Intertidal and subtidal habitats of Mimiwhangata Marine Park and adjacent shelf

DOC RESEARCH & DEVELOPMENT SERIES 201

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Published by
Department of Conservation
PO Box 10–420
Wellington, New Zealand

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Individual contributions to the series are first released on the departmental website in pdf form. Hardcopy is printed, bound, and distributed at regular intervals. Titles are also listed in our catalogue on the website, refer http://www.doc.govt.nz under Publications, then Science and research.

ISSN 1176-8886
ISBN 0-478-22678-0

This is a client report commissioned by Northland Conservancy and funded from the Science Advice Fund. It was prepared for publication by Science & Technical Publishing Section; editing and layout by Lynette Clelland. Publication was approved by the Chief Scientist (Research, Development & Improvement Division), Department of Conservation, Wellington, New Zealand.

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ABSTRACT

The habitat maps of the marine area at Mimiwhangata Marine Park and Paparahi Point, northen New Zealand, completed in 1973 and 1981 respectively, have been updated and extended. Areas of seafloor between 33 m and 100 m depth were surveyed using a combination of remote operated vehicle (ROV) drop video, and side-scan and single-beam sonar techniques. Aerial photographs were used to map shallow (< 12 m depth) habitats and to assess historical changes in the distribution and extent of algal forest. A map of physical and biological habitats was produced covering an area of approximately 8700 ha. A significant finding was that extensive long-term habitat change has occurred in the shallow rock reef habitats at Mimiwhangata. The change is an increase in the 'urchin (kina, *Evechinus chloroticus*) barrens' or urchin (kina)-grazed zone. This has extended upwards into the lower depths of the shallow mixed weed habitat and downwards into the kelp forest zone dominated by common kelp (*Ecklonia radiata*). The offshore deep reefs of the Mimiwhangata system are a species-rich and ecologically important habitat. The past history of scientific study at Mimiwhangata coupled with the variety of habitats and diversity of marine life present suggest that Mimiwhangata is an ideal candidate site for greater marine protection and further scientific inquiry.

Keywords: Mimiwhangata, habitat mapping, aerial photography, habitat change, habitat map, kina barrens, urchin barrens, kina-grazed zone, urchin-grazed zone, algal forest decline, predator removal hypothesis, deep reefs, marine reserve boundaries, New Zealand.

Kerr, V.; Grace, R. 2005: Intertidal and subtidal habitats of Mimiwhangata Marine Park and adjacent shelf. *DOC Research & Development Series 201*. Department of Conservation, Wellington. 55 p.

1. Introduction

The Mimiwhangata Marine Park (visitor car park: 35°26′38″S, 174°25′29″E) is located approximately halfway between Whangarei Harbour and Cape Brett on Northland's east coast, North Island, New Zealand. The land adjacent to the Marine Park is a Coastal Park, managed as a farm and conservation area. The Marine Park, established in 1984, covers 15.4 km of coastline to 1 km offshore. It has a total area of 1890 ha (Fig. 1). The Marine Park is partially protected under the Fisheries Act. Commercial fishing is banned and recreational fishing with single hook and unweighted line is permitted. The Mimiwhangata peninsula extends seaward just over 1 km, forming an array of bays and shallow reef environments. A set of small offshore islands adds further variety to the underwater topography and habitats.

The marine area of Mimiwhangata was the subject of considerable scientific interest and study between 1972 and 1987. Ballantine et al. (1973) mapped and described intertidal and shallow subtidal habitats. A combination of mapping approaches was used to produce the 1973 habitat map: aerial photography, diving surveys and a descriptive habitat classification which combined dominant physical features with major biological communities. The Ballantine et al. (1973) investigation briefly explored the deeper areas off Mimiwhangata with scuba and a preliminary description of the deep reef sponge-dominated habitat was made. The report also recommended that 'urgent and immediate steps are taken to negotiate for a Marine Park Reserve under the Marine Reserves Act (1971). The rich variety of fishes and marine life around Mimiwhangata is highly susceptible to exploitation and full protection is needed.'

In 1981, a habitat map of the subtidal area off Paparahi Point adjacent to the Marine Park (Fig. 1) was completed by Grace (1981b) using an updated habitat classification developed by Ayling et al. (1981).

The present study at Mimiwhangata involved a series of investigations between 2001 and 2004. This work has updated the 1973 and 1981 habitat maps (Ballantine et al. 1973; Grace 1981b) and extended habitat description and mapping into the deeper water surrounding the Marine Park. Where there was adequate pre-existing information, the investigation aimed to identify and document any habitat change over the thirty years since the original 1973 study. In addition to the habitat investigation, species monitoring was carried out on permanent transects set up in the 1970s by Grace (1978, 1981a, 1984, 1985, 1986). From 1987 to 2001, monitoring at Mimiwhangata lapsed, despite the establishment of the Marine Park in 1983. The results of our species monitoring are reported in Grace & Kerr (2002, 2003, 2004). Auckland University established a fish and rock lobster (*Jasus edwardsii*) monitoring program with sites both within and outside the Marine Park and using modern methodology. This has enabled comparison of monitoring results at Mimiwhangata with those from other protected and reference areas (Denny & Babcock 2002; Usmar et al. 2003; Denny & Babcock 2004).

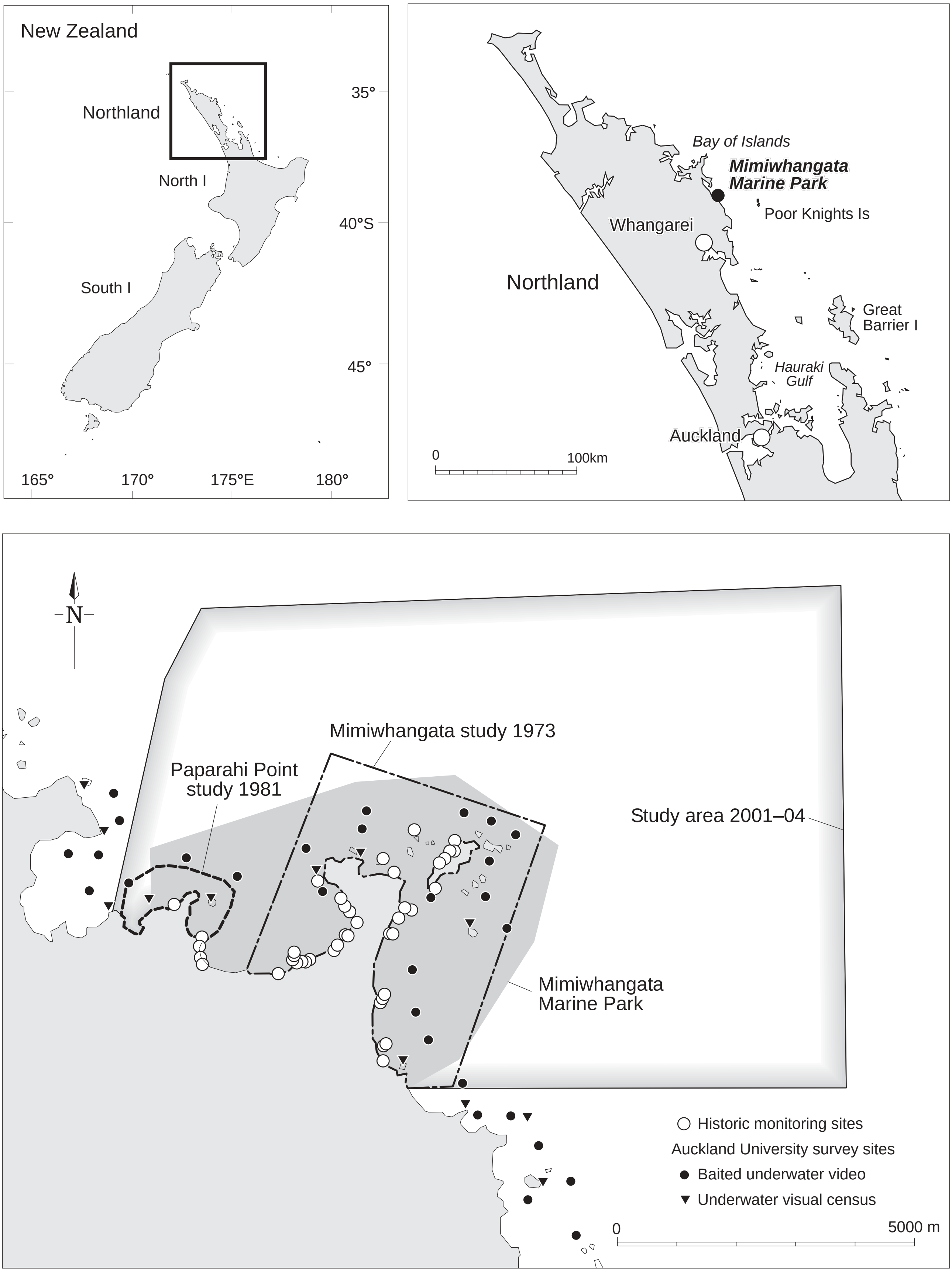

Figure 1. Location map, showing Mimiwhangata Marine Park boundary, outlines of Paparahi Point 1981 and Mimiwhangata 1973 habitat maps, historic transects and Auckland University survey sites.

2. Methods

2.1 HABITAT CLASSIFICATION AND DESCRIPTIONS

The habitat classification used in this study is based on work by Ballantine et al. (1973); Ayling (1978); Ayling et al (1981) and Grace (1981b, 1983). All of the habitat descriptions use a combination of physical substrate characteristics and groupings of habitat-forming macroalgae. Qualitative habitat descriptors were used to enable rapid mapping of the study area using a combination of sonar and video methods, dredge sampling and aerial photography. Table 1 compares historic habitat classifications with a current classification (Shears et al. 2004) and the one adopted for this study. The Shears et al. (2004) study examined the degree of concordance between qualitative habitat descriptors and quantitative species data from various locations along the northeastern coast of the North Island. They concluded that qualitative habitat descriptors for rocky reefs do accurately define biologically distinct species assemblages and are therefore an efficient means of mapping subtidal rocky reef habitats. It is worth noting that

TABLE 1. HABITAT CLASSIFICATIONS.

HABITAT PHOTOS This report	MIMIWHANGATA This report	NORTHEASTERN NEW ZEALAND Shears et al. 2004	PAPARAHI Grace 1981	LEIGH Ayling 1978	MIMIWHANGATA Ballantine et al. 1973
Fig. 8a	Sandy beach	No equivalent	Sandy beaches	No equivalent	Light-coloured sand beaches
Fig. 8b	Gravel beach	No equivalent	Gravel beaches	No equivalent	Dark-coloured sand beaches
Fig. 8c	Rocky shore	No equivalent	Rocky shores	No equivalent	Solid rock shores
Fig. 9	Shallow mixed weed	Shallow *Carpophyllum*	Shallow mixed weed	Shallow broken rock	Shallow exposed zone
Fig. 10	Kina barrens	Urchin barrens	Rock flats	Rock flats	Medium-depth without kelp
Fig. 11	Tangle-weed (kelp) forest	*Carpophyllum flexuosum* forest	*Carpophyllum flexuosum* forest	No equivalent	Shallow sheltered zone
Fig. 12	*Ecklonia* forest	*Ecklonia* forest	*Ecklonia* forest	*Ecklonia* forest	Medium-depth kelp bed
Fig. 13	*Ecklonia* forest mixed rock and sand	No equivalent	Mixed sand and rock	Mixed rock and sand	No equivalent
Fig. 14a	Sand / mud	No equivalent	Sand (sand / mud)	Sand and gravel (in part)	Clean sand
Fig. 14b	Gravel / cobble	No equivalent	Gravel (gravel / cobbles)	Sand and gravel (in part)	Coarse gravely sand, gravel
Fig. 14b	Gravel / cobble	Cobbles	Cobbles	Cobbles (in part)	Coarse gravely sand, gravel, cobbles
Fig. 15	Deep reef mixed rock and sand	No equivalent	No equivalent	No equivalent	No equivalent
Figs 16–18	Deep reef	No equivalent	No equivalent	No equivalent	No equivalent

Shears et al. (2004) describe five additional habitats on the shallow reef not used in this study: mixed algae, red foliose algae, turfing algae, *Caulerpa* mats and encrusting invertebrates. While all these habitat assemblages occur at Mimiwhangata, all but turfing algae occur in patches or mixed areas at spatial scales too small to map with the methods chosen for this study. Turfing algae would make up some of the habitat classified as 'urchin or kina barrens' in this study. The two algal types cannot be distinguished in aerial photos, which were used as the basis for mapping the shallow areas.

The area investigated in the present survey (Fig. 1) includes the entire Marine Park plus areas extending approximately 4 km beyond the Marine Park boundary to the north and east. The survey was completed in stages over three years. Each year, field work was carried out from February to June. Aerial photography was used to map habitats in shallow waters (< 12 m depth). In deeper waters, sonar methods were used. Video techniques were used in both shallow and deeper water to ground truth the resulting habitat classification. Information from the previous habitat maps and dive records from other investigations were also referred to. Following the sonar surveys, soft bottom areas were investigated in more detail with dredge surveys. The stages of work and equipment used are described in the following sections.

2.2 SIDE-SCAN SONAR SURVEY (2002) AND REMOTE OPERATED VEHICLE (ROV) GROUND TRUTHING

The side-scan equipment used was an Imagenex 858 Sonar Processor. The transducer frequency was 330 Khz, beam width 0.9º horizontal, 60º vertical, maximum range 240 m. The transducer was mounted on a towfish which was towed behind the vessel at 10–30 m off the seafloor. The sonar images were displayed in real time on a RGB monitor and recorded onto a SyQuest disc drive. The side-scan sonar is a colour imaging sonar system using a digital signal processing chip and a graphic processor chip. The processor outputs standard VGA video and so can be used with standard computer monitors. The track width range is selectable from 10 to 200 m and was generally used at 200 m. A number of different colour tables can be selected to represent sonar echo levels, thus assisting interpretation of the images. The system GPS interface records boat position and track plot. The survey vessel used—'MV Norseman' (Tutuakaka)—had a Furuno GP31, 12-channel receiver linked to a Furuno Chart Plotter navigation system. Position accuracy is estimated at 15 m. Win858 viewing software for Windows was used on an IBM-compatible computer to analyse images and produce the snapshot still images shown in this report.

The ROV system used was a modified Benthos Mini Rover MkII. The system has a maximum depth rating of 330 m and includes: 2 × 150-watt quartz halogen lights, a pan & tilt colour video camera, a single function claw device. The video records on mini-DV format.

Effort was concentrated on areas > 20 m deep east of Rimariki, but adjoining areas to the north and south were also surveyed in an attempt to locate reef edges and determine the overall extent of the reef system. The sonograph images from the side-scan sonar were analysed and classified into five initial habitat / substrate types:

- high-relief rocky reef with vertical structures > 3 m
- low-relief rock reef
- mixed reef and soft sediments
- gravel / cobble
- sand / muds

At each point along the image track, where the substrate / habitat classification was judged to have changed, the coordinates of the point were recorded (Fig. 2, Appendix 1). This subjective classification interpretation was informed by diving experience in some of the areas, and by previous experience with side-scan sonar and the ROV. Where rock structures were visible, representative areas were studied by measuring the sonar 'shadows' cast by the vertical structure. This gives a relatively accurate calibration of vertical features (Fish & Carr 1990). Classification of the side-scan image was also ground truthed with ROV video footage. With the inbuilt geo-referencing capability of the side-scan software and the GPS fixes that were taken on the video deployment, it was possible to accurately check the interpretation of the side-scan imagery with the video images. The ROV system used was manoeuvrable, enabling us to survey an area of reef of approximately 1000 m^2.

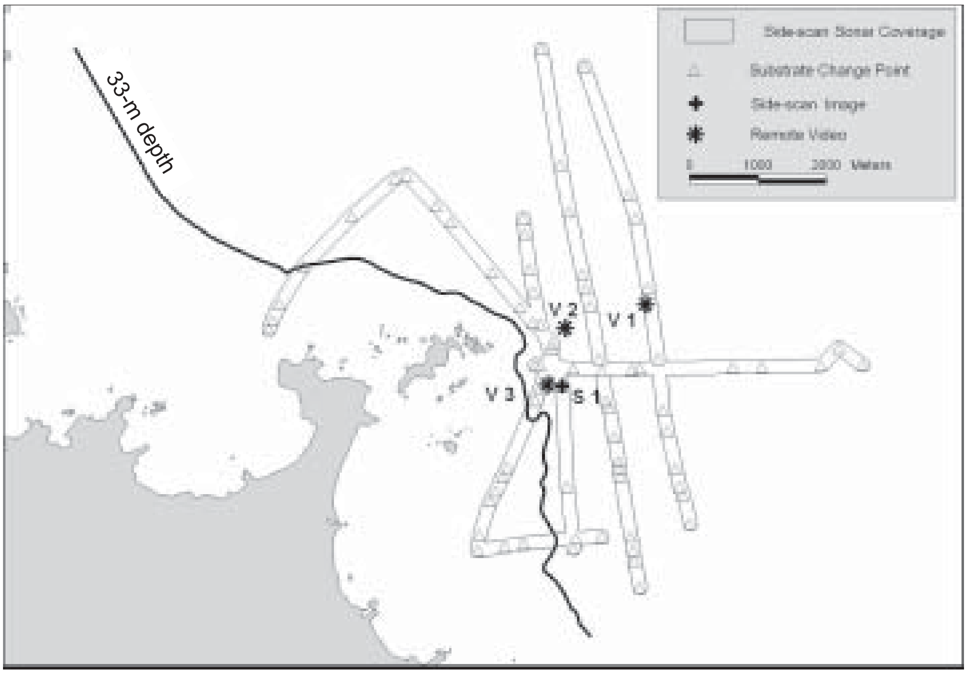

Figure 2. Side-scan tracks, ROV video sites (indicated V 1–3), side-scan image location indicated as S 1.

