Marine habitats of the proposed Waewaetorea Marine Reserve

Vince Kerr and Roger Grace, August 2015

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Ngā ika āke, ake ake, Ipipiri

Contents

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Summary

A marine habitat map for the waters around the Okahu, Waewaetorea, Motukiekie, and Urupukapuka Islands in the Bay of Islands, Northeastern Coastal Biogeographic region, New Zealand has been completed and is presented in a series of maps. The maps cover an area of 993 ha extending out to sea as far as 1.5 km and the 50 m depth contour. Habitats were classified according to the Marine Protected Areas (MPA): Classification, Protection Standard and Implementation Guidelines. Additional biogenic habitats, algal turf beds, and seagrass beds were also mapped. Algal turf beds and seagrass beds are of particular interest for the assemblages of algal species present and the associated marine life: these habitats could be considered special habitats in the context of marine protected area planning. The MPA classification 'shallow rocky reef' was further defined into its primary biological communities of 'shallow mixed weed', 'kina barrens' *Evechinus chloroticus*, and '*Ecklonia* forest' *Ecklonia radiata*.

The survey takes in the marine reserve area proposed in 2014 by the community group Fish Forever. Results of the survey support Fish Forever's proposal by demonstrating the special values of the area and it's representation of outstanding examples of representative habitats and species for this bioregion. The area includes a high diversity of complementary habitats spanning a range of depths, substrates, exposures and physical and biogenic processes as defined in the MPA Guidelines. Habitats are described in detail and illustrated with underwater photos, and a preliminary list of 54 fish species observed including several subtropical species rarely seen at coastal sites.

The high resolution of mapping in this study made it possible to accurately delineate kina barrens as part of the shallow rocky reef environment. This study indicates that the extent of kina barrens in sheltered areas is a concern, and now covers 43% of shallow rocky reef at this location. Kina barrens also cover 10.3% and 1% of moderately exposed and exposed reef habitats have respectively.

The decline in kelp forests outside of marine reserves contrasts with the recovery from the kina barren condition back to healthy kelp forest observed following the establishment of marine reserves with full protection from fishing at Goat Island and Tawharanui marine reserves. The authors recommend that the size and scale of this decline and the threat it poses becomes the focus of additional studies at representative sites along the Northland coast. In this way the dynamics between kina, kelp and fishing can be examined at a useful scale. Given the potential risk of losing kelp forests and lessons learned from overseas and our own existing marine reserves, every effort should be made to install no take marine reserves in Northland as soon as possible.

Introduction

In May 2014, the Bay of Islands community group "Fish Forever" released a public consultation document proposing a marine reserve in an area surrounding Okahu and Waewaetorea Islands and parts of the surrounding waters of Motukiekie and Urupukapuka Islands in the eastern Bay of Islands, Northland (Fish Forever, 2014). This proposal was supported by two previous technical reports prepared for Fish Forever: a report on the geological origins and current geological features of the proposal area (Gibb, 2012), and a second report which analysed the proposed boundaries for the marine reserves (Kerr, 2014). Based on the strength of the proposal and the significant support documented in a report on consultation results (Kerr et al., 2014), Fish Forever decided to continue with a program of habitat and diversity studies at the proposed marine reserve area, thus initiating this project.

A 1992 study, (Brook and Carlin) based on fixed transect lines characterised fish and algal communities combined with a simple exposure map. This study was helpful in indicating major rocky reef communities and the affect of exposure on the diverse shorelines within the study area.

Figure 1 The marine reserves proposed by Fish Forever in 2014. Note that the area centred on Waewaetorea Island is the area of interest for this study.

Previous habitat mapping in Northland, including the methods used, and mapping classifications is provided in the Northland Marine Habitat Map (Kerr, 2010). Variations on the approaches used previously are presented here in the methods section. Because this study is designed primarily to support MPA planning, emphasis is placed on the habitat classification introduced in the Marine Protected Areas:

Classification, Protection Standard and Implementation Guidelines (DOC & MFish, 2008) (MPA Guidelines) shown here in Table 1.

Level 2	**Environ-ment type**	**Marine**						
Level 3	**Depth**	**Intertidal (MHWS MLWS)**			**Shallow Subtidal (MLWS – 30m)**			**Deep Subtidal (30m – 200m)**
Level 4	**Exposure**	low	med	high	low	med	high	low
Level 5	**Habitat type**	Mud flat	Sandy beach	Sandy beach	Shallow mud	Shallow sand	Shallow sand	Deep mud
			Gravel beach	Gravel beach		Shallow gravel field	Shallow gravel field	Deep sand
			Cobble beach	Cobble beach		Shallow cobble field	Shallow cobble field	Deep gravel field
			Boulder beach	Boulder beach		Shallow boulder reef	Shallow boulder reef	Deep cobble field
			Rocky platform	Rocky platform		Shallow rocky reef	Shallow rocky reef	Deep boulder field
						Shallow biogenic reef	Shallow biogenic reef	Deep rocky reef
								Deep biogenic reef

Table 1 Habitat classification from the Marine Protected Areas Implementation Plan.

