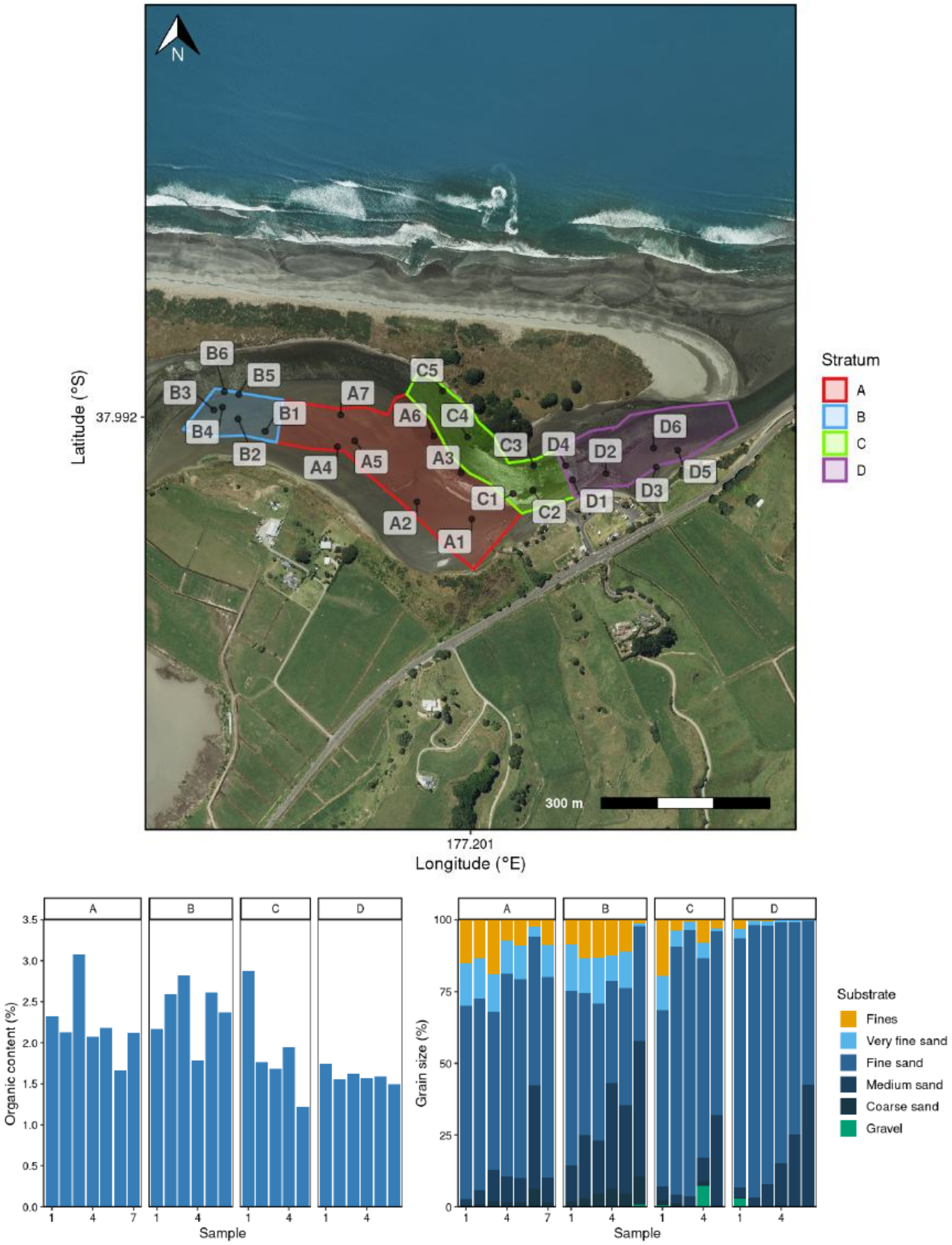

Figure 39: Sediment sample locations and characteristics at Waiotahe Estuary. Labels correspond to stratum and sample number. Graphs show organic content (% dry weight) and cumulative grain size (%). Sediment grain size fractions include fines (silt and clay, ≤63 µm), sands (very fine, >63 µm; fine, >125 µm; medium, >250 µm; coarse, >500 µm), and gravel (>2000 µm) (see details in Table B-1).

3.9.1 Cockles at Waiotahe Estuary

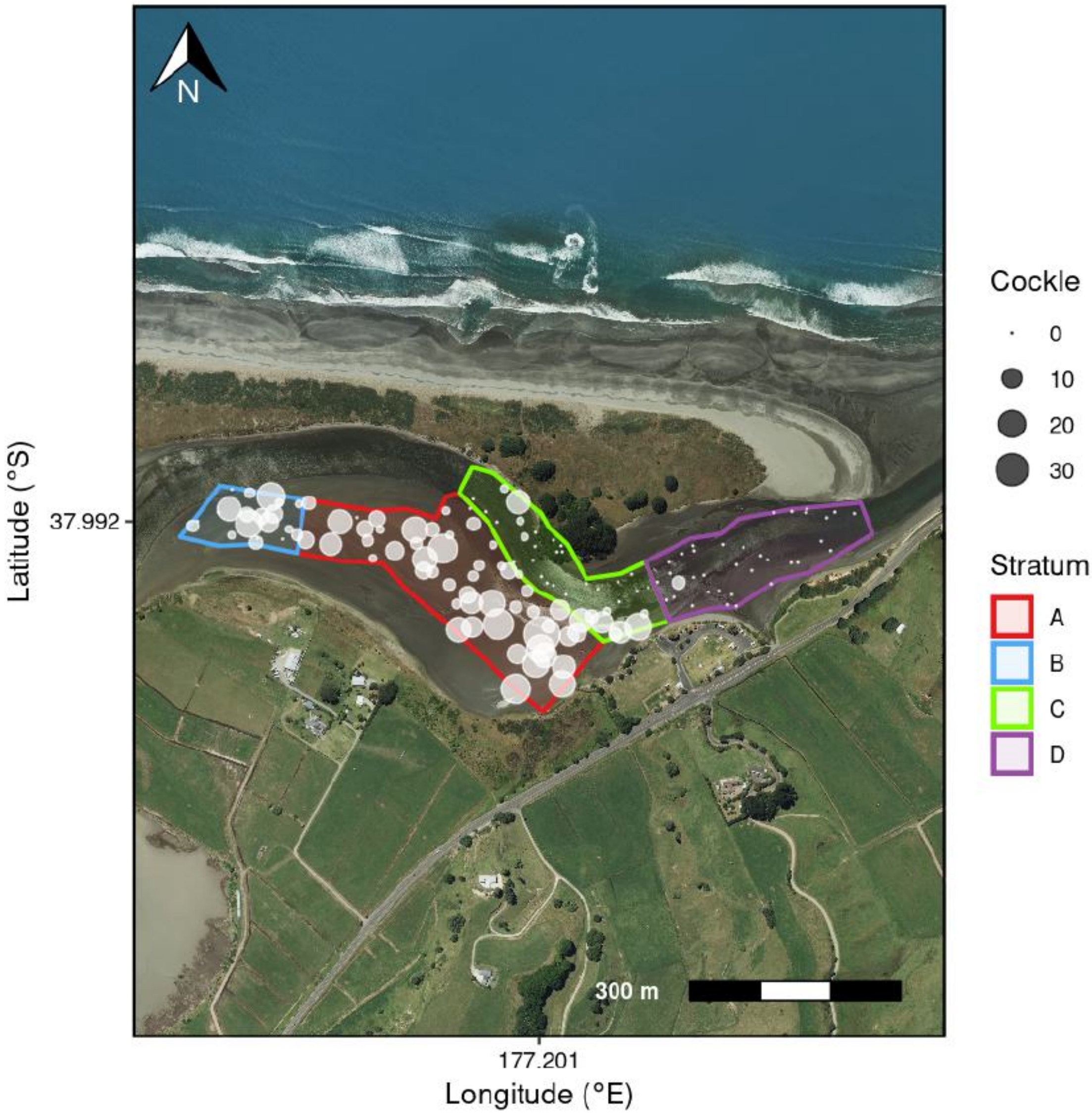

Figure 40: Map of sample strata and individual sample locations for cockles at Waiotahe Estuary, with the size of the circles proportional to the number of cockles (per 0.035 m^2) found at each location. Samples with zero counts are shown as small dots.

Table 34: Estimates of cockle abundance at Waiotahe Estuary, by stratum, for 2024–25. Presented are the area surveyed, the number of points and the number of cockles sampled, the mean total estimate, the mean density, and the coefficient of variation (CV).

Stratum		Sample		Population estimate		
	Area (ha)	Points	Cockle	Total (millions)	Density (m^{-2})	CV (%)
A	5.3	50	459	13.86	262	12.77
B	1.1	20	103	1.69	147	29.32
C	2.5	35	89	1.78	73	35.59
D	2.9	35	4	0.09	3	>100

Table 35: Estimates of cockle abundance at Waiotahe Estuary for all sizes and large size (≥30 mm) cockles. Columns include the mean total estimate, mean density, and coefficient of variation (CV).

Year	Extent (ha)	Population estimate			Population ≥ 30 mm		
		Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
2002–03	8.5	36.67	431	8.08	0.52	6	16.42
2003–04	8.5	5.77	68	9.16	0.09	1	34.2
2004–05	9.5	1.13	12	12.12	0.04	<1	>100
2005–06	9.5	5.88	62	10.53	0.09	<1	52.32
2009–10	9.5	20.17	212	15.50	0.06	<1	70.81
2013–14	11.2	47.37	422	10.10	0.00	0	
2016–17	12.0	48.61	406	16.66	0.12	1	80.6
2019–20	12.0	13.51	113	12.26	0.07	<1	69.67
2022–23	12.0	11.69	98	15.91	0.00	0	
2024–25	11.8	17.42	148	11.18	0.00	0	

Table 36: Summary statistics of the length-frequency (LF) distribution of cockles at Waiotahe Estuary. The LF distributions (in mm) were estimated for all strata in each survey and subsequently summed for the distribution of total LFs. Recruits were defined by a shell length of ≤15 mm and large individuals by a shell length of ≥30 mm.

Year	Mean	Mode	Range	Recruits (%)	Medium (%)	Large (%)
2019–20	16.57	22	6–31	45.39	54.07	0.54
2022–23	14.85	12	6–29	60.74	39.26	0.00
2024–25	15.41	18	6–29	50.82	49.18	0.00

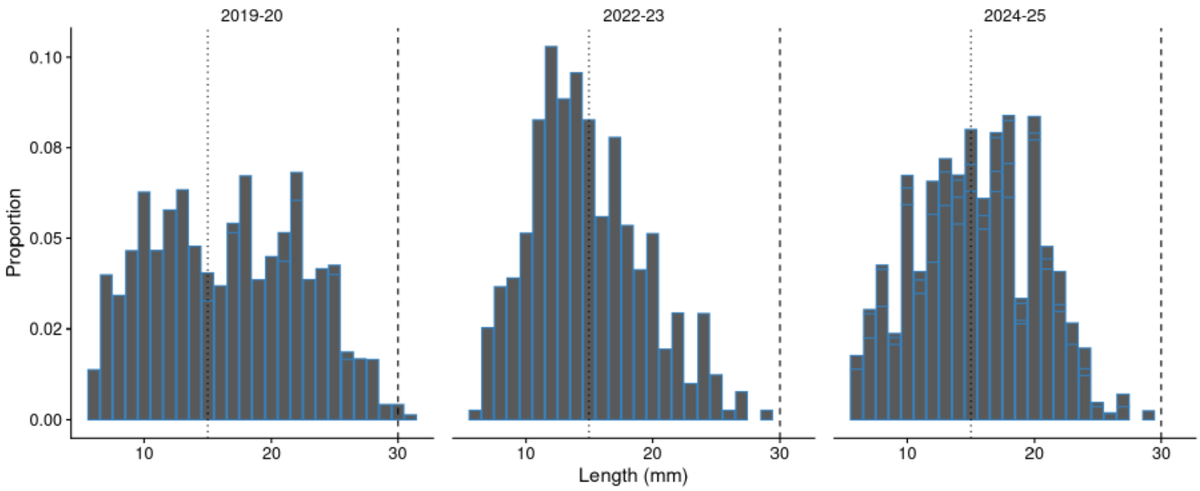

Figure 41: Weighted length-frequency (LF) distribution of cockles for the present and previous surveys at Waiotahe Estuary. Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively.

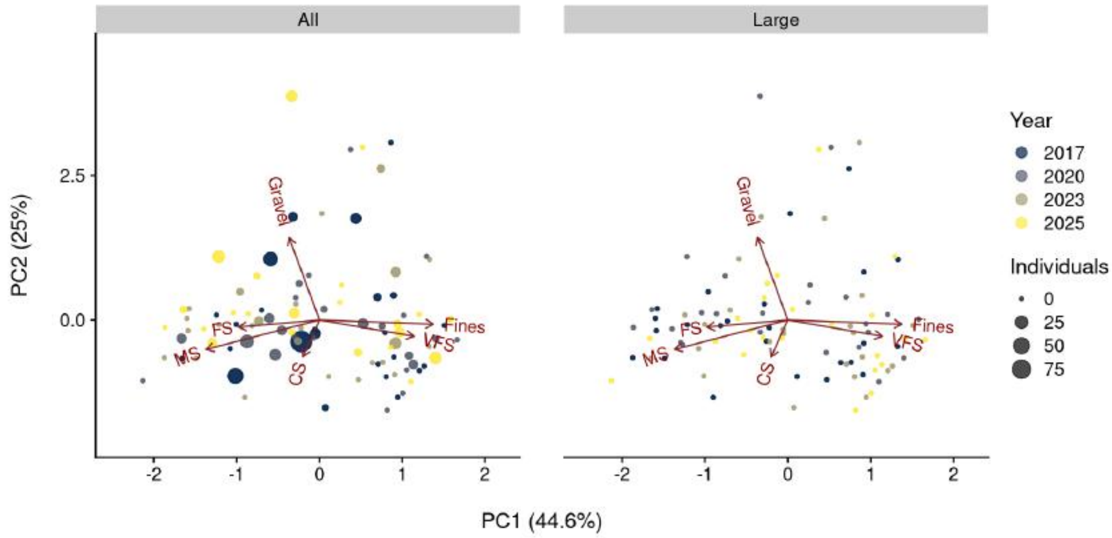

Figure 42: Cockle abundance along two principal components (standardised PCs, including % variance explained) of sediment granulometry for all cockle size classes (all) and large cockles (≥30 mm shell length) at Waiotahe Estuary. Sediment grain size fractions are defined as fines (silt and clay) ≤63 µm, very fine sand (VFS) >63 µm, fine sand (FS) >125 µm, medium sand (MS) >250 µm, coarse sand (CS) >500 µm, and gravel >2000 µm.

3.9.2 Pipi at Waiotahe Estuary

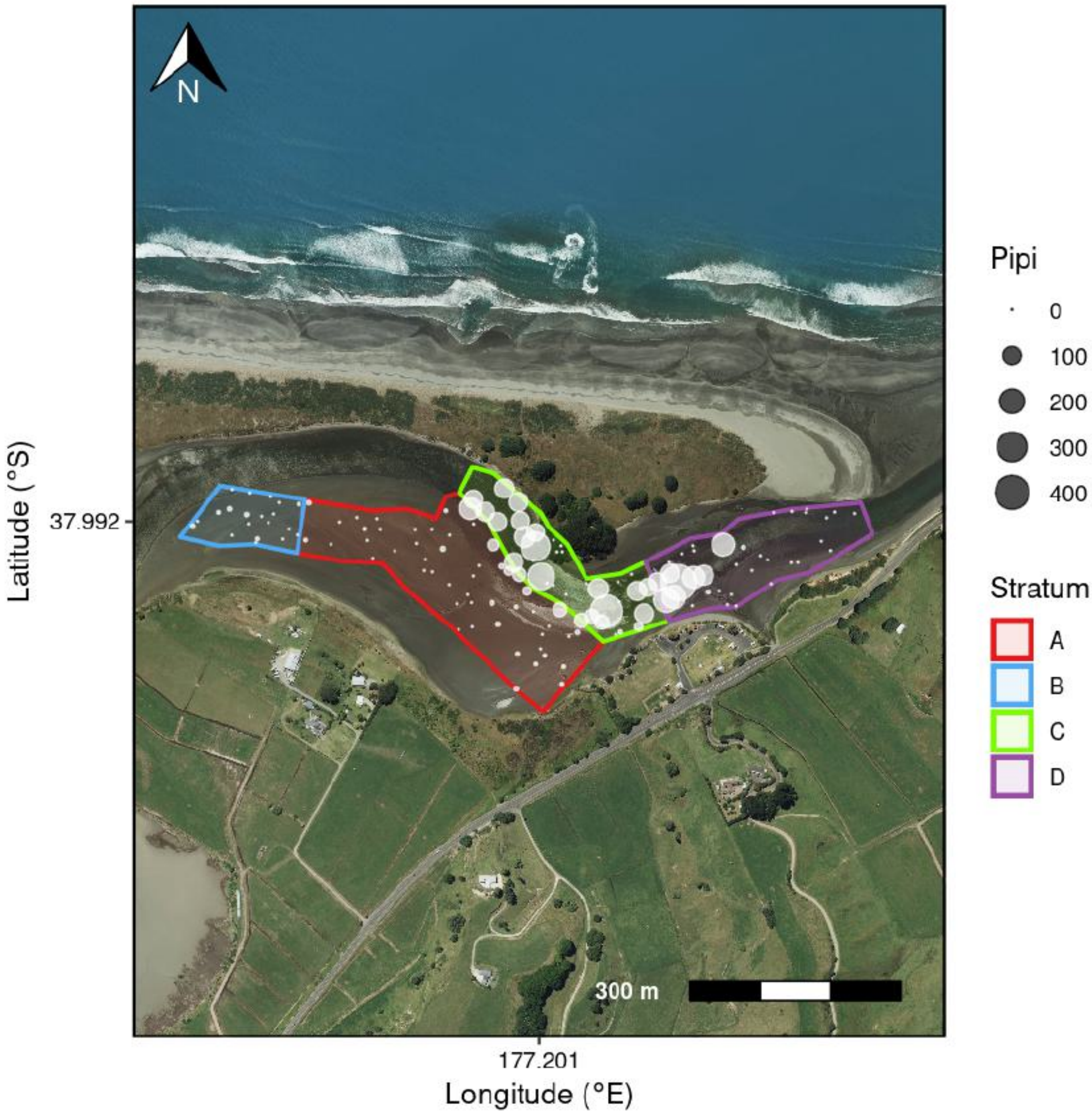

Figure 43: Map of sample strata and individual sample locations for pipi at Waiotahe Estuary, with the size of the circles proportional to the number of pipi (per 0.035 m^2) found at each location. Samples with zero counts are shown as small dots.

Table 37: Estimates of pipi abundance at Waiotahe Estuary, by stratum, for 2024–25. Presented are the area surveyed, the number of points and the number of pipi sampled, the mean total estimate, the mean density, and the coefficient of variation (CV).

Stratum		Sample		Population estimate		
	Area (ha)	Points	Pipi	Total (millions)	Density (m^{-2})	CV (%)
A	5.3	50	309	9.33	177	53.03
B	1.1	20	9	0.15	13	37.72
C	2.5	35	2 573	51.56	2 100	19.75
D	2.9	35	1 488	34.85	1 215	37.34

Table 38: Estimates of pipi abundance at Waiotahe Estuary for all sizes and large size (≥50 mm) pipi. Columns include the mean total estimate, mean density, and coefficient of variation (CV).

Year	Extent (ha)	Population estimate			Population ≥ 50 mm		
		Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
2002–03	8.5	183.91	2 164	5.14	1.46	17	15.83
2003–04	8.5	47.91	564	5.70	0.20	2	19.63
2004–05	9.5	41.41	436	5.00	0.81	9	12.1
2005–06	9.5	40.61	427	9.30	1.24	13	19.83
2009–10	9.5	96.71	1 018	12.48	3.56	38	23.71
2013–14	11.2	150.21	1 338	12.57	0.09	<1	65.16
2016–17	12.0	166.25	1 388	18.36	1.05	9	43.81
2019–20	12.0	80.45	672	17.15	0.69	6	55.33
2022–23	12.0	27.90	233	25.01	0.07	<1	>100
2024–25	11.8	95.89	816	17.99	0.00	0	

Table 39: Summary statistics of the length-frequency (LF) distribution of pipi at Waiotahe Estuary. The LF distributions (in mm) were estimated for all strata in each survey and subsequently summed for the distribution of total LFs. Recruits were defined by a shell length of ≤20 mm and large individuals by a shell length of ≥50 mm.

Year	Mean	Mode	Range	Recruits (%)	Medium (%)	Large (%)
2019–20	31.15	34	9–59	14.86	84.27	0.86
2022–23	26.08	24	8–54	17.80	81.93	0.27
2024–25	26.75	28	7–48	26.55	73.45	0.00

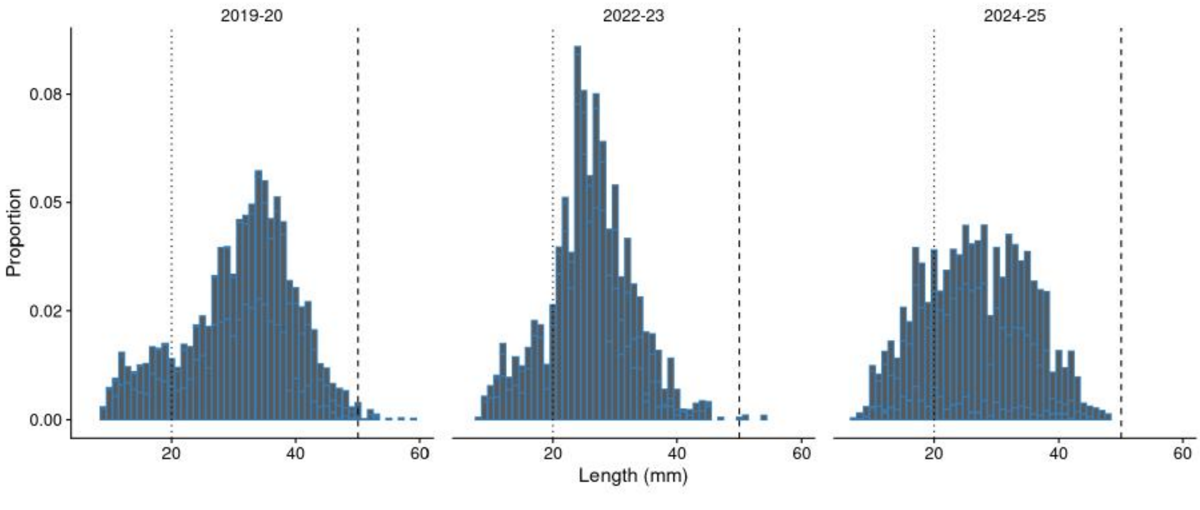

Figure 44: Weighted length-frequency (LF) distribution of pipi for the present and previous surveys at Waiotahe Estuary. Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively.

3.10 Whangapoua Harbour

Whangapoua Harbour is on north-eastern Coromandel Peninsula, in the Waikato region. The harbour is extensive and the sampling covers two different areas within it, at Matarangi and at Whangapoua. The harbour was first included in the northern surveys in 2002–03, with most recent previous survey in 2022–23 (see Appendix A, Tables A-1, A-2). Bivalves are surveyed in two disjunct strata in each of the two separate areas, including one pipi bed close to the harbour entrance. Across the four strata, the 2024–25 survey effort consisted of 140 points.

In the three cockle strata, the sediment was consistently low in organic matter, with a maximum organic content of 3.0% (Figure 45, and see details in Appendix B, Table B-1). The sediment grain size composition was largely determined by varying proportions of fine and medium sands (grain sizes >125 µm and >250 µm). The proportion of sediment fines (≤63 µm) was consistently low, ranging from none to 3.0% of sediment in this size fraction.