2.3 SINGLE-BEAM SONAR SURVEY (2003) AND DROP VIDEO GROUND TRUTHING

Following analysis of the initial side-scan sonar survey, it was decided to extend the sonar survey of the area as well as complete sufficient video surveying to allow mapping of broad habitat boundaries and to test interpretations of the sonar imagery. In several areas, a line of video drops approximately 100 m apart were made along a depth gradient. These yielded finer-scale information on depth-dependent boundaries of biological communities.

Because of limited resources and the relatively large scale of the investigation area, we used single-beam sonar in conjunction with a simple drop video ground truthing apparatus for the extended survey. The single-beam sonar method involved having the survey vessel travel a predetermined grid course, while one person constantly watched and evaluated the sonar image for any change in bottom substrate. Each time a change was observed, a GPS fix was taken and recorded along with the habitat change and depth. The same habitat classification was used as for the side-scan sonar. This resulted in a single line broken into a series of habitat segments.

Interpretation of the single-beam sonar takes some practice, and we spent considerable time practicing it with the skipper (P. Bendle) who has extensive experience with the equipment. Practice runs in known areas, and in areas where the bottom could be observed from the boat were helpful. Differentiating between sand and mud substrates was difficult, and determinations were not reliable, so these habitats were grouped together. In some cases, identifying changes between gravels and sand was challenging. Areas where habitat discrimination was uncertain were noted to assist the design of the video ground truthing.

2.4 DROP VIDEO GROUND TRUTHING

The drop video apparatus was a Sony TRV6e mini DV camera mounted in a simple, robust housing built by us from a recycled scuba cylinder and Plexiglas sheet material. The housing was arranged with a bottom weight attached to a 1-m line attached to the bottom edge of the housing. Another line was attached to the top edge of the housing, extending upwards to a series of floats starting at 1 m above the housing. By adjusting these attachment points, weights and floats, we were able to arrive at an arrangement that allowed us to ‘feel’ when the unit hit the bottom. We would then let out 3–5 m of slack in the line. The floats then allowed the unit to hang vertically with the camera approximately 1 m above the bottom. We found that the arrangement would naturally rotate the housing in a circle or semi-circle, effectively panning the camera and greatly increasing the viewing area. We also devised a method of bouncing the unit along the bottom for short distances; this also increased the area photographed. The housing unit had no external camera controls. The camera was simply turned on, set on automatic focus and exposure, placed in the housing and deployed. A remote on / off device was used to place the camera on standby between drops on the surface. Using this system, drops could be made with a minimum of time and effort, thus maximising the number of drops that could be made during surveys. Most of the drop video work was done using a small runabout which allowed for fast movement around the relatively large distances of the survey area. GPS location of survey points was done with a hand-held Garmin 12 GPS unit. The position accuracy of this unit given by the manufacturer is 15 m. Our own checks of accuracy of the unit (by returning to known points) indicated an accuracy of 5–7 m.

Once the single-beam sonar survey was mapped, target points for the drop video were chosen. These points were selected to identify:

- all the major physical habitat types
- inconsistent interpretations between the side-scan and single-beam sonar surveys
- areas where it was likely that habitat boundaries were still not covered by the survey
- reef areas where major biological boundaries were likely to occur
- areas to ground truth the analysis of aerial photography

Figures 3 & 4 provide maps of the single-beam sonar tracks and video drop ground truthing sites. The data sheets for the single-beam sonar survey and video drops are included in Appendices 2 & 3. Figure 5 shows the drop video apparatus.

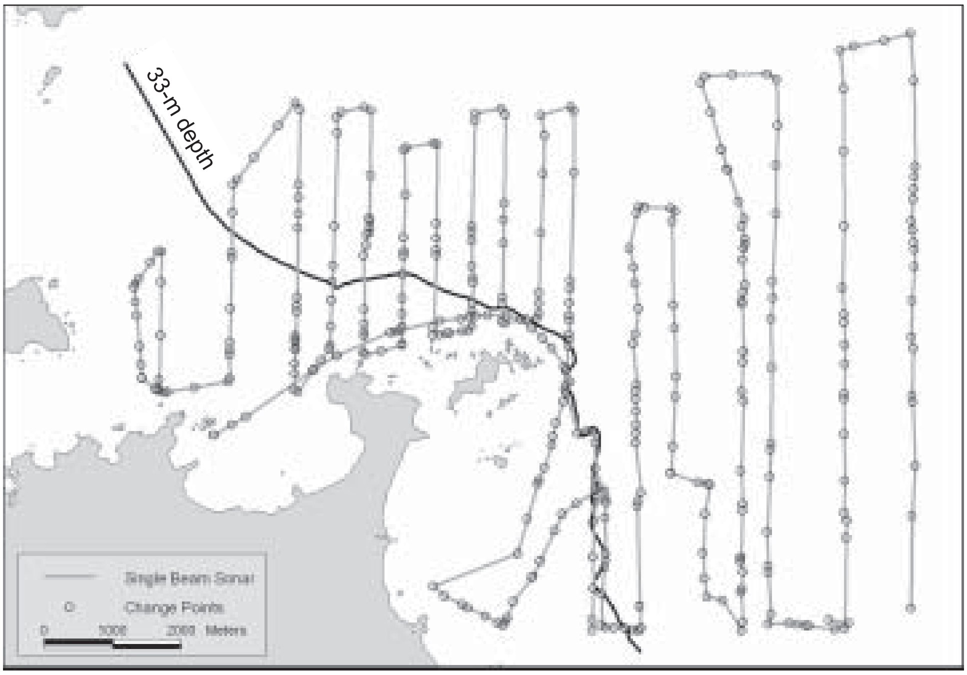

Figure 3. Single-beam sonar survey tracks. 'Change points' are positions on the sonar tracks where the habitat classification was recorded as changed from one type to another. Note: Some change points were marked only to denote change in track direction.

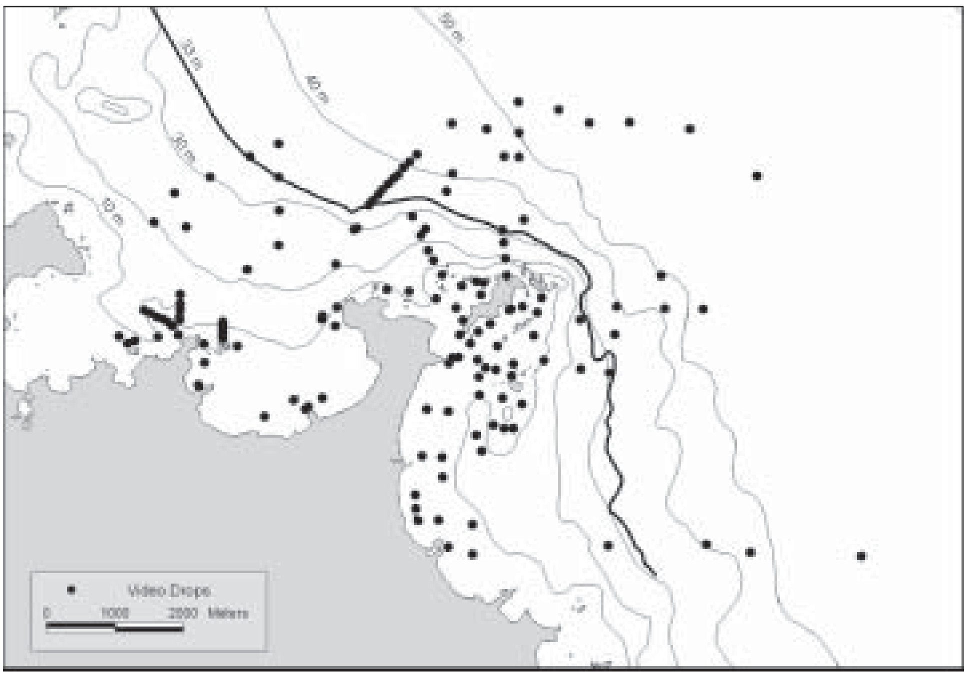

Figure 4. Drop video survey points (ground truthing).

A B

Figure 5. A—ROV; B—drop video apparatus.

2.5 AERIAL PHOTOGRAPHY

Available aerial photographs were assembled and reviewed to facilitate updating of the 1973 and 1981 habitat maps (Ballantine et al. 1973 and Grace 1981b). A 1950 black and white photograph series (NZ Aerial Mapping Service 551 and 552 series) was most useful for determining reef outlines and interpreting the historic habitat maps. This photograph series had been extensively used for both the historic maps. In June 2003, we successfully photographed the study area with a Hasselblad camera (CM version, medium format 80-mm lens). Suitable conditions for aerial photography and methods of analysis for habitat mapping are described in Ekebom & Erkkila (2002), Fyfe et al. (1999) and Andrew & O'Neil (2000). We found that optimal conditions for aerial photography were between 10:30 and 11:30 a.m. at low tide, with very light to no wind, no swell, unusually clear water and a flight elevation of 6000 ft. The aircraft used was a Cessna 182 with a removable passenger door. A set of georeferencing points was established on the ground with a Garmin 12 GPS unit. Georeferencing of the aerial photo series was done using an ArcView GIS system. The film used was Fujichrome Velvia 50ASA transparency film. An incident light meter was used to determine exposure, which was 1/500 second at f2.8. Part of the seaward and southern part of the survey area was covered with lower-level oblique photos taken with a 35-mm camera and print film because of clouds formed during the later stage of the flight. Digital video footage of the study area was also taken during the flight.

2.6 DREDGE SAMPLING (2004)

Fifty dredge sites were predetermined on a map with 10-m depth contours, stratified according to depth and existing knowledge of gross sediment grade, then located in the field using a hand-held Garmin 12 GPS. Samples were collected using a new model of a small dredge, as described by Grace & Whitten

(1974). The dredge was hand-hauled from a 4.2-m runabout. It held approximately 4.5 L of sediment and, under ideal conditions, sampled an area of approximately 0.075 m^2 to a depth of 60 mm.

When the dredge arrived at the surface, the volume of each sample was estimated on the basis of how many tenths of the dredge it filled, to enable crude estimates of the area sampled and, hence, quantitative estimates of the biota to be made. A qualitative description of the sediment grade was noted. Where depths were greater than 40 m, a sediment sample (c. 50 ml) was collected for forwarding to Dr Bruce Hayward of Geomarine Ltd. for analysis of foraminifera. The rest of the sample was then washed though a wire mesh sieve with 2-mm openings. Organisms and residue retained on the sieve wire were placed in labelled plastic bags and preserved in 3% formalin for later processing. In the laboratory, animals that were judged to be alive at the time of sampling were carefully sorted from the residues, identified as far as possible, and counted. Estimates of the volume of residue remaining after sorting were also made, to give an indication of the quantity of sediment coarser than 2-mm particle size. A datasheet including the sediment descriptions for this work is included in Appendix 4. Analysis of the biota in the dredge samples will be reported separately. Figure 6 shows locations where dredge samples were collected, and type of sediment sampled.

Figure 6. Sediment dredge sample points.

2.7 HABITAT MAPPING

Sonar, video and dredge information was brought together in a series of GIS layers. The NZAMS 551 and 552, and June 2003 aerial photographs were digitised, georeferenced and adjusted for light / dark balance and contrast in a graphics programme to provide maximum visibility of underwater structures. The photos were then added as a further layer in the GIS system. A series of work maps were created from all the line and point data, which was overlaid on the aerial photo layer, where doing this was helpful. In the areas of shallow water, aerial photographs allowed very close resolution of detail, in the order of

3–15 m. A line shown on the map in Fig. 7 indicates the seaward extent of the usefulness of the aerial photos for the mapping exercise. Beyond this line, the distance between the sonar images combined with the video points determined the accuracy of the habitat polygons. In the final mapping exercise, all the information was assessed collectively to make the best possible approximations of the habitat polygons, which were drawn free-hand on hard copy work maps (1:2000 scale). The hand-drawn habitat polygons on the work map were then digitised through a combination of scanning and computer drawing methods and transferred to the GIS system to produce the final habitat map.

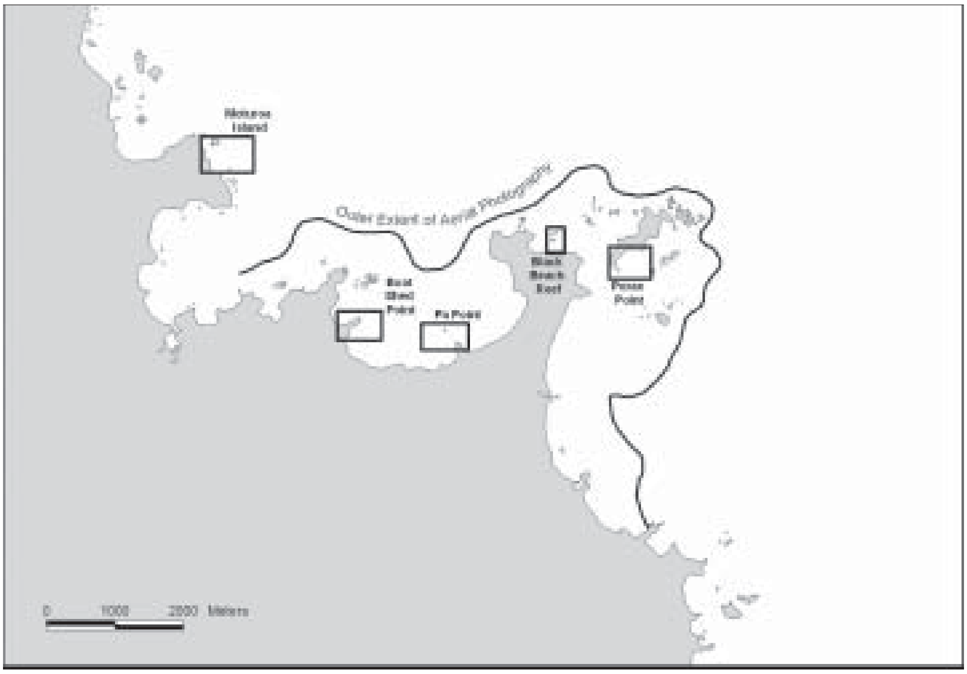

Figure 7. Locations of areas photographed in algal change aerial photos 1950–2003 (Figs 19–23).

2.8 CHANGE IN ALGAL FORESTS ASSESSMENT

Time series photos were prepared for five comparison sites (Fig. 7). Four comparison sites are within the Marine Park—Boat Shed Point, Pa Point, Porae Point and Black Beach Reef—and one outside, at Moturoa Island, 2.2 km to the northeast of the Park. Permanent transects are located on reefs at Pa Point and Porae Point. The comparison sites selected had adequate-quality aerial photography available, and were representative of the shallow reef habitats of their localised area. In total, we were able to source aerial photos of varying quality and coverage of the study areas from the years 1950, 1951, 1959, 1961, 1993 and 2003.

Interpretation of the habitat areas from the aerial photography was done by a subjective visual assessment of the photographs in a computer graphics program. As we worked through this process we checked our interpretation against all current information from this study and historic information available for each site. The historic information used was the existing Mimiwhangata subtidal habitat map (Ballantine et al. 1973), field observations and descriptive notes taken on 10 permanent transects monitored from 1976 to 1986 (Grace & Grace 1978; Grace 1981a, 1984, 1985, 1986) and the Paparahi Point subtidal habitat map (Grace 1981b). After 1987, no formal monitoring took place until the current study began in 2001.

3. Results

3.1 HABITAT DESCRIPTIONS

3.1.1 Intertidal beaches and rocky shores

There are many sandy beaches in the Mimiwhangata area, the largest being Mimiwhangata Beach and Okupe Beach. Other smaller sandy beaches occur south of Okupe, at Whale Bay, Waikahoa Bay and Ngahau. Biologically, they generally support little life, with species abundance and diversity low compared with all other habitats in the Marine Park except gravel beaches. Apart from sand hoppers on the drift line, marine life consists of several species of worms and tiny crustaceans on the middle or lower parts of the beaches. Tuatua (shellfish—*Paphies subtriangulata*) have been reported from Ngahau and Waikahoa Beaches and, at times, have been abundant on Mimiwhangata Beach. Tuatua have appeared and disappeared over a number of years (Grace 1986; Grace & Kerr 2002). During summer 2003 / 04, small beds of medium-sized tuatua were seen at the western end of Mimiwhangata beach, but these were not surveyed.

Most of the smaller beaches in the area consist of gravel and pebbles, or gravel with sandy areas at certain tidal levels. There are many small gravel beaches in coves in the rocky shore all around the coast. This habitat is hostile to macroinvertebrates, since movement of gravel and pebbles even in very light wave action causes mechanical disruption of the substrate.

A high proportion of the shoreline at Mimiwhangata consists of hard greywacke rock, criss-crossed with numerous joints. These joints are zones of weakness along which preferential erosion occurs. Consequently, many rocky shoreline features, on both a large and small scale, are aligned parallel to the jointing system within the rocks. Marine life on the rocky shores is rich and varied. The types of animals and plants present and their distribution are controlled mainly by tidal level and the degree of exposure to wave action (Morton & Miller 1973). The shape of the coastline in this area, and the presence of offshore islands and reefs, means there is a wide range of exposure to wave action, and a correspondingly wide range of patterns of marine life. Rock oysters (*Crassostrea glomerata*) are commonly present on the most sheltered shores, and surf barnacles (*Chamaesipho brunnea*) on the more exposed rocky points and headlands. There are also examples of rocky shores where the major patterns of life are further modified by shade, sand scour, standing water in rock pools, and freshwater runoff (Ballantine et al. 1973). Examples of the three main intertidal habitats are shown in Fig. 8.

3.1.2 Shallow mixed weed (depth range 0–6 m)

This habitat occurs on rocky reefs between low water and about 6 m depth, and is often restricted to the shallower part of this range. The rocky substrate is usually very broken and dissected, with tumbled boulders, ridges and crevices. Several species of large brown algae are visually dominant. The most abundant of these is flapjack kelp (*Carpophyllum maschalocarpum*). Small plants of the kelp *Ecklonia radiata* occur in the deeper areas or more sheltered parts of the zone.

A B C

Figure 8. Intertidal habitats. A: sandy beach—Okupe Beach. B: gravel beach—Flax Bush Bay. C: rocky shores—Waikahoa.

