Okahu Bay restoration

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A report on the survey of the marine benthic population and bathymetry in Okahu Bay

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A final report for Ngā Pae o te Māramatanga
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ABSTRACT

This project fulfils part of the Ngā Pae o te Māramatanga summer studentship project that looks at the elements of ecological and *Mauri* restoration at Okahu Bay. This current study focused on the population abundance and distribution of marine benthic shellfish pipi (*Paphies australis*) and common cockle (proper name New Zealand Littleneck Clam; *Austrovenus stutchburyi*), and seagrass (*Zostera*) population. This project also measured the bathymetry within Okahu Bay, site that receives input from stormwater from the surrounding urban area.

The current study illustrated that at the mid-tidal range there was rarely any pipi, with a few cockle species present across the bay. There was a clear difference in the percentage of seagrass cover in the bay at the mid-tidal range with the amount at nil on the outer transect lines and increasing towards the centre of the bay. The result of the current population could still be recovering from the past and current input of stormwater and runoff. The bathymetry results illustrated a gradient in depth with an increase seaward, with shallower areas at the high tidal zone (beach) and outer areas of the bay.

The survey of the marine benthic fauna and flora has illustrated that there are ecological relationships that potentially combine to support the function of this environment. However, this current study can only be conservative in the discussion of marine benthic population results and comparison to past trends. Okahu Bay's location makes it a sink for the disposal of urban stormwater and associated contaminants. Further research and focus on remediation are required in this ecologically and culturally important area.

ACKNOWLEDGEMENTS

He mihi tēnei ki te tini kua āwhina i ahau, ko ētahi kāore kua tuhia ki tēnei whārangi, engari ka tuku mihi atu ki a koutou katoa. Ki te kore koutou, kore rawa te rangahau nei ka ea.

Ngā mihi nui ki a kōrua ngā kaiurungi mō tēnei kaupapa Dr Dan Hikuroa rāua ko Dr Kepa Morgan. Your supervision in this busy period has given further experience to collaborate with another discipline, and further marine science work.

Thank you to Malcolm Paterson and Richelle Kahui-McConnell for your guidance on behalf of Ngāti Whātua o Orakei and keeping the project aligned with the greater and initial goals. Also thanks to Malcolm for the help in the bathymetry field work!

Thank you also to Adrian Croucher and Mike O'Sullivan for agreeing to feed the data into completing a hydrological study for Okahu Bay that would give invaluable information to this project.

Finally I am thankful to Ngā Pae o te Māramatanga for the opportunity to work and collaborate with a great group to complete a project that is contributing to a local iwi and hope that this goes towards the development of their ultimate objectives.

Ngā mihi nui kia koutou katoa.

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CHAPTER ONE

Introduction

GENERAL INTRODUCTION

This project fulfils part of the Ngā Pae o te Māramatanga summer studentship project that looks at the elements of ecological and *Mauri* restoration at Okahu Bay. This Bay is connected to the *hapū* Ngāti Whātua o Ōrākei as *Mana Whenua*. This project involved the collaboration between students Elliot Hurst (Engineering student), Tumanako Fa'aui (Engineering student), and myself (Ani Kainamu; Māori studies, Marine science) with supervision by Dr. Dan Hikuroa and Dr. Kepa Morgan, and guidance by iwi consultants Malcolm Paterson and Richelle Kahui-McConnell to ensure research related to the objectives of the overall cultural use of Ngāti Whātua o Ōrākei. This project was composed of four projects that included the analysis of the Mauri Model, the benthic population and biodiversity, the levels of sediment contaminants, and the hydrological modelling of Okahu Bay.

The Mauri Model created by Dr. Kepa Morgan was used by Tumanako Fa'aui to assess the possible situations/courses of action to restore Okahu bay. The measurement of sediment contaminants was undertaken by Elliot Hurst. I conducted the marine benthic population survey, as well as the bathymetry survey with Malcolm Paterson. The bathymetry data will be used by the Engineer researchers Adrian Croucher and Mike O'Sullivan to model the hydrological dynamics. This current document reports the study of the benthic biota population survey, and the bathymetry data collected for the hydrological model study.

METHODOLOGY

To establish a framework of *Mātauranga Māori* methodology this project was informed by the document of Collaboration and Consultation by Kahui-McConnell (2007), and the initial Mauri Model draft by Tumanako Fa'aui, in consultation also with both the cultural advisors Malcolm and Richelle. As reported by Kahui-McConnell (2007), the *Mātauranga* retained and transmitted by Ngāti Whātua o Ōrākei describes a thriving ecosystem as a *mahinga kai* site with 'species diversity was common in the nets hauled in from Okahu Bay' (Kawherau, 2004). This gives anecdotal evidence of the historical status of population abundance, and the importance of this site and its wellbeing to the *hapū*.

The importance of this lies with the connection to the indigenous people, in which this bay is the *mauri* of the *hapū*. The wellbeing of the *hapū* sits within the practicing of *tikanga*, one being the role to practice *kaitiakitanga*. *Kaitiakitanga* is a fundamental concept practiced over an area and its associated resources, for example the wellness of an ecosystem for the wellbeing of future generations to come. *Kaitiakitanga* of traditional food gathering sites give rise to the *mana* of a *hapū* and their ability to provide *manaakitanga* to their extensive *whānau* and especially their *manuhiri*. The degradation of this bay has lead to the decrease of these practices in this area which degrades the cultural rights and values that has been transferred traditionally from generation to generation. The *hapū* continues to perform guidance in order to attempt restoration of important food gathering and cultural practice sites such as Okahu Bay.

CURRENT STUDY

In the most recent, 2006 Census the Auckland region continued to have the largest population in New Zealand, with 1,060,653 residents, a population growth of more than 100,000 since the 2001 population (Willis, 2008). The urbanisation of land is a direct consequence of these population trends and urbanisation is one of the great drivers of change in the state of the Hauraki Gulf's environment (Willis, 2008). The Waitemata Harbour is used extensively for recreation, industry, fishing, trade and tourism. At the same time, the Harbours are sinks for the disposal of urban stormwater and associated contaminants (NIWA, 2012a).

I aim to address some of the environmental factors of Okahu Bay, as indicated by the Mauri Model draft, such as estimating the marine fauna - the abundance of indicator species, health of aquatic species, changes over time of size classes of species; marine flora - plant health, plant abundance over time; and discuss the history of pollution - litter, sewage and stormwater overflow into the bay. Biota that are most directly impacted by reduced water quality are sessile plants and animals, such as seagrass and benthic infauna, since they are most persistently exposed to pollutants and degraded conditions (DSE, 2012). Due to trophic and other ecological links between these more mobile species, impacts have extended to many parts of the marine ecosystem (Jenkins *et al*., 1992).

ECOLOGICAL IMPORTANCE OF SHELLFISH

Bivalves are a useful tool for monitoring changes within a system, as they typically comprise one of the largest and longest lived groups in many infaunal communities and are typically the most abundant suspension feeders in estuaries (Dame, 1996). Filter-feeding bivalves are linked to the material they process and affect the system with bio-deposits of wastes to the benthic layer. Filter feeding is one of the most ecologically significant features of aquatic environments and facilitates benthic-pelagic coupling as well as influencing water quality (Dame, 1996). Bivalves have a tremendous capacity to filter water, and in some enclosed estuaries and bays can filter the entire volume of water in the system in a manner of hours (e.g. Cloern, 1982; Beukema and Cadée, 1996). Estimates of the filtering capacity of mussels and cockles in the Dutch Wadden Sea indicate that the bivalve populations filter the entire water mass of the sea in less than a week (Dankers and Zuidema, 1995). Thus bivalve filter-feeders are both a product of their habitat as well as influence their environment. For example, the loss of extensive bivalve beds in New York harbour and other regions on the eastern seaboard of the United States from overfishing and pollution has had profound influences on the water quality and food webs of these estuaries (Lenihan and Peterson, 1998). Consequently, likely declines and further loss of the bivalve population may have a major impact on the coastal system in terms of the productivity of the system and the stability of the resource base.

Many of the species dwellings in coastal and estuarine soft-sediments around the Auckland region play important roles in the cycling of sediments and consequently organic and inorganic contaminants. The common cockle, *Austrovenus stutchburyi*, when in sufficient density will accelerate sediment deposition and contamination accumulation in the sediment through its ability to filter material from the water column (Gadd *et al*., 2010). Species such as *Macomona liliana* can affect sediment movement by significant decreasing the sediment stability (Lelieveld *et al*., 2004).

ECOLOGICAL IMPORTANCE OF SEAGRASS

The ecological importance of seagrasses is now reasonably well documented worldwide (Hemminga and Duarte, 2000), there are more than 50 species identified globally, which occupy a wide ecological range, from the intertidal zone down to depths of greater than 50 m where water clarity is sufficiently high (Reed *et al*., 2004). Seagrass beds are considered to be one of the most productive marine ecosystem, with high biodiversity and habitat value, as they play a vital role in supporting fisheries, protecting other components of the ecosystem (including coral reefs) by binding sediment and reducing turbidity, and providing defence from coastal erosion (Hemminga and Duarte, 2000).

