Auckland Regional Council
TE RAUHĪTANGA TAIAO

Tamaki Strait: Marine benthic habitats, ecological values and threats

August TR 2010/038

Auckland Regional Council
Technical Report No.038 August 2010
ISSN 1179-0504 (Print)
ISSN 1179-0512 (Online)
ISBN 978-1-877540-94-3

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Date: 1st October 2010

Recommended Citation:

Chiaroni, L., Hewitt, J.E., Hailes, S. F. (2010) Tamaki Strait: Marine benthic habitats, ecological values and threats. Prepared by National Institute of Water and Atmospheric Research for Auckland Regional Council. Auckland Regional Council TR2010/038.

Tamaki Strait: Marine benthic habitats, ecological values and threats

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Prepared for
Auckland Regional Council

NIWA Client Report: HAM2009-080
June 2007

NIWA Project: ARC09212

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1 Executive Summary

Tamaki Strait has high value for the Auckland region. It is used for a wide range of recreational and commercial purposes, and has intrinsic value as well as aesthetic, educational, spiritual and cultural significance (Lohrer 2008). For the purposes of this report, the limits of Tamaki Strait include the eastern coast of Rangitoto and Motutapu Islands, Southern Waiheke and the Waiheke Channel, the west coasts of Ponui and Pakihi Islands, as well as the Tamaki coast on the mainland. It encloses an area of 335.36 km^2 of which 27.31 km^2 is intertidal (8.14%) and the rest is predominantly subtidal soft-sediments. Given the large amount of development in the surrounding catchment, the number of people using the area, and the degree of threat to its ecology, the ARC asked NIWA to survey the benthic habitats and determine both their ecological values, and the types of threats to those values.

The ARC has a three tier strategy for monitoring the State of the Environment in the Auckland Region, based on flora and fauna living in marine benthic habitats. Tier I is temporally detailed monitoring at a few intertidal sentinel sites in important harbours. Tier II focuses on defining geospatial patterns of ecological habitats and describing macrobenthic communities present in intertidal and near-shore (<20 m) subtidal areas, with a return period of approximately 16 years. Tier III is broad-scale remote assessment, in waters deeper than 20 m, with limited benthic ecological community sampling. These three tiers are interlinked: Tier I sampling provides information on the ecological relevance of changes observed in Tiers II and III. Tier II sampling provides a broader spatial context in which to interpret the findings of Tier I sentinel site monitoring.

Sampling in Tamaki Strait had three components: large-scale sampling of subtidal areas by video and side-scan; transect sampling of intertidal and subtidal habitats by video; and point sampling of intertidal and subtidal fauna using quadrats and cores. The data collected is summarised in a series of GIS layers, displaying the spatial distribution of habitat types and ecological communities. The raw data is included in the GIS files, facilitating new interpolations and queries.

Six broad-scale habitat zones were apparent in the Tamaki Strait, strongly related to exposure to tidal currents:

- high current zone; the fast flowing areas of Tamaki Strait and Waiheke Channel. High diversity infauna dominated by;
- **mid current zone;** in the central areas of the Strait. Predominantly sandy mud to muddy sediments with patches of *Atrina*. The infauna is dominated by *Theora*-bioturbator and *Theora-Echinocardium* complexes;
- **low current zone;** in the central areas of the Strait. Muddy sediments with little epifauna. The infauna is dominated by *Theora*-bioturbator complexes;
- **south Eastern low current zone** & **South Eastern mid current zones**; the higher shell content of the sediments is associated with different infaunal communities to the mid and low current zones.

- **Waiheke Channel Mid current zone**; characterised by sandy muds with low diversity, low abundance *Echinocardium* communities.

The major threats to the ecology of Tamaki Strait are considered to be:

- Increased muddiness of the sediment and spread of mud into presently sandy habitats, and decreased water clarity associated with climatic and land use changes.
- Urbanisation, apart from increasing sediment loads and recreational use, urbanisation may result in increased sewage and storm water contaminant inputs into the environment.
- Non-indigenous species (NIS). The sediments of the Waitemata-Tamaki Strait have been invaded by as many as 66 marine NIS (Hayward 2008, Hayward 1997, Cranfield et al. 1998, Inglis et al. 2005).
- Increase dominance of mangrove dominated habitats. Mangroves will tend to benefit from increased amounts of sediment input associated with climatic and land use changes.
- Effects of sea level rise. While hard to predict, increases in the mean level of the sea could result in reduction in the overall intertidal area and/or intertidal habitat diversity.
- Aquaculture. There are currently few mussel and oyster farms in Tamaki Strait at present, based mostly around Waiheke Island. Numbers are likely to increase in the future, with changes to the areas designated as Aquaculture Management Areas (AMA's) in the region.
- Trampling of intertidal communities. Communities on intertidal rock platforms can be strongly affected by a number of people walking across the surface. Humans, horses and vehicles can also impact sand flats, though sediment movement and the small cryptic nature of sand flat organisms makes such impacts difficult to detect and measure.
- Anchoring, boat wakes and propeller wash. Boat anchors can cause considerable damage to areas with diverse epifauna. Many such areas occur in Tamaki Strait. There are several zones within the Strait where cables are run, and anchoring is prohibited, and may act as de facto protection from anchor damage.
- Shellfish and finfish extraction. While the harvest of shellfish and finfish is not within the ability of the ARC to manage, this type of extraction is still a threat to the communities of Tamaki Strait, both intertidally and subtidally. Impacts include disruption to community structure by removal of critical species and the damage caused both to other species and to the seafloor by scallop dredging (Thrush et al. 1998).
- Marinas. Development and maintenance (including associated dredging) of marinas has a number of potential impacts including location-specific changes to circulation patterns and increased contaminant levels.

In summary Tamaki Strait contains a variety of habitats, with catchment derived sediment (intertidal), tidal current exposure (subtidal) and wave exposure (inter and sub tidal) being important drivers of community structure.

As one of the most utilised areas of the coast in New Zealand in terms of urbanisation and sea traffic, Tamaki Strait has immense value in both the range of goods and services provided and its intrinsic cultural and societal importance.

These values are at risk from a number of threats of anthropogenic origin. The major risks are associated with the effects of urbanisation, diffuse source pollution and increased pressure on the Tamaki Strait area through recreational and commercial use (including aquaculture). The ecological communities of Tamaki Strait are vulnerable to habitat degradation and changes brought about by increased levels of sediment loading and the introduction of non-indigenous species.

2 Introduction

2.1 General introduction

In 2000, the Auckland Regional Council (ARC) commissioned NIWA to design a State of the Environment Monitoring Programme for marine ecology in the region (Hewitt 2000). The resultant nested design has three tiers for the monitoring of flora and fauna living in and on marine substrates. Tier I involves spatially constrained but temporally detailed (2-3 monthly sampling return) monitoring at sentinel sites in important harbours, aimed at detecting benthic ecological trends. Tier II involves spatially intense sampling of intertidal and near-shore (<20 m) subtidal areas with the objective of defining geospatial patterns of habitats and describing the ecological communities present. Areas to be sampled under the Tier II plan were prioritised by the ARC and it was envisaged that re-sampling would occur every 16 years, allowing any large changes in habitats or communities to be identified. Tier III involves broad-scale habitat mapping with only limited benthic ecological community sampling in waters deeper than 20 m. The temporally intensive Tier I sampling was designed to provide information on the ecological relevance of changes observed in Tier II and III sampling, while the more extensive spatial coverage from Tier II would provide a broader spatial context to assist with the interpretation of Tier I sentinel site monitoring.

Elements of Tier I monitoring have been in operation since 1987, and have provided important feedback for resource management and State of the Environment reporting (Hewitt et al. 1994, Cummings et al. 2003, Hewitt et al. 2004b, Thrush et al. 2004). Tier II monitoring was initiated in 2003 in the Kaipara Harbour. This information has proved to be highly useful for the ARC's management of aquaculture. In 2005-6, Tier II monitoring of Kawau Bay was undertaken, and monitoring of Tamaki Strait was initiated in 2007. Both Kawau Bay and Tamaki Strait were chosen as high priority areas by the ARC as they are diverse systems with a number of uses, and the pressures on them are forecast to increase.

It is important to note that the original design of Tier II monitoring focused on identifying sites along gradients of predicted anthropogenic activity. Sites were to be sampled intensively one year apart, to give a good spatial resolution of communities at each site and an indication of short-term temporal changes that could be compared to similar Tier I sentinel sites. Return sampling would then be carried out in another 16 years. However, by the time that sampling began in the Southern Kaipara, the ARC found that its requirement for general ecological information about areas had increased. In light of this, Tier II objectives were shifted. Ecological habitat types and communities were to be compared across areas of interest by increasing spatial resolution of sampling within an area, decreasing spatial resolution at a site and removing temporal information. The description of habitats and communities for the area were to be developed in the context of biodiversity, ecosystem goods and services and vulnerability to potential anthropogenic threats.

This change in the objective and sample design does not preclude the ability to determine if change has occurred when a return visit has been made, but does alter the way that change would be assessed. Assessment of change would be predominantly at a large scale, considering changes in communities and habitat types across the area as a whole, or within large subsections. Somewhat less effective site-by-site comparisons could also be made for sediment particle size, species and assemblages, using natural temporal variability apparent from the sentinel monitoring sites (Tier I) in the region to set limits on the magnitude of effects detected. Given the changes to the Tier II programme, this report focuses on determining general similarities between sites and the spatial distribution of habitat types and ecological communities, with the raw data necessary for specific site descriptions contained in GIS files.

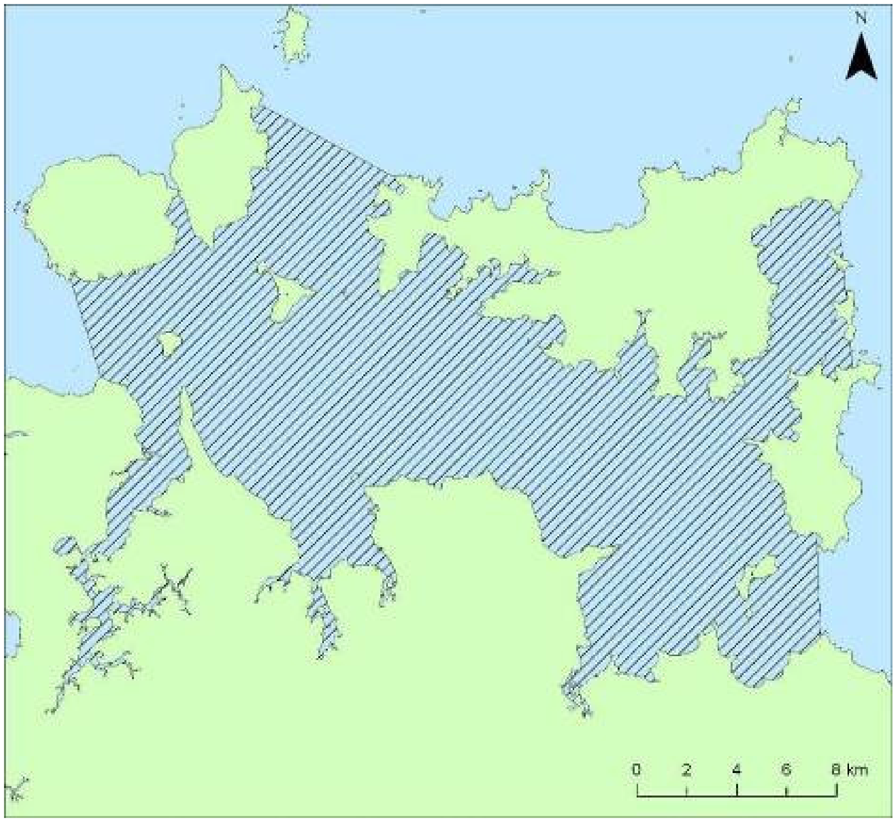
2.2 Area of interest

Tamaki Strait has high value for the Auckland region. It is used for a wide range of recreational and commercial purposes: it is the main access to New Zealand's busiest commercial port, and is utilised by tens of thousands of private yachts and launches. It is a place of recreational and commercial fishing, and contains a marine reserve. It has intrinsic value as well as aesthetic, educational, spiritual and cultural significance (Lohrer 2008).

The coastline is highly modified, with at least 2 km of coast lined with seawalls or armoured shoreline (ARC 2004).

For the purposes of this report, the western limit of Tamaki Strait is delineated as running from the southern tip of Rangitoto Island to Achilles Point, and the south-eastern coasts of Rangitoto and Motutapu Islands (Figure 2.1). The northern limit extends from Station Bay on Motutapu Island to Owhanake Bay on Waiheke Island, and the southern coast of Waiheke Island. The Waiheke Channel is included, as is the west side of Ponui Island.

Figure 2.1:
Area of Interest.



The Tamaki Strait area of interest is 335.36 km^2. Less than 10% of this area is intertidal (27.31 km^2, 8.14%); the remainder is dominated by subtidal soft-sediment habitats. There are 4.78 km^2 of mangroves, (17% of the intertidal area).

The coastline (including stretches of Rangitoto, Waiheke, Ponui & Motukorea-Browns Islands) and its associated inlets measures approximately 312.5 km, of which 69.8 km (22.3%) is rocky, and the remaining 242.6 km (77.7%) is soft sediment (data obtained from LINZ).

Tidal currents are also variable throughout the area, from low current activity in the middle of the bay and near the southern beaches, to strong currents through the Motukorea, Motuihe & Sergeant Channels in the western entrances to Tamaki Strait, and areas of the Waiheke Channel and southern Ponui Island (Sandspit passage).

Te Matuku Marine Reserve (690 ha) protects one of Waiheke Island's largest and least disturbed estuaries and an area outside Te Matuku Bay in the Waiheke Channel.

In October 2002 the ARC notified variations to the proposed Auckland regional plan with regard to Aquaculture Management Areas (AMA's): with variation six concerning Waiheke Island and Tamaki Strait.

3 Methods

Although the sampling strategy used in the Tamaki Strait is largely similar to that developed for Tier II sampling in the Southern Kaipara and Kawau Bay, differences between these three areas, in the amount of subtidal vs. intertidal areas, and rocky vs. subtidal sediment, meant that some adaptations to the methods used were necessary.

3.1.1 Intertidal Sampling

3.1.2 Soft sediment broad-scale sampling

This focused on assessing both physical and biological features at 54 intertidal soft sediment sites (Figure 3.1). Description of biological features focused on the mid tide area. The homogeneity of the beach or estuarine flat across the entire area (for a small beach) or across 200 m (for larger areas) was also assessed so that a good description of the area could be given. Land-use around the site and the presence of man-made structures was also noted.

Physical features assessed were the slope, type of sediment and presence of swales. Beach slopes were characterised into flat, medium and steep and frequently the upper, mid and lower shore were characterised separately due to marked differences. Sediment type categories used were rocky (>25 cm largest dimension), cobbly (> 6 cm), pebbly (>4 m), gravelly (>2 mm), shelly (>2 mm), sandy (firm), sand-mud (abrasive but footprints visible), muddy (may still feel gritty but adult sinks to ankles) and mud (no grittiness, adult sinks to above ankle).

Biological features assessed were the presence of mangroves, seagrass, gastropods, tube worms, crabs and adult shellfish (i.e., cockles, pipis and *Macomona*). The presence of mangroves was noted as a sparse or thick fringe at the head of the beach, and whether there were patches of adults, single adults or saplings on the rest of the beach. Seagrass was assessed as present in patches (number and range of sizes) or meadows. The percent cover of the seagrass blades within the patches or meadows was assessed from a 50 x 50 cm quadrat randomly placed. The density of crab burrows was also assessed from a 50 x 50 cm quadrat as was density of any large tube worms and gastropods. Smaller tube worms that would not be easily counted at that scale were categorised into high or moderate density based on a 20 x 20 cm area. Densities of adult cockles, *Macomona* and pipis were assessed from two 30 x 15 cm areas.

3.1.3 Soft sediment finer-scale sampling

Fine-scale sampling was undertaken at 32 locations, selected to cover all the broad-scale habitats, hydrodynamic gradients (e.g., different current types and wave exposure) and potential for differing degrees of anthropogenic impacts.

Areas previously sampled by the ARC or NIWA during the last 10 years were not resampled but will be discussed in this report. The rough locations of sites were determined in conjunction with ARC staff (Shane Kelly).

At each site, samples were taken for macrofauna, sediment chlorophyll *a*, organic content and grain size. Macrofauna were sampled by three replicate cores (13 cm diameter, 15 cm deep) taken over a 5 m area. The sediment characteristics were sampled by two replicate cores (2 cm diameter, 2 cm deep) taken over the same area but amalgamated before sample processing. Macrofauna samples were sieved across a 1 mm mesh screen and all retained materials were preserved in 50% isopropyl alcohol. Invertebrates were sorted, counted and identified to the lowest practical taxonomic level (mostly to genus or species level).

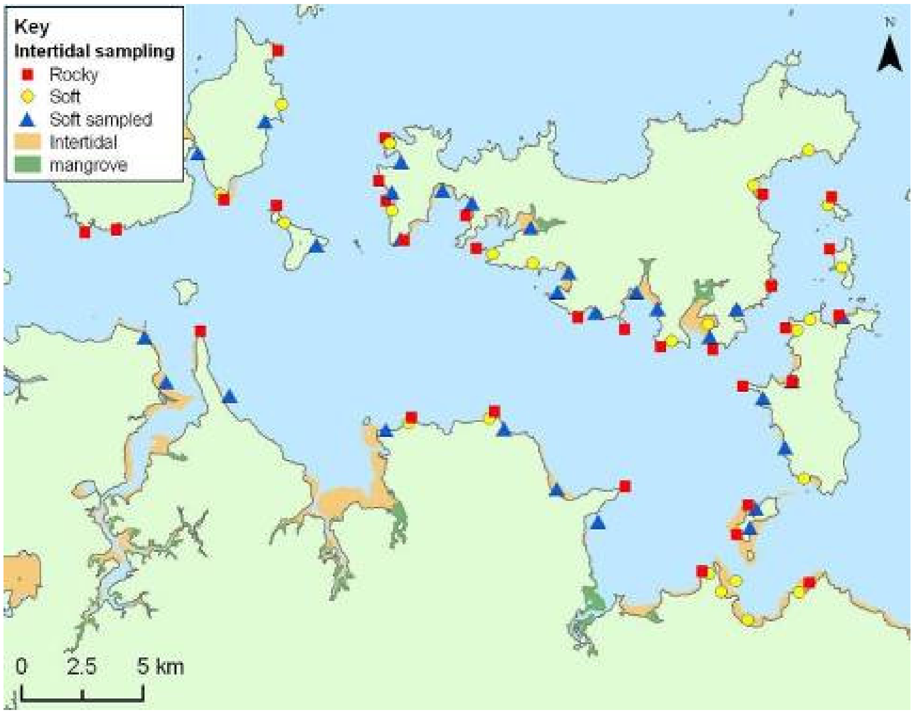
3.1.4 Hard substrate broad-scale sampling

Tamaki Strait contains a large number of rocky intertidal areas, of which 33 were chosen for broad-scale sampling (Figure 3.1). A systematic survey of the coast by boat was used to make notes on structure and characteristics such as topography, rock type and size, presence or absence of zonation (including major zoning flora and fauna) and catchment characteristics. A site was chosen for the survey if it was different compared to the previous two to three sites visited, moving along the coastline.

3.1.5 Hard substrate finer-scale sampling

Using the broad-scale survey data, eight sites were chosen for finer-scale sampling. Site selection was based on variables including geographic position, accessibility, site differences (each site was different from each other in terms of site characteristics) and representativeness (of the types of rocky shore habitats found around Tamaki Strait).

Figure 3.1:
Tamaki Strait with all initial intertidal survey sites.



The full sampling of eight sites was conducted during November 2008. For each site notes were taken describing the characteristics of the area which included assessing the substrate type and size (e.g., bedrock, sand, shingle, pebble, cobbles, boulders with reference to the Wentworth scale of particle size), slope (e.g., flat, gently sloping, steep), catchment practices (e.g., urban, pastoral, forestry, vegetation) and anthropogenic influences (e.g., drains and pipes, evidence of trampling, boat ramps).

A tape measure transect was placed perpendicular to the shore, starting at the top of the high tide zone (0 m) (reference marker is a metal peg and cow tag drilled into the rock and fixed with cement (Figure 3.2)) to the bottom of the low tide zone. GPS coordinates were taken at the reference marker and a compass bearing of the transect was also recorded (Table 3.1). Three zones (high, mid and low tide) along the transect were determined based on elevation and zonation patterns. Within each zone, three 0.25 m^2 quadrats were placed to capture the major habitats present. The position in metres along the transect was noted and percent cover of flora and fauna inside the quadrat was recorded. Furthermore, in each zone, one quadrat covering a rock pool was selected and percent cover of all flora and fauna within that quadrat was also recorded. Specimens of all flora observed within the quadrats at each site were collected and sent to NIWA Wellington for identification and fauna were identified to lowest practicable level on site. A survey of the number, size and depth of the rock pools within 1 m of the transect both sides, along the entire length was also conducted. Measuring the longest length of the rock pool we determined size as being small, medium or large (<30 cm, 30-100 cm and >100 cm, respectively) and depth was recorded as being shallow, medium or deep (< 10 cm, 10-25 cm and > 25 cm, respectively). Photos were taken of the surrounding catchment, quadrats and the shore profile (see Appendix II).

Figure 3.2:
Photo of a reference marker secured at 0 m at each site.

Table 3.1:

Site name (often the bay adjacent to the site), site field abbreviation, GPS Coordinates of the reference peg and compass bearing of the transect at each site.

Site Name	Site Abbreviation	Latitude	Longitude	Compass Bearing
Motunau Bay	R3	36.89636	175.18246	160°
Chamberlains Bay	R5	36.83462	175.19526	210°
Pasadena Bay	R12	36.82495	175.16479	70°
Schnapper Point	R14	36.87677	174.99914	345°
Te Pene Beach	R15	36.87314	175.04020	45°
Whakakaiwhara Point	R16	36.90035	175.09873	50°
Whites Bay	RH	36.84684	175.11229	260°
Woodside Bay	RJ	36.83697	175.07581	235°

3.2 Subtidal sampling of broad-scale physical features

Collection of continuous information on sediment characteristics over large scales is generally done using acoustic devices; indirect techniques that require ground truthing and interpretation (Bax et al. 1999, Kloser et al. 2001, Hewitt et al. 2004c). While there are a number of types of acoustic devices that could have been used, following recommendations from Hewitt and Funnell (2005), side-scan was used, rather than QTC or multibeam. For side-scan, the acoustic device was towed behind a boat and "flown" 5 m above the sediment surface resulting in a consistent area being covered by the scan. For both QTC and multibeam, the device is attached to a boat, resulting in the area of seafloor over which data is recorded being depth-dependent. This affects the coverage able to be obtained by the device such that in 10 m depth only a 1.9 and 60 m wide area is sampled by QTC and multibeam respectively (cf. 300 m for side-scan).