Cockles were abundant in the three cockle strata (A to C), with only few individuals in the pipi bed (Figure 46, Table 40). Their total abundance estimate was 46.07 million (CV: 9.33%) cockles, reflecting an increase from the preceding survey 2022–23. Cockle densities showed a similar increase, with an estimated mean density of 868 individuals per m^2 in 2024–25 (Table 41). Both recent estimates were similar to estimates in 2020–21, and these population fluctuations were also evident across earlier surveys. The current population included a small number of large cockles (≥30 mm shell length), with abundance and density estimates of 1.34 million (CV: 15.08%) large cockles and 25 large individuals per m^2, respectively.

This size class only made a small contribution (2.91%) to the population overall, which was determined by a strong cohort of medium-sized cockles and a small proportion (12.31%) of recruits (≤15 mm shell length) (Table 42, Figure 47). This population size structure was stable across the three most recent surveys, characterised by a unimodal population with consistent mean and modal sizes between 20 and 25 mm shell length.

The PCA analysis showed a general pattern of total cockle abundances associated with fine grain size fractions, particularly fine sand and very fine sands (Figure 48).

The pipi population was exclusively in the pipi bed, stratum D, close to the harbour entrance (Figure 49, Table 43). The current population consisted of a total of 20.33 million (CV: 9.94%) pipi, and their average density was 383 pipi per m^2 (Table 44). Both pipi abundance and density were the highest estimates in the survey series, and the increases were particularly notable compared with low estimates in the preceding survey in 2022–23. There were few large pipi (≥50 mm shell length) in the population, and the current estimates for this size class were similar to the 2022–23 estimates, although with a higher CV; there were 0.32 million large pipi and 6 large pipi per m^2 in 2024–25, but the CV associated with these estimates was 30.40%.

The overall increase in the pipi population was accompanied by a decrease in the proportion of large pipi, whereas recruits (≤20 mm shell length) remained similar to their proportion in the preceding survey at 6.50% (Table 45, Figure 50). In contrast, the medium pipi size class showed a notable increase from 72.44% in 2022–23 to 91.92% in 2024–25. At the same time, the single cohort of mostly medium-sized pipi underwent a considerable shift towards smaller sizes between the two most recent surveys, with modal length decreasing from 47 mm to 33 mm shell length in 2024–25. This change in the population size composition indicates that the marked increase in the pipi population was related to significant recruitment, followed by the growth of recruits into the medium size class between the two most recent surveys. There was also a concomitant loss of medium-size pipi at shell lengths close to the upper end of this size class.

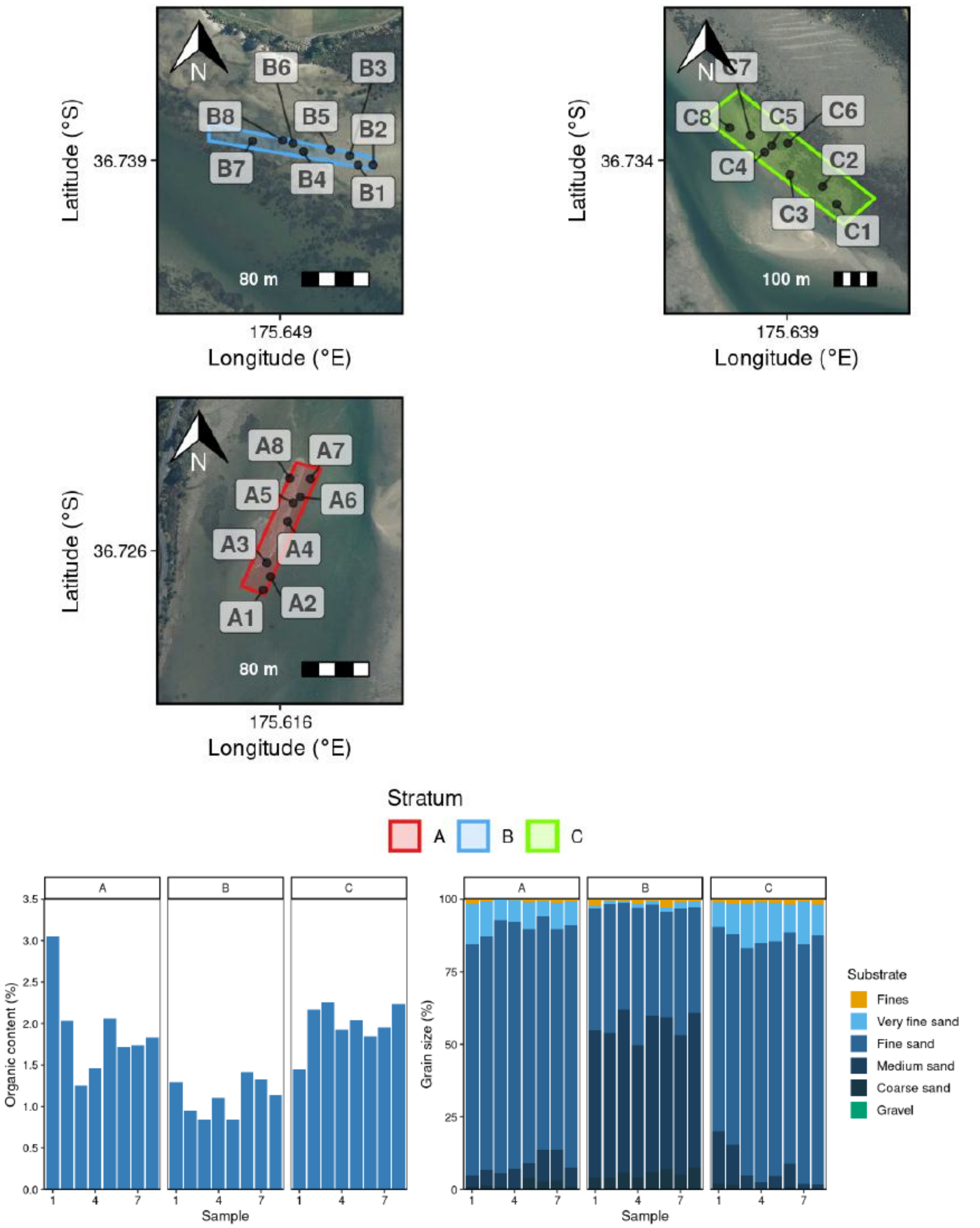

Figure 45: Sediment sample locations and characteristics at Whangapoua Harbour. Labels correspond to stratum and sample number. Graphs show organic content (% dry weight) and cumulative grain size (%). Sediment grain size fractions include fines (silt and clay, ≤63 µm), sands (very fine, >63 µm; fine, >125 µm; medium, >250 µm; coarse, >500 µm), and gravel (>2000 µm) (see details in Table B-1).

3.10.1 Cockles at Whangapoua Harbour

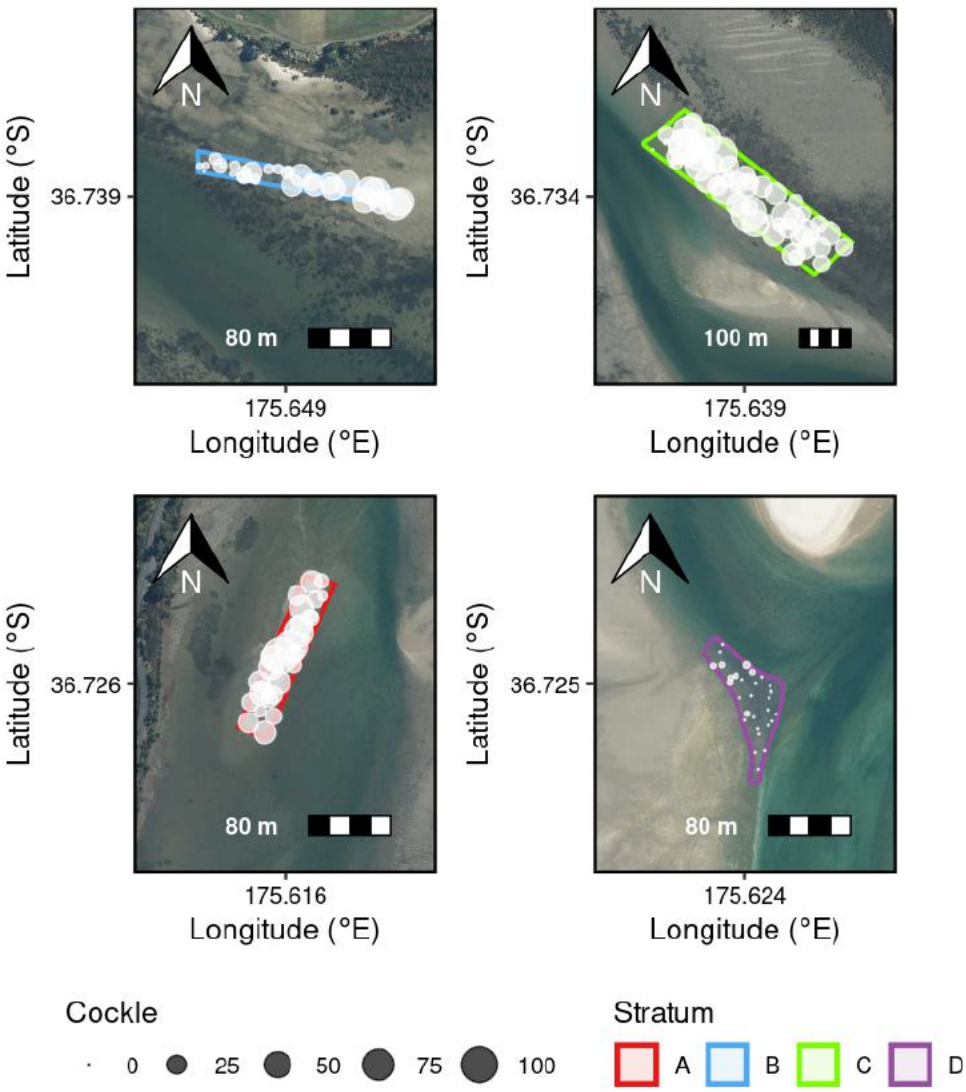

Figure 46: Map of sample strata and individual sample locations for cockles at Whangapoua Harbour, with the size of the circles proportional to the number of cockles (per 0.035 m^2) found at each location. Samples with zero counts are shown as small dots.

Table 40: Estimates of cockle abundance at Whangapoua Harbour, by stratum, for 2024–25. Presented are the area surveyed, the number of points and the number of cockles sampled, the mean total estimate, the mean density, and the coefficient of variation (CV).

Stratum		Sample		Population estimate		
	Area (ha)	Points	Cockle	Total (millions)	Density (m^{-2})	CV (%)
A	0.5	30	863	3.94	822	14.04
B	0.3	30	684	2.21	651	16.52
C	4.1	50	1 710	39.89	977	10.65
D	0.4	30	9	0.03	9	32.56

Table 41: Estimates of cockle abundance at Whangapoua Harbour for all sizes and large size (≥30 mm) cockles. Columns include the mean total estimate, mean density, and coefficient of variation (CV).

Year	Extent (ha)	Population estimate			Population ≥ 30 mm		
		Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
2002–03	1.7	11.30	680	4.87	2.71	163	7.69
2003–04	5.2	19.19	369	4.23	6.37	122	8.45
2004–05	5.2	33.19	638	4.07	5.18	100	9.22
2010–11	5.2	32.06	617	9.71	2.83	54	18.88
2014–15	6.3	33.67	533	9.54	1.43	23	15.18
2016–17	5.3	43.80	827	16.02	1.08	17	16.30
2018–19	5.3	64.97	1 229	10.62	0.52	10	27.22
2020–21	5.3	46.59	884	8.85	0.49	9	18.95
2022–23	5.1	31.30	617	10.05	1.84	36	15.53
2024–25	5.3	46.07	868	9.33	1.34	25	15.08

Table 42: Summary statistics of the length-frequency (LF) distribution of cockles at Whangapoua Harbour. The LF distributions (in mm) were estimated for all strata in each survey and subsequently summed for the distribution of total LFs. Recruits were defined by a shell length of ≤15 mm and large individuals by a shell length of ≥30 mm.

Year	Mean	Mode	Range	Recruits (%)	Medium (%)	Large (%)
2020–21	20.26	20	5–36	11.42	87.54	1.04
2022–23	22.12	25	5–36	13.96	80.15	5.89
2024–25	21.39	23	5–38	12.31	84.79	2.91

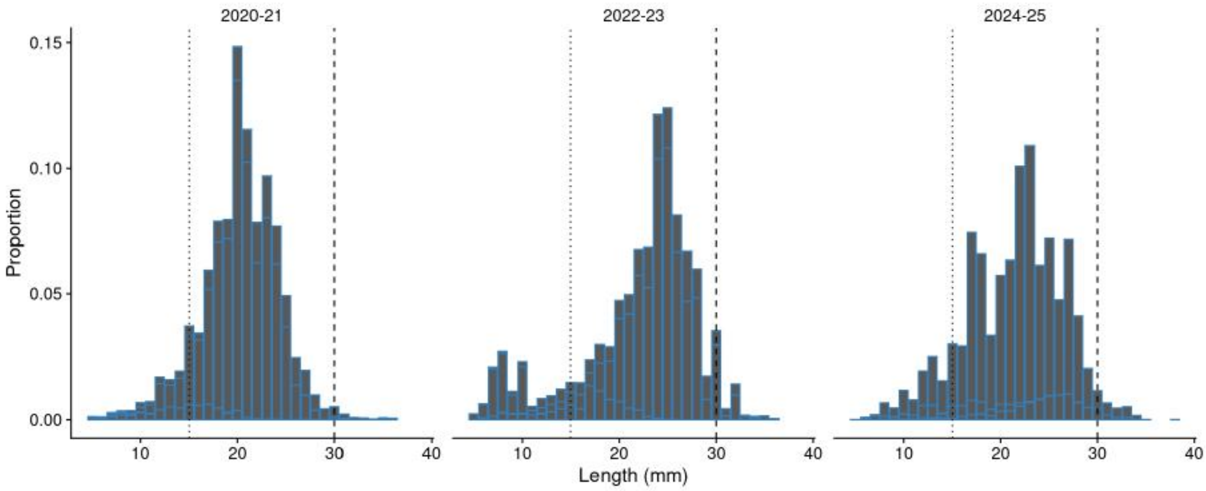

Figure 47: Weighted length-frequency (LF) distribution of cockles for the present and previous surveys at Whangapoua Harbour. Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively.

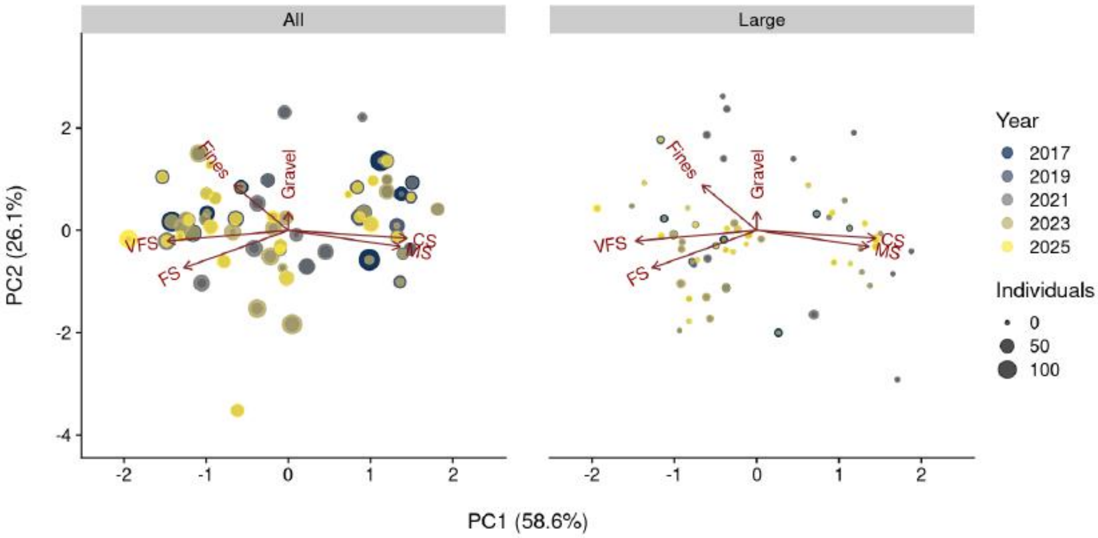

Figure 48: Cockle abundance along two principal components (standardised PCs, including % variance explained) of sediment granulometry for all cockle size classes (all) and large cockles (≥30 mm shell length) at Whangapoua Harbour. Sediment grain size fractions are defined as fines (silt and clay) ≤63 µm, very fine sand (VFS) >63 µm, fine sand (FS) >125 µm, medium sand (MS) >250 µm, coarse sand (CS) >500 µm, and gravel >2000 µm.

3.10.2 Pipi at Whangapoua Harbour

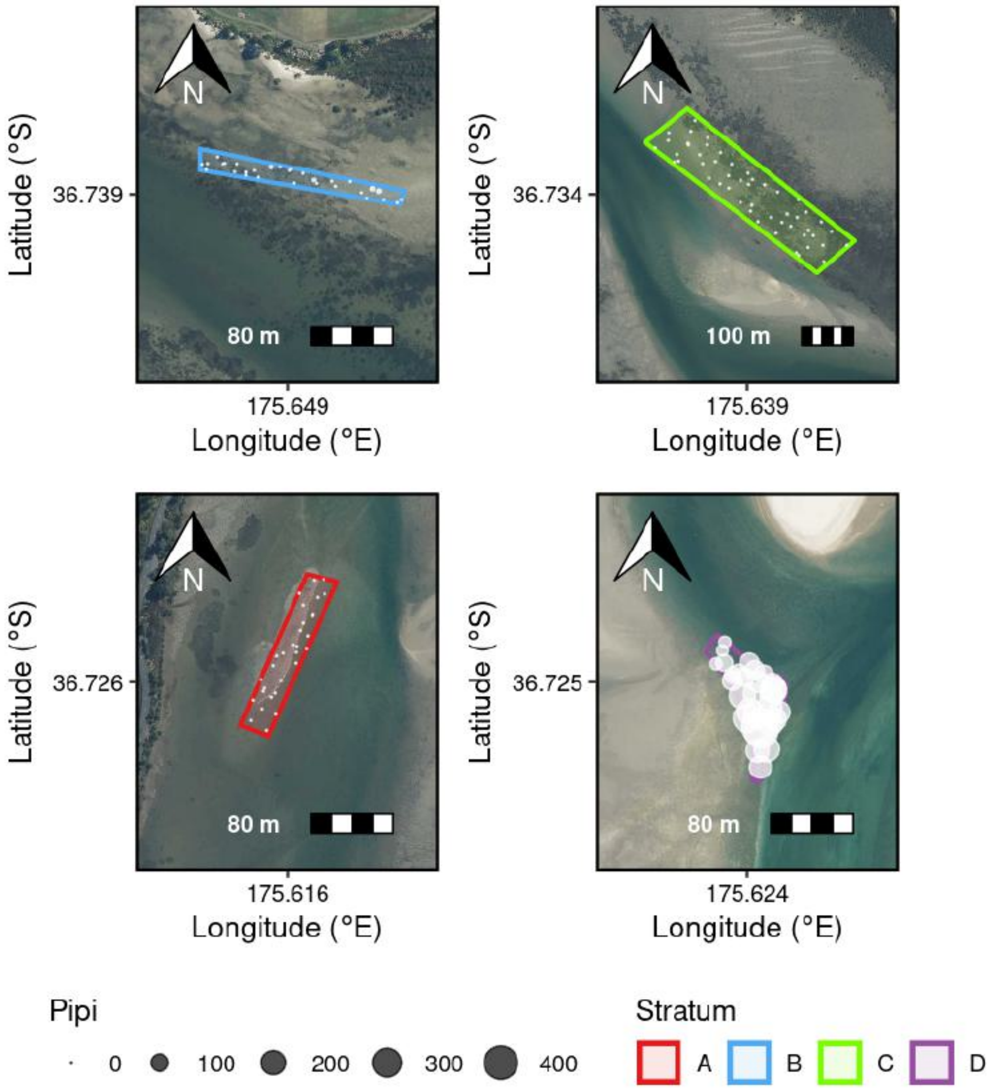

Figure 49: Map of sample strata and individual sample locations for pipi at Whangapoua Harbour, with the size of the circles proportional to the number of pipi (per 0.035 m^2) found at each location. Samples with zero counts are shown as small dots.

Table 43: Estimates of pipi abundance at Whangapoua Harbour, by stratum, for 2024–25. Presented are the area surveyed, the number of points and the number of pipi sampled, the mean total estimate, the mean density, and the coefficient of variation (CV).

Stratum		Sample		Population estimate		
	Area (ha)	Points	Pipi	Total (millions)	Density (m^{-2})	CV (%)
A	0.5	30	0	0.00	0	
B	0.3	30	6	0.02	6	50.29
C	4.1	50	0	0.00	0	
D	0.4	30	5 224	20.31	4 975	9.95

Table 44: Estimates of pipi abundance at Whangapoua Harbour for all sizes and large size (≥50 mm) pipi. Columns include the mean total estimate, mean density, and coefficient of variation (CV).

Year	Extent (ha)	Population estimate			Population ≥ 50 mm		
		Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
2002–03	1.7	5.62	338	10.16	1.73	104	8.28
2003–04	5.2	5.05	97	9.98	1.75	34	7.90
2004–05	5.2	7.47	144	5.25	3.75	72	5.08
2010–11	5.2	2.74	53	18.82	1.18	23	22.54
2014–15	6.3	2.27	36	20.24	0.34	5	22.32
2016–17	5.3	2.01	38	21.05	0.66	10	29.84
2018–19	5.3	4.17	79	14.71	1.44	27	13.32
2020–21	5.3	5.50	104	13.42	0.41	8	18.90
2022–23	5.1	1.50	30	9.96	0.34	7	11.34
2024–25	5.3	20.33	383	9.94	0.32	6	30.40

Table 45: Summary statistics of the length-frequency (LF) distribution of pipi at Whangapoua Harbour. The LF distributions (in mm) were estimated for all strata in each survey and subsequently summed for the distribution of total LFs. Recruits were defined by a shell length of ≤20 mm and large individuals by a shell length of ≥50 mm.

Year	Mean	Mode	Range	Recruits (%)	Medium (%)	Large (%)
2020–21	30.65	30	6–64	21.28	71.22	7.51
2022–23	41.26	47	9–63	4.86	72.44	22.70
2024–25	32.88	33	10–60	6.50	91.92	1.58

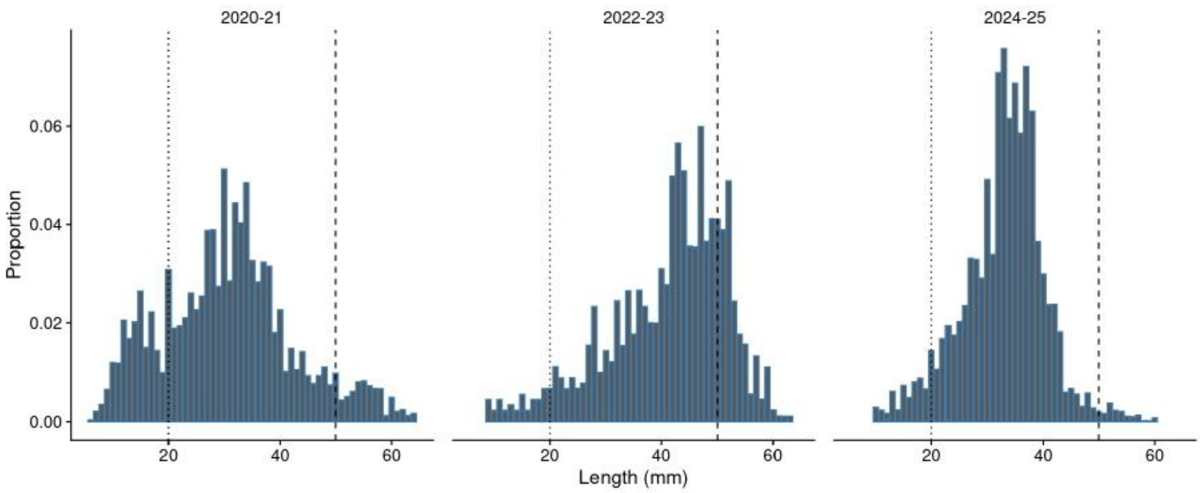

Figure 50: Weighted length-frequency (LF) distribution of pipi for the present and previous surveys at Whangapoua Harbour. Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively.

