Auckland
Regional Council
TE RAUHĪTANGA TAIAO

Benthic Marine Habitats and Communities of Kawau Bay

August 2008 TR 2008/006

Auckland Regional Council
Technical Report No.006 August 2008
ISSN 1179-0504 (Print)
ISSN 1179-0512 (Online)
ISBN 978-1-877483-32-5

Reviewed by:

Name: Marcus Cameron

Position: Project Leader – Marine

Organisation: Auckland Regional Council

Date: August 2008

Approved for ARC Publication by:

Name: Grant Barnes

Position: Group Manager – Monitoring and Research

Organisation: Auckland Regional Council

Date: August 2008

Recommended Citation:

Chiaroni, L.; Hewitt, J.E.; Hancock, N. (2008). Benthic Marine Habitats and Communities of Kawau Bay. Prepared by NIWA for Auckland Regional Council. Auckland Regional Council Technical Report 2008/006.

Benthic Marine Habitats and Communities of Kawau Bay

Chiaroni, L.
Hewitt, J.E.
Hancock, N.

Prepared for
Auckland Regional Council

NIWA Client Report: HAM2007-123
June 2007

NIWA Project: ARC07212

National Institute of Water & Atmospheric Research Ltd
Gate 10, Silverdale Road, Hamilton
P O Box 11115, Hamilton, New Zealand
Phone +64-7-856 7026, Fax +64-7-856 0151
www.niwa.co.nz

Contents

Reviewed by:

Dr S.F. Thrush

Approved for release by:

Dr D. Roper

Formatting checked

1 Executive Summary

The area considered in this report to be Kawau Bay includes the southern half of the Tawharanui Peninsula, the west coast of Kawau Island, the South and Inner Channels down to the mouth of the Mahurangi and all estuaries and bays within this area. It encloses 121.5 km^2 and consists of a diverse array of physical habitats (intertidal and subtidal areas, rock and soft-sediments, estuaries and wave exposed areas). The Kawau Bay area has high recreational and aesthetic values and is a multi-use area for the people of the Auckland Region. As increased development is planned for the surrounding catchment, the number of people using the area, and the degree of threat to its ecology, is likely to increase. The ARC, therefore, asked NIWA to monitor the benthic habitats and determine both their ecological values, and the types of threats to those values.

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

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

Kawau Bay was found to be an area of high habitat diversity, with communities varying from those dominated by large macroalgae to dense epifauna. The soft-sediment subtidal areas, in particular, display high taxonomic diversity. Many of the taxa are large and long-lived and include those commonly associated with more pristine environments. However, unlike the Southern Kaipara, no subtidal seagrass beds were located, nor were any unique associations of fauna and flora.

Four broad-scale habitat zones were apparent in Kawau Bay, strongly related to exposure to waves and currents: north and west sheltered; western and inner channel; high current eastern; and north and south channel. These broad-scale habitats all contained a range of community types representing different ecological functions: such that a large number of ecological functions were observed. Dominant taxa observed were those that contribute to benthic productivity, nutrient fluxes and water column productivity; affect sediment stability and water clarity; provide refugia and food for fish: and/or provide food and recreational value for humans.

The major threats to the ecology of Kawau Bay are considered to be:

Recreational uses: Kawau Bay is extensively used for recreational pursuits. While recreational pursuits are generally thought to be relatively benign, this is not always the case. (i) Communities on intertidal rock platforms can be strongly affected by a number of people walking across the surface. We recommend that a six monthly monitoring programme based on photographic records should be initiated at intertidal rock platforms within easy access. (ii) Boat anchors can cause considerable damage to areas with diverse epifauna, such as sponge gardens, *Atrina* beds and kelp beds. Protection of at least some of these areas by "no anchor" zones should be considered. (iii) While recreational extraction is not within the ability of the ARC to manage, it is still a threat to the communities of Kawau Bay, both intertidally and subtidally. Impacts include: disruption to community structure by removal of critical species; and the damage caused both to other species and to the seafloor by recreational scallop dredging.

Urbanisation and sedimentation: The increasing urban development planned for land surrounding Kawau Bay may have distinct impacts on the habitats of Kawau Bay. The risk of impacts associated with increased sedimentation, nutrients and stormwater contaminants are generally considered higher in depositional areas of estuaries, such as Matakana and Mahurangi, than in coastal areas. However, recent studies on sediment effects suggest that this may be erroneous, due to higher sensitivity of organisms living outside estuaries. The recently ARC-developed Benthic Health Model also suggests that effects from contamination may occur in wave-exposed areas.

In summary, Kawau Bay displays a healthy and diverse ecology. The range of goods and services provided by the benthic fauna and flora result in Kawau Bay having both high ecological values and high societal values. Without careful management, these ecological and societal values are at risk from increased direct use and catchment development.

2 Introduction

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

Elements of Tier I monitoring have been in operation since 1987, and have provided important feedback for resource management and State of the Environment reporting (Hewitt et al. 1994, Cummings et al. 2003, Hewitt et al. 2004b, Thrush et al. 2004). Tier II monitoring was initiated in 2003 in the Kaipara. This information proved to be highly useful for the ARC's management of aquaculture. In 2005, Tier II monitoring of Kawau Bay was initiated. Kawau Bay was chosen as it is a diverse system with a number of uses, and the ARC forecasts these uses are likely to increase.

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

This change in the objective and sample design does not preclude the ability to determine if change has occurred when a return visit has been made in 16 years, but does alter the way that change would be assessed. Assessment of change would be predominantly at a large scale, considering changes in communities and habitat types across the area as a whole, or within large subsections. Somewhat less effective site-by-site comparisons could also be made for sediment particle size, species and assemblages, using natural temporal variability apparent from the sentinel monitoring sites (Tier I) in the region to set the limit on the magnitude of effects detected. Given the changes to the Tier II programme, this report focuses on determining general similarities between sites and the spatial distribution of habitat types and ecological communities, with the raw data necessary for specific site descriptions contained in GIS files.

For the purposes of this report, Kawau Bay is delineated as running from the end of the Tawharanui Peninsula out to the East coast of Kawau Island, then from the southeast of Kawau Island to Motuora Island and into Dairy Bay, just north of Mahurangi Harbour (Fig. 1). It contains 121.5 km^2 of which 8.9 km^2 is intertidal (7.3%) and is predominantly subtidal soft-sediments. Of the 120 km^2 of coastline, 40 km^2 of the coastline is sheltered and 80km^2 relatively exposed to wave activity. Tidal currents are also variable throughout the area, from low current activity in the middle of the bay and near the southern beaches, to strong currents through the North Channel between Tawharanui Peninsula and Kawau Island. Kawau Bay abuts the Tawharanui regional park, located on the Tawharanui peninsula separating Omaha Bay from Kawau Bay, which covers an area of 588 Hectares. At present this park is managed by the ARC. The marine park on the northern coastline of Tawharanui peninsula (395 Hectares) is outside Kawau Bay. This marine park is currently administered by the Ministry of Fisheries and the ARC, although there is a proposal to reclassify it as a 400 hectare Marine Reserve, administered by a committee made up of key stakeholders including DOC, ARC and representatives of the tangata whenua (Ngati Manuhiri).

3 Methods

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

3.1 Intertidal sampling

3.1.1 Large-scale features

Unlike the Kaipara, no vegetation classifications were available from ARC for the area around Kawau Bay. However, the coastal land interface is generally comprised of cliffs and beaches; wetlands and mangroves being confined to the upper reaches of the estuaries flowing into the bay. Only one other large-scale intertidal feature existed, an extensive bed of *Zostera* at Snells Beach. The extent of the bed was mapped by walking around its outline and capturing the area with a handheld GPS and comparisons made with aerial photographs from 1999 and 2001 (http://maps.arc.govt.nz).

3.1.2 Macrofauna

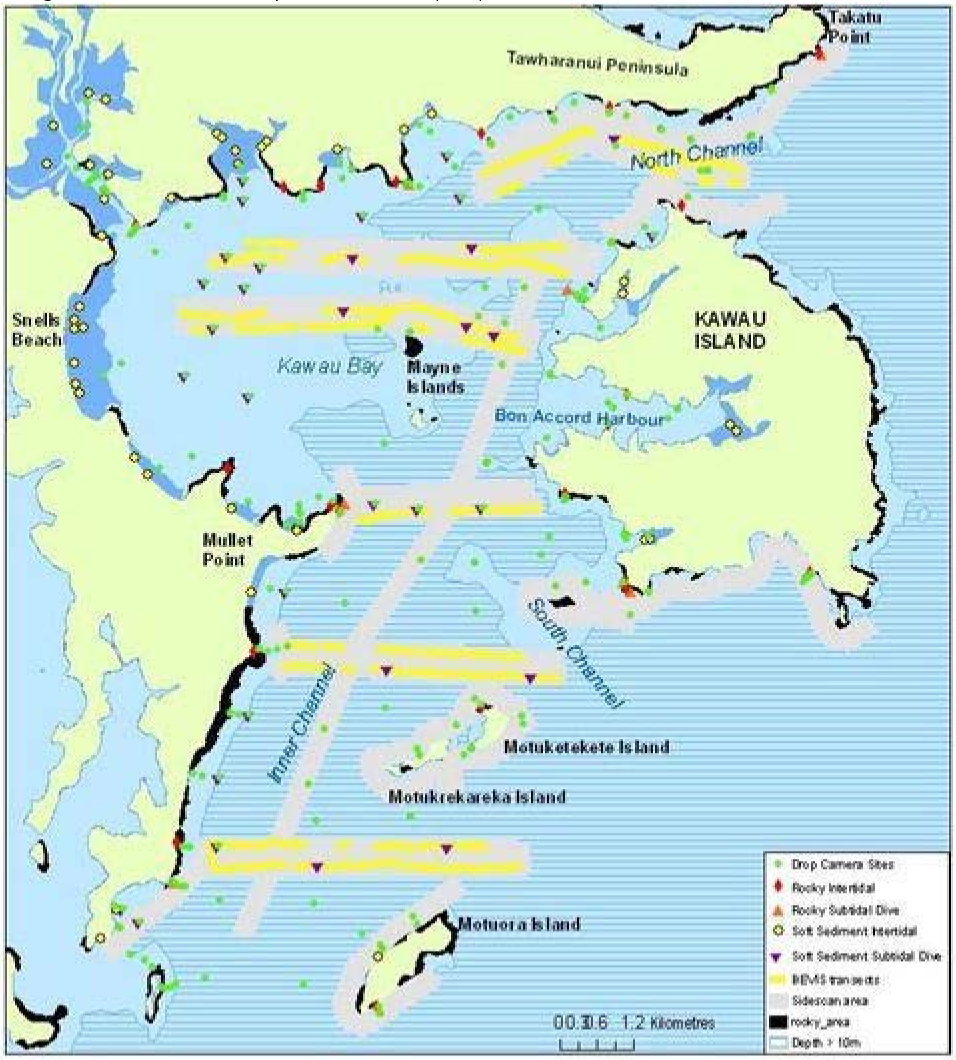
3.1.2.1 Hard substrata

Kawau Bay has a number of rocky intertidal areas, from which 21 locations were chosen for sampling (Fig. 3.1). During sampling, site characteristics (rock type, algae cover, wave exposure or currents, presence and type of animals observed) and the relative homogeneity of these characteristics were noted. Based on whether adjacent sites were similar to each other either a full sampling protocol or a partial sampling protocol was used. As a result, 7 "full" and 14 'partial' sites were sampled.

For each site a general classification was carried out which included assessing: rock type (e.g. bedrock, boulders), slope (e.g. flat, gentle slope, steep) and width of the intertidal area. Sampling was carried out at three elevations in the eulittoral (high, mid, and within 50 cm of the low tide observed on tides between neap and spring). For two sites, low tide sampling was not possible because the rock dropped too steeply into the water. Full sampling consisted of three 0.25m^2 quadrats at each elevation (Hewitt and Funnell 2005), while partial sampling consisted of one only. Quadrats were placed to capture the major habitats present at each elevation (i.e. where the elevations to be sampled displayed obvious patchiness in habitat, samples were taken in each habitat). For each quadrat, percent cover of dominant organisms and bare rock was assessed using ranks (< 5% = 1, 5 – 10% = 2, 10 – 25% = 3, 25 – 50% = 4, 50 – 80% = 5, 80 –

100% coverage = 6) and the presence of all other taxa >4 mm in size noted. For fully sampled sites, abundance and size class data were also collected.

Figure 3.1: Kawau Bay with all sample positions.



3.1.2.2 Soft substrata

Positions for sampling were dispersed throughout Kawau Bay with locations determined using hydrographic chart data, ecological knowledge, size of intertidal area, sediment type and distance to freshwater inputs.

Soft-sediment infauna were sampled at 39 sites (Fig. 3.1) using an adaptive sampling design (as per Hewitt and Funnell 2005). Site characteristics (sediment type, sediment compaction, evidence of vegetation, indications of wave exposure or high current, presence and type of benthic animals able to be observed at the sediment surface) and the relative homogeneity of these characteristics were noted. If these characteristics were the same as those noted at the next closest site, the site was not sampled further. If they were different, three sediment samples (13cm diameter, 15cm deep) were taken, within a 10 by 10 m area. As a result of this sampling 5 sites were assessed using 1 replicate only.

Within the seagrass bed, at Snells Beach, four transects were run from the upper reaches of the bed to low on the intertidal flat. Down each transect, a single core was taken at four locations and processed in the same way as the other intertidal samples.

All sediment samples were sieved on a 1mm mesh, preserved in 50% Isopropyl alcohol and stained with 5% Rose Bengal. Invertebrates were sorted, identified to the lowest practical taxonomic resolution and counted.

3.2 Subtidal sampling

3.2.1 Large-scale physical features

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

Side-scan data was collected using a C-Max CM2 Side-scan Sonar system comprising a digital recorder and tow fish operating in 102 kHz mode, with a 250m SCX tow-cable running through a digital pulley block for displaying playback. Side-scan lines were run in an east-west direction using HydroPro for navigation with a line spacing of 250m to ensure side-scan overlap. Swath width was 150m either side of the fish that was towed at a constant height from the bottom at about four knots boat speed. Sound velocity profiles were obtained at the start of each day using an AML SmartProbe. The data was processed using a CODA DA50 and georeferenced TIFF files suitable for input into a GIS were produced.

As full coverage of the entire survey area would be cost prohibitive, a transect sampling method was used (Fig. 3.1). Transects were oriented down depth gradients for two reasons. Firstly, we wanted to be able to detect any transitions between mud and sand. Secondly, previous side-scan/epibenthic work in Kawau Bay demonstrated more similarity across depths than down depth gradients (Hewitt et al. 2004) making interpolation across depth more likely to be accurate. An additional transect was included running in a north-south direction to determine if there were any major transitions evident in this direction.

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

The first system, BEVIS (Benthic Ecology Information Video System), has two high-resolution colour zoom cameras (Benthos 4802 camera, at 480 lines of horizontal resolution). It has scaling lasers and 900 watts of lighting and collects depth/heading information. This video sled setup is capable of covering a relatively large area in a short period. It can thus be used to detect transition boundaries and gradients of physical and ecological habitat change, as well as provide data on community type. Two transects were run through each side-scan transect, except for the side-scan transect crossing a submarine cable. The first transect of each area had 70-100% video coverage while the second had 30-70% coverage. In heterogeneous areas the video was run continuously to capture as much variability as possible. This method has been used to effect in work for DOC at Tonga Island Marine reserve (Thrush et al 2003).

The second system was a high resolution Tritech Typhoon camera, with 470 lines of horizontal resolution. The camera was mounted in a depressor frame with integrated lights and laser scaling system. Drop cameras are used to cover medium sized transects (generally 10-20m per drop), as the lack of directional controls prevent effective coverage of larger areas. Drops generally ran for 10 m, but where habitats changed during a drop, another 10m section was sampled. In rocky reef areas, this can occur multiple times during one drop and results in multiple sections being analysed. Locations of sampling were decided upon to complement the BEVIS footage, cover areas where BEVIS could not be used (rocky shore and shallow coastal areas) and to cover areas that were likely to show habitats that had not yet been sampled (based on information such as depth, currents, exposure). A total of 235 drop camera sections were analysed from a total of 169 drops (Fig. 3.1).

3.2.2 Epibenthos and infauna

3.2.2.1 Soft substrata

Soft-sediment subtidal sampling concentrated on both infauna and epifauna.

Data from the drop camera was analysed to produce counts of epifauna and flora (or percentage cover for colonial organisms). Information was also recorded that represented the presence of different types of infauna (density of burrows, visible evidence of tubeworms etc.).

Infaunal sampling was conducted at 41 locations, (Fig. 3.1). While grab-sampling devices had been used in the Southern Kaipara, grab efficiency is poor in the type of coarse shelly sediments frequent in Kawau Bay. Instead, four contiguous 13cm diameter cores were collected by SCUBA and bulked to approximate a grab sample. Depending on similarity between sites, 1 – 3 replicate sets of cores were collected. As with the intertidal survey, all samples were sieved on a 1mm mesh and preserved in 50% Isopropyl alcohol. Invertebrates were sorted, counted and identified to the lowest practical taxonomic level (mostly to genus or species level).

3.2.2.2 Hard substrate

From each of the drop camera sections over hard substrates, flora and fauna were identified and coverage estimated as rank abundance. At seven locations, more detailed sampling was conducted (Fig. 3.1). This consisted of three replicate 1m^2 quadrats, at two depths (between 3-4m and 7-9m) where possible. The data was collected to be as consistent as possible with other subtidal rocky reef data collected for the ARC (Ford et al. 2004). For each quadrat, abundance data were collected for all taxa greater than 10mm in size. For encrusting sponges, ascidians and algae, percent cover was used as appropriate. Quadrats were placed to capture the major habitats present at each elevation (i.e. where the sampled area displayed obvious patchiness in habitat, samples were taken in each habitat).

3.3 Sediment particle size

At all soft-sediment intertidal and subtidal core sites, three 2 cm diameter, 2 cm deep cores were taken and aggregated. Samples were stored frozen until processed. Prior to analysis, the samples were homogenised and a subsample of approximately 5 g of sediment taken, and digested in ~ 9% Hydrogen peroxide until frothing ceased. The sediment sample was then wet sieved through 2000 μm, 500 μm, 250 μm and 63 μm mesh sieves. All fractions were then dried at 60°C until a constant weight was achieved (fractions were weighed at ~ 40 h and then again at 48 h). The results of the analysis are presented as percentage weight of gravel/shell hash (> 2000 μm), coarse sand (500 – 2000 μm), medium sand (250 – 500 μm), fine sand (63 – 500 μm) and mud (< 63 μm).

3.4 Other data used

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

3.5 Analyses

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

1. Two-dimensional ordination plots produced using non-metric multidimensional scaling had stress values > 0.19 (indicative of a poor 2-dimensional fit) and showed no distinct patterns.

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

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

Sediment characteristics were analysed in two ways. Firstly, the relationship (if any) between sediment variables (coarse > 0.5 mm, medium and fine sediment and muds <63 um) and other environmental factors (i.e., depth, vegetation (type and percentage cover) and side-scan information) was assessed using generalised linear models (GLM) with appropriate data transformations where necessary. The likely distribution of sediment variables were then determined by interpolation between sampled locations using spatial kriging including appropriate covariables identified by the GLM. Secondly, a sediment habitat type was determined for each sampling location, based on the overall sediment characteristics (Table 3.1). This data was used to determine whether communities had specific affiliations with certain sediment types. Note that these characteristics differ slightly from those used for the Southern Kaipara. The preponderance of muddy sediments in the subtidal suggested a split between mud and sandy muds. The category called sandy muds in the Southern Kaipara should, more realistically, have been called muddy sands.

Statistical techniques used to analyse macrofaunal data were:

Analyses of differences in community structure were done using ANOSIM (Clarke 1993) on Bray Curtis similarities of untransformed data. Average dissimilarities between communities were derived using SIMPER (Clarke 1993).

Analyses of differences in number of taxa, number of orders and total numbers of individuals were assessed using generalised linear modelling, using an appropriate error structure and link function, followed by a multiple contrast (McCullagh and Nelder 1989).

Analyses of factors affecting numbers of taxa and orders were done using generalised linear models (as above). Factors used were depth, sediment particle size characteristics, wave exposure, and tidal current information. Backwards selection was used to select the most appropriate model based on changes to the Akaike Information Criteria.

Interpolations were performed using inverse distance weighting (ArcGIS Spatial Analyst extension).

Table 3.1 A description of the sediment types found in Kawau Bay.

