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Manatū Ahu Matua

Survey of intertidal shellfish in Te Awarua-o-Porirua Harbour (Onepoto Arm), February March 2015

New Zealand Fisheries Assessment Report 2015/70

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Te Awarua-o-Porirua Harbour once boasted a healthy and diverse ecosystem that supported shellfish and fish that were prized by Ngāti Toa as kaimoana since the iwi's arrival. The physical nature of the harbour changed following the introduction of intensive industry and development within the harbour catchment. Despite Te Awarua-o-Porirua Harbour being the only significant estuary in the southern North Island very few studies have been undertaken on the shellfish of the Onepoto Arm. This research was the first systematic, exploratory survey of the intertidal shellfish of Onepoto and recorded the distribution, density, and population estimates for all shellfish found.

In February and March 2015, teams from NIWA and Ngāti Toa estimated the distribution and density of 13 shellfish species or species groups within the Onepoto Arm intertidal area. A total of 24 randomly chosen transects were selected and subsampled. Species were identified, counted, and in some cases, measured to estimate their length frequency distribution.

Cockles (*Austrovenus stutchburyi*) were found at 22 of the 24 transect sites around Onepoto. More than 7000 cockles were counted and almost 5000 were measured. The highest densities of cockles were found at Mana sandbank and Takapūwāhia, areas dominated by muddy-sand or sandy-mud substrate. Very few cockles were found adjacent to the railway line, which was dominated by boulders, cobbles and pebbles. A population estimate of 190 million cockles was made for the Onepoto intertidal areas. Wedge shells (*Macomona Liliana*) were found at 14 of the 24 transects, mostly in the northern and southern parts of Onepoto that were dominated by muddy-sand or sandy-mud substrate. None were found adjacent to the railway line in between the boulders, cobbles or pebbles. The highest densities of wedge shells were found at Takapūwāhia, Porirua stream, and at Mana sandbank. These areas are dominated by muddy-sand or sandy-mud substrate. Only 37 pipi (*Paphies australis*) were found during the survey, and were distributed around Onepoto at 9 of the 24 transects. They were absent from the sites adjacent to the railway line. Mudflat topshells (*Diloma subrostrata*) were found at 20 of the 24 transect sites, and like many of the gastropods, their numbers were higher at the railway line sites, which were dominated by boulders, cobbles and pebbles. A population estimate of 15.4 million mudflat topshells was made for the Onepoto intertidal areas. Mud whelks (*Cominella glandiformis*) were spread through 19 of the 24 intertidal sites around Onepoto. They were found in almost all sediment types from boulders to muddy-sand. More precise population estimates may be obtained by post stratifying the survey area based on the distribution of density for the species of interest. This was the first systematic survey of shellfish in Onepoto, and these findings can be used as a baseline to track changes and to evaluate management strategies.

The intertidal sediments vary within Onepoto Arm, with sand opposite Ngāti Toa Domain in the north, muddy-sand at Mana sandbank, and in the south of Onepoto at Porirua Stream and Takapūwāhia. The areas along the sides of Onepoto (east and west) are of mixed sediment, but in many places it is dominated by pebbles, cobbles, boulder or bedrock. Most bivalves had higher densities in the sandy-muddy sediments in the north and south, while the highest densities of gastropods were found on the hard stony sediment sites on the east and west of Onepoto Arm. The depth of oxygenated sediment above the redox layer was shallowest in the inner harbour and deepest at the harbour mouth where the sediments are likely to undergo higher levels of mixing or may be influenced less by fine sediment input from streams and stormwater.

The highest densities of cockles and wedge shells from the intertidal areas of Onepoto Arm were found at Takapūwāhia in the inner harbour and at Mana sandbank in the outer harbour. This pattern of

the inner estuary habitats supporting similar densities of bivalves to the outer estuarine habitats suggests habitats of similar quality in the inner and outer Onepoto intertidal areas.

1. INTRODUCTION

Te Awarua-o-Porirua Harbour has been held in high regard as a rich food basket for Ngāti Toa from when they gained guardianship of the harbour up until the 1940s, when industry, intensive housing, and other developments within the catchment intensified. The introduction of these anthropomorphic impacts changed the physical shape of the harbour and with that came habitat and ecosystem changes. Today, Onepoto is still impacted by sedimentation, eutrophication, and habitat modification (Stevens & Robertson 2013).

This report is part of a larger goal to assist Ngāti Toa to manage and measure the outcomes from customary practices within their rohe moana to add to their traditional and customary well-being. This has already included the recording of Ngāti Toa Kaumatua oral histories (Michael & Naylor 2013), a fish resources survey (Francis 2013; Lyon et al. 2013), and a project on shellfish survey design (Michael et al. 2014). This project includes a survey of shellfish species present in the Onepoto Arm of Te Awarua-o-Porirua Harbour (bivalves and gastropods), the estimation of their densities, the mapping of their distributions, a population estimate, a description of the size structures of the populations, and a shellfish species identification guide.

There has been no previous systematic survey of shellfish in Onepoto Arm. Some limited studies have been undertaken but sampling has been confined to intertidal sand flats (Robertson & Stevens 2010; De Luca 2014) and did not sample all intertidal habitat.

This is the first systematic survey, and the findings will provide critical information on the species present, their distributions, and estimates of the variance in species densities, to allow random stratified survey designs to be developed for baseline surveys of populations of interest. Baseline surveys need to have clear objectives for monitoring so that survey time series data can effectively track specific changes and evaluate management strategies. This survey was only undertaken on the intertidal shellfish, those found between the high-water mark and the low water mark, no subtidal work was undertaken. From this survey we have prepared distribution and density plots and estimated shellfish population numbers for the Onepoto Arm intertidal area using a NIWA built program (SurvCalc, Francis & Fu 2012). This project was funded by the Ministry for Primary Industries under project CUS2014-02.

2. OBJECTIVES

Objective 1: Review available data to inform the design of a baseline survey of shellfish in the Onepoto Arm.

Objective 2: Undertake a survey to identify the shellfish species present (bivalves and gastropods), their densities, map the distributions of species densities, and estimate the size structures of the populations.

Objective 3: To present a report to the Ministry for Primary Industries Shellfish Working Group.

Objective 4: To produce an identification guide of common species.

3. METHODS

We undertook a number of web-based searches using the Thomson Reuters Web of Science, Google scholar and Google, and asked for relevant reports from the Porirua City Council and Greater Wellington Regional Council. There have been no systematic surveys of intertidal shellfish distribution or abundance in the Onepoto Arm of Te Awarua-o-Porirua Harbour.

The intertidal shellfish survey of Te Awarua-o-Porirua Harbour – Onepoto Arm was accomplished between late February and mid-March 2015. The dates were selected to coincide with low tides in the early morning. The survey area (Onepoto Arm intertidal) was considered as a single stratum, with only phase one sampling. Twenty four randomly selected transects were chosen (Figure 1) within the Onepoto Arm and harbour entrance, with a minimum distance of 20 m between each transect. Each transect was measured at low tide, and the transect length was divided into three evenly spaced groups, high, medium, and low tidal areas. The tidal zones were categorised by distance along a transect, and were not representative of the actual depth of the intertidal tidal zones or the zonation of species within the intertidal area. The transect positions at the high tide mark, mid tide, low tide and water's edge were recorded using GPS, and photographs were taken down each transect, looking from the high water mark towards the water.

Along each transect, within each tidal area, 3 replicate quadrats (25 × 25 cm) were randomly placed, and this was done between 1 and 3 times in each tidal area, for a total of between 3 and 9 quadrat samples in each tidal area, or 9 – 27 quadrats per transect. All sediment within each quadrat was dug out to a depth of 10 cm if the sediment was soft. If the sediment was hard no digging was done and animals on the surface were counted. All sediment was placed into a sieve with 5 mm mesh, then washed from the sieves leaving anything larger than 5 mm. The main things retained were shellfish, stones, and other debris. All non-biological objects were removed from each quadrat sample and the shellfish were identified, counted, and some were measured (Appendix 1). Shellfish were measured for length along the anterior–posterior axis to the nearest millimetre down with callipers. We defined large cockles as those individuals with shell lengths 30 mm or larger. Almost all wedge shells and pipis were measured, but only a sub-sample of the cockles were measured when there were more than 40 in a quadrat.

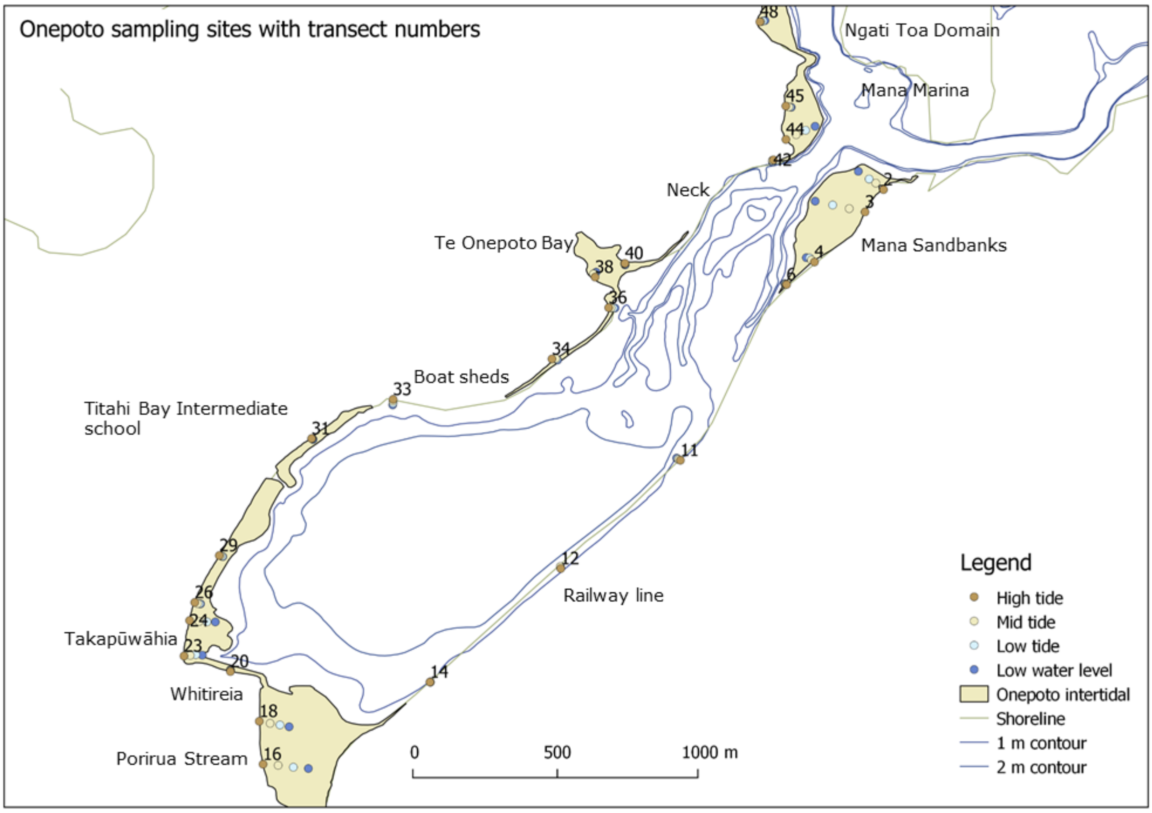

Figure 1: Onepoto Arm of Te Awarua-o-Porirua Harbour with numbered sampling sites (transect numbers) where shellfish were sampled, and places mentioned in the text.

In addition to recording all shellfish, each 25 × 25 cm quadrat was photographed, the topography was recorded as were the substrate types, and any algae species present and its percentage cover. The redox layer depth was recorded from quadrats at all transects where the layer was present.

Density was estimated as the mean number of shellfish per 25 × 25 cm quadrat. Mean population size (numbers), coefficients of variation (CV), and 95% confidence intervals were estimated using a NIWA built program, (SurvCalc, Francis & Fu 2012). Overall biomasses were calculated as

$$B_s = AD_s a'_s / 1000$$

$$B = \sum_s B_s$$

And their standard errors were calculated as

$$\text{s.e.}(B_s) = \text{s.e.}(AD_s) a'_s / 1000$$

$$\text{s.e.}(B) = \left[\sum_s \text{s.e.}(B_s)^2 \right]^{0.5}$$

where (for more detail see Francis & Fu (2012))

a'_s	population area (km^2)	$\sum_s$	the n strata in the survey
AD_s (ad_s)	mean areal density (kg.km^{-2})		
B (b)	overall biomass (t)		

The intertidal area of the Onepoto Arm was surveyed as a single stratum. Aerial expansion of mean density per square metre to the size of the stratum was used to give the survey total population size. The CV, used to judge the accuracy of the population estimates, was calculated as the standard deviation of the unweighted means divided by the square root of the number of transects.

To calculate the intertidal area of Onepoto Arm five areas were identified and the areas were measured using the GIS program QGIS. The Onepoto intertidal area was calculated as 0.7527 km^2 (Table 1).

Table 1: Onepoto intertidal area calculation.

Area	Name	GIS area (m^2)	GIS area (km^2)
OA Intertidal	Mana sandbank	148 273.930	0.148
OA Intertidal	Porirua Stream	389 928.829	0.390
OA Intertidal	Te Onepoto bay	31 082.322	0.031
OA Intertidal	Takapūwāhia	71 180.336	0.071
OA Intertidal	Outer bays	112 248.370	0.112
Intertidal total	Onepoto	752 713.788	0.7527

The eastern side of Onepoto Arm was reclaimed in the 1950s to provide a railway corridor north (Figure 2). This reclaimed area has a steep intertidal profile resulting in short transects. The substrate in this area comprises of bedrock amongst slabs of concrete, boulders, cobble and pebbles.

Figure 2: Aerial view (looking south towards Porirua) of Porirua railway deviation in 1959. Since then much of the land to the left of the causeway has been infilled so that the present sampling was on the bank to the right of the railway causeway. Negatives of the Evening Post newspaper. Ref: EP/1959/1453-F. Alexander Turnbull Library, Wellington, New Zealand.

4. RESULTS

4.1 Literature review

Information was only available for up to three, fine-spatial scale sampling sites (Robertson & Stevens 2010, De Luca 2014). In summary, sampling was confined to intertidal sand flats, and there was no sampling of other substrates or habitats.

Robertson & Stevens (2010) sampled epifauna (surface-dwelling animals) from two sites in the Onepoto Arm: an outer site opposite the Paremata railway station (Por A), and an inner site opposite the Whitireia Community Polytechnic (Por B) in January 2010. They used one randomly placed 25 cm^2 quadrat within each of ten plots. All animals observed on the sediment surface were identified and counted, and any visible microalgal mat development was noted. The species, abundance and related descriptive information was recorded. The five most abundant species sampled were: *Austrovenus stutchburyi* (cockle), *Diloma subrostrata* (mudflat topshell), *Cominella glandiformis* (mudflat whelk), *Zeacumantus lutulentus* (spire shell), and *Macomona liliana* (wedge shell).

De Luca (2014) sampled three intertidal sites in the Onepoto Arm from Takapūwāhia to the inner harbour river mouth, as part of a four survey time series between January 2014 and June 2014. Each site was subdivided into fifteen 10 m × 10 m smaller grids and each of these grids further 'divided' into four 5 m × 5 m grids. One core (13 cm diameter × 15 cm deep) and one 0.25 m^2 quadrat was sampled from a single grid at each site. Site 1 (IO1) is located near the mouth of the Porirua Stream. The cores contained some gastropods (*Potamopyrgus estuarinus*) and the quadrats had no obvious epifauna. Site 2 (IO2) is located approximately 100 m south-east of the Waka shed on Wineera Drive. Shellfish composition was dominated by cockles (*Austrovenus stutchburyi*) and wedge shells (*Macomona liliana*). The quadrats surveyed at this site also showed no obvious epifauna. Site 3 (IO3) was located approximately 400 m north-west of the Waka shed on Wineera Drive. The substrate was stony in some parts. The Shellfish included the mud flat whelk (*Cominella glandiformis*), the limpet (*Notoacmea helmsi*), cockles, wedge shells, and nut shells (*Nucula hartvigiana*).