3.11 Whitianga Harbour

Whitianga Harbour is one of the Waikato sites, and on the eastern side of Coromandel Peninsula. Initially, the survey only included a pipi bed at the beach by the harbour entrance, with subsequent surveys also assessing an intertidal cockle bed within the harbour. The cockle bed was added because it was part of the Hauraki Gulf Forum community monitoring programme. In the current survey series, populations of both species have been assessed in a total of five surveys since 2015–16, with pipi also surveyed in 2012–13 (see Appendix A, Tables A-1, A-2). Across these surveys, the sampling extent has remained largely consistent, with some variation in its size linked to changes in the pipi bed. The present assessment was based on a separate stratum each for cockles and pipi, with a total of 80 sampling points across these two strata.

The sediment organic content was generally below 3%, except for one sample with about 7% of organic matter (Figure 51, and see details in Appendix B, Table B-1). There was a variable proportion of sediment fines (grain size <63 µm), ranging between 4.0 and 16.2%. Most of the sediment consisted of fine sand (grain size >250 µm), with a smaller proportion of medium sand (grain size >500 µm).

Cockles were distributed throughout stratum A, and only present in this stratum (Figure 52, Table 46). The total population estimate for Whitianga Harbour was 80.04 million (CV: 9.71%) cockles, signifying a notable increase from the 2021–22 estimate of 57.22 million (CV: 11.53%) cockles (Table 47). Similarly, the density estimate increased to 1617 cockles per m^2 compared with 1055 cockles per m^2 previously. Within this population, large cockles ($\geq$30 mm shell length) have been lacking throughout the survey series. The current cockle population largely consisted of recruits ($\leq$15 mm shell length), which represented 87.79% of all individuals, with only a small contribution 12.21% of medium-sized cockles (Table 48, Figure 53). Although this general population size structure was consistent in the three most recent surveys, there was a marked increase in the proportion of recruits in 2024–25, leading to a 5-mm reduction in modal size to 12 mm shell length, well below the 15-mm upper threshold of the recruits size class. The generally high proportion of recruits reflected strong recruitment events that maintain the resident cockle population.

Whitianga Harbour has also been part of the Hauraki Gulf Forum community monitoring programme that surveys cockles in a transect sampling design (Auckland Council 2013). Although recent data are not publicly available, a survey summary[2] indicates a cockle population of generally small individuals. Population variations have been linked to fluctuating recruitment, with juveniles ($<$15 mm shell length) making up over 75% of the population in some years. Although based on different methods, these general findings were consistent with the current survey results for this site.

Cockle abundances in relation to sediment grain size fractions showed no consistent patterns across surveys in the PCA (Figure 54).

The distribution of pipi was limited to the pipi bed, stratum B (Figure 55, Table 49). Total pipi abundance was estimated at 13.93 million (CV: 9.68%) pipi, decreasing from 28.36 million (CV: 9.48%) pipi in 2021–22 (Table 50). There was a concomitant decrease in pipi density, from an estimated 523 pipi per m^2 in the preceding survey, to 281 pipi per m^2 in 2024–25. Throughout the time series, the pipi population at Whitianga Harbour was characterised by notable fluctuations.

Within the population, there were few large pipi ($\geq$50 mm shell length; e.g., $<$1 pipi per m^2), and there was high uncertainty with these estimates with a CV of 57.61%. Their low abundance also meant that large pipi contributed few individuals (0.08%) to the total population (Table 51, Figure 56). Instead, the latter was primarily determined by medium-sized individuals and recruits ($\leq$20 mm shell length), with 81.90% and 18.02% of the population in these two size classes, respectively. The bimodal population structure reflected the two size classes, but mean and modal sizes were determined by the stronger cohort of medium-sized pipi; for example, the modal size was 37 mm shell length.

[2] https://www.waikatoregion.govt.nz/environment/coast/ecosystem-health/hgf-community-shellfish-monitoring

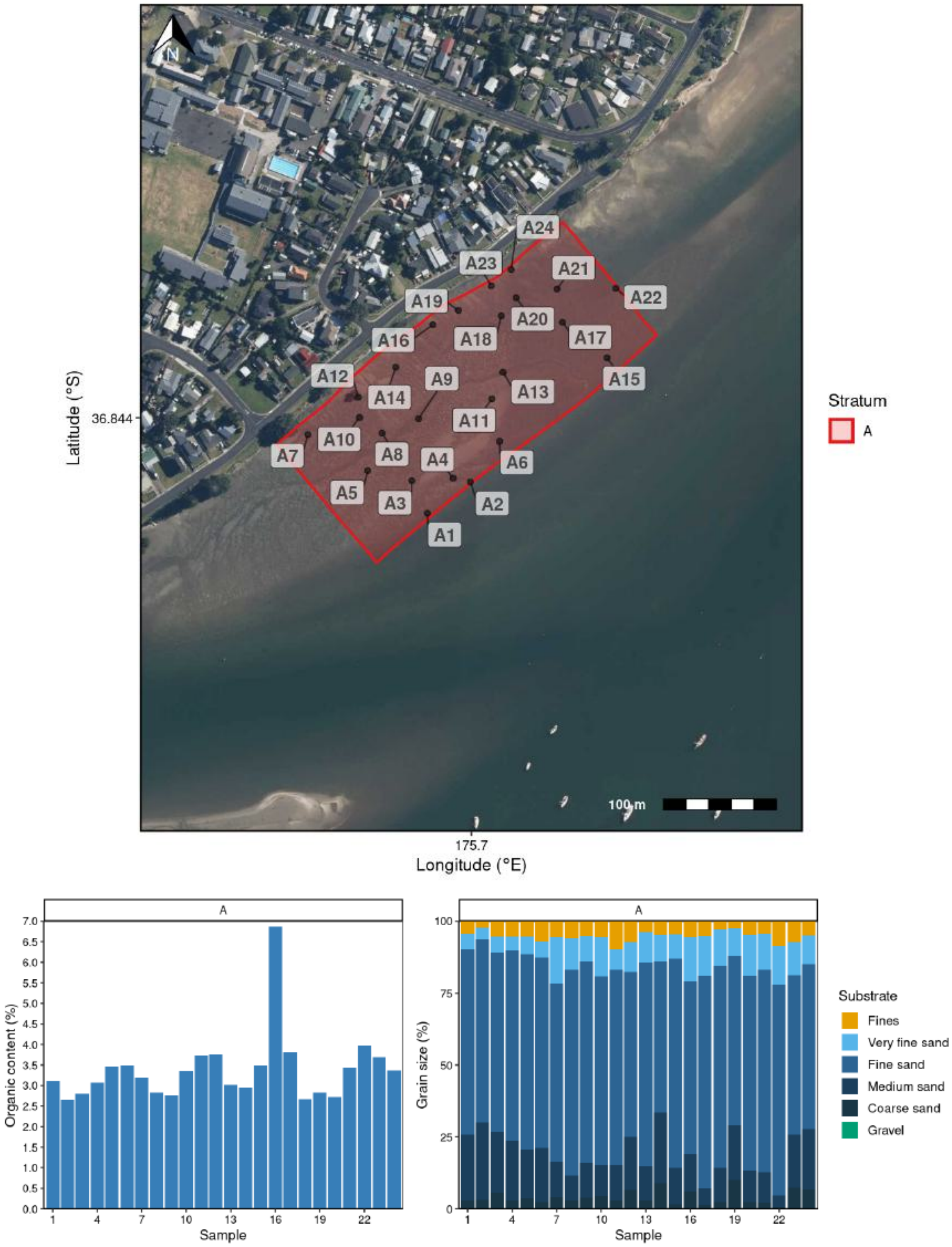

Figure 51: Sediment sample locations and characteristics at Whitianga Harbour. Labels correspond to stratum and sample number. Graphs show organic content (% dry weight) and cumulative grain size (%). Sediment grain size fractions include fines (silt and clay, ≤63 µm), sands (very fine, >63 µm; fine, >125 µm; medium, >250 µm; coarse, >500 µm), and gravel (>2000 µm) (see details in Table B-1).

3.11.1 Cockles at Whitianga Harbour

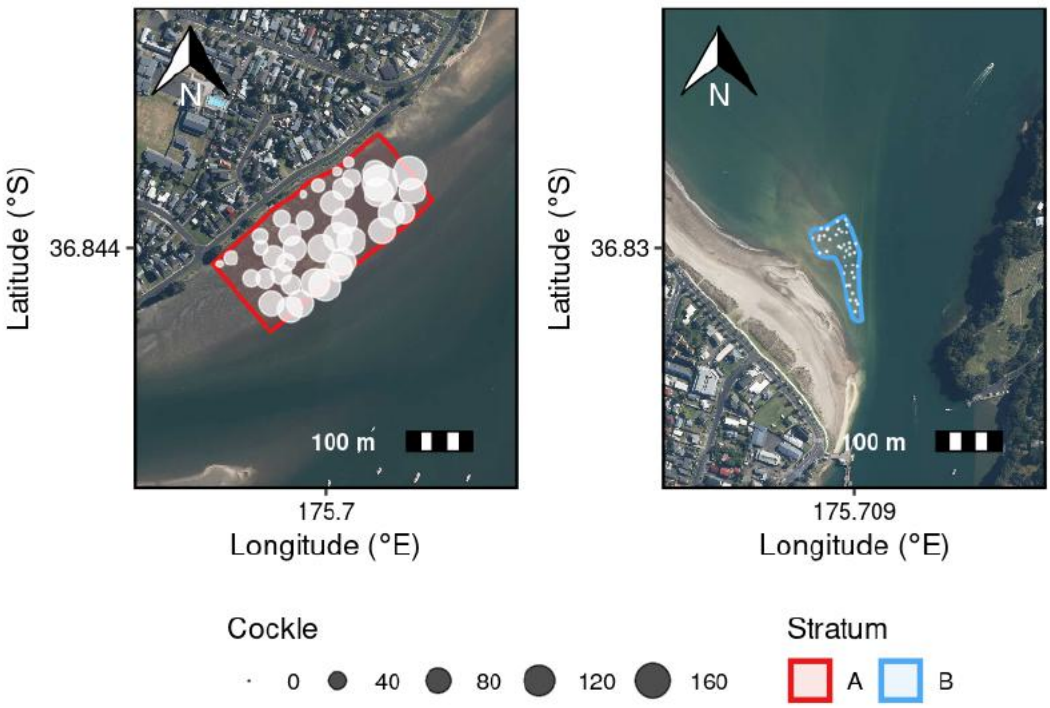

Figure 52: Map of sample strata and individual sample locations for cockles at Whitianga Harbour, with the size of the circles proportional to the number of cockles (per 0.035 m^2) found at each location. Samples with zero counts are shown as small dots.

Table 46: Estimates of cockle abundance at Whitianga Harbour, by stratum, for 2024–25. Presented are the area surveyed, the number of points and the number of cockles sampled, the mean total estimate, the mean density, and the coefficient of variation (CV).

Stratum		Sample		Population estimate		
	Area (ha)	Points	Cockle	Total (millions)	Density (m^{-2})	CV (%)
A	4.4	40	2 543	80.04	1 816	9.71
B	0.5	40	0	0.00	0	

Table 47: Estimates of cockle abundance at Whitianga Harbour for all sizes and large size (≥30 mm) cockles. Columns include the mean total estimate, mean density, and coefficient of variation (CV).

Year	Extent (ha)	Population estimate			Population ≥ 30 mm		
		Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
2015–16	6.1	51.98	852	9.16	0.00	0	
2017–18	5.8	51.43	885	11.21	0.00	0	
2019–20	5.4	59.00	1 084	12.50	0.00	0	
2021–22	5.4	57.22	1 055	11.53	0.00	0	
2024–25	4.9	80.04	1 617	9.71	0.00	0	

Table 48: Summary statistics of the length-frequency (LF) distribution of cockles at Whitianga Harbour. The LF distributions (in mm) were estimated for all strata in each survey and subsequently summed for the distribution of total LFs. Recruits were defined by a shell length of ≤15 mm and large individuals by a shell length of ≥30 mm.

Year	Mean	Mode	Range	Recruits (%)	Medium (%)	Large (%)
2019–20	14.14	15	5–24	68.63	31.37	0.00
2021–22	13.23	17	3–25	68.46	31.54	0.00
2024–25	12.58	12	6–22	87.79	12.21	0.00

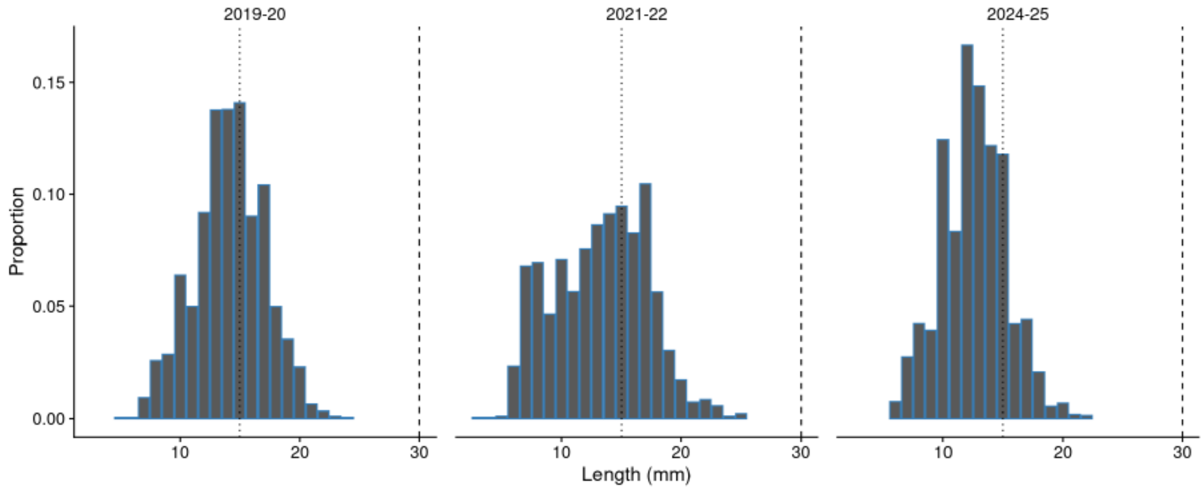

Figure 53: Weighted length-frequency (LF) distribution of cockles for the present survey at Whitianga Harbour. Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively.

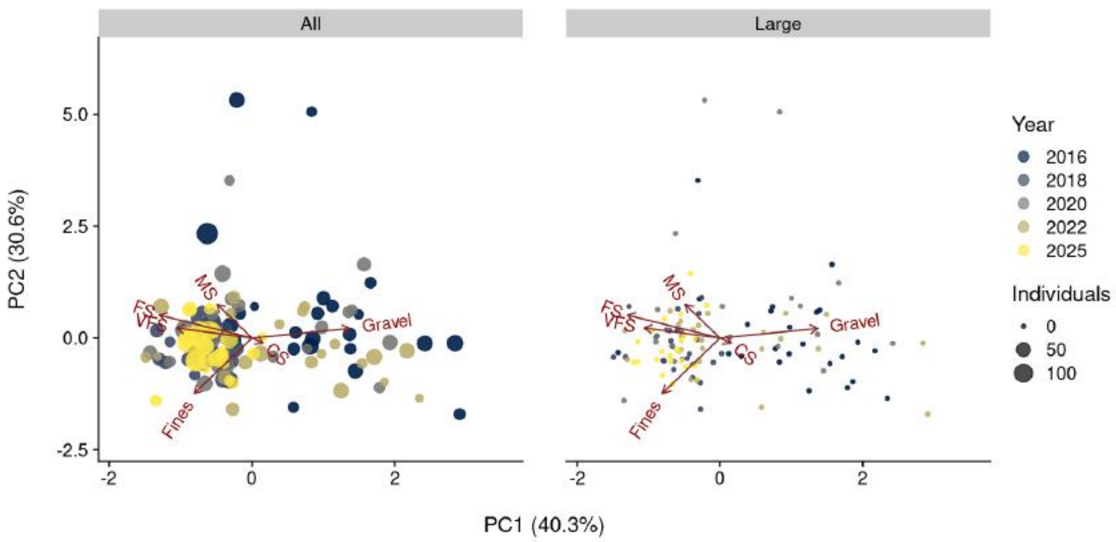

Figure 54: Cockle abundance along two principal components (standardised PCs, including % variance explained) of sediment granulometry for all cockle size classes (all) and large cockles (≥30 mm shell length) at Whitianga Harbour. Sediment grain size fractions are defined as fines (silt and clay) ≤63 µm, very fine sand (VFS) >63 µm, fine sand (FS) >125 µm, medium sand (MS) >250 µm, coarse sand (CS) >500 µm, and gravel >2000 µm.

3.11.2 Pipi at Whitianga Harbour

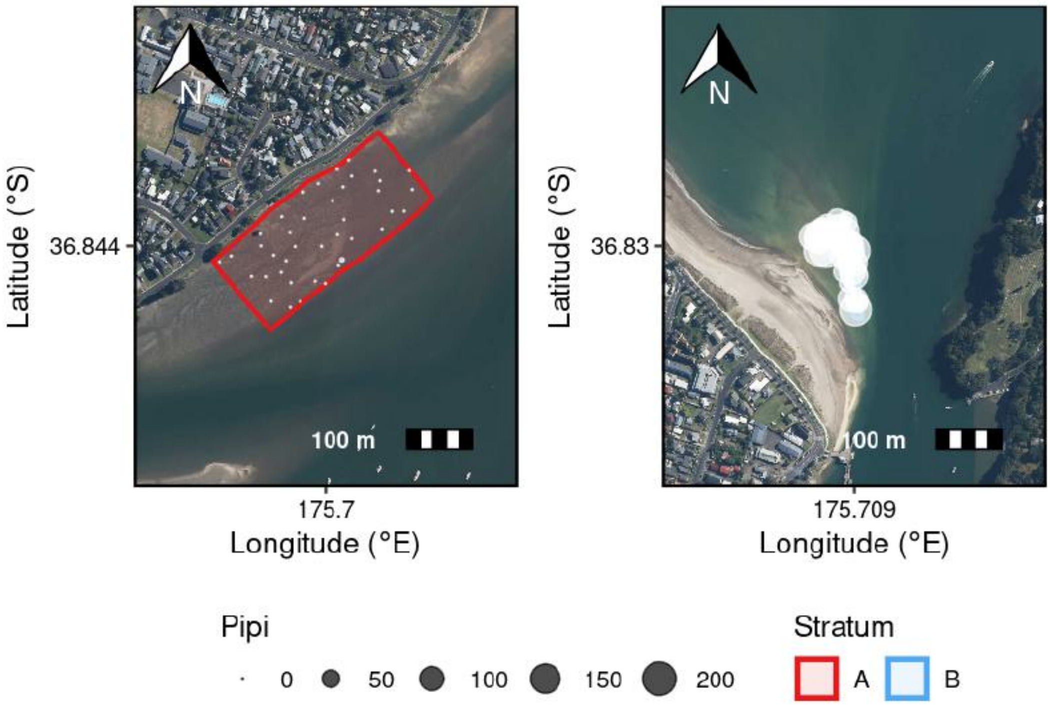

Figure 55: Map of sample strata and individual sample locations for pipi at Whitianga Harbour, with the size of the circles proportional to the number of pipi (per 0.035 m^2) found at each location. Samples with zero counts are shown as small dots.

Table 49: Estimates of pipi abundance at Whitianga Harbour, by stratum, for 2024–25. Presented are the area surveyed, the number of points and the number of pipi sampled, the mean total estimate, the mean density, and the coefficient of variation (CV).

Stratum		Sample		Population estimate		
	Area (ha)	Points	Pipi	Total (millions)	Density (m^{-2})	CV (%)
A	4.4	40	1	0.03	<1	>100
B	0.5	40	3 583	13.90	2559	9.7

Table 50: Estimates of pipi abundance at Whitianga Harbour for all sizes and large size (≥50 mm) pipi. Columns include the mean total estimate, mean density, and coefficient of variation (CV).

Year	Extent (ha)	Population estimate			Population ≥ 50 mm		
		Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
2012–13	7.1	18.65	263	18.39	1.99	28	22.27
2015–16	6.1	6.36	104	18.17	1.91	31	22.66
2017–18	5.8	95.12	1 637	12.93	2.37	41	14.68
2019–20	5.4	8.86	163	13.38	0.86	16	19.02
2021–22	5.4	28.36	523	9.48	0.80	15	16.22
2024–25	4.9	13.93	281	9.68	0.01	<1	57.61

Table 51: Summary statistics of the length-frequency (LF) distribution of pipi at Whitianga Harbour. The LF distributions (in mm) were estimated for all strata in each survey and subsequently summed for the distribution of total LFs. Recruits were defined by a shell length of $\leq$20 mm and large individuals by a shell length of $\geq$50 mm.

Year	Mean	Mode	Range	Recruits (%)	Medium (%)	Large (%)
2019–20	40.01	42	10–64	0.18	90.14	9.68
2021–22	27.67	30	7–60	22.45	74.71	2.84
2024–25	32.05	37	5–53	18.02	81.90	0.08

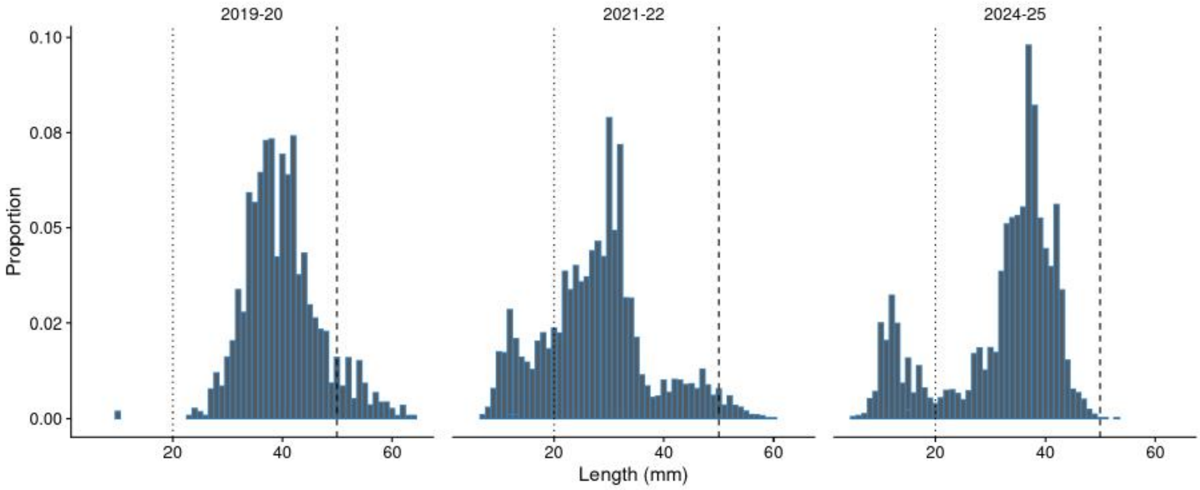

Figure 56: Weighted length-frequency (LF) distribution of pipi for the present and previous surveys at Whitianga Harbour. Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively.

4. SUMMARIES

4.1 Cockle populations

The 2024–25 survey sampled bivalve beds across eleven northern sites, and cockle populations were present at all of them. The sites represented diverse soft-sediment habitats, including sheltered beaches in city and urban settings, such as Cockle Bay and Ōkahu Bay in Auckland, and Okoromai Bay, Kawakawa Bay (West), and Mill Bay in the wider Auckland region. Other sites included extensive tidal inlets and beaches, such as Ōhiwa Harbour and Otūmoetai in Bay of Plenty, and Whangapoua and Whitianga harbours on Coromandel Peninsula. Both Pataua Estuary in Northland and Waiotahe Estuary in Bay of Plenty were small tidal estuaries.