The intention of the MPA classification is to provide a basic classification founded on primary physical substrate types, exposure and depth zones that drive community and ecosystem structure thereby acting as a proxy for more complex ecosystems or biological communities. At the relatively fine scale of this study, it is possible to include additional biological habitats. Our decision to include significant biological habitats in the mapping exercise was supported by work done by Shears et al. (2004 and 2007). This study had examined the degree of concordance between qualitative habitat descriptors and quantitative species data from various locations along the northeast coast. The authors 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.

Methods

Habitat Surveys

Each summer between 2011 and 2015, habitat information was recorded at the study site (Kerr and Grace Survey). Various methods were adopted to maximise efficiency of boat time and equipment available. The methods varied also according to the depths we were working at and the specific objectives we had in collecting the information. Figure 2 shows the spatial distribution of records produced in the survey area including additional data from other sources. Table 2 details by method the number of information records.

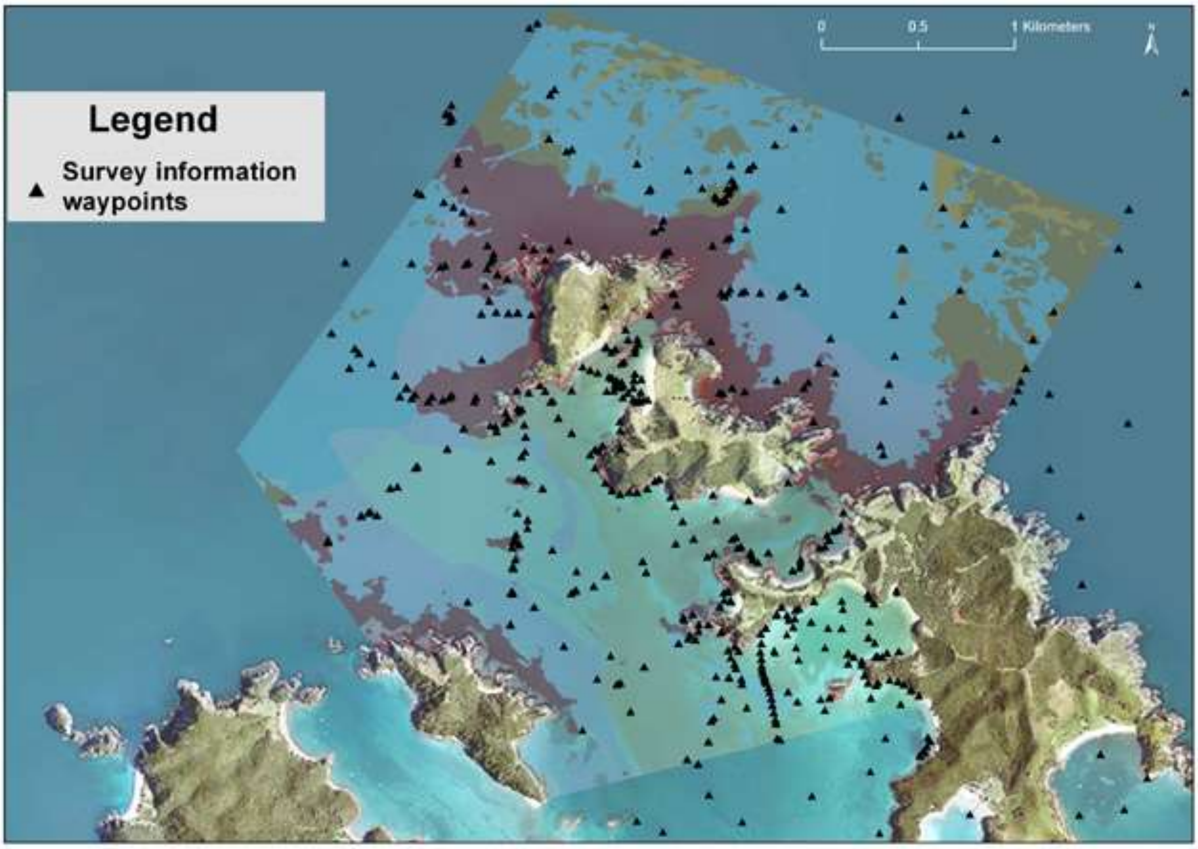

Figure 2 Waypoints where habitat information was recorded, Kerr and Grace survey, and additional data.