Side-scan data was collected using a C-Max CM2 Sidescan Sonar system comprising a digital recorder and tow fish operating in 325 kHz mode, with a 250 m SCX tow-cable running through a digital pulley block for displaying cable scope, which is then used to calculate layback. Sidescan lines were run using Nobeltech software for navigation. Swath width was 200 m either side of the fish that was towed at a constant height of 5 m from the bottom at about four knots boat speed. Sound velocity profiles were estimated at 1500 m s^{-1} SV. The data was processed using a CODA DA50 and geo-referenced TIFF files suitable for input into a GIS were produced.

As full coverage of the entire survey area would be cost prohibitive, a transect sampling method was used (Figure 3.1). Transects were oriented to cover as much of the Strait as practicable. Areas of the North West were left out of the survey design, as the Department of Conservation (DOC) has commissioned a survey using similar methods in this area.

Acoustic devices do not collect data directly related to specific biological variables (Hamilton et al. 1999, Smith et al. 2001), and thus two visual systems were used for ecological habitat determination.

3.3 Broad-scale ecological subtidal sampling

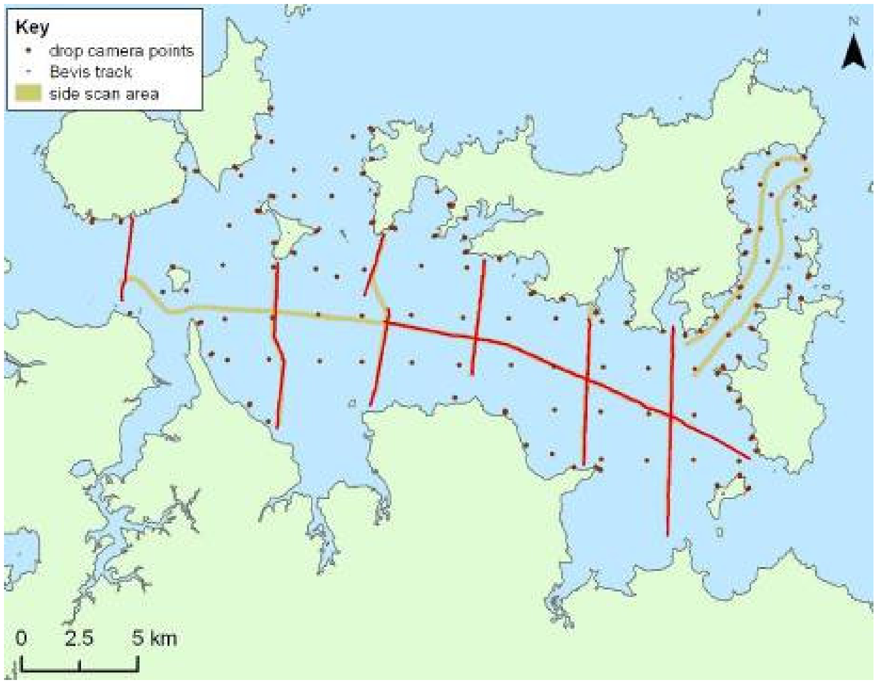
The first system, BEVIS (Benthic Ecology Information Video System), has two high-resolution colour zoom cameras (Benthos 4802 camera, at 480 lines of horizontal resolution). It has scaling lasers and 900 watts of lighting and collects depth/heading information. This video sled setup is capable of covering a relatively large area in a short period. Thus it can be used to detect transition boundaries and gradients of physical and ecological habitat change, as well as provide data on community type. Transects were run along several of the sidescan transects to enable ground truthing of the sidescan images. In heterogeneous areas, the video was run continuously to capture as much variability as possible. This method has been used to effect in work for DOC at Tonga Island Marine Reserve (Thrush et al. 2003).

The second system was a high resolution Tritech Typhoon camera, with 470 lines of horizontal resolution. The camera was mounted in a depressor frame with integrated lights and laser scaling system. Drop cameras are used to cover medium sized transects (generally 10-20m per drop), as the lack of directional controls prevent effective coverage of larger areas. Drops generally ran for 10 m, but where habitats changed during a drop, another 10m section was sampled. In rocky reef areas, multiple drops were used to characterise the transition zone. Locations of sampling were decided upon to complement the BEVIS footage and Sidescan information, to cover areas where BEVIS could not be used (rocky shore and shallow coastal areas) and to cover areas that were likely to show habitats that had not yet been sampled (based on information such as depth, currents, exposure). Additionally, the sample design ensured one sample was placed every 2 km^2. A total of 249 drop camera sections were analysed from a total of 126 drops (Figure 3.2).

Photographic data was analysed to produce counts of epifauna and flora (or rank percentage cover for colonial organisms and high coverage flora). Information was recorded that indicated or represented the presence of infauna (density of burrows, visible evidence of tube worms etc.).

Figure 3.2:

Broad scale subtidal sampling sites.

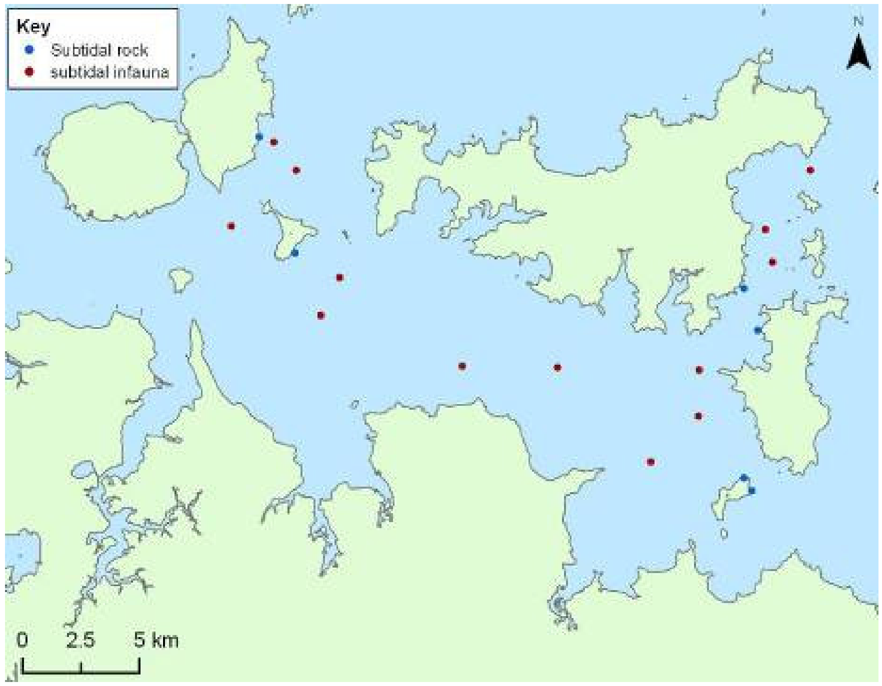


3.4 Finer-scale ecological subtidal sampling

3.4.1 Soft-sediment

Infaunal sampling was conducted at 15 locations, (Figure 3.3). Four contiguous 13 cm diameter cores were collected per location by SCUBA divers. Samples were bulked to approximate the size of a standard grab sample (which have been used in the past for other studies). At each site, three replicate sets of cores were collected. As with the intertidal survey, all samples were sieved across a 1 mm mesh screen and preserved in 50% isopropyl alcohol. Invertebrates were sorted, counted and identified to the lowest practical taxonomic level (mostly to genus or species level).

Figure 3.3:
Fine scale subtidal sampling points in Tamaki Strait.



3.4.2 Hard substrate

At seven locations (Figure 3.1), three replicate 1 m^2 quadrats were collected at two depths (between 3-4m and 5-7m) where possible. The data was collected to be as consistent as possible with other subtidal rocky reef data collected for the ARC (Ford et al. 2004). For each quadrat, abundance data were collected for all taxa greater than 10 mm in size. For encrusting sponges, ascidians and algae, ranking of percent cover was used as appropriate (after Dahl 1981). Quadrats were placed to capture the major habitats present at each elevation (i.e., where the sampled area displayed obvious patchiness in habitat, samples were taken in each habitat).

3.5 Sediment particle size

At all intertidal and subtidal core sites, three 2 cm diameter, 2 cm deep cores were taken and aggregated. Samples were stored frozen until processed. Prior to analysis, the samples were homogenised and a subsample of approximately 5 g of sediment taken, and digested in 9% Hydrogen Peroxide until frothing ceased. The sediment sample was then wet sieved through 2000 µm, 500 µm, 250 µm and 62.5 µm mesh sieves. All fractions were then dried at 60°C until a constant weight was achieved (fractions were weighed at ~ 40 h and then again at 48 h). The results of the analysis are presented as percentage weight of gravel/shell hash (> 2000 µm), coarse sand (500 – 2000 µm), medium sand (250 – 500 µm), fine sand (62.5 – 500 µm) and mud (< 62.5 µm).

3.6 Other data used

Some environmental data was available for the subtidal areas of Tamaki Strait from the Marine Environment Classification (Hadfield et al. 2002, Hewitt and Snelder 2003). This data came from a grid of 200 m square cells and included depth, the mean and 95th percentile peak orbital bed velocity (representing force exerted on the bed by waves) and the depth averaged maximum tidal current.

3.7 Analyses

There are a number of methods for determining community associations of biological data. Generally, these involve different statistical techniques for determining clusters of like communities. Such techniques were demonstrated as not suitable for the Southern Kaipara (Hewitt and Funnell 2005). Similar statistical problems were found in the Kawau Bay and Tamaki analyses.

Two-dimensional ordination plots produced from the intertidal soft sediment and subtidal data using non-metric multidimensional scaling had stress values > 0.19 (indicative of a poor 2-dimensional fit) and showed no distinct patterns.

Dendrograms showed that there were a large number of groups exhibiting >50 % similarity and these generally were comprised of three or less members.

Therefore, the systems of ecological classification rules developed for macrofauna of the intertidal and subtidal areas of the Southern Kaipara were used again (Appendix 1a and b) for soft-sediment sampling in the Tamaki Strait. For the subtidal rocky sampling, a modified version of the Shears and Babcock classification system was used (Shears et al. 2004, Appendix 1c).

Statistical techniques used to analyse macrofaunal data were:

- Analyses of differences in community structure were done using ANOSIM (Clarke 1993) on Bray Curtis similarities of untransformed data. Average dissimilarities between communities were derived using SIMPER (Clarke 1993).
- Analyses of differences in number of taxa, number of orders and total numbers of individuals were assessed using generalised linear modelling, using an appropriate error structure and link function, followed by a multiple contrast (McCullagh and Nelder 1989).
- Analyses of factors driving biotic habitats were determined using discriminant analysis.
- Analyses of factors affecting numbers of taxa and orders were done using generalised linear models (as above). Factors used were depth, sediment particle size characteristics, wave exposure, and tidal current information. Backwards selection was used to select the most appropriate model based on changes to the Akaike Information Criteria.

4 The physical environment

More than 90% of the Tamaki Strait survey area is subtidal. This is equal to 335.36 km^2 of which 27.31km^2 is intertidal (8.14%). The subtidal area also contains both hard and soft substrates, but the vast majority of it is soft sediment.

A number of gradients in depth, wave exposure, currents (Figure 4.1a-d) and sediment particle size, run through the survey area. Ponui, Pakihi and Waiheke islands provide a measure of shelter for the inner parts of the Strait from the prevailing easterly swells.

The majority of the Strait is <15 m deep (Figure 4.1a), with areas >20 m depth lying in areas of high current flow off the coasts of Motuihe, Ponui and Waiheke Islands, associated with the Motuihe, Sergeant and Waiheke Channels. Over most of the seafloor, slopes are slight (Figure 4.1b).

However, around many of the rocky cliffs sharp drops in reef profile are present. In areas >10 m deep, orbital water velocity at the bed is low (Figure 4.1c), increasing towards the shore. Orbital velocity at the bed is an indication of the amount of wave-generated disturbance at the seafloor. Together with tidal currents, it also represents the likelihood of physical resuspension and removal of fine particles from the seafloor. As in Kawau Bay, while the mean orbital velocities do not strongly differentiate near shore areas, the mean orbital velocity suggests greater exposure to waves occurs on the south and west exposed shores along the southern coast of Waiheke Island and the north-westerly exposed Tamaki coastline (Figure 4.1d).

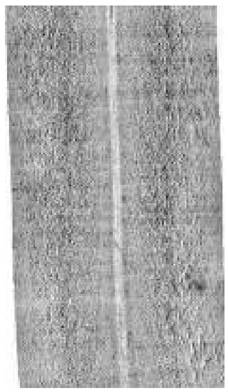
Tamaki Strait is strongly differentiated in terms of tidal currents, with areas of strong tidal currents occurring in areas of the Motuihe and Sergeant channels to the northwest and southeast of Motuihe Island, and in the narrower areas of the Waiheke Channel. While maximum current speed found here is lower than that observed in the Southern Kaipara, there are larger areas of strong tidal current than were found in Kawau Bay (Chiaroni et al. 2007). Information from observations and previous studies in the area (Powell 1937, Hayward 1999, Lohrer et al. 2008) show that in areas of high tidal current the sediment is coarser with a high gravel-shell content.

The intertidal physical habitat is strongly driven by geology and nearness to sources of terrestrial sediment inputs with some very coarse sediment in relatively sheltered areas e.g., the island below Ponui.

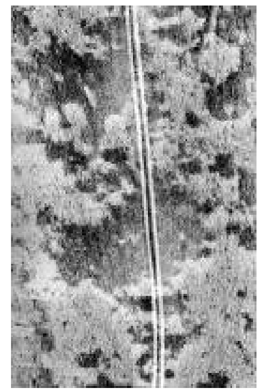
Particle size analysis of sediments taken at a range of the broad-scale categories revealed concordance with the broad-scale categories. Mud content of the sediment varied from 0 – 84% (the latter occurring in the upper Tamaki estuary. K-means analysis used to group the particle size data suggested 5 main sediment types: gravelly (>2 mm fraction comprises more than 15% by weight); shelly (shell fraction >2 mm comprises more than 15% by weight); muddy (<0.063 mm fraction comprises more than 20% by weight); fine sand (fraction sized between 0.063 mm and 0.250 mm comprises more than 85% by weight); and medium sand.

Unlike the variety of habitats able to be determined directly from the side-scan imagery in the Southern Kaipara, side-scan imagery delineated only four main habitat types (Figure 4.2): rock, isolated shell-mud, areas of significant shell material, and soft-sediment without shell.

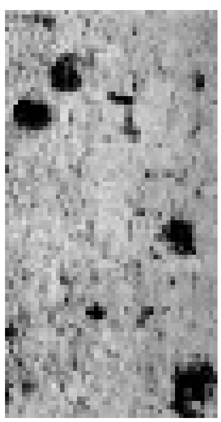
Figure 4.2:
Side scan images showing different habitat types.



a. Fine sediment without shell



b. Shell hash



c. fine sediment with isolated shell material

d. Rock

As in Kawau Bay this was due to the extreme contrast imposed by the presence of both hard and soft substrates and the absence of large epifaunal reefs (such as those produced by serpulids, oysters and bryozoans) or large areas of macrophytes associated with the soft sediment. The majority of the Strait outside the channel areas consists of muddy sand or muddy sand with isolated patches of shell. Extended patches of shell hash dominated sediments in the south and south east of the Strait, often covered with a layer of fine sediment.

Large epifauna were mostly patchy in distribution, and where present were often in areas with high shell content sediments. While areas of side scan were truthed using a towed camera array (BEVIS), the inability of the side scan to discern whether shell belongs to a living organism or is a component of the substrate precluded extrapolation of results to other areas (Figure 4.3).

Figure 4.3:
Sidescan images with BEVIS ground truthing data superimposed.

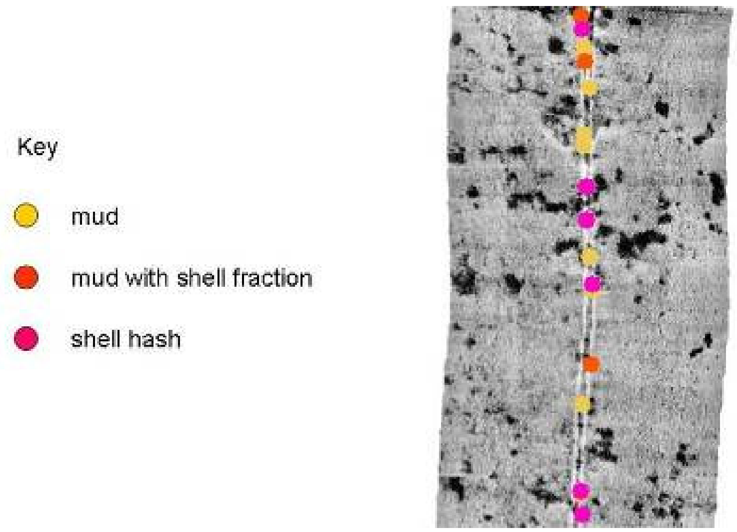
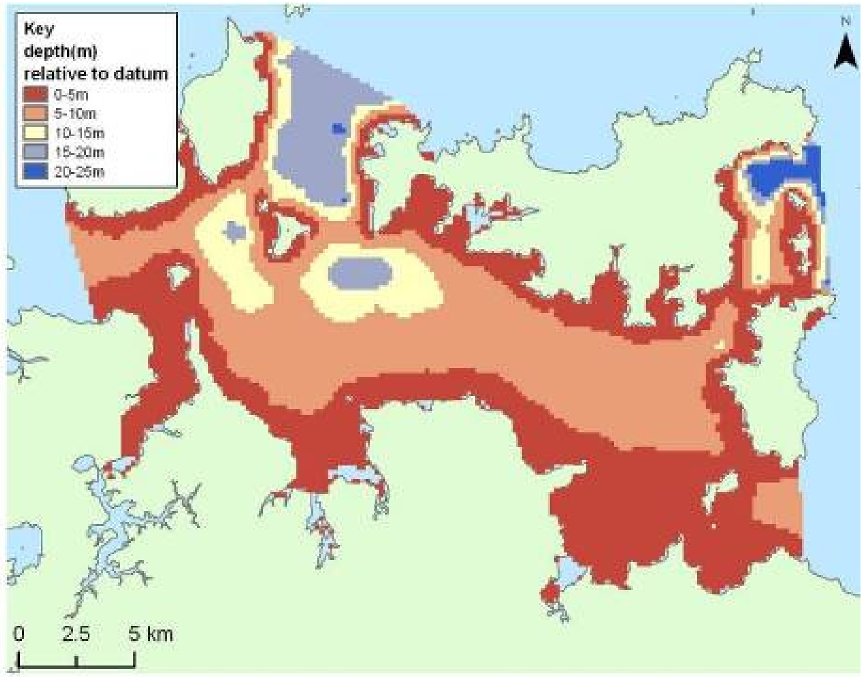
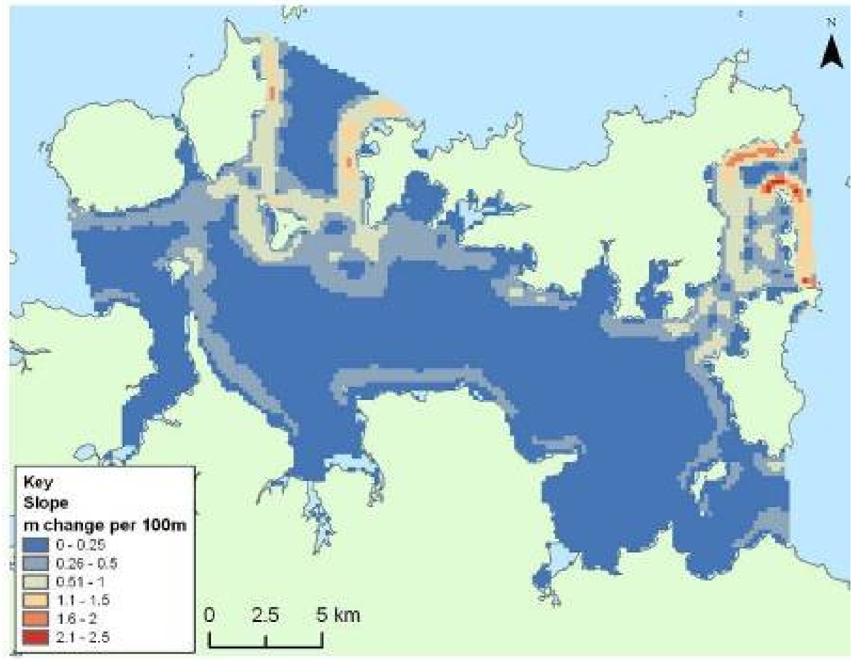


Figure 4.1:

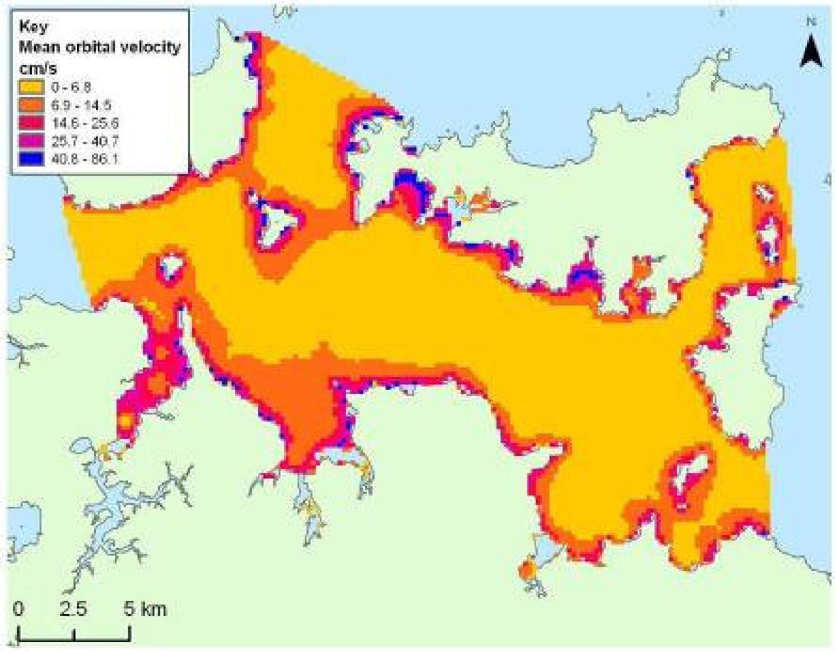
A. Depth data (m), from the Marine Environment Classification (Hadfield et al. 2002, Hewitt and Snelder 2003) for Tamaki Strait.