Sediment type	Description
Muds	Sediment sized < 63 µm comprises more than 50% of the sediment
Sandy muds	Sediment sized < 63 µm comprises more than 20% of the sediment
Muddy sands	Sediment sized 63 – 250 µm comprises more than 70% of the sediment, sediment sized < 63 µm comprises more than 5% of the sediment and sediment sized > 0.5 mm comprises less than 20% of the sediment.
Coarse sand-muds	Sediment sized 63 – 250 µm comprises more than 70% of the sediment, sediment sized < 63um comprises more than 5% of the sediment and sediment sized > 0.5 mm comprises greater than 20% of the sediment.
Fine sands	Sediment sized 63 – 250 µm comprises more than 70% of the sediment
Medium sands	Sediment sized 250 -500 µm comprises more than 30% of the sediment
Sandy	Sediment sized 63 – 250 µm comprises more than 70% of the sediment, sediment sized < 63 µm comprises less than 5% of the sediment and sediment sized > 0.5 mm comprises less than 20% of the sediment.
Coarse sands	Sediment sized > 0.5 mm comprises more than 20% of the sediment

4 The physical environment

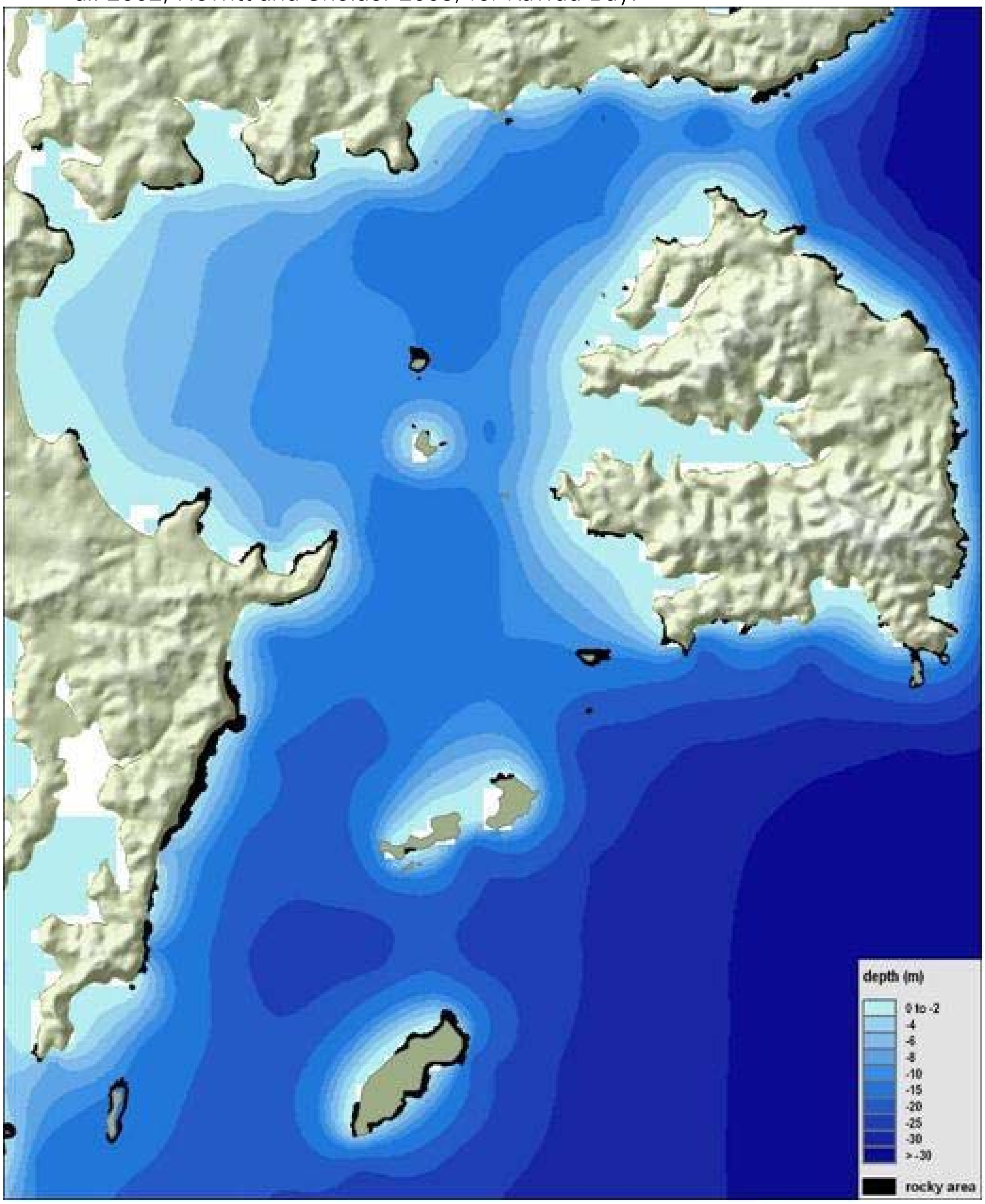
Kawau Bay is an extensive, predominantly subtidal, area. The coastline of the bay, and its associated inlets, (including the Matakana estuary as far as Tongue Point) measures approximately 84 kilometers, of which 40% is Rocky, 16% is mangroves, and the remaining 44% is soft sediment (data obtained from LINZ chart NZ5227). The subtidal area also contains both hard and soft substrates, but the vast majority of it is soft sediment. A number of gradients in depth, wave exposure, currents (Fig. 4.1a - e) and sediment particle size (Fig.4.2a - d), run through the bay. Kawau, Moturekareka, Motuketekete and Motuora Islands provide a measure of shelter for the Bay from the prevailing swells.

The majority of the bay is < 15 m deep (Fig. 4.1a), with a small area of 15 -20 m lying between the coast and Moturekareka Island and deeper areas offshore towards the south. Over most of the seafloor, slopes are slight (Fig. 4.1b). However, around many of the rocky cliffs sharp drops in reef profile are present. In areas > 10 m deep, orbital water velocity at the bed is low (Fig. 4.1c), increasing towards the shore. Orbital velocity at the bed is an indication of the amount of wave-generated disturbance the seafloor is exposed to. Together with tidal currents, it also represents the likelihood of physical re-suspension and removal of fine particles from the seafloor. In Kawau Bay, while the mean orbital velocity does not strongly differentiate near-shore areas, the 95th percentile of wave orbital velocity suggests that greater exposure to waves occurs around the northeast of Kawau Island and along the Tawharanui Peninsula (Fig. 4.1d).

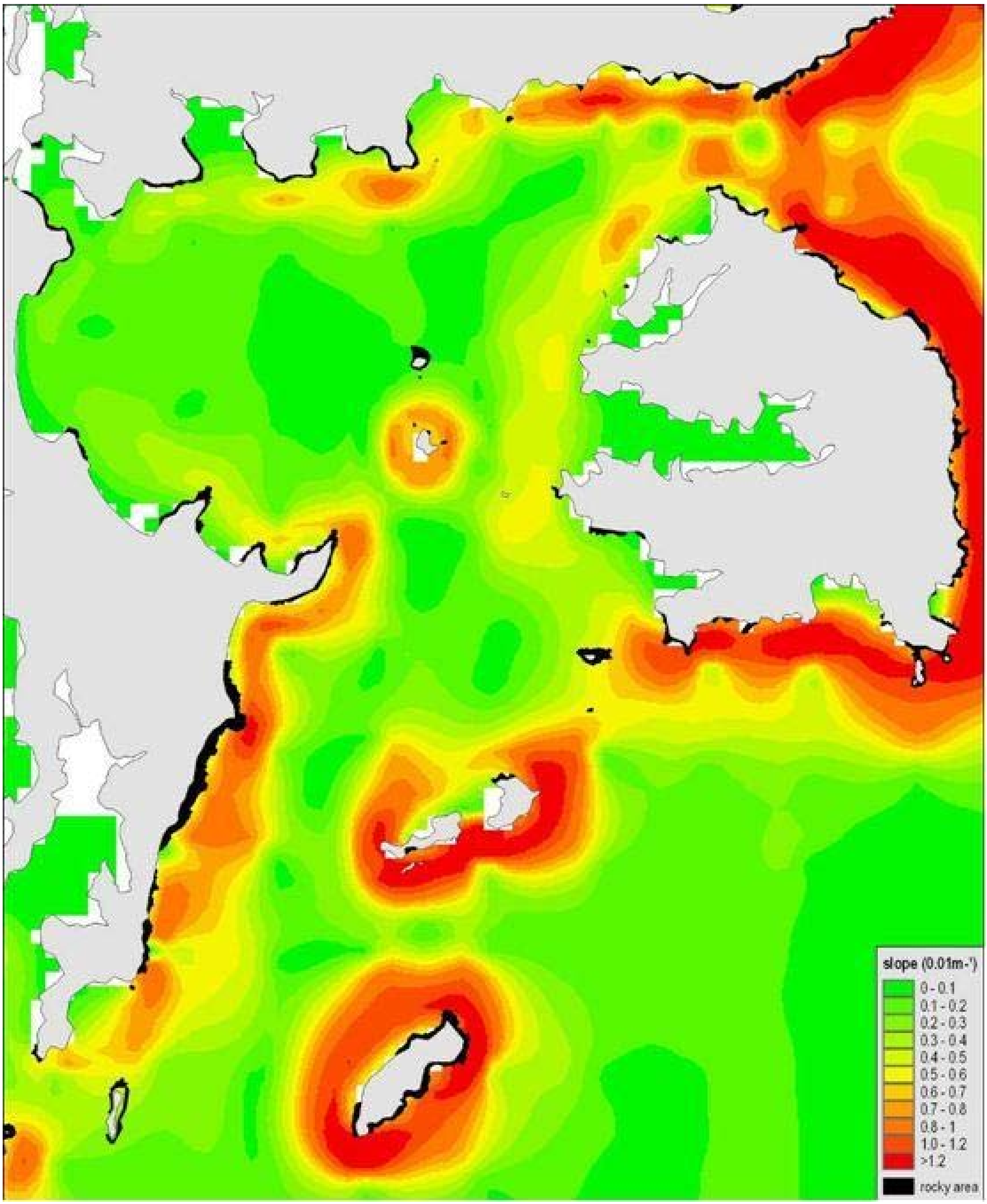
Kawau Bay is also strongly differentiated in terms of tidal currents (Fig 4.1e) with an area of strong currents occurring between Jones Bay and north-west Kawau Island, and again on the southeast point of Kawau Island (Kawau Point). However, the maximum current speed found here is lower than that observed in the Southern Kaipara. The relatively lower wave and tidal current energy found in Kawau Bay is probably the reason why the side-scan did not show any strongly rippled or large dune surface features.

Sediment data from samples taken intertidally and subtidally within Kawau Bay was interpolated to give an indication of the soft sediment environment (Fig. 4.2). As expected, areas of high wave exposure (as indicated by orbital velocity) and tidal current exhibited highest percentages of coarse sediments (Fig. 4.2a). Areas of > 50% coarse sediment occurred in the south channel off the north of Motuketekete Island and the northern channel between the coast and Kawau Island, extending into the bay between Kawau Island and Rabbit Island. The sediments within the inner western part of Kawau Bay and Matakana estuary are predominantly fine sand to muds (Fig 4.2b-d), presumably a combination of lower tidal currents and sediment input into the Bay. Sediments high in mud are found in Bon Accord Bay of Kawau Island (Fig 4.2d), and in the inner channel of Kawau Bay, in the lee of the southern islands (Motuketekete Moturekareka and Motuora).

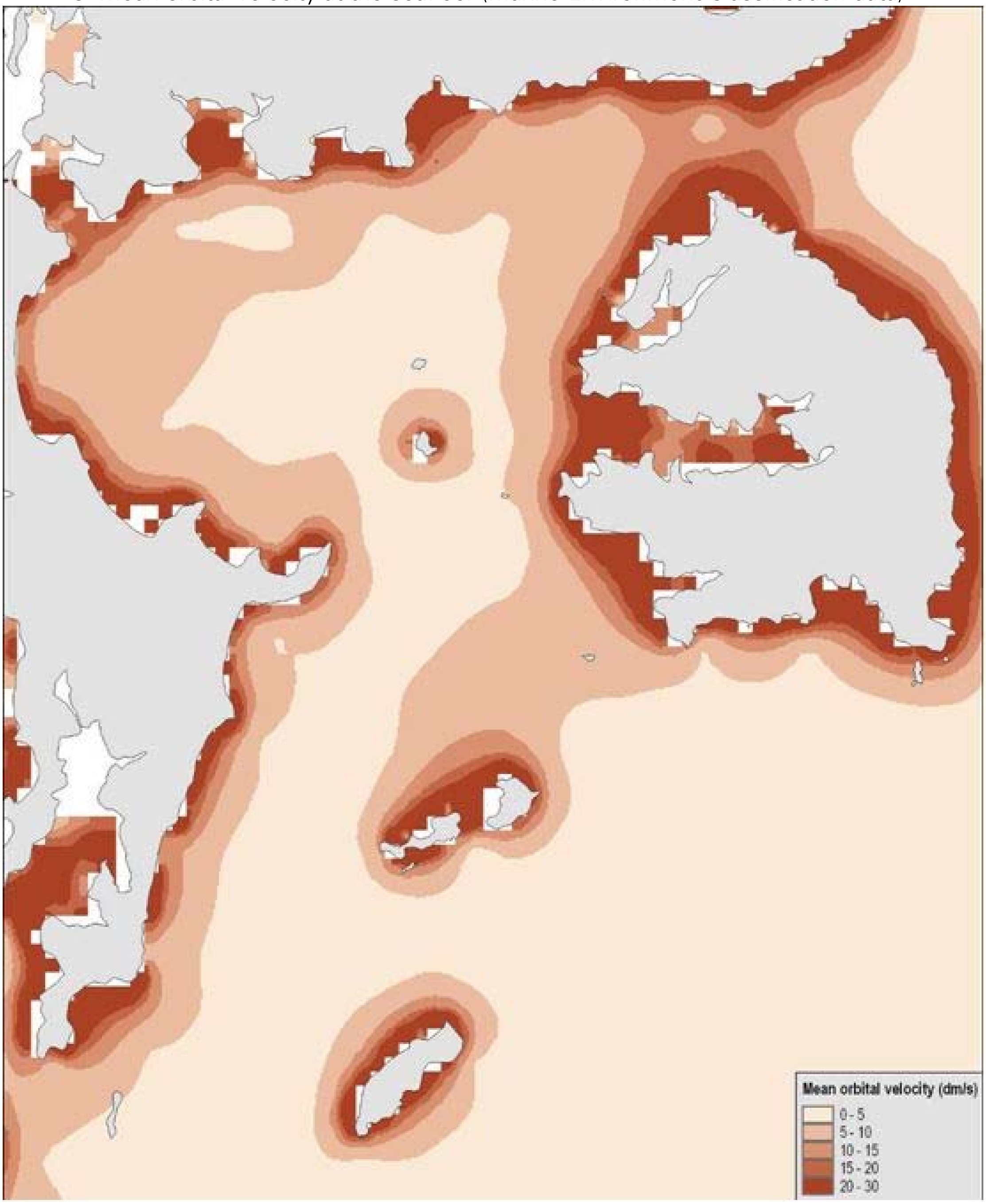
Figure 4.1A Depth data from the Marine Environment Classification (Hadfield et al. 2002, Hewitt and Snelder 2003) for Kawau Bay.



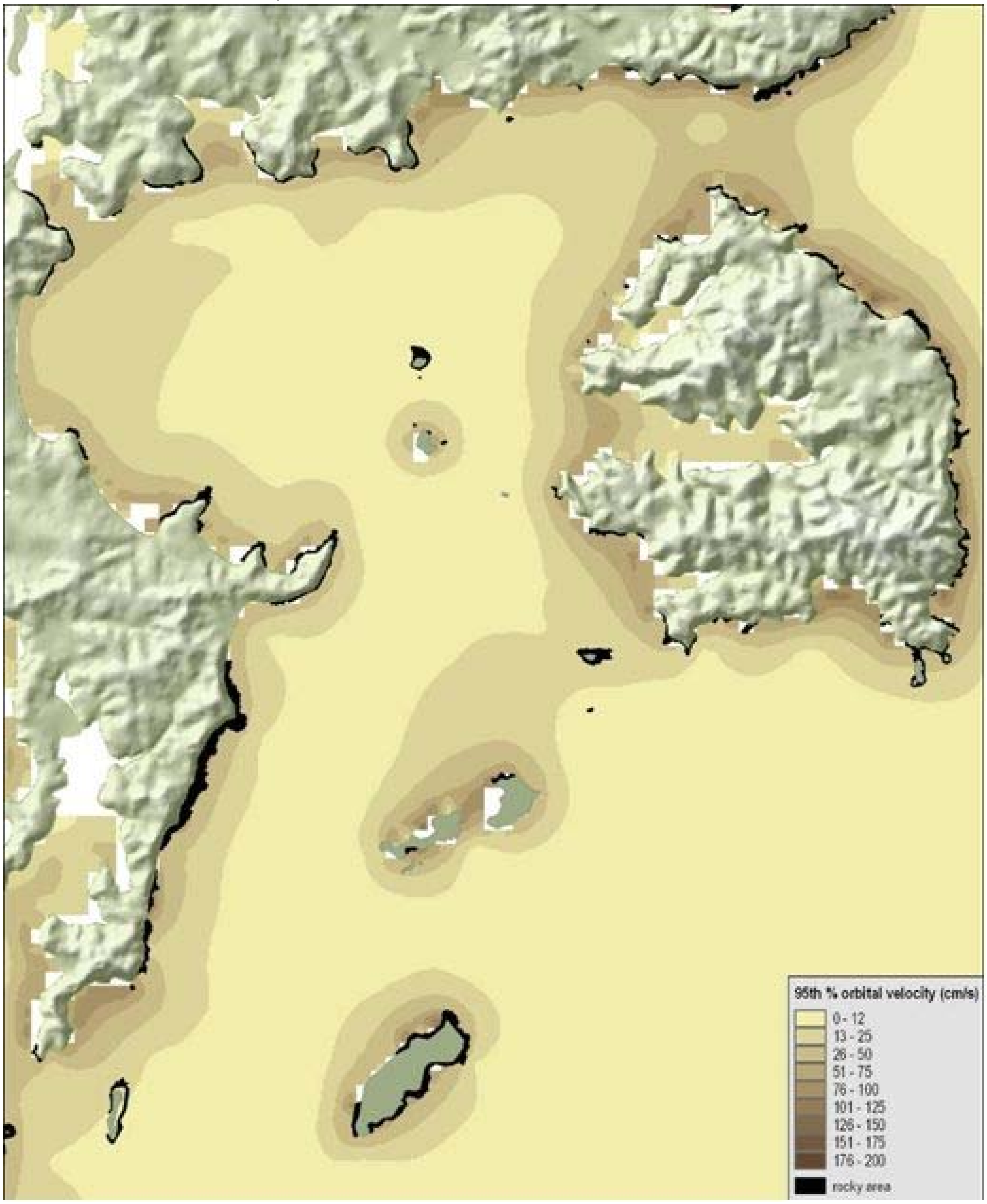
B. Change in seafloor slope calculated from Marine Environment Classification data.



C. Mean orbital velocity at the seafloor (Marine Environment Classification data).



D. 95th percentile of orbital velocity at the seafloor (Marine Environment Classification data).



E. Depth averaged maximum tidal current (Marine Environment Classification data).

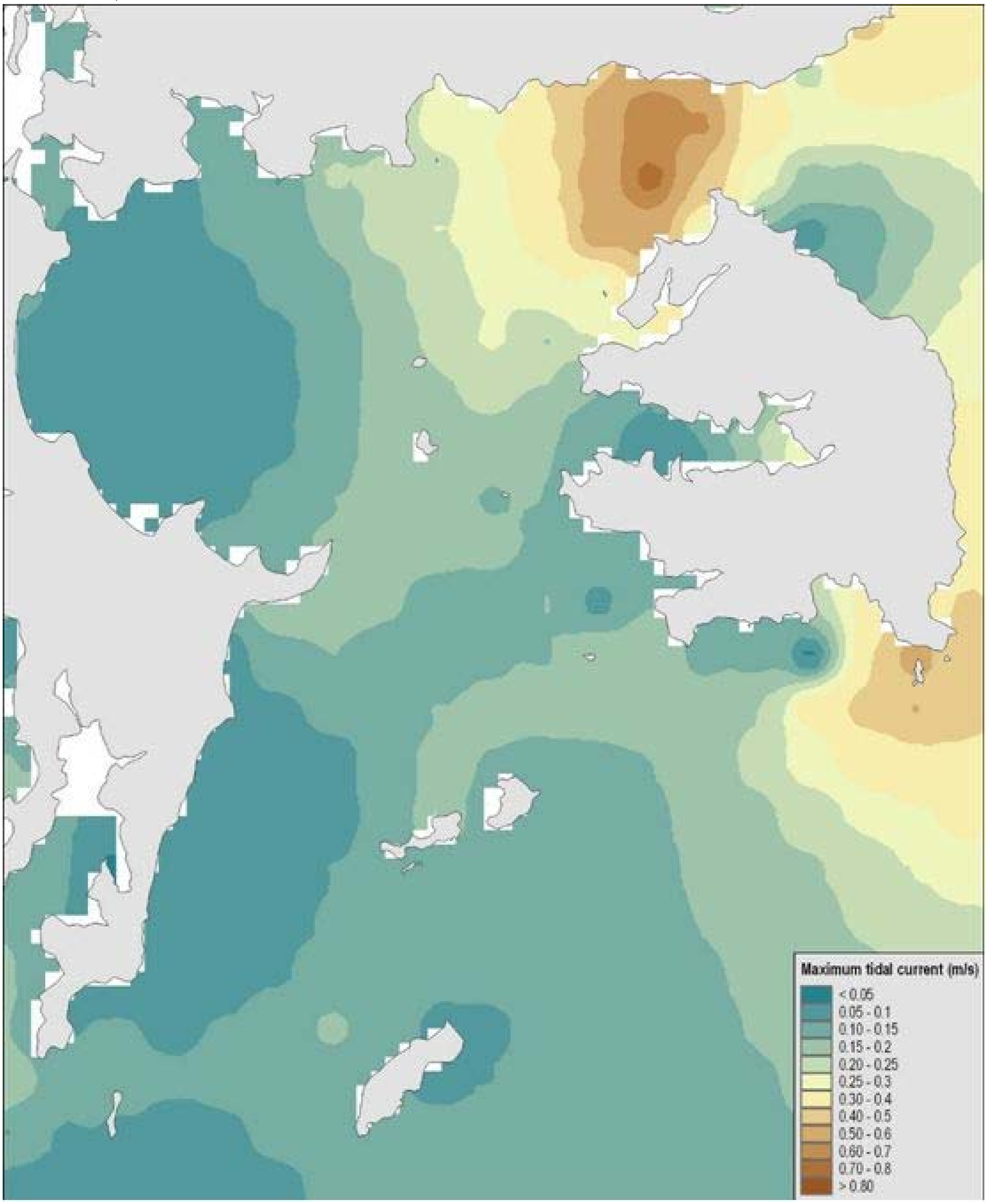
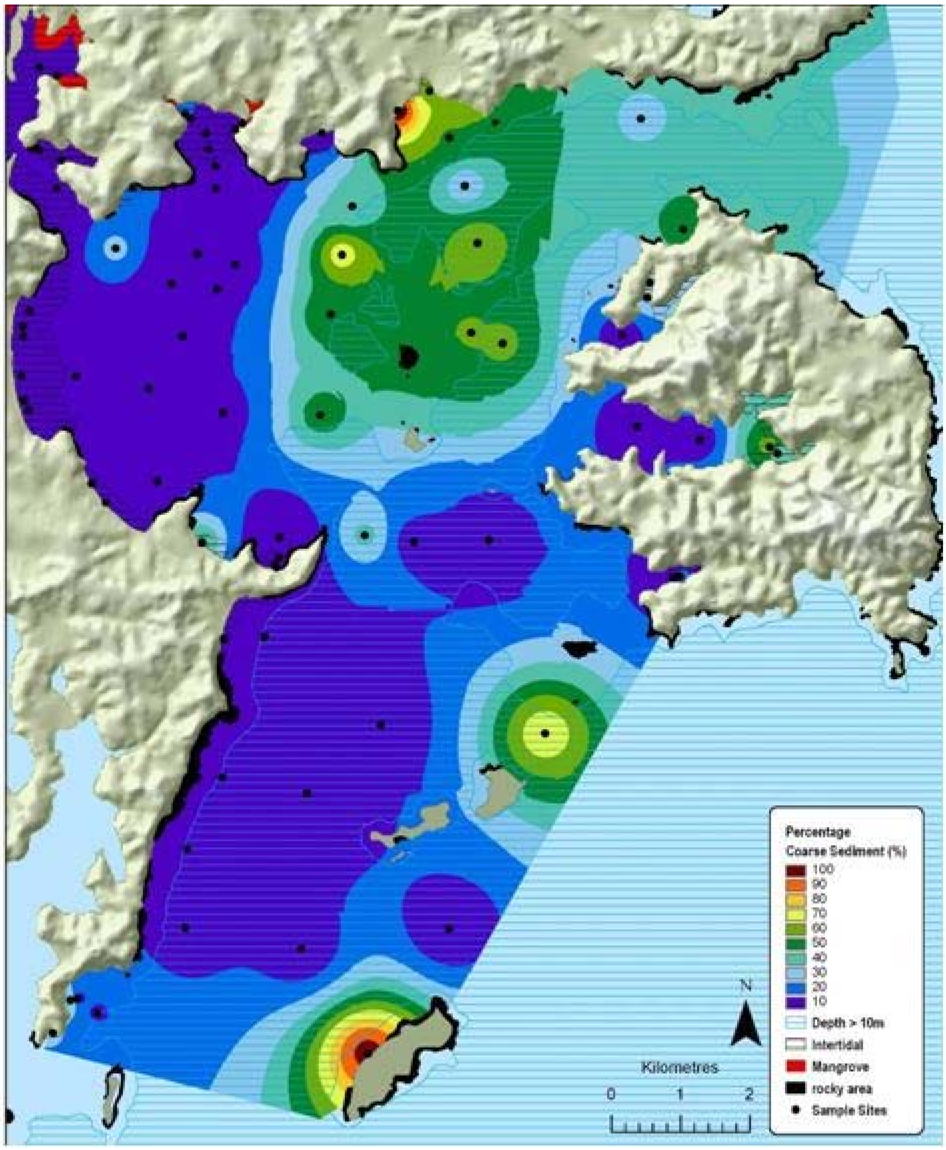
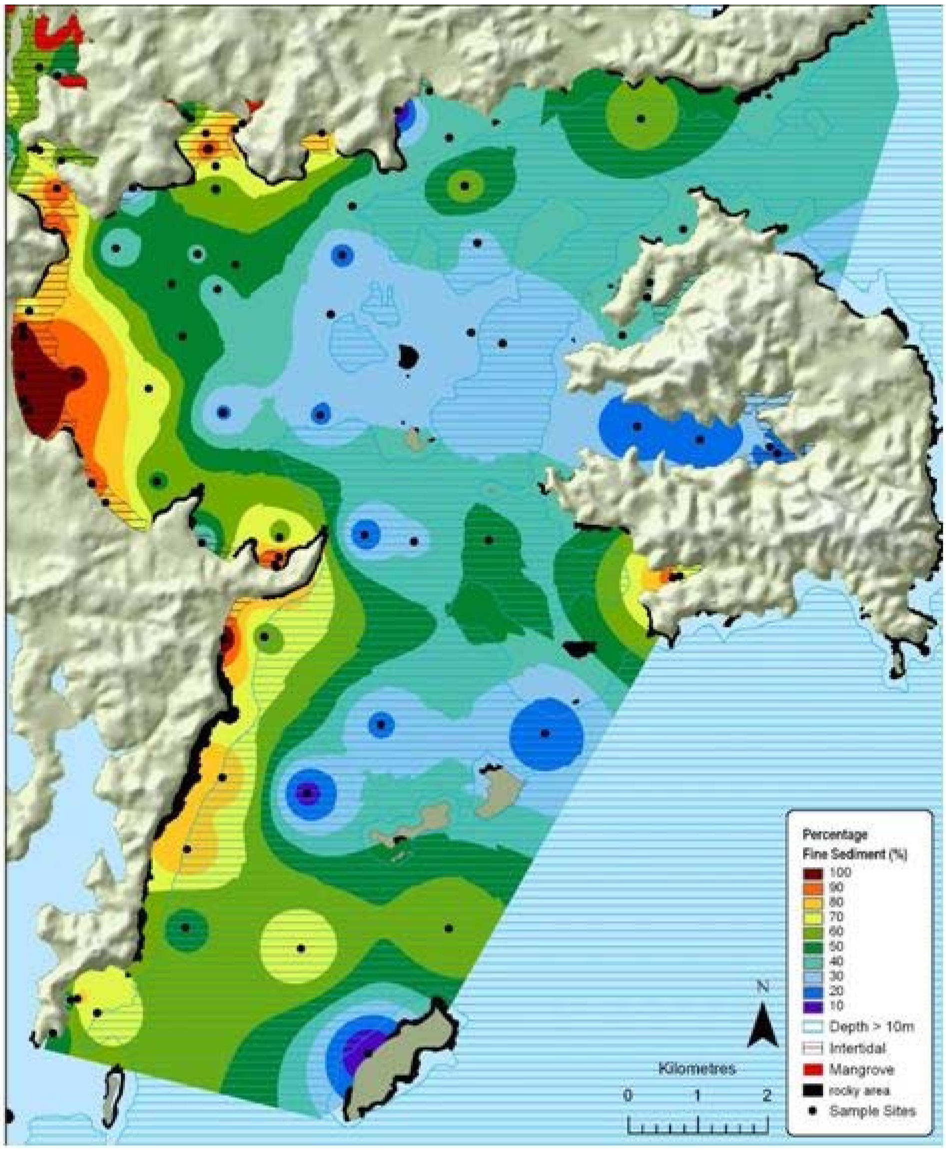