Apart from Ōkahu Bay, the cockle populations at the present sites have been regularly surveyed as part of this monitoring series. Population estimates in 2024–25 ranged from the smallest population of 10.22 (CV: 17.05%) million cockles at Ōhiwa Harbour to the largest population of 292.13 (CV: 14.29%) million individuals at Pataua Estuary (Table 52). Ōkahu Bay had a relatively small cockle population and was the only site where the CV of the estimates exceeded 20%, in spite of phase-2 sampling.

Comparing cockle densities across sites documented high density estimates of several hundred individuals per square metre at most sites. The lowest density of 148 cockles per m^2 (CV: 11.18%) was at Waiotahe Estuary. Both Pataua Estuary and Whitianga Harbour had comparatively high densities at 1031 cockles per m^2 and 1617 cockles per m^2 (CV: 9.71%), respectively. Regardless of population density, none of the populations included a notable number of large cockles ($\geq$30 mm shell length), and their population estimates were accompanied by high CV values. The latter was also evident for four of the five sites where the average density of large cockles exceeded 15 individuals per square metre; only the density estimate at Whangapoua Harbour of 25 large cockles per m^2 had a CV of less than 20% (i.e., CV: 15.08%).

Considering population trends over time, a number of sites with temporal data showed recent increases in cockle densities, usually following a decline at some point in the time series (Figure 57). Although these increases were generally small, they were notable at two sites, Cockle Bay and Whitianga Harbour. At Cockle Bay, the recent increase followed relatively stable densities in preceding surveys after a marked decline early in the survey series. At Whitianga Harbour, the increase in cockle density in 2024–25 continued the upward population trend at this site. In contrast to these recent increases, the cockle population at Mill Bay showed a marked decline in 2024–25, although density estimates for this site remained generally high (about 500 individuals per m^2). At Waiotahe Estuary, cockle density remained low, lacking sufficient increases to return to the high density estimates that characterised the population earlier in the survey series.

The combined length-frequency distributions illustrated a growing influence of recruits on the population size structures over time (Figure 58). The size compositions were generally unimodal and largely determined by medium-sized cockles; however, in recent surveys, the modal size of the single cohort shifted towards smaller sizes, around the 15-mm cutoff for the recruits size class. At the same time, there was a universal reduction of large cockles, and this size class was scarce in recent assessments.

The scarcity of large cockles across most of the 2024–25 sites was evident in the time-series data, and their density estimates were frequently accompanied by considerable variation (Figure 59). At Mill Bay, Ōhiwa Harbour, Otūmoetai (Tauranga Harbour), and Waiotahe Estuary, their densities were low throughout the survey series, generally not exceeding ten individuals per square metre. At Cockle Bay, Okoromai Bay, Pataua Estuary, and Whangapoua Harbour, estimated densities of large cockles were high (about several 100s of individuals per square metre) in early surveys, but subsequently declined and remained low. Although their current density estimates at Cockle Bay and Whangapoua Harbour were low compared with estimates in earlier surveys, these two sites, together with Kawakaway Bay (West), had the highest densities of large cockles in 2024–25.

Table 52: Estimates of cockle abundance for all sites where more than ten cockles were found in the 2024–25 survey. For each site, the table includes the estimated mean number, the mean density, and coefficient of variation (CV) for all cockles (total) and for large cockles (≥30 mm shell length).

Survey site	Population estimate			Population ≥30 mm		
	Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
Cockle Bay	76.74	487	13.65	5.81	37	22.4
Kawakawa Bay	205.04	337	16.60	20.22	33	70.46
Mill Bay	25.51	523	14.25	0.15	3	38.73
Ōhiwa Harbour	10.22	469	17.05	0.20	9	24.47
Ōkahu Bay	15.48	257	30.77	0.02	<1	>100
Okoromai Bay	55.16	278	9.47	4.46	22	25.79
Otūmoetai	17.83	398	12.15	0.04	<1	62.88
Pataua Estuary	292.13	1 031	14.29	5.52	19	45.25
Waiotahe Estuary	17.42	148	11.18	0.00	0	
Whangapoua Harbour	46.07	868	9.33	1.34	25	15.08
Whitianga Harbour	80.04	1 617	9.71	0.00	0	

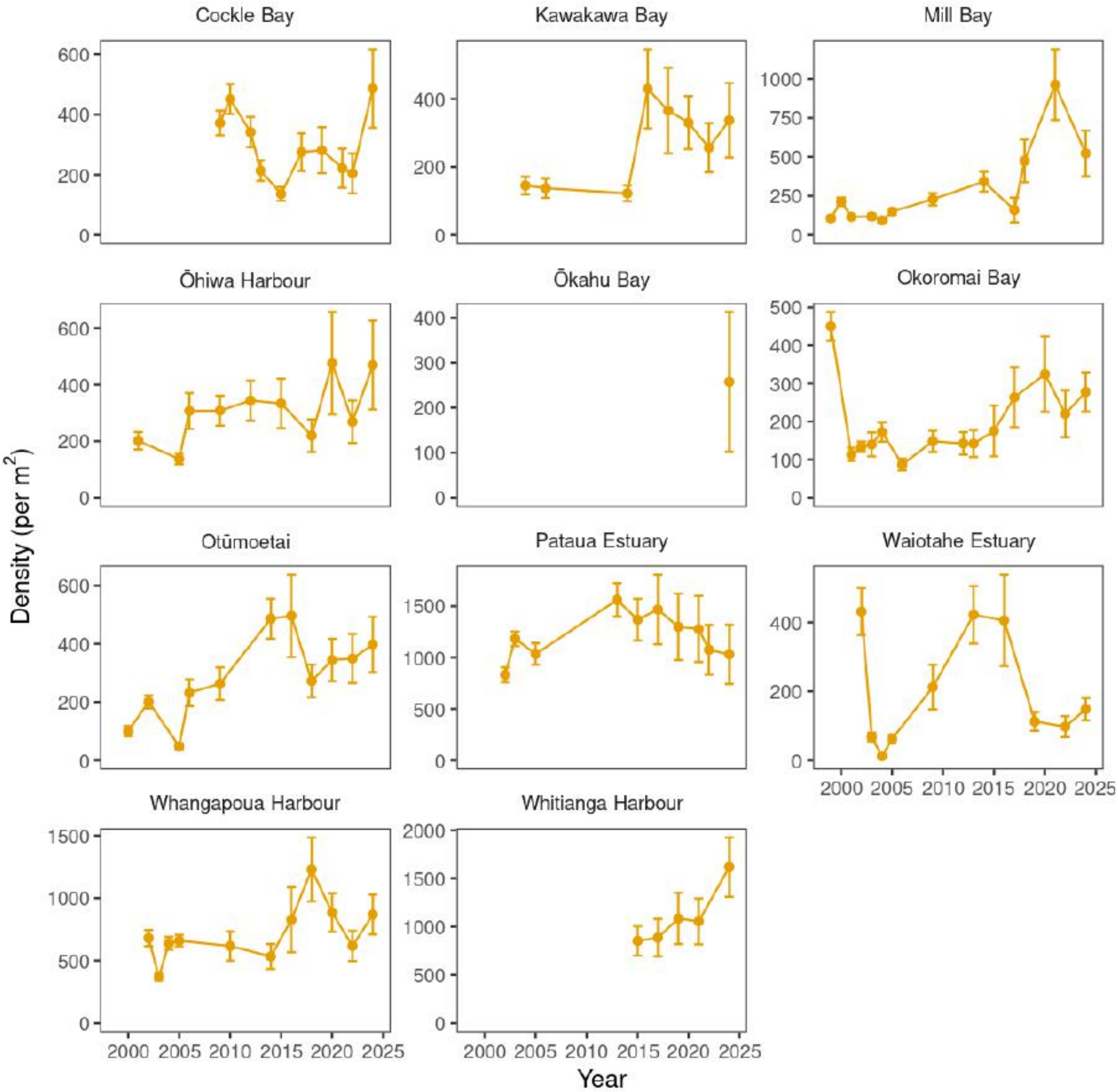

Figure 57: Estimated density of cockles for all sites included in the 2024–25 survey. Shown are the mean estimated densities across years, with bars indicating the 95% confidence interval. (Note different scales on the y-axes. Not all sites were surveyed each year, and the sampling extent may vary across years.)

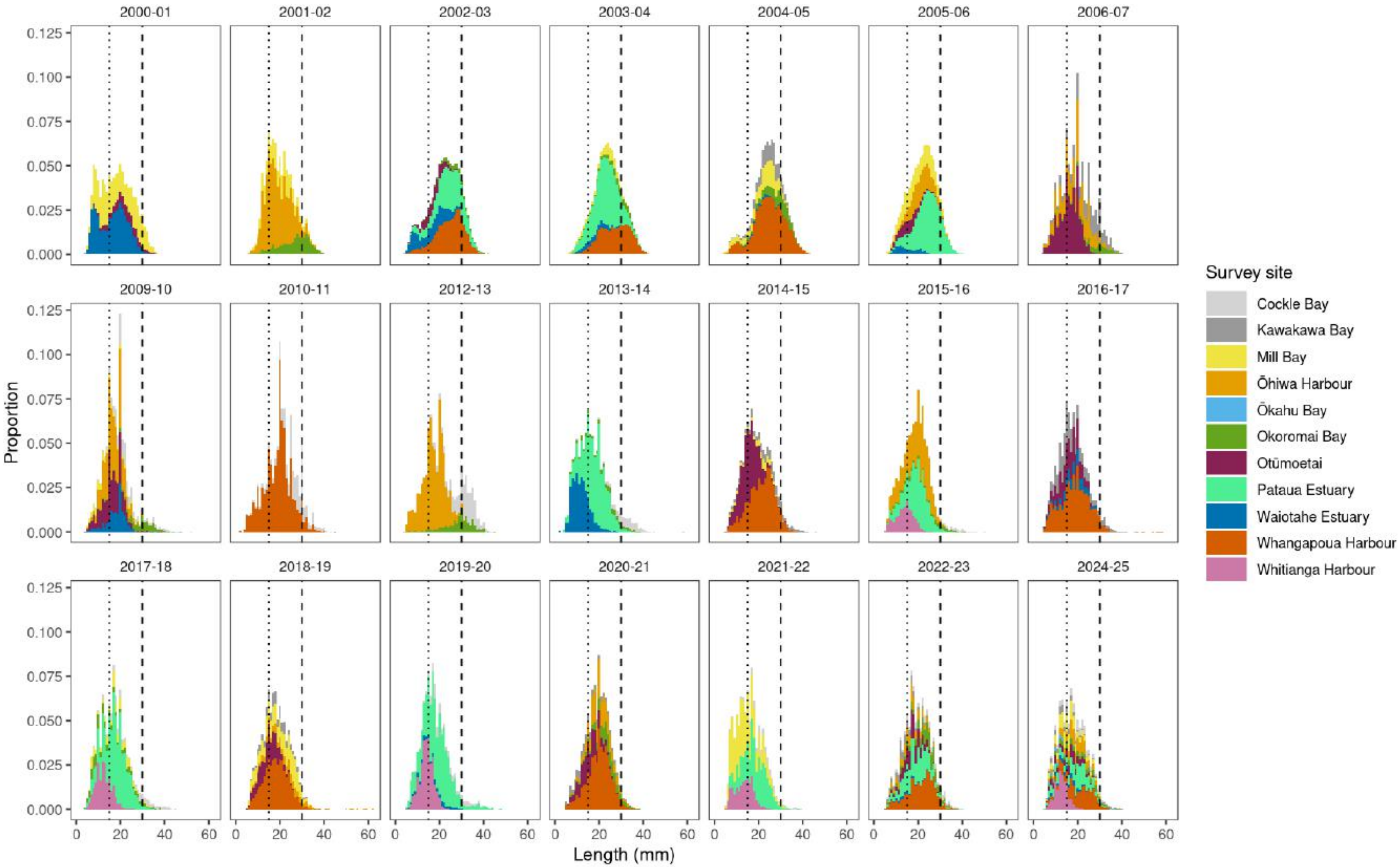

Figure 58: Weighted length-frequency (LF) distributions of cockles over time at sites included in the 2024–25 survey. LF distributions were estimated independently for all strata in each survey to provide the total LF distribution. Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively. (Note, not all sites were surveyed each year, and the sampling extent may vary across years.)

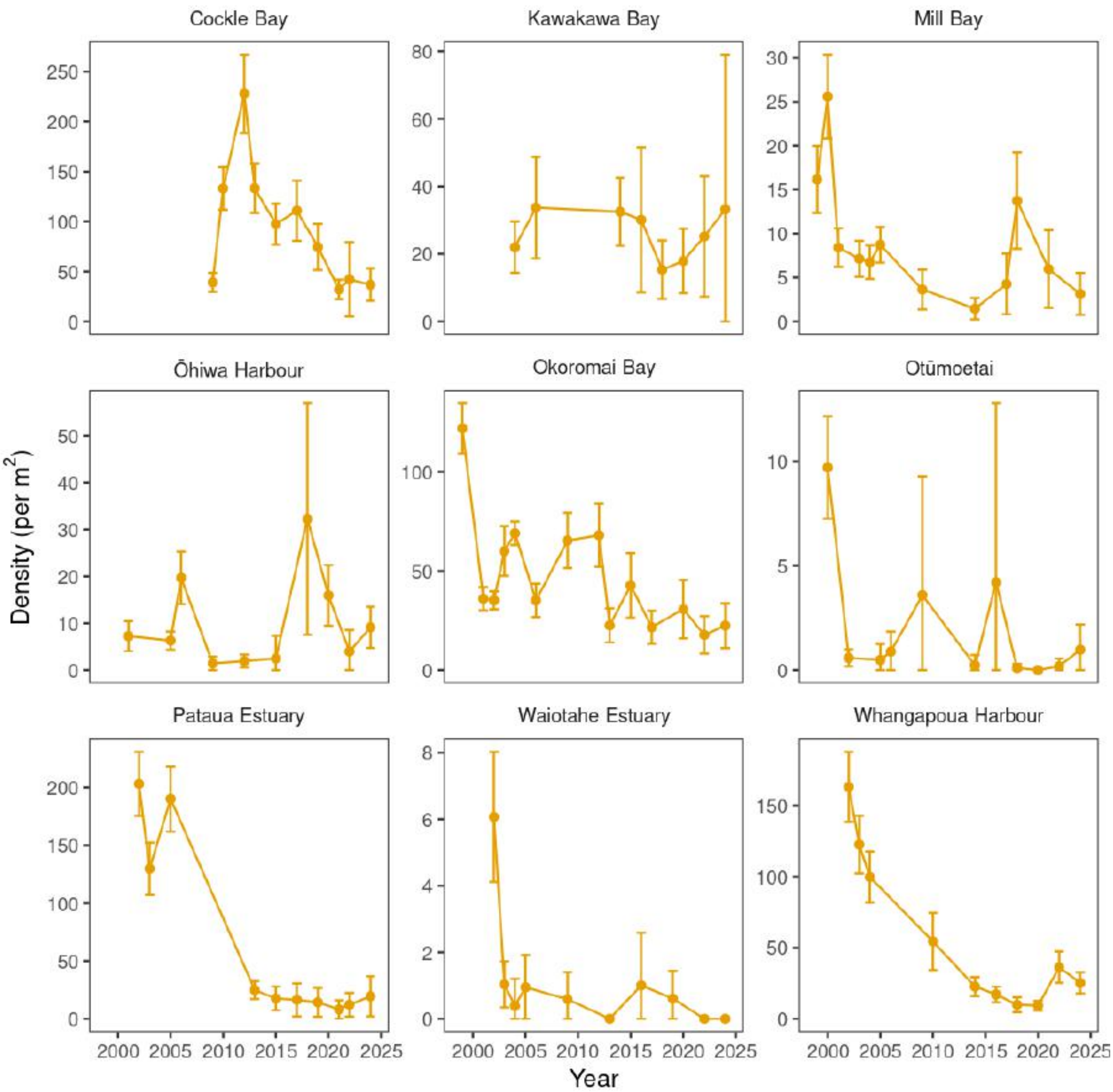

Figure 59: Estimated density of large cockles (≥30 mm shell length) for all sites where cockles in this size class were present in at least one survey. Shown are the mean estimated densities across years, with bars indicating the 95% confidence interval. (Note, different scales on the y-axes. Not all sites were surveyed each year, and the sampling extent may vary across years.)

4.2 Pipi populations

Six of the survey sites supported pipi populations, and their population sizes were largely similar, regardless of the site and habitat type (Table 53). The smallest population was at Whitianga Harbour, where pipi abundance was estimated at 13.93 million (CV: 9.68%) pipi, whereas Waiotahe Estuary supported the largest population at 95.89 million (CV: 17.99%) individuals (Table 53). All population estimates had CV values of less than 20%.

Pipi densities were generally high (i.e., several hundred individuals per square metre) across the northern sites, with only Pataua Estuary having a relatively low estimate of 60 pipi per m^2 (CV: 11.47%). The maximum density was at Ōhiwa Harbour, with an estimated 1110 pipi per m^2 (CV: 7.62%). Large pipi (≥50 mm shell length) were scarce or absent across all of the sites, and their estimates had an associated uncertainty with CV values above 20%.

Population trends over time showed a uniform pattern of a significant decline in pipi densities at each site, although its timing varied depending on the site (Figure 60). At Pataua Estuary, the decline early in the survey series was followed by consistently low pipi densities subsequently, including in 2024–25. At Otūmoetai and Waiotahe Estuary, pipi densities remained high in spite of the decline, and showed subsequent increases. These recent increases were also evident at Ōhiwa Harbour, Pataua Estuary, and Whangapoua Harbour. In contrast, Whitianga Harbour was the only site with a recent decrease in pipi density.

Some of the population fluctuations were explained by the combined length-frequency distributions over time, which highlighted the influence of small-sized recruits on the pipi populations (Figure 61). This size class was important at particular times, indicating strong recruitment events that preceded the pipi assessment; for example, in 2017–18, 2021–22, and in the current study. In some survey years, this recruitment led to a bimodal population size structure (e.g., in 2015–16), although medium-sized indiduals most consistently determined the size composition, often as a single cohort augmented by recruits.

Although large pipi were largely lacking in the current populations, individuals in this size class occurred at relatively high densities (i.e., about 100 indvididuals per m^2) in earlier surveys at three of the sites (Figure 62). At Ōhiwa Harbour, Otūmoetai, and Whangapoua Harbour large pipi densities were high in initial surveys, but underwent a continuous decline subsequently, to the current low estimates. The decline was similar at Waiotahe Estuary and Whitianga Harbour, but occurred at a different time, and from lower initial densities of large pipi. The pipi population at Pataua Estuary only contained few individuals in the large size class throughout the survey series, and the variation in their low estimates was consistently high.

Table 53: Estimates of pipi abundance for all sites where more than ten pipi were sampled in the 2024–25 survey. For each site, the table includes the estimated mean number, the mean density, and coefficient of variation (CV) for all pipi (total) and for large pipi (≥50 mm shell length).

Survey site	Population estimate			Population ≥50 mm		
	Total (millions)	Density (m^{-2})	CV (%)	Total (millions)	Density (m^{-2})	CV (%)
Ōhiwa Harbour	24.17	1 110	7.62	0.06	3	30.66
Otūmoetai	27.31	609	5.48	0.09	2	51.06
Pataua Estuary	16.93	60	11.47	0.13	<1	25.08
Waiotahe Estuary	95.89	816	17.99	0.00	0	
Whangapoua Harbour	20.33	383	9.94	0.32	6	30.40
Whitianga Harbour	13.93	281	9.68	0.01	<1	57.61

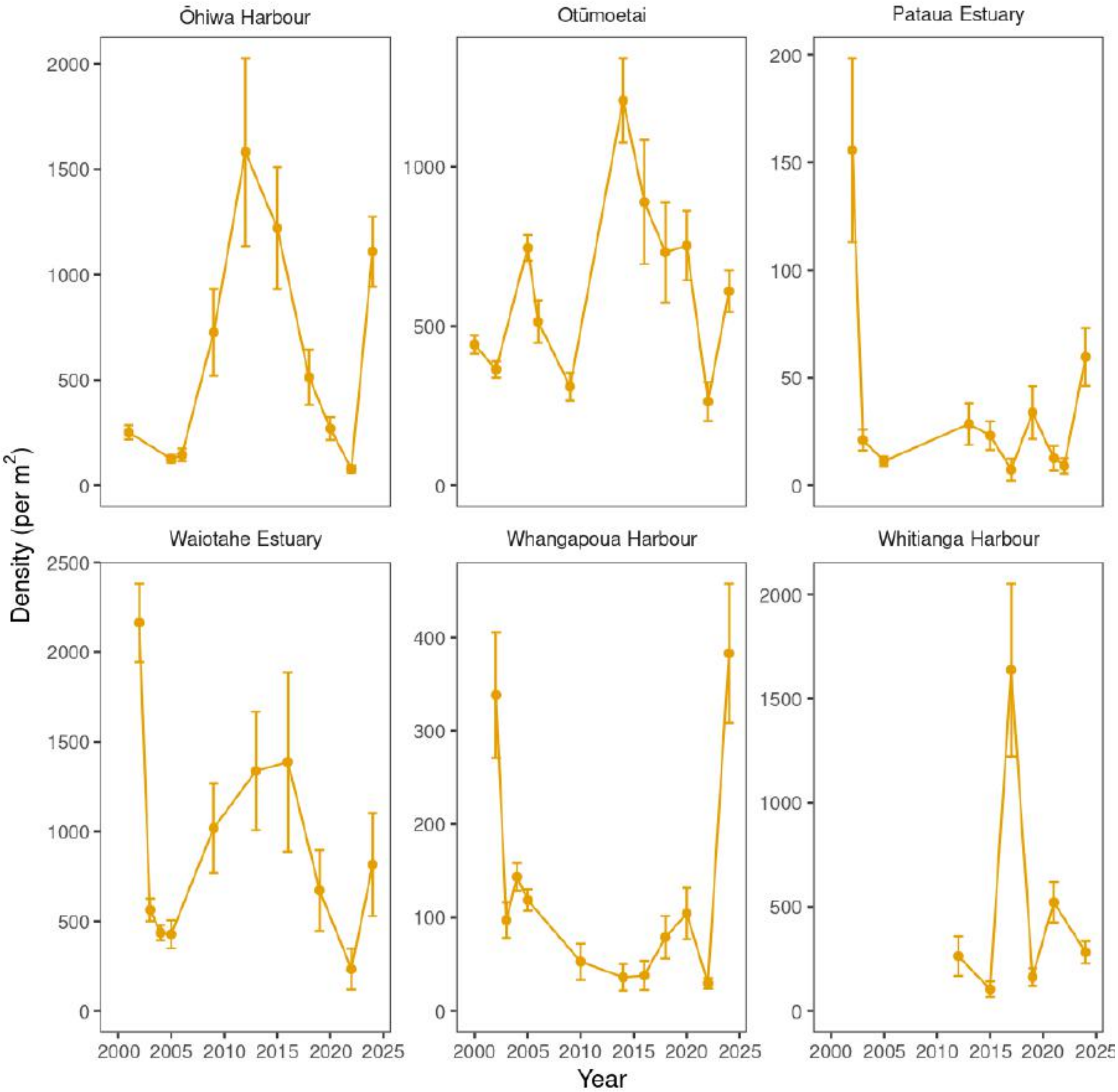

Figure 60: Estimated density of pipi for all sites included in the 2024–25 survey. Shown are the mean estimated densities across years, with bars indicating the 95% confidence interval. (Note different scales on the y-axes. Not all sites were surveyed each year, and the sampling extent may vary across years.)

