Cawthron Report No. 913

Broad Scale Habitat Mapping of Sandy Beaches and River Estuaries – Wellington Harbour and South Coast

Prepared for

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Prepared for

greater WELLINGTON
THE REGIONAL COUNCIL

by

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EXECUTIVE SUMMARY

Greater Wellington Regional Council (GWRC) recently contracted the Cawthron Institute to map the substrate and vegetation of 13 sandy beaches and 3 river estuaries within Wellington Harbour and the adjoining South Coast. The purpose was to provide a big picture overview of the health of these intertidal habitats which provide significant amenity and environmental value, but which are potentially under pressure due to their location within a densely populated city. This information will assist in both strategic planning and in the management of specific issues associated with resource consents, pollution, and state of the environment monitoring

The approach used field-verified broad scale mapping of habitat zones, supported by fine scale sampling undertaken at specific locations (Petone (2), Lowry Bay, Fitzroy Bay, Hutt River Estuary) to provide a systematic classification of different areas.

- **Broad-scale habitat mapping** provides a robust Geographical Information System (GIS) based methodology for mapping the spatial distribution of intertidal and estuarine substrate characteristics, and flora and fauna features >2m? .
- **Fine-scale environmental monitoring** uses a standardised methodology to measure the spatial variation and inter-relationships of a suite of commonly measured physical, chemical and biological indicators in a common low-mid water intertidal habitat.

This report presents the results of the 2004 sampling programme. Overall, all of the sites were found to be in a healthy condition. Clearly, some localised impacts are present, but across the majority of the habitat at all of the sites, the intertidal sediment quality of the sites was high. At the fine scale sites, selected to provide a picture of the areas most likely to be affected, sediment analyses found no signs of adverse nutrient enrichment or chemical contamination. All sites supported a biological community typical of other NZ beaches and estuaries in good condition.

Grain Size: The beaches and estuaries were predominantly (>95%) sand, the only exceptions being Hutt River Estuary (84% sand, 16% mud), and Fitzroy Bay (estimated >80% gravel).

Nutrient and Organic Enrichment: There were no obvious signs of adverse enrichment at any of the sites. For example, no extensive growths of sea lettuce (*Ulva*), or anoxic sediments were observed. At the fine scale sites, chemical analyses showed the organic loading (measured as AFDW), total nitrogen, and total phosphorus levels were all low.

Toxic Contaminants: Using sediment heavy metal concentrations as an indicator of potentially toxic contaminants, fine scale sites all had levels well below ANZECC (2000) ISQG-Low trigger values. This is a particularly interesting finding for the Hutt River Estuary which was thought to be contaminated prior to this study. However, the results show that the intertidal flats in Hutt River Estuary and the adjacent beaches are uncontaminated and in good health.

Sediment Biota: The animals living within the estuary and beach sediments were typical of other New Zealand estuaries and beaches in good condition. The Hutt River Estuary was dominated by gastropod snails, bivalve shellfish (cockles and pipi), and oligochaete and polychaete worms. Petone Beach was dominated by bivalve shellfish (pipi), and numerous different polychaetes worms. Lowry Bay had very few bivalve shellfish but a similar range of polychaetes worms to Petone. At Fitzroy Bay, only amphipods (sand hoppers) and an oligochaete worm were recorded.

This reflects the harsh natural environment present with abrasive mobile gravels greatly limiting what can survive in the intertidal zone.

Environmental pressures: This study identified the following pressures on beaches and river estuaries during sampling:

- Flooding
- Gravel Extraction
- Grooming
- Introduced Weeds
- Landfill Leachate
- Nutrient Pollution
- Sand Extraction
- Shellfish Collection
- Stormwater
- Vehicles

Overall, the identified pressures were not considered to be significantly adversely affecting the sites investigated beyond localised areas. The low impact reflects mainly the low percentage of each area affected, and to a lesser extent, the intermittent nature of the pressure, the assimilative capacity of the environment, and/or likely recovery rates. Those pressures with longer recovery times all relate to point source impacts *e.g.* landfill leachate, stormwater outfalls, or specific activities *e.g.* gravel extraction. Therefore, while significant at a fine scale, such impacts are quite minor in the broader context of the areas being assessed.

It was also noted that most of the beaches surveyed had little or no buffering vegetation between the beach and the road. Where small buffer strips existed, most were small plantings, and almost all contained weeds with the potential to become pest species. Only Breaker Bay, Camp Bay, and Fitzroy Bay had undeveloped areas extending beyond the back beach, and weeds were also present at these sites. However, while areas of buffering vegetation were limited, many of the beaches have planting initiatives in place where dune and foreshore areas are being revegetated, which is starting to address this issue and greatly increase the aesthetic and ecological value of the areas.

In conclusion, this study found that the intertidal sandy beaches and river estuaries of the Wellington Harbour and South Coast were generally all in a healthy condition and showed no signs of adverse nutrient enrichment or chemical contamination. Environmental pressures do exist but are quite localised and currently do not significantly threaten the health of the majority of the areas investigated.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Approved for release by:
Dr Barry Robertson, Manager – Coastal and Estuarine

1. INTRODUCTION

Greater Wellington Regional Council (GWRC) recently identified a need to gather information on the biological resources of river estuaries and sandy beaches present within Wellington Harbour and the adjoining South Coast to assist in both strategic planning and in the management of specific issues associated with resource consents, pollution, and state of the environment monitoring.

Cawthron were subsequently contracted to collect data using an approach based on the National Estuary Monitoring Protocol (Robertson *et al.* 2002) which uses field-verified broad scale mapping of habitat zones, supported by fine scale sampling undertaken at specific locations to provide a systematic classification of different areas. This approach is a rapid and cost effective way of identifying concerns and prioritising areas requiring more detailed investigation.

- **Broad-scale habitat mapping** provides a robust Geographical Information System (GIS) based methodology for mapping the spatial distribution of intertidal and estuarine substrate characteristics, and flora and fauna features >2m? .
- **Fine-scale environmental monitoring** uses a standardised methodology to measure the spatial variation and inter-relationships of a suite of commonly measured physical, chemical and biological indicators in a common low-mid water intertidal habitat.

The information collected is designed specifically for use within a GIS platform which provides an open and flexible way of using the data to meet management needs as appropriate. GWRC already have a well developed GIS system, and the outputs of this project have been provided as GIS shape files that will directly integrate with this system. This allows each site to be viewed at any scale, and enables other relevant data to be linked to each site of interest using GIS layers or an underlying database as appropriate. This hard copy report provides examples of the type of information that can be generated for representative sites to indicate what is contained within the supplied GIS data layers.

This report describes the methodology and results of the 2004 broad-scale habitat mapping of 3 river estuaries and 13 beaches in Wellington Harbour and the South Coast (Figure 1, Table 1). It also describes the fine-scale physical, chemical and biological monitoring undertaken at the Hutt River Estuary, Petone Beach (2 sites), Lowry Bay, and Fitzroy Bay. For each site we have reviewed existing literature for the area made available by GWRC, and summarised key points where relevant.

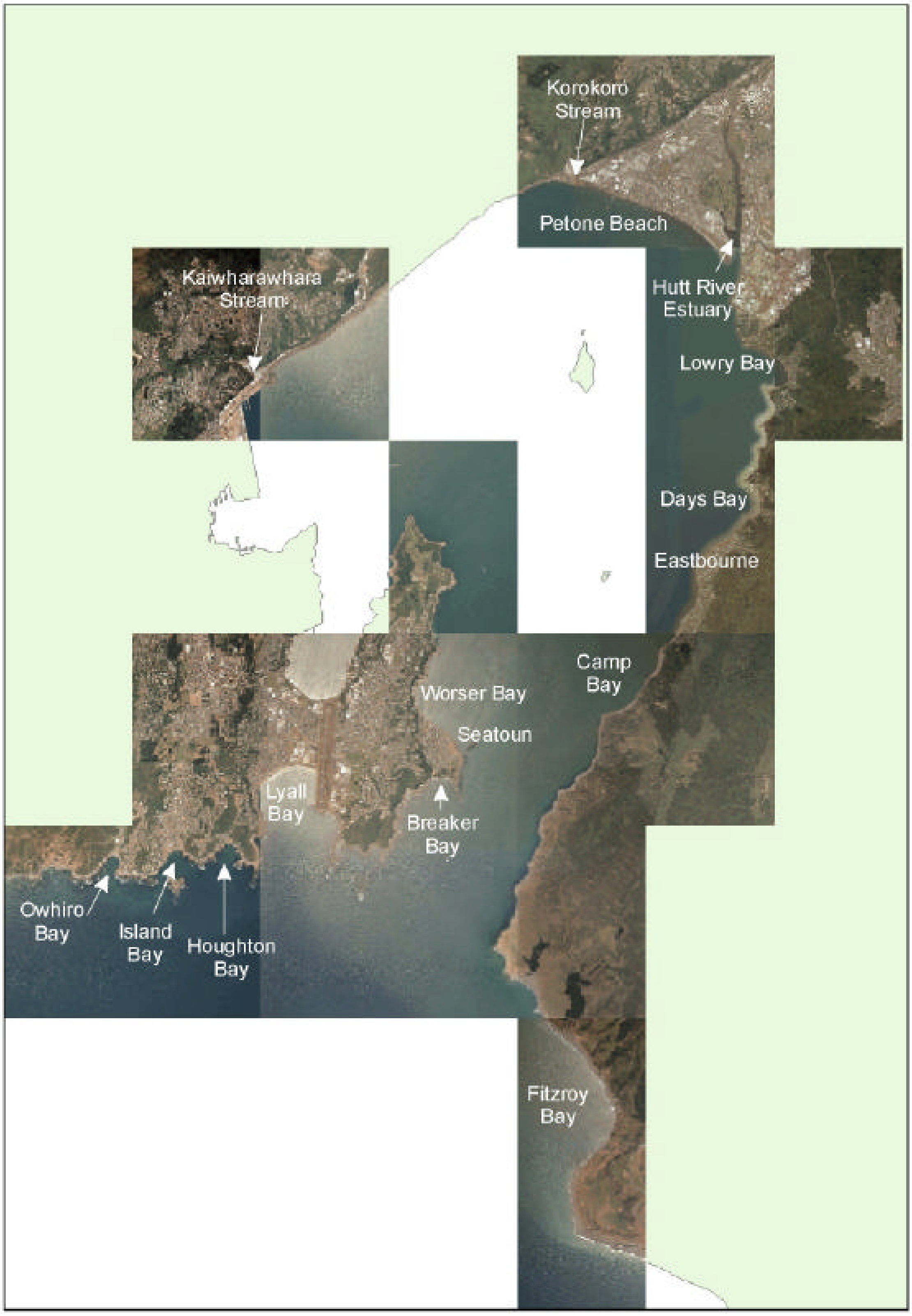


Figure 1 Location of study sites within Wellington Harbour and the South Coast.

Table 1 River estuary and sandy beach monitoring sites assessed for this project.

Location	Broad scale	Fine scale
River Estuary sites		
Kaiwharawhara Stream	✍	
Korokoro Stream	✍	
Hutt River Estuary	✍	✍
Sandy Beach sites	✍	
Owhiro Bay		
Island Bay	✍	
Houghton Bay	✍	
Lyall Bay	✍	
Breaker Bay	✍	
Seatoun	✍	
Worser Bay	✍	
Petone Beach	✍	✍
Lowry Bay	✍	✍
Days Bay	✍	
Eastbourne	✍	
Camp Bay	✍	
Fitzroy Bay	✍	✍

During field sampling we also noted any obvious environmental pressures at each site. A simple risk assessment matrix (Figure 2) was used to define the level of concern associated with different pressures on a habitat in terms of potential sensitivity and consequence using a colour ranking from high (red) to low (green). The use of letters and numbers (A1-D4) enables further definition of the drivers for the level of concern based on the percentage of the resource affected, and the likely timeframe for recovery. It is important to note that the matrix does not confirm the presence of an impact, it simply indicates where pressures may be present, and the possible consequences associated with specific pressures should they occur.

RECOVERY FROM IMPACT

% OF HABITAT AFFECTED		(SLOW) >10 years	5-10 years	1-4 years	(RAPID) <1 year
		1	2	3	4
>50% (LARGE)	A	A1	A2	A3	A4
30-50%	B	B1	B2	B3	B4
10-30%	C	C1	C2	C3	C4
0-10% (SMALL)	D	D1	D2	D3	D4

Figure 2 Risk assessment matrix for evaluating levels of concern to habitat pressures at each site.

The environmental pressures identified at different sites and covered in this report are:

- Flooding
- Gravel Extraction
- Grooming
- Introduced Weeds
- Landfill Leachate
- Nutrient Pollution
- Sand Extraction
- Shellfish Collection
- Stormwater
- Vehicles

This inclusion of such information is not intended to provide a complete or detailed assessment of pressures, but is a broad overview of the activities that may be influencing the environmental quality at each site, and to provide some indication of their likely significance.

Section 2 and 3 of this report describe the broad scale and fine scale sampling methods. Section 4 provides an overview of the work undertaken and gives the results of fine scale chemical sampling of other estuaries and beaches in NZ to place the results in a wider context. Summaries are then provided, including broad scale habitat maps and the results of the fine scale sampling where relevant, for each site.

2. BROAD-SCALE HABITAT MAPPING

The aim of the broad-scale habitat mapping is to describe the intertidal environment according to dominant habitat types based on surface features of substrate characteristics (mud, sand, cobble, rock, *etc*) and vegetation type (eelgrass, salt marsh, coastal plant species, *etc*), in order to develop a baseline map. This procedure involves the use of aerial photography together with detailed ground-truthing and digital mapping using GIS technology. Once a baseline map has been constructed, habitat information can be used to indicate the potential sensitivity of different areas to identified pressures such as beach grooming, vehicle use, stormwater discharges, *etc*. or to identify areas where further information may be needed to improve resource management. It also provides an indication of the organisms likely to be present in different substrate types, an aspect that can be confirmed through fine scale sampling.

The mapping also provides a template whereby changes in the position and/or size of habitats (MfE Confirmed Indicators for the Marine Environment, ME6, 2001) can be assessed by repeating the mapping exercise, or comparing it to historical data (usually aerial photographs). This information can then be used to evaluate the implications of natural and human induced changes (and ultimately land use characteristics and related water and sediment quality) on the structure and function of the intertidal ecosystem. An outline of the approach is provided below, with full detail in Robertson *et al.* (2002).

2.1 Classification and definitions of habitat types

The classification of estuarine habitat features follows the proposed national classification system (with adaptations), which was developed under a Ministry of the Environment SMF (Sustainable Management Fund) programme (Monitoring Changes in Wetland Extent: An Environmental Performance Indicator for Wetlands) by Lincoln Environmental, Lincoln. The classification system for wetland types is based on the Atkinson System (Atkinson 1985) and covers four levels, ranging from broad to fine-scale. The broad-scale mapping focuses on Levels III and IV. Substrate classification is based on surface layers only and does not consider underlying substrate; *e.g.* cobble or gravel fields covered by sand would be classed as sand flat.

Table 2 Classification of estuarine habitat types.

Estuarine Habitat Classification System		
Level I	Hydrosystem	(*e.g.* intertidal river delta)
Level II	Wetland Class	(*e.g.* saltmarsh, mud/sand flat, macroalgal bed)
Level III	Structural Class	(*e.g.* marshland, mobile sand, cobble)
Level IV	Dominant Cover	(*e.g.* Leptocarpus similis)

The specific level III structural classes form the basis of the broad scale mapping and are detailed in Table 3.

Although the above classification has been developed primarily for wetland and estuarine areas, it is applicable to most of the current project due to it being restricted to sandy beach and river estuary habitats which are predominantly made up of gravel, sand, and mud. Where habitat types are not covered by the above structural classes, for example creviced intertidal rock, we have utilised the National Marine Habitat Classification for Britain and Ireland (Connor *et al.* 2003) as there is no coastal habitat classification system specific to New Zealand. Connor *et al.* (2003) provides an appropriate and cost effective structure suitable for use in New Zealand. The classification is structured in hierarchical format, and through a series of habitat matrices (Table 4).

Table 3 Definitions of Classification of Level III Structural Class - Estuaries.

Cushionfield: Vegetation in which the cover of cushion plants in the canopy is 20-100% and in which the cushion-plant cover exceeds that of any other growth form or bare ground. Cushion plants include herbaceous, semi-woody and woody plants with short densely packed branches and closely spaced leaves that together form dense hemispherical cushions.

Herbfield: Vegetation in which the cover of herbs in the canopy is 20-100% and in which the herb cover exceeds that of any other growth form or bare ground. Herbs include all herbaceous and low-growing semi-woody plants that are not separated as ferns, tussocks, grasses, sedges, rushes, reeds, cushion plants, mosses or lichens.

Lichenfield: Vegetation in which the cover of lichens in the canopy is 20-100% and in which the lichen cover exceeds that of any other growth form or bare ground.

Reedland: Vegetation in which the cover of reeds in the canopy is 20-100% and in which the reed cover exceeds that of any other growth form or open water. If the reed is broken the stem is both round and hollow – somewhat like a soda straw. The flowers will each bear six tiny petal-like structures – neither grasses nor sedges will bear flowers, which look like that. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either hollow or have a very spongy pith. Example include Typha, Bolboschoenus, Scirpus lacutris, Eleocharis sphacelata, and Baumea articulata.

Rushland: Vegetation in which the cover of rushes in the canopy is 20-100% and in which the rush cover exceeds that of any other growth form or bare ground. A tall grasslike, often hollow-stemmed plant, included in the rush growth form are some species of Juncus and all species of, Leptocarpus. Tussock-rushes are excluded.