Where wave action is moderate or heavy, the upper part of the zone is characterised by a fringe of *Carpophyllum angustifolium*, which forms a dense swirling carpet, the vertical extent of which is determined largely by the degree of wave turbulence. *Lessonia variegata* occurs in the deeper part of the zone in areas with maximum wave-exposure. *Lessonia* is superficially similar to *Ecklonia radiata*, but differs in having a divaricating stipe or stalk. The oak-leaved kelp (*Landsburgia quercifolia*) also occurs frequently in areas of heavy wave exposure. The smaller, finely-branched *Carpophyllum plumosum* is tolerant of a wide range of wave exposures. Several species of red algae occur, including *Pterocladia lucida* and *Melanthalia abscissa*. The sea urchin or kina (*Evechinus chloroticus*) is common in this habitat, usually nestled in holes, crevices and depressions. It often feeds on seaweed which has been torn off the rocks by heavy wave action. A wide variety of grazing molluscs is also present in this habitat. Figure 9 shows an example of the shallow mixed weed habitat.

Figure 9. Shallow mixed weed habitat.

3.1.3 Kina (urchin) barrens (depth range 6–15 m)

This rocky habitat is characterised by a lack of large brown algae, the rock surface appearing bare and relatively barren. Upon close inspection, the rock surface is almost completely covered in a thin film of mauve- to pink-coloured encrusting coralline seaweed. The most conspicuous animal in this habitat is kina or sea urchin, which is often present at a density of $5–10/m^2$, but can be present in much denser patches. It is the grazing by kina that maintains the habitat in its relatively barren state. Kina scrape the rock surface, removing recently settled algae and encrusting animals before they have a chance to grow. Kina may also graze directly on large attached algae. This is relatively uncommon but, when it does occur, can lead to an extension of the kina-grazed

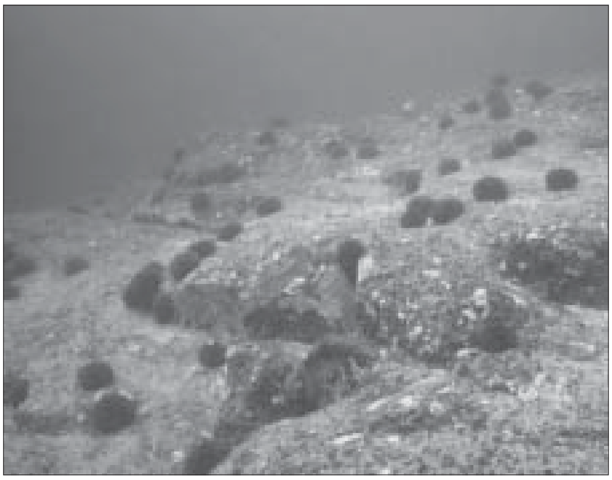

Figure 10. Kina barren habitat.

zone into formerly algal-covered areas. The kina-grazed zone is also home to a number of small grazing molluscs, such as limpets and chitons. The most spectacular grazing mollusc here is the large Cook's turban shell (*Cookia sulcata*), a rough-surfaced gastropod which can grow to 10 cm or more in diameter. Some parts of this habitat have a very sparse covering of *Carpophyllum angustifolium*. In two places, the kina barren is present on an unusual substrate of loose boulders. In these areas—a large area to the southwest of Seagull Island and a smaller area to its southeast—kina are as abundant as they are on more solid rock substrates. An example of the kina (urchin) barren habitat is shown in Fig. 10.

3.1.4 Tangle-weed forest (depth range 6–15 m)

In the most sheltered areas of rock substrate, a thick, almost impenetrable tangled forest of the brown seaweed *Carpophyllum flexuosum* occurs. Individual plants may reach a height of over 3 m. With increasing wave exposure, this habitat intergrades with *Ecklonia* forest; and towards shallower areas it usually gives way to *Carpophyllum maschalocarpum* and a narrow strip of the shallow mixed weed zone. The seaweed and the rock substrate of this zone is nearly always covered with a thin layer of fine silt, which settles out from the usually relatively turbid water. This detritus provides food for a range of specialised detritus and deposit feeders, such as the sea cucumber (*Stichopus mollis*), which is found on the rocks and in crevices beneath the weed canopy. Figure 11 shows tangle-weed *Carpophyllum flexuosum* forest.

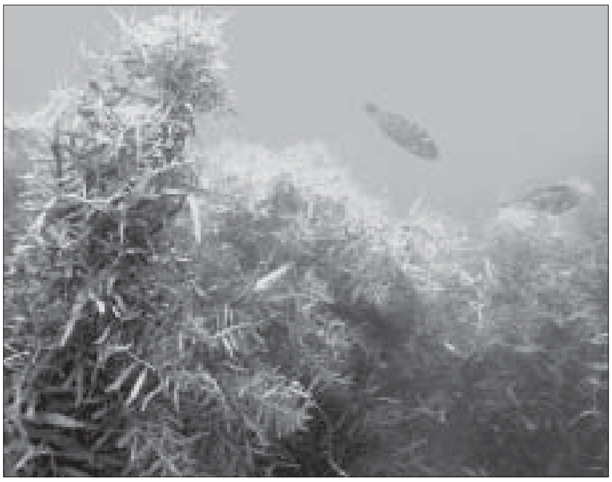

Figure 11. Tangle-weed, *Carpophyllum flexuosum* forest.

3.1.5 *Ecklonia* forest (depth range 6–40 m)

This zone usually occupies areas of rocky reefs between the kina barrens zone and the sandy seafloor, generally in a depth range of 6–33 m. Targeted video drops allowed us to identify the transition zone where the lower boundary of the kina barren changed into the upper boundary of the *Ecklonia radiata* forest. This boundary is at 8–12 m depth. Sometimes, particularly in relatively sheltered areas, the *Ecklonia* forest occurs adjacent to the shallow mixed weed zone, and may imperceptibly intergrade with it. A second habitat transition zone at 33–40 m was also identified with the video drop survey. At this depth *Ecklonia radiata* forest weakens and thins out, while sponge and other encrusting invertebrate life become more diverse and abundant. The *Ecklonia* forest is characterised by dominance of the large brown laminarian kelp *Ecklonia radiata*. This seaweed attaches to the rock surface by a branched holdfast, and has a single cylindrical stalk or stipe, on top of which is a bushy top or lamina. The density of the plants varies considerably, with perhaps 5/m^2 in 'thin' beds, often in deeper water, and about 50 plants/m^2 in dense, usually shallower, beds. The length of the stipe also varies, apparently with depth, from about 20 cm in adult plants in shallow, slightly turbulent water, to about 80–100 cm in some deeper sites. The canopy of the *Ecklonia* forest greatly reduces the light intensity on the rock surface beneath, which provides more favourable conditions for small encrusting animals such as bryozoans, hydroids, sponges and ascidians. The holdfasts of *Ecklonia* provide crevice-like habitats for a diversity of animals and plants. In many areas, the rocky bottom occupied by *Ecklonia* forest is of low relief, but where high-relief rocky substrate occurs within this zone, *Ecklonia* plants are usually found on the tops of the rocks, but not on their more shaded vertical sides which, typically, are covered in a rich variety of encrusting animal life. As light levels diminish with increasing water depth, sponges of numerous types become increasingly common within the thinning *Ecklonia* forest. Along reef edges where the *Ecklonia* forest drops onto a sandy substrate, there is often a fringe of the green seaweed *Caulerpa flexilis* on the rock immediately adjacent to the sand. It appears that *Caulerpa* is more able to survive periodic burial by sand and to colonise the more frequently disturbed sand / reef edge than *Ecklonia*.

A significant species record of a combfish (*Coris picta*) was made in this habitat during the drop video survey. The specimen was seen over *Ecklonia* forest at 28 m depth. Combfish is a subtropical species rarely seen on the mainland coast, but commonly recorded at the Poor Knights Islands. This species had not been recorded at Mimiwhangata since records began in the 1970s (Kerr & Grace 2004). Figure 12 shows *Ecklonia* forest habitat.

Figure 12. *Ecklonia radiata* forest.

3.1.6 Mixed sand and rock comprising: depth range 0–33 m—algal communities on patch reef; depth range 33–40 m—sponge and encrusting invertebrate communities on patch reefs

This habitat type occurs in transition zones between reef and sediment as well as in areas comprising a patchy mixture of rock and sediment. It is ecologically important, as it is the preferred habitat of some fish species and is important for various life stages of other species (e.g. goatfish (*Upeneichthys lineatus*), juvenile snapper (*Pagrus auratus*) and blue cod (*Parapercis colias*)). It is usually the habitat in which foraging by species (e.g. rock lobsters) that shelter on reefs but feed in the sediments is most intense. Sandager's wrasse (*Coris sandageri*) shelter in these areas at night by burying themselves in the sand.

Figure 13. Mixed sand and rock, patch reef habitats (> 33 m depth).

The individual patches of rock and sandy areas are each of such small extent that it is not possible to map them individually at the scale or the degree of precision used in this survey. Areas of mixed sand and rock occur most commonly where a gently shelving rocky substrate meets a flat sandy bottom. If the rock surface is dissected by crevices and gullies, sand fills these gullies as the rock dips beneath the sand surface. At depths < 33 m, there may be sand and / or gravels combined with a kina-grazed zone or *Ecklonia* forest on the rocky patches. At depths > 33 m, sponges and other encrusting invertebrates dominate the rock habitat adjacent to soft sediments. Figure 13 shows an example of the mixed rock and sand habitat.

3.1.7 Soft sediment areas: sand, gravel and cobbles (depth range 0–100 m)

The dredge study of the sediment areas (Fig. 6, Appendix 4) provided extra information for the habitat mapping. Several small changes to the final habitat map resulted from this work. In the northwest corner of the study area, a significant area of gravel habitat was found that had not been identified from the sonar work. Two other small areas—one in a channel west to southwest of Awash Rock and the other midway along the southern end of the survey area—were found to be incorrectly mapped as reef. In both cases, the areas in question fell between sonar tracks and ground truthing video drops.

Sand extends well offshore from most of the sandy beaches and larger gravel beaches, and most of the sheltered rocky shores drop quickly onto sand below low water. In deep water beyond about 60 m, where the influence of storm waves is rarely felt, the sediment is firm and composed of various combinations of sand and mud. The sandy bottom is characterised by ripples—a series of small parallel wave forms on the surface of the sand—except in the most sheltered areas. There is generally far more animal life in permanently submerged sandy areas than on the sandy shores, partly as a result of the greater stability and lack of violent wave action in subtidal areas. Coarser sand frequently supports dense beds of the morning star shell (*Tawera spissa*), a bivalve shellfish 20 to 25 mm long. In places, these beds reach densities exceeding 5000/m^2. Finer sand is often occupied by large numbers of the turret shellfish *Zeacolpus pagoda*, a tall-spired gastropod shellfish 20 to 30 mm long which also reaches densities of several thousand/m^2. The shells of dead turret shellfish provide homes for hermit crabs, which are persent in high numbers in parts of the study area and particularly in the eastern half of Mimiwhangata Bay. Slightly muddy stable fine sand in Taiwawe Bay contains a greater variety of marine life, but each species occurs in relatively low numbers. Several species of polychaete worms, the burrowing heart urchin (*Echinocardium cordatum*) and several species of molluscs are characteristic of these sediments.

Sediments dominated by gravel and cobbles are less widespread than those characterised by sand and mud. The major gravel areas tend to occur on the sheltered sides of gaps between islands, or between islands and the mainland. Gravel sediments often have large ripples, some being up to 300–400 mm high and 1 m from crest to crest. There are also substantial areas of gravel in deeper water to the north and southeast of Rimariki Island, and in the northwest corner of the study area. The more mobile gravel bottom areas are usually poor in macroinvertebrate life but, where the bottom material tends to be more stable, dense populations of some sturdy bivalve shellfish are found. The morning star shell is equally at home in these areas as it is in coarse sand, but in gravel it may also be accompanied by the purple sunset shell (*Gari stangeri*). The large dog cockle (*Tucetona laticostata*), which has large strong shells up to 8 cm in diameter that are frequently cast ashore on beaches in the area, is abundant in the southern part of the gravel habitat southwest of Seagull Island, where it reaches densities of > 80/m^2. Cobble areas dominated by fist-sized rocks with pebbles, gravel, and coarse sand between, occur to the southwest of Paparahi Reef, and off the coast between Motutaniwha and Paparahi Point. Other cobble areas are found south of the channel between Seagull Island and Paparahi Point, south and west of Motutaniwha Island, and north of Trig Point. Cobble areas are often small and usually occur adjacent to solid rock or boulder bottom, often between rock and sand. Under normal conditions, a cobble bottom is fairly stable, but during storms some of the cobbles and pebbles may move. This semi-stability allows some types of algae or seaweeds to grow on the more stable rocks. One of the commonest algae in this habitat is the red seaweed *Gigartina circumcincta* which grows as reddish or greenish-red sheets less than 1 mm thick, attached to a cobble or pebble by a tiny holdfast 3 to 5 mm in diameter. This weed tends to be seasonal, and the size to which it grows is determined, to some extent, by the length of calm between successive storms. Storms readily dislodge rocks with this weed attached, which may then be cast ashore in quantity on nearby gravel beaches. Another seaweed often found in this habitat, particularly in the presence of moderate amounts of sand, is the sea rimu (*Caulerpa flexilis*), a bright green finely branched seaweed growing from a creeping stolon. Figure 14 shows examples of soft sediment habitats.

Figure 14. Soft sediment habitats. A—sand and mud. B—gravel and cobbles.

A

B

3.1.8 Deep reef, patch reef, sponge and soft coral habitats (depth 33–100 m)

On the rocky bottom deeper than 33 m there is insufficient light to support the large brown seaweeds found in shallower water. Sponge species become the dominant life form on the deep reef. From 35 m to 55 m depth, the pink beaded octocoral or gorgonian fan *Primnoides* sp. is abundant, reaching a density of > 50/m². Occasional colonies have been parasitised by a small cream zoanthid which smothers the gorgonian animal and takes over the horny fan-like skeleton. A massive grey sponge *Ancorina alata* is common, as well as the orange branching *Raspailia* sp. and purplish thin branching fingers of *Callyspongia ramosa*. Red cup sponges (*Stelleta hauraki*) and a wide variety of other large and small sponges are present. Beyond 55 m, *Primnoides* diminishes in prominence, sponges again becoming the main feature. Seastars present include the yellow *Knightaster bakeri*, the yellow and brown *Ophidiaster kermadecensis*, and the multi-coloured firebrick star (*Asterodiscus truncatus*). Molluscs include the circular saw shell (*Astraea heliotropum*). Soft corals (*Alcyonium* sp.) and pencil bryozoans (*Steganoporella novaezelandiae*) are also common. Black coral (*Apanipathes* sp.) colonies as well as small cup corals (*Monomyces rubrum*) also occur in this habitat. The sponges and corals habitat is most extensive on low-relief rock. In a few places and, in particular, in an extensive area east of Rimariki Island, the rock bottom is more dissected and irregular, with frequent gullies and rocks taller than 3 m. These high-relief areas provide opportunities for an even greater variety of life than on the low-relief deep reef. In particular, the cold-water ivory coral (*Oculina virgosa*) occurs in clumps up to 0.5 m across attached to the vertical sides of upstanding rocks (Ballantine et al. 1973).

3.2 SIDE-SCAN SONAR AND REMOTE OPERATED VEHICLE (ROV) IMAGES

3.2.1 Side-scan sonar

Each swath of the side-scan sonar creates a 200-m wide three-dimensional sonograph image of the seafloor. The actual width of each side-scan image is shown in Fig. 2. A representative still image of the side-scan track is given in Fig. 15. In Fig. 15, the size of the seabed features can be estimated by comparison with the indicated scale. The dark centre part of the image is a representation of the depth of water under the boat. The centre line is the boat's horizontal track. The first line to the right and to the left is the position of the sonar fish device, the edge of the solid area to the right and to the left is the bottom directly under the boat. The distances from the boat track to the sonar fish device and to the bottom are to scale, with the vertical lines 80 m apart. It is thus possible to measure the depth of the bottom directly from the image. The solid area that extends to the right and to the left represents an image of the bottom surface. Shadows showing on this image of the bottom are made by vertical rock structures blocking the signal.

3.2.2 Remote operated vehicle (ROV)

Total recorded video time on the three reef sites was approximately 1.5 hours. Identification of species from video footage was limited to just the larger species where taxonomic features could be clearly distinguished. The three

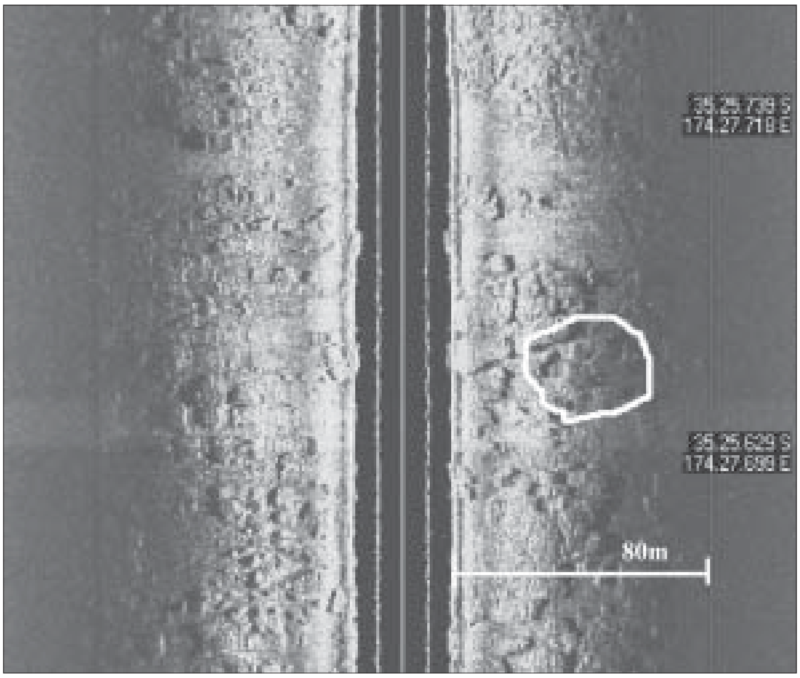

Figure 15. Example of side-scan image. The white circle is the location of ROV video drop 3. The location of this image is shown as S 1 in Fig. 2. The habitat in this image is interpreted as high-relief rocky reef. Within this reef area there are patches of gravel and cobble. This image is typical of the large area of reef lying east of Rimariki Island in the centre of the survey area. The depth of this area ranges from 35 to 40 m.