Although in New Zealand seagrasses are largely intertidal, similar roles have been recognised here (Inglis, 2003), *Zostera* beds normally support a rich and varied biota (Droomgoole *et al*., 1983). Research has found that seagrass beds in New Zealand (especially those that remain permanently submerged) are a particularly important habitat for juvenile fish (Morrison and Francis, 2004), in their role as a transition habitat for juvenile fish, and as a protective nursery habitat, and influence the diversity and abundance of small fish as well as the abundance of large fish on the open coast (Reed *et al.*, 2004). Seagrass beds also support shellfish populations, and provide a transitional habitat for migrating birds (Mason and Ritchie, 1979; Inglis, 2003). Therefore the degradation and/or disappearance of seagrass habitats is likely to have significant effects on other associated organisms.

STUDY AREA

This study involved Okahu Bay (Figure 1.4 and 1.5) that sits within the Waitemata Harbour, a large tidal estuary adjacent to New Zealand’s largest and fastest growing city, Auckland (Figure 1.3; Changes in benthic assemblages). The iconic Waitemata Harbour and Manukau Harbour are both fundamental parts of urban living in Auckland. The Waitemata Harbour in particular is the country’s busiest commercial port, it has tens of thousands of private yachts and launches, it is a place of recreational and commercial fishing, and it contains a bird sanctuary and diverse shellfish beds.

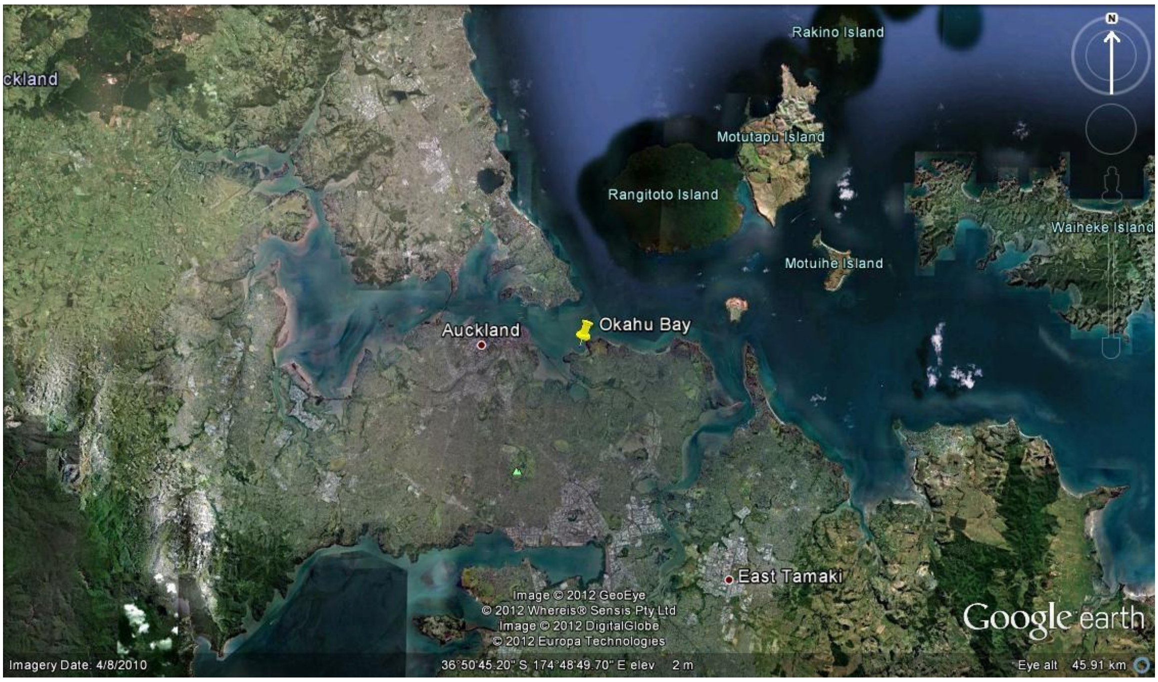


Figure 1.1 Map of Auckland with the position of Okahu Bay (Google™ Earth, 2012).

Figure 1.2 Map of the wider Okahu Bay area with Judges and Hobson Bays (Google™ Earth, 2012).

Figure 1.3 Map of Okahu Bay area with the Marina Development on the left, Takaparawha on the hill, right of the bay.

STUDY OBJECTIVES

The objective of this study was to assess the marine benthic population and the hydrological movements within Okahu Bay. The specific studies were to assess the trend of benthic shellfish and seagrass, and to estimate the current bathymetry to be used in the hydrological modelling.

CHAPTER LAYOUT

CHAPTER 1: Introduction

This section introduces the project topic and study direction.

CHAPTER 2: The shellfish and seagrass survey at Okahu Bay

This chapter measures the current shellfish and seagrass abundance and distribution across the bay with comparison to the past estimates of Okahu Bay.

CHAPTER 3: Hydrology Model – bathymetry

The current bathymetry is measured to use in the hydrological model.

CHAPTER 4: Discussion and Conclusion

This section discusses the overall results and the implications this has for the Okahu Bay environment.

CHAPTER TWO

The benthic population abundance and distribution

INTRODUCTION

The focus of this population survey was on the two dominant shellfish pipi (*Paphies australis*) and common cockle (proper name New Zealand Littleneck Clam; *Austrovenus stutchburyi*), as well as the flora seagrass (*Zostera*) that were present in the past study by Kahui-McConnell (2007) of Okahu Bay. A survey of the inter-tidal area is useful to get an indication of the health of the bay by looking at the benthic biota biodiversity and distribution. This study may provide information of the habitat along the bay and across the intertidal zone, and to identify whether this habitat support these species. Furthermore, the current survey can be used to compare with past surveys to see if there are any changes in the benthic population over time.

THE BENTHIC POPULATION

In New Zealand, the seagrass, *Zostera capricorni* can be found throughout the North and South Islands, from Parengarenga Harbour to Stewart Island (Inglis, 2003). Before 1921, Zostera was once very abundant in Waitemata Harbour and dominated large areas of areas of Hobson Bay and Stanley Bay, but by 1931 had depleted (Hounsell, 1935; Powell 1937). Seagrasses are sensitive to changes in certain environmental conditions (eg. light, nutrients, toxins; see Reed *et al.*, 2004, for further information) with the loss or severe degradation in New Zealand’s harbours and estuaries (apparently those most impacted by human development), including beds in Tauranga Harbour, Waitemata Harbour, Manukau Harbour, Whangarei Harbour and Avon-Heathcote Estuary (Inglis, 2003). The disappearance of *Zostera* extends the Waitemata Harbour, with seagrass bed loss from the Tamaki estuary, Howick Beach, Okahu Bay, Torpedo Bay and Cheltenham (Armiger, 1964). Whilst this can be largely attributed to a disease by the *Labyrinthula* slime mould (Armiger, 1964) it is conceivable that pathogenic susceptibility is enhanced by unfavourable conditions for growth such as increased sediment load, reduced salinity or pollutants (Droomgoole *et al*., 1983). Similar epidemic losses were recorded in the Avon-Heathcote estuary during 1929-1953 and in many Northern Hemisphere locations in the 1930s (Droomgoole *et al*., 1983) that shows this is not unique to Auckland, and New Zealand.

A faunal survey of biota in Waitemata Harbour was conducted by Hayward *et al*. (1997) to revisit many of Powell's (1937) sampling stations which were based largely on molluscs, was the first analyses of benthic soft-sediment communities in the harbour, which showed a decline in the abundance, and a restricted range in molluscs since the 1930s. For example there was a decline in gastropods *Amalda australis* and *A. novaezelandiae,* and of the bivalves *Tucetona laticostata, Neilo australis, Dosinia lambata,* and *Tellinota edgari* (Hayward *et al*., 1997). In comparison to this, there was an abundance of shell debris found throughout the harbour of *Zeacolpus pagoda, Anomia trigonopsis,* and *Austrovenus stutchburyi* but were found alive hardly at all in the 1930s or 1990s surveys (Hayward *et al*., 1997). The cockle, *A. Stutchburyi,* was the most abundant intertidal bivalve with its shells being washed and floated out into deeper water (Hayward and Stillwell, 1995).

The Ministry of Fisheries is aware of the depletion of intertidal shellfish populations throughout the Auckland Metropolitan Area and in 1992 established an "Intertidal Shellfish Monitoring Programme" within this greater area to assess the populations through regular suveys (Akroyd *et al*., 2000). The potential stressors identified to affect the status stocks of cockle, pipi, tuatua, and wedge shells in the Hauraki Marine Park Area include antropogenic contaminants such as organotin compounds and organic booster biocides, heavy metals, organochlorides and polyaromatic hydrocarbons; human harvesting; changes in the marine environment associated with human activity such as increased sediment loading, nutrient enrichment and climate change; natural phenomena of an extraordinary nature such as harmful algal blooms, and diseases/parasite events (Coral and Hay, 2003).

PAST COMMUNITY SURVEY

The first benthic community survey of Okahu Bay was conducted in 2007 and repeated to 2010 using the Hauraki Gulf Shellfish Monitoring methodology and working with Ngāti Whātua and the Ōrākei Community (ARC, 2012a). In these past surveys, the species cockle, *Austrovenus stutchburyi*, pipi, *Paphies australis*, were surveyed as key indicators of ecological health of Okahu Bay. The successive surveys indicated an increase in density of cockles and pipi over time (Figure 2.1) with an increase in juvenile size class, and decline in larger size class in both shellfish (Figure 2.3). It is also shown that in the years 2008 and 2009 the density of both shellfish were higher in the eastern end of the bay (Transect lines A-D) than the western end (F-I) (Figure 2.2). However, the report results by (Coral and Hay, 2003) should be looked at closely as the graph axes are in different scales (Figure 2.3). Furthermore, this is a small time frame so there is insufficient information to confirm trends. The seagrass, *Zostera capricorni*, was included into the study of the bay in 2007 (Kahui-McConnell, 2007).

