Waikato Regional Council Technical Report 2011/33

Wharekawa Harbour shellfish and benthic habitat mapping (2010)

www.waikatoregion.govt.nz
ISSN 2230-4355 (Print)
ISSN 2230-4363 (Online)

Waikato
REGIONAL COUNCIL
Te Kaunihera ā Rohe o Waikato

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December 2013

Document #: 1741755

Peer reviewed by:
Malene Felsing Date 14 June 2013

Approved for release by:
Peter Singleton Date 9 December 2013

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Prepared for Waikato Regional Council

NATURAL SOLUTIONS
Marine & Terrestrial Ecologists Ltd

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Acknowledgements:

The authors would like to acknowledge the advice and support received for this project from Catherine Beard, Nathan Singleton, Dan Borman and Mark Williams (Waikato Regional Council), Hamish Kendal (Natural Solutions) and field assistance from Robert Kuchlein.

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Executive summary

Estuaries are highly valued and productive systems. Shellfish are key components of estuarine communities. Apart from their value as a food resource, shellfish perform important ecosystem services. Although relatively resilient compared to other types of intertidal biota, shellfish populations may be sensitive to a number of pressures associated with human activities, including sediment contamination

Waikato Regional Council's shellfish and habitat mapping survey in Wharekawa estuary aimed to map the distribution and abundance of three species of shellfish that are important to humans and the wider ecosystem in order to provide baseline information and provide information to assist ecologically sound resource consent decision making, policy setting and to support the sustainable management of estuaries. The species mapped were the cockle (*Austrovenus stutchburyi*), pipi (*Paphies austrialis*) and wedge shell (*Macomona liliana).* The distribution of estuary sediment types and associated estuarine vegetation were also mapped.

This survey of Wharekawa Harbour sampled a total of 7,049 individuals over 160 sampling points. Bivalves were numerically more dominant than gastropod species (accounting for 88% of individuals sampled), with *Austrovenus* clearly being more abundant than the other bivalves species. The highest densities of individual shellfish found during the sampling were 2,800/m^2 for *Austrovenus*, 7,312/m^2 for *Paphies* and maximum of 608/m^2 for *Macomona.* Of the quadrats sampled, 91 had vegetation present, which was predominantly seagrass.

Medium sand (grain size 250-500 µm) and fine sand (grain size 63-250 µm) dominate Wharekawa estuary. The surface sediment showed a marked gradation of muddy sands in the upper sheltered reaches of the harbour to cleaner sands in the lower reaches of the harbour and in areas of high current.

With respect to the subjective substrate categories, the surface sediment composition in Wharekawa estuary was dominated by 'soft mud/sand', followed by 'very soft mud/sand' and 'soft sand'. 'Firm sand', 'mobile sand' and 'soft sand' are prevalent in the lower estuary, while 'soft mud/sand' and 'very soft mud/sand' are the common sediment types of the upper reaches. 'Soft sand' can be found associated with the main channel of the upper harbour and 'gravels' are associated with outwash flats within the upper tidal reaches of the Wharekawa River and the Kapakapa Stream.

The subjective substrate classification method was relatively successful in identifying fine sediments. The categories 'very soft mud / sand' and, to a lesser extent, 'soft mud / sand' correspond to different relative amounts of grain size classes (grain size distribution) and different median grain sizes. The coarser substrate categories 'soft sand', 'firm sand' and 'mobile sand' could not be associated with distinct grain size distributions or median grain sizes. These categories need to be reviewed if they were to be used in future surveys. More gravel sites (if present in the estuary) need to be investigated to allow an assessment of the usefulness of this category.

The distributions of *Austrovenus*, *Macomona* and *Paphies* among substrate categories reflect their sensitivity to muddy sediments in Wharekawa Harbour. *Paphies* demonstrated the least tolerance for mud with low abundances in sediments containing high levels of mud ('very soft mud / sand' and 'soft mud / sand'). *Austrovenus* were rarely found in the muddiest sediments ('very soft mud / sand') but showed greater tolerance for the moderate mud content in sediments categorised as 'soft mud / sand'. *Macomona* extended more widely over substrate categories, displaying the least sensitivity to mud.

For this estuary, the substrate categories were useful in identifying fine sediment habitats that are likely to be unsuitable for *Austrovenus* and *Paphies.* Due to the weak correlation of sediment categories with coarser grain sizes, the findings of this study are only of limited use for identifying habitats that are suitable for species with a low tolerance for mud.

Seagrass cover differed substantially among sites with different substrate categories and was mainly associated with fine sediments. Mangrove pneumatophores were only found at sites classified as 'very soft mud / sand' and 'soft mud / sand'.

Recommendations for modification of the sampling protocol are similar to that proposed by Felsing & Giles (2011), who reported on a similar mapping survey in Tairua Harbour, including improvements to the substrate classification system, sampling the edges of subtidal channels and possibly determining shellfish biomass.

1. Introduction

1.1. Benthic shellfish and habitat mapping project background

Estuaries are highly significant and sensitive ecosystems and have been identified as one of the coastal ecosystems within the Waikato region most at risk from human activities. The ecosystem services provided by estuaries are many and varied. They provide feeding, spawning and nursery habitats for many fish, shellfish and bird species, thereby supporting diverse biological communities. Estuaries also provide a buffer between the land and sea interface, influencing coastal erosion and filtering contaminants from the land before they enter the coastal zone. In addition to their important ecological and biogeochemical role, estuaries are also greatly valued by people who use them for cultural, commercial and recreational activities.

Our estuaries are coming under increasing pressure from estuary margin development through population growth and coastal settlement, increased demands for recreational uses (e.g. boating and fishing), development in estuaries (e.g. marine farms and marinas), catchment development (e.g. forestry and agriculture), land clearance and reclamation, excavation and dredging (e.g. for boat ramps and boat channels), introduction of invasive species (e.g. Spartina and saltwater paspalum), resource extraction (e.g. through fishing) as well as long term climate changes including sea-level rise.

Effective management of our estuaries requires a good understanding of the composition and abundance of biological communities and an awareness of potential long term increases or decreases in extent and distribution. Shellfish are very common in estuaries and along intertidal beaches all around New Zealand. They form a major link between the water column and benthic habitats and are an important food source for many fish and bird species. They are also a popular food source for people. Most of the familiar edible shellfish belong to a group of molluscs known as bivalves. In this report the terms shellfish and bivalves are used interchangeably. Shellfish populations are sensitive to habitat changes occurring as a result of human activities, such as sediment accumulation, contaminant enrichment or the development of physical structures. For these reasons assessments of bivalve population trends are often used to underpin ecological health or environmental impact assessments.

Waikato Regional Council has a statutory obligation to protect the region's natural coastal resources. Because of their cultural and ecological importance, the protection of shellfish beds is a priority. In order to protect shellfish beds, or detect any changes to them arising from human activity, it is essential to know their extent, i.e. to map where they are found, and how large and dense the beds are.

Waikato Regional Council has been mapping shellfish beds and habitats in three estuaries: Tairua Harbour, Wharekawa Harbour and Otahu Estuary. The results of the Tairua Harbour survey have been reported in Felsing and Giles (2010). This report presents the results of the Wharekawa Harbour survey and a report of the results of the Otahu Estuary survey is currently in preparation (Singleton et al., 2013). Similar mapping surveys have been conducted by the Department of Conservation in Aotea and Kawhia Harbours (Hillock & Rohan, 2011).

1.2. Benthic shellfish and habitat mapping project objectives

The objectives of this estuary benthic shellfish and habitat mapping project are to:

- provide baseline information on the location of shellfish beds, substrate type and vegetation cover within the intertidal area of Wharekawa Harbour; and
- provide information to assist ecologically sound resource consent decision making, policy setting and to support the sustainable management of estuaries in the Waikato region.

1.3. Shellfish species

This project focuses on three bivalve species common in the region's estuaries: the cockle (*Austrovenus stutchburyi*), the pipi (*Paphies australis*) and the wedge shell (*Macomona liliana*).

Austrovenus is a surface suspension feeder. Individuals burrow just below the surface (2-4 cm). They can grow up to 50 mm in length and mature at 18-20 mm. *Austrovenus* is only found in New Zealand where it prefers a soft mud to fine sand substrate (Gibbs & Hewitt 2004; Hillock & Rohan, 2011).

Paphies is also a surface suspension feeder, occurring near channels and burrowing to 2-3 cm below the sediment surface. Juveniles are usually found higher on the shore than adults and migrate slowly down the shore as they mature. While juveniles can be found in fine sand to sandy mud habitats, adults prefer coarser sediments and faster currents (Norkko et al., 2001; Thrush et al., 2004; Felsing & Giles, 2011). *Paphies* can grow up to 75 mm in length with maturity being reached around 40 mm.

Macomona is a surface deposit feeder and burrows to depths of 5-15 cm. Individuals can grow up to 70 mm in length (more common around 40 mm) and mature around 20-22 mm. They prefer habitats similar to *Austrovenus* (Cummings et al. 2002; Gibbs & Hewitt 2004; Hillock & Rohan, 2011) although may be less tolerant than *Austrovenus* of muddy sediment (Norkko et al., 2001; Thrush et al, 2004).

1.4. Wharekawa Harbour

Wharekawa Harbour is a medium sized estuary on the East coast of the Coromandel peninsula, with a total area of approximately 250 ha and a catchment area of roughly 10,000 hectares. It is a site of cultural significance to a number of Hauraki iwi, including Ngati Hako, Ngati Hikairo, Ngati Pu, Ngati Tamatera and Ngati Whanaunga.

Wharekawa Harbour and the associated sand spit are recognised as an Areas of Significant Conservation Value in the Waikato Regional Coastal Plan. The harbour and sand spit support regionally and nationally significant populations of common and threatened wading, coastal and freshwater bird species, such as NZ dotterel, wrybill, southern and variable oystercatchers, reef heron, Australasian bittern and banded rail. Most of the estuary consists of intertidal sandflats and channels (~ 42%), with intertidal vegetated areas accounting for the remaining 58% of the total area. The majority of vegetation as shown in Figure 2 is made up of mangroves (20%), seagrass (20%), saltmarsh (rush/sedge and saltmarsh ribbonwood) (11%), and the exotic saltwater paspalum (7%) (Graeme, 2008).

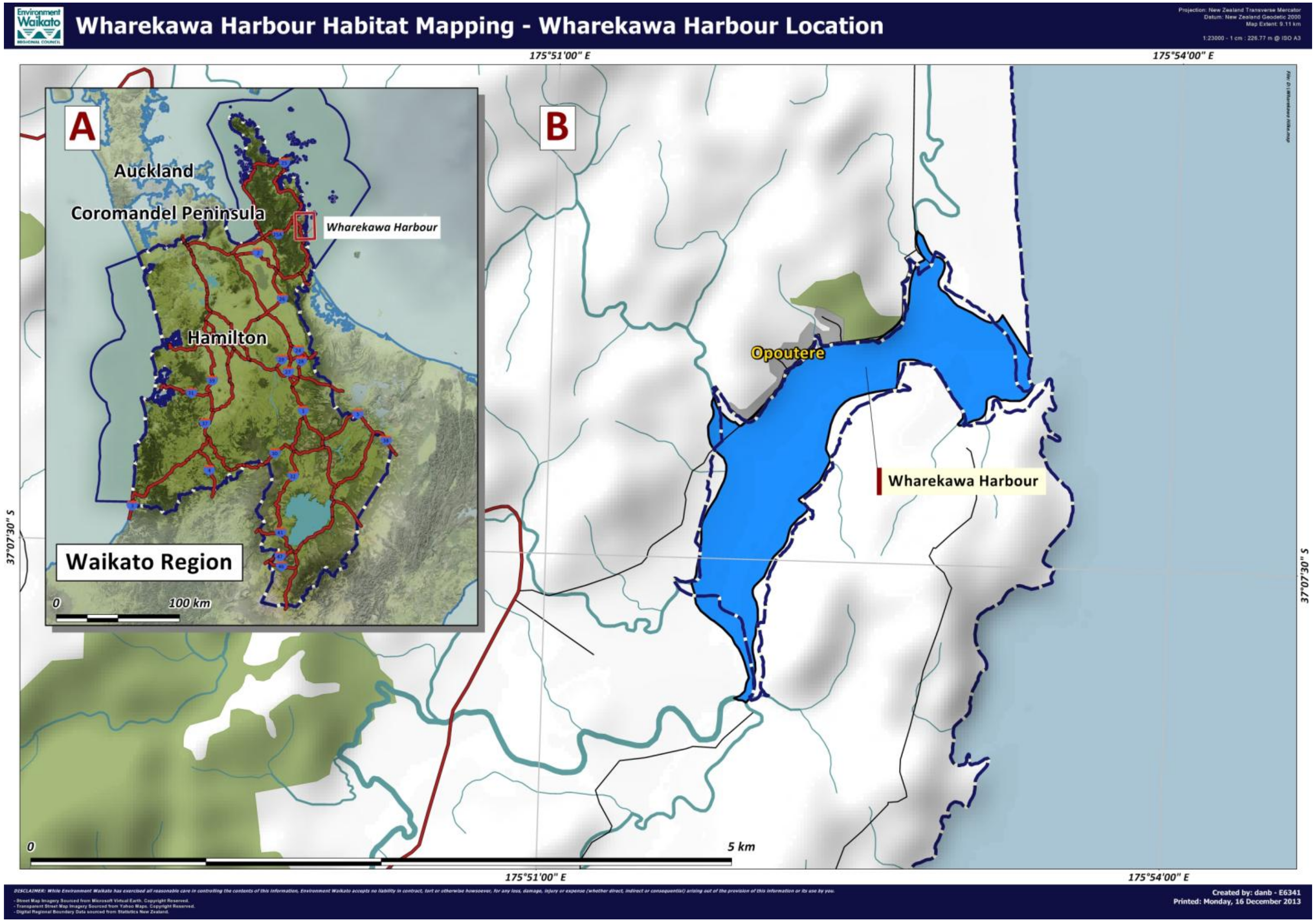

Figure 1: Maps of (A) the Waikato region and (B) south-eastern Coromandel indicating the location of Wharekawa Estuary.

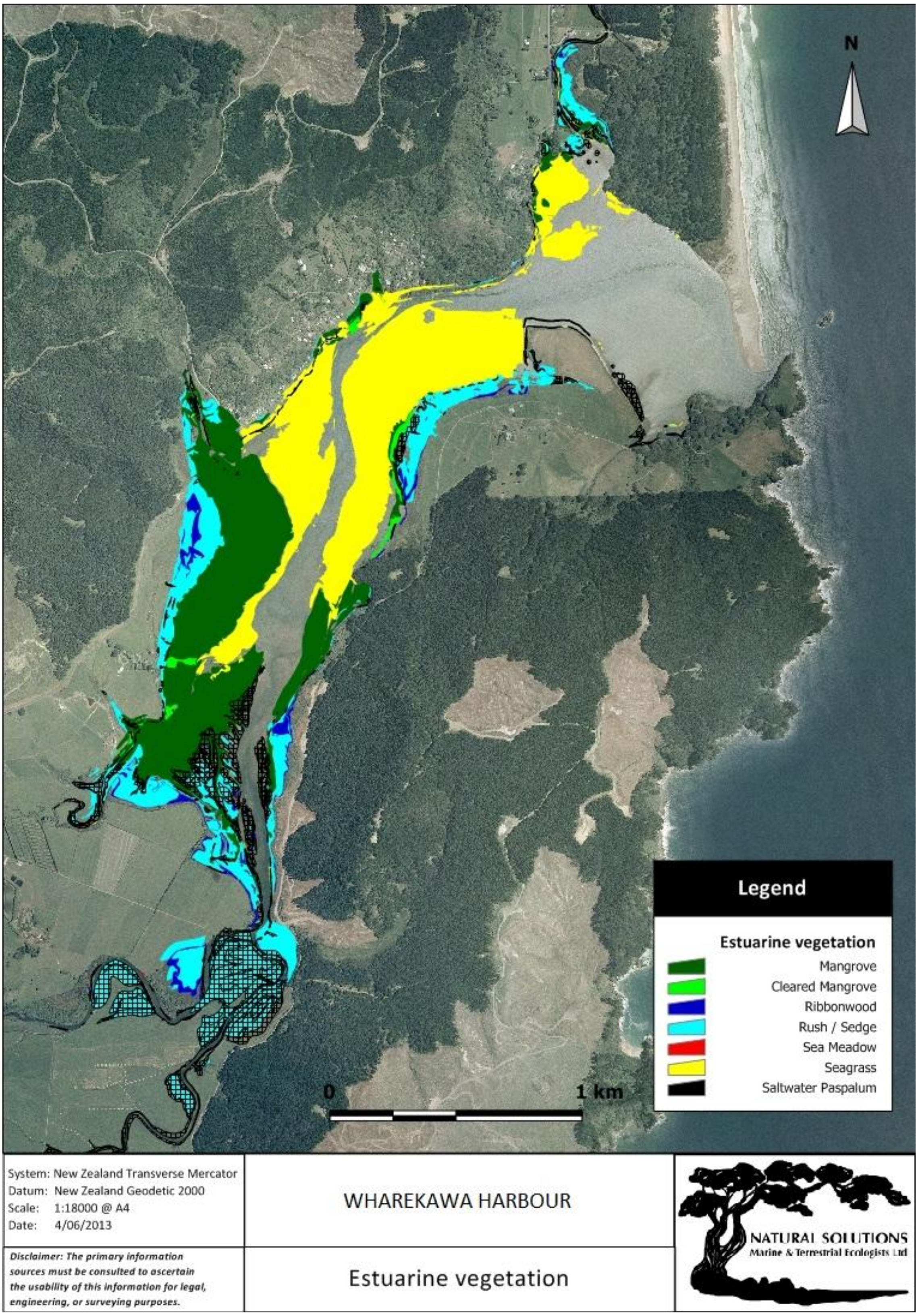

Figure 2: Map of Wharekawa Harbour intertidal vegetation (Graeme, 2008).

2. Methodology

Shellfish and benthic habitat mapping was conducted in the Wharekawa Harbour between February and March 2010.

2.1. Sampling sites

Benthic sampling points were located at the intersections of lines of a 150 m grid overlaid across the harbour. 160 sites were sampled using this methodology. Sampling near the channels was undertaken at spring low tides to access some of the low bed level sites along the channel edges. Where sampling points fell in subtidal channels their position was moved to the channel edge. This was done to ensure that *Paphies* populations, which often reach high densities along channel margins, were sampled.

2.2. Benthic biota

At each sampling location, the following was documented in relation to benthic biota:

- Counts and size class classification of *Austrovenus*, *Paphies*, and *Macomona*
- Counts of epifaunal organisms
- Fringing and intertidal vegetation in the near vicinity, including macro and micro-algae

At each sampling location one 25 cm x 25 cm quadrat was randomly placed and all epifauna recorded with gastropods identified to genus level. Percent coverage of macroalgae, microalgae and other vegetation within the quadrat was also recorded.

After the epifauna were recorded, the sediment within each quadrat was dug to a depth of 15 cm and sieved through a 0.5 mm sieve. All live bivalves were retained, identified and counted on-site, then returned to the shallows to allow them to reburrow.

Cockles and wedge shells were separated into 3 size categories:

small:	0 – 20 mm (this size class represents juveniles)
medium:	20 – 30 mm
large	> 30 mm

The size categories used for pipi were:

small:	0 – 20 mm
medium:	20 – 40 mm
large	> 40 mm (this size class represents adults)

Any vegetation found within close proximity to a sampling point was recorded; for example:

- seagrass (*Zostera* sp.)
- paspalum
- spartina
- mangroves
- rush/sedgeland
- sand dune grasses
- sea meadow (eg. sarcocornia)

- native forest
- exotic forest

2.3. Sediment characteristics

At each sampling location, the following was documented:

- Characteristics of surface sediment using subjective substrate categories
- The approximate depth of redox potential discontinuity (RPD) layer; RPD depth is an indication of sediment oxygenation

Surface sediments were described using descriptive categories listed in Robertson & Peters (2006). Note that the category 'Firm mud / sand' from Robertson & Peters (2006) was omitted so the categories used in this survey were:

Very soft mud sand:	A mix of mud and sand, surface brown and may have a black anoxic layer below; you will sink more than 5 cm
Soft mud/sand:	A mix of mud and sand, surface appears brown and may have a black anoxic layer
Soft sand:	Contains over 90% sand but you will sink more than 2 cm
Firm sand:	Will feel granular between your fingers; you will sink no more than 2 cm
Mobile sand:	Granular sand that is rippled
Shellbed:	The surface is dominated by shell material
Gravelbed:	Surface is dominated by gravel and cobble sized grains

The depth where the sediment colour changed to a dark brown or black was recorded on a fresh vertical surface created by a spade cut through the sediment for each quadrat (following Robertson & Stevens 2008). In some cases it was difficult or impossible to measure the exact distance from surface to colour change as there were grey, grey/black or mottled grey/orange/black layers of sand at varying depths. Where the depth could be established it was used as a proxy for the RPD layer which indicates the depth at which sediment becomes anoxic. It is often the maximum depth at which many species will be found.

Random sediment samples were also collected for grain size analysis. Seventy-three of the sampling locations were randomly chosen; in these locations three surface grabs (of 2 cm sediment depth) were collected roughly 1 m apart and combined into one sample bag, returned to the lab and frozen until analysis for grain size. Prior to analysis, samples were pre-treated with 10% hydrogen peroxide to remove organic material, and 1M HCl to remove carbonate material. Calgon was added as a dispersant and samples were placed in an ultrasonic bath for 10 minutes to aid disaggregation. Samples were analysed with a Malvern Mastersizer 2000 sediment analyser.

Grain size data were grouped into the following grain size classes: mud (<63 um); fine sand (63-250 um); medium sand (250-500 um); coarse sand (500-1000 um); and very coarse sand (>1000 um), according to the Wentworth sediment classification.

2.4. Statistical analysis

All statistical analyses and associated visual display of data were carried out using STATISTICA (version 10, StatSoft Inc., www.statsoft.com). Statistical analyses were similar to those used by Felsing and Giles (2011) to examine data from the benthic shellfish and habitat mapping survey conducted in Tairua Harbour.

In order to determine whether the subjective substrate data provides an indication of sediment grain size, the substrate data were compared to the results from the grain size analysis for the 73 sampling points where both sets of data were available. For the purposes of this and following analyses, the grain size analysis data was grouped into the following grain size categories: mud (<63 um); fine sand (63-250 um); medium sand (250-500 um); coarse sand (500-1000 um); and very coarse sand (>1000 um) (following the Wentworth sediment classification). The data did not meet the required assumptions of parametric tests (homogeneity of variances and normal distribution). For this reason, the non-parametric Kruskal-Wallis test was used to test for differences in grain size data, abundance of shellfish, vegetation cover and RPD depth among different substrate categories. Post-hoc pairwise comparisons of mean ranks were done for significant results (at $\alpha<0.05$); p-values were adjusted using the Bonferroni correction.