Blaschke et al. (2010) compiled a literature summary and review of the Porirua Harbour and its catchment but did not include any information on the species composition, distribution and abundance of intertidal shellfish in the Onepoto Arm.

4.2 Species summary

In total we found 13 different shellfish species or species groups in the Onepoto Arm intertidal area. Five were bivalves and eight were gastropods. The top-5 sampled species were 7465 cockles (*Austrovenus stutchburyi*) followed by 1158 wedge shells (*Macomona liliana*), 471 mudflat topshells (*Diloma subrostrata*), 320 mud whelks (*Cominella glandiformis*) and 194 nut shells (*Nucula hartvigiana*) (Table 2). Three out of the top four species were listed as of importance to Ngāti Toa. We measured almost 5000 cockles and over 1000 wedge shells.

Table 2: Species list of the shellfish present in Onepoto, number counted, and number measured. Highlighted are those of most interest to Ngāti Toa.

Common name	Scientific name	Code used	No. counted	No. measured
Cockle	*Austrovenus stutchburyi*	COC	7465	4740
Wedge shell	*Macomona liliana*	LWS	1158	1158
Mudflat topshell	*Diloma subrostrata*	DIL	471	
Mud whelk	*Cominella glandiformis*	PMW	320	
Nut shell	*Nucula hartvigiana*	NUT	194	
Spire shell	*Zeacumantus lutulentus*	ZLL	129	
Periwinkle	*Austrolittorina* sp.	PWI	113	
Mussels	Mytilidae	MUS	108	
Limpet	Acmaeidae	LIM	73	
Whelk (cominella)	*Cominella* sp.	CMN	40	
Pipi	*Paphies australis*	PPI	37	36
Cat's eye	Turbinidae	TUR	13	
Bubble shell	*Haminoea zelandiae*	HZE	10	

A summary (Table 3) allows cross species comparisons between the numbers of shellfish counted within each quadrat, the mean species density per metre squared, the size range of the species measured, the population estimates with their appropriate CV, and the number of transects where the species was present.

Table 3: Summary of shellfish densities, sizes, population estimates, CV, and number of strata where the species was found.

	Density range per **quadrat**	Mean density per **1 m^2**	Size range (mm)	Pop est. (millions)	CV (%)	Transects present
Cockle	0 – 102	524.8 / m^2	5 – 45	190.8	23.1	22
Wedge shell	0 – 28	113.6 / m^2	7 – 49	28.9	26.1	14
Mudflat topshell	0 – 18	52.8 / m^2	–	15.4	22.1	20
Mud whelk	0 – 21	40 / m^2	–	10.6	34.5	19
Nut shell	0 – 13	51.2 / m^2	–	5.9	38.2	12
Spire shell	0 – 16	49.6 / m^2	–	4.5	34.5	16
Periwinkle	0 ~ 100	601.6 / m^2	–	6.3	100	1
Mussels	0 – 36	101.6 / m^2	–	5.2	77.5	6
Limpet	0 – 10	55.5 / m^2	–	1.9	36.8	9
Whelk (cominella)	0 – 9	30.4 / m^2	–	1.9	58.8	7
Pipi	0 – 3	23.7 / m^2	9 – 44	1.1	41.6	9
Cat's eye	0 – 2	17.3 / m^2	–	0.5	61.3	5
Bubble shell	0 – 4	22.4 / m^2	–	0.5	55.5	5

Shade plots (Figure 3) are a quick way of identifying the relative abundance of shellfish species and sediment types found at each transect. At Mana sandbank (transects 2, 3, 4) the dominant shellfish species were cockles, followed by wedge shells and mud whelks and the dominant sediment type was sandy-mud. Along the railway line (transects 6, 11, 12, 14) the dominant species were mudflat topshells and periwinkles both gastropods on a mix of hard sediments (boulders, cobble and bedrock), at Porirua stream (transect 16, 18) and Takapūwāhia (transects 23, 24) the dominant shellfish species were cockles and wedge shells both bivalves in the dominant soft sediments (muddy-sand and sandy-mud).

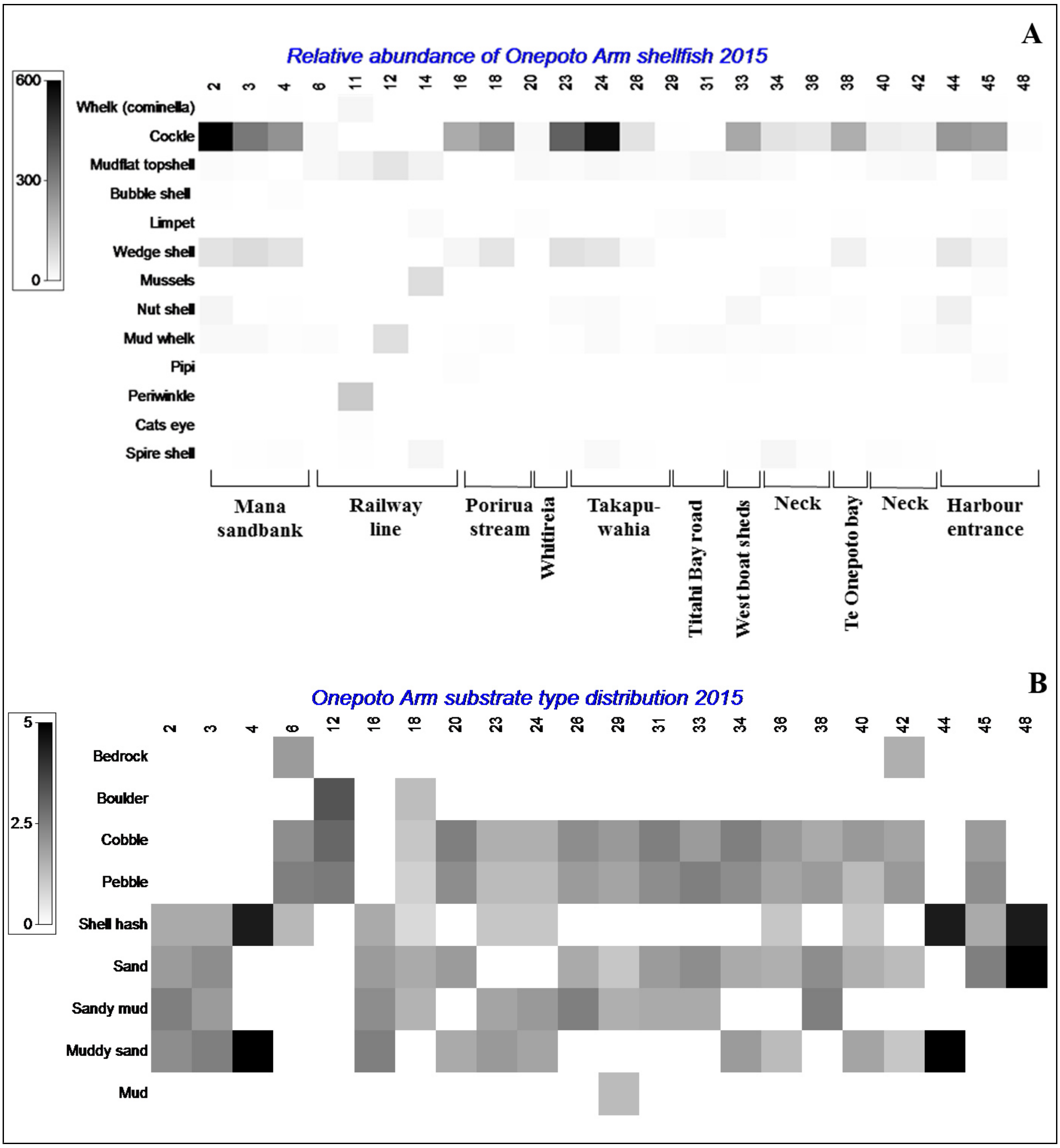

Figure 3: Shade plots for the intertidal areas of Onepoto Arm, the numbers (2 – 48) represent transect numbers. Shading in A shows the abundance of shellfish across transects, B shows the ranking of substrate types across transects (with 5 being the most dominant sediment type and 0 the least).

4.3 Individual species summaries: distribution, density, and population estimates

4.3.1 Cockle (*Austrovenus stutchburyi*)

Distribution

Cockles were found at 22 of the 24 sites around Onepoto Arm (Figure 4), occurring in a diverse range of habitats. The sites where cockles were not found were adjacent to the railway line where the substrate was dominated by bedrock. Cockles were found wherever the substrate was dominated by sand, sandy-mud, muddy-sand, pebbles or cobble, with between zero and 95% seagrass cover.

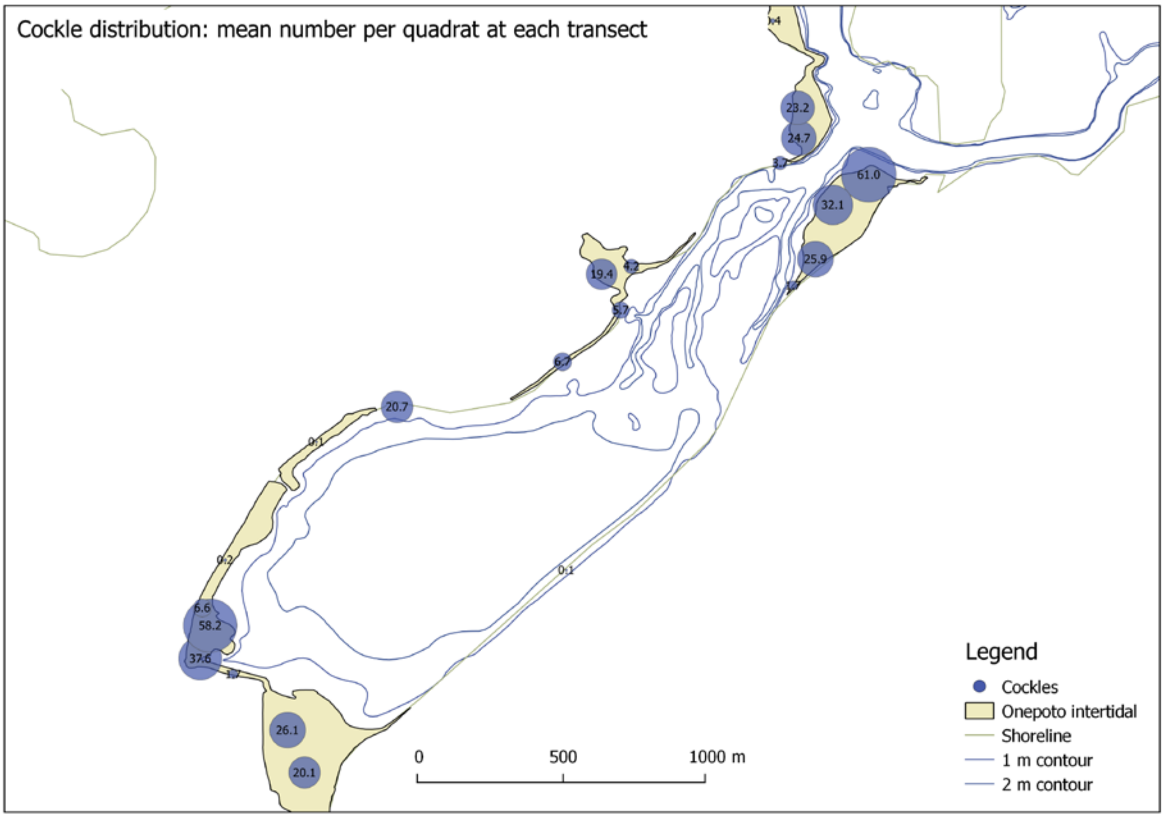

Figure 4: Distribution and density plot for cockles found in Onepoto. Numbers indicate the mean number of cockles found per quadrat at each transect site.

The mean number of cockles found in all three tidal areas was very similar (31 – 36 cockles), as was the inter quartile range, minimum and maximum numbers (Figure 5). The maximum numbers of cockles found per quadrat in each high mid and low areas was about 100 cockles, and the minimum was 0 found at each tidal area.

The largest cockles were found at site 40 just north of Te Onepoto bay (45 mm). However, site 33 at the western edge of the boat sheds had the most consistent large cockles above 40 mm. Other areas with large cockles were site 2 at the Mana sandbanks, site 24 at Takapūwāhia, and site 42 at the northern neck of the inlet.

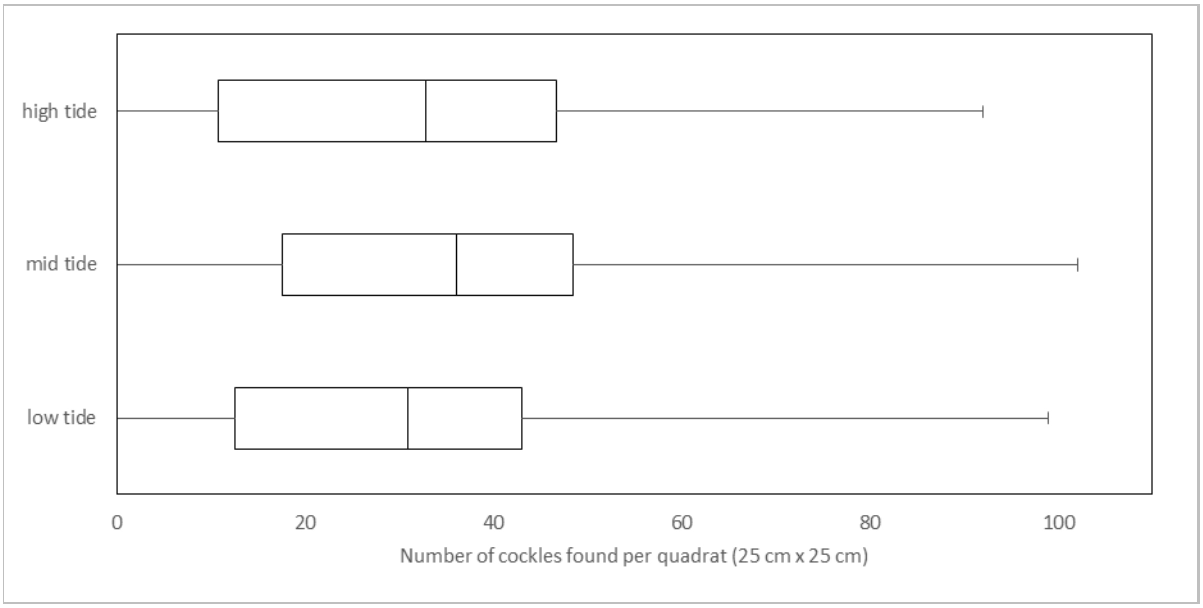

Figure 5: Box and whiskers plot of numbers of cockles found per quadrat in each tidal area. Boxes represent the 25th percentile, the mean, and the 75th percentile, with the whiskers representing the minimum and maximum numbers of cockles found.

Around Onepoto Arm, the mean cockle size was largest in the low tidal area, and smallest in the high tidal areas, but the difference was not significant. The largest cockle (45 mm) was found in the low tidal area, a 41 mm cockle was the largest found in the mid tidal area, and in the high tidal area the largest cockle was 30 mm (Figure 6).