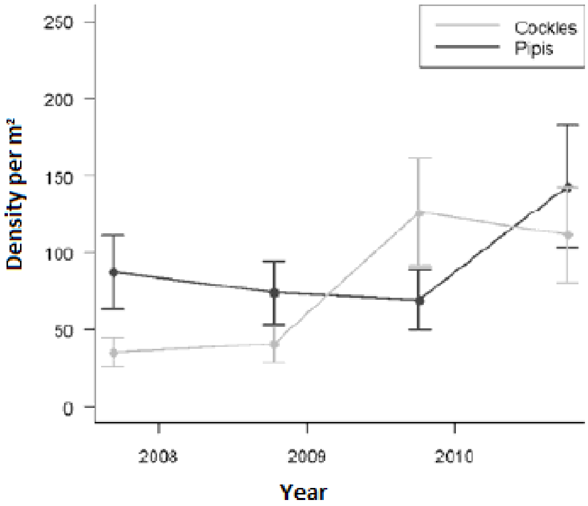


Figure 2.1 The reported population density per m² of cockle (light grey line) and pipi (dark grey line) at Okahu Bay from 2007 to 2011 (ARC, 2011).

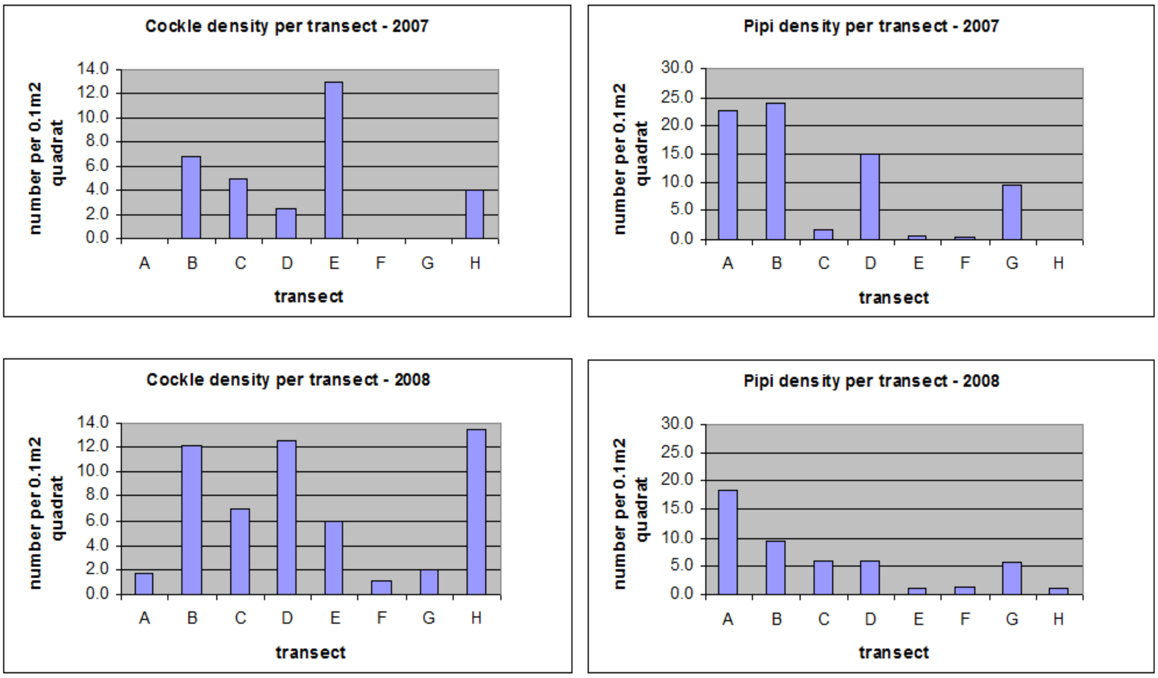


Figure 2.2 The reported population density per 0.1 m² of cockle and pipi per transect line at Okahu Bay in 2007 and 2008 (Kahui-McConnell, 2007).

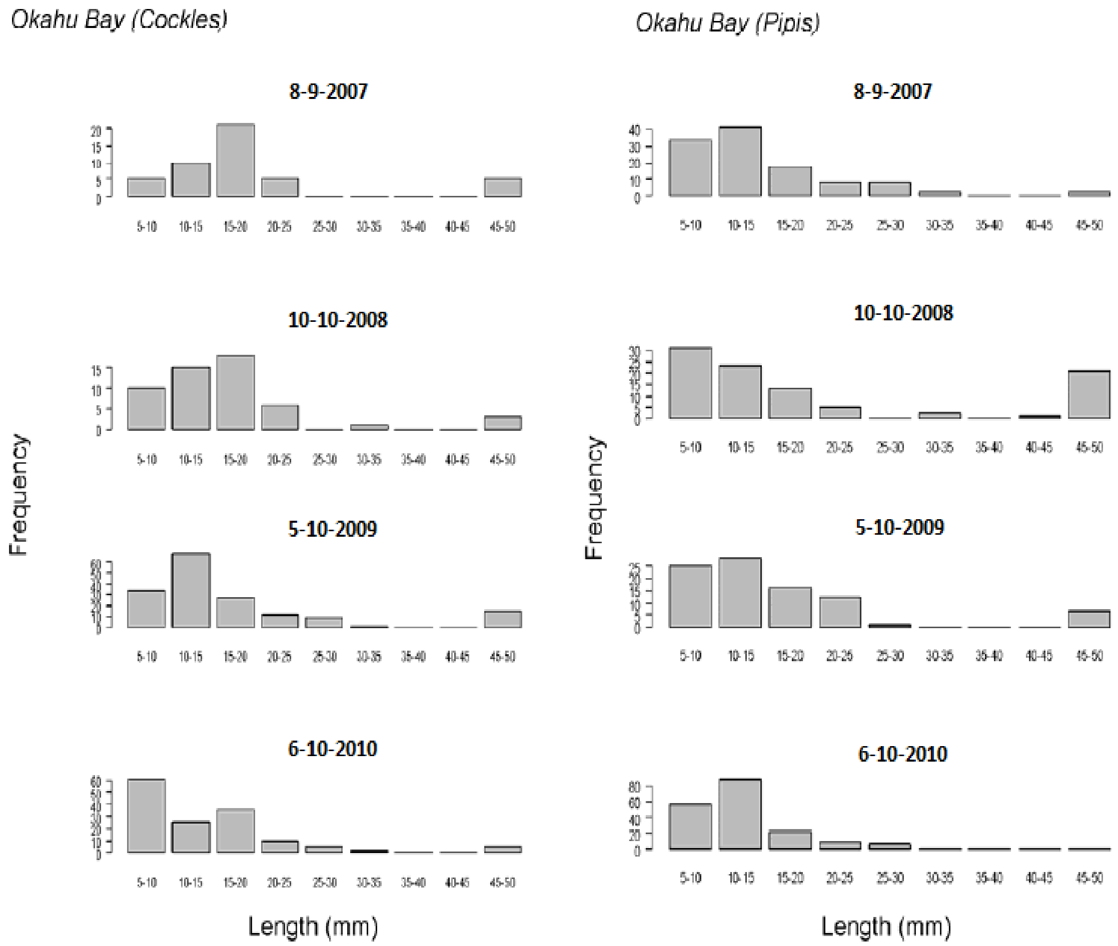


Figure 2.3 The reported size frequency of cockle and pipi at Okahu Bay for the years 2007 to 2010 (Coral and Hay, 2003).

STUDY SCOPE

This chapter measures the current shellfish and seagrass abundance and distribution across the bay with comparison to the past estimates at Okahu Bay. This would be useful to assess the trend of marine biota over time and assess the ‘wellness’ of the habitat for these species. The potential decline or loss of the shellfish population could affect the ecological function to capture large amounts or pelagic organic matter through filter-feeding and deliver it to the infaunal community. The examination of the seagrass would also provide information on the current productivity and nursery site for other species of the bay.

METHODS

POPULATION ABUNDANCE AND DISTRIBUTION SURVEY

STUDY DESIGN

This study used the stratified systematic sample design similar to that in the most previous survey (Kahui-McConnell, 2007). This design was used as this is where existing flora and fauna abundance were known to exist from previous surveys.

The previous GPS (Global Positioning System) coordinates from the most recent survey (Kahui-McConnell, 2007), were converted from NZTM Projection to NZGD2000 to give the sampling design outline (see Appendix 1.1 for detailed method). Google™ Earth was useful to plot the survey design and view the overall position of the bay in relation to other physical characteristic such as the main road (Tamaki Drive), pylons, boats, and nearby buildings. Transects were parallel to one another with transect lines perpendicular to the shore, with a distance of 50 m between transects, total of nine (marked 'A' to 'I'), across the beach, and with a distance of 20 m between sampling points (numbered) from high to low tidal mark.

In this current survey, the sample effort was focussed on the overall sampling across the bay and more so the lowest tidal point possible. The coordinates of longitude and latitude were loaded onto handheld GPS unit for location of sampling points. The GPS required adjustment to the navigational map set-up to match the New Zealand map units (see Appendix 1.2). From the existing survey outline, the sampling objective was to sample from sampling point 3 of each transect line and systematically sample out to the lowest tidal mark, with the transect lines A, C, E, G, I were sampled. Due to the constraints of the low tide over both sampling days sampling points beyond 6 of each transect line could not be reach, the sampled area were mapped (Appendix 1.3). Other data collected were the elevation of the upper tidal zone to investigate the area available for sampling during the low tide, and also may give an understanding of the slope that water may travel along into the bay.