Method	Sites/data points	Survey distance
Kerr and Grace (2015)		
snorkel dives	4	0.8 km
scuba dives	19	7.9 km
drop video recorded	51	
drop video on-board interpretation notes	163	
rapid sediment sampler	67	
sediment samples	4	
manta board recorded (video)	5	7.5 km
manta board unrecorded	2	2.6 km
observation from vessel based bathyscope in shallow water (0-7m)	11	
on-board sonar interpretation	28	
BUV 2015	24	
Additional data		
Fish and algal transects Brook (2002)	4	
OS 20/20 survey Drop video	6	
OS 20/20 rocky reef transects	5	
NIWA 2015 BUV	19	
NIWA 2015 beam trawls	6	3.0 km
Totals	**418**	**21.8 km**

Table 2 Details of the number of site records for all Kerr and Grace surveys and data sources used in the mapping. For beam trawls and manta board surveys the distance of the actual survey was also recorded.

Drop video surveys

Two drop video systems were used. A live system consisted of an underwater camera connected to a small monitor screen by cable. The system could be deployed quickly with types of seabed and biota observed, recorded and interpreted in real time. The second system used a video camera mounted in a simple, robust housing built from a recycled scuba cylinder and plexiglass. The housing had a weight attached to a one-metre line attached to the bottom of the housing. Another line led from the top of the housing to a series of floats starting one metre above the housing (Figure 3). When deployed the unit hangs vertically approximately one metre above the seabed. The arrangement allows for rotation of the camera effectively panning the camera and increasing the viewing area. The camera is turned on and off for each drop. At each drop site, time, GPS position, and depth were recorded and video footage archived for later interpretation.

Figure 3 Drop video system, (second system).

Rapid sediment sampler

Due to the large areas being interpreted from sonar there was a need to verify sediment characteristics in the field. A sediment sampling system devised by the authors was based on a method used in historic marine surveys (Grace & Kerr, 2005). A lead weight with its bottom surface smeared with margarine is dropped to the bottom and samples a layer of sediment. For larger grain sizes the sediment makes an impression on the margarine indicating its size. The sampler is brought to the surface rapidly, photographed and its GPS position recorded. An example of the lead weight with sediment collected is shown in Figure 4.

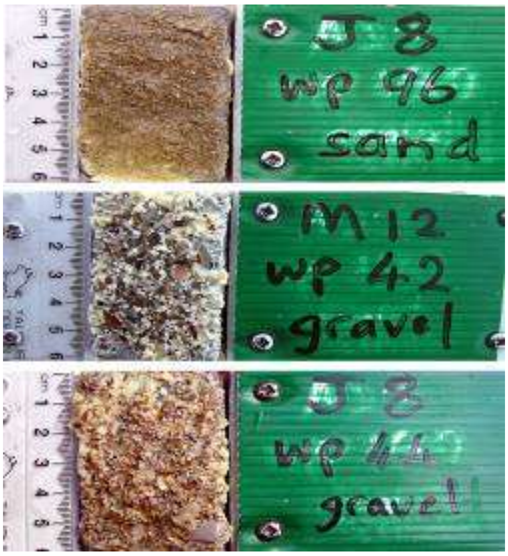

Figure 4 Example of rapid sediment samples

Sonar survey

A 4.2 m Mac boat, equipped with a Humminbird 987-C SI side-scan unit was used for navigation, recording sample locations and surveying bathymetry and seabed structure. Drop video cameras were used to verify and identify structures evident on the sidescan imagery including:

- major physical habitat types
- inconsistent interpretations of sonar data
- areas where substrate boundaries were expected
- reef areas, depth profiles where major biological boundaries might occur
- representative sites chosen to ground-truth interpretation of aerial photography

In addition to observing and recording sonar profiles, screen grabs of specific locations were captured, annotated and archived to assist later interpretation. Typically these images represented significant habitat boundaries.

Snorkel and scuba dives

The snorkel and scuba dives used in this survey were done with a team of three divers (Vince Kerr, Roger Grace, and Joe Moretti). The methods used for the dives varied for different objectives. To describe algal assemblages, zonation by depth, and to take representative photographs, scuba divers typically swam down a reef profile to approximately 25 m depth or the edge of the reef, taking photographs as they went and recording depth and species observed. The second half of the dive usually involved a swim parallel to shore where more observations were made and photographs taken. Following the dive, notes were checked between divers. GPS coordinates were recorded for each dive start and finish. The path each diver swam was roughly sketched on a map to be transferred to the Geographic Information System (GIS) database. The figures for survey distance for the dives recorded in Table 2 are estimated from these post-dive sketches and represent the area covered by each diver. Detailed notes and samples of conspicuous algal species were checked post-dive to confirm identification.

Manta board survey

Manta board surveys were used to achieve a greater spatial coverage than the drop video method in depths between 0-25 m. The technique is adapted from a similar technique used successfully by Grace (1981) at Paparahi, Mimiwhangata. The manta board is a simple flat piece of marine plywood attached by a bridle to a thin tow line which is in turn attached to the stern of the boat. A diver holds on to the front of the board and is towed at about two knots between 20 and 50 m behind the boat. By tilting the front of the board up or down the diver can use the board like a paravane and cruise above the bottom following the bottom contour, allowing observation of large areas of marine habitats. The simple design of the board enables it to be controlled with one hand, leaving the other hand free for writing notes while travelling over the seabed. A video in a housing was attached to the manta board to allow video footage to be taken for later analysis.