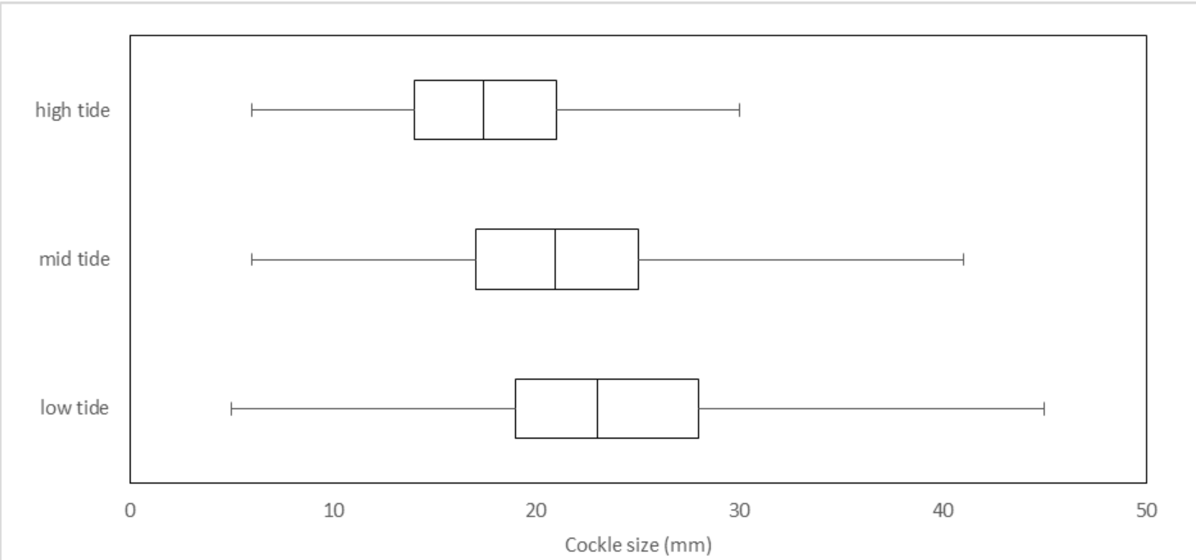

Figure 6: Box and whiskers plot showing the size of cockles found in Onepoto (n=7465) within each tidal area. Boxes represent the 25th percentile, the mean and the 75th percentile, with the whiskers representing the minimum and maximum size of cockles found in each tidal area.

After measuring almost 5000 cockles and scaling the subsample to match the 7465 cockles counted, the scaled length frequency for our sample of cockles from the Onepoto intertidal area is shown in Figure 7 which has an average cockle length of 21 mm (std = 6.75 mm). 11.3 % of the measured cockles were classified as large (at least 30 mm), with an estimated population size of 21.6 million large cockles in the intertidal area.

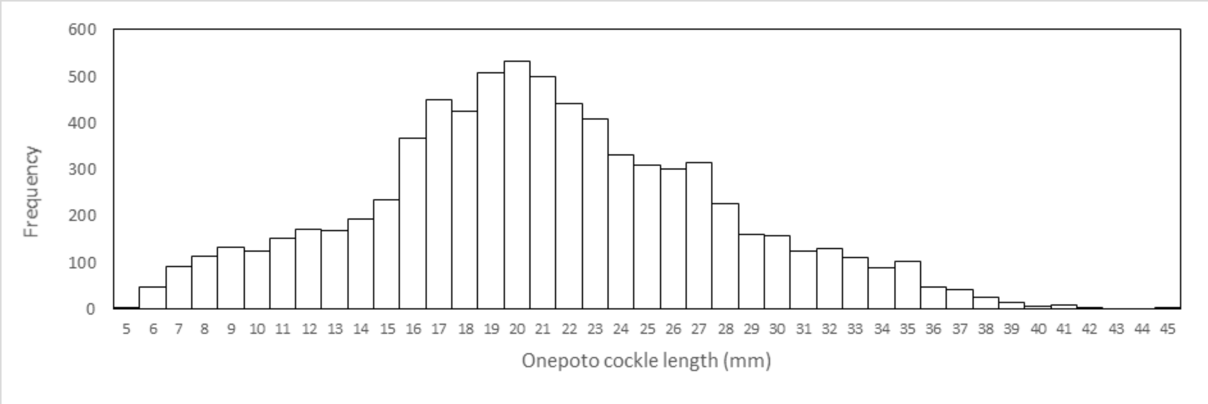

Figure 7: Length frequency weighted by the size of samples for all the cockles sampled in the Onepoto Arm intertidal area.

Density

The highest densities of cockles found in Onepoto were at the Mana sandbank site 2 closest to the Pauatahanui Inlet channel (Table 4) and at Takapūwāhia (closest to the Marae), with sediment types from sand to sandy-mud and muddy-sand. At the Mana sandbank site the cockles were also some of the largest with a mean size of 26.5 mm

Table 4: Cockle density, substrate categories (in decreasing order of dominance), average number of cockles per (25 × 25 cm) quadrat and square metres, the average size of the shellfish, and the size range at each transect. Substrate categories are mud (m), muddy-sand (m-s), sandy-mud (s-m), sand (s), pebble (Pe), cobble (Co), boulder (Bu), bedrock (Bk), shell-hash (sh).

Site No.	Site name	Substrate categories	Average No. of cockles per quadrat	Average No. of cockles per m^2	Average cockle size (mm)	Cockle size range (mm)
2	Mana sandbanks	s-m, m-s, s, sh	61.0	976	26.5	6 – 41
24	Takapūwāhia	s-m, m-s, Co, Pe, sh	58.3	932.8	21	6 – 41
23	Takapūwāhia	m-s, s-m, Co, Pe, sh	37.6	601.6	20.3	6 – 32
3	Mana sandbanks	m-s, s, s-m, sh	32.1	513.6	20.5	7 – 30
18	Porirua stream	s, s-m, Bu, Co, Pe, sh	26.1	417.6	16.4	6 – 27
4	Mana sandbanks	m-s, sh	25.9	414.4	23.1	6 – 33
44	Opposite marina	m-s, sh	24.7	395.2	26.3	8 – 38
45	Opposite marina	s, Pe, Co, sh	23.2	371.2	18.5	6 – 34
33	Boat sheds	Pe, s, Co, s-m	20.7	331.2	22	5 – 42
16	Porirua stream	m-s, s-m, s, sh	20.1	321.6	16.5	8 – 27
38	Te Onepoto bay	s-m, m-s, Pe, Co	19.4	310.4	19.1	6 – 29
34	Northern boat sheds	Co, Pe, m-s, s	6.7	107.2	23.8	7 – 35
26	Takapūwāhia	s-m, Co, Pe, s	6.6	105.6	27.9	10 – 35
36	Neck	Co, Pe, s, m-s, sh	5.7	91.2	19.3	7 – 31
40	Neck	Co, m-s, s, Pe, sh	4.2	67.2	24.8	6 – 45
42	Neck	Pe, Co, Bk, s, m-s	3.7	59.2	31.3	7 – 41
6	Railway line	Pe, Co, Bk, sh	1.7	27.2	23	12 – 32
20	Whitireia	Co, Pe, s, m-s	1.7	27.2	16.4	6 – 28
48	opposite Domain	s, sh	0.4	6.4	16.8	5 – 37
29	Takapūwāhia	Co, Pe, s-m, m, s	0.2	3.2	27.5	22 – 38
12*	Railway line	Bu, Co, Pe	0.1	1.6	26	26
31	Titahi Bay intermediate	Co, Pe, s, s-m	0.1	1.6	27.25	10 – 36

*** Only one cockle was found at this site.**

The length frequencies of cockles are different at the three highest density sites, Takapūwāhia, Porirua stream, and Mana sandbank (Figure 8). At Takapūwāhia (transects 23 and 24) there were a high proportion of juvenile cockles, and a broad range of intermediate sized cockles 16 – 28 mm in length. At Porirua stream (transects 16 and 18), there were few large cockles, and the mode of the distribution was between about 15 and 19 mm. At Mana sandbank (transects 2, 3, and 4) the cockle length distribution was slightly bi-modal. There were small numbers of small and large cockles and the mode was between about 20 and 25 mm.

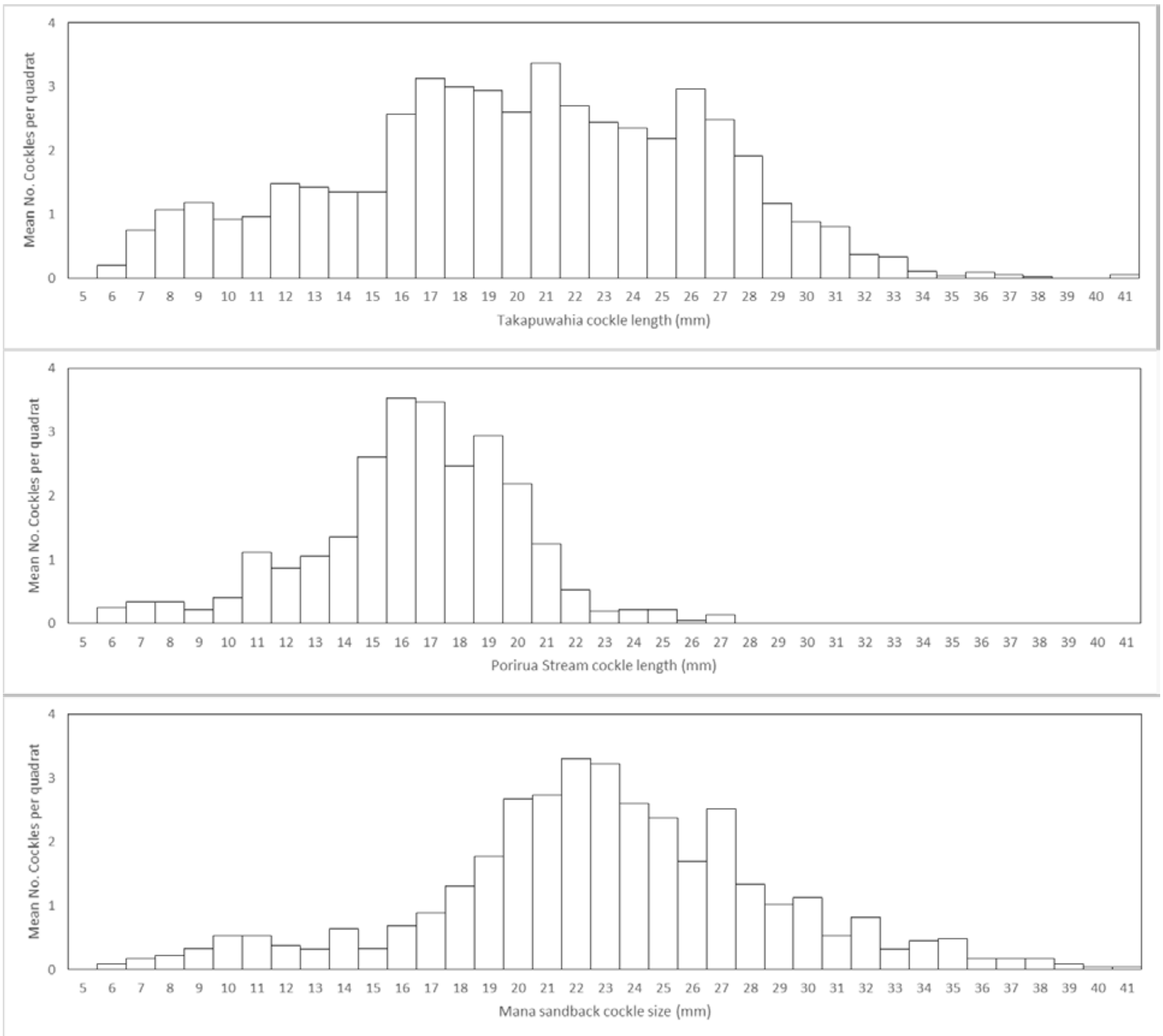

Figure 8: Length frequency distributions for cockles in Onepoto intertidal areas of interest, the mean number of cockles found at each site is per quadrat. Takapūwāhia includes transects 23 and 24, Porirua stream include transects 16 and 18, and Mana sandbank includes transects 2, 3, 4.

Population estimate

The estimated number of cockles found throughout the intertidal area of Onepoto Arm was 190 million and has a 95% probability of being between 102 and 279 million, with a coefficient of variation (CV) of 23.1% (Table 5).

Table 5: Abundance figures for cockles, abundance values are in numbers of shellfish within the Onepoto intertidal area. Bounds are 95% CI; CV coefficient of variation.

Species	Lower bound	Abundance	Upper bound	CV (%)	No. transects found
Cockle	102 546 000	190 788 000	279 031 000	23.1	22/24

Juveniles

A total of 509 juveniles cockles (5 – 10 mm) were measured (6.8 % of all cockles measured). Juvenile cockles were present at 19 of 26 transects, but were not found at any sites adjacent to the railway line where the sediment was relatively hard.

4.3.2 Wedge shell (*Macomona liliana*)

Distribution

Wedge shells were found at 14 of 24 transects, mostly in the northern and southern parts of Onepoto Arm. No wedge shells were found adjacent to the railway line (Figure 9). The size range of wedge shells was between 7 mm and 49 mm, and the largest wedge shell was found at the Mana sandbank. Wedge shells were found in higher numbers in muddy-sand or sandy-mud substrate, with lower numbers at sites with high amounts of pebble or cobble. Wedge shells were found in habitats with zero to 90 % cover of seagrass.

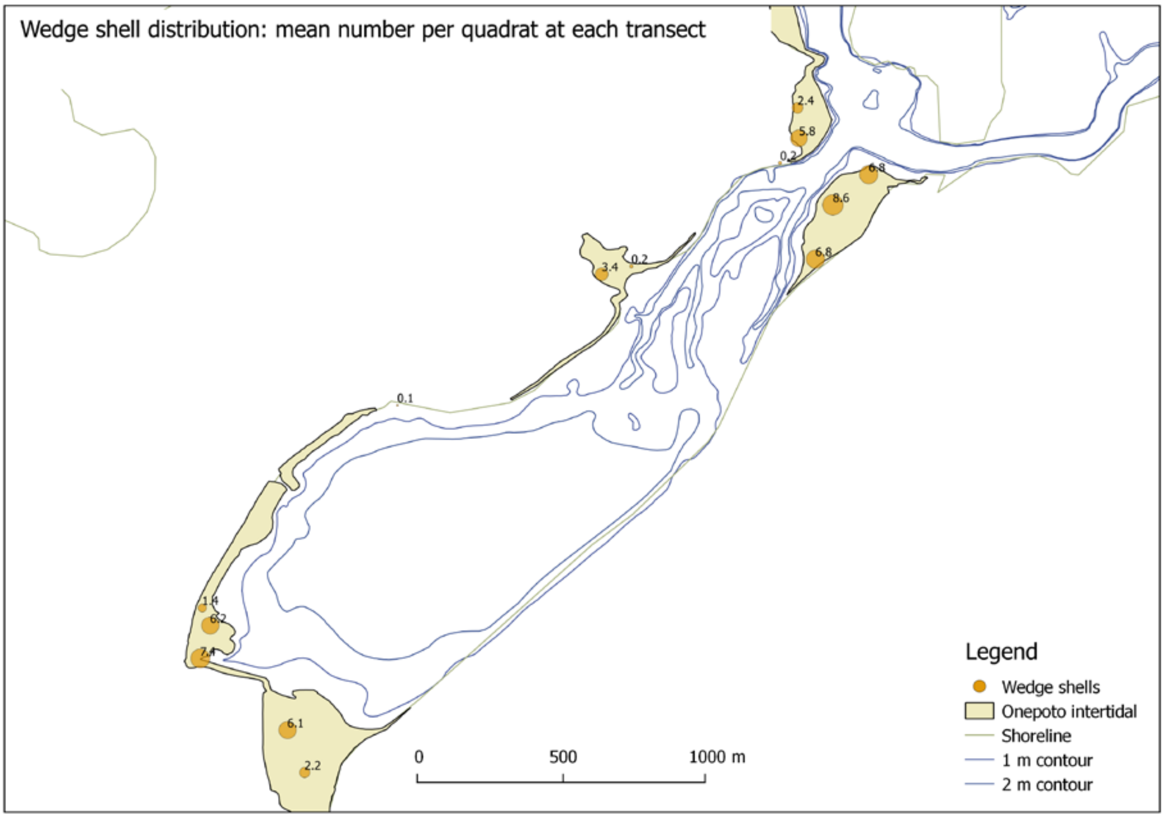

Figure 9: Distribution and density plot for wedge shells found in Onepoto. Numbers indicate the mean numbers caught per quadrat at each transect.