3. Results

3.1. Overview and summary statistics

A summary of the abundance of bivalve and gastropod species, surface sediment sampled and vegetation type is listed in Table 1. The raw data, including sample site locations, is presented in Appendix A. Overall, a total number of 7,049 individuals were sampled at 160 sampling sites.

The surface sediment showed a marked graduation of muddy sands in the upper sheltered reaches of the harbour to cleaner sands in the lower reaches of the harbour and in areas of high current. The surface sediment composition in Wharekawa estuary was dominated by 'soft mud/sand', followed by 'very soft mud/sand' and 'soft sand'. No sites were categorised as 'shellbed'.

Of the 160 quadrats sampled, 91 had vegetation present, which was predominantly seagrass and, to a lesser extent, mangrove pneumatophores.

Bivalves were numerically more dominant than gastropod species (accounting for 88% of individuals sampled), with *Austrovenus* clearly being more common than the other two sampled bivalves species, in terms of total individuals (3507, 56% of bivalve species), quadrat average (22 individuals/quadrat), proportion of quadrats *Austorovenus* present in (63%) and average density (351/m^2). The majority of *Austrovenus* found were of the small size category, i.e. juveniles (81%). *Paphies* and *Macomona* likewise had a predominance of small individuals but also a significant number of individuals in the medium size category. *Paphies* were found in 31% of the quadrats sampled and had an average density of 174/m^2. *Macomona* was found in 60% of the quadrats sampled and had an average density of 97/m^2.

Table 1: Overview of shellfish, surface sediment and vegetation type sampled in Wharekawa Harbour

Species	Total number individuals	Average per quadrat	% number quadrats present	% small size of total	% medium size of total	% large size of total	Average density (per m^2)
Bivalves							
Austrovenus stutchburyi (cockle)	3507	21.9	63.1	80.7	18.4	0.9	350.7
Paphies australis (pipi)	1739	10.9	31.3	68.9	30.4	0.7	173.9
Macomona liliana (wedge shell)	970	6.1	60.0	44.7	40.8	14.4	97.0
Total bivalves	**6216**	**38.8**	**78.1**				**621.6**
Gastropods							
Cominella	164	1.0	41.3				16.6
Zeacumantus	521	3.3	36.3				52.1
Diloma	148	0.9	28.1				14.9
Total gastropods	**833**	**5.2**	**60.0**				**83.6**
Surface sediment							
gravel			0.6				
mobile sand			11.9				
firm sand			12.5				
soft sand			16.3				
soft mud/sand			40				
very soft mud sand			18.8				
Vegetation							
Seagrass (*Zostera* sp.)	42 quadrats		26.3				
Mangrove pneumatophores	10 quadrats		6.3				
Saltwater paspalum	4 quadrats		2.5				
Sea meadow	1 quadrat		0.6				
ulva	2 quadrats		1.3				
gracilaria	2 quadrats		1.3				
algal film/mat	5 quadrats		3.1				
Total quadrats with vegetation	91 quadrats		56.9				
Total quadrats	**160**						

3.2. Sediments

3.2.1. Subjective substrate classification

Within the estuary, six substrate categories were present: 'Very soft mud / sand', 'Soft mud / sand', 'Soft sand', 'Firm sand', 'Mobile sand' and gravel

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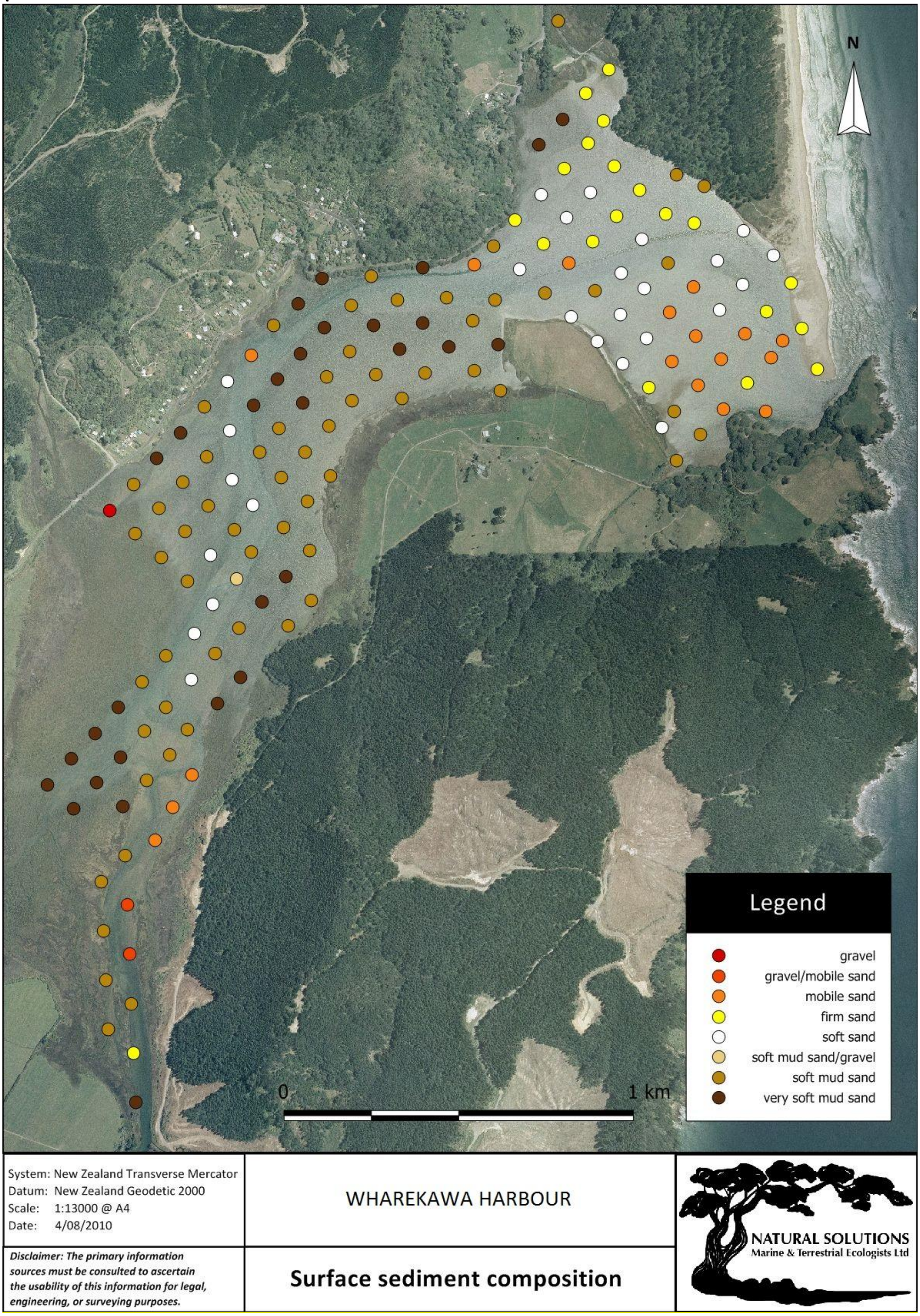


Figure 3). Three sites were classified as combinations of categories: 'gravel / mobile sand' or 'soft mud / sand / gravel'. These three sites were removed from all analyses.

The surface sediment composition in Wharekawa estuary was dominated by 'soft mud/sand' (40%), followed by 'very soft mud/sand' (19%) and 'soft sand' (16%) (Table 1 and Figure 4).

'Firm sand', 'mobile sand' and 'soft sand' are prevalent in the lower estuary, while 'soft mud/sand' and 'very soft mud/sand' are the common sediment types of the upper reaches (

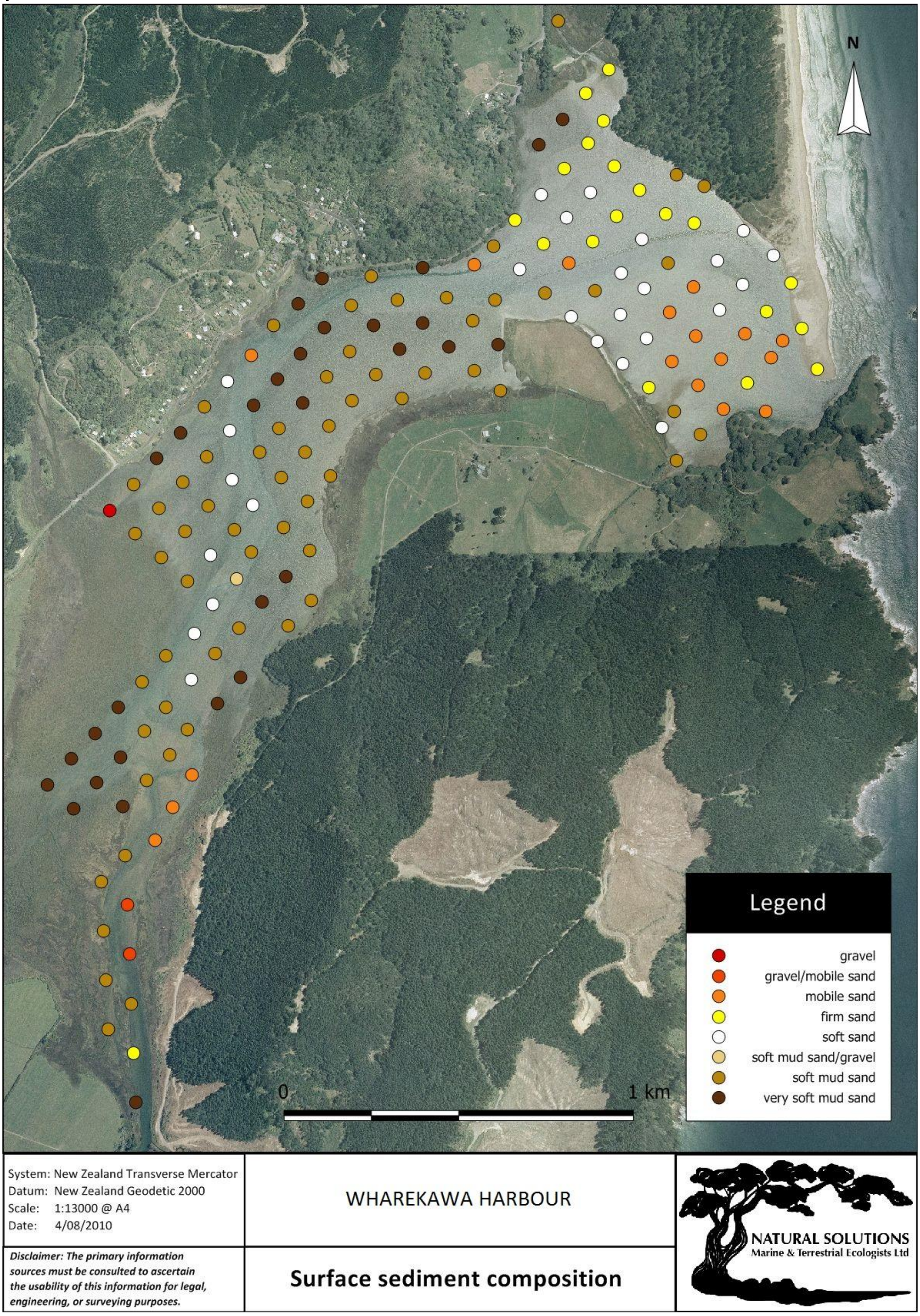


Figure 3). 'Soft sand' can be found associated with the main channel of the upper harbour and 'gravels' are associated with outwash flats within the upper tidal reaches of the Wharekawa River and the Kapakapa Stream.

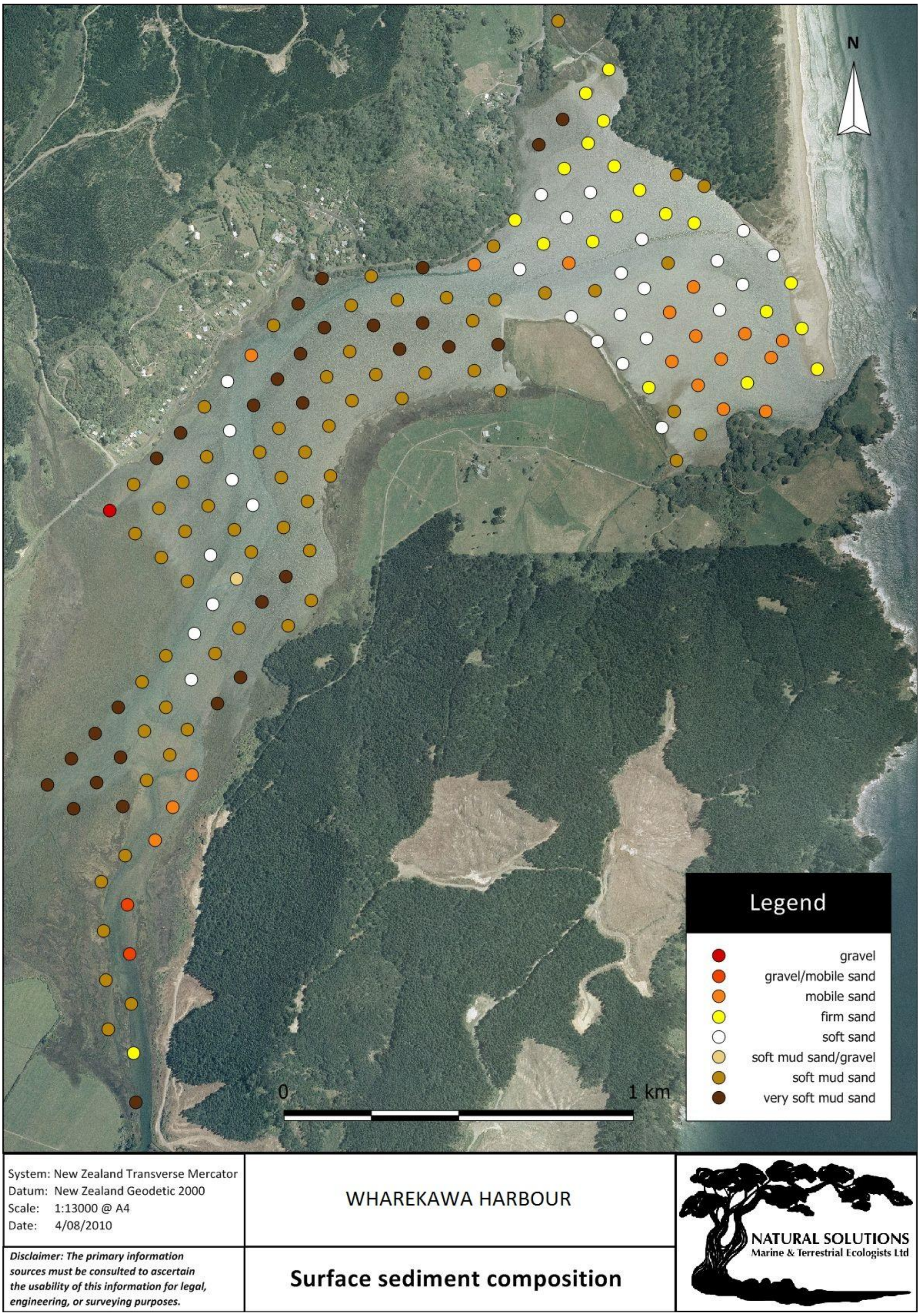
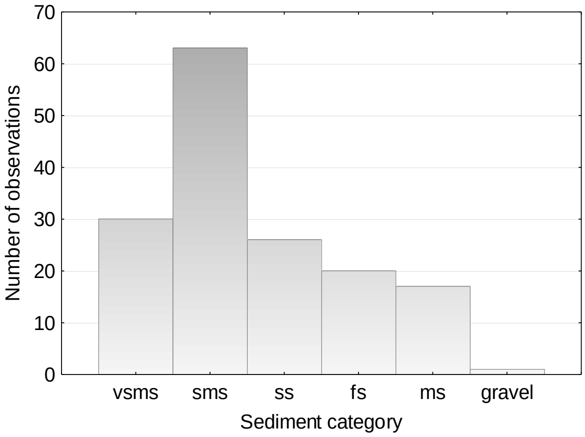


Figure 3: Classification of surface sediments at sampling locations in Wharekawa Harbour. Colours indicates surface sediment substrate category as described in Table 1. Three sites were assigned two categories as characteristics matched both.

(A)



(B)

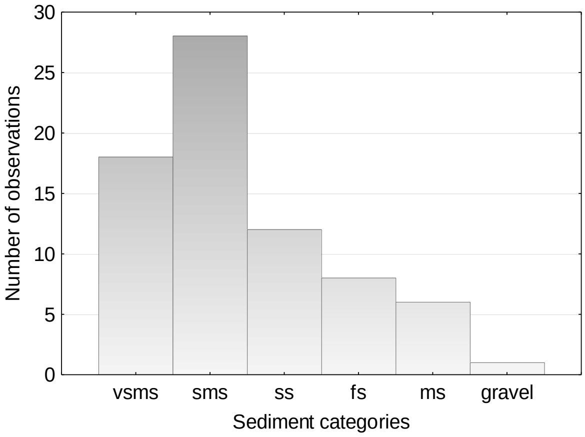


Figure 4: Number of sites classified into the different substrate categories for (A) all sites; (B) the subset of sites for which grain size analysis data were available. Substrate categories from Robertson & Peters (2006): vsms = very soft mud / sand, sms = soft mud / sand, ss = soft sand, fs = firm sand, ms = mobile sand.

3.2.2. Sediment grain size

The sediment grain size analysis data showed medium sand (grain size 250-500 µm) and fine sand (grain size 63-250 µm) to dominate in the estuary (Figure 5 and Figure 6). The majority (52%) of samples contained 39% or more medium sand. Twenty-five per cent of samples contained 39% or more fine sand. Coarse sand (grain size 500-1000 µm) was found in all but one sample and 30% of samples contained more than 25% coarse sand. Mud (grain size <63 um) was found in 84% of all samples, with the majority of samples (64% of those which contained mud) containing less than 10% mud. Very coarse sand (grain size >1000 µm) was present in 78% of all sampling sites. Only 3 sites contained more than 10% very coarse sand with a maximum content of 28%.

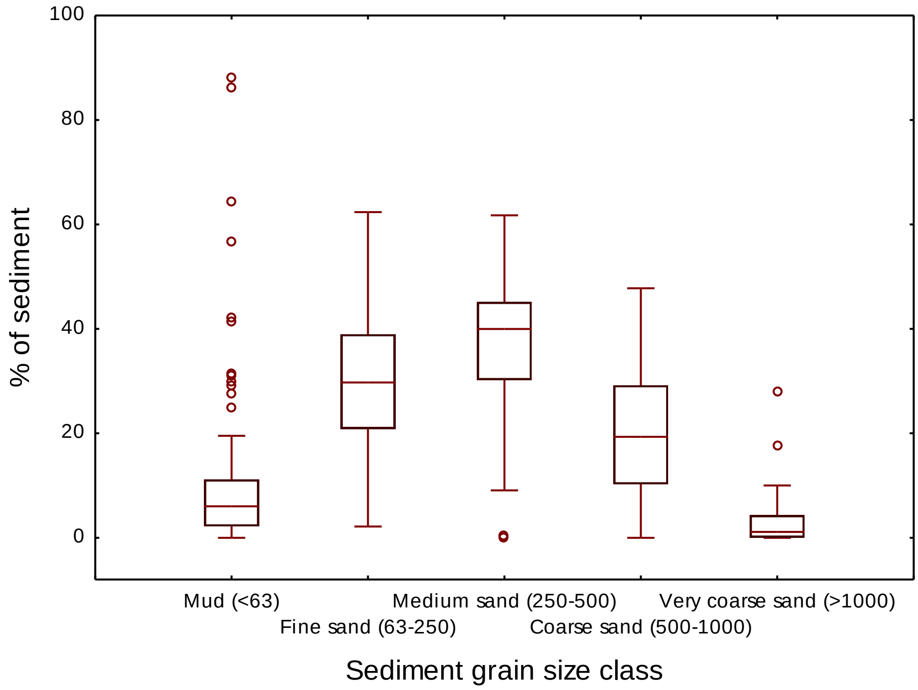


Figure 5: Boxplot[1] showing contribution of grain size classes to sediment composition at the 73 sites where grain size was analysed.

[1] Boxplot: Lower and upper hinges represent 25th and 75th percentiles, respectively; the line across the box denotes the median; the ends of the vertical lines indicate the minimum and maximum data values, unless outliers are present in which case the whiskers extend to a maximum of 1.5 times the inter-quartile range; the points outside the ends of the whiskers are outliers or suspected outliers.

