Biological mapping and depth contours of Pohatu Marine Reserve, Banks Peninsula

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1.0 Abstract

The present report is the second part of a two-part study aimed at mapping habitats from Pohatu Marine Reserve. The first part of the study involved the collection of side-scan sonar data (Rodger and Grange 2008). The second part of the study involved the collection of 221 drop camera photographs and 245 depth measurements from locations throughout the reserve. Only selected drop camera photographs have been presented in the present report. All photographs and their locations will be made available on the DoC website (www.doc.govt.nz) under Conservation > Marine & coastal > Marine protected areas> Marine reserves A-Z > Pohatu.

The present report outlines (1) major depth contours, (2) major substrata types and boundaries, and (3) major habitat types and boundaries for Pohatu Marine Reserve.

All depths within Flea Bay proper (eastern and western (Dyke Head) headlands) were < 24 m, with most areas were between 10 m to 20 m depth. Two depth regimes were present within Flea Bay: (1) Flea Bay central flats and (2) Flea Bay edges. Four depth regimes were recorded from the open coastline: (1) inshore drop-off, (2) shallow shelf, (3) deep drop-off, and (4) offshore deep flats.

Substrata were divided in two major types being (1) soft substrata (i.e. sands, silt, shell) representing 74 % of the reserve; and (2) hard (i.e. rock, boulder, cobble, pebble) comprising 26% of the reserve. The location and boundaries of these substrata types were mapped.

Three major hard substrata habitats were mapped using visual criteria during the present study: (1) *Carpophyllum* forest, (2) sheltered, shallow rocky barren, and (3) encrusting community from exposed rock.

Soft shore habitats were also mapped using visual criteria. Soft habitats were: (1) rippled, mobile sand flat habitat, (2) stable shallow sand flat habitat, (3) red algal bed, and (4) deep mud-shell flat habitat.

A discussion of the limitations of the data and recommendations for future habitat mapping and descriptive work conclude the report.

2.0 Introduction

2.1 Present study

In late 2007, the Department of Conservation commissioned contractors to produce a habitat map for Pohatu Marine Reserve, Banks Peninsula. The work was assigned as two stages:

Stage 1: side-scan the marine reserve and produce a preliminary map of habitats; and

Stage II: ground truth habitats identified by the side-scan using a drop camera and where possible identify the main community types and identify any habitats or communities of special interest (e.g. biogenic reef). Lastly, to assist the Department to produce a final habitat map for the marine reserve.

In November 2007, Rodgers and Grange (2008) conducted a side-scan sonar survey of Pohatu Marine Reserve to characterise the seabed and location of reefs and other seabed structures. Rodgers and Grange (2008) converted the sonograph files and GSP coordinates into mosaicing software , which were in turn imported in GIS for display in relation to the coastline and marine reserve boundaries. The authors stated that it was not possible to side-scan the entire marine reserve, however they did cover all areas where reef habitat was expected to occur. The authors also produced a map of habitats based on the side-scan images, showing relatively extensive reef areas outside the bay compared to a narrow strip of rocky reef along the sides of Flea Bay.

The present report aimed to:

- ground truth the habitats identified by the side-scan sonar survey;
- fine tune the boundaries identified by the NIWA habitat map;
- investigate inshore areas of Flea Bay not able to be covered by the side-scan sonar; and
- investigate offshore areas not surveyed by NIWA due to time constraints.

2.2 Background biological information

Since the establishment of Pohatu Marine Reserve in 1999 relatively little scientific work has been carried out. The following section provides a brief summary of biological work that has occurred in the marine reserve.

Conspicuous edible species such as lobsters, paua, kina and reef fish were quantitatively sampled in 2000 (Davidson *et al.* 2001) and again in 2002 (Davidson and Abel 2003). The authors sampled a variety of sites within the reserve and from adjacent bays where control sites were established. Fish densities were established using standard diver transects, while lobster size, sex and density were established using haphazardly-located quadrats. Both sets of data were aimed to provide a baseline for future biological monitoring of the marine reserve. Davidson *et al.* (2001) briefly noted rocky habitat types observed within Flea Bay proper being either rock with (1) brown macroalgal forest, (2) barren rocky substrata or (3) rock with an encrusting invertebrate fauna. The authors also noted the present of sand immediately offshore of rocky substrata.

Shears and Babcock (2007) quantitatively sampled a range of plant and animal species from five sites located in Flea Bay and compared that data with other sites around New Zealand. The authors reported low algal diversity from this area. Inside Flea Bay, they stated that brown macroalgae comprised a shallow band of narrow flap-jack (*Carpophyllum maschalocarpum)*, with wide flap-jack (*C. flexuosum)* forests dominating the deeper strata. Shears and Babcock (2007) stated that the Cook's turban (*Cookia sulcata)* and topshell (*Trochus viridis)* were abundant across all depths and the black foot paua (*Haliotis iris)* was common in the deepest strata (7–9 m and 10–12 m). They reported that crustose coralline algae were the dominant encrusting form at all depths; however, the percentage cover of sediment was high in the deepest strata.

At moderately exposed sites (eastern Flea Bay), Shears and Babcock (2007) reported a relatively low biomass of macroalgae at all depths. They stated that this may be due to shading effects as both sites were south facing with steeply sloping reefs. *Carpophyllum maschalocarpum,* bull kelp *(Durvillaea willana)* and brown alga (*Marginariella urvilliana)* dominated the shallow stratum, whereas *C. flexuosum* and the giant kelp (*Macrocystis pyrifera)* dominated at 4–6 m. Low numbers of paddle weed (*Ecklonia radiata)* and *Marginariella urvilliana* (sheltered morphology; Adams 1994) were present at 10–12 m. Red foliose, red turfing and green algal species were rare at all depths, and the percentage cover of crustose coralline algae declined with depth and

cover of sediment increased. Green lipped mussel (*Perna canaliculus)* and sea tulip (*Pyura pachydermatina)* were abundant at shallow depths. *Trochus viridis* was abundant at all depths and low numbers of *Cookia sulcata, Haliotis iris* and tiger shell (*Calliostoma punctulatum)* also occurred. The authors investigated one site near the western entrance to Flea Bay and reported that it was dominated by *Carpophyllum maschalocarpum,* brown alga *(Lessonia variegata)* and *D. willana* at 0–2 m, and *C. maschalocarpum* at 4–6 m, whereas all fleshy macroalgae were rare at greater depths. Crustose coralline algae were the dominant substratum cover at all depths although sponges and solitary ascidians had a relatively high percentage cover in the deeper strata. *Pyura pachydermatina* was abundant at 4–6 m (28.2 ± 11.9/m^2) and 7–9 m (13.3 ± 7.2/m^2). Red foliose algae were more common at these sites, particularly as epiphytes on *P. pachydermatina*, e.g. red alga (*Callophyllis hombroniana* and *Hymenocladia sanguinea)*. Large specimens of *H. iris* (up to 145 mm shell length) were common at 10–12 m.

A variety of other biological studies have occurred in the Banks Peninsula area and provide background information for the Peninsula (Davidson 1999a-e, Davidson 2000a-h, Schiel and Hickford 2001)

3.0 Methods

Pohatu Marine Reserve was sampled on 20th and 21st March 2007. The weather was relatively calm, with an approximate 1 m southerly swell outside Flea Bay and calm conditions inside the Bay. Water visibility varied between days, during each day, within the study area, and with depth of sample. Clarity ranged from 0 to 6 m.

Prior to fieldwork, the marine reserve boundaries were plotted onto mapping software (TUMONZ 3.11). The laptop running the mapping software was linked to a GPS receiver allowing real-time plotting of the survey vessel's position and all drop camera photographs. This GPS system has a maximum error of +/- 5 m distance.

On the days of the survey, high tide was:

20th March: low 9.44 am, (0.56 m), high 3.51 pm (2.68 m)

21st March: low 10.32 am, (0.67 m), high 4.39 pm (2.68 m)

3.1 Substrata and biogenic components

An IKELITE underwater splash camera fixed to an aluminium frame was used to collect 221 photographs of the seafloor (Figure 1). The frame was lowered to the seafloor and one oblique still photograph was collected where the frame landed. Photographs were captured onto a memory stick via a Sony digital video camera.

The location of photograph stations were selected in an effort to:

1. ground truth areas and habitats identified by NIWA;

2. fine tune the location of sediment types in the reserve by locating the edge or boundary of hard and soft shores; and

3. gather representative photographs of sediments and dominant biogenic components in the reserve.

Additional photographs were taken when any features of particular interest were detected on the dpeth sounder. In particular instances, the boat was left to drift so that observations of the benthos could be made via the camera monitor.

All digital images were transferred onto a desktop computer for storage. A copy of each photograph was digitally enhanced using Photoshop Elements 2 in an effort to improve picture colour, clarity, contrast and brightness.

3.2 Depths contours

At each of the 221 drop camera locations, the depth adjusted to datum were also collected. An additional 24 depth positions were fixed using the GPS and depth sounder in an effort to gain a good coverage of depth data for the marine reserve area (Figure 2).

Arbitrary depth contours of 10 m, 20 m, 25 m, 30 m, 35 m and 40 m were selected for mapping. Contours were established by bisecting points. In some instances where depth data were sparse, contours were estimated based on the shore gradient established by adjacent data points.

Figure 1. Location of drop camera stations from Pohatu Marine Reserve.