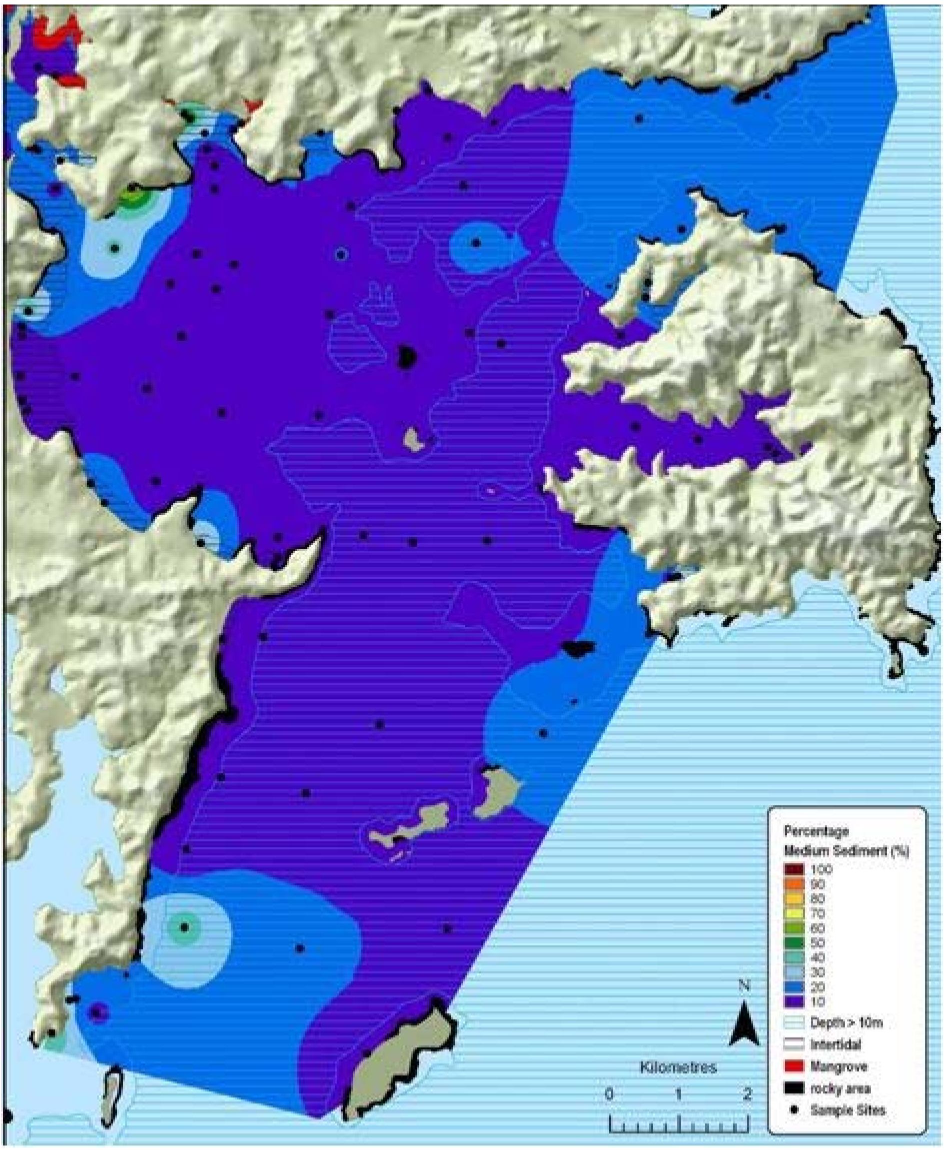
Figure 4.2A Interpolated plot of coarse sand (>500µm sediment particle size) found in both subtidal and intertidal areas.



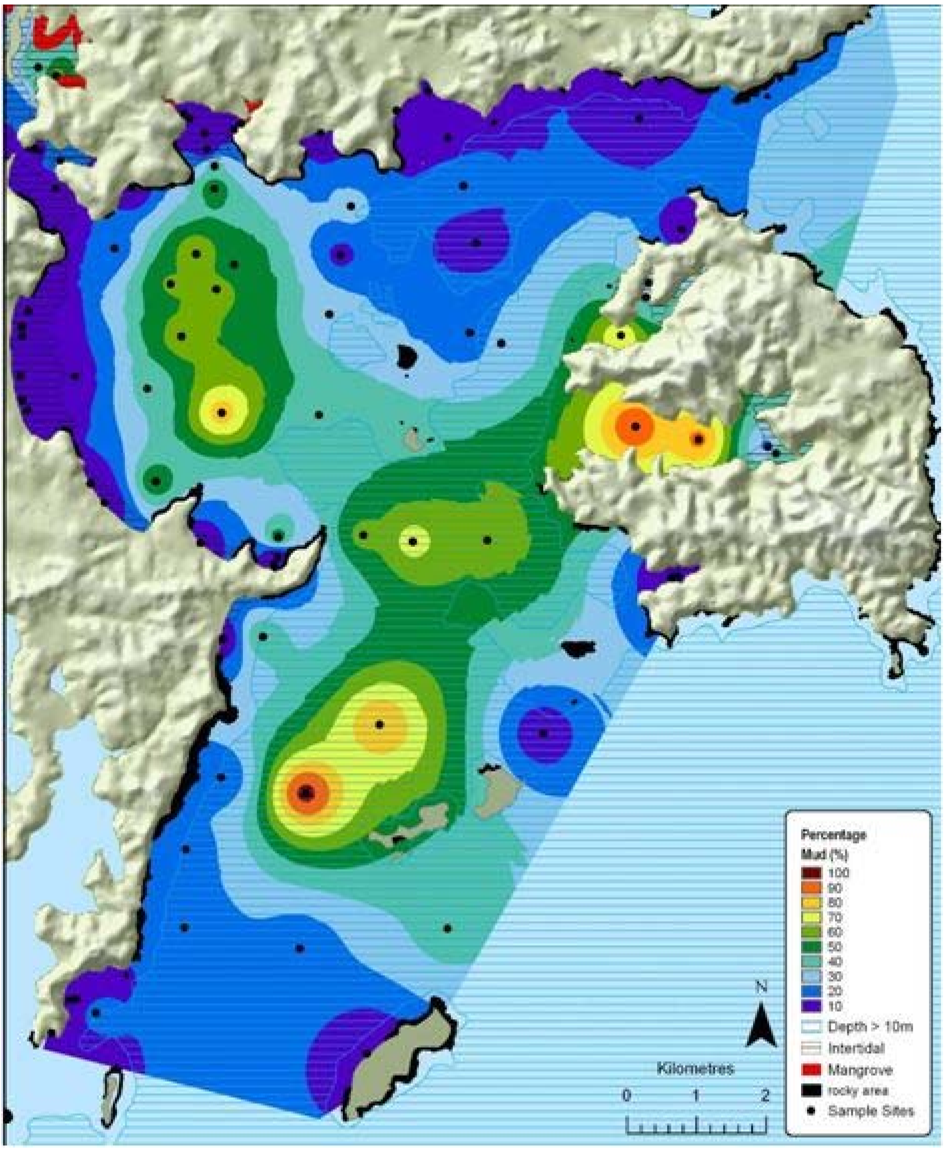
B. Interpolated plot of fine sand (63-250µm sediment particle size) found in both subtidal and intertidal areas.



C. Interpolated plot of medium sand (250-500µm sediment particle size) found in both subtidal and intertidal areas.



D. Interpolated plot of mud content (<63µm sediment particle size) found in both subtidal and intertidal areas.



5 Subtidal

5.1 Subtidal epibenthic habitats

A number of epibenthic habitats were observed in the subtidal areas of Kawau Bay (Fig. 5.1). Most of the soft sediment habitats were defined by the presence of habitat structuring epifauna, such as sponges and *Atrina* (Table 5.1). These epifaunal habitats were varied in their distribution and frequently occurred in more than one sedimentary environment.

Figure 5.1 Distribution of subtidal epibenthic habitats found in Kawau Bay (see Table 5.1 for a full description of habitat types).

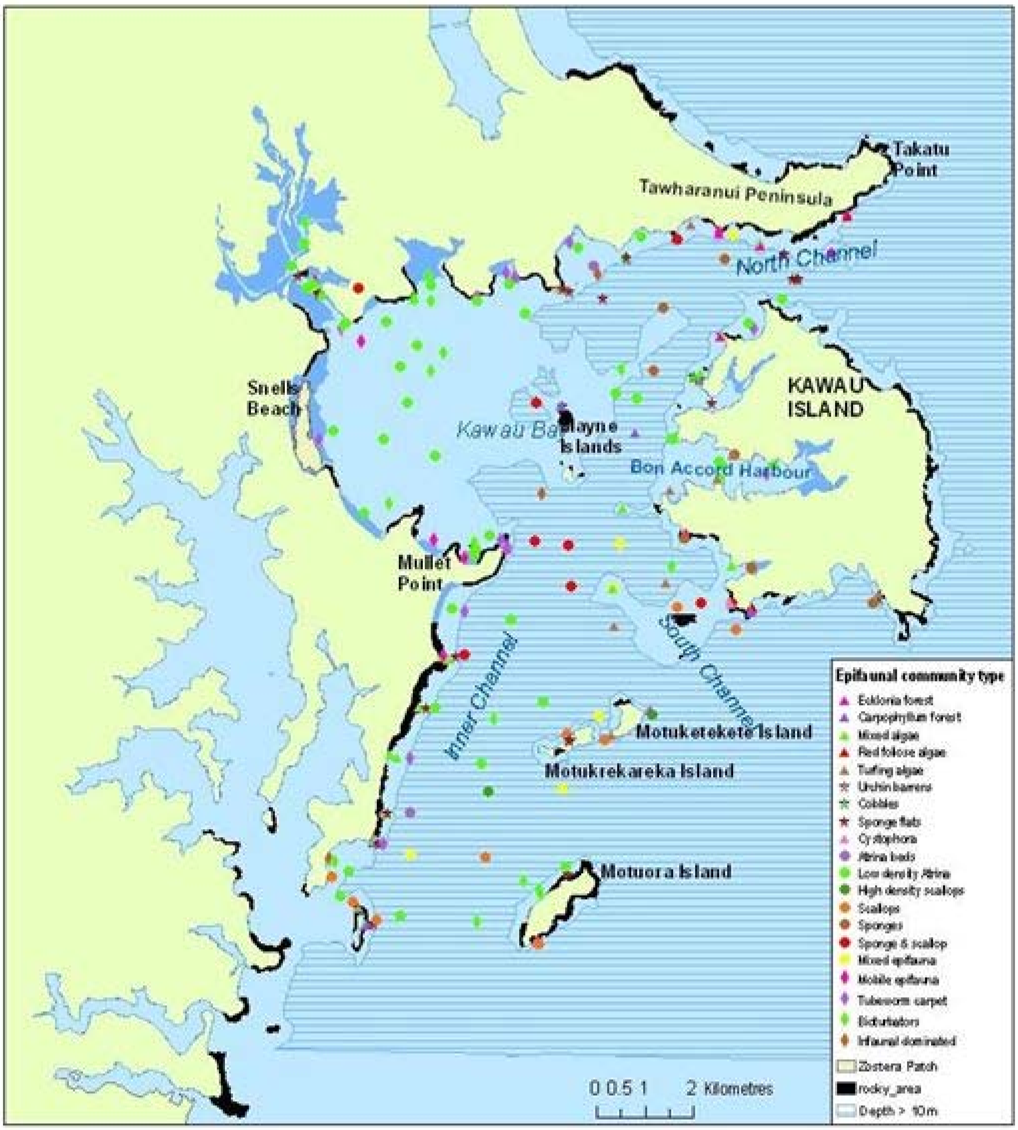


Table 5.1 Subtidal epibenthic habitats of Kawau Bay obtained from video.

Key species	Dominant large organisms and approximate densities
Ecklonia forest	Monospecific *Ecklonia radiata* (>4 plants/m^2), occasional *Carpophyllum flexuosum* plants or urchins. Exclusively found on hard rock.
Carpophyllum forest	*Carpophyllum* dominated and plants are large. Found on sheltered reefs.
Mixed algae	Mixture of *Ecklonia*, *Carpophyllum* and occasionally *Cystophora*. Found on soft and hard rock
Red foliose algae	Predominantly red foliose algae, may have low numbers of large brown algae.
Turfing algae	Predominantly, articulated corallines and other red turfing algae with low numbers of large brown algae.
Urchin barrens	Soft rock, mostly bare, with stunted *Carpophyllum*, low-density turf and high numbers of kina. Kina also found in crevices with high densities of coralline paint
Cobbles	Dominated by crustose coralline algae. Substrate unstable and subject to agitation, Low densities of encrusting animals and no brown algae present.
Sponge flats	Sponges dominant, rock and sand present. Usually occurs on the reef-sand interface. Low number of *Ecklonia* may be present.
Cystophora	*Cystophora* dominant. Sheltered, depths of 1-10m.
Atrina beds	*Atrina zelandica* in beds, with sponges. *Atrina* are adults, patchy distribution with 2 – 10 *Atrina* per patch, beds are 10's of m's in size. Found in high tidal current areas of Kawau Bay.
Low density Atrina	Low to very low density *Atrina*. *Atrina* are adults, 1 – 2 per 10 m.
High density scallops	High densities of *Pecten novaezelandiae* (2 per m). Sometimes with low densities of sponge or *Atrina*. Found in muddy sandy sediments.
Scallops	Medium density *Pecten* (2 per 5 m). Found in muddy to fine sands
Sponges	Dominated by sponges, patchily distributed with 1 - 30 per 5 m.
Sponge & scallop	Sponges (1 per 3 m) and *Pecten* (2 per 5 m).
Mixed epifauna	Mix of sponges, *Pecten* and *Atrina*.
Mobile epifauna	Dominated by mobile epifauna, such as starfish, gastropods and hermit crabs. Associated with medium to coarse sand.
Tubeworm carpet	Mix of large (Maldanid) and small tubeworms (*Boccardia* or Serpulids), forming dense carpets, patchy at m's scale. Associated with coarser sediments.
Bioturbators	Areas of relatively flat soft sediment, dominated by burrowing animals
Infaunal dominated	Areas of bare sediment. Generally coarse sand/sandy with high current flow.

Along the exposed coast from Mullet Point to Mahurangi Heads, the nearshore is predominantly rocky, quickly changing to sandy sediment. Nearest the land, the rocky areas were dominated by *Carpophyllum* forest (Fig. 5.2a) or mixed algae (Fig. 5.2b). At a few places, in <5m water depth, urchin barrens were observed (Fig. 5.2c). Generally the transition from macroalgal dominated to soft-sediment dominated habitats was a small area dominated by sponge flats (Fig. 5.2d). Once in the soft sediments, habitats were dominated by low density *Atrina* (Fig. 5.3a), scallops (Fig. 5.3b), or patches of tube worms (Fig. 5.3c). In Big Bay and Martins Bay, the shallow areas (<5m) were either dominated by infauna or were highly bioturbated (Fig. 5.3d), with low density *Atrina* in deeper waters (<10m) and patches of tubeworm carpets in the Inner Channel.

Figure 5.2 Pictures of subtidal epibenthic habitat types found in Kawau Bay.

Figure 5.3 Pictures of subtidal epibenthic habitat types found in Kawau Bay.

On the east side of Mullet Point, the rocky substrate stretched out further into the surrounding sand than on the north side, and was covered with *Carpophyllum* forest, cobbles (Fig. 5.4a) or mobile epifaunal habitats (Fig. 5.4b) and sponge flats. On both sides, tube worm habitats were found in near the rocks with low density *Atrina* in deeper waters. The four beaches that make up most of the area between Mullet Point and the mouth of the Matakana River generally had habitats dominated by mobile epifauna in shallow waters, with low density *Atrina* and bioturbated sediments further offshore.

Figure 5.4 Pictures of subtidal epibenthic habitat types found in Kawau Bay.

A. Cobbles B. Mobile Epifaunal Habitats

In the Matakana Estuary south of Sandspit, this mixture of low density *Atrina*, tubeworm habitats and bioturbated sediment continued. On the small area of rocky substrate, a mixed algal community was observed that changed to sponge flats near to the soft-sediment transition. Further up the estuary, the presence of *Atrina* reduced and the sediments were either dominated by infauna or were highly bioturbated.