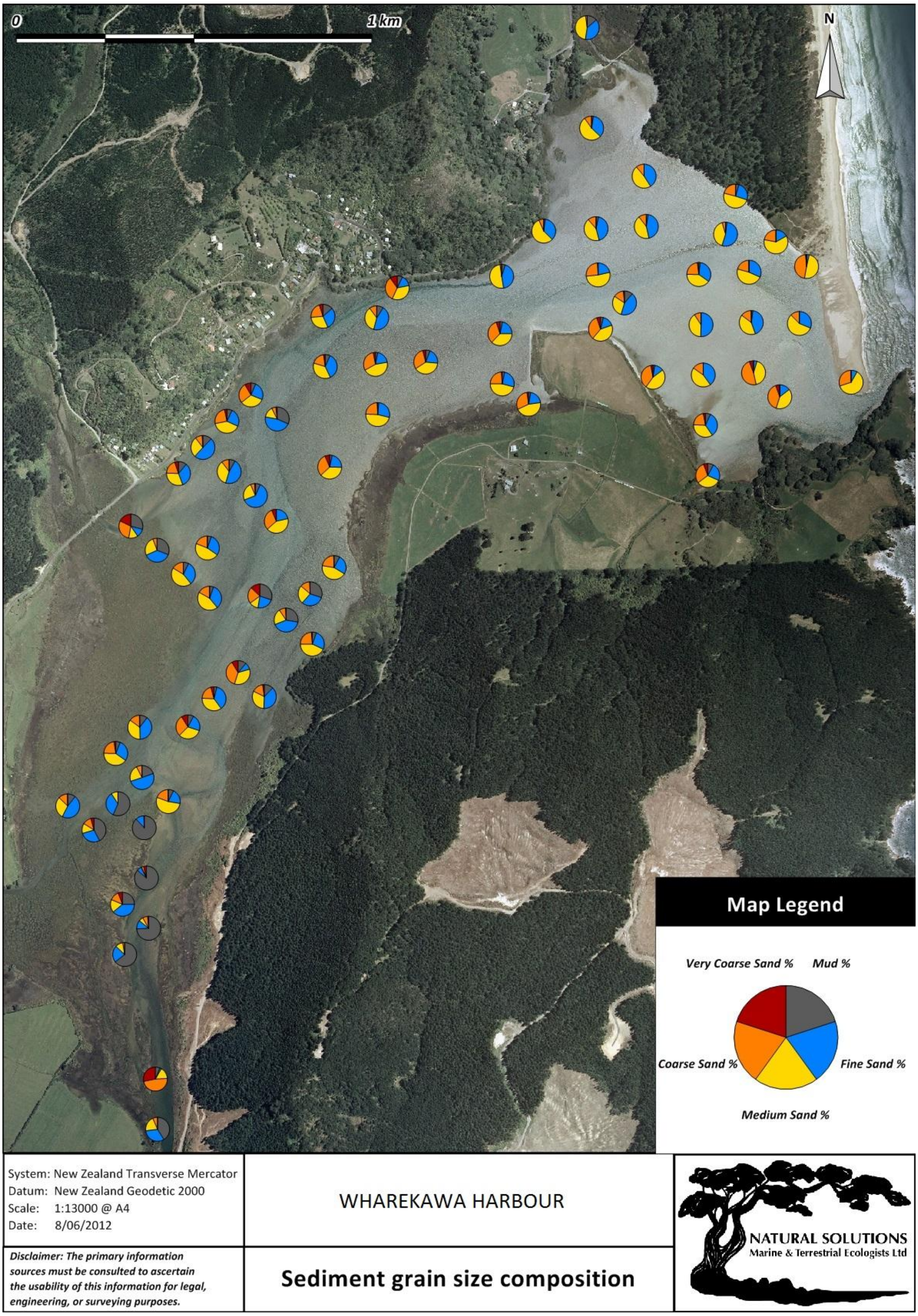


Figure 6: Results from the grain size analysis for the 73 sampling points within Wharekawa Harbour where sediment grain size analysis was carried out.

3.2.3. Comparison of subjective categories and grain size

The use of a subjective descriptive method to classify sediments is a potential alternative to costly grain size analysis if it can be shown to provide a consistent and meaningful description of surface sediments. The extent to which the subjective substrate classes identified in this survey represent sediment grain size categories was determined by comparing the descriptive categories to the sediment grain size data for the 73 sites where both are available.

The results from grain size analysis offers a full picture of the sediment composition by providing single measures, such as median grain size, but also detailed information about the full composition of the sediment in terms of the relative amounts of different grain sizes. In comparison, the single descriptive term used for the subjective substrate categories provides only restricted information. Therefore a more comprehensive comparison of the two methods is to establish whether the descriptive sediment categories correspond to different relative amounts of different grain sizes (grain size distribution), or different median grain sizes.

The two sediment assessment methods were compared by (1) comparing the relative amounts of different grain sizes (grain size distribution) of the substrate classes and (2) comparing the median grain sizes[2] of substrate classes.

Figure 7 displays the relationships of grain size distribution and median grain size with substrate categories. Substrate categories are arranged in order from finest to coarsest sediment (based on their description). Only one site was classified as 'gravel'. As expected, this site has the largest median grain size. Due to the lack of replicates, this site is not included in the following description of results.

Overall, some meaningful relationships were found between the subjective substrate classes and sediment grain size distribution (Table 2 and Table 3). Sites classified as 'very soft mud / sand' contained the highest proportion of mud (median = 13%), followed by those classified as 'soft mud / sand' (median = 7%). Some sites of both categories comprised very large proportions of mud (up to 88 and 86%, respectively). The differences in proportion of mud at sites of these categories were statistically significant compared to sites classified as 'soft sand', 'fine sand' and 'mobile sand' (Table 3). The proportion of fine sand shows a less pronounced relationship with substrate categories.

The contribution of medium sand increased with increasing coarseness of the substrate categories as derived from their description, ranging from a median of 29% ('very soft mud / sand') to 48% ('mobile sand'). No consistent trends were found among substrate categories for coarse sand or very coarse sand.

Median grain size was lowest at sites classified as 'very soft mud / sand' (median = 208 µm). At these sites median grain size was significantly lower than sites classified as 'soft mud / sand' (median = 329 µm) and 'soft sand' (median = 371 µm). Median grain size did not display any trends among substrate categories 'soft sand', 'firm sand' and 'mobile sand'.

[2] Median grain size is the midpoint of the grain-size distribution, where 50% of the sediment is coarser and 50% is finer than the median grain size. Here 50% refers to 50% by volume.

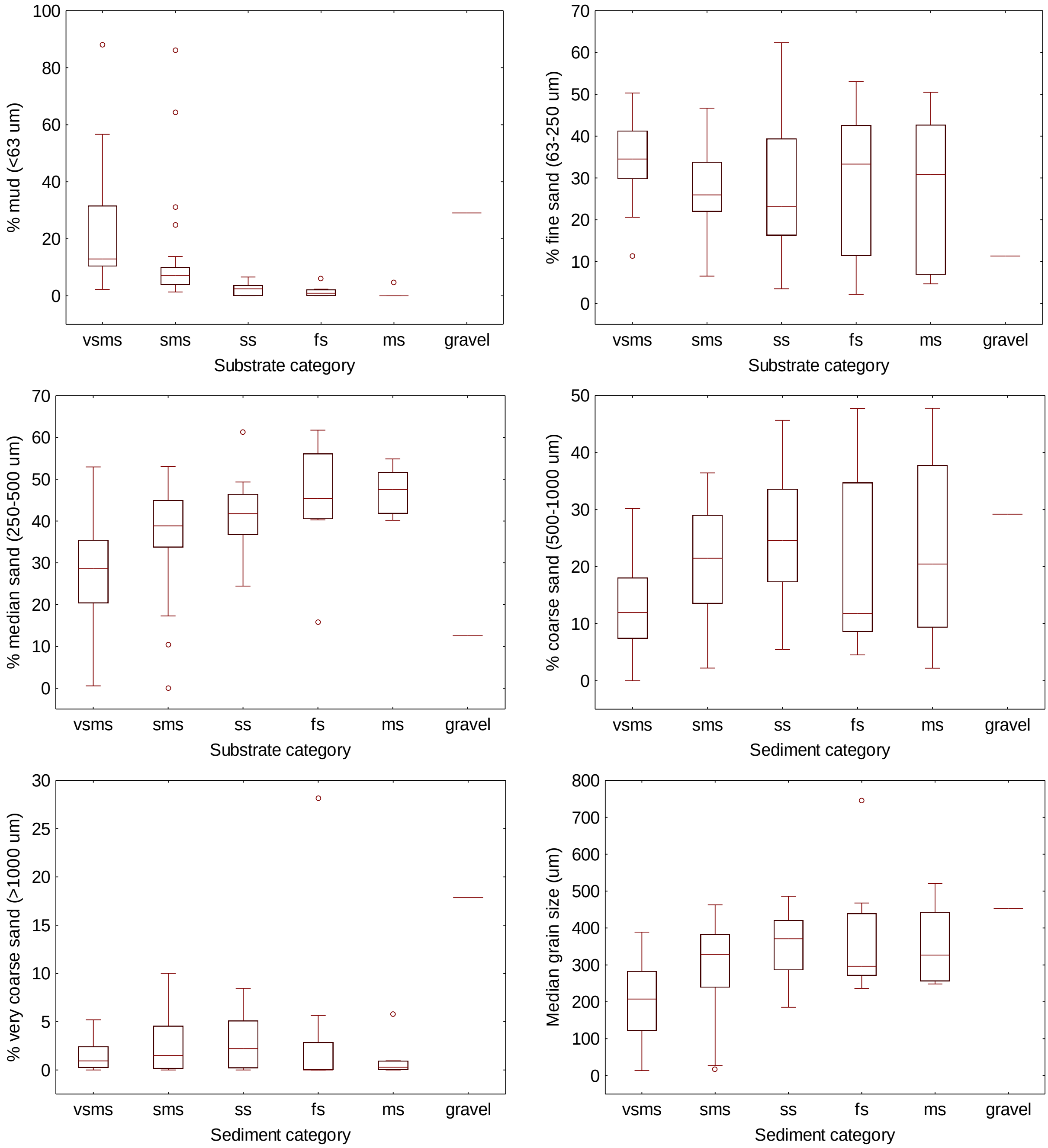


Figure 7: Boxplots showing sediment grain size characteristics of sites classified into different substrate categories. Substrate categories: VSMS = Very soft mud / sand, SMS = Soft mud / sand, SS = Soft sand, FS = Firm sand; MS = Mobile sand.

Table 2: Results of Kruskal-Wallis tests for differences of grain size data (sediment classes and median grain size) among substrate categories. N = number of cases, DF = degrees of freedom. Statistically significant results are denoted by bold P-values.

Grain size variable	N	DF	H-statistic	P-value
% mud	73	5	42.21	**<0.001**
% fine sand	73	5	7.05	0.217
% medium sand	73	5	23.77	**<0.001**
% coarse sand	73	5	10.43	0.064
% very coarse sand	73	5	7.91	0.161
Median grain size	73	5	19.15	**<0.050**

Table 3: Statistically significant differences in (A) per cent mud, (B) per cent medium sand and (C) median grain size between substrate categories (post-hoc comparisons of mean ranks, Kruskal-Wallis test results are displayed in Table X1). Stars indicated statistically significant differences between pairs (p<0.05). Substrate categories: VSMS = Very soft mud / sand, SMS = Soft mud / sand, SS = Soft sand, FS = Firm sand; MS = Mobile sand.

(A)

% mud (<63 µm)	VSMS	SMS	SS	FS	MS	Gravel
VSMS			*	*	*	
SMS			*	*	*	
SS						
FS						
MS						
Gravel						

(B)

% medium sand (250-500 µm)	VSMS	SMS	SS	FS	MS	Gravel
VSMS			*	*	*	
SMS						
SS						
FS						
MS						
Gravel						

(C)

Median grain size	VSMS	SMS	SS	FS	MS	Gravel
VSMS		*	*			
SMS						
SS						
FS						
MS						
Gravel						

3.2.4. Comparison of substrate categories with redox potential discontinuity layer

The depth of the Redox Potential Discontinuity (RDP) layer ranged from 0 to 13 cm but at 90% of all sites it was no greater than 1.5 cm. The RPD depth did not display any consistent trends between substrate categories (Figure 8 and Table 4). A correlation analysis indicated statistically significant relationships between the RPD depth and per cent very coarse sediment and median grain size (Table 5) but a visual inspection revealed that these relationships were strongly influenced by one data point (Figure 9). This data point relates to a sampling site (499) with unusually coarse sediment and an unusually deep RPD.

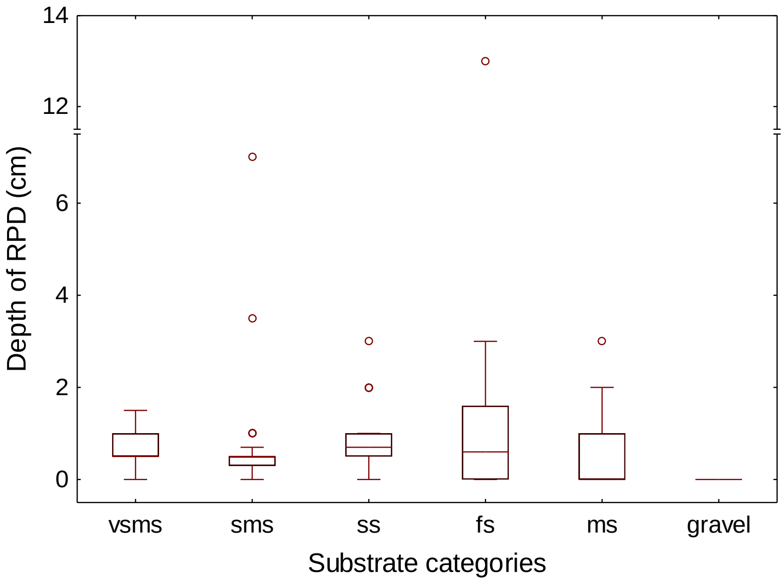


Figure 8: Boxplot showing approximate depth of Redox Potential Discontinuity (RDP) at sites classified into different substrate categories. Substrate categories: VSMS = Very soft mud / sand, SMS = Soft mud / sand, SS = Soft sand, FS = Firm sand; MS = Mobile sand.

Table 4: Results of Kruskal-Wallis tests for differences of depth of Redox Potential Discontinuity (RDP) among substrate categories. N = number of cases, DF = degrees of freedom.

Variable	N	DF	H-statistic	P-value
RDP	73	5	5.30	0.380

Table 5: Results of correlation analysis between the depth of the Redox Potential Discontinuity (RDP) and sediment grain size variables. N = number of cases, r = correlation coefficient.

Variable	N	r	P-value
% mud	73	-0.07	0.550
% fine sand	73	-0.07	0.533
% medium sand	73	-0.16	0.185
% coarse sand	73	0.16	0.184
% very coarse sand	73	0.57	**<0.001**
Median grain size	73	0.32	**<0.01**

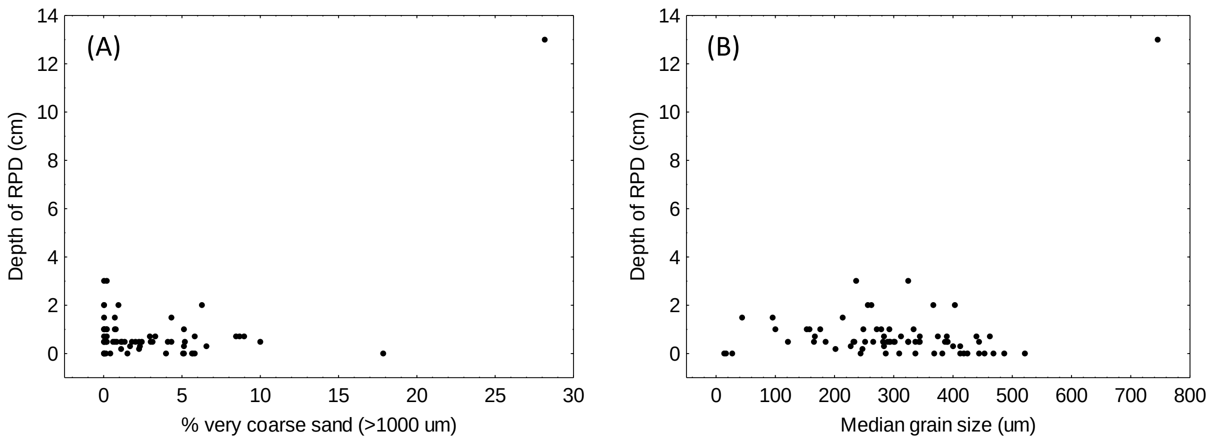


Figure 9: Relationships between depth of Redox Potential Discontinuity (RDP) and (A) percent very coarse sand and (B) median grainsize.

3.3. Bivalves

3.3.1. Abundance and spatial distribution

Austrovenus was the most common bivalve species found in Wharekawa estuary with a total of 3507 individuals recorded in 63% of the quadrats sampled and with an average of 22 per quadrat (351/m^2, see Table 1). Juveniles dominated the population and accounted for 81% of the individuals, with 18% sub-adults and <1% adults within the samples.

Paphies was the second most abundant bivalve with a total of 1739 individuals but was only present in 31% of the samples, with an average of 11 individuals per quadrat (174/m^2). The *Paphies* population was similarly dominated by juveniles, with very few large individuals recorded (juveniles 69%, sub-adults 30%, and adults <1%).

Macomona was the third most common bivalve species with a total of 970 individuals recorded from 60% of the samples and with an average of 6.1 individuals per quadrat (97/m^2). Juveniles accounted for 45% of the sampled population, sub-adults 41% and adults 14%.

The only other bivalves found during sampling were the nut shell (*Nucula sp.)* which was common in a couple of samples, a few of the tiny *Arthritica bifurca* and the Asian date mussel (*Musculista senhousia*) of which only one live mussel was found in samples.

In terms of the density of individuals per quadrat (Figure 10), an abundance of 0 individuals per quadrat was most common for all three bivalve species. For *Austrovenus* counts of 1-8 and 31-150 individuals per quadrat was also relatively common. One quadrat had 175 *Austrovenus* (=2,800/m^2). Counts of 1-2 *Paphies* were relatively common, with a couple of quadrats having very high numbers, with a maximum of 457 individuals per quadrat (7,312/m^2). *Macomona* had a diverse range of densities per quadrat but the maximum per quadrat was only 38 individuals (608/m^2).

Figure 11 shows the relative abundance of bivalve species, and Figures 11-13 indicate the density of the bivalve species found throughout Wharekawa Harbour. *Austrovenus* was found over most of the estuary (though less commonly in the upper harbour reaches and the harbour mouth), both near channels and over the larger intertidal flats. Dense beds commonly ranged from 496 individuals/m^2 to 2,384/m^2 and were found on sandy flats of the mid and lower harbour reaches (Figure 12).

Paphies presence was quite patchy and concentrated in the firm and mobile sands along the channel banks near the harbour mouth and to a much lesser extent at the riverine end of the harbour (Figure 13). A number of sampling points coincided with dense beds of *Paphies* at the harbour mouth (densities ranging from 5,200/m^2 to 7,312/m^2).

Macomona is found throughout the harbour. A number of dense beds (maximum of 608/m^2) were found along the channels of the upper-middle harbour and at the mouth of the Waahi Tapu Stream embayment (Figure 14).

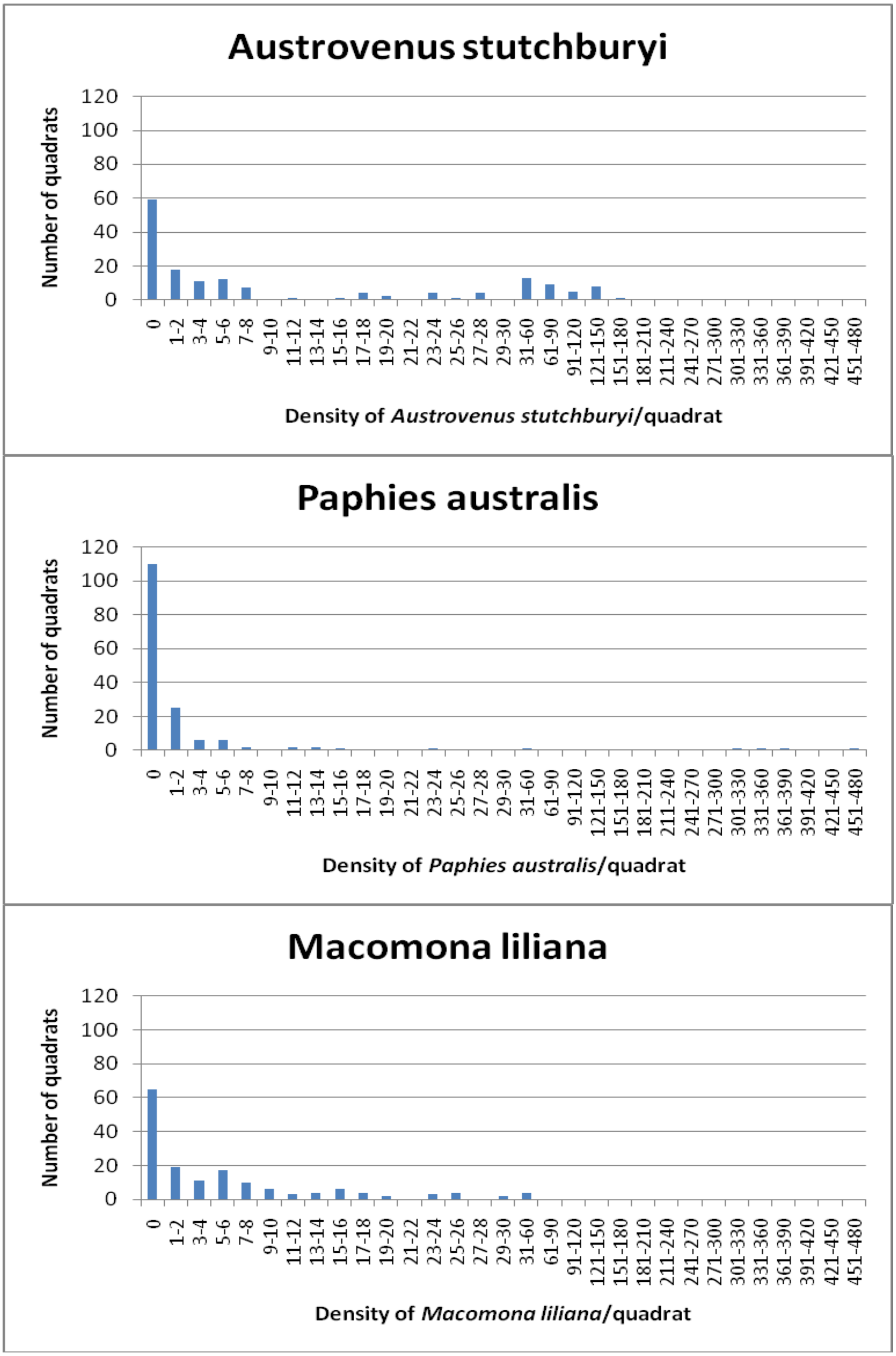


Figure 10: Frequency of bivalve counts (density per quadrat)

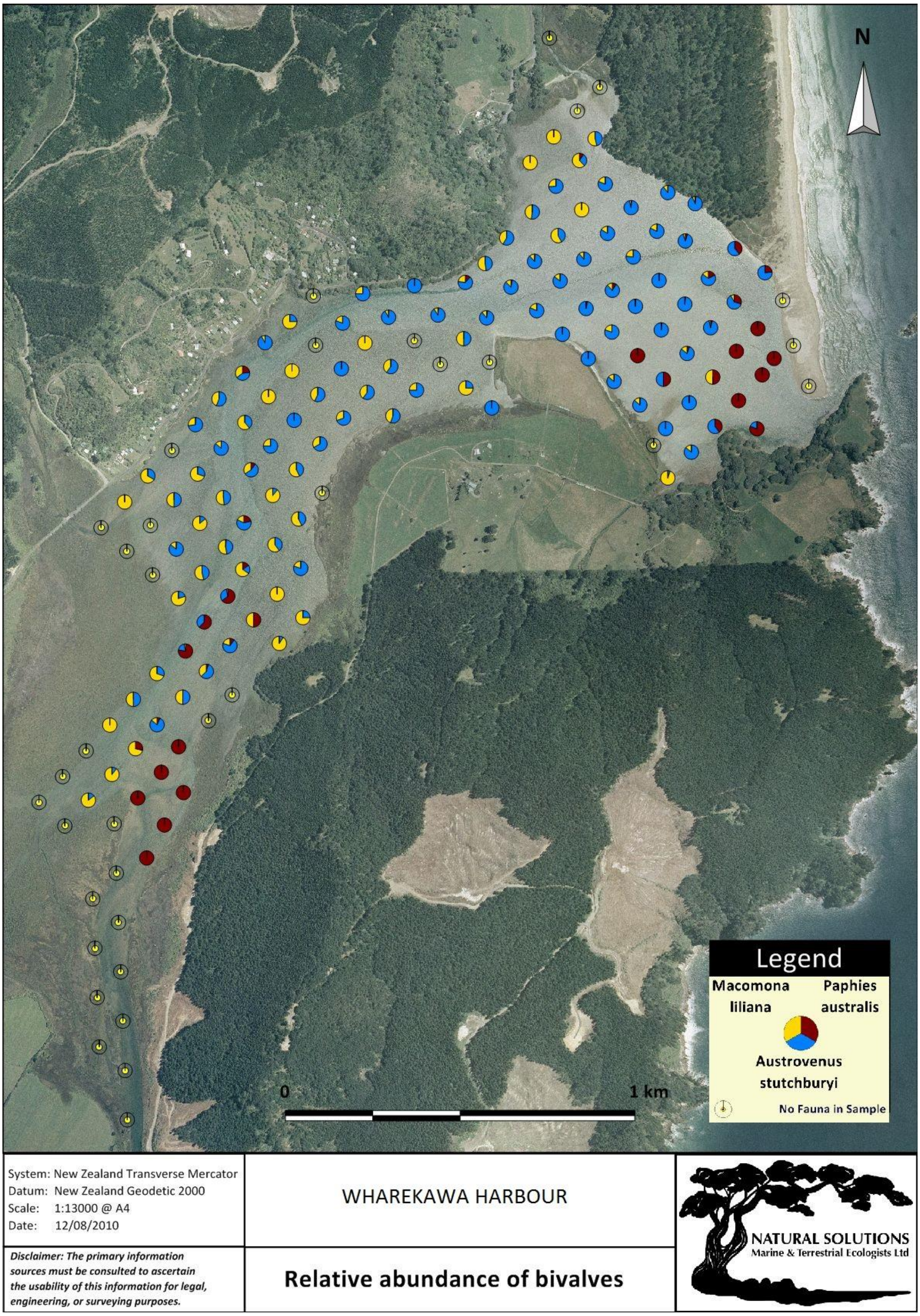


Figure 11: Map of relative abundance of bivalve species.

