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Broad Scale Subtidal Habitat Mapping of Bluff Harbour

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Broad Scale Subtidal Habitat Mapping of Bluff Harbour

Prepared for

environment SOUTHLAND
Te Taiao Tonga

by

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Cover photo: Morning light over Bluff Harbour

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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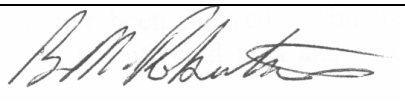


1. INTRODUCTION

Environment Southland (ES) recently contracted the Cawthron Institute (Cawthron) to map the subtidal substrate and habitat complexes present in Bluff Harbour. The purpose was to provide a broad overview of habitat features to assist in strategic planning, and in the management of specific issues associated with resource consents, pollution, and state of the environment monitoring.

The methodology used to collect data was based on the National Estuary Monitoring Protocol (Robertson *et al.* 2002) which uses field-verified broad scale mapping of habitat zones. The broad-scale habitat mapping approach provides a description of the subtidal environment according to dominant habitat types based on substrate characteristics (mud, sand, cobble, rock, *etc*) and plants and animals present (*e.g.* eelgrass, seaweed, shellfish, *etc*), in order to develop a baseline map.

While this is a relatively easy process in terrestrial and intertidal areas, the subtidal environment requires a slightly expanded approach. As for previous intertidal mapping, aerial photography has been combined with ground-truthing and digital mapping using GIS technology. In addition, side-scan sonar has been used to survey the seabed and identify boundaries between different seafloor features. Within each identified feature, SCUBA divers have ground-truthed the substrate, described the conspicuous epibiota (plants and animals living on the surface of the seabed) and collected samples of the infauna (animals living within the sediment). From this information broad habitat biotype and substrate maps have been developed. Sampling locations are shown in Figure 1.

Because the majority of the data were collected using remote sensing techniques, the final outputs have by necessity involved interpolation and expert judgement. While for clarity we have defined boundaries for each substrate at a fixed point in space, it is recognised that the situation is usually more complex. For example, the change in surface features from sand to gravel is generally a transition, rather than an abrupt change. Further, the visible surface layers may hide subsurface features *e.g.* a thin veneer of sand may lie over gravel, or contain subdominant features, *e.g.* broken shell, that are difficult to discriminate with the techniques used. Therefore we have attempted to provide a representative picture of the dominant surface features evident in the different parts of the harbour that are appropriate for broad scale mapping and planning purposes. In relation to vegetation, we have mapped the broad boundaries within which vegetation is present and, as not all of this area is actually vegetated, we have provided a subjective assessment of the percent cover within each zone.

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

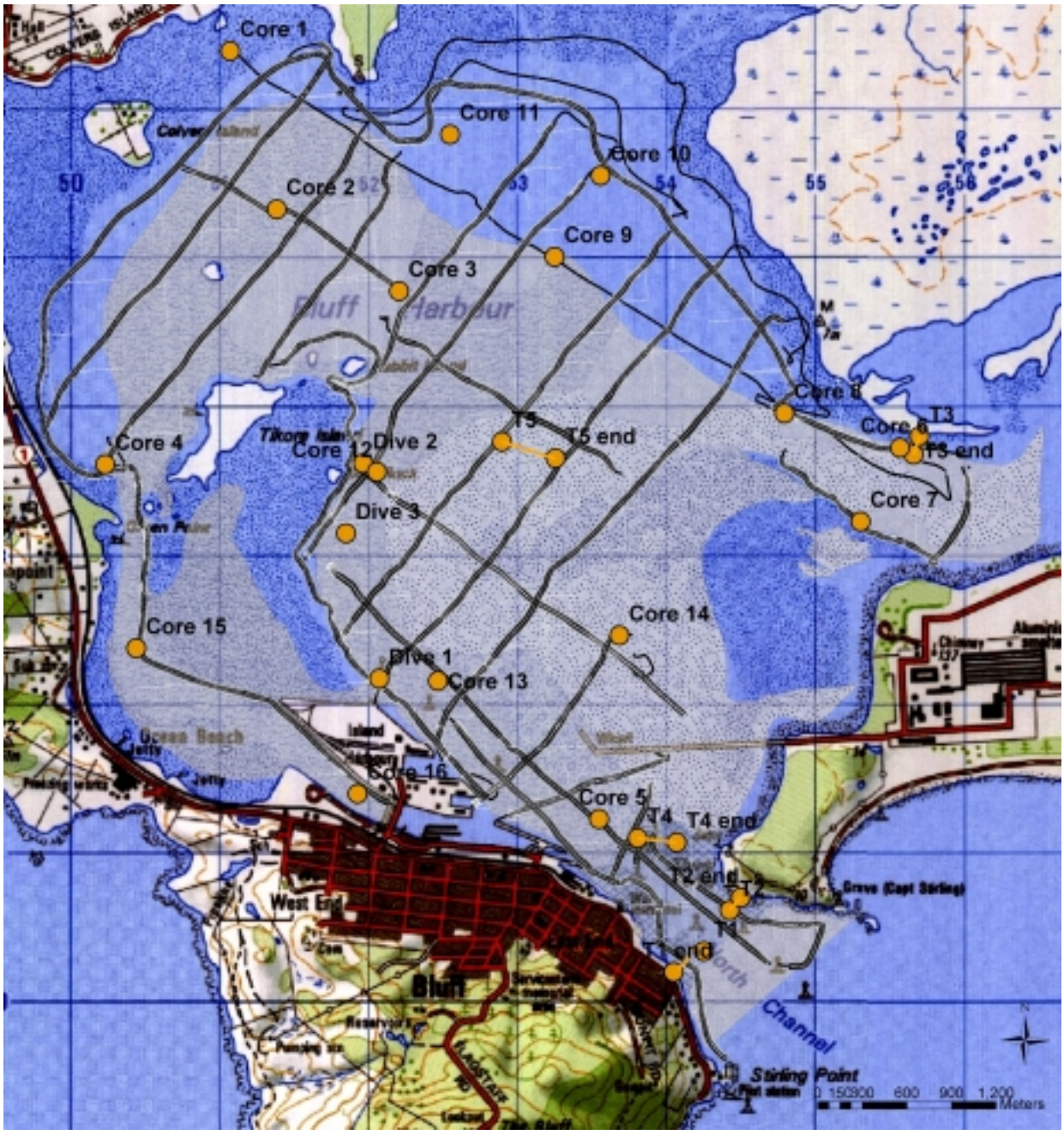


Figure 1 Bluff Harbour showing dive locations and side-scan sonar tracks, and the boundary of the subtidal area mapped (shaded area).

2. CLASSIFICATION AND DEFINITIONS OF HABITAT TYPES

The classification of substrate and habitat features has been based on the proposed estuarine national classification system (with adaptations), which was developed under a Ministry of the Environment SMF (Sustainable Management Fund) programme (Monitoring Changes in Wetland Extent: An Environmental Performance Indicator for Wetlands) by Lincoln Environmental, Lincoln. The classification system for wetland types is based on the Atkinson System (Atkinson 1985) and covers four levels, ranging from broad to fine-scale. The broad-scale mapping focuses on Levels III and IV (Table 1). Substrate classification is based on surface layers only and does not consider underlying substrate; *e.g.* gravel fields covered by sand would be classed as sand.

Table 1 Classification of estuarine habitat types.

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

The above classification has been developed primarily for wetland and estuarine areas. For subtidal habitat types we have set the upper boundary at MLWS (Mean Low Water Spring) and designed the current survey results to link seamlessly with the intertidal mapping currently being undertaken by Cawthron for ES. For habitat types not covered by the estuarine structural classes, for example high energy subtidal boulders, or creviced tide swept rock, we have utilised relevant aspects of the National Marine Habitat Classification for Britain and Ireland (Connor *et al.* 2003). The key difference in the estuarine and marine habitat classification systems is that the latter allows for any number of unique features to be categorised in a hierarchical format to describe the habitat present. This includes physical aspects such as the current regime, wave exposure, rock type, texture *etc*, and biological aspects such as the types of plants and animals present. To fully adapt the classification system of Connor *et al.* (2003) for NZ species is beyond the scope of the current project. However, for the purposes of broad scale mapping, it is possible to develop and use broad **biotype complexes** and **biotype** classifications relevant to NZ. A broad description of the system is provided in Table 2, with specific detail in Table 3. In essence, the categories in Table 3 are used to develop a unique classification string that describes the structural features present in each biotype.

Table 2 Classification of marine habitat types.

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

2.1.1 Habitat codes and terminology

As used in the EMP (Robertson *et al.* 2002), we have classified the biota present (Biotypes) using an interpretation of the Atkinson system, whereby dominant species are coded by using the two first letters of their Latin species and genus names *e.g.* bladder kelp *Macrocystis pyrifera*, is coded as Mapy. An indication of dominance is provided by the use of ( ) to distinguish subdominant species *e.g.* Masp(Mapy) indicates that the brown algae *Marginariella* sp. is dominant over bladder kelp *Macrocystis pryifera*. The use of ( ) is not based on percentage cover but the subjective observation of which vegetation is the dominant or subdominant species within the patch. The criteria for inclusion was algae that had a spatial coverage of >2m∅ and was visually obvious. Where relevant, the presence of conspicuous species within algal beds (*e.g.* fish, molluscs, gastropods) were also noted, although no attempt was made to provide a detailed description of all the species available.

Table 3 outlines the classification parameters developed for this subtidal survey. It is important to appreciate that the classification is being undertaken for a broad scale survey therefore it is limited to recording the dominant habitat features present. Table 4 provides written descriptions of the structural classes that form the basis of the broad scale substrate mapping.

Table 3 Classification structure and codes used for the subtidal assessment of Bluff Harbour.

Level I Hydro-system	Level IA Sub-System	Level II Habitat Class		Level III Physical Class		Level IV Dominant Biota		Level V Biotope	
	Infra-littoral	Water		Water	Water				
		Mud/sandflat		Firm shell/sand (<1cm)	FSS				
				Firm sand (<1cm)	FS				
				Soft sand	SS				
				Mobile sand (<1cm)	MS				
				Firm mud/sand (0-2cm)	FMS				
				Soft mud/sand (2-5cm)	SM				
				Very soft mud/sand (>5cm)	VSM				
		Stonefield		Gravel field	GF				
				Cobble field	CF				
		Boulderfield		Boulder field	BF				
		Shell bank		Shell bank	ShB			Shell	
		Shellfish field		Cocklebed	CkB			Cockle	
				Musselreef	MuR			Mussel	
				Oysterreef	OyR			Oyster	
		Worm field		Sabellid field	Sb			Sabellid	
		Rock	R	**Feature**					
		High energy rock	HIR	Smooth rock	Sm	Large brown algae	AlgBr	*Brongniartella australis*	Brau
		Mod. energy rock	MIR	Textured rock	Tx	Red/green algae	AlgR, AlgG, AlgRG	*Carpophyllum* spp	Casp
		Low energy rock	LIR	Crevices	Cr	Mussels	Mu	*Caulerpa brownii*	Cabr
				Caves/overhangs	Cv	Oysters	Oy	*Durvillaea* spp	Dusp
				Surge gullies	SG	Sponges	Spg	*Ecklonia* spp	Ecsp
				Faunal turfs	FauT	Echinoderms	Ech	*Macrocystis pyrifera*	Mapy
						Ascidians and brachipods	Asc, Brac, AscBrac.	*Maoriculpus roseus*	Maro
						Coralline algae	AlgCor	*Marginariella* spp	Masp
						Tubeworms	Tubw	*Polysiphonia* spp	Posp
						Hydroids	Hyd	*Pyura* sp.	Pysp
						Bryozoans	Bry	*Xiphophora gladiata*	XiGl
						Horse mussels	HorMu		

Table 4 Definitions of the Substrate Classes used for the subtidal assessment of Bluff Harbour.

Firm mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When pushing the flat palm of your hand into the seabed it penetrated 0-2 cm.

Soft mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When pushing the flat palm of your hand into the seabed it penetrated 2-5 cm.

Very soft mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When pushing the flat palm of your hand into the seabed it penetrated greater than 5 cm.

Mobile sand: The substrate is clearly recognised by the granular beach sand appearance and the often rippled surface layer. Mobile sand is continually being moved by strong tidal or wind-generated currents and often forms bars and beaches. When pushing the flat palm of your hand into the seabed it penetrated 0-1 cm.

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

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

Gravel field: Land in which the area of unconsolidated gravel (2-20 mm diameter) exceeds the area covered by any one class of plant growth-form.