SAMPLING DESIGN

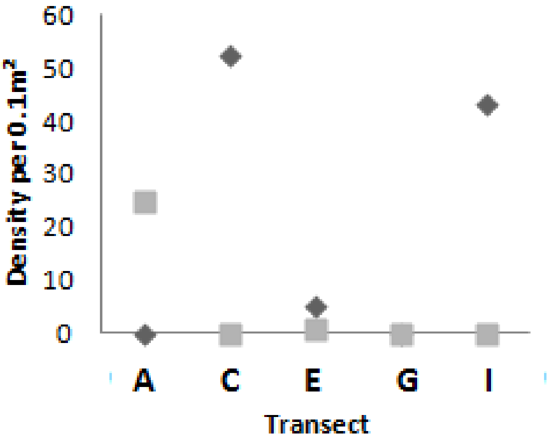
Okahu Bay was sampled on the 17th and 18th of January 2012 at low tide. A 25cm x 25cm quadrat was placed onto the substrate at each sampling point, the seagrass density (recorded in percentage of quadrat coverage) was measured with 10 leaf blades collected into a labelled bag, and measured. The shovel was then used to remove all contents of the quadrat to a depth of just less than 10 cm to ensure all the shellfish were removed. The extracted material was washed on a sieve with a 2 mm aperture mesh so that the shellfish were free of substrate. The live shellfish were counted and measured (along their longest dimension) at a size class interval of at least 5 mm length, then returned to the sample place and covered to minimise disturbance. A final note, the measuring technique was guided by the “Introduction to shellfish monitoring” (ARC, 2012b) with the shell placed against the ruler with the hinge at the side so that you are measuring its longest dimension.

RESULTS

THE CURRENT POPULATION ABUNDANCE AND DISTRIBUTION

BENTHIC SURVEY

The current study illustrated that at the mid-tidal range (transect sampling points 3-6) there was rarely any pipi, with a few cockle species present across the bay (Figure 2.4). There was no clear difference between the transect lines to the density of shellfish found, a slight noticeable data is that the outer transect have shellfish compared to little or nil in the more centre area of the bay (Figure 2.4).



Figures 2.4 The density per 0.1 m^2 for cockle (dark diamonds) and pipi (light grey squares) at Okahu Bay for January 2012.

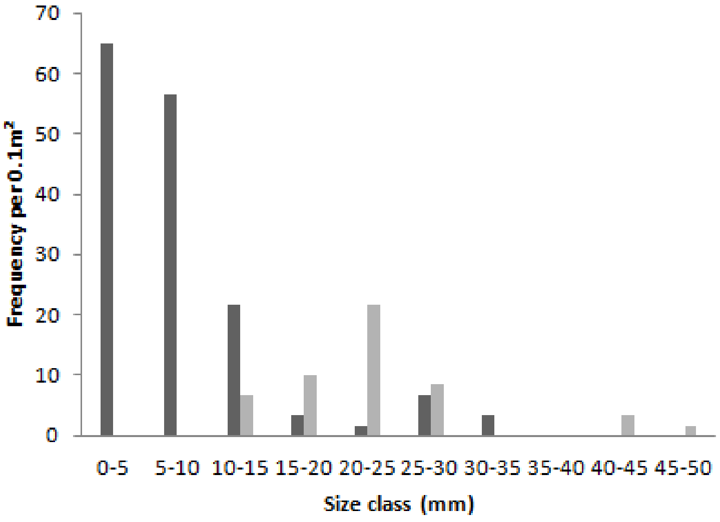


Figure 2.5 The size class frequency per 0.1 m^2 of cockle (dark diamonds) and pipi (lighter squares) at Okahu Bay for January 2012.

The size class observation show that cockle were more abundant in their juvenile population with no representation in sizes larger than 35mm (Figure 2.5). The medium and mature pipi sizes were more abundant, with lower frequency of largest sizes (40-50mm) and no juvenile present at this tidal height (Figure 2.5). Overall, there was a difference in the size class range present between cockle and pipi at this tidal range within the bay.

SEAGRASS

There is a clear difference in the percentage of seagrass cover in the bay at the mid-tidal range with the amount at nil on the outer transect lines and increasing towards the centre of the bay (transect E) (Figure 2.6).

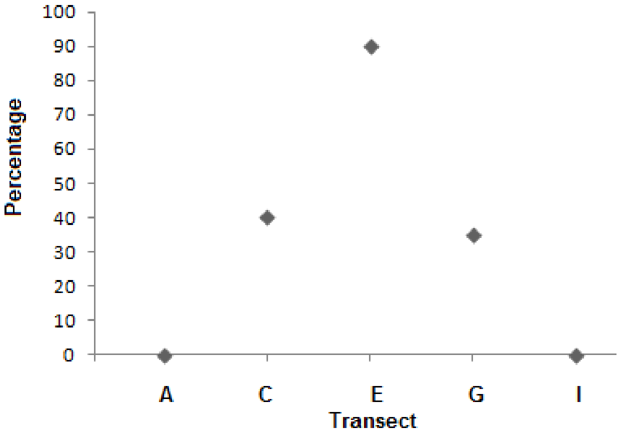


Figure 2.6 The percentage of seagrass per sampling point of the transect lines at Okahu Bay.

THE COMPARISON TO PAST DATA

BENTHIC SURVEY

The comparison to the reported 2007 and 2008 results (Kahui-McConnell, 2007) show that the current density was less than in the past, however of the shellfish counted, the pipi in transect A, and cockles in transect C and I, these figures were much higher (Figure 2.2 and Figure 2.4).

The comparison of the general size class pattern of shellfish (Figure 2.5) to the past reported data (Figure 2.3) illustrates that there is a continuation of cockle juvenile settlement in this bay. Since this study was limited in the area of survey, these particular cockles were found in transect areas of C and I in the mid-tidal range. The pipi size class showed that there was no recruitment in this year (2012) compared to the past figures, however there is possible growth of these pipi into the medium size class as well as few in the larger size class.

The comparison of the seagrass to that of the past (Appendix 1.4) is different in that the current status showed that there was further seagrass growth in the mid-tide zones for transect C, where as the transects E and G were similar, if perhaps a little more growth (Figure 2.6).

OTHER OBSERVATIONS

The extra measurements taken of elevation using the GPS from the beach to mid-tide zone (transect point 3, where the lowest tide was) of the bay, it was noticeable the there was an existing slope down to the tide (Appendix 1.3 for coordinates and map). There is also an unevenness in the surface of the bay, with the middle of the bay (transect E) being approximately 5 metres in elevation, at least a metre less than the adjacent areas (Appendix 1.3). The mid-tide measurements of transect G was 5m to 8m, and transect D was 5m to 7m (Appendix 1.3).

Another observation was the type of substrate present at each sampling point. There was a high proportion of mud present at 56% of the sites, more than half of the mud sites had no seagrass cover, there was rock at 33% of the sites, and both sand and dead shells were 11% each. There was no mud in the middle transect E; the dead shell, rock and sand were at transect A, with rock also at transect I.

There was very little biodiversity, with three other species found comprising a total of 13 animals including mud whelk (*Cominella glandiformis*), pūpū/whētiko/cats eye (*Diloma subsostrate*), and wedge shell (*Macomona liliana*).

DISCUSSION

This chapter measured the current shellfish and seagrass abundance and distribution across the bay with comparison to the past estimates at Okahu Bay. This study was restricted in the area available to sample, with a conservative approach the results are discussed to the past trends for this area.

BENTHIC SURVEY

This study suggested that the live shellfish preferred the higher end zone of the beach. It was expected that a greater number of shellfish would be at the low tidal end of the intertidal zone as there would be a greater amount of nutrients available, with a longer period of submergence for filter-feeding to occur. Perhaps there is not enough nutrient content, such as algae, coming into the bay perhaps there is consumption by another population within the outer Eastern Harbour. Perhaps the marine population within Okahu Bay relies on the nutrients from input into outer areas of the bay environment, as the higher shellfish populations sampled were in the outer transects. Research has reported that seagrass beds support shellfish populations, and provide a transitional habitat for migrating birds (Mason and Ritchie, 1979; Inglis, 2003). However, in this case the shellfish were found on the outer end of the bay, with seagrass beds on the inner area. A further look at the substrate type and permeability of oxygen, and contaminant load within the bay may give further information to the distribution of both these benthic populations.

Overtime there has been juvenile recruitment in both pipi and cockle as reported by Coral and Hay (2003). This trend of juvenile settlement, but small adult populations may suggest this population spat is sourced from elsewhere and settle in Okahu Bay. It would also suggest that the conditions may not be favourable to the growth of these shellfish.

SEAGRASS SURVEY

The high growth in seagrass cover since the past survey is probably due to the summer season (compared to the spring season reported in Kahui-McConnell, 2007) with higher temperature allowing for higher levels of productivity. It does seem that the seagrass cover is more concentrated in the middle of the bay compared to the past. This could be due to the effects of the hydrological pattern within the bay from the observed lack of tidal flushing and outflow of stormwater into the Eastern end of the bay.