After counting and measuring 1158 wedge shells from the Onepoto Arm intertidal areas, the length frequency distribution has an average wedge shell length of 21 mm (std = 7.11 mm), and there is potentially a strong year class currently measuring 11 mm (Figure 10).

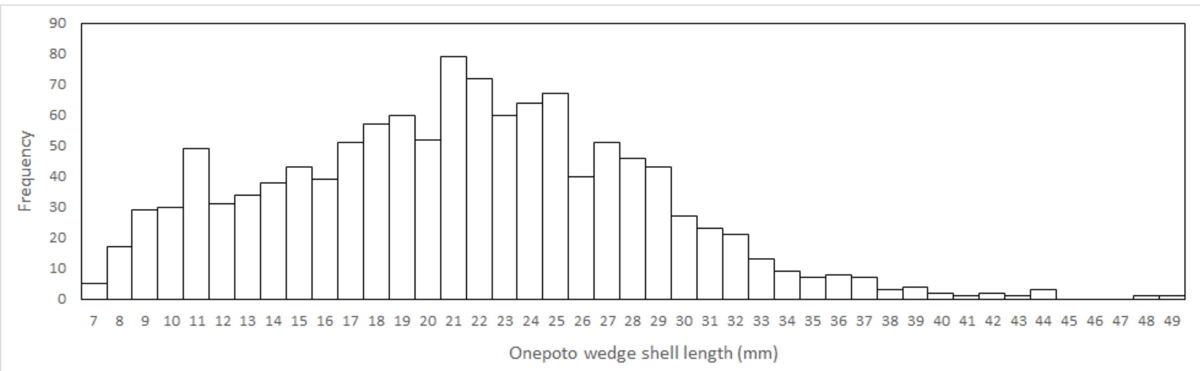

Figure 10: Length frequency distribution of all wedge shells sampled in the Onepoto Arm intertidal area.

Density

The highest densities of wedge shells in Onepoto Arm were found at Mana sandbank and at Takapūwāhia, with a mean range of between 6.2 and 8.6 wedge shells in each quadrat (Table 6).

Table 6: Wedge shell density, substrate categories (in decreasing order of dominance), average number of wedge shells per (25 × 25 cm) quadrat and square metre, the average size of the shellfish, and the size range at each transect. Substrate categories are mud (m), muddy-sand (m-s), sandy-mud (s-m), sand (s), pebble (Pe), cobble (Co), boulder (Bu), bedrock (Bk), shell-hash (sh).

Site No.	Site name	Substrate categories	Average No. of wedge shells per quadrat	Average No. of wedge shells per m^2	Average wedge shell size (mm)	Wedge shell size range (mm)
3	Mana sandbanks	m-s, s, s-m, sh	8.6	137.6	21.3	9– 33
23	Takapūwāhia	m-s, s-m, Co, Pe, sh	7.4	118.4	16	7 – 30
2	Mana sandbanks	s-m, m-s, s, sh	6.8	108.8	23.2	9– 33
4	Mana sandbanks	m-s, sh	6.8	108.8	24.1	12– 49
24	Takapūwāhia	s-m, m-s, Co, Pe, sh	6.2	99.2	21.4	7 – 37
18	Porirua stream	s, s-m, Bu, Co, Pe, sh	6.1	97.6	22	8 – 34
44	opposite marina	m-s, sh	5.8	92.8	20.6	9– 36
38	Te Onepoto bay	s-m, m-s, Pe, Co	3.4	54.4	22.6	10– 38
45	Opposite marina	s, Pe, Co, sh	2.4	38.4	28.6	11– 44
16	Porirua stream	m-s, s-m, s, sh	2.2	35.2	33.3	9 – 48
26	Takapūwāhia	s-m, Co, Pe, s	1.4	22.4	18.7	7– 32
40	Neck	Co, m-s, s, Pe, sh	0.2	3.2	18.5	14– 23
42	Neck	Pe, Co, Bk, s, m-s	0.2	3.2	13	13
33	Boat sheds	Pe, s, Co, s-m	0.1	1.6	10.5	8– 13

Population estimate

The estimated number of wedge shells found throughout the intertidal area of Onepoto Arm was almost 29 million (Table 7), with a CV of about 26%.

Table 7: Abundance figures for wedge shells, abundance values are in numbers of wedge shells within the Onepoto intertidal area. Bounds are 95% CI; CV coefficient of variation.

Species	Lower bound	Abundance	Upper bound	CV (%)	No. transects found
Wedge shell	13 846 000	28 908 000	43 970 000	26.1	14/24

4.3.3 Pipi (*Paphies australis*)

Distribution

Only 37 pipi were found during the survey, at 9 of the 24 transects (Figure 11). The pipi were distributed throughout the intertidal area of Onepoto Arm. The size range of pipi was between 9 mm and 44 mm. The largest pipi (44 mm) was found at site 33 at the western end of the boat sheds. There seemed to be no pattern to where pipi were found as they were found in all substrate types, in sand, muddy-sand, around pebbles, cobble, and boulders. They were also found in areas with very little seagrass.

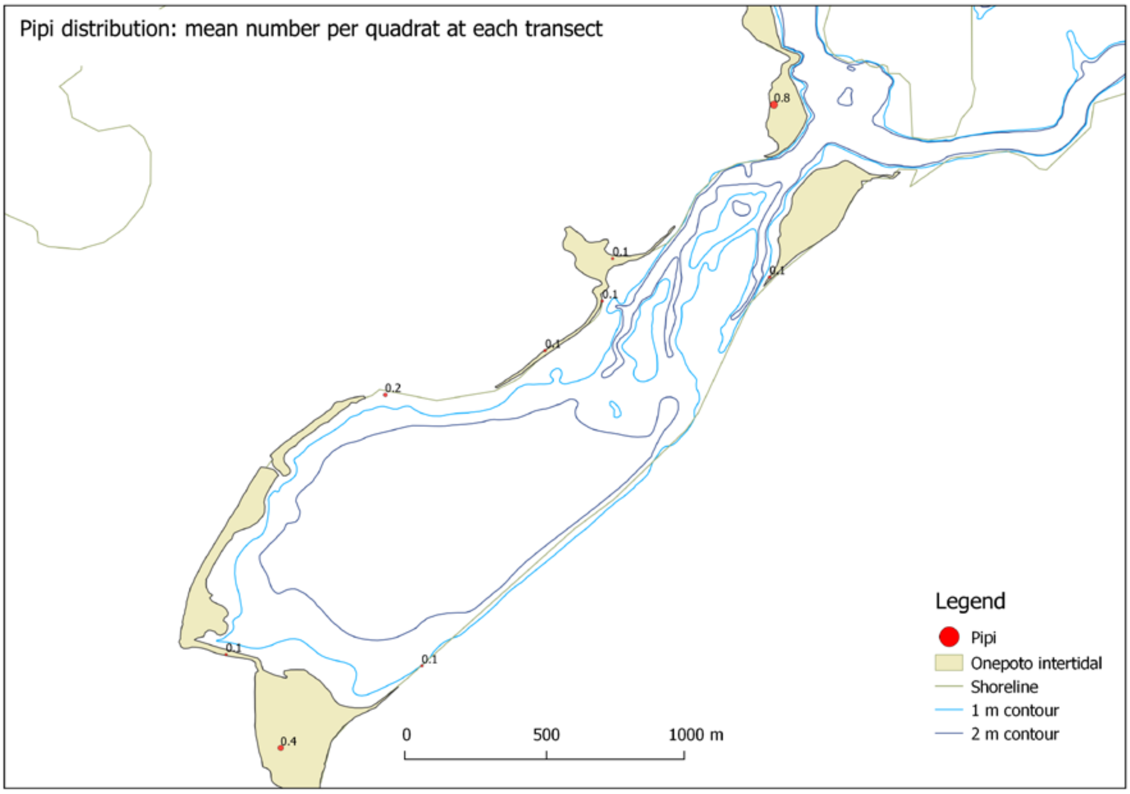

Figure 11: Distribution and density plot for pipi found in Onepoto. Numbers indicate the mean number found per quadrat at each transect.

Density

The highest density of pipi within Onepoto Arm was only 0.8 pipi per quadrat, and that was found at site 45 opposite the Mana Marina (Table 8).

Table 8: Pipi density, habitat types (in decreasing order of dominance), average number of pipi per (25 × 25 cm) quadrat and square metre, the average size of the shellfish, and the size range at each transect. Substrate categories are mud (m), muddy-sand (m-s), sandy-mud (s-m), sand (s), pebble (Pe), cobble (Co), boulder (Bu), bedrock (Bk), shell-hash (sh).

Site No.	Site name	Substrate categories	Average No. of pipi per quadrat	Average No. of pipi per m^2	Average pipi size (mm)	Pipi size range (mm)
45	opposite Mana marina	s, Pe, Co, sh	0.8	12.8	25.3	12– 36
16	Porirua stream	m-s, s-m, s, sh	0.4	6.4	27.8	19 – 40
33	Boat sheds	Pe, s, Co, s-m	0.2	3.2	25.3	9 – 44
6*	northern Railway line	Pe, Co, Bk, sh	0.1	1.6	20	–
14*	southern Railway line	Bu, Bk, Co, Pe	0.1	1.6	36	–
20*	Whitireia	Co, Pe, s, m-s	0.1	1.6	31	–
34*	northern Boat sheds	Co, Pe, m-s, s	0.1	1.6	11	–
36*	Neck	Co, Pe, s, m-s, sh	0.1	1.6	24	–
40*	Neck	Co, m-s, s, Pe, sh	0.1	1.6	19	–

*** Only one pipi was found at this site.**

Population estimate

The estimated number of pipi found throughout the intertidal area of Onepoto Arm was one million (CV 41.6 %, Table 9).

Table 9: Abundance figures for pipi, abundance values are in numbers of pipi within the Onepoto intertidal area. Bounds are 95% CI; CV coefficient of variation.

Species	Lower bound	Abundance	Upper bound	CV (%)	No. transects found
Pipi	177 000	1 059 000	1 941 000	41.6	9/24

4.3.4 Mudflat topshells (*Diloma subrostrata*)

Distribution

A total of 471 mudflat topshells were found during the Onepoto Arm intertidal survey, at 20 of the 24 transect sites (Figure 12). The higher number of mudflat topshells were found at pebble, cobble, and boulder transect sites, such as the railway line, at Whitireia, and along the northwest edge of Onepoto.

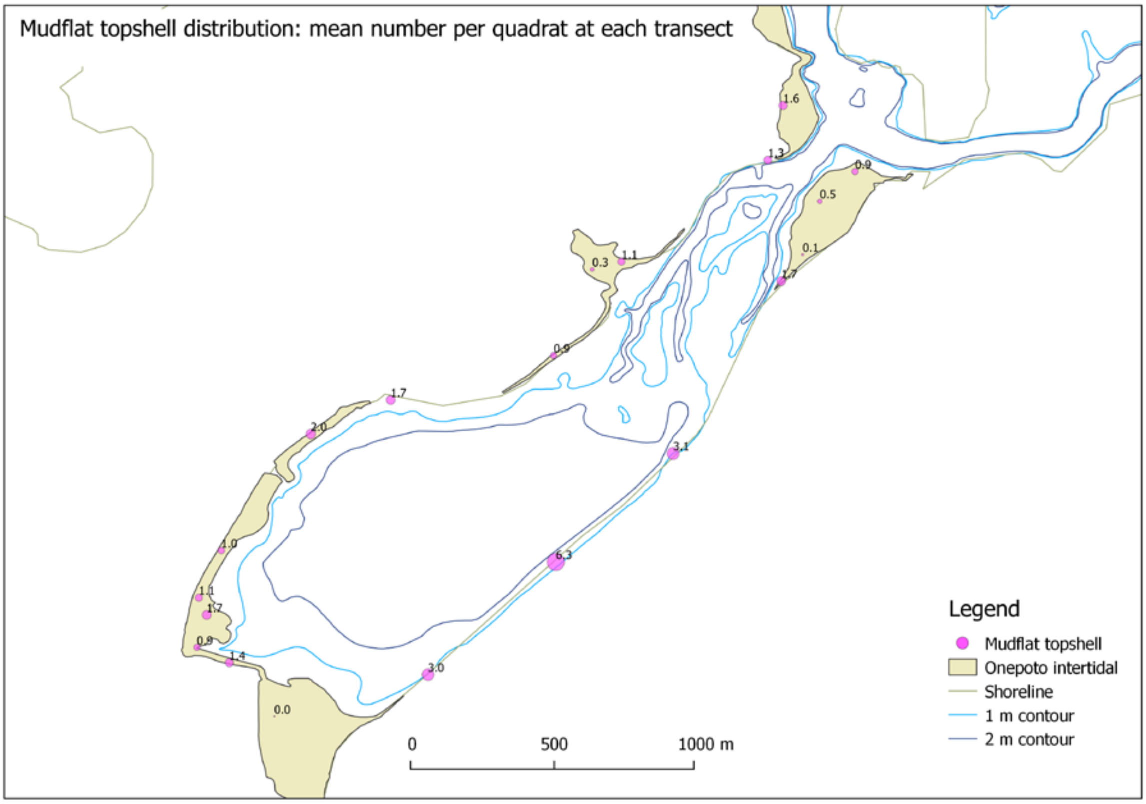

Figure 12: Distribution and density plot for mudflat topshells found in Onepoto. Numbers indicate the mean number found per quadrat at each transect.

Density

The highest density of mudflat topshells was over six per quadrat at site 12 (mid-railway line transect site). The 2nd and 3rd highest densities were also adjacent to railway line sites (Table 10). The three sites with the highest densities of mudflat topshells all had sediment dominated by cobbles and pebbles.

Table 10: Mudflat topshell density, substrate categories (in decreasing order of dominance), and average number of mudflat topshells per (25 × 25 cm) quadrat and square metre at each transect. Substrate categories are mud (m), muddy-sand (m-s), sandy-mud (s-m), sand (s), pebble (Pe), cobble (Co), boulder (Bu), bedrock (Bk), shell-hash (sh).

Site No.	Site name	Substrate categories	Average No. of shells per quadrat	Average No. of shell per m^2
12	Railway line	Bu, Co, Pe	6.3	100.8
11	Railway line	Bk, Pe, sh	3.1	49.6
14	Railway line	Bu, Bk, Co, Pe	3.0	48
31	Titahi Bay intermediate	Co, Pe, s, s-m	2.0	32
6	Railway line	Pe, Co, Bk, sh	1.7	27.2
24	Takapūwāhia	s-m, m-s, Co, Pe, sh	1.7	27.2
33	Boat sheds	Pe, s, Co, s-m	1.7	27.2
45	Opposite marina	s, Pe, Co, sh	1.6	25.6
20	Whitireia	Co, Pe, s, m-s	1.4	22.4
42	Neck	Pe, Co, Bk, s, m-s	1.3	20.8
26	Takapūwāhia	s-m, Co, Pe, s	1.2	19.2
40	Neck	Co, m-s, s, Pe, sh	1.1	17.6
29	Takapūwāhia	Co, Pe, s-m, m, s	1.0	16
23	Takapūwāhia	m-s, s-m, Co, Pe, sh	0.9	14.4
34	Northern boat sheds	Co, Pe, m-s, s	0.9	14.4
2	Mana sandbanks	s-m, m-s, s, sh	0.9	14.4
3	Mana sandbanks	m-s, s, s-m, sh	0.5	8
38	Te Onepoto bay	s-m, m-s, Pe, Co	0.3	4.8
4*	Mana sandbanks	m-s, sh	0.1	1.6
18*	Porirua stream	s, s-m, Bu, Co, Pe, sh	0.04	0.64

*** Only one mudflat topshell was found at this site.**

Population estimate

The estimated number of mudflat topshells in the intertidal area of Onepoto Arm was 15.4 million (CV 22.1 %, Table 11).