ROV locations are shown in Fig. 2. Video site 1 is predominately low-relief rocky reef with some gravel areas, and few structures reaching 3 m in height. Video sites 2 and 3 are predominately reef areas with vertical faces and protruding large rock formations 3 m in height, making for a complex habitat and providing sheltered sites for delicate encrusting communities to establish. Two specific observations are notable. A yellow fin foxfish (*Bodianus flavipinnis*), a subtropical species associated with deep off-shore reefs, was recorded at Mimiwhangata for the first time. Snapper (*Pagrus auratus*) were not observed on these deep reefs.

ROV video Site 1 (63–65 m depth)

This site is below the depth at which wave action commonly moves the sediments. Currents are not sufficiently strong by themselves to keep the rocks clear of silt. A range of sponges dominate (Fig. 16), as they are capable of moving silty sediment off their surfaces. The cleanest parts in this deepest area are on upstanding rocks, which protrude several metres above the surrounding seabed, and on the steep sides of rocks and overhangs.

ROV video Site 2 (45–48 m depth)

At this site, light levels are too low to support large seaweeds. Some encrusting coralline paint and small red seaweeds are present, and the bottom is covered with encrusting animal life, including *Primnoides* sp. gorgonians (Fig. 17). The weak current would not keep this area sufficiently clear of silt to allow rich encrusting life to grow, but occasional storm waves do reach these depths to sweep the rocks clean. The gravel beds close by move during heavy storm swells (evidence of 2-m wavelength ripples in the gravel beds was observed) and damage any delicate encrusting life. The best-developed gorgonian fields, sponges and corals are present on the higher rock areas remote from the influence of moving gravel.


A


B

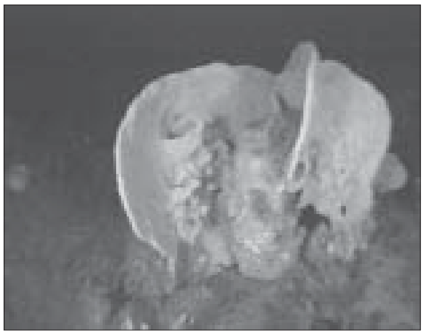
C

Figure 16. ROV video site 1 still images, depth 65 m.
A—Rock surfaces noticeably siltier than at ROV video site 2. Unknown cream-coloured sponge in foreground, with *Alcyonium aurantiacum* (soft coral) at left of sponge.
B—Finger sponge *Raspaillia* sp. is on right-hand side of photo and in background. Sponge in foreground is *Stelleta* sp.
C—Unidentified sponge (possibly *Petrozia* sp.) or perhaps two sponges grown together.


A

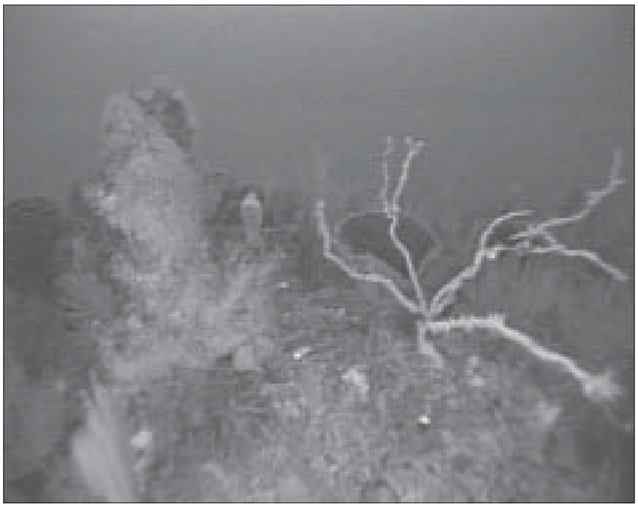
B

Figure 17. ROV video site 2 still images, depth 45 m.
A. Rich bed of *Primnoides* gorgonian fans. The specimen at right has been killed and taken over by a zoanthid. Encrusting coralline algal 'paint' is common. Encrusting sponges with several species possible but a common one is *Tedania* sp.
B. Large orange / yellow upright sponge mass at left is *Stelleta* sp. and a dead black coral is on the right with zoanthids and other encrusting organisms attached. There is a great diversity of encrusting life on rocks, including the large cup-shaped sponge *Stelleta hauraki*, and the calcareous flask sponge *Leucetusa lancifer* in the background.

Figure 18. ROV video site 3, 35-m depth. High-relief (c. 3-m vertical height), broken reef area with rich encrusting life on the rocks. Sparse, stunted *Ecklonia radiata* on rock tops.

ROV video Site 3 (35–40 m depth)

This area is sufficiently shallow to allow large seaweeds such as *Ecklonia radiata* to grow on the higher rocks. Sea rimu (*Caulerpa flexilis*) is also present. Sponges are common but, notably, *Primnoides* sp. gorgonians are absent at this depth. There is very little silt deposited at this site. Moderate currents and occasional storm wave action keep the rock surfaces relatively free of silt (Fig. 18). Tables 2 & 3 show invertebrate, algal and fish species identified in the video survey.

3.3 CHANGE IN AREAS OF ALGAL FOREST

The aerial photograph time series is shown in Figs 19–23 (locations of aerial photograph sites are shown in Fig. 7). This time series illustrates the long-term trend of decline in algal forest cover of seafloor between 2 m and 12 m depth at Mimiwhangata. The shallow mixed weed zone has shrunk upwards towards low-water mark, and the top or shallowest boundary of the *Ecklonia radiata* forest zone has become progressively deeper. In the 1973 and 1981 habitat maps, the extent of the kina-grazed zone was intermediate between the nearly 'full algal cover' condition of the 1950 photo series and the expansive kina barren condition which exists today. This suggests that there has been a continuous gradual decline in kelp forest cover since 1950.

A number of Ngatiwai hapu traditionally fished the reefs of the Mimiwhangata area. The authors interviewed Houpeke Piripi and Puke Haika, Kaumatua of Te Uri O Hikihiki hapu. We asked them to describe changes to the algal forest in the shallow reef areas over their life time and experience which extends back into the 1940s. They stated in their discussion with us that they routinely harvested kina and crayfish and other kaimoana species on these reefs and had noticed a gradual decline of the algal forest over the last 15 to 20 years. They expressed considerable concern that what they saw happening there now was definitely not consistent with the ebb and flow of the algal forest and extent of kina barrens they had observed over this period. They described the reefs as having lost much of their 'life'. They had no memory or historical knowledge of the extent of the kina barrens ever being similar to the condition that exists today.

3.4 THE HABITAT MAP

The habitat map included in this report (Fig. 24, end of report) represents the summation of all the information assembled in this investigation. The total area mapped is 8700 ha. The mapped area extends approximately 5.6 km to the east of Rimariki and 4.2 km north from trig point on the Mimiwhangata peninsula. Approximately 365 ha of high-relief deep reef lies at the centre of a larger area (approx. 2840 ha) of low-contour reef and patch reef located beyond the 33-m depth mark. This significant offshore reef system is an extension of the shallow reef systems of the Mimiwhangata peninsula, and Rimariki, Wide Berth and Otawhanga Islands. A variety of soft sediments border the reef system to the north and the south. The northeast corner of the survey area reached depths of 100 m. The areas of the various habitats identified within the study area are shown in Table 4.

TABLE 2. INVERTEBRATE AND ALGAL SPECIES IDENTIFIED IN VIDEO SURVEY.

SCIENTIFIC NAME	COMMON NAME OR DESCRIPTION
Algae brown	
Ecklonia radiata	common kelp
Algae green	
Caulerpa flexilis	sea rimu
Sponges Porifera	
Tedania sp.	red encrusting sponges
Stelleta crater	grey cup sponge
Desmacella dendyi	orange encrusting species covering cup sponge
Geodina regina	large grey sponge
Axinellid	tall red finger sponge
Stelleta hauraki	red crimson sponge
Raspailia sp.	branching orange finger sponge
Leucetusa lancifer	calcareous flask sponge
Hormaxinella erecta	tall thin yellow sponge
Aaptos aaptos	small round brown sponge
Iophon proximum	yellow finger sponge
Callyspongia ramosa	thin finger sponge
Polymastia granulosa	yellow round sponge
Vagocia imperialis	giant tube sponge
Tethya fastigata	round yellow ball-shaped sponge
Aplysilla rosea	pink branching 'prickly' sponge
Ancorina alata	large grey rambling cup sponge
Coral Cnidaria	
Alcyonium aurantiacum	soft coral
Apanipathes sp.	black coral
Primnoides sp.	gorgonian coral
Echinodermata	
Asterodiscus truncatus	firebrick star
Knightaster bakeri	yellow seastar
Ophidiaster kermadecensis	seastar
Bryozoa	
Steganoporella neozelanica	pencil bryozoan

TABLE 3. FISH SPECIES IDENTIFIED IN VIDEO SURVEY.

SCIENTIFIC NAME	COMMON NAME OR DESCRIPTION
Bodianus flavipinnis	yellow-finned foxfish
Bodianus unimaculatus	red pigfish
Caesioperca lepidoptera	butterfly perch
Canthigaster callisternus	sharp-nosed pufferfish
Centroberyx affinis	golden snapper
Cheilodactylus spectabilis	red moki
Chromis dispilus	demoiselle
Coris sandageri	Sandager's wrasse
Forsterygion flavonigrum	yellow-black triplefin
Helicolenus percoides	Jock Stewart, sea perch
Hypoplectrodes huntii	red-banded perch
Nemadactylus douglasii	porae
Optivus elongatus	slender roughy
Parapercis colias	blue cod
Parika scaber	leatherjacket
Pempheris adspersus	bigeye / bullseye
Pseudocaranx dentex	trevally
Pseudolabrus miles	scarlet wrasse
Scorpaena cardinalis	scorpionfish
Scorpis violaceus	blue maomao
Upeneichthys lineatus	goatfish

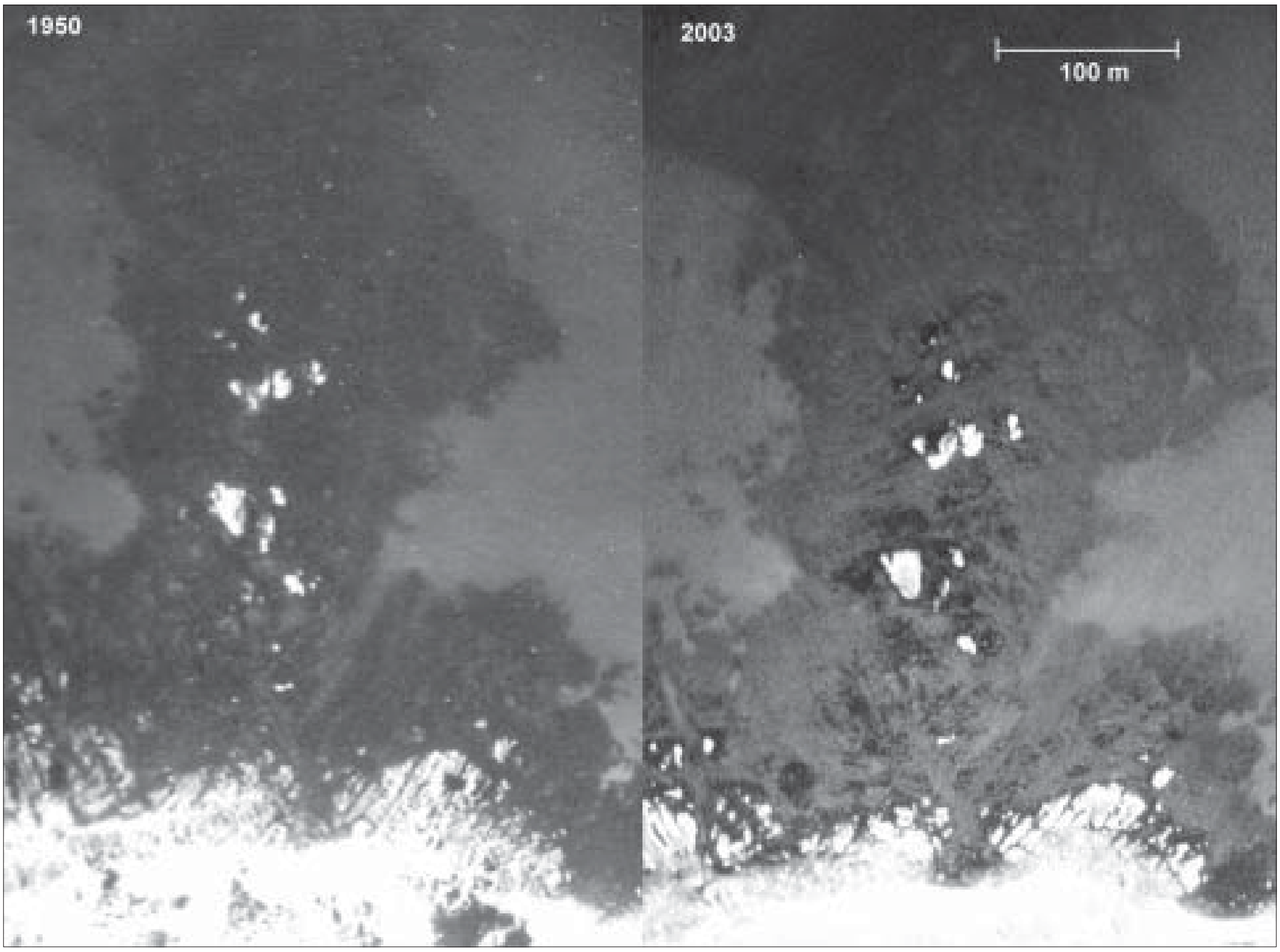

Figure 19. Change in algal forests, Black Beach Reef.

The white areas in the photographs are intertidal and higher rocks, with underwater reefs showing as dark areas. The mid-grey tones are sandy seabed, showing as a darker grey with increasing water depth. Deepest rock / sand edge in these photos is at about 12 m depth.

1950: The underwater reefs are very dark, indicating almost complete cover of algae. Early 1970s observations indicate that the shallowest areas are shallow mixed weed habitat, merging directly into *Ecklonia* forest in deeper water, particularly around the deeper edges of the reef in the upper half of the picture.

2003: Darkest areas around intertidal rocks and on shallow rock areas are shallow mixed weed habitat, restricted to about the upper 2 m. Most of the rest of the rock shows as pale grey. This is a kina-grazed zone devoid of large algae. In the upper part of the photo, patchy dark areas on the deeper reef are *Ecklonia* forest. A kina-grazed zone now occupies an 8-m depth range separating the shallow mixed weed habitat from the *Ecklonia* forest habitat.

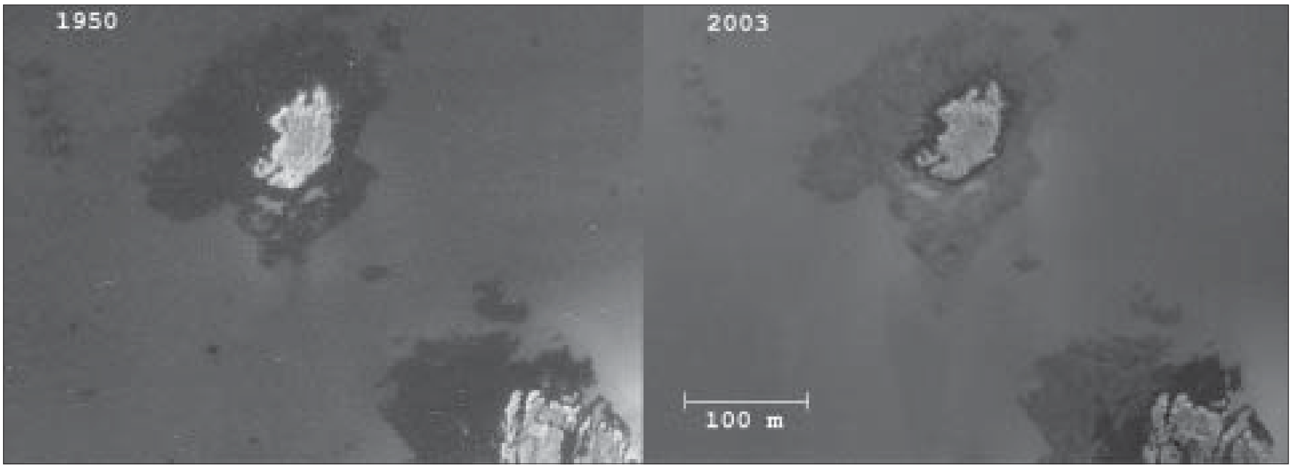

Figure 20. Change in algal forests, Pa Point.

The palest areas are the rock platform on the end of Pa Point, and the low platform of Flat Reef separated from the mainland. Underwater reefs can be distinguished easily from the pale grey sandy seabed. Depth of the rock / sand boundary is 8–10 m.

1950: The dark underwater reefs are interpreted as being covered in algal forest. Observations in the early 1970s (Ballantine et al. 1973) showed these to be predominantly tangle-weed (kelp) forest, particularly the large area off Pa Point. Around Flat Reef, the algal forest was predominantly *Ecklonia*, with tangle-weed kelp in more sheltered parts. Shallowest areas were shallow mixed weed habitat. All algal forest types merged into each other.