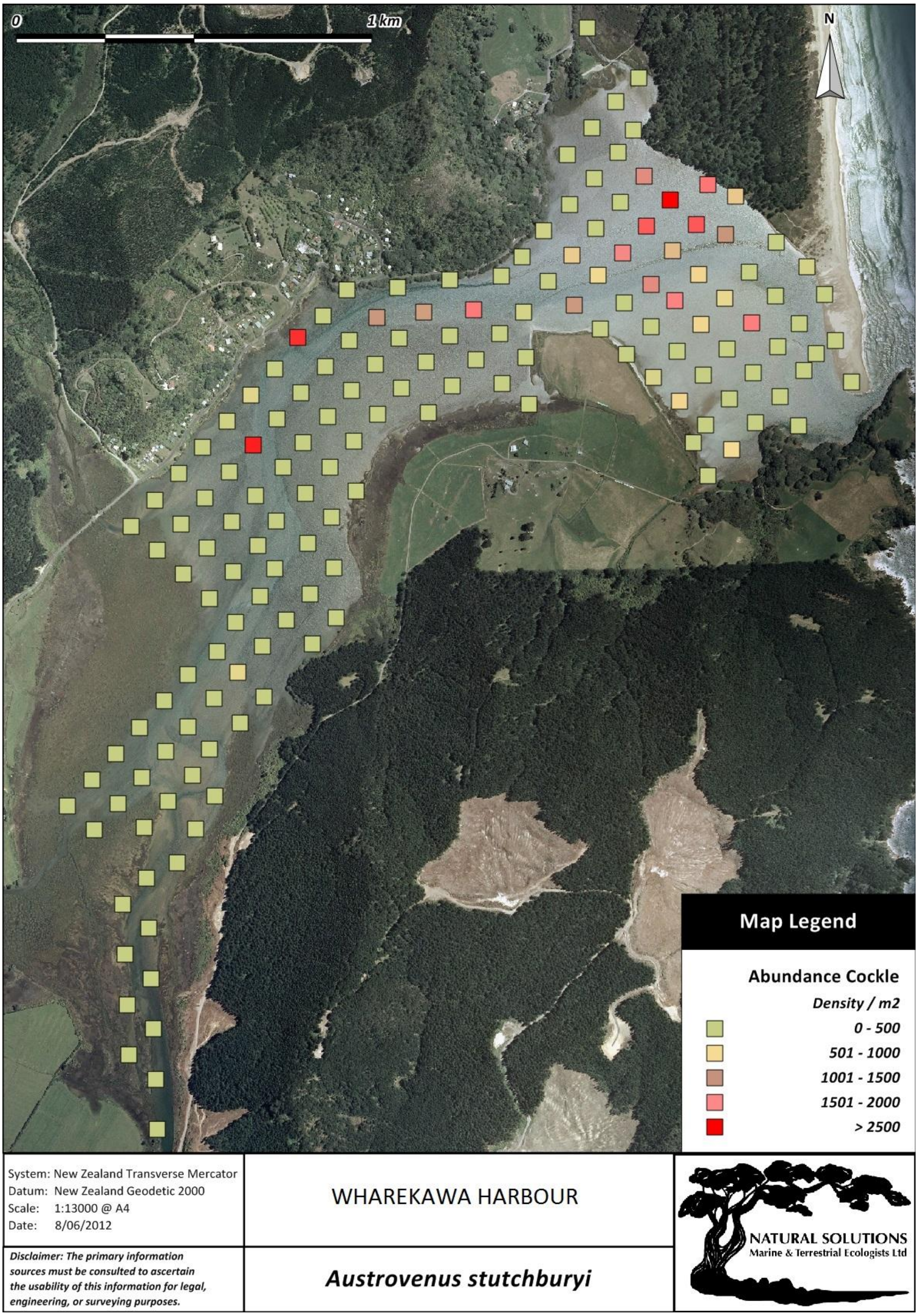


Figure 12: Density of cockles (*Austrovenus stutchburyi*)

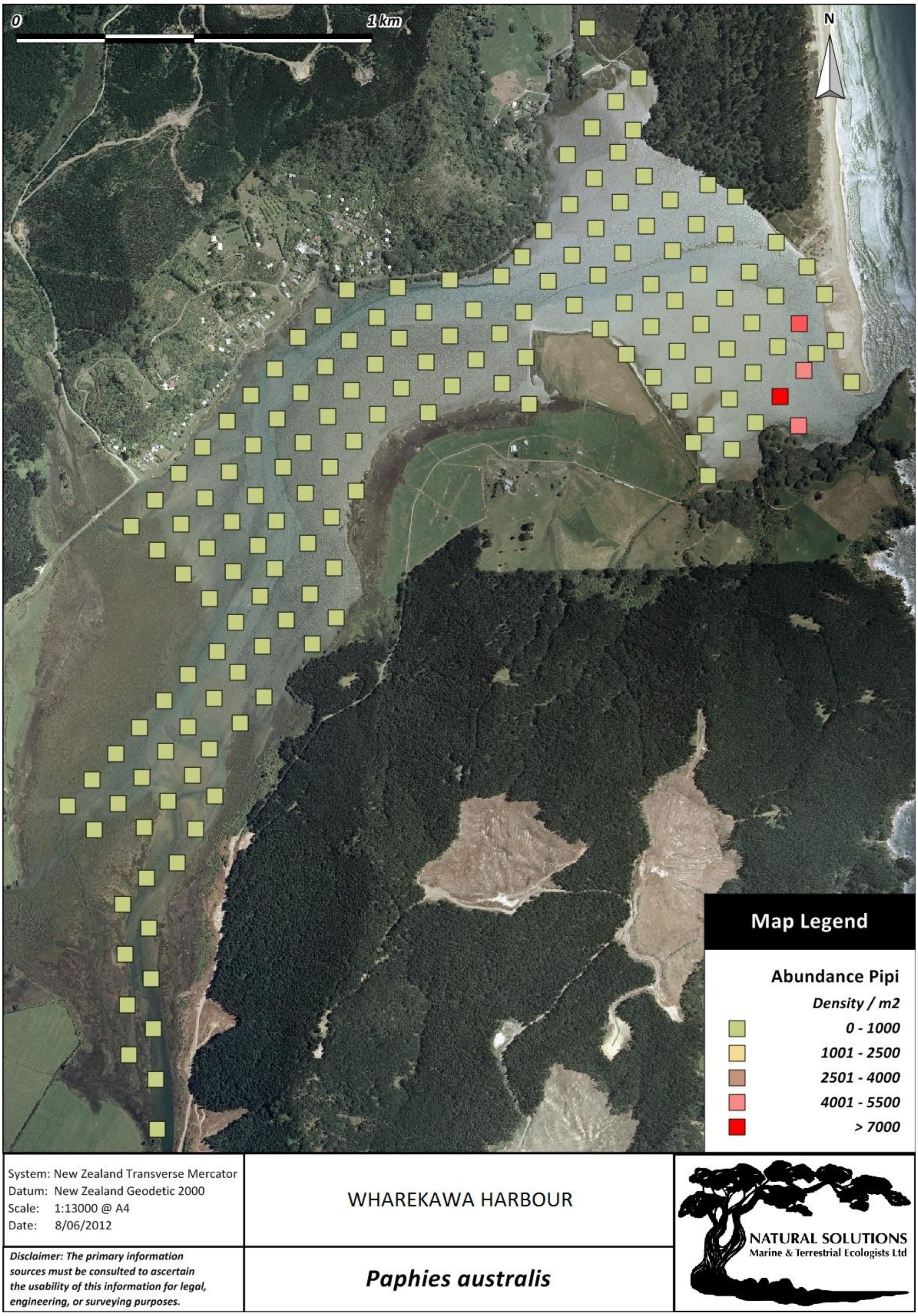


Figure 13: Density of pipi (*Paphies austrialis*)

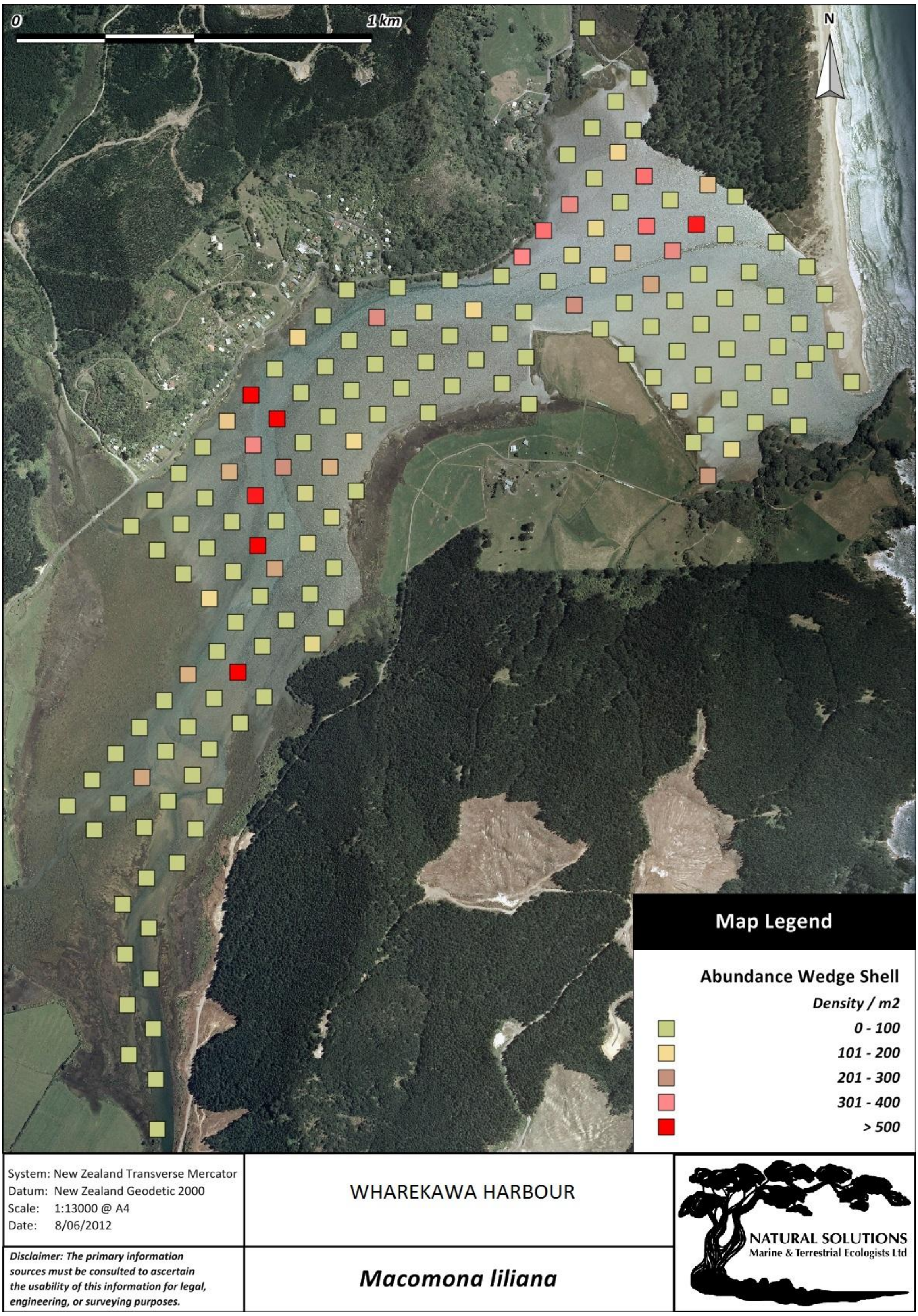


Figure 14: Density of wedge shells (*Macomona liliana*)

3.3.2. Size class distribution

Small sized *Austrovenus* were the dominant size class (Table 1) and found throughout the harbour, while the few large and most of the medium sized individuals sampled were found close to channels (Figure 15).

Small individuals of *Paphies* were found throughout the harbour where coarser sediment existed, i.e. associated with the upper harbour channel banks and the lower harbour channel banks and open flats. However medium and large individuals were restricted to the coarse sediments of the lower harbour channel edges (Figure 16).

Macomona juveniles appear to be more commonly associated with channels and were less commonly found in muddier areas, whereas the medium and larger individuals where found throughout the harbour but became patchy towards the harbour mouth (Figure 17).

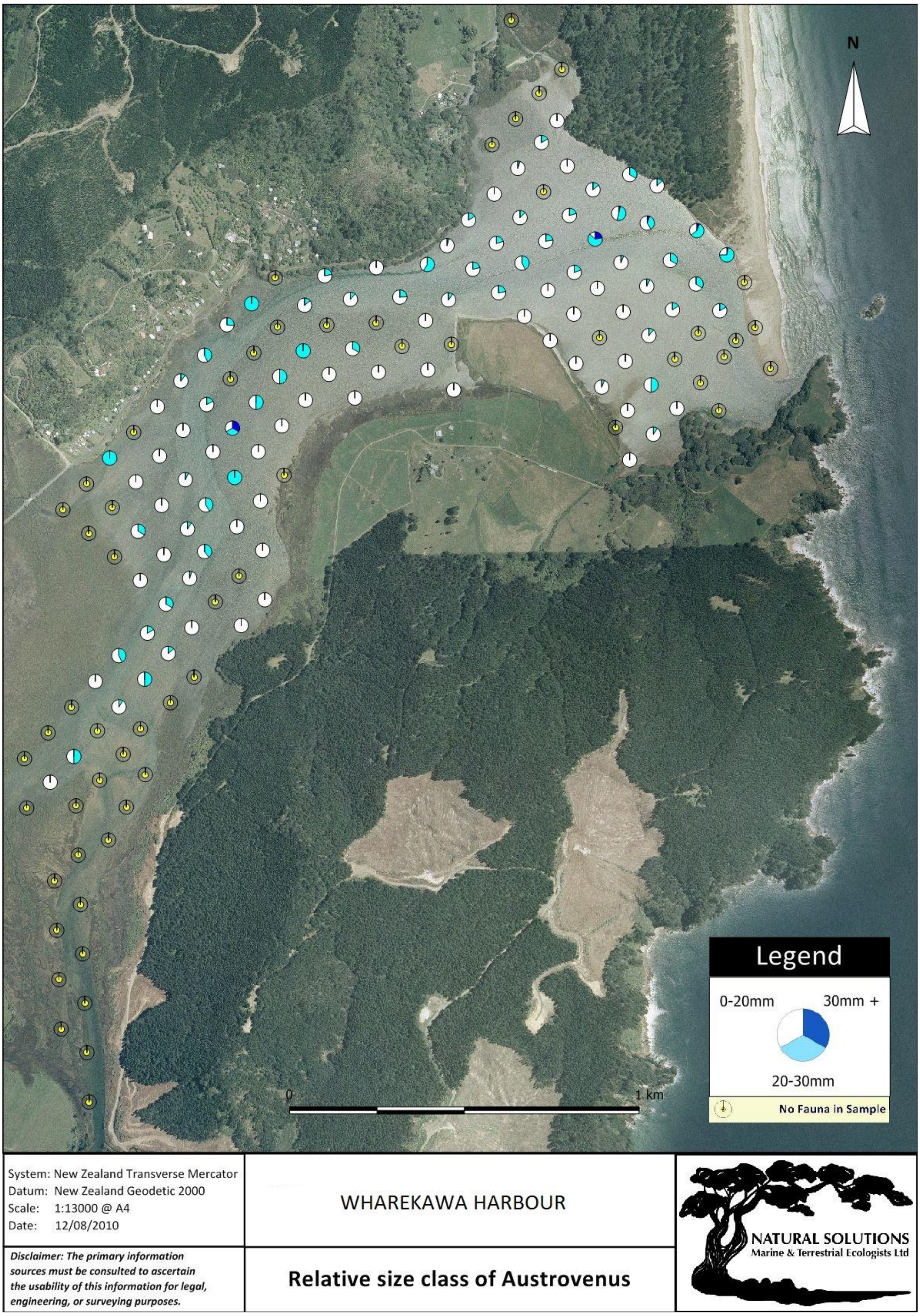
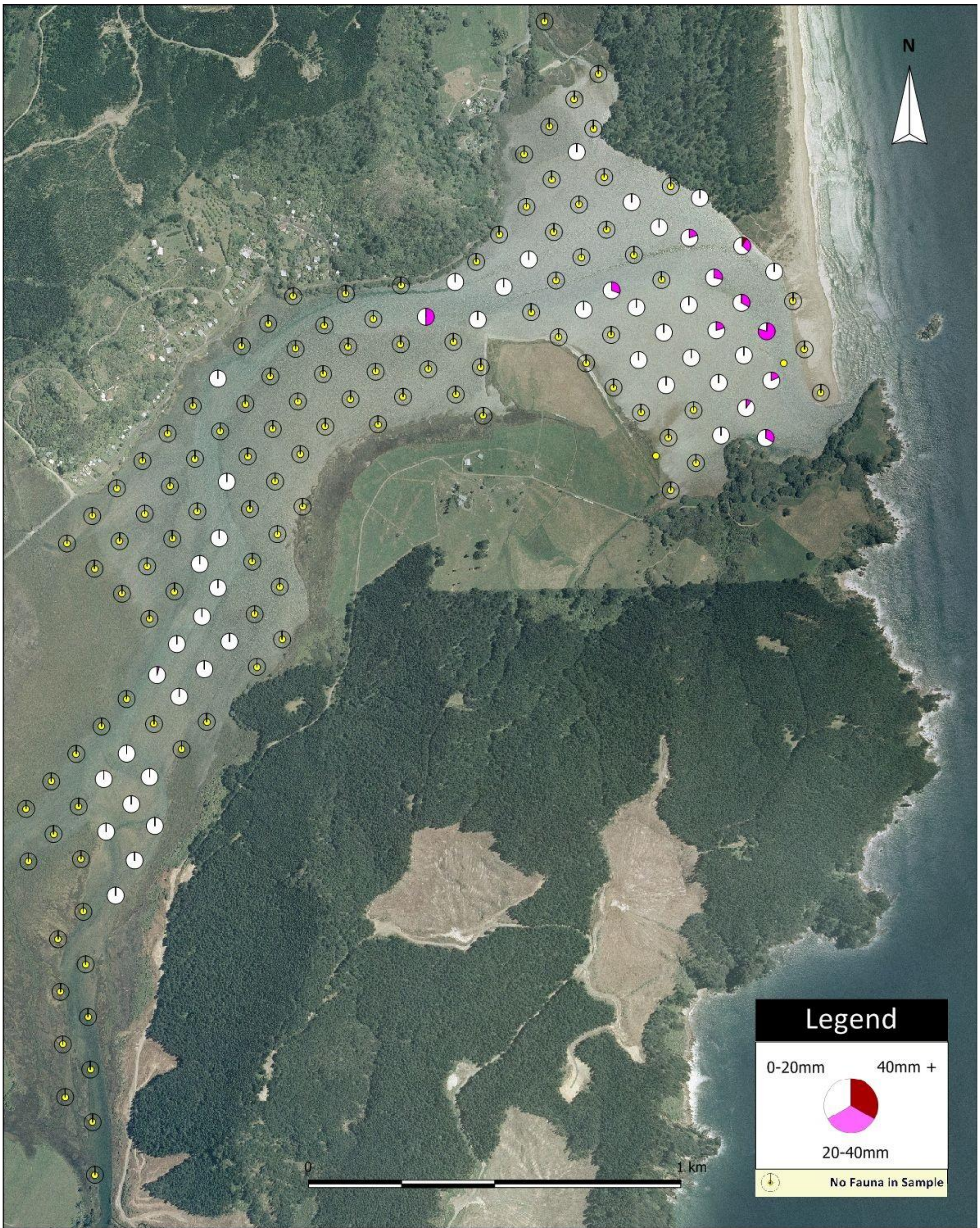
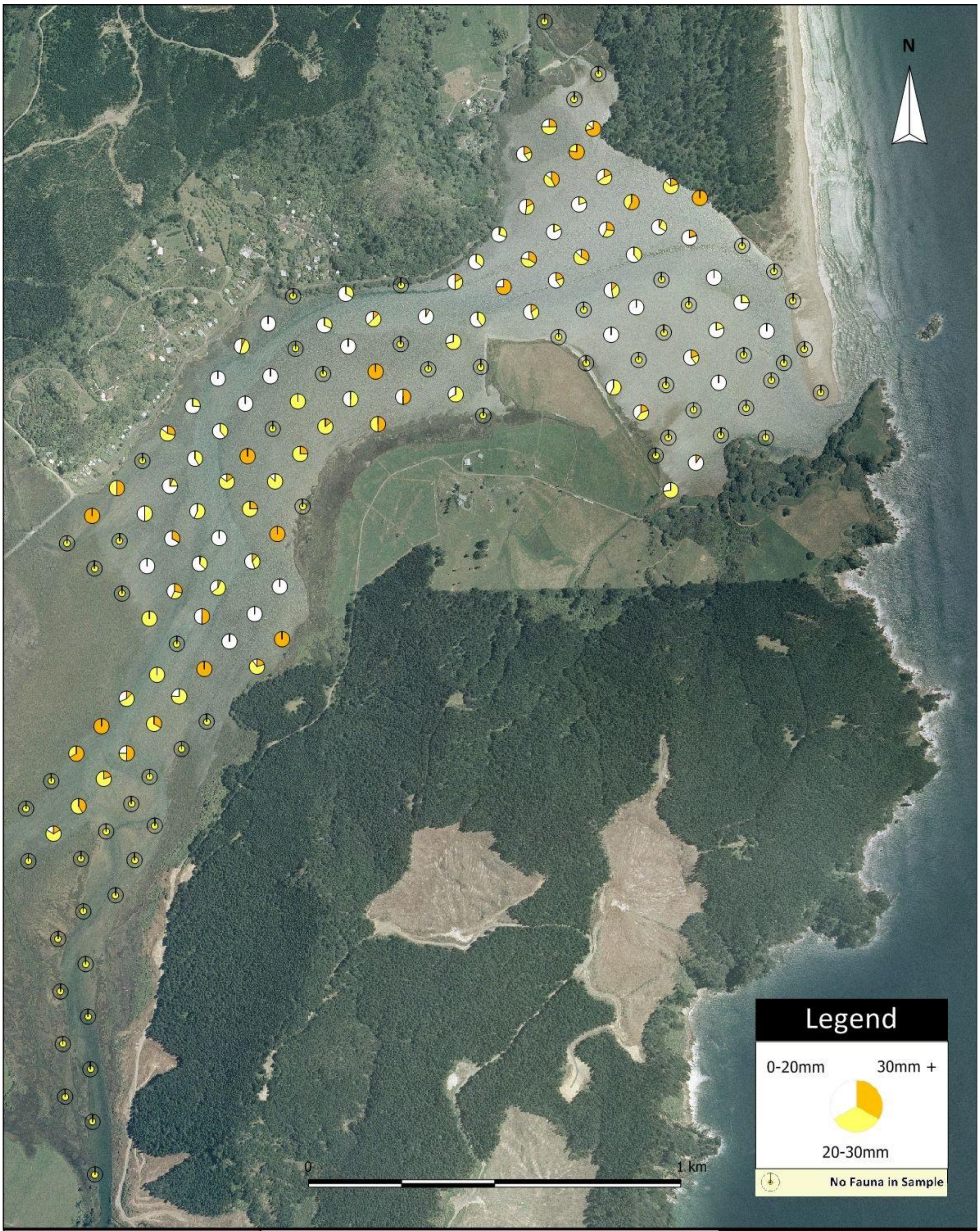