Sedgeland: Vegetation in which the cover of sedges in the canopy is 20-100% and in which the sedge cover exceeds that of any other growth form or bare ground. "Sedges have edges." Sedges vary from grass by feeling the stem. If the stem is flat or rounded, it's probably a grass or a reed, if the stem is clearly triangular, it's a sedge. Sedges include many species of Carex, Uncinia, and Scirpus. Tussock-sedges and reed-forming sedges (c.f. REEDLAND) are excluded.

Grassland: Vegetation in which the cover of grass in the canopy is 20-100%, and in which the grass cover exceeds that of any other growth form or bare ground. Tussock-grasses are excluded from the grass growth-form.

Tussockland: Vegetation in which the cover of tussock in the canopy is 20-100% and in which the tussock cover exceeds that of any other growth form or bare ground. Tussock includes all grasses, sedges, rushes, and other herbaceous plants with linear leaves (or linear non-woody stems) that are densely clumped and >100 cm height. Examples of the growth form occur in all species of Cortaderia, Gahnia, and Phormium, and in some species of Chionochloa, Poa, Festuca, Rytidosperma, Cyperus, Carex, Uncinia, Juncus, Astelia, Aciphylla, and Celmisia.

Shrubland: Cover of shrubs in canopy 20-80%. Shrubs are woody plants <10 cm diameter at breast height (dbh).

Scrub: Woody vegetation in which the cover of shrubs and trees in the canopy is > 80% and in which shrub cover exceeds that of trees (c.f. FOREST).

Treeland: Cover of trees in canopy 20-80%. Trees are woody plants >10cm dbh

Forest: Woody vegetation in which the cover of trees and shrubs in the canopy is >80% and in which tree cover exceeds that of shrubs. Trees are woody plants = 10 cm dbh. Tree ferns = 10cm dbh are treated as trees.

Seagrass meadows: Seagrasses are the sole marine representatives of the Angiospermae. They all belong to the order Helobiae, in two families: Potamogetonaceae and Hydrocharitaceae. Although they may occassionally be exposed to the air, they are predominantly submerged, and their flowers are usually pollinated underwater. A notable feature of all seagrass plants is the extensive underground root/rhizome system which anchors them to their substrate. Seagrasses are commonly found in shallow coastal marine locations, salt-marshes and estuaries.

Macroalgal bed: Algae are relatively simple plants that live in freshwater or saltwater environments. In the marine environment, they are often called seaweeds. Although they contain cholorophyll, they differ from many other plants by their lack of vascular tissues (roots, stems, and leaves). Many familiar algae fall into three major divisions: Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae). Macroalgae are algae observable without using a microscope.

Firm mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When walking on the substrate you'll sink 0-2 cm.

Soft mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When walking on the substrate you'll sink 2-5 cm.

Very soft mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When walking on the substrate you'll sink greater than 5 cm.

Mobile sand: The substrate is clearly recognised by the granular beach sand appearance and the often rippled surface layer. Mobile sand is continually being moved by strong tidal or wind-generated currents and often forms bars and beaches. When walking on the substrate you'll sink less than 1 cm.

Firm sand: Firm sand flats may be mud-like in appearance but are granular when rubbed between the fingers, and solid enough to support an adult's weight without sinking more than 1-2 cm. Firm sand may have a thin layer of silt on the surface making identification from a distance impossible.

Soft sand: Substrate containing greater than 99% sand. When walking on the substrate you'll sink greater than 2 cm.

Gravel field: Land in which the area of unconsolidated gravel (2-20 mm diameter) exceeds the area covered by any one class of plant growth-form. Gravel fields are named from the leading plant species when plant cover of = 1%.

Cobble field: Land in which the area of unconsolidated cobbles/stones (20-200 mm diam.) exceeds the area covered by any one class of plant growth-form. Cobble fields are named from the leading plant species when plant cover of = 1%.

Boulder field: Land in which the area of unconsolidated bare boulders (> 200mm diam.) exceeds the area covered by any one class of plant growth-form. Boulderfields are named from the leading plant species when plant cover is = 1%.

Rock/Rock field: Land in which the area of residual bare rock exceeds the area covered by any one class of plant growth-form. Cliff vegetation often includes rocklands. They are named from the leading plant species when plant cover is = 1%

Table 4 Classification of marine habitat types.

Marine Habitat Classification System (adapted from Connor *et al.* 2003)		
Level 1	Environment	A single category is defined within EUNIS to distinguish the marine environment from terrestrial and freshwater habitats.
Level 2	Broad habitats	These are extremely broad divisions (e.g. intertidal, shallow subtidal, deep subtidal)
Level 3	Habitat complexes	These serve to provide very broad divisions which reflect major differences in biological character (such as high energy rock).
Level 4	Biotope complexes	These are groups of biotopes with similar overall physical and biological character (such as kelp and/or red seaweeds).
Level 5	Biotopes	These are typically distinguished by their different dominant species or suites of conspicuous species (such as *Perna canaliculus* and *Macrocystis pyrifera*).
Level 6	Sub-biotopes	These are typically defined on the basis of less obvious differences in species composition (e.g. less conspicuous species), minor geographical and temporal variations, more subtle variations in the habitat or disturbed and polluted variations of a natural biotope. They will often require greater expertise or survey effort to identify.

The existing system can be used with very little modification to level 4, the lowest level the broad-scale mapping focuses on. New Zealand specific adaptation is required at levels 5 and 6 and falls outside the scope of the current project. As it was not a targeted habitat in this study, all intertidal rock was grouped as "rock", and then further classified based on the presence of the following attributes where present: textured, creviced, rock pools, and surge gullies. Fine scale assessment in intertidal areas where such habitat was common would require further adaptation of this classification system.

2.1.1 Habitat codes and terminology

At most beach sites vegetation patches were present in the upper margins of the beach or river estuaries. Vegetation provides an important buffer between the land and the sea, influencing the visual character of an area, and playing an important role in dune stability, mitigation of contaminant inputs, erosion protection, and the provision of wildlife habitat.

Due to its important role we have classified the vegetation present using an interpretation of the Atkinson system, whereby dominant plant species are coded by using the two first letters of their Latin species and genus names *e.g.* ribbonwood, *Plagianthus divaricatus,* is coded as Pldi. An indication of dominance is provided by the use of ( ) to distinguish subdominant species *e.g.* Core(Pldi) indicates that taupata, *Coprosma repens,* is dominant over ribbonwood. The use of ( ) is not based on percentage cover but the subjective observation of which vegetation is the dominant or subdominant species within the patch. In this study vegetation was not specifically classified based on height, although a measure of this is obtained based on the structural class vegetation is placed in *e.g.* treeland vs scrub vs shrubland. The criteria for inclusion was dominant vegetation that had a spatial coverage of >2m? and was visually obvious. Where relevant, the presence of invasive weeds and exotic vegetation has also been noted, although in many cases invasive weeds were present in patches <2m? .

2.1.2 Ground-truthing and digitisation of habitat features

Field surveys are undertaken to verify aerial photography, and identify dominant habitat and map boundaries. The approach involves an experienced coastal scientist walking over the whole estuary or beach at low-mid tide, identifying the dominant habitats/substrate types and their spatial extents, and recording these as codes on colour aerial images at a scale of approximately 1:5,000 or 1:10,000 (*e.g.* Figure 3).

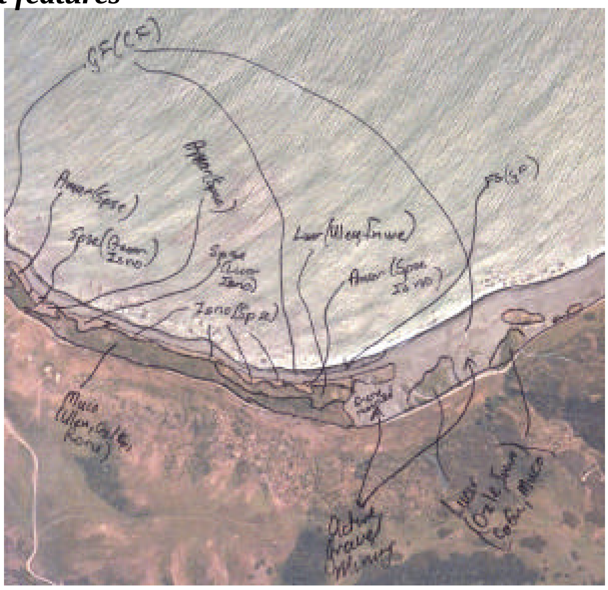


Figure 3 Example of field sheet showing habitat classification on an aerial photo.

The lower boundary is set at MLWS (Mean Low Water Spring). The upper boundary is set at MHWS (Mean High Water Spring), however in some areas it extends above this into supra-littoral habitat where it is considered integral with the upper intertidal. As the vegetation buffering beach and estuary margins in the Wellington region has important implications for the management of these areas, we have generally extended the mapping to the nearest clear delineation point *e.g.* roads, manmade seawalls, ridgelines, *etc*.

Vegetation and substrate features identified during the field surveys were then digitally mapped as precisely as possible on-screen from the rectified photograph. The GIS shape files were then used to visually represent each specific feature, as well as to calculate the area cover for different habitat types.

3. FINE-SCALE ASSESSMENT

3.1 Overview

Fine-scale monitoring involves measuring environmental characteristics that are known to be indicative of estuary or coastal condition, and are likely to provide a means for detecting habitat degradation, as well as providing a measure of subsequent change. The environmental characteristics assessed usually include a suite of commonly used benthic indicators (see Robertson *et al.* 2002, Section 2.4 for justification). Fine scale sampling was undertaken between 15-19 March 2004 as follows:

- Hutt River Estuary: four sites in dominant mid-low water intertidal habitat.
- Petone Beach (2), Lowry Bay, Fitzroy Bay: three sites in the upper tidal zone and three sites in the lower tidal zone.

At Petone Beach, sites were selected from sections of the beach that are maintained by beach grooming to remove seaweed and driftwood, and from ungroomed sections. This was to see if there was any obvious impact from grooming that was evident in the biological community or chemical characteristics. The selection of sites from Fitzroy Bay through Lowry Bay to Petone Beach sought to capture the identified gradient from exposed gravel beaches to more sheltered sandy beaches.

This approach sought to link the broad scale mapping of substrates to the chemical and biological status of the different substrates identified. By verifying the chemical and biological status, general predictions can then be made of the health and likely susceptibility to impact of sites elsewhere in the region within corresponding substrate types. For example, the community present in the firm sand of Petone Beach will indicate the community likely to be present in other firm sands within the Harbour. Similarly, the chemical status of the different sediment types will indicate likely accumulation within each, and the potential for subsequent biological effects.

At each site, composite sediment samples were taken and analysed for the following variables;

- Grain size (% sand, mud, gravel)
- Ash free dry weight (organic content)
- Total Nitrogen
- Total Phosphorus
- Cadmium
- Chromium
- Copper
- Lead
- Nickel
- Zinc
- Macroinvertebrate abundance and diversity (infauna and epifauna)

3.2 Sampling methods

The specific sampling methods used are detailed below.

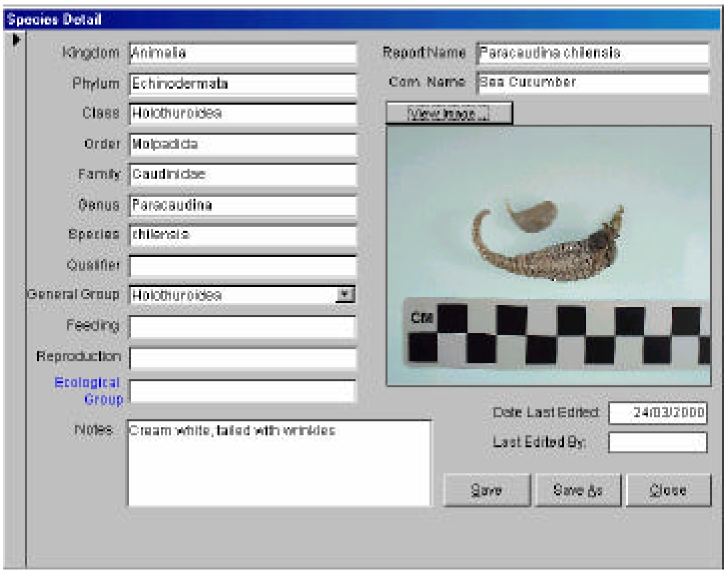
1. **Sediment core profiles** (and depth of Redox Discontinuity Layer):
   - One randomly positioned 60 mm perspex core was collected to a depth of at least 100 mm from each plot.
   - The core was extruded onto a white plastic tray, split lengthwise (vertically) into two halves and photographed along side a ruler and a corresponding label.
   - The stratification of colour and texture, particularly the occurrence of any black (anoxic) zones, were used to assess the depth of the lighter-coloured surface layer - the depth of the Redox Discontinuity Layer (RDL).

2. **Epifauna** (surface-dwelling animals):
   - Epifauna were assessed from one randomly placed 0.25 m^2 quadrat within 1m of the Perspex core sample in each plot. All animals observed on the sediment surface were identified and counted, and any visible microalgal mat development noted. The species, abundance and related descriptive information were recorded on specifically designed, waterproof field data sheet containing a checklist of expected species.
   - Field notes were transferred to a spreadsheet or database for statistical analyses.

3. **Macroalgae** (seaweeds) % cover:
   - Where a significant macroalgal cover existed, the percent coverage was estimated using a grid quadrat. Vegetation that overlaped grid intersections (49 in total, including the outer frame) was counted and the result converted to a percent (*i.e.* No. x 2 = %).

4. **Infauna** (animals living buried in the sediments):
   - Three replicate sediment cores were collected from each site at random positions using a 130 mm diameter (area = 0.0133 m^2) PVC tube.
   - The core tube was manually driven 150 mm into the sediments, removed with core intact and inverted and washed through an attached 0.5 mm nylon mesh bag using local seawater. The remaining contents were carefully emptied into a plastic container with a waterproof label and preservative (95% ethanol - enough to roughly double the volume of the sample).
   - Sample processing was done in a laboratory where samples were washed through a series of sieves (from 4.0 mm to 0.5 mm) within a fume cabinet to roughly sort invertebrates into size classes.
   - The contents of each sieve were systematically scanned, by eye or by microscope, and the invertebrate species identified (to at least the family level), counted and recorded.
   - The data were then transferred to a spreadsheet or database (as illustrated on the following page). Cawthron's database uses a standardised format for all benthic monitoring data which allows for direct and easy comparisons with other regional data. It also utilises a master species list which ensures data accuracy and reporting.
   - At Petone Beach we compared the results of sampling using a 0.5 mm core, with the results obtained using a series of larger sieves (2mm, 5mm, 10mm and 20mm). The advantage was that the coarse sieves allowed larger volumes of sediment to be rapidly processed in the field

with sampled animals counted and released. This enabled a greater spatial coverage. However, the trade off was the reduced sampling resolution, with many small animals passing unobserved through the sieves. These results are discussed further in Section 4.2.2.



5. Chemical analyses

- Composite samples (each approx 250 gms) were collected from the top 20 mm of fine sediment areas at each site into pre-labelled ziplock plastic bags. Samples were stored on ice in the field and then frozen prior to shipping to the laboratory for analysis.

4. RESULTS AND DISCUSSION

4.1 Overview

A general overview of results is presented and discussed below, with broad scale maps of each site and site specific summary tables presented in Sections 4.2 to 4.17, starting with sites where fine scale assessments were undertaken, followed by remaining sites discussed in geographical sequence from west (Owhiro Bay) to east (Camp Bay). Tables 5 and 6 summarise the substrate and vegetation data for sandy beach and river estuary sites respectively. Table 7 summarises the dominant coastal foredune species identified across all sites. Fine scale chemical and biological results are presented in Tables 8a and 9.

Table 5 Summary of the area (Ha) of substrate and vegetation mapped at each sandy beach site.