2003: Algal forest is restricted to a dark fringe of shallow mixed weed habitat around Flat Reef and the end of Pa Point. All the remaining reef areas, showing as a mid-grey tone, are kina-grazed zones devoid of large algae. At Pa Point in the early 1980s, it was noted that the kelp forest (*Carpophyllum flexuosum*) was reducing (Grace 1986). We monitored a permanent fish and crayfish transect at Pa Point over three years (Grace & Kerr 2002, 2003, 2004). By summer 2002, the kelp forest had completely gone. The ecological changes brought about by the loss of the kelp appear to have been dramatic. The rock at Pa Point is now covered in a thin layer of silt, urchins and two species of starfish are abundant, and an abundance of the invasive parchment worm, *Chaetopterus* sp. inhabit every rock crevice. In 2003, siltation was not as evident as in 2002; however, there was little sign of algal forest recovery.

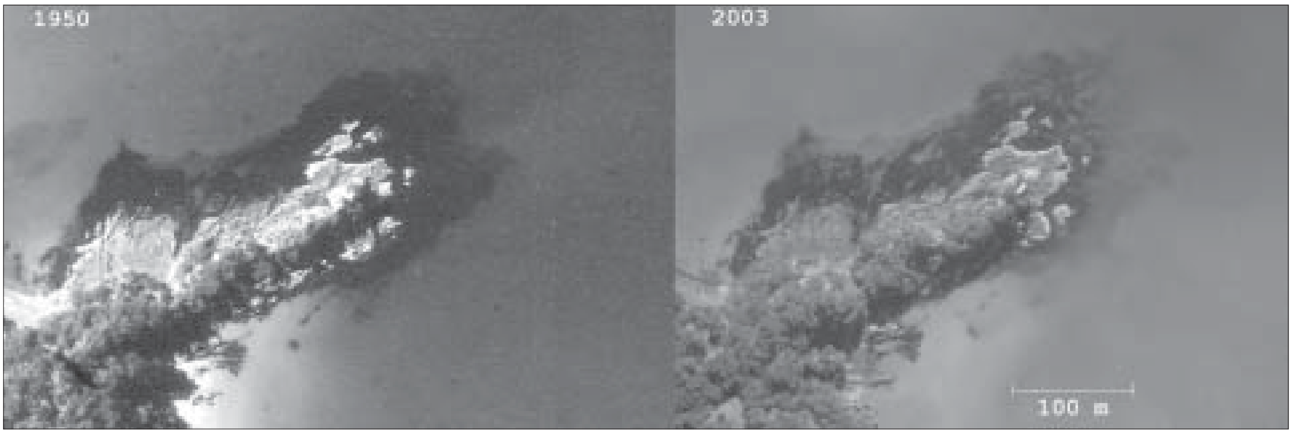

Figure 21. Change in algal forests, Boat Shed Point.

Land and intertidal rock platforms show as pale areas, separated from mid-grey tones of the sandy seabed by darker-grey reef areas, some with dark algal forest. The deepest edge of the reef is around 8 m.

1950: Dark algal forest is continuous from low water down to the rock / sand boundary. 1981 observations (Grace 1981) showed this to be shallow mixed weed habitat fringing the intertidal rocks, and tangle-weed kelp forest in deeper, sheltered areas along the northern side of the point. Deepest areas in the upper right were predominantly *Ecklonia* forest. In 1981 there was a narrow band of kina barren separating the *Ecklonia* forest from the shallow mixed weed near the end of the point (Grace 1981).

2003: By 2003, the only algal forest remaining is the fringe of shallow mixed weed habitat around the rock platform and in shallow water, and a thinning tangle-weed kelp forest on the deeper rocks along the north side of the point. The remaining reef areas, showing a mid-grey tone, are kina barrens with a few sparse *Carpophyllum flexuosum* plants.

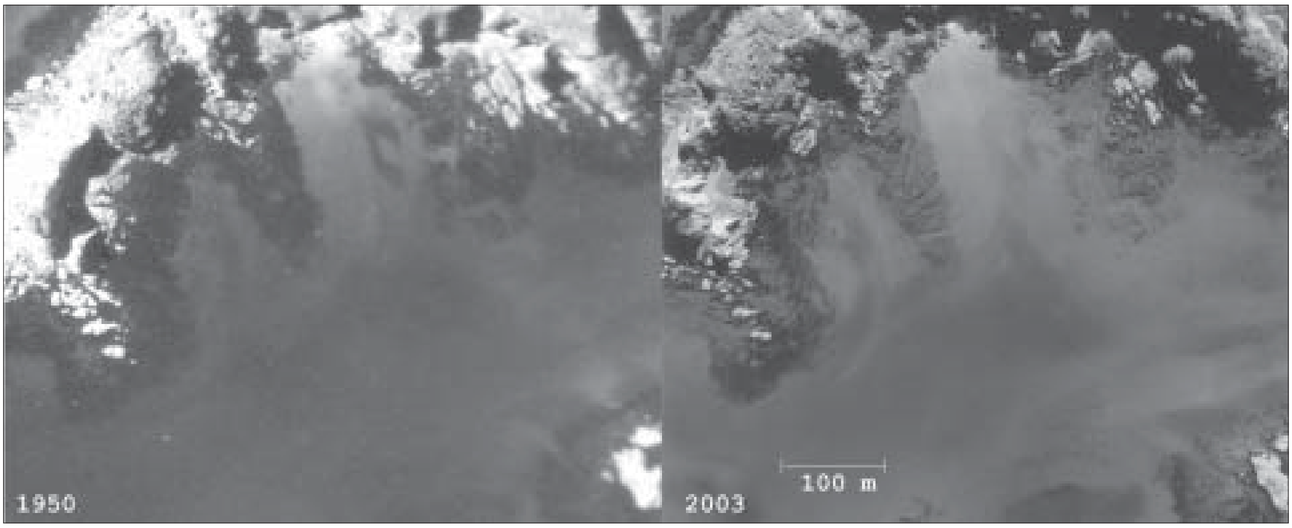

Figure 22. Change in algal forests, Porae Point.

The area shown in the photographs is complex, with land and intertidal rock platforms of Rimariki Island in the top of the photo, and the western end of Middle Reef showing at lower right. Rocky reefs can be distinguished from the paler sediments, which are sandy in the palest zones and gravely where the sediment is darker. The deepest rock / sand boundaries are at around 8 m.

1950: The dark reef areas are covered in algal forest. There is a fringe of shallow mixed weed habitat around the intertidal rocks. In some places there appears to be a paler zone deeper than this which may be the start of a kina-grazed zone. Observations in the early 1970s showed most of the deeper reefs to be covered in a tall forest of tangle-weed kelp. The deepest area showing dark on the end of Middle Reef was *Ecklonia* forest.

2003: The shallow mixed weed habitat is restricted to a narrow fringe around the intertidal rocks and on some other shallow rock areas. Most of the remaining reef shows as mid-grey, devoid of large algae in a kina barrens zone. Because of the lack of tangle-weed kelp cover, detail of the rock structure of the rock reef is visible. Near the southern end of Porae Point (at left) there is still an area of tangle-weed kelp on the deeper parts of the reef. Off the end of Middle Reef there is a fringe of dark algae remaining close to the rock / sand boundary. This area also has a permanent transect, allowing us to make field notes of the habitats on dives in 2002, 2003, 2004.

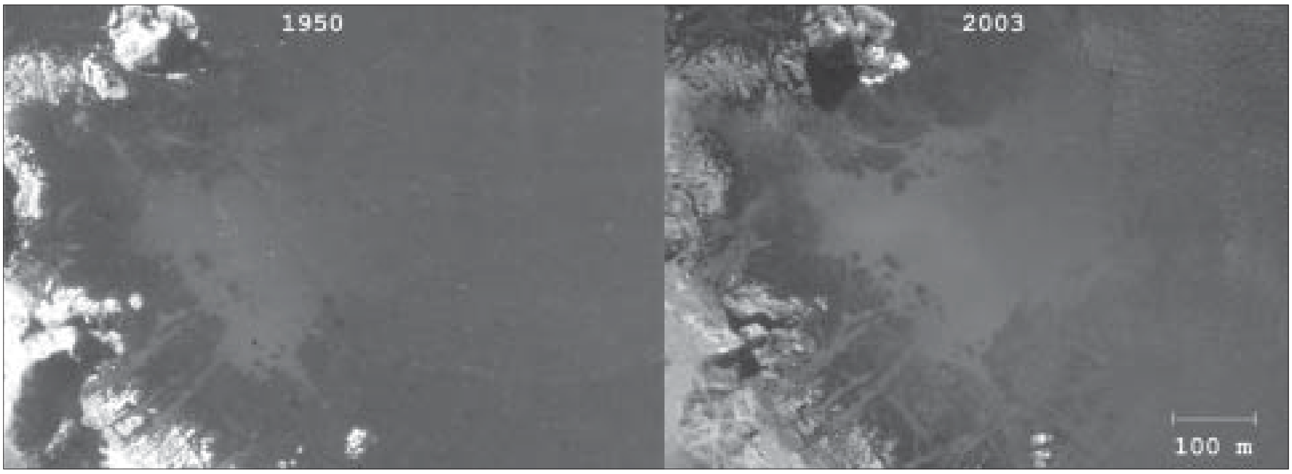

Figure 23. Change in algal forests, Moturoa Island.

Land and intertidal rock platforms are easily distinguished from dark shallow areas and paler sandy areas offshore. We have no ground-truthing in this area outside the Marine Park, so interpretations are directly from the photographs only.

1950: The dark reef areas appear to have a continuous algal cover. This is probably shallow mixed weed habitat in shallow water, and *Ecklonia* forest on the deeper reef areas with increasing depth towards the right in the photos. This area is exposed to wave action so it is not expected that tangle-weed forest would occur here.

2003: Most of the reef areas are much paler than in the 1950 photograph, suggesting kina-grazed zone is the major habitat type. The darkest areas, interpreted as shallow mixed weed habitat, are restricted to a narrow band around intertidal rocks and to a few shallow rocks near the bottom of the photograph. Some of the deeper rock areas close to the sand are a little darker, suggesting that there may be some sparse algal cover in these areas.

TABLE 4. AREAS OF PARTICULAR HABITAT TYPES AT MIMIWHANGATA.

HABITATS IDENTIFIED IN STUDY AREA	AREA (ha)	% OF STUDY AREA
Intertidal		
Sand	48	.55
Gravel	6	.07
Rock	66	.76
Subtidal		
Shallow mixed weed	72	.83
Kina barren	243	2.79
Carpophylum flexuosum forest	6	.07
Ecklonia forest	732	8.41
Rock and sand mixed shallow	90	1.03
Gravel	568	6.53
Sand and mud	3504	40.28
High-relief deep reef	365	4.20
Rock and sand mixed deep reef	700	8.05
Rock low-relief deep reef	2299	26.43
Total area	8700	

4. Discussion

The habitat map of Mimiwhangata Marine Park and the adjacent shelf produced in this study is intended as a tool for managers making decisions about marine protection and as a baseline for studies of change over time. The historic surveys, monitoring data, aerial photographs and habitat maps provide a unique opportunity to assess changes occurring over a period longer than the lifespan of the marine park. This is greatly assisted by the fact that the 1973 and 1981 habitat maps employed methods that are comparable and relevant to current approaches (Shears et al. 2004).

In the current survey we had the opportunity to adapt a range of modern habitat mapping methods which enabled us to extend the depth range and extent of the area studied. We were also able to explore the practicalities of how the various techniques could be used in combination to gather the most information for the least effort. In pragmatic terms, this is a significant factor when attempting to map habitats at the scale of this study. The combined use of GIS and GPS has created many advantages and opportunities for the future. Having the ability to georeference all data and photos and then arrange them in various 'layers' greatly enhanced our ability to interpret the data. The GIS layers we created can be spatially analysed and used for future research, greatly increasing the value of the habitat map.

4.1 LIMITATIONS OF THIS STUDY

There were some limitations to our methods which should be noted. Precision changed with water depth, reflecting the methods used, being greatest in shallow areas and decreasing as depth increased. However, we suggest that this variation is of limited concern in that significant biological boundaries tend to occur across much smaller distances in shallow waters and at greater distances in deeper water. This pattern directly correlates with the increasing cost of survey work as one moves from shallow to deeper waters. In deeper waters, side-scan sonar surveys give the most detailed sea floor coverage, but their use in our study was limited because of financial constraints. Single-beam sonar surveys were used to help verify the side-scan sonar results and to fill in gaps between side-scan swaths. While the use of single-beam sonar is cost-effective, the information obtained is limited to a single line of data. This limitation was partially overcome by the wider areas observed in drop video and the ROV deployments. Areas on the map not covered by the sonar swaths or tracks, deeper that 15 m and / or not observed in video drops, are interpretations or approximations between known points or areas. In the offshore areas, habitat variation between observations is unknown and can only be determined by 100% survey cover (e.g. side-scan or multibeam sonar). However, given the broad scale of the main habitat features documented in deeper water areas, we expect these variations will not be major. Our methodology also involved subjective judgements regarding which habitat descriptor (or class) 'best described' the sonar or video image of the area we were observing. This necessarily reduces the level of habitat 'patchiness' that can be represented in the habitat map.

In water less than 15 m deep, the accuracy of the mapping was determined by the interpretation of aerial photography which, in most areas, afforded resolution of detail down to 3–5 m. However, overall accuracy was limited by the georeferencing error (i.e. approximately 10–15 m).

Interpretation of algal forest cover in historic photos was limited to visual estimates of habitat extent. Quantification of habitat extent in the historic aerial photographs and habitat maps was beyond the scope of this study and would be limited by the inability to 'ground truth' spatial analysis of historic photographs, even though there is some historic field descriptive information available for the survey area. Other limitations include the large time gaps that exist in both the historic descriptive field work and aerial photographic records.

4.2 CHANGES TO THE SHALLOW ALGAL FOREST ZONE

Differences between present-day and earlier time-series photographs, habitat maps and descriptive work indicate a large-scale contraction in the area of algal forest in the 2–12 m depth zone. There is very little published information available to validate our interpretation of the 1950 aerial photos beyond consistent anecdotal accounts by long-time residents of the area of the presence in the 1950s of lush kelp beds on these reefs. The most relevant published material is a survey of algal forest zonation in Northland by Bergquist (1960) which describes a continuous progression with depth of the shallow mixed weed habitats into the *Ecklonia* forests at five sites from Spirits Bay to Leigh. Significantly, Bergquist (1960) did not find any large areas of kina (urchin) barrens at any of these sites. Expansion of urchin barrens has been documented elsewhere in New Zealand, and internationally (e.g. Lawrence 1975; Sala & Zabala 1996; Andrew & O'Neill 2000; Pinnegar et al. 2000), and the cause of this form of habitat change has become an important and active area of research. A predator removal hypothesis has been proposed, which has the basic premise that the expansion of 'urchin-grazed zones' on shallow reefs is caused by the depletion of urchin predators such as snapper and rock lobster by fishing (e.g. Babcock et al. 1999; Shears & Babcock 2002; Shears & Babcock 2003). This 'trophic cascade' model is based on comparative studies between marine reserves and fished areas outside reserves. The various studies cited previously examined predator-prey relationships between snapper and rock lobster and kina, abundance data and long-term measurement and mapping of algal forests and kina-grazed zones. Environmental factors which may affect algal forest / kina (urchin) barrens dynamics can be significant (Cole & Babcock 1996; Cole & Keuskamp 1998; Dayton et al. 1998). These include storm damage, changes in water temperature, increased sedimentation and / or nutrification and other ecological interactions such as algal blooms or outbreaks of kina disease. Shears & Babcock (2003) discuss the evidence for the short-term nature of affects of storm damage and disease outbreaks, but generally discount these and other environmental factors as mechanisms for explaining observed long-term changes and contrasting states between reserve and non-reserve sites.

We suggest that the observations of algal forest decline at Mimiwhangata in this study are consistent with the predator removal hypothesis (Babcock et al.

1999). Fish and rock lobster monitoring (Grace 1978, 1981a, 1984, 1985, 1986; Grace & Kerr 2002, 2003, 2004) indicate that predator levels (snapper and rock lobster) in Mimiwhangata Marine Park are reduced to low levels. A second monitoring programme conducted by Auckland University compared Mimiwhangata Marine Park (Denny & Babcock 2002; Usmar et al. 2003) to other 'fished' areas outside the Marine Park. Furthermore, predator levels in 'fished' areas are low compared with nearby marine reserves (Denny & Babcock 2004). Considering all the available information, it is possible to infer that the level of protection from fishing for predators such as rock lobster and snapper afforded by the existing marine park arrangement at Mimiwhangata is not adequate. The numbers of predatory fish have thus continued to decline, with a corresponding increase in numbers of kina (urchins) leading to a corresponding reduction in the area of algal forests and increase in the area of kina (urchin) barrens. The extent of the algal forest decline at Mimiwhangata now appears to represent a substantial ecological change to a habitat that is important to valuable recreational and commercial species such as snapper, kina, paua (*Haliotis iris*) and rock lobster. This change has most likely resulted in an overall decline in productivity and diversity of the shallow reef zone. It is notable that the algal forest decline trend appears consistent over the 50-year time period for which we have information about Mimiwhangata. In all our observations, we have not recorded any large-scale events or short-term changes in the trend which might suggest causal environmental disturbance factors operating as primary long-term controls of algal forest decline or recovery at Mimiwhangata.

4.3 DEEP REEFS

Recently, considerable attention has been drawn to the ecological importance of offshore benthic communities and their biological diversity, and to understanding the role they play in underpinning fisheries productivity. Cryer et al. (2000) describe detailed survey work off Spirits Bay, Northland. Although there are obvious differences in oceanography and biogeography between Mimiwhangata and Spirits Bay, there are also similarities. While it is probable that the reef communities off Mimiwhangata are not as diverse and complex as those off Spirits Bay, a more detailed study would be required to quantify these differences.

A special aspect of the Mimiwhangata reef systems is that they have extensive areas of soft bottom habitats surrounding them to the north and south. Recent ecological studies of rock lobster (*Jasus edwardsii*) (Kelly 2001) demonstrate that important ecological connections exist between deep reef habitats, patch reefs, shallow reefs and surrounding soft sediment areas. In these studies, crayfish were found to regularly migrate up to several kilometres out onto sand and gravel areas from their reef habitats to feed on bivalves and other benthic organisms.