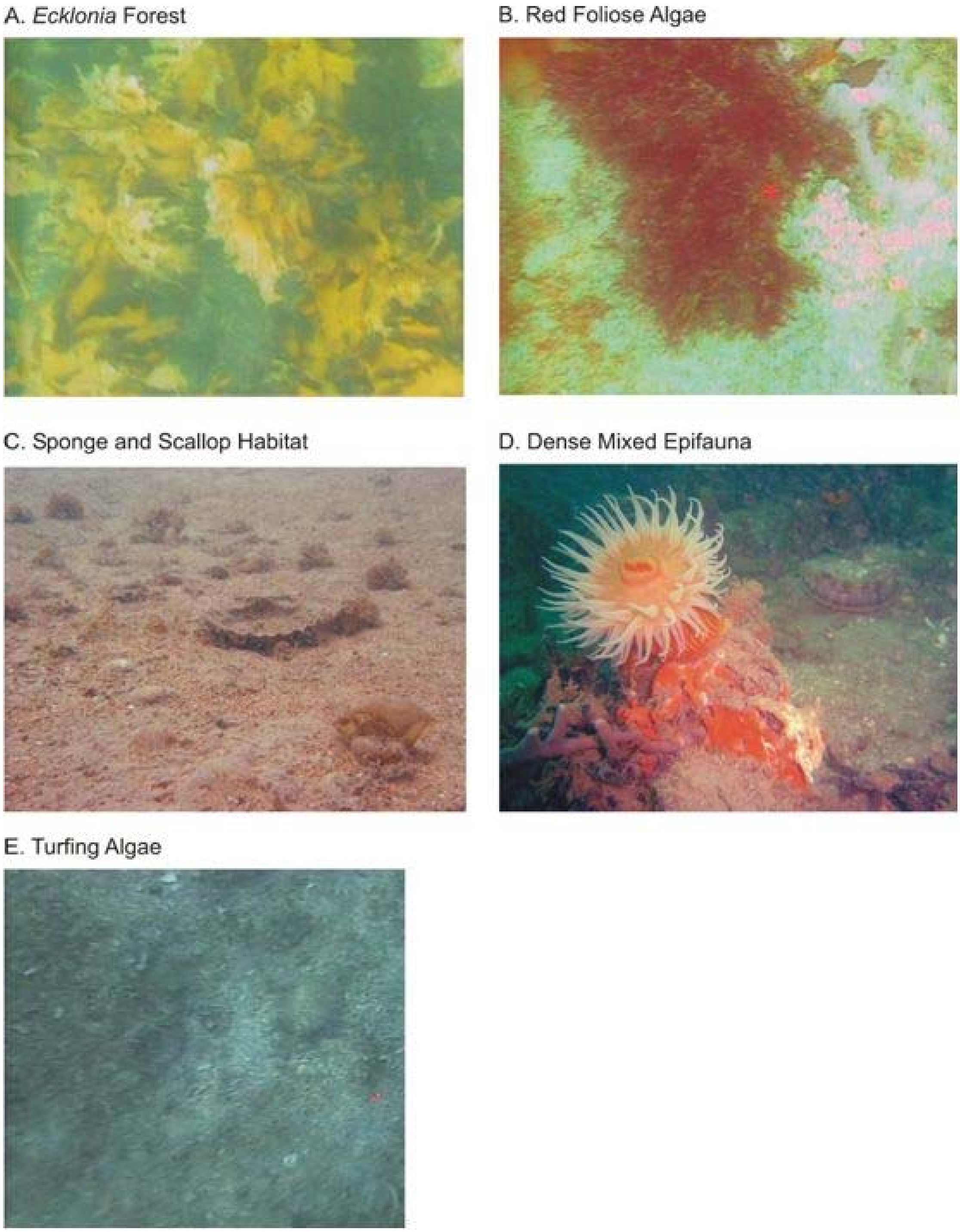
Most of the area along the south of Takatu Peninsula (Wanns Bay to Waikauri Bay) is soft sediment, and again a mix of bioturbated, tubeworm and very low density of *Atrina* habitats was observed. The few rocky areas were relatively steep short sections of *Carpophyllum* forest and mixed algae. The point between Prospect and Christian Bays was different, having an area of *Cystophora* (Fig. 5.5a) and extensive sponge flats. Christian Bay itself had a bed of patchy high density *Atrina* (Fig. 5.5b).

Figure 5.5 Pictures of subtidal epibenthic habitat types found in Kawau Bay.

A. *Cystophora* B. Patchy *Atrina* bed

Along the rest of the peninsula, high current flows occur close to land and the wave exposure is high. The rocky habitat there was dominated by *Ecklonia* forest (Fig. 5.6a), although a red foliose algal habitat (Fig. 5.6b) occurred by Bluebell Point. Sponge flats, sponge/scallop (Fig. 5.6c) habitats and dense mixed epifauna (Fig. 5.6d) were common. On the other side of the channel, on Kawau Island, soft sediments were again mainly dominated by low density *Atrina*, although patchy tubeworm carpets were also seen and, on the low flat rocks, and rocky/sand matrix, sponge flats were common. *Ecklonia* forest, *Carpophyllum* and mixed algae habitats dominated the rocky areas.

Figure 5.6 Pictures of subtidal epibenthic habitat types found in Kawau Bay.



On the more sheltered west coast of Kawau Island, *Ecklonia* forest was not observed. Instead urchin barrens and turfing algae (Fig. 5.6e) were common habitats in shallow waters, with mixed algae found in deeper waters. In the soft sediment areas, tube worms, low densities of *Atrina*, sponge and scallop habitats were found. Around Elizabeth and Brownrigg Points, where exposure to wave increases, the incidence of large brown macroalgae increased. Moving offshore from Elizabeth Point, *Cystophora* or *Carpophyllum* habitats were quickly replaced by mixed algal habitats which were replaced by sponge and scallop habitats on the nearby soft sediment.

The various channels between the islands (Motuketekete, Moturekareka, Motuora and Te Haupo) were predominantly scallop and sponge habitats. On the rocky areas, similar to Kawau Island, *Ecklonia* forest dominated on exposed sites, while mixed algae, *Carpophyllum* or turfing algae was observed in more sheltered areas. Similar habitats were recorded around Martello rock and the Mayne Islands.

The inner channel, running up from Mahurangi Harbour on the west side of Motuora Island, varied from 0 to 100% mud content, but was predominantly fine sand, with small amounts of coarse material and occasional rocks. The rocks were generally covered in mixed or turfing algae. The area of high mud content (off Moturekareka) was highly bioturbated. The rest of the area contained a variety of habitats (low density *Atrina*, sponges, scallops and mixed epifauna).

The North Channel, with high tidal currents, had a much higher content of medium sand and little mud (<20%) and a higher proportion of scattered rocks. While a few areas of bioturbated sediment occurred, most of the habitats observed were *Ecklonia* forests or sponge flats.

In Kawau Bay proper, mud content was generally high (>30%), although areas of coarser sediment occurred, mainly off the mouth of the Matakana River. Very low density *Atrina* with bioturbated sediment was the most common habitat, although a patch of tubeworm carpet was observed off the mouth of the Matakana River and an area of sponge habitat was observed near the start of North Channel.

In summary, the exposed rocky eastern coasts of Kawau, Motuketekete and Moturekareka Islands, plus the Tawharanui peninsula were characterised by high current flora and fauna, particularly *Ecklonia* forests and sponge flats. The lower tidal current areas of the south-western coast and the sheltered northern areas of the bay contained mixed algae and *Cystophora* habitats. The western side of Kawau Island contained *Carpophyllum*, mixed algae and turfing algae habitats. The shallow subtidal areas of Kawau Bay itself, which are less exposed to waves and have relatively weak tidal currents, generally had low epifaunal diversity with low to very low densities of *Atrina*, and bioturbated muddy sediments. Relatively sheltered deeper areas, such as western Kawau Bay and the sheltered western side of Kawau Island, were dominated by *Atrina* beds. The more exposed central area of Kawau Bay and the area around Moturekareka, Motuketekete and Motuora Islands contained a more diverse array of epifauna, with mixed epifauna, scallop, and sponge & scallop habitats observed. The area around the southern tip of Kawau Island generally had coarser sediments and the highest exposure to waves and tidal currents. Epifaunal habitats in these areas were dominated by sponges and several patches of *Atrina* beds.

It is important to note that the results involving scallop presence and density should be treated with caution. The populations of scallops in the North Island appear to be undergoing a recovery from low numbers at the turn of the century. The reasons for the low numbers in the 1990's are unknown, but possibly resulted from 'black gill' disease, fishing pressure and habitat alteration caused by the invasive tubeworm *Chaetopterus* sp.. Scallops have a high natural mortality, and exhibit highly variable recruitment (Morrison & Cryer 2003). This combination of life history characteristics results in a biomass that can fluctuate wildly, and Cryer (1994) has shown that recruitment and subsequent biomass cannot be predicted from historical biomass estimates.

5.2 Subtidal rocky communities

Higher resolution sampling of rocky subtidal areas was conducted at 7 sites. At 4 of these sites, relatively flat reefs were found at both shallow (~3m) and deeper (~7m) depths (Table 5.2). For the other three sites, the only flat areas occurred around 3m. Bottom type at the sites was generally heterogeneous, particularly off Elephant Point, and similar at both depths (except for south Elizabeth Point).

Table 5.2 Sediment characteristics of the intensively sampled rocky subtidal sites (refer to Figure 3.1).

Location	Depth (m)	Sediment type
Elephant Pnt	4.2	Heterogeneous bedrock, cobbles, gravel shell coarse sand
	7.4	Heterogeneous bedrock, cobbles, gravel shell coarse sand
Karangatuoro Pnt	3	Rock/sand-gravel mix, cobbles
Mullet Pnt	4.5	Cobble/boulders/silt
Elizabeth Pnt- nth	3.3	Bedrock/Sand
Elizabeth Pnt- sth	3	Boulders
	6.2	Rock in a sand matrix
Nth Big Bay	3.5	Boulders/bedrock
	7.6	Boulders/bedrock
Pembles Is	3.5	Rocks, boulders, cobbles sand
	7.1	Rocks, boulders, cobbles sand

While brown algae provided canopy at all sites (generally a mix of *Carpophyllum maschalocarpum* and *Ecklonia radiata*), percent cover over the 1m^2 quadrat varied markedly both within and between sites (Table 5.3). *Cystophora* sp. was only observed at shallow areas of Elizabeth Point north (where it replaced *Carpophyllum*) and south and at Karangatuoro Point (where no *Ecklonia* was found). *Ecklonia* cover was higher at exposed locations, e.g., off Elephant Point in the Northern channel, and at Elizabeth Point. *Carpophyllum* was dominant within the bay, and along the Inner channel. Overall canopy cover was markedly less at the deeper area off Pembles Island, but no general pattern was observed either in percent cover or dominant algal type between the shallow and deeper areas across sites.

Table 5.3 Brown algae coverage (%) observed, together with dominant types of taxa at the different locations and depths. Dominant types of taxa run from most dominant to least.

Location	Depth	Macroalgae	Dominant types of taxa
Elephant Pnt	shallow	0 – 60 *Carpophyllum* 10 – 40 *Ecklonia*	Ascidians, Kina, Barnacles, Limpets
	deep	10 – 50 *Carpophyllum* 0 – 5 *Ecklonia*	Foliose coralline, Ophiuroids, Gastropods, Encrusting bryozoans and sponges
Karangatuoro Pnt	shallow	15 – 75 *Carpophyllum* 1 – 20 *Cystophora*	*Turbo smaragdus,* Foliose coralline, Chitons, Sponges
Mullet Pnt	shallow	75 – 100 *Carpophyllum*	Sponges, Gastropods
Elizabeth Pnt-nth	shallow	25 – 70 *Cystophora* 0 - 10 *Ecklonia*	Gastropods, *Chaetopterus* sp, Coralline turf
Elizabeth Pnt-sth	shallow	30 – 80 *Carpophyllum* 0 – 30 *Cystophora* 0 – 30 *Ecklonia*	Gastropods , Sponges, Colonial Ascidians
	deep	40 – 50 *Carpophyllum* 20 – 40 *Ecklonia*	*Chaetopterus*, *Trochus viridis*, Sponges, Colonial Ascidians
Nth Big Bay	shallow	40 – 60 *Carpophyllum*	Turfing reds, coralline turfs, Gastropods, Sponges
	deep	0 – 100 *Carpophyllum* 0 – 10 *Ecklonia*	Foliose coralline, Sponges, Gastropods
Pembles Is	shallow	25 – 35 *Carpophyllum* 0 – 25 *Ecklonia*	*Chaetopterus*, Ascidians
	deep	0 – 10 *Carpophyllum* 0 – 5 *Ecklonia*	*Chaetopterus*, Sponges, Colonial ascidians

For those sites for which both depths were sampled, slightly higher taxa diversity was generally observed on deeper reefs. Taxa diversity based on quadrat sampling ranged from 12- 22 taxa on deep reefs and 13 – 20 taxa on shallow reefs. Despite the range of diversity, no significant differences were observed between sites, probably because of high within-site variability at all but Elizabeth Point south.

Of the red algae, a crustose coralline (*Corallinales* sp.) was the most common. The cover of small turfing algae (red and coralline) was inversely related to the brown algae canopy cover, particularly *Carpophyllum*, with areas of high canopy cover having little or no turfing algae.

Again, no consistent differences between shallow and deep areas were observed across sites, although there were strong site differences. The site located off Elephant Point was the most exposed site, and was notable for the absence of significant numbers of gastropods (especially *Turbo smaragdus*) and higher numbers of kina (*Evechinus chloroticus*), ophiuroids and chitons. Tubes from the parchment worm (*Chaetopterus* sp.) were found in significant numbers (20-50 per quadrat) at all sites on the coast of Kawau Island, and many were occupied.

5.3 Subtidal soft sediment

Community data were analysed to determine whether the major epifaunal habitat types supported significantly different infaunal assemblages. Not surprisingly, results varied. Some differences between communities in different sediment types were evident, with significant differences ($P<0.05$) in average number of individuals, taxa and orders present in samples taken. Communities found in coarse and muddy sediment types differed from those found in all other sediment types, with dissimilarity in community composition between sediment types ranging between 65% (mud cf sandy mud) to 84% (coarse sand cf mud). However, community composition found within a sediment type was usually highly variable (within-group dissimilarities of 60-69%). These results suggest that, unsurprisingly for healthy heterogeneous environments, distinct assemblages did not occur. Rather, replicate samples at a site frequently showed that patchiness on the scale of 10 m was occurring.

Similar to the analysis of the Southern Kaipara, distinct infaunal assemblages were not associated with particular epifaunal habitats. Within-group dissimilarities based on epifaunal habitats were high, ranging from around 60% for sponges, *Atrina* beds, and mixed epifauna habitats to over 70% for *Atrina*, tubeworm, worm carpet and scallop habitats, suggesting that infauna were patchily distributed in space within habitats. Despite this, significant differences between epifaunal habitats ($P<0.05$) did occur for the number of taxa, orders and individuals, with high diversity and abundance occurring in the more complex and patchy sponge and *Atrina* bed habitat types, similar to findings by Thrush et al. (2001) and Norkko et al. (2001).

Six ecologically important communities were defined (Table 5.4). Four of these community types included tube-dwelling polychaetes (Fig. 5.7). Generally, these community types occurred throughout the Bay. However, sites in the Inner Channel were a mix of bioturbators or tube dwellers, with higher diversity generally occurring in depths greater than 11m. In areas to the west of Kawau Island and in the North Channel greater than 10m depth, communities of high diversity tube-dwellers, deposit feeders, suspension feeders and bioturbators were found.

Number of taxa and orders found in the subtidal soft-sediment sites were markedly higher than in the intertidal (maximum 50 and 26 respectively). Highest diversity was observed in North Channel and spreading west of Kawau Island, off Sandspit and at one site in the Inner channel (Fig. 5.8 a and b). Unusually, these areas also had highest total number of individuals (Fig. 5.8c).

Table 5.4 Ecologically important subtidal soft sediment infaunal communities found in Kawau Bay using the hierarchical rules given in Appendix 1b.

Deposit Feeding + Bivalves	*Nucula* dominated, with other deposit feeding (*Felaniella*, *Theora*) or suspension feeding bivalves (*Austrovenus*, *Venerupis*). Sometimes with deposit feeding polychaetes (*Chaetozone*, *Euclymene* and *Labiosthenolepis*). Found in sand to mud, at all depths, within the northern half of the bay. Diversity and number of individuals increases with sediment coarseness.
High diversity, mixed	A high diversity community, not dominated by any functional group. Found in North Channel.
Bioturbated	*Echinocardium* dominated. Sometimes associated with sparse *Atrina*, sponges and scallops, in either coarse sediment or mud, deeper than 5m. In the North Channel these communities have high diversity.
High diversity + tube dwellers	A high diversity community dominated by tube dwellers (*Macroclymenella*, *Euclymene*, *Maldane* and *Euchone*) found deeper than 10m or in coarse substrate.
Tube dwellers	Dominated by the tube dwellers *Maldane*, *Euchone* and *Polydora*. Associated with shallower (<10m) muddier sediments, except for one station north of Motuora Island.
Tube dwelling + deposit feeding	Low to medium diversity community dominated by tube dwelling detritovores (*Amaeana*, *Labiosthenolepis* & *Chaetozone*), and the bivalves *Theora* and *Nucula*. Found in sand to mud, at all depths. Diversity and number of individuals increases with sediment coarseness.

Figure 5.7 Distribution of ecologically significant subtidal communities found in Kawau Bay.

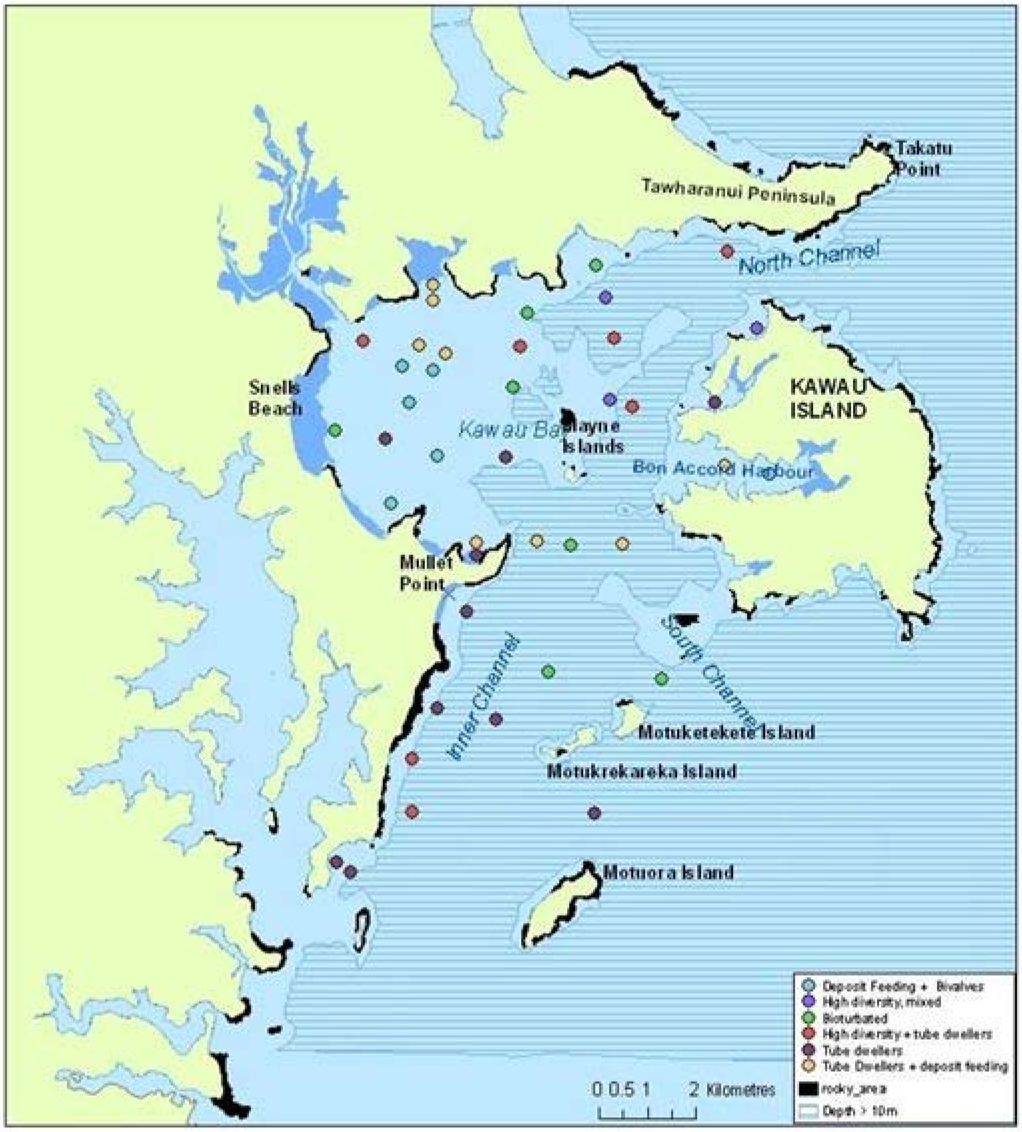
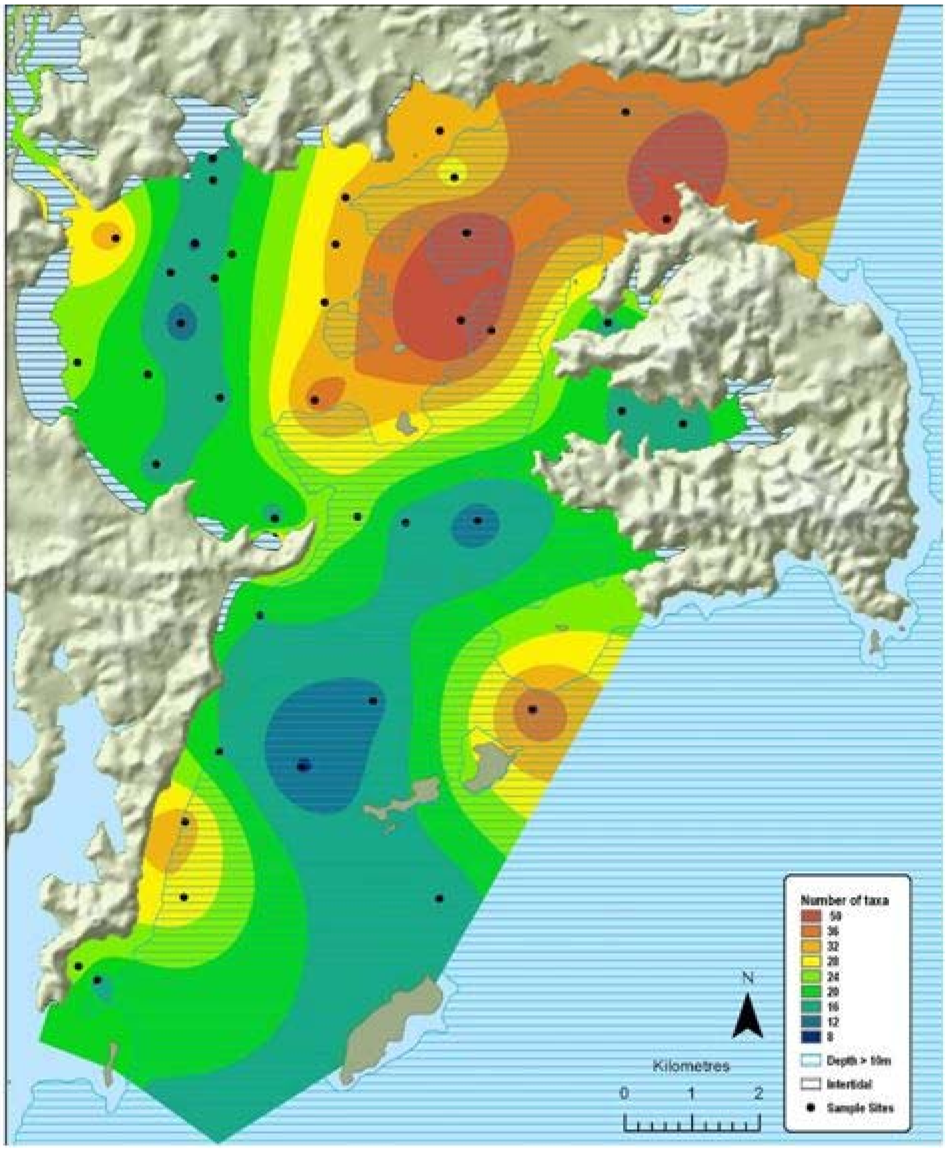
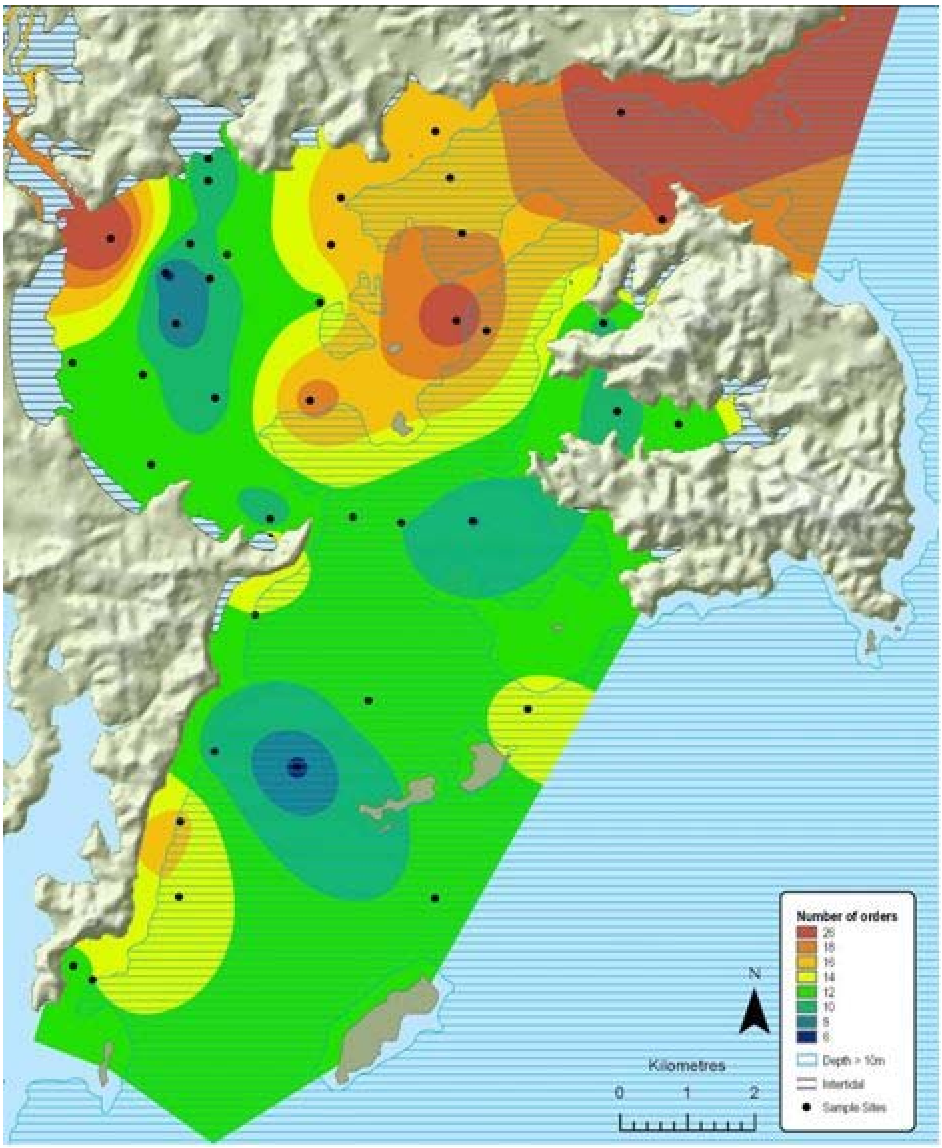