Habitat type / Dominant species	Owhiro Bay	Island Bay	Houghton Bay	Lyall Bay	Breaker Bay	Seatoun	Worser Bay	Petone	Lowry Bay	Days Bay	Eastbourne	Camp Bay	Fitzroy	Grand Total	% area mapped
Treeland							**0.05**				**0.27**			**0.32**	**0.3**
Metrosideros excelsa							0.05				0.27			0.32	0.3
Scrub	**0.27**	**0.01**	**0.10**	**0.01**	**0.08**	**0.19**	**0.29**						**2.58**	**8.18**	**7.5**
Coprosma repens	0.27	0.01	0.04	0.01	0.08	0.17	0.29							0.87	0.8
Metrosideros excelsa						0.02								0.02	0.0
Muehllenbeckia complexa													2.58	2.58	2.4
Pittosporum crassifolium			0.06											0.06	0.1
Shrubland		**0.04**	**0.13**		**0.52**	**0.21**		**1.31**					**1.87**	**4.08**	**3.8**
Coprosma repens								0.81						0.81	0.7
Cupressus macrocarpa						0.21								0.21	0.2
Lupinus arboreus		0.04											1.87	1.91	1.8
Metrosideros excelsa					0.11									0.11	0.1
Myoporum laetum								0.49						0.49	0.5
Pittosporum crassifolium			0.13		0.41									0.54	0.5
Rushland													**0.24**	**0.24**	**0.2**
Isolepis nodosa													0.24	0.24	0.2
Grassland	**0.08**	**0.18**	**0.03**	**1.02**	**0.16**	**0.31**	**0.37**	**0.86**		**0.18**	**2.79**	**0.03**	**1.01**	**7.03**	**6.5**
Ammophila arenaria		0.14	0.00	0.90		0.31	0.37	0.77		0.18	2.54		0.82	6.04	5.6
Desmoschoenus spiralis	0.08	0.04	0.03	0.13							0.25	0.03		0.55	0.5
Pennisetum clandestinum					0.16									0.16	0.1
Spinifex sericeus								0.09					0.19	0.28	0.3
Tussockland		**0.06**	**0.14**		**2.52**			**0.22**					**0.27**	**3.38**	**3.1**
Austrofestuca littoralis		0.06												0.06	0.1
Cortaderia fulvida													0.27	0.27	0.3
Phormium tenax			0.14		2.52			0.22						2.87	2.6
Herbfield		**0.02**	**0.02**										**0.14**	**0.88**	**0.8**
Carpobrotus edulis		0.02	0.02											0.04	0.0
Sarcocornia quinqueflora													0.14	0.14	0.1
Weeds											**0.40**			**0.40**	**0.4**
Introduced weeds											0.40			0.40	0.4
Unvegetated	**7.14**	**2.87**	**2.22**	**10.86**	**3.19**	**2.39**	**1.61**	**8.61**	**0.44**	**1.25**	**7.10**	**3.89**	**23.50**	**81.73**	**75.2**
Boulder field		0.00	0.03	0.67	0.09	0.17						0.02		0.99	0.9
Cobble field	0.10		0.05		0.02	0.02	0.14							0.33	0.3
Firm sand	0.59	1.78	1.05	8.15		0.93	1.14	5.72	0.98	1.05	1.62			23.02	21.2
Gravel field	0.72	0.21		0.79	2.58	1.24		2.89		0.16	5.06	3.85	23.50	41.00	37.7
Mobile sand														0.00	0.0
Rock	5.73	0.88	1.08	1.25	0.50		0.32		0.74	0.04	0.42	0.02		10.98	10.1
Rock field									1.11					1.11	1.0
Grand Total	**7.49**	**3.18**	**2.64**	**11.90**	**6.47**	**3.10**	**2.32**	**11.00**	**2.83**	**1.44**	**10.56**	**3.92**	**29.62**	**108.62**	**100.0**

As the survey predominantly targeted sandy beaches, it was no surprise that the most dominant habitat was unvegetated sand and gravel (Table 5). Most beaches were flanked by either natural rock or constructed rockwalls, while many also contained upper margins characterised by the presence of artificial seawalls immediately adjacent to roads. It was notable that there were no forest areas bordering any of the beaches, with the vegetation generally limited to grassland in the upper dune areas, flanked by small patches of shrubland and scrub. Many of these areas include revegetation plantings *e.g.* Petone Beach, Island Bay, Seatoun, Days Bay. The sites with the largest naturally vegetated margins were Fitzroy Bay, Camp Bay, and Breaker Bay.

In the river estuaries, Korokoro and Kaiwharawhara were both gravel dominated and not particularly estuarine in character, having confined beds and little intertidal area. There was little vegetation present at the mouths of either Korokoro or Kaiwharawhara Streams. Kaiwharawhara was dominated by introduced weeds and potential pest species and is a highly modified area. Korokoro is also highly modified and cuts through reclaimed land. In contrast the Hutt River estuary had large tidal flats comprising predominantly soft mud (Table 6). Hutt River had the widest range of substrate types present of all the sites included in this study. The vegetation present was limited to amenity plantings bordering the north and west of the estuary.

Table 6 Summary of the area (Ha) of substrate and vegetation mapped at each river estuary site.

Habitat type Dominant species	Kaiwharawhara	Korokoro	Hutt River	Grand Total	% area mapped
Scrub	**4.26**		**0.38**	**4.64**	**38.2**
Acacia spp.	4.26			**4.26**	**35.0**
Coprosma repens			0.38	**0.38**	**3.1**
Tussockland			**0.18**	**0.18**	**1.4**
Phormium tenax			0.18	**0.18**	**1.4**
Herbfield		**0.70**		**0.70**	**5.8**
Sarcocornia quinqueflora		0.70		**0.70**	**5.8**
Unvegetated	**0.55**	**1.69**	**4.40**	**6.64**	**54.6**
Boulder field		0.51	0.15	**0.66**	**5.4**
Cobble field	0.03		0.32	**0.35**	**2.9**
Firm sand			0.08	**0.08**	**0.7**
Gravel field	0.52	1.18	0.31	**2.00**	**16.5**
Mobile sand			0.07	**0.07**	**0.5**
Rock field			1.50	**1.50**	**12.4**
Soft mud			1.98	**1.98**	**16.2**
Grand Total	**4.81**	**2.40**	**4.96**	**12.16**	**100.0**

A problem encountered in analysing and writing up the data was that the margins of the sandy beaches and river estuaries (*e.g.* rocky outcrops, constructed rockwalls, vegetated dunes, plantings, *etc.*) were mapped, but the extent mapped was not standardised across each beach or estuary area. This prevented the direct comparison of beaches. In retrospect, it would have been preferable to have used a tighter definition of the sandy beach boundaries to standardise this aspect.

Table 7 Coastal foredune species identified across all sites.

Coastal Foredune Species					
Code	**Native Species**	**Common Name**	**Code**	**Non-native Species**	**Common name**
Auli	*Austrofestuca littoralis*	Sand tussock	Acsp	*Acacia* spp.	Wattle
Cofu	*Cortaderia fulvida*	Toitoi	Amar	*Ammophila arenaria*	Marram grass
Core	*Coprosma repens*	Taupata	Caed	*Carpobrotus edulis*	Ice plant
Coau	*Cordyline australis*	Cabbage tree	Cose	*Cortaderia selloana*	Pampas grass
Cyus	*Cyperus ustulatus*	Giant umbrella sedge	Cuma	*Cupressus macrocarpa*	Macrocarpa
Desp	*Desmoschoenus spiralis*	Pingao	Erca	*Erharta calycina*	Veldt grass
Isno	*Isolepis nodosa*	Knobby clubrush	Inwe	*Introduced weeds*	Unidentified weeds
Lesi	*Leptocarpus similis*	Jointed wire rush (Oioi)	Loma	*Lobulariamaritima*	Sweet alyssum
Meex	*Metrosideros excelsa*	Pohutukawa	Luar	*Lupinus arboreus*	Tree lupin
Muco	*Muehllenbeckia complexa*	Small-leaved pohuehue	Pecl	*Pennisetum clandestinum*	Kikuyu grass
Myla	*Myoporum laetum*	Ngaio	Roru	*Rosa rubiginosa*	Sweet briar
Ozle	*Ozothamnus leptophyllus*	Tauhinu, cassinia	Seel	*Senecio elegans*	Purple groundsel
Phte	*Phormium tenax*	Flax (Harakeke)	Segl	*Senecio glastifolius*	Holly-leaved senecio
Picr	*Pittosporum crassifolium*	(Karo)	Uleu	*Ulex europeus*	Gorse
Poas	*Poa astonii*	Blue shore tussock			
Saqu	*Sarcocornia quinqueflora*	Glasswort			
Spse	*Spinifex sericeus*	Spinifex			

4.1.1 Grain size

Tables 8a, 8b, and 9 show the average physico-chemical characteristics of sediments from the sites where fine scale studies were undertaken, and compares them to sediment quality guidelines and results from sites elsewhere in NZ and overseas. The results confirm the sandy nature of the beach substrate, and the predominantly sandy nature of Hutt River Estuary, accompanied by a silt and clay fraction. The results indicating that Lowry Bay contained more gravel than Fitzroy Bay does not reflect the true nature of the beaches as Fitzroy Bay was gravel dominated and the result is an anomaly resulting from the samples targeting finer sediments for chemical analyses.

Table 8a Average physico-chemical characteristics of sediments from fine scale sites assessed in the present study compared to ANZECC sediment quality guidelines ($mg.kg^{-1}$).

Site	AFDW	Silt&Clay	Gravel	Sands	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
Hutt Estuary	3.2	15.6	0.8	83.7	<0.2	13.8	8.1	18.5	11.5	92.8
Petone Beach	1.8	0.9	0.2	99.0	<0.2	11.8	3.9	15.1	9.8	98.1
Lowry Bay	1.0	0.9	5.4	93.8	<0.2	5.9	2.8	10.2	4.5	62.7
Fitzroy Bay	1.4	0.8	3.9	95.4	<0.2	11.3	5.4	6.5	10.4	57.0
ANZECC ISQG-Low					***1.5***	***80***	***65***	***50***	***21***	***200***
ANZECC ISQG-High					***10***	***370***	***270***	***220***	***52***	***410***

Table 8b Average heavy metal characteristics of sediments from sites in NZ and overseas ($mg.kg^{-1}$).

	Location	Cd	Cr	Cu	Pb	Ni	Zn
EMP Study*	Otamatea Arm	0.4	20.5	13.8	11.4	9.4	54.5
	Ohiwa	0.1	7.4	4	3.4	3.9	27.7
	Ruataniwha	0.1	24	7.1	4.7	13.7	37.5
	Waimea	0.3	67.6	9.6	7.4	72.5	41.8
	Havelock	0.3	48.8	10.7	5.6	26.5	43
	Avon-Heathcote	0.1	15.6	3.2	6.3	6.6	38.3
	Kaikorai	0.1	48.4	16.8	45.3	15.6	184.2
	New River	0.1	11.1	3.8	0.7	5	17.1
Other NZ sites	New River Estuary	0.2	11.1	3.7	3.7	5.6	15.7
	Jacobs River Estuary	0.3	12.3	11.9	5.6	7.6	35.9
	Tamaki A (E1) [a]		14.5	27.8	132.1	56.9	136.1
	Tamaki B (E2) [a]		20.6	26.1	72.9	6.6	167
	Tamaki C (E3) [a]		17.3	29.4	69.7	9.3	173
	Tamaki D (E4)[a]		35.9	38.5	145.2	12.8	233
	Manukau (rural catch)[b]	0.03		20	9	15	114
	Manukau (industrial catch) [b]	0.25		90	58	14	285
	Waitemata Harbour [h]	<0.5	52	60	65	28	161
	Otago (mid-upper harbour)[c]	0.26	21	17	19	9.7	110
	Lambton Harbour, Wellington [d]		91	68	183	21	249
	Porirua Harbour, Wellington [e]		20	48	93	20	259
	Aparima Estuary[f]	0.067	15	12	11	10	49
	Mataura Estuary[f]	0.024	7.1	6.6	6.2	6	27
Overseas sites	Delaware Bay, USA [g]	0.24	27.8	8.3	15		49.7
	Lower Chesapeake Bay, USA[g]	0.38	58.5	11.3	15.7		66.2
	San Diego Harbour, USA [g]	0.99	178	218.7	51		327.7
	Salem Harbour, USA [g]	5.87	2296.7	95.1	186.3		238
	Rio Tinto Estuary, Spain[f]	4.1		1400	1600		3100
	Restronguet Estuary, UK[f]	12	1060	4500	1620		3000
	Nervión Estuary, Spain[i]	0.2-15	50-300	50-350	50-400	20-100	200-2000
	Sorfjord, Norway[f]	850		12000	30500		118000

*Robertson *et al.* (2002)
a Sites positioned from inner (E4) to outer (E1) estuary locations in heavily urbanised area (Thompson 1987)
b Subtidal on open coast (Roper 1990)
c Largely undisturbed estuary near Nelson (Gillespie & MacKenzie 1990)
d Slightly modified estuary near Nelson; affected by urban stormwater, roading, marina development (Gillespie & MacKenzie 1990)
e Slightly modified estuary near Motueka; affected by food processing industry wastes, urban runoff (Gillespie *et al.* 1995)
f Site affected by a high nutrient freezing works discharge (Gillespie & MacKenzie 1990)
g Below detection limit (250 mg kg^{-1})
h Total Kjeldahl Nitrogen (does not include nitrate/nitrite)
i Probable artifact of decomposing terrestrial plant debris

4.1.2 Toxic contaminants

In terms of potentially toxic contaminants, using sediment heavy metal contaminants as the indicator, fine scale sites at Hutt River Estuary, Petone Beach, Lowry Bay and Fitzroy Bay all had levels well below ANZECC (2000) ISQG-Low trigger values. This is a particularly interesting finding for the Hutt River estuary which is widely regarded as being contaminated. However, the results show that the tidal flats in Hutt River and the adjacent beaches are in good health. It is quite possible that previous sampling in these areas have targeted hotspots immediately adjacent to point source discharge points, which provide a skewed perspective of the overall quality of the area. It was beyond the scope of the current job, but it would be well worth reviewing existing monitoring data and scientific publications on the Hutt River Estuary to explore this further.

4.1.3 Nutrient and organic enrichment

None of the fine scale sites were considered enriched. The organic loading, nitrogen, and phosphorus levels were low across all sites (Table 9) and there were no other indicators of enrichment such as the presence of algal growths like sea lettuce (*Ulva*) or anoxic sediments. At Fitzroy Bay, there were very few signs of sewage outfall effects other than a very slightly elevated total phosphorus level. Further study would be needed to determine the significance of this result and to determine whether it is related to the sewage outfall.

4.1.4 Sediment biota

The abundance of infauna - animals living within the estuary and beach sediments (Appendix 1) - were typical of other New Zealand estuaries and beaches in good condition (*e.g.* Robertson *et al.* 2002). In the Hutt River Estuary, the infauna was dominated by gastropod snails, bivalve shellfish (cockles and pipi), and oligochaete and polychaete worms. The abundance of animals living on the sediment surface (epifauna) was dominated by snails and bivalves.

Petone Beach infauna was dominated by bivalve shellfish (pipi), and numerous different polychaetes worms. No epifauna, and no gastropod snails were recorded. Lowry Bay had very few bivalve shellfish but a similar range of polychaete worms to Petone. At Fitzroy Bay, only amphipods (sand hoppers) and an oligochaete worm were recorded. This reflects the harsh natural environment present with abrasive mobile gravels greatly limiting what can survive in the intertidal zone.

Table 9 Average nutrient and organic content of sediments in the present study and from other NZ estuarine sites.

	%Mud %	TN mg kg^{-1}	TP mg kg^{-1}	AFDW %
Present study (2004)				
Hutt River Estuary	15.6	558	355	3.2
Petone Beach	1.8	200	288	1.8
Lowry Bay	1.0	177	192	1.0
Fitzroy Bay	1.4	89	564	1.4
Other NZ sites				
New River (2003)[1]	1.6	130	276	0.8
Jacobs River (2003)[1]	2.6	163	324	1.3
Otamatea Arm (Kaipara)[2]	56	1630	526	7
Ohiwa[2]	20	650	278	3
Ruataniwha[2]	9	263	458	1
Waimea[2]	25	506	433	2
Havelock[2]	19	421	330	2
Avon-Heathcote[2]	5	301	327	1
Kaikorai[2]	27	1650	799	5
New River (2001)[2]	2	250[g]	268	1
Tamaki A (E1)[a]	48	110		
Tamaki B (E2)[a]	86	200		
Tamaki C (E3)[a]	54	250		
Tamaki D (E4)[a]	67	520		
Tauranga Hbr (10 m from outfall)[b]	15	650[h]	275	
Tauranga Hbr (1 km from outfall)[b]	15	460[h]	175	
Delaware Inlet (4 sites)[c]	7	303	540	2
Delaware Inlet (5 sites)[c]	73	1260	716	6
Nelson Haven (6 sites)[d]	23	347	403	2
Moutere Inlet (5 sites)[e]	>50	1305	648	6
Moutere Inlet (13 sites)[e]	<50	546	419	2
Waimea (enriched site)[f]	83	4340	1063	9

1 Robertson and Asher (2003)
2 Robertson *et al.* (2002)
a Sites positioned from inner (E4) to outer (E1) estuary locations in heavily urbanised area (Thompson 1987)
b Subtidal on open coast (Roper 1990)
c Largely undisturbed estuary near Nelson (Gillespie & MacKenzie 1990)
d Slightly modified estuary near Nelson; affected by urban stormwater, roading, marina development (Gillespie & MacKenzie 1990)
e Slightly modified estuary near Motueka; affected by food processing industry wastes, urban runoff (Gillespie *et al.* 1995)
f Site affected by a high nutrient freezing works discharge (Gillespie & MacKenzie 1990)
g Below detection limit (250 mg kg^{-1})
h Total Kjeldahl Nitrogen (does not include nitrate/nitrite)
i Probable artifact of decomposing terrestrial plant debris

4.1.5 Environmental pressures

A summary of the environmental pressures identified at each site, and a subjective assessment of the level of concern for each, is provided in Table 10 using the matrix presented in Figure 2. Blank cells indicate that the identified pressure is not considered significant/relevant, while a “?” indicates that the pressure may be present but needs confirmation.

Bacterial contamination was excluded from this assessment as it is monitored and addressed elsewhere through GWRC water quality monitoring. Introduced weeds were widely present but their spatial coverage was often limited to the extent that they were not recorded under the broad scale mapping in this study. In many instances, introduced plantings may provide important protection for the establishment of native species, or may have been introduced for their amenity or functional value. For example, marram grass carries out an important dune stabilisation role. Table 10 therefore notes where introduced species with the potential to become pests are present. No attempt has been made to assess their likely influence or recovery as their impact is species and location specific.

A subjective assessment of the degree of modification to the beach area has also been included, such as the construction of seawalls, reclamations, stream culverts, building developments, *etc.* to provide an indication of "naturalness".

Table 10 Summary of identified pressures at each site and level of concern.