Table 11: Abundance figures for mudflat topshell, abundance values are in numbers of mudflat topshells within the Onepoto intertidal area. Bounds are 95% CI; CV coefficient of variation.

Species	Lower bound	Abundance	Upper bound	CV (%)	No. transects found
Mudflat topshell	8 581 000	15 400 000	22 218 000	22.1	20/24

4.3.5 Mud whelk (*Cominella glandiformis*)

Distribution

A total of 320 mud whelks were found during the Onepoto Arm intertidal survey, at 19 of the 24 transect sites (Figure 13). The mud whelk distribution is spread evenly throughout the Onepoto intertidal area. Mud whelks were found in almost all sediment types from muddy-sand, sandy-mud, sand, pebbles, cobbles, and boulders and in areas with some algal cover.

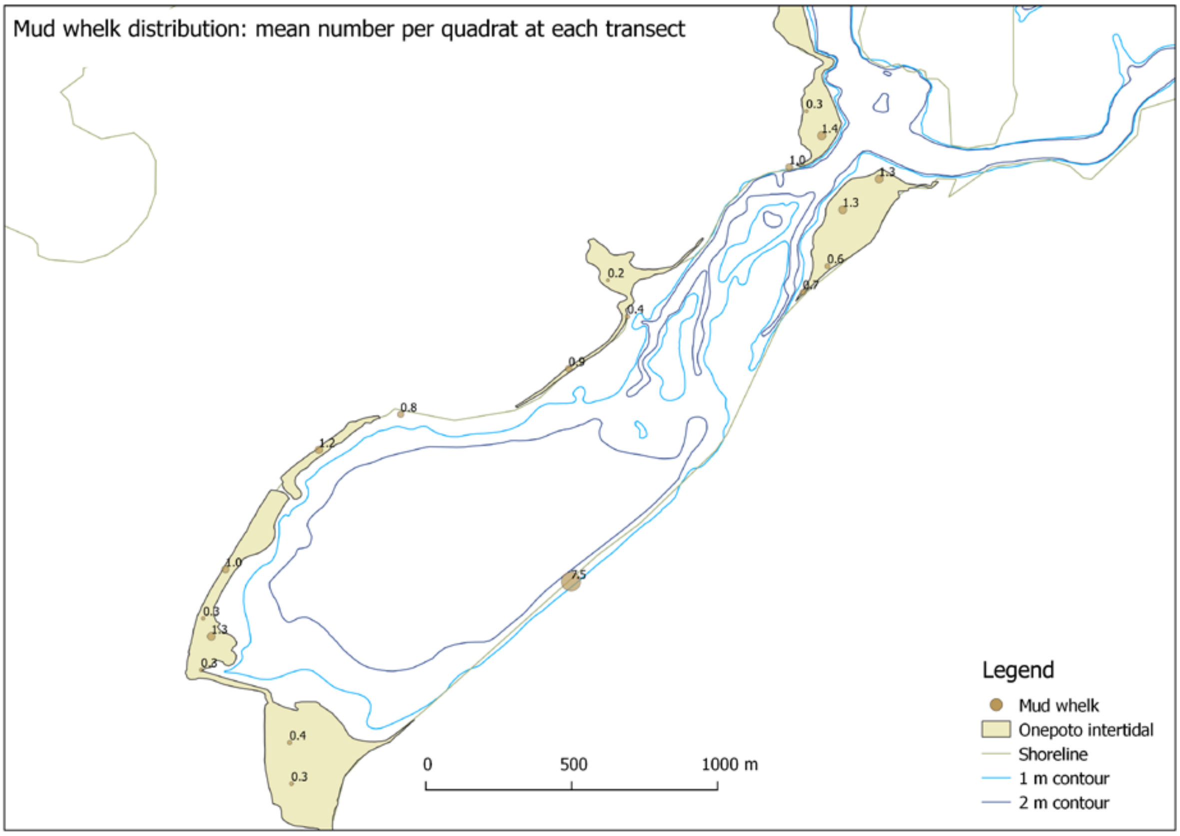

Figure 13: Distribution and density plot for mud whelks found in Onepoto. Numbers indicate the mean number found per quadrat at each transect.

Density

The highest density of mud whelks was 7.5 per quadrat at site 12 (the mid-railway line transect site, Table 12). The 2nd and 3rd highest densities were opposite Mana marina and at Takapūwāhia respectively. The site with the highest density of mud whelks had a dominant sediment type of boulder, cobble and pebbles.

Table 12: Mud whelk density, substrate categories (in decreasing order of dominance), and average number of mud whelks per (25 × 25 cm) quadrat and square metre at each transect. Substrate categories are mud (m), muddy-sand (m-s), sandy-mud (s-m), sand (s), pebble (Pe), cobble (Co), boulder (Bu), bedrock (Bk), shell-hash (sh).

Site No.	Site name	Substrate categories	Average No. of shell per quadrat	Average No. of shell per m^2
12	Railway line	Bu, Co, Pe	7.5	120
44	Opposite marina	m-s, sh	1.4	22.4
2	Mana sandbanks	s-m, m-s, s, sh	1.3	20.8
3	Mana sandbanks	m-s, s, s-m, sh	1.3	20.8
24	Takapūwāhia	s-m, m-s, Co, Pe, sh	1.3	20.8
31	Titahi Bay intermediate	Co, Pe, s, s-m	1.2	19.2
42	Neck	Pe, Co, Bk, s, m-s	1.0	16
29	Takapūwāhia	Co, Pe, s-m, m, s	1.0	16
34	Northern boat sheds	Co, Pe, m-s, s	0.9	14.4
33	Boat sheds	Pe, s, Co, s-m	0.8	12.8
6	Railway line	Pe, Co, Bk, sh	0.7	11.2
4	Mana sandbanks	m-s, sh	0.6	9.6
18	Porirua stream	s, s-m, Bu, Co, Pe, sh	0.4	6.4
36	Neck	Co, Pe, s, m-s, sh	0.4	6.4
45	Opposite marina	s, Pe, Co, sh	0.3	4.8
26	Takapūwāhia	s-m, Co, Pe, s	0.3	4.8
23	Takapūwāhia	m-s, s-m, Co, Pe, sh	0.3	4.8
16	Porirua stream	m-s, s-m, s, sh	0.3	4.8
38	Te Onepoto bay	s-m, m-s, Pe, Co	0.2	3.2

Population estimate

The estimated number of mud whelks found throughout the intertidal area of Onepoto Arm was 10 million (CV 34.5 %, Table 13).

Table 13: Abundance figures for mud whelks, abundance values are in numbers of mud whelks within the Onepoto intertidal area. Bounds are 95% CI; CV coefficient of variation.

Species	Lower bound	Abundance	Upper bound	CV (%)	No. transects found
Mud whelk	3 298 000	10 629 000	17 961 000	34.5	19/24

4.3.6 Nut shell (*Nucula hartvigiana*)

Distribution

A total of 194 nut shells were found during the Onepoto Arm intertidal survey, at half of the 24 transect sites (Figure 14). There was an uneven distribution of nut shells through the Onepoto intertidal areas. They were found at Takapūwāhia but not at Porirua Stream, and found among the pebbles and cobbles of the north-western side of the estuary, but not adjacent to the railway line with similar sediments. Nut shells are found in a range of sediment type's, muddy-sand, sandy-mud, pebbles and cobbles.

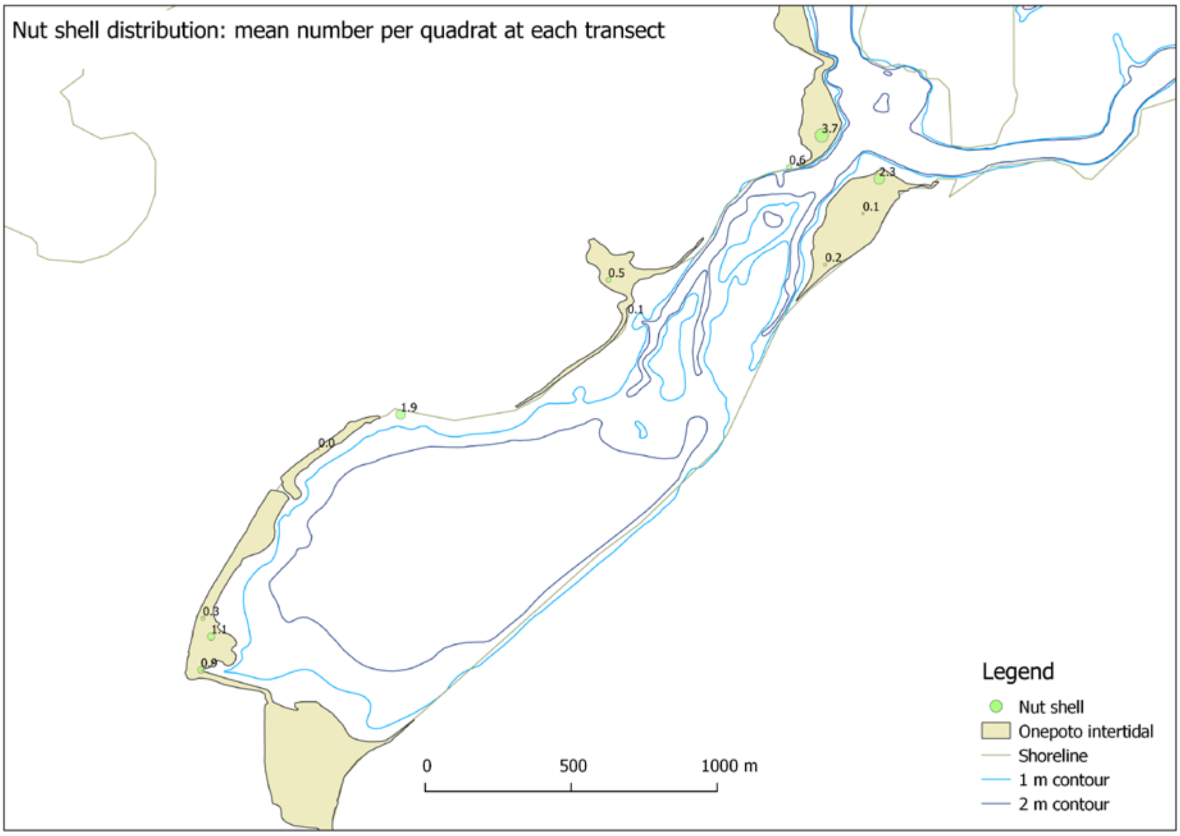

Figure 14: Distribution and density plot for nut shells found in Onepoto. Numbers indicate the mean number found per quadrat at each transect.

Density

The highest density of nut shells was 3.7 per quadrat at site 44 opposite Mana marina. The 2nd and 3rd highest densities were at Mana sandbank and the boat sheds respectively (Table 14). The site with the highest density of nut shells had a dominant sediment type of muddy-sand and shell hash.

Table 14: Nut shell density, Substrate categories (in decreasing order of dominance), and average number of nut shells per (25 × 25 cm) quadrat and square metre at each transect. Habitat types are mud (m), muddy-sand (m-s), sandy-mud (s-m), sand (s), pebble (Pe), cobble (Co), boulder (Bu), bedrock (Bk), shell-hash (sh).

Site No.	Site name	Substrate categories	Average No. of shell per quadrat	Average No. of shell per m^2
44	Opposite marina	m-s, sh	3.7	59.2
2	Mana sandbanks	s-m, m-s, s, sh	2.3	36.8
33	Boat sheds	Pe, s, Co, s-m	1.9	30.4
24	Takapūwāhia	s-m, m-s, Co, Pe, sh	1.2	19.2
23	Takapūwāhia	m-s, s-m, Co, Pe, sh	0.9	14.4
42	Neck	Pe, Co, Bk, s, m-s	0.6	9.6
38	Te Onepoto bay	s-m, m-s, Pe, Co	0.5	8
26	Takapūwāhia	s-m, Co, Pe, s	0.3	4.8
4	Mana sandbanks	m-s, sh	0.2	3.2
3	Mana sandbanks	m-s, s, s-m, sh	0.1	1.6
36*	Neck	Co, Pe, s, m-s, sh	0.1	1.6
31*	Titahi Bay intermediate	Co, Pe, s, s-m	0.04	0.64

*** Only one nut shell was found at this site.**

Population estimate

The estimated number of nut shells found in the intertidal area of Onepoto Arm was almost 6 million (CV 38.2 %, Table 15).

Table 15: Abundance figures for nut shells, abundance values are in numbers of nut shells within the Onepoto intertidal area. Bounds are 95% CI; CV coefficient of variation.

Species	Lower bound	Abundance	Upper bound	CV (%)	No. transects found
Nut shell	1 390 000	5 896 000	10 403 000	38.2	12/24

4.3.7 Spire shell (*Zeacumantus lutulentus*)

Distribution

A total of 129 spire shells were found during the Onepoto Arm intertidal survey, at 16 of the 24 transect sites (Figure 15). There was an even distribution of spire shells throughout the Onepoto intertidal areas where they were found in most habitats. Spire shells were found in a wide range of sediment types, muddy-sand, sandy-mud, sand, pebble, cobble, boulder, and bedrock.

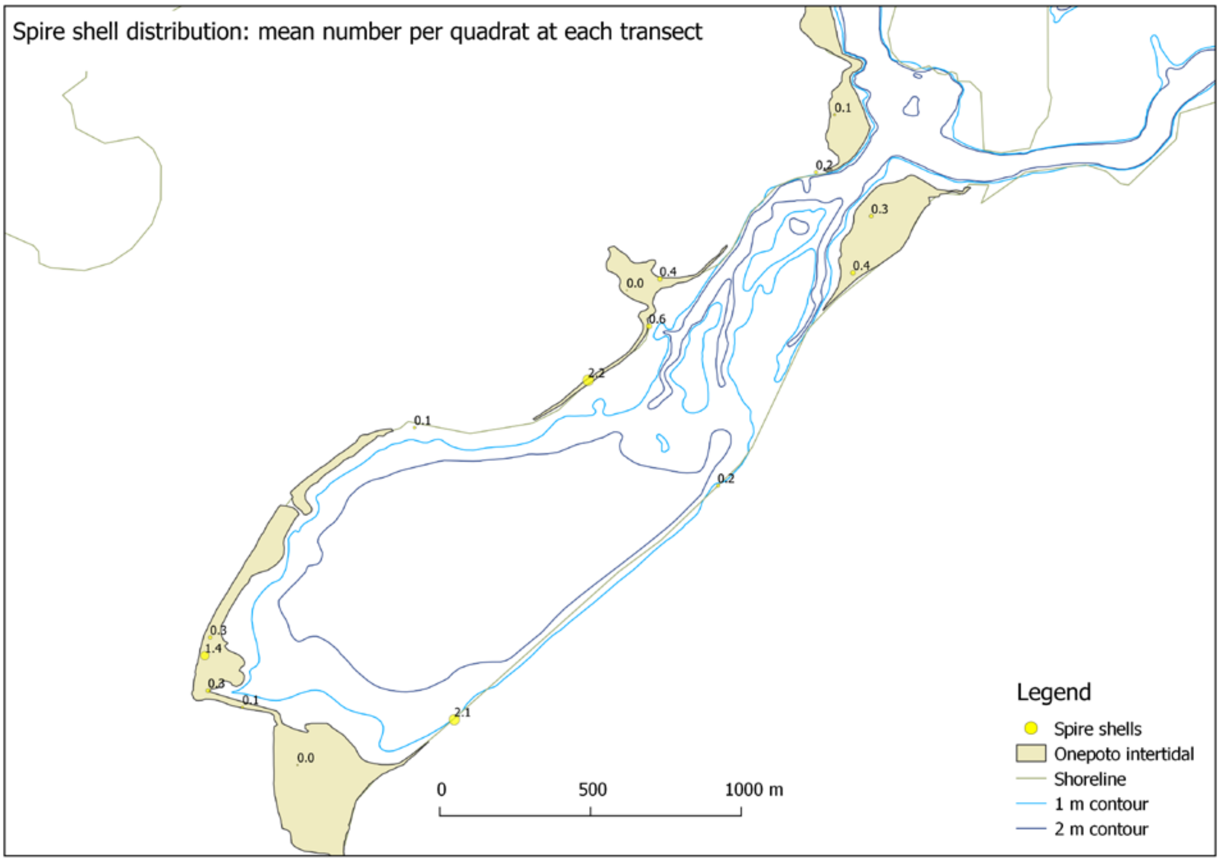

Figure 15: Distribution and density plot for spire shells found in Onepoto. Numbers indicate the mean number found per quadrat at each transect.