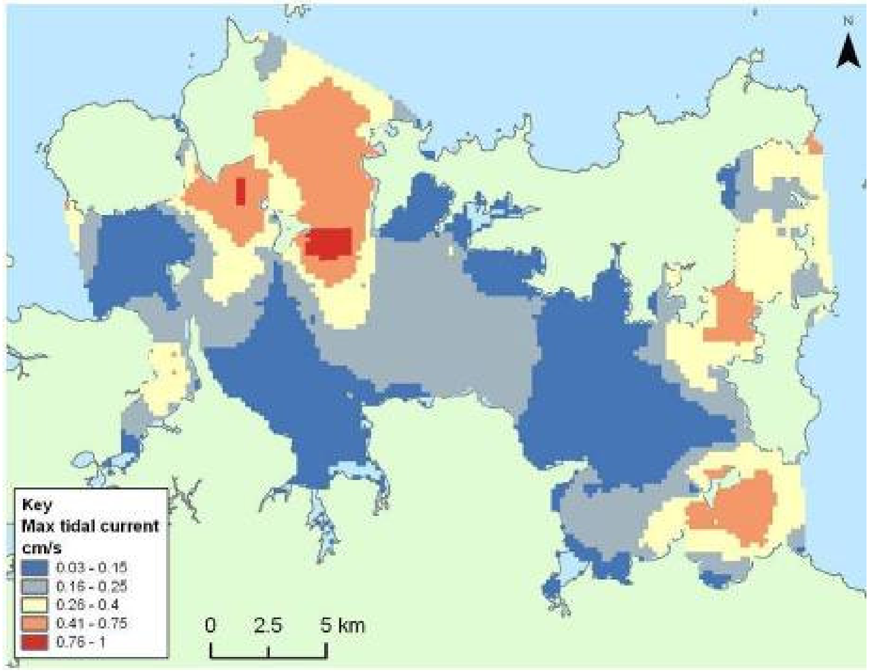
B. Map of seafloor slopes (metres of elevation change per 100 m horizontal distance, i.e., values are dimensionless (i.e., 0.01 m/m) calculated from Marine Environment Classification data.



C. Mean orbital velocity at the seafloor in cm/s (Marine Environment Classification data).



D. Depth averaged maximum tidal current in cm/s ((Marine Environment Classification data).



5 Broad-scale intertidal habitats

5.1 Estuaries and beaches

We have identified six broad classes of intertidal soft-sediment habitats within the Tamaki Strait. The three features that factor into this classification are (1) the degree of slope of the shore, from flat to steeply sloped, (2) the sediment granulometry (how muddy, gravelly, etc.), and (3) the types of organisms visible during a typical low tide. Some of the observations that went into the classification were subjective, for example, the degree of slope of the shore. The characterisations made on the sand flats visited during this survey are shown in Figures 5.1 to 5.3. The six broad classes identified were:

- Moderate to steeply sloping beaches with gravely to cobbly sediment (Figure 5.4). These are mainly located on the islands, the exposed coast of southern and western Waiheke and around Kawakawa Bay. These beaches have few signs of animal life on the surface, with the exception of encrusting organisms on the larger rocks and rocky shore gastropods.
- Moderate to steeply sloping beaches with shelly sand sediment are found throughout the Strait (Figure 5.5). Again there are few visible signs of animal life on the surface of the sediment near mid tide. Pipis, *Macomona* and infaunal worms (Figure 5.6) may be in patches of finer sediment.
- Flat to moderate sloping sandy areas are also found throughout the Strait (Figure 5.7). These often show patches of many different types of fauna and flora (Figure 5.8), e.g., seagrass, tube worms, cockles, gastropods and *Macomona*.
- Flat mud to muddy-sand areas are common in the upper reaches of bays and estuaries (Figure 5.9). Crab burrows increase in number (Figure 5.10) and cockle density decreases as the muddiness of the sediment increases.
- Flat to moderately sloping shelly sand areas are also found throughout the Strait (Figure 5.11). Many different types of fauna are again found here, although denser beds of large cockles are more common and fewer dense beds of *Macomona* are found.
- Flat low tide areas with a coarse sediment matrix of pebbles, cobbles and sand are found on the southern Islands, and the more exposed areas of southern Waiheke and around Kawakawa Bay (Figure 5.12).

Figure 5.1:

Distribution of slopes of intertidal areas around the Tamaki Strait area.

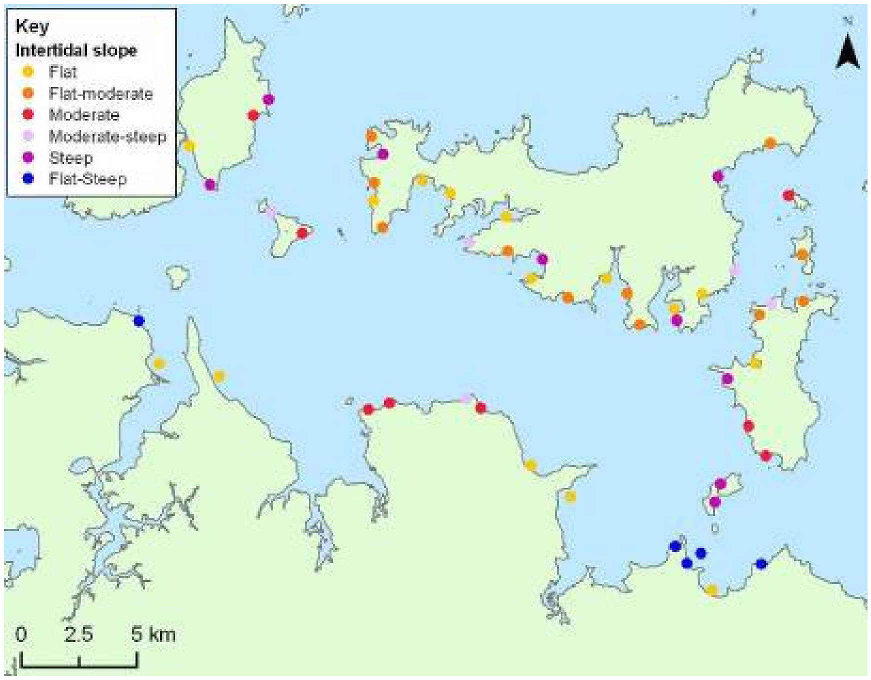


Figure 5.2:

Distribution of sediment types of intertidal areas around the Tamaki Strait area.

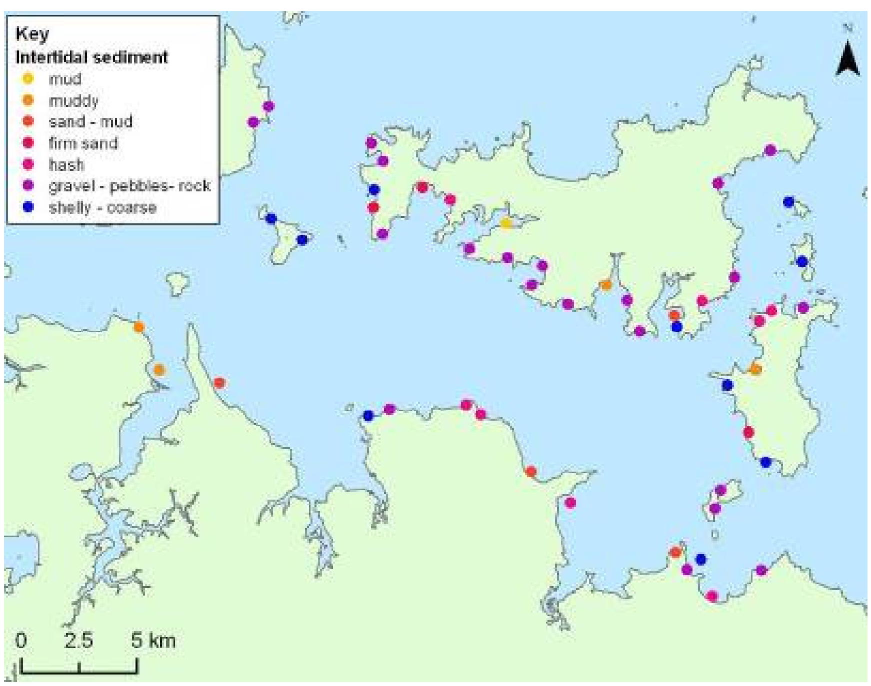


Figure 5.3:
Distribution of habitat types of intertidal areas around the Tamaki Strait area.

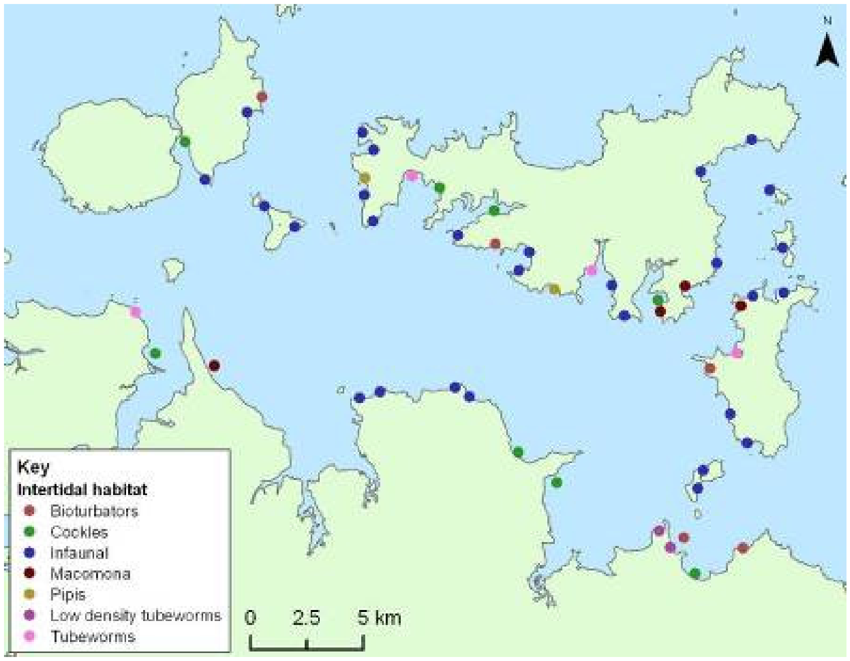


Figure 5.4:
Moderate to steeply sloping beaches with gravely to cobbly sediment.

Figure 5.5:
Moderate to steeply sloping beaches with shelly sand sediment are found throughout the Strait.

Figure 5.6:

Sediment with (A) *Macomona* feeding tracks and (B) infaunal worms.

A

B

Figure 5.7:
Flat to moderate sloping sandy areas are also found throughout the Strait.

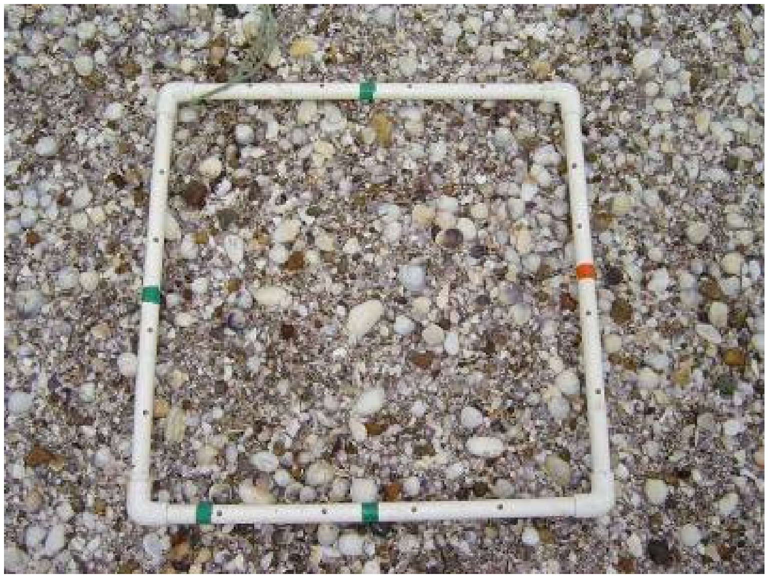
Figure 5.8:

Sediment with (A) seagrass, (B) tube worms, (C) cockles, and (D) gastropods.

A

B

C



D

Figure 5.9:
Flat mud to muddy-sand areas are common in the upper reaches of bays and estuaries.

Figure 5.10:
Crab burrows are found in muddy sediment.

Figure 5.11:
Flat to moderately sloping shelly sand areas are also found throughout the Strait.

Figure 5.12:
Flat low tide areas with a coarse sediment matrix of pebbles, cobbles and sand.

Tamaki Estuary

The intertidal area of Tamaki Estuary has recently been sampled (2002-5) and described by Hayward and Morley (2008). The estuary also has six sites that have been sampled every other year since 2002 as part of the ARC RPD programme. Mostly these sites are muddy and crabs are common (Bowden, Otahuhu, Pakuranga and Panmure). However, Bengazi is predominantly fine sand with sparse polydorid tube worm mats and Princess has a high proportion of shell hash.

Sampling in this study was conducted near the mouth of the estuary on the western side (Tahuna Torea) where there is a large intertidal flat of fine sand-mud which becomes muddier near low tide. Site 32, located on this flat at mid tide had abundant tube worms (*Macroclymenella stewartensis*) and low densities of cockles, the shellfish *Macomona,* and the snails *Cominella glandiformis* and *Zeacumantus lutulentus*. Near low tide the gastropods were replaced by low densities of crabs. Further out on the coast, Karaka Bay (site 30) is a sandy beach steeply sloping in the upper half and flat towards low tide. A thick seagrass meadow covers the much of the bay with dense tube worms (*Macroclymenella*), snapping shrimps and snails (*C. glandiformis* and *C. adspersa*). Mud patches became more common towards low tide.

Musick Point and the Whitford Embayment

Eastern Beach (site 31) is a flat sandy beach with some areas of gravel, shell and pebbles. At mid tide there were occasional tube worms (*Macrocylmenella*), predatory gastropods (*C. glandiformis*) and low densities of *Macomona*. Moving down the beach the tube worm density increased and crab burrows (*Macrophthalmus hirtipes*) became common, replacing *Cominella* and *Macomona*.

The Whitford Embayment was extensively sampled under an ARC programme in 2000 and the results are described in Norkko et al. 2001. The beaches down the western side are coarse sand often with dense cockles, particularly at Cockle Bay. The eastern side is an extensive sand flat with the sand coarsening towards Motukaraka Island. The inner area of the embayment is primarily three extensive intertidal flats with steep channel sides. The biogenic habitats are variable with patches of dense cockle beds, *Macomona* beds, tube mats (*Macrocylmenella*), pipi beds, worm mounds but no seagrass. The heads of the three tidal inlets (Mangemangeroa, Turanga and Waikopua Creeks) are very muddy and mangrove dominated.

Motukaraka Island to Whakakaiwhare Point

Between Whitford and Whakakaiwhare Point there are 12 bays with urban/rural catchments. The bays are small, between rocky outcrops, generally with boathouses and boat ramps. Beach slopes are moderate and generally covered with coarse sand. Sunkist Bay (Site 10) became shelly down towards low tide mark often armoured with large whole shells. Bedrock occasionally broke through the sandy surface. No biological features were visible and there were not high numbers of adult cockles, *Macomona* or pipis within the sediment. Further down the coast catchments were more rural, but beach slopes were still moderate or moderate to steep. At Schnapper Point (Site 10a) cobbles and sand covered the beach from mid tide up. Near low tide bedrock was often exposed with sand or fine shelly sediment in between. Large predatory worms were observed near mid tide and low tide areas had low densities of *Macomona*. Omana Beach (Site 10b) had sandy/shelly sediment covering the whole beach and no visible biological features or adult shellfish beds.

Some larger bays and beaches occur (Kellys, Maraetai, Ohinerangi, Umupuia). Kelly's Bay was not sampled due to the shallow rocky reef stretching across the entrance. Maraitai (Site 11) and Ohineranhi Beach, however, have many characteristics common to the smaller bays. The slopes of the beaches are moderate, although near the low tide they flatten out, and the sediment type is a shelly sand with no visible biological features.

Down before Whakakaiwhare Point is Umupuia Beach with a predominantly rural catchment. An extensive flat comprises most of the beach (Site 12). The beach is shelly above mid tide and muddy sand below. Maldanid tube worms and predatory gastropods (*Cominella glandiformis*) are common and there are patches of dense large cockles. Near low tide, crabs also become abundant.

Wairoa

While the inner part of Wairoa Estuary is highly infilled and muddy, the bay that it opens into is more variable in composition. Near where Wairoa Stream flows in there are extensive mudflats. To the north, there is an extensive flat sandy beach (Site 13), although in many places the fine sand overlies large pieces of shell, easily visible in the numerous ray pits. Towards mid tide the shell component of the sediment increases, medium densities of large cockles are found with numerous gastropods (*Zeacumantus* and *Diloma*) seen on the surface. Near low tide, maldanid tube worms and *Cominella* are common. On the southern side of the bay, there are some small embayments with variable sediment characteristics. Flat slopes are common from low to mid tide with steeper areas from mid tide to high tide. Site 13a between Mataitai Point and Koherurahi Point had fine sand near the high tide mark but cobbly, shelly sand matrix further down the beach, with bedrock occasionally breaking through this surface at low tide. Occasional maldanid tube worms were present near mid tide and the low tide had copious evidence of infaunal worms (faecal mounds and feeding holes), occasional crabs and, at the low tide mark, dense coverage of the sand dollar *Fellaster zelandiae*.

Koherurahi Point to Raukura Point

The beaches on the southern side of Koherurahi Point are similar to those of the north. These beaches have variable sediment characteristics and flat slopes from low to mid tide with steep areas from mid tide to high tide. In Waitawa Bay, fine sand was found near high tide with a cobbly, shelly sand matrix further down the beach. Occasional maldanid tube worms were present near mid tide and the low tide had abundant evidence of infaunal worms (faecal mounds and feeding holes), occasional crabs and, at the low tide mark, dense coverage of the sand dollar *Fellaster zelandiae*.

A number of shallow sand banks are scattered through out the bay. Sampling at one of these (Site 13b) showed that *Cominella maculosa*, crustaceans and large polychaetes were common. Near the low tide mark, starfish (*Patriella* and *Coscinasterias*), *Styela* and chaetopterid tube worms were common.

Kawakawa Bay itself is a large heterogeneous beach. The slope is predominantly flat with shelly sand at high tide. Near mid-tide, at site 1, patches of low density cockles and *Macomona* and the crab *Hemigrapsus crenulatus* can be found. Near low tide there are areas with numerous signs of worm activity, crab holes, low density patches of cockles, *Patriella* and *Fellaster*, *Zeacumantus* and also a large pebbly-rocky area.

The beach at the southern end is flat near low tide becoming steeper moving to high tide. There is a fringe of sand near high tide, which grades into a matrix of rocks, cobbles, pebbles and sand. Gastropods (*Cominella*), crustaceans and predatory polychaetes were observed near mid-tide. Near low tide, crabs, *Cominella* and cats-eyes (*Turbo smaragdus*) were seen.

Southern end of Tamaki Strait (Pakihi, Ponui, Rotoroa and Pakatoa Islands)

Around the small island off Pakihi the beaches are steep and comprised of red scoria pebbles (e.g., Site 2). On Pakihi Island itself, the beaches although still steep have finer sediment (cobbles and sand e.g., site 3). The cobbles are frequently coated with barnacles, mussels and serpulids.

Across the channel, on the southern side of Ponui island (Site 3a), the beaches have more moderate slopes with shelly pebbly sediment. The sediment decreases in size moving north, Omega Bay (Site 4) is predominantly sand with coarse shell found below the initially sandy surface. Few biological features were observed although a patch of mainly dead pipis was seen in the low intertidal. The small bay of Apuapua (Site 5) south of Kauri Point is again predominantly pebbly and steep in the mid to upper area, although a fine sand-mud was found lower with numerous tube worms (maldanids and phoronids) and hermit crabs and *Cominella* moving on the surface. The biggest bay on the island (Oranga Bay) has a number of beaches and inlets, typically with long flat intertidal sand-mud areas. Within the bay, the mid tide area of Site 6 was heterogeneous, with patches of tube worms (both *Boccardia* and *Macroclymenella*) and a small patch of seagrass (~3 m across). The *Boccardia* tube mats create a hummocky surface. The lower intertidal area has numerous *Patriella*, *Fellaster* and *Cominella adspersa*. Here in places, a hummocky surface is comprised of a thick diatom mat with crab burrows. Further up the coast, the sediment is sandier, sometimes with a shelly layer and the slopes of the beaches become steeper, particularly above mid tide. At Site 6a patches of tube worms are again found at mid tide, interspersed with patches of medium density *Macomona*. Lower down the shore *Macrocylmenella* are still found with some of the larger maldanid *Asychis*. *Cominella adspersa* and *C. glandiformis* are common and occasional *Patriella* are found. At Te Kawau Bay (Site 6b) the slope of the beach is moderate to steep and the shelly sand shows no biological features, however *Patriella* are common at low tide. At the northern most end of the island (Chamberlains Bay Site 7), the sediment has become even coarser. The mid tide area is mainly pebbles and steep but sand interspersed with cobbles are found further down the shore on a long flat stretching to an offshore bank.

Across the channel on the southern side of Rotoroa Island (Site 7A), the beach is similar, although the sediment is more shelly. This pattern continues with the beach visited on Pakatoa Island (Site 7b) also having a moderate slope and being comprised of coarse sand, shell hash and some pebbles.

Eastern end of Waiheke

Bays on the eastern end of Waiheke towards the north (e.g., Huse Bay, Site 7c and Man of War Bay, Site 7d) are primarily moderate in slope, sometimes with long flat low tide areas. Sediment is mainly cobbles. Moving southwards, the beach slopes steepen and the sediment becomes a sandy, gravelly (or shell hash) pebble mix (e.g., Paradera Bay Site 8A). No visible biological features can be seen. However, within Omaru Bay (Site 9) there are some flatter beaches with finer sediment. At site 9, the sediment was a firm shelly sand with evidence of worms and *Macomona* being common. More worm mounds, together with occasional *Patriella* were found at mid tide.