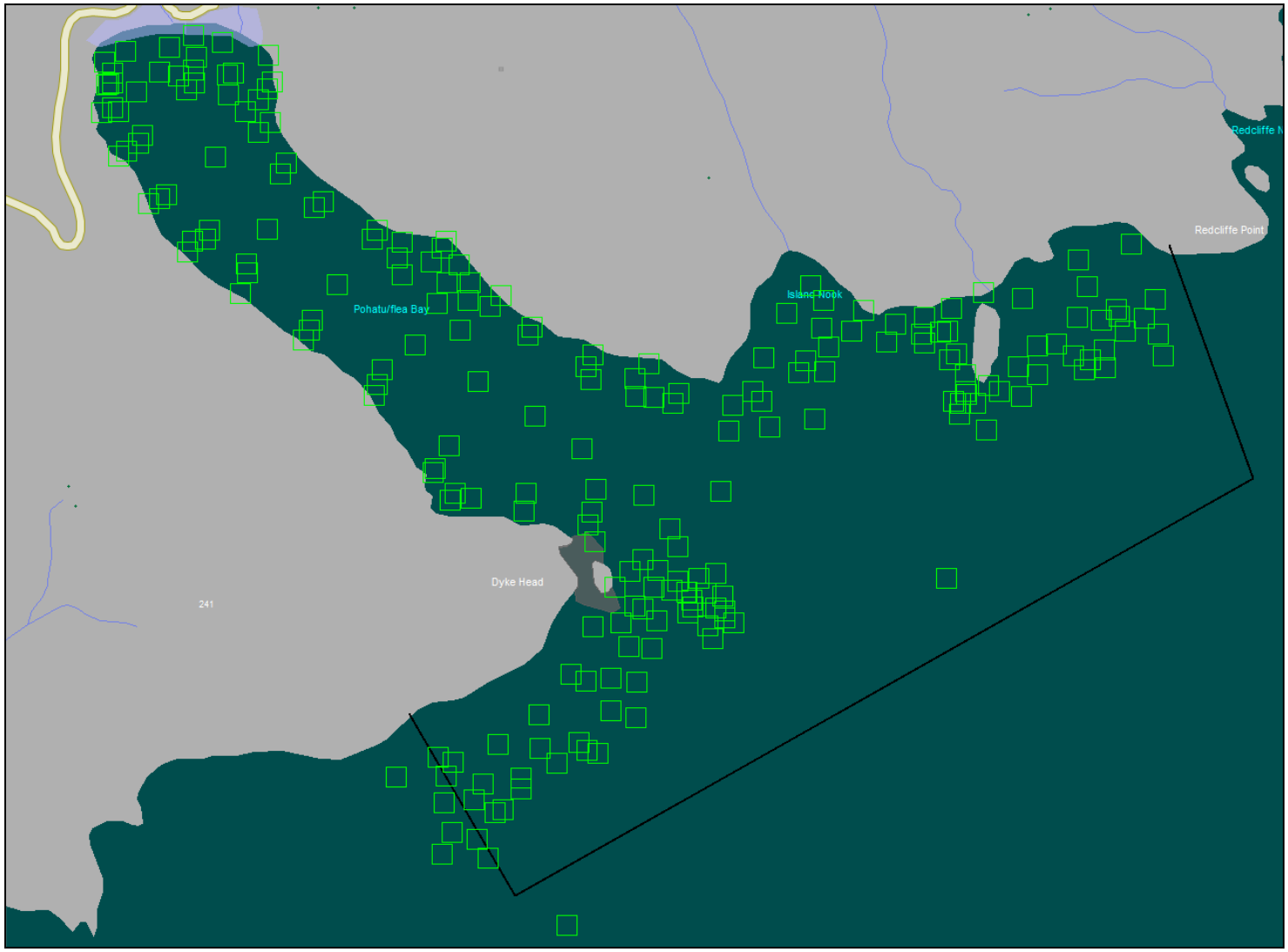
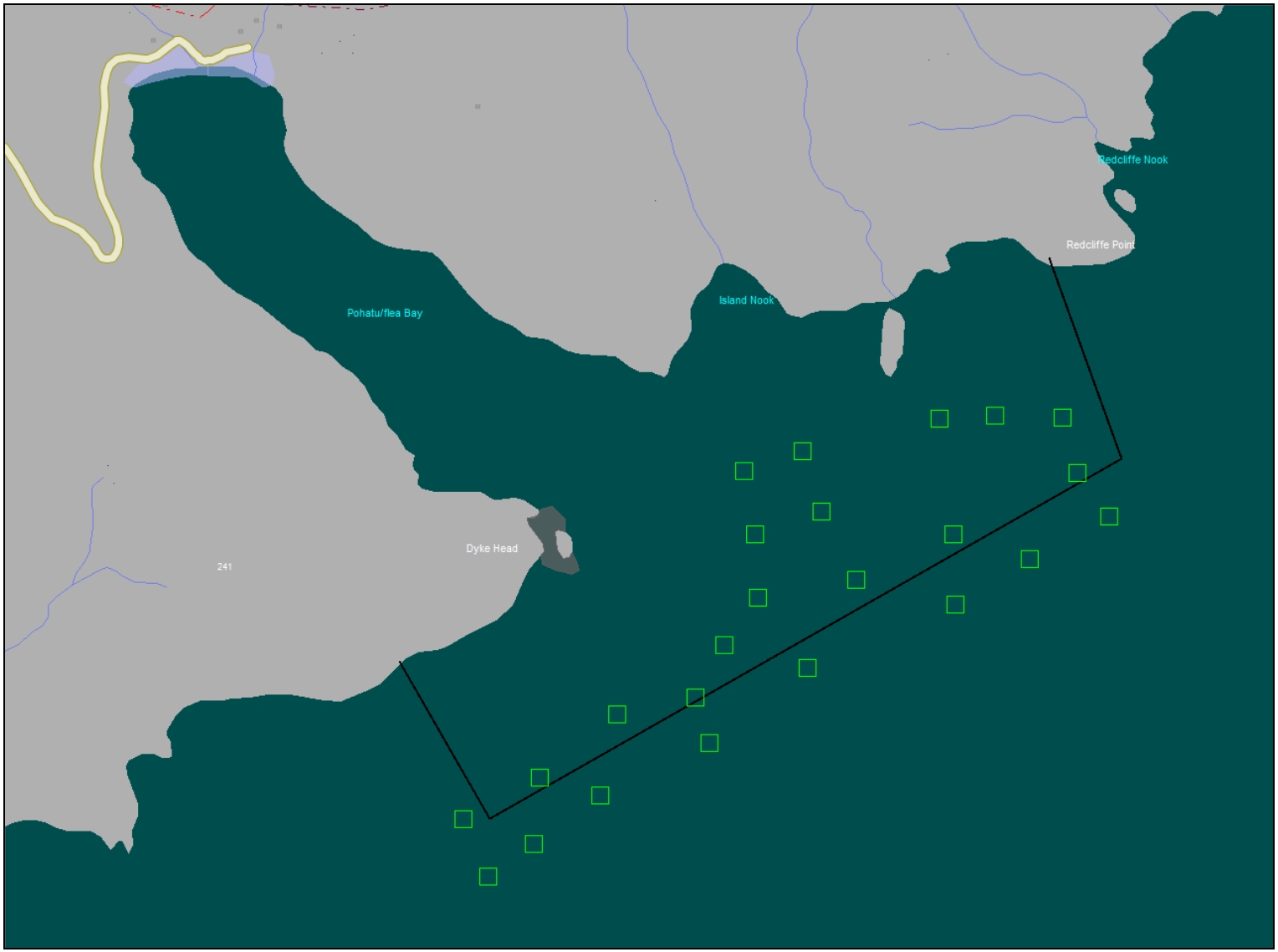


Figure 2. Location of additional depth stations from Pohatu Marine Reserve.



3.3 Video

At three locations representative of habitats including (rock with macroalgae forest, sand, red algae on sand, and rock with various communities of encrusting fauna), and substrata including bedrock, boulder, cobble, sand). Video footage also attempted to gain representative footage of fish species present at the three locations.

The drop camera was suspended above the sea floor and video footage was recorded directly onto the laptop on the survey vessel (Figure 3). Video footage is held by the Department of Conservation, Private Bag 4715, Christchurch.

Figure 3. Location of three video stations in Pohatu Marine Reserve.

4.0 Results

4.1 Depths

The 245 depth stations collected during fieldwork were used to fix depth contour lines for Pohatu Marine Reserve (Figure 4). All depths within Flea Bay proper were < 24 m, with most areas between 10 m to 20 m depth (i.e yellow to green lines in Figure 4).