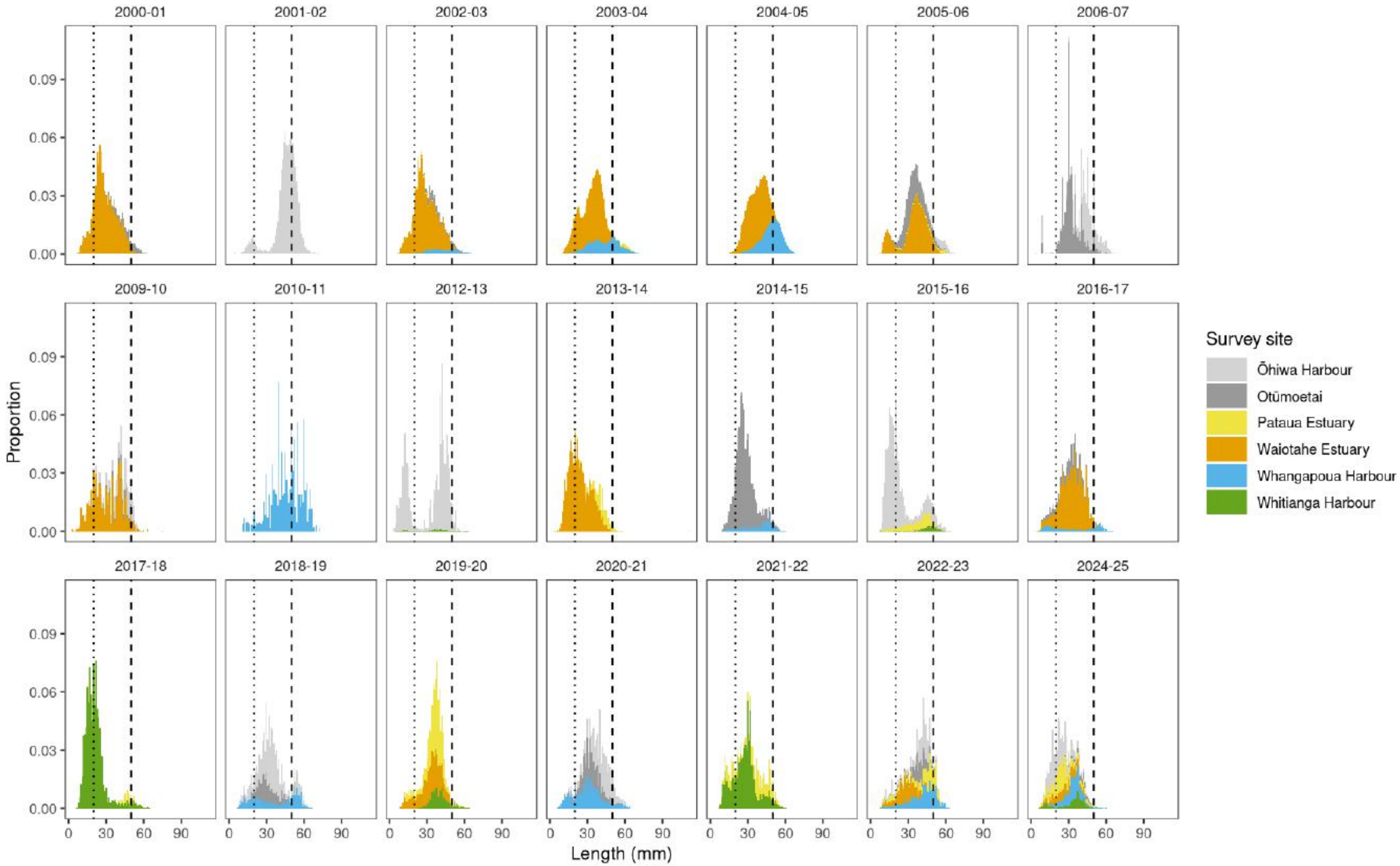

Figure 61: Weighted length-frequency (LF) distributions of pipi over time at sites included in the 2024–25 survey. LF distributions were estimated independently for all strata in each survey to provide the total LF distribution. Vertical dotted and dashed lines indicate the cut-off sizes for recruits and large individuals, respectively. (Note, not all sites were surveyed each year, and the sampling extent may vary across years.)

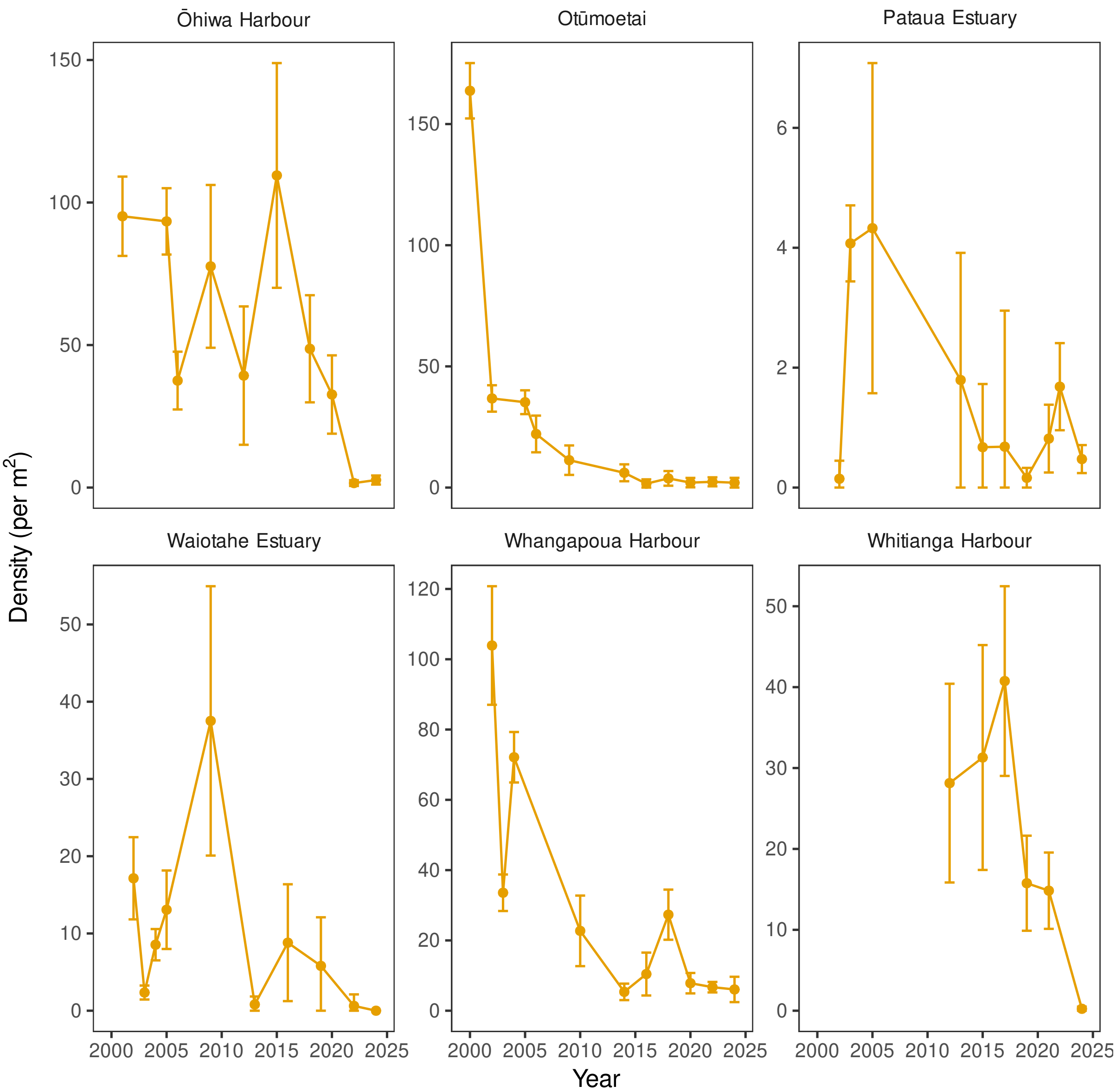

Figure 62: Estimated density of large pipi (≥50 mm shell length) for all sites where pipi in this size class were present in at least one survey. Shown are the mean estimated densities across years, with bars indicating the 95% confidence interval. (Note, different scales on the y-axes. Not all sites were surveyed each year, and the sampling extent may vary across years.)

4.3 Sediment data

All of the cockle strata at the 2024–25 sites contained sediment that was low in organic content, ranging between 1.7 and 3.4% (Figure 63). The sediment grain size composition was predominantly fine sand (grain size >125 µm) in combination with either medium sand or very fine sand (>250 and >63 µm, respectively). The proportion of sediment fines (<63 µm) varied across sites, with the average proportion of sediment in this grain size fraction exceeding 7% at Cockle Bay, Kawakawa Bay (West), Mill Bay, Ōkahu Bay, and Waiotahe Estuary. At these sites, individual sediment samples contained a high proportion of sediment fines, ranging from 19% at Mill Bay and Waiotahe Estuary to 69% at Cockle Bay.

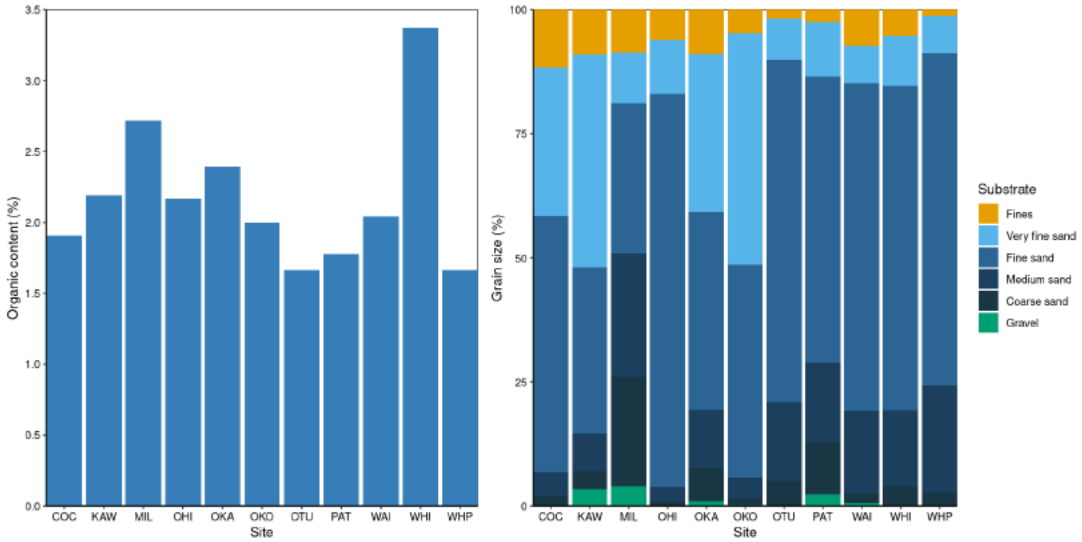

Figure 63: Sediment organic content and grain size composition (averages per site) at the 2024–25 northern survey sites with cockle strata. Sediment grain size fractions are defined as fines (silt and clay) ≤63 µm, very fine sand >63 µm, fine sand >125 µm, medium sand >250 µm, coarse sand >500 µm, and gravel >2000 µm. The sites were Cockle Bay, Kawakawa Bay (West), Mill Bay, Ōhiwa Harbour, Ōkahu Bay, Okoromai, Otūmoetai (Tauranga Harbour), Pataua Estuary, Waiotahe Estuary, Whitianga Harbour, and Whangapoua Harbour.

4.4 Geostatistical model predictions of cockle density

Ten of the 2024–25 survey sites with cockle populations have been surveyed multiple times; the exception was Ōkahu Bay, which was added to the northern monitoring series for the first time. For the cockle populations with multiple assessments, geostatistical modelling allowed predictions of cockle densities in space and time (see Appendix C, Figures C-1 to C-10). These predictions provide visual assessments of high-density cockle areas at the survey sites, referred to as "hotspots", including changes over time.

For a number of sites, these hotspots were mostly determined by the predicted densities of large cockles, evident at Cockle Bay, Ōhiwa Harbour, Okoromai Bay, Pataua Estuary, Waiotahe Estuary, and Whangapoua Harbour. Across the spatial extent of the cockle strata, density hotspots were localised in particular areas. At two of the sites, Ōhiwa Harbour and Waiotahe Estuary, hotspots did not persist over time, corresponding to the disappearance of large cockles at both sites.

At Mill Bay, Otūmoetai (Tauranga Harbour), and Whitianga Harbour, extensive high-density areas were consistently linked to the predicted densities of all cockles, whereas large cockles were generally scarce throughout the survey series. At Otūmoetai (Tauranga Harbour), there was a notable reduction in the spatial extent of high-density cockle areas over time, whereas the opposite pattern was evident at Whitianga Harbour. At this latter site, the hotspot of total cockles extended throughout most of the cockle stratum in the current survey, signifying a marked extension compared with preceding density predictions.

At Kawakawa Bay (West), cockle hotspots were highly localised, and showed a general reduction in spatial extent over time, while remaining in the north-eastern area of the bay.

5. DISCUSSION

The 2024–25 survey sites were spread across the northern North Island regions, with Pataua Estuary in Northland; Cockle Bay, Kawakawa Bay (West), Mill Bay, Ōkahu and Okoromai bays in Auckland and its wider region; Ōhiwa Harbour, Otūmoetai (Tauranga Harbour), and Waiotahe Estuary in Bay of Plenty; and Whangapoua and Whitianga harbours in Waikato. Excepting Ōkahu Bay which was surveyed for the first time as part of this monitoring series, all sites have had multiple bivalve assessments since 1999–2000. Recent surveys at most sites have been biannual, with the overall sampling frequency ranging from five assessments (at Whitianga Harbour) to 14 assessments (at Okoromai Bay); most sites had a minimum of ten bivalve assessments throughout the survey series.

In addition to providing regular updates on the current status of the northern cockle and pipi populations, the frequent assessments allow examination of temporal population trends at each site. These time-series data highlighted notable population fluctations at some sites, which appeared to be determined by recruitment events. For cockles, the proportion of recruits was relatively high (i.e., exceeding 20% of the total population) at Kawakawa Bay (West), Ōhiwa Harbour, Ōkahu Bay, Okoromai Bay, Otūmoetai (Tauranga Harbour), Pataua and Waiotahe estuaries, and Whitianga Harbour. At Ōkahu Bay and Whitianga Harbour, over 80% of the population consisted of recruits. For pipi, there was a high proportion of recruits at Ōhiwa Harbour, Pataua Estuary, and Waiotahe Estuary.

Significant recruitment of cockles and pipi was also documented in the preceding bivalve survey which assessed bivalves at other northern sites (Berkenbusch & Hill-Moana 2024). These previous survey data indicated strong cockle recruitment across several sites in different northern regions, whereas pipi recruitment was particularly high at the Northland sites surveyed.

Although regular recruitment is crucial for maintaining the resident bivalve populations, recruits are vulnerable to high post-settlement mortality and dispersal, so may not persist at notable numbers within the benthic populations. This aspect is particularly relevant at Ōkahu Bay and Whitianga Harbour, where the cockle population largely consisted of recruits, with over 80% of all individuals in this size class.

In addition to the general vulnerability of recruits, recent research highlighted the importance of adult cockles (defined as individuals at 38 to 50 mm shell length) for providing predation refuge for post-settlement juveniles (Fenton et al. 2024). The findings from this study suggested that a particular density threshold of adult individuals may be required to enhance juvenile survival and retention, necessary to maintain the resident population.

In spite of the precariousness of strong recruitment leading to lasting population increases, most of the current populations included a significant cohort of medium-sized individuals. At these sites, length-frequency data from the three most recent surveys indicated relatively stable bivalve populations of either or both species. At several of these sites, the medium size class of cockles included notable numbers of individuals exceeding the 18-mm shell length indicating maturity; examples include Cockle Bay, Ōhiwa Harbour, Okoromai Bay, Pataua Estuary, and Whangapoua Harbour. Similarly, several sites included medium-sized pipi at shell lengths that exceeded the 40-mm maturity threshold, most notably the pipi populations at Otūmoetai (Tauranga Harbour) and Whitianga Harbour.

Considering the collection of cockles and pipi in non-commercial fisheries, there is a general expectation that the large individuals are preferably taken, i.e., cockles greater than 30 mm shell length, and pipi exceeding 50 mm shell length (Fisheries New Zealand 2024a, 2024b). Nevertheless, without detailed fishing data, the quantities and size distributions of cockles and pipi taken in recreational and customary fisheries remain unknown. Although the national panel surveys of marine recreational fishers provide some information pertaining to the take of both species in recreational fisheries (e.g., see Heinemann & Gray 2024), the small sample sizes limit the value of the data, and the latter do not contain size information.

Cockle Bay was the only site in the current survey that had fishery restrictions in place, prohibiting the take of cockles. The current population estimates were the highest values in the survey series, signifying more than double the population estimates of 2022–23. This increase may have been caused by significant recruitment in the interim period between the two most recent surveys, with some of the recruits growing into the medium size class. At the same time, large cockles underwent a marked decline, leading to a notable reduction in their contribution to the total population.

In addition, the spatial distribution of cockles at this site has become increasingly limited compared with previous surveys (e.g., in 2019–20; see Berkenbusch & Neubauer 2020). In 2024–25, most of the population was restricted to the upper to mid-intertidal zone of the sampling extent. Sediment samples taken in this area were characterised by high proportions of sediment fines, indicating some degradation of the benthic habitat. This degradation may impact on cockles in the future, and may have already affected large cockles, which are particularly susceptible to high amounts of resuspended sediment (caused by elevated levels of sediment fines).

At Ōhiwa Harbour, there were considerable changes in the pipi beds between the two most recent surveys, likely related to significant movement of sand following severe cyclone Gabrielle in 2023. This sand movement was evident in the main channel where a previously-surveyed pipi bed had become inaccessible in 2024–25 (and may have been buried); another pipi bed in a side channel close to the harbour entrance was buried in sand in 2022–23 (see Berkenbusch & Hill-Moana 2023), but started to become re-established (mostly through recruits) prior to the current survey.

At Waiotahe Estuary, consistent recruitment of cockles and pipi in recent surveys has led to considerable increases in the population estimates for both species. Nevertheless, their populations remain small compared with earlier estimates (i.e., in 2013–14 and 2016–17), following their marked declines in 2018–19. This estuary has been exposed to significant degradation from landuse impacts, including high faecal (*Escherichia coli*) contamination in 2017 (Bay of Plenty Regional Council 2021). Landuse and contamination impacts continue to affect the estuary's state and condition, for example, leading to high mud content (48 to 60%) in the upper estuary (see Land and Water Aotearoa, https://www.lawa.org.nz); however, the current population estimates reflect signs of recovery of the cockle and pipi beds in the estuary.

The present survey was the first bivalve assessment at Ōkahu Bay. Although pipi were recorded in other surveys and research studies, the current sampling only recorded cockles. In addition to predominantly consisting of recruits, the cockle population was largely confined to a small area in the north-eastern part of the bay. The reason for this spatial (recruitment) pattern is unknown, but it increases the vulnerability of newly-settled recruits. Subsequent surveys at this site will help elucidate the population dynamics of cockle in the bay, including their persistence following the strong recruitment event recorded in the current assessment.

6. FULFILMENT OF BROADER OUTCOMES

As required under Government Procurement rules,[3] Fisheries New Zealand considered broader outcomes (secondary benefits such as environmental, social, economic or cultural benefits) that would be generated by this project.

Provided below are the broader outcomes specific to this project.

- The findings from the surveys support local iwi and hapū in their efforts to look after kaimoana species and coastal environments. We actively engage with iwi contacts to provide information about the survey, with subsequent updates about the survey outcomes.
- The project supports local businesses across the northern North Island region, including rental car companies, accommodation providers, and food stores. As the timing of the field surveys is outside of holiday periods, this support complements the main tourism income for many of these businesses, including in relatively remote locations.
- As part of this project, we are purposefully transferring knowledge and responsibility from the experienced project lead to the early-career scientist who is part of the Dragonfly project team. This transfer has been planned as a gradual process, allowing the development of skills and expertise over the course of the project, with ongoing support from the senior project lead. This aspect is also relevant in the context of supporting a Māori graduate in their professional development, and expanding their research skills towards leading fisheries research (and other) projects in the future.
- The fixed-term recruitment of staff members for the field surveys provides postgraduate students and recent graduates in relevant earth science domains with practical research and work experience. In addition to expanding their skillset, this work experience also provides an income opportunity over the summer months.
- Both project scientists are female, and recruitment to the survey team is open to candidates from a range of ethnic backgrounds and gender identification. Past survey teams have reflected this diversity, and we continue our inclusive approach regarding all aspects of this project.
- One of the project scientists is affiliated to hapū and iwi of Waikato-Tainui, Rongowhakaata and Te Aitanga a Mahaki. For her, being involved in this project builds stronger connections with tangata whenua around the motu and enables her to exercise kaitiakitanga of the taiao and taonga species.
- At a number of beaches, the bivalve surveys are important for resident communities, iwi, and hapū, where these coastal environments are an intrinsic part of cultural identity and wellbeing. To support this aspect, we endeavour to engage with local communities through their contacts, informing them of the surveys and the survey outcomes. This engagement also includes regional councils and unitary authorities that manage coastal environments and resources on behalf of their residents.

[3] https://www.procurement.govt.nz/principles-charter-and-rules/government-procurement-rules/planning-your-procurement/broader-outcomes/

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Aerial imagery data were sourced from the LINZ Data Service. These data are licensed for reuse under the CC BY 4.0 licence.

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APPENDIX A: Sampling dates and extent of northern North Island bivalve surveys

Table A-1: Sampling years (coloured blue) for sites included in the northern North Island bivalve surveys since 1999–2000. Fishing years are referred to by the latter year (e.g., 1999–2000 is shown as 2000).

Survey site	Year																						
	2000	2001	2002	2003	2004	2005	2006	2007	2010	2011	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Aotea Harbour							X		X				X		X		X		X		X		
Bowentown Beach			X							X	X			X		X		X		X		X	
Cheltenham Beach														X									
Clarks Beach						X																	
Cockle Bay									X	X	X	X		X		X		X		X	X		X
Cornwallis Wharf			X																				
Eastern Beach			X										X		X			X			X		
Grahams Beach								X		X	X	X			X			X			X		
Hokianga Harbour																	X				X		
Howick Harbour							X																
Kawakawa Bay (West)						X		X					X		X		X		X		X		X
Little Waihi Estuary		X		X	X	X		X	X		X	X		X		X		X		X		X	
Mangawhai Harbour	X	X	X	X	X					X			X		X		X			X		X	
Marokopa Estuary							X			X				X									
Marsden Bank									X		X	X				X				X		X	
Mill Bay	X	X	X		X	X	X		X				X			X	X			X			X
Ngunguru Estuary					X	X				X			X		X		X			X		X	
Ōhiwa Harbour			X				X	X	X		X			X			X		X		X		X
Ōkahu Bay																							X
Okoromai Bay	X		X	X	X	X		X	X		X	X		X		X			X		X		X
Otūmoetai		X		X			X	X	X				X		X		X		X		X		X
Papamoa Beach	X																						
Pataua Estuary				X	X		X					X		X		X		X		X	X		X
Raglan Estuary	X	X		X	X				X		X		X			X		X		X		X	
Ruakākā Estuary								X		X			X		X		X			X		X	
Tairua Harbour	X	X	X	X			X	X		X		X		X		X		X		X		X	
Te Haumi Bay	X	X	X	X				X	X		X		X		X		X			X		X	
TeMata Bay																			X	X		X	
Umupuia Beach	X	X	X	X	X	X	X	X	X	X	X	X		X		X		X		X		X	
Waikawau Beach	X	X				X	X					X											
Waiotahe Estuary				X	X	X	X		X			X			X			X			X		X
Whangamatā Harbour	X	X	X	X	X	X		X		X			X		X		X		X		X		
Whangapoua Harbour				X	X	X	X			X			X		X		X		X		X		X
Whangateau Harbour			X		X	X		X	X	X	X	X		X		X		X		X		X	
Whitianga Harbour											X			X		X		X		X			X

Table A-2: Sampling dates and size of the sampling extent for sites included in the northern North Island bivalve surveys since 1999–2000, including the present survey in 2024–25. Surveys are ordered by site and year.