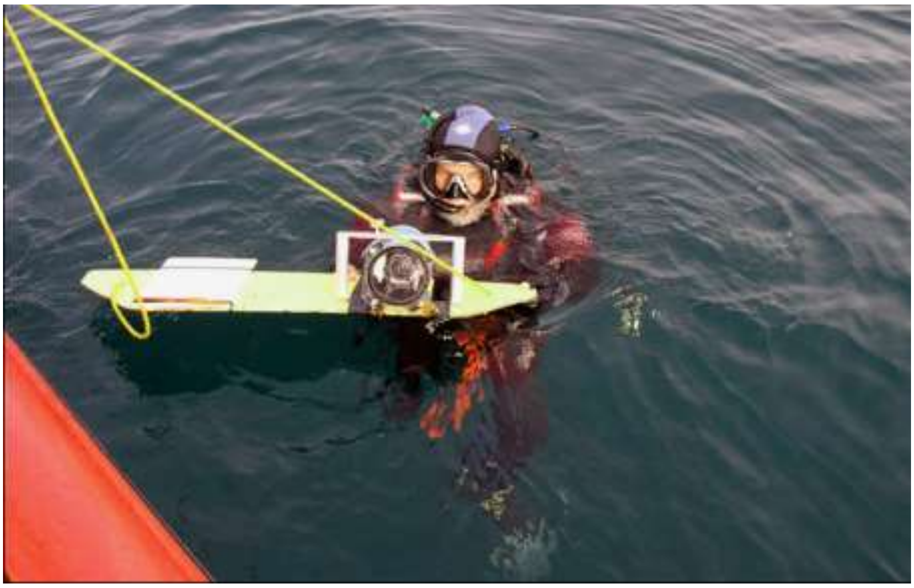

Figure 5 Manta board fitted with video camera

Additional data from other sources

To assist the current investigation, data collected in previous studies of the area were collated and analysed. These included data sets produced by NIWA in the 2009 Oceans Survey 20/20 (OS 20/20) Bay of Islands project including high resolution aerial photography, multi-beam sonar surveys, drop video and towed video, and shallow rocky reef diver transects (Mitchell et al., 2010). We were also able to extract habitat information from 2014-2015 surveys using beam trawl with camera and baited underwater video (BUV), (pers com., Meredith Lowe, NIWA). Other historic surveys included regional fish and algal surveys at several sites (Brook, 2002), and a fish diversity study (Nicholson and Roberts, 1980).

Analyses of these data included:

- interpretation of OS 20/20 drop and towed video for habitat information
- mapping and general habitat descriptions from OS 20/20 rocky reef transect notes on algal communities, zonation, and fish communities
- mapping with OS 20/20 multi-beam backscatter, seabed contour (hillshade) GIS layers and high resolution aerial photography (see further section on mapping process)
- interpretation of seabed structure and algal communities from NIWA (2014-2015) beam trawl, video and notes on trawl contents
- interpretation of bottom substrata and algal communities from NIWA (2015) baited underwater video (BUV) and screen grabs

Determination of exposure

Exposure to wind, wave energy and currents is known to influence the development of biological communities. The MPA Guidelines identify exposure as important in defining marine habitats for the purpose of its classification system. The guidelines define three exposure categories: low, medium, and high.

- High – areas of high wind/wave energy along open coasts facing prevailing winds and oceanic swell (fetch > 500 km e.g. ocean swell environments or currents > 3 knots).
- Medium – areas of medium wind/wave energy along open coasts facing away from prevailing winds and without a long fetch (fetch 50-500 km e.g. open bays and straits).
- Low – areas where local wind/wave energy is low (fetch <50 km e.g. sheltered areas; small bays and estuaries; current <3 knots).

This definition was applied by drawing a series of lines on a map outward from the coastlines within the survey area to approximately indicate the degree of exposure and fetch.

Investigation of biological zonation and algal communities in relation to reef depth profiles.

In addition to the general survey completed, four sites were selected for more detailed investigation of algal communities and depth zonation. Two sites were located on exposed shorelines and the other two sites were located on sheltered shores. At each of these sites scuba divers swam from shore along the bottom and perpendicular to the shore. Notes were recorded on depth, distance from shore, habitat boundaries, and the composition of algal communities. In the shallow parts of these profiles these data was checked against aerial photos for position of the community/habitat boundaries. Beyond 25 m deep, the 2 m resolution OS 20/20 multi-beam sonar data were used to check boundaries. Drop video transects were also used to help interpret biological assemblages at greater depths. Figure 6 shows the locations of the four profile investigations.