Density

The highest density of spire shells was 2.2 per quadrat at site 34 the northern end of the boat sheds. The 2nd and 3rd highest densities were adjacent to the railway line and Takapūwāhia respectively (Table 16). The site with the highest density of nut shells had a dominant sediment type of cobble and pebbles.

Table 16: Spire shell density, Substrate categories (in decreasing order of dominance), and average number of spire shells per (25 × 25 cm) quadrat and square metre at each transect. Substrate categories are mud (m), muddy-sand (m-s), sandy-mud (s-m), sand (s), pebble (Pe), cobble (Co), boulder (Bu), bedrock (Bk), shell-hash (sh).

Site No.	Site name	Substrate categories	Average No. of shell per quadrat	Average No. of shell per m^2
34	Northern boat sheds	Co, Pe, m-s, s	2.2	35.2
14	Railway line	Bu, Bk, Co, Pe	2.1	33.6
24	Takapūwāhia	s-m, m-s, Co, Pe, sh	1.4	22.4
36	Neck	Co, Pe, s, m-s, sh	0.6	9.6
4	Mana sandbanks	m-s, sh	0.4	6.4
40	Neck	Co, m-s, s, Pe, sh	0.4	6.4
26	Takapūwāhia	s-m, Co, Pe, s	0.3	4.8
3	Mana sandbanks	m-s, s, s-m, sh	0.3	4.8
23	Takapūwāhia	m-s, s-m, Co, Pe, sh	0.3	4.8
11	Railway line	Bk, Pe, sh	0.2	3.2
42	Neck	Pe, Co, Bk, s, m-s	0.2	3.2
20*	Whitireia	Co, Pe, s, m-s	0.1	1.6
45	Opposite marina	s, Pe, Co, sh	0.1	1.6
33	Boat sheds	Pe, s, Co, s-m	0.1	1.6
18*	Porirua stream	s, s-m, Bu, Co, Pe, sh	0.04	0.64
38*	Te Onepoto bay	s-m, m-s, Pe, Co	0.04	0.64

*** Only one spire shell was found at this site.**

Population estimate

The estimated number of spire shells found in the intertidal area of Onepoto Arm was 4.5 million (CV 34.5 %, Table 17).

Table 17: Abundance figures for spire shells, abundance values are in numbers of spire shells within the Onepoto intertidal area. Biomass bounds are 95% CI; CV coefficient of variation.

Species	Lower bound	Abundance	Upper bound	CV (%)	No. transects found
Spire shell	1 398 000	4 496 000	7 594 000	34.5	16/24

4.3.8 Periwinkle (*Austrolittorina* sp.)

Distribution

A total of 113 periwinkles were found during the Onepoto Arm intertidal survey, at only one of the 24 transect sites (Figure 16). Periwinkles were only found at site 11 next to the railway line where the sediment was dominated by bedrock, and pebbles.

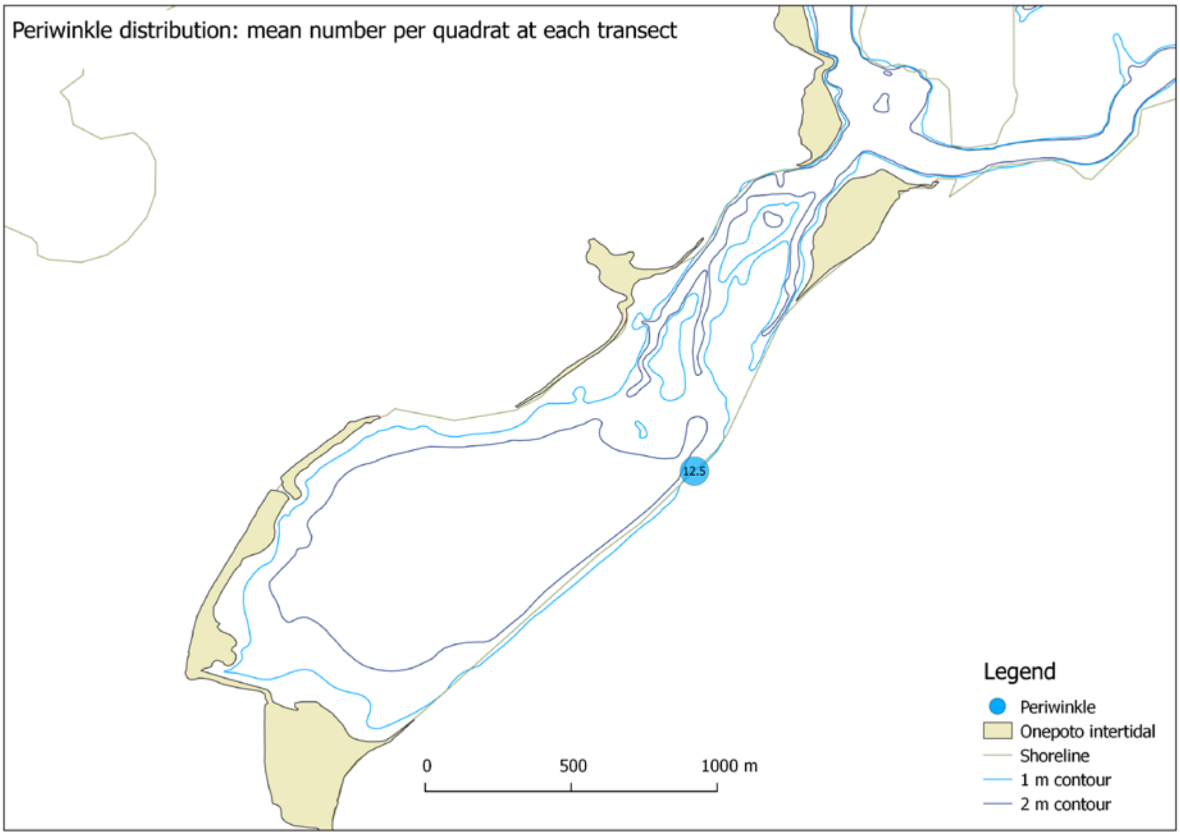

Figure 16: Distribution and density plot for periwinkles found in Onepoto. Numbers indicate the mean number found per quadrat at each transect.

Population estimate

The estimated number of periwinkles found in the intertidal area of Onepoto Arm was 6.2 million (CV 100 %, Table 18).

Table 18: Abundance figures for periwinkles, abundance values are in numbers of periwinkles within the Onepoto intertidal area. Bounds are 95% CI; CV coefficient of variation.

Species	Lower bound	Abundance	Upper bound	CV (%)	No. transects found
Periwinkle	0	6 273 000	18 818 000	100	1/24

4.3.9 Mussels (Mytilidae)

Distribution

A total of 108 mussels were found during the Onepoto Arm intertidal survey, at only 6 of the 24 transect sites (Figure 17). The mussels were a mixture of species and were found at a mixture of sites from site 14 adjacent to the railway line amongst the boulders and pebbles, to site 45 opposite Mana marina where the sediment was dominated by sand.

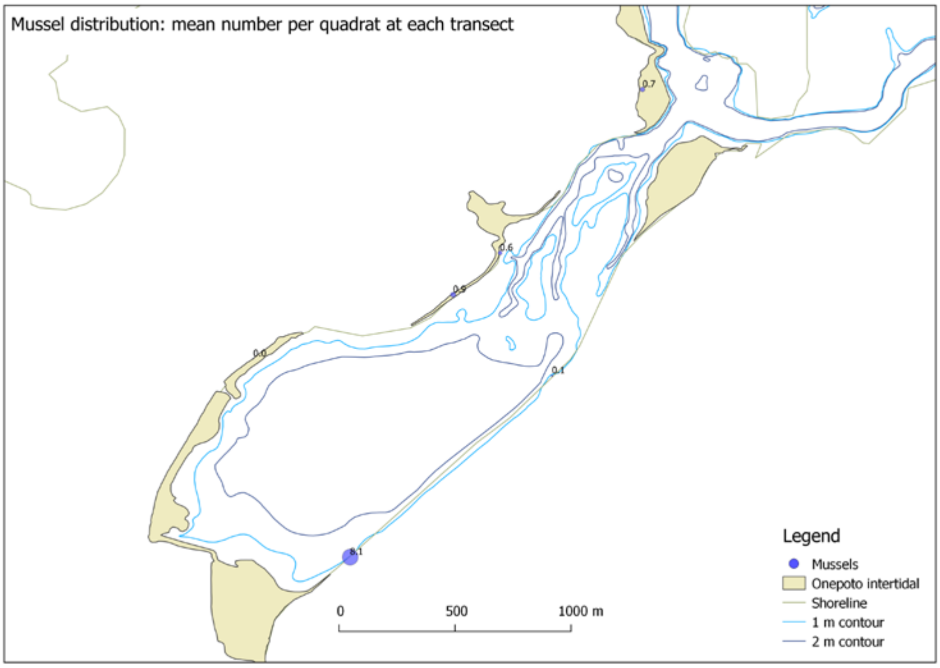

Figure 17: Distribution and density plot for mussels found in Onepoto. Numbers indicate the mean number found per quadrat at each transect.

Density

The highest density of mussels came from site 14 next to the railway line (Table 19), where the sediment was dominated by boulders and pebbles.

Table 19: Mussel density, substrate categories (in decreasing order of dominance), and average number of mussels per (25 × 25 cm) quadrat and square metre at each transect. Substrate categories are mud (m), muddy-sand (m-s), sandy-mud (s-m), sand (s), pebble (Pe), cobble (Co), boulder (Bu), bedrock (Bk), shell-hash (sh).

Site No.	Site name	Substrate categories	Average No. of shell per quadrat	Average No. of shell per m^2
14	Railway line	Bu, Bk, Co, Pe	8.1	129.6
34	Northern boat sheds	Co, Pe, m-s, s	0.9	14.4
45	Opposite marina	s, Pe, Co, sh	0.7	11.2
36	Neck	Co, Pe, s, m-s, sh	0.6	9.6
11*	Railway line	Bk, Pe, sh	0.1	1.6
31*	Titahi Bay intermediate	Co, Pe, s, s-m	0.04	0.64

*** Only one mussel was found at this site.**

Population estimate

The estimated number of mussels found throughout the intertidal area of Onepoto Arm was 5.2 million with a high CV of 77.5 % (Table 20).

Table 20: Abundance figures for mussels, abundance values are in numbers of mussels within the Onepoto intertidal area. Biomass bounds are 95% CI; CV coefficient of variation.

Species	Lower bound	Abundance	Upper bound	CV (%)	No. transects found
Mussels	0	5 236 000	13 356 000	77.5	6/24

4.3.10 Limpets (Acmaeidae)

Distribution

A total of 73 limpets were found during the Onepoto Arm intertidal survey, at 9 of the 24 transect sites (Figure 18). Limpets were found at most of the sites along the west side of Onepoto Arm, as well as at site 14 adjacent to the railway line. Limpets were found in sediments dominated by boulders, cobble and pebbles.

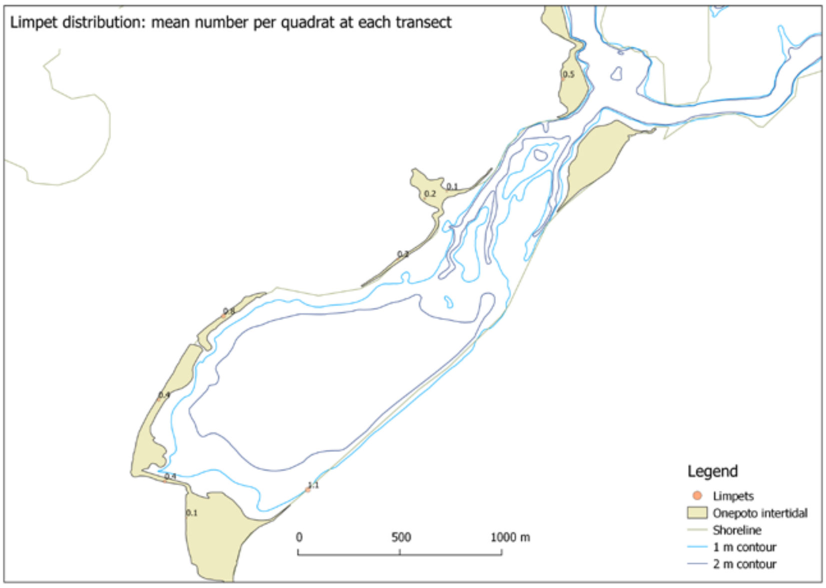

Figure 18: Distribution and density plot for limpets found in Onepoto. Numbers indicate the mean number found per quadrat at each transect.

Density

The highest density of limpets (Table 21) came from the railway line and opposite Titahi Bay intermediate, where the sediment type was dominated by cobble, pebbles, and sandy-mud.

Table 21: Limpet density, substrate categories (in decreasing order of dominance), and average number of limpets per (25 × 25 cm) quadrat and square metre at each transect. Substrate categories are mud (m), muddy-sand (m-s), sandy-mud (s-m), sand (s), pebble (Pe), cobble (Co), boulder (Bu), bedrock (Bk), shell-hash (sh).

Site No.	Site name	Substrate categories	Average No. of shell per quadrat	Average No. of shell per m^2
14	Railway line	Bu, Bk, Co, Pe	1.1	17.6
31	Titahi Bay intermediate	Co, Pe, s, s-m	0.9	14.4
45	Opposite marina	s, Pe, Co, sh	0.5	8
29	Takapūwāhia	Co, Pe, s-m, m, s	0.4	6.4
20	Whitireia	Co, Pe, s, m-s	0.4	6.4
38	Te Onepoto bay	s-m, m-s, Pe, Co	0.2	3.2
34	Northern boat sheds	Co, Pe, m-s, s	0.2	3.2
18	Porirua stream	s, s-m, Bu, Co, Pe, sh	0.1	1.6
40*	Neck	Co, m-s, s, Pe, sh	0.1	1.6

*** Only one limpet was found at this site.**

Population estimate

The estimated number of limpets found throughout the intertidal area of Onepoto Arm was 2 million (CV 36.8 %, Table 22).

Table 22: Abundance figures for limpets, abundance values are in numbers of limpets within the Onepoto intertidal area. Bounds are 95% CI; CV coefficient of variation.