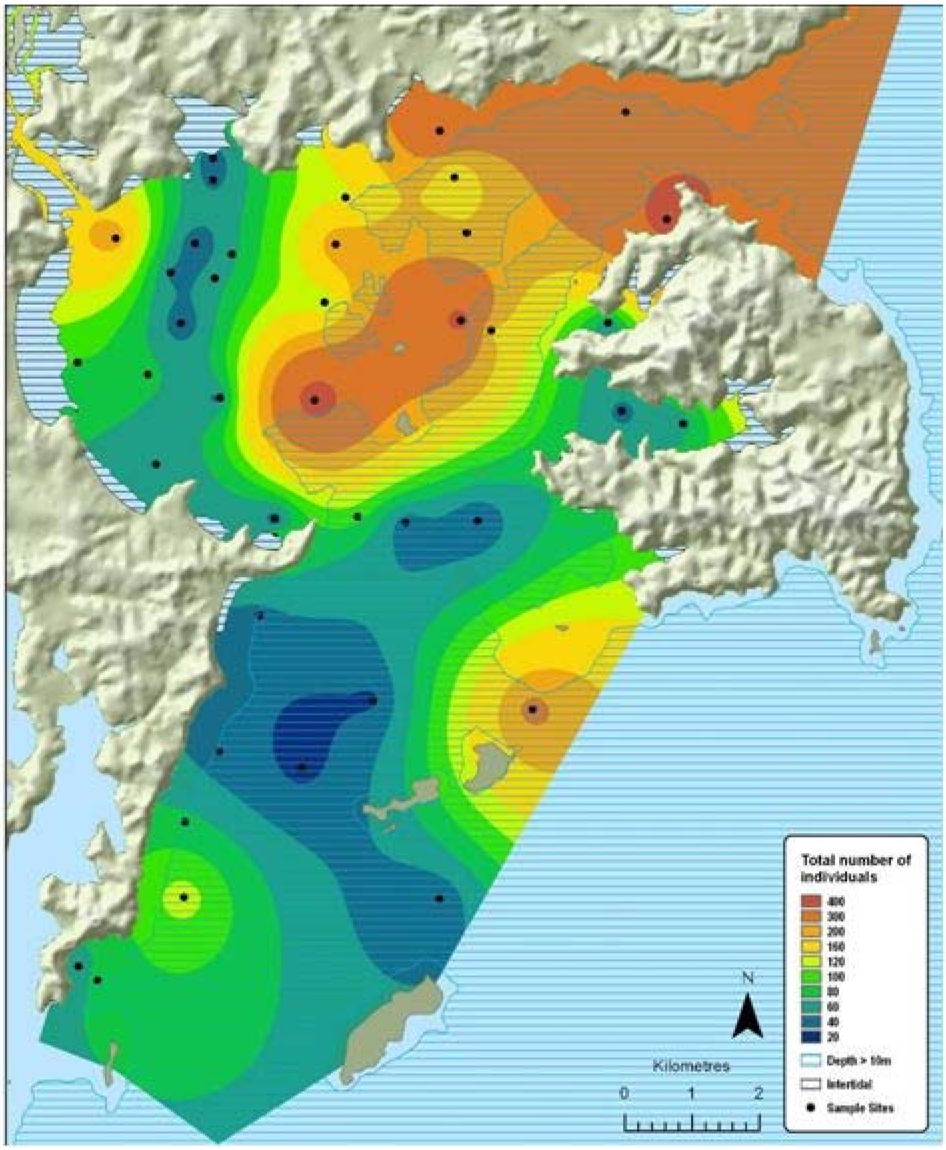
Figure 5.8 A Interpolated plots of the distribution of number of taxa found in the cores taken from the subtidal sites.



B. Interpolated plot of the distribution of number of orders found in the cores taken from the subtidal sites



C. Interpolated plot of the total numbers of individuals found in the cores taken from the subtidal sites



6 Intertidal

Only two types of large-scale vegetation occur in Kawau Bay, mangrove areas and a single patch of the seagrass *Zostera* at Snells Beach. Mangroves are confined to the upper reaches of the estuaries flowing into the bay, representing only 16% of the coastline (data obtained from LINZ chart NZ5227). The *Zostera* bed covers approximately 0.58 km^2, ~ 40% of the intertidal area at Snells beach. Comparison with aerial photos reveals that the bed experienced a slight reduction in the years from 1999 to 2001, and has been stable in size since.

6.1 Intertidal rocky areas

Physically the Kawau Bay rocky shore can be divided into seven groups based on rock type and slope:

1. Most common were wide shore platforms, relatively flat with a few, small boulders. Steps and other remnants of older eroded shore platforms were sometimes obvious (Fig. 6.1a).
2. Narrow high tidal bench platform dropping steeply into deep water (eastern side of Motuora Island) (Fig. 6.1b).
3. Narrow strips (<5m) of pebble beach followed by a ~20m zone of craggy, hard, jutting rocky reef (e.g., northern shore of Kawau Bay) (Fig. 6.1c).
4. Steep slopes of crumbling rock, yellow and orange oxide stained (western areas of Kawau and Motuketekete Islands) (Fig. 6.1d).
5. Crevice dominated sedimentary rock with deep, narrow clefts (south-west Kawau Island) (Fig. 6.1e).
6. High steep platforms with large boulders on the mid-low shore, dropping off into deep water (north and south end of Kawau Island) (Fig. 6.1f).
7. Predominantly vertical cliff, with large boulders that stretched from deep water to 3-4 meters above sea level (Takatu Point) (Fig. 6.1g).

Zonation of reef communities associated with tidal elevations, such as described by Morton (2004), even when exposure was considered, was not obvious at most sites. To some extent this was due to the number of tidal pools, crevices and large boulders present at most sites. However, even at the sites with wide shore platforms and few small boulders, zonation was not strong.

Figure 6.1 Physical types of intertidal rocky areas observed.

A. Wide Flat Shore Platform

B. Narrow High Tidal Bench

C. Narrow Pebble Beach

D. Steep Crumbling Rock Slope

E. Crevice Dominated Sedimentary Rock

F. Steep Platform with Large Boulders

G. Vertical Cliff with Large Boulders

The rocky area between Big Bay and Martins Bay contains a number of wide, relatively flat intertidal platforms. Just south of Martins Bay, the intertidal platforms have large 1-2m flattened boulders. This area contained fewer species, and less coverage with bare rock being common (up to 50%) in the mid to upper intertidal. The upper intertidal had sparse coverage of a red algae (*Apophlaea sinclairii*) or surf barnacles (*Chaemosiphon brunnea*) and black periwinkles (*Melanerita atramentosa* previously *Nerita melanotragus*) (Fig. 6.2a), while the mid intertidal had a sparse coverage of coralline turf (*Corallina officinalis*) and Neptune's necklace (*Hormosira banksii*). Further south, where the boulders are not common, less bare rock was seen at all tidal heights. High tide areas contained *Apophlaea* or *Chaemosiphon* and *Melanerita*. *Apophlaea* was not apparent in the mid tide areas, which was predominantly covered by *Chaemosiphon* and *Corallina*. The low intertidal had 20 – 30% cover of *Corallina*, *Hormosira* and coralline paint. Diversity (as number of taxa observed) was similar at all tidal heights, although it varied between locations (i.e., ~5 taxa at each tidal height near Martin's Bay and ~14 taxa further south).

Figure 6.2 Pictures of intertidal species found in Kawau Bay.

A. Sparse *Chaemosiphon* and *Melanerita*

B. Diverse communities exist under overhangs

At Mullet Point, long sloping intertidal platforms are found on both sides, but these were inhabited by different communities. On the southern side of the point, the upper intertidal was sparsely covered by *Apophlaea* and *Corallina* with *Melanerita.* Greater coverage by *Corallina* was observed at mid tide (>50%) with *Hormosira* and *Chaemosiphon*. Near low tide *Corallina* coverage remained high and *Hormosira* and *Chaemosiphon* were still observed. Similar communities were found on the point between Goldsworthy and Algies Bay, although oyster flats were more extensive and the low tide community was sparser. In both these areas highest diversity was observed at mid tide. In comparison, on the northern side of Mullet Point, highest diversity was found at low tide, where overhangs provided a rich environment (Fig. 6.2b). Sparse coverage of lichen, calcareous tube worms (*Pomatoceros cariniferus*), *Chaemosiphon* and *Melanerita* graded from high tide to predominantly *Chaemosiphon* at mid tide and *Corallina* at low tide.

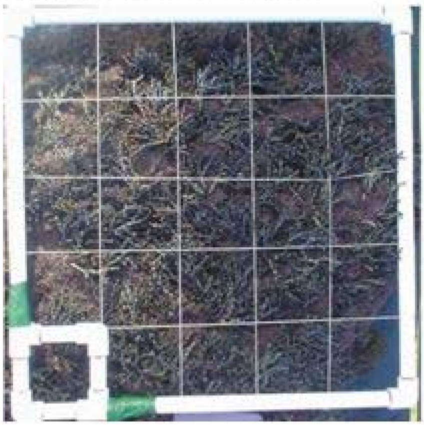
Round the mouth of the Matakana River, narrow shore platforms occur. *Chaemosiphon* dominated the upper intertidal of the northern side (Fig. 6.3a), with oysters (*Saccostrea* (previously *Crassostrea) glomerata*) (Fig. 6.3b) in the mid intertidal and under boulders, and *Hormosira* (Fig. 6.3c) and *Corallina* at low tide.

Figure 6.3 Pictures of intertidal species found in Kawau Bay.

A. *Chaemosiphon*

B. *Sacossotrea*

C. *Homosira* and *Corallina*



Along the Tawharanui Peninsula, sites were located on the broad rocky area between Million and Prospect Bays, and at Karangatuoro, Motutara, Scow and Elephant Points. Structure of the intertidal was varied along this area. Intertidal areas between Million and Prospect Bays, and at Karangatuoro Point, were generally wide shore platforms. *Chaemosiphon* dominated at the high intertidal, *Corallina* sometimes with *Saccostrea* or *Hormosira* occurred at mid tide and dense *Corallina* near low tide. Diversity was generally highest, and more variable, near high tide. At Motutara Point, large rocky crevices were common. A red/brown coloured turfing algae together with *Corallina* provided patchy cover at high tide, and plicate barnacles (*Epopella plicatus*) (Fig. 6.4a) dominated the mid tide area. From mid tide, the rock dropped sharply into deep water. Off Scow point, the intertidal rocky area was more of a rocky beach than a platform. In the upper intertidal bare rock was common, although *Chaemosiphon* and *Melanerita* occurred. Below this, *Chaemosiphon*, chitons (*Cellana* spp.), and *Melanerita* were common with *Hormosira*, *Corallina* and coralline paint in the many small rock pools. Off Elephant Point, the intertidal zone is short (~3m) and steep and comprised of small (~1m) boulders at the base of the cliff. A gradient in decreasing coverage of *Epopella* and increasing coverage of *Chaemosiphon* was observed from high to low tide. High variability in the number and type of other taxa occurring was apparent from mid to low tide, with average diversity highest at mid tide.

Figure 6.4 Pictures of intertidal species found in Kawau Bay.

A. *Epopella*

B. *Carpophyllum* in crevice near low tide

On Kawau Island, broad intertidal platforms were rarely found. At Kawati Point 2-3m high boulders and small crevices were found on a rough rocky platform, covered by *Chaemosiphon* up to the high tide mark, and *Corallina, Hormosira* and coralline paint near low tide. Some *Carpophyllum* was also observed (Fig. 6.4b). The north side of Bon Accord Harbour had a steep rocky shore, the upper to mid portions of which were predominantly bare, with a few *Chaemosiphon*, *Melanerita* and *Apophlaea,* and *Corallina, Hormosira* and coralline paint near low tide. On the south was a sloping platform of boulders and crevices, again with predominantly bare upper to mid portions and *Corallina, Hormosira* and coralline paint near low tide. Near Dispute Cove a wide shore platform was found. A brown turfing algae covered up to 50% of the rock surface in the high intertidal, with some *Chaemosiphon*. *Saccostrea* dominated the mid intertidal and *Hormosira* and *Corallina* were common near low tide.

On the southern end of Kawau Island, around Elizabeth Point, the intertidal area was moderately steep with 1-2m high rugged crevices. Two sites were located here, facing west and south respectively. Bare rock was observed less on the west facing site. *Chaemosiphon* and *Saccostrea* dominated the high elevation, with a diverse array of algae and other taxa at the mid tide elevation and coralline paint and *Apophlaea* was common near low tide. At the south facing site, bare rock was more common. *Corallina* was found at all tidal heights, although it was more abundant near low tide, *Hormosira* was common at the mid tide elevation and a variety of algae were found near low tide. Near Brownrigg Point a site was located on a steep slope, with huge boulders >2m, and many rock pools. Strong zonation was not observed, although lichens and short turfing algae were more common at high elevations, *Chaemosiphon* dominated mid elevations and coralline paint and *Carpophyllum* were found near low tide.

Two sites were located on the islands to the south. On the north of Motuketekete Island the intertidal platform was rugged, with large blocks and pools. Bare rock was common at the upper two elevations. Near high tide *Chaemosiphon* was dominant; however, at mid tide *Corallina* was dominant with a number of other encrusting and turfing algae and gastropods. Near low tide was a mix of *Corallina, Hormosira* and *Carpophyllum.* On the south side of Motuora Island, a narrow high tidal bench shore platform was found. *Chaemosiphon* and *Saccostrea* dominated near high tide, while *Epopella* was dominant (up to 50%) at mid tide.

The ecology of rocky intertidal areas generally varies according to exposure, amongst other factors (Morton 2004). In Kawau Bay, more sheltered sites (generally low sloping platforms) tended to have more bare rock, *Saccostrea, Chaemosiphon* and high numbers of *Melanerita* at high shore. At mid shore, *Saccostrea*, *Chaemosiphon*, *Corallina* and/or *Hormosira* occurred, and the low shore was generally dominated by *Corallina*, *Hormosira* and coralline paint. In exposed sites, *Epopella* was more frequently found in the upper and mid tide areas and large brown algae (*Xiphophora, Carpophyllum)* were often found in crevices near low water. In between sheltered and exposed, short turfing and encrusting algae were more common in the high intertidal, plicate barnacles increased in abundance at all elevations, and coralline paints were common, particularly at low tide.

Based on the composition over all tidal elevations, each site was assigned to an ecological function group (Table 6.1).

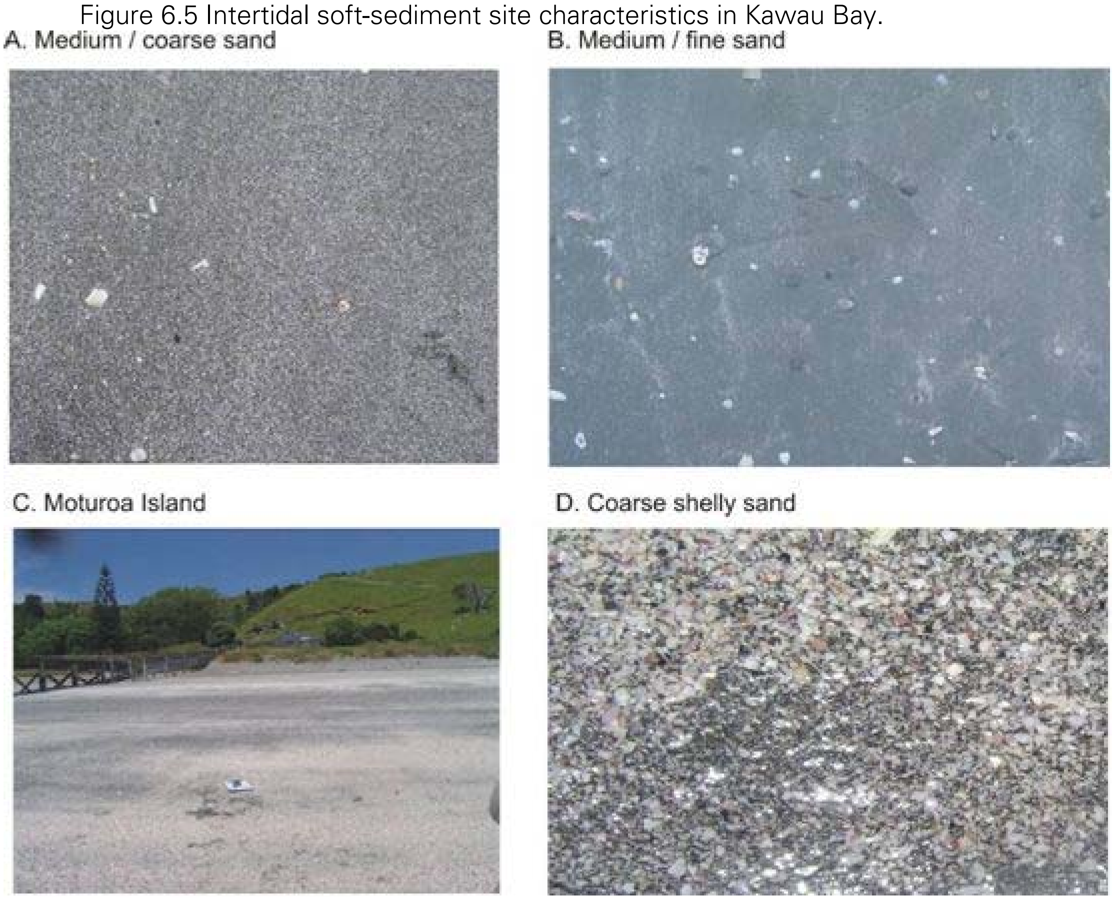
Table 6.1 Ecologically important rocky intertidal communities found in Kawau.

Community type	Description
Large brown algae	Contains > 30% cover of large brown algae in low intertidal. Mainly found in exposed sites.
Erect flora	Mid and low tide elevations have > 50% cover of turfing flora (mainly *Corallina* and *Hormosira*) and highest elevation is predominantly bare rock.
Encrusting/erect flora	A mix of encrusting algae (mainly coralline paint) and erect flora comprises >50% of cover.
Erect flora/Suspension feeders	A mix of erect flora (mainly *Corallina* and *Hormosira*) and suspension feeders (*Chaemosiphon*, *Saccostrea*, or *Epopella*) comprises >50% of cover. Mainly found in semi-exposed sites.
Suspension feeders	Suspension feeders (*Chaemosiphon*, *Saccostrea*, or *Epopella*) comprise >50% of cover. Mainly found in exposed sites.