In the current Mimiwhangata study, analysis of life on the deeper reefs was limited to observations of video footage. This footage shows that these deep reefs support a diverse encrusting community dominated by numerous sponge species. Notable species recorded include gorgonian fans, soft corals and black coral. We reviewed video footage with Steve O'Shea (Auckland University of

Technology) and Michelle Kelly (National Institute of Water and Atmosphere, NIWA), specialists in offshore benthic communities. They commented that the abundance and diversity of invertebrates on the deep reefs at Mimiwhangata was very high, particularly in the zone around 45 m depth, with abundance tapering off at 65 m depth. This distribution of abundance is similar to that observed in the same depth zone between North Cape and Cape Reinga (Cryer et al. 2000). The high-diversity area at Mimiwhangata includes the high-relief deepwater habitats contiguous with the extensive shallow reef system around Rimariki Island.

Another aspect of the deep reef at Mimiwhangata is the variation in the degree of siltation observed at different depths. Examination of the video images from the three depth zones—35, 45 and 65 m—shows that the deeper zones have substantially more silt sediments deposited on the reef and the encrusting organisms. The degree of siltation on the reef surface is influenced by currents, wave action, depth and silt loading of the system. In the 35- and 45-m zones, relatively little siltation of the reef is apparent. It is known that wave action at these depths is significant in storm conditions (Ballantine et al. 1973). We suggest that the higher vertical relief of the reef at these depths may also result in greater turbulence over these areas, thus preventing long-term deposition of fine sediments. Currents may also be stronger in these areas because of the effect of the nearby coastline. In contrast, terrain in the deeper zone is relatively flat, and at 60 m, wave action would have less effect. A similar pattern of wave / current / topography effecting deep reef habitats was observed in a study of deep reefs off Great Barrier Island (Sivaguru & Grace 2004; Morrison et al. 2001). In about 70 m of water southeast of Rakitu Island, the rocky areas support an extensive sponge community and the rock surface is covered in silt. These reefs are in a back-eddy with little current, and the site is believed to be too deep for wave action to reach. As a result, silt has accumulated on the reef. In contrast, the reefs north of Rakitu Island, despite being deeper (80 or 90 m), have a constant and moderate current passing over them, and are some 20 m above the surrounding seabed. Here, the upper parts of the reefs are relatively silt free and very rich in delicate hydroids, bryozoans, black corals and sponges.

4.4 SOFT SEDIMENTS DREDGE SURVEY

The dredge survey of soft bottom habitats in the study area provided a useful check of our mapping methodology. Preliminary findings of the dredge survey are summarised below:

- Confirmation that the soft bottom substrates at Mimiwhangata are highly variable, with a wide range of combinations of shell debris, sand, mud, silt and gravels appearing in the samples from the study area.
- Preliminary analyses of species assemblages indicate correlations with both major substrate divisions and depth.
- The diversity of fauna is high when compared with other studies of similar depths and substrates on Northland's northeast coast. (Note: detailed analysis of the dredge samples is still in progress.)

5. Recommendations

We make the following recommendations for future study and management at Mimiwhangata:

5.1 RESEARCH AND MONITORING

- Research and monitoring should continue at Mimiwhangata. The marine environment is highly varied in terms of both substrate and biology. It contains a complex habitat matrix that is one of the most amenable to study along the Northland coast. Past studies and habitat maps, along with the habitat map from this report, provide an ideal basis for further studies.
- Matauranga Maori (traditional ecological knowledge) in the Mimiwhangata area is an important source of ecological and management knowledge for the future. Although beyond the scope of this report, the details of these personal accounts and the traditional knowledge associated with them deserve careful documentation and study.
- The observations of change in the extent of algal forests and the collection of photographs and habitat maps contained in this report should be regarded as a preliminary study which warrants expansion and incorporation into a long-term monitoring program. The ecological questions surrounding the decline of algal forests should be considered a priority research area.
- Mimiwhangata should be recognised as providing an ideal situation to test the 'predator removal' hypothesis and other ecological questions if a full no-take marine reserve is put in place. The historic studies plus the current habitat map provide a scientific opportunity not available elsewhere in Northland north of Leigh. Mimiwhangata has a monitoring history which would assist multi-reserve impact studies with other northeast coast reserves. This approach has significance internationally.
- An additional site south of Mimiwhangata Park at Whananaki should be established as a 'reference' site for future investigations into changes in algal forests over time.

5.2 CONSERVATION MANAGEMENT

- The habitat complex described in this study meets criteria for a marine reserve as set out in the Marine Reserves Act (1971) as it has an exceptional array of northern New Zealand east-coast habitats together in one area. These habitats contain species and species assemblages that are of scientific interest, and present numerous opportunities for further and ongoing study.
- Coastal marine reserves generally, and Mimiwhangata in particular, should include deeper reef areas that are contiguous with any shallow reef systems. These reef systems should include areas of soft sediment habitat extending outwards at least 1 km from reef edges to allow uninterrupted movement of species between deep and shallow reef habitats, and to ensure that species that regularly cross these habitat boundaries—rock lobsters for example—enjoy the full benefits of protection.

6. Acknowledgements

There are many people involved with Mimiwhangata who have contributed over the years to our work; we apologise to all those not specifically mentioned here.

We thank the staff of Ngatiwai Trust Board who introduced us to the kaumatua and kuia of the hapu surrounding Mimiwhangata. We appreciate their patience with our strange methods, their support and freely given advice. We will long remember the oral history that we were privileged to hear.

We thank the Department of Conservation for the funding support that made much of this work possible. We would like to thank the following people for their direct contributions to this project: Terry Conaghan and Lorraine Wells, Information Management Unit, Northland Conservancy, for GIS work and mapping; Phil Bendle for his knowledge of the area and able skippering of our work boat (MV Norseman); Keith Gordon for expert application of his side-scan and ROV equipment; Kathy Walls, Leane Makey, Wade Doak, Rawiri Morunga, Charlie Morunga, Pat Haika and Chris Moretti for helping out with the field work and offering valuable comments.

Special thanks to the following peer reviewers for their significant contributions to the editing of this manuscript: Nick Shears, Clinton Duffy, Martin Cryer and Bill Ballantine. We also thank Diane Kerr for proof-reading the manuscript.

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Appendix 1

LOCATIONS OF VIDEO DROP SITES AND SIDE-SCAN IMAGES APPEARING IN FIG. 2

Data collected January 23, 2002.

EAST	NORTH	DEPTH	PHOTOS
2644823	6641532	63	Video 1
2643651	6641183	44	Video 2
2643395	6640355	35	Video 3
2643593	6640335	45	S.Scan 1

Appendix 2

SINGLE-BEAM SONAR ANALYSIS POINTS

Deep Reef Sonar 'Habitat Change Points' April 23–24, 2003.

Habitat code: 1 = sand / mud; 2 = gravel / cobble; 3 = mixed sand / reef; 4 = low-relief reef; 5 = high-relief reef.

POINT	EAST	NORTH	HABITAT CODE	DEPTH (m)	DATE (2003)
69	2647952	6637306	1	69	23 Apr
70	2647969	6638659	1	71	23 Apr
71	2648014	6639391	1	75	23 Apr
72	2647974	6640320	1	78.5	23 Apr
73	2647967	6640420	1		23 Apr
74	2647985	6641113	1	81	23 Apr
75	2647956	6641276	1		23 Apr
76	2647972	6641811	2	86	23 Apr
77	2648001	6642307	2	89	23 Apr
78	2648008	6642560	4		23 Apr
79	2647994	6642660	3	90	23 Apr
80	2647980	6642836	3		23 Apr
81	2647961	6642973	4	91	23 Apr
82	2647988	6643294	4		23 Apr
83	2647998	6643448	3	93	23 Apr
84	2648002	6643623	1		23 Apr
85	2648015	6643777	4	95	23 Apr
86	2647998	6645029	4	99	23 Apr
87	2647939	6645718	4	101	23 Apr
88	2647564	6645611	4	96	23 Apr
89	2647125	6645526	4	94	23 Apr
90	2646915	6645472	4	94	23 Apr
91	2646971	6644915	4	92	23 Apr
92	2646972	6643997	4	87	23 Apr
93	2646977	6642900	4	84	23 Apr
94	2646958	6641992	4	81	23 Apr
95	2646983	6641607	1		23 Apr
96	2646982	6641488	4		23 Apr
97	2646994	6641158	4	76	23 Apr
98	2646989	6640885	4		23 Apr
99	2646979	6640449	1		23 Apr
100	2646983	6640378	4		23 Apr
101	2646978	6639851	1	68	23 Apr
102	2646991	6639178	4	70	23 Apr
103	2646978	6638705	1		23 Apr
104	2647013	6638590	4	67	23 Apr
105	2647011	6638343	2		23 Apr
106	2646990	6637013	2	60	23 Apr
107	2646759	6637135	2	60	23 Apr
108	2647046	6637098	2		23 Apr
109	2646844	6636998	4		23 Apr

POINT	EAST	NORTH	HABITAT CODE	DEPTH (m)	DATE (2003)
110	2646461	6637051	4	56	23 Apr
111	2646424	6637057	5		23 Apr
112	2646296	6637073	4		23 Apr
113	2646180	6637091	5	54	23 Apr
114	2645866	6637078	5		23 Apr
115	2645912	6637218	4	52	23 Apr
116	2645871	6637829	1		23 Apr
117	2645867	6637928	2	66	23 Apr
118	2645864	6638427	1	57	23 Apr
119	2645897	6639225	4	62	23 Apr
120	2645906	6639630	3		23 Apr
121	2645910	6639714	4	64	23 Apr
122	2645922	6640827	4	68	23 Apr
123	2645914	6641546	4	70	23 Apr
124	2645945	6641852	3	73	23 Apr
125	2645932	6642092	4	74	23 Apr
126	2645987	6643082	2	76	23 Apr
127	2645982	6643793	4	79	23 Apr
128	2646010	6644368	4	84	23 Apr
129	2645991	6645050	4	87	23 Apr
130	2645858	6645122	4	86	23 Apr
131	2645353	6645114	4	82	23 Apr
132	2644956	6645093	4	77	23 Apr
133	2644894	6644995	3	77	23 Apr
134	2645045	6644565	4	78	23 Apr
135	2645191	6644026	2	77	23 Apr
136	2645193	6644016	4	77	23 Apr
137	2645276	6643729	2	76	23 Apr
138	2645279	6643722	4	75	23 Apr
139	2645444	6643262	4	73	23 Apr
140	2645520	6643005	4	72	23 Apr
141	2645490	6642893	4	73	23 Apr
142	2645528	6642715	4	73	23 Apr
143	2645527	6642634	4		23 Apr
144	2645514	6642574	5		23 Apr
145	2645492	6642403	4	71	23 Apr
146	2645530	6642038	3	70	23 Apr
147	2645512	6641935	4	71	23 Apr
148	2645490	6641807	4	68	23 Apr
149	2645496	6641766	4	67	23 Apr
150	2645518	6641065	5		23 Apr
151	2645517	6641057	5	62	23 Apr
152	2645507	6640909	4	65	23 Apr
153	2645490	6640482	5	59	23 Apr
154	2645516	6640344	4	58	23 Apr
155	2645477	6639314	4	57	23 Apr
156	2645509	6638834	2	56	23 Apr
157	2645500	6638744	4	57	23 Apr
158	2645476	6638056	5	52	23 Apr
159	2645473	6638043	4		23 Apr
160	2645468	6637997	5	52	23 Apr
161	2645508	6637840	4	52	23 Apr
162	2645488	6637592	5	48	23 Apr

POINT	EAST	NORTH	HABITAT CODE	DEPTH (m)	DATE (2003)
163	2645475	6637536	4		23 Apr
164	2645507	6637104	5	47	23 Apr
165	2645489	6636980	5	44	23 Apr
166	2645212	6637419	5	46	23 Apr
167	2644982	6637481	5	46	23 Apr
168	2644942	6637746	4	48	23 Apr
169	2644926	6638119	4		23 Apr
170	2644950	6638688	3	48	23 Apr
171	2645026	6639117	3		23 Apr
172	2644988	6639134	4	53	23 Apr
173	2644851	6639146	5		23 Apr
174	2644459	6639284	5	46	23 Apr
175	2644459	6639288	5	43	23 Apr
176	2644485	6639675	5	50	23 Apr
177	2644517	6640405	4	50	23 Apr
178	2644525	6640700	4	51	23 Apr
179	2644508	6641410	4	57	23 Apr
180	2644493	6641743	4	61	23 Apr
181	2644476	6642975	4	65	23 Apr
182	2644515	6643112	4		23 Apr
183	2644455	6643163	4	67	23 Apr
184	2644070	6643178	2	65	23 Apr
185	2643993	6643190	1	65	23 Apr
186	2643959	6643091	2		23 Apr
187	2643852	6642573	3		23 Apr
188	2643917	6642299	1	59	23 Apr
189	2643931	6642064	1	59	23 Apr
190	2643981	6641689	4	55	23 Apr
191	2643936	6641316	4	51	23 Apr
192	2643903	6641174	5	48	23 Apr
193	2643955	6640584	4	45	23 Apr
194	2643940	6640482	5	43	23 Apr
195	2643942	6640368	5	35	23 Apr
196	2643949	6640190	4		23 Apr
197	2643952	6639991	5	38	23 Apr
198	2643947	6639866	4	38	23 Apr
199	2643943	6639729	5	38	23 Apr
200	2644018	6638994	5	41	23 Apr
201	2643979	6638869	4		23 Apr
202	2643969	6638798	1	38	23 Apr
203	2644000	6637347	3		23 Apr
204	2644000	6637338	4	39	23 Apr
205	2644023	6637019	4	39	23 Apr
206	2643989	6636979	4		23 Apr
207	2643908	6636996	5	37	23 Apr
208	2643896	6636998	4		23 Apr
209	2643793	6637010	5	34	23 Apr
210	2643632	6637027	5	30	23 Apr
211	2643507	6637031	5	30	23 Apr
212	2643452	6637060	4	31	23 Apr
213	2643451	6637510	1	33	23 Apr
214	2643488	6637906	3		23 Apr
215	2643501	6638008	1	33	23 Apr

POINT	EAST	NORTH	HABITAT CODE	DEPTH (m)	DATE (2003)
216	2643505	6638118	1	33	23 Apr
217	2643494	6638636	4	36	23 Apr
218	2643512	6638858	1	36	23 Apr
219	2643501	6638905	5	35	23 Apr
220	2643497	6639017	5	35	23 Apr
221	2643436	6639080	5	33	23 Apr
222	2643075	6638836	5	36	23 Apr
223	2642872	6638687	1	27	23 Apr
224	2642767	6638446	1	26	23 Apr
225	2642553	6638004	4		23 Apr
226	2642549	6637999	5		23 Apr
227	2642441	6637768	5	19	23 Apr
228	2642437	6637758	1	21	23 Apr
229	2642157	6637406	5	18	23 Apr
230	2642074	6637163	1	18	23 Apr
231	2642048	6637114	4	17	23 Apr
232	2642010	6637058	4	17	23 Apr
233	2641935	6637095	5	16	23 Apr
234	2641753	6637188	1	14	23 Apr
235	2641495	6637318	4	13	23 Apr
236	2641414	6637358	5	9	23 Apr
237	2641151	6637488	1	11	23 Apr
238	2640999	6637626	1	10	23 Apr
239	2642225	6638105	1	20	23 Apr
240	2642369	6638611	5	21	23 Apr
241	2642512	6639128	1	25	23 Apr
242	2642532	6639188	5	24	23 Apr
243	2642616	6639366	5	18	23 Apr
244	2642723	6639692	5	18	23 Apr
245	2642740	6639821	4	21	23 Apr
246	2642786	6640019	5	26	23 Apr
247	2642888	6640329	4	28	23 Apr
248	2642941	6640460	4	31	23 Apr
249	2642991	6640627	4		23 Apr
250	2642937	6640788	4	34	23 Apr
251	2642908	6640841	4	30	23 Apr
252	2642723	6641112	5	23	23 Apr
253	2642583	6641260	4	27	23 Apr
254	2642426	6641404	5	28	23 Apr
255	2642277	6641530	4	34	23 Apr
256	2642060	6641587	1	31	23 Apr
257	2641791	6641594	3	29	23 Apr
258	2641608	6641586	3	28	23 Apr
259	2641528	6641573	4	27	23 Apr
260	2641399	6641546	5	24	23 Apr
261	2641093	6641515	5	14	23 Apr
262	2640505	6641370	4	15	23 Apr
263	2640446	6641357	5	20	23 Apr
264	2640372	6641345	4	20	23 Apr
265	2639586	6641008	5	18	23 Apr
266	2639580	6641005	4	17	23 Apr
267	2639236	6640785	1	19	23 Apr
268	2638264	6640108	1	13	23 Apr

POINT	EAST	NORTH	HABITAT CODE	DEPTH (m)	DATE (2003)
269	2638059	6639990	3	10.5	23 Apr
270	2637802	6639841	1	10	23 Apr
271	2637797	6639839	1	9	23 Apr
272	2637064	6640355			24 Apr
273	2637064	6640358			24 Apr
274	2637071	6640382			24 Apr
275	2637074	6640405			24 Apr
276	2637071	6640425			24 Apr
277	2637063	6640454			24 Apr
278	2637062	6640474			24 Apr
279	2637071	6640521			24 Apr
280	2637078	6640569			24 Apr
281	2637079	6640610			24 Apr
282	2637079	6640666			24 Apr
283	2637081	6640780			24 Apr
284	2636997	6640522	4		24 Apr
285	2636941	6640523	1	16	24 Apr
286	2636753	6640671	1	15	24 Apr
287	2636753	6640679	1	15	24 Apr
288	2636738	6640874	1		24 Apr
289	2636714	6641141	1	17.5	24 Apr
290	2636674	6641598	4	21	24 Apr
291	2636654	6641792	4		24 Apr
292	2636634	6642005	4	23	24 Apr
293	2636651	6642059	1	23	24 Apr
294	2636701	6642128	4	24	24 Apr
295	2636873	6642369	1	26	24 Apr
296	2636987	6642527	1	28	24 Apr
297	2637037	6642530	4	26	24 Apr
298	2637031	6642086	1	24	24 Apr
299	2637019	6641301	1	19.5	24 Apr
300	2637001	6640648	4	15	24 Apr
301	2636998	6640489	4	11	24 Apr
302	2637076	6640466	4		24 Apr
303	2637123	6640476	1	15.5	24 Apr
304	2637513	6640539	1	18	24 Apr
305	2638003	6640622	1	20	24 Apr
306	2638032	6640670	1	20	24 Apr
307	2638028	6641016	4		24 Apr
308	2638031	6641087	4	24	24 Apr
309	2638033	6641206	1	24	24 Apr
310	2638039	6641693	1	27	24 Apr
311	2638057	6642444	3	31	24 Apr
312	2638063	6642524	4	31	24 Apr
313	2638072	6643100	1	35	24 Apr
314	2638081	6643504	1	36	24 Apr
315	2638136	6643581	1	36.5	24 Apr
316	2638378	6643909	1	38	24 Apr
317	2638734	6644371	1	40	24 Apr
318	2638986	6644711	1	42	24 Apr
319	2639052	6644603	1		24 Apr
320	2639029	6643506	1	40	24 Apr
321	2639026	6643320	4	39	24 Apr