Cobble field: Land in which the area of unconsolidated cobbles/stones (20-200 mm diam.) exceeds the area covered by any one class of plant growth-form.

Boulder field: Land in which the area of unconsolidated bare boulders (> 200mm diam.) exceeds the area covered by any one class of plant growth-form.

Rock/Rock field: Land in which the area of residual bare rock exceeds the area covered by any one class of plant growth-form.

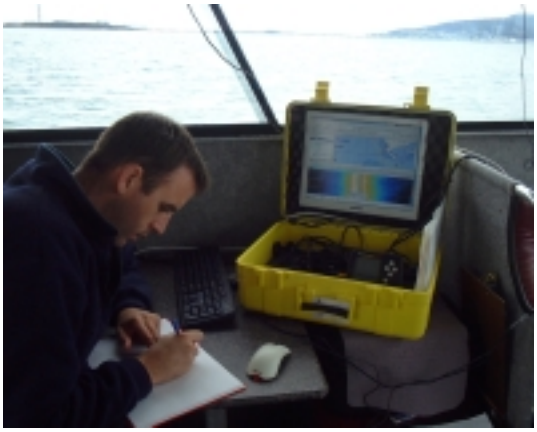
3. METHODS

Field sampling was undertaken over six days between 2 – 8 March 2004 during a period of calm and clear weather. Sampling was undertaken from the local charter vessel *Virago* skippered by Brent Christiansen who has extensive local knowledge of the harbour. Mid channel areas were sampled over low tides and intertidal margins at high tide when there was sufficient water depth for the *Virago* to tow the side-scan sonar. In order to facilitate the ground-truthing of side scan data, and to ensure consistency with the intertidal mapping being undertaken as part of a separate project, some intertidal areas in the northeast of the harbour were included in the areas surveyed.

3.1 Side–scan Sonar

Side-scan sonar data were collected by lowering a Tritech™ sonar 'fish' behind the work boat and towing it above the seabed at approximately 2 knots (Figures 2 and 3). The sonar 'fish' sends out and receives an acoustic signal that records the different sound-absorbing and reflecting characteristics of the seabed. Strong signals are returned from solid features like rock, while weaker signals are returned from substrate like sand. The side-scan swathe width was set to 60 m (30 m either side of the fish) and GPS positions were simultaneously logged with the side-scan sonar output to on onboard computer using Tritech™ software, allowing the relocation of any areas of interest for verification.

Figure 2 Deploying the sonar fish.



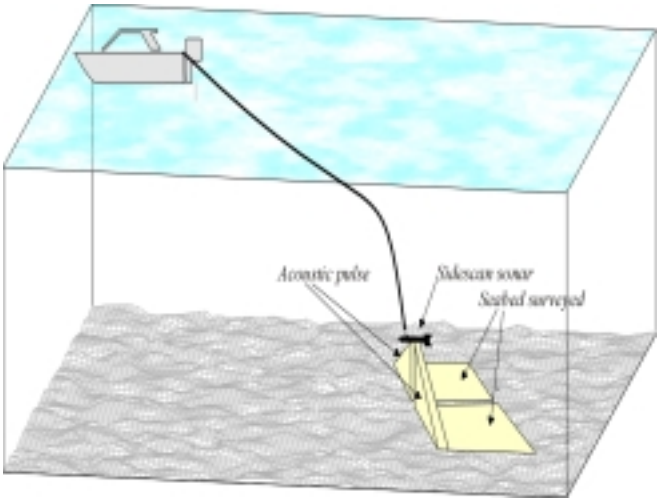


Figure 3 Diagram of side-scan deployment (right) and data capture (above).

Examples of side-scan sonar signals are shown in Figure 4. There is a blank area directly below the side-scan where no signal is reflected back to the hydrophone. The side-scan data collected in the field were used to define and locate changes in habitat features which were noted on field maps of the harbour.

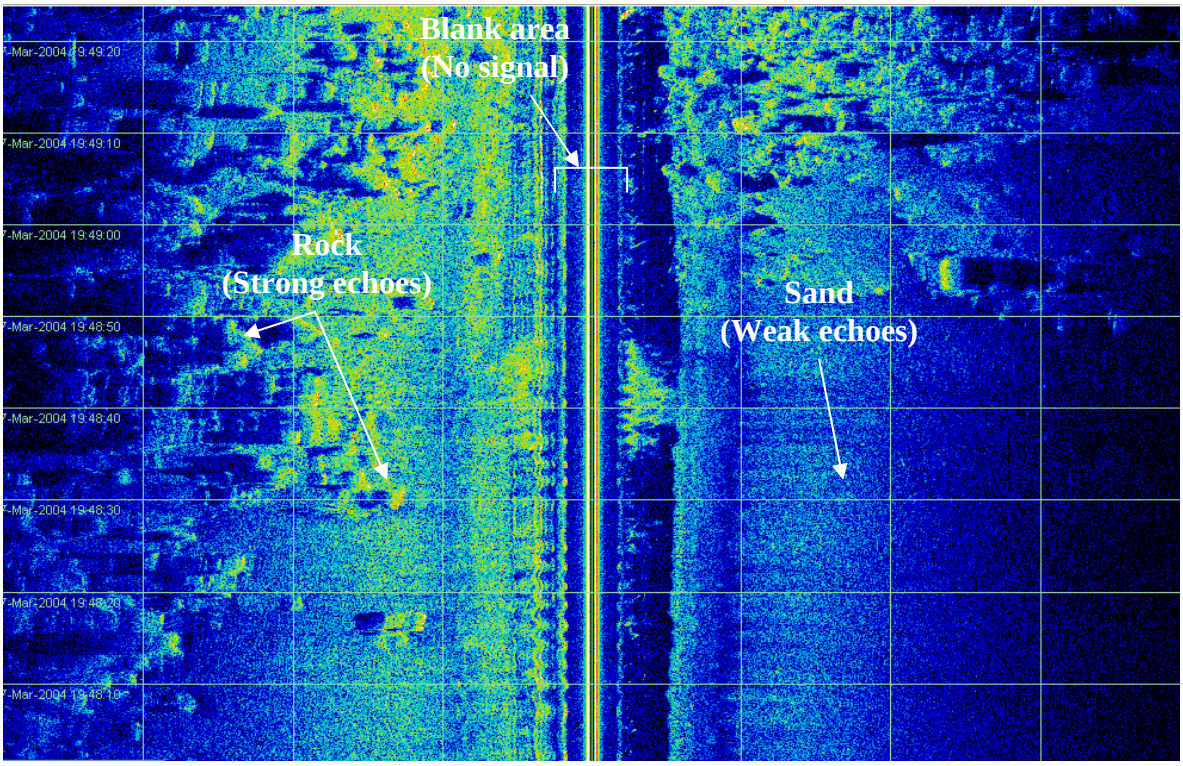


Figure 4 Side-scan sonar image showing different signal responses.

Examples of the digital images of the side-scan sonar output from Bluff Harbour are presented in Figure 5. Where distinctive signals were returned from the side-scan, representative examples were dived to ground-truth the signal and verify the type of habitat present. Following the ground-truthing, sediment samples and biota sites were selected approximately in proportion to the amount of each substrate present within the harbour. That is, most samples were collected from muddy sand areas, the most common substrate in the harbour.

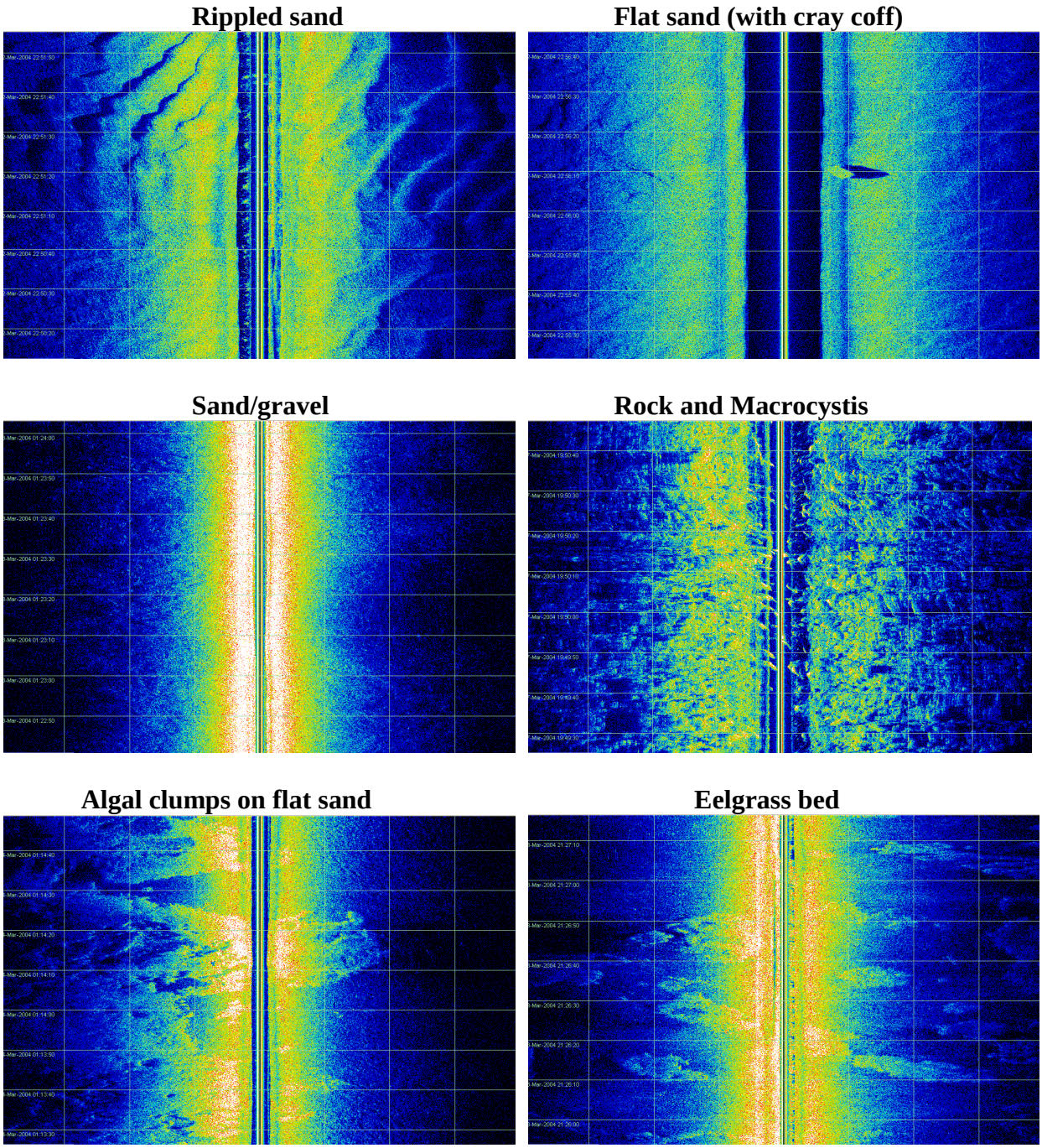


Figure 5 Side-scan sonar images from within Bluff Harbour.

3.2 Seabed sampling methods

Seabed sampling consisted of 24 sites dived using SCUBA for the collection of sediment samples and to describe the plants and animals present (see Figure 1 for locations). Five dive transects (T1-T5) were used to provide a perspective on the extent and complexity of the biotypes present, particularly in rock and boulder habitat where infauna sampling was not possible. At 16 sites sediment cores were collected from sand and gravel substrates to assess sediment enrichment and infauna. Three additional sites were dived to verify biotype boundaries. Specific methods are described below.

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

2. **Epifauna** (surface-dwelling animals):
   - Epifauna was assessed during SCUBA dives to provide an indication of the type of assemblage present. The presence of conspicuous species and related descriptive information were recorded on specifically designed, waterproof field data sheets containing a checklist of expected species and through the collection of video footage.

3. **Vegetation** (seaweeds and plants) % cover:
   - Where vegetation was detected from the side-scan data, SCUBA divers visually estimated percent cover at representative locations and extrapolated the findings across the whole extent of the vegetation.