6.2 Intertidal soft sediment

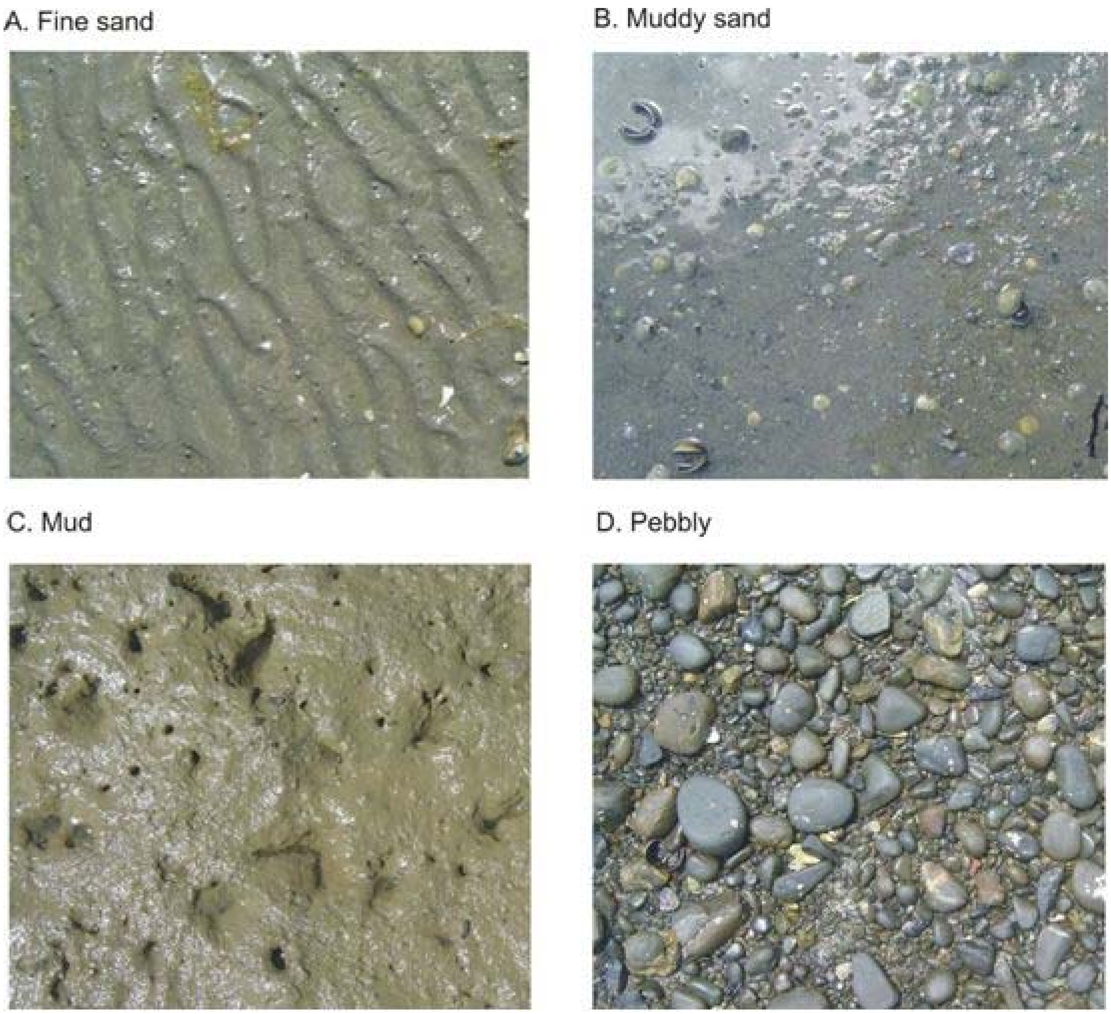
The three beaches along the exposed coast from Mullet Point to Mahurangi Heads (Dairy Bay, Big Bay and Martins Beach) are amongst the most exposed in Kawau Bay. Sediment type was predominantly medium to coarse sand (Fig. 6.5a), diversity and abundance was low as, is typical for beaches. A distinct assemblage dominated by isopods and amphipods was observed, although genera differed between the three beaches. Sediment at Martins Bay had more medium – fine sand than coarse sand (Fig. 6.5b), and more polychaete taxa were found than at the other beaches. Another exposed beach was sampled (on Motuora Island (Fig. 6.5c)). This site had coarse shelly sand (Fig. 6.5d), and was dominated by polychaetes and amphipods.

Figure 6.5 Intertidal soft-sediment site characteristics in Kawau Bay.



The section of coast between Mullet Point and the Matakana River mouth is dominated by sheltered beaches (Scandretts Bay, Goldsworthy Bay, Algies Bay and Snells Beach). Sediment type varied but was predominantly fine sand (Fig 6.6a). Some medium sand occurred in parts of Snells Beach, and Goldsworthy Bay was predominantly coarse sand with shell hash. The communities were frequently diverse with a number of species of bivalves, polychaetes and other orders occurring. The Goldsworthy Bay site was most similar to the more exposed, coarse sand beaches, being dominated by amphipods and isopods. Sites at Scandretts and Algies Bay were generally bivalve-dominated (the pipi *Paphies australis*, the cockle *Austrovenus stutchburyi*, the nut shell *Nucula hartvigiana* or the wedge shell *Macomona liliana*). Sites at Snells Beach contained bivalves but were often numerically dominated by other orders (the polychaetes *Prionospio aucklandica* and *Pseudopolydora* sp. and phoxocephalid amphipods). Diversity was highest at Snells Beach and Scandretts Bay. Taxa observed at these sites did not form a distinct assemblage ($p > 0.05$).

Figure 6.6 Intertidal soft-sediment site characteristics in Kawau Bay.



Differences were observed between the assemblages at sites inside the *Zostera* bed at Snells beach, and those nearby. This result is similar to that from studies in Manukau, Whangapoua and Wharekawa, which found pairwise differences between assemblages inside and outside a single *Zostera* bed (Turner et al. 1999, Hewitt et al. 2003, van Houte-Howes et al. 2004), although there was little consistency of effect across locations and studies. At Snells Beach higher numbers of *Austrovenus*, amphipods and *Prionospio* were found inside the *Zostera* bed, while higher densities of *Macomona* and *Paphies* were found outside. Due to the extent of the seagrass bed at Snells Beach it is hard to tell whether highest diversity was associated with the central area of the seagrass bed (Fig. 6.7a), or varied spatially across the bay in response to some other factor. Regardless, diversity nearer the edge of the seagrass patch was less than 10% higher than that outside and no significant differences in diversity at the taxa or order level were observed. Furthermore, similar to other studies (Turner et al. 1999, Hewitt et al. 2003, van Houte-Howes et al. 2004, Hewitt and Funnell 2005), the taxa found in the *Zostera* bed were not a unique assemblage. That is, the communities found in the *Zostera* bed were not significantly different from communities found in the rest of Kawau Bay.

Sediment type continued to become finer moving into the Matakana Estuary, changing from fine sand to muddy sand (Fig. 6.6b), then finally to sandy muds and mud (Fig. 6.6c) near Tongue Point. In the fine sand and muddy sand sites *Austrovenus* dominated, often with *Nucula*, or some polychaetes. In the muddy area near Tongue Point the polychaetes *Heteromastus filiformis* and Paraonidae were numerically dominant and crabs were common.

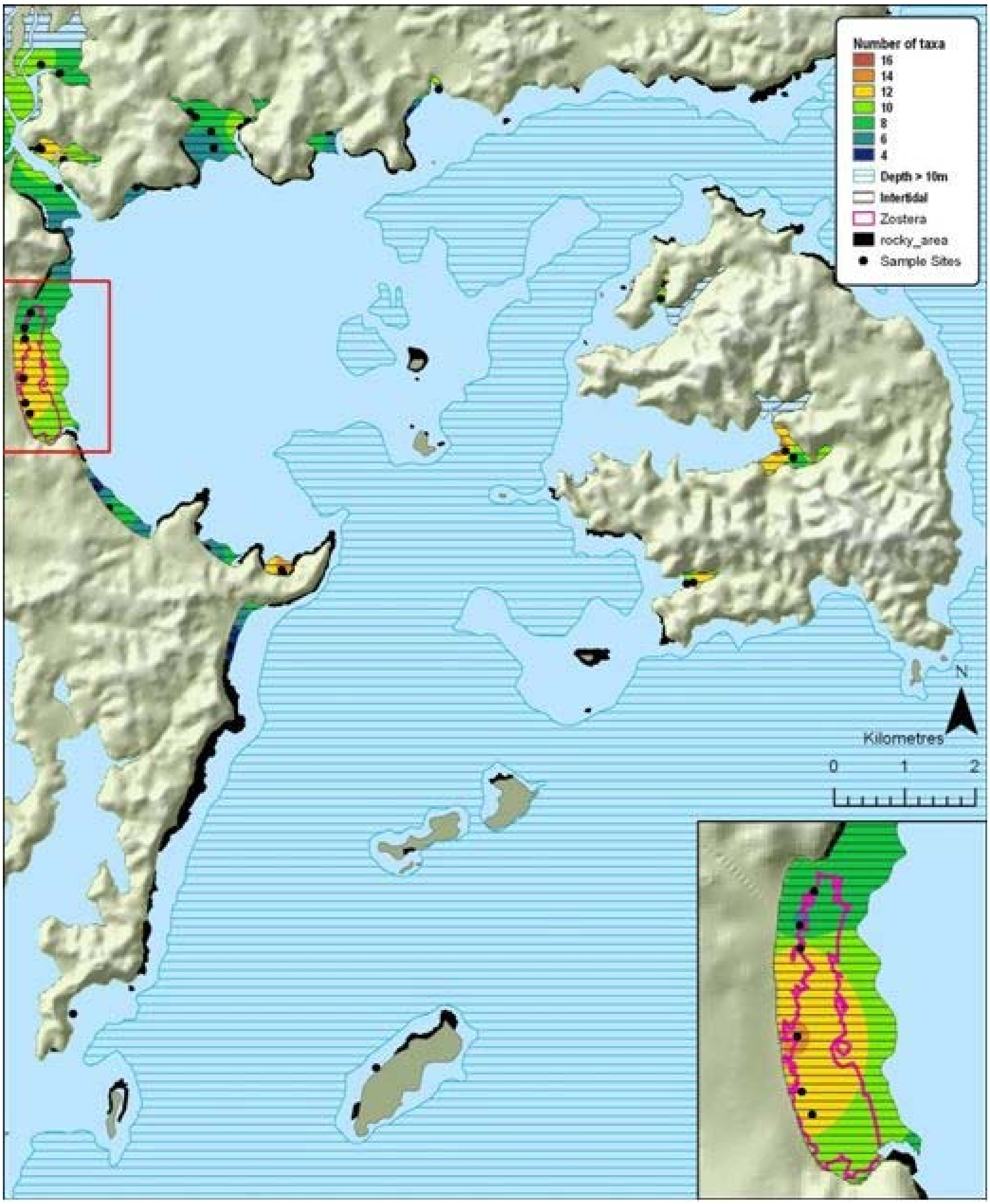
The bays to the north of the Matakana River mouth (Wanns, Million, Prospect and Christian) vary from sheltered to more exposed. Wanns, and parts of Christian Bay, had coarser sediment and were dominated by pipis and isopods. The lower part of Christians Bay was very pebbly (Fig. 6.6d) with high diversity and a community dominated by *Nucula* and *Austrovenus*. Million Bay varied from coarse sand to muddy sand. Communities were generally numerically dominated by *Austrovenus* with polychaetes, isopods and amphipods common. The one site sampled in Prospect Bay had low diversity, and was dominated by tube dwelling polychaetes (*Boccardia syrtis* and *Macroclymenella stewartensis*).

On Kawau Island, North Cove, South Cove and Moores Bay in Bon Accord Harbour were sampled. Sites in North Cove and Moores Bay were predominantly coarse sandy mud, and were reasonably diverse. North Cove was numerically dominated by *Austrovenus* and *Nucula*, although the upper site was highly bioturbated by crabs and the lower site contained some tube worms. The upper site in Moores Bay was highly bioturbated and dominated by *Boccardia* with some individuals of the invasive bivalve *Musculista senhousia*. The lower site was dominated by *Nucula* and *Macroclymenella*. South Cove was sandier, with one site dominated by polychaetes and amphipods and the other by bivalves. This variability in taxa and overlap between the taxa observed here and in Matakana Estuary meant that no significant difference was observed between community composition of sites in the estuaries on Kawai Island and those in Matakana Estuary.

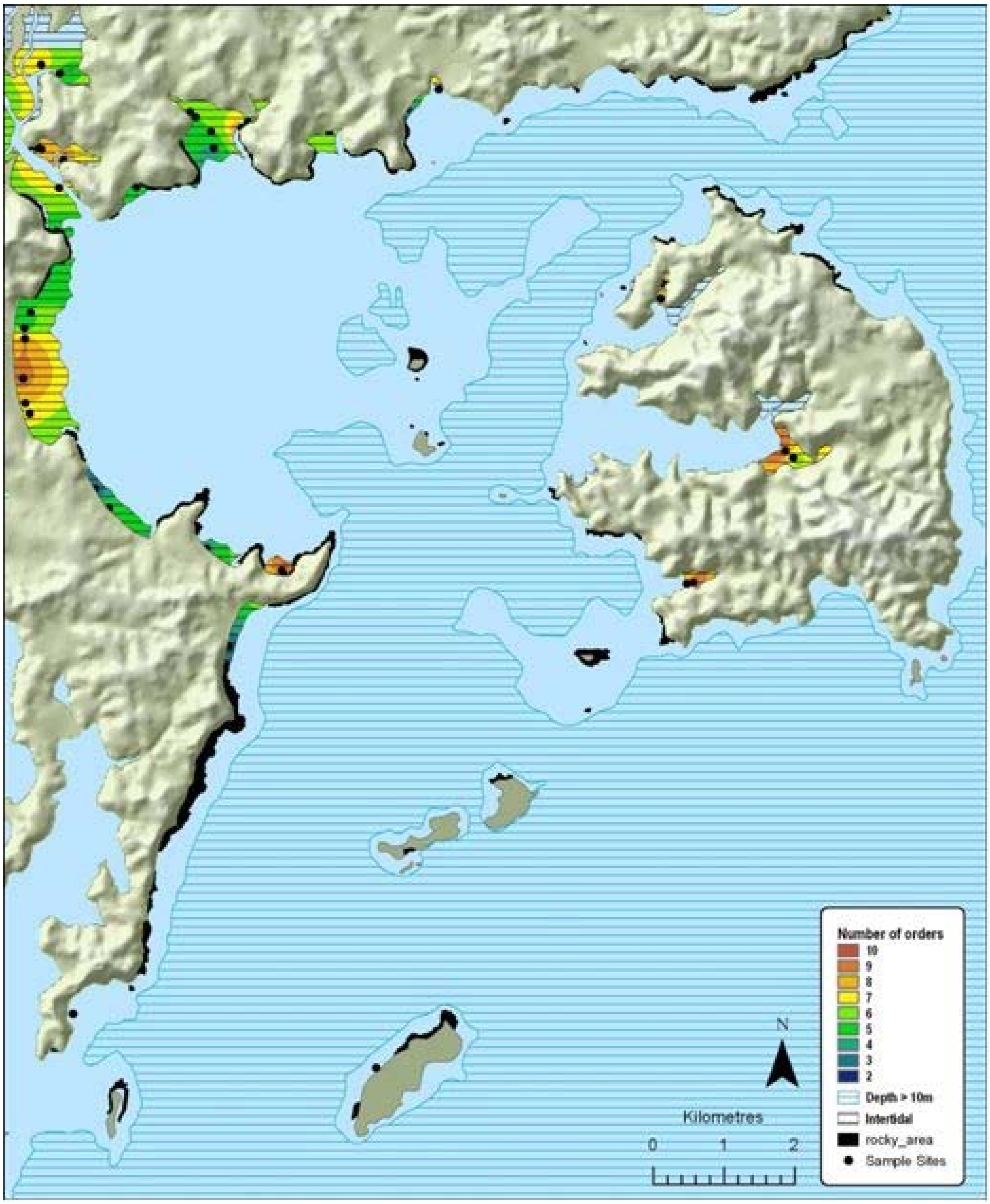
Taxa data were analysed to determine whether sediment type defined significantly different assemblages. This was not the case, although the community composition of sites in mud was significantly different to that of sites in coarse sand.

Numbers of taxa found at a site ranged between low diversity (4 taxa per site) to 16. No general pattern was observed between beaches and estuaries (Fig. 6.7a), but lowest numbers of taxa were found on the exposed coarse sand beaches. This same pattern was observed for number of orders (Fig. 6.7b); with numbers varying between 2 to 10 orders. Numbers of individuals generally followed the inverse pattern with higher numbers in muddy areas (Fig. 6.7c).

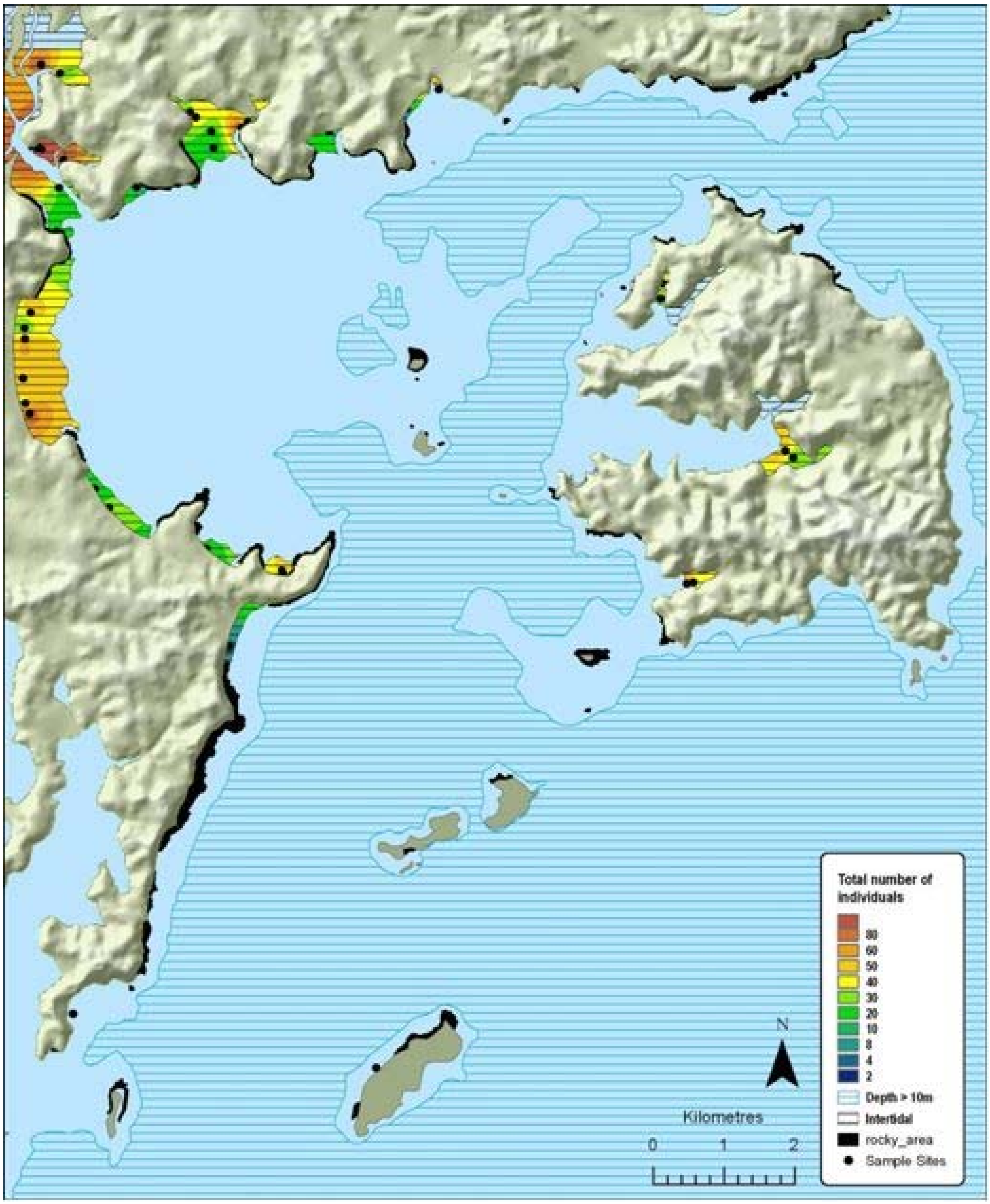
Figure 6.7 A. Interpolated plot of the distribution of number of taxa found in the cores taken from the intertidal sites.



B. Interpolated plot of the distribution of number of orders found in the cores taken from the intertidal sites.



C. Interpolated plot of total numbers of individuals, found in the cores taken from the intertidal sites.



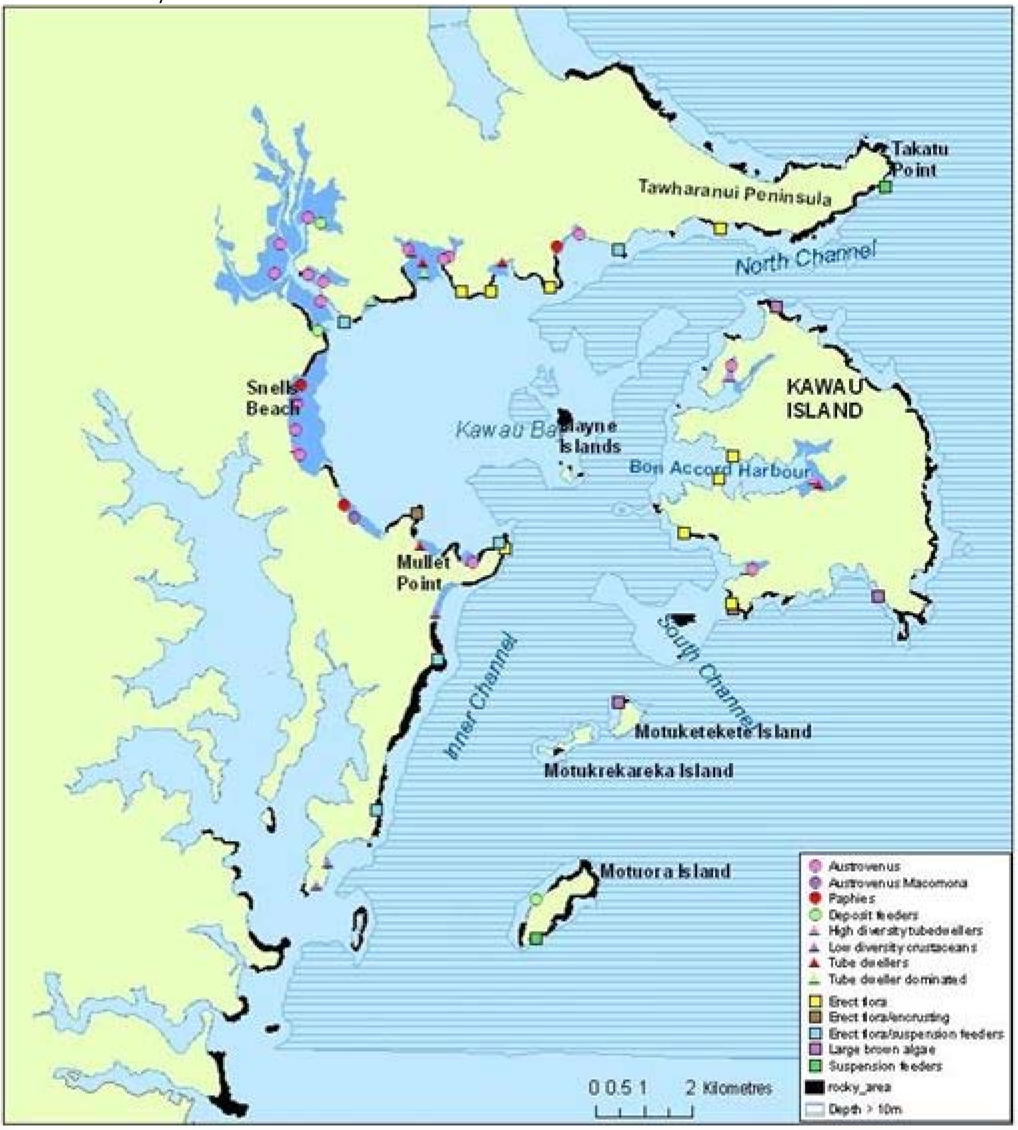
In the intertidal soft-sediment, ten community types were identified (Table 4, Fig. 6.8). Three types were based on biomass of adult bivalves; an *Austrovenus stutchburyi* community, a mixed *Austrovenus-Macomona liliana* community and a *Paphies australis* community. The remaining communities were dominated by tube building polychaetes or deposit feeding animals. High taxonomic diversity and high densities of individual animals were found at a number of sites within the bay in communities dominated by *Austrovenus* or tube-dwellers (*Euchone* sp., *Boccardia* and *Macroclymenella*). Like many of New Zealand's estuaries and harbours, polychaete-dominated communities were widespread, displaying a mix of functional types (e.g., tube-dwellers, large predatory/scavenging polychaetes and deposit feeders). All communities identified by the hierarchical community rules were more than 80% dissimilar; most were greater than 93% dissimilar. More similarities were found between the communities dominated by either

Austrovenus or *Paphies* and the other communities, as the similarity analysis was based on numeric data and these communities were selected by biomass.