Figure 6 Reef profile investigation locations

Habitat mapping process

To support the habitat mapping process, a GIS project was created containing all the data acquired for the study. The GIS environment allows for a range of display and spatial analysis approaches to be used. Data layers were attributed with notes and references to source imagery and metadata written to document properties and development history of the different data sets.

Base maps were prepared of the OS 20/20 aerial photos and multi-beam backscatter imagery and terrain model (hillshade) layer. These two layers could be switched on and off and examined with field data overlays. Polygons of the habitat classification were then hand-drawn at scales ranging from 1:4,000 in the deeper areas to 1:1,000 for the shallow areas. A visual estimate was mapped of the Mean High Water Level and the Mean Low Water Level.

Figure 7 shows the OS 20/20 multi-beam backscatter layer (at 40% transparency) overlaid on the 2 m resolution bathymetry hillshade layer (OS 20/20) to identify rocky reef edges.

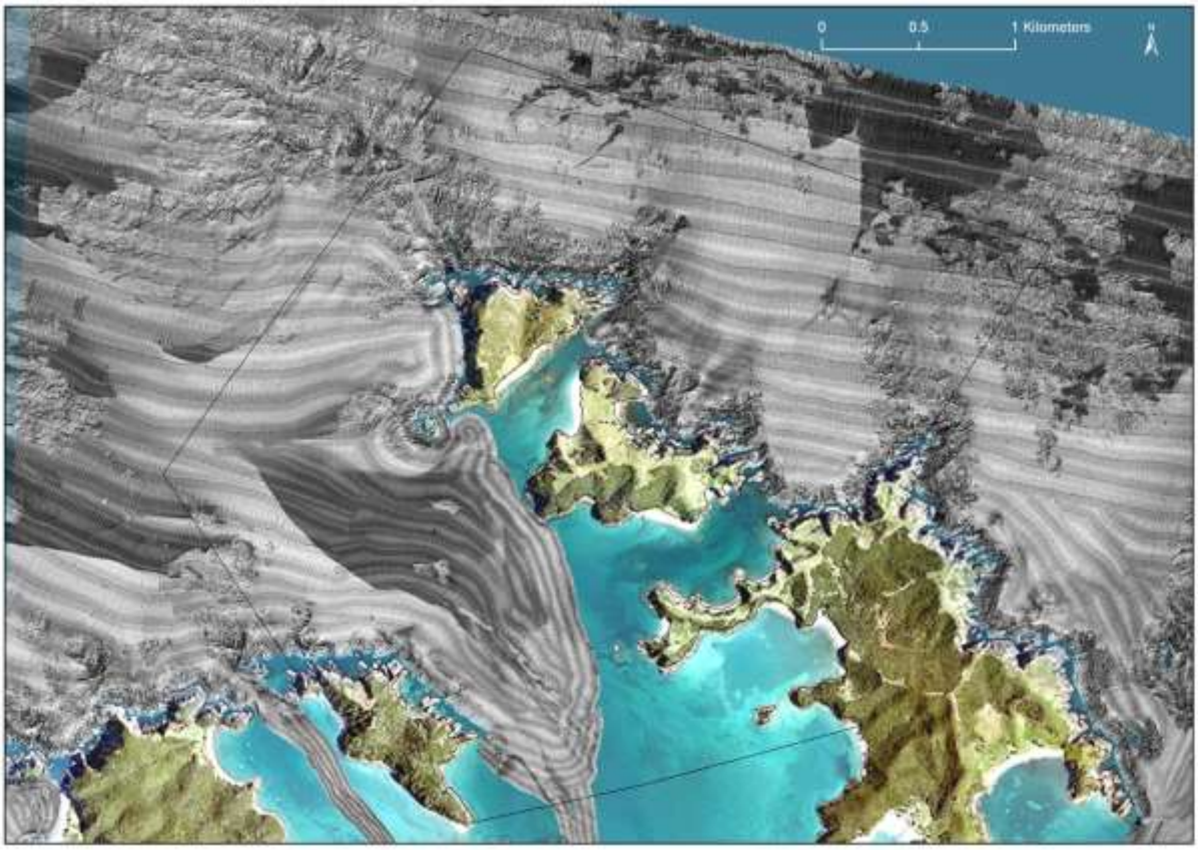

Figure 7 OS 20/20 multibeam backscatter layer displayed over a contour hillshade bathymetry layer. The thin black line depicts the mapping area.

Figure 8 shows an example of the quality and resolution of the aerial photography available from the OS 20/20 study. In this example you can clearly see substrata boundaries, sandy beach, rocky reefs and various biological communities. Algal species appear as dark brown and kina barrens appear as light blue rocky areas. While there was full aerial coverage of the study area, wave conditions, sun angle, and shore topography meant that not all images were as easily interpreted as this example. Over much of the survey area, conditions for aerial photography allowed mapping to extend seaward to a depth of 10 – 15 m. In most locations this was at or near the shallow edge of the multi-beam sonar data coverage enabling a good overlap between the two surveys.