4. **Infauna** (animals living buried in the sediments):
   - Three replicate sediment cores were collected from within representative substrate types at random positions using a 130 mm diameter (area = 0.0133 m^2) PVC tube.
   - The core tube was manually driven 150 mm into the sediments, removed with core intact and inverted and washed through an attached 0.5 mm nylon mesh bag using local seawater. The remaining contents were carefully emptied into a plastic container with a waterproof label and preservative (95% ethanol - enough to roughly double the volume of the sample).
   - Sample processing was done in a laboratory where samples were washed through a series of sieves (from 4.0 mm to 0.5 mm) within a fume cabinet to roughly sort invertebrates into size classes.
   - The contents of each sieve were systematically scanned, by eye or by microscope, and the invertebrate species identified (to at least the family level), counted and recorded.
   - The data were then transferred to a spreadsheet or database (Figure 6). Cawthron's database uses a standardised format for all benthic monitoring data which allows for direct and easy comparisons with other regional data. It also utilises a master species list which ensures data accuracy and reporting.

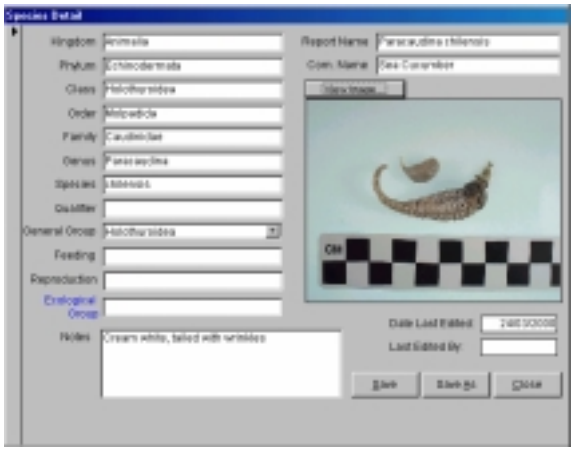


Figure 6 Example of Cawthron's marine database.

4. RESULTS AND DISCUSSION

4.1 Overview

In total, 1679 Hectares of Bluff Harbour's subtidal features were mapped. Table 5 summarises the key substrate features showing that the harbour is dominated by sand and gravel, well ahead of cobbles, boulders and rock (Figure 7). The biotype features identified in the harbour are summarised in Table 6 and Figure 8. Detail on each biotype is provided in Section 4.3 and in the Appendices.

4.2 Substrate features

Overall the harbour tended to have firm muddy sand in the north and west, changing to gravels in the east. The mud content of sandy sediments was generally low and the harbour appeared well flushed. Visual assessment of sediments showed the highest enrichment near Site 1 in the north of the harbour compared to other areas. This was predominantly in the intertidal and shallow subtidal and is attributed to the accumulation of seaweed blown into this area by prevailing winds. Neither this site, nor any of the other 15 dive sites were considered enriched. Sediments showed no common indicators of enrichment such as anoxic sediments or the presence of algal growths at nuisance levels.

Subtidal rock was limited to the mouth of the harbour and in close proximity to the islands within the harbour. The harbour entrance channel contained relatively flat bedrock across the bottom of the main channel, often overlaid with gravel and cobble, while boulders overlay bedrock heading up to the shorelines of both Bluff and Tiwai Point. This area of the harbour had strong currents and there was little deposition of finer material evident among boulders. Beyond the entrance substrate was sand dominated. Around islands, rock seldom extended into the subtidal area and were not included in mapping.

Table 5 Summary of the area (Ha) of subtidal substrate mapped in Bluff Harbour.

Substrate	Ha	% of total
Firm muddy sand	747.4	44.5
Firm sand/gravel	567.7	33.8
Firm sand	235.4	14.0
Firm sand/gravel/cobble	61.0	3.6
Gravel/rock/boulders	27.7	1.6
High energy textured rock/sand	23.3	1.4
High energy textured rock/boulders	16.9	1.0
Total	**1679**	**100**

Figure 7 Substrate types present within Bluff Harbour.

4.3 Biotype features

Table 6 shows the overall area that biotypes were present within. However, it is important to keep in mind that biotype features generally covered much less than the total area they were present within. For example the foliose red biotype (*Brongniartella australis* dominant over *Polysiphonia* spp.) was present across a relatively large area, yet the total percent cover on the seabed for these species was on average only 1-10%. We have provided an indication of the percent cover of each biotype to indicate their distribution (Table 6).

Figure 8 Biotype features present within Bluff Harbour.

Table 6 Summary of the area (Ha) of biotype features mapped in Bluff Harbour.

Biotype Name	Biotype Code	Ha	% of total	% cover
Foliose Red Algae	Brau(Pospp)	430.0	46.7	1-10
Zostera	Zosp	253.3	27.5	30-50
Gracilaria/Zostera	Crch(Zosp)	91.5	9.9	30-50
Maoricolpus	Maro(Brau)	78.7	8.5	20-30
Green & Red Algae	AlgRG Cabr(Pysp)AlBrR	23.3	2.5	30-50
Brown Algae	AlgBr (Mapy)Masp(Casp-Ecsp-Dusp)	21.0	2.3	10-20
Brown & Red Algae	AlgBr (Mapy)Masp(Casp-Ecsp)/AlR	16.0	1.7	10-20
Durvillaea	AlgBr Dusp(Mapy)Masp(Casp-Ecsp)AlRG	7.6	0.8	10-20
	Total	**922**	**100**	

In the following sections we present a brief overview of each biotype and characterise the main features of each. Detailed results of sediment sampling for infauna are described in Appendix 1 along with a full species list.

4.3.1 Foliose Red Algae

This biotype had the largest coverage within the harbour and was found in almost all areas, but had a low percent cover (1-10%). Areas where the cover was less than 1% were not mapped. The biotype was dominated by the foliose red algae *Brongniartella australis* and several *Polysiphonia* spp. The algae are relatively small (~20 cm high) and flaccid (soft to the touch) and are attached to stones and cobbles on the seabed (Figures 9 and 10). Because these algae are found attached to small stones, shell and cobbles, it was often difficult to distinguish using side-scan output the presence of just these substrate features, and their presence with algae attached - particularly in channel areas where drifting algae was also present. It is therefore likely that this biotype is also present in the channel heading up to Awarua Bay, between sites 6, 7, and 8 although this area was not ground-truthed by SCUBA to confirm this.

Figure 9 Foliose red algae

Figure 10 Foliose red algae on sand.

4.3.2 Zostera (eelgrass)

Zostera (eelgrass) beds tended to occur predominantly around channel margins (Figure 11) and were generally contiguous with intertidal beds. They were generally limited by depth, seldom extending beyond 1-2 metres below MLWS. Within the beds, sediments were predominantly clean sands (Figure 12). Beds were characterised by numerous juvenile fish and attached epibiota including crabs, limpets, and topshells (refer Appendix 1 and 2 for details). The overall surface cover of *Zostera* was generally high, but beds tended to have a patchy rather than continuous cover, particularly when near to the intertidal margins. Although *Zostera* was the dominant species, other

algae (*e.g. Brongniartella australis, Polysiphonia* spp. and *Gracilaria chiliensis*) were also present around the margins and in areas between beds. The *Zostera* beds appeared stable and are likely to provide a good indicator of wider changes in Harbour conditions.

Figure 11 *Zostera* at channel edge (Site 6).

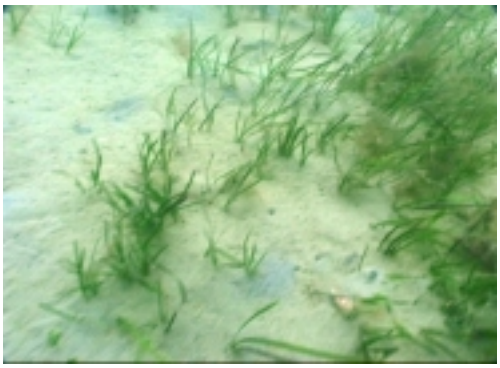


Figure 12 Clean sand within *Zostera* (Site 10).

4.3.3 Gracilaria (a red algae) / *Zostera* (eelgrass)

The *Gracilaria/Zostera* biotype was very similar to that described for *Zostera*, with *Gracilaria* the dominant species. The density of the plants present tended to be lower than for the *Zostera* biotype, and coverage was generally patchier. Foliose red algae (*e.g. Brongniartella australis, Polysiphonia* spp) were common in patches between beds. The beds extended along the lower margin of the large gravel dominated intertidal area in the centre of the harbour west of the smelter. This area was relatively difficult to assess visually, and water depth limited the side-scan data that could be collected, therefore the characterization is drawn partly from the intertidal survey. It is therefore possible that this biotype could be merged into a *Zostera* biotype in subtidal areas.

4.3.4 Maoricolpus (turret shell)

The *Maoricolpus* biotype is an area in the main channel up-harbour of the wharf and port which has a high density of the turret shell *Maoricolpus roseus roseus* (Figures 13 and 14). The *Maoricolpus* beds extended from the bottom of the channel (depth 5-7 metres at MLWS) and up the channel sides into relatively shallow water (~2 metres deep). Sediments tended to be flat and featureless with a low cover of foliose red algae attached to sparsely distributed stones and cobbles. The substrate was generally muddy sand and was dominated by deposit feeders and scavengers. The area had a moderate to high current flow and there was a constant flow of drifting algae passing through the site while it was surveyed. Fish were common in this area, including blue cod up to 25cm long.

Figure 13 *Maoricolpus* bed (Site 12).

Figure 14 *Maoricolpus* bed (Site 13).

4.3.5 Green and Red Algae

This biotype was present in the middle of the main entrance to Bluff Harbour at a depth of 6-8m at MLWS. This habitat is characterised by areas of clean gravel/cobble intermittently dispersed between areas of bedrock. Algal coverage across the area was around 30-50 percent, with high densities where bedrock was present, but large patches where mobile sand and gravel had no algal cover. Dense algae beds on the relatively flat bedrock present in the channel were a mixed assemblage of predominantly soft algae dominated by *Caulerpa brownii* (Figure 15), but also containing several smaller foliose brown and red algae and the sea tulip *Pyura* sp. (*e.g.* Figure 16). The bedrock itself supported a variety of common rocky habitat species including cushion stars, sea tulips, sponges, topshells, brittle stars, wandering anemones, kina, and coralline algae (*e.g.* Figure 17). Several species of fish were present including greenbone, blue cod, wrasse, and red moki. The area was exposed to high currents (1-2 knots), evident in Figure 15 where particulate matter can be seen streaming through the water column.

Figure 15 *Caulerpa brownii*

Figure 16 Sea tulip in mixed algae.

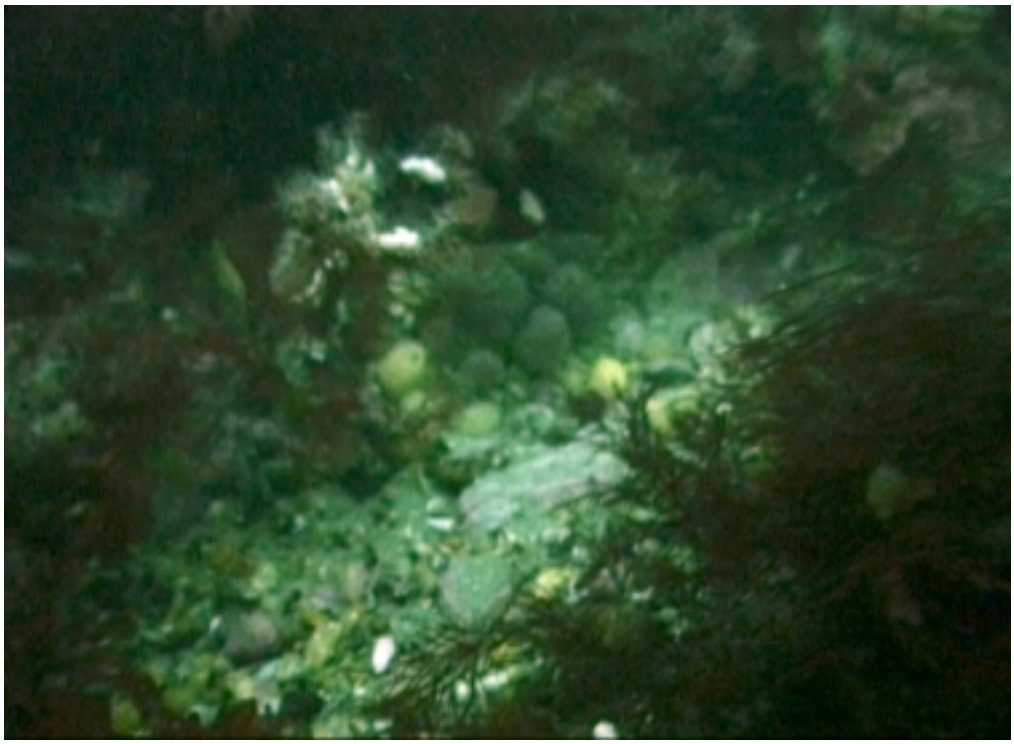


Figure 17 Example of encrusted bedrock in the channel entrance.