Survey site	Year	Sampling dates	Sampling extent (ha)	Project
Aotea Harbour	2005–06	17 Jan–18 Jan	9.60	AKI2005-01
	2009–10	26 Mar–13 Jul	28.10	AKI2009-01
	2014–15	19 Feb	19.46	AKI2014-01
	2016–17	9 Feb	19.46	AKI2016-01
	2018–19	3 Feb	19.46	AKI2018-01
	2020–21	26 Feb	19.40	AKI2018-01
	2022–23	6 Feb	19.40	AKI2021-01
Bowentown Beach	2001–02	26 Apr–25 May	1.58	AKI2001-01
	2010–11	18 Mar	1.58	AKI2010-01
	2012–13	8 Feb	1.58	AKI2012-01
	2015–16	20 Jan	1.50	AKI2015-01
	2017–18	22 Feb	1.50	AKI2017-01
	2019–20	25 Feb	1.50	AKI2018-01
	2021–22	21 Feb–22 Feb	1.50	AKI2021-01
	2023–24	26 Feb	1.50	AKI2021-01
Cheltenham Beach	2015–16	14 Jan	31.92	AKI2015-01
Clarks Beach	2004–05	3 Feb–24 Feb	144.71	AKI2004-01
Cockle Bay	2009–10	16 Feb	16.00	AKI2009-01
	2010–11	5 May	16.00	AKI2010-01
	2012–13	31 Jan	16.00	AKI2012-01
	2013–14	29 Mar	15.77	AKI2013-01
	2015–16	18 Jan	15.77	AKI2015-01
	2017–18	27 Jan–28 Jan	15.77	AKI2017-01
	2019–20	15 Feb	15.77	AKI2018-01
	2021–22	17 Feb	15.59	AKI2021-01
	2022–23	11 Feb	15.77	AKI2021-01
	2024–25	3 Feb	15.77	AKI2024-01
Cornwallis Wharf	2001–02	26 Mar–20 Apr	2.65	AKI2001-01
Eastern Beach	2001–02	14 Mar–16 Apr	43.38	AKI2001-01
	2014–15	27 Jan–18 Feb	41.42	AKI2014-01
	2016–17	16 Feb	22.58	AKI2016-01
	2019–20	10 Feb	22.58	AKI2018-01
	2022–23	9 Mar	22.39	AKI2021-01
Grahams Beach	2006–07	20 Apr	24.75	AKI2006-01
	2010–11	17 May	25.15	AKI2010-01
	2012–13	11 Mar	20.06	AKI2012-01
	2013–14	28 Mar	26.76	AKI2013-01
	2016–17	10 Feb–28 Feb	26.78	AKI2016-01
	2019–20	9 Feb	26.78	AKI2018-01
	2022–23	8 Mar	26.46	AKI2021-01
Hokianga Harbour	2018–19	20 Feb	10.07	AKI2018-01
	2022–23	10 Feb–11 Feb	10.07	AKI2021-01
Howick Harbour	2005–06	23 Dec–24 Jan	6.90	AKI2005-01
Kawakawa Bay (West)	2004–05	5 Feb–8 Apr	60.37	AKI2004-01
	2006–07	19 Apr	62.94	AKI2006-01
	2014–15	17 Feb–25 Feb	60.90	AKI2014-01
	2016–17	27 Feb	60.89	AKI2016-01
	2018–19	4 Feb–25 Feb	60.89	AKI2018-01
	2020–21	10 Feb	60.89	AKI2018-01
	2022–23	10 Mar	60.89	AKI2021-01
	2024–25	12 Feb	60.91	AKI2024-01
Little Waihi Estuary	2000–01	21 Mar–31 Mar	3.00	AKI2000-01

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Table A-2 – *Continued from previous page*

Survey site	Year	Sampling dates	Sampling extent (ha)	Project
	2002–03	30 Jan–1 Feb	3.00	AKI2002-01
	2003–04	7 Jan–19 Jan	3.12	AKI2003-01
	2004–05	14 Jan–15 Jan	3.75	AKI2004-01
	2006–07	15 Jun–28 Jun	3.16	AKI2006-01
	2009–10	2 Mar	13.92	AKI2009-01
	2012–13	10 Feb	15.42	AKI2012-01
	2013–14	19 Mar–20 Mar	17.09	AKI2013-01
	2015–16	8 Feb–11 Feb	18.38	AKI2015-01
	2017–18	23 Feb–24 Feb	18.38	AKI2017-01
	2019–20	28 Feb–29 Feb	16.76	AKI2018-01
	2021–22	19 Feb–20 Feb	16.63	AKI2021-01
	2023–24	27 Feb–28 Feb	16.63	AKI2021-01
Mangawhai Harbour	1999–00	23 Mar–30 Jun	9.40	AKI1999-01
	2000–01	29 Jan–31 Jan	8.40	AKI2000-01
	2001–02	15 Mar–14 Apr	8.40	AKI2001-01
	2002–03	1 Jan–31 Jan	8.40	AKI2002-01
	2003–04	1 Jan–31 Jan	8.40	AKI2003-01
	2010–11	24 Mar–15 Apr	9.00	AKI2010-01
	2014–15	21 Jan–22 Jan	8.55	AKI2014-01
	2016–17	11 Feb–16 Feb	8.59	AKI2016-01
	2018–19	18 Jan–19 Jan	7.23	AKI2018-01
	2021–22	1 Feb–2 Feb	7.17	AKI2018-01
	2023–24	10 Feb–16 Feb	7.17	AKI2021-01
Marokopa Estuary	2005–06	18 Feb–20 Feb	2.35	AKI2005-01
	2010–11	16 May	2.35	AKI2010-01
	2015–16	12 Feb–13 Feb	2.58	AKI2015-01
Marsden Bank	2009–10	13 Nov	11.51	IPA2009-12
	2012–13	12 Dec	6.31	AKI2012-01
	2013–14	2 Feb	15.43	AKI2013-01
	2017–18	4 Feb–5 Feb	0.85	AKI2017-01
	2021–22	5 Feb	0.87	AKI2021-01
	2023–24	14 Feb	0.37	AKI2021-01
Mill Bay	1999–00	4 May–30 Jun	4.60	AKI1999-01
	2000–01	20 Feb–23 Feb	4.80	AKI2000-01
	2001–02	20 Mar–22 Apr	4.50	AKI2001-01
	2003–04	26 Jan–28 Jan	4.50	AKI2003-01
	2004–05	24 Dec–24 Jan	4.50	AKI2004-01
	2005–06	20 Dec–24 Dec	4.50	AKI2005-01
	2009–10	13 May	4.95	AKI2009-01
	2014–15	26 Feb	4.88	AKI2014-01
	2017–18	30 Jan–31 Jan	4.86	AKI2017-01
	2018–19	26 Jan	4.86	AKI2018-01
	2021–22	16 Feb	4.84	AKI2021-01
	2024–25	29 Jan	4.88	AKI2024-01
Ngunguru Estuary	2003–04	6 Mar–7 Mar	1.70	AKI2003-01
	2004–05	6 Feb–7 Feb	1.80	AKI2004-01
	2010–11	23 Mar	1.80	AKI2010-01
	2014–15	23 Jan–24 Jan	5.46	AKI2014-01
	2016–17	13 Feb–15 Feb	6.28	AKI2016-01
	2018–19	22 Feb	6.47	AKI2018-01
	2021–22	3 Feb	6.35	AKI2018-01
	2023–24	11 Feb–14 Feb	6.01	AKI2021-01
Ōhiwa Harbour	2001–02	9 Apr–11 Apr	2.25	AKI2001-01
	2005–06	25 Feb–26 Feb	2.70	AKI2005-01

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Table A-2 – *Continued from previous page*

Survey site	Year	Sampling dates	Sampling extent (ha)	Project
	2006–07	13 Jun–29 Jun	5.70	AKI2006-01
	2009–10	3 Mar	2.10	AKI2009-01
	2012–13	9 Feb–15 Mar	2.63	AKI2012-01
	2015–16	9 Feb–10 Feb	4.58	AKI2015-01
	2018–19	1 Feb–2 Feb	2.54	AKI2018-01
	2020–21	16 Feb–19 Feb	2.65	AKI2018-01
	2022–23	15 Mar–16 Mar	1.87	AKI2021-01
	2024–25	8 Feb–10 Feb	2.18	AKI2024-01
Ōkahu Bay	2024–25	2 Feb	6.01	AKI2024-01
Okoromai Bay	1999–00	19 Apr–24 Apr	20.00	AKI1999-01
	2001–02	8 Apr–12 Apr	24.00	AKI2001-01
	2002–03	26 Dec–29 Dec	20.00	AKI2002-01
	2003–04	17 Mar–20 Mar	20.00	AKI2003-01
	2004–05	15 Jan–16 Jan	20.00	AKI2004-01
	2006–07	20 Mar	20.00	AKI2006-01
	2009–10	17 Feb	20.00	AKI2009-01
	2012–13	30 Jan	20.00	AKI2012-01
	2013–14	31 Mar	19.84	AKI2013-01
	2015–16	11 Jan	19.84	AKI2015-01
	2017–18	6 Feb	19.83	AKI2017-01
	2020–21	27 Feb	19.83	AKI2018-01
	2022–23	7 Feb	19.83	AKI2021-01
	2024–25	30 Jan	19.84	AKI2024-01
Otūmoetai	2000–01	27 Mar–2 Apr	5.60	AKI2000-01
	2002–03	3 Mar–5 Mar	5.60	AKI2002-01
	2005–06	15 Feb–28 Feb	4.60	AKI2005-01
	2006–07	13 Jun–14 Jun	4.60	AKI2006-01
	2009–10	1 Mar–17 Mar	5.60	AKI2009-01
	2014–15	31 Jan–1 Feb	7.67	AKI2014-01
	2016–17	20 Feb–21 Feb	8.09	AKI2016-01
	2018–19	30 Jan–31 Jan	8.06	AKI2018-01
	2020–21	17 Feb	6.52	AKI2018-01
	2022–23	14 Mar	4.44	AKI2021-01
	2024–25	7 Feb–11 Feb	4.48	AKI2024-01
Papamoa Beach	1999–00	1 May–3 May	2.00	AKI1999-01
Pataua Estuary	2002–03	4 Mar–28 Mar	10.65	AKI2002-01
	2003–04	14 Feb–16 Feb	10.45	AKI2003-01
	2005–06	14 Feb–16 Feb	10.45	AKI2005-01
	2013–14	3 Feb–6 Feb	26.30	AKI2013-01
	2015–16	12 Jan–13 Jan	27.78	AKI2015-01
	2017–18	3 Feb–4 Feb	27.71	AKI2017-01
	2019–20	13 Feb	27.92	AKI2018-01
	2021–22	6 Feb–7 Feb	27.88	AKI2021-01
	2022–23	8 Feb–9 Feb	28.18	AKI2021-01
	2024–25	31 Jan–1 Feb	28.34	AKI2024-01
Raglan Estuary	1999–00	26 May–30 Jun	10.10	AKI1999-01
	2000–01	13 Feb–10 Mar	10.04	AKI2000-01
	2002–03	13 Jan–16 Jan	8.24	AKI2002-01
	2003–04	14 Jan–16 Jan	8.24	AKI2003-01
	2009–10	26 Apr	9.20	AKI2009-01
	2012–13	11 Jan	8.24	AKI2012-01
	2014–15	20 Feb–23 Feb	7.24	AKI2014-01
	2017–18	29 Jan	7.24	AKI2017-01
	2019–20	8 Feb	7.38	AKI2018-01

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Table A-2 – *Continued from previous page*

Survey site	Year	Sampling dates	Sampling extent (ha)	Project
	2021–22	30 Jan	7.32	AKI2021-01
	2023–24	22 Feb	7.47	AKI2021-01
Ruakākā Estuary	2006–07	21 Mar	7.00	AKI2006-01
	2010–11	22 Mar	11.01	AKI2010-01
	2014–15	25 Jan–26 Jan	6.51	AKI2014-01
	2016–17	14 Feb	5.61	AKI2016-01
	2018–19	23 Feb	3.93	AKI2018-01
	2021–22	5 Feb–6 Feb	4.09	AKI2018-01
	2023–24	13 Feb	2.07	AKI2021-01
Tairua Harbour	1999–00	1 Apr–1 May	3.70	AKI1999-01
	2000–01	15 Feb–16 Feb	3.90	AKI2000-01
	2001–02	23 May–24 May	3.90	AKI2001-01
	2002–03	23 Feb–28 Mar	3.90	AKI2002-01
	2005–06	14 Jan–15 Jan	3.90	AKI2005-01
	2006–07	3 May–1 Aug	4.80	AKI2006-01
	2010–11	20 Apr	5.80	AKI2010-01
	2013–14	13 Mar–22 Mar	9.38	AKI2013-01
	2015–16	6 Feb–7 Feb	8.17	AKI2015-01
	2017–18	20 Feb–22 Feb	6.48	AKI2017-01
	2019–20	23 Feb	6.12	AKI2018-01
	2021–22	23 Feb	5.95	AKI2021-01
	2023–24	25 Feb	5.45	AKI2021-01
Te Haumi Bay	1999–00	7 Mar–30 Mar	10.00	AKI1999-01
	2000–01	12 Mar	13.53	AKI2000-01
	2000–01	15 Jan–26 Jan	9.90	AKI2000-01
	2001–02	15 Mar–15 Apr	9.90	AKI2001-01
	2002–03	21 Jan–22 Apr	9.90	AKI2002-01
	2006–07	22 Mar	9.81	AKI2006-01
	2009–10	18 Feb	12.06	AKI2009-01
	2012–13	13 Dec	12.06	AKI2012-01
	2014–15	24 Jan–26 Jan	12.78	AKI2014-01
	2016–17	12 Feb	12.77	AKI2016-01
	2018–19	21 Feb–24 Feb	11.91	AKI2018-01
	2021–22	4 Feb	10.64	AKI2018-01
	2023–24	12 Feb	10.04	AKI2021-01
Te Mata Bay	2020–21	14 Feb–20 Feb	0.97	AKI2018-01
	2021–22	24 Feb–26 Feb	0.68	AKI2021-01
	2023–24	23 Feb–24 Feb	0.73	AKI2021-01
Umupuia Beach	1999–00	1 Apr–12 Apr	25.00	AKI1999-01
	2000–01	15 Feb–16 Feb	36.00	AKI2000-01
	2001–02	28 Mar–12 Apr	36.00	AKI2001-01
	2002–03	28 Dec–2 Jan	36.00	AKI2002-01
	2003–04	25 Mar–28 Mar	36.00	AKI2003-01
	2004–05	22 Jan–23 Jan	36.00	AKI2004-01
	2005–06	28 Jan–29 Jan	36.00	AKI2005-01
	2006–07	18 Apr	36.00	AKI2006-01
	2009–10	15 Feb	36.00	AKI2009-01
	2010–11	4 May	36.00	AKI2010-01
	2012–13	13 Mar	36.00	AKI2012-01
	2013–14	30 Mar–1 Apr	33.86	AKI2013-01
	2015–16	18 Jan–19 Jan	33.90	AKI2015-01
	2017–18	28 Jan	33.43	AKI2017-01
	2019–20	14 Feb	33.43	AKI2018-01
	2021–22	18 Feb	32.72	AKI2021-01

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Table A-2 – *Continued from previous page*

Survey site	Year	Sampling dates	Sampling extent (ha)	Project
	2023–24	9 Feb	33.90	AKI2021-01
Waikawau Beach	1999–00	20 May–30 Jun	2.90	AKI1999-01
	2000–01	24 Feb–15 May	2.70	AKI2000-01
	2004–05	18 Jan–10 Mar	3.10	AKI2004-01
	2005–06	15 Feb–27 Feb	3.10	AKI2005-01
	2013–14	21 Mar		AKI2013-01
Waiotahe Estuary	2002–03	7 Feb–10 Feb	8.50	AKI2002-01
	2003–04	21 Jan–24 Jan	8.50	AKI2003-01
	2004–05	21 Jan–25 Jan	9.50	AKI2004-01
	2005–06	10 Feb–12 Feb	9.50	AKI2005-01
	2009–10	4 Mar	9.50	AKI2009-01
	2013–14	17 Mar–20 Mar	11.23	AKI2013-01
	2016–17	22 Feb	11.98	AKI2016-01
	2019–20	26 Feb–27 Feb	11.98	AKI2018-01
	2022–23	16 Mar–17 Mar	11.98	AKI2021-01
	2024–25	9 Feb–10 Feb	11.75	AKI2024-01
Whangamatā Harbour	1999–00	20 May–29 May	5.48	AKI1999-01
	2000–01	15 Feb–16 Feb	5.48	AKI2000-01
	2001–02	9 May–26 May	5.48	AKI2001-01
	2002–03	9 Mar–28 Mar	5.48	AKI2002-01
	2003–04	1 Jan–31 Jan	5.48	AKI2003-01
	2004–05	6 Feb–8 Feb	5.48	AKI2004-01
	2006–07	2 May–2 Aug	24.61	AKI2006-01
	2010–11	19 Apr	5.89	AKI2010-01
	2014–15	28 Jan–30 Jan	7.62	AKI2014-01
	2016–17	24 Feb–26 Feb	7.71	AKI2016-01
	2018–19	29 Jan–30 Jan	7.55	AKI2018-01
	2020–21	11 Feb	8.18	AKI2018-01
	2022–23	11 Mar	8.09	AKI2021-01
Whangapoua Harbour	2002–03	30 Mar–6 Apr	1.66	AKI2002-01
	2003–04	1 Feb–3 Feb	5.20	AKI2003-01
	2004–05	8 Mar–10 Mar	5.20	AKI2004-01
	2005–06	8 Mar–10 Mar	5.20	AKI2005-01
	2010–11	21 Apr	5.20	AKI2010-01
	2014–15	24 Feb–25 Feb	6.32	AKI2014-01
	2016–17	25 Feb–26 Feb	6.32	AKI2016-01
	2018–19	27 Jan–28 Jan	5.28	AKI2018-01
	2020–21	12 Feb–13 Feb	5.27	AKI2018-01
	2022–23	12 Mar–13 Mar	5.07	AKI2021-01
	2024–25	4 Feb–5 Feb	5.31	AKI2024-01
Whangateau Harbour	2001–02	7 Apr–22 May	64.19	AKI2001-01
	2003–04	17 Dec–2 Mar	64.15	AKI2003-01
	2004–05	2 Feb–26 Mar	64.15	AKI2004-01
	2006–07	19 Mar–2 May	64.15	AKI2006-01
	2009–10	18 Mar–14 Jul	64.51	AKI2009-01
	2010–11	19 May–20 May	64.15	AKI2010-01
	2012–13	14 Dec–17 Dec	64.20	AKI2012-01
	2013–14	29 Jan–6 Feb	110.91	AKI2013-01
	2015–16	15 Jan–17 Jan	110.71	AKI2015-01
	2017–18	1 Feb–2 Feb	110.91	AKI2017-01
	2019–20	11 Feb	110.88	AKI2018-01
	2021–22	31 Jan–1 Feb	111.20	AKI2021-01
	2023–24	15 Feb–16 Feb	111.32	AKI2021-01
Whitianga Harbour	2012–13	7 Feb	7.08	AKI2012-01

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Table A-2 – *Continued from previous page*

Survey site	Year	Sampling dates	Sampling extent (ha)	Project
	2015–16	5 Feb	6.10	AKI2015-01
	2017–18	19 Feb–21 Feb	5.81	AKI2017-01
	2019–20	24 Feb	5.44	AKI2018-01
	2021–22	22 Feb–24 Feb	5.43	AKI2021-01
	2024–25	6 Feb	4.95	AKI2024-01

APPENDIX B: Sediment properties

Table B-1: Sediment organic content and sediment grain size distributions at sites surveyed in 2024–25 as part of the northern North Island bivalve surveys. Position of the sampling points is indicated in decimal degrees (World Geodetic System 1984). Sediment grain size fractions are defined as fines (silt and clay) ≤63 µm, very fine sand (VFS) >63 µm, fine sand (FS) >125 µm, medium sand (MS) >250 µm, coarse sand (CS) >500 µm, and gravel >2000 µm.

						Sediment grain size fraction (%)					
Survey site	Stratum	Sample	Latitude	Longitude	Organic content (%)	Fines	VFS	FS	MS	CS	Gravel
Cockle Bay	A	1	-36.90021	174.95399	2.9	22.2	36.1	33.1	6.0	2.7	0.0
	A	2	-36.90014	174.95325	1.6	3.1	36.6	52.2	5.6	2.6	0.0
	A	3	-36.89992	174.95283	2.9	69.7	22.6	7.0	0.7	0.0	0.0
	A	4	-36.89939	174.95263	1.8	8.7	32.7	40.3	10.4	7.9	0.0
	A	5	-36.89910	174.95227	5.4	54.0	17.1	17.6	5.8	5.5	0.0
	A	6	-36.89873	174.95239	3.1	27.0	38.8	25.8	5.6	2.8	0.0
	A	7	-36.89856	174.95210	2.5	15.7	45.0	30.9	6.3	1.8	0.3
	B	9	-36.89775	174.95280	1.7	3.6	27.6	66.5	1.8	0.5	0.0
	B	1	-36.90084	174.95455	1.8	5.2	26.3	58.9	7.3	2.3	0.0
	B	2	-36.89952	174.95493	1.3	3.5	33.6	55.9	4.2	2.8	0.0
	B	3	-36.89881	174.95369	1.4	3.9	30.1	55.9	6.5	3.6	0.0
	B	4	-36.89873	174.95492	1.4	3.6	26.5	62.6	5.8	1.6	0.0
	B	5	-36.89868	174.95731	1.3	3.0	30.9	65.5	0.5	0.1	0.0
	B	6	-36.89859	174.95323	2.2	18.9	35.5	38.0	4.8	2.7	0.0
	B	7	-36.89820	174.95364	1.8	3.9	27.7	58.1	7.6	2.7	0.0
	B	8	-36.89806	174.95291	2.0	5.9	36.3	46.8	6.0	5.0	0.0
	C	1	-36.89760	174.95476	1.7	2.9	29.2	64.2	3.1	0.5	0.0
	C	2	-36.89759	174.95445	1.3	4.1	24.8	66.7	4.1	0.2	0.0
	C	3	-36.89749	174.95460	1.4	3.2	31.0	61.8	3.9	0.2	0.0
	C	4	-36.89737	174.95334	1.3	2.7	31.2	63.5	2.5	0.1	0.0
	C	5	-36.89734	174.95367	1.0	5.1	21.9	67.0	4.7	1.4	0.0
	C	6	-36.89727	174.95443	1.7	3.8	27.0	64.6	4.1	0.5	0.0
	C	7	-36.89720	174.95344	1.3	3.0	22.8	70.9	3.2	0.1	0.0
	C	8	-36.89699	174.95398	1.1	2.9	24.4	69.7	2.8	0.2	0.0

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Table B-1 – *Continued from previous page*

Survey site	Stratum	Sample	Latitude	Longitude	Organic matter (%)	Sediment grain size fraction (%)					
						Fines	VFS	FS	MS	CS	Gravel
Kawakawa Bay	A	1	-36.94987	175.16187	1.8	6.5	30.1	28.1	8.9	10.4	15.9
	A	2	-36.94945	175.15640	1.9	11.4	42.2	26.6	8.9	5.7	5.2
	A	3	-36.94922	175.16340	1.7	9.5	17.8	28.7	12.2	9.2	22.6
	A	4	-36.94707	175.15619	2.0	6.5	29.4	63.1	0.8	0.3	0.0
	A	5	-36.94629	175.15650	1.1	0.9	22.9	75.5	0.6	0.0	0.0
	A	6	-36.94627	175.15131	2.9	15.6	72.6	10.6	0.7	0.6	0.0
	A	7	-36.94572	175.15464	1.2	2.4	31.0	65.6	0.9	0.1	0.0
	A	8	-36.94443	175.15110	2.5	9.8	61.0	22.5	5.9	0.7	0.0
	B	1	-36.95051	175.15829	3.3	12.9	8.3	31.7	17.9	14.9	14.3
	B	2	-36.94889	175.16163	1.6	7.4	38.6	31.4	7.2	7.6	7.7
	B	3	-36.94865	175.16352	1.6	9.3	27.0	46.7	10.3	4.9	1.8
	B	4	-36.94814	175.15780	1.9	5.7	35.0	53.0	5.9	0.4	0.0
	B	5	-36.94805	175.15523	3.7	10.9	56.8	31.0	0.7	0.7	0.0
	B	6	-36.94789	175.16105	2.0	7.0	12.2	56.2	15.8	8.1	0.6
	B	7	-36.94571	175.15241	2.3	9.0	57.6	32.0	1.0	0.4	0.0
	B	8	-36.94456	175.15377	1.7	5.0	45.9	48.7	0.4	0.0	0.0
	B	9	-36.94417	175.15169	1.8	6.8	62.8	28.7	1.5	0.2	0.0
	C	1	-36.94321	175.15004	2.5	5.9	2.0	15.5	70.9	3.1	2.6
	C	2	-36.94308	175.15077	2.2	8.5	66.0	17.8	7.3	0.4	0.0
	C	3	-36.94252	175.15243	1.7	3.3	53.6	42.5	0.6	0.0	0.0
	C	4	-36.94221	175.15073	2.7	19.3	70.4	7.6	1.0	1.6	0.0
	C	5	-36.94211	175.15106	2.1	9.2	78.9	9.8	0.9	1.3	0.0
	C	6	-36.94148	175.15153	2.4	10.0	69.0	13.8	1.5	4.3	1.4
	C	7	-36.94123	175.15149	3.9	24.4	38.2	16.9	3.0	8.4	9.0
Mill Bay	A	1	-36.99522	174.60755	1.9	6.4	7.9	39.4	29.0	15.3	1.9
	A	2	-36.99504	174.60740	1.8	6.2	5.1	25.8	37.9	23.8	1.2
	A	3	-36.99496	174.60756	1.7	3.7	3.2	28.1	40.7	23.1	1.2
	A	4	-36.99494	174.60692	3.2	8.4	7.3	15.2	32.3	31.6	5.2