Species	Lower bound	Abundance	Upper bound	CV (%)	No. transects found
Limpet	524 000	1 982 000	3 440 000	36.8	9/24

4.3.11 Cominella whelk (*Cominella* sp.)

Distribution

A total of 40 Cominella whelks were found during the Onepoto Arm intertidal survey, at only 7 of the 24 transect sites (Figure 19). The distribution of Cominella whelks was limited to the northern end of Onepoto Arm with sediments ranging from muddy-sand, to sandy-mud, sand, pebble and bedrock.

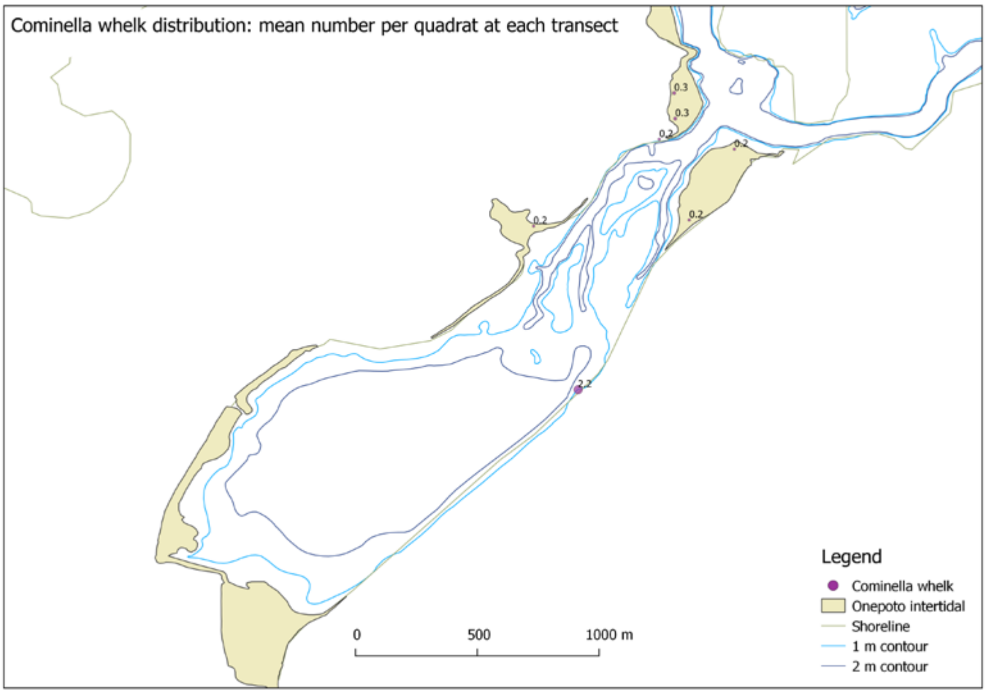

Figure 19: Distribution and density plot for Cominella whelks found in Onepoto. Numbers indicate the mean number found per quadrat at each transect.

Density

The highest density of Cominella whelks (Table 23) came from site 11 adjacent to the railway line where the sediment type was dominated by bedrock.

Table 23: Cominella whelk density, substrate categories (in decreasing order of dominance), and average number of Cominella whelks per (25 × 25 cm) quadrat and square metre at each transect. Substrate categories are mud (m), muddy-sand (m-s), sandy-mud (s-m), sand (s), pebble (Pe), cobble (Co), boulder (Bu), bedrock (Bk), shell-hash (sh).

Site No.	Site name	Substrate categories	Average No. of shell per quadrat	Average No. of shell per m^2
11	Railway line	Bk, Pe, sh	2.2	35.2
44	Opposite marina	m-s, sh	0.3	4.8
45	Opposite marina	s, Pe, Co, sh	0.3	4.8
2	Mana sandbank	s-m, m-s, s, sh	0.2	3.2
4	Mana sandbank	m-s, sh	0.2	3.2
40	Neck	Co, m-s, s, Pe, sh	0.2	3.2
42	Neck	Pe, Co, Bk, s, m-s	0.2	3.2

Population estimate

The estimated number of Cominella whelks found throughout the intertidal area of Onepoto was 1.8 million (CV 58.8 %, Table 24).

Table 24: Abundance figures for Cominella whelks, abundance values are in numbers of whelks within the Onepoto intertidal area. Bounds 95% CI; CV coefficient of variation.

Species	Lower bound	Abundance	Upper bound	CV (%)	No. transects found
Cominella whelk	0	1 885 000	4 101 000	58.8	7/24

4.3.12 Cat's eye (Turbinidae)

Distribution

A total of 13 cat's eyes were found during the Onepoto Arm intertidal survey, at only 5 of the 24 transect sites (Figure 20). The distribution of cat's eyes was limited to the central sites (east and west) of Onepoto Arm where sediments were dominated by bedrock, cobble, and pebbles.

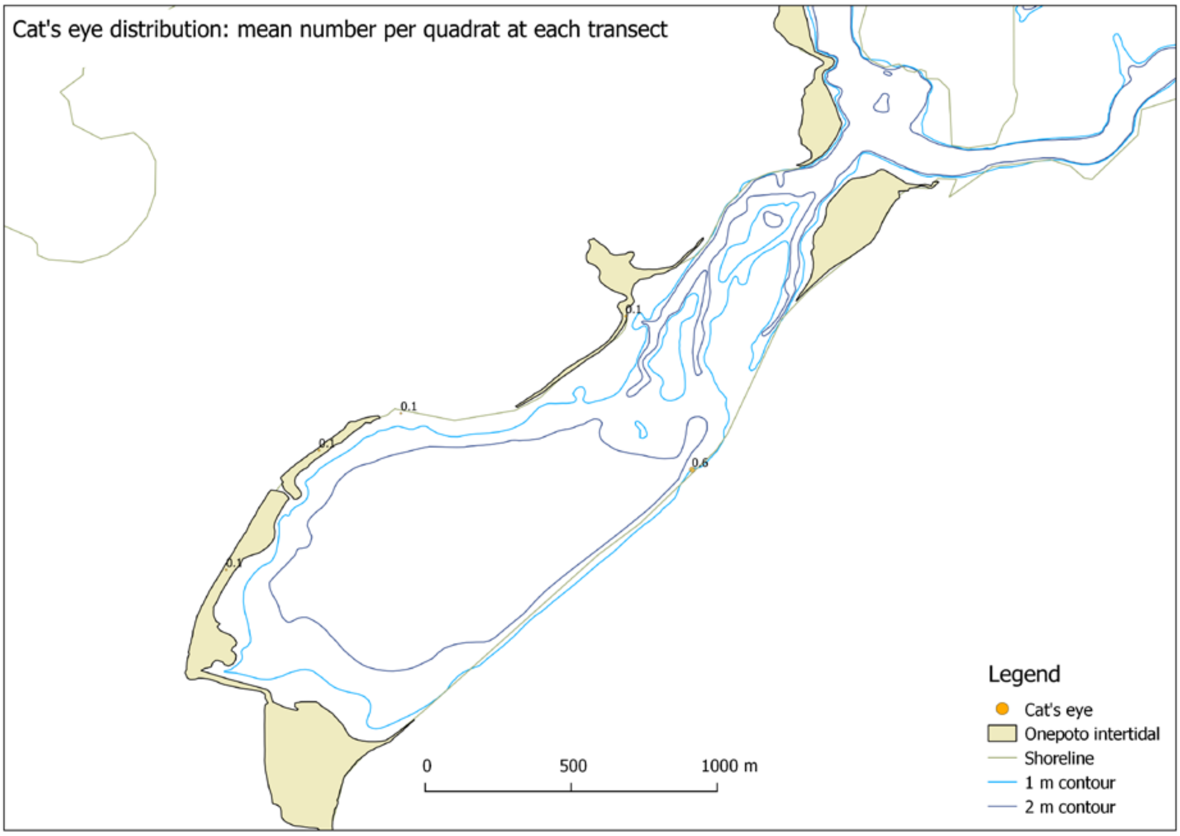

Figure 20: Distribution and density plot for cat's eyes found in Onepoto. Numbers indicate the mean number found per quadrat at each transect.

Density

The highest density of cat's eyes (Table 25) was at site 11 adjacent to the railway line where the sediment type was dominated by bedrock.

Table 25: Cat's eye density, substrate categories (in decreasing order of dominance), and average number of cat's eye's per (25 × 25 cm) quadrat and square metre at each transect. Substrate categories are mud (m), muddy-sand (m-s), sandy-mud (s-m), sand (s), pebble (Pe), cobble (Co), boulder (Bu), bedrock (Bk), shell-hash (sh).

Site No.	Site name	Substrate categories	Average No. of shell per quadrat	Average No. of shell per m^2
11	Railway line	Bk, Pe, sh	0.6	9.6
29	Takapūwāhia	Co, Pe, s-m, m, s	0.1	1.6
33	Boat sheds	Pe, s, Co, s-m	0.1	1.6
31	Titahi Bay intermediate	Co, Pe, s, s-m	0.1	1.6
36*	Neck	Co, Pe, s, m-s, sh	0.1	1.6

*** Only one cat's eye was found at this site.**

Population estimate

The estimated number of cat's eyes found throughout the intertidal area of Onepoto Arm was 0.5 million (CV 61.3 %, Table 26).

Table 26: Abundance figures for cat's eyes, abundance values are in numbers of cat's eyes within the Onepoto intertidal area. Bounds are 95% CI; CV coefficient of variation.

Species	Lower bound	Abundance	Upper bound	CV (%)	No. transects found
Cat's eye	0	465 000	1 034 000	61.3	5/24

4.3.13 Bubble shell (*Haminoea zelandiae*)

Distribution

Only ten bubble shells were found during the Onepoto Arm intertidal survey, at only 5 of the 24 transect sites (Figure 21). Bubble shells were found at the Mana sandbank in the north and at the Porirua Stream and Takapūwāhia in the southern end of Onepoto. Sediment types in these two areas were dominated by sandy-mud and muddy-sand.

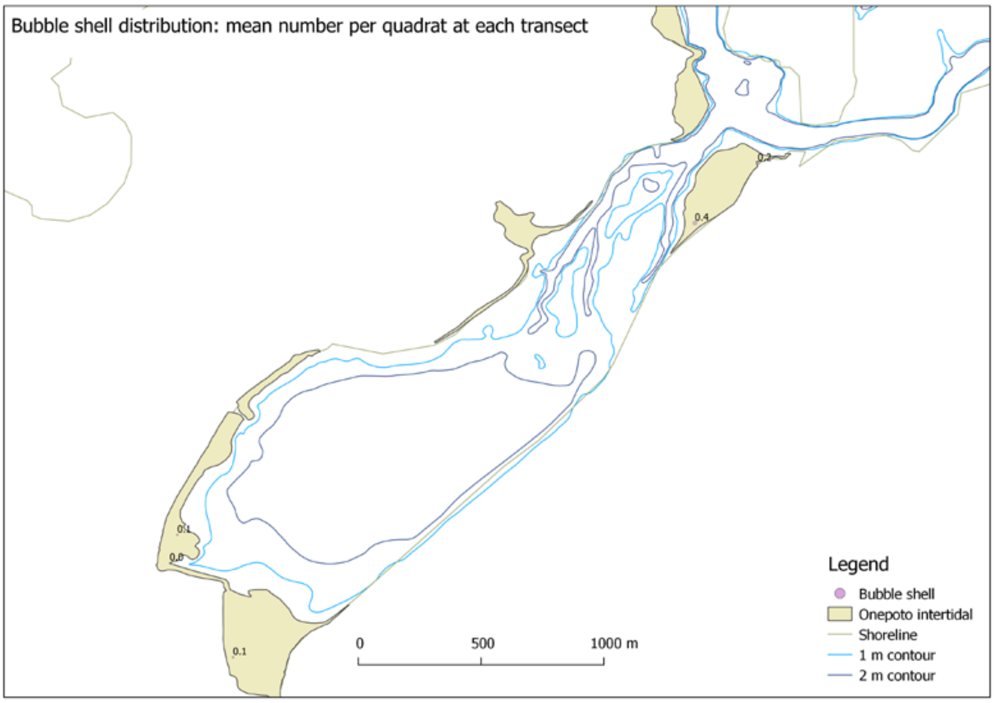

Figure 21: Distribution and density plot for bubble shells found in Onepoto. Numbers indicate the mean number found per quadrat at each transect.

Density

The highest density of bubble shells (Table 27) came from Mana sandbank, where the sediment type was dominated by muddy-sand.

Table 27: Bubble shell density, substrate categories (in decreasing order of dominance), and average number of bubble shells per (25 × 25 cm) quadrat and square metre at each transect. Substrate categories are mud (m), muddy-sand (m-s), sandy-mud (s-m), sand (s), pebble (Pe), cobble (Co), boulder (Bu), bedrock (Bk), shell-hash (sh).

Site No.	Site name	Substrate categories	Average No. of shell per quadrat	Average No. of shell per m^2
4	Mana sandbank	m-s, sh	0.4	6.4
2	Mana sandbank	s-m, m-s, s, sh	0.2	3.2
24	Takapūwāhia	s-m, m-s, Co, Pe, sh	0.1	1.6
16*	Porirua stream	m-s, s-m, s, sh	0.1	1.6
23*	Takapūwāhia	m-s, s-m, Co, Pe, sh	0.04	0.64

*** Only one bubble shell was found at this site.**

Population estimate

The estimated number of bubble shells found throughout the intertidal area of Onepoto Arm was 0.5 million (CV 55.5 %, Table 28).

Table 28: Abundance figures for bubble shells, abundance values are in numbers of bubble shells within the Onepoto intertidal area. Bounds are 95% CI; CV coefficient of variation.

Species	Lower bound	Abundance	Upper bound	CV (%)	No. transects found
Bubble shell	0	446 000	941 000	55.5	5/24

4.4 Redox layer

The oxygenated sediment above the redox layer was shallowest in the inner harbour and deepest at the harbour mouth where the sediment has undergone higher levels of mixing (Figure 22).

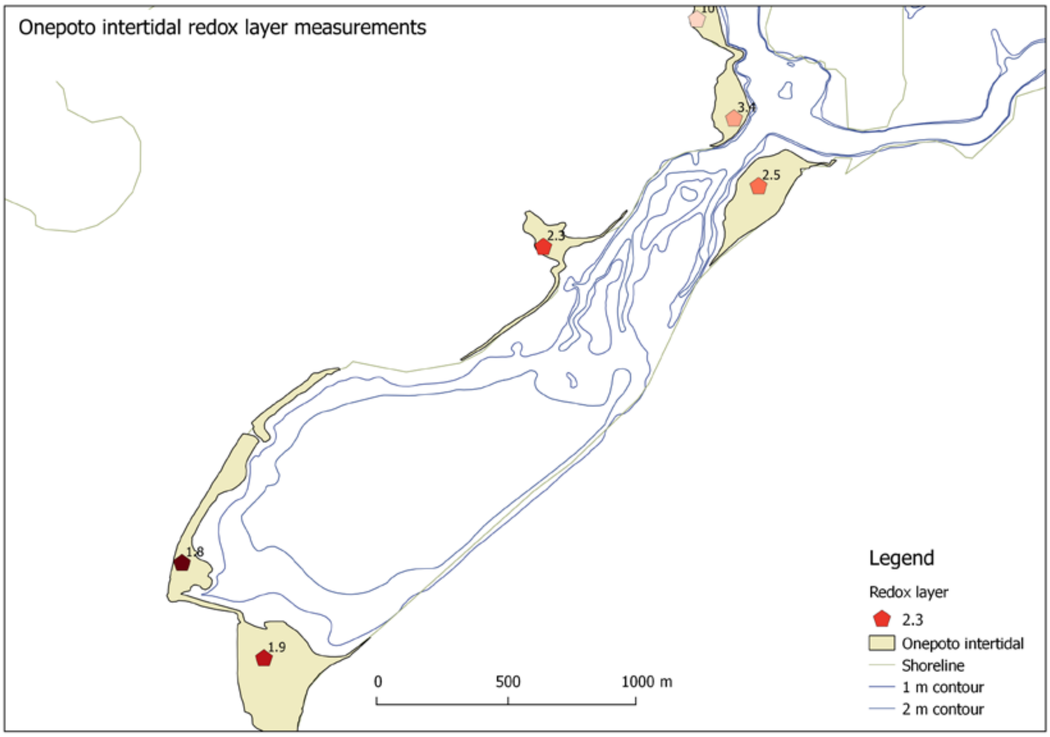

Figure 22: The mean redox layer depth (in centimetres) was calculated for each individual transect or groups of transects in the Onepoto Arm that were dominated by soft sediments.