4.3.6 Brown Algae

The Brown algae biotype was present on both sides of the harbour entrance at a depth of 3-6 metres, predominantly on boulder habitat. The algal assemblage was dominated through the water column and at the sea surface by the bladder kelp *Macrocystis pyrifera* (Figure 18), while at the seabed a mixture of *Marginariella*, *Carpophyllum*, *Ecklonia* (*e.g.* Figure 19) and small quantities of *Durvillaea* were present. No green algae were obvious in this biotype. There was a strong tidal surge in these areas. The algal coverage was generally thick, while the seabed beneath the algae supported common rocky habitat species including cushion stars, sponges, topshells, paua, anemones, kina and coralline algae. Greenbone, blue cod, red moki, wrasse, and spotties were common.

Figure 18 *Macrocystis pyrifera*

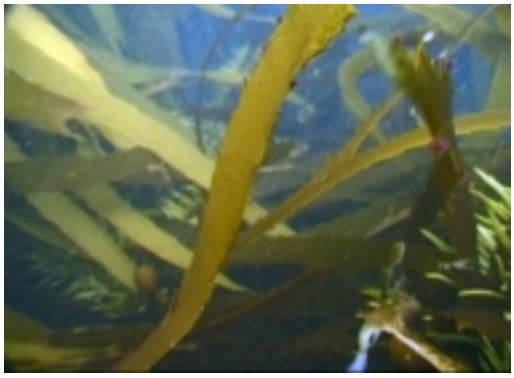


Figure 19 Mixed brown algae.

4.3.7 Brown and Red Algae

The Brown and Red algae biotype was present on the Tiwai Point side of the harbour entrance at a depth of 3-6 metres. There was a mix of species present, foliose brown and red algae and sea tulips in current swept areas on bedrock around 5-6 metres (Figure 20), and on boulders and rocks a mixture of the brown algae *Marginariella, Carpophyllum*, *Ecklonia* (*e.g.* Figure 21) were present above foliose reds and browns. The algal coverage was generally thick, although there were extensive patches of sand and gravel that were unvegetated. Beneath the algae common rocky habitat species including cushion stars, sponges, topshells, paua, anemones, kina and coralline algae were all present. Greenbone, blue cod, red moki, and spotties were common.

Figure 20 Sea tulips in mixed algae

Figure 21 Mixed brown algae on boulder

4.3.8 Durvillaea

The *Durvillaea* biotype was present on the Bluff side of the harbour entrance at a depth of 1-3 metres. There was a mix of brown algae present including *Marginariella*, *Carpophyllum*, *Ecklonia* but the area was dominated by the bull kelp *Durvillaea.* The algae formed a thick surface cover in at the water surface and was difficult to physically part to easily determine what was present on underlying rocks, although the assemblage contained many the common intertidal/shallow subtidal encrusting and motile species. The area was subjected to strong wave surge and was dominated by boulders.

4.4 Sediment Infauna

Sediment infauna were sampled from 16 sites within the harbour with results summarized in Table 7 and fully detailed in the following section and in Appendix 1. Overall the infauna present in Bluff Harbour included a wide range of different groups and species. Based on past experience at other locations, the total diversity in the harbour was considered high, as was the diversity within different substrate groups. The types of animals present reflected a diverse and varied community

associated with the range of different substrates present. Infauna included mainly deposit feeders and scavengers and a wide range of epifaunal species, the composition reflecting the clean, well flushed, and unenriched nature of the harbour.

Table 7 Summary of the infaua sampled from different substrates within Bluff Harbour.

Substrate	Site No's	No. of Taxa	Dominated by:
Firm muddy sand	1,2,4,9,11	63	Polychaetes and roundworms
Firm muddy sand	15,16	40	Polychaetes and amphipods
Firm sand/gravel	7,8,14	60	Oligochaetes, amphipods, and polychaetes
Firm sand	3,6,10	30	Amphipods, gastropods and crustaceans
Firm sand/gravel/cobble	5,12,13	86	Polychaetes and amphipods

4.4.1 Sediment infauna results

Infaunal samples were collected approximately in proportion to the area of each substrate present, and results are grouped by the dominant substrate they were sampled from (Table 8). Representative photographs are included to provide examples of each substrate or biotype.

Table 8 Number of samples collected from substrate types in Bluff Harbour.

Substrate	Ha	No of infauna sites	Site & Transect No's
Firm muddy sand	747.4	7	1,2,4,9,11,15,16
Firm sand/gravel	567.7	3	7,8,14, T3
Firm sand	235.4	3	3,6,10, T3
Firm sand/gravel/cobble	61.0	3	5,12,13, T4
Gravel/rock/boulders	27.7	0	T1, T2, T4
High energy textured rock/sand	23.3	0	T1, T2,
High energy textured rock/boulders	16.9	0	T1, T2,
Total	**1679**	**16**	

To assist with the interpretation of the biotic information collected we have undertaken a statistical grouping of the infauna data collected from sediment samples using a multi-dimensional scaling (MDS) technique. This essentially separates out similar and dissimilar sites and defines the species that contribute most to the differences evident. The approach provides an indication of the relative similarity between habitat types in terms of the type of species present and their relative density.

The four groupings are shown in Figure 22 (indicated by the dotted lines)[1]. The close grouping of the three replicates samples (A, B, C) for each site indicates that sampling provides a representative picture of each area sampled. As infaunal assemblages are likely to be similar within the same types of substrate, it is no surprise that the MDS groupings largely reflect the different sediment types sampled.

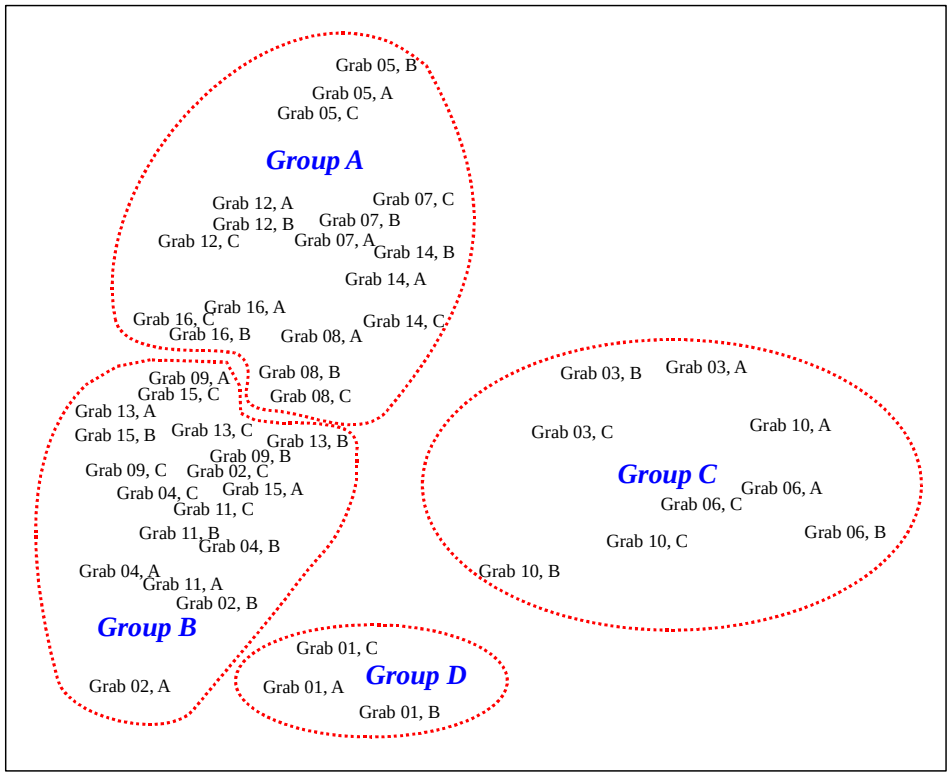


Figure 22 MDS plot showing groupings of infaunal assemblages sampled from Bluff Harbour.

Group A (Sites 5, 7, 8, 12, 14, 16) consists of samples collected predominantly from the firm sand/gravel and firm sand/gravel/cobble habitats. The fact that these samples are grouped indicates that the difference in habitat types is minor, differences largely reflected by the presence of sparse cobbles on the surface of the sediment at sites 5, 12, and 14. Site 16 was taken from firm muddy sand, which again was not too dissimilar from the other sites. Group A was distinct from other groups based on the high abundance of oligochaetes.

[1] Samples within each group had a Bray-Curtis similarity measure of at least 52%, with a 2-D ordination stress value of 0.08 indicating that the patterns in Figure 22 are a good representation of the data, and provide little prospect of a misleading interpretation.

Group B (Sites 2, 4, 9, 11, 13, 15) consists of samples collected predominantly from within the firm muddy sand habitat, the exception being Site 13 from the firm sand/gravel/cobble habitat. This group was dominated by the polychaetes *Aricidea* sp. and *Heteromastus filiformis*.

Group C (Sites 3, 6, and 10) are all samples collected from firm sand within eelgrass (*Zostera* sp.) beds. These samples contained a relatively high abundance of amphipods and a low abundance of polychaetes (Paraonidae, *Polydora* sp. and *Scolecolepides* sp.).

Group D (Site 1) contained a single sample from the muddy sand habitat. The presence of anemones (*Anthopleura aureoradiata*), limpets, (*Notoacmea helmsi*) and the spire shell (*Zeacumantus subcarinatus*) indicate Site 1 was within the intertidal area.

In the following sections, details are provided for each of the habitat groupings on the number of species and individuals present, along with photographs representative of the different habitat types. Full species listings are provided in Appendix 1.

4.4.2 Firm muddy sand (Sites 1, 2, 4, 9, 11, 15, 16)

This habitat is predominantly characterised by a relatively flat and featureless seabed in the north and west of the harbour. Sites 1, 2, 4, 9, 11 were in relatively shallow water (<5m), while sites 15 and 16 were slightly deeper (5-7m) (see Figures 23 and 24).

Figure 23 Firm muddy sand habitat (Site 11).

Figure 24 Firm muddy sand habitat (Site 15).

A total of 63 infaunal taxa were identified from the 5 shallower sites. Animal abundance and species richness (number of taxa per sample) were variable between sites (Figure 25), but overall indicated a balanced, healthy infaunal community. Samples collected were dominated, in terms of abundance and number of taxa, by polychaetes (Paraonidae, *Polydora* sp. and *Aricidea* sp.) and roundworms (Table 9).

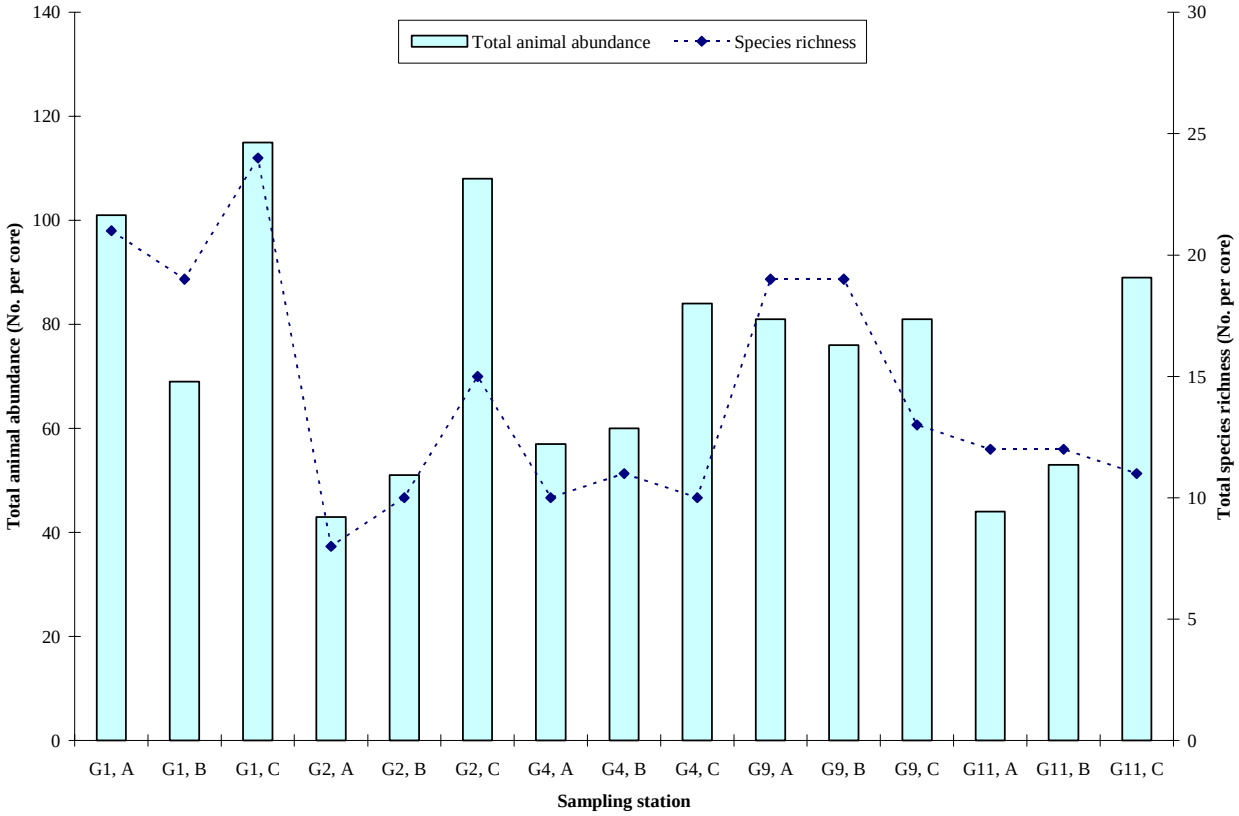


Figure 25 Animal abundance and species richness of sediments sampled from Sites 1, 2, 4, 9, 11.