Figure 15: Size class distribution of cockles (*Austrovenus stutchburyi*)



System: New Zealand Transverse Mercator Datum: New Zealand Geodetic 2000 Scale: 1:13000 @ A4 Date: 12/08/2010	WHAREKAWA HARBOUR	NATURAL SOLUTIONS Marine & Terrestrial Ecologists Ltd
Disclaimer: The primary information sources must be consulted to ascertain the usability of this information for legal, engineering, or surveying purposes.	**Relative size class of Paphies**	

Figure 16: Size class distribution of pipi (*Paphies australis*).



System: New Zealand Transverse Mercator
Datum: New Zealand Geodetic 2000
Scale: 1:13000 @ A4
Date: 12/08/2010

WHAREKAWA HARBOUR

Disclaimer: The primary information sources must be consulted to ascertain the usability of this information for legal, engineering, or surveying purposes.

Relative size class of Macomona

NATURAL SOLUTIONS
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Figure 17: Size class distribution of wedge shells (*Macomona liliana*).

3.4. Gastropods

Three main epifaunal gastropod species were found in Wharekawa estuary
(

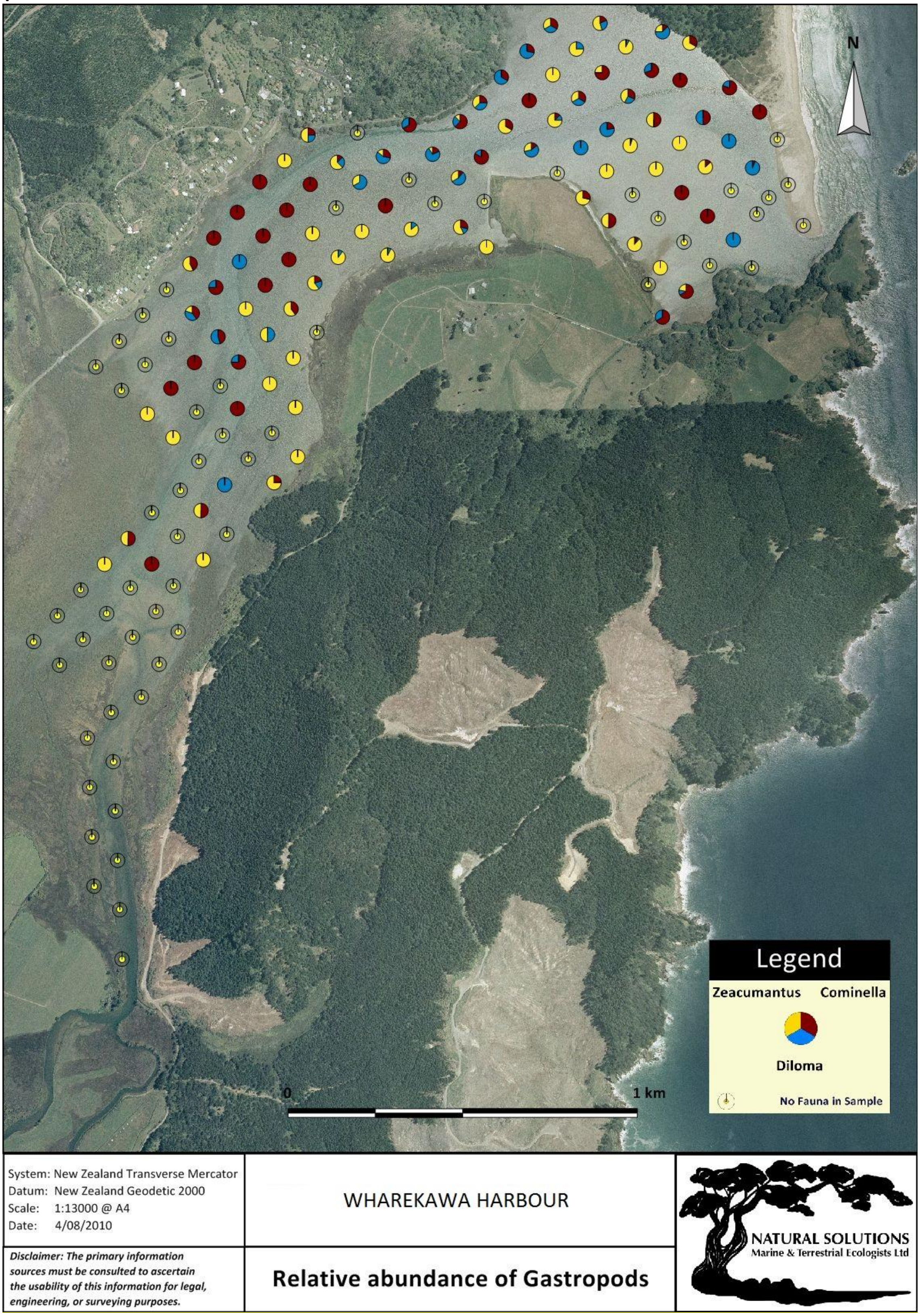


Figure 18) - *Cominella glandiformis* (mud whelk), *Diloma subrostrata* (mudflat top shell) and the horn shell *Zeacumantus* sp. (both *Z. subcarinatus* and *Z.* lutulentus were noted). To simplify data collection and save confusion with similar species, gastropods were identified to their genus. Table 1 presents summary data for gastropods found within the sample quadrats.

Zeacumantus was the dominant species in terms of total individuals sampled (521) and average number of individual per quadrat (8.7) (Table 1). However, *Cominella* was found to be present more widely and was recorded in the most quadrats (41.3%) than the other two gastropod species. *Cominella* and *Diloma* had similar numbers of individuals sampled (164 and 148 respectively), with *Cominella* having a quadrat average of 2.5 and *Diloma* 3.3 individuals.

Cominella has relatively high density patches throughout the middle and lower harbour (Figure 19), with the highest density recorded as 128 individuals/m^2.

The highest densities of *Zeacumantus* were found on the large harbour mouth flats (Figure 20), with the maximum number of individuals recorded being 2400 m^2. The average density for *Zeacumantus* is 52.1/m^2.

Diloma has a distinct patchy spread through the lower harbour (Figure 21). The maximum density of *Diloma* found in sampling quadrats was 256 individuals/m^2.

Other gastropods noted in the samples included a few *Bulla quoyii* and *Haminoea zelandiae(*?) (bubble shells) found amongst seagrass, as well as *Potamophyrgus estuarinus* and *Marinula filholi* (ear shell) found in brackish saltwater paspalum upstream of the Wahitapu Stream walking bridge. *Amphibola crenata* (titiko or mud snails) were found only at relatively high bed heights and often associated with fine sediment and mangroves (or old cut mangrove stumps). Their egg cases were also often seen in this zone.

3.5. Other biota

Polychaetes were commonly present in the samples, however they were only noted when particularly high densities occurred. It was also noted that only low numbers were seen in samples at the head of the harbour. No polychaetes were seen in the saltwater paspalum samples.

Other species noted generally in the samples include the small estuarine limpet (*Notoacmea helmsi*), the barnacle (*Elminius modestus*), the green chiton (*Chiton glaucua*), and the crabs *Halicarcinus* sp., *Helice Crassa, M. Hertipes,* as well as the odd hermit crab.

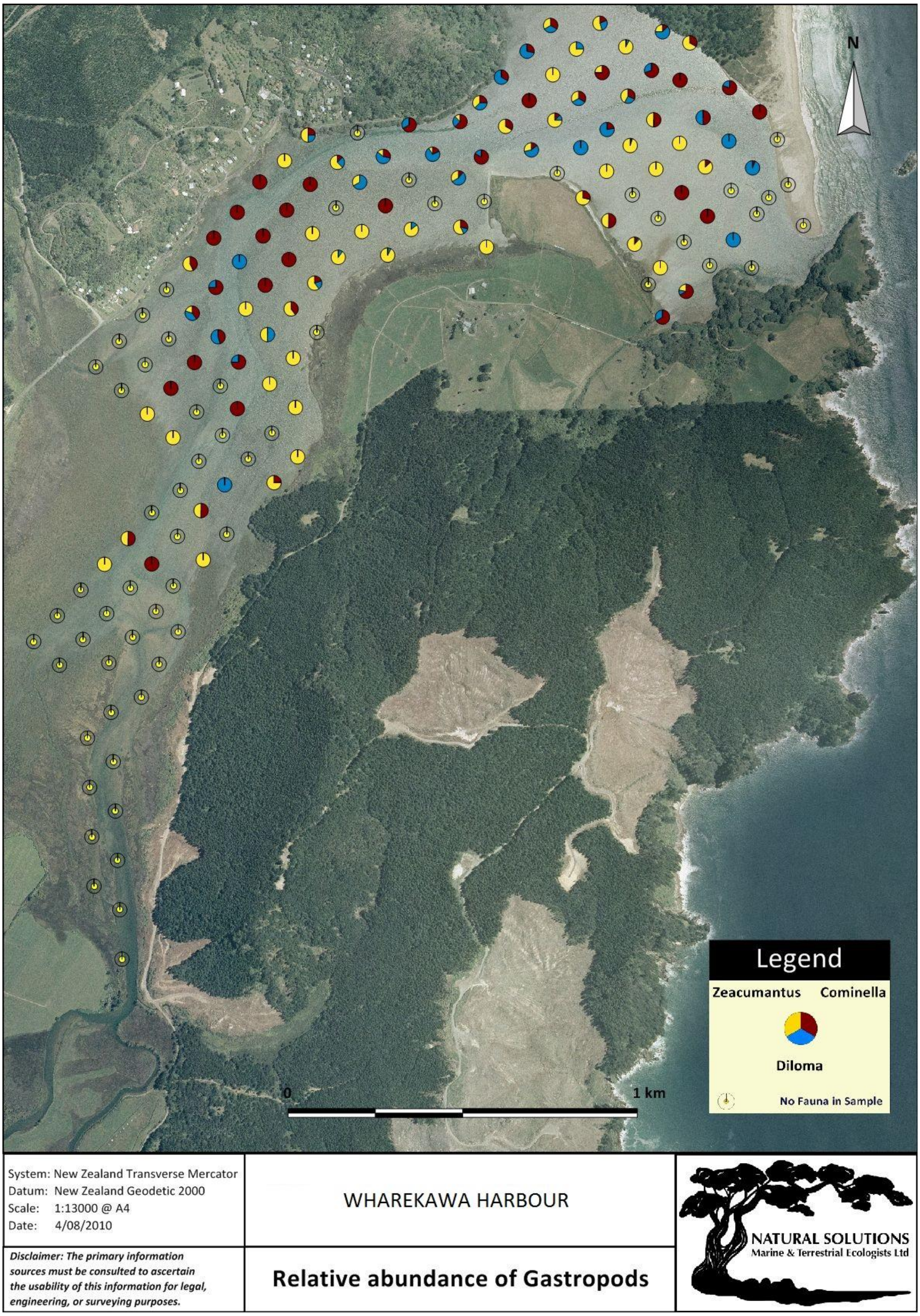


Figure 18: Relative abundance of gastropod species.

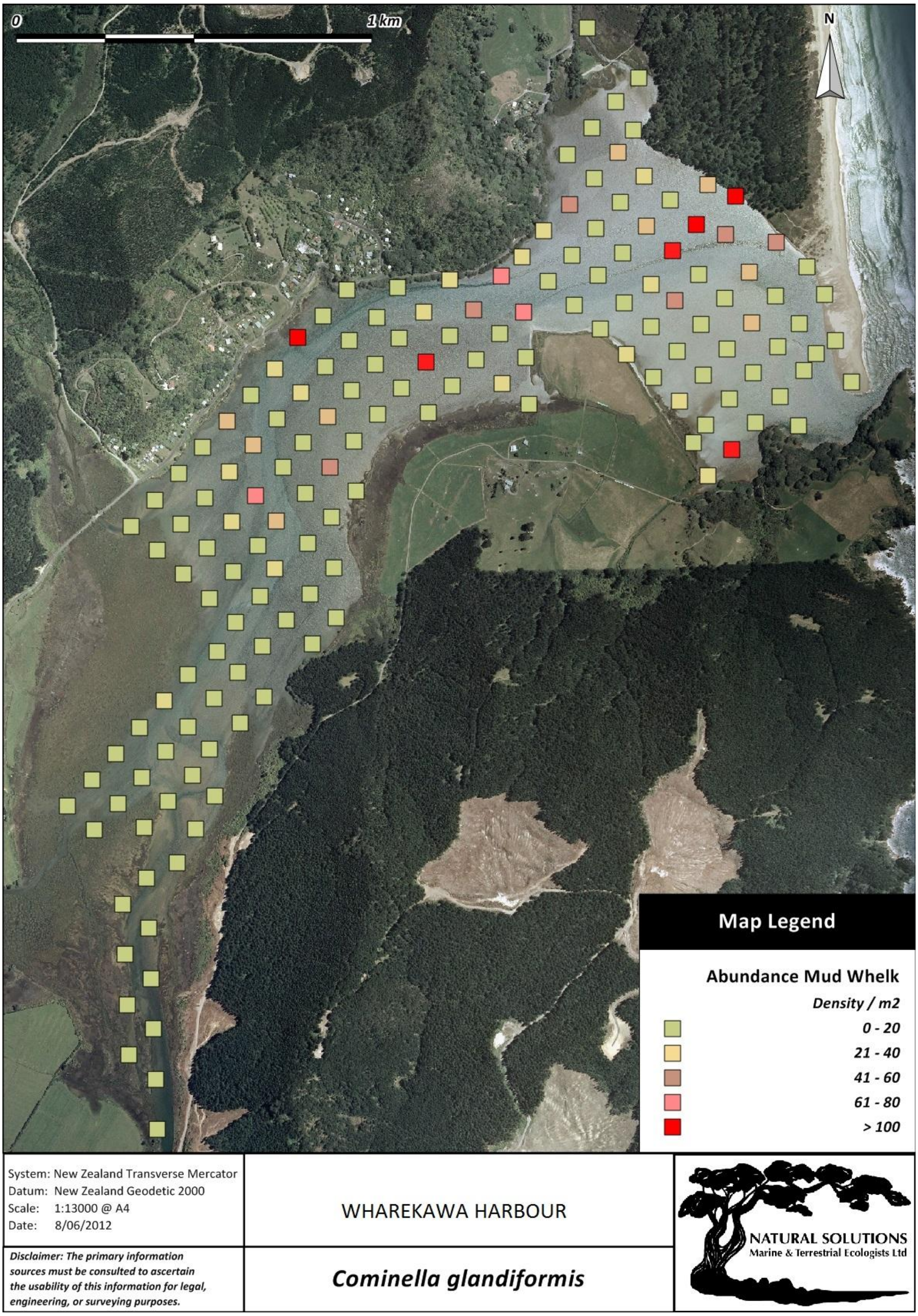


Figure 19: Density distribution of *Cominella glandiformis*

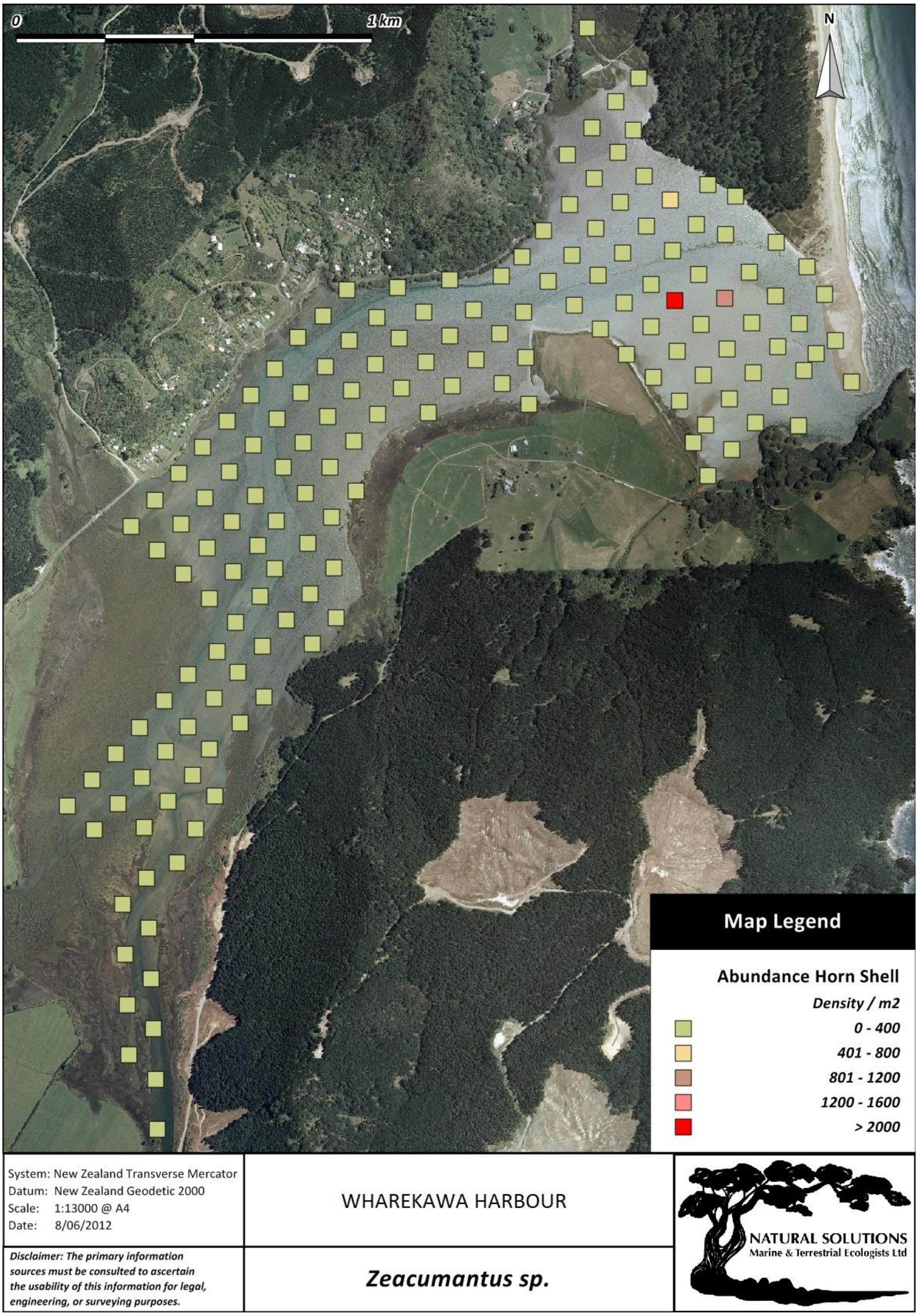


Figure 20: Density distribution of *Zeacumantus* sp.