Figure 8 OS 20/20 aerial photo of the east shore of Motukiekie Island displayed at the 1:1,500 mapping scale. Pale areas are kina barrens.

Results

The habitat maps

Detailed maps for this project can be viewed in a map book in Appendix 3. Map 1 shows the habitats viewed at the broad scale of the entire survey area (1:21,000). Table 3 lists the spatial area and percentage coverage of each of the 17 habitats mapped in the 993 ha study area. Of particular note is the high diversity of habitats within a relatively small area. The habitat maps and area calculations show a good representation of the full range of shallow and deep habitats. It is significant that arrays of shallow habitats extend to seaward and connect with an impressive series of deep reef and soft sediment environments beyond 30 m depth.

Depth	**Habitat**	**Hectares**
intertidal	rock platform	19.5
intertidal	gravel beach	1.5
intertidal	mangrove	0.02
intertidal	sand beach	4.6
shallow	*Ecklonia* forest	149.9
shallow	shallow mixed weed	15.3
shallow	kina barren	17.3
shallow	cobble	0.04
shallow	gravel	7.3
shallow	gravelly coarse sand	160.7
shallow	fine sand	93.9
shallow	algal turf bed	134.2
shallow	seagrass bed	24.8
deep	rocky reef	75.80
deep	gravelly coarse sand	267.88
deep	fine sand	5.20
deep	mud	14.75
	Total	**993**

Table 3 Habitat area totals

Map 2 shows the underlying substrata and sediments of the habitat survey area. This version of the map is based on the physical substrates omitting the finer resolution of the biological habitats.

In Map 3, the exposure classification is added to the analysis. Each substrata appears within the exposure classification further defining habitats by the degree of wave energy it is exposed to. In this classification the number of habitats classified expands to 33. Table 4 shows the calculated area of each habitat when exposure is added to the classification. Again it is important to note how diverse this area is, with its habitats divided evenly between the three exposure groups. This is a fundamental attribute of islands which offer exposure throughout 360 degrees and often have complex coastlines and rugged topography, as is the case of the islands in this study.

Exposure	Depth	Habitat	Hectares
high	intertidal	gravel beach	0.25
high	intertidal	rock platform	7.96
high	shallow	*Ecklonia* forest	92.77
high	shallow	gravelly coarse sand	47.73
high	shallow	kina barren	1.05
high	shallow	shallow mixed weed	7.98
high	deep	rocky reef	74.26
high	deep	gravelly coarse sand	206.34
high	deep	mud	14.75
medium	shallow	*Ecklonia* forest	47.19
medium	shallow	shallow mixed weed	3.75
medium	shallow	kina barren	5.86
medium	shallow	gravelly coarse sand	73.14
medium	shallow	algal turf bed	2.00
medium	shallow	fine sand	43.46
medium	intertidal	rock platform	4.68
medium	intertidal	sand beach	0.25
medium	deep	rocky reef	1.54
medium	deep	gravelly coarse sand	61.54
medium	deep	fine sand	5.20
low	shallow	Ecklonia forest	9.89
low	shallow	shallow mixed weed	3.56
low	shallow	kina barren	10.35
low	shallow	cobble	0.04
low	shallow	gravel	7.34
low	shallow	gravelly coarse sand	39.85
low	shallow	fine sand	50.46
low	shallow	algal turf bed	132.20
low	shallow	seagrass bed	24.80
low	intertidal	rock platform	6.82
low	intertidal	gravel beach	1.27
low	intertidal	sand beach	4.38
low	intertidal	mangrove	0.02
	Total		**993**

Table 4 Exposure and habitat area totals

Maps 4-8 show a fine scale of the habitat map prepared at a 1:7,000 scale. The areas shown are Okahu Island, Waewaetorea Island, Urupukapuka Island northwest coast, Urupukapuka Island west coast, and Motukiekie Island.

Maps 9 and 10 show a finer scale (1:3,000) view of Akeake Point and the adjacent reef, illustrating the quality of the OS 20/20 aerial photography used.

Biological zonation

Boundaries between shallow rocky reefs dominated by *Ecklonia* forest and encrusting invertebrate communities on deeper reef were consistently observed between 25 m and 35 m depths. We used 30 m as the mapping boundary for consistency. Adopting this uniform depth boundary is consistent with the MPA classification scheme and helps consolidate boundaries. In reality, this transition zone is only approximate and varies under different conditions (see below). In this area, light levels decrease markedly beyond 20 m depth, the density of the *Ecklonia* forest decreases and various groups of invertebrates like sponges, hydroids, gorgonians, and bryozoans increase in abundance and diversity. These organisms are filter feeders and benefit from the ample currents and water column movements common at these depths. The deepest we saw *Ecklonia* kelp was at 34 m but this was uncommon.

On the shallow rocky reefs we mapped the boundaries of the shallow mixed weed zone, kina barren, and *Ecklonia* forest primarily using aerial photographs. Our notes from scuba dives, snorkel dives, and manta board runs were an additional aid.