	Owhiro Bay	Island Bay	Houghton Bay	Lyall Bay	Breaker Bay	Seatoun	Worser Bay	Petone	Lowry Bay	Days Bay	Eastbourne	Camp Bay	Fitzroy	Kaiwharawhara	Korokoro	Hutt River
Flooding								C4	D4	D4	D4			D3	D3	C3
Gravel/Sand Extraction								D1					C1			
Grooming				?			?	C3	C3	C3	?					
Landfill Leachate			D2													
Nutrient Enrichment																
Shellfish collection	?	?	?	?	?	?	?	D3	D3	?	?					
Stormwater	D3	D3	D3	D3		D3	D3	D2	D3	D3	D3			D3	D3	D2
Vehicles	D3			?				D3		D3	?		D3			
Introduced weeds	✍	✍	✍	✍	✍	✍	✍	✍			✍	✍	✍	✍	✍	✍
Degree of modification*	H	H	H	H	L	M	H	H	VH	VH	M	L	L	VH	H	VH

*VH=Very High, H=High, M=Moderate, L=Low

This identification and ranking of pressures should be viewed as a starting point for discussion. Detailed information is likely to be available on many aspects, and local knowledge could greatly expand on this process, activities which are outside the scope of the current project. Clearly, defining the specific impacts of particular pressures would require further investigation. It is envisaged that this summary will provide a starting point for deciding whether further investigation is justified, and if so, where the priorities may lie.

Overall, the large number of unshaded cells, and the presence of only a single red cell, in Table 10 indicates that the sites investigated are not considered to be significantly adversely affected by the pressures identified at the present point in time. This reflects mainly the low percentage of each beach area affected, and to a lesser extent, the intermittent nature of the pressure, the susceptibility of the environment, and/or likely recovery rates. This is reflected in the scoring largely all being C's and D's (<30% affected), and the recovery from impacts scoring 3's and 4's (<5 years). Those pressures with longer recovery times all relate to point source impacts *e.g.* landfill leachate, stormwater outfalls, or specific activities *e.g.* gravel extraction. Therefore, while significant, are quite isolated in the broader context of the environment being assessed. No sites were considered to be nutrient enriched.

4.2 Petone Beach

4.2.1 Broad scale assessment

Due to the length of Petone Beach, it has been split in two for broad scale mapping (Figures 4 and 5). The western end of Petone Beach is almost exclusively firm sand. Extending from the vicinity of Petone wharf to the reclaimed land at Korokoro Stream, the upper margins of the beach are sand dunes dominated by plantings of taupata, flax, and marram grass.

Further along in the middle section of the beach, the substrate is firm sand. The upper shore comprises of a concrete seawall backing onto parking areas and the road. This section of beach is groomed, with debris collected and removed from the beach using diggers and trucks.

At the eastern end of the beach, the substrate becomes mixed with gravel fields towards the low tide mark, and gravel fields and shell are present along the upper beach. Firm sand continues to dominate the mid shore. Along this area, there is a relatively natural back dune, with areas fenced to protect plantings of spinifex, pingao, and marram grass. Further up the beach again are a number of smaller shrubs and trees that back onto grassed playing fields and parks.

Table 11 Summary of habitat type and dominant species at Petone Beach.

Habitat type / **Dominant species**	Petone	Grand Total (Ha)	% area mapped
Shrubland			
Coprosma repens	0.81	0.81	7.4
Myoporum laetum	0.49	0.49	4.5
Grassland			
Ammophila arenaria	0.77	0.77	7.0
Spinifex sericeus	0.09	0.09	0.8
Tussockland			
Phormium tenax	0.22	0.22	2.0
Unvegetated			
Firm sand	5.72	5.72	52.0
Gravel field	2.89	2.89	26.3
Grand Total	**11.00**	**11.00**	**100.0**

Petone Beach foreshore was identified as an important conservation area (an *area of environmental concern or conservation*) by Ward (1988, cited in Wear and Haddon 1992). It is considered a valuable roosting and feeding ground for variable oystercatchers, gulls, pied stilts and terns that feed on the invertebrate fauna of the beach (EHEA 1998).

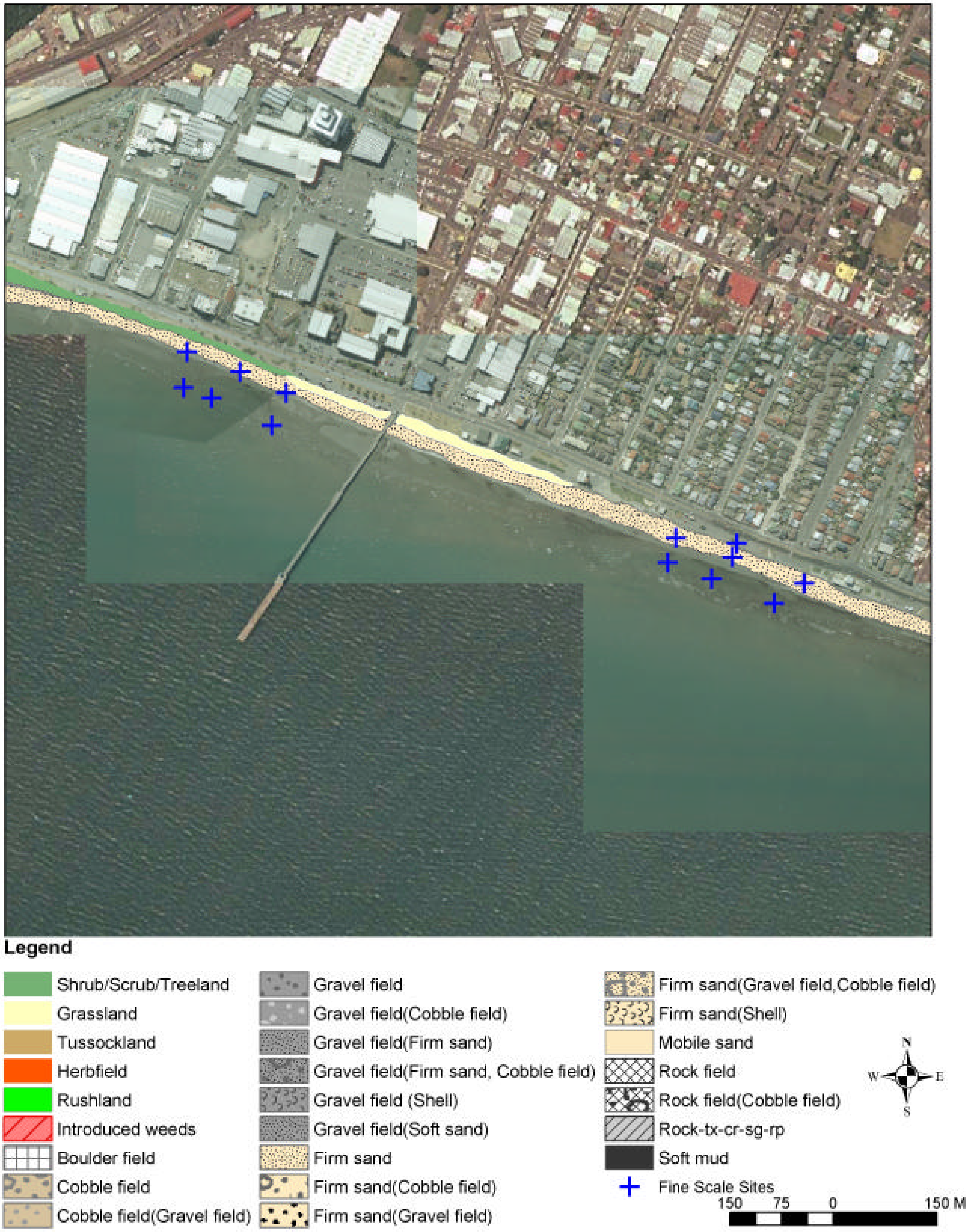


Figure 4 Broad scale habitat map of Petone Beach (western end).

Figure 5 Broad scale habitat map of Petone Beach (eastern end).

Wear & Dalziell (1987) reported a relatively high organic content within the sand, fairly evenly distributed over the beach. The invertebrate fauna were patchily distributed and dominated by the amphipod *Orchestia chilensis* on the upper shore and the pipi *Paphies australis* on the lower shore, which also extended to subtidal beds. The pipi densities can be very high. Also commonly found within the lower tidal zone was the deposit-feeding bivalve *Macomona liliana* and a large population of polychaete lugworms (which favour organically-enriched sediments). Significant beds of pipi and cockle *Austrovenus stutchburyi* are known to extend in the shallow soft substrates from the western end of Petone Beach to Lowry Bay (EHEA 1998). The beach has high recreational value.

4.2.2 Fine scale assessment

Fine scale sampling was undertaken at Petone Beach to provide detail on the chemical and physical properties of the dominant sandy habitat (Figure 6). Results are presented in Tables 12 and 13 for ungroomed and groomed sections of the beach respectively. These areas of the beach were sampled to determine if any gross differences were present in areas managed differently. Replicate samples were collected from upper and lower intertidal areas containing fine grained sediments. Fine sediment has a greater tendency to accumulate sediment bound contaminants and was targeted to provide a worst case assessment of beach quality.

Figure 6 Processing biological samples on Petone Beach.

The results indicated no significant difference in the chemical status of the differently managed areas. That is, the presence or absence of beach grooming activities was not correlated with any differences in the physical or chemical parameters analysed.

Small differences were present between the upper and lower intertidal results with a higher organic content, and slightly higher mud fractions present in the lower shore. This is a common finding and, not unexpectedly, was associated with slightly higher levels of nitrogen and phosphorus in the lower shore also. Overall, the nutrient and chemical results do not indicate any adverse enrichment of Petone Beach.

It is also interesting to note the very small amount of variability between replicates. This suggests that for sandy beaches, a single composite sample may provide sufficient information to rapidly characterise the chemical status of sediments. Although reducing the number of replicates would decrease the information gained and the associated confidence in the results obtained, it should still provide an appropriate indication of potential beach degradation, but would allow more sites to be assessed for the same cost.

Table 12 Summary of the physical and chemical sediment properties of ungroomed habitat at Petone Beach.

Petone Beach – Ungroomed	**Upper Beach**					**Lower Beach**				
Variable	**Rep1**	**Rep2**	**Rep3**	**Mean**	**(±SD)**	**Rep1**	**Rep2**	**Rep3**	**Mean**	**(±SD)**
Ash Free Dry Weight % w/w	1.4	1.6	1.7	1.6	0.2	1.9	2.0	2.0	2.0	0.1
Mud <63um % w/w	0.7	0.7	0.9	0.8	0.1	1.2	1.1	1.2	1.2	0.1
Sand <2mm >63um % w/w	98.5	99.3	99.0	98.9	0.4	98.7	98.7	98.8	98.7	0.1
Gravel >2mm % w/w	0.8	<0.1	<0.1	0.3	0.4	<0.1	0.2	<0.1	0.1	0.1
Cadmium mg/kg	<0.2	<0.2	<0.2	<0.2	-	<0.2	<0.2	<0.2	<0.2	-
Chromium mg/kg	11	12	12	11.7	0.6	12	12	13	12.3	0.6
Copper mg/kg	3.0	3.4	3.5	3.3	0.3	3.9	4.0	4.3	4.1	0.2
Lead mg/kg	17	17	17	17.0	0.0	17	17	17	17.0	0.0
Nickel mg/kg	8.6	9.2	9.2	9.0	0.3	9.8	9.7	10.0	9.8	0.2
Zinc mg/kg	100	99	100	99.7	0.6	110	110	110	110.0	0.0
Total Nitrogen mg/kg (dry)	170	170	200	180.0	17.3	260	230	250	246.7	15.3
Total Phosphorus mg/kg (dry)	282	277	268	275.7	7.1	290	285	298	291.0	6.6

Table 13 Summary of the physical and chemical sediment properties of groomed habitat at Petone Beach.

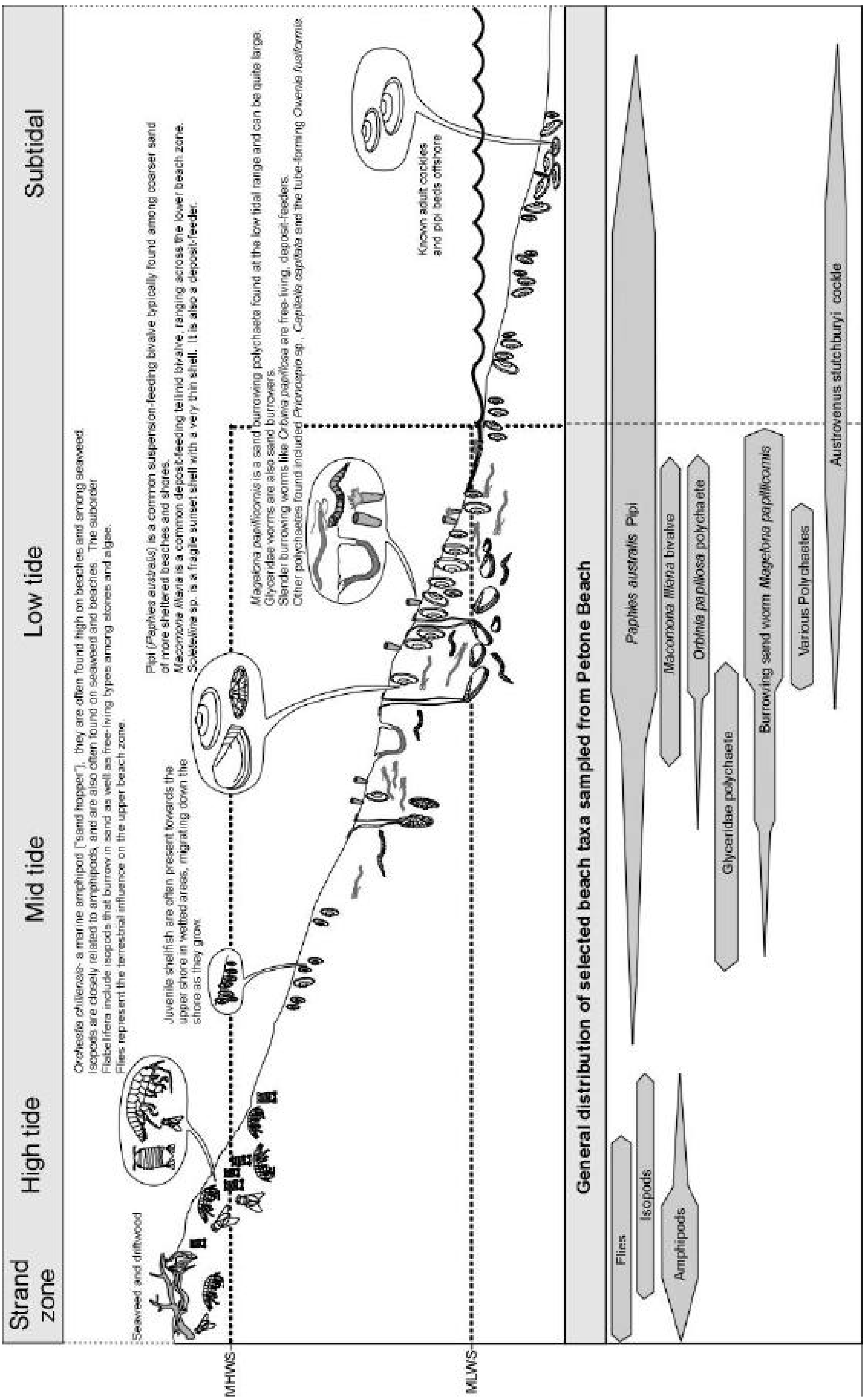
Petone Beach – Groomed	Upper Beach					Lower Beach				
Variable	**Rep1**	**Rep2**	**Rep3**	**Mean**	**(±SD)**	**Rep1**	**Rep2**	**Rep3**	**Mean**	**(±SD)**
Ash Free Dry Weight % w/w	1.5	1.7	1.5	1.6	0.1	2.0	1.9	1.9	1.9	0.1
Mud <63um % w/w	0.3	0.5	0.3	0.4	0.1	1.2	1.1	1.2	1.2	0.1
Sand <2mm >63um % w/w	99.6	99.5	99.2	99.4	0.2	98.8	98.9	98.8	98.8	0.1
Gravel >2mm % w/w	0.1	<0.1	0.4	0.2	0.2	<0.1	<0.1	<0.1	0.1	0.0
Cadmium mg/kg	<0.2	<0.2	<0.2	<0.2	-	<0.2	<0.2	<0.2	<0.2	-
Chromium mg/kg	11	11	11	11.0	0.0	13	12	11	12.0	1.0
Copper mg/kg	3.6	4.8	4.1	4.2	0.6	4.3	4.0	3.9	4.1	0.2
Lead mg/kg	12	12	12	12.0	0.0	16	13	14	14.3	1.5
Nickel mg/kg	9.8	9.6	9.8	9.7	0.1	11.0	11.0	9.7	10.6	0.8
Zinc mg/kg	93	90	90	91.0	1.7	95	87	93	91.7	4.2
Total Nitrogen mg/kg (dry)	160	160	160	160.0	0.0	210	240	190	213.3	25.2
Total Phosphorus mg/kg (dry)	286	275	279	280.0	5.6	305	316	289	303.3	13.6

Biological samples were also collected from the same areas as chemical and physical samples and are presented in Table 14. A schematic cross section indicating the location and type of organisms present in Petone Beach is provided in Figure 7.

Table 14 Sediment dwelling infauna collected from Petone Beach.