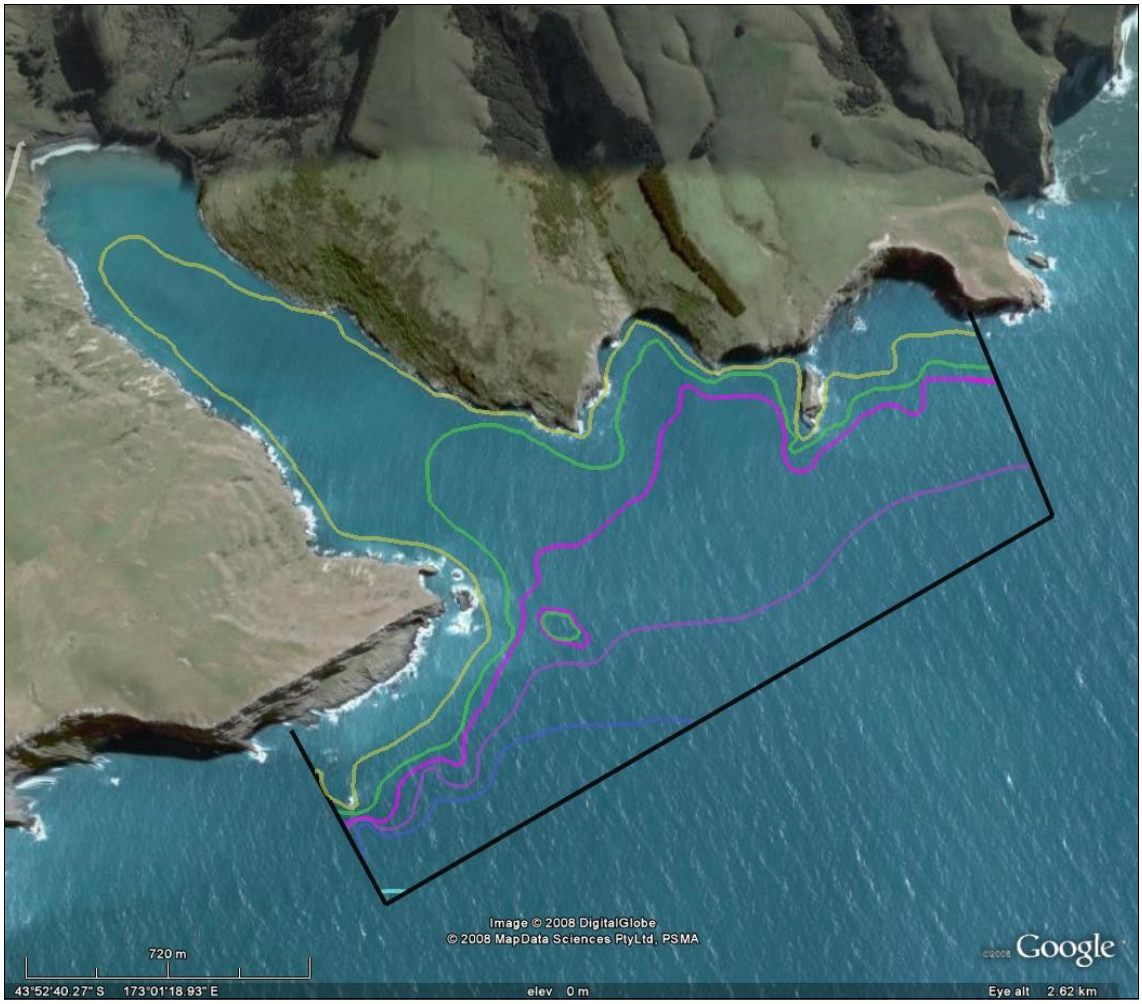


Figure 4. Depth strata from Pohatu Marine Reserve. Yellow = 10 m, green = 20 m, pink = 25 m, purple = 30 m, blue = 35 m and light blue = 40 m depth.

Two depth contour regimes relating to the bay edges and the central sand flats were present within Flea Bay.

(1) Flea Bay central flats: The depths for central areas of Flea Bay increased gradually from the intertidal beach located at the head of the Bay towards the entrance where depths reached 24 m. All of the central areas of Flea Bay were relatively flat with no holes, depressions or abnormalities being recorded. No shallow area was recorded in the mouth of Flea Bay.

(2) Flea Bay edges: The depths of Flea Bay decreased rapidly in the immediate proximity of the shoreline (Figure 4). This rapid increase in depth coincided with the rocky edges within Flea Bay.

Four depth contour regimes were recorded from the open coastline.

(1) Inshore coastal edge drop-off: For the first bay located east of Flea Bay, depths of 20 m were reached relatively quickly (i.e. 40 m to 100 m distance from shore) suggesting a steeply shelving shore close to the cliffs.

(2) Shallow shelf: The remaining open coast to the east of Flea Bay and all of the open coast to the west of Flea Bay increased in depth relatively slowly reaching 20 m depth by 180 to 270 m distance from shore. This suggested a relatively wide shallow shelf area with a relatively low gradient slope.

(3) Deep offshore drop-off: Offshore of the shallow shelf, depths increased rapidly below 20 m. This was most apparent in the west, where depths increased to 35 m depth within a relatively short distance offshore from the shallow shelf area (Figure 4).

(4) Offshore deep flats: For these offshore areas, depths changed relatively slowly suggesting a low gradient contour. These offshore deep flats occupied most of the outer coast (Figure 4). These shores gradually increased in depth from 25 m in the east to 40 m in the south-west offshore corner of the reserve (Figure 4).

4.2 Substrata

A total of 221 drop camera stations were sampled throughout the Pohatu Marine

Reserve. From all but two of the photographs, the substrata could be determined from the photograph. From the remaining two photos, the visibility combined with the depth made interpretation of the substrata type impossible.

A brief description of the dominant substratum types and any characteristic biological components were annotated to the GPS position of each drop camera station (Appendix 1). Combinations of substrata types were listed from most common to least common as observed in the photograph.

Substrata categories observed within the reserve were:

Bedrock:	solid rock formed as rock faces, walls, platforms
Boulder:	ranging in size from small (>256 mm) to very large
Cobble:	ranging in size from 64 mm - 256 mm width
Pebble:	ranging in size from 4 mm to 64 mm
Sand:	ranging in size from coarse to very fine sand
Silt:	ranging in size from silt to clay particle sizes
Shell:	comprising dead whole and dead broken shell material

Once substrata types were determined for each drop camera photograph, the approximate boundaries of major substrata changes could be determined and mapped. Substrata were divided in two major divisions being (1) soft (sands, silt, shell); and (2) hard (rock, boulder, cobble, pebble).

Hard substrata

Within Flea Bay proper, hard substratum was generally located around the bay edges ranging from 40 m to 80 m distance from the shore (Figure 5). This substratum was dominated by bedrock close to shore, however, with increasing distance form shore boulders, cobbles and pebble substrata became more common. With increasing distance from shore, the bedrock component often disappeared leaving combinations of boulders, cobbles and pebbles. In some areas soft substratum were interspersed with hard material. The exception to this pattern was an area located in the north-eastern head of the Bay where a relatively large area of boulders and cobbles interspersed by sand was recorded (Figure 5, Plate 1). This area was approximately 200 m wide by 110 m across.

Outside Flea Bay along the open coastline, the rocky substrata extended further from shore than inside the Bay (Figure 5). Rocky material outside the Bay was dominated by

bedrock, however, with increasing distance from shore a variable-sized boulders were observed from drop camera photographs (Plate 2). At the foot of the steep subtidal slopes, areas comprising combinations of boulders, cobbles, pebbles and some soft sediment components such as sand and shell were observed from photographs (Plates 3 & 4).

A small isolated rocky reef was also recorded from offshore of the western entrance headland to Flea Bay (Figure 5). No other offshore or isolated rocks or reef systems were recorded during the present study, however, these features are difficult to detect due to their often small size.

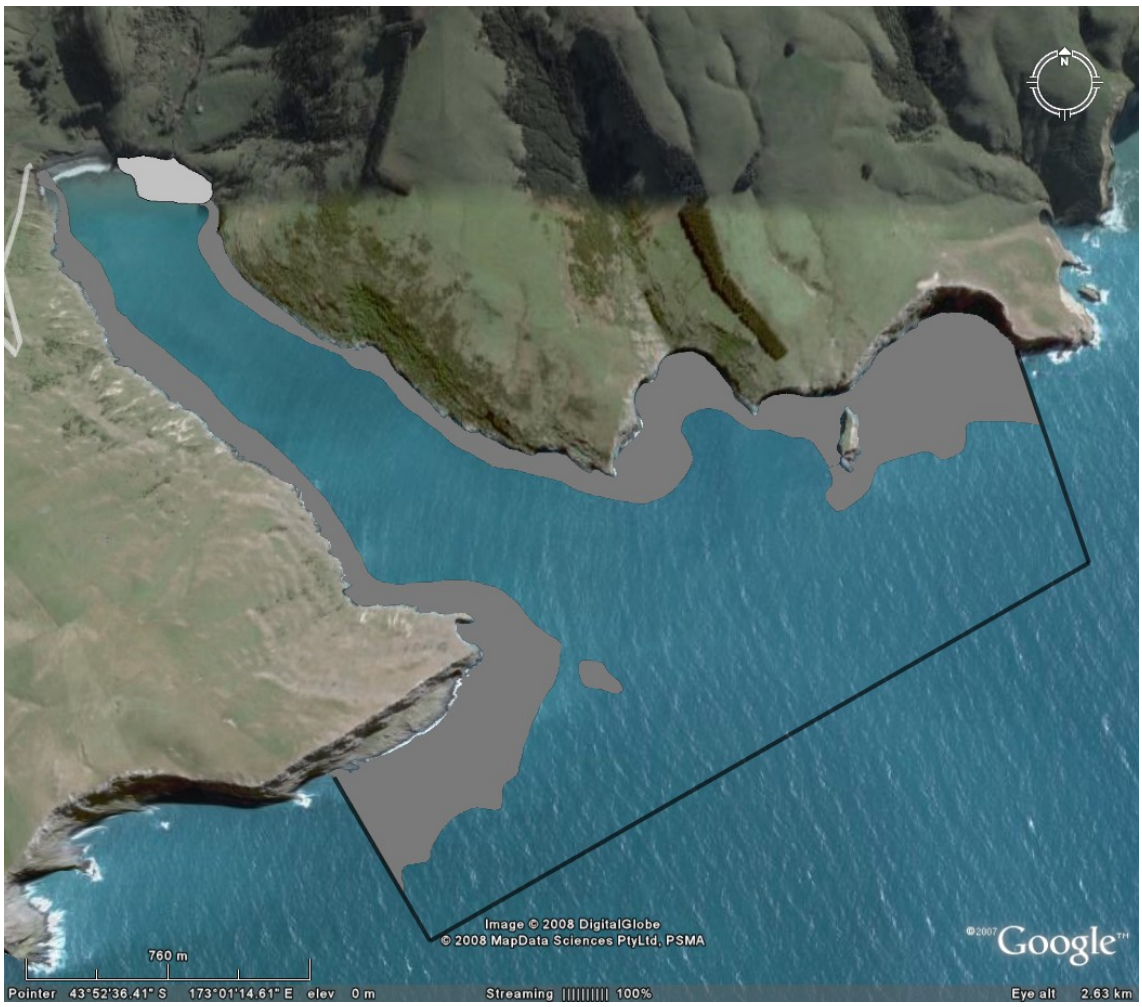


Figure 5. Location of hard substrata located within Pohatu Marine Reserve. Dark grey = combinations of bedrock, boulder, cobbles and pebbles; light grey = boulder and cobble.

A small series of offshore rocks located in the west of the reserve extended into the intertidal zone. One of these rocks was exposed at high tide while the other rocks were only exposed near low water and between swell surges. It is probable that these rocks are part of a reef that extends from an associated promontory located at the base of a series of large cliffs. A further series of shallow rocks were located at and west of the eastern headland to Flea Bay. The largest of these were located adjacent to the east headland entrance to Flea Bay. One large island and a small rock platform were located along the coast east of Flea Bay. These islands were also probably once linked to the adjacent cliffs, but now only have subtidal links to the adjacent shore.