Southern Waiheke Bays

Te Matuku is one of the largest bays (2 km^2) and was recently designated a marine reserve. The intertidal and subtidal areas have been sampled extensively by DOC. Three muddy sites in the inner area of the bay near the stream inlet were sampled in 2003 as part of an ARC programme examining effects of historical sediment accumulation rates on East Coast Auckland Region estuaries (Lundquist et al. 2003). The bay on the north eastern end of Te Matuuku has been extensively sampled under the FRST programme (Eco-diagnostics) in 2006. This area was very heterogeneous, consisting of dense patches of tube worms (*Macroclymenella* and *Asychis*), *Macomona* and cockles. The intertidal area of the bay slopes very gradually and is primarily fine sand to mud. Further out towards the mouth, Site E was similar to the north eastern end: a flat broad beach of sand-mud with ripples approximately 3-5cm apart, patches of *Cominella glandiformis*, cockles and *Macomona,* with higher densities of cockles towards low tide. Pearl Bay (Site 21) nearer the mouth had a steep slope, pebbly shelly sediment and low densities of pipis.

On the peninsula between Te Matuuku and Awaawaroa Bay there are a few small bays with very coarse sediment even though their slopes are relatively flat. Little Bay (Site F) was flat with large pebbles/cobbles and a muddy shingle matrix overlaying clay. No visible signs of animal life were observed.

A mud-sand gradient in Awaawaroa Bay had previously been sampled (FRST funding, 2001). In the muddy areas dense crab burrows were observed (*Macrophthalmus*) and the sandier areas had dense beds of *Macomona*. In this study, two other sites were sampled. Site 22 on the eastern side of the bay had a moderate slope reducing to flat near low tide, and a shingle and shell hash sediment type with increasing siltiness near low tide. Site 23 in the upper end of the bay was flat with a complex sediment type; mud with shell hash and some rocks. Occasional *Macroclymenella* tubes and low densities of crab burrows were seen, along with a number of gastropod species (*Diloma*, *Cominella* and *Turbo*).

Along the mainly rocky coast between Awaawaroa Bay and Rocky (Whakanewha) Bay lies Woodside Bay (Site 24). The sediment type was rockier than at Site 23. Occasional maldanid tubes and worm activity was observed together with high densities of crab burrows (mainly *Helice crassa*), gastropods (*Cominella* and *Diloma*) and high densities of pipis at low tide.

In the next major embayment are Kauroa (Site 25) and Rocky Bay (Site 20). Rocky Bay had steep slopes comprised of a mix of sand, shell and gravel, while

Kauroa was flatter (flat to moderate), although the sediment type was similar. Neither of these bays had visible signs of biological features.

Beaches along the open coast of this and the next embayment (e.g., Kurakarau Bay, Site D and Te Whau Bay, Site C) were flatter, varying from moderate to steep at Te Whau Bay to flat at Kurakarau Bay. Sediment type varied from gravel and cobbles at Kurakarau Bay to sand, gravel and pebbles at Te Whau Bay. Patches of oysters and mussels (*Mytilus*) were found at Kurakarau Bay.

Anzac Bay has two main inlets (Tawaipareira Creek and Rangihoua Creek) and an outer area. The inlets were fringed with mangroves. At the sampled beach (Site 19) the mangroves formed a thick fringe with single adults occurring further out. The beach was flat and muddy with abundant crab burrows and some patches of abundant cockles. One patch of dense oysters was seen. In the outer areas of the bay, the beaches were flat to moderate in slope. The sampled beach (Putiki Bay, Site B) had a sandy shell hash sediment with some rocks. Low densities of cockles were found but patches of pipis occurred from mid tide becoming very dense at low tide.

Huruhi Bay Site 18 to 16 is the biggest embayment on Waiheke Island and is quite open. Two bays at the upper end were sampled. The first (site18) was flat but heterogeneous. Near low tide an expansive seagrass meadow covered the beach. Cockles were abundant in the few clear patches, otherwise crab burrows and *Cominella glandiformis* were visible. Near mid tide the beach ranged from a very dense seagrass meadow at one end to patches of seagrass to clear shelly sand. The clear areas contained patches of maldanid tubes, *Cominella glandiformis*, *Zeacumantus*, dense *Macomona* and abundant cockles. At Site 17 (Blackpool Beach) an expansive seagrass meadow covered the flat beach from just below low tide to hightide. Mounds and burrows containing *Macrophthalmus* were obvious. *Cominella glandiformis* were common and low densities of *Macomona* were found, although both of these disappeared near low tide. In the outer area of the bay, Site 16 had a moderate slope, although this flattened out near low tide. Some patches of seagrass were still present near low tide (3 x 4 m to 30 x 4m). Elsewhere the sediment was gravel overlying firm sand, although near low tide some rock platforms protruded and small rocks were present.

Eastern Waiheke

Eastern Waiheke Island has a number of bays of varying types, 4 of which were sampled. Site G in Owhanake Bay was flat, with a gravel, pebble and rock sediment. Matiatia Bay (Site 26) had a steep slope with small swales. The sediment types was not as coarse: pebbles and cobbles in sand-gravel matrix becoming sandy with small pebbles near low tide. Cable Bay (Site H) was flat with coarse sand. Church Bay (Site 27) was also flat but with distinctive swales, and a much coarser sediment type (shell, pebbles and cobbles). Church Bay also had medium densities of small pipis across the beach.

Motuihe, Rangitoto and Motutapu Islands

Motuihe Island has extensive sand flats around it. These are moderately sloping and very shelly on both the western (Site 28) and eastern sides (Waihaorangaruni Bay, Site I), although Site I also had some pebbles.

Most of the intertidal area around the Rangitoto and Motutapu Islands is rocky habitat, but some soft-sediment beaches were found in the long gut (Islington Bay) between the two islands. Sampling here, at Site 15, revealed a flat beach with some shelly swales, very shelly coarse sand with patches of maldanid tube worms (mainly *Macrocylmenella* but some *Asychis*), *Cominella glandiformis*, dense cockle beds, *Macomona* and pipis. The beach was reasonably heterogeneous with some rocky areas and large boulders and some ray pits. The small rocky areas had barnacles, oysters and snails (*Turbo samaragdus*). Further out of the gut near Emu Point was a small bay (Site A) with a steep short beach made of pebbles and cobbles, nearer low tide the sediment became a sandy pebbly matrix. On the western side of Motutapu Island, two bays were sampled Home Bay (Site 29) and Site J. These had moderate to steep slopes and very coarse sediment: large cobbles over shingle at Site J and gravel, pebbles and cobbles at Site 29.

5.2 Rocky areas

Intertidal rocky areas in the Tamaki Strait are extensive, especially around the offshore Islands. Physically it is possible to divide the rocky shore habitats into seven broad groups based on gradient and substrate (Table 5.1; Figure 5.2):

1. shore platforms with relatively smooth flat rock. Occasionally small shallow crevices in the bedrock are present creating sheltered microhabitats. Furthermore, 'steps' and other remnants of older eroded platforms are sometimes present (e.g., R14, Schnapper Point, Beachlands) (Figure 5.1 a);
2. shore platforms with rough broken rock, boulders and crevices. Often the intertidal area drops sharply into deep water at the low tide level (e.g., R12, Pasadena Bay, East Waiheke Island) (Figure 5.1 b);
3. gently sloping rough sedimentary rocks and boulders with many crevices and rock pools (e.g., R17, Wairoa Bay) (Figure 5.1 c);
4. gently sloping rough rocks and boulders with crevices and overhangs that are sand influenced (e.g., R9, Rotoroa Island) (Figure 5.1 d);
5. large intertidal area that is steeply sloping rough broken rock and boulders, dropping off into deep water (e.g., R4, East Ponui Island) (Figure 5.1 e);
6. narrow rocky intertidal area (slope mainly steep) at the base of a vertical cliff, rough rock and large boulders, dropping off into deep water (e.g., RH, Whites Bay) (Figure 5.1 f);
7. predominantly vertical cliff face with boulders and crumbling rough rock. Rock has yellow and orange oxide stains (e.g., RF, adjacent to Te Whau Point) (Figure 5.1 g).

Figure 5.1:
Physical types of intertidal rocky areas observed in Tamaki Strait.

a. 1) Smooth low gradient platform

b. (2) Rough low gradient platform

c. (3) Gently sloping rough rock

d. (4) Gently sloping sand influenced

e. (5) Steeply sloping rough rock

f. (6) Rocky and narrow at cliff base

g. (7) Steep cliff with rough crumbling rock

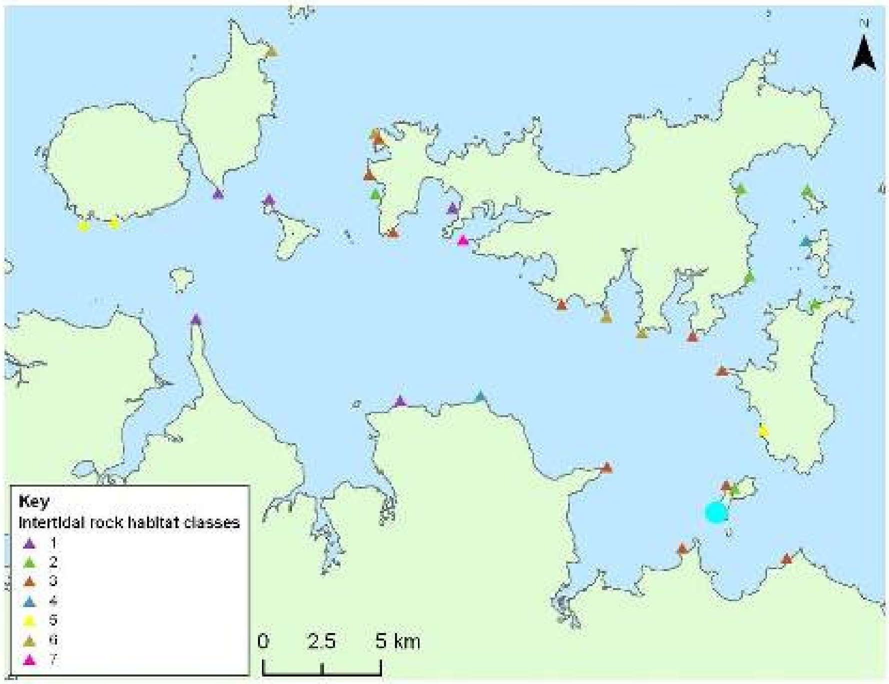
Table 5.1:

Sites sampled in the broad-scale survey, separated into seven groups based on physical characteristics, slope and substrate. Site field abbreviations and geographic names of the sites are also presented. Sites highlighted in red were selected for the fine-scale survey.

Group	Field Abbreviation	Geographic name
1 – Shore platform with smooth flat rock	R13	Whahakaiwhara Point
	R14	Schnapper Point, Beachlands
	RC	Emu Point
	RE	Huruhi Bay
	RO	Motuihe Island
	RQ	Musick Point
2 - Shore platform with rough rock, boulders and crevices	R3	Motunau Bay, South Ponui Island
	R5	Chamberlains Bay, North Ponui Island
	R10	Pakatoa Island
	R11	Man O' War Bay
	R12	Pasadena Bay
	RN	Motukaha Island
3 - Gently sloping rough rock and boulders	R1	Pakihi Island
	R2	Pakihi Island
	R6	West Pakihi Island
	R16	Whahahaiwhara Point
	R17	Wairoa Bay
	R18	Raukura Point
	RD	Park Point
	RG	Pearl Bay
	RJ	Woodside Bay
	RL	Matiatia Bay
	RM	Mahuehue Point
4 - Gently sloping, sand influenced, rough rock and boulders	R9	Rotoroa Island
	R15	Te Pene Beach
5 - Steeply sloping rough rock and boulders	R4	East Ponui Island
	RA	Rangitoto Island
	RB	Rangitoto Island
6 - Narrow rocky intertidal at the base of a vertical cliff	RH	Whites Bay
	RI	Adjacent to Deadman's Bay
	RK	Matiatia Bay
	RP	NE-Motutapu Island
7 - Vertical cliff face with rough crumbling rock	RF	Adjacent to Te Whau Point

Figure 5.2:

Broad scale survey (denoted by the dots), separated into seven broad groups (see previous text and Table 5.1 for group definitions and examples) based on physical characteristics, gradients and substrate.



Musick Point and the Whitford Embayment

Site RQ (Musick Point) and the next rocky outcrop site R14 (Schnapper Point, Beachlands) are similar in geomorphology (Figure 5.1 a). Both sites are expansive flat shore platforms covered with crevices and small rock pools creating little microhabitats. Both sites have narrow high tide (dominated by barnacles) and low tide zones (brown seaweeds, i.e., *Hormosira banksii*), while the extensive mid tide zone is dominated by dense *Corallina officinalis*.

Motukaraka Island to Whakakaiwhare Point

Between Motukaraka Island and Whakakaiwhare Point, the rocky outcrops are dispersed along the coast with sandy areas. The adjacent catchment is urban/rural and the rocky areas are easily accessible to people for recreational purposes. Site R15 (Omana Beach, next to the beginning of the underwater power cables to Waiheke Island), is characteristic of the outcrops along to Whakakaiwhare Point. It is a gently sloping, rough and highly creviced, sand influenced rocky outcrop. According to Murray et al. (2006), the influence of sand is an important variable in the structuring of the rocky shore as it is abrasive in conjunction with wave action and there are often a higher number of resistant macrophytes that tolerate sand abrasion and burial. Tidal pools are numerous at this site and it difficult to see clear bands of zonation.

Moving east, site R16 at Whakakaiwhara Point is a gently sloping (high tide zone) to steeply sloping (mid tide and beyond) area at the base of a steep cliff vegetated with grass, pine trees and shrubs. The substrate ranges from small to large boulders where zonation of barnacles to oysters to brown kelps from high to low water are clearly visible.

Whakakaiwhare Point to Raukura Point

Around the point is site R13, a site that is characteristic of the rocky areas in the Wairoa Embayment. The site is a flat, smooth, shore platform with 'steps' of elevated platforms at the base of the eroded cliff. The bedrock is sandstone and is very flaky at the top of the cliff there are houses. Several trees have fallen off the edge of the eroding cliff.

Sites R17 and R18 are located at Mataitai Point (eastern headland of Wairoa Bay) and Raukura Points (eastern Kawakawa Bay), respectively. Both are similar in terms of gradient and substrate texture, being gently sloping with rough bedrock and boulders (Figure 5.1c). Strong bands of zonation are clearly visible and both are easily accessed with roads nearby. The sites are representative of rocky outcrops along this part of the coast.

Southern end of Tamaki Strait (Pakihi, Ponui, Rotoroa and Pakatoa Islands

Sites R1 and R2 are situated on the west of Pakihi Island. The rocky intertidal areas surrounding the Island are similar to R1 and R2 and are generally gently sloping rough rock (small to large sized boulders) with crevices (cobbles and pebbles) and obvious zonation (barnacles, oysters, neptune's necklace, from high to low tide, respectively). The surrounding catchment is mainly pasture with forestry (pine) and some native shrubs and trees immediately adjacent to the rocky shore.

Across the channel, the expansive rocky intertidal areas around Ponui Island are generally flat with rough sedimentary rocks, crevices and strong zonation. Starting at the southern coast of Ponui Island, R3 is an expansive flat platform with rough substrate. The surrounding catchment is predominately pastoral with sporadic stands of pine. Moving around to the west of the Island, site R4 is different and is a flat rough platform at the base of a steep exposed cliff face (Figure 5.1e). At high water, the substrate consists of pebbles and cobbles moving down to small and large boulders close to the water. Native and exotic trees hang over the top of the cliff and there are signs of erosion. Moving north, site R6 is a rough gently sloping site; while R7 moving north again along the west coast is a rough flat bench. Both sites have shingle and pebbles at the high water mark moving down to small and large boulders, followed by a sharp drop into deep water. At both sites there is clear zonation consisting of barnacles (high tide) to kelps and oysters (mid tide) and then to mussels, *Hormosira banksii* (Neptune's necklace) and broad leaf seaweeds (low tide level). The catchments are rocky and steep with native vegetation. On the northern coast of the Island site R5 is similar to the previous sites and is an expansive flat platform with rough bedrock containing numerous crevices and rock pools.

Across the channel is Rotoroa Island, site R9 is located on the western coast and is characteristic of the rocky outcrops on the Island. The site is an example of one of the two gently sloping shores influenced by sand that we sampled (Figure 5.1d). At the site, there are a number of crevices and rock pools, creating microhabitats and zonation is obvious ranging from barnacles, oysters and then to *Hormosira banksii* at the low water mark. The catchment is steep and sparsely vegetated with both native and non-native trees. Across the channel is Pakatoa Island and the rocky intertidal area we sampled, R10. Again, the area is gently sloping and expansive with many crevices and rock pools. Shingle and cobbles line the crevices while the majority of the substrate is large boulders. Similar to the catchment on Rotoroa Island, the catchment adjacent to the rocky intertidal areas on Pakatoa Island is steep and vegetated with pines and other native flora.

Eastern Coast of Waiheke Island

On the eastern side of Waiheke Island, the rocky intertidal areas are similar to sampled sites R11 (Man O' War Bay) and R12 (Pasadena Bay) (Figure 5.1 b). Both have similar gradients, flat expansive platforms with rough substrate, small to large boulders and large crevices. Based on the gradient and substrate alone, they are similar to those across the Waiheke Channel on Pakatoa and Ponui Islands. The adjacent catchment is steep cliff that is sparsely vegetated. Zonation is obvious at both sites, with bands of barnacles, oysters and broad-leaf brown kelps from high to low water.

Southern Waiheke Island

Much of the southern coastline of Waiheke Island is rocky intertidal. Moving south, site RG is dissimilar to sites R11 and R12. Site RG is located on the eastern headland of the mouth of Te Matuku Bay and is gently sloping rock that drops off suddenly into deep water. The substrate is rough with many large boulders and crevices. Zonation bands of barnacles, oysters, *Hormosira banksii* and brown kelps are prominent. The rocky intertidal area is at the base of a steep cliff face, vegetated with exotic forest and grasses.

On both headlands of Awaawaroa Bay, west of Te Matuku Bay are sites RH and RI (eastern and western points, respectively). The sites are narrow intertidal areas at the base of a cliff (Figure 5.1f). The intertidal areas are only 5-10 m with a very steep gradient, dropping off suddenly into deep water. Zonation is very clear with bands of green and black terrestrial lichen, moving down to barnacles, then oysters and kelp at low water. Large deep crevices are carved into the rock, mainly in the mid tide zone. The immediate catchment is grass scattered with exotic shrubs and trees.

Moving west, the rocky intertidal areas are similar until site RJ situated on western point of the mouth of Woodside Bay. The site is an expansive low gradient, rough platform. Large boulders creating deep crevices cut through the zonation bands of barnacles, then oysters and *Hormosira banksii* down to kelps and taxa less tolerant to dehydration at low water. The immediate catchment is a steep cliff vegetated with native and exotic trees and shrubs.

Moving west again, the rocky intertidal at site RF (Te Whau Point) is the only example we found where the intertidal is at the base of the cliff of unstable crumbling rock (Figure 5.1g). At this site there is evidence of wave scouring and erosion at base of the cliff. Bands of vertical zonation were difficult to observe, but barnacles and oysters were present. The cliff was vegetated with sparse exotic trees and shrubs. Around the corner of the point, heading into Putiki Bay is site RE. Site RE is an expansive flat shore platform with flat rock that drops off suddenly into deeper water. At this site there are obvious 'steps' in the rock, a sign of a previously eroded, higher elevated platform. Zonation is present but the major structuring organisms were difficult to observe from a distance. The adjacent catchment was a steep cliff with a house on top. The side of the cliff had scattered exotic trees, many of which had fallen with the recent erosion of the base of the cliff at this site.

On the eastern side of the mouth of Putiki Bay, is site RD (Kennedy Point). RD is another example of a gently sloping rocky intertidal with rough rocks and deep crevices. The sediment ranges from shingle at the high tide mark and in the crevices, to pebbles and cobbles in the mid tide zone and then small and large boulders close to low water. Strong patterns of zonation are present with barnacles, gastropods, and chitons in the high tide zone, oysters in the mid tide zone and then green-lipped mussels and *Hormosira banksii* close to low water. The adjacent catchment is farmland (a house nearby) with sparse stands of exotic forest.

Western Waiheke Island

The western coast of Waiheke Island is again mostly rocky intertidal and three sites were sampled. Moving up the coast sites, RM (Mahuehue Point), RL and RK (Matiatia Bay) were sampled. RM and RL both have gently sloping gradients with rough rock, large boulders, crevices and rock pools lined with pebbles and cobbles. Site RK is a narrow strip of rocky intertidal area at the base of a steep cliff. Bands of zonation are present at all sites (barnacles, oysters, broad-leaf kelps from the high to low tide zones). The adjacent catchments at all sites are semi-urbanised with houses on the tops of the cliffs, farmland and exotic trees and shrubs. In addition, site RN on Motukaha Island was sampled. Site RN is a flat expansive bench that drops off into deep water. The rock is rough with large boulders close to low water and deep crevices.

Motuihe, Motutapu and Rangitoto Islands

Motuihe Island is located between Waiheke Island and Rangitoto and Motutapu Islands. The Motuihe Channel runs to the west of the Island and joins up with the Sergeant Channel that runs past the east of the Island. Most of the rocky intertidal area around the island is gently sloping rough rock, similar to that seen previously in Tamaki Strait; however site RO (situated on the northern point of the Motuihe Island) is a very expansive flat platform with flat rock. The bedrock has little indentations on the surface, creating many small tidal pools. Zonation is not as obvious here as at the other sites. The top of the platform is covered with major structuring organisms, oysters and barnacles. Erosion is obvious at this site with 'steps' of elevated platforms present at the base of the eroded cliff.

Two sites were selected on Motutapu Island: Site RP (northern point of the Island), which is characteristic of the northern rocky areas on the Island, and Site RC (south-eastern point of the Island), which is characteristic of rocky areas on the eastern side of the Island. Site RP is a narrow, steep intertidal area at the base of a steep cliff. The rocks are jagged and highly fractured with many tidal pools present down the shore. Zonation bands of barnacles, oysters and then large broad-leaf algal species are present from high tide to the waters edge. Site RC is somewhat different in appearance to RP, as it is a gently sloping expansive platform which drops off to deep water at low tide. Erosion is obvious at this site with ‘steps’ of past elevated platforms present at the base of the eroded cliff. There are large boulders to either side of the platform and the steep adjacent cliff is sparsely vegetated. Distinct community compositions and zonation patterns were not observed.