Table 9 Average and relative abundance (%) of the top 10 infaunal species at Sites 1, 2, 4, 9, 11.

Taxa	Common name	Feeding type	Ave abundance	Rel abundance
Paraonidae	Polychaete	Infaunal deposit feeder	16.4	22.1
Aricidea sp.	Polychaete		14.2	19.2
Polydora sp.	Polychaete	Surface deposit & filter feeder	12.1	16.3
Heteromastus filiformis	Polychaete	Infaunal deposit feeder	5.5	7.5
Nematoda	Roundworm		3.3	4.4
Sphaerosyllis hirsula	Polychaete	Omnivorous	2.6	3.5
Oligochaeta	Oligochaete worms	Infaunal deposit feeder	2.0	2.7
Caprellidae	Polychaete		1.7	2.3
Amphipoda	Amphipods	Epifaunal scavenger	1.6	2.2
Anthopleura aureoradiata	Cnidaria	Filter feeder	1.4	1.9

Within the firm muddy sand habitat there is a secondary habitat feature at Sites 15 and 16 which is possibly due to slightly softer sediments being present, and increased depth. These sites have on average a higher total animal abundance (mean=146) and species richness (mean=20) than those communities sampled from within shallower firm muddy sand (total animal abundance=74, species

richness=14). From Sites 15 and 16 a total of 40 infaunal taxa were identified. Animal abundance and species richness (number of taxa per sample) were variable between sites (Figure 26), but overall indicated a balanced, healthy infaunal community. Samples collected were dominated, in terms of abundance and number of taxa, by polychaetes (*Polydora* sp. and *Heteromastus filiformis*) and amphipods (Table 10).

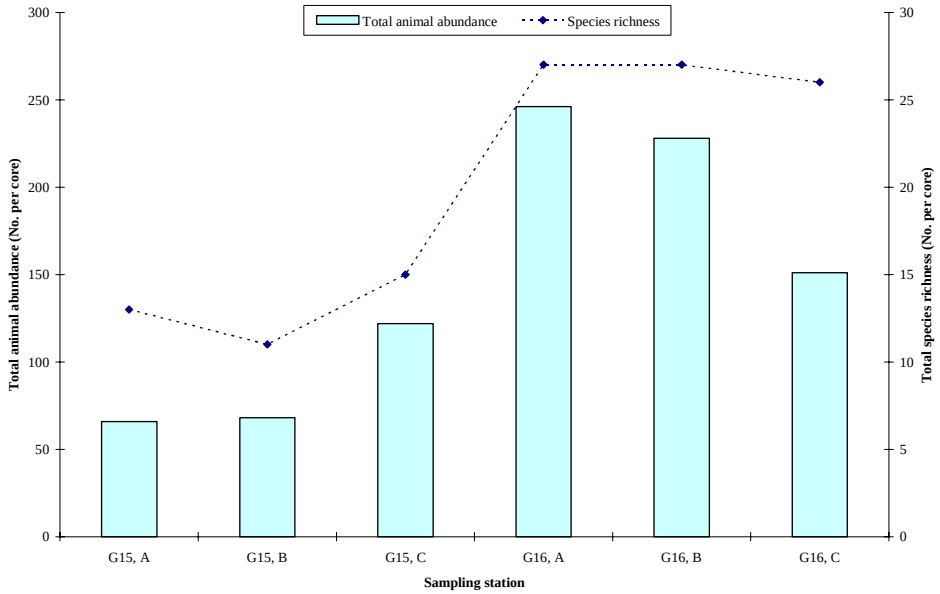


Figure 26 Animal abundance and species richness of sediments at Sites 15 and 16.

Table 10 Average and relative abundance (%) of the top 10 infaunal species at Sites 15 and 16.

Taxa	Common name	Feeding type	Ave abundance	Rel abundance
Polydora sp.		Surface deposit & filter feeder	26.8	18.3
Heteromastus filiformis		Infaunal deposit feeder	18.5	12.6
Amphipoda	Amphipods	Epifaunal scavenger	16.5	11.2
Aricidea sp.			15.0	10.2
Sphaerosyllis hirsula		Omnivorous	13.3	9.1
Paraonidae		Infaunal deposit feeder	10.3	7.0
Oligochaeta	Oligochaete worms	Infaunal deposit feeder	7.3	5.0
Cirratulidae		Deposit feeder	6.8	4.7
Spionidae		Surface deposit feeder	4.7	3.2
Tanaid sp.	Tanaid Shrimp	Epifaunal scavenger	3.7	2.5

4.4.3 Firm sand/gravel (Sites 7, 8, 14, T5)

This habitat is characterised by sand/gravel with a relatively sparse cover of small foliose red algae (*e.g. Brongniartella australis*, *Polysiphonia* spp) (Figures 27 and 28). This type of substrate was

mostly located in the south and east of the harbour in areas with strong current flows. The seabed was often rippled by the current with alternating gravel troughs and sand ridges. Sediments contained very little mud.

Figure 27 Firm sand and Gravel (Site 7).

Figure 28 Firm sand and Gravel (Site 14).

A total of 60 infaunal taxa were identified from samples collected. There was some variability between stations (Figure 29), but overall a balanced, healthy infaunal community was present. Samples collected were dominated, in terms of abundance and number of taxa, by oligochaete worms, amphipods and polychaetes (Spionidae) (Table 11).

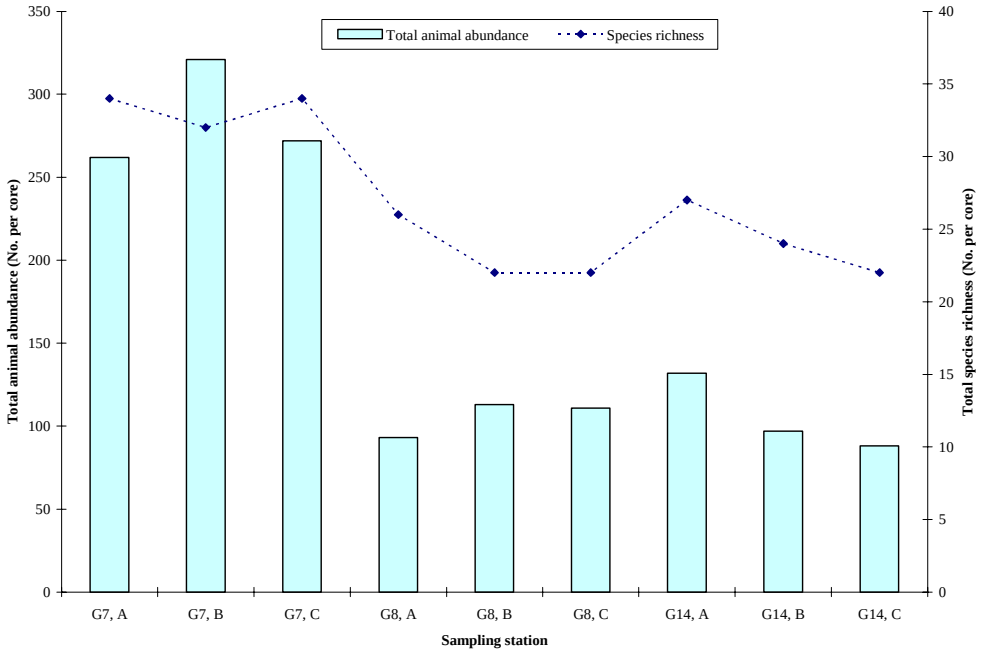


Figure 29 Animal abundance and species richness of sediments sampled from Sites 7, 8, and 14.

Table 11 Average and relative abundance (%) of the top 10 infaunal species at Sites 7, 8, and 14.

Taxa	Common Name	Feeding	Ave abundance	Rel abundance
Oligochaeta	Oligochaete worms	Infaunal deposit feeder	25.6	15.4
Amphipoda	Amphipods	Infaunal deposit feeder	18.6	11.2
Spionidae	Polychaete	Surface deposit feeder	17.0	10.3
Ralfsia sp.	Phaeophyta (plant)		11.7	7.1
Tanaid sp.	Tanaid Shrimp	Epifaunal scavenger	7.7	4.6
Heteromastus filiformis	Polychaete	Infaunal deposit feeder	7.1	4.3
Sphaerosyllis hirsula	Polychaete	Omnivorous	5.9	3.6
Nematoda	Roundworm		5.8	3.5
Paraonidae	Polychaete	Infaunal deposit feeder	5.4	3.3
Ostracoda	Ostracods	Omnivorous scavenger	5.4	3.3

4.4.4 Firm sand (Sites 3, 6, 10, T3)

All of the firm sand sites sampled were from within eelgrass (*Zostera*) beds located in the shallow subtidal zone (1-2m below MLWS). A total of 30 infaunal taxa were identified from the three sites. Animal abundance and species richness (number of taxa per sample) were variable between stations (Figure 30), but overall indicated a balanced, healthy infaunal community.

Sites 6 and 10 have a lower overall animal abundance and species richness when compared to Site 3. This may reflect that Sites 6 and 10 were more closely located to the intertidal area than Site 3. Samples were dominated, in terms of abundance and number of taxa, by amphipods, gastropods (*Eatoniella sp.*) and crustaceans (*Halicarcinus cookii*). The *Zostera* beds increase habitat complexity, which result in an increase in community diversity, shown by the presence of higher order taxa in the species list (Table 12).

Table 12 Average and relative abundance (%) of the top 10 infaunal species at Sites 3, 6, and 10.