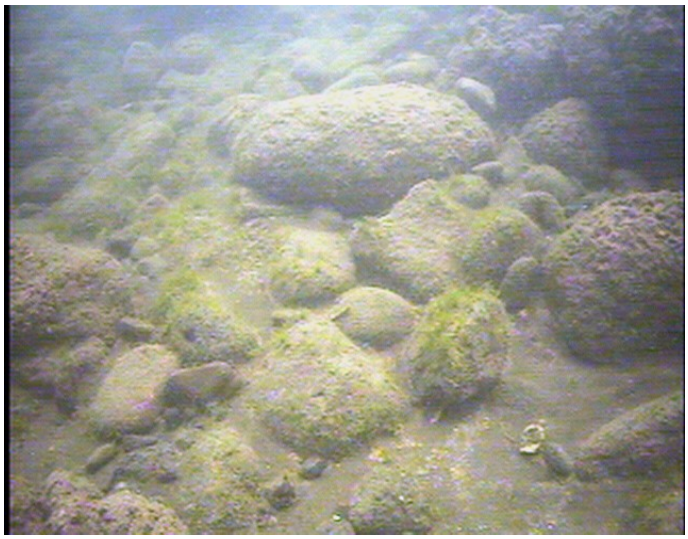


Plate 1. Boulders and cobbles interspersed by sand located in the north-eastern head of Flea Bay (photo 58).

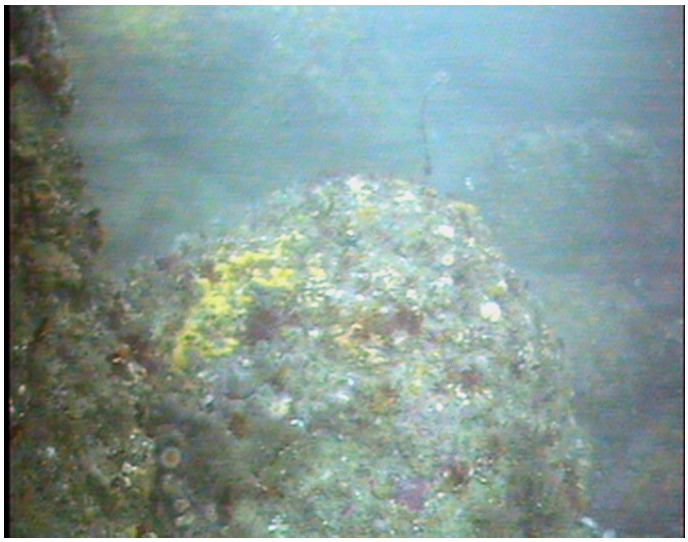


Plate 2. Bedrock and large boulders located along the western coastline (photo 93).

Plate 3. Boulder, cobble and pebble substrata located along the western outer coast at the foot of a bedrock face (photo 44).

Plate 4. Cobble, pebble and dead broken shell substrata located along the eastern outer coast at the foot of a bedrock face (photo 167).

Soft substrata

Inshore areas of Flea Bay near the beach were characterised by rippled sand substratum (Figure 6, Plate 5). The rippled appearance is probably due to the effects of wave action in these shallow inshore areas. With increasing distance from the beach and in depths > 9 m, the soft substrata inside Flea Bay was characterised by what appeared to be fine

sand-silt substrata (Figure 6, Plate 6). In this area, the substrata also appeared to grade from coarser in the western to finer nearing the eastern edges of Flea Bay.

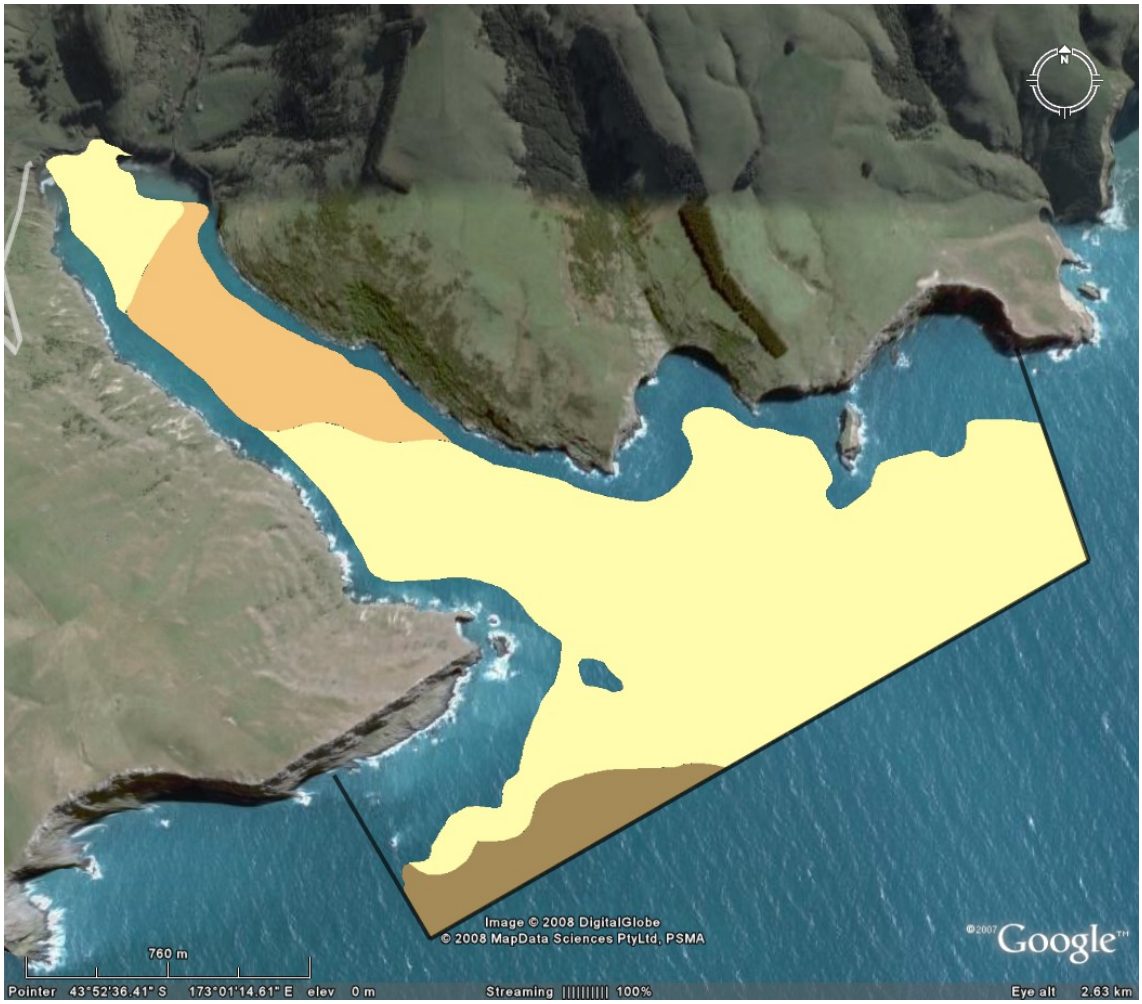


Figure 6. Location of soft substrata located within Pohatu Marine Reserve. Yellow = rippled sand, orange = sand and silt, brown = silt, clay, shell.

With decreasing proximity to the headlands of Flea Bay (460 m distance in the east and 760 m in the west), the substrata was again characterised by rippled sand (Figure 6, Plate 7). Within this strata there were small areas, usually located around the foot of rocky areas, where ripples were relatively large (mega-ripples). In these areas, components of broken shell and granule-sized material were also observed. Although these areas were deeper than the fine sand-silt zone, it is probably the influence of wave action that has resulted in the ripples and the domination of sand-sized particles.

Plate 5. Rippled sand from inshore areas of Flea Bay (photo 124).

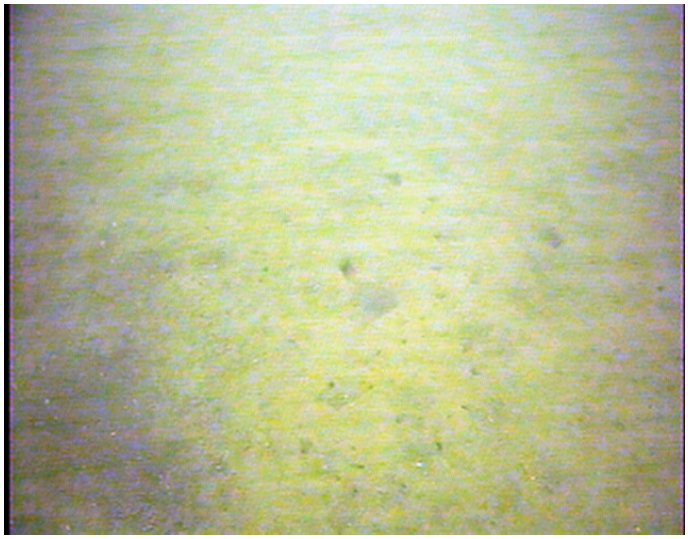


Plate 6. Fine sand-silt substrata located from central areas of Flea Bay > 9 m depth (photo 124).

Only one photograph from the soft substrata zone located at depths > 35 m could be interpreted due to low light combined with high turbidity. Photograph 219 was collected from 36 m depth and appeared only slightly rippled and characterised by relatively fine sediment, probably silt with a component of dead shell.

Plate 7. Rippled sand from offshore areas of the entrance and central offshore areas of Pohatu Marine Reserve (photo 46).

The area (in hectares and percentage of the total reserve area) of each substrata was calculated from polygons and have been displayed in Table 1. Soft substrata occupy the largest area of the reserve (74%), mostly represented by sand substrata. Rocky shores were relatively equally spread between western and eastern shores being (Table 1).

Table 1. Area and percentage of the Pohatu Marine Reserve occupied by each major substrata.