There seems to be a relationship between the substrate type and seagrass cover, where there was large cover of seagrass at sites of little to no mud substrate. The mud may be too dense for there to be enough oxygen to allow for plant growth and water penetration to the initial seedling and shoot of the plant. There was also no seagrass cover at sites of dead shells, sand and rocks. This would suggest that the substrate is not suitable to holding the roots in place and supporting the growth of seagrass in these 'looser' substrates.

Finally the bay does not seem to support an abundance of biodiversity, perhaps the substrate of a high percentage of mud and little sand, has created an anoxic environment that is unsuitable for shellfish to survive and thus grow into more mature stages of development. This is discussed further in the Overall Discussion chapter.

OTHER OBSERVATIONS

The measured slope (elevation) on the shore as well as the intertidal zone (that could be reached) may influence the way that the excess groundwater, nutrients, and contaminants run into the bay from the park above, the surrounding landscape, and the roads in this area. This could potentially affect the habitat placement of benthic organisms and seagrass when this is not flushed out, or mixed-well into a stratified water column. The hydrological modelling of this bay is recommended to assess the movement within the bay, the potential sediment build-up, and sediment addition. This is discussed further in Chapter Three.

CONSTRAINTS AND FURTHER RECOMMENDATION

This current study was restricted in the access to the lowest tidal margins that the past surveys had sampled. This is likely due to the difference in the season that the study was undertaken. Spring tides are usually the tides with the largest tidal range. These tides occur about every 7 months when New or Full Moon occurs at the same time as the Moon is in its perigee (when the Moon is closest to Earth). The tide chart predictions show that the tidal range average was 0.1-0.9m for September to October 2011, 0.3-1.0 for November to December 2011, and 0.4-1.0 for January 2012 (LINZ 2011, 2012). The low tides were 0.7m and 0.8m on the sampling dates of this study, January 17th and 18th 2012. Therefore the intertidal range is greater in the period of September to October than it is for the period of November to January. The samples taken would create a misrepresentation of the actual population. Therefore repetition of this particular study during periods of lower tide heights would be beneficial to the comparison and confidence of the data.

Although this study was restricted by tidal height according to the season, sub-tidal sampling is not recommended as New Zealand seagrass are intertidal organisms (Inglis, 2003), they require the light and shallow depths. The intertidal zone is also suitable habitat for shellfish such as the cockle.

It is recommended that this study be continued as a community conducted project as this gives accountability and connection to the place of Okahu Bay and have been shown to successful in the past (e.g. Cummings, 2006). The sampling quantity would benefit from a larger sampling effort.

CONCLUSION

The past trends in the population indicate that there is little success in the shellfish population reaching the larger adult sizes. The proliferation of seagrass is also evidence through past surveys, and from this study. This current study can only be conservative in the discussion of results and comparison to past trends. Both the shellfish and seagrass population have ecologically important roles in the ecosystem. The potential decline or loss of the shellfish population could affect the ecological function to capture large amounts or pelagic organic matter through filter-feeding and deliver it to the infaunal community. Continued surveys of the bay would give further evidence to the trend analysis, and to the relationship between the substrate, seagrass and shellfish relationships.

CHAPTER THREE

The bathymetry of Okahu Bay

INTRODUCTION

The focus of this section was to gather the current bathymetry of Okahu Bay to model the hydrological dynamics. The hydrology of the bay is important to understand the impacts to tidal flows within an area, the effects of outflow sources, which can have an effect on the level of sedimentation and build-up of contaminants from anthropogenic activities. Research has demonstrated that modifications and construction can directly influence tidal flows and tidal flushing.

Nutrients within bays and estuaries can benefit sea life when in moderation, but this is problematic when there is too much enrichment in too small an area (GESAMP, 2001). For example, nutrient enhancement can lead to an increased growth of cyanobateria, which can dominate and change the aquatic ecosystem dynamics (ANZECC, 2000; EPA, 2001). Too much nutrients also enriches the water and sediment with organic matter, stimulating the increase in oxygen-consuming microbes, which may kill marine organisms by anoxia (an absence of oxygen), or by related hydrogen sulphide production (ANZECC, 2000).

Various structures including bridges, causeways, culverts, floodgates, fords and weirs, have been identified to potentially reduce tidal flows (Williams and Watford, 1997). The prevention of tidal flushing can cause environmental problems from a build up of nutrients, and significant reductions in salinity. This may lead to a depletion of seagrass, excessive algal growth, blooms of toxic algal species, oxygen depletion and declines in the diversity of fish and other aquatic life. An example of these impacts is in Tasmania where reduced tidal flushing allowed nutrients to accumulate, causing eutrophication and algal blooms (Brett, 1992; Jones *et al.,* 1994).

Studies have reported that sediment transport processes are altered at coastal ports and marinas through reflection of waves of port structures and hydrographical modifications caused by dredging. Permanent loss of habitat and biological productivity occurs where structures occupy the foreshore and seabed, or where major dredging works are performed to establish harbours and shipping channels (Coleman *et al*., 1999). The constructions of marinas and associated structures, such as jetties and boat ramps, along the South-east Marine Region coast (Australia) suggest that the cumulative impacts are significant (Zann, 1995). The proliferation of marinas and related facilities in some areas, such as the Gipps Lakes in Victoria, has grossly altered the nature of the shoreline and inshore habitats (Winstanley, 1995). Due to their shallower bathymetry, marinas can be more susceptible to reduced flushing and anoxia (Edgar *et al.*, 1999).

HYDROLOGY MODEL

The Auckland City Integrated Catchment Study (ICS) was set up to aid decision-makers in the identification of a works programme to improve drainage services, and mitigate adverse environmental and community effects created by draining discharges. The Coastal Receiving Environment Assessment (CREA) forms part of the ICS of Auckland City (Bogle *et al.*, 2006). The objective of the CREA project is to develop an understanding of the effects outflow from Auckland City Council/Metrowater's Drainage Management Areas on their respective coastal receiving environments (Croucher *et al.*, 2005b). From a policy perspective, the model is useful for comparing the benefits of different load reduction options (Bogle *et al.*, 2006).

In this case the model may give a specific understanding of the effects of outflow into Okahu Bay. Okahu Bay has been included in a past CREA, where the project modelled bacterial counts provided for bathing beaches around Auckland City to simulate the bacteria in the coastal receiving environment (Croucher *et al.*, 2005b). Okahu Bay was one of the 11 bathing beaches in the CREA study area, eight on the Waitemata Harbour coasts and three on the Manukau Harbour coast. For these simulations the full Hauraki Gulf / Waitemata Harbour model grid was employed, therefore it was a coarse view of the effects at Okahu Bay, and further accuracy would be required to repeat this study for Okahu Bay alone. A study to update on the current bathymetry would be useful to refine the grid information for Okahu Bay. The technical aspects of the framework for the hydrological model carried out within the CREA is discussed in detail by Croucher *et al.* (2005a)

BATHYMETRY

The bathymetry is the shape of the ocean floor in terms of map of its depth (NIWA, 2012c). A bathymetric chart is the submerged equivalent of an above-water topographic map.

Bathymetric charts are designed to present accurate, measurable description and visual presentation of the submerged terrain. The existing bathymetry is from the New Zealand Charts, in particular the East Auckland Harbour chart (Figure 3.1) from which has been formatted for a closer view of Okahu Bay (Figure 3.2) (NZ Charts, 2012).

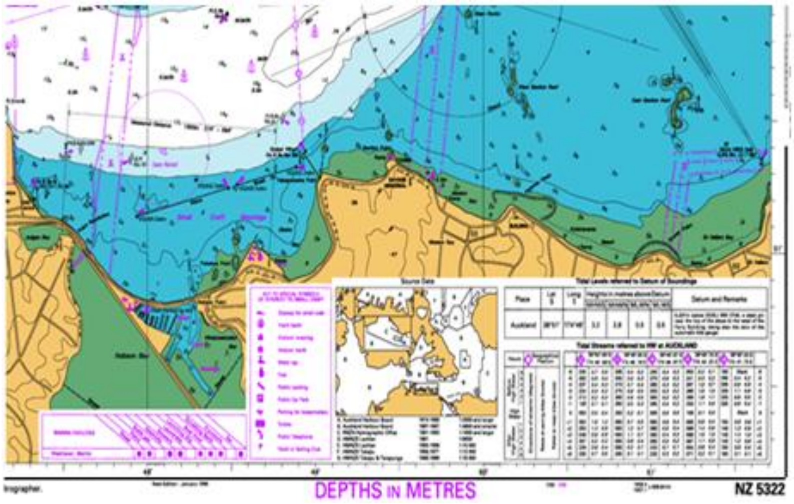


Figure 3.1 New Zealand Marine Chart, NZ 5322 (NZ Chart, 2012).

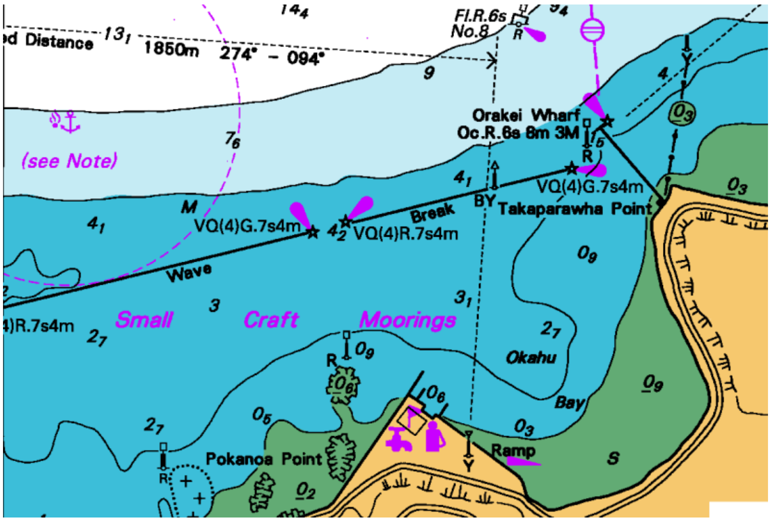


Figure 3.2 View of Okahu Bay, New Zealand Marine Chart, NZ 5322 (NZ Chart, 2012).