Taxa	Common name	Feeding type	Ave abundance	Rel abundance
Amphipoda	Amphipods	Epifaunal scavenger	48.2	42.8
Zostera sp.	Algae		20.0	17.8
Eatoniella sp.	Gastropod		15.7	13.9
Polysiphonia decipiens	Rhodophyta (plant)		9.0	8.0
Halicarcinus cookii	Pill-box Crab	Eats small organisms & some weed	3.7	3.3
Micrelenchus tenebrosus	Grazing snail	Microalgal grazer	3.0	2.7
Paraonidae	Polychaete	Infaunal deposit feeder	1.7	1.5
Notoacmea helmsi	Limpet	Microalgal & detrital grazer	1.6	1.4
Heteromastus filiformis	Polychaete	Infaunal deposit feeder	1.4	1.3
Pontophilus australis	Shrimp		1.1	1.0

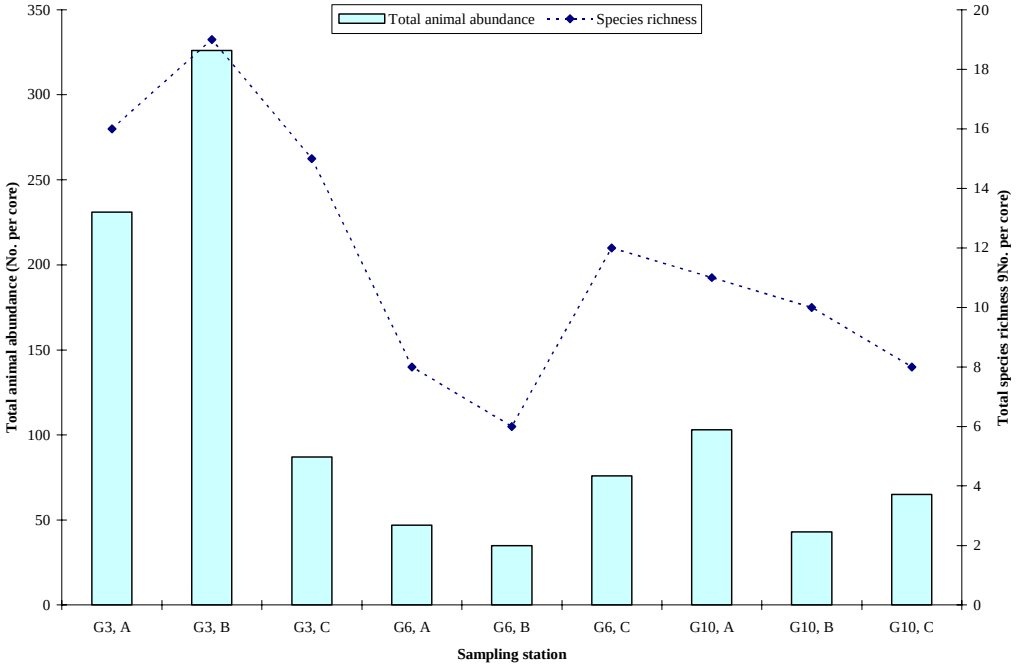


Figure 30 Animal abundance and species richness of sediments sampled from Sites 3, 6, and 10.

4.4.5 Firm sand/gravel/cobble (Sites 5, 12, 13)

The underlying sediments were not visibly different from sites classified as firm sand and gravel and this biotype was dominated by high densities of the turret shell (*Maoricolpus roseus roseus*) and the presence of occasional cobbles, particularly towards the harbour entrance, which provided substrate for small foliose red algae (*e.g. Brongniartella australis*, *Polysiphonia* spp). Within this turret shell dominated habitat a total of 86 infaunal taxa were identified. Differences were evident between sites (Figure 31) which are likely to be attributable to both differences in depth, and current regimes. Samples were dominated by polychaetes (*Prionospio* sp. and *Heteromastus filiformis*) and amphipods (Table 13).

Table 13 Average and relative abundance (%) of the top 10 infaunal species at Sites 5, 12, and 13.

Taxa	Common Name	Feeding	Ave abundance	Rel abundance
Prionospio sp.	Polychaete	Surface deposit feeder	23.9	15.6
Amphipoda	Amphipods	Epifaunal scavenger	17.2	11.3
Heteromastus filiformis	Polychaete	Infaunal deposit feeder	15.6	10.2
Paraonidae	Polychaete	Infaunal deposit feeder	10.9	7.1
Oligochaete	Oligochaete worms	Infaunal deposit feeder	10.8	7.1
Nematoda	Roundworm		8.6	5.6
Corallina (encrusting pink)	Pink paint		8.4	5.5
Aricidea sp.	Polychaete		6.4	4.2
Cirratulidae	Polychaete	Deposit feeder	5.0	3.3
Sphaerosyllis hirsula	Polychaete	Omnivorous	4.6	3.0

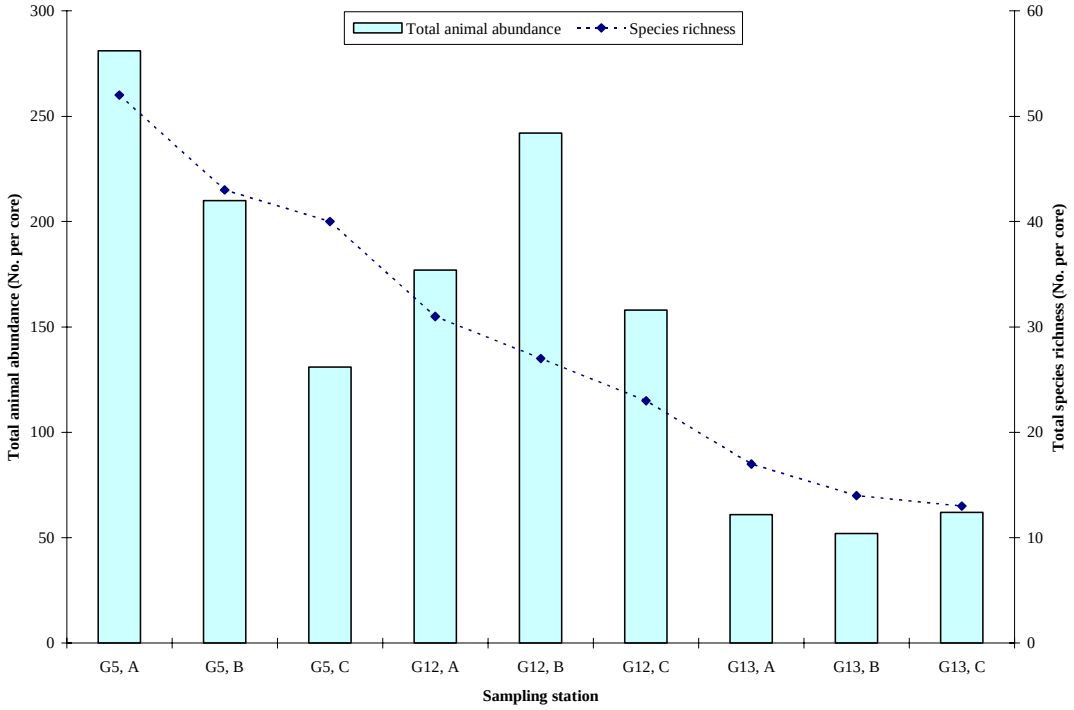


Figure 31 Animal abundance and species richness of sediments sampled from Sites 5, 12, and 13.

5. SUMMARY

Subtidal mapping of Bluff Harbour showed it to have a substrate dominated by sand and gravel (>90%), with only a small amount of cobbles, boulders and rock present. Firm muddy sand was dominant in the north and west, changing to gravels in the east. The mud content of sandy sediments was generally low and the harbour appeared well flushed with good water clarity. Sediments showed no common indicators of enrichment such as anoxic sediments or the presence of algal growths at nuisance levels.

Around the harbour entrance there was relatively flat bedrock across the bottom of the main channel, often overlain with gravel and cobble, while boulders overlay bedrock heading up to the shorelines of both Bluff and Tiwai Point. This area of the harbour had strong currents and there was little deposition of finer material evident among boulders. A diverse range of seaweeds, fish and encrusting organisms were present. While only a small part of the total harbour area mapped, four broad biotypes were identified within it based primarily on the types of macroalgae present.

The other major biotypes present in the harbour were characterised by the key species present: 1). *Zostera* (eelgrass beds), 2). the red algae *Gracilaria* and *Zostera*, 3). a relatively sparse cover of foliose red algae (*e.g. Brongniartella australis* and *Polysiphonia* spp.), and 4). *Maoricolpus* (turret shells). Each biotype covered a relatively large area, although the percent cover of key species was often relatively low. The presence of these visually distinct biotypes, and the range of different substrate types present, contributed to a wide range of different species being present. This was reflected in the sediment infauna results which showed a diverse and varied infaunal community.

Overall, the impression gained during sampling was that the subtidal areas within Bluff Harbour was:

- Dominated by sand and gravel
- Relatively unmodified
- Clean, well flushed, and unenriched
- Exhibited a high biodiversity of both plant and animal life
- Showed little sign of contaminant effects

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7. ACKNOWLEDGEMENTS

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8. APPENDIX 1 – TAXONOMIC COUNT DATA

Firm muddy sand (Sites 1, 2, 4, 9, 11)

Taxa	Common Name	Feeding	G1,A	G1,B	G1,C	G2,A	G2,B	G2,C	G4,A	G4,B	G4,C	G9,A	G9,B	G9,C	G11,A	G11,B	G11,C	Ave abund
Hydroida(thecate)			0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0.2
Anthopleura aureoradiata		Filter feeder	4	9	8	0	0	0	0	0	0	0	0	0	0	0	0	1.4
Edwardsia sp.			0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Nemertea	Proboscis worms		1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0.2
Nematoda	Roundworm		0	0	0	0	0	4	1	10	10	10	4	5	4	0	1	3.3
Leptochiton inquinatus			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Eatoniella sp.			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Maoricolpus roseus roseus	Turret shell		0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0.1
Micrelenchus tenebrosus	Grazing snail	Microalgal grazer	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0.3
Notoacmea helmsi	Limpet	Microalgal & detrital grazer	1	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0.4
Zeacumantus subcarinatus	Small Mud Snail	Microalgal & detrital grazer	2	10	2	0	0	0	0	0	0	0	0	0	0	0	0	0.9
Volvulella truncata			0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0.1
Arthritica bifurca		Infaunal deposit feeder	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Austrovenus stutchburyi	Cockle (21-30mm)	Infaunal deposit feeder	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Nucula nitidula	Nut shell	Infaunal deposit feeder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Paphies subtriangulata	Tuatua	Filter feeder	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Peronaea gaimardi		Infaunal suspension feeder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Soletellina sp.		Infaunal suspension feeder	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0.1
Tawera spissa	Morning Star		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Oligochaeta	Oligochaete worms	Infaunal deposit feeder	0	0	0	0	0	3	0	0	1	8	2	2	1	3	10	2.0
Orbinia papillosa		Infaunal deposit feeder	1	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0.3
Paraonidae		Infaunal deposit feeder	47	6	52	14	26	39	2	2	4	6	8	12	6	3	19	16.4
Aricidea sp.			13	1	6	4	6	18	17	14	15	21	14	17	5	27	35	14.2
Spionidae		Surface deposit feeder	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0.1
Aonides sp.		Surface deposit feeder	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Polydora sp.		Surface deposit & filter feeder	5	2	10	0	8	11	28	19	29	8	17	17	10	9	8	12.1
Prionospio sp.		Surface deposit feeder	0	0	1	0	0	0	0	0	0	4	2	1	0	0	0	0.5
Scolecolepides sp.		Surface deposit feeder	3	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0.7

Firm muddy sand (Sites 1, 2, 4, 9, 11) cont…

Cirratulidae		Deposit feeder	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Capitella capitata		Infaunal deposit feeder	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Heteromastus filiformis		Infaunal deposit feeder	9	3	6	4	2	8	2	5	14	3	7	7	5	3	5	5.5
Notomastus zeylanicus		Infaunal deposit feeder	0	0	0	0	0	0	0	0	0	1	3	3	0	1	0	0.5
Maldanidae	Bamboo Worms	Infaunal deposit feeder	0	0	1	1	1	1	1	0	2	1	2	5	2	1	2	1.3
Travisia olens		Infaunal deposit feeder	0	0	0	0	0	0	1	1	0	2	0	0	0	0	0	0.3
Phyllodocidae	Paddle worms	Carnivore & scavenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Hesionidae		Carnivore and deposit feeder	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0.1
Syllidae		Omnivorous	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0.2
Sphaerosyllis hirsula		Omnivorous	0	0	1	0	4	6	2	1	6	6	3	9	0	1	0	2.6
Nereidae	Rag worms	Omnivorous	3	6	5	0	0	0	0	0	0	0	0	0	0	0	0	0.9
Nicon aestuariensis		Omnivorous	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Glyceridae		Infaunal carnivore & deposit feeder	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0.1
Goniadidae		Infaunal carnivore	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0.3
Aglaophamus sp.		Infaunal carnivore	1	3	0	2	0	1	1	1	0	0	2	0	3	2	1	1.1
Lumbrineridae		Infaunal carnivore & deposit feeder	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Dorvilleidae		Facultative carnivore	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0.1
Owenia fusiformis		Infaunal deposit feeder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Pectinaria australis		Infaunal deposit feeder	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.1
Terebellidae		Infaunal deposit feeder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Cumacea	Cumaceans	Infaunal filter or deposit feeder	0	1	0	0	0	0	0	1	0	0	1	0	0	0	1	0.3
Tanaid sp.	Tanaid Shrimp	Epifaunal scavenger	0	0	0	0	0	4	0	0	0	2	1	0	0	1	3	0.7
Flabellifera	Sea louse	Epifaunal scavenger	2	10	5	0	0	0	0	0	0	0	0	0	0	0	0	1.1
Caprellidae			0	0	0	16	1	7	0	0	0	0	2	0	0	0	0	1.7
Amphipoda	Amphipods	Epifaunal scavenger	1	3	1	0	1	3	0	4	2	1	3	0	0	1	4	1.6
Paguridae	Hermit Crab Unid.	Epifaunal scavenger	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0.1
Macrophthalmus hirtipes	Stalk-eyed Mud Crab	Deposit feeder & scavenger	0	1	1	0	1	0	0	0	0	1	2	0	1	0	0	0.5
Pinnotheres atrinocola.	Horse Mussel Pea Crab		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Pontophilus australis	Shrimp		0	0	0	0	0	0	0	2	0	1	1	0	0	0	0	0.3
Ostracoda	Ostracods	Omnivorous scavenger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Enteromorpha sp.		Photosynthetic	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0.1
Rhizoclonium sp.			2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0.3