POINT	EAST	NORTH	HABITAT CODE	DEPTH (m)	DATE (2003)
322	2639028	6643076	1	39	24 Apr
323	2639023	6642876	4	38	24 Apr
324	2639011	6641866	4	32	24 Apr
325	2639006	6641735	1	30.5	24 Apr
326	2639001	6641649	4	26.5	24 Apr
327	2638987	6641299	3	24.5	24 Apr
328	2638986	6641244	1	24.5	24 Apr
329	2638986	6641213	3		24 Apr
330	2638987	6641124	1	24	24 Apr
331	2638986	6641085	4	23	24 Apr
332	2638980	6640890	4	23	24 Apr
333	2638978	6640737	1	20	24 Apr
334	2638970	6640510	1	18	24 Apr
335	2639025	6640476	1	17.5	24 Apr
336	2639261	6640805	4	20	24 Apr
337	2639360	6640937	4	19.5	24 Apr
338	2639485	6641104	4	20.5	24 Apr
339	2639494	6641160	4	22.5	24 Apr
340	2639505	6641432	3	27	24 Apr
341	2639509	6641815	1	29	24 Apr
342	2639510	6641821	3	31	24 Apr
343	2639530	6642096	1	34	24 Apr
344	2639533	6642321	3	36.5	24 Apr
345	2639557	6642902	1	40.5	24 Apr
346	2639599	6644263	1	43.5	24 Apr
347	2639585	6644495	1	44.5	24 Apr
348	2639652	6644564	1	44.5	24 Apr
349	2639994	6644633	1	46.5	24 Apr
350	2640085	6644591	1	46	24 Apr
351	2640077	6643638	1	43	24 Apr
352	2640063	6643017	3		24 Apr
353	2640067	6642971	4	42	24 Apr
354	2640066	6642898	4		24 Apr
355	2640067	6642801	4	39	24 Apr
356	2640024	6642778	4	41	24 Apr
357	2640017	6642621	4	39	24 Apr
358	2639981	6642466	4	358	24 Apr
359	2639988	6641688	1	29.5	24 Apr
360	2639992	6641474	4	26.5	24 Apr
361	2639991	6641357	3		24 Apr
362	2639992	6641292	4	24.5	24 Apr
363	2639976	6641051	4	15.5	24 Apr
364	2640009	6641025	4	9.5	24 Apr
365	2640236	6641070	5		24 Apr
366	2640542	6641160	5	13	24 Apr
367	2640540	6641176	5	11	24 Apr
368	2640541	6641423	5	17	24 Apr
369	2640541	6641428	4	17	24 Apr
370	2640545	6641612	4	24.5	24 Apr
371	2640545	6641846	3	31	24 Apr
372	2640554	6642204	4	33	24 Apr
373	2640563	6642463	3	40	24 Apr
374	2640566	6642532	1	41	24 Apr

POINT	EAST	NORTH	HABITAT CODE	DEPTH (m)	DATE (2003)
375	2640563	6642735	1		24 Apr
376	2640582	6643359	1	43.5	24 Apr
377	2640565	6644018	1	46.5	24 Apr
378	2640607	6644053	1	46.5	24 Apr
379	2641001	6644115	1	48.5	24 Apr
380	2641052	6644091	1		24 Apr
381	2641043	6642939	1	43	24 Apr
382	2641043	6642726	4	41	24 Apr
383	2641038	6642554	5	39	24 Apr
384	2641036	6642479	4		24 Apr
385	2640994	6641420	5		24 Apr
386	2640984	6641306	5	9.5	24 Apr
387	2641085	6641308	5	13	24 Apr
388	2641191	6641328	4	17.5	24 Apr
389	2641234	6641335	5	15.5	24 Apr
390	2641409	6641361	4	22.5	24 Apr
391	2641503	6641375	1	26.5	24 Apr
392	2641557	6641439	1	27.5	24 Apr
393	2641554	6641659	3	30.5	24 Apr
394	2641562	6641769	4		24 Apr
395	2641576	6642079	3	37.5	24 Apr
396	2641576	6642140	1	38.5	24 Apr
397	2641558	6642314	3	39.5	24 Apr
398	2641554	6642685	1	44.5	24 Apr
399	2641556	6642812	3	45.5	24 Apr
400	2641558	6642903	1	45.5	24 Apr
401	2641603	6644441	1	53.5	24 Apr
402	2641610	6644544	1	54.5	24 Apr
403	2641979	6644615	1	57.5	24 Apr
404	2642046	6644533	1	57.5	24 Apr
405	2642031	6643232	3	52	24 Apr
406	2642021	6642987	4	49	24 Apr
407	2642020	6642654	2	44.5	24 Apr
408	2641997	6641859	4	35.5	24 Apr
409	2642000	6641761	4	33.5	24 Apr
410	2641993	6641502	2	31.5	24 Apr
411	2642046	6641479	2	32.5	24 Apr
412	2642348	6641534	4	32	24 Apr
413	2642504	6641550	4	33.5	24 Apr
414	2642537	6641622	3	37.5	24 Apr
415	2642537	6641769	3	41	24 Apr
416	2642538	6641928	2	44.5	24 Apr
417	2642561	6642804	2	54.5	24 Apr
418	2642600	6643668	1	59	24 Apr
419	2642612	6644230	1	60.4	24 Apr
420	2642559	6644519	1	61.5	24 Apr
421	2642993	6644647	1	65	24 Apr
422	2643041	6644581	1	65.5	24 Apr
423	2643039	6643682	1	63.5	24 Apr
424	2642992	6642098	4	49.5	24 Apr
425	2642992	6641984	2	49.5	24 Apr
426	2642980	6641775	4	46.5	24 Apr
427	2642973	6641592	4		24 Apr

POINT	EAST	NORTH	HABITAT CODE	DEPTH (m)	DATE (2003)
428	2642982	6641513	4	40	24 Apr
429	2642967	6641320	4	36.5	24 Apr
430	2642966	6641238	5		24 Apr
431	2642965	6641141	4	32	24 Apr
432	2642926	6640788	3	33	24 Apr
433	2642917	6640567	4	31.5	24 Apr
434	2642920	6640499	4	30.5	24 Apr
435	2643092	6639873	5	33	24 Apr
436	2643198	6639890	4	34	24 Apr
437	2643258	6639900	5		24 Apr
438	2643323	6639916	5	31	24 Apr
439	2643352	6639727	4		24 Apr
440	2643352	6639350	4	35	24 Apr
441	2643353	6639204	4		24 Apr
442	2643349	6639099	5	32	24 Apr
443	2643349	6639035	1		24 Apr
444	2643349	6638941	2	35.5	24 Apr
445	2643349	6638860	4	33.5	24 Apr
446	2643337	6638593	1	34	24 Apr
447	2643315	6638060	1	32	24 Apr
448	2643330	6637600	4	33	24 Apr
449	2643308	6637141	5	27	24 Apr
450	2643304	6636990	5	25	24 Apr

Appendix 3

DROP VIDEO GROUND TRUTHING POINTS

POINT	EAST	NORTH	HABITAT CODE	DEPTH (m)	DATE (2003)	HABITAT DESCRIPTION
1	2638309	6638993	1	6.4	22 Apr	Think mostly sand, few rocks with kelp showing, poor visibility, video poor.
2	2638734	6639237	4	6.1	4 Mar	Mostly kina barren, low-relief rock with some isolated *Ecklonia.*
3	2638900	6639103	4	3.3	22 Apr	Kina barren. *Patiriella*, corallines, *Tethya*, parore.
4	2638952	6639139	3	5.1	22 Apr	Kina barren, next to sand ripples.
5	2639154	6639267	4	4.1	22 Apr	Kina barren, spotty.
6	2639342	6640319	4	2.6	4 Feb	Edge of shallow mixed weed and kina barren next to rocks emerging to near the surface. One moki seen from boat and one sweep seen on video. Scattered *Carpophyllum flexuosum* to 0.5 m high. Rock 2 m+.
7	2639147	6640422	1	15	4 Feb	Sandy bottom near edge of reef had *Ecklonia radiata* forest. Sand bottom rippled. Reef is habitat 4.
7a	2639156	6640477	1	15.1	3 Apr	Sand, no sign of reef.
8	2639368	6640598	4	9.2	3 Apr	*Ecklonia* forest, semi sparse on rock with sand patches.
9	2640097	6640853	5	8.8	3 Apr	High-relief rocky reef kina barren, few scattered *Ecklonia.* Note: Two awash rocks—one 20 m to N and one 25 m to NE. Both would have shallow mixed weed zone, also more shallow rocks further to the NE.
10	2640417	6640833	4	9.1	3 Apr	Rocky reef, kina barren, few scattered *Ecklonia*, and *Carpophyllum* sp.
11	2640810	6640725	4	6.9	3 Apr	Undulating rock, kina barren with small *Carpophyllum flexuosum* plants scattered. Sweep present.
12	2640899	6641066	5	8.4	4 Mar	High-relief rock, kina barren, scattered *Carpophylum flexuosum,* a few *Ecklonia.*
13	2641184	6640911	4	7.1	4 Apr	Low rock, kina barren, scattered *Carpophyllum flexuosum.*
14	2641398	6640973	4	10.1	4 Apr	Low-relief rock, mixed weed with sand, kina barren, sparse small *Carpophyllum flexuosum.*
15	2641505	6640952	4	7.8	4 Apr	Low-relief rock, *Carpophyllum flexuosum* forest, 1–1.5 m high, not dense, patches of kina barren and few *Ecklonia.*
16	2641466	6640778	3	6.2	4 Apr	Mixed low rock and cobbly sand, kina barren and very few algae, some *Gigartina circumcincta* and red algae.
17	2641097	6640592	4	5.8	4 Apr	Low-relief broken rock, gravel areas, kina barren with sparse *Carpophyllum flexuosum*, black angel fish, spotty and sweep.
18	2641203	6640401	4	3.9	4 Apr	*Carpophyllum flexuosum* forest, 1.5 m on low rock, dense.
19	2641157	6640192	4	4.5	4 Apr	*Carpophyllum flexuosum* forest, on low rock next to gravel, dense forest 1.5 m tall.
20	2641302	6640064	2	8.4	4 Apr	Gravel with few scattered rock outcrops, with *Carpophyllum flexuosum*, gravel, no ripples, few *Caulerpa* and red algae.
21	2641330	6640210	4	4.2	4 Apr	*Carpophyllum flexuosum* forest interspersed with kina barren.

POINT	EAST	NORTH	HABITAT CODE	DEPTH (m)	DATE (2003)	HABITAT DESCRIPTION
22	2641423	6640246	4	9.4	21 Feb	*Carpophyllum* forest heading toward kina barren, plants at approx. 3-m centres 1–1.5 m high.
23	2641603	6640356	4	7.6	21 Feb	Similar to Pt 22 but much more advanced towards kina barren. Approx. one algae *Carpophyllum flexuosum* to 10-m centres. Shallower part is mixed weeds zone, no *Ecklonia* forest.
24	2641879	6640556	4	12.3	21 Feb	Shallow mixed weed zone dropping straight into kina barren with some scattered *Ecklonia* & *Carpophyllum angustifolium*, no healthy algal forest at all.
25	2642074	6640603	4	9.3	21 Feb	Kina barren running onto narrow fringe of *Ecklonia* where reef merges onto sand.
26	2642281	6640521	5	8.8	4 Apr	High-relief rock, kina barren, *C. angustifolium* clumps, *Lessonia* on top, parore, sweep.
27	2642350	6640732	4	10.1	4 Apr	*Ecklonia* forest, rock with sand gutters, demoiselles, 10 juvenile Sandager's wrasse cleaning drummer; sweep, spotty and leatherjacket. Nearby rocky edge of rock with clumps of *Lessonia* and dropping down to *Ecklonia* forest.
28	2641838	6641060	5	7.8	4 Apr	High-relief rock, kina barren with *Carpophyllum flexuosum* clumps, few *Lessonia*, demoiselle, black angelfish, red moki.
29	2642228	6640178	5	11.1	4 Apr	High-relief rock, *Ecklonia* forest, demoiselle, sweep, red moki.
30	2641709	6640027	1	9.2	4 Apr	Sand, medium ripples.
31	2642385	6639811	4	13.1	4 Apr	Medium-relief rock (not high), dense *Ecklonia*, demoiselle, female pigfish.
32	2641936	39773	3	9.1	4 Apr	Mixed sand / rock with high-relief rock, *Ecklonia* forest.
33	2641911	6639591	4	3.5	4 Apr	Shallow mixed weed adjacent to gravely cobbles.
34	2641680	6639683	4	6.5	4 Apr	Medium-relief rock (lowish), sparse *Ecklonia / C. maschalocarpum*, probably recovering barren.
35	2641528	6639704	3	8.9	22 Apr	Mixed lowish rock kina barren & few *Carpophyllum flexuosum* and gravel with ripples.
36	2641415	6639820	5	7.6	21 Feb	Rock coming up to 2 m, shallow mixed weed dropping down to rock with scrappy shallow mixed weed, few small *Carpophyllum flexuosum.* Mostly kina barren.
37	2641137	6639869	4	6.9	4 Apr	Undulating rock, kina barren, sparse *Carpophyllum flexuosum* and occasional *Ecklonia*, goatfish, spotty.
38	2640158	6639857	4	8.2	22 Apr	Kina barren, *Carpophyllum flexuosum*. Clumps to 0.5 m, red moki.
39	2640994	663970	4	7	22 Apr	Kina barren, some *Carpophyllum flexuosum*—small clumps, sweep.
40	2641426	6639576	2	6.5	22 Apr	Gravel / cobbles, scattered *Gigartina circumcincta.*
41	2641442	6639305		7.3	22 Apr	
42	2641775	6639263	4	13.5	22 Apr	Kina barren with small *Carpophyllum flexuosum,* spotty, female red pigfish.
43	2642063	6639173	4	10.3	22 Apr	Kina barren, few *Carpophyllum flexuosum,* parore, leatherjacket.
44	2641940	6638820	5	14.4	22 Apr	Kina barren, few *Carpophyllum flexuosum.*
45	2641801	6638820	3	16.4	22 Apr	Sand & big ripples. Few rocks with *Ecklonia.*
46	2641643	6638872	4	13.1	22 Apr	*Ecklonia* forest next to kina barren. Sweep. Female pigfish.
47	2641473	6638492	4	13.6	22 Apr	*Ecklonia* forest.
48	2641398	6638723	5	11.7	22 Apr	*Ecklonia* forest. *Ancorina. Charonia.*

POINT	EAST	NORTH	HABITAT CODE	DEPTH (m)	DATE (2003)	HABITAT DESCRIPTION
49	2640987	6639064	3	10.9	22 Apr	Cobbles & *Gigartina*, next to low rock kina barren.
50	2640676	6639105	2	7.1	22 Apr	Poor video. Could be cobbly gravel with occasional *Carpophyllum flexuosum.*
51	2640603	6638415	4	5.8	22 Apr	Kina barren. Rock 2 m +.
52	2640899	6638400	1	12.9	22 Apr	Sand, medium ripples.
53	2640901	6638111	1	9.9	22 Apr	Sand, medium ripples.
54	2641338	6637414	5	11.1	22 Apr	Kina barren, few *Carpophyllum flexuosum* plants.
55	2641344	6636974		9.4	22 Apr	
56	2640985	6637087	5	3.3	22 Apr	Shallow mixed weed, *C. angustifolium.*
57	2640846	6637476		9.2	22 Apr	
58	2640548	6637468	5	4.9	22 Apr	Shallow mixed weed, some kina.
59	2640510	6637648	5	4.4	22 Apr	Shallow mixed weed *C. maschalocarpum.* Some kina.
60	2640504	6637850		3.9	22-Apr	
61	2640773	6641280	4	16.6	3 Apr	Undulating rock, with gravely sand patches, sparse *Ecklonia* forest.
62	2640689	6641429	5	13.7	4 Mar	High-relief rock, medium–dense *Ecklonia* forest with abundant demoiselle and sweep.
63	2640585	6641649	4	24.9	4 Mar	Undulating rock with medium-density *Ecklonia, Ancorina* sponge, abundant demoiselle. Sand gutter.
64	2640464	6641936	4	32.1	3 Apr	Low-relief rock, sponge zone. Scarlet wrasse, cup sponge.
65	2641825	6641309	4	20.8	4 Apr	High-relief undulating rock, sparse *Ecklonia*, sand patches, sponges near sand, *Polymastia granulosa, Ancorina, Raspaillia*, Calcareous sponge. Fishes: demoiselle, sweep, goatfish. Rock to 2 m+.
66	2641798	6641543	2	30.3	4 Apr	Sandy gravel, megaripples.
67	2641781	6641730	3	33.8	4 Apr	Gravely cobbles, few small patch reefs with sponges, some megaripples.
68	2642084	6641880	2	38.1	4 Apr	Sandy gravel, megaripples, distant small patch reef, pink maomao.
h69	2642918	6639693	5	25.8	4 Apr	High-relief rock, tall sparse *Ecklonia*, some sponges, *Ancorina*, calcareous sponges demoiselle, porae. Rock only just reaches habitat 5.
h70	2643335	6639641	5	32.8	4 Apr	High-relief rock, sparse *Ecklonia*, sponges include *Calyspongia, Stelleta, Ancorina*, calcareous sponges. Four pigfish, leatherjacket, scarlet wrasse and bigeyes. Rock is marginal habitat 4–5.
p1	2638062	6641147	1	24.8	28 Apr	Sand. Edge of habitat 2 with megaripples. Goatfish.
p2	2638511	6641501	3	29.7	28 Apr	(Upside-down). Sparse *Ecklonia*, cobbly bits. Female pigfish.
p3	2638524	6642008	3	29.9	28 Apr	Mixed low rock and coarse gravely sand with megaripples.
p4	2638514	6642505	2	33	28 Apr	Gravely sand with megaripples.
p5	2638513	6642988	4	35.4	28 Apr	Low rock with *Ancorina* sponges. Few gorgonians.
p6	2638092	6642801	4	33	28 Apr	Sponges, few gorgonians. Sand patches.
p7	2637516	6642501	1	29.8	28 Apr	Sand. No ripples.
p8	2637001	6642271	4	29.5	28 Apr	Low rock, very sparse *Ecklonia*. Sponges, sand patches, various fishes. Edge of reef.
p9	2636701	6641842	3	23	28 Apr	Low rock, scattered *Ecklonia.* Sand areas, no ripples.
p10	2637172	6641775	1	22.5	28 Apr	Sand, few small weak ripples. Few drift *Ecklonia*.
p11	2636187	6640171	3	8.5	28 Apr	Low-relief rock, kina barren. Few *C. angustifolium*. Sand with medium ripples.