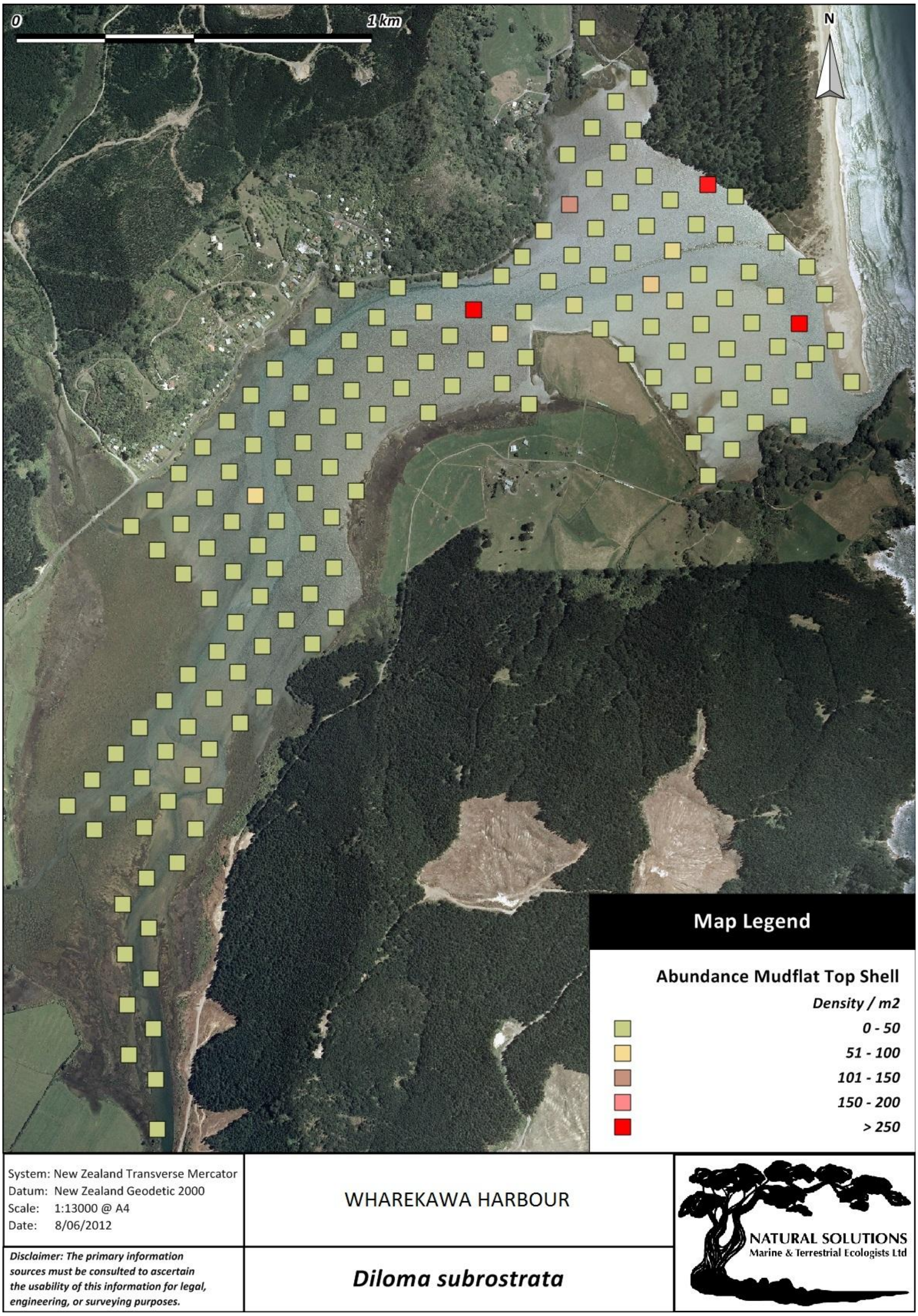


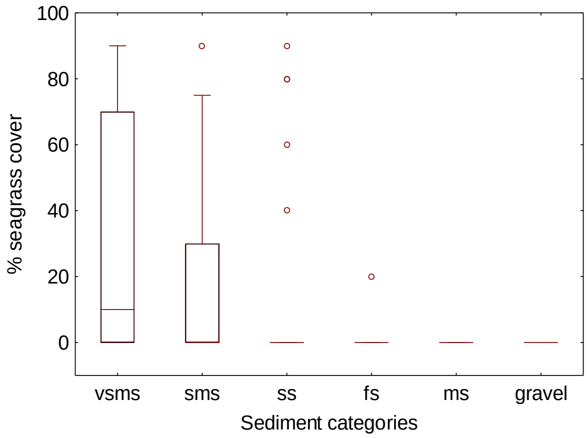
Figure 21: Density distribution of *Diloma subrostrata*

3.6. Vegetation

Vegetation (including algae) was found in 57% of the quadrats sampled (Table 1). The majority of the vegetated quadrats had seagrass present (26% of the 160 quadrats). 10 quadrats sampled had mangrove pneumatophores within them (6.3%), 4 quadrats had the invasive saltwater paspalum (2.5%), and the remaining 10 sites (6.3%) had seaweed, algae or sea meadow present. Mangrove pneumatophores have an associated dense mat of fine roots under the surface. The root mass of saltwater paspalum however was generally noted to be denser than that of mangroves.

Seagrass cover differed substantially among sites with different substrate categories (Figure 22 and Table 6) and was mainly associated with fine sediments. At sites classified as 'very soft mud / sand' and 'soft mud / sand' seagrass cover ranged from 0 to 90%; however, median values were much lower. The median seagrass cover was 10% at sites classified as 'very soft mud / sand' and 0 at all other sites. No seagrass was found at sites classified as 'gravel' and 'mobile sand' and it was only found at one site classified as 'firm sand' and four sites classified as 'soft sand'. Only few differences were statistically significant (Table 7) due to the large variability in seagrass cover.

Mangrove pneumatophores were only found at sites classified as 'very soft mud / sand' and 'soft mud / sand' (Table 6).



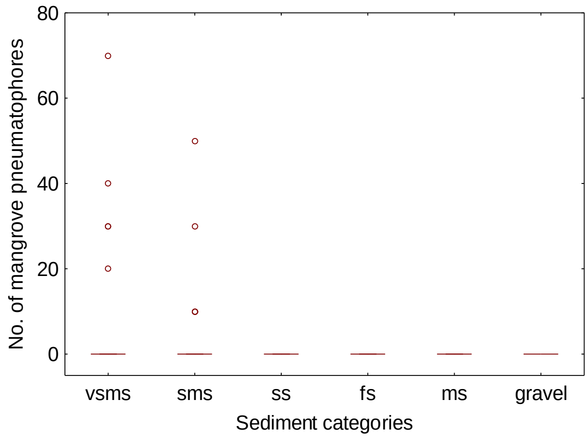


Figure 22: Boxplots showing seagrass cover and number of mangrove pneumatophores at sites classified into different substrate categories. Substrate categories: VSMS = Very soft mud / sand, SMS = Soft mud / sand, SS = Soft sand, FS = Firm sand; MS = Mobile sand.

Table 6: Results of Kruskal-Wallis tests for differences in seagrass cover and number of pneumatophores among substrate categories. N = number of cases, DF = degrees of freedom. Statistically significant results are denoted by bold P-values.

Variable	N	DF	H-statistic	P-value
% seagrass cover	157	5	22.30	**<0.01**
No. of mangrove pneumatophores	157	5	10.12	0.072

Table 7: Statistically significant differences in the per cent cover of seagrass among substrate categories (post-hoc comparisons of mean ranks, Kruskal-Wallis test results are displayed in Table 6). Stars indicated statistically significant differences between pairs (p<0.05). Substrate categories: VSMS = Very soft mud / sand, SMS = Soft mud / sand, SS = Soft sand, FS = Firm sand; MS = Mobile sand.

% seagrass cover	VSMS	SMS	SS	FS	MS	Gravel
VSMS					*	
SMS						
SS						
FS						
MS						
Gravel						

3.7. Relationship between bivalve density, sediment properties and vegetation

3.7.1. Bivalve density at sites with different sediment properties

Austrovenus were mainly found at sites classified as ‘firm sand’ or ‘soft sand’ (Figure 23). At these sites the median abundances were 13 and 21 per quadrat (208 and 336 per m^2), respectively, and the maximum numbers of *Austrovenus* found were 175 and 149 per quadrat (2800 and 2384 per m^2), respectively. At sites classified as ‘very soft mud / sand’, 90% of all samples contained only two or less *Austrovenus* and almost three quarters of samples (73%) contained no *Austrovenus*. The abundance of *Austrovenus* in this substrate category was significantly lower than the categories ‘soft mud/ sand’, ‘soft sand’ and ‘firm sand’ (Table 9).

Macomona were found at similarly high densities at sites classified as ‘soft mud / sand’, ‘soft sand’ and ‘firm sand’ (median abundance between four and seven per quadrat, 64 and 112 per m^2). Abundances were also high at two sites classified as ‘very soft mud / sand’ but were generally much lower in this category as well as at sites classified as ‘mobile sand’. The Kruskal-Wallis test (Table 8) indicated significant differences among substrate categories for *Macomona*; however, post-hoc comparisons revealed no significant differences between categories.

Paphies were only present at one site classified as ‘very soft mud / sand’ and only one individual was found. The median number of *Paphies* was also zero at sites classified as ‘soft mud / sand’ and ‘soft sand’ and maximum numbers there were 7 and 24 per quadrat (112 and 384 per m^2), respectively. *Paphies* occurred at high densities (up to 457 individuals per quadrat or 7312 per m^2) at four sites, two classified as ‘firm sand’ and two as ‘mobile sand’; however, they were only found at 35% of sites classified as ‘firm sand’. *Paphies* were found at 88% of all sites classified as ‘mobile sand’ and abundance at these sites was significantly higher than at sites classified as ‘very soft mud / sand’ and ‘soft mud / sand’.

Figure 24 shows bivalve abundance at sites with different Redox Potential Discontinuity layer (RPD) depths. None of the three bivalve species displayed a clear relationship with RPD depth, instead, the data showed a large amount of scatter. At most sites the RPD was located at depths of up to 2 cm. High numbers of *Austrovenus* occurred at sites within the upper part of this range. High abundances of *Macomona* were found at sites with RPD depths of 0.5-1 cm. Except for the four sites with very high abundance, *Paphies* were relatively even distributed among sites of all RPD depths up to 2 cm.

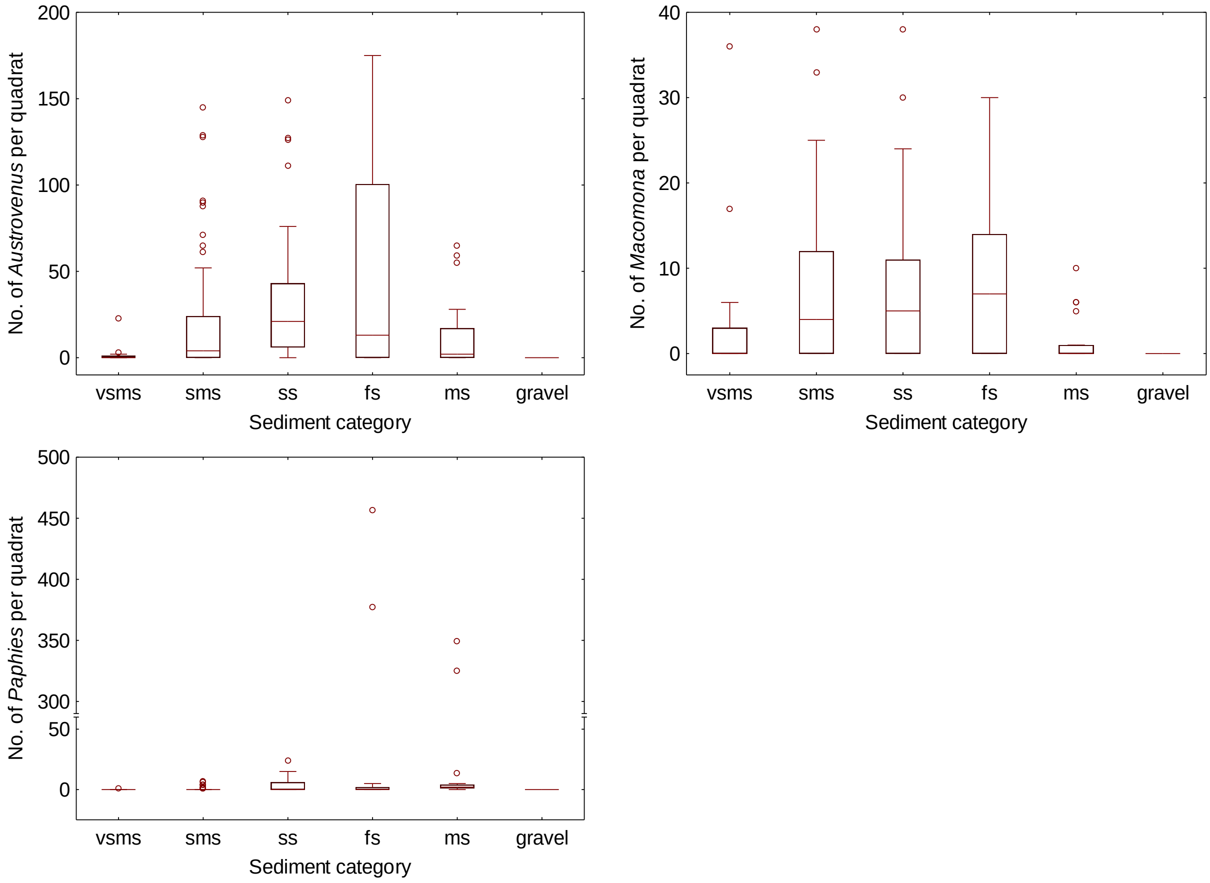


Figure 23: Boxplot showing the abundance of cockles (*Austrovenus stutchburyi*), wedge shells (*Macomona liliana*) and pipi (*Paphies australis*) at sites classified into different substrate categories. Substrate categories: VSMS = Very soft mud / sand, SMS = Soft mud / sand, SS = Soft sand, FS = Firm sand; MS = Mobile sand.

Table 8: Results of Kruskal-Wallis tests for differences in shellfish abundance among substrate categories. N = number of cases, DF = degrees of freedom. Statistically significant results are denoted by bold P-values.

Variable	N	DF	H-statistic	P-value
Cockles (*Austrovenus stutchburyi*)	157	5	36.94	**<0.01**
Wedge shell (*Macomona liliana*)	157	5	18.97	**<0.05**
Pipi (*Paphies australis*)	157	5	42.05	**<0.01**

Table 9: Statistically significant differences in the abundance of (a) cockles (*Austrovenus stutchburyi*) and (b) pipi (*Paphies australis*) among substrate categories (post-hoc comparisons of mean ranks, Kruskal-Wallis test results are displayed in Table 8). Stars indicated statistically significant differences between pairs (p<0.05). Substrate categories: VSMS = Very soft mud / sand, SMS = Soft mud / sand, SS = Soft sand, FS = Firm sand; MS = Mobile sand. Post-hoc comparisons revealed no significant differences for *Macomona*.

(a) Cockles (*Austrovenus stutchburyi*)	VSMS	SMS	SS	FS	MS	Gravel
VSMS		*	*	*		
SMS						
SS						
FS						
MS						
Gravel						

(b) Pipi (*Paphies australis*)	VSMS	SMS	SS	FS	MS	Gravel
VSMS			*		*	
SMS					*	
SS						
FS						
MS						
Gravel						

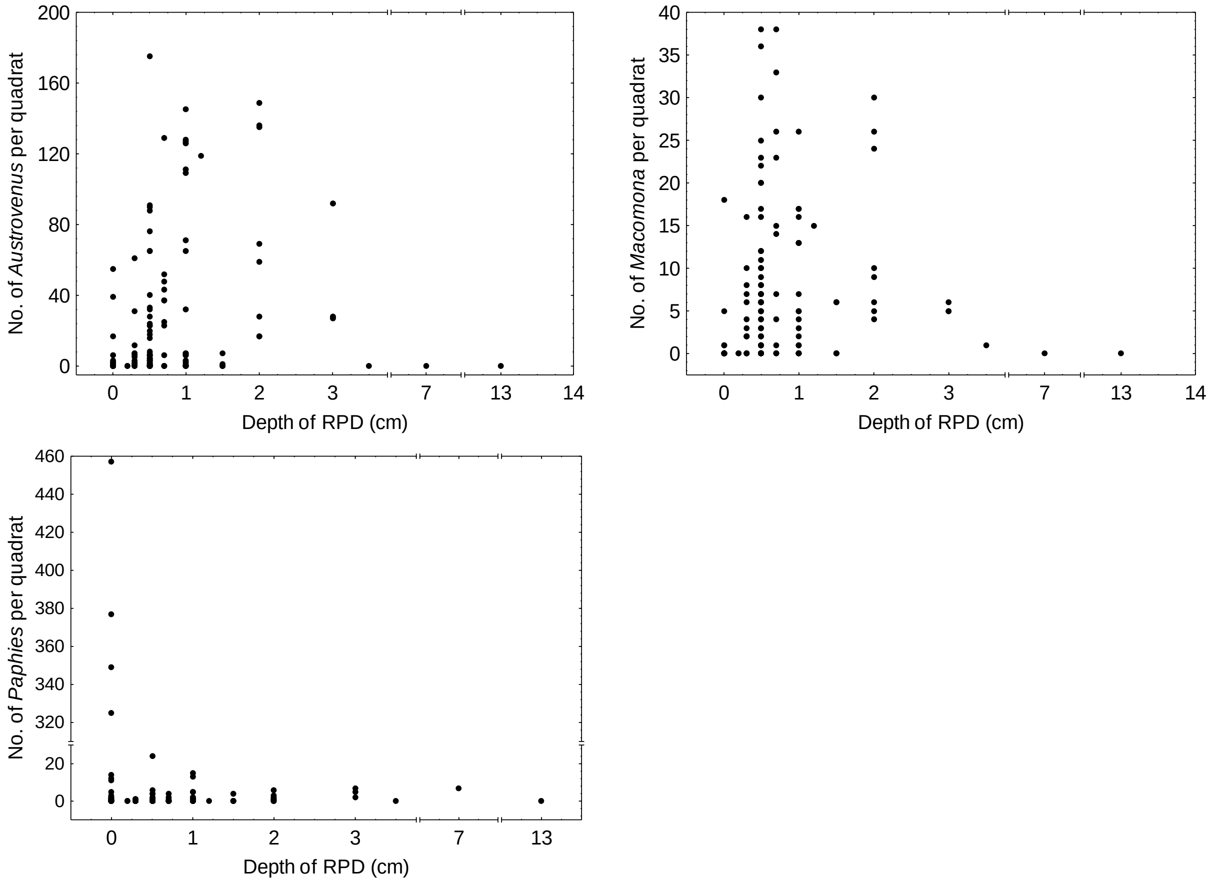
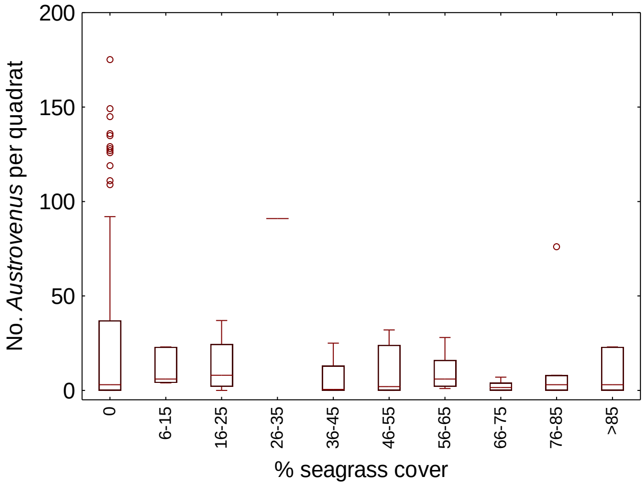


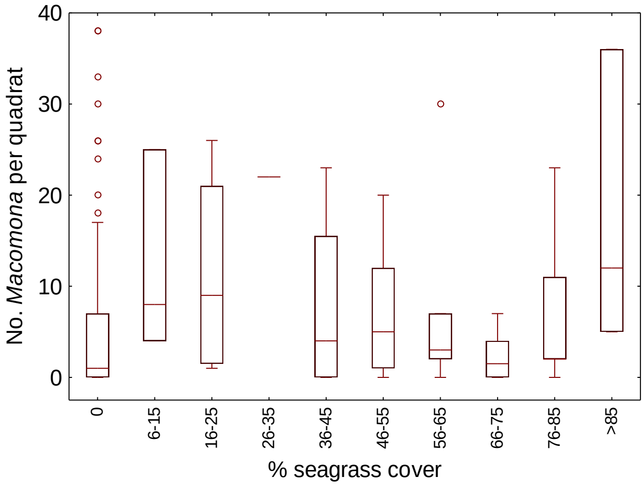
Figure 24: Relative abundance of cockles (*Austrovenus stutchburyi*), wedge shell (*Macomona liliana*) and pipi (*Paphies australis*) at sites with different Redox Potential Discontinuity layer (RPD) depths. Note breaks in x-axis scale.

3.7.2. Bivalve density at sites with different vegetation cover

(A)



(B)



(C)

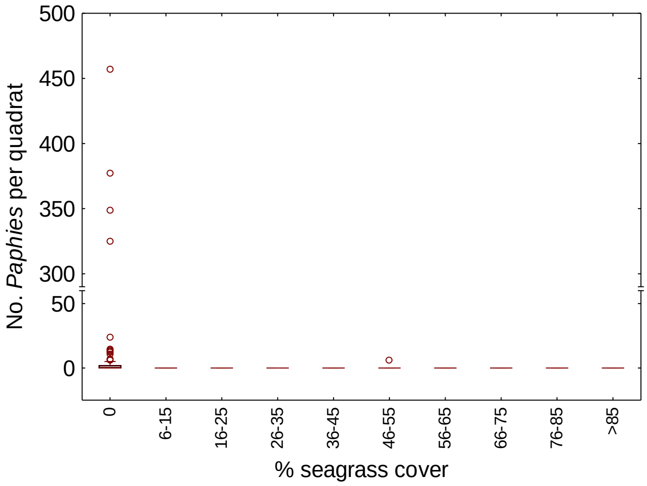


Figure 25: Boxplots showing the abundance of (A) cockles (*Austrovenus stutchburyi*), (B) wedge shells (*Macomona liliana*) and (C) pipi (*Paphies australis*) at sites with different seagrass coverage.

High numbers of *Austrovenus* and *Paphies* were associated with a lack of seagrass but *Macomona* was found at similar numbers across all seagrass densities (Figure 25). *Austrovenus* occurred at low to moderate numbers at sites covered by seagrass at all densities but, except for one site, *Paphies* were not found at any site where seagrass was present. The Kruskal-Wallis test found a significant difference in the abundance of *Austovenus* and seagrass cover (Table 10) however post-hoc comparisons did not reveal any statistically significant differences between pairs of seagrass cover ranges for *Paphies* due to the low abundances.