Petone Beach			**A - Ungroomed**						**B - Groomed**					
			Lower			**Upper**			**Lower**			**Upper**		
Taxa	**Common Name**	**FEEDING TYPE**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
PLATYHELMINTHES	Flat Worm	Predator								1				
NEMERTEA	Proboscis worms		1	1					1	1	1			
NEMATODA	Roundworm		2	1		2	5	6				1		
BIVALVIA														
Macomona liliana	Wedge shell, Hanikura	Infaunal suspension feeder		1	2				1	1	2			
Paphies australis	Pipi	Filter feeder	74	37	24		1		3	28	63			
POLYCHAETA	Bristle worms													
Orbinia papillosa		Infaunal deposit feeder		2	1				1	1	1			
Aonides sp.		Surface deposit feeder	1	2							1			
Prionospio sp.		Surface deposit feeder							2	32	3			
Magelona papillicornis		Surface deposit feeder	12	25	24		1		5	21	33	2	1	2
Capitella capitata		Infaunal deposit feeder	2	2						1				
Heteromastus filiformis		Infaunal deposit feeder								2				
Sphaerosyllis hirsula		Omnivorous							4	1	1			
Glyceridae		Infaunal carnivore & deposit feeder								2				
Pectinaria australis		Infaunal deposit feeder								2				
ISOPODA														
Flabellifera	Sea louse	Epifaunal scavenger					1	1						
Total No. of Taxa			**6**	**8**	**4**	**1**	**4**	**2**	**7**	**12**	**8**	**2**	**1**	**1**
Total No. of Individuals			**92**	**71**	**51**	**2**	**8**	**7**	**17**	**93**	**105**	**3**	**1**	**2**

Figure 7 Schematic cross section showing the organisms living in Petone Beach.



The results of the infaunal sampling show a common assemblage of organisms that are indicative of a healthy and unenriched beach. These results were collected using a single 130 mm diameter core sieved to 0.5mm (area = 0.0133 m^2) from each of three sites at two tide levels. Sampling was also undertaken at six heights across the tidal range with 10 cores collected at each tidal height, and sorted using 20mm, 10mm, 5mm, and 2mm sieves. The raw data were then used to produce Figure 7. The use of coarse sieves enabled the rapid processing of samples in the field, and developed a clear picture of the beach inhabitants. However, the information collected did not differ greatly from that obtained using 3 replicate cores at upper and lower shore levels. It did confirm the presence of cockles in the sampling area by capturing a single large cockle, a species not included in the core data presented in Table 14. However, the sieve sizes generally were too coarse to capture the high numbers of juvenile pipi and worm species that were present in the beach. One advantage of the field sieving was the removal of larger gravel and pebbles from the samples which made the subsequent handling and processing of samples easier.

Overall, Petone Beach infauna was dominated by bivalve shellfish (pipi), and numerous different polychaetes worms. No epifauna, and no gastropod snails were recorded.

In relation to pressures such as vehicles use on the beach, it is obvious from Figure 7 that the entire beach contains a variety of living organisms. The majority are present in the wetted areas of the beach, therefore the impact of beach grooming, if it is confined to areas above MHWS, is unlikely to impact significantly on the most densely populated parts of the beach. Vehicles driving on beaches are also a potential issue, perhaps more so in the wider region than specifically at Petone. Again, the impact is likely to be minimised if vehicles are confined to areas above MHWS. Vehicles using the wetted part of the beach where shellfish beds are present are a legitimate concern although further information is needed to determine exactly how susceptible shellfish are. It was also noted that the average size of bivalve shellfish increased toward the lower intertidal area. The larger shellfish are likely to be less susceptible to vehicle impacts, therefore avoiding upper-mid beach areas where juveniles may be most common could help to limit potential impacts.

Petone Beach also has large subtidal shellfish beds. Harvesting pressure on these beds is unknown but could well be an issue due to the easy access to the beds, and their location to a large population centre.

All along Petone Beach stormwater flows enter the foreshore. Stormwater, particularly road runoff, is well recognised as a significant pollutant. The sampling results indicate that the sandy sediments at Petone are not acting as a significant sink for common stormwater contaminants such as copper, lead and zinc. However, contaminants like these have a strong affinity to sorb to fine particulate sediment, and their absence in beach sands does not mean that they will not be present elsewhere, particularly in areas of fine sediment accumulation that may be present further offshore.

Flooding impacts at Petone were evident during this survey, predominantly through the presence of debris littering the upper beach, and also buried beneath an overlying layer of sand in some areas. This debris was largely organic in nature and will provide an input of nutrients to the beach. Such inputs are normal and generally not a problem, but large deposits could cause undesirable accumulations of nuisance species (*e.g.* flies) or result in odours from decaying vegetation.

A site specific pressure at Petone is the gravel works at the far east of the beach bordering the Hutt River where discharges of fine mud enter the beach area.

4.3 Hutt River Estuary

4.3.1 Broad scale assessment

The Hutt River Estuary intertidal substrate is predominantly soft sandy mud, although it comprises a variety of different substrate types (Table 15). The whole Hutt River Estuary has been extensively reclaimed and modified, and features large areas of block protection along its shores, which is reflected in the relatively high area of rock field mapped. The margins of the western arm have been planted in native species, but elsewhere Hutt River Estuary is largely unvegetated. Hutt River Estuary is unique because it is the only soft sediment estuarine environment remaining in the lower North Island (EHEA 1998). Land reclamation, by deposition of dredge tailings in the western bank and for industrial use of the east, has significantly reduced the wetland area (EHEA 1998). While historically supporting a productive whitebait fishery, modifications such as rocky steep sides (block protection) make it unsuitable for inanga spawning (Taylor & Kelly 2001).

Table 15 Summary of habitat type and dominant species at Hutt River Estuary.

Habitat type / Dominant species	Hutt River	Grand Total (Ha)	% area mapped
Scrub			
Coprosma repens	0.38	0.38	7.7
Tussockland			
Phormium tenax	0.18	0.18	3.5
Unvegetated			
Boulder field	0.15	0.15	3.0
Cobble field	0.32	0.32	6.5
Firm sand	0.08	0.08	1.7
Gravel field	0.31	0.31	6.2
Mobile sand	0.07	0.07	1.3
Rock field	1.50	1.50	30.3
Soft mud	1.98	1.98	39.9
Grand Total	**4.96**	**4.96**	**100.0**

The western arm tidal flat is an important roosting, wading and feeding area for a number of birds, including variable oystercatchers, shags (*Phalacrocorax* sps.), reef heron, mallards and grey ducks, gulls, terns, and other common waders (EPA 1990; Wear & Haddon 1992, EHEA 1998). It was deemed an area of ecological importance (a 'preservation area') (Ward, 1988 cited in Wear and Haddon, 1992) for birds and fish, and is an important nursery area for juvenile flatfish (EHEA 1998). The Hutt River is thought to provide a significant contribution of suspended sediments to the Harbour during flood events. A low salinity and high turbidity layer has been shown to extend into the harbour, widely distributing the sediments into the Harbour rather than locally depositing them around Hutt River mouth (Wear & Haddon 1992). Water quality tests in 1981 suggested that the Hutt River contributed to high bacteria levels in the area during flood events (Davis 1982, cited in EHEA 1998).

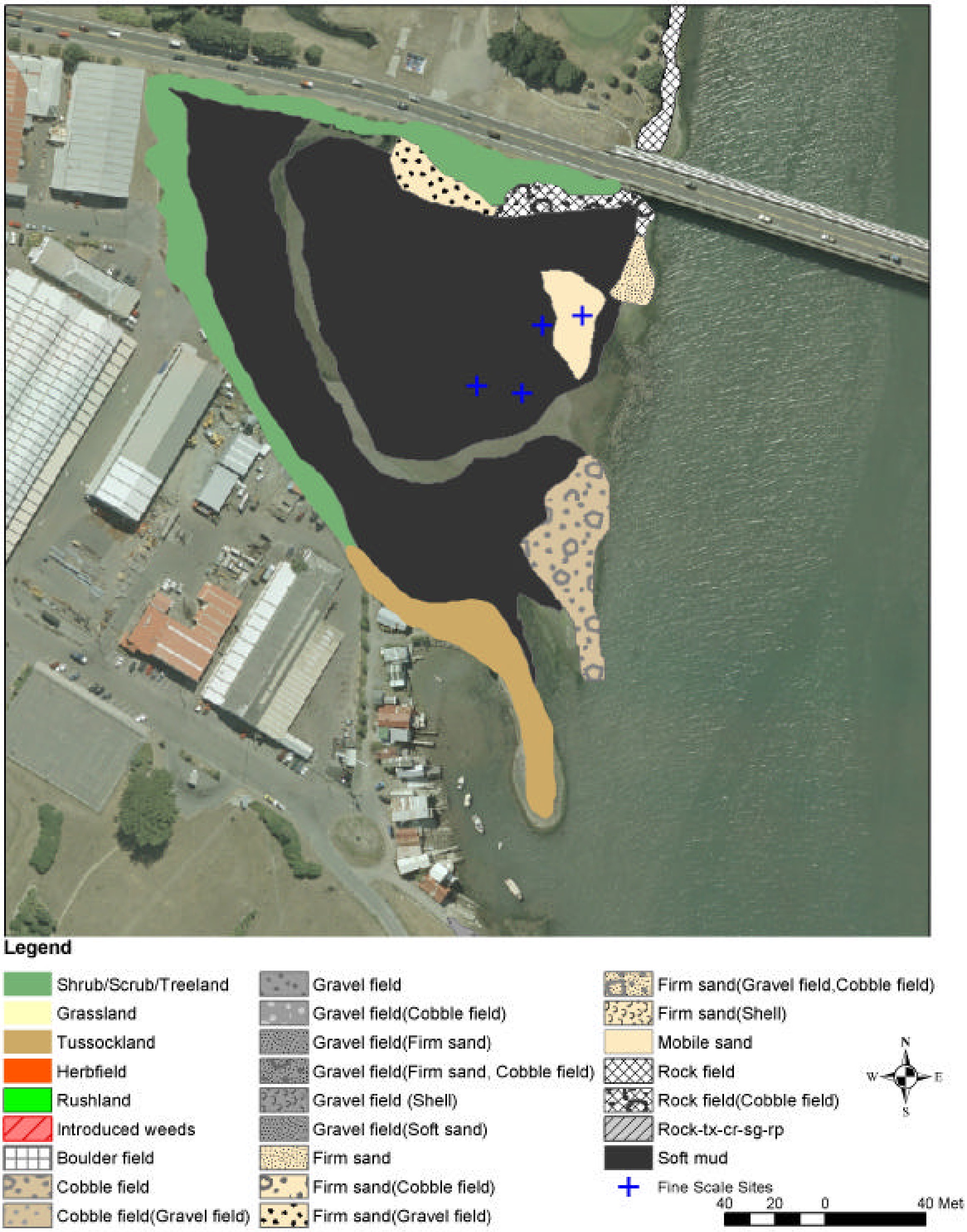


Figure 8 Broad scale habitat map of Hutt River Estuary (western arm).

4.3.2 Fine scale assessment

The sediment results showed that, like most typical New Zealand estuaries, the sites within the Hutt River were dominated by muddy sand. The mud content was higher in the lower estuary than the upper estuary (26% compared to 5%) which was associated with an increase in the AFDW and total nitrogen, and to a lesser extent, phosphorus levels (Table 16). Of the chemical parameters measured, none were significantly elevated and the site was not enriched.

The finding that sediment heavy metal contaminants were well below ANZECC (2000) ISQG-Low trigger values shows that the tidal flats in Hutt River are in good health. It is quite possible that previous sampling in these areas have targeted hotspots immediately adjacent to point source discharge points, which provide a skewed perspective of the overall quality of the environment. It is also a possibility that recent flood events have either flushed out or buried contaminants. Regardless, the findings show that the current surface sediment in the intertidal flats is uncontaminated.

Table 16 Summary of the physical and chemical sediment properties of Hutt River Estuary.

Hutt River Estuary	**Upper Estuary**				**Lower Estuary**			
Variable	**Rep1**	**Rep2**	**Mean**	***(±SD)***	**Rep1**	**Rep2**	**Mean**	***(±SD)***
Ash Free Dry Weight % w/w	2.5	2.4	**2.5**	*0.1*	3.6	4.3	**4.0**	*0.5*
Mud <63um % w/w	5.2	4.8	**5.0**	*0.3*	28.1	24.1	**26.1**	*2.8*
Sand <2mm >63um % w/w	94.8	93.7	**94.3**	*0.8*	70.7	75.4	**73.1**	*3.3*
Gravel >2mm % w/w	<0.1	1.5	**0.8**	*1.0*	1.2	0.5	**0.9**	*0.5*
Cadmium mg/kg	<0.2	<0.2	**<0.2**	-	<0.2	<0.2	**<0.2**	-
Chromium mg/kg	12	13	**12.5**	*0.7*	15	15	**15.0**	*0.0*
Copper mg/kg	7.3	6.6	**7.0**	*0.5*	9.3	9.0	**9.2**	*0.2*
Lead mg/kg	15	20	**17.5**	*3.5*	20	19	**19.5**	*0.7*
Nickel mg/kg	11.0	11.0	**11.0**	*0.0*	12.0	12.0	**12.0**	*0.0*
Zinc mg/kg	85	97	**91.0**	*8.5*	100	89	**94.5**	*7.8*
Total Nitrogen mg/kg (dry)	390	400	**395.0**	*7.1*	760	680	**720.0**	*56.6*
Total Phosphorus mg/kg (dry)	329	328	**328.5**	*0.7*	390	371	**380.5**	*13.4*

In the Hutt River Estuary, the infauna was dominated by gastropod snails, bivalve shellfish (cockles and pipi), and oligochaete and polychaete worms (Table 17). The abundance of animals living on the sediment surface (epifauna) was dominated by snails and bivalves. The biota were predominantly deposit feeders and detrital grazers - infauna typically present in muddy estuarine environments.

Table 17 Sediment dwelling infauna collected from Hutt River Estuary.

Hutt Estuary			**A**		**B**	
Taxa	**Common Name**	**FEEDING**	**1**	**2**	**1**	**2**
NEMERTEA	Proboscis worms			1		1
GASTROPODA						
Amphibola crenata	Mud Snail	Microalgal grazer	2			1
Potamopyrgus antipodarum	Estuarine snail	Microalgal & detrital grazer		13	20	28
Potamopyrgus estuarinus	Estuarine snail	Microalgal & detrital grazer	1	3	4	4
Potamopyrgus pupoides	Estuarine snail	Microalgal & detrital grazer	3	4	14	10
BIVALVIA						
Austrovenus stutchburyi (0-5mm)	Cockle (0-5mm)	Infaunal deposit feeder	2	2	2	
Austrovenus stutchburyi (06-10mm)	Cockle (6-10mm)	Infaunal deposit feeder	1			
Austrovenus stutchburyi (11-20mm)	Cockle (11-20mm)	Infaunal deposit feeder	6	1		1
Austrovenus stutchburyi (21-30mm)	Cockle (21-30mm)	Infaunal deposit feeder	2		1	1
Paphies australis	Pipi	Filter feeder	1	1	12	4
OLIGOCHAETA	Oligochaete worms	Infaunal deposit feeder	13	13	8	19
POLYCHAETA	Bristle worms					
Orbinia papillosa		Infaunal deposit feeder	1			
Scolecolepides sp.		Surface deposit feeder				1
Scolelepis sp.		Surface deposit feeder			1	9
Capitella capitata		Infaunal deposit feeder	4	1	1	7
Nicon aestuariensis		Omnivorous	4	1	4	3
AMPHIPODA						
Amphipoda	Amphipods	Epifaunal scavenger	112	294	244	251
Total No. of Taxa			**13**	**11**	**11**	**14**
Total No. of Individuals			**152**	**334**	**311**	**340**

4.4 Lowry Bay

4.4.1 Broad scale assessment

Lowry Bay was an easy site to map as it is bounded along the top margin by a concrete seawall immediately adjacent to the road. There is no buffering strip and no vegetation present. The beach sediment is predominantly firm sand. An artificial rock walls and reclamation has been constructed to the south. A small area of natural rock is present to the north of the sandy beach.

Table 18 Summary of habitat type and dominant species at Lowry Bay.

Habitat type Dominant species	Lowry Bay	Grand Total (Ha)	% area mapped
Unvegetated			
Firm sand	0.98	0.98	34.6
Rock	0.74	0.74	26.1
Rock field	1.11	1.11	39.2
Grand Total	**2.83**	**2.83**	**100.0**

Haddon *et al*. (1988, cited in Wear & Haddon 1992) investigated the marine ecology in Lowry Bay as part of the development of the Seaview Marina. Lowry Bay sediments graded with depth from fine sand to coarse sand then to silt and mud. There was no shellfish bed offshore, as compared to the cockle and pipi beds that were present in adjacent Seaview Bay prior to the marina development. Two small eelgrass beds (*Zostera* sp.) were identified at the south end of Lowry Bay, and are also noted to have been recorded previously (EHEA 1998). They were the only eelgrass beds identified at any of the sandy beaches surveyed as part of this project. The reason they do not feature on the habitat map is that they were present subtidal beds, and as such were outside the scope of what could be included in this study.

In the shallow subtidal, soft sediments bivalves such as cockles, pipi and *Cyclomactra* and *Macomona* are present from Petone Beach to Lowry Bay (EHEA 1998). The threatened reef heron is often seen in Lowry Bay (EHEA 1998).

Lowry Bay Stream was studied by Taylor & Kelly (2001) investigating inanga spawning grounds in the Wellington region. The Lowry Bay stream was a small shaded, tidally-influenced stream, more suited to other whitebait species, such as the banded kokopu (which were seen during the survey).

Figure 9 Broad scale habitat map of Lowry Bay.