POINT	EAST	NORTH	HABITAT CODE	DEPTH (m)	DATE (2003)	HABITAT DESCRIPTION
p12	2636315	6640065	5	8	28 Apr	Low rock, kina barren. Few Actinothoe, small *Carpophyllum flexuosum.*
p13	2636424	6640108	1	11.5	28 Apr	Sand, medium ripples. Distant low rock with *Ecklonia.*
p14	2636757	6640158	2	14	28 Apr	Cobbles with occasional *Ecklonia* and smaller algae. *Gigartina circumcincta*.
p15	2637051	6640189	5	6	28 Apr	Kina barren with moderate *Carpophyllum flexuosum* to 0.4 m. Red moki.
p16	2636962	6640320	5	8.5	28 Apr	Kina barren with scattered *Carpophyllum flexuosum*. Sweep, demoiselle, kelpfish, banded wrasse.
p17	2636908	6640374	5	13	28 Apr	Boundary, kina barren above and *Ecklonia* below.
p18	2636833	6640418	5	12.5	28 Apr	Mostly kina barren with *Ecklonia* below. *Ancorina.*
p19	2636746	6640458	4	13	28 Apr	Low rock with mixed *Ecklonia* patches and kina barren. Gravely sand gutters with megaripples.
p20	2636643	6640505	3	13.5	28 Apr	Low rock, *Ecklonia*, and sand with some megaripples.
p21	2636560	6640551	1	13.5	28 Apr	Sand, small ripples, small bug holes.
p22	2637079	6640782	1	17	28 Apr	Smooth sand, to megaripples. Eagle ray.
p23	2637077	6640654	4	14	28 Apr	Good *Ecklonia* forest. Banded wrasse, sweep, red moki. Apparently a patch reef.
p24	2637079	6640559	3	15.5	28 Apr	Low rock, *Ecklonia* and gravely sand, megaripples. Leatherjacket
p25	2637068	6640454	4	13	28 Apr	Low rock, good *Ecklonia*, abundant sweep.
p26	2637072	6640400	5	10	28 Apr	Mostly kina barren with small *Carpophyllum flexuosum*, and *Ecklonia* below. Demoiselles, sweep.
p27	2637050	6640190	5	6	28 Apr	Kina barrens with *Carpophyllum flexuosum* to 0.5 m. Sweep, few demoiselle.
p28	2637423	6640057	3	7	28 Apr	Low rock, good *Ecklonia*, some sand. Goatfish, several juvenile Sandager's wrasse (cleaning station), trevally.
p29	2637702	6640137	5	8	28 Apr	Kina barren, scattered *Carpophyllum flexuosum* to 0.3 m. Sweep.
p30	2637700	6640178	5	12	28 Apr	*Ecklonia*, with kina barren above. Sweep.
p31	2637704	6640225	5	8	28 Apr	Kina barrens, scattered *Carpophyllum flexuosum* to 0.4 m. Leatherjacket, spotty.
p32	2637704	6640290	4	15	28 Apr	(High rock nearby). *Ecklonia*, with kina barren higher at about 12 m. Near sand. Spotty.
p33	2637702	6640341	1	16	28 Apr	Sand, bug holes, fading ripples.
p34	2637702	6640386	1	17	28 Apr	Sand, bug holes, fading ripples. Fish hole (eagle ray?).
p35	2637920	6640029	4	16.5	28 Apr	Good *Ecklonia* forest. Sweep.
p36	2637433	6639787	3	4	28 Apr	Low cobbly reef, *Gigartina circumcincta*, some *C. maschalocarpum*. Leatherjacket.
p37	2637359	6639439	4	2	28 Apr	*Carpophyllum flexuosum* forest.
p38	2637348	6639460	4	5	28 Apr	Tall *Carpophyllum flexuosum* forest. Lots of spotties.
v4	2641900	6640572	4	4	24 Apr	*Carpophyllum angustifolium* and kina barren, some mixed weed, bigeye. Shallow mixed weed dropping to kina barren.
v5	2643312	6637101	4	28	24 Apr	Low rock. Sparse *Ecklonia*. *Ancorina*, *Caulerpa*, demoiselles, porae, scarlet wrasse.
v6	2644747	6637121	4	41	24 Apr	Low rock, sponges, video dark—not sure of gorgonians. Female red pigfish.
v7	2645391	663700	4	43.5	24 Apr	Gorgonians, sponges, *Ancorina*, *Calyspongia.*
v8	2647004	6636953	1	60	24 Apr	Sand.

POINT	EAST	NORTH	HABITAT CODE	DEPTH (m)	DATE (2003)	HABITAT DESCRIPTION
g1	2642909	6640408	4	25	16 May	Low rock with moderate *Ecklonia* forest. Some sand patches with *Caulerpa* close to the sand. One *Ancorina*. No fish.
g2	2643436	6640610	4	38	16 May	Low rock with gorgonians, some *Stelleta*, *Ancorina*, tall thin *Raspailia*? One *Knightaster* seastar. Dead circular saw shell. Some loose rocks. Female red pigfish, goatfish, male red pigfish.
g3	2644141	6640582	3	42	16 May	Mixed gravel with megaripples, and low rock with gorgonians. Dog cockle shells. Gorgonians close to gravel. Calcareous sponge (*Leucetucer lancifer*). Sweep. *Raspailia* sponge. *Callyspongia*. Male red pigfish.
g4	2644086	6641057	3	49	16 May	Mixed gravel with megaripples and dog cockle shells, and patches of low rock with gorgonians. Not a good view of rocks—glimpse of *Ancorina*. Female red pigfish. Leatherjacket.
g5	2644702	6640570	3	53	16 May	Mostly low rock with gorgonians, *Raspailia*, *Stelleta*, small finger sponges. Also gravel with megaripples. Gorgonians very close to gravel. *Ancorina*. Goatfish, scarlet wrasse, starfish (probably *Knightaster* but could be *Ophidiaster*).
g6	2640534	6642833	3	43	16 May	Mixed highish rock and sand. Sand has bug holes but no fish feeding holes. Sponges include *Polymastia granulosa* and *P. fusca*, *Ancorina*. No obvious gorgonians. Scarlet wrasse, goatfish, leatherjacket, snapper, slender roughy, female red pigfish.
g7	2640436	6642724			16 May	Video failed.
g8	2640424	6642728	3	40	16 May	Fine sand no ripples, small bug holes. Goatfish, female red pigfish. Next to habitat 4 rock with rich gorgonians. Leatherjacket. Depth estimate.
g9	2640336	6642643	5	39	16 May	Low rock with high vertical walls with few sandy gutters. Gorgonians (nice closeups) small finger sponges. *Ancorina, Stelleta*, goatfish, female pigfish, leatherjacket. Depth estimate.
g10	2640258	6642534	5	38	16 May	Low rock, high vertical walls, lots of sponges—*Ancorina, Stelleta*, gorgonians, pencil bryozoans, small finger sponges, female red pigfish, leatherjacket, scarlet wrasse, butterfly perch. Depth estimate.
g11	2640187	6642475	2	37	16 May	Gravel with megaripples, sandier in hollows. Fairly obvious recent movement. Few dog cockle shells. Male red pigfish. Small rock outcrop probably with small gorgonians. Demoiselle school on way up. Depth estimate.
g12	2640111	6642404	4	35	16 May	Low rock with sandy gutters. Sponges, *Ancorina*, *Stelleta*. No obvious gorgonians. Pencil bryozoans. Leatherjacket. One higher rock with finger sponges on top. No other fish. Depth estimate.
g13	2640026	6642318	3	35	16 May	Low rock with sandy gutters with cobbly patches. *Stelleta*, pencil bryozoans. No obvious gorgonians. Few small finger sponges. Depth estimate.
g14	2639965	6642233	4	34	16 May	Low rock with several loose rocks, with sponges, *Ancorina, Stelleta, Raspailia*, one small *Ecklonia*, pencil bryozoans, leatherjacket, demoiselle. No obvious gorgonians. Depth estimate.

POINT	EAST	NORTH	HABITAT CODE	DEPTH (m)	DATE (2003)	HABITAT DESCRIPTION
g36	2640957	6642299	3	c. 36	13 May	Gravelly sand with megaripples and dog cockle shells. Areas of rock 2 m+ high, with lots of sponges, *Ancorina*. Probably gorgonians on higher rocks but can't be sure. Lots of demoiselles. Also butterfly perch, scarlet wrasse, female red pigfish.
g37	2640652	6641746	5	c. 28	13 May	High rock with moderate *Ecklonia* and corallines. Red moki, female red pigfish, combfish!!
g38	2639659	6641756	3	c. 29	13 May	Mixed low rock and coarse gravelly sand with megaripples. (Glimpse only at end of tape).

Appendix 4

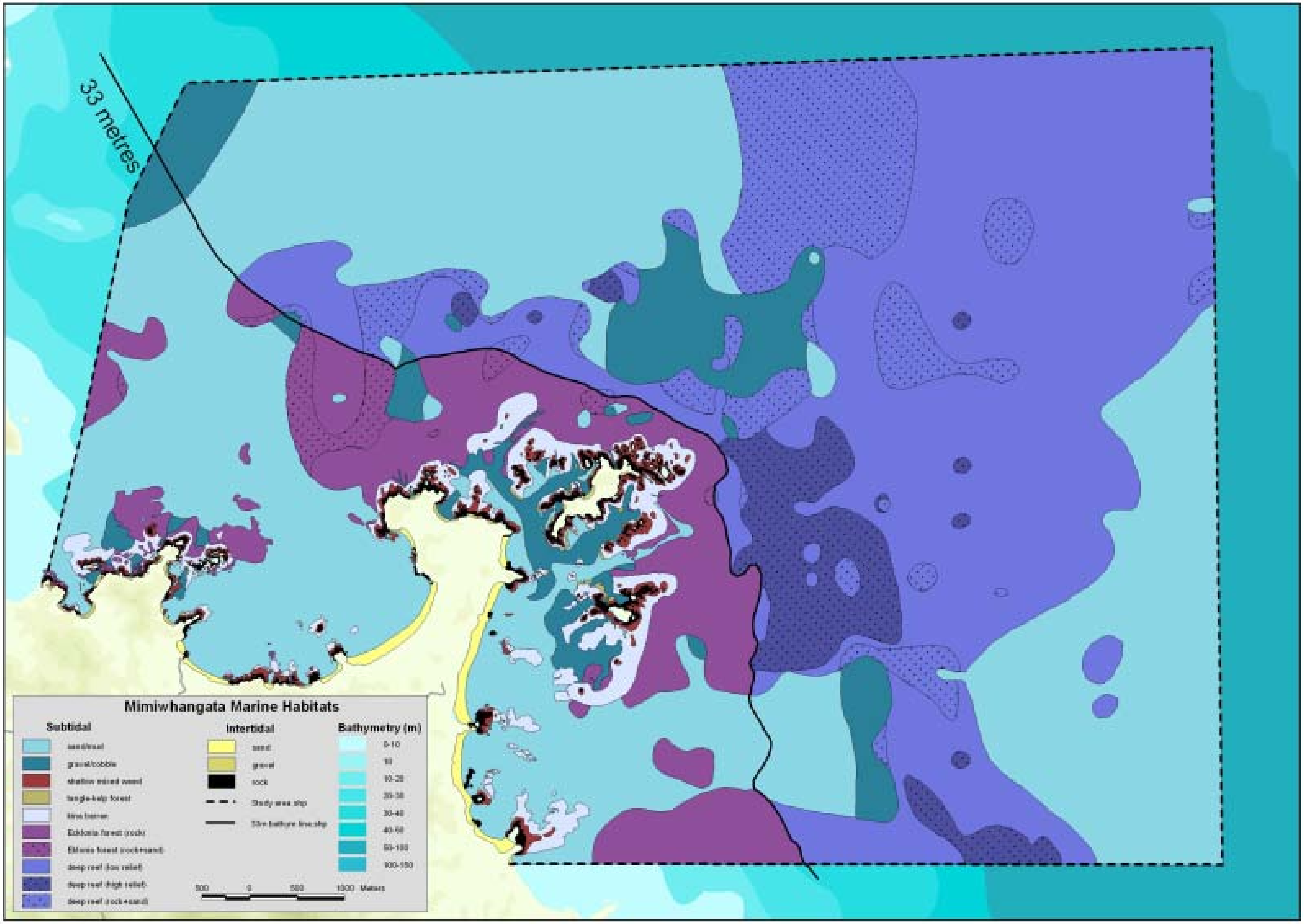
SOFT BOTTOM SEDIMENT STUDY SAMPLING POINTS

Mimiwhangata Sediment Study 2004.

Habitat code: 1 = sand / mud; 2 = gravel /cobble; 3 = mixed sand / reef; 4 = low-relief reef; 5 = high-relief reef.

SITE	EAST	NORTH	HABITAT CODE	DATE (2004)	SEDIMENT DESCRIPTION
1	2639526	6639619	1	Feb 24	fine sand
2	2638651	6639577	1	Feb 24	fine sand
3	2638062	6639368	1	Feb 24	fine sand
4	2638665	6640379	1	Feb 24	fine sand
5	2637544	6640781	1	Feb 24	gravely shelly sand
6	2636586	6641165	1	Feb 24	slightly silty fine sand
7	2637613	6641832	1	Feb 24	silty fine sand
8	2636782	6642598	1	Feb 24	silty fine sand
9	2637735	6642848	1	Feb 24	silty fine sand
10	2637068	6644078	2	Feb 24	gravel
11	2641433	6636910	1	Feb 24	fine sand
12	2640951	6637857	1	Feb 24	fine sand
13	2640944	6638685	1	Feb 24	fine sand
14	2640897	6640105	1	Feb 24	fine sand
15	2641769	6639918	1	Feb 24	medium sand
16	2642083	6637582	1	Feb 24	fine sand
17	2641828	6638324	1	Feb 24	fine sand
18	2642893	6637665	4	Feb 24	rock
19	2642863	6638477	1	Feb 24	fine sand
21	2641774	6639019	2	Feb 24	gravely coarse sand, cobbles
22	2641411	6639021	1	Feb 24	coarse gravely sand
23	2641277	6639456	2	Feb 24	gravely coarse sand
24	2641224	6640075	1	Feb 24	gravely coarse sand
25	2641589	6640154	2	Feb 24	gravely coarse sand
26	2641868	6640363	2	Feb 24	gravely coarse sand
27	2641013	6640474	1	Feb 24	gravely coarse sand
28	2641294	6640800	1	Feb 24	gravely coarse sand
29	2640624	6640987	4	Feb 24	rock
30	2639721	6641655	2	Feb 24	sandy gravel
31	2644149	6638086	1	Feb 24	fine sand
32	2646283	6638884	1	Mar 18	muddy fine sand
33	2647972	6636864	1	Mar 18	muddy fine sand
34	2648183	6638672	1	Mar 18	very muddy fine sand
35	2648066	6641528	1	Mar 18	very muddy fine sand
36	2637477	6644846	2	Feb 24	sandy gravel
37	2638413	6643448	1	Feb 24	muddy fine sand
38	2639444	6644847	1	Mar 18	muddy fine sand
39	2640713	6643820	1	Mar 18	muddy fine sand
40	2641591	6644719	1	Mar 18	muddy fine sand
41	2642026	6641975	2	Feb 24	muddy gravel

SITE	EAST	NORTH	HABITAT CODE	DATE (2004)	SEDIMENT DESCRIPTION
42	2642625	6642447	2	Mar 18	muddy gravel
43	2642341	6643300	1	Mar 18	muddy fine sand
44	2643650	6642408	2	Mar 18	silty shelly gravel
45	2645958	6643472	1	Mar 18	muddy shelly fine sand
46	2647979	6642392	1	Mar 18	very muddy fine sand
47	2647584	6640871	1	Mar 18	very muddy fine sand
48	2647297	6637538	1	Mar 18	muddy fine sand
49	2646247	6638041	1	Mar 18	muddy fine sand
50	2644540	6638636	2	Mar 18	slightly muddy sandy gravel
51	2639036	6639922	1	Feb 24	fine sand
18a	2642917	6637264	4	Feb 24	rock
18b	2643001	6638077	1	Feb 24	fine sand
29b	2640650	6640763	1	Feb 24	gravely coarse sand


33 metres
Mimiwhangata Marine Habitats
Subtidal
Intertidal
sand
gravel
rock
Bathymetry (m)
0-10
100-150
500
0
500
1000
Meters