The rocky intertidal areas around Rangitoto Island are all similar to those observed at sites RA and RB. The dark volcanic rock, shingle to small boulder size, made up the steep narrow intertidal area. The adjacent catchment contained houses, farmland and native and exotic shrubs and trees. Community composition and zonation patterns were difficult to discern due to rough sea, but *Hormosira banksii* was distinctly visible at mid to low tide.

6 Intertidal communities and diversity

6.1 Estuaries and beaches

Fine-scale sampling of the Tamaki Strait area revealed a range of communities and diversity. The average number of taxa observed at a site in this sampling programme (Figure 6.1a) ranged from 2 – 32 (cf maximum of 36 found in the Whitford study). Average number of animals found at a site ranged from 2 – 96 (Figure 6.1b). Evenness ranged from 0.33 to 0.98 and Shannon-Weiner diversity ranged from 0.9 to 2.8 (Figure 6.1c & d).

Some differences were observed between different areas. Tamaki Estuary sites had significantly different community compositions to everywhere else. Southern Waiheke sites had significantly different community compositions than Eastern Waiheke sites and Whitford. North Coast and Island sites had significantly different community compositions than Whitford and each other. Whitford sites also had significantly different community compositions to the south-eastern sites. No differences were detected in number of taxa, individuals or diversity, although communities in the Island area were more even than those in the south-west coast.

Many of these compositional differences were driven by the beach type. For example, estuarine flats, more exposed sand flats and moderately to steeply sloping beaches all had significantly different community compositions (>80% dissimilar, although within group similarity was low (7-20%)). Table 6.1 shows the taxa driving the differences between these beach types. Shannon-Weiner diversity and average number of species found at a site was higher in the exposed sand flats than in the estuarine or moderate to steeply sloping sites.

Sediment type was also an important determinant of macrofaunal community characteristics. Communities found in different sediment types were all different with the exception of medium sand being similar to shelly sediment and fine sand. It was a less important factor in driving univariate measures of communities with only a few species showing an effect. Average number of species found at a site was higher in shelly and fine sand sites than in the other sediment types.

Figure 6.1 a & b:

Macrofauna in the intertidal soft sediment areas around Tamaki Strait. Average number of species (A) and individuals (B) per core.

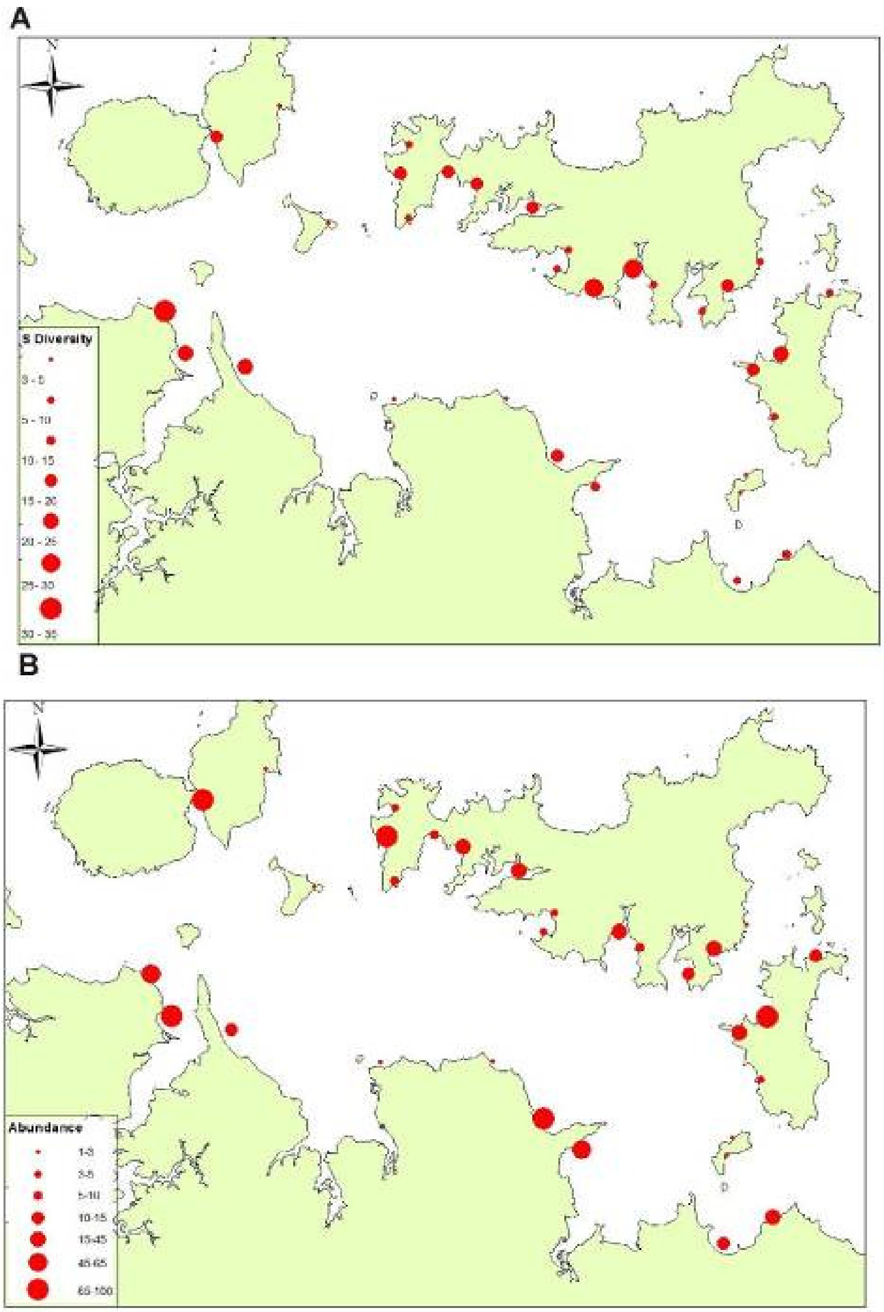


Figure 6.1 c & d:

Macrofauna in the intertidal soft sediment areas around Tamaki Strait. Evenness (C) and Shannon-Weiner Diversity Index (D) per core.

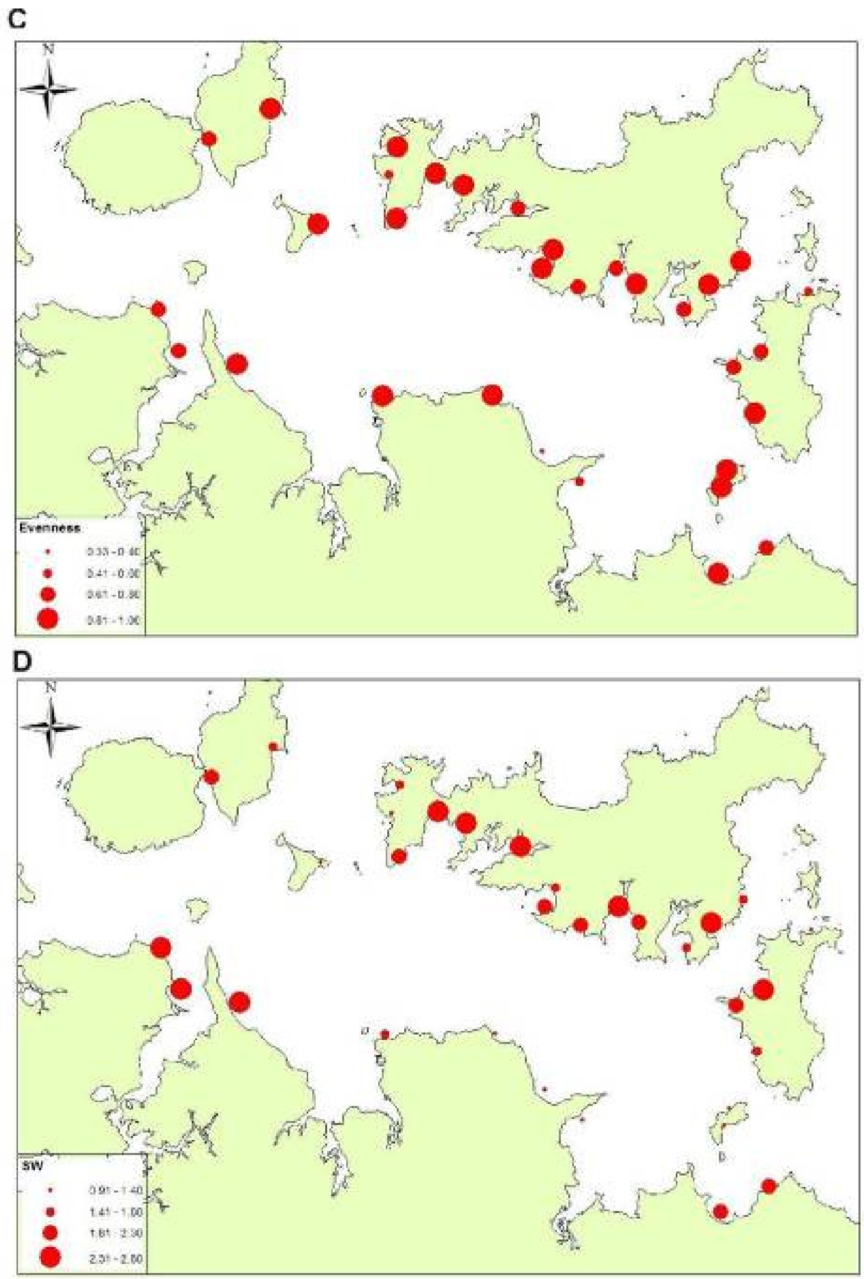


Table 6.1:

Taxa that differentiate between the communities of estuarine flats, more exposed sand flats and moderately to steeply sloping beaches. L or H denotes whether abundance is low or high between two different categories.

Estuarine flats	Sand flats	Beaches
Heteromastus filiformis	*Nucula hartvigiana*	*Glycera sp.*
Nicon aestuarensis	*Macomona liliana*	*Aonides trifida H*
Macropthalmus hirtipes	*Austrovenus stutchburyi*	*Prionospio aucklandica L*
Prionospio aucklandica H	*Aonides trifida*	*Paphies australis*
Helice crassa	*Anthopleura aureoradiata*	*Aricidea sp.*
Austrovenus stutchburyi	*Macroclymenella stewartensis*	*Paramoera chevreuxi*
Arthritica bifurca	*Scoloplos cylindifera*	

6.1.1 Rocky Intertidal

Intertidal shorelines are a mosaic of habitats, with patchiness at every scale of observation. Abiotic and biotic factors strongly influence the distributions and interactions of marine plants and animals, such that biotic communities are generally linked to factors such as wave exposure and substrate type (Schoch and Dethier 1996). Exposure of a site (in terms of the energy and impact of waves) is correlated with the gradient of the rocky shore, zonation patterns and also the community composition within the zoning bands (Morton 2004, Murray et al. 2006; Schoch & *Dethier*, 1996). Shores that have a steep gradient (e.g., site RH and other sites in groups 5 to 7), are generally situated on headlands and islands that are subjected to large continuous swell (Table 5.1 in broad scale survey section). Sites in groups 3 and 4 (e.g., R16, RJ) are gently sloped and are examples of semi exposed rocky intertidal areas. All of these sites are on the open coast but are not subjected to waves of great intensity for long periods, as on exposed shores. Sites in groups 1 and 2 (e.g., R12 and R14) that have flat to low gradients are all situated in bays or are protected by headlands and are not frequently exposed to wave swell. Exposed rocky shores in Tamaki Strait also seem to have more of a supra-littoral and littoral fringe (zone above the high tide mark, that generally receives only sea spray from waves), with organisms, especially periwinkles and lichen seen higher up the shore. On sheltered rocky intertidal areas with flat to low gradient bedrock, zonation patterns are not as obvious and species like *Corallina officinalis* and *Hormosira banksii* that are adapted to withstand longer periods between the tides are more dominant and widespread (Morton 2004).

Fine scale sampling of the rocky intertidal areas of Tamaki Strait concentrated on eight sites selected from the broad scale survey. The fine scale sampling revealed a range of communities and diversity (Table 6.2). The average number of taxa at a site across all zones ranges from 10 to 18 at sites R14 and R3, respectively. Furthermore, the average number of taxa observed from the high, mid and low tide zones was 10, 15 and 18 species, respectively. Evenness (d) ranges from 0.69 to 4.50, while Shannon-Weiner diversity ($H'(\log_e)$) ranges from 0.43 to 1.73 and generally there was a higher diversity of taxa in the low tide zone (except RJ, R16 and R14).

Table 6.2:

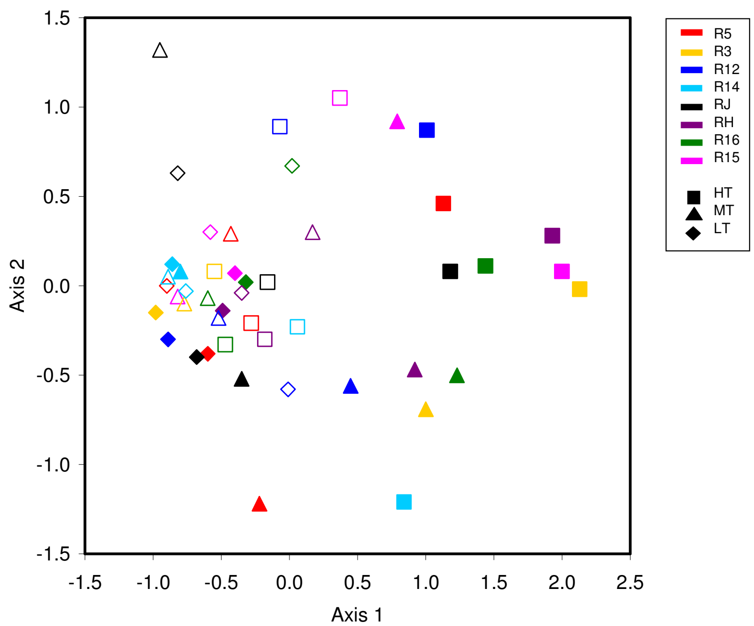
Number of taxa (S), species richness (d), Pielou's evenness (J') and Shannon-Weiner diversity ($H'(\log_e)$) of the communities found in the high (HT), mid (MT) and low (LT) tide zones at each site.

		S	d	J'	$H'(\log_e)$
R12	HT	8	1.74	0.61	1.27
	MT	20	4.36	0.48	1.43
	LT	17	3.14	0.57	1.63
R15	HT	8	1.78	0.41	0.85
	MT	12	2.51	0.42	1.05
	LT	19	3.80	0.43	1.27
RH	HT	4	0.69	0.58	0.81
	MT	15	3.05	0.30	0.80
	LT	14	2.76	0.41	1.08
RJ	HT	21	4.37	0.57	1.73
	MT	11	2.14	0.31	0.75
	LT	15	2.95	0.48	1.31
R16	HT	8	1.69	0.62	1.29
	MT	17	3.63	0.45	1.29
	LT	22	4.50	0.36	1.11
R3	HT	12	2.57	0.28	0.70
	MT	19	3.97	0.44	1.31
	LT	22	4.45	0.56	1.73
R5	HT	6	1.28	0.56	1.01
	MT	18	4.37	0.39	1.11
	LT	21	3.88	0.51	1.55
R14	HT	10	2.91	0.47	1.08
	MT	8	1.55	0.39	0.81
	LT	13	2.56	0.17	0.43

A multi-dimensional scaling plot of the raw untransformed data shows the dissimilarities in community composition between zones, and rock pools within each zone, across sites (Figure 6.2). The communities within zones across sites are grouped together (high, mid and low distinct from each other), with the exception of the mid tide community at site R15. In terms of exposure, the sheltered (low gradient) sites R12 and R14 are grouped together and are dissimilar to those sites that are semi exposed and exposed for the high tide communities. The high tide community at RH (exposed) is similar to that at the semi-exposed sites. There seems to be no significant difference in the community composition at each site in the low tide zone as they are all grouped together.

Generally the rock pool communities are similar to communities of the low tide zone across all sites. Furthermore, there seems to be no difference between rock pool communities across zones.

Figure 6.2:
Multi-Dimensional Scaling (MDS) plot displaying the dissimilarity of communities in rock pools and on bedrock within each zone across sites. Stress=0.15, which indicates that the high dimensional relationships among samples should be interpreted with caution. Coloured points denote sites R5 (red), R3 (orange), R12 (dark blue), R14 (light blue) RJ (black), RH (purple), R16 (dark green) and R15 (pink); zones HT, MT and LT are denoted by squares, triangles and diamonds, respectively; closed and open symbols represent communities on bedrock and in rock pools, respectively. The further away the points are in the ordination space, the more dissimilar the community composition is. Thus, the tightly clustered points represent similar communities.



Dominant organisms that determine patterns of zonation are consistent across sites and are responsible for driving the differences in the groupings between zones (Figure 6.2; Table 6.3). Across all sites, the high tide zone is dominated by encrusting organisms resilient to physical stress including long periods of exposure to air and radiation (e.g., barnacles (*Chamaesipho brunnea, Elminius modestus*) and periwinkles (*Austrolittorina antipodum*)). The mid tide level is dominated by a mixture of flora and fauna and the main zoning organism is the rock oyster (*Saccostrea glomerata*) and Neptune's necklace (*Hormosira banksii*). The low tide zone is mainly structured by encrusting and larger macroalgae (e.g., *Corallina officinalis, Hormosira banksii*).

The physical appearance of each site varies but represents the intertidal rocky areas across throughout the Tamaki Strait (Appendix II-pictures of sites and quadrat photos). In addition, the similarity between communities at each site across zones is low and ranges from between 0 to 48%.

Table 6.3:

The three most abundant taxa (percent cover) found in each zone at each site. B=barnacle, BA=brown algae, C=chiton, E=encrusting algae, GA=green algae, O=oysters, P=periwinkle, T=turf algae, S=spiny tube worm.

	High Tide Zone	Mid Tide Zone	Low Tide Zone
R5	*Chamaesipho brunnea* (B)	*Saccostrea glomerata* (O)	*Cladophora sp.* (GA)
	Gelidium pusillum (E)	*Hormosira banksii* (BA)	*Corallina officinalis* (T)
	Austrolittorina antipodum (P)	*Scytothamnus australis* (BA)	*Hormosira banksii* (BA)
R12	*Elminius modestus* (B)	*Hormosira banksii* (BA)	*Corallina officinalis* (T)
	Rhizoclonium curvatum (GA)	*Saccostrea glomerata* (O)	*Cladophora sp.* (GA)
	Black terrestrial lichen	*Chamaesipho brunnea* (B)	*Hormosira banksii* (BA)
RJ	*Chamaesipho brunnea* (B)	*Hormosira banksii* (BA)	*Corallina officinalis* (T)
	Corallina officinalis (T)	*Corallina officinalis* (T)	*Hormosira banksii* (BA)
	Elminius modestus (B)	*Saccostrea glomerata* (O)	*Cystophora retroflexa* (BA)
RH	*Chamaesipho brunnea* (B)	*Saccostrea glomerata* (O)	*Corallina officinalis* (T)
	Gelidium caulacantheum (T)	*Chamaesipho brunnea* (B)	*Hormosira banksii* (BA)
	Austrolittorina antipodum (B)	*Sypharochiton pelliserpentis* (C)	*Leathesia* sp. (BA)
R15	*Chamaesipho brunnea* (B)	*Pomatoceros caeruleus* (S)	*Corallina officinalis* (T)
	Elminius modestus (B)	*Elminius modestus* (B)	*Hormosira banksii* (BA)
	Austrolittorina antipodum (B)	*Saccostrea glomerata* (O)	*Scytothamnus australis* (BA)
R14	*Elminius modestus* (B)	*Corallina officinalis* (T)	*Corallina officinalis* (T)
	Pomatoceros caeruleus (S)	*Hormosira banksii* (BA)	*Hormosira banksii* (BA)
	Hormosira banksii (BA)	*Leathesia* sp. (BA)	Orange encrusting sponge
R16	*Chamaesipho brunnea* (B)	*Saccostrea glomerata* (O)	*Corallina officinalis* (T)
	Ulva spp. (GA)	*Pomatoceros caeruleus* (S)	*Hormosira banksii* (BA)
	Apophlaea sinclaiirii (E)	*Chamaesipho brunnea* (B)	*Elminius modestus* (B)
R3	*Chamaesipho brunnea* (B)	*Saccostrea glomerata* (O)	*Corallina officinalis* (T)
	Epopella plicatus (B)	*Chamaesipho columna* (B)	*Leathesia* sp. (BA)
	Gelidium caulacantheum (T)	*Apophlaea sinclaiirii* (E)	Orange encrusting sponge

7 Subtidal

7.1 Subtidal epibenthic habitats

A number of distinct epibenthic habitats were observed in the subtidal areas of Tamaki Strait (Figure 7.1). The majority of the substrate below 5m in Tamaki Strait is dominated by burrowing invertebrates and bioturbators. Additional soft sediment habitats were defined by the presence of habitat structuring epifauna, such as sponges and *Atrina zelandica* (Table 7.1). These epifaunal habitats were varied in their distribution and frequently occurred in more than one sedimentary environment.

Figure 7.1a:

A. Distribution of subtidal soft sediment epibenthic habitats found in Tamaki Strait by drop camera (see Table 7.1 for a full description of habitat types).