The redox layer was very shallow, about 2 cm, in the southern parts of Onepoto Arm near Takapūwāhia and the Porirua stream (Table 29). The redox layer was deeper (there is more mixing of sediments) at more northern sites. At Mana sandbank, the mean redox layer depth is at 2.5 cm, and no layer was present at site 48 opposite Ngāti Toa Domain.

Table 29: The redox depth was measured at all transect sites dominated by soft sediments. The mean redox depth (cm) was recorded for each individual transect or group of transects.

Site No.	Site name	Mean redox depth (cm)	Quadrats measured
23, 24	Takapūwāhia	1.8	30
16, 18	Porirua Stream	1.9	18
38	Te Onepoto bay	2.3	19
2, 3, 4	Mana sandbank	2.5	42
44	Outer Bay opposite mana marina	3.4	3
48	Outer bay opposite domain	no layer	27

4.5 Shellfish identification guide

A pictorial guide for the identification of Onepoto intertidal shellfish species is shown in Appendix 1.

5. DISCUSSION

This exploratory survey was the first systematic survey of intertidal shellfish in Te Awarua-o-Porirua Harbour Onepoto Arm and describes the shellfish species present, their densities and distributions and the size structure of the populations. There were no data available to stratify the survey area and the whole area was treated as a single stratum. This resulted in a large number of zero catches in quadrats for most of the less common species, resulting in high CVs for the estimates of population size. The data on the distribution of species and their densities are invaluable for designing a survey to provide improved baseline estimates for species of interest.

Species that had a ubiquitous distributions generally had lower CVs than patchily distributed species. Coefficients of variation for population estimates for most of these species were too high to be used as baseline estimates, but estimates for two of the key taonga species (cockles and mudflat topshells) and for wedge shells, CVs were reasonable and the population estimates can be more readily compared with future survey estimates to determine trends in shellfish abundance. The Onepoto population estimates complement the Pauatahanui Inlet (cockle only survey since 1971) estimates and provide some information for a whole of the harbour approach to restoration and management.

The Onepoto Arm intertidal sites with the highest densities of cockles were Mana sandbank and Takapūwāhia. The mean number of cockles found in each tidal area throughout Onepoto Arm showed very little difference in numbers whether in low, mid or high tidal areas, possibly reflecting the shallow dissipative profile of intertidal areas. However, the size of cockles did slightly change, increasing in size from high water to low water, as has been documented elsewhere e.g. Dobbinson et al. (1989). The population estimates for cockles show that it is the dominant shellfish species in the intertidal area of Onepoto Arm, as they are in Pauatahanui Inlet. They comprise over half the combined total of all shellfish species there. The population estimate of cockles in Pauatahanui Inlet in 2013 was 336 million (Michael & Wells 2014), 75% more cockles than in the Onepoto Arm with a population estimate of 190 million. The intertidal area of Onepoto is smaller (one quarter the size) of Pauatahanui Inlet. Considerable areas of intertidal flats were lost in the 1950s to the main-trunk railway expansion along the eastern side of the in the Onepoto Arm (see Figure 2). The land reclamation changed the intertidal zone there from shallow-sloping soft substrates to short steep intertidal areas dominated by hard substrate. The habitat in these areas became more suitable for gastropods than for bivalves. The cockle length frequency distribution from Pauatahanui Inlet in 2013 was very similar to the Onepoto Arm length frequency distribution, with both having a mode at 20 mm, and the bulk of cockles between 15 and 30 mm, and only a small number of cockles larger than 40 mm (Michael & Wells 2014). The Pauatahanui Inlet population estimate had an acceptable CV of 14%, the Onepoto estimate with a CV of 23% has a slightly lower precision associated with it, and just outside the CV range from the Pauatahanui Inlet cockle population estimates of 14 – 20% since 1998 (Michael & Wells 2014). A random stratified survey of cockles should achieve a lower CV. Sensitivity analysis could be conducted on these survey data by post-stratifying the area and re-estimating population size and CV. Juvenile cockles in Onepoto (6.8%) have a similar distribution to the larger cockles and are found throughout Onepoto except for opposite Titahi Bay intermediate school and the railway line sites. Directly comparing these numbers with Pauatahanui Inlet (16.2% in 2013) was not valid because in Pauatahanui Inlet the cockles were measured down to a minimum size of 2 mm in length, while cockles in Onepoto were measured down to a minimum of 5 mm in length. A direct comparison could be made between the two harbour arms if the raw data from the Pauatahanui Inlet cockle count could be accessed.

Some shellfish have been grouped into species-groups, these include limpets which were rarely above 10 mm in length, and were difficult to identify in the field. Small mussels (less than 20 mm long) were also difficult to identify to species level in the field, but were likely to be *Xenostrobus pulex,* which form large dense mats. The mussels grouping did not include any generally popular edible mussels such as the greenshell (*Perna canaliculus*) or blue (*Mytilus edulis*) mussels.

All the shellfish species observed by De Luca (2014) were also seen during this Onepoto Arm intertidal survey, with one exception: mud snails (*Potamopyrgus estuarinus*) which had been recorded from the mouth of Porirua Stream (Site IO2). The reason for not seeing any mud snails (*Potamopyrgus* spp.) which prefer freshwater habitats, in this survey, was probably a result of none of this survey's transects passing through freshwater streams.

Surveys of cockle population from selected northern North Island intertidal sites in 2013–14 gave population estimates ranging from 4.4 million at Graham's beach on the Manukau Harbour heads to 545 million cockles at Whangateau Harbour, south of Leigh (Berkenbusch et al. 2015). The 190 million cockles estimated in the Onepoto intertidal area sits near the middle of that northern North Island range. If the highest cockle densities from Onepoto (1632 per m^2) at Mana sandbank were compared with the highest densities from the nine northern North Island sites (1317 cockles per m^2 at Pataua Estuary), Onepoto had the highest cockle densities. This shows that although some areas of Onepoto have very high densities of cockles, that density is not consistent throughout all the Onepoto intertidal areas.

Large cockles (at least 30 mm shell length) comprised a relatively small proportion (11.3%) of the cockles measured (N = 4740). The highest percentage of large cockles from the northern North Island sampling was 62% at Cockle Bay, Auckland which has been closed to shellfish gathering for 6 months of the year (over summer) and for the remaining six months has had a catch limit imposed on gatherers (Berkenbusch et al. 2015). Two northern sites had more large sized cockles than Onepoto (Okoromai Bay 16%, Umupuia Beach 26%), and five sites had only 1 – 2% large sized cockles (Berkenbusch et al. 2015), considerably less than Onepoto.

The depth of oxygenated sediment above the redox layer was shallowest in the inner harbour and deepest at the harbour mouth where the sediments may undergo higher levels of mixing, or are influenced less by the higher sedimentation rates found near Takapūwāhia and Porirua stream (Discovery Marine Ltd 2015). With an increase in the depth of the redox layer there is more oxygenated sediment for burrowing shellfish to live in.

Contaminant levels in cockles from Te Awarua-o-Porirua Harbour Onepoto Arm were measured in 2006 (Milne 2006). Cockles at Mana sandbank and Takapūwāhia (sites with the highest densities of cockles) had levels of faecal contamination just above detection levels and well below Ministry of Health and New Zealand Food Safety Authority recommended guidelines for edible tissue (Milne 2006). The heavy metals cadmium, mercury, and lead were also recorded in cockle samples from Mana Sandbank and Takapūwāhia but not at concentrations that exceeded the New Zealand Food Standards for edible tissue (Milne 2006). There were additional contaminants found in Onepoto Arm cockles (chromium, copper, nickel, and zinc) but no standards governing their effect on people. Because of this, the current advice from the Greater Wellington Regional Council and Regional Public Health is to avoid eating shellfish from Te Awarua-o-Porirua Harbour.

The highest densities of cockles from the intertidal areas of Onepoto were found at Takapūwāhia and Mana sandbank, in the inner and outer harbour and in two very different environments. Takapūwāhia was dominated by muddy-sand or sandy-mud sediment, in the sheltered south-western corner of Onepoto. Mana sandbank has similar sediments but is in the outer Onepoto estuary next to the main channel. Wedge shells also had their sites of highest densities in both the inner and outer Onepoto. This pattern, of the inner estuary habitats supporting similar densities of bivalves to the outer estuarine habitats, suggests habitats of similar quality in the inner and outer Onepoto intertidal areas.

Only cockles (190 million) and mudflat topshells (15.4 million) had population estimates with a CV less than 25%. When a shellfish species has a population estimate with a CV higher than 25% it becomes more difficult to make comparisons between surveys, as it is less likely that differences between estimates will be significant. Better stratification based on the core distributions of these species are likely to give much improved estimates assuming an appropriate level of sampling. This was only an intertidal survey, with cockles and other shellfish species likely to also be located sub-tidally. These population estimates will be used as a baseline against which future surveys can be compared in order to determine trends in shellfish abundance.

The Porirua Harbour and catchment strategy and action plan, March 2012 (Calder 2012) aims to expand the three-yearly cockle survey in the Pauatahanui Inlet to include the Onepoto Arm (objective EB6). Data from the Onepoto Arm intertidal survey undertaken in March 2015 could be used to develop a standard survey design to provide an ongoing time series of surveys.

A number of factors could be taken into consideration for developing a survey design to provide a comparable time-series of information. The most important consideration is clearly defining the specific objectives for the monitoring surveys. The application of different survey designs for Onepoto shellfish surveys are summarised in Michael et al. (2014).

Random stratified surveys are expected to be the most effective designs for detecting changes in abundance for the whole harbour and defined subareas (strata) within the Onepoto Arm. The survey area needs to be stratified (divided into subareas based on the distribution of species density). This stratification should include the depth range of the species across the intertidal zone (high to low water) and the distribution along the coastline. Multispecies surveys need to rank the species of interest by importance. In the absence of information on the distribution of species, the distribution of substrate categories could be used as a proxy. Samples need to be randomly allocated within strata and the level of sampling effort proportional to the density of the target shellfish. Further, levels of funding for surveys need to be adequate to enable sufficient sampling to be undertaken to provide precise estimates of population sizes that can be compared with estimates from other surveys. This survey has provided the information required to develop random stratified survey designs for the Onepoto.

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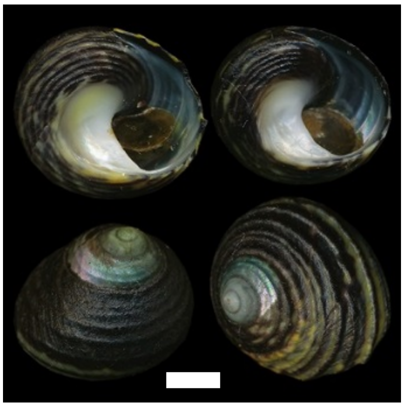
8. APPENDIX 1

Te Awarua-o-Porirua Harbour Onepoto Arm shellfish ID Guide (scale bar is 10 mm long)

Cockle (*Austrovenus stutchburyi*)
Common up to 35 mm, rarely over 50 mm.
A rounded shell. Surface is rough like a file with a criss-cross pattern of ridges. Shell is coloured creamy-white to biscuit brown. May be tainted green with algal growth.

Wedge shell (*Macomona Liliana*)
Commonly grows up to 40 mm in length, rarely over 70 mm.
A thin, smooth, delicate white shell, sometimes stained with black lines. The shell is rounded at one end and has a straight side tapering to a point at the other end. The pointed end of the shell is bent over to one side.



Mudflat topshell (*Diloma subrostrata*)
Commonly grows up to 10 mm in length, rarely over 20 mm.
A small round snail, which has a shell shaped like a spinning top when turned upside down. Its grey black shell is flecked with yellow marks and the inner rim of the opening is yellow.

Spire shell (*Zeacumantus lutulentus*)
Commonly grows up to 25 mm in length, rarely over 30 mm.
This snail has a horn-shaped corkscrew shell which lies on the mud flat surface. Shells are usually grey brown like the muddy sand they lie on. Young horn shells are often darker (brownish black) than older horn shells.

Nut shell (*Nucula hartvigiana*)
Commonly grows up to 7 mm in length, rarely over 10 mm.
A tiny shell, round in shape and fat like a little cherry stone. The shell is shiny smooth and light brown in colour. Empty shells are glossy white inside, like mother of pearl.

Cat's eye. Turbinidae
(July/15 www.teara.govt.nz)
Commonly grows to 35 mm in length, rarely over 60 mm
Has a strong shell with a circular greenish operculum, which is meant to resemble a 'cat's eye' its most conspicuous feature.

Mud whelk (*Cominella glandiformis*)
Commonly grows up to 20 mm in length, rarely over 30 mm.
Has a bullet shaped shell, bluntly pointed at the spire, with small knobbly lumps along the ridges. Often coloured light grey with darker, purplish to brown markings (colours vary). Inner shell beside notch is purple.

Pipi (*Paphies australis*)
Commonly less than 40 mm in length in sheltered areas.
Has a triangular/ oval shaped shell with a smooth surface. Shell is coloured creamy white sometimes patchily stained with orange, brown or black from the sediment.

Limpet (*Notoacmea helmsi*)
Rarely grows above 10 mm in length.
Fragile shell variably coloured though usually light brown, black or greyish green with 30–40 radiating dark lines.

Periwinkles (*Austrolittorina unifasciata*)
(July/2015 www.seafriends.org.nz)
Rarely grows over 10 mm in length.
Commonly found high in the intertidal area, a small shell, with a broad spiral blue and white band, can be clustered together in large groups.

Bubble shell (*Haminoea zelandiae*)
Commonly around 25 mm in length.
Has a delicate white oval shaped shell, which can be translucent in live animals.

9. APPENDIX 2

High tide coordinates for each Onepoto Arm transect sampled

Transect no.	Date	High tide latitude	High tide longitude
2	13/03/2015	-41.10496	174.86642
3	27/02/2015	-41.10589	174.86565
4	13/03/2015	-41.10797	174.86354
6	16/03/2015	-41.10890564	174.8623775
11	13/03/2015	-41.11621	174.85795
12	27/02/2015	-41.12071	174.85296
14	16/03/2015	-41.12543081	174.8475046
16	26/02/2015	-41.12884401	174.8405438
18	26/02/2015	-41.12705908	174.8403864
20	13/03/2015	-41.12499152	174.8391833
23	24/02/2015	-41.12434720	174.8372459
24	24/02/2015	-41.12287006	174.8374819
26	24/02/2015	-41.12211937	174.8376961
29	25/02/2015	-41.12017025	174.8387186
31	25/02/2015	-41.11530656	174.8425685
33	25/02/2015	-41.11367855	174.8459672
34	13/03/2015	-41.11199915	174.8525914
36	13/03/2015	-41.10986813	174.8549574
38	26/02/2015	-41.10859618	174.8543915
40	13/03/2015	-41.10802588	174.8556372
42	13/03/2015	-41.10372344	174.8618291
44	13/03/2015	-41.10287578	174.8623502
45	27/02/2015	-41.10148531	174.8623468
48	27/02/2015	-41.09798452	174.8612631