Table 10: Results of Kruskal-Wallis tests for differences in the abundance of cockles (*Austrovenus stutchburyi*), wedge shells (*Macomona liliana*) and pipi (*Paphies australis*) among different ranges of seagrass cover. N = number of cases, DF = degrees of freedom. Statistically significant results are denoted by bold P-values. Post-hoc comparisons of mean ranks for *Paphies* did not reveal any statistically significant differences between pairs of seagrass cover ranges.

Variable	N	DF	H-statistic	P-value
Cockles (*Austrovenus stutchburyi*)	157	9	6.24	0.716
Wedge shell (*Macomona liliana*)	157	9	13.61	0.137
Pipi (*Paphies austrialis*)	157	9	21.29	**<0.05**

4. Summary and discussion

4.1. Sediments

Medium sand (grain size 250-500 µm) and fine sand (grain size 63-250 µm) dominate Wharekawa estuary. The surface sediment showed a marked gradation of muddy sands in the upper sheltered reaches of the harbour to cleaner sands in the lower reaches of the harbour and in areas of high current.

With respect to the subjective substrate categories, the surface sediment composition in Wharekawa estuary was dominated by ‘soft mud/sand’, followed by ‘very soft mud/sand’ and ‘soft sand’. ‘Firm sand’, ‘mobile sand’ and ‘soft sand’ are prevalent in the lower estuary, while ‘soft mud/sand’ and ‘very soft mud/sand’ are the common sediment types of the upper reaches. ‘Soft sand’ can be found associated with the main channel of the upper harbour and ‘gravels’ are associated with outwash flats within the upper tidal reaches of the Wharekawa River and the Kapakapa Stream.

A comparison of the two sediment assessment methods used (subjective substrate categories and grain size analysis) revealed some meaningful relationships. Sites classified as ‘very soft mud / sand’ contained the highest proportion of mud, followed by those classified as ‘soft mud / sand’. The contribution of medium sand increased with increasing coarseness of the substrate categories as derived from their description. However, no consistent trends were found among substrate categories for fine, coarse or very coarse sand. Median grain size was lowest at sites classified as ‘very soft mud / sand’. At these sites median grain size was significantly lower than that of sites classified as ‘soft mud / sand’ and ‘soft sand’. Median grain size did not display any trends among substrate categories ‘soft sand’, ‘firm sand’ and ‘mobile sand’.

Overall, the subjective substrate classification method was relatively successful in identifying fine sediments. The categories ‘very soft mud / sand’ and, to a lesser extent, ‘soft mud / sand’ correspond to different relative amounts of grain size classes (grain size distribution) and different median grain sizes. The coarser substrate categories ‘soft sand’, ‘firm sand’ and ‘mobile sand’ could not be associated with distinct grain size distributions or median grain sizes. These categories need to be reviewed if they were to be used in future surveys. More gravel sites (if present in the estuary) need to be investigated to allow an assessment of the usefulness of this category.

The subjective substrate classification method was slightly more successful in identifying fine sediments in this survey than in the habitat mapping survey conducted in Tairua (Felsing and Giles, 2011). However, in Tairua coarse sediments (‘mobile sand’) seemed to be better related to grain size data.

Two potential reasons for the different results between the estuaries are:

1. While the sediments of both estuaries were dominated by fine and medium sand, mud was found in 84% of samples in Wharekawa estuary but only in 60% of samples in Tairua. Since the subjective substrate classification appears to be most successful in fine sediments containing mud, the better association between substrate categories and grain size data might just be a consequence of the higher occurrence of mud at the sites sampled in Wharekawa estuary.

2. The surveys were conducted by different people and no cross-validation of how the subjective substrate categories were interpreted was carried out. It is possible that some sediment types were not consistently classified.

The general results of the method comparisons for both surveys were similar. The evaluation and proposed improvements of methods presented in Felsing and Giles (2011) are also valid for this survey and are therefore not discussed in detail in this report.

The depth of the RPD did not display any consistent trends among substrate categories. The RPD depth was much shallower in Wharekawa estuary than measurements made in Tairua. Furthermore, in Tairua the RPD depth was statistically significantly deeper at 'mobile sand' sites than at most other sites. These differences may represent substantial differences in the sediments of both estuaries but may also indicate inconsistencies in the survey conduct.

4.2. Vegetation

Fifty-seven % of all sites were vegetated. The main vegetation was seagrass (26% of sites), followed by mangroves (quantified as pneumatophores, 6.3% of sites). Seagrass was mainly found at sites classified as 'very soft mud / sand' and 'soft mud / sand' and mangrove pneumatophores were only found at sites of these categories.

The association of seagrass and mangrove pneumatophores with fine sediments was expected and supports that that the substrate categories used in this survey successfully identify potential seagrass and mangrove habitats.

4.3. Bivalve abundance and distribution

Bivalves were numerically more dominant than gastropod species (accounting for 88% of individuals sampled), with *Austrovenus* clearly being more common than the other two sampled bivalves species, in terms of total individuals (3507, 56% of bivalve species), quadrat average (22 individuals/quadrat), proportion of quadrats found in (63%) and average density (351/m2).

Austrovenus were found over most of the estuary (though less commonly in the upper harbour reaches and the harbour mouth), both near channels and over the larger intertidal flats. Dense beds ranged from 496 individuals/m^2 to 2,384/m^2 and were found on sandy flats of the mid and lower harbour reaches. The maximum density was slightly lower than those of the densest *Austrovenus* beds found in Tairua Harbour (>3000/m^2; Felsing and Giles, 2011) and Otahu Estuary (about 4500/m^2; Singleton et al., 2013) but most likely higher than findings in Kawhia and Aotea Harbours from Department of Conservation surveys (>480/m^2 but exact numbers are unknown; Killock & Rohan, 2001).

Paphies presence was quite patchy and concentrated in the firm and mobile sands along the channel banks near the harbour mouth and to a much lesser extent at the riverine end of the harbour. A number of sampling points coincided with dense beds of *Paphies* at the harbour mouth (densities ranging from 5,200/m^2 to 7,312/m^2). A similar patchiness of *Paphies* abundance was found in Tairua Harbour (Felsing and Giles, 2011) and Otahu Estuary (Singleton et al., 2013).

Macomona were found throughout the harbour. A number of dense beds (maximum of 608/m^2) were found along the channels of the upper-middle harbour and at the mouth of the

Waahi Tapu Stream embayment. The densities of *Macomona* found in Wharekawa Harbour were similar to those found in Tairua Harbour (Felsing and Giles, 2011), Otahu Estuary (Singleton et al., 2013) and Kawhia and Aotea harbours (Killock & Rohan, 2001).

4.4. Relationships of bivalve abundances with sediment characteristics and vegetation

The denser areas of *Austrovenus* were mainly associated with sites classified as 'firm sand' or 'soft sand'. This distribution is consistent with the known preference of *Austrovenus* for sandy over muddy sediments. Abundances in very fine sediments ('very soft mud / sand') were very low, reflecting the low optimal mud range of *Austrovenus* of 0-10% (Gibbs and Hewitt, 2004).

Macomona populations extended more widely over substrate categories with similar distributions at sites classified as 'soft mud / sand', 'soft sand' and 'firm sand'. Abundances were lower in very fine sediments ('very soft mud / sand') but of the three shellfish species, *Macomona* displayed the least dislike for very fine sediments. This is consistent with research findings that estimated the optimal mud range of *Macomona* as 0-30% compared to much lower upper thresholds for *Austrovenus* and *Paphies* (Gibbs and Hewitt, 2004).

In Tairua Harbour, *Macomona* distribution was more restricted. Numbers were largest at sites classified as 'firm sand' and 'soft sand' and especially at sites classified as 'soft mud / sand' *Macomona* abundance was much lower than in Wharekawa Harbour (Felsing and Giles, 2011). Juvenile *Macomona* have been found to be more sensitive to mud than adults (Gibbs and Hewitt, 2004) but this was not evident in this survey.

Paphies were mainly associated with sediments categorised as 'mobile sand'. These sediments contained very little mud and *Paphies* were not present or only present at very low numbers in the categories associated with fine sediments ('very soft mud / sand' and 'soft mud / sand'). This distribution reflects the preference of *Paphies* for fast-flowing waters, which typically is associated with coarser sediments.

In summary, the distributions of *Austrovenus*, *Macomona* and *Paphies* among substrate categories reflect their sensitivity to muddy sediments in Wharekawa Harbour. *Paphies* demonstrated the least tolerance for mud with low abundances in sediments containing high levels of mud ('very soft mud / sand' and 'soft mud / sand'). *Austrovenus* were rarely found in the muddiest sediments ('very soft mud / sand') but showed greater tolerance for the moderate mud content in sediments categorised as 'soft mud / sand'. *Macomona* extended more widely over substrate categories, displaying the least sensitivity to mud.

For this estuary, the substrate categories were useful in identifying fine sediment habitats that are likely to be unsuitable for *Austrovenus* and *Paphies.* Due to the weak correlation of sediment categories with coarser grain sizes, the findings of this study are only of limited use for identifying habitats that are suitable for species with a low tolerance for mud.

Bivalve abundance was not consistently related to RPD depth for any of the three bivalve species. Within the dominant RPD depth range of 0-2 cm, high numbers of *Austrovenus* were found at the upper part of this range, high abundances of *Macomona* were found at sites with RPD depths of 0.5-1 cm, and *Paphies* were relatively evenly distributed. The large scatter in these data could indicate a lack of functional relationship between RPD depths and bivalve abundance or inconsistencies in estimating the RPD depth among field workers. However, it could also be evidence of the inherent problem of this methodology arising from the fact that the RPD often does not form a straight horizontal line in the sediment. Sediments can be patchy mosaics of oxygenated and de-oxygenated areas, which present as light brown to black shades and light and dark patches.

High numbers of *Austrovenus* and *Paphies* were associated with a lack of seagrass but *Macomona* was found at similar numbers across all seagrass densities. *Austrovenus* occurred at low to moderate numbers at sites covered by seagrass at all densities but, except for one site, *Paphies* were not found at any site where seagrass was present. This is not surprising as *Paphies* prefer coarser sediments (and higher currents) to seagrass which is generally found on sediments classified as 'very soft mud / sand' and 'soft mud / sand'. The relationships between *Austrovenus* and *Paphies* with seagrass were much less pronounced in Tairua Harbour (Felsing and Giles, 2011), where there were only marginally higher abundances of *Austrovenus* and *Paphies* at sites with no seagrass.

4.5. Evaluation of habitat mapping and suggestions for improvement of methods

This survey provides baseline data on the location of the main bivalve species within Wharekawa Harbour, substrate characteristics, as well as information on vegetation, grain size distribution and epifaunal ecology of the harbour.

The continued infilling of the harbour with fine sediment from land run-off can be expected to influence the presence and distribution of harbour species, increasingly favouring those that can cope with the effects of high sedimentation (especially increasing mud content). By comparing this information with future data, changes within the harbour over time can be ascertained and used to support the protection of natural resources.

Sediment grain size is an important parameter known to influence intertidal communities. This was further supported by a canonical correspondence analysis conducted on the results of the Tairua benthic shellfish and habitat mapping survey, which suggested that bivalve community composition correlates with sediment grain size (Felsing and Giles, 2011). However, grain size analysis is expensive, and the use of proxies for grain size data can provide cost savings.

A fundamental requirement of any proxy for grain size data is that the methodology must be robust and able to generate meaningful and consistent results over time as well as over spatial gradients, i.e. within and between estuaries. The subjective substrate classification used in this study was originally designed to map sediment types and provide a means to assess change over time, including the effects of mud entering estuaries (Robertson & Peters, 2006).

The estuary shellfish and habitat mapping survey of Wharekawa Harbour proved successful in mapping abundances of bivalves and estuary vegetation but some improvements of the subjective substrate classification system are required. The findings of this survey are generally consistent with those of the shellfish and habitat mapping survey conducted in Tairua and support the suggestions for improvements made by Felsing and Giles (2011). For this reason, detailed improvements and recommendations are not repeated in this report; instead a brief summary of the suggestions made by Felsing and Giles (2011) is provided.

Suggestions made by Felsing and Giles (2011) in regards to the subjective substrate classification system include:

- Efforts should be made to either improve the substrate categories used or to develop a new classification system to better represent sediment grain size distribution. Specific suggestions for improvements of the present substrate categories as well alternative classification systems are listed in Felsing and Giles (2011).
- Training of field workers on how to recognise different substrate categories should be improved.
- Results from individual and different field workers should be cross-validated to maximise consistency.
- Portable examples of the different substrate types should be provided to field workers to use for comparison.

Other suggestions made by Felsing and Giles (2011) include:

- If the distribution of *Paphies* is to be assessed accurately, channel habitats, or at least the edges on both sides of subtidal channels, should be included in the survey.
- Bivalve biomass should be determined since biomass is likely to be a better indicator of the functionality (e.g. as a food resource, or in terms of filtering capacity) of bivalve populations than just abundances. Bivalve biomass can be estimated from shell length providing accurate shell length is recorded.
- It would be interesting to explore if predictive models of bivalve presence or abundance based on environmental data could be developed, which may allow more targeted sampling when bivalve beds are mapped.

Felsing and Giles (2011) also support continuing the estimation of the depth of the RPD in future surveys. In Tairua, the approximate RPD depth was found to correlate with *Austrovenus* and *Macomona* presence (revealed by a regression tree analysis that was not conducted for this study). The weak relationship between RPD depth and bivalve abundance indicated in the data from Wharekawa Harbour was different from that correlation. Based on the scatter in the data observed in the Wharekawa as well as Tairua Harbour studies, the methodology used to estimate the RPD depth should be reviewed. Similar to the suggestions above in regards to the substrate classification system, cross-validation of results from field workers should be conducted. Furthermore, consistent procedures should be developed on how to estimate the RPD depth (if possible) if it does not present as a straight horizontal line.

5. Conclusions

The Wharekawa habitat mapping proved successful in generating coarse maps (grid points 150 m apart) of the distribution and abundances of three species of bivalves (cockles, *Austrovenus stutchburyi*; wedge shells, *Macomona liliana*; and pipi, *Paphies australis*), sediment type, and type and extent of cover of estuarine vegetation.

Bivalves are known to provide important ecosystem services. They are important as food for fish, birds, invertebrates and humans, their bioturbation increases nutrient recycling, and as suspension feeders they filter large quantities of water, improving water quality. Although generally resilient, bivalves are vulnerable to impacts arising from human activity, including runoff of terrestrial sediments and nutrients, habitat modification, and effects from fishing. Given their ecological importance, estuary wide declines in distribution and abundance of bivalves could have important negative consequences for estuarine functioning.

The Wharekawa habitat data, together with similar habitat mapping in Tairua Harbour, provide important information to support the management of these important resources. Initial maps provide an inventory of resources that help identify areas within estuaries of particular significance to bivalves. Repeat mapping (of entire estuaries, or selected areas therein) has the potential to generate important information on estuary-wide trends in bivalve abundances.

Two measures of sediment types were mapped in this study. A subjective substrate classification system was used to classify sediments into qualitative types, and samples for grain size analysis were collected as well. Limited correlations between the two methods demonstrate that improvements to the subjective substrate classification system are needed if it is to be used as a robust proxy for grain size distribution.

The results of this project support the recommendations by Felsing & Giles (2011) to improve the habitat mapping methodology as follows:

- Before it is used in further habitat mapping, the subjective substrate classification should be improved. Detailed suggestions for how to improve it are outlined in Felsing & Giles (2011) - Section 4.5.3).
- To enable bivalve biomass estimates, it is recommended that accurate shell length data be recorded.
- To provide a better map of *Paphies* beds, it is recommended that sampling points be located every 150 m either side of main subtidal channels.

Because it is so labour intensive, habitat mapping may not be feasible to carry out for all the estuaries in the Waikato Region. However, because of the ecological and cultural significance of bivalve species such as *Austrovenus*, *Macomona* and *Paphies*, mapping of bivalve populations is an important tool to use for estuaries where bivalves are thought to be of particular importance (e.g. where high numbers are known to exist, or where they are of special importance to humans or bird populations etc), and/or where there is concern that anthropogenic factors, such as sediment or nutrient inputs from the catchment, may adversely affect bivalve populations. Repeat surveys in vulnerable estuaries would provide important information on estuary-wide trends in bivalve distribution and abundance, which could be used in state of the environment reporting and evaluations of the efficiency of policy.

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Appendix A: Sampling locations