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Table B-1 – *Continued from previous page*

Survey site	Stratum	Sample	Latitude	Longitude	Organic matter (%)	Sediment grain size fraction (%) Fines	VFS	FS	MS	CS	Gravel
	A	5	-36.99475	174.60721	2.4	7.1	7.7	34.6	30.4	18.0	2.1
	A	6	-36.99455	174.60715	3.0	14.7	8.9	35.0	26.9	14.1	0.4
	A	7	-36.99439	174.60748	2.8	6.9	4.1	19.0	26.2	42.0	1.8
	A	8	-36.99425	174.60746	2.3	8.1	6.4	33.6	27.8	23.1	1.0
	B	1	-36.99465	174.60606	2.3	9.0	20.8	38.5	19.7	11.0	1.0
	B	2	-36.99455	174.60634	2.1	6.1	10.6	33.8	28.3	20.1	1.1
	B	3	-36.99436	174.60643	2.0	9.1	11.2	49.9	16.8	12.5	0.6
	B	4	-36.99409	174.60659	3.4	15.1	13.8	33.4	17.1	18.1	2.5
	B	5	-36.99402	174.60654	3.9	15.9	16.1	28.1	19.5	19.1	1.1
	B	6	-36.99400	174.60625	2.4	4.8	9.5	36.8	19.2	22.1	7.6
	B	7	-36.99367	174.60692	3.4	15.8	9.6	27.6	24.9	21.2	1.0
	B	8	-36.99351	174.60675	2.9	10.4	17.8	41.1	16.9	13.3	0.5
	C	1	-36.99417	174.60559	3.5	19.3	18.2	32.0	13.4	13.8	3.3
	C	2	-36.99408	174.60589	2.6	9.3	11.5	27.3	21.8	23.9	6.3
	C	3	-36.99369	174.60510	3.2	2.6	6.7	18.2	25.5	34.2	12.7
	C	4	-36.99354	174.60525	3.0	6.8	12.5	21.6	20.6	30.2	8.4
	C	5	-36.99345	174.60538	2.7	7.5	8.9	29.0	24.1	20.7	9.8
	C	6	-36.99336	174.60554	2.4	3.0	5.8	22.4	27.6	26.5	14.6
	C	7	-36.99334	174.60590	2.7	4.6	13.2	24.2	26.3	24.5	7.1
	C	8	-36.99316	174.60598	3.8	6.2	9.9	29.1	25.6	25.4	3.8
Ōhiwa Harbour	A	1	-38.00960	177.13948	2.5	11.7	22.4	64.1	1.3	0.5	0.0
	A	2	-38.00949	177.13946	2.7	11.0	20.5	67.2	1.0	0.3	0.0
	A	3	-38.00941	177.13961	2.0	5.0	5.1	88.3	1.5	0.1	0.0
	A	4	-38.00933	177.13966	2.0	5.8	5.7	87.1	1.3	0.1	0.0
	A	5	-38.00866	177.13951	1.7	1.3	3.6	93.3	1.7	0.1	0.0
	A	6	-38.00862	177.13927	2.1	8.4	14.1	76.4	0.9	0.2	0.0
	A	7	-38.00807	177.13911	2.1	3.9	6.7	85.0	3.1	1.3	0.0
	A	8	-38.00789	177.13942	1.7	2.0	3.4	87.2	6.7	0.6	0.0

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Table B-1 – *Continued from previous page*

Survey site	Stratum	Sample	Latitude	Longitude	Organic matter (%)	Sediment grain size fraction (%)					
						Fines	VFS	FS	MS	CS	Gravel
	A	9	-38.00768	177.13914	1.8	2.7	6.1	88.7	2.0	0.5	0.0
	A	10	-38.00724	177.13921	1.8	2.8	4.3	83.6	6.6	2.6	0.0
	A	11	-38.00695	177.13896	1.8	4.2	4.6	88.4	2.4	0.3	0.0
	A	12	-38.00651	177.13895	1.5	1.3	4.2	81.0	9.5	3.9	0.0
	B	1	-38.01485	177.13797	2.2	4.2	10.5	82.9	2.1	0.2	0.0
	B	2	-38.01471	177.13788	2.0	1.3	7.2	89.3	2.0	0.3	0.0
	B	3	-38.01456	177.13820	2.4	7.3	12.4	76.7	3.1	0.4	0.0
	B	4	-38.01448	177.13823	2.2	7.0	14.0	75.9	2.6	0.4	0.1
	B	5	-38.01429	177.13842	2.0	4.1	9.4	81.1	4.7	0.7	0.0
	B	6	-38.01401	177.13841	2.1	5.1	10.7	82.9	1.2	0.2	0.0
	B	7	-38.01380	177.13882	3.4	14.0	21.6	58.5	4.8	1.1	0.0
	B	8	-38.01360	177.13887	2.9	14.4	20.6	62.3	2.2	0.6	0.0
	B	9	-38.01346	177.13887	2.3	8.5	15.5	73.7	2.0	0.3	0.0
	B	10	-38.01344	177.13901	2.7	9.7	17.0	68.5	3.7	1.0	0.0
	B	11	-38.01336	177.13911	2.0	3.6	10.5	79.6	4.4	1.8	0.0
	B	12	-38.01330	177.13895	2.2	7.2	10.6	77.5	3.9	0.8	0.0
Ōkahu Bay	A	1	-36.85122	174.81361	1.7	5.4	61.0	31.9	1.2	0.5	0.0
	A	2	-36.85088	174.81342	2.4	7.6	48.0	31.4	3.9	2.0	7.0
	A	3	-36.85083	174.81573	2.4	9.1	33.8	41.6	10.7	4.8	0.0
	A	4	-36.85081	174.81583	2.7	15.6	32.6	35.6	9.8	6.4	0.0
	A	5	-36.85079	174.81482	2.0	7.9	33.2	38.4	14.7	5.8	0.0
	A	6	-36.85073	174.81323	1.7	5.6	42.8	50.6	0.8	0.2	0.0
	A	7	-36.85066	174.81422	2.0	6.6	37.6	47.4	7.0	1.3	0.0
	A	8	-36.85057	174.81388	1.8	4.8	52.0	36.3	6.0	0.9	0.0
	A	9	-36.85042	174.81608	2.1	6.8	17.9	33.9	24.3	16.9	0.2
	A	10	-36.85029	174.81427	1.5	3.8	33.8	60.3	2.0	0.1	0.0
	A	11	-36.85026	174.81584	1.9	7.0	32.9	40.3	14.0	5.8	0.0
	A	12	-36.85025	174.81536	2.4	6.2	37.6	51.8	4.2	0.2	0.0

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Table B-1 – *Continued from previous page*

Survey site	Stratum	Sample	Latitude	Longitude	Organic matter (%)	Sediment grain size fraction (%)					
						Fines	VFS	FS	MS	CS	Gravel
	A	13	-36.84998	174.81710	1.8	4.1	34.5	46.7	9.6	5.1	0.0
	A	14	-36.84991	174.81596	1.9	5.4	36.1	47.4	3.5	1.5	6.1
	A	15	-36.84987	174.81672	1.9	6.7	10.6	39.6	24.9	17.9	0.4
	A	16	-36.84977	174.81531	2.7	6.1	30.1	61.0	2.7	0.1	0.0
	A	17	-36.84975	174.81618	2.0	6.2	32.5	38.3	11.9	7.6	3.5
	A	18	-36.84961	174.81683	1.9	7.3	11.4	28.3	32.4	20.5	0.0
	A	19	-36.84951	174.81701	2.9	8.6	24.7	32.3	19.2	15.2	0.0
	A	20	-36.84932	174.81782	2.8	18.4	7.7	27.7	27.3	18.4	0.4
	A	21	-36.84915	174.81746	3.4	11.3	27.5	29.6	19.0	12.6	0.0
	A	22	-36.84878	174.81750	4.9	18.2	25.2	23.8	15.1	12.8	4.9
	A	23	-36.84875	174.81706	1.9	8.3	24.9	57.9	7.8	1.1	0.0
	A	24	-36.84860	174.81757	4.6	28.1	35.3	23.8	10.3	2.5	0.0
Okoromai Bay	A	1	-36.61094	174.80864	2.1	3.0	46.4	48.6	1.9	0.2	0.0
	A	2	-36.61057	174.81009	1.7	3.5	51.1	45.0	0.3	0.1	0.0
	A	3	-36.61048	174.80929	1.8	4.4	47.8	47.0	0.8	0.1	0.0
	A	4	-36.61017	174.81060	1.6	4.2	55.6	39.6	0.5	0.1	0.0
	A	5	-36.61003	174.80991	1.9	4.2	57.4	37.8	0.5	0.1	0.0
	A	6	-36.60987	174.80960	1.7	3.2	66.3	30.0	0.4	0.1	0.0
	A	7	-36.60976	174.80836	2.1	3.0	72.6	23.7	0.6	0.1	0.0
	A	8	-36.60945	174.80868	1.9	4.8	59.8	34.0	1.2	0.1	0.0
	B	1	-36.61258	174.80801	1.9	1.3	38.2	58.8	1.7	0.0	0.0
	B	2	-36.61207	174.80796	2.0	1.6	15.1	66.5	16.2	0.6	0.0
	B	3	-36.61202	174.80949	1.7	1.0	32.3	66.1	0.5	0.1	0.0
	B	4	-36.61187	174.80765	2.7	2.8	13.0	47.8	29.0	7.5	0.0
	B	5	-36.61171	174.80770	2.2	2.0	26.4	62.7	7.5	1.4	0.0
	B	6	-36.61157	174.80771	2.0	0.9	15.8	76.9	5.8	0.5	0.0
	B	7	-36.61114	174.81104	1.9	3.9	37.6	58.0	0.4	0.1	0.0
	B	8	-36.60991	174.81148	1.6	5.2	51.8	41.8	1.1	0.2	0.0

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Table B-1 – *Continued from previous page*

Survey site	Stratum	Sample	Latitude	Longitude	Organic matter (%)	Sediment grain size fraction (%)					
						Fines	VFS	FS	MS	CS	Gravel
	C	1	-36.60971	174.81180	2.0	5.0	58.0	36.0	0.8	0.1	0.0
	C	2	-36.60948	174.81099	1.7	7.4	54.5	36.8	1.1	0.3	0.0
	C	3	-36.60931	174.81031	1.9	6.6	60.1	32.5	0.6	0.1	0.0
	C	4	-36.60874	174.81219	2.3	11.0	64.7	21.9	1.9	0.5	0.0
	C	5	-36.60840	174.80920	2.1	9.5	73.0	16.9	0.5	0.2	0.0
	C	6	-36.60826	174.80885	2.2	6.6	36.3	46.9	9.6	0.6	0.0
	C	7	-36.60821	174.81168	2.9	7.2	12.4	40.3	16.8	18.5	4.7
	C	8	-36.60806	174.80949	2.0	10.4	74.6	14.3	0.4	0.2	0.0
Otūmoetai	A	1	-37.66462	176.15037	1.5	0.7	7.3	58.8	20.9	12.4	0.0
	A	2	-37.66457	176.15018	1.3	0.0	7.5	54.2	19.4	18.7	0.2
	A	3	-37.66453	176.15149	1.2	1.1	4.8	65.5	21.6	7.0	0.0
	A	4	-37.66445	176.15092	1.1	1.6	6.4	62.1	15.1	14.6	0.0
	A	5	-37.66429	176.15072	1.4	0.4	7.0	74.0	13.8	4.8	0.0
	A	6	-37.66429	176.15176	1.7	1.2	6.3	70.2	18.3	3.9	0.0
	A	7	-37.66426	176.15203	1.6	0.4	8.2	65.1	20.6	5.7	0.0
	A	8	-37.66426	176.15125	1.6	1.8	8.2	73.5	12.4	4.0	0.0
	A	9	-37.66426	176.15155	1.8	1.5	9.1	69.4	16.5	3.5	0.0
	A	10	-37.66425	176.15192	1.4	0.7	7.1	63.5	20.8	7.8	0.0
	A	11	-37.66424	176.15069	1.7	2.5	7.8	72.4	13.0	4.4	0.0
	A	12	-37.66418	176.15176	1.8	1.1	7.8	71.1	16.5	3.5	0.0
	B	1	-37.66417	176.14994	1.7	0.4	8.6	65.0	17.9	7.8	0.3
	B	2	-37.66416	176.15148	1.6	2.5	8.3	69.0	17.0	3.2	0.0
	B	3	-37.66415	176.15118	1.9	3.1	8.4	70.8	15.0	2.6	0.0
	B	4	-37.66409	176.15143	1.6	1.6	8.4	74.7	13.4	2.0	0.0
	B	5	-37.66400	176.15085	1.8	3.2	12.4	71.3	11.5	1.6	0.0
	B	6	-37.66399	176.15115	1.8	1.9	9.9	75.6	11.3	1.2	0.0
	B	7	-37.66395	176.15080	2.0	3.4	10.5	72.6	12.2	1.3	0.0
	B	8	-37.66392	176.15143	1.8	2.0	9.2	70.2	16.9	1.7	0.0

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Table B-1 – *Continued from previous page*

Survey site	Stratum	Sample	Latitude	Longitude	Organic matter (%)	Sediment grain size fraction (%)					
						Fines	VFS	FS	MS	CS	Gravel
	B	9	-37.66391	176.15196	1.9	1.6	10.4	73.2	13.3	1.5	0.0
	B	10	-37.66386	176.15043	1.9	0.9	10.1	71.5	15.5	2.0	0.0
	B	11	-37.66382	176.15168	1.8	3.5	8.6	74.1	12.3	1.5	0.0
	B	12	-37.66375	176.15017	1.9	4.2	9.3	67.1	16.2	3.3	0.0
Pataua Estuary	A	1	-35.71913	174.51680	1.7	1.6	10.1	85.7	2.2	0.4	0.0
	A	2	-35.71908	174.51602	1.4	1.2	6.8	67.3	19.5	5.2	0.0
	A	3	-35.71866	174.51500	1.8	1.4	11.4	47.5	13.8	15.0	10.8
	A	4	-35.71860	174.51718	2.4	3.3	9.9	76.5	8.5	1.7	0.0
	A	5	-35.71845	174.51580	2.3	4.9	15.0	63.2	11.1	5.7	0.1
	A	6	-35.71822	174.51556	1.4	1.5	6.9	62.3	23.7	5.6	0.0
	A	7	-35.71785	174.51698	1.8	2.1	6.4	49.5	30.1	11.8	0.0
	A	8	-35.71738	174.51828	1.4	1.1	5.0	33.7	19.9	24.4	15.9
	A	9	-35.71730	174.51654	2.0	2.0	19.2	61.4	12.0	4.6	0.8
	A	10	-35.71702	174.51904	1.5	0.9	2.4	81.0	14.9	0.8	0.0
	A	11	-35.71624	174.51795	1.6	1.9	5.9	48.9	19.5	22.0	1.7
	A	12	-35.71612	174.51784	1.5	3.4	3.6	50.9	26.6	15.3	0.3
	B	1	-35.72128	174.51306	1.9	5.6	10.7	28.4	16.9	12.6	25.8
	B	2	-35.72089	174.51372	1.4	1.9	10.3	48.3	22.9	15.9	0.7
	B	3	-35.72068	174.51210	1.7	5.0	10.5	33.1	22.9	27.7	0.7
	B	4	-35.72011	174.51430	1.6	2.7	12.0	69.3	11.5	4.5	0.0
	B	5	-35.71989	174.51039	2.3	2.6	10.3	45.2	22.1	19.9	0.0
	B	6	-35.71980	174.51172	1.5	1.2	11.6	56.2	18.9	11.3	0.8
	B	7	-35.71919	174.51327	1.3	2.8	5.5	33.3	29.5	28.8	0.0
	B	8	-35.71889	174.51258	1.5	0.6	13.0	71.3	9.4	5.6	0.0
	B	9	-35.71874	174.51340	1.5	1.2	7.9	69.8	16.7	4.4	0.0
	B	10	-35.71818	174.51312	2.9	5.0	26.8	66.9	0.8	0.5	0.0
	B	11	-35.71818	174.51188	1.6	2.3	13.9	69.4	9.0	5.5	0.0
	B	12	-35.71757	174.51305	2.8	4.0	27.4	64.8	2.5	1.2	0.0

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Table B-1 – *Continued from previous page*

						Sediment grain size fraction (%)					
Survey site	Stratum	Sample	Latitude	Longitude	Organic matter (%)	Fines	VFS	FS	MS	CS	Gravel
Waiotahe Estuary	A	1	-37.99363	177.20053	2.3	15.1	14.8	67.4	2.1	0.6	0.0
	A	2	-37.99335	177.19942	2.1	13.5	13.8	66.9	4.8	1.0	0.0
	A	3	-37.99289	177.20031	3.1	18.9	13.1	55.1	11.1	1.7	0.1
	A	4	-37.99247	177.19781	2.1	7.4	11.4	70.7	9.0	1.4	0.1
	A	5	-37.99238	177.19816	2.2	9.1	11.7	69.3	8.6	1.2	0.1
	A	6	-37.99230	177.19975	1.7	2.4	3.4	51.8	36.4	5.9	0.2
	A	7	-37.99197	177.19787	2.1	8.7	11.4	69.8	8.7	1.4	0.0
	B	1	-37.99223	177.19634	2.2	8.7	16.1	60.8	12.5	1.9	0.0
	B	2	-37.99203	177.19579	2.6	13.4	12.0	49.6	22.1	2.9	0.0
	B	3	-37.99188	177.19530	2.8	13.2	15.9	47.9	18.4	4.5	0.1
	B	4	-37.99184	177.19547	1.8	12.5	8.9	35.5	37.0	6.2	0.0
	B	5	-37.99164	177.19581	2.6	11.2	12.7	40.8	30.8	4.4	0.1
	B	6	-37.99159	177.19551	2.4	1.4	0.9	40.1	47.2	9.7	0.8
	C	1	-37.99321	177.20136	2.9	19.5	12.0	61.2	5.1	1.7	0.5
	C	2	-37.99317	177.20176	1.8	3.7	5.8	86.4	2.8	1.1	0.3
	C	3	-37.99277	177.20179	1.7	0.8	2.7	92.9	3.4	0.1	0.0
	C	4	-37.99232	177.20044	1.9	8.0	5.4	69.6	8.2	1.4	7.4
	C	5	-37.99158	177.19994	1.2	3.1	0.9	64.2	31.5	0.3	0.0
	D	1	-37.99300	177.20257	1.8	3.3	3.1	86.8	3.4	0.4	2.9
	D	2	-37.99290	177.20324	1.6	0.4	1.5	94.8	3.3	0.0	0.0
	D	3	-37.99280	177.20426	1.6	0.4	1.5	90.2	7.7	0.1	0.0
	D	4	-37.99277	177.20242	1.6	0.0	1.1	83.6	14.7	0.6	0.0
	D	5	-37.99253	177.20470	1.6	0.0	0.9	73.9	25.0	0.2	0.0
	D	6	-37.99249	177.20420	1.5	0.0	0.3	57.3	42.2	0.2	0.0
Whangapoua Harbour	A	1	-36.72642	175.61617	3.0	1.6	13.9	79.7	3.7	1.1	0.0
	A	2	-36.72628	175.61627	2.0	1.0	11.9	80.3	5.7	1.2	0.0
	A	3	-36.72613	175.61623	1.2	0.0	7.2	87.3	4.8	0.7	0.0
	A	4	-36.72569	175.61651	1.5	0.4	7.3	85.2	6.7	0.5	0.0

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Table B-1 – *Continued from previous page*

Survey site	Stratum	Sample	Latitude	Longitude	Organic matter (%)	Sediment grain size fraction (%)					
						Fines	VFS	FS	MS	CS	Gravel
	A	5	-36.72549	175.61657	2.1	1.2	9.2	80.6	5.4	3.7	0.0
	A	6	-36.72542	175.61667	1.7	0.8	5.1	80.4	11.0	2.8	0.0
	A	7	-36.72523	175.61681	1.7	1.4	8.8	76.1	10.4	3.2	0.0
	A	8	-36.72523	175.61653	1.8	1.0	8.1	83.4	6.8	0.7	0.0
	B	1	-36.73875	175.65015	1.3	2.3	1.1	41.8	50.8	4.0	0.0
	B	2	-36.73875	175.65035	0.9	0.6	1.1	44.5	49.9	4.0	0.0
	B	3	-36.73865	175.65003	0.8	0.8	0.6	36.6	56.3	5.6	0.0
	B	4	-36.73860	175.64942	1.1	1.5	1.5	47.3	45.6	4.0	0.0
	B	5	-36.73859	175.64978	0.8	0.8	1.1	38.2	54.1	5.8	0.0
	B	6	-36.73852	175.64927	1.4	2.9	1.6	36.4	52.3	6.9	0.0
	B	7	-36.73849	175.64874	1.3	1.2	2.2	43.4	48.2	5.0	0.0
	B	8	-36.73848	175.64914	1.1	1.0	1.8	36.4	53.3	7.5	0.0
	C	1	-36.73493	175.64003	1.4	1.2	8.5	70.2	18.1	1.9	0.0
	C	2	-36.73456	175.63965	2.2	1.7	10.3	72.5	14.0	1.5	0.0
	C	3	-36.73430	175.63877	2.3	1.7	15.1	78.4	4.3	0.5	0.0
	C	4	-36.73382	175.63811	1.9	1.1	14.1	82.2	2.2	0.4	0.0
	C	5	-36.73368	175.63830	2.0	1.3	13.2	80.7	4.2	0.5	0.0
	C	6	-36.73363	175.63872	1.8	1.8	9.8	79.7	7.9	0.9	0.0
	C	7	-36.73346	175.63773	2.0	1.1	14.5	82.5	1.8	0.1	0.0
	C	8	-36.73330	175.63717	2.2	1.8	10.6	86.0	1.4	0.1	0.0
Whitianga Harbour	A	1	-36.84476	175.69956	3.1	4.3	5.6	64.3	22.8	2.9	0.0
	A	2	-36.84451	175.69999	2.7	2.3	4.0	63.8	26.8	3.1	0.0
	A	3	-36.84450	175.69940	2.8	5.5	5.5	62.4	21.3	5.4	0.0
	A	4	-36.84448	175.69982	3.1	5.4	4.8	66.2	20.7	2.9	0.0
	A	5	-36.84442	175.69897	3.5	5.5	6.2	67.9	16.9	3.5	0.0
	A	6	-36.84419	175.70028	3.5	7.1	5.6	66.2	18.9	2.3	0.0
	A	7	-36.84414	175.69837	3.2	5.6	16.2	62.0	12.2	4.0	0.0
	A	8	-36.84412	175.69911	2.8	5.8	11.0	71.6	8.7	2.7	0.2