Firm muddy sand (Sites 1, 2, 4, 9, 11) cont…

Ralfsia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Polysiphonia strictissima	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Zostera sp.	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0.3
Total No. of Individuals	**101**	**69**	**115**	**43**	**51**	**108**	**57**	**60**	**84**	**81**	**76**	**81**	**44**	**53**	**89**	
Total No. of Taxa	**21**	**19**	**24**	**8**	**10**	**15**	**10**	**11**	**10**	**19**	**19**	**13**	**12**	**12**	**11**	

Firm muddy sand (Sites 15, 16)

Taxa	Common Name	Feeding	G15, A	G15, B	G15, C	G16, A	G16, B	G16, C	Ave abundance
Hydroida(thecate)			0	0	0	0	0	1	0.2
NEMERTEA	Proboscis worms		0	0	0	1	0	1	0.3
NEMATODA	Roundworm		0	0	1	3	6	0	1.7
Leptochiton inquinatus			0	0	0	0	0	1	0.2
Eatoniella sp.			0	0	0	1	0	0	0.2
Arthritica bifurca		Infaunal deposit feeder	0	1	7	0	0	0	1.3
Austrovenus stutchburyi	Cockle (21-30mm)	Infaunal deposit feeder	0	0	0	4	1	3	1.3
Nucula nitidula	Nut shell	Infaunal deposit feeder	0	0	0	1	0	0	0.2
Peronaea gaimardi		Infaunal suspension feeder	0	0	0	0	1	0	0.2
Tawera spissa	Morning Star		0	0	0	2	2	2	1.0
OLIGOCHAETA	Oligochaete worms	Infaunal deposit feeder	4	4	8	13	13	2	7.3
Orbinia papillosa		Infaunal deposit feeder	0	0	0	2	1	0	0.5
Paraonidae		Infaunal deposit feeder	2	0	0	15	34	11	10.3
Aricidea sp.			14	11	14	10	27	14	15.0
Spionidae		Surface deposit feeder	0	0	1	14	8	5	4.7
Polydora sp.		Surface deposit & filter feeder	2	2	2	67	46	42	26.8
Prionospio sp.		Surface deposit feeder	3	1	2	2	0	1	1.5
Cirratulidae		Deposit feeder	8	18	9	4	2	0	6.8
Heteromastus filiformis		Infaunal deposit feeder	15	11	46	13	15	11	18.5
Maldanidae	Bamboo Worms	Infaunal deposit feeder	0	2	2	3	3	2	2.0

Firm muddy sand (Sites 15, 16) cont…

Phyllodocidae	Paddle worms	Carnivore & scavenger	0	0	0	0	0	2	0.3
Sphaerosyllis hirsula		Omnivorous	3	0	2	22	34	19	13.3
Nicon aestuariensis		Omnivorous	2	5	1	0	0	0	1.3
Glyceridae		Infaunal carnivore & deposit feeder	0	0	0	2	0	1	0.5
Goniadidae		Infaunal carnivore	0	0	0	5	1	2	1.3
Aglaophamus sp.		Infaunal carnivore	1	0	1	0	2	0	0.7
Lumbrineridae		Infaunal carnivore & deposit feeder	0	0	0	0	1	3	0.7
Dorvilleidae		Facultative carnivore	0	0	0	1	1	0	0.3
Owenia fusiformis		Infaunal deposit feeder	0	0	0	1	2	1	0.7
Pectinaria australis		Infaunal deposit feeder	0	0	0	0	0	1	0.2
Terebellidae		Infaunal deposit feeder	0	0	0	0	1	1	0.3
Cumacea	Cumaceans	Infaunal filter or deposit feeder	0	0	0	13	1	1	2.5
Tanaid sp.	Tanaid Shrimp	Epifaunal scavenger	0	0	0	7	10	5	3.7
Caprellidae			1	0	0	0	1	0	0.3
Amphipoda	Amphipods	Epifaunal scavenger	8	11	20	32	11	17	16.5
Macrophthalmus hirtipes	Stalk-eyed Mud Crab	Deposit feeder & scavenger	3	2	6	1	0	0	2.0
Pontophilus australis	Shrimp		0	0	0	0	1	0	0.2
Ostracoda	Ostracods	Omnivorous scavenger	0	0	0	6	2	0	1.3
Ralfsia sp.			0	0	0	1	1	1	0.5
Polysiphonia strictissima			0	0	0	0	0	1	0.2
Total No. of Individuals			**66**	**68**	**122**	**246**	**228**	**151**	
Total No. of Taxa			**13**	**11**	**15**	**27**	**27**	**26**	

Firm sand (Zostera) (Sites 3, 6, 10)

Taxa	Common Name	Feeding	G3, A	G3, B	G3, C	G6, A	G6, B	G6, C	G10, A	G10, B	G10, C	Ave abund
Amphipoda	Amphipods	Infaunal deposit feeder	134	155	40	3	6	24	37	8	27	48.2
Zostera sp.			20	20	20	20	20	20	20	20	20	20.0
Eatoniella sp.			15	75	1	14	5	18	12	1	0	15.7
Polysiphonia decipiens			20	20	5	5	1	0	20	0	10	9.0
Halicarcinus cookii	Pill-box Crab	Eats small organisms & algae	11	14	1	2	0	2	2	0	1	3.7
Micrelenchus tenebrosus	Grazing snail	Microalgal grazer	12	7	2	0	0	0	6	0	0	3.0
Paraonidae		Infaunal deposit feeder	0	5	1	1	0	2	0	6	0	1.7
Notoacmea helmsi	Limpet	Microalgal & detrital grazer	3	4	3	0	2	2	0	0	0	1.6
Heteromastus filiformis		Infaunal deposit feeder	1	2	4	0	0	1	1	2	2	1.4
Pontophilus australis	Shrimp		2	0	3	0	0	0	1	1	3	1.1
Maoricolpus roseus roseus	Turret shell		4	5	0	0	0	0	0	0	0	1.0
Caprellidae			2	4	0	0	0	2	0	0	0	0.9
Prionospio sp.		Surface deposit feeder	1	2	2	1	0	0	0	0	0	0.7
Nereidae	Rag worms	Omnivorous	2	0	0	0	1	1	0	1	0	0.6
Ostracoda	Ostracods	Omnivorous scavenger	2	3	0	0	0	0	0	0	0	0.6
Aricidea sp.			0	1	1	0	0	0	0	2	0	0.4
Macrophthalmus hirtipes	Stalk-eyed Mud Crab	Deposit feeder & scavenger	1	3	0	0	0	0	0	0	0	0.4
NEMATODA	Roundworm		0	2	1	0	0	0	0	0	0	0.3
Tawera spissa	Morning Star		0	1	2	0	0	0	0	0	0	0.3
Turbonilla sp.			0	0	0	0	0	0	2	0	0	0.2
Ostrea chilensis	Flat / Dredge Oyster		0	2	0	0	0	0	0	0	0	0.2
Spionidae		Surface deposit feeder	0	0	0	0	0	2	0	0	0	0.2
Notomastus zeylanicus		Infaunal deposit feeder	0	0	0	0	0	0	1	1	0	0.2
Maldanidae	Bamboo Worms	Infaunal deposit feeder	0	0	0	0	0	0	0	1	1	0.2
Cumacea	Cumaceans	Infaunal filter or deposit feeder	1	0	1	0	0	0	0	0	0	0.2
Valvifera			0	0	0	1	0	1	0	0	0	0.2
Zeacumantus subcarinatus	Small Mud Snail	Microalgal & detrital grazer	0	0	0	0	0	1	0	0	0	0.1
Macomona liliana	Wedge shell, Hanikura	Infaunal suspension feeder	0	0	0	0	0	0	1	0	0	0.1
Polydora sp.		Surface deposit & filter feeder	0	0	0	0	0	0	0	0	1	0.1
Lumbrineridae		Infaunal carnivore & deposit feeder	0	1	0	0	0	0	0	0	0	0.1

Firm sand (Zostera) (Sites 3, 6, 10) cont…

Total No.ofIndividuals	**231**	**326**	**87**	**47**	**35**	**76**	**103**	**43**	**65**
Total No.ofTaxa	**16**	**19**	**15**	**8**	**6**	**12**	**11**	**10**	**8**

Firm sand/gravel habitat (Sites 7, 8, 14)

Taxa	Common Name	Feeding	G7, A	G7, B	G7, C	G8, A	G8, B	G8, C	G14, A	G14, B	G14, C	Ave abund
OLIGOCHAETA	Oligochaete worms	Infaunal deposit feeder	35	77	30	4	32	28	12	6	6	25.6
Amphipoda	Amphipods	Epifaunal scavenger	18	31	31	17	7	7	22	19	15	18.6
Spionidae		Surface deposit feeder	30	47	22	13	13	9	11	4	4	17.0
Ralfsia sp.			10	10	10	10	10	10	15	15	15	11.7
Tanaid sp.	Tanaid Shrimp	Epifaunal scavenger	18	29	16	2	0	2	1	0	1	7.7
Heteromastus filiformis		Infaunal deposit feeder	12	7	9	4	5	2	6	6	13	7.1
Sphaerosyllis hirsula		Omnivorous	18	7	10	4	3	3	2	4	2	5.9
NEMATODA	Roundworm		9	10	28	0	2	0	3	0	0	5.8
Paraonidae		Infaunal deposit feeder	22	4	8	2	8	4	0	0	1	5.4
Ostracoda	Ostracods	Omnivorous scavenger	20	14	14	0	0	0	0	1	0	5.4
Prionospio sp.		Surface deposit feeder	11	4	2	3	9	4	8	4	2	5.2
Maoricolpus roseus roseus	Turret shell		5	11	13	7	4	3	0	0	0	4.8
Cirratulidae		Deposit feeder	5	12	10	0	0	0	5	1	3	4.0
Rhizoclonium sp.			1	1	1	1	1	0	10	10	10	3.9
Maldanidae	Bamboo Worms	Infaunal deposit feeder	7	6	5	4	2	5	1	1	1	3.6
Nereidae	Rag worms	Omnivorous	9	9	5	0	1	1	4	0	0	3.2
Nucula nitidula	Nut shell	Infaunal deposit feeder	1	2	21	1	0	0	0	0	0	2.8
Polydora sp.		Surface deposit & filter feeder	0	0	0	5	4	16	0	0	0	2.8
Aricidea sp.			4	5	0	2	3	7	2	1	0	2.7
Polysiphonia decipiens			0	5	1	1	1	1	5	5	5	2.7
Syllidae		Omnivorous	4	6	4	0	0	0	2	4	0	2.2
Caprellidae			1	0	2	0	0	0	8	0	1	1.3
Leptomyaretiaria retiaria			0	3	8	0	0	0	0	0	0	1.2
glaophamus sp.		Infaunal carnivore	0	0	0	2	3	2	2	1	1	1.2
Armandia maculata		Infaunal deposit feeder	3	4	1	1	1	0	0	0	0	1.1