Substrata	Ha	% of total
Rippled sand (inner Flea Bay)	7.3	3.4
Fine sand, silt (inner Flea Bay)	20	9.2
Rippled sand (outer coast)	119	55.0
Silt, sand, shell (outer coast)	13	6.0
Boulder, cobble, sand (inner Flea Bay)	2.2	1.0
Rock, boulder, cobble (west)	28	12.9
Rock, boulder, cobble (east)	27	12.5
Total	216.5	100

4.3 Biological communities

The biological communities inhabiting Pohatu Marine Reserve vary depending on environmental variables including substrata, wave exposure/shelter, water clarity/turbidity and sedimentation. Plants and animals inhabit areas where environmental variables are suitable to their colonisation and growth. Particular species, often termed "key species", become dominant where conditions suit and can be used to visually identify a habitat.

Based on dominant species or physical variables observed from drop camera photographs, major biological habitats have been mapped for Pohatu Marine Reserve (Figure 7).

Hard substrata habitats

Three major hard substrata habitats were mapped during the present study:

- *Carpophyllum* forest
- Sheltered, shallow rocky barren
- Encrusting community from exposed rock

Carpophyllum forest was dominated by the macroalgae *Carpophyllum fleuosum* and *C. maschallocarpum* (Plate 8). Other macroalgal species known from this area include coralline paint and turf, *Xiphophora gladiata*, *Marginariella urvilliana, and Landsburgia quercifolia.* Rocky shores with high percentage cover of these macroalgae were located within Flea Bay along most of the western shoreline and from the inner eastern shoreline of Flea Bay (Figure 7).

An area dominated by shallow rock (boulders, cobbles, pebbles) that was relatively devoid of macroalgae was recorded from the inner western shoreline of Flea Bay (Figure 7, Plate 9). This area is relatively sheltered and shallow and may be devoid of algae due to intermittent smothering by sand or fine sediment substrata. Other areas of boulder barrens were observed from drop camera photographs along the western rocky edge of Flea Bay proper, however they were too localised to map. There did not appear to be any common depth regime or pattern to the location of these barrens.

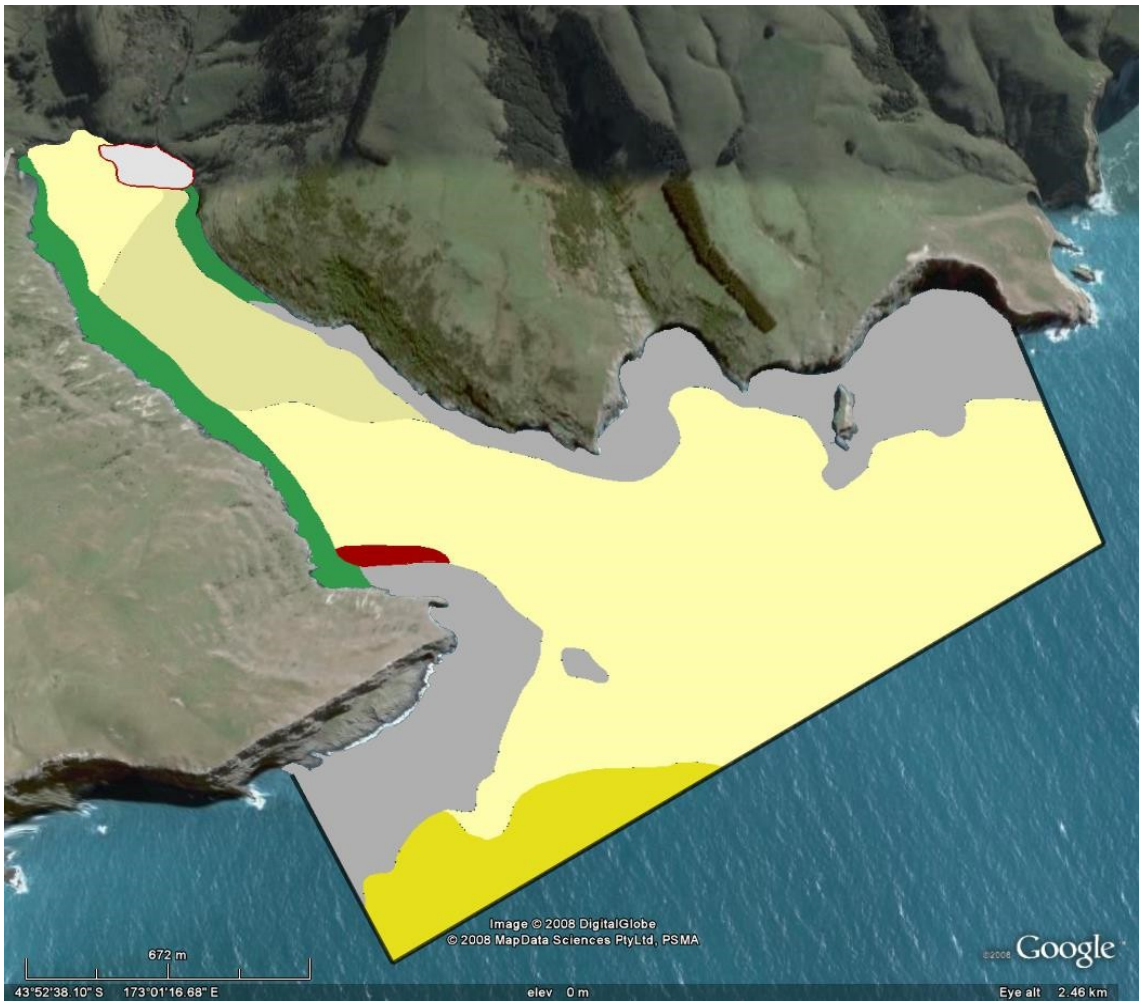


Figure 7. Location of habitat and community types located within Pohatu Marine Reserve. Pale yellow = mobile sand habitat, fawn = stable sand habitat, bright yellow = deep mud, shell habitat, red = red algal bed on soft substrata, pale grey = shallow rock barren, medium grey -= encrusting rock community (exposed), and green = *Carpophyllum* forest.

For exposed rocky shores along the outer coast and for the eastern shoreline of Flea Bay, the rocky substrata was characterised by relatively little macroalgae. Macroalgae that were observed were often growing as epiphytes on sea tulips (Plate 10). Instead these areas were dominated by encrusting invertebrate communities and crustose and turfing coralline algae. Invertebrates were dominated by mussels (*Perna canaliculus*), sea tulip (*Pyura pachydermatina),* anemone (*Actinothoe albocincta*), unidentified sponges and a

variety of bryozoans. It is probable that macroalgae were more common in the shallows < 8 m depth (e.g. *Durvillaea willana*, *Lessonia variegata*), however these areas were not photographed due to wave conditions.

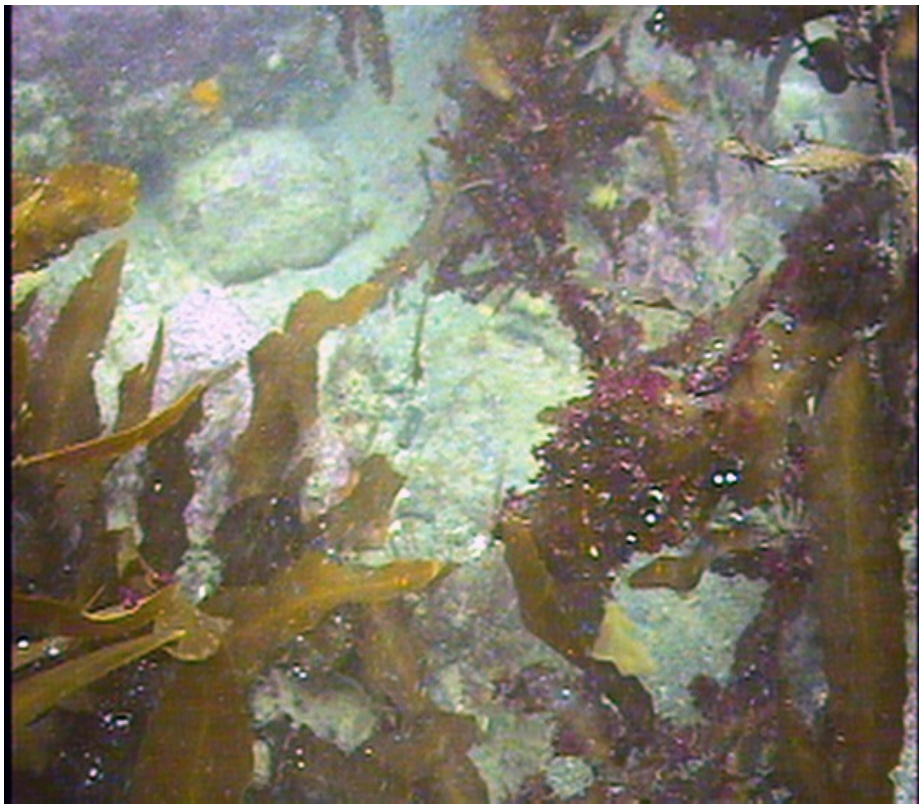


Plate 8. *Carpophyllum flexuosum* forest growing on rock located along the western shoreline of Flea Bay (photo 32).

Plate 9. Rocky barren located from the inner eastern shoreline of Flea Bay (photo 122).