Table 6.2 Ecologically important soft sediment intertidal communities found in Kawau Bay using the hierarchical rules given in Appendix 1a.

Community type	Description
Austrovenus	Dominated by large *Austrovenus stutchburyi,* found in high to low intertidal in a mix of sediment types. Usually found in conjunction with anemones, limpets and small *Nucula hartvigiana*.
Austrovenus-Macomona	Adults of both *Austrovenus* and *Macomona liliana* found. Found on sandy exposed beaches.
Paphies	Low diversity, dominated by *Paphies australis*. Found in exposed sandy sediments.
High diversity tube dwellers	High diversity, dominated by tube dwellers, although high numbers of other large organisms including shrimps and predatory/scavenging polychaetes also occurred. Found in mud to sandy sediments.
Deposit feeders	Dominated by deposit feeding polychaetes. Variable species but often including *Magelona* sp. Moderate diversity, frequently includes burrowing crabs and/or shrimps. Found in a range of sediment types.
Tube dweller dominated	Dominated by *Macroclymenella stewartensis* or *Euchone* sp. Moderate diversity. Associated with sandy exposed sediments
Low diversity tube dwellers	*Boccardia syrtis* dominated. Found in coarse sand to sandy mud.
Low diversity crustaceans	Low diversity, found on sandy exposed beaches, dominated by crustaceans such as isopods and amphipods.

Figure 6.8 Distribution of ecologically significant intertidal communities found in Kawau Bay

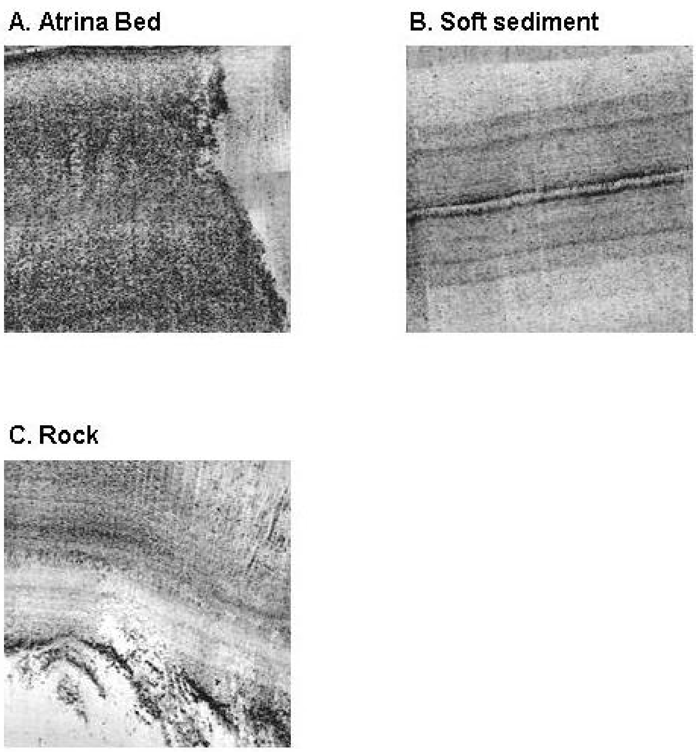


7 Kawau Bay Ecology

7.1 Habitats of Kawau Bay

Unlike the variety of habitats determined directly from the side-scan imagery in the Southern Kaipara, in Kawau Bay side-scan imagery delineated only three main habitat types: rock, *Atrina* beds and soft-sediment (Fig. 7.1). This was due to the extreme contrast imposed by the presence of both hard and soft substrates and the absence of large epifaunal reefs (such as those produced by serpulids, oysters and bryozoans) or large areas of macroalgae associated with the soft sediment. Furthermore, large epifauna were mostly patchy in distribution. An additional issue arose in that acoustic data suggested patchy beds of *Atrina*, which BEVIS sampling showed to be comprised of dead shells, with an acoustically identical signal to live animals. However, examination of the BEVIS and drop camera transects showed a number of bottom habitat types within the soft-sediment. Once these had been identified, it was possible to track their existence onto the side-scan. Thus, the side-scan could be used to extend the known coverage of these habitat types.

Figure 7.1 Side-scan image groups observed in Kawau Bay.



The bay can be divided into four broad habitat zones (Fig. 7.2).

1. In northern and western sheltered subtidal soft-sediment areas < 10 m deep, bioturbated sediments and low densities of *Atrina* were found. The

corresponding infaunal communities were heterogeneous, with low diversity tube dweller, bioturbated and deposit feeding communities found. Subtidal hard substrates were also heterogeneous and were occupied by sponge flats, *Carpophyllum* forest and cobble habitats. The intertidal soft-sediments were generally dominated by adult *Austrovenus* and exhibited a range of diversity. In muddy areas, polychaetes increased in abundance and *Austrovenus* decreased. Intertidal rocky platforms were predominantly bare near high tide. At mid shore, *Saccostrea*, *Chaemosiphon*, *Corallina* and/or *Hormosira* occurred, and the low shore was generally dominated by *Corallina* and *Hormosira.*

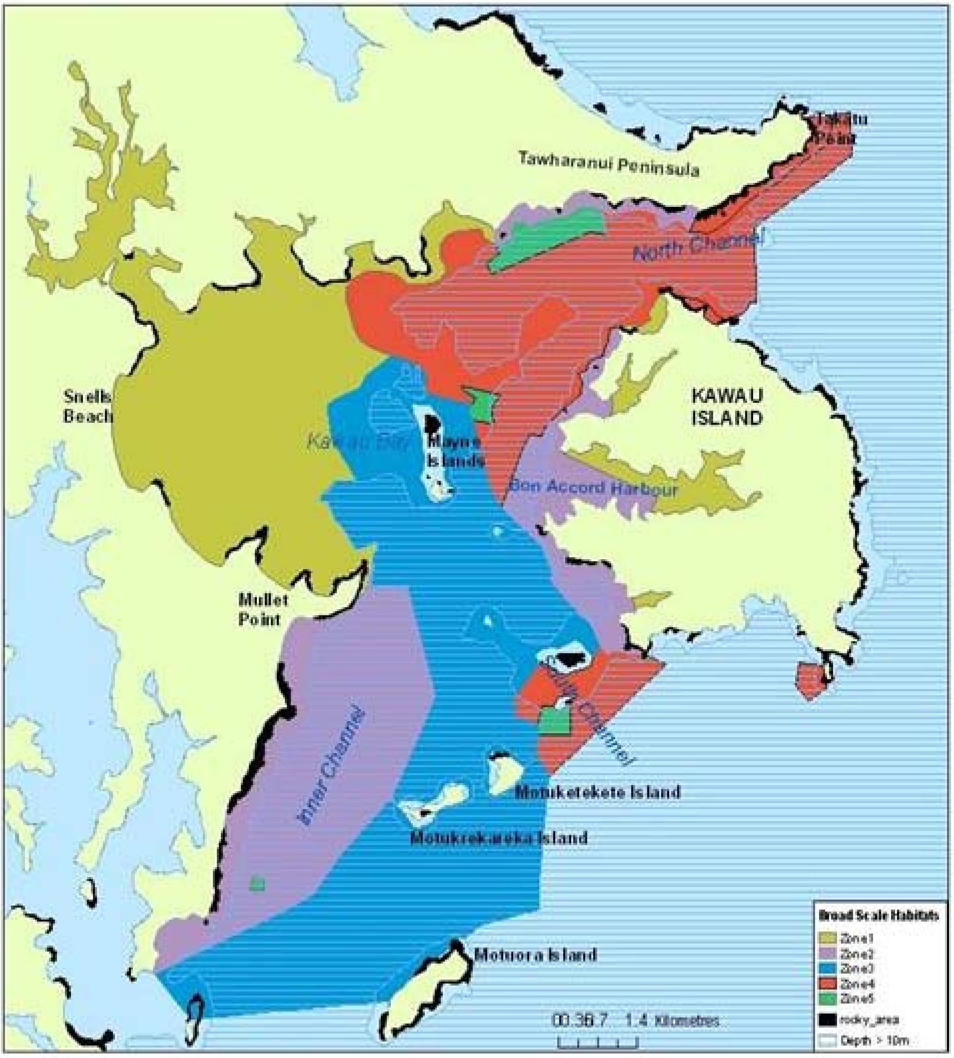
2. The soft-sediment on the western side of Kawau Island and the Inner channel generally had low to medium densities of *Atrina*, in a variety of substrate types, but mostly finer sands and mud. A heterogeneous mix of other epifaunal habitats also occurred: tube-worm carpets; mobile epifauna; and some sponges and scallops. A mix of hard substrates was also found: *Carpophyllum* forest; mixed algae; urchin barrens; *Cystophora*; turfing algae and sponge flats. Similarly, a range of patchy infaunal communities were observed: low diversity tube dwellers (<10m depth), high diversity tube-dwellers; bioturbators and deposit feeding bivalves. In the intertidal, the sandy beaches of the inner channel were characterised by mobile crustacean communities, while the rocky shore platforms were characterised by semi-exposed communities. Short turfing algae, *Chaemosiphon* and encrusting algae were common in the high intertidal, *Corallina* and/or *Hormosira* were common at mid and low tide. Overall, communities belonged to the erect flora/suspension feeder mix on the mainland or erect flora community on Kawau Island.

3. The higher current areas of the eastern part of the bay were predominantly mixed epifauna habitat, although as patch sizes of the different taxa overlapped, scallops, high density scallops, sponge & scallops, infauna, *Atrina* and bioturbated habitats also occurred. Hard substrate epibenthic habitats found were similar to those in western and inner channel areas, although urchin barrens and *Cystophora* were not found. Only three infaunal community types were observed: low diversity tube-dwellers; deposit feeders; and bioturbators

4. The north and south channels around Kawau Island were characterised by high diversity, strong currents and coarse sediments. The soft sediments were dominated by sponge habitats although *Atrina*, bioturbated, mobile epifauna and infaunal dominated habitats also occurred. *Ecklonia* forest and mixed epifauna habitats dominated subtidal rocky areas, while sponge flats and cobble habitats were found in rock and sand matrix areas. Only two infaunal community types were observed: high diversity mixed and high diversity tube dwellers. No intertidal soft-sediment areas were sampled in this area. In the rocky intertidal, exposed communities were found. *Epopella* rather than *Chaemosiphon* was found in the upper and mid tide areas and large brown algae (*Xiphophora, Carpophyllum)* were often found in crevices near low water. Communities were either dominated by suspension-feeders, or had > 30% large brown algae at low tide.

5. Several areas of high density *Atrina* and associated sponges were also found in the bay in a range of sediment types (Zone 5 in Fig. 7.2). Their infaunal communities were highly diverse and contained tubeworm-suspension feeding mix, high diversity tube-dwellers and bioturbator community types. In hard substrates near these areas *Ecklonia* forest and mixed algae habitats were found.

Figure 7.2 Broad-scale habitat map of Kawau Bay.



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

7.2 Comparison with other localities

7.2.1 Intertidal

Diversity at the taxa and order level is similar in both Kawau Bay and the Southern Kaipara, but there are differences in the community types found in the two locations. Notable in Kawau Bay are the sandy sediments dominated by *Paphies* and the absence of sediments dominated by *Macomona* (common in the Southern Kaipara and elsewhere in northern New Zealand) and communities of the invasive bivalve *Musculista.* Both Kawau Bay and Kaipara Harbour contain *Austrovenus* and *Austrovenus – Macomona* communities, tube-dwelling polychaete communities, and deposit-feeding communities in similar sediment types.

An ARC monitoring programme at Long Bay and surrounds (Ford et al. 2003) also provides an area for comparison of the intertidal soft sediment communities of Kawau Bay. There, several beaches (Browns, Mairangi & Long Bays) are dominated by polychaetes, particularly a Hessionid, which was not found in any samples in Kawau Bay. Small numbers of *Paphies australis* were found at Long and Browns Bays, while Torbay Beach had a *Paphies* dominated community similar to that found in Kawau Bay.

The muddier sediments of the Matakana can be compared with those found in the neighbouring Mahurangi estuary. Differences were observed with much of Mahurangi being dominated by *Nucula hartvigiana*, *Heteromastus filiformis,* Polydorids and *Cossura* sp*.* The majority of the communities in the Matakana area were dominated by *Austrovenus*, a community type that is also found in the Mahurangi estuary, in the areas less impacted by sedimentation (Cummings et al. 2005).

7.2.2 Subtidal

A number of studies have been conducted in the subtidal environments of Kawau Bay (Lohrer et al 2003, Thrush et al 2006, Thrush et al 2002, Thrush et al 2001, Thrush et al 1998, Hewitt et al 2004c, Norkko et al. 2001, Ellingsen et al. in press). Where these and the present study's sampling overlap, similar results have been observed. Moreover, Hewitt et al (2004) carried out limited mapping of soft sediment epifaunal communities in the central region of the northern channel and in the southern channel of Kawau Bay and found similar epifaunal habitat classifications to the ones used in this study, despite the smaller spatial scale of sampling.

Epifaunal habitats observed for Kawau Bay overlap little with those observed in the Southern Kaipara, unsurprising given the very different hydrodynamic environments. While the Southern Kaipara had many areas dominated by *Fellaster*, gastropods, hydroids and the invasive bivalve *Musculista* respectively*,* these were rare or absent within Kawau Bay. Conversely, *Atrina*, uncommon in the Kaipara, was one of the dominant epifauna within Kawau Bay. Common in both areas was the occurrence of sponge dominated communities in coarser sediment areas of high tidal current flow. The infaunal subtidal communities within Kawau Bay had higher abundances and considerably higher diversity at the taxa and order level than in the Southern Kaipara, particularly in the coarser sediments of the northern channel.

Of particular note was the identification of several individuals of the small pisionid (*Pisione oerstedii)* in two samples within Kawau Bay itself. While this species has been found elsewhere in the southern hemisphere (Type locality is Valparaiso, Chile) only a single specimen has previously been recorded in New

Zealand waters (Augener 1924), also from Kawau Bay. If it occurs elsewhere in New Zealand, it is certainly genuinely rare (G. Read *pers comm*.).

While the rocky subtidal in Kawau Bay was diverse and comprised of a number of different algal habitats, the mixed algal habitat surveyed in Kawau Bay can be compared to the rocky subtidal sites at Long Bay and surrounding environs (Ford et al 2004). In both areas, the largest percentage cover was crustose coralline algae/coralline paint algae, with communities dominated by large brown algae (*Carpophyllum maschalocarpum, Carpophyllum plumosum, Ecklonia radiata*). Both areas are relatively sheltered, and were characterised by an abundance of the gastropods *Turbo smaragdus* and *Trochus viridis*. One difference was the presence of significant numbers of the algae *Zonaria turneriana* and *Sargassum sinclairii* in the samples at Long Bay compared to Kawau Bay.

Previous studies have found the algal community structures at sites within the Hauraki Gulf generally reflect the wave exposure of those sites (Grace 1983, Cole 1993, Walker 1999), although there can be considerable variation over relatively small spatial scales, depending on the exposure gradients (Shears & Babcock 2004). The results from both Long Bay and Kawau Bay, where there was considerable within-site variability, demonstrate this. In particular, a key influence on community composition in more exposed sites (Shears & Babcock 2004) is *Evechinus chloroticus*, the numbers of which, and subsequent role in determining algal composition, are reduced in sheltered environments such as found within Kawau Bay.

7.3 Vulnerability of habitats to anthropogenic threats

Likely impacts on habitats in Kawau Bay include:

- recreational uses (trampling on intertidal reef communities, boating, fishing);
- spread of mangrove cover, as mangroves trap increased amounts of sediment input associated with climatic and land use changes;
- increased muddiness of the sediment and spread of mud into presently sandy habitats and decrease in water clarity again associated with climatic and land use changes;
- urbanisation, apart from increasing sediment loads and recreational use, urbanisation may result in increased sewage and stormwater inputs into the environment;

For areas containing *Zostera*, the potential for decreased *Zostera* cover is usually a threat. However, as the appearance of Zostera is relatively recent in this area, its disappearance is not considered a threat.

7.3.1 Recreational uses

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

- Trampling of intertidal reef communities: Communities on intertidal rock platforms can be strongly affected by a number of people walking across the surface (Brown and Taylor 1999, Schiel and Taylor 1999) (Fig. 7.3). While this level of impact may sound excessive, given the number of people likely to visit these areas, 800 or so visits over a particular area is not unreasonable. We recommend that a six monthly monitoring programme based on photographic records be initiated at intertidal rock platforms within easy access.
- Anchoring: Boat anchors can cause considerable damage to areas with diverse epifauna, such as sponge gardens, Atrina beds and kelp beds (Backhurst & Cole 2000). Many such areas occur in Kawau Bay (Fig. 5.1, Fig. 7.1). In many Marine Protected Areas, the Department of Conservation has set up "no anchor" areas to protect sensitive locations. There is a charted area enclosed by three cables, Goldsworthy Bay to Takangaroa Island (the southern most of the Mayne Islands) to Manning Point (Kawau Island) and back to Mullet Point, within which anchoring is prohibited. However, this area does not enclose all 4 of the broad-scale habitat zones; in particular it does not enclose the areas of highest diversity or the areas with the largest numbers of soft-sediment habitat-forming taxa. A preliminary benthic survey of the area has shown the potential for up to 100% higher densities of habitat forming epifauna inside the no-anchor area of Kawau Bay compared to unprotected areas in the vicinity (Ross 2007).
- Extraction: While extraction is not within the ability of the ARC to manage, it is still a threat to the communities of Kawau Bay, both intertidally and subtidally. Impacts include disruption to community structure by removal of critical species (Lilley and Schiel 2006, Schiel 2006) and the damage caused both to other species and to the seafloor by scallop dredging (Thrush et al. 1998). Unfortunately, information on the effect of extraction is limited to work on a few species.
- Marinas: Development of marinas can have a number of potential impacts including: location-specific changes to circulation patterns, increased contaminant levels and increased biosecurity risk but see Turner et al. (1994). Indeed, at the time of writing a proposal for a ~140 berth marina in the Matakana Estuary behind Sandspit had recently been lodged with the ARC.

Figure 7.3 Path worn by one person walking to edge of intertidal platform daily for a year (taken by Prof. David Schiel, University of Canterbury).

7.3.2 Increased muddiness

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

As Lundquist et al. (2003) demonstrate, soft-sediment muddy habitats do not necessarily exhibit low diversity and functionality. They describe a gradient of decreasing numbers of taxa, functions and large animals with increasing sedimentation rates, as well as muddy communities from different types of estuaries and harbours becoming more similar. Muddy habitats of Kawau Bay presently fit into the intermediate area of the Lundquist model. Increased sedimentation of both muddy and sandy areas would therefore result in changes to the animals inhabiting the muddy areas, decreasing diversity and increasing mobile surface dwelling species such as corophid amphipods and the mud crab (*Helice crassa*).

Subtidally, with increasing turbidity, suspension feeders (such as sponges and *Atrina*) would likely decrease (Ellis et al. 1999, Ellis et al. 2002, Lohrer et al. 2003). Some suspension feeders (*Crassostrea*, *Perna*) are not as susceptible and would require much higher levels of elevated turbidity before exhibiting reductions (Hawkins et al. 1999). The response of grazers is difficult to determine as many grazers can switch from grazing on algal species to detritus. If increased sedimentation as well as increased turbidity occurred, taxa likely to exhibit changes could be determined using the field experimental results of Lohrer et al. (2003): sponges, ascidians, scallops, *Atrina*, Lysianassid and Phoxocephalid amphipods, orbinid polychaetes, *Fellaster*, *Echinocardium*, *Boccardia*., Glycerid and Syllid polychaetes, *Heteromastus*, *Macroclymenella*, *Cossura*, *Aricidea* sp., and *Macrophthalmus hirtipes*. Flora are also likely to be affected as deposition will affect settlement, growth and photosynthetic activity. Field results from the central South island (Schiel et al. 2006) suggest that limpets (*Cellana* spp.), encrusting coralline and *Hormosira* are likely to be impacted.

At present, a large patch of subtidal mud (>60% mud) occurs off the mouth of the Matakana River in around 5m water depth. Three other patches occur, one in shallow water (<5m) on the west coast of Kawau Island, and two patches of >10m water depth in the inner channel. Increased delivery of mud may result in these areas becoming larger, although the tidal currents in the North and South channels are likely to keep them clear of sedimentation. This would impact the sensitive taxa and communities observed in zone 2 and 3, as well as several vulnerable rocky substrate communities along the channel into Sandspit, and the nearby coast.

7.3.3 Urbanisation and rural intensification

The increasing urban development planned for land surrounding Kawau Bay may have distinct impacts on the habitats of Kawau Bay. Similar to sediment impacts, impacts associated with increased nutrients (from sewage and gardens) and stormwater contaminants are generally considered to be higher in depositional areas of estuaries, such as Matakana and Mahurangi, than in coastal areas. However, the few studies on sediment effects outside estuaries suggest this is erroneous, and therefore the possibility remains that the same may be true for sewage and stormwater inputs. Some evidence supporting this theory exists in the Benthic Health Model developed for the ARC which includes data from exposed sites in the Waitemata Harbour (Anderson et al 2002, Anderson et al. 2006).