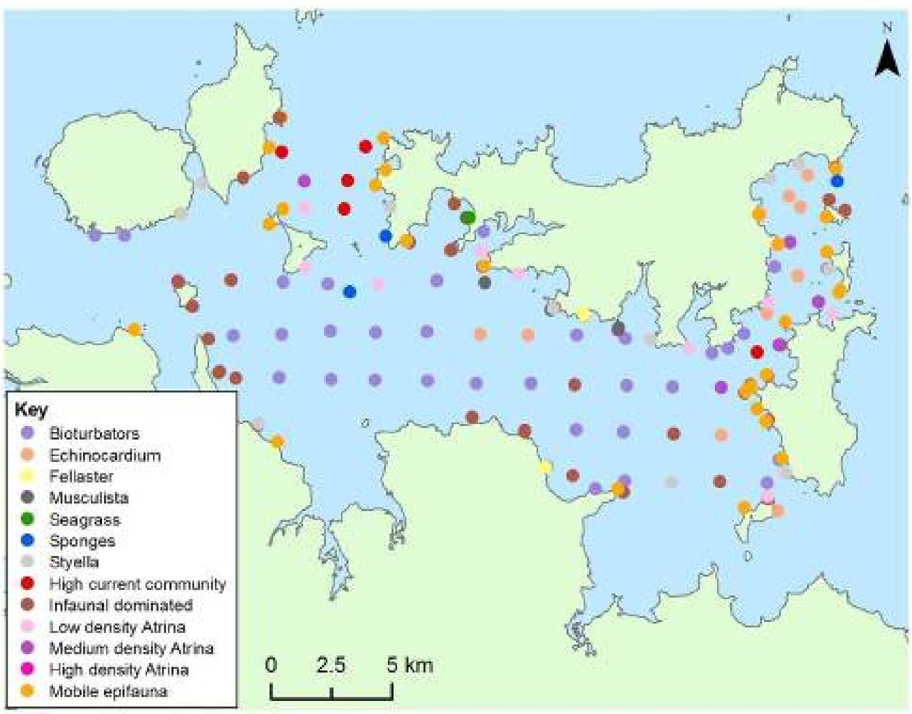
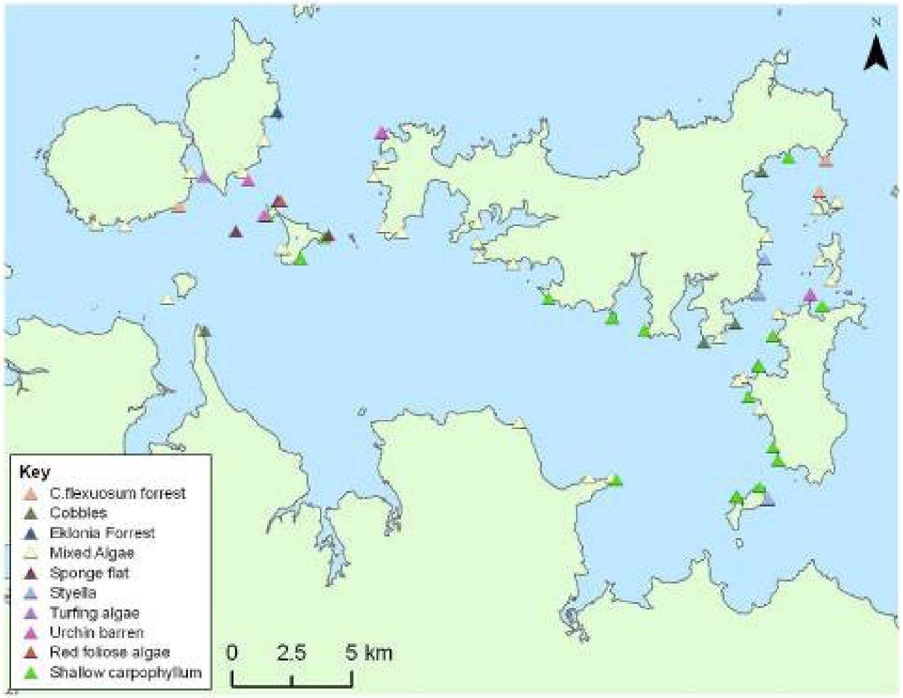


Figure 7.1b:

B. Distribution of subtidal rocky epibenthic habitats found in Tamaki Strait by camera (see Table 5.1 for a full description of habitat types).



Epifaunal groups (i.e., those observable with cameras above the seabed) were highly dissimilar with the percent dissimilarity varying between 82-99%. Most soft-sediment groups also had low within group similarity (14-20% for Burrower and Infauna dominated groups through to 40-50% for *Atrina* groupings and Mobile epifauna). Hard substrate epifaunal groups tended to have a high degree of within group similarity. For example the groups based on macro algae (e.g., Shallow *Carpophyllum* and Mixed algae) displayed better within group similarity (61-70%). Some groups were well explained by the combination of tidal currents and maximum orbital velocity (80% of the HCC, 64% of bioturbator, 40% of urchin and 30% of the sites within *Echinocardium* groups were correctly allocated based on these two factors.

Table 7.1a:

Subtidal Hard Substrate Epibenthic habitats of Tamaki Strait obtained from video.

Key species	Dominant large organisms and approximate densities
Ecklonia radiata forest	Monospecific *Ecklonia radiata* (>4 plants/m^{-2}), occasional *Carpophyllum flexuosum* plants or urchins. Exclusively found on hard rock on exposed coast.
Carpophyllum flexuosum forest	*C. flexuosum* plants dominate (>4 plants m^{-2}). On sheltered reefs. Plants are large and associated with high sediment levels. On more exposed reefs, plants are short and associated with *Evechinus chloroticus*.
Shallow *Carpophyllum*	Dominated by C. *maschalocarpum*, *C. plumosum* and *C. angustifolium. Eklonia radiata* and red algae are also common.
Mixed algae	Mixture of *Ecklonia*, *Carpophyllum* and occasionally *Cystophora*. Found on soft and hard rock.
Red foliose algae	Predominantly red foliose algae, may have low numbers of large brown algae.
Turfing algae	Predominantly articulated corallines and other red turfing algae with low numbers of large brown algae.
Urchin barrens	Soft rock, mostly bare, with stunted *Carpophyllum*, low-density turf and high numbers of *E. chloroticus*. *E. chloroticus* also found in crevices with high densities of coralline paint.
Cobbles	Dominated by crustose coralline algae. Substrate unstable and subject to agitation, Low densities of encrusting animals and no brown algae present.
Sponge Flat	Sponges dominant, rock and sand present. Occurs on the reef-sand interface.
Styela	Sand-shell areas or Rock. *Styela* growing on solid substrate.

Table 7.1b:

Subtidal Hard Substrate Epibenthic habitats of Tamaki Strait obtained from video.

Key species	Dominant large organisms and approximate densities
Sponge complex	Found predominantly in high current flow areas high in shell-gravel substrate.
High Density *Atrina* beds	*Atrina zelandica* in beds (> 1 per m^2). *Atrina* are adults, often associated with *Styela clava*. They display patchy distribution with 2 – 10 *Atrina* per patch, beds are 10's of m's in size.
Low density *Atrina*	Low to very low density *Atrina* (<0.5 per m^2). *Atrina* are adults, 1 – 2 per 10 m, often associated with *Styela clava.*
Medium density *Atrina*	Mid to high densities of *Atrina* (0.5-1 per m^2). *Atrina* are adults and often associated with *Styela clava.*
High current community	Found mostly in coarse sediments in high tidal flow areas. Dominated by filter feeding sessile invertebrates such as ascidians, and mobile scavengers such as *Pateriella*.
Fellaster	Found in coarse sand. Dominated by the Sand Dollar *Fellaster zelandiae.*
Echinocardium	Areas of well mixed soft sediment with moderate to high densities of *Echinocardium sp.*
Infauna dominated	Areas of bare sediment with no identifiable epifauna.
Mobile epifauna	Dominated by mobile epifauna, such as starfish, gastropods & hermit crabs.
Burrowers	Areas of soft sediment with large burrows, dominated by excavating organisms such as crabs.
Musculista	Areas where *Musculista* patches occupy greater than 10% of sediment surface.
Seagrass	Found in Huruhi Bay. Shallow subtidal seagrass in muddy sand substrate.
Styela	Sand-shell areas or Rock. Low densities of *Styela* spp. growing on solid substrate.

7.1.1 Summary by area of common benthic habitats in Tamaki Strait

Motukorea and Motuihi channels (including the Tamaki Estuary)

The subtidal rocky areas sampled are mostly steep rocky shore with mixed algae cover, with some shallow *Carpophyllum* and *C. flexuosum* dominated communities found on the coast of Motuihe Island. *Eklonia* forest is found on the exposed NE coast of Motutapu and Motuihe Islands. The algal cover gives way to a reef-sediment interface with either urchin barren or low numbers of *Styela clava*. Below 5 m depth, the substrate was as Powell (1937) described: muddy sediments with little epifaunal cover (Infauna dominated and Burrowers). Relatively high densities of *Atrina* occur off the northern tip of Browns Island. In the deeper areas (>10 m) of the Motuihe Channel, the tidally scoured substrate is coarser and dominated by mobile epifauna and high current communities.

Morrison et al. (2003) noted low densities of *Atrina* off the SW coast of Motuihe Island.

Tamaki Strait westward of Rocky Bay and channel between Waiheke and Motuihe Islands

The subtidal rocky areas of the south west coast of Waiheke Island and Northern coast of Tamaki are predominantly mixed brown algal habitats, with *Eklonia* forest found on the coast of Kauakarau Bay. The soft sediments of the western Tamaki Strait are mud-sand sediments dominated by infauna or burrowing communities. In the high current areas of the Sergeant Channel between Motuihe and Waiheke Islands, coarser shelly sediments are dominated by high current communities and mobile epifauna. Notable were several areas of *Atrina* on the fringes of the channel, and in the sediments fringing the Putiki Bay -Te Whau Point-Rocky Bay area. There is a patch of subtidal seagrass in Huruhi Bay.

Southern Coast of Waiheke Island and Tamaki Strait to the Eastward of Rocky Bay

The rock areas of the southern coast of Waiheke Island are predominantly shallow *Carpophyllum* communities . The soft sediment areas are similar to the western areas of the Tamaki Strait. Burrower and infaunal dominated muddy sands are prevalent with patches of shell hash-mud, consistent with the findings of Powell (1937). Patches of *Atrina* were found at the entrance of Awaawaroa Bay.

Te Matuku Bay

Morrison et al. (2003) recorded that samples taken in the Te Matuku reserve were entirely soft mud-sand with little epifaunal cover, similar to the surrounding Tamaki Strait. Notable subtidal epifauna include patches of low and medium density *Atrina* off sandy bay.

Waiheke Channel

The Waiheke Channel has a large diversity of habitats. The subtidal rocky areas at the northern exposed tip are dominated by *Carpophyllum flexuosum*. As exposure decreases moving down the channel, there is a mixture of brown algae species and bare rock. The invasive tunicate *Styela clava* is found at several areas in the channel in low densities. The soft sediment is mostly muddy sand dominated by *Echinocardium* and *Atrina*. In areas of high current where the channel narrows mobile epifauna and high current communities occur.

South eastern Tamaki Strait and Area around Ponui and Pakihi Islands

The rocky areas of the sheltered western side of Ponui and Pakihi Islands are dominated by shallow *Carpophyllum* communities. Notable is the presence of *Styela clava* on the exposed western coast of Pakihi Island. The sediments in this area contain significant shell material, the legacy of substantial historical mussel beds. There are large patches of low to medium *Atrina*, these seem to be associated with moderate tidal currents that occur between Pakihi Island and Wairoa estuary.

Figure 5.2:

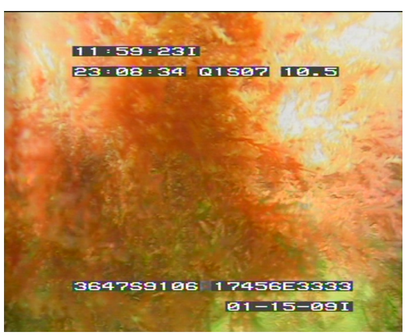
A. Pictures of subtidal epibenthic habitat types found in Tamaki Strait.

a. Ecklonia radiata forest

b. *Carpophyllum flexuosum* forest

c. Shallow *Carpophyllum*

d. Mixed algae



e. Red foliose algae

f. Turfing algae

B. Pictures of subtidal epibenthic habitat types found in Tamaki Strait.

a. Urchin barrens

b. Cobbles

c. Sponge flats

d. *Styela*

e. *Atrina* bed

f. High current community

C. Pictures of subtidal epibenthic habitat types found in Tamaki Strait.

a. *Fellaster*

b. Sponge complex

c. Infauna dominated

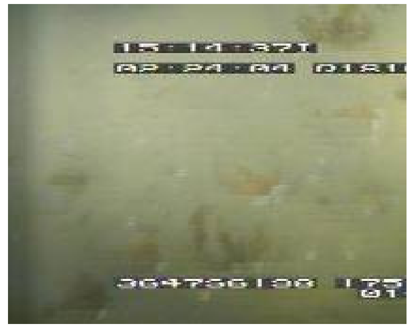
d. Mobile epifauna

e. Burrowers

f. *Musculista*

D. Pictures of subtidal epibenthic habitat types found in Tamaki Strait.

a. Seagrass



b. *Echinocardium*

7.1.2 Summary by area of rocky habitats

Rocky coastlines within the Tamaki Strait would seem to be structured largely according to exposure. The majority of the coast can be considered wave sheltered in comparison to the wider Hauraki Gulf, and the assemblages are dominated by species of brown algae, specifically several species of *Carpophyllum*. This is similar to other areas of the region including Kawau Bay (Chiaroni et al. *2007*). It is probable that one of the main drivers of epifaunal and infaunal structure in the sediment environments is current flow at the sediment surface. Powell (1937) and Hayward (1997) noted areas of higher current flow are associated with coarser sediments and filter feeding communities. In contrast, areas of lower flow have more accumulated fine sediments, and bioturbating organisms such as *Echinocardium*. Data collected during Tamaki Strait Tier II sampling largely conformed with this generality.

7.2 Subtidal soft sediment

Community data were analysed to determine whether the major epifaunal habitat types supported significantly different infaunal assemblages.

As with previous studies community composition found within a site was usually highly variable (within site dissimilarities of 47-68%). When grouped by sediment type within group dissimilarities were also high (58-71%).

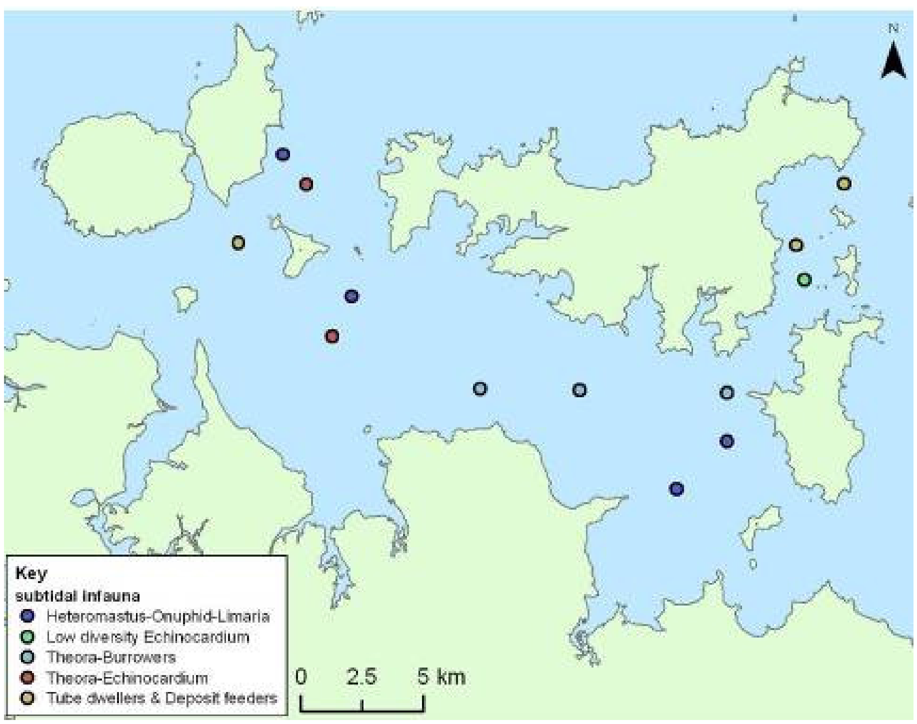
Similar to the analysis of the Southern Kaipara and Kawau Bay, distinct infaunal assemblages were not always associated with particular epifaunal habitats. Within-group dissimilarities based on epifaunal habitats were relatively high, ranging from around 50-60% for coarser substrates such as sponges, high current communities to over 70% for *Atrina* and burrower groups, suggesting that infauna were patchily distributed in space within the finer sedimentary habitats.

Five ecologically important communities were defined (Table 7.2). Two of the community types (*Heteromastus*[*]*-Onuphid-Limaria* and tube dwellers) were found in coarse sand-gravel areas such as the northern entrance to Waiheke Channel and the high current flow areas around Motuihe and Sergeant Channels. The other community types were found in the soft sediments of Tamaki Strait itself and the Waiheke Channel.

Hayward et al. (1997) and Lohrer (2008) documented the increasing presence of the non-indigenous species, *Theora lubrica* in most parts of the Waitemata Harbour. It appears to be similar in the Tamaki Strait, with most shallow soft sediment sites within the harbour having *Theora* present, if not numerically dominant. In the coarser sediments associated with high current flows, another non-indigenous species mentioned by Hayward, the bivalve *Limaria orientalis*, was one of the dominant species.

It is of interest that the sites in the Waiheke Channel were free of both *Limaria orientalis* and *Theora lubrica*. The channel is not free of other non-indigenous species however, with small numbers of the tunicate *Styela clava* and the parchment worm *Chaetopterus sp.* observed.

Figure 7.2:
Subtidal infaunal habitat types in the Tamaki Strait.



Lundquist et al. (2003) describes the subtidal sediments of Te Matuku as being dominated by *Labiosthenolepis leavis*, *Theora lubrica,* Cirratulidae and *Aotearia sulcaticeps*, which is similar to the samples taken in muddy sand sediment in other areas of Tamaki Strait (the *Theora*-burrower association).

[*] Preliminary identification. Awaiting definitive taxonomic analysis

The number of taxa and orders found in the subtidal soft-sediment sites were markedly higher than in the intertidal (maximum 69 compared to 32). There was a positive relationship between community diversity (number of taxa) and sediment coarseness. These areas also had the highest abundances (Table 7.2). When looking at the main community defining organisms, several trends can be seen. Tidal current strength and sediment coarseness would seem to be the main habitat drivers within Tamaki Strait. This is not surprising given the role that bedflow plays in structuring the habitat (sediment resuspension and transport) and delivering food sources to filter feeders. More suspension-feeders were found in coarse sediments which represent high flow complex biogenic habitats of the type described by Hewitt et al. (2008).

Table 7.2:

Relationships seen in subtidal soft sediment infaunal communities found in Tamaki Strait.

Predictor variable	Response Variable	Relationship	p-value	r^2
Sediment coarseness (% >0.5mm)	Diversity (# taxa)	Positive	<0.0001	0.742
	Abundance	Positive	<0.0001	0.712
Tidal current strength	Diversity (H" diversity measure)	Positive	0.0338	0.302
	Sediment coarseness (% >0.5mm)	Positive	0.0229	0.338
	Onuphid abundance	Positive	0.0236	0.336
	Theora lubrica	Negative	0.0168	0.366
	Limaria orientalis	Positive	0.0142	0.381
	Echinocardium	Negative	0.0471	0.270
Depth	*Theora lubrica*	Positive	0.0170	0.365

Table 7.3:

Ecologically important subtidal soft sediment infaunal communities found in Tamaki Strait using the hierarchical rules given in Appendix 1b.

Tube dwellers & deposit feeders	Found in the coarser sediments of the Waiheke Channel, and the north western coast of Motutapu Island
Low diversity *Echinocardium*	Found in fine sediments of the Waiheke Channel. Low abundance and diversity, dominated by *Echinocardium cordatum*.
Heteromastus-Onuphid-Limaria	Associated with coarse sand and gravel-shell sediments. Found in the high tidal flow channel areas such as Motuihe and Sergeant Channels, and coarser sediments of the south eastern section of Tamaki Strait.
Theora-Burrowers	Found in sites with a high mud content throughout the Tamaki Strait bar the Waiheke Channel. Dominated numerically by the invasive bivalve *Theora lubrica*, with lesser numbers of lumbrinereid and cirratulid polychaetes and the bivalves *Lasaea sp*. and *Athritica bifurca*.
Theora-Echinocardium	Found in sites with a high mud content in the eastern part of the Tamaki Strait. Dominated by high numbers of the invasive bivalve *Theora lubrica,* with the burrowing urchin *Echinocardium cordatum* present in significant numbers.

7.3 Subtidal rocky communities

Higher resolution sampling of rocky subtidal areas was conducted at six sites within the Tamaki Strait area. At three of these sites, relatively flat reefs were found at both shallow (~2 m) and deeper (~5 m) depths (Table 7.4). For the other three sites, the only flat areas occurred around 3 m.

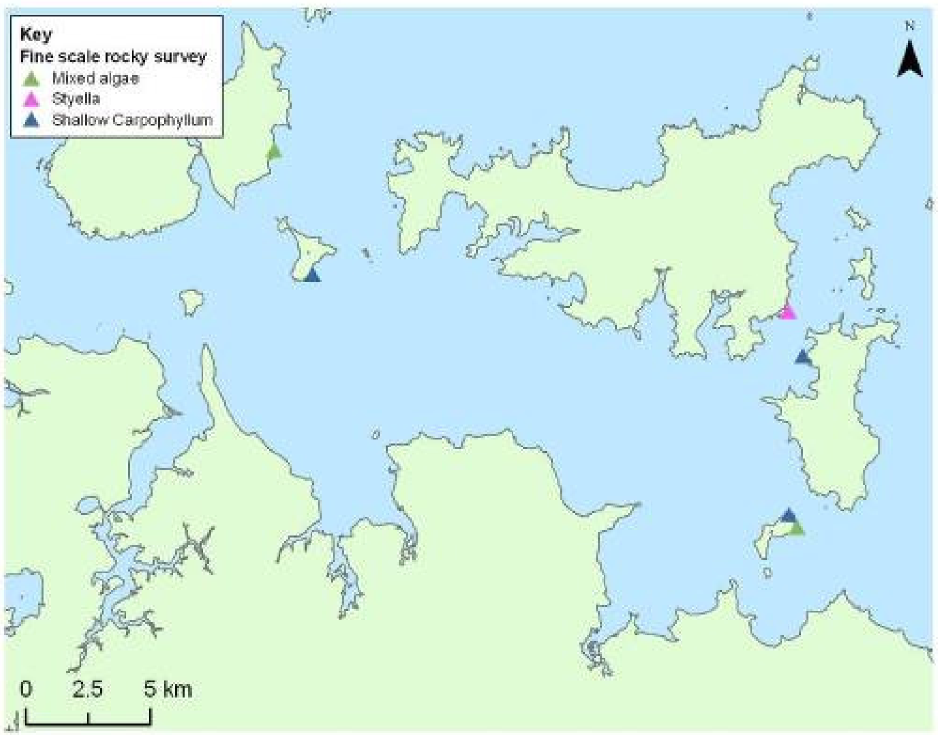
Table 7.3:

Location of fine scale rocky sites.