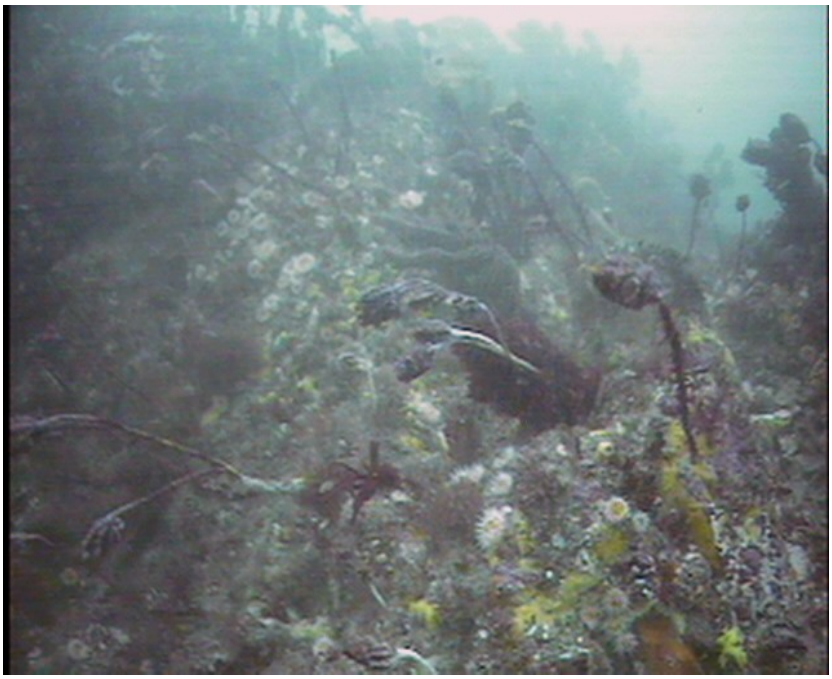


Plate 10. Encrusting community located from the exposed rocky shores outside Flea Bay (photo 154).

Soft substrata habitats

The infaunal community of soft substrata habitats have not been sampled. The following habitat descriptions have been based on physical observation of the sediment surface. Three major soft substrata habitats were mapped during the present study, however more soft sediment types were observed from localised areas. Habitats were:

- rippled, mobile sand flat habitat
- stable shallow sand flat habitat
- red algal bed
- deep mud, shell flat habitat

Rippled sand substrata was recorded from shallow areas of inner Flea Bay and from the entrance and outer coast < 35 m depth (Plate 5 and 7). The ripples are a result of wave action moving soft sediment particles. The mobile nature of this habitat results in a biological community able to cope with regular disturbance. It is probable that these areas are dominated by relatively rapid colonisers such as amphipods, isopods and polychaete worms. Particular species of bivalves may also be present in this mobile habitat. Rippled sand was recorded in relatively deep areas. It is probable that this is a factor of the exposure to southerly storm events where relatively large waves are produced.

Stable shallow sand flats were recorded in the central area of Flea Bay. These areas were located in the sheltered environment of Flea Bay, below the depth where wave action disturbed the sediment resulting in ripples, but in a depth where sand was the dominant particle (Plate 6). This habitat is distinguished by the lack of ripples and the holes created by its infauna. As these areas are more stable than the rippled sand areas, they are likely to support a greater diversity of species including bivalves, amphipods, isopods, echinoderms, and decapods.

A relatively isolated area of sand substrata colonised by red algae was recorded from an area immediately inside the western head to Flea Bay (Figure 7, Plate 11). Red algae appeared to be attached to dead whole shell or pebble substrata. Occasional plants were observed from the eastern edge of Flea Bay (photo 71), but no areas that would be considered to constitute an algal bed were observed.

Deep mud and shell habitat was located in offshore deep areas of the reserve. Few photographs could be collected from this habitat due to low light and high turbidity.

These areas are below the influence of wave action and probably support a typical mud community dominated by echinoderms.

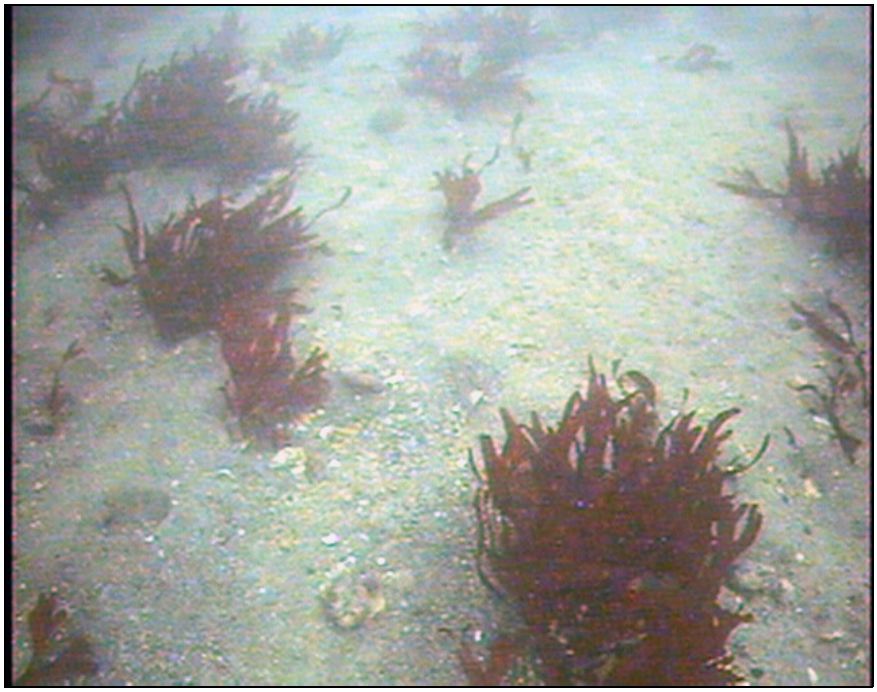


Plate 11. Red algal bed located from an area immediately inside Flea Bay (photo 31).

Fish

A variety of reef fish were observed from video footage collected from three stations near the western entrance to Flea Bay. Species most often observed from footage were blue moki, blue cod, banded wrasse and spotty. Occasional leatherjacket and scarlet wrasse were observed from video footage. In general a greater variety of species were observed from the two stations located at the western headland and on the outer coast compared to the station located within Flea Bay.

5.0 Discussion

The present report is the second part of a two part study aimed at mapping habitats from Pohatu Marine Reserve. The first part of the study involved the collection of side-scan sonar data (Rodger and Grange 2008). The second part of the study involved the collection of 221 drop camera photographs and 245 depth measurements from locations throughout the reserve. Based on these data, the present report describes:

- Major substrata types and boundaries
- Major habitat types and boundaries
- Major depth contours boundaries

It should be recognised, however, that these data have limitations and these are discussed in the following section.

5.1 Drop camera limitations

Drop camera photos were collected from 221 locations within the Pohatu Marine Reserve, however, not all areas could be sampled using this technique. Attempts to sample the deep areas in the south-western corner of the reserve were unsuccessful due to poor light and high turbidity. Inshore shallow areas close to the outer coast cliffs were not sampled due to ocean swell making it dangerous to operate the boat and drop camera equipment. As a result there are physical gaps in the data. It is therefore probable that the deep soft bottom habitat and substrata could be better described. In addition, it is probable that the outer coast has a shallower zone dominated by a mixed macroalgal forest.

When the drop camera reaches the sea floor, a photograph is collected. The photograph samples a small area of seabed. It is assumed that the photograph is a representation of the substrata and habitats for the general area of the sample. It is possible, however, that the photograph does not sample all habitats or substrata, or provides an inaccurate representation of the general area due to a substrata anomaly such as an isolated rock surrounded by sand. During fieldwork, the chance of this occurring was minimised by viewing the screen during the deployment and retrieval of the camera, viewing the benthos on the remote screen prior to the photograph collection and viewing of the depth sounder. The interpretation of benthic features was also supported by side-scan data.

5.2 Identification of habitat and substrata and their boundaries

Only habitats and substrata that occupied relatively large areas were identified during the present study. During the survey, other habitats and substrata were observed but these features were often isolated to one photograph. Examples of these features include mega-rippled sand, mega-rippled gravel and shell. These features appeared as narrow strips at the foot of some rock areas along the open coast.

5.3 Recommendations for future work

Substrata and habitat work conducted during the present study and NIWA study have been based on remote sampling techniques. Shears and Babcock (2007) conducted quantitative sampling of particular plants and animals, while Davidson *et al.* (2001) and Davidson and Abel (2003) quantitatively sampled target edible species.

To date, no diver work aimed at describing habitats, substrata and their distribution down the shore slope have been conducted in Pohatu Marine Reserve.

The following research is therefore recommended in relation to determination of substrata and habitat description and location:

- Collection of core samples from soft substrata habitats to determine grain size and infauna.
- Collection of shore profiles at representative locations to plot depth, distance, and major communities.
- Collection of video footage of shore profiles.

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Appendix 1. Drop camera stations, depths, coordinates, substratum and biology.