4.4.2 Fine scale assessment

The sediment chemistry results indicate that Lowry Bay is relatively free of contaminants. Again, as is commonly found, the lower beach samples had a higher organic content, associated with slightly higher nitrogen and phosphorus levels, but the site was not enriched. There is a very small but consistent trend for metal contaminants to be higher in the lower shore sediments which would be expected given the stormwater and road runoff directly entering the beach. As with the other sites investigated in this study, the metal levels were very low and do not indicate contamination of the sediments.

Table 19 Summary of the physical and chemical sediment properties of Lowry Bay.

Lowry Bay	Upper Beach					Lower Beach				
Variable	Rep1	Rep2	Rep3	Mean	(±SD)	Rep1	Rep2	Rep3	Mean	(±SD)
Ash Free Dry Weight % w/w	0.9	0.7	0.9	0.8	0.1	1.2	1.3	1.3	1.3	0.1
Mud <63um % w/w	1.0	0.4	1.1	0.8	0.4	1.1	0.7	1.1	1.0	0.2
Sand <2mm >63um % w/w	99.0	99.0	98.9	99.0	0.1	98.3	68.4	98.9	88.5	17.4
Gravel >2mm % w/w	<0.1	0.6	<0.1	0.2	0.3	0.7	30.9	<0.1	10.6	17.6
Cadmium mg/kg	<0.2	<0.2	<0.2	<0.2	-	<0.2	<0.2	<0.2	<0.2	-
Chromium mg/kg	5.8	5.0	5.4	5.4	0.4	7.1	6.2	6.0	6.4	0.6
Copper mg/kg	2.5	2.5	2.6	2.5	0.1	3.1	3.4	2.7	3.1	0.4
Lead mg/kg	15	7.9	7.9	10.3	4.1	9	12	9.5	10.2	1.6
Nickel mg/kg	4.4	3.8	4.2	4.1	0.3	5.3	4.5	4.5	4.8	0.5
Zinc mg/kg	60	56	61	59.0	2.6	69	64	66	66.3	2.5
Total Nitrogen mg/kg (dry)	190	140	170	166.7	25.2	230	140	190	186.7	45.1
Total Phosphorus mg/kg (dry)	193	155	184	177.3	19.9	227	197	198	207.3	17.0

The sediment infauna (Table 20) was dominated by polychaete worms, with two species of bivalve shellfish also present. The absence of fine sediments is a likely reason for the absence of shellfish species like cockles and pipi in the intertidal zone.

It is notable however, that further down the shore from the sandy sediment below the low tide level, rocky substrate is present and supports a community commonly found on rocks either side of the beach including mussels (*Perna canaliculus*), seaweed, crabs and topshells. The eelgrass beds also supported a diverse range of species including juvenile fish and appeared to be healthy populations.

Table 20 Sediment dwelling infauna collected from Lowry Bay.

Lowry Bay			**Lower**			**Upper**		
Taxa	**Common Name**	**FEEDING TYPE**	**1**	**2**	**3**	**1**	**2**	**3**
NEMERTEA	Proboscis worms				2			
BIVALVIA								
Macomona liliana	Wedge shell, Hanikura	Infaunal suspension feeder	1					
Soletellina sp.		Infaunal suspension feeder			1			
OLIGOCHAETA	Oligochaete worms	Infaunal deposit feeder						11
POLYCHAETA	Bristle worms							
Orbinia papillosa		Infaunal deposit feeder		1	1			
Spionidae		Surface deposit feeder	2	1				
Aonides sp.		Surface deposit feeder	1					
Boccardia sp.		Surface deposit feeder	1					
Magelona papillicornis		Surface deposit feeder	11	20	91	1		
Capitella capitata		Infaunal deposit feeder	2	2	3			
Heteromastus filiformis		Infaunal deposit feeder			1			
Syllidae		Omnivorous	1	1	1			
Glyceridae		Infaunal carnivore & deposit feeder		2	2			
ISOPODA								
Flabellifera	Sea louse	Epifaunal scavenger					2	
AMPHIPODA								
Amphipoda	Amphipods	Epifaunal scavenger	1		1	2	2	
Total No. of Taxa			**8**	**6**	**9**	**2**	**2**	**1**
Total No. of Individuals			**20**	**27**	**103**	**3**	**4**	**11**

4.5 Fitzroy Bay

4.5.1 Broad scale assessment

The substrate mapped at Fitzroy Bay was exclusively gravel, which appeared highly mobile and was subjected to high energy wave action. Sand patches were interspersed within the gravel but did not exceed the >2m? criteria for mapping. In contrast, the vegetation present along the upper beach margins was quite diverse, particularly at the eastern end of the beach where there was an almost continuous cover. Further west, the vegetation was only present in small isolated patches.

A major influence in the middle of the beach is extensive gravel extraction which has removed large segments of the back beach. The extraction has significantly modified the profile of the beach and has resulted in the removal of vegetation.

Table 21 Summary of habitat type and dominant species at Fitzroy Bay.

Habitat type Dominant species	Fitzroy	Grand Total (Ha)	% area mapped
Scrub			
Muehllenbeckia complexa	2.58	2.58	8.7
Shrubland			
Lupinus arboreus	1.87	1.87	6.3
Rushland			
Isolepis nodosa	0.24	0.24	0.8
Grassland			
Ammophila arenaria	0.82	0.82	2.8
Spinifex sericeus	0.19	0.19	0.6
Tussockland			
Cortaderia fulvida	0.27	0.27	0.9
Herbfield			
Sarcocornia quinqueflora	0.14	0.14	0.5
Unvegetated			
Gravel field	23.50	23.50	79.4
Grand Total	**29.62**	**29.62**	**100.0**

Fitzroy Bay and the harbour entrance have been studied as part of the environmental assessments of impacts from the sewage outfall at Bluff Point near Pencarrow Head (*e.g.* Anderlini & Wear 1989; Anderlini 1998; Barter *et al.* 2004). Generally, macrofauna and flora in Fitzroy Bay are deemed typical of an open exposed south-facing coastline, with the ecology limited by the available habitat and degree of exposure. The intertidal habitats were typically rocky and exposed with little vegetation. The amphipod *Orchestia chilensis* was common on the upper rocky shore, and barnacles, blue and green mussels, chitons, limpets, paua and macroalgae (*e.g. Porphyra*, *Carpophyllum*, *Macrocystis*, *Durvillea* kelp) were found lower down (Anderlini and Wear 1989).

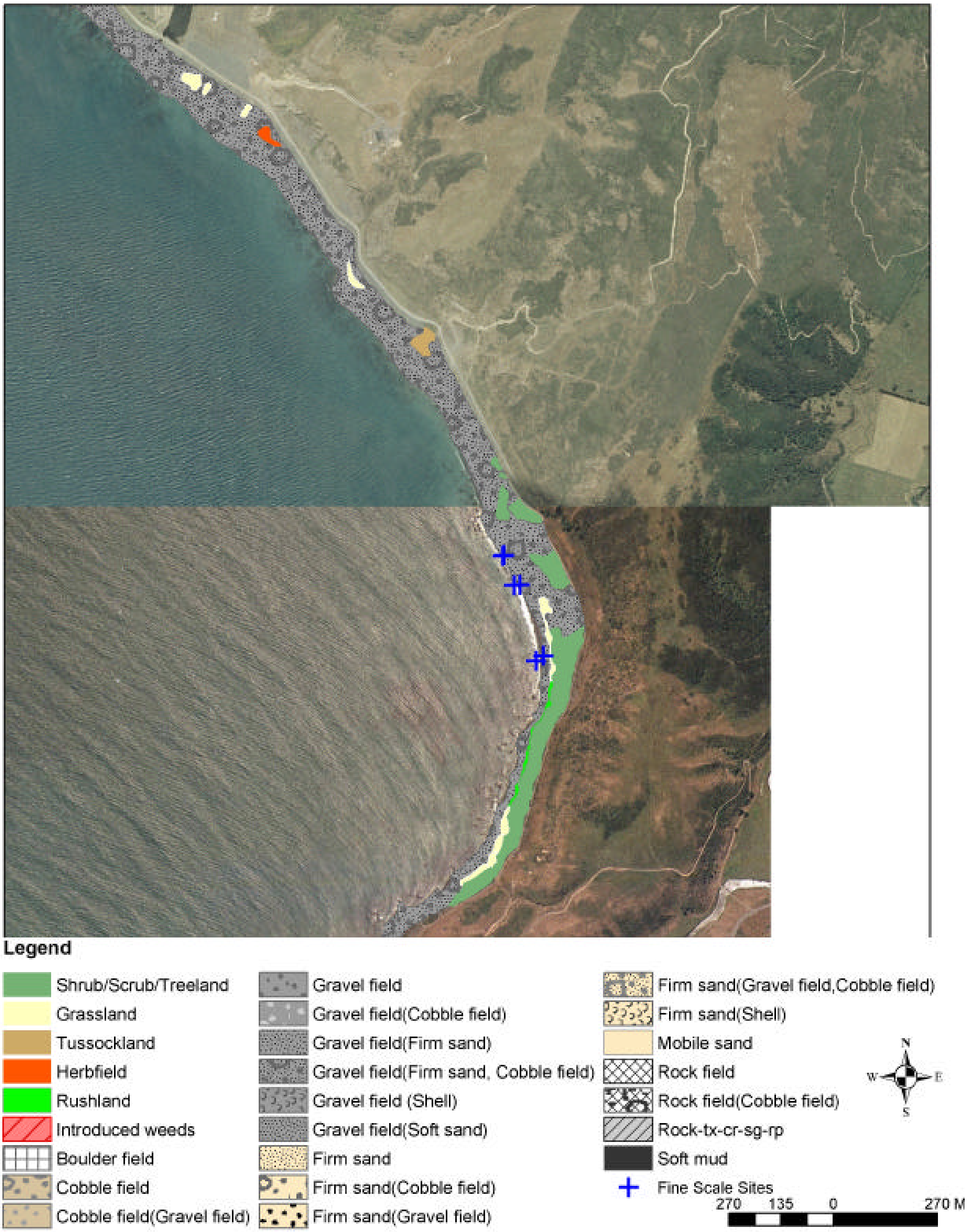


Figure 10 Broad scale habitat map of Fitzroy Bay.

The benthic communities in the immediate vicinity of the outfall revealed an outfall-related disturbance, with a fine sediment coating over the substrate, decreased faunal diversity but increased opportunistic polychaete abundance. The rest of the bay appeared generally unaffected by the effluent discharge (Anderlini 1998). The shellfish in the region showed high bacteriological contamination due to their proximity to the sewage outfall (Goldsmith 1989, cited in Wear & Haddon 1992). However, an upgrade of the treatment plant in 2002 improved the overall quality of the effluent, including reducing the bacterial load, and the state of the subtidal environment appeared to have improved as well (Barter *et al.* 2004).

4.5.2 Fine scale assessment

Because of the gravel nature of Fitzroy Bay, sediment chemistry samples targeted patches of fine sand to provide a conservative picture of sediment chemistry. As there was a limited number of areas where fine sand was present, a single composite sample was collected from multiple areas across the upper and lower sampling sites. The results of the physical and chemical analyses indicate that Fitzroy Bay is free of significant contamination. The slightly elevated total phosphorus level detected may indicate a sewage outfall effect, but further work would be required to confirm this.

Table 22 Summary of the physical and chemical sediment properties of Fitzroy Bay.

Fitzroy Bay Variable	Upper Beach	Lower Beach
Ash Free Dry Weight % w/w	1.5	1.3
Mud <63um % w/w	0.8	0.8
Sand <2mm >63um % w/w	98.0	92.8
Gravel >2mm % w/w	1.2	6.5
Cadmium mg/kg	<0.2	<0.2
Chromium mg/kg	13	9.5
Copper mg/kg	5.8	5.0
Lead mg/kg	6.3	6.7
Nickel mg/kg	12.0	8.8
Zinc mg/kg	63	51
Total Nitrogen mg/kg (dry)	110	67
Total Phosphorus mg/kg (dry)	557	570

The biological infauna at Fitzroy bay was very sparse (Table 23). Only 9 individuals of 2 species were collected. This is a natural occurrence due to the mobile nature of the sediments which provides a very harsh environment for infaunal communities.

Table 23 Sediment dwelling infauna collected from Fitzroy Bay.

Fitzroy Bay			**Lower**			**Upper**		
Taxa	**Common Name**	**FEEDING TYPE**	**1**	**2**	**3**	**1**	**2**	**3**
OLIGOCHAETA	Oligochaete worms	Infaunal deposit feeder						6
AMPHIPODA								
Amphipoda	Amphipods	Epifaunal scavenger	1				2	
Total No. of Taxa			**1**	**0**	**0**	**0**	**2**	**6**
Total No. of Individuals			**1**	**0**	**0**	**0**	**1**	**1**

4.6 Owhiro Bay

Owhiro Bay has a predominantly gravel upper beach with a firm sand and gravel mix along the lower shore. The bay is tightly bounded by the road, and sits between rocky platforms at both ends of the bay that extend down into the subtidal. In the head of the bay a carpark has been formed next to the road, and there was evidence of vehicles driving on the beach. Road runoff and stormwater inputs occur directly onto the beach. Owhiro Bay is noted to have contained sewage outfalls that discharged into the harbour (EHEA 1998).

Very little vegetation is present adjacent to the gravel beach. The plantings listed in the following table all come from gardens that have been established around carparks at the eastern end of the bay. Owhiro Bay Stream, which enters to the west of the bay, was identified by Taylor & Kelly (2001) as having good inanga spawning grounds upstream of the bridge on the true right bank, although the ford and weir structures will make access to rearing habitat difficult further upstream.

Table 24 Summary of habitat type and dominant species at Owhiro Bay.

Habitat type / **Dominant species**	Owhiro Bay	Grand Total (Ha)	% area mapped
Scrub			
Coprosma repens	0.27	0.27	3.6
Grassland			
Desmoschoenus spiralis	0.08	0.08	1.1
Unvegetated			
Cobble field	0.10	0.10	1.3
Firm sand	0.59	0.59	7.9
Gravel field	0.72	0.72	9.6
Rock	5.73	5.73	76.5
Grand Total	**7.49**	**7.49**	**100.0**

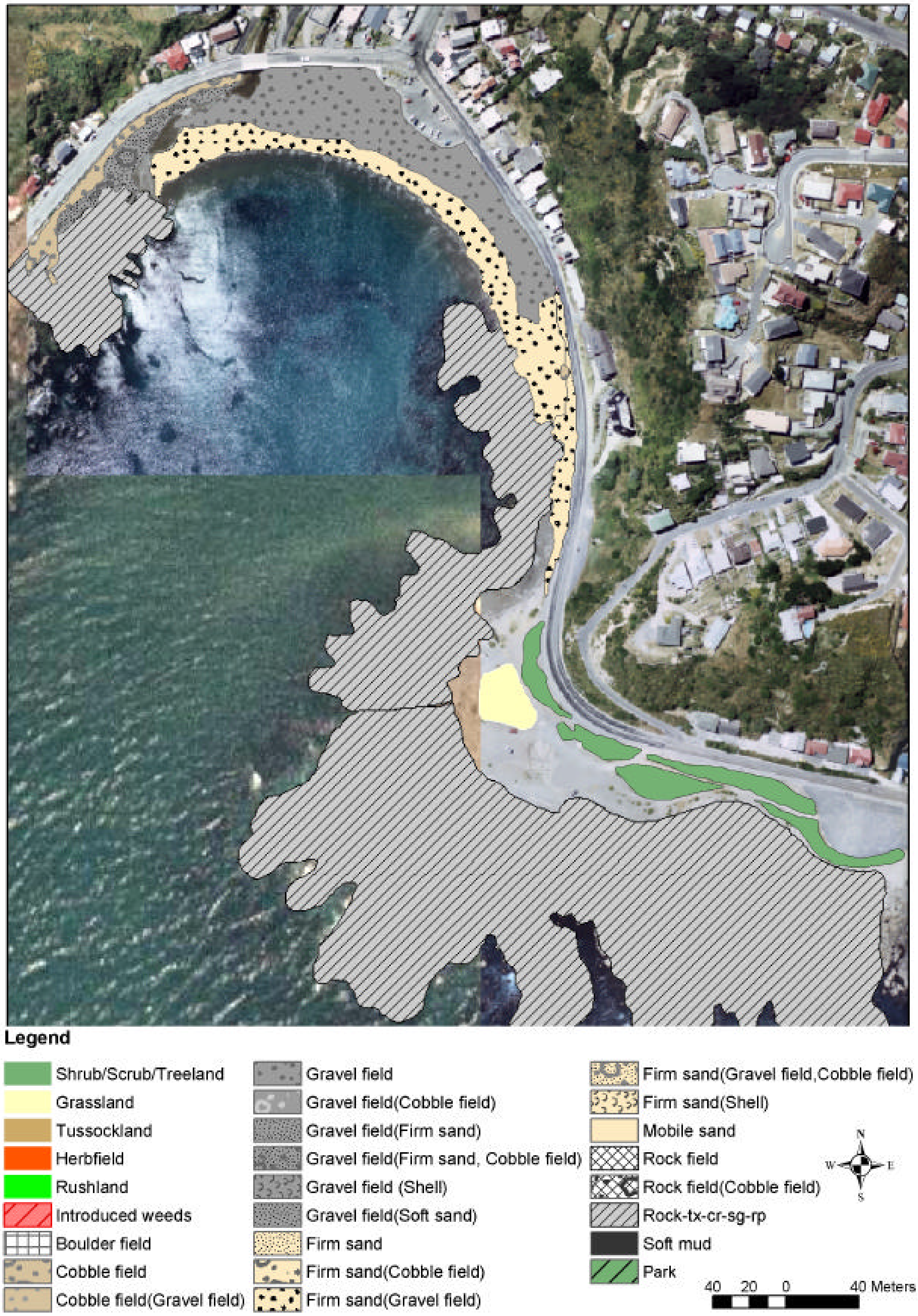


Figure 11 Broad scale habitat map of Owhiro Bay.