Location	Depth (m)	Sedimentation (based on site observation)	Sediment type
East Motutapu Island	2.4	Low	Heterogeneous bedrock, cobbles, gravel-shell-coarse sand
	5.1	Low	Heterogeneous bedrock, cobbles, gravel shell coarse sand
East Motuihe Island	1.9	Low	Heterogeneous bedrock, coarse sand
	4.5	Low	Heterogeneous bedrock, cobbles, gravel shell coarse sand
East Waiheke Island	2	High	Bedrock/Sand
	4.5	High	Boulders, gravel-shell-sand
West Ponui	2.5	High	Heterogeneous bedrock, cobbles, gravel-shell-coarse sand
East Pakihi	2.5	None	Boulders/ bedrock
West Pakihi	2.5	High	Heterogeneous bedrock, cobbles, sand.

At all sites there was significant within site dissimilarity, ranging from 42% for Motutapu Deep to 71% for East Pakihi Island, indicating patchy distribution of flora and fauna at these sites. This is consistent with previous studies in the Hauraki Gulf and Tamaki Strait (Walker 1999). Taxonomic diversity based on quadrat sampling ranged between 4 and 16. For those sites where two depths were sampled, as with Kawau Bay, no consistent differences in abundance or diversity between shallow and deep areas were observed.

Figure 7.3:
Rocky fine scale habitats in Tamaki Strait.



When grouped using the Epifaunal classification developed by Shears et al. (2004) there was considerable overlap by habitat type between the Mixed Algae and Shallow *Carpophyllum* groups. This is not surprising given the similarity of characterising Brown Algae flora that are dominant in these groups. As Shears et al. (2004) showed, this is a consequence of any classification system that is separating habitat types that intergrade from one to another.

The majority of the sites surveyed can be considered relatively wave sheltered (as are most sited within the Strait) and so additional factors such as sedimentation are likely to play an increased role in structuring communities (Dayton 1985, Airoldi 2003, Walker 1999). However, given the relative homogeneity of the epifaunal sites within the Strait, the number of samples taken is insufficient to provide insight into the role of these factors.

As noted by Walker (1999), two species associated with reefs in the Hauraki Gulf, were absent (the crayfish *Jasus edwardsii*) or found at only a few sites within the Strait (the Urchin *Evechinus chloroicus*). These species are generally found at reefs with higher wave exposure (of which Tamaki Strait has few). One site where *E. chloroticus* was found in significant numbers was in the Waiheke Channel - a site that was also associated with noticeable amounts of fine sediment cover on the substratum. Fine sediment deposition has been linked with the inhibition of juvenile urchin survival and recruitment within the Hauraki Gulf (Walker 1997).

Tubes from the parchment worm (*Chaetopterus* sp.) were found in low numbers (0-3 per quadrat) at the sheltered sites in Waiheke Channel, Ponui Island and west Pakihi Island, sites at which noticeable amounts of fine sediment deposition also occurred.

8 Tamaki Strait Ecology

8.1 Habitats of Tamaki Strait

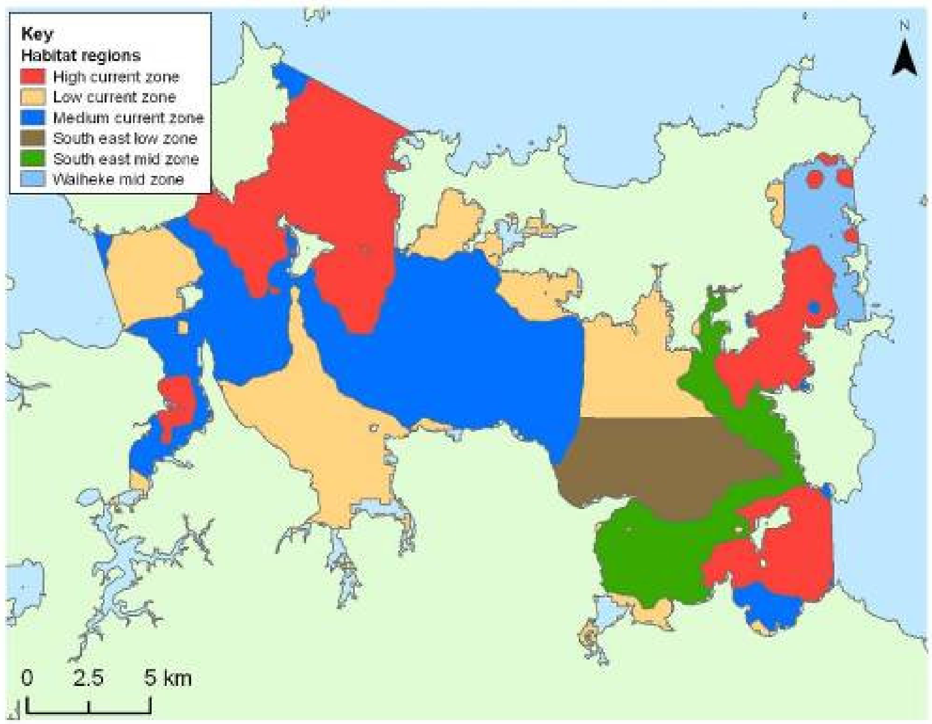
Unlike the variety of habitats able to be determined directly from the side-scan imagery in the Southern Kaipara, side-scan imagery delineated only four main habitat types: rock, *Atrina* beds, areas of significant shell hash and soft-sediment. This was due to the extreme contrast imposed by the presence of both hard and soft substrates and the absence of large epifaunal reefs (such as those produced by serpulids, oysters and bryozoans) or large areas of macroalgae associated with the soft sediment. Furthermore, large epifauna were mostly patchy in distribution.

Using tidal current flow, substrate type and biological community type, the subtidal regions of Tamaki Strait can be divided into several broad habitat zones (Figure 8.2):

- **High current zone**: Found in the fast flowing areas of Tamaki Strait and Waiheke Channel. Coarse tidally-scoured sediments with a high percentage of shell and/or gravel. Where present the epifauna is dominated by filter feeders such as sponges ascidians and *Atrina*. Where *Atrina* is present, it is often associated with sponges or solitary ascidians such as *Styela*. The infauna is dominated by the *Heteromastus-Onuphid-Limaria* complex. The high current zones also contain the more exposed subtidal rocky areas, including *Eklonia radiata* dominated habitats.
- **Mid current zone**: Lower current flow with muddy sand to sandy mud sediments. Prominent epifaunal habitats are patchily distributed, and dominated by *Atrina*. The infauna is characterised by *Theora-Echinocardium* or *Theora*-Burrower communities.
- **Low current zone**: The lowest tidal currents within the study area. The sediments are amongst the muddiest in the Strait, and prominent epifaunal habitats are patchily distributed. Infauna are dominated by *Theora-Echinocardium* or *Theora*-Burrower communities.
- **South Eastern low current zone**: Similar epifaunal habitats to the low current zone. However the very high shell content in the sediments due to historical mussel beds result in the dominant infauna bearing a closer resemblance to those found in the coarser sediments of the Strait associated with higher tidal flows (the complex).
- **South Eastern mid current zone**: Similar epifaunal habitats to the Lower current flow habitat zone. Prominent epifaunal habitats are patchily distributed, and dominated by *Atrina*. As with the south eastern low current zone the coarser shelly sediment in this zone is dominated by *Heteromastus-Onuphid-Limaria* communities.
- **Waiheke Channel Mid current**: Lower current flow with muddy sand–sandy mud sediments. Prominent epifaunal habitats are patchily distributed and

dominated by *Atrina*. The infauna is characterised by low diversity, low abundance, *Echinocardium* dominated communities. There is a notable absence of two prominent invasives: *Theora lubrica* and *Limaria orientalis*.

Figure 8.2:
Broad-scale habitat map of Tamaki Strait, the areas correspond well to categories of tidal current.



It is important to note that while this report describes the general habitats found within Tamaki Strait, the sampling effort within general areas was not at a scale that could discern all of the components of the heterogeneous habitats described.

Powell in 1937 produced one of the first descriptions of benthic soft-sediment communities in the Tamaki Strait. He utilised information from dredge samples to create a map the seabed that included the distributions of several broad groupings of animals. These associations were differentiated intuitively (rather than quantitatively), and reflected the dominance of large, abundant creatures living in the sediments of the harbour (Lohrer 2008). Powell's associations were based largely on molluscs, but also provided information on dominant echinoderms, crustaceans and polychaetes. The habitat areas he described appeared broadly similar to the habitats found today; however there appear to have been changes in the faunal communities over time.

While direct comparison with the Powell study is challenging due to the different techniques employed, there would appear to be a decline in *Echinocardium* communities within the Strait, and a rise in communities dominated by burrow creating-excavating animals. Hayward et al. (1997) also documented changes occurring during the 60 year sampling interval. Hayward suggested that one of Powell's major assemblage types—the "*Echinocardium* association"—had declined in the neighbouring Waitemata Harbour, whereas an "*Atrina zelandica* association" had emerged, and this would appear to be the case for Tamaki Strait as well.

Importantly, many of Hayward's associations of the late 1990's included the non-indigenous bivalves that occur commonly as dominants in assemblages within Tamaki Strait; *Musculista senhousia*, *Theora lubrica* and *Limaria orientalis*.

Compared to Kawau Bay, Tamaki Strait is more homogeneous subtidally, potentially due to larger areas with similar hydrology. Epifaunal habitats observed for Tamaki Strait overlap little with those observed in the Southern Kaipara, unsurprising given the very different hydrodynamic environments. While *Musculista* habitats were seen in both areas, the *Musculista* patches in the Tamaki Strait were less dominant.

The rocky subtidal in Tamaki Strait was diverse and comprised of a number of different algal habitats. Previous studies have found the algal community structures at sites within the Hauraki Gulf generally reflect the wave exposure of those sites (Grace 1983, Cole 1993, Walker 1999), although there can be considerable variation over relatively small spatial scales, depending on the exposure gradients (Shears & Babcock 2004). Most of the habitat within the Tamaki Strait can be considered wave-sheltered, and is made up of several species of *Carpophyllum* (shallow *Carpophyllum* communities or mixed algae in the Shears classification system).

The mixed algal habitat surveyed in Tamaki Strait can be compared to the rocky subtidal sites at Long Bay and surrounding environments (Ford et al. 2004). In both areas, the largest percentage cover was crustose coralline algae /coralline paint algae, with communities dominated by large brown algae (mostly *Carpophyllum sp.*). Both areas are relatively sheltered, and were characterised by an abundance of the gastropods *Turbo smaragdus*. One difference was the presence of significant numbers of the algae *Zonaria turneriana* and *Sargassum sinclairii* in the samples at Long Bay compared to most sites within Tamaki Strait.

8.2 Vulnerability of habitats to anthropogenic threats

Likely impacts on habitats in Tamaki Strait include:

- Increased muddiness of the sediment and spread of mud into presently sandy habitats and decrease in water clarity again associated with climatic and land use changes.
- Urbanisation. Apart from increasing sediment loads and recreational use, urbanisation may result in increased sewage and stormwater inputs into the environment.
- Non-indigenous species (NIS). The sediments of the Waitemata-Tamaki Strait have been invaded by as many as 66 marine NIS (Hayward 2008, Hayward 1997, Cranfield et al. 1998, Inglis et al. 2005).

- Potential for expansion of mangrove dominated habitats, as mangroves may benefit from increased amounts of sediment input associated with land use changes.
- Effects of potential sea level rise on available habitat area and diversity.
- Aquaculture. There are currently few mussel and oyster farms based mostly around Waiheke Island. Numbers are likely to increase in future, with changes to the area designated as Aquaculture Management Areas (AMA's) in the region.

8.2.1 Recreational uses

Tamaki Strait is extensively used for recreation. While recreational pursuits are generally thought to be relatively benign in terms of impacts, they are not without effect on marine benthic communities. Recreational activities that are likely to impact on Tamaki Strait include:

- Trampling of intertidal reef communities. Communities on intertidal rock platforms can be strongly affected by a number of people walking across the surface (Brown and Taylor 1999, Shiel and Taylor 1999) (Figure 8.3). While this level of impact may sound excessive, given the number of people likely to visit these areas, 800 or so visits per year over a particular area is not unreasonable.
- Anchoring, boat wakes and propeller wash. Boat anchors can cause considerable damage to areas with diverse epifauna, such as sponge gardens, *Atrina* beds and kelp beds (Backhurst & Cole 2000). Many such areas occur in Tamaki Strait (Figure 5.1, Figure 7.1). In many Marine Protected Areas, the Department of Conservation has set up "no anchor" areas to protect sensitive locations. There are several zones within the Strait where cables are run, and anchoring is prohibited, and may act as de facto protection from anchor damage. Increasing evidence suggests that the waves produced by even low-wash vessels can have a sizeable impact on infaunal assemblages in otherwise sheltered estuaries. Although this impact is widely regarded to be a consequence of wash coarsening sediment grain-size, it may be due to a number of alternative mechanisms which include enhanced turbidity, decreased larval supply, changed resource availability and/or erosion of animals from the sediment (Bishop 2007).
- Shellfish and finfish extraction. While the harvest of shellfish and finfish is not within the ability of the ARC to manage, this type of extraction is still a threat to the communities of Tamaki Strait, both intertidally and subtidally. Impacts include disruption to community structure by removal of critical species (Lilley and Shiel 2006, Schiel 2006) and the damage caused both to other species and to the seafloor by scallop dredging (Thrush et al. 1998). Unfortunately, information on the effect of extraction is limited to work on a few species.
- Marinas. Development and maintenance (including associated dredging) of marinas has a number of potential impacts including location-specific changes to circulation patterns and increased contaminant levels, but see Turner et al. (1994).

Figure 8.3:

Path worn by one person walking to edge of intertidal platform daily for a year (taken by Prof. David Shiel, University of Canterbury).

8.2.2 Increased muddiness

Sediment accumulation rates in the Auckland region have almost doubled over the last 50 years. This is related to human activities in particular catchment deforestation, something that will be exacerbated by increased urbanisation within the Tamaki region (Swales et al. 2002).

The Wairoa Estuary in particular is in an advanced stage of infilling and will contribute increasing amounts of sediment to the Tamaki Strait in the future. (Lundquist et al. 2003, Swales et al. 2002). Swales et al. (2002) hypothesised that sediment from Wairoa is contributing to the rapid infilling of the Te Matuku estuary, which would also imply sediments from Wairoa are impacting wide areas of the Tamaki Strait.

Effects of increased sediment loads into the marine environment have been Documented in a number of areas. While it is generally considered that effects observed after heavy rain will be confined to depositional environments, the converse may occur if sediment loads increase in sheltered coastal waters. In such areas plants, sensitive to lowered light levels, and suspension feeders, sensitive to lowered food content, or sedimentation frequently occur (Schwarz et al. 2007, Lohrer et al. 2006a, b). Sedimentation onto rocky areas can also disrupt natural patterns of settlement both of fauna e.g., Kina (*Evechinus* chloroticus) (Walker 2007) and flora, e.g., *Homosira* and *Durvillea* (Shiel et al. 2006).

Evidence from prior studies (reviewed in Hume et al. 2002) has linked catchment development and sediment accumulation to ecological effects on estuarine macrofaunal communities.

Long-term monitoring programmes have implicated increased quantities of fine sediments in the decline of populations of the horse mussel *Atrina zelandica* and changes in the structure of benthic faunal communities (Mahurangi estuary: Cummings et al. 2003). More direct and stronger evidence of the effects of mud deposition on benthic fauna is provided by biological process studies that have directly examined the effects of sudden increases in the rate of sedimentation (Hewitt et al. 1998, Norkko et al. 1999, Nicholls et al. 2000, Lohrer et al. 2003) and increased levels of suspended sediments (Thrush et al. 1998, Ellis et al. 1999, Hewitt et al. 2001).

For a summary of the history and potential effects of catchment sediment runoff in the Tamaki Strait region, see Hume et al. (2002), Swales et al. (2002), and Lundquist et al. (2003).

8.2.3 Urbanisation

Auckland is one of New Zealand's fastest growing cities and coastal environments in the Tamaki Strait region will continue to be impacted by urbanisation and development. The coast itself in many areas has been modified to provide for roads and housing has been built close to the coastline. Approximately 4.5 km of coast in the Tamaki Strait has been modified with seawalls/armoured shoreline, and there are around 200 structures on the Tamaki Strait coastline (ARC 2004). Small harbours and estuaries are utilised as marinas or moorings. Development in surrounding catchments has resulted in increased sedimentation and run-off (ARC, 1999).

There are few point sources of contaminants that discharge directly into the Tamaki Strait, and most are relatively localised, e.g., TBT contamination in marinas such as in the Tamaki Estuary (Hayward & Morely 2008). Increased urbanisation can result in increases in diffuse source contamination, e.g., increased nutrient input.

Similar to sediment impacts, ecological impacts associated with increased nutrients (from sewage and gardens) and stormwater contaminants are generally considered to be higher in depositional areas of estuaries than in coastal areas. As the few studies done on sediment effects outside estuaries suggest that this is erroneous, the possibility remains that the same may be true for sewage and stormwater inputs. Some evidence that this may be the case exists in the Benthic Health Model developed for the ARC that includes data from exposed sites in Waitemata Harbour (Anderson et al. 2002, Anderson et al. 2006).

8.2.4 Non Indigenous Species (NIS)

NIS introductions to the Strait are mostly accidental and a side effect of the movements of private and commercial boats internationally as well as nationally (Hayward & Morely 2008, Lohrer et al. 2008), either as fouling on ships' hulls or in ballast tanks.

Like the neighbouring Waitemata Harbour, NIS are common and conspicuous components of hard and soft-sediment habitats in Tamaki Strait and Hauraki Gulf (Lohrer 2008, Hayward & Morely 2008, Inglis et al. 2006). The NIS bivalves

Musculista senhousia, *Theora lubrica*, *Limaria orientalis* and *Crassostrea gigas* are dominants in areas of the Tamaki Strait.

Non-indigenous marine species can have a range of adverse impacts through interactions with native organisms. For instance, NIS can cause ecological impacts through competition, predator-prey interactions, hybridisation, parasitism or toxicity and can modify physical habitat characteristics (Inglis et al. 2006).

8.2.5 Spread of mangrove cover

The preferred habitat for mangroves in general is soft, muddy, waterlogged sediment. While they have some value as in the coastal zone as a buffer against erosion and storm surges (Morrisey et al. 2007), they are not commercially important, and the few ecological community studies that have been done suggest low diversity (Ellis et al. 2004). Their role in the estuarine ecosystem is still under study; Morrisey et al. (2003) suggests that the export of mangrove derived carbon to the open coast is not as important as elsewhere in the world. There does not appear to be any evidence for mangrove-dependency in any New Zealand species of fish, marine invertebrates or birds (Morrisey et al. 2007). There is no evidence for a uniquely characteristic benthic assemblage associated with mangroves (Morrisey 2007). Communities found in dense mangroves are often dominated by the mud crab (*Helice crassa*), with low numbers of nereid polychaetes and the small bivalve *Arthritica bifurca (*Funnell & Hewitt 2005) . As mangroves prograde we would expect to lose the more diverse mud communities as they became more like the low density mangrove areas, followed by more loss in diversity as the low density mangrove areas became high density forests (Morrisey 2007).

Mangrove Habitat expansion has been reported in the upper reaches of the Tamaki Estuary (Hayward 2008) and Whitford Embayment and its tributary creeks (Ellis et al. 2004). Mangrove expansion in the Tamaki Strait is almost exclusively seaward, with landward expansion restricted by the presence of rock or artificial structures (Morrisey et al. 2007). Historical mangrove-habitat expansion was linked to increased sedimentation accumulation rates (SAR) in the tidal creeks and estuaries close to catchment outlets (Swales et al. 2009). While the SAR in most estuaries are predicted to stay the same or increase in the next 100 years (Swales et al. 2002), the predicted acceleration in sea level rise is predicted to limit potential mangrove-habitat availability. The estuaries within Tamaki Strait (Putiki, Awaawaroa, Te Matuku, Tumaki, Whitford, and Wairoa Estuaries) are seen as having low likelihood of significant mangrove-habitat expansion (Swales et al. 2009).

8.2.6 Effect of sea level rise

The intergovernmental Panel for Climate Change (IPCC) predict accelerated sea level rise over the next century due to thermal expansion of ocean waters and loss of ice sheets and glaciers on land. Projected global sea level rise is estimated to be at least 0.5 m, and potentially more than 0.8 m by 2099 (IPCC 2007).

It is difficult to predict the effects of accelerated sea-level rise due to climate warming. Organisms themselves have the potential to evolve and adapt to gradually changing conditions. However, any significant rise in the mean level of the sea could drown intertidal habitats that are not accumulating sediments (i.e., sandy intertidal flats, rocky intertidal zones, etc.). Thus, there is potential for an increase in mangrove-habitat as a proportion of total intertidal habitat within the Strait. At an estuarine scale, the loss of habitat diversity due to increasing proportions of mangrove-habitat may lead to overall loss of biological diversity (Morrisey 2007).

8.2.7 Aquaculture.

Under the current regional plan, areas on Waiheke Island and in the Wairoa estuary have been designated as potential Aquaculture Management Areas (AMA's).

Currently at Waiheke Island there are oyster farms located in Putiki Bay, Awaawaroa Bay, and Te Matuku Bay (within the reserve). A long established mussel farm operates in the Waiheke Channel near Taniwhanui Point. There is an intertidal oyster farm at Kauri Bay in Waroa Bay.

Aquaculture can have adverse effects on the environment such as alteration to natural coastal processes from structures associated with marine farms, or depositional material beneath the farms themselves. Adverse impacts can be minimised by appropriate site selection and aquaculture management practices (ARC 2004).

8.3 Ecological values of Tamaki Strait

Ecosystems are important not just for their biodiversity, but because they provide a range of ecological functions and services that directly or indirectly contribute to society. Direct services include recreation (e.g., diving), aesthetics (e.g., commercial property values), and food (e.g., commercial, traditional and recreational harvesting). Indirect services are more frequently related to ecological function. A large number of ecological functions and services are being provided by the communities observed in Tamaki Strait:

- contributions to benthic productivity, nutrient fluxes and water column productivity (e.g., bioturbating, suspension feeding, macroalgal and deposit feeding communities);
- influences on sediment stability and water clarity (e.g., suspension feeding and tube worm communities);
- provisioning of refugia for juvenile and small fishes (habitat structuring communities such as *Atrina*, sponges and macroalgal communities);
- provisioning of food for predatory and herbivorous fishes (most communities);
- provisioning of food and recreational value for humans (e.g., fishing and shellfish collection, shore and in water activities such as boating and diving).