STUDY SCOPE

This chapter measures the current depth within Okahu Bay so that there can be current data for the hydrological model.

METHODS

SAMPLING DESIGN

Okahu Bay was sampled on the 20th of February 2012 at high tide. The objective was to develop a stratified systematic sample design across the bay. The Eagle Cuda™ 128 Fish-finding & Depth Sounding Sonar was used to measure the depth at each sampling station, the coordinates were recorded using a hand held Global Positioning System (GPS) unit, as well as the time taken at the start and end of each transect. The position nearest the West end of the bay was the starting point of the sampling. Once the data were recorded, the boat was angled to remain straight according to physical markers, parallel to the beach, to sample every 100m. Once a transect line was completed, the boat was moved 100m further seaward, to begin the next transect line across the bay. The eventual map was close to a 100m² grid, the exception occurred as there were other boats/small craft moored within the bay that distorted the line of direction. The final transect line was taken within the wave break (pylon boundary). The GPS positions were converted from NZTM to NZGD2000 (as done in chapter two methods, see Appendix 1.1 for detailed method), and these were mapped using Google™ Earth (Figure 3.3).

ASSUMPTIONS

The assumptions are made: a) that the high-tide time reported for Auckland (Westhaven) Tide Table is consistent with that of the actual Okahu Bay tidal behaviour; b) that the tidal height remains at the same height for the duration of each transect line; c) however the time is taken for the start and end of the transect line, so it is assumed that this time difference could account for the difference in tidal height during the sampling time; d) that the bathymetry of the bay is fairly consistent to within 100m² areas.

DATA ANALYSIS

The data were used to create a table (Appendix 1.5) using Microsoft™ Excel with both NZTM and NZGD2000 coordinates, the depth in metres recorded using the fish finder, the time at the beginning and end of each transect line. The data is sent to the engineer researchers who had created the CREA model, in particular to Adrian Croucher, to run the hydrological model for Okahu Bay specifically. Both sets of tidal data, that is the tide times and height from the tidal chart, as well the times of sampling with measured tidal height, have been graphed to observe any difference in the tidal change over the period of sampling.

RESULTS

BATHYMETRY

The mapped sampling points have shown that the first three transects were fairly done in a systematic 100m² grid design, however the final transect follows the inside of the pylon boundary, whereas another transect could probably be completed in between this line and the third (i.e. sampling points 12 and 13)(Figure 3.3).

Figure 3.3 The depth in metres (in brackets) across Okahu Bay.

The gradient in depth shows in increase in depth seaward, with shallower areas at the high tidal zone (beach) and outer areas of the bay near the road and whaft on the Eastern side, and near the road and marina on the Western side (Figure 3.3 and 3.4). There is a relationship with time and tidal height, as with time we moved seaward where the bathymetry would be deeper (Figure 3.4). The data also illustrates that the depth increases towards the centre of the bay for each transect line, with the deepest range 5.6m to 6.3m, and shallow range of 1.7m to

2.1m (Figure 3.4). Furthermore, the complete set of sampling stations, tidal height (m) measured, and time taken is given in Appendix 1.5.

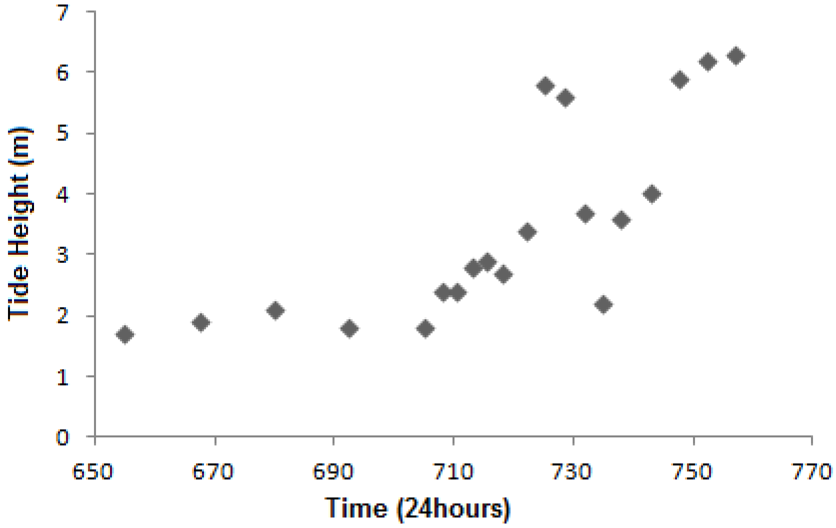


Figure 3.4 The tidal height (m) data measured across the bay from high tidal mark seaward on 20/02/12.

TIME OF SAMPLING PERIOD

The period of sampling was relatively short (1 hour; Figure 3.4) compared to the time for the tide to make significant change from high to low tide (6 hours; Figure 3.5). During this sampling hour the tidal time is estimated to have decreased by 0.5 m which may create a slight underestimation of the sampling points taken towards that end of the tidal period (Figure 3.5).

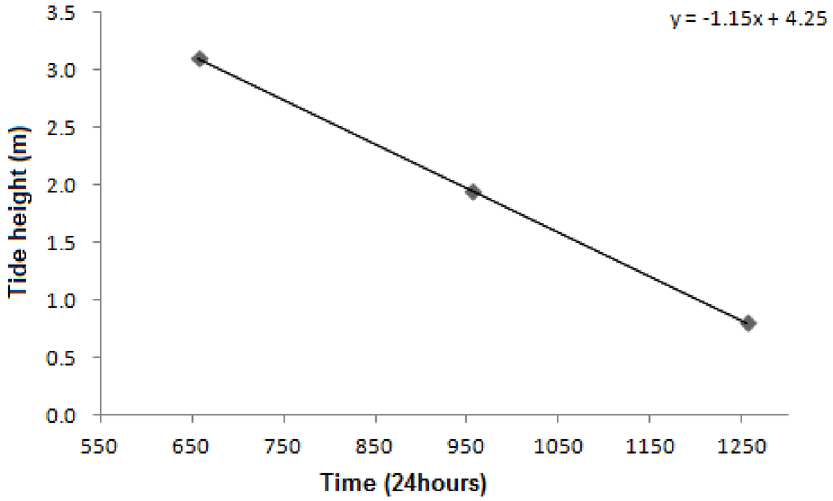


Figure 3.5 The tidal height (m) data from LINZ (2012) from high to low tide for 20/02/12.

DISCUSSION

BATHYMETRY

It is clear to see that the general bathymetry of the existing NZ Chart (Figure 3.1) is similar to the current layout in depth measured in this study (Figure 3.3). There was a large area of shallow area that is highlighted in this study, with the deeper points further out where there is many small craft moored. The shallow areas are potentially maintained from little tidal flushing from the bay due to the wave break (pylon wall) and wharf, although there is a current that runs across the deeper part of the Bay. Further investigation of this would be necessary using the CREA model, as well as further data collected from within Okahu Bay.

SAMPLING PERIOD

The time was taken with a comparison to the tide chart prediction was to account for the difference in tidal height during the sampling period. It is assumed that period of high to low tide is a longer period than the low to high tide as this is a shallow area. Tides in bays, estuaries, and rivers are affected by the extremely shallow water depths, freshwater flow, and friction with the seafloor. Therefore, the high tends to catch up to the low tide, that is there is a long period between high and low tide, but a very short period between low and high (Segar, 2007).

FURTHER RECOMMENDATIONS

No further analysis was taken in this study, as the objective was to estimate the bathymetry and provide this data for further modelling. A geographical information system (GIS) would be useful to analyse, and present the bathymetry data would be highly useful especially to see the similarities and differences across the bay. The Eagle Cuda™ 128 Fish-finding & Depth Sounding Sonar give single point depth, whereas a multiple point device would give greater accuracy in the variation of bathymetry at each sampling station. Constant data recordings from flow meters would give an indication of the volume flux and velocity out of Okahu Bay.

CONCLUSION

This study illustrated the general bathymetry of Okahu Bay that could be used to model the hydrology. This can then be used to further analyse the associated activities in the environment, such as the sedimentation, the friction, the tidal flushing and contaminant load.

CHAPTER FOUR

Discussion

STUDY AIMS

This project fulfils part of the Ngā Pae o te Māramatanga summer studentship project that looks at the elements of ecological and *Mauri* restoration at Okahu Bay. This project was composed of four projects that included the analysis of the Mauri Model, the benthic population and biodiversity, the levels of sediment contaminants, and the hydrological modelling of Okahu Bay. As this forms part of a larger project it is necessary to combine the findings from each project to give an overview of the Okahu Bay Restoration Project.

The objective of this study was to assess the environmental factors of Okahu Bay, as indicated by the Mauri Model draft, such as to estimate the current marine fauna and the trend of size classes; to estimate the marine flora, and measure the bathymetry as it is a requirement for the hydrological model.