No. & Depth (m)	Coordinates	Substratum	Biogenic element
1, 1.6 m	43 52 10.76,173 00 13.82	Bedrock	Brown macroalgae
2, 1.9m	43 52 10.69,173 00 14.05	Boulder	Brown macroalgae
3, .1.8m	43 52 10.63,173 00 14.47	Sand (rippled)	
4, 1.8 m	43 52 12.95,173 00 13.37	Bedrock	Brown macroalgae
5, 4.6.m	43 52 12.85,173 00 15.16	Sand (rippled)	Sea lettuce
6, 3 m	43 52 12.59,173 00 14.48	Bedrock	Brown macroalgae
7, 3 m	43 52 16.32,173 00 15.16	Bedrock	Brown macroalgae
8, 6.4 m	43 52 15.97,173 00 15.99	Boulder, cobble, sand	
9, 6.5 m	43 52 15.38,173 00 17.28	Boulder, cobble, sand	
10, 7.3 m	43 52 14.71,173 00 17.67	Sand (rippled)	
11, 9.9 m	43 52 19.35,173 00 20.32	Sand (rippled)	
12, 7.6 m	43 52 19.66,173 00 19.52	Bedrock	Brown macroalgae
13, 4.5 m	43 52 20.03,173 00 18.36	Bedrock	Brown macroalgae
14, 4.5 m	43 52 23.87,173 00 22.49	Bedrock	Brown macroalgae
15, 7.9 m	43 52 23.03,173 00 23.01	Sand, cobble	
16, 11.1 m	43 52 22.81,173 00 24.47	Boulder, cobble	Brown macroalgae (sparse)
17, 11.2 m	43 52 22.16,173 00 24.88	Sand	
18, 11.8 m	43 52 24.81,173 00 28.79	Sand, pebble	
19, 10.3 m	43 52 25.47,173 00 28.96	Bedrock, boulder	Brown macroalgae
20, 4 m	43 52 27.06,173 00 28.17	Bedrock	Brown macroalgae
21, 13.4 m	43 52 29.18,173 00 35.84	Sand	
22, 11.2 m	43 52 29.97,173 00 35.54	Boulder, cobble	
23, 4.4m	43 52 30.70,173 00 34.90	Bedrock	Brown macroalgae
24, 14.5 m	43 52 33.01,173 00 43.31	Sand (rippled)	
25, 14.3 m	43 52 34.22,173 00 42.85	Sand (rippled)	
26, 8.8 m	43 52 35.05,173 00 42.47	Bedrock, boulder	
27, 15.7 m	43 52 39.01,173 00 50.52	Sand (rippled)	
28, 11 m	43 52 40.77,173 00 49.06	Sand (rippled)	
29, 6.8 m	43 52 41.05,173 00 48.84	Bedrock	Brown macroalgae (sparse)
30, 11.5 m	43 52 43.10,173 00 52.86	Sand, shell	Red macroalgae
31, 13.3 m	43 52 42.72,173 00 51.17	Sand, shell	Red macroalgae
32, 8.5 m	43 52 43.25,173 00 50.65	Bedrock	Brown macroalgae
33, 15.7 m	43 52 42.74,173 00 58.75	Sand, shell, pebble	Red macroalgae
34, 7.4 m	43 52 44.07,173 00 58.56	Boulder, cobble, sand, shell	
35, 21 m	43 52 42.41,173 01 06.18	Sand (rippled)	
36, 18.5 m	43 52 44.15,173 01 05.83	Boulder, cobble	
37, 11 m	43 52 45.20,173 01 05.41	Boulder, cobble	
38, 9 m	43 52 46.48,173 01 06.12	Bedrock, boulder, cobble	
39, 24.9 m	43 52 45.45,173 01 14.12	Sand (rippled)	
40, 20.9 m	43 52 47.91,173 01 11.29	Cobble, boulder	
41, 15.1 m	43 52 48.78,173 01 09.81	Bedrock	Anemone, sea tulip
42, 9.6 m	43 52 50.03,173 01 08.30	Bedrock, boulder	Anemone, red algae
43, 16.9 m	43 52 51.53,173 01 10.42	Bedrock	Anemone, sea tulip
44, 25 m	43 52 48.73,173 01 12.89	Boulder, cobble	
45, 25.3 m	43 52 46.91,173 01 14.98	Sand (rippled)	
46, 24.7 m	43 52 42.56,173 01 19.61	Sand (rippled)	
47, 24.4 m	43 52 37.53,173 01 24.80	Sand (rippled)	
48, 23.9 m	43 52 32.38,173 01 28.62	Bedrock	Anemone
49, 24 m	43 52 29.79,173 01 30.33	Sand (rippled)	
50, 24.3 m	43 52 27.65,173 01 30.55	Bedrock	
51, 18.7 m	43 52 34.77,173 01 23.02	Bedrock	Anemone, sea tulip
52, 24 m	43 52 37.81,173 01 20.43	Sand (rippled)	
53, 15.1 m	43 52 35.85,173 01 20.82	Bedrock	Anemone
54, 23 m	43 52 35.66,173 01 14.41	Sand (rippled)	
55, 19 m	43 52 34.89,173 01 15.12	Bedrock	Anemone
56, 21.5 m	43 52 33.77,173 01 10.34	Boulder, cobble	
57, 23 m	43 52 35.21,173 01 12.41	Sand (rippled)	
58, 2.5 m	43 52 09.88,173 00 27.44	Cobble, boulder	

Appendix 1 (cont.). Camera stations, depths, coordinates, substratum and biology.

No. & Depth (m)	Coordinates	Substratum	Biogenic element
59, 4.6 m	43 52 12.88,173 00 28.67	Sand, silt	
60, 3.2 m	43 52 11.93,173 00 30.06	Sand, silt	
61, 2.0 m	43 52 11.10,173 00 31.03	Sand (rippled)	
62, 1 m	43 52 10.58,173 00 31.54	Bedrock	Brown macroalgae
63, 5.6 m	43 52 14.51,173 00 30.11	Cobble, pebble, silt	Brown macroalgae (sparse)
64, 2.7 m	43 52 13.72,173 00 31.34	Bedrock	Brown macroalgae
65, 8. m	43 52 17.72,173 00 32.42	Silt, pebble, shell	
66, 6 m	43 52 16.90,173 00 33.10	Bedrock	Brown macroalgae
67, 12.8 m	43 52 20.38,173 00 36.05	Silt	
68, 8.4 m	43 52 19.88,173 00 37.02	Bedrock	Brown macroalgae
69, 13.7 m	43 52 22.81,173 00 42.24	Silt	
70, 11.2m	43 52 22.13,173 00 42.81	Bedrock	
71, 12.7 m	43 52 24.59,173 00 48.55	Shell, silt, pebble	Red macroalgae
72, 9.5 m	43 52 23.57,173 00 49.72	Sand, shell	
73, 6.1 m	43 52 22.96,173 00 50.13	Bedrock	Brown macroalgae
74, 16.3 m	43 52 28.08,173 00 54.88	Boulder, cobble, silt	
75, 9 m	43 52 27.22,173 00 56.02	Bedrock	Brown, red macroalgae
76, 15.5 m	43 52 27.83,173 00 49.18	Sand (rippled)	
77, 15.3 m	43 52 26.26,173 00 50.28	Silt	
78, 6.6 m	43 52 24.89,173 00 51.58	Bedrock, boulder	
79, 17.6 m	43 52 30.36,173 00 58.99	Cobble, silt	
80, 12.8 m	43 52 29.74,173 00 59.34	Boulder, cobble	
81, 18.8 m	43 52 32.82,173 01 05.10	Boulder, cobble, silt	
82, 12.7 m	43 52 31.89,173 01 05.84	Boulder, bedrock	
83, 20.9 m	43 52 33.85,173 01 05.65	Rippled sand	
84, 22.8 m	43 52 35.10,173 01 10.52	Ripled sand	
85, 15.5 m	43 52 32.61,173 01 11.91	Boulder, bedrock	
86, 30.3 m	43 52 54.05,173 01 18.73	Rippled sand	
87, 27.7 m	43 52 48.98,173 01 19.06	Mega rippled sand	
88, 17.3 m	43 52 50.53,173 01 17.95	Bedrock	Sea tulip, red algae
89, 13.3 m	43 52 50.43,173 01 15.95	Bedrock	Sea tulip
90, 27.2 m	43 52 49.38,173 01 17.21	Mega rippled sand, shell	
91, 21 m	43 52 51.92,173 01 20.01	Bedrock	Sea tulip, mussel
92, 29.4 m	43 52 59.71,173 01 07.82	Bedrock, rippled sand	
93, 14.2 m	43 52 57.40,173 01 05.17	Bedrock, boulders	Red algae, anemone
94, 39 m	43 53 11.26,173 00 54.69	Unknown	
95, 35 m	43 53 07.70,173 00 55.47	Unknown	
96, 7.2m	43 53 04.79,173 00 50.24	Bedrock	Sea tulip, red algae
97, 24.5 m	43 53 06.89,173 00 49.97	Cobble, shell	
98, 11 m	43 53 04.92,173 00 44.84	Bedrock	
99, 10.5 m	43 53 03.31,173 00 49.29	Bedrock, boulder	Red algae
100, 13 m	43 53 02.33,173 00 55.71	Bedrock	Sea tulip, red algae
101, 10. m	43 53 00.03,173 01 00.12	Bedrock	Sea tulip, red algae
102, 9.2 m	43 52 56.81,173 01 03.55	Bedrock	Sea tulip, red algae
103, 8.6 m	43 52 53.15,173 01 05.88	Bedrock	Sea tulip, red algae
104, 27 m	43 52 54.87,173 01 12.20	Rippled sand	
105, 23 m	43 52 54.70,173 01 09.78	Bedrock	Sponge, anemone
106, 24 m	43 52 50.06,173 01 12.38	Boulder, bedrock	
107, 23.5 m	43 52 42.86,173 01 11.36	Rippled sand	
108, 22m	43 52 39.23,173 01 04.75	Rippled sand	
109, 19.5 m	43 52 36.68,173 00 59.64	Rippled sand	
110, 17.5 m	43 52 34.01,173 00 53.56	Rippled sand	
111, 16 m	43 52 31.10,173 00 46.86	Rippled sand, silt	
112, 14 m	43 52 26.41,173 00 38.49	Sand, silt	
113, 13.2 m	43 52 22.04,173 00 31.09	Sand, silt	
114, 11.2 m	43 52 16.47,173 00 25.53	Sand, silt	
115, 4.7 m	43 52 11.21,173 00 22.43	Rippled sand	

Appendix 1 (cont.). Camera stations, depths, coordinates, substratum and biology.