8.4 Summary

Tamaki Strait contains a variety of habitats, with catchment derived sediment (intertidal), tidal current (subtidal), and wave exposure (inter and subtidal) being important drivers of community structure.

As one of the most utilised areas of coast in New Zealand in terms of urbanisation and sea traffic, Tamaki Strait has immense value both in the range of goods and services provided and its intrinsic cultural and societal importance.

These values are at risk from a number of threats of anthropogenic origin. The major risks are associated with the effects of urbanisation, diffuse source pollution and an increased pressure on the Tamaki Strait area through recreational and commercial use (including aquaculture). The ecological communities of Tamaki Strait are vulnerable to habitat degradation and changes brought about by increased levels of sediment loading and the introduction of non-indigenous species.

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10 Acknowledgements

NIWA acknowledges the help of ARC staff (D. McCarthy, S. Kelly, J. Walker, M. Stewart) in providing advice. Other NIWA staff involved in this project were; A. Miller, D. Lohrer, S. Edhouse, A. Wright –Stow, S. Wadhwa, R. Budd, P. Geering.

11 Appendix I: Ecologically-based Community Classification Rules

11.1 A: Subtidal Soft Sediment

Explanation of the rules and references are given in Hewitt and Funnell (2005), although an extra category (scallops) has been added.

Did the site have high densities of large sedentary surface dwelling organisms (e.g., *Atrina, Perna,* sponges, *Ecklonia, Carpophyllum* or tunicates)?

Did the site have high diversity at the order level? And if so, were there high numbers of large, burrowing or surface mobile organisms or echinoderms, tube builders or suspension feeders?

Was the site dominated by polychaetes? And if so, were they tube-builders, deposit feeders or large predators/scavengers?

Was the site dominated by bivalves? And if so, were they invasive, deposit feeders or suspension feeders?

Finally, was the site dominated by large animals, surface Burrowers or sedentary epibenthic animals?

11.2 B: Rocky subtidal

Explanation of the rules and references are given in Shears et al. (2004).

Habitat	Description	Depth (m)	Notes
Shallow *Carpophyllum*	High abundance *Carpophyllum maschalocarpum*, *C. plumosum* and *C. angustifolium*. *Ecklonia radiata* and red algae also common. Urchins in crevices.	<3	Common within Tamaki Strait, particularly on the wave sheltered southern coast of Waiheke Island.
Ecklonia forest	Monospecific *Ecklonia* (>4 plants/m^2), occasional *C. flexuosum* plants. Urchins.	>5	Found only in the most exposed areas in the Strait such as the north west of Motutapu Island and Rangitoto Island
Carpophyllum flexuosum forest	*C. flexuosum* dominates; on sheltered reefs plants are large and associated with high levels of sediment. On exposed reefs plants are shorter and associated with urchins.	3-12	Found in the more wave exposed areas of the Strait and Waiheke Channel.
Mixed algae	Mixture of large blown algal species. No clear dominance of species, usually partial canopy. Urchins may occur.	2-10	Quite a lot of overlap with Shallow *Carpophyllum*. Common throughout the Strait..
Red foliose algae	>40% cover of red foliose algae. Low number of large brown algae (<4/m^2)	2-9	Not common in the Tamaki strait area, though red foliose algae was a common component of the understory of Macroalgal populations
Turfing algae	>30 cover by turfing algae (e.g., articulated corallines and other red turfing algae). Low numbers large brown algae. Urchins	3-12	Not common in the Tamaki strait area.
Caulerpa mats	Green algae, usually *Caulerpa flexsis* form dense mats.	3-12	Not described in this survey
Urchin barrens	Low numbers large brown algae (<4/m^2), crustose coralline algae. Urchins.	3-9	Where occurred, Urchin abundance was not as great as in other areas of the Hauraki Gulf.
Cobbles	Cobbles (c. <0.5 m diameter), unstable and subject to agitation. Crustose coralline algae dominant as well as high cover bare rock and sand.	~	Found in the more wave exposed areas of the Strait.
Encrusting invertebrates	Usually vertical walls, covered by community of encrusting ascidians, sponges, hydroids and bryozoans.		Not described in this survey
Sponge flats	Sponges visually dominant, high cover of sediment. Usually occurs on the reef-sand interface. Low number of *Ecklonia* may be present.	>10	Observed only within the vicinity of Motuihe Island.
Cystophora		0-10	Not described in this survey

12 Appendix II: Descriptions of the sites sampled in the rocky fine scale survey

12.1 Site R3 (South Ponui Island)

Located on the southern coast of Ponui Island, site R3 is a gently sloping rocky intertidal area with rough sedimentary rock and no major changes in elevation, except for a 1.5 m drop between the high and mid tide zones (Figs 4.4 & 4.4). Clear physical zones are identified: high tide 0 – 11.20 m, mid tide 11.20 – 17 and then the low tide zone 17 – 25 m (waters edge). The site is situated at the base of a steep eroded cliff (reference marker) vegetated with exotic trees, many of which were hanging over the cliff edge. On either side of the rock area, small beaches are present consisting of a graduation of shells, pebbles, sand then mud from high to low tide. On top of the cliff and the neighbouring beaches, the immediate catchment is farmland and a few houses are also present. Directly above the rocky site is a water pipe emerging from the cliff face.

Figure 12.3:
Photograph taken of site R3 (from high to the drop down to mid-low tide), displaying the gentle gradient of the site. It is also possible to see the bands of bare rock and barnacles (high tide water level) and then oysters (mid tide water level).

Zonation bands seem to generally correspond with the physical tidal zones defined, based on elevation and tidal height in relation to the rock. In the high tide zone, this area contained fewer species but the major structuring organism, the brown surf barnacle (*Chamaesipho brunnea*), covers approximately 90% of the rock surface in this zone (Figure 12.5). Moving down to the mid intertidal zone, species diversity is greater but the main species structuring this zone is the rock oyster (*Saccostrea glomerata*) covering between 95-98% of the area. Other species recorded that are in lesser abundance include Neptune's necklace (*Hormosira banksii*) (1-10%), spiny scarlet tube worms (*Pomatoceros caeruleus*) (10%), barnacle species including *Chamaesipho brunnea* and *Chamaesipho columna* (10-20% in some areas). Other common species present that have a percent cover of less than 1% (within the quadrats) include the snakeskin chiton (*Sypharochiton pelliserpentis*) and the dark rock shell (*Haustrum haustorium*). Moving down to 22 m, the low tide zone consists of large 1-2 m boulders sitting on a sandy bottom substrate. Coralline algae (*Corallina officinalis*), *Gelidium caulacantheum*, *Ecklonia radiata* and *Leathesia* sp. are some of the main algal species with average percent covers of approximately 62%, 15%, 5-10% and 30%, respectively. Encrusting sponge species are well represented at this site and include orange encrusting sponges (10-20%) and pink golf ball sponges, *Tethya ingalli* (15%). Many species are found in low abundance in the low intertidal zone including nudibranchs, tunicates (*Cnemidiocarpa bicornuta*), gastropods (*Bulla quoyi*) and small sparse patches of algae such as *Colpomenia peregrine*, *Dictyota ocellata* and *Polysiphonia strictissima*.

Figure 12.5:
Pictures of intertidal species found in each intertidal zone (a. high, b. mid and c. low) at site R3.

a. b. c.

12.2 Site R5 (North Ponui Island)

Site R5 is relatively sheltered and the substrate consists of pebbles and cobbles overlying the bedrock which is extremely fractured with many crevices containing water (tidal pools), in the high tide zone. With a transect stretched from the high water line to the water at low tide we were able to determine the high tide zone (0 – 19 m), mid tide zone (19 -28 m) and low tide zone (28 – 35 m) (Figure 12.7). The major change in elevation at this site is a drop of 1.8 m between the high and mid tide zones and consequently there are notable changes in the communities. The catchment is a very steep eroded cliff, with pine trees scattered along the top and also falling down the face of the cliff.

Figure 12.6:

Photograph taken of site R5 (upper intertidal zone), displaying the flat-gentle gradient of the site.

There is bare rock exposed in the upper intertidal area and there is a patchy distribution of *Chamaesipho brunnea* (5-85%) and *Gelidium pusillum* (1-10%) (Figure 12.8). The mid intertidal is dominated by *Saccostrea glomerata* and *Hormosira banksii*, average percent coverage of 50% and 15%, respectively. In the low intertidal zone *Corallina officinalis*, *Cladophora sp*. and *Hormosira banksii* covers most of the area. Other species found in the crevices and depressions of the rock include gastropods *Turbo smaragdus*, *Perna canaliculus* and *Melagraphia aethiops*.

Figure 12.8:

Pictures of intertidal species found in each intertidal zone (a. high, b. mid and c. low) at site R5.

a. b. c.

12.3 Site R12 (Pasadena Bay)

Across the Waiheke Channel from Ponui Island, site R12 (Pasadena Bay) is located on the eastern coast of Waiheke Island and is an example of many of the kinds of intertidal rocky sites around this area. The expansive flat platform extends 42 m to the waters edge at low tide and is comprised of rough, highly creviced rock littered with many rock pools. Although the overall gradient is minimal (Figs 12.9 & 12.10) the area has drops in elevation (1 m between the high and mid tide zones and again between the mid and low tide zones) due to the large boulders present. The tidal zones defined were 0-25 m for the high tide (60% of the intertidal area), 25-39 m for the mid tide zone and then 39-42 m for the low tide zone. The site is located at the base of a very steep, jagged cliff, dominated by pine, manuka and pohutukawa.

Figure 12.9:
Profile photograph of site R12.

The upper intertidal zone is characterized by large amounts of exposed rock, *Elminius modestus* and terrestrial lichens (e.g., green moss-like, *Rhizoclonium curvatum*) (Figure 12.11). The mid tide zone is dominated by *Saccostrea glomerata* and *Hormosira banksii*, but has considerably more species than those inhabiting the upper intertidal. Interestingly, in the crevices and sheltered by the larger oysters and kelp, there is muddy sediment deposited in this area. As seen in Figure 12.12, many shield limpets (*Scutus breviculus*) inhabit these muddy deposits. In the low tide zone, species diversity is high; however *Corallina officinalis*, covers between 60-95% of the area. Other species were lesser in abundance and were often found in and amongst the *C. officinalis*, for example *Cladophora* sp. and *Hormosira banksii*. Many chiton species (e.g., *Sypharochiton pelliserpentis, Ischnochiton maorianus)* are common in the lower intertidal and also in the mid intertidal as they can withstand high wave energy in exposed areas.

Figure 12.11:
Pictures of intertidal species found in each intertidal zone (a. high, b. mid and c. low) at site R12.

a. b. c.

Photograph of shield limpets (*Scutus breviculus)* on the muddy deposits found at site R12.

12.4 Site R14 (Beachlands)

Site 14 is an expansive rocky intertidal platform, flat and smooth in the upper intertidal and rock with many depressions and small crevices forming micro-tidal pools in the mid and lower inter tidal area(Figure 12.13). The site is situated at the bottom of a very steep and highly eroded cliff. There are houses on top of the cliff; one in particular looks as though it may fall down. The sediment is siltstone and shards very easily. Exotic trees and shrubs overhang the top of the cliff and there are many roots exposed from the cliff face. This site appears to be highly urbanised as there are many drainage pipes protruding from the cliff, there is a steep ladder and stairs allowing access and there is a considerable amount of rubbish and debris on the shore platform itself (e.g., spark plugs, bottles, jars and fishing line. The platform itself is very expansive, with the high tide zone extending from 0-24 m, the mid zone 24-100 m and then the low tide zone 100-112 m (Figure 12.14). At the base of the cliff there are branches, boulders, pebbles and cobbles (many of which appear to have come from the cliff).

Figure 12.13:
Photograph looking up the expansive flat shore platform at site R14. The site is at the base of an eroded cliff which is highly vegetated and urbanised.

Zonation is not very clear at this site, yet there are differences in community composition as you move down the transect to the water. Despite the differences in community composition, species diversity is relatively similar throughout the zones at this site. In the high tide zone, there are many boulders and the bedrock is flat and smooth, with crevices and depressions creating tidal pools. Although most of the area is bare rock, *Pomatoceros caeruleus* and *Elminius modestus*, are the dominant species (Figure 4.15). Anemones (e.g., *Oulactis muscosa* and *Isactina tenebrosa*) and whelks (e.g., *Haustrum scobinia* and *Cominella virgata*) are also present but with low percentage cover. From the mid tide zone through to the waters edge, there is a thick carpet of *Corallina officinalis* (percent cover of approximately 60% in the mid tide and 100% in the low tide zones) and a thin layer of silty mud covering the community (see Figure b and c). *Hormosira banksii*, *Leathesia* sp. and *Turbo smaragdus* are also well represented in the mid tide zone. The low tide zone is not as broad as the other zones (12 m) and is covered with *Corallina officinalis* (100% coverage). Other species present but in low abundance include *Tethya ingalli* (pink golf ball sponge), *Petrolisthes elongates* (half crab), *Coscinasterias calamana* (spiny starfish), *Hormosira banksii* (Neptune's necklace) and orange encrusting sponges.

Figure 12.15:
Pictures of intertidal species found in each intertidal zone (a. high, b. mid and c. low) at site R12.

a.

b.

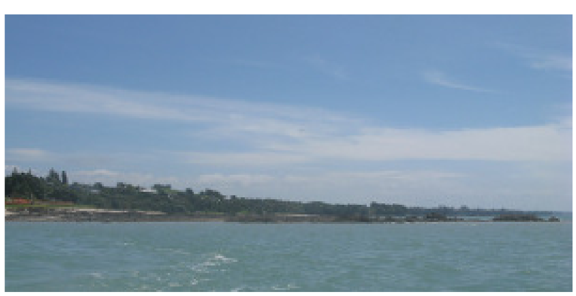
c.

12.5 Site R15 (Omana Beach)

Site R15 is at Omana Beach. The shore is gently sloping and the rocks are very jagged. High tide starts at 0 m and stretches 56 m, mid tide is between 56 and 84 m and low tide is from 85 to 95 m (Figs 4.16 & 4.17). The underwater cables to Waiheke Island begin just to the right. The bedrock is very hard and highly fractured and creviced. Pebbles, cobbles and sand line the crevices, and there are many rock pools along the entire length of the transect. Furthermore, in many of the crevices and rocky pools there is silty sediment, which also smothers the low tide zone. The catchment is highly urbanised (houses and road approximately 20 m away) and is easily accessible. Above high tide (approximately 5-10 m) there are some earth works of some kind and there are also a little sandy/shell hash area extending to the beaches either side of the rocky area.

Figure 12.16:
Profile photograph (a) and looking up the transect (b) at site R15.

a.



b.

Patches of barnacles (*Elminius modestus* and *Chamaesipho brunnea*) have the largest abundance in the high tide zone (Figure 4.18). The periwinkle *Austrolittorina antipodum*, is also relatively common in this zone, along with scattered abundances of *Saccostrea glomerata* and gastropods *Melagraphia aethiops*, *Haustrum scobinia* and *Haustrum haustorium*. Moving down to the mid tide zone, *E. modestus* is still common (50-85% on the tops of larger rocks and boulders). The main taxa found in this area are *Cominella virgata*, *Turbo smaragdus*, *Zeacumatus* sp. and *Nerita atramentos*. In shallow rock pools created by the crevices, many anemones are found to be abiding, especially the speckled anemone *Oulactis muscosa*. At low tide, as mentioned before, the majority of the rocks and boulders were covered with a thin silty layer, similar to that seen at site R14. Despite this, the diversity of species is greater than that found in the two other zones. As at R14, *Corallina officinalis* covered the majority of the available area (between 60-90%). Amongst the turf, *Scytothamnus australis*, *Apophlaea sinclaiirii* and *Hormosira banksii* was also commonly found (around 10% coverage). Other species intolerant of long dry periods like the wrinkled sea squirt (*Cnemidiocarpa nisiotis*), starfish (*Asterina regularis* and *Coscinasterias calamaira*) and a variety of gastropods were also found in low abundances.

Figure 12.18:
Pictures of intertidal species found in each intertidal zone (a. high, b. mid and c. low) at site R16.

a. b. c.

12.6 Site 16 (Whakakaiwhara Point)

Site 16, located on Whakakaiwhara Point, is an example of a short, rocky intertidal area at the base of a steep cliff, where the upper intertidal zone is relatively flat and then it is steep from mid tide to the water edge (Figure 4.19). Between the high and mid tide zones and then the mid to low tide zones there are 1.5-2 m drops (Figure 4.20). Intertidal zones defined were high tide, 0-20 m (most of the area); mid tide 20-22 m and the low tide 22-28 m. Above the high tide mark, there are boulders with orange and green terrestrial lichen at the base of the steep eroding cliff. The bedrock is very hard with many cracks and cobble-lined crevices. The surrounding catchment is predominately grassed with a variety of exotic trees and. A burnt out fire and footwear scattered at the site are signs that people have access to the site.

Figure 12.19:
Photograph of the relatively flat and then steep gradient profile of site R16.

A large covering of *Ulva* spp. was observed in the high tide zone at this site, an approximate covering of 5-45% (Figure 4.21). In addition, *Chamaesipho brunnea*, *Apophlaea sinclaiirii* and *Austrolittorina antipodum* were the other main species in this zone with average percent coverage of 65%, 17% and 3%, respectively. At the mid tide level, rock oysters have the highest percent coverage of approximately 48%. Other species including *Chamaesipho brunnea*, *Hormosira banksii* and *Pomatoceros caeruleus* are also well represented. The number of species is much greater than that in the high tide zone but is comparable to the low tide zone (10 species found in the mid tide zone compared to 13 in the low tide zone). In all, approximately 100% of the low intertidal area is covered by *Corallina officinalis* and *Hormosira banksii*. Many other algal species were found in and around those two dominant species and include *Leathesia* sp., *Codium convolutum*, *Gigartina* sp., *Laurencia distichophylla* and *Gelidium caulacantheum*. Faunal species found that were not as common as snake skin chitons (*Sypharochiton pelliserpentis*) or cat's eyes (*Turbo smaragdus*) were the butterfly chiton (*Crytoconchus porosus*) and the hairy crab (*Pilumnus lumpinus*).

Figure 12.21:
Pictures of intertidal species found in each intertidal zone (a. high, b. mid and c. low) at site R16.

a.

b.

c.

12.7 Site RH (Whites Bay)

Sit RH is located on Waiheke Island's southern coast adjacent to Whites Bay. It is overall a steep rocky intertidal area and is close to a yellow triangular marine reserve marker on the point. The high tide zone (0 m to 14 m) has a relatively flat gradient moving down to the mid tide zone (14m to 16.5 m) where the gradient is a little steeper and then there is a 2 m drop down to the low tide zone from 16 to 20 m along the transect (Figure 12.22 & 4.23). The bedrock is very hard, rough and sharp and there are many ledges, crevices, tidal pools and large boulders. The surrounding catchment is very steep and is vegetated with a mix of both exotic and native trees and grasses. In addition, some trees have eroded from the cliff and are hanging over the cliff top.

Figure 12.22:
Photographs showing (a) the profile of site RH and (b) looking down the transect.

The high intertidal is less species rich compared to the other zones. Whilst there is a large amount bare rock, the brown surf barnacle (*Chamaesipho brunnea*) and *Gelidium caulacantheum* are the main species found occupying much of the area (Figure 12.24). Moving down to the mid tide zone, rock oyster *Saccostrea* *glomerata* and *Chamaesipho brunnea* occupy 75 and 21% of the area, respectively. Gastropod species are well represented but their percent cover of the quadrats is low (<1%) and includes *Melagraphia aethiops*, *Haustrum haustorium*, *Comenella virgata* and *Haustrum scobinia*. Dropping down 2 m to the low tide area, there is a large ledge with a myriad of different species including a noble chiton (*Eudoxochiton nobilis*), butterfly chiton (*Cryptoconchus porosus*), Paua (*Haliotis iris*), and many species of encrusting algae (e.g., *Codium convolutum*) and sponges. The low tide area consists of many large boulders (often 1-2 m diameter) and they are covered with *Corallina officinalis*, *Hormosira banksii* and *Leathesia* sp. (average of 77%, 20% and 6% cover, respectively). Many of the rarer species found during the survey were found at this site in the lower intertidal including, orange golf ball sponges (*Tethya aurantium*), furry chitons (*Acanthochiton* sp.) and the turret shell (*Maoricolpus roseus*).

Figure 12.24:
Photographs of intertidal species found in each intertidal zone (a. high, b. mid and c. low) at site RH.

a. b. c.

12.8 Site RJ (Woodside Bay)

Site RJ is also on the southern coast of Waiheke Island, west of site RH, adjacent to Woodside Bay. It is a sheltered, flat to gently sloping shore platform that drops off into deeper water after the low tide zone (Figure 12.25 & 4.26). The bedrock is very hard and rough, with boulders in the mid tide zone up to 1 m in width. There are many crevices and rock pools and the crevices are filled with cobbles, pebbles and sandy mud. The site is at the base of a very steep cliff vegetated with gorse and other exotic and native trees and shrubs. Farmland can be seen on top of the cliff and on the steep slopes either side of the site. At the base of the cliff there are many boulders and large to small cobbles. There appears to have been a recent land slip, as there was rock and shingle with small trees and shrubs at the base of the cliff above the high tide mark.

Figure 12.25:
Photograph showing the profile of site RJ.

Barnacles *Chamaesipho brunnea* and *Elminius modestus* dominate the high tide zone, whilst there were moist areas with *Hormosira banksii* and *Corallina officinalis* dominating (Figure 12.27). Moving to the mid tide zone, a band of *Hormosira banksii* is clearly visible and covers 85 to 95% of the available area. Amongst the *Hormosira banksii*, *Notheia anomala* is found and is an epiphyte exclusive to the beaded algae. *Saccostrea glomerata* and *Corallina officinalis* are also found in the mid tide zone with approximately 5 to 15% coverage for each in some places. The cat's eye (*Turbo smaragdus*) is the only gastropod found in this zone. In the lower intertidal zone, species diversity is greatest compared to the other intertidal heights. Algal species *Corallina officinalis*, *Hormosira banksii*, *Sargassum sinclari*, *Colpomenia peregrina Cystophora retroflexa* and *Leathesia* sp. are well represented and dominate the low tide in terms of percent coverage. Again, *Turbo smaragdus* is the only gastropod species found. Other species that occupy this niche include pink golf ball sponges (*Tethya ingalli*), hermit crabs (*Pagurus* spp.) and spiny starfish (*Coscinasterias calamaria*).

Figure 12.27:
Photographs of intertidal species found in each intertidal zone (a. high, b. mid and c. low) at site RJ.

a. b. c.