BENTHIC POPULATION AND HYDROLOGY

The population abundance is a key indicator to assess the health of an area. Biota that are most directly impacted by reduced water quality are sessile plants and animals, such as seagrass and benthic infauna, since they are most persistently exposed to pollutants and degraded conditions (DSE, 2012). As urban development increases runoff of water and sediment during the earthworks phase, and contamination loads increase as urban areas mature (ARC, 2003). The result of the current population could still be recovering from the past and current input of stormwater and runoff. In addition, upper contaminants (e.g., copper, lead, zinc) are known to affect functionally important species such as *Austrovenus stutchburyi* and *Macomona liliana* (Thrush *et al.*, 2008). Too much nutrients also enriches the water and sediment with organic matter, stimulating the increase in oxygen-consuming microbes, which may kill marine organisms by anoxia (an absence of oxygen), or by related hydrogen sulphide production (ANZECC, 2000). An observation made in this study was dark substrate with an odour that is usually associated with the absence of oxygen.

The survey of the marine benthic fauna and flora has illustrated that there are many ecological relationships that combine to support the function of this environment. The benthic survey would benefit from the comparison to the sediment contaminant study (by Elliot Hurst) to analyse these relationships further. It has been shown in the past that due to trophic and other ecological links between these more mobile species, impacts have extended to many parts of the marine ecosystem (Jenkins *et al*., 1992). Therefore supporting the notion of benthic-pelagic coupling and that an ecological scope is necessary to answer any questions of the Okahu Bay ecosystem dynamics.

The hydrodynamic aspect of Okahu Bay would highlight the importance in ecological links between the tidal movement and the behaviour of sediment and benthic populations. Studies have reported that sediment transport processes are altered at coastal ports and marinas through reflection of waves of port structures and hydrographical modifications caused by dredging. Permanent loss of habitat and biological productivity occurs where structures occupy the foreshore and seabed, or where major dredging works are performed to establish harbours and shipping channels (Coleman *et al*., 1999).

FUTURE RECOMMENDATIONS

In addition to the level of contaminants that income with the stormwater outflow into the sea, another important factor is the amount of freshwater input. The measurement of salinity levels could assess whether the bay maintains a natural level of salinity that is tolerated by marine species. Especially if there is little tidal flushing, there could be a lower level of salinity, higher concentration of bacteria, or other factors that may contribute to the ecosystem health. This is especially of concern with the continual increase in Auckland's urban population. Past studies have noted this change, over time with the vast increase in urbanisation, the harbour catchment would have greatly increased freshwater, sediment, and pollution run-off into the Waitemata harbour at times of heavy rain (van Roon, 1983). This is reflected in heavy metal concentrations in the harbour sediments and possibly in salinities periodically lower than would have been the natural range (Droomgale *et al*., 1983)

CONCLUSION

This current study can only be conservative in the discussion of marine benthic population results and comparison to past trends. Both the shellfish and seagrass population have ecologically important roles in the ecosystem. Continued surveys of the bay would give further evidence to the trend analysis, and to the relationship between the substrate, seagrass and shellfish relationships. With an increase in the Auckland population, the pressure on receiving waters would continue to increase and ultimately affect these ecosystems and their marine populations. Like the larger Auckland Harbours, Okahu Bay is a sink for the disposal of urban stormwater and associated contaminants. Further research and focus on remediation are required in these ecologically and culturally important areas.

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APPENDICES

APPENDIX 1.1 GPS Coordinates, Conversion and Mapping

The GPS coordinates from the survey by Kahui-McConnell (2007) were converted from NZTM (NZ Transverse Mercator) to NZGD2000 (NZ Grid Datum 2000) using an online conversion application (LINZ, 2011) and then plotted using Google™ Earth (Google™ Earth, 2011) to give the sampling design outline (below).

An example of these results of the converted coordinates for Transect A.

	NZTM Projection		NZGD 2000	
Transect	Northing	Easting	Latitude	Longitude
A02	5920305.967	1762074.784	36 50 57.377 S	174 49 04.390 E
A03	5920318.185	1762066.082	36 50 56.986 S	174 49 04.030 E
A04	5920330.403	1762057.381	36 50 56.595 S	174 49 03.669 E
A05	5920342.622	1762048.679	36 50 56.205 S	174 49 03.309 E
A06	5920354.840	1762039.978	36 50 55.814 S	174 49 02.948 E
A07	5920367.058	1762031.276	36 50 55.423 S	174 49 02.587 E
A08	5920379.276	1762022.575	36 50 55.032 S	174 49 02.227 E
A09	5920391.494	1762013.873	36 50 54.641 S	174 49 01.866 E
A10	5920403.712	1762005.172	36 50 54.250 S	174 49 01.506 E
A12	5920415.931	1761996.470	36 50 53.859 S	174 49 01.145 E

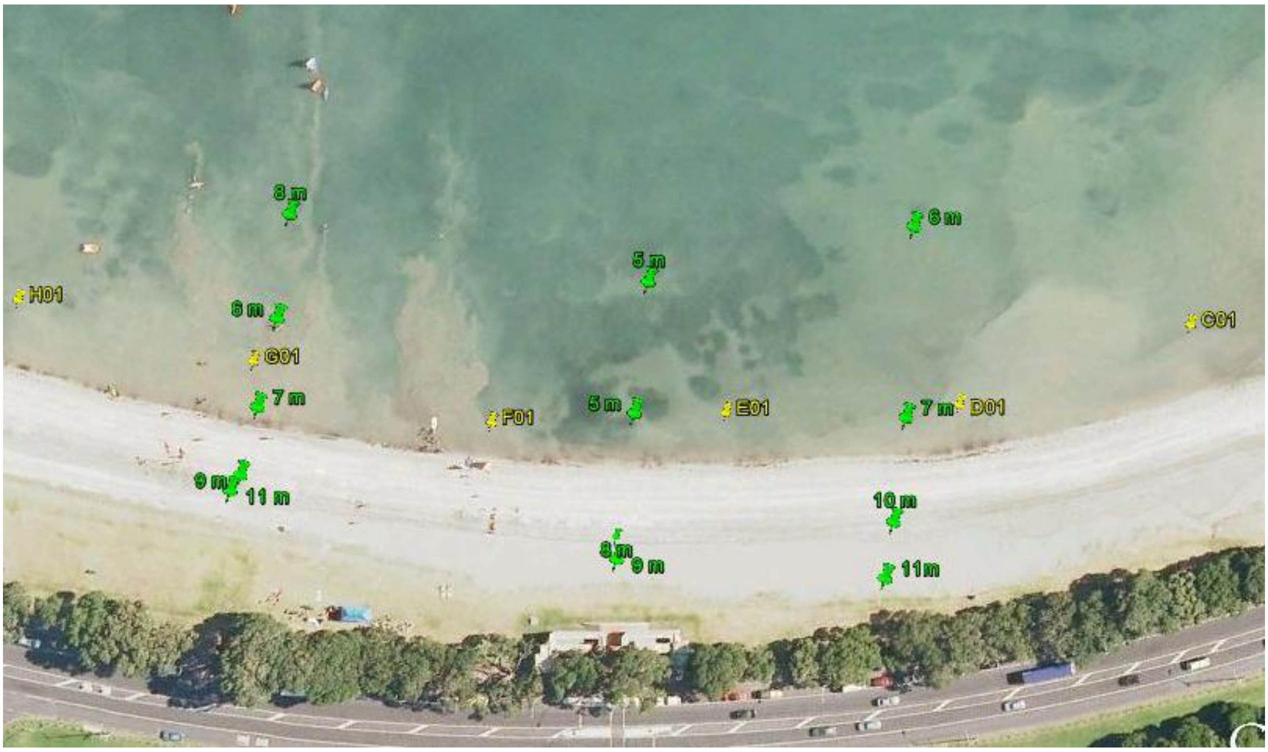
APPENDIX 1.2 The set up for the GPS system

To load the GPS coordinates according to the NZTM, the units for this on the handhold GPS are set up as:

Position Format: User Grid
Map Datum: WGS 84
Units: Metric
North Ref: Grid
Variance: 001°W
Angle: Degrees

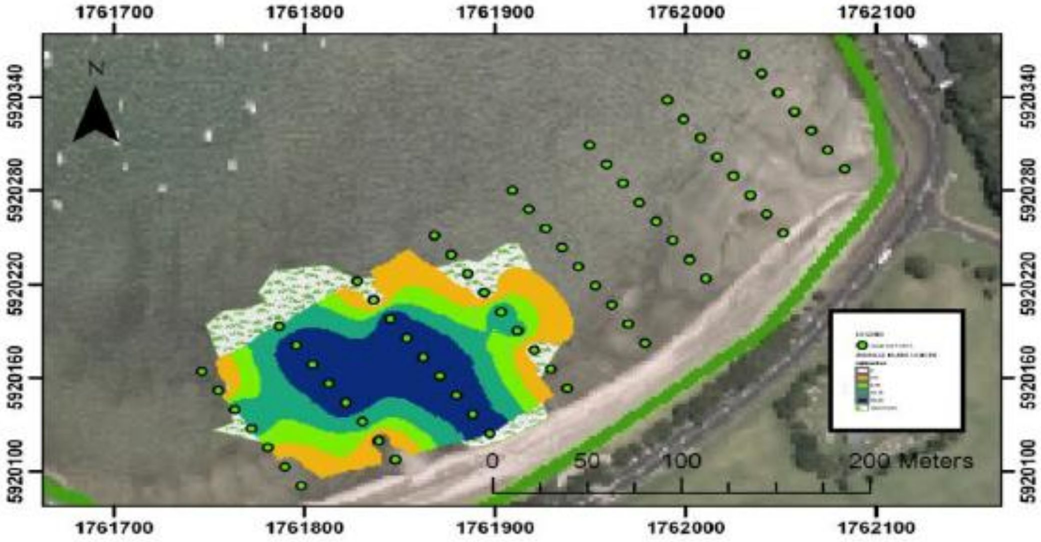
APPENDIX 1.3 The extra coordinates taken at the study area