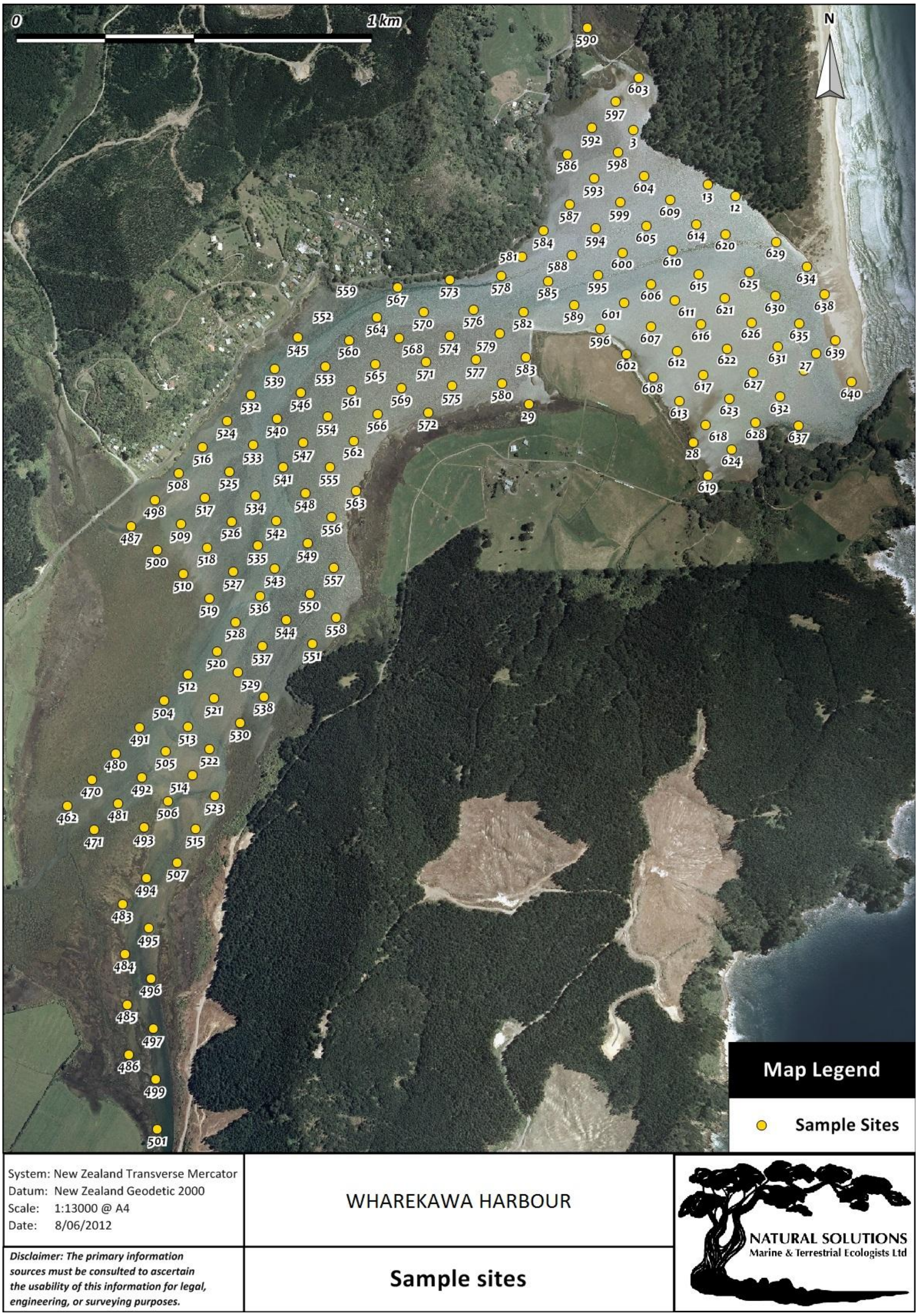

Figure 26: Sampling sites

Appendix B: Data

XI	YI	LongitudeI	LatitudeI	Original GPSSite	Date	TimeNZST	Lowtide time	RPDDepth mm	Cockle 0-20mm	Cockle 20-30mm	Cockle >30mm	Pipi 0-20mm	Pipi 20-40mm	Pipi >40mm	Maco 0-20mm	Maco 20-30mm	Maco >30mm	Cominella	Zeacum	Diloma
1856264	5889090	175.8839501	-37.10947559	620	23/02/2010	7.38	7.26	30	54	33	5	4	1	0	4	0	1	4	0	0
1856006	5889383	175.880947	-37.10690763	3	23/02/2010	11.40	7.26	10	6	0	0	0	0	0	1	1	5	1	0	0
1856019	5889530	175.8810503	-37.10557901	603	23/02/2010	11.55	7.26	5	0	0	0	0	0	0	0	0	0	0	0	0
1855752	5889099	175.8781981	-37.10953686	584	23/02/2010	18.45	19.54	7	31	6	0	0	0	0	18	7	1	2	0	4
1855061	5888799	175.8705267	-37.1124272	545	24/02/2010	9.25	0.35	10	106	39	0	0	0	0	6	6	1	7	0	0
1854725	5888417	175.8668837	-37.11595489	508	24/02/2010	11.25	0.35	5	0	1	0	0	0	0	0	1	1	0	0	0
1856617	5888673	175.8880634	-37.11312809	640	24/02/2010	17.35	20.54	0	0	0	0	0	0	0	0	0	0	0	0	0
1856573	5888790	175.8875323	-37.11208932	639	24/02/2010	17.45	20.54	0	0	0	0	0	0	0	0	0	0	0	0	0
1856542	5888920	175.8871393	-37.11093203	638	24/02/2010	17.55	20.54	0	0	0	0	0	0	0	0	0	0	0	0	0
1856292	5889197	175.8842306	-37.10850564	12	24/02/2010	18.25	20.54	10	62	9	0	1	0	0	0	0	5	8	16	0
1856214	5889229	175.8833395	-37.10824077	13	24/02/2010	18.45	20.54	7	86	43	0	0	0	0	2	10	3	3	6	15
1854813	5887641	175.8681361	-37.12291581	522	26/02/2010	9.40	10.33	70	0	0	0	7	0	0	0	0	0	0	0	0
1854752	5887704	175.8674238	-37.12236436	513	26/02/2010	10.10	10.33	7	21	2	0	2	0	0	1	1	2	1	0	0
1854827	5887510	175.8683394	-37.12409363	523	26/02/2010	10.25	10.33	0	0	0	0	1	0	0	0	0	0	0	0	0
1854773	5887417	175.8677585	-37.12494406	515	26/02/2010	10.35	10.33	0	0	0	0	5	0	0	0	0	0	0	0	0
1854722	5887323	175.8672188	-37.12580689	507	26/02/2010	10.45	10.33	0	0	0	0	1	0	0	0	0	0	0	0	0
1854833	5887915	175.8682672	-37.12044189	520	26/02/2010	12.20	10.33	5	5	1	0	23	1	0	0	1	0	0	0	0
1855986	5888753	175.8809425	-37.11258612	602	7/03/2010	16.10	18.29	10	7	0	0	0	0	0	0	0	0	2	5	0
1856469	5888552	175.8864376	-37.11426225	637	8/03/2010	8.05	6.58	0	0	0	0	233	112	4	0	0	0	0	0	0
1856518	5888753	175.886922	-37.11243598	27	8/03/2010	9.00	6.58	0	0	0	0	14	0	0	0	0	0	0	0	0
1856173	5888504	175.8831294	-37.11477295	28	8/03/2010	11.30	6.58	0	0	0	0	0	0	0	0	0	0	0	0	0
1855710	5888612	175.8778878	-37.11393225	29	8/03/2010	16.45	19.20	5	3	0	0	0	0	0	0	0	0	0	1	0
1856472	5888839	175.88637	-37.1116797	635	29/03/2010	13.05	12.13	0	5	1	0	77	294	6	1	0	0	1	0	16
1856055	5888949	175.8816505	-37.11080438	606	29/03/2010	13.45	12.13	10	89	22	0	9	4	0	9	6	2	2	0	7
1855695	5888870	175.8776314	-37.11161281	582	29/03/2010	14.10	12.13	5	36	4	0	1	0	0	3	2	0	5	0	1
1855488	5888962	175.8752774	-37.11083824	573	29/03/2010	14.30	12.13	5	1	0	0	0	0	0	0	0	0	2	0	1
1855000	5888283	175.8700212	-37.11708896	542	30/03/2010	13.30	13.08	20	10	7	0	6	0	0	5	0	0	3	0	1
1854997	5888149	175.8700273	-37.11829176	543	30/03/2010	13.50	13.08	5	3	2	0	4	0	0	6	10	1	2	0	0
1855021	5888435	175.8701993	-37.11571525	541	30/03/2010	14.05	13.08	5	32	0	0	6	0	0	3	14	3	0	5	0
1855283	5888855	175.8730039	-37.11186226	564	30/03/2010	15.20	13.08	5	78	13	0	0	0	0	15	7	0	1	5	2
1855905	5888975	175.8799601	-37.11060505	595	31/03/2010	14.40	14.00	20	34	25	0	0	0	0	6	2	2	1	6	1
1856406	5889068	175.8855516	-37.109633	629	31/03/2010	15.05	14.00	0	6	10	1	7	3	1	0	0	0	4	0	1
1856492	5888999	175.8865431	-37.11023139	634	31/03/2010	15.20	14.00	0	10	28	1	12	0	0	0	0	0	1	0	0
1855634	5888971	175.8769127	-37.11071586	578	31/03/2010	14.45	14.00	20	7	10	0	3	0	0	3	2	1	5	1	2
1854414	5887482	175.8636988	-37.12445808	462	25/02/2010	11.35	0.40	15	0	0	0	0	0	0	0	0	0	0	0	0
1854481	5887556	175.8644332	-37.1237752	470	25/02/2010	11.45	0.40	15	0	0	0	0	0	0	0	0	0	0	0	0
1854488	5887414	175.8645516	-37.12504607	471	25/02/2010	11.10	0.40	15	0	0	0	0	0	0	0	0	0	0	0	0
1854549	5887629	175.8651675	-37.12309241	480	25/02/2010	12.05	0.40	5	0	0	0	0	0	0	0	0	0	0	0	0
1854555	5887488	175.865286	-37.12436328	481	25/02/2010	11.00	0.40	15	1	0	0	0	0	0	1	4	1	0	0	0
1854568	5887205	175.8655227	-37.12690492	483	25/02/2010	8.10	0.40	7	0	0	0	0	0	0	0	0	0	0	0	0
1854574	5887064	175.8656412	-37.12817579	484	25/02/2010	8.28	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0
1854580	5886923	175.8657596	-37.12944665	485	25/02/2010	8.45	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0
1854586	5886781	175.865878	-37.13071743	486	25/02/2010	9.00	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0
1854591	5888269	175.8654283	-37.11732633	487	24/02/2010	6.40	0.35	0	0	0	0	0	0	0	0	0	0	0	0	0
1854616	5887703	175.8659019	-37.12240962	491	26/02/2010	11.00	10.33	5	0	0	0	0	0	0	0	1	2	0	1	0
1854623	5887562	175.8660203	-37.12368049	492	25/02/2010	10.50	0.40	10	1	1	0	0	0	0	0	10	7	0	0	0
1854629	5887421	175.8661386	-37.12495135	493	25/02/2010	7.50	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0
1854635	5887279	175.8662571	-37.12622213	494	25/02/2010	10.20	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0
1854641	5887138	175.8663755	-37.127493	495	26/02/2010	9.00	10.33	0	0	0	0	0	0	0	0	0	0	0	0	0
1854648	5886996	175.866494	-37.12876378	496	26/02/2010	9.15	10.33	0	0	0	0	0	0	0	0	0	0	0	0	0
1854654	5886855	175.8666124	-37.13003464	497	25/02/2010	10.00	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0
1854659	5888342	175.8661626	-37.11664354	498	24/02/2010	6.30	0.35	35	0	0	0	0	0	0	0	0	1	0	0	0
1854660	5886714	175.8667308	-37.1313055	499	25/02/2010	9.45	0.40	130	0	0	0	0	0	0	0	0	0	0	0	0
1854665	5888201	175.866281	-37.11791432	500	24/02/2010	6.50	0.35	5	0	0	0	0	0	0	0	0	0	0	0	0
1854666	5886572	175.8668493	-37.13257628	501	25/02/2010	9.28	0.40	10	0	0	0	0	0	0	0	0	0	0	0	0
1854684	5887777	175.8666362	-37.12172683	504	24/02/2010	7.30	0.35	5	1	0	0	0	0	0	0	0	1	2	2	0
1854690	5887636	175.8667546	-37.1229977	505	25/02/2010	12.15	0.40	0	0	0	0	2	0	0	0	4	1	0	0	0
1854696	5887494	175.866873	-37.12426848	506	25/02/2010	7.35	0.40	0	0	0	0	1	0	0	0	0	0	0	0	0
1854733	5888275	175.8670152	-37.11723153	509	24/02/2010	11.12	0.35	3	0	0	0	0	0	0	0	0	0	0	0	0
1854739	5888134	175.8671337	-37.1185024	510	24/02/2010	7.05	0.35	5	0	0	0	0	0	0	0	0	0	0	1	0
1854751	5887851	175.8673705	-37.12104404	512	26/02/2010	11.10	10.33	10	4	3	0	0	0	0	5	9	2	0	0	0
1854764	5887568	175.8676073	-37.12358569	514	25/02/2010	10.35	0.40	5	0	0	0	4	0	0	0	0	0	0	0	0
1854794	5888490	175.8676311	-37.11527788	516	26/02/2010	13.15	10.33	2	0	0	0	0	0	0	0	0	0	0	0	0
1854800	5888349	175.8677495	-37.11654874	517	24/02/2010	11.00	0.35	5	4	0	0	0	0	0	2	2	0	0	0	0
1854807	5888207	175.8678679	-37.11781961	518	24/02/2010	8.05	0.35	7	4	2	0	0	0	0	1	0	0	1	0	0
1854813	5888066	175.8679864	-37.11909039	519	24/02/2010	7.50	0.35	5	3	0	0	0	0	0	0	12	0	0	1	0
1854825	5887783	175.8682232	-37.12163203	521	26/02/2010	11.25	10.33	5	3	3	0	0	0	0	0	4	2	0	0	0
1854862	5888564	175.8683653	-37.11459509	524	24/02/2010	10.40	0.35	7	37	0	0	0	0	0	2	8	4	3	4	0
1854868	5888422	175.8684837	-37.11586596	525	24/02/2010	8.36	0.35	5	7	0	0	0	0	0	12	3	1	2	1	2
1854874	5888281	175.8686022	-37.11713674	526	24/02/2010	8.15	0.35	3	1	0	0	0	0	0	4	0	2	2	0	0
1854880	5888140	175.8687206	-37.1184076	527	26/02/2010	12.55	10.33	5	6	0	0	0	0	0	3	2	2	0	0	0
1854887	5887998	175.868839	-37.11967838	528	26/02/2010	12.40	10.33	10	2	1	0	5	0	0	0	0	0	0	0	0
1854893	5887857	175.8689575	-37.12094924	529	26/02/2010	12.00	10.33	7	45	7	0	4	0	0	8	25	0	1	1	0
1854899	5887716	175.8690759	-37.12222011	530	26/02/2010	11.40	10.33	5	0	0	0	0	0	0	0	0	0	0	1	0
1854929	5888638	175.8690996	-37.1139123	532	24/02/2010	9.05	0.35	7	43	5	0	0	0	0	28	10	0	1	0	0
1854935	5888496	175.869218	-37.11518317	533	24/02/2010	8.50	0.35	20	149	0	0	0	0	0	14	10	0	3	0	1
1854942	5888355	175.8693364	-37.11645395	534	24/02/2010	8.25	0.35	5	26	2	0	0	0	0	13	17	0	5	0	6
1854948	5888214	175.8694549	-37.11772481	535	30/03/2010	13.00	13.08	5	30	3	0	1	0	0	24	13	1	0	0	0
1854954	5888072	175.8695733	-37.11899559	536	30/03/2010	13.20	13.08	5	19	1	0	40	0	0	1	0	1	0	0	0
1854960	5887931	175.8696917	-37.12026645	537	9/03/2010	8.50	7.52	3	7	0	0	1	0	0	0	0	2	0	0	1
1854967	5887790	175.8698102	-37.12153723	538	26/02/2010	11.50	10.33	2	0	0	0	0	0	0	0	0	0	0	0	0
1854997	5888711	175.8698337	-37.11322951	539	30/03/2010	14.50	13.08	15	4	3	0	4	0	0	6	0	0	2	0	0

XI	YI	LongitudeI	LatitudeI	Original GPSSite	Date	TimeNZST	Lowtide time	RPDDepth mm	Cockle 0-20mm	Cockle 20-30mm	Cockle >30mm	Pipi 0-20mm	Pipi 20-40mm	Pipi >40mm	Maco 0-20mm	Maco 20-30mm	Maco >30mm	Cominella	Zeacum	Diloma
1855003	5888570	175.8699522	-37.11450029	540	30/03/2010	14.20	13.08	5	19	4	0	0	0	0	22	14	0	0	0	1
1855028	5888005	175.870426	-37.11958358	544	9/03/2010	8.40	7.52	10	0	0	0	1	0	0	1	0	0	0	0	0
1855070	5888644	175.8706864	-37.1138175	546	30/03/2010	14.35	13.08	5	0	0	0	0	0	0	6	0	0	2	0	0
1855077	5888503	175.8708049	-37.11508828	547	9/03/2010	7.45	7.52	5	1	1	1	0	0	0	0	0	1	1	0	0
1855083	5888361	175.8709233	-37.11635915	548	9/03/2010	7.55	7.52	3	0	1	0	0	0	0	0	6	2	0	1	1
1855089	5888220	175.8710417	-37.11762993	549	9/03/2010	8.10	7.52	5	6	0	0	0	0	0	5	3	1	0	1	0
1855095	5888078	175.8711602	-37.11890079	550	9/03/2010	8.25	7.52	10	0	0	0	0	0	0	1	0	0	0	0	0
1855102	5887937	175.8712787	-37.12017157	551	9/03/2010	9.15	7.52	5	1	0	0	0	0	0	1	7	2	1	3	0
1855132	5888859	175.8713021	-37.11186385	552	24/02/2010	9.50	0.35	10	0	1	0	0	0	0	3	0	0	0	1	0
1855138	5888718	175.8714206	-37.11313463	553	30/03/2010	15.00	13.08	3	0	0	0	0	0	0	2	0	0	1	0	0
1855144	5888576	175.871539	-37.11440549	554	8/03/2010	18.30	19.20	3	1	1	0	0	0	0	0	0	0	3	0	0
1855150	5888435	175.8716575	-37.11567627	555	8/03/2010	18.15	19.20	3	12	0	0	0	0	0	2	14	0	4	6	0
1855157	5888294	175.871776	-37.11694714	556	9/03/2010	10.10	7.52	5	6	0	0	0	0	0	0	0	8	0	3	0
1855163	5888152	175.8718944	-37.11821792	557	9/03/2010	9.45	7.52	5	4	0	0	0	0	0	1	0	0	0	3	0
1855169	5888011	175.8720129	-37.11948878	558	9/03/2010	9.30	7.52	3	1	0	0	0	0	0	0	0	3	0	6	0
1855199	5888933	175.8720362	-37.11118106	559	24/02/2010	10.00	0.35	10	0	0	0	0	0	0	0	0	0	1	2	1
1855206	5888791	175.8721548	-37.11245184	560	30/03/2010	15.10	13.08	7	0	0	0	0	0	0	0	0	0	1	0	0
1855212	5888650	175.8722732	-37.11372262	561	7/03/2010	8.10	6.06	5	2	2	0	0	0	0	0	3	0	0	1	0
1855218	5888509	175.8723917	-37.11499348	562	8/03/2010	18.00	19.20	5	24	0	0	0	0	0	0	9	3	1	3	1
1855224	5888367	175.8725102	-37.11626426	563	9/03/2010	10.20	7.52	0	0	0	0	0	0	0	0	0	0	0	0	0
1855279	5888724	175.8730074	-37.11303983	565	7/03/2010	7.55	6.06	5	0	2	0	0	0	0	0	0	0	0	0	0
1855286	5888583	175.8731259	-37.11431061	566	8/03/2010	17.45	19.20	5	16	0	0	0	0	0	0	6	1	0	9	1
1855341	5888939	175.873623	-37.11108617	567	31/03/2010	13.35	14.00	5	14	4	0	0	0	0	4	2	0	0	0	0
1855347	5888798	175.8737415	-37.11235696	568	7/03/2010	7.30	6.06	5	0	0	0	0	0	0	2	0	0	0	1	2
1855353	5888656	175.8738601	-37.11362782	569	8/03/2010	17.35	19.20	3	3	0	0	0	0	0	1	1	0	0	2	0
1855414	5888872	175.8744757	-37.11167417	570	8/03/2010	18.50	19.20	5	78	10	0	0	0	0	3	4	1	2	1	4
1855421	5888730	175.8745942	-37.11294495	571	7/03/2010	8.30	6.06	5	2	1	0	0	0	0	0	0	2	6	0	0
1855427	5888589	175.8747127	-37.11421581	572	8/03/2010	17.08	19.20	3	5	0	0	0	0	0	0	2	2	0	12	1
1855488	5888804	175.8753283	-37.11226216	574	7/03/2010	8.50	6.06	5	0	0	0	0	0	0	0	0	0	0	0	0
1855494	5888663	175.8754468	-37.11353294	575	8/03/2010	17.25	19.20	3	6	0	0	0	0	0	1	0	1	0	6	1
1855556	5888878	175.8760625	-37.11157928	576	31/03/2010	14.00	14.00	10	97	31	0	1	1	0	12	1	0	4	2	16
1855562	5888736	175.876181	-37.11285006	577	9/03/2010	7.05	7.52	3	0	0	0	0	0	0	0	0	0	0	0	0
1855630	5888810	175.8769151	-37.11216727	579	9/03/2010	7.15	7.52	3	7	0	0	0	0	0	2	5	0	1	3	5
1855636	5888669	175.8770337	-37.11343805	580	8/03/2010	16.55	19.20	5	2	0	0	0	0	0	2	4	0	2	4	1
1855691	5889025	175.8775307	-37.11021353	581	29/03/2010	14.45	12.13	5	22	1	0	0	0	0	16	9	0	2	3	3
1855703	5888743	175.8777678	-37.11275518	583	8/03/2010	16.30	19.20	5	0	0	0	0	0	0	0	0	0	0	0	0
1855765	5888958	175.8783834	-37.11080153	585	31/03/2010	14.25	14.00	20	22	6	0	1	0	0	1	0	3	1	2	0
1855820	5889314	175.8788802	-37.10757701	586	23/02/2010	17.40	19.54	5	0	0	0	0	0	0	3	1	1	0	0	0
1855826	5889173	175.8789988	-37.10884787	587	23/02/2010	18.30	19.54	7	25	0	0	0	0	0	11	8	4	4	0	10
1855832	5889032	175.8791174	-37.11011865	588	23/02/2010	9.05	7.26	20	55	14	0	1	0	0	2	4	3	1	0	0
1855838	5888890	175.879236	-37.11138943	589	29/03/2010	12.05	12.13	5	70	20	0	0	0	0	11	6	3	1	2	4
1855875	5889671	175.8793772	-37.10435257	590	23/02/2010	17.05	19.54	0	0	0	0	0	0	0	0	0	0	0	0	0
1855887	5889388	175.8796143	-37.10689422	592	23/02/2010	17.27	19.54	5	0	0	0	0	0	0	1	2	1	0	1	0
1855893	5889247	175.8797329	-37.108165	593	23/02/2010	17.50	19.54	5	19	1	0	0	0	0	1	3	3	1	1	1
1855900	5889105	175.8798514	-37.10943578	594	23/02/2010	9.25	7.26	5	7	1	0	0	0	0	9	2	0	0	1	0
1855912	5888823	175.8800887	-37.11197742	596	7/03/2010	15.50	18.29	0	1	0	0	0	0	0	0	0	0	0	0	0
1855955	5889462	175.8803483	-37.10621134	597	23/02/2010	17.16	19.54	0	0	0	0	0	0	0	0	0	0	0	0	0
1855961	5889321	175.8804669	-37.10748212	598	23/02/2010	11.30	7.26	10	5	1	0	2	0	0	0	3	10	3	0	0
1855967	5889179	175.8805855	-37.1087529	599	23/02/2010	18.07	19.54	5	0	0	0	0	0	0	4	1	0	0	3	1
1855974	5889038	175.8807041	-37.11002368	600	23/02/2010	8.45	7.26	12	92	26	1	0	0	0	2	8	5	1	1	1
1855980	5888897	175.8808227	-37.11129455	601	29/03/2010	14.00	12.13	3	31	0	0	1	0	0	0	0	0	0	0	3
1856035	5889253	175.8813195	-37.10807003	604	23/02/2010	11.07	7.26	10	109	0	0	0	0	0	9	12	5	2	6	3
1856041	5889112	175.8814382	-37.10934081	605	23/02/2010	9.45	7.26	20	107	27	1	0	0	0	11	8	7	3	1	0
1856054	5888829	175.8816754	-37.11188246	607	7/03/2010	16.50	18.29	5	4	0	0	0	0	0	1	0	0	0	19	0
1856060	5888688	175.881794	-37.11315324	608	7/03/2010	16.30	18.29	7	43	0	0	0	0	0	3	4	0	1	1	0
1856109	5889185	175.8821722	-37.10865794	609	23/02/2010	10.40	7.26	5	150	25	0	2	0	0	0	3	4	1	47	3
1856115	5889044	175.8822908	-37.10992872	610	23/02/2010	8.20	7.26	5	10	49	17	0	0	0	14	9	0	6	8	5
1856121	5888903	175.8824095	-37.11119958	611	7/03/2010	17.05	18.29	10	126	0	0	1	0	0	2	0	0	4	150	4
1856127	5888761	175.8825281	-37.11247036	612	8/03/2010	10.45	6.58	7	0	0	0	1	0	0	0	0	0	0	0	0
1856134	5888620	175.8826468	-37.11374114	613	8/03/2010	11.00	6.58	5	61	4	0	0	0	0	4	4	2	2	22	1
1856182	5889118	175.8830249	-37.10924584	614	23/02/2010	10.20	7.26	20	63	68	5	2	0	0	20	8	2	7	0	3
1856189	5888977	175.8831435	-37.11051662	615	29/03/2010	12.25	12.13	5	61	4	0	0	0	0	0	0	0	1	1	0
1856195	5888835	175.8832622	-37.11178749	616	8/03/2010	9.40	6.58	10	65	0	0	1	0	0	0	0	0	0	21	0
1856201	5888694	175.8833808	-37.11305827	617	8/03/2010	10.35	6.58	0	2	0	0	2	0	0	0	0	0	0	0	0
1856207	5888553	175.8834995	-37.11432905	618	8/03/2010	11.10	6.58	5	1	0	0	0	0	0	0	0	0	0	2	0
1856214	5888411	175.8836182	-37.11559983	619	9/03/2010	11.05	7.52	0	1	0	0	0	0	0	5	13	0	2	0	1
1856262	5888909	175.8839962	-37.11110453	621	7/03/2010	17.25	18.29	0	51	4	0	1	0	0	0	0	0	0	80	0
1856269	5888768	175.8841149	-37.11237531	622	8/03/2010	9.55	6.58	30	25	3	0	2	0	0	3	1	1	1	0	0
1856275	5888626	175.8842336	-37.11364618	623	8/03/2010	10.25	6.58	0	1	1	0	0	0	0	0	0	0	0	0	0
1856281	5888485	175.8843523	-37.11491696	624	9/03/2010	11.15	7.52	3	55	6	0	0	0	0	9	0	1	6	2	1
1856330	5888983	175.8847302	-37.11042166	625	29/03/2010	12.40	12.13	30	18	9	0	5	2	0	6	0	0	3	0	3
1856336	5888842	175.8848489	-37.11169244	626	7/03/2010	17.45	18.29	10	107	20	0	4	1	0	4	1	0	3	20	0
1856343	5888700	175.8849676	-37.11296322	627	29/03/2010	12.55	12.13	0	0	0	0	1	0	0	1	0	0	1	0	0
1856349	5888559	175.8850863	-37.114234	628	9/03/2010	11.35	7.52	0	3	0	0	2	0	0	0	0	0	0	0	0
1856404	5888915	175.885583	-37.11100956	630	29/03/2010	13.30	12.13	10	21	11	0	10	5	0	3	1	0	0	0	4
1856410	5888774	175.8857017	-37.11228034	631	7/03/2010	18.05	18.29	0	0	0	0	3	0	0	0	0	0	0	0	0
1856416	5888633	175.8858204	-37.11355112	632	8/03/2010	7.15	6.58	0	0	0	0	412	44	1	0	0	0	0	0	1
1856484	5888706	175.8865544	-37.11286825	636	7/03/2010	18.15	18.29	0	0	0	0	265	60	0	0	0	0	0	0	0