Figure 9 Species key for reef profile illustrations

Exposed shores

The two reef profiles selected to portray zonation on the exposed shores of Urupukapuka and Waewaetorea Islands were typical of the exposed coasts in the survey area and were significantly different from the shores on the sheltered channel side of the islands. On the exposed shores there is a distinct top band of the subtidal habitat referred to as the shallow mixed weed zone. This algal community group is especially resilient to the high wave energy in this habitat. The upper levels of this sublittoral zone are dominated by two species *Xiphophora chondrophylla* and *Carpophyllum augustifolium.* Below is often a mixture of the common red algae *Pterocladia lucida* and the deep red coloured *Osmundaria colensoi.* Another indicator of surge and high wave energy is the brown kelp *Lessonia variegata*. Occasionally *Carpophyllum maschalocarpum* and *Carpophyllum plumosum* feature in the lower reaches of the shallow mixed weed. In addition to this list of common species, there are also other cryptic or rarely occurring algae that occur in the exposed shallow mixed weed zone. There are also encrusting coralline species like *Corallina officinalis* covering the rocks commonly in the lower reaches of the zone. This zone of specialised algae extends down to approximately 8 m on these exposed shores. At the bottom of the shallow mixed weed zone *Ecklonia radiata* starts to appear signalling a decrease in the impact of wave energy and transition to the next zone dominated by this large brown algae species.

On the exposed shores, the *Ecklonia* forest extends from about 8 m depth to somewhere around 30 m depth or to the edge of the reef if that occurs at less than 30 m. In most cases the stands of algae appear to be monotypic. The *Ecklonia* in places can form quite dense canopies effectively competing against other algal species for light. As you travel down in depth the canopy becomes scattered or sparse and encrusting invertebrates start to feature. Common species associated with *Ecklonia* forest depicted in our diagrams are kina and the brown algae *Carpophyllum plumosum.* Also in this zone, as you travel down the reef slope, some of the common sponges begin to appear. First is the grey sponge *Ancorina alata*. Towards the deeper zones the grey cup sponge *Geodia regina* and the *Raspalia sp.* finger sponges are present.

We found very few kina barrens on these exposed coasts in the survey area. Kina barrens if they occur are normally found below the shallow mixed weed boundary and in the upper part of the *Ecklonia* forest habitat. The profile site at Urupukapuka Island (Figure 11) had a small isolated kina barren (less than 20 m^2) occurring at between 8 and 12 m depth. At the Waewaetorea Island site (Figure 12) there were no kina barrens observed, only scattered kina amongst the kelp. This variation and general lack of large kina barrens was typical of the exposed shores of the three islands in the survey area. It is worth noted that there are small numbers of another urchin species present in these habitats; Centrostephanus rodgersii has colonised the area from Australia and is becoming more common over the last few years.

In our two exposed shore profile examples we reached the end of the reef slope at 20 and 22 m depth and 100 m offshore. With images from the drop video and high resolution bathymetry from the OS 20/20 surveys it is possible to extend this zonation sequence out to the depth boundary of 30 m where the *Ecklonia* forest thins out and is replaced by encrusting invertebrate communities. For both these profile sites the reef slope eases beyond 100 m and runs out to between 250 and 300 m offshore before the depth reaches 30 m and the deep zone begins.

Due to the differing topography of the exposed versus sheltered coasts a different horizontal scale showing distance offshore is used This obscures the reality that the exposed sites have reefs that run out much further off shore and much deeper waters. The vertical scales representing depth were also varied in order to portray different sites in a common format.