4.7 Island Bay

Island Bay is dominated by firm sand, with a small area of rock and gravel near the centre of the beach, and a constructed boulder field at the far west of the beach. The upper margin of the beach is bordered by the road with both ends of the beach flanked by creviced rock that has numerous surge gullies and rock pools. The vegetation present (predominantly marram grass, pingao, and tree lupin) is limited in area and has been planted to stabilise steep dune habitat.

At the centre of the beach, two large stormwater discharge points enter the beach, with numerous other smaller discharge points also present. Island Bay is noted to have contained sewage outfalls that discharged into the harbour (EHEA 1998).

Table 25 Summary of habitat type and dominant species at Island Bay.

Habitat type / **Dominant species**	Island Bay	Grand Total (Ha)	% area mapped
Scrub			
Coprosma repens	0.01	0.01	0.3
Shrubland			
Lupinus arboreus	0.04	0.04	1.2
Grassland			
Ammophila arenaria	0.14	0.14	4.5
Desmoschoenus spiralis	0.04	0.04	1.2
Tussockland			
Austrofestuca littoralis	0.06	0.06	1.9
Herbfield			
Carpobrotus edulis	0.02	0.02	0.6
Unvegetated			
Boulder field	0.00	0.00	0.1
Firm sand	1.78	1.78	55.7
Gravel field	0.21	0.21	6.5
Rock	0.88	0.88	27.8
Grand Total	**3.18**	**3.18**	**100.0**

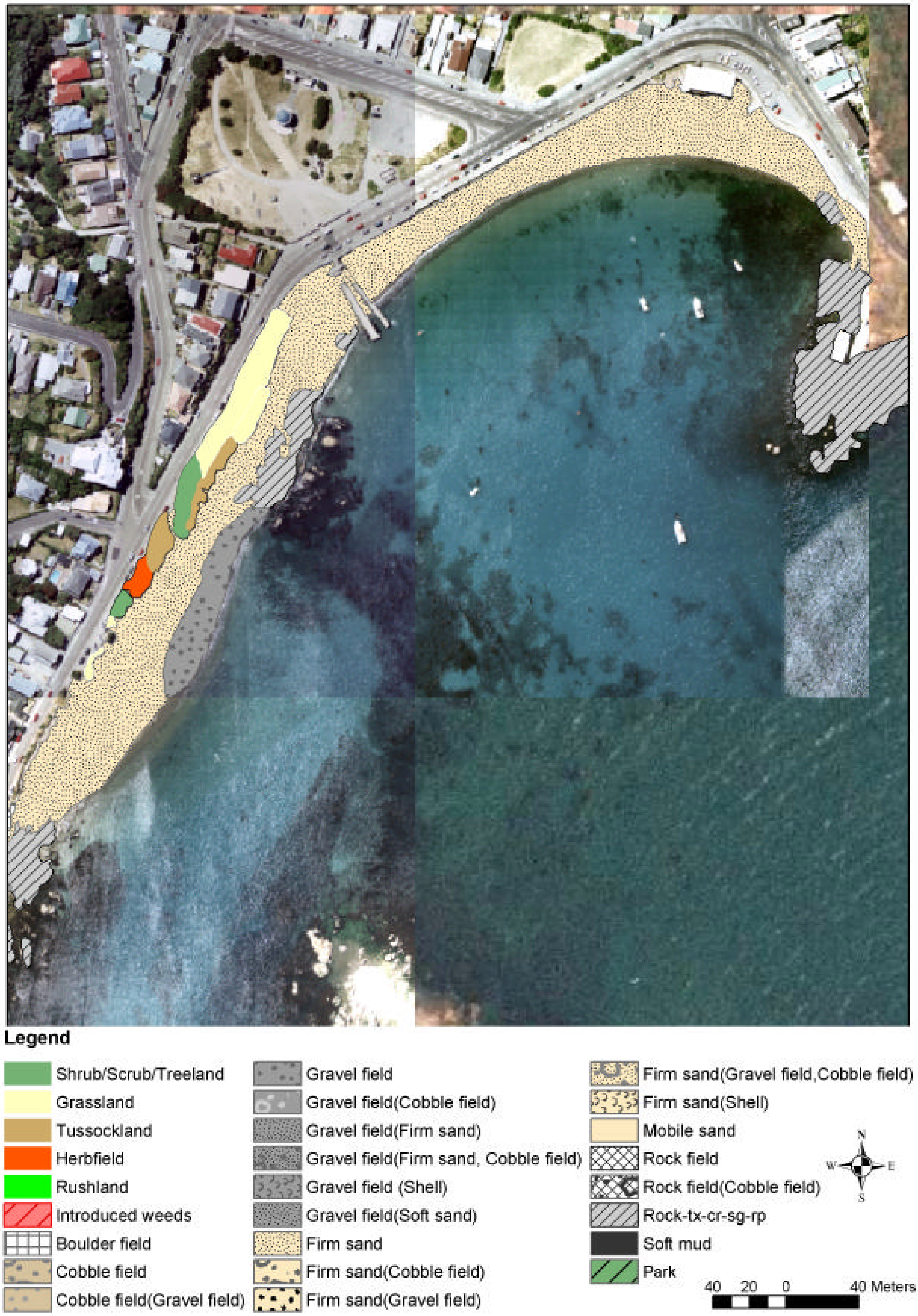


Figure 12 Broad scale habitat map of Island Bay.

4.8 Houghton Bay

Houghton Bay is predominantly a firm sand beach characterised by a relatively steep back dune area extending up to the road. The boulder field comprises a manmade retaining wall supporting the road. Extending to the east of the bay beyond a prominent rocky headland is a small cobble beach before another rocky headland leads to another firm sand beach. A stream enters into the centre of the bay and had an iron floc and extensive iron staining indicating leachate inputs from an old landfill further upstream.

The vegetation was dominated by flax, karo, and taupata along the upper margins by the road, with smaller amounts of marram grass, pingao, and ice plant towards the top of the beach. All provide a buffer between the road and the beach, except for a small unvegetated area directly in front of the carpark.

Table 26 Summary of habitat type and dominant species at Houghton Bay.

Habitat type Dominant species	Houghton Bay	Grand Total (Ha)	% area mapped
Scrub			
Coprosma repens	0.04	0.04	1.6
Pittosporum crassifolium	0.06	0.06	2.4
Shrubland			
Pittosporum crassifolium	0.13	0.13	4.8
Grassland			
Ammophila arenaria	0.00	0.00	0.2
Desmoschoenus spiralis	0.03	0.03	1.0
Tussockland			
Phormium tenax	0.14	0.14	5.2
Herbfield			
Carpobrotus edulis	0.02	0.02	0.7
Unvegetated			
Boulder field	0.03	0.03	1.3
Cobble field	0.05	0.05	2.1
Firm sand	1.05	1.05	39.9
Rock	1.08	1.08	40.9
Grand Total	**2.64**	**2.64**	**100.0**

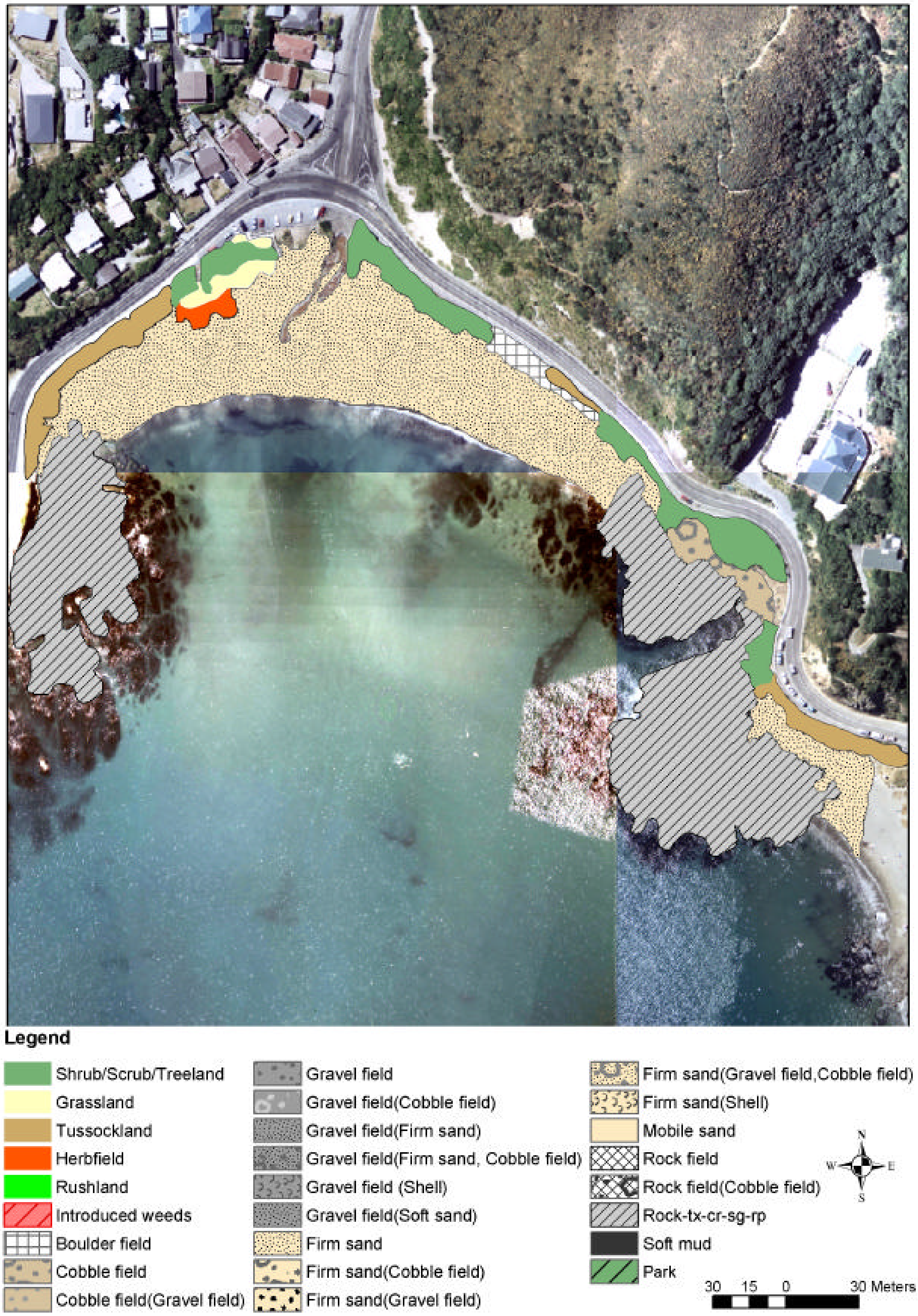


Figure 13 Broad scale habitat map of Houghton Bay.

4.9 Lyall Bay

Lyall Bay is a long gently sloping firm sand beach with two smaller gravel beds present within the sand. The western end of the beach is flanked by rock, with the eastern end having a constructed rip-rap wall. The upper margins of the beach have a narrow strip of buffering vegetation in front of a concrete wall adjacent to the road. The dominant vegetation is marram grass, with some pingao towards the eastern end of the beach. Stormwater discharge points enter to the east of the beach. Lyall Bay is noted to have contained sewage outfalls that discharged into the harbour (EHEA 1998).

Table 27 Summary of habitat type and dominant species at Lyall Bay.

Habitat type **Dominant species**	Lyall Bay	Grand Total (Ha)	% area mapped
Scrub			
Coprosma repens	0.01	0.01	0.1
Grassland			
Ammophila arenaria	0.90	0.90	7.6
Desmoschoenus spiralis	0.13	0.13	1.1
Unvegetated			
Boulder field	0.67	0.67	5.7
Firm sand	8.15	8.15	68.5
Gravel field	0.79	0.79	6.6
Rock	1.25	1.25	10.5
Grand Total	**11.90**	**11.90**	**100.0**

Figure 14 Broad scale habitat map of Lyall Bay.

4.10 Breaker Bay

Breaker Bay is a moderately steeply sloping gravel beach with a relatively uniform substrate across the entire beach. Small areas of rock are present at the seaward margin, and extend subtidally. A constructed boulder field provides an accessway at the western side of the bay, and a small amount of cobble is also present in this area. The most distinguishing feature of Breaker Bay, compared to the other beaches surveyed, is the relatively large undeveloped area which extends up to the ridgeline behind the beach. This provides an extensive buffer and gives the beach an isolated and rugged feel. The vegetation is dominated by flax, with smaller numbers of karo, pohutukawa, and taupata. A number of introduced weeds are also present.

Table 28 Summary of habitat type and dominant species at Breaker Bay.

Habitat type / **Dominant species**	Breaker Bay	Grand Total (Ha)	% area mapped
Scrub			
Coprosma repens	0.08	0.08	1.2
Shrubland			
Metrosideros excelsa	0.11	0.11	1.7
Pittosporum crassifolium	0.41	0.41	6.4
Grassland			
Pennisetum clandestinum	0.16	0.16	2.4
Tussockland			
Phormium tenax	2.52	2.52	39.0
Unvegetated			
Boulder field	0.09	0.09	1.4
Cobble field	0.02	0.02	0.3
Gravel field	2.58	2.58	39.9
Rock	0.50	0.50	7.8
Grand Total	**6.47**	**6.47**	**100.0**

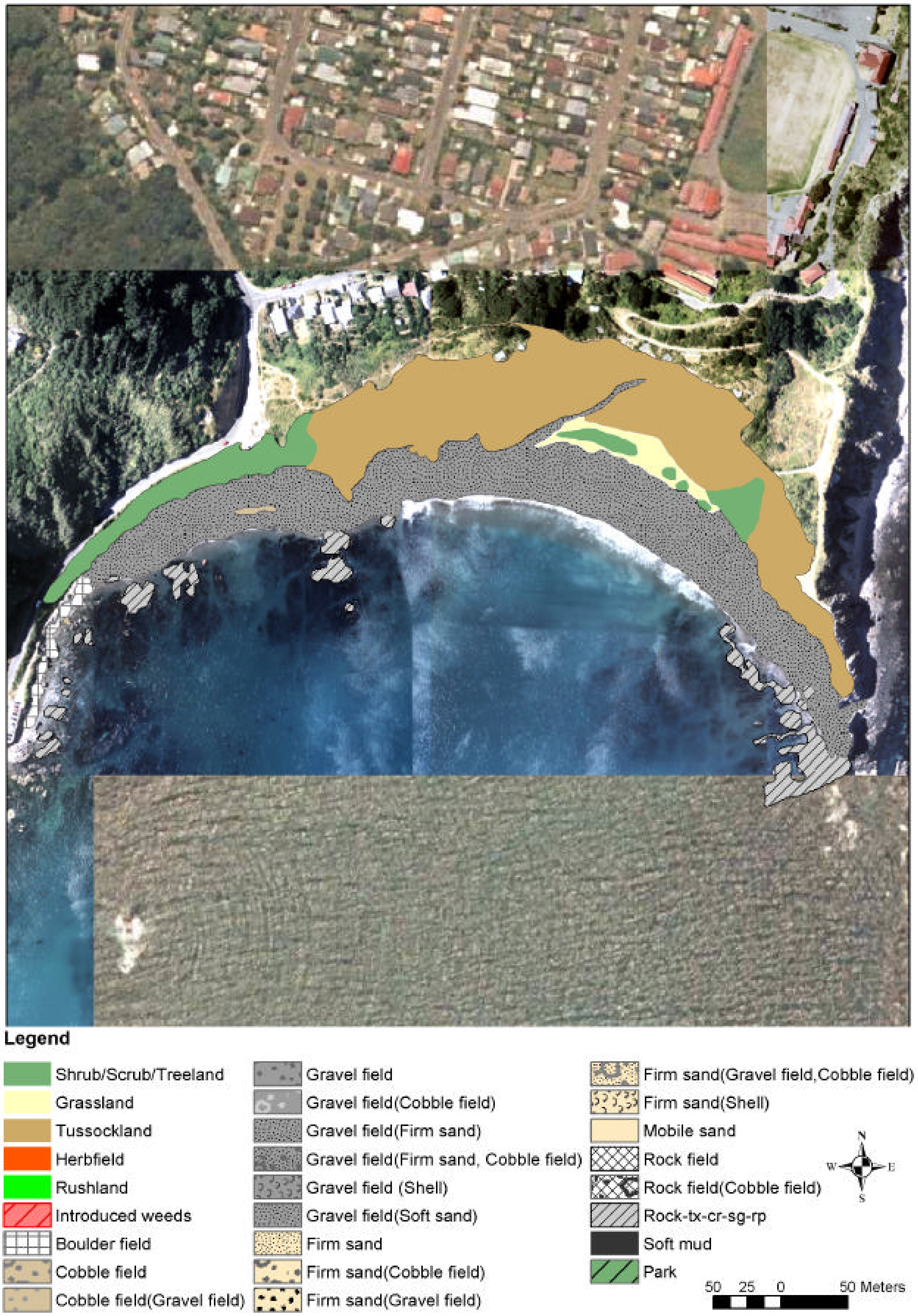


Figure 15 Broad scale habitat map of Breaker Bay.

4.11 Seatoun

Seatoun Beach has approximately equal areas of gravel and sand, gravel dominant to the southeast and firm sand in the northwest by Worser Bay. Towards the southeast an extensive boulder seawall has been constructed and plantings have been established inland of this. Public access to the area is generally good with open parks, walkways, and road along most of the beach. Along the northeast section of the beach is a concrete seawall immediately seawards of the road. A small area of dune planting has been undertaken between the wharf and the boat ramp. Features of local significance are the rocks lying off Seatoun (southern end), which feature a variety of seaweeds (EHEA 1998).