	NZTM Projection		NZGD 2000		
Points	Northing	Easting	Latitude	Longitude	Elevation (m)
8	5920142	1761986	36 51 02.751 S	174 49 00.933 E	11
9	5920153	1761981	36 51 02.397 S	174 49 00.723 E	10
10	5920173	1761971	36 51 01.754 S	174 49 00.304 E	7
11	5920208	1761950	36 51 00.632 S	174 48 59.429 E	6
12	5920167	1761909	36 51 01.987 S	174 48 57.806 E	5
13	5920142	1761922	36 51 02.790 S	174 48 58.350 E	5
14	5920119	1761933	36 51 03.529 S	174 48 58.811 E	8
15	5920114	1761936	36 51 03.690 S	174 48 58.936 E	9
16	5920081	1761859	36 51 04.808 S	174 48 55.854 E	11
17	5920085	1761859	36 51 04.678 S	174 48 55.851 E	9
18	5920099	1761854	36 51 04.227 S	174 48 55.638 E	18
19	5920117	1761847	36 51 03.647 S	174 48 55.342 E	6
20	5920137	1761837	36 51 03.005 S	174 48 54.923 E	8

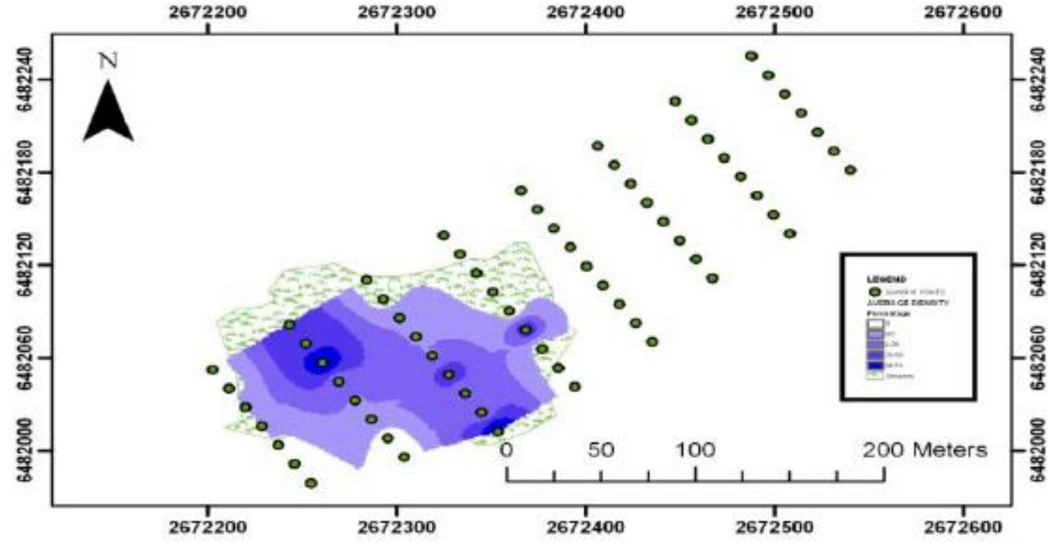


APPENDIX 1.4 The average sea grass blade length and density at Okahu Bay by Kahui-McConnell (2007).

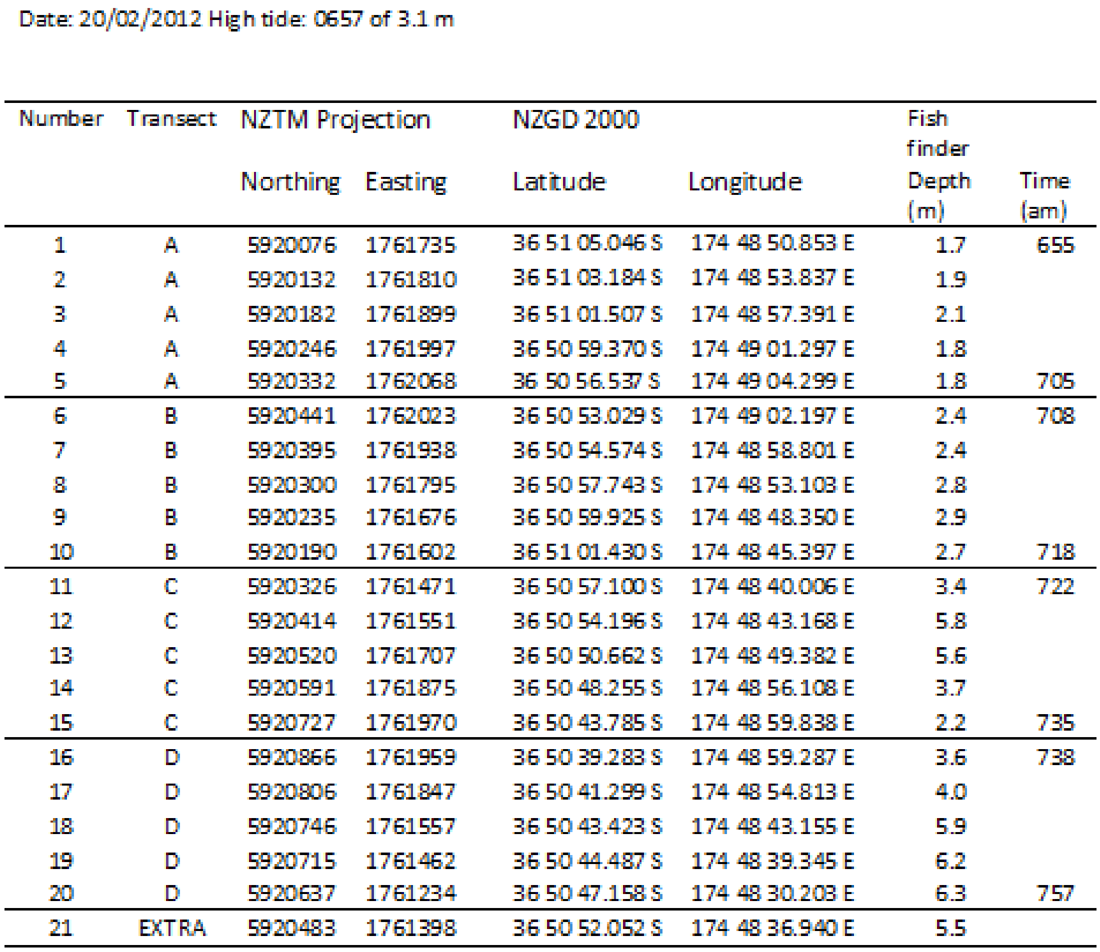
AVERAGE SEA GRASS BLADE LENGTH



AVERAGE SEA GRASS DENSITY



APPENDIX 1.5 The bathymetry coordinates and recorded depth (m).



Date: 20/02/2012 High tide: 0657 of 3.1 m

Number	Transect	NZTM Projection		NZGD 2000		Fish finder	
		Northing	Easting	Latitude	Longitude	Depth (m)	Time (am)
1	A	5920076	1761735	36 51 05.046 S	174 48 50.853 E	1.7	655
2	A	5920132	1761810	36 51 03.184 S	174 48 53.837 E	1.9	
3	A	5920182	1761899	36 51 01.507 S	174 48 57.391 E	2.1	
4	A	5920246	1761997	36 50 59.370 S	174 49 01.297 E	1.8	
5	A	5920332	1762068	36 50 56.537 S	174 49 04.299 E	1.8	705
6	B	5920441	1762023	36 50 53.029 S	174 49 02.197 E	2.4	708
7	B	5920395	1761938	36 50 54.574 S	174 48 58.801 E	2.4	
8	B	5920300	1761795	36 50 57.743 S	174 48 53.103 E	2.8	
9	B	5920235	1761676	36 50 59.925 S	174 48 48.350 E	2.9	
10	B	5920190	1761602	36 51 01.430 S	174 48 45.397 E	2.7	718
11	C	5920326	1761471	36 50 57.100 S	174 48 40.006 E	3.4	722
12	C	5920414	1761551	36 50 54.196 S	174 48 43.168 E	5.8	
13	C	5920520	1761707	36 50 50.662 S	174 48 49.382 E	5.6	
14	C	5920591	1761875	36 50 48.255 S	174 48 56.108 E	3.7	
15	C	5920727	1761970	36 50 43.785 S	174 48 59.838 E	2.2	735
16	D	5920866	1761959	36 50 39.283 S	174 48 59.287 E	3.6	738
17	D	5920806	1761847	36 50 41.299 S	174 48 54.813 E	4.0	
18	D	5920746	1761557	36 50 43.423 S	174 48 43.155 E	5.9	
19	D	5920715	1761462	36 50 44.487 S	174 48 39.345 E	6.2	
20	D	5920637	1761234	36 50 47.158 S	174 48 30.203 E	6.3	757
21	EXTRA	5920483	1761398	36 50 52.052 S	174 48 36.940 E	5.5	