Firm sand/gravel habitat (Sites 7, 8, 14) cont…

Polysiphonia strictissima			0	0	0	0	0	0	5	5	0	1.1
Eatoniella sp.			0	0	8	0	0	0	1	0	0	1.0
Halicarcinus cookii	Pill-box Crab	Eats small organisms & some weed	1	4	1	0	0	0	0	1	1	0.9
Travisia olens		Infaunal deposit feeder	3	0	0	2	1	0	0	0	0	0.7
Cumacea	Cumaceans	Infaunal filter or deposit feeder	2	1	0	1	0	1	0	0	1	0.7
Coralline turf	Coralline Turf		1	1	1	1	1	1	0	0	0	0.7
Notomastus zeylanicus		Infaunal deposit feeder	0	3	1	0	1	0	0	0	0	0.6
NEMERTEA	Proboscis worms		1	2	1	0	0	0	0	0	0	0.4
Micrelenchus tenebrosus	Grazing snail	Microalgal grazer	0	0	0	0	0	0	1	1	2	0.4
Zeacumantus subcarinatus	Small Mud Snail	Microalgal & detrital grazer	1	2	1	0	0	0	0	0	0	0.4
Phyllodocidae	Paddle worms	Carnivore & scavenger	1	1	1	1	0	0	0	0	0	0.4
Nereis cricognatha	Rag Worm	Omnivorous	4	0	0	0	0	0	0	0	0	0.4
Pontophilus australis	Shrimp		1	0	2	0	0	0	0	0	1	0.4
Notoacmea helmsi	Limpet	Microalgal & detrital grazer	0	0	0	1	0	1	0	1	0	0.3
Tawera spissa	Morning Star		0	0	1	0	0	0	1	1	0	0.3
Zenatia acinaces		Infaunal suspension feeder	0	0	0	2	1	0	0	0	0	0.3
Hesionidae		Carnivore and deposit feeder	0	0	2	1	0	0	0	0	0	0.3
Glyceridae		Infaunal carnivore & deposit feeder	0	0	0	0	0	0	1	2	0	0.3
Macrophthalmus hirtipes	Stalk-eyed Mud Crab	Deposit feeder & scavenger	1	0	0	0	0	2	0	0	0	0.3
Kolostoneura novaezelandiae	Sea Cucumber		1	0	0	0	0	1	1	0	0	0.3
Ennucula strangei			1	1	0	0	0	0	0	0	0	0.2
Lumbrineridae		Infaunal carnivore & deposit feeder	0	0	0	0	0	0	1	1	0	0.2
Owenia fusiformis		Infaunal deposit feeder	0	0	0	0	0	0	0	2	0	0.2
COPEPODA	Copepods		0	0	1	0	0	0	0	1	0	0.2
Sipuncula	Peanut Worm	Infaunal deposit feeder	0	1	0	0	0	0	0	0	0	0.1
Diloma zelandica		Microalgal & detrital grazer	0	0	0	1	0	0	0	0	0	0.1
Nucula hartvigiana	Nut Shell	Infaunal deposit feeder	0	0	1	0	0	0	0	0	0	0.1
Ruditapes largillierti			0	0	0	0	0	0	0	0	1	0.1
Capitella capitata		Infaunal deposit feeder	1	0	0	0	0	0	0	0	0	0.1
Polynoidae	Scale worms	Infaunal carnivore	0	0	0	0	0	0	1	0	0	0.1
Dorvilleidae		Facultative carnivore	0	0	0	0	0	0	0	0	1	0.1
Nectocarcinus antarcticus	Hairy Red Swimming Crab		0	0	0	0	0	0	0	0	1	0.1
Squilla armata	Mantis Shrimp		0	1	0	0	0	0	0	0	0	0.1

Firm sand/gravel habitat (Sites 7, 8, 14) cont…

Diplosoma listerianum	0	0	0	0	0	1	0	0	0	0.1
Scytosiphon lomentaria	0	0	0	0	0	0	1	0	0	0.1
Total No. of Individuals	**262**	**321**	**272**	**93**	**113**	**111**	**132**	**97**	**88**	
Total No. of Taxa	**34**	**32**	**34**	**26**	**22**	**22**	**27**	**24**	**22**	

Firm sand/gravel/cobble (Sites 5, 12, 13)

Taxa	Common Name	Feeding	G5, A	G5, B	G5, C	G12, A	G12, B	G12, C	G13, A	G13, B	G13, C	Aver abundance
Prionospio sp.		Surface deposit feeder	50	34	12	45	41	29	1	2	1	23.9
Amphipoda	Amphipods	Epifaunal scavenger	45	40	31	17	11	5	1	3	2	17.2
Heteromastus filiformis		Infaunal deposit feeder	20	10	3	28	22	24	14	14	5	15.6
Paraonidae		Infaunal deposit feeder	5	4	0	12	46	9	7	5	10	10.9
OLIGOCHAETA	Oligochaete worms	Infaunal deposit feeder	3	2	5	7	31	16	7	10	16	10.8
NEMATODA	Roundworm		12	6	4	8	28	14	2	2	1	8.6
Corallina (encrusting pink)			5	5	5	20	20	20	1	0	0	8.4
Aricidea sp.			2	1	1	1	7	4	19	5	18	6.4
Cirratulidae		Deposit feeder	7	6	6	6	7	11	1	0	1	5.0
Sphaerosyllis hirsula		Omnivorous	12	16	5	1	4	2	0	0	1	4.6
Diplosoma listerianum			20	5	5	0	0	0	0	0	0	3.3
Spirorbidae		Suspension feeder	10	10	5	0	0	0	0	0	0	2.8
Paguridae	Hermit Crab Unid.	Epifaunal scavenger	2	1	3	5	3	4	1	0	0	2.1
Ostracoda	Ostracods	Omnivorous scavenger	6	8	3	0	1	1	0	0	0	2.1
Gelidium longipes			0	0	0	5	5	5	0	2	0	1.9
Pontophilus australis	Shrimp		6	4	2	2	0	2	0	0	0	1.8
BRYOZOA (encrusting)			5	5	5	0	0	0	0	0	0	1.7
Nereidae	Rag worms	Omnivorous	4	4	2	0	0	0	0	0	0	1.1
Aplidium sp.	Compound ascidian		6	1	2	1	0	0	0	0	0	1.1
Polysiphonia decipiens			2	2	2	1	1	0	0	2	0	1.1
Ralfsia sp.			0	0	0	2	2	1	0	2	2	1.0
Hydroida(thecate)			2	4	2	0	0	0	0	0	0	0.9
Armandia maculata		Infaunal deposit feeder	2	2	3	1	0	0	0	0	0	0.9

Firm sand/gravel/cobble (Sites 5, 12, 13) cont…

Phyllodocidae	Paddle worms	Carnivore & scavenger	3	1	1	1	0	2	0	0	0	0.9
Owenia fusiformis		Infaunal deposit feeder	2	4	2	0	0	0	0	0	0	0.9
OPHIUROIDEAUNID.	Brittle star Unid.		1	3	3	1	0	0	0	0	0	0.9
Ischnochiton maorianus	Chiton		3	1	1	0	1	0	0	0	0	0.7
Maldanidae	Bamboo Worms	Infaunal deposit feeder	1	0	1	2	1	1	0	0	0	0.7
Asellota	Isopod		3	3	0	0	0	0	0	0	0	0.7
Caprellidae			1	3	2	0	0	0	0	0	0	0.7
Zegalerus tenuis		Microalgal grazer	4	1	0	0	0	0	0	0	0	0.6
Spionidae		Surface deposit feeder	3	0	1	0	1	0	0	0	0	0.6
Glyceridae		Infaunal carnivore & deposit feeder	0	4	1	0	0	0	0	0	0	0.6
Capitella capitata		Infaunal deposit feeder	0	0	0	1	1	0	0	2	0	0.4
Aglaophamus sp.		Infaunal carnivore	0	0	1	0	0	0	1	1	1	0.4
Lumbrineridae		Infaunal carnivore & deposit feeder	2	0	0	1	0	0	0	1	0	0.4
Plakathrium typicum			1	3	0	0	0	0	0	0	0	0.4
Decapoda(larvaeunid.)	Crab Larvae		1	0	0	0	1	2	0	0	0	0.4
COPEPODA	Copepods		0	0	0	1	2	1	0	0	0	0.4
NEMERTEA	Proboscis worms		2	0	1	0	0	0	0	0	0	0.3
Micrelenchus tenebrosus	Grazing snail	Microalgal grazer	2	1	0	0	0	0	0	0	0	0.3
Notoacmea helmsi	Limpet	Microalgal & detrital grazer	2	0	0	1	0	0	0	0	0	0.3
Trochus viridis			3	0	0	0	0	0	0	0	0	0.3
Nucula nitidula	Nut shell	Infaunal deposit feeder	0	1	2	0	0	0	0	0	0	0.3
Ostrea chilensis	Dredge Oyster		1	2	0	0	0	0	0	0	0	0.3
Tawera spissa	Morning Star		0	1	1	0	0	0	1	0	0	0.3
Polydora sp.		Surface deposit & filter feeder	2	0	0	0	0	0	1	0	0	0.3
Hesionidae		Carnivore and deposit feeder	2	0	0	0	1	0	0	0	0	0.3
Syllidae		Omnivorous	0	0	1	0	1	0	0	1	0	0.3
Goniadidae		Infaunal carnivore	0	0	0	1	1	1	0	0	0	0.3
Dorvilleidae		Facultative carnivore	2	0	0	0	0	1	0	0	0	0.3
Terebellidae		Infaunal deposit feeder	0	0	0	0	0	0	1	0	2	0.3
Flabellifera	Sea louse	Epifaunal scavenger	1	0	1	0	1	0	0	0	0	0.3
Corella eumyota	Sea Squirt		0	1	0	0	0	2	0	0	0	0.3
Didemnum sp.	Sea Squirt		0	2	1	0	0	0	0	0	0	0.3
Leptochiton inquinatus			2	0	0	0	0	0	0	0	0	0.2

Firm sand/gravel/cobble (Sites 5, 12, 13) cont…

Diloma subrostrata		Microalgal & detrital grazer	2	0	0	0	0	0	0	0	0	0.2
Maoricolpus roseus roseus	Turret shell		0	0	0	1	1	0	0	0	0	0.2
Xymene ambiguus			2	0	0	0	0	0	0	0	0	0.2
OPISTHOBRANCHIAUNID.			1	1	0	0	0	0	0	0	0	0.2
Gari stangeri			0	2	0	0	0	0	0	0	0	0.2
Sigalionidae		Infaunal carnivore	0	0	1	0	0	0	1	0	0	0.2
Cumacea	Cumaceans	Infaunal filter or deposit feeder	0	0	0	0	0	0	0	0	2	0.2
Halacaridae	Sea spiders		0	2	0	0	0	0	0	0	0	0.2
Rhizoclonium sp.			1	1	0	0	0	0	0	0	0	0.2
SPONGE(BREAD)	Sponge Unid.		0	0	0	1	0	0	0	0	0	0.1
Anthopleura aureoradiata		Filter feeder	0	1	0	0	0	0	0	0	0	0.1
PLATYHELMINTHES	Flat Worm	Predator	1	0	0	0	0	0	0	0	0	0.1
Atalacmea fragilis	Fragile Limpet		1	0	0	0	0	0	0	0	0	0.1
Neoguraleus lyallensis			1	0	0	0	0	0	0	0	0	0.1
Borniola reniformis			0	0	1	0	0	0	0	0	0	0.1
Orbinia papillosa		Infaunal deposit feeder	0	0	0	1	0	0	0	0	0	0.1
Magelona papillicornis		Surface deposit feeder	0	0	0	0	0	0	1	0	0	0.1
Nereis cricognatha	Rag Worm	Omnivorous	0	0	1	0	0	0	0	0	0	0.1
Eunicidae		Facultative carnivore	1	0	0	0	0	0	0	0	0	0.1
Pectinaria australis		Infaunal deposit feeder	0	0	0	0	0	0	1	0	0	0.1
Galeolaria hystrix	Fanworm	Suspension feeder	0	0	0	1	0	0	0	0	0	0.1
Pomatoceros sp.		Suspension feeder	1	0	0	0	0	0	0	0	0	0.1
Anthuridea sp.		Epifaunal scavenger	0	1	0	0	0	0	0	0	0	0.1
Cirolana sp.			0	1	0	0	0	0	0	0	0	0.1
Halicarcinus cookii	Pill-box Crab	Eats small organisms & some weed	0	0	0	0	1	0	0	0	0	0.1
Macrophthalmus hirtipes	Stalk-eyed Mud Crab	Deposit feeder & scavenger	0	0	0	1	0	0	0	0	0	0.1
Trochodota dendyi	Sea cucumber	Epifaunal deposit feeder	0	0	1	0	0	0	0	0	0	0.1
Cnemidocarpa bicornuta			0	0	0	0	0	1	0	0	0	0.1
Cystodytes dellechiajei			0	0	1	0	0	0	0	0	0	0.1
Codium sp.			0	0	0	1	0	0	0	0	0	0.1
Total No. of Individuals			**281**	**210**	**131**	**177**	**242**	**158**	**61**	**52**	**62**	
Total No. of Taxa			**52**	**43**	**40**	**31**	**27**	**23**	**17**	**14**	**13**	