No. & Depth (m)	Coordinates	Substratum	Biogenic element
116, 1 m	43 52 07.87,173 00 20.60	Rippled sand	
117, 0.6 m	43 52 06.95,173 00 23.19	Boulders, sand	
118, 0.4 m	43 52 07.48,173 00 26.21	Boulders, cobbles	Brown macroalgae, mussels
119, 0.1 m	43 52 08.51,173 00 31.14	Boulders, cobbles	Sea lettuce
120, 4 m	43 52 10.60,173 00 23.30	Rippled sand	
121, 2.8 m	43 52 09.80,173 00 19.49	Rippled sand	
122, 1.8 m	43 52 08.64,173 00 23.45	Cobbles, silt	
123, 2.8 m	43 52 09.63,173 00 23.16	Boulders, cobbles	
124, 3m	43 52 10.07,173 00 21.60	Rippled sand	
125, 2m	43 52 10.03,173 00 26.73	Cobbles, rippled sand	
126, 4.4 m	43 52 11.54,173 00 26.84	Rippled sand	
127, 14.4 m	43 52 25.66,173 00 45.48	Silt	
128,12.8 m	43 52 23.07,173 00 45.45	Cobbles, boulders	
129, 14.2 m	43 52 24.33,173 00 44.94	Silt	
130, 16.4 m	43 52 29.96,173 00 51.72	Silt	
131, 15.8 m	43 52 27.60,173 00 52.57	Silt	
132, 11.9 m	43 52 26.21,173 00 52.70	Bedrock, boulders	
133, 24.8 m	43 52 33.24,173 01 27.86	Cobbles	
134, 19.8 m	43 52 32.10,173 01 24.14	Boulders, cobbles	
135, 25.2 m	43 52 36.87,173 01 29.57	Rippled sand	
136, 25 m	43 52 33.17,173 01 30.66	Rippled sand	
137, 24.2 m	43 52 31.25,173 01 31.05	Rippled sand	
138, 21 m	43 52 28.63,173 01 26.63	Bedrock	
139, 24 m	43 52 26.46,173 01 29.17	Bedrock, boulders	
140, 25 m	43 52 30.03,173 01 33.57	Rippled sand	
141, 22.8 m	43 52 28.36,173 01 34.79	Bedrock, boulders	
142, 24.7 m	43 52 29.49,173 01 38.28	Bedrock, boulders	
143,25.8 m	43 52 30.92,173 01 41.31	Rippled sand, shell	
144, 19.5 m	43 52 28.28,173 01 44.25	Bedrock, boulder, cobble, shell	
145, 8 m	43 52 27.00,173 01 47.62	Boulders, cobbles	
146, 6.8 m	43 52 27.45,173 01 51.79	Bedrock	Red algae
147, 18.8 m	43 52 32.78,173 01 51.42	Bedrock	
148, 27 m	43 52 35.08,173 01 51.69	Rippled sand	
149, 26 m	43 52 32.29,173 01 59.07	Bedrock	
150, 29.8 m	43 52 31.97,173 02 06.91	Rippled sand	
151, 16.8 m	43 52 27.57,173 02 06.08	Bedrock	Anemone
152, 7.5 m	43 52 23.21,173 02 03.45	Bedrock	Red algae, sea tulip
153, 5.5 m	43 52 24.47,173 01 57.82	Bedrock	Red algae
154, 11 m	43 52 28.95,173 01 57.68	Bedrock	Red algae, sea tulip, anemone
155, 19 m	43 53 06.66,173 00 53.18	Bedrock	
156, 13 m	43 53 05.42,173 00 54.12	Bedrock	Mussels, anemone
157, 24 m	43 53 02.17,173 01 04.43	Bedrock	
158, 17 m	43 52 51.68,173 01 19.04	Bedrock	Anemone, mussels
159, 15 m	43 52 51.07,173 01 16.43	Bedrock	Sponge
160, 19 m	43 52 35.54,173 01 23.97	Rock	Sponge, sea tulip
161, 24 m	43 52 34.71,173 01 45.77	Gravel	
162, 15 m	43 52 34.97,173 01 45.84	Bedrock	Sea tulip
163, 17 m	43 52 34.25,173 01 48.22	Bedrock	Sea tulip, anemone
164, 14 m	43 52 33.40,173 01 45.78	Boulders, cobbles	Mussels
165, 19 m	43 52 31.83,173 01 44.74	Boulder, bedrock	
166, 25 m	43 52 32.27,173 01 43.98	Gravel	
167, 23 m	43 52 30.13,173 01 43.02	Gravel, cobble	
168, 19 m	43 52 29.98,173 01 43.86	Bedrock	Sponge, anemone
169, 21 m	43 52 28.97,173 01 41.41	Boulders, cobbles	
170, 24 m	43 52 30.22,173 01 40.99	Boulders, gravel	
171, 25 m	43 52 30.91,173 01 37.31	Gravel, sand, shell	
172, 21 m	43 52 35.66,173 01 46.77	Bedrock	

Appendix 1 (cont.). Camera stations, depths, coordinates, substratum and biology.

No. & Depth (m)	Coordinates	Substratum	Biogenic element
173, 26 m	43 52 37.77,173 01 47.94	Rippled sand	
174, 24 m	43 52 36.50,173 01 45.05	Rippled sand	
175, 20 m	43 52 35.64,173 01 45.22	Bedrock	Sponge, anemone
176, 25m	43 52 35.49,173 01 44.41	Rippled sand	
177, 23 m	43 52 34.74,173 01 49.42	Boulders, cobbles	
178, 27 m	43 52 31.98,173 01 57.27	Gravel	
179, 23 m	43 52 30.99,173 01 55.50	Bedrock	Anemone
180, 26 m	43 52 33.42,173 01 53.44	Rippled sand	
181, 21 m	43 52 31.18,173 01 53.41	Boulders	
182, 12.8 m	43 52 26.53,173 01 58.81	Bedrock, boulder	
183, 29 m	43 52 30.27,173 02 06.36	Rippled sand	
184, 23 m	43 52 28.97,173 02 04.86	Boulders, cobbles	
185, 28.5 m	43 52 30.03,173 02 02.78	Mega rippled sand, shell	
186, 24 m	43 52 28.84,173 02 02.15	Bedrock	Sponges
187, 20.5 m	43 52 28.31,173 02 01.84	Bedrock, boulders	
188, 18 m	43 52 29.19,173 02 00.22	Boulders, bedrock	Songe, bryozoan
189, 20.5 m	43 52 31.50,173 02 00.57	Bedrock	Sponge, bryozoan
190, 27.5 m	43 52 32.84,173 02 00.75	Rippled sand	
191, 27 m	43 52 33.00,173 01 58.49	RIppled sand	
192, 27.5 m	43 52 50.76,173 01 19.76	Rippled sand, shell	
193, 21 m	43 52 52.43,173 01 19.97	Bedrock	
194, 29 m	43 52 52.85,173 01 20.95	Mega rippled sand	
195, 29 m	43 52 53.07,173 01 18.20	Rippled sand	
196, 28 m	43 52 52.05,173 01 16.06	Mega rippled sand, shell	
197, 15 m	43 52 51.62,173 01 16.58	Bedrock	Sea tulip, mussel, sponge
198, 27.5 m	43 52 50.24,173 01 14.38	Mega rippled sand, shell	
199, 26.5 m	43 52 49.56,173 01 14.94	Mega rippled sand, shell	
200, 28 m	43 52 52.66,173 01 12.78	Rippled sand, pebbles	
201, 19.5 m	43 52 51.72,173 01 11.27	Boulders, cobbles	Anemone
202, 11 m	43 52 52.84,173 01 08.89	Boulders, bedrock	Red algae, anemone
203, 23.5 m	43 52 57.19,173 01 07.81	Boulders	
204, 28.5 m	43 52 57.46,173 01 10.61	Rippled sand, silt, shell	
205, 33.3 m	43 53 00.25,173 01 10.45	Rippled sand	
206, 25.5 m	43 53 02.80,173 01 05.29	Bedrock	Sponge
207, 27.5 m	43 53 03.02,173 01 06.46	Rippled sand	
208, 33 m	43 53 03.79,173 01 02.08	Pebbles, sand, shell	
209, 21 m	43 53 02.66,173 01 00.20	Bedrock, boulders	Anemone, bryozoan
210, 24 m	43 53 05.00,173 00 58.23	Bedrock, pebble, sand, shell	
211, 1.2 m	43 52 09.85,173 00 14.46	Rippled sand	
212, 1 m	43 52 09.03,173 00 13.68	Ripppled sand	
213, 1.3 m	43 52 08.13,173 00 15.91	Ripppled sand	
214, 4.5 m	43 52 11.32,173 00 17.11	Ripppled sand	
215, 30.5 m	43 52 49.34,173 01 43.72	Rippled sand	
216, 25 m	43 53 07.47,173 00 56.33	Bedrock	Bryozoan
217, 24 m	43 53 05.80,173 00 58.24	Pebble, sand, shell	
218, 34 m	43 53 09.79,173 00 53.54	Bedrock	
219, 36 m	43 53 10.95,173 00 49.80	Sand, silt	
220, 34 m	43 53 09.20,173 00 50.85	Bedrock	
221, 3 m	43 53 03.72,173 00 50.93	Bedrock	

Appendix 2. Depth sample locations and location of video footage.

No. & Depth (m)	Coordinates
222,, 26.5 m	43 52 42.67,173 01 29.44
223, 26.5m	43 52 40.86,173 01 36.69
224, 28 m	43 52 37.83,173 01 53.79
225, 29.5 m	43 52 37.59,173 02 00.74
226, 30 5 m	43 52 37.82,173 02 09.20
227, 31.5 m	43 52 42.81,173 02 11.11
228, 33.5 m	43 52 46.77,173 02 15.10
229, 34 m	43 52 50.62,173 02 05.16
230, 32 m	43 52 48.34,173 01 55.52
231, 34.5 m	43 52 54.73,173 01 55.88
232, 32 m	43 52 52.54,173 01 43.38
233, 29 m	43 52 46.29,173 01 39.09
234, 28.5 m	43 52 48.36,173 01 30.72
235, 32 m	43 52 54.11,173 01 31.07
236, 35 m	43 53 00.50,173 01 37.39
237, 34.4 m	43 52 58.42,173 01 26.86
238, 36 m	43 53 03.17,173 01 23.33
239, 37.5 m	43 53 07.29,173 01 25.02
240, 37.5 m	43 53 04.74,173 01 13.48
241, 39 m	43 53 12.04,173 01 11.34
242, 39.5 m	43 53 10.49,173 01 03.88
243, 40 m	43 53 16.44,173 01 03.12
244, 40 m	43 53 19.44,173 00 57.38
245, 41 m	43 53 14.24,173 00 54.27
VIDEO 1	43 52 47.46,173 01 06.00
VIDEO 2	43 52 42.68,173 00 49.11
VIDEO 3	43 52 50.80,173 01 07.66