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Table B-1 – *Continued from previous page*

Survey site	Stratum	Sample	Latitude	Longitude	Organic matter (%)	Sediment grain size fraction (%)					
						Fines	VFS	FS	MS	CS	Gravel
	A	9	-36.84401	175.69947	2.7	5.1	8.9	69.8	12.3	3.8	0.0
	A	10	-36.84400	175.69889	3.4	5.6	13.5	65.6	10.9	4.4	0.0
	A	11	-36.84385	175.70021	3.7	9.8	7.1	68.0	12.3	2.9	0.0
	A	12	-36.84383	175.69887	3.8	7.3	10.4	57.2	18.5	6.5	0.0
	A	13	-36.84364	175.70032	3.0	3.8	10.5	71.0	11.7	3.0	0.0
	A	14	-36.84360	175.69925	2.9	4.8	9.3	52.4	24.5	8.7	0.2
	A	15	-36.84352	175.70135	3.5	4.6	8.4	72.9	12.5	1.5	0.0
	A	16	-36.84326	175.69962	6.9	5.6	15.3	60.1	13.1	5.9	0.0
	A	17	-36.84324	175.70091	3.8	5.2	13.7	73.9	6.1	1.2	0.0
	A	18	-36.84319	175.70030	2.7	2.8	12.8	70.2	11.8	2.3	0.0
	A	19	-36.84314	175.69987	2.8	2.4	9.5	59.1	19.1	10.0	0.0
	A	20	-36.84304	175.70045	2.7	4.8	14.2	67.7	11.0	2.3	0.0
	A	21	-36.84297	175.70085	3.4	4.4	12.5	70.4	10.6	2.1	0.0
	A	22	-36.84297	175.70144	4.0	8.7	13.5	73.2	4.0	0.7	0.0
	A	23	-36.84295	175.70020	3.7	7.3	11.5	55.5	18.4	7.3	0.0
	A	24	-36.84282	175.70040	3.4	5.1	9.8	57.4	21.0	6.8	0.0

APPENDIX C: Geostatistical model predictions

C.1 Cockle Bay

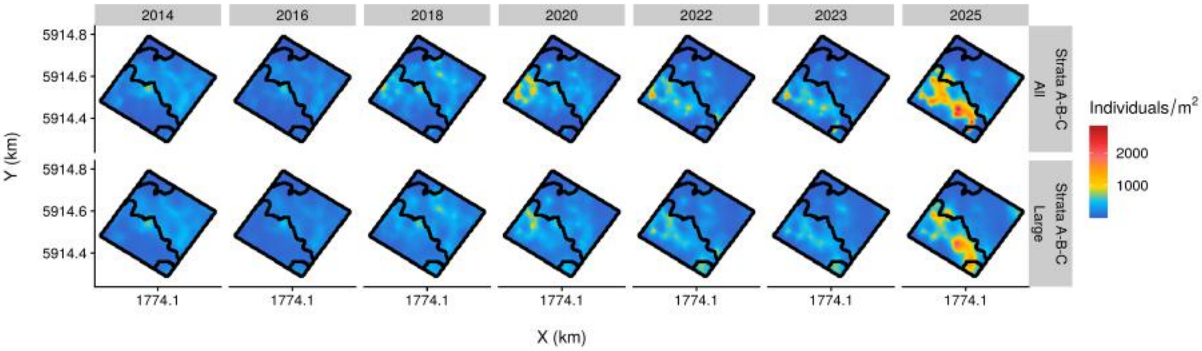

Figure C-1: Predicted cockle densities from the spatio-temporal model for Cockle Bay. Predictions are shown for all and for large cockles (≥30 mm shell length) for each year the site was surveyed (since 2013–14, when high-resolution spatial data became available). Fishing years are indicated by the end year, e.g., 2025 refers to the 2024–25 fishing year.

C.2 Kawakawa Bay (West)

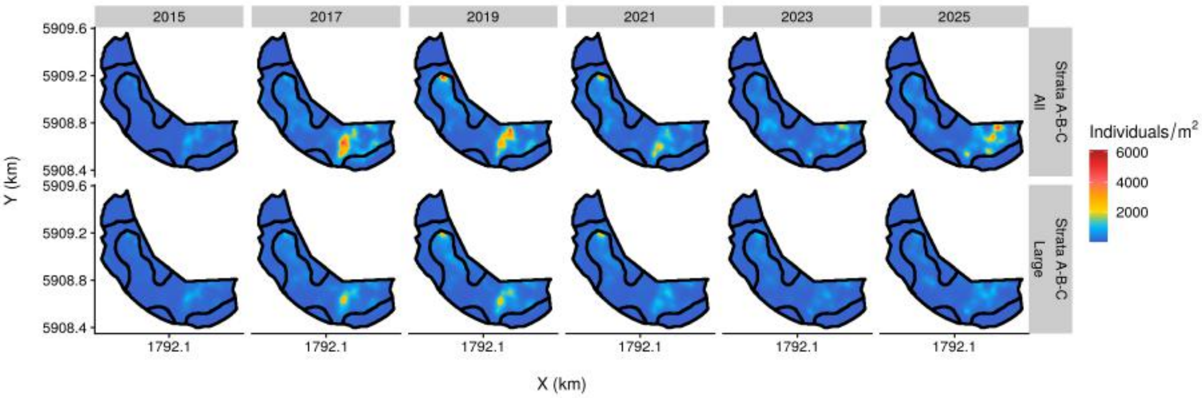

Figure C-2: Predicted cockle densities from the spatio-temporal model for Kawakawa Bay (West). Predictions are shown for all and for large cockles (≥30 mm shell length) for each year the site was surveyed (since 2013–14, when high-resolution spatial data became available). Fishing years are indicated by the end year, e.g., 2025 refers to the 2024–25 fishing year.

C.3 Mill Bay

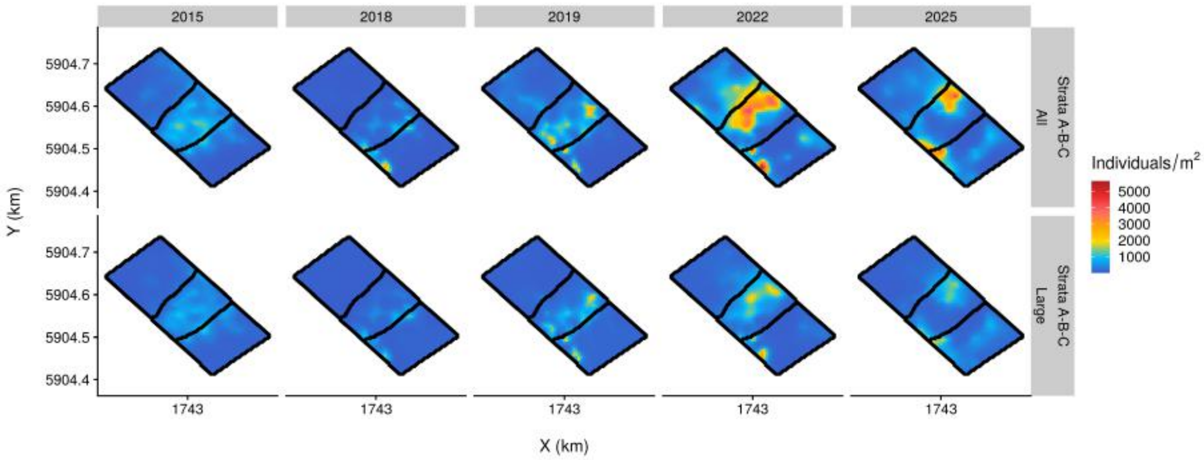

Figure C-3: Predicted cockle densities from the spatio-temporal model for Mill Bay. Predictions are shown for all and for large cockles (≥30 mm shell length) for each year the site was surveyed (since 2013–14, when high-resolution spatial data became available). Fishing years are indicated by the end year, e.g., 2025 refers to the 2024–25 fishing year.

C.4 Ōhiwa Harbour

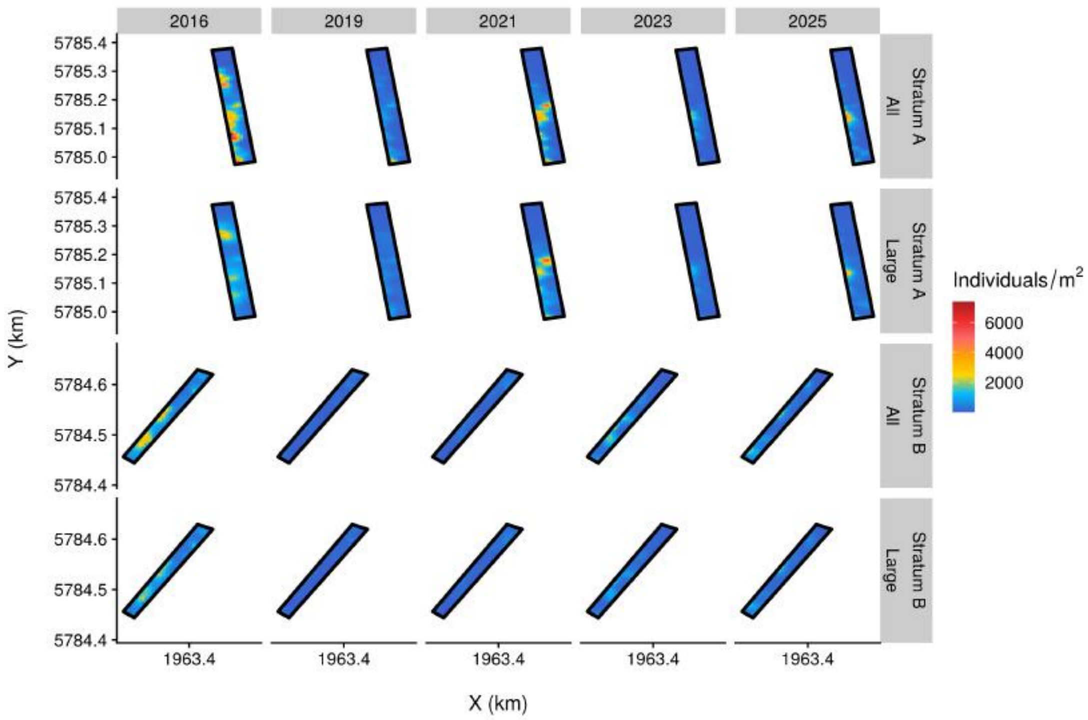

Figure C-4: Predicted cockle densities from the spatio-temporal model for Ōhiwa Harbour. Predictions are shown for all and for large cockles (≥30 mm shell length) for each year the site was surveyed (since 2013–14, when high-resolution spatial data became available). Fishing years are indicated by the end year, e.g., 2025 refers to the 2024–25 fishing year.

C.5 Okoromai Bay

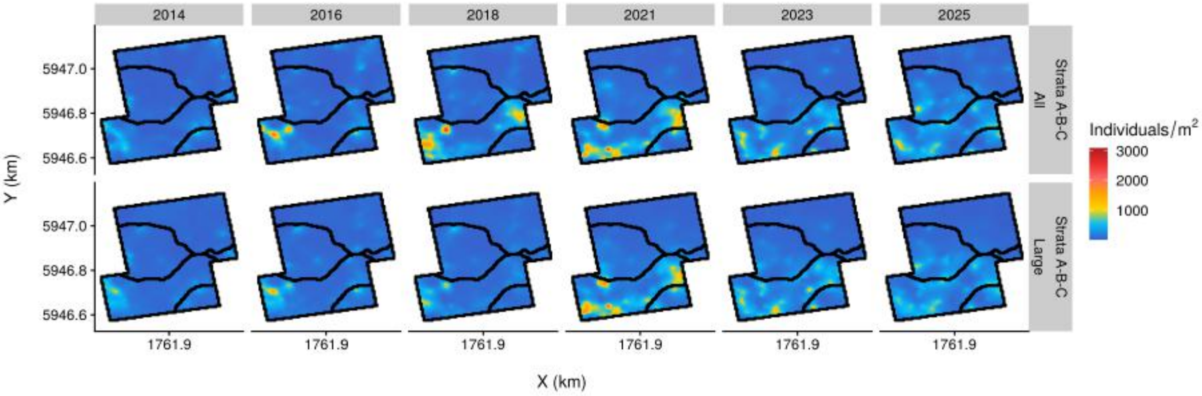

Figure C-5: Predicted cockle densities from the spatio-temporal model for Okoromai Bay. Predictions are shown for all and for large cockles (≥30 mm shell length) for each year the site was surveyed (since 2013–14, when high-resolution spatial data became available). Fishing years are indicated by the end year, e.g., 2025 refers to the 2024–25 fishing year.

C.6 Otūmoetai (Tauranga Harbour)

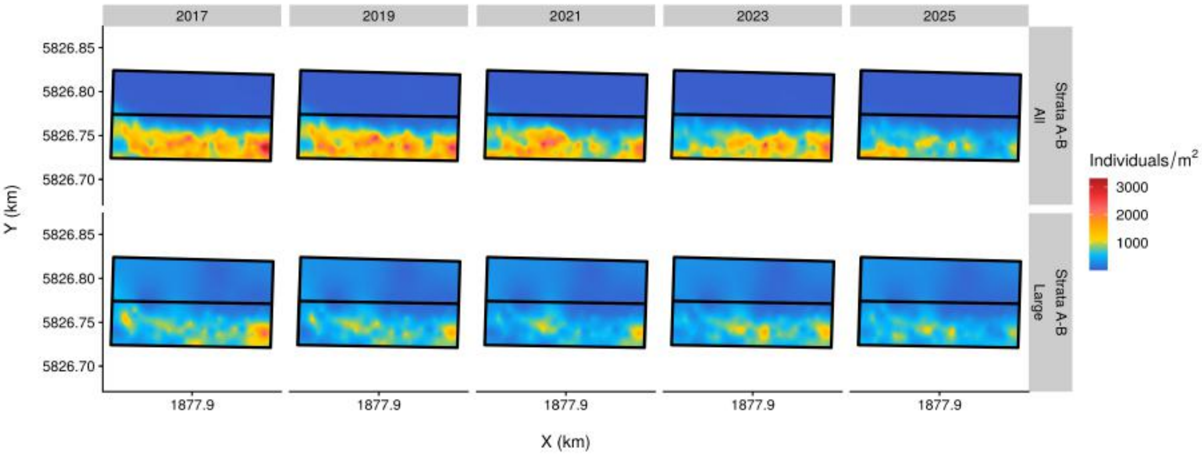

Figure C-6: Predicted cockle densities from the spatio-temporal model for Otūmoetai (Tauranga Harbour). Predictions are shown for all and for large cockles (≥30 mm shell length) for each year the site was surveyed (since 2013–14, when high-resolution spatial data became available). Fishing years are indicated by the end year, e.g., 2025 refers to the 2024–25 fishing year.

C.7 Pataua Estuary

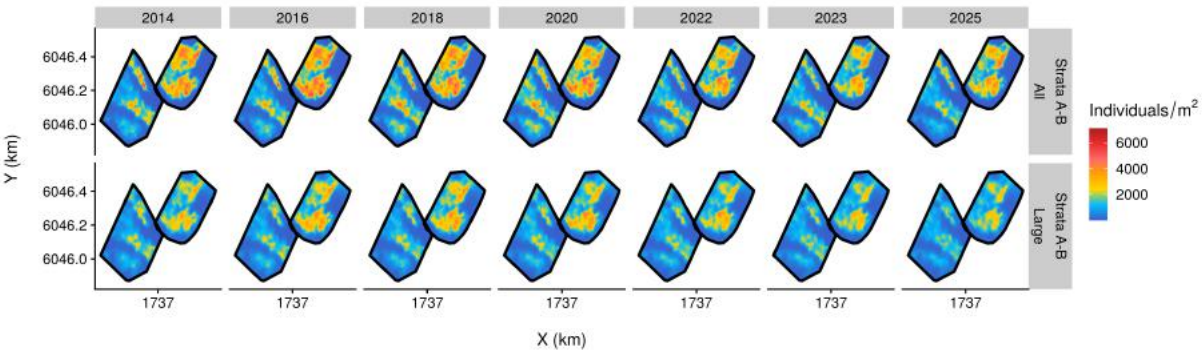

Figure C-7: Predicted cockle densities from the spatio-temporal model for Pataua Estuary. Predictions are shown for all and for large cockles (≥30 mm shell length) for each year the site was surveyed (since 2013–14, when high-resolution spatial data became available). Fishing years are indicated by the end year, e.g., 2025 refers to the 2024–25 fishing year.

C.8 Waiotahe Estuary

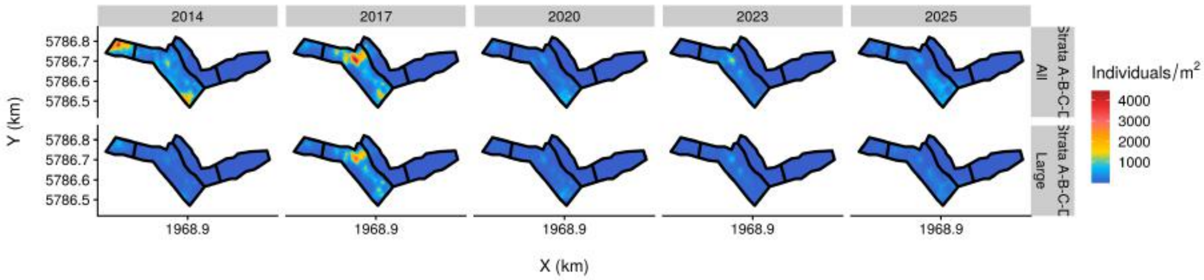

Figure C-8: Predicted cockle densities from the spatio-temporal model for Waiotahe Estuary. Predictions are shown for all and for large cockles (≥30 mm shell length) for each year the site was surveyed (since 2013–14, when high-resolution spatial data became available). Fishing years are indicated by the end year, e.g., 2025 refers to the 2024–25 fishing year.

C.9 Whangapoua Harbour

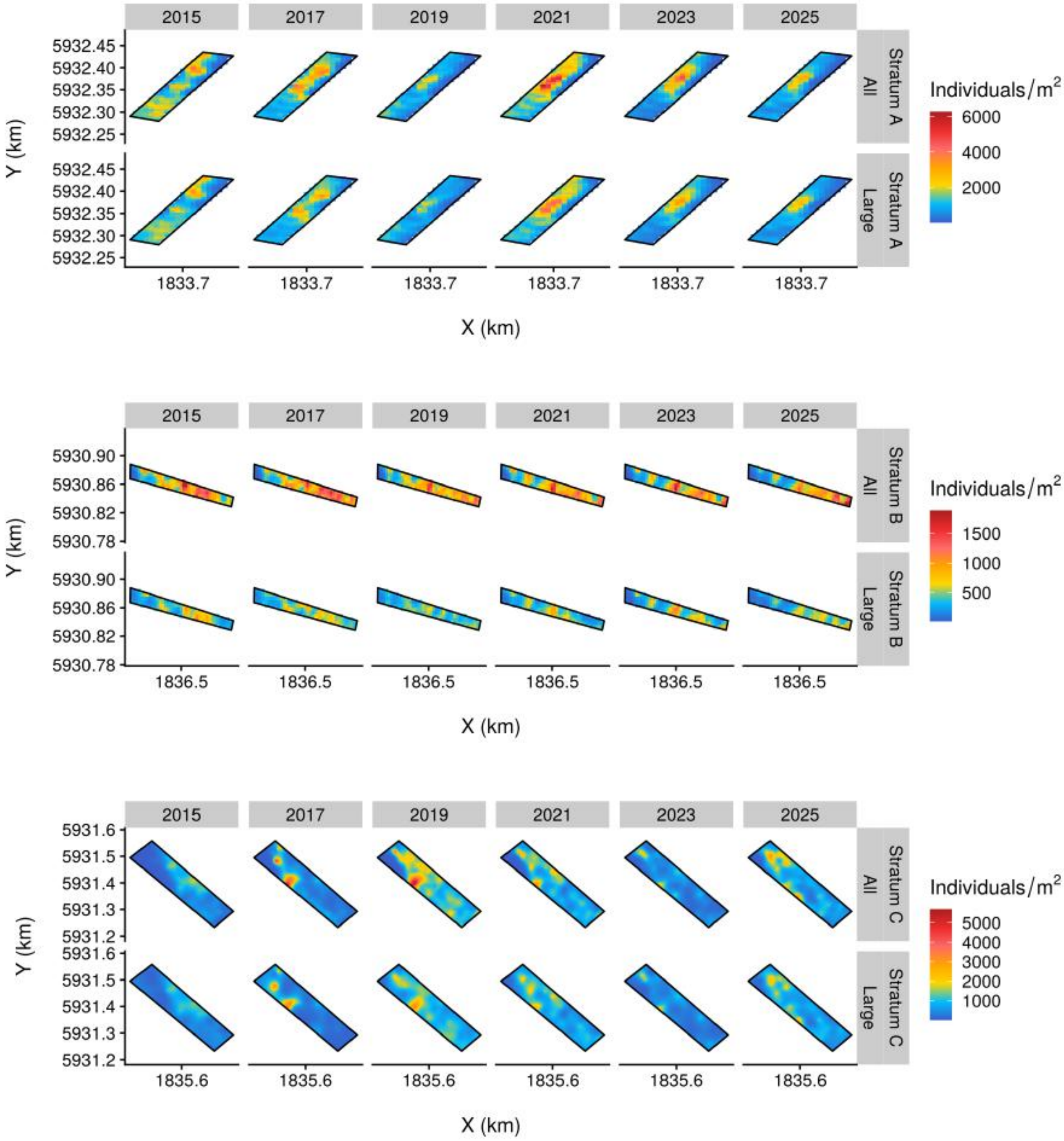

Figure C-9: Predicted cockle densities from the spatio-temporal model for Whangapoua Harbour. Predictions are shown for all and for large cockles (≥30 mm shell length) for each year the site was surveyed (since 2013–14, when high-resolution spatial data became available). Fishing years are indicated by the end year, e.g., 2025 refers to the 2024–25 fishing year.

C.10 Whitianga Harbour

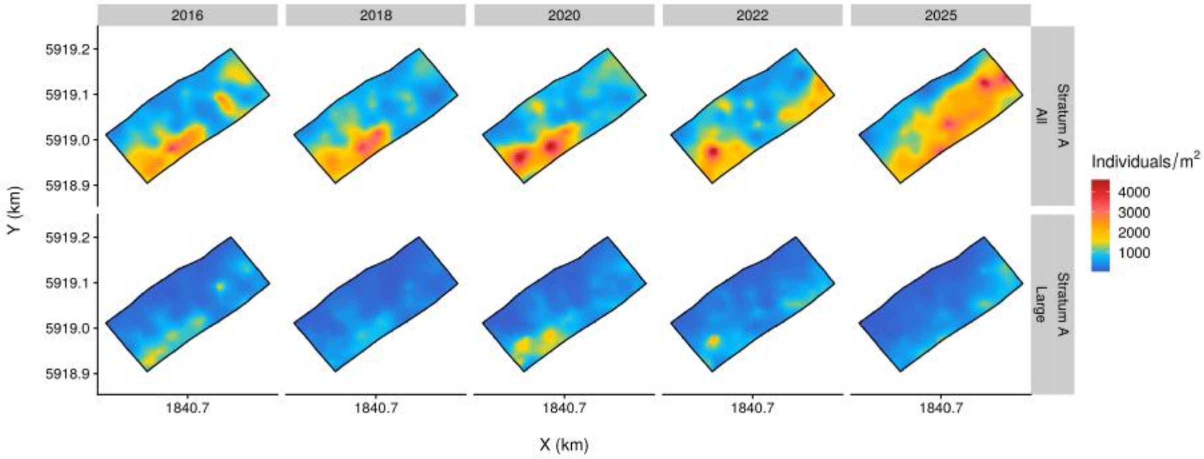

Figure C-10: Predicted cockle densities from the spatio-temporal model for Whitianga Harbour. Predictions are shown for all and for large cockles (≥30 mm shell length) for each year the site was surveyed (since 2013–14, when high-resolution spatial data became available). Fishing years are indicated by the end year, e.g., 2025 refers to the 2024–25 fishing year.