Table 29 Summary of habitat type and dominant species at Seatoun.

Habitat type / **Dominant species**	Seatoun	Grand Total (Ha)	% area mapped
Scrub			
Coprosma repens	0.17	0.17	5.6
Metrosideros excelsa	0.02	0.02	0.6
Shrubland			
Cupressus macrocarpa	0.21	0.21	6.8
Grassland			
Ammophila arenaria	0.31	0.31	9.9
Unvegetated			
Boulder field	0.17	0.17	5.4
Cobble field	0.02	0.02	0.6
Firm sand	0.96	0.96	31.1
Gravel field	1.24	1.24	40.0
Grand Total	**3.10**	**3.10**	**100.0**

Figure 16 Broad scale habitat map of Seatoun.

4.12 Worser Bay

Worser Bay is predominantly a firm sand beach backing onto a park and planted dunes before the road is reached. In the park to the north are some large pohutukawa trees. Moving south, the beach changes form with rocky outcrops dropping 1-2m steeply from the road which is very close to the top of the beach. The rocky outcrops are interspersed with firm sand and there is a narrow strip of vegetation buffering the beach from the road. A variety of introduced weeds are present in this area.

Table 30 Summary of habitat type and dominant species at Worser Bay.

Habitat type / **Dominant species**	Worser Bay	Grand Total (Ha)	% area mapped
Treeland			
Metrosideros excelsa	0.05	0.05	2.3
Scrub			
Coprosma repens	0.29	0.29	12.4
Grassland			
Ammophila arenaria	0.37	0.37	16.1
Unvegetated			
Cobble field	0.14	0.14	6.2
Firm sand	1.14	1.14	49.3
Rock	0.32	0.32	13.7
Grand Total	**2.32**	**2.32**	**100.0**

Figure 17 Broad scale habitat map of Worser Bay.

4.13 Kaiwharawhara Stream

The Kaiwharawhara coastline is made up of approximately 5 ha of reclaimed land. The shoreline has been modified with the deposition of man-made rubble (EHEA 1998), which is flanked by a steep 2-4m high bank of unconsolidated fill, which inland is a dump site and storage area for railway and port equipment. An ecological study was conducted following reclamation in the 1970s, and did not record any unique or rare organisms so it was deemed of low ecological value (Truebridge *et al.* 1978, cited in EHEA 1998). Nothing was observed in this study to alter that summary.

This area has had a long-term pollution problem. The shipping activities increase disturbance of the sediments and add heavy metal contaminants to the area (EHEA 1998). Stoffers *et al.* (1986, cited in Wear & Haddon 1992) found elevated levels of metals in sediments off Kaiwharawhara, and shellfish were found to have high lead levels from this area (Wilson 1984, cited in Wear & Haddon 1992).

Kaiwharawhara Bay Stream was identified by Taylor & Kelly (2001) as having limited potential as inanga spawning grounds. This streamway is highly modified and comprises, in the lower reaches, a concrete raceway providing very little natural habitat.

The vegetation present is almost exclusively introduced tree and weed species with the potential to become pests. The exception is a very small area of native plantings that have been established immediately behind the gravel beach. Access to the area is very limited being restricted inland by the motorway and requiring approval from Tranzrail to pass through the interislander ferry vehicle loading area to reach it.

Table 31 Summary of habitat type and dominant species at Kaiwharawhara Stream.

Habitat type	Dominant species	Kaiwharawhara	Grand Total (Ha)	% area mapped
Scrub				
	Acacia spp.	4.26	4.26	88.6
Unvegetated				
	Cobble field	0.03	0.03	0.6
	Gravel field	0.52	0.52	10.7
Grand Total		**4.81**	**4.81**	**100.0**

Figure 18 Broad scale habitat map of Kaiwharawhara Stream.

4.14 Korokoro Stream

The Korokoro foreshore has a predominantly gravel beach flanked at either end by manmade boulder fields. It is a highly modified reclamation area which includes motorway, railway and rubble (EHEA 1998). Wear & Haddon (1987) described the vegetation in the area as mostly introduced or noxious weeds, with small colonies of native grasses (pingao and spinifex) outside the reclamation site. To the east, a relatively large area of native glasswort (*Sarcocornia*) has established. Otherwise the area is almost completely bare of vegetation other than grass.

Wear & Haddon (1987) reported the Korokoro site was dominated by blue mussels, barnacles and substantial green algae around the stream outlet. The interitdal flora and fauna was not deemed unique. In general, the Korokoro area was concluded to have low ecological value. A rocky subtidal reef extends offshore of the stream mouth for approximately 20 m to a depth of 10 m, and supports a rich macroalgal habitat with associated fish and invertebrates (EHEA 1998). Korokoro Bay Stream was identified by Taylor & Kelly (2001) as having limited potential as inanga spawning grounds.

Although highly modified, the immediate beach foreshore offers a fairly natural setting, with both high recreation values and wildlife values, due to significant levels of birds roosting in the area (EPA 1990).

Table 32 Summary of habitat type and dominant species at Korokoro Stream.

Habitat type Dominant species	Korokoro	Grand Total (Ha)	% area mapped
Herbfield			
Sarcocornia quinqueflora	0.70	0.70	29.4
Unvegetated			
Boulder field	0.51	0.51	21.3
Gravel field	1.18	1.18	49.3
Grand Total	**2.40**	**2.40**	**100.0**

Figure 19 Broad scale habitat map of Korokoro Stream.

4.15 Days Bay

Days Bay is largely made up of firm sand with smaller pockets of gravel and isolated rock at the very north of the beach. The northern end of the beach has been planted with marram grass to protect a small dune area, while to the south there are seawalls with little other beach vegetation, although some large established trees border the road which extends along the entire top margin of the beach. There are sealed parking areas between the beach and the road.

Beach grooming takes place at Days Bay in the upper portion of the beach.

Pipi (*Paphies australis*) are present in Days Bay, while beds of the cockle (*Austrovenus stutchburyi*) are known to extend in the shallow water soft substrates from the western end of Petone Beach to Days Bay (EHEA 1998). Days Bay features the Little Blue Penguin Foundation. There have been sanctuaries established around the harbour and some have successfully been used for breeding (EHEA 1998).

Table 33 Summary of habitat type and dominant species at Days Bay.

Habitat type Dominant species	Days Bay	Grand Total (Ha)	% area mapped
Grassland			
Ammophila arenaria	0.18	0.18	12.8
Unvegetated			
Firm sand	1.05	1.05	73.2
Gravel field	0.16	0.16	11.2
Rock	0.04	0.04	2.8
Grand Total	**1.44**	**1.44**	**100.0**

Figure 20 Broad scale habitat map of Days Bay.

4.16 Eastbourne

Eastbourne is predominantly a gravel beach with firm sand/gravel and cobble present along the lower shore. The upper margins of the beach have a buffer of vegetation (marram grass, pingao) that extends across the northern half of the beach, but there is very little vegetation to the south other then introduced weeds.

Eastbourne features a *Macrocystis* algal forest that is extensive and unique. This extends south of Eastbourne to Makaro/Ward Island, and may be a significant area for fish within the Harbour (EHEA 1998). As Eastbourne and the southern bays of the Wellington harbour are more saline than the inner harbour, the cockle beds are replaced by a variety of soft-substrate infaunal bivalves, such as scallops, mussels, horse mussels, *Dosinia subrosea*, *Tawera spissa* and others (EHEA 1998).

Diver observations off the beach at Eastbourne described the shore as a band of boulders and sand near low water level with red algae and *Ulva* (sea lettuce) growing over it. The substrate shifted from sand to muddy sand subtidally, and the visible epifauna was dominated by the cushion star *Patiriella regularis* and hermit crabs (to 5 m). Deeper water (15-17 m) revealed algal drift, sea cucumbers and large *Coscinasterias* starfish (Lewis 1990, cited in Wear & Haddon 1992).

Robinson Bay, south of Eastbourne, has an erosion problem due to foreshore modifications from residential development, and have a seawall and groynes to prevent erosion. However, the beach to 300 m north has been accreting for many years (EHEA 1998).

Table 34 Summary of habitat type and dominant species at Eastbourne.

Habitat type / Dominant species	Eastbourne	Grand Total (Ha)	% area mapped
Treeland			
Metrosideros excelsa	0.27	0.27	2.5
Grassland			
Ammophila arenaria	2.54	2.54	24.1
Desmoschoenus spiralis	0.25	0.25	2.4
Weeds			
Introduced weeds	0.40	0.40	3.8
Unvegetated			
Firm sand	1.62	1.62	15.4
Gravel field	5.06	5.06	47.9
Rock	0.42	0.42	4.0
Grand Total	**10.56**	**10.56**	**100.0**

Figure 21 Broad scale habitat map of Eastbourne (northern end).

Figure 22 Broad scale habitat map of Eastbourne (southern end).

4.17 Camp Bay

The substrate at Camp Bay is dominated by a gravel field, with a constructed boulder field at the northern end which ensures vehicle access is only via a locked gate. A gravel road follows the back of the gravel beach providing access to Pencarrow and beyond. A small amount of pingao was present, and several introduced weed species were evident in the upper margins of the beach.

A benthic and intertidal ecological assessment of Camp Bay was carried out by Wear *et al.* (1990, cited in Wear & Haddon 1992), as part of a planned sewage outfall and pipeline development. The Camp Bay intertidal zone consisted of natural rock substrate with red and green algae, blue mussels, barnacles, periwinkles, limpets and chitons.

Table 35 Summary of habitat type and dominant species at Camp Bay.

Habitat type / **Dominant species**	Camp Bay	Grand Total (Ha)	% area mapped
Grassland			
Desmoschoenus spiralis	0.03	0.03	0.8
Unvegetated			
Boulder field	0.02	0.02	0.5
Gravel field	3.85	3.85	98.3
Rock	0.02	0.02	0.4
Grand Total	**3.92**	**3.92**	**100.0**

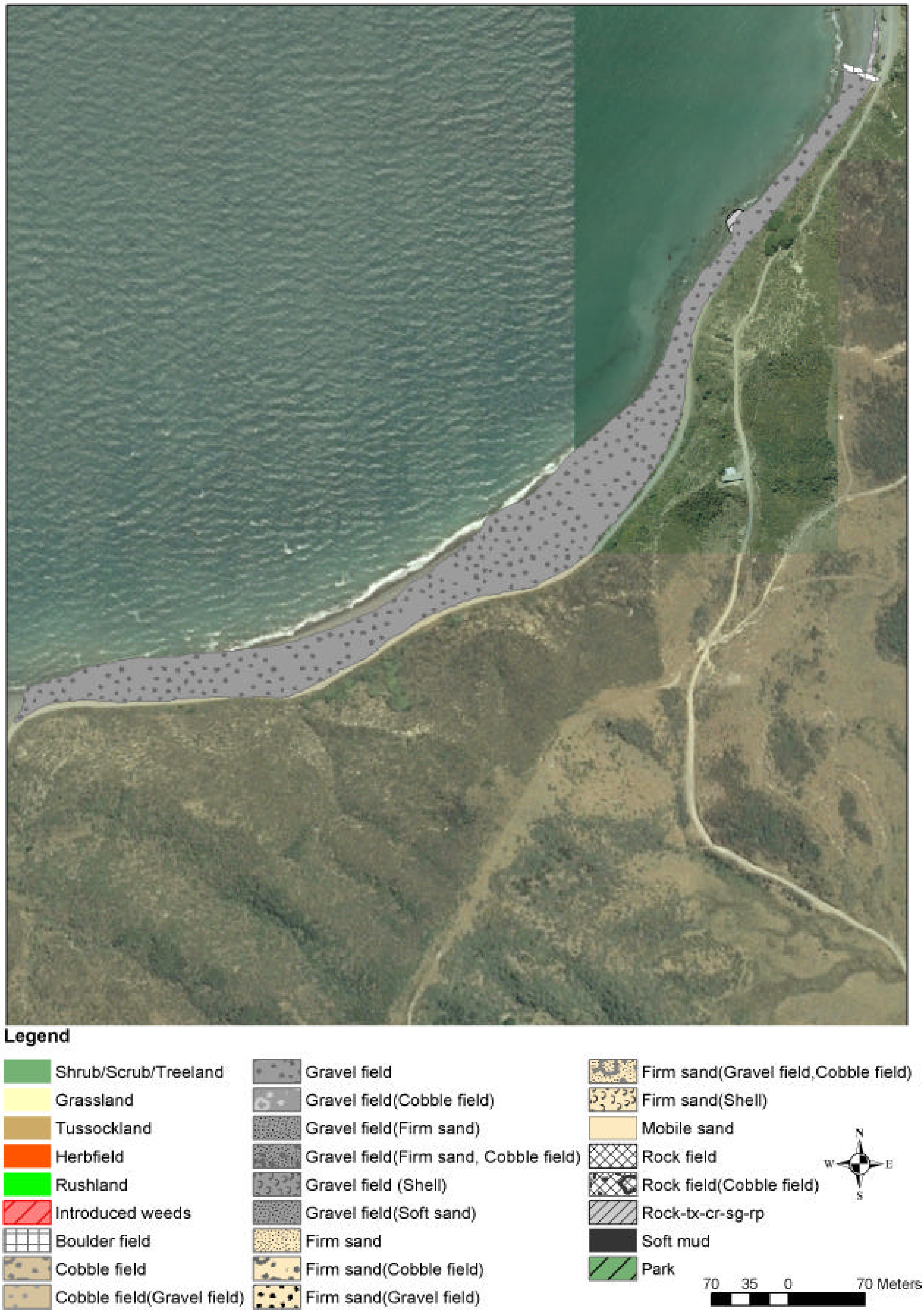


Figure 23 Broad scale habitat map of Camp Bay.

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7. APPENDIX 1 – SUMMARY OF BIOLOGICAL DATA

Wellington Coastal Mapping

16/03/2004 *Data Type:* *Count*

Taxa	***Common Name***	Fitzroy Bay A, 1lo	Fitzroy Bay A, 2up	Fitzroy Bay A, 3up	Hutt Estuary, A1	Hutt Estuary, A2	Hutt Estuary, B1	Hutt Estuary, B2	Lowry Bay A, 1lo	Lowry Bay A, 1up	Lowry Bay A, 2lo	Lowry Bay A, 2up	Lowry Bay A, 3lo	Lowry Bay A, 3up	Petone Beach A, 1lo	Petone Beach A, 1up	Petone Beach A, 2lo	Petone Beach A, 2up	Petone Beach A, 3lo	Petone Beach A, 3up	Petone Beach B, 1lo	Petone Beach B, 1up	Petone Beach B, 2lo	Petone Beach B, 2up	Petone Beach B, 3lo	Petone Beach B, 3up
PLATYHELMINTHES	Flat Worm																									
PLATYHELMINTHES	Flat Worm																						1			
NEMERTEA	Proboscis worms																									
NEMERTEA	Proboscis worms					1		1					2		1		1				1		1		1	
NEMATODA	Roundworm																									
NEMATODA	Roundworm														2	2	1	5		6		1				
GASTROPODA	Snails, Limpets, Paua, etc.																									
Amphibola crenata	Mud Snail				2			1																		
Potamopyrgus antipodarum	Estuarine snail					13	20	28																		
Potamopyrgus estuarinus	Estuarine snail				1	3	4	4																		
Potamopyrgus pupoides	Estuarine snail				3	4	14	10																		
BIVALVIA	Bivalves																									
Austrovenus stutchburyi (0-5mm)	Cockle (0-5mm)				2	2	2																			
Austrovenus stutchburyi (06-10mm)	Cockle (6-10mm)				1																					
Austrovenus stutchburyi (11-20mm)	Cockle (11-20mm)				6	1		1																		
Austrovenus stutchburyi (21-30mm)	Cockle (21-30mm)				2		1	1																		
Macomona liliana	Wedge shell, Hanikura								1								1		2		1		1		2	
Paphies australis	Pipi				1	1	12	4							74		37	1	24		3		28		63	
Soletellina sp.													1													
OLIGOCHAETA	Oligochaete worms																									
OLIGOCHAETA	Oligochaete worms			6	13	13	8	19						11												
POLYCHAETA	Bristle worms																									
Orbiniidae																										
Orbinia papillosa					1						1		1				2		1		1		1		1	
Spionidae									2		1															
Aonides sp.									1						1		2								1	
Boccardia sp.									1																	
Prionospio sp.																					2		32		3	
Scolecolepides sp.								1																		
Scolelepis sp.							1	9																		
Magelonidae																										
Magelona papillicornis									11	1	20		91		12		25	1	24		5	2	21	1	33	2
Capitellidae																										
Capitella capitata					4	1	1	7	2		2		3		2		2						1			
Heteromastus filiformis													1										2			
Syllidae									1		1		1													
Sphaerosyllis hirsula																					4		1		1	
Nereidae																										
Nicon aestuariensis					4	1	4	3																		
Glyceridae											2		2										2			
Pectinariidae																										
Pectinaria australis																							2			
ISOPODA	Isopods																									
Flabellifera	Sea louse											2						1		1						
AMPHIPODA	Amphipods																									
Amphipoda	Amphipods	1	2		112	294	244	251	1	2		2	1													
Total No. of Individuals:		1	2	6	152	334	311	340	20	3	27	4	103	11	92	2	71	8	51	7	17	3	93	1	105	2
Total No. of Taxa:		1	1	1	13	11	11	14	8	2	6	2	9	1	6	1	8	4	4	2	7	2	12	1	8	1