7.3.4 Spread of mangrove cover

Mangrove spread is not of high importance in much of Kawau Bay, as the majority of intertidal areas are either rocky or too exposed for mangroves to establish. However, in the upper reaches of Matakana Harbour, a few sheltered areas on the Tawharanui Peninsula and in the small estuaries of Kawau Island mangrove spread may occur. This spread would be particularly associated with increased sedimentation if it was to occur. Increase in the area covered by mangroves is likely to decrease benthic diversity and upset the balance of nutrient production, macrobenthic production and fish utilisation of the intertidal area.

7.3.5 Aquaculture

At present, no part of Kawau Bay is designated as an Aquaculture Management Area, and there are no existing farms. With the increasing development of the aquaculture industry, it is likely that areas of Kawau Bay may be identified as suitable for aquaculture e.g. high-flow and estuarine low tide areas. In high flow areas, aquaculture development would need to be balanced against recreational and conservational worth. These areas occur in channels that give access to shelter and the open sea. They also support the most diverse and picturesque benthic communities (in terms of epiflora, epifauna and infauna). Many of the intertidal areas also support diverse communities and shellfish populations of recreational value, therefore their use for aquaculture would have to be balanced against this. Any aquaculture development would require an impact assessment that would take into account specifics of location and aquacultural method. However, it is beyond the scope of this report to provide background information as to where appropriate locations may be.

7.4 Ecological values of Kawau Bay

Kawau Bay is an area of high habitat diversity, encompassing bays and estuaries of various sizes, sheltered coastal environments and more exposed rocky and soft-sediment areas. Unlike the Southern Kaipara, no subtidal seagrass beds were found, nor were any unique associations of fauna and flora. However, a high degree of heterogeneity was observed. Communities in Kawau Bay varied from those dominated by large macroalgae to dense epifauna and diverse infauna and many of the taxa were large and long-lived. Many areas displayed high taxonomic diversity at both a species and order level (over 50 taxa in over 26 orders per site, compared to 10 taxa in 7 orders found in the higher diversity areas of the Southern in Kaipara). Utilising newly developed species accumulation techniques, Thrush et al. (2006) predicted that the subtidal soft-sediments of the bay would hold ~400 infaunal species, indicating that this is a highly diverse coastal ecosystem. Taxa found are those often commonly associated with pristine environments e.g. sponges, ascidians, *Atrina*, *Ecklonia* forests, scallops and pipis.

Although the area likely to be gazetted for a marine reserve lies outside the Bay on the northern side of Tawharanui Peninsular, the southern side, dominated by high current flow, is an area of high diversity and spectacular epifauna and flora. Generally, subtidal diversity at the order and taxa resolution is very high, with up to 30 orders and 50 taxa being present in a number of places. Intertidal diversity was lower, with a maximum of 14 taxa spread over 10 orders; but again high diversity occurred in a number of places.

Ecosystems are, however, not important just for their biodiversity, but because they provide a range of ecological functions and services that directly or indirectly contribute to society. Direct services include recreation (e.g. diving), aesthetics (e.g. commercial property values), and food (e.g. commercial, traditional and recreational harvesting). Indirect services are more frequently directly related to ecological function, for example, maintaining primary productivity for human food sources. A large number of ecological functions and services were displayed by the communities observed in Kawau Bay:

- contributing to benthic productivity, nutrient fluxes and water column productivity (e.g., bioturbating, suspension feeding, macroalgal and deposit feeding communities),
- affecting sediment stability and water clarity (e.g., suspension feeding and tube worm communities),
- providing refugia for juvenile and small fishes (habitat structuring communities such as *Atrina*, sponges and macroalgae),
- providing food for predatory and herbivorous fishes (most communities), and
- providing food and recreational value for humans (e.g., *Austrovenus*, *Paphies*, scallops, sponge gardens, kelp and turfing gardens).

7.5 Summary

The diversity of communities and habitats and the range of goods and services found result in Kawau Bay having both high ecological and societal values. These values are at risk from a number of anthropogenic threats, primarily recreational use and urbanisation (and the accompanying inputs of sediment). Use of Kawau Bay is only likely to increase in the future, and as population density increases in the surrounding area there will be a corresponding increase in associated risks to this marine environment.

8 References

Anderson, M.J.; Hewitt, J.E.; Thrush, S.F. (2002). *Using a multivariate statistical model to define community health.* Prepared by NIWA for the Auckland Regional Council, NIWA Project ARC02221.

Anderson, M.J.; Hewitt, J.E.; Ford, R.B. & Thrush, S.F. (2006). *Regional models of benthic ecosystem health: predicting pollution gradients from biological data.* Prepared by Uniservices Ltd for the Auckland Regional Council.

Augener, H. (1924). Papers from Dr Th Mortensen's Pacific Expedition 1914—1916 No 18 Polychaeta II Polychaeten von Neuseeland 1 Errantia. *Videnskabehge Meddelelser fra Dansk naturhistorisk Forenig i København 75:* 241-441.

Backhurst, M.K.; Cole, R.G. (2000); Biological impacts of boating at Kawau Island, north-eastern New Zealand. *Journal of Environmental Management 60*: 239-251.

Bax, N.J.; Kloser, R.J.; Williams, A.; Gowlett-Holmes, K. & Ryan, T. (1999). Seafloor habitat definition for spatial management in fisheries: a case study on the continental shelf of southeast Australia using acoustics and biotic assemblages. *Oceanologica Acta 22*: 705-719.

Brown, P.J. & Taylor, R.B. (1999). Effects of trampling by humans on animals inhabiting coralline algal turf in the rocky intertidal. *Journal of Experimental Marine Biology and Ecology 235:* 45-53

Clarke, K.R. (1993). Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology 18*: 117-143.

Cole, R.G. (1993). *Distributional relationships among subtidal algae, sea urchins and reef fish in northeastern New Zealand.* PhD thesis, University of Auckland, New Zealand.

Cryer, M. (1994). *Estimating CAY for northern commercial scallop fisheries: a technique based on estimates of biomass and catch from the Whitianga bed.* New Zealand Fisheries Assessment Research Document 94/18. 21 p. (Unpublished report held in NIWA library, Wellington).

Cummings, V.J.; Nicholls, P. & Thrush, S.F. (2003). *Mahurangi Estuary ecological monitoring programme - report on data collected from July 1994 to January 2003.* Prepared by NIWA for the Auckland Regional Council.

Cummings, V.J.; Halliday, N.J.; Thrush, S.F.; Hancock, N. & Funnell, G.A. (2005). *Mahurangi Estuary ecological monitoring programme- report on data collected from July 1994 to January 2005.* Prepared by NIWA for the Auckland Regional Council. NIWA Consultancy Report No. ARC05207,

Ellingsen K.E.; Hewitt, J.E. & Thrush, S.F. (In press). The contribution of rare species to biodiversity. *Journal of Sea Research*

Ellis, J.; Cummings, V.; Hewitt, J.; Thrush, S. & Norkko, A. (2002). Determining effects of suspended sediment on condition of a suspension-feeding bivalve (*Atrina zelandica*): results of a survey, a laboratory experiment and a field transplant experiment. *Journal of Experimental Marine Biology and Ecology 267*: 147-174.

Ellis, J.I.; Thrush, S.F.; Funnell, G.A.; Hewitt, J.E.; Norkko, A.M.; Schultz, D. & Norkko, J.T. (1999). *Developing techniques to link changes in the condition of horse mussels (Atrina zelandica) to sediment loading.* Prepared by NIWA for the Auckland Regional Council.

Ford, R.; Honeywell, C.; Brown, P. & Peacock, L. (2003). *The Long Bay monitoring program report 2002-2003.* Prepared for Auckland Regional Council by Auckland Uniservices Ltd.

Grace, R.V. (1983). Zonation of sublittoral rocky bottom marine life and its changes from the outer to the inner Hauraki Gulf, northeastern New Zealand. *Tane 29*: 97-108.

Hadfield, M.; Goring, D.; Gorman, R.; Wild, M.; Stephens, S.; Shankar, U.; Niven, K.; Snelder, T. (2002). *Physical Variables for the New Zealand Marine Environment Classification System: Development and Description of Data Layers* NIWA Client Report for MfE: CHC02, Christchurch.

Hawkins, A.J.S.; James, M.R.; Hickman, R.W.; Hatton, S. & Weatherhead, M. (1999). Modelling of suspension-feeding and growth in the green-lipped mussel Perna canaliculus exposed to natural and experimental variations in seston availability in the Marlborough Sounds, New Zealand. *Marine Ecology Progress Series 191*: 217-232.

Hewitt, J.E.; Snelder, T. (2003). *Validation of environmental variables used for New Zealand Marine Environment Classification (Regional scale – Hauraki Gulf).* NIWA Client Report HAM2003-020, Prepared for the MfE.

Hewitt, J.E. (2000). *Design of a State of the Environment monitoring programme for the Auckland Marine Region*. Prepared by NIWA for the Auckland Regional Council.

Hewitt, J.E.; Funnell, G.A. (2005). *Benthic marine habitats and communities of the southern Kaipara.* Prepared by NIWA for Auckland Regional Council. Auckland Regional Council Technical Publication Number 275.

Hewitt, J.E.; Lundquist, C.J.; Hancock, N. & Halliday, J. (2004b). *Waitemata Harbour Ecological Monitoring Programme - summary of data collected from October 2000 - February 2004*. Prepared by NIWA for Auckland Regional Council.

Hewitt, J.E.; Thrush, S.F.; Legendre, P.; Funnell, G.A.; Ellis, J. & Morrison, M. (2004c). Mapping of marine soft-sediment communities: integrating sampling technologies for ecological interpretation. *Ecological Applications 14*:1203-1216.

Hewitt, J.E.; Thrush, S.F.; Pridmore, R.D. & Cummings, V.J. (1994). *Ecological monitoring programme for Manukau Harbour: Analysis and interpretation of data collected October 1987 - February 1993.* Prepared by NIWA for Auckland Regional Council.

Hewitt, J.E.; Turner, S.J.; van Houte, K. & Pilditch, C. (2003). The influence of seagrass landscapes on benthic macrofauna in New Zealand estuaries. *In Estuaries on the edge,* 17th biennial conference, 14 - 18th September, 2003. Estuarine Research Federation, Seattle, Washington.

Kloser, R.J.; Bax, N.J.; Ryan, T.; Williams, A. & Barker, B.A. (2001). Remote sensing of seabed types in the Australian South East Fishery; development and application of normal incident acoustic techniques and associated 'ground truthing'. *Marine and Freshwater Research 52*:475-489.

Lilley, S.A. & Schiel, D.R. (2006). Community effects following the deletion of a habitat-forming intertidal alga from rocky marine shores. *Oecologia 148*: 672-681.

Lohrer, A.M.; Hewitt, J.E.; Thrush, S.F.; Lundquist, C.J.; Nicholls, P.E. & Liefting, R. (2003). *Impact of terrigenous material deposition on subtidal benthic communities.* Prepared by NIWA for Auckland Regional Council.

Lohrer, A.M.; Hewitt, J.E. & Thrush, S.F. (2006a). Assessing far-field effects of terrigenous sediment loading in the coastal marine environment. *Marine Ecology Progress Series 315*:13-18.

Lohrer, A.M.; Thrush, S.F.; Lundquist, C.J.; Vopel, K.; Hewitt, J.E. & P.E. Nicholls. (2006b). Deposition of terrigenous sediment on subtidal marine macrobenthos: response of two contrasting community types. *Marine Ecology Progress Series 307*: 115-125.

Lundquist, C.J.; Vopel, K.; Thrush, S.F. & Swales, A. (2003). *Evidence for the physical effects of catchment sediment runoff preserved in estuarine sediments: Phase III macrofaunal communities.* Prepared by NIWA for Auckland Regional Council.

McCullagh, P. & Nelder, J.A. (1989). *Generalised Linear Models,* 2nd Ed edition. Chapman and Hall, London.

Morrison, M.; Cryer, M. (2003). *Potential for artificial enhancement of scallops in Northland.* Report prepared for Aquaculture Development Group. NIWA client report AKL2003-038.

Morton, J. (2004). *Seashore ecology of New Zealand and the Pacific.* David Bateman Ltd, Auckland.

Norkko, A.; Hewitt, J.E.; Thrush, S.F. & Funnell, G.A. (2001a). Benthic- pelagic coupling and suspension feeding bivalves: linking site-specific sediment flux and biodeposition to benthic community structure. *Limnology & Oceanography 46*: 2067-2072.

Ross, P.M. (2007). *Habitat associations of juvenile snapper.* MSc Thesis, University of Auckland.

Shears, N.T.; Babcock, R.C.; Duffy, C.A.J.; Walker, J.W. (2004). Validation of Qualitative habitat descriptions commonly used to classify subtidal reef assemblages in northeastern New Zealand. *New Zealand Journal of Marine and Freshwater Research 38:* 743-752.

Shears, N.T. & Babcock, R.C. (2004). Community composition and structure of shallow subtidal reefs in northeastern New Zealand.

Schiel, D.R. & Taylor, D.I. (1999). Effects of trampling on a rocky intertidal algal assemblage in southern New Zealand. *Journal of Experimental Marine Biology and Ecology 235:* 213-235

Schiel, D.R. (2006). Rivets or bolts? When single species count in the function of temperate rocky reef communities. *Journal of Experimental Marine Biology and Ecology 338*: 233-252.

Schiel, D.R.; Wood, S.A.; Dunmore, R.A.; Taylor, D.I. (2006). Sediment on rocky intertidal reefs: effects on early post-settlement stages of habitat-forming seaweeds *Journal of Experimental Marine Biology and Ecology 331*:158-172.

Schwarz, A.; Taylor, R.; Hewitt, J.; Phillips, N.; Shima, J.; Cole, R. & Budd, R. (2005). *Impacts of terrestrial runoff on the biodiversity of rocky reefs.* New Zealand Aquatic Environment and Biodiversity Report No. 3. Ministry of Fisheries, Wellington

Thrush, S.F.; Cummings, V.J. & Cooper, A.B. (2004). *Response to Dr Skilleter's review of Mahurangi Estuary benthic marine ecology monitoring effects.* Prepared by NIWA for Auckland Regional Council.

Thrush, S.F.; Gray, J.S.; Hewitt, J.E.; Ugland, K.I. (2006). Predicting the effects of habitat homogenization on marine biodiversity. *Ecological Applications 16*. 1636-1642.

Thrush, S.F.; Hewitt, J.E.; Cummings, V.J.; Dayton, P.K.; Cryer, M.; Turner, S.J.; Funnell, G.; Budd, R.; Milburn, C.; Wilkinson, M.R. (1998). Disturbance of the marine benthic habitat by commercial fishing: impacts at the scale of the fishery. *Ecological Applications 8.* 866-879.

Thrush, S.F.; Hewitt, J.E.; Funnell, G.A.; Nicholls, P.; Budd, R. & Drury, J. (2003). *Development of mapping and monitoring strategies for soft-sediment habitats in marine reserves.* Unpublished report for Department of Conservation.

Thrush, S.F.; Hewitt, J.E.; Funnell, G.A.; Cummings, V.J.; Ellis, J.I.; Schultz, D.; Talley, D. & Norkko, A. (2001). Fishing disturbance and marine biodiversity: the role of habitat structure in simple soft-sediment systems. *Marine Ecology Progress Series 223*: 277-286.

Thrush, S.F.; Schultz, D.; Hewitt, J.E. & Talley, D. (2002). Habitat structure in soft-sediment environments and the abundance of juvenile snapper (*Pagrus auratus* Sparidae): Developing positive links between sustainable fisheries and seafloor habitats. *Marine Ecology Progress Series 245*: 273-280.

Turner, S.J.; Thrush, S.F.; Cummings, V.J.; Maskery, M.; Hewitt, J.E. & Hickey, B. (1994). *Assessing the ecological effects of marina operations.* Prepared by NIWA for Auckland Regional Council.

Turner, S.J.; Hewitt, J.E.; Wilkinson, M.R.; Morrisey, D.J.; Thrush, S.F.; Cummings, V.J. & Funnell, G. (1999). Seagrass patches and landscapes: the influence of wind-wave dynamics and hierarchical arrangements of spatial structure on macrofaunal seagrass communities. *Estuaries 22*: 1016-1032.

van Houte-Howes, K.S.; Turner, S.J. & Pilditch, C.A. (2004). Spatial differences in Macroinvertebrate communities in intertidal seagrass habitats and unvegetated sediment in three New Zealand estuaries. *Estuaries 27:* 945-957.

Walker, J.W. (2007). Effects of fine sediments on settlement and survival of the sea urchin *Evechinus chloroticus* in northeastern New Zealand. *Marine Ecology Progress Series 331*: 109-118

Walker, J.W. (1999). *Subtidal reefs of the Hauraki Gulf.* MSc thesis, University of Auckland, New Zealand

9 Acknowledgements

NIWA acknowledges the help of ARC staff (D. McCarthy and S. Kelly) in providing advice. Other NIWA staff involved in this project were N. Hancock, D. Lohrer, S. Edhouse, S. Hailes, J. Halliday, S. Wadhwa, R. Budd, P. Geering. We would also like to acknowledge Greig Funnels' role in developing the sampling design and running the project prior to his departure to DoC.

10 Appendix I: Ecologically-based Community Classification Rules

10.1 A: Intertidal Soft Sediment

Explanation of the rules and references are given in Hewitt and Funnell (2005).

1. Did the sites have densities of adult *Macomona, Austrovenus,* or *Paphies* (or some combination of these) greater than or equal to 226 individuals per m^2 (3 individuals per core)?
2. Did the sites have high diversity at a high taxonomic (order) level (e.g., amphipods, polychaetes, bivalves)? And if so, were there high numbers of large organisms, burrowing organisms, surface mobile bioturbators, tube builders or suspension feeders?
3. Were the sites dominated by polychaetes? And if so, were they tube-builders, deposit feeders or large predators/scavengers?
4. Were the sites dominated by bivalves? And if so, were they invasive, deposit feeders or suspension feeders?
5. If the sites were not dominated by either polychaetes or bivalves, were they dominated by large animals or surface bioturbators?

10.2 B: Subtidal Soft Sediment

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

1. Did the site have high densities of large sedentary surface dwelling organisms (e.g., *Atrina, Perna,* sponges, *Ecklonia, Carpophyllum* or tunicates)?
2. Did the site have high densities of scallops?
3. Did the site have high diversity at the order level? And if so, were there high numbers of large, burrowing or surface mobile organisms or echinoderms, tube builders or suspension feeders?
4. Was the site dominated by polychaetes? And if so, were they tube-builders, deposit feeders or large predators/scavengers?
5. Was the site dominated by bivalves? And if so, were they invasive, deposit feeders or suspension feeders?
6. Finally, was the site dominated by large animals, surface bioturbators or sedentary epibenthic animals?

10.3 C: Rocky subtidal

Explanation of the rules and references are given in Shears et al. (2004). The table includes notes as to the effectiveness of the habitat description in Kawau Bay.

Habitat	description	Depth (m)	Notes
Shallow *Carpophyllum*	High abundance of *Carpophyllum maschalocarpum, C. plumosum* and *C. angustifolium. Ecklonia radiata* and red algae also common. Urchins in crevices.	<3	No sites in Kawau Bay were exposed enough for these species (and thus this habitat) to occur. Instead, *C. flexuosum* and/or *Cystophora sp.* took up this niche.
Ecklonia forest	Monospecific *Ecklonia* (>4 plants/m^2), occasional *C. flexuosum* plants. Urchins.	>5	On the edge of the reef where sand and sponges begin to occur and *Ecklonia* numbers are lower, the distinction between *Ecklonia* forest and Sponge flats can become uncertain.
Carpophyllum flexuosum forest	*C. flexuosum* dominates; on sheltered reefs plants are large and associated with high levels of sediment. On exposed reefs plants are shorter and associated with urchins.	3-12	Predominantly found on hard rock. High sedimentation observed on algae occasionally.
Mixed algae	Mixture of large blown algal species. No clear dominance of species, usually partial canopy. Urchins may occur.	2-10	Some separation of this habitat may be possible
Red foliose algae	>40% cover of red foliose algae. Low number of large brown algae (<4/m^2)	2-9	Difficult to see using Drop Camera as they are small and best identified by their colour and small, pinnate blade shape.
Turfing algae	>30% cover by turfing algae (e.g., articulated corallines and other red turfing algae). Low numbers of large brown algae. Urchins	3-12	Substrate varies equally between coarse sand, pebbles and cobbles, soft rock and rock. Therefore a number of fauna can co-occur.
Caulerpa mats	Green algae, usually *Caulerpa flexsis*, form dense mats.	3-12	Not present in Kawau Bay.
Urchin barrens	Low numbers of large brown algae (<4/m^2), crustose coralline algae. Urchins.	3-9	Possible differentiation into two main types of habitats 1) Soft rock mostly bare with stunted *Carpophyllum*, low density turf and high numbers kina. 2) Rock with kina in crevices and high densities of coralline paint
Cobbles	Cobbles (c. <0.5 m diameter), unstable and subject to agitation. Crustose coralline algae dominant as well as high cover bare rock and sand.	~	
Encrusting invertebrates	Usually vertical walls, covered by community of encrusting ascidians,		Not present in Kawau Bay.

	sponges, hydroids and bryozoans.		
Sponge flats	Sponges visually dominant, high cover of sediment. Usually occurs on the reef-sand interface. Low number of *Ecklonia* may be present.	>10	
Cystophora		0-10	*Cystophora* is a large brown algae species and is common in places in Kawau Bay, in two cases the reef was dominated by *Cystophora* only.

10.4 D: Rocky intertidal

These rules are an amalgamation of the habitats determined as important for subtidal hard substrates (Shears et al. 2004), trophic categories important for ecosystem modelling in intertidal rocky communities (Lundquist et al. 2006) and community types with high vulnerability to anthropogenic impacts likely to be common in Kawau Bay. Thus, important factors are: the amount of flora and its capability to provide refuge; trophic groups and their relative size and mobility; the presence of taxa likely to be extracted; and the presence of taxa likely to be damaged by trampling.

1. Did the site have > 30 % cover of large Brown algae?
2. Did the site have > 50 % cover of any erect flora?
3. Did the site have > 50 % coralline paint?
4. Was the site dominated by suspension feeders, such as mussels, oysters or barnacles?
5. Was the site dominated by sessile predators (e.g., anemones)?
6. Was the site dominated by grazers (e.g., limpets, gastropods)
7. Did the site have large mobile predators (e.g., crabs)?
8. Did the site have large mobile deposit feeders?