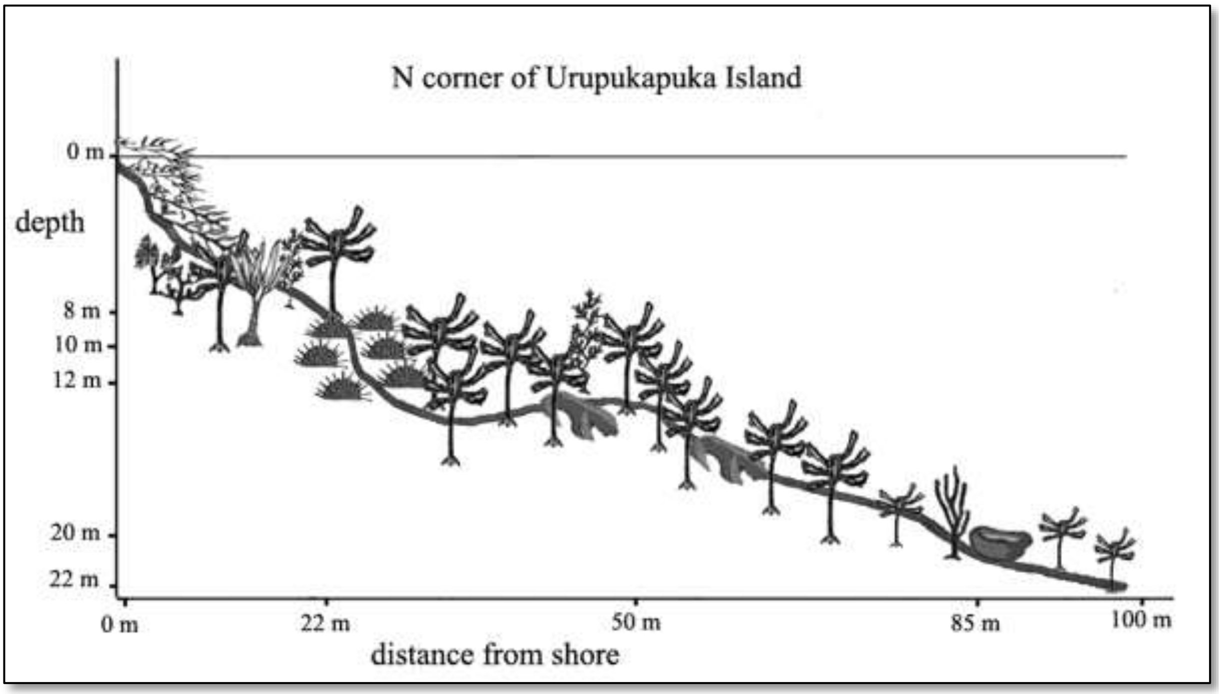

Figure 10 Profile 1, North corner of Urupukapuka Island reef profile showing common indicator species depth and distance offshore (see fig.6)

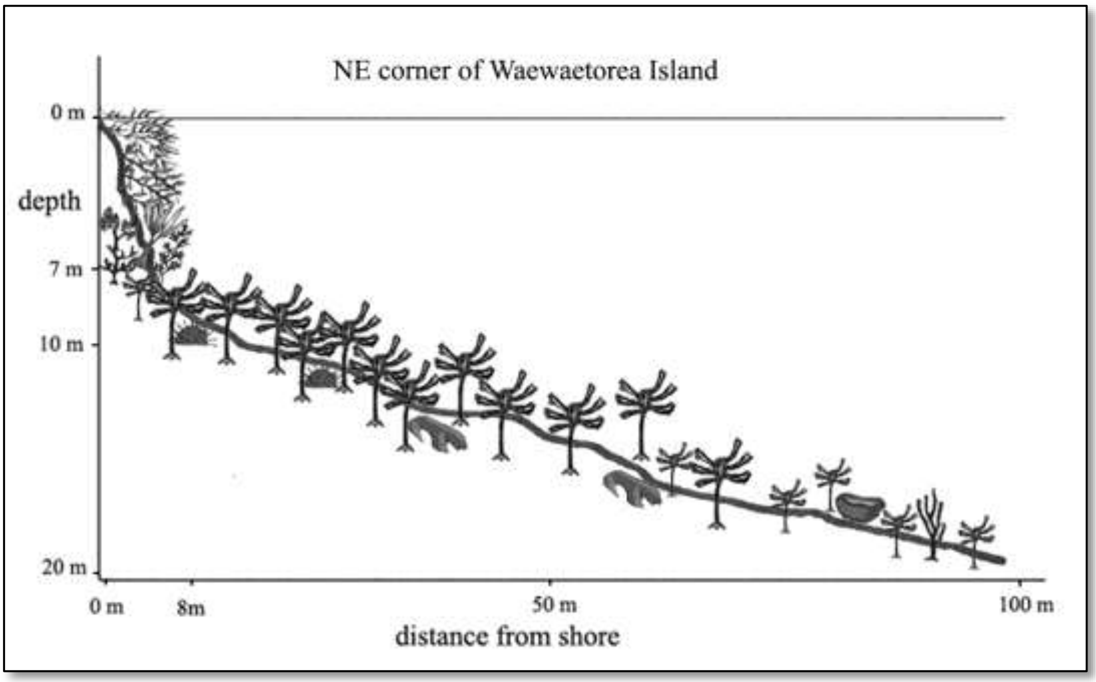

Figure 11 Profile 2, Northeast corner of Waewaetorea Island reef profile showing common indicator species depth and distance offshore (see fig.6)

Sheltered shores

The profile of Akeake Point on the western side of Urupukapuka Island is a classic example of a sheltered shore for this locality and a dramatic example of the extent of kina barrens on these shores (Figure 13). Gone are specialised algae species of the high wave energy exposed coast. Here, the shallow mixed weed zone is a narrow band extending only to about 1.5 m depth. The hardy brown kelp *Carpophyllum maschalocarpum* forms the main band below the low water mark. Mixed into this zone is the common red algae *Pterocladia lucida* with some *Ecklonia radiata* present. Below this level at Ake Ake Point, kina barrens occur, dominating the habitat down to between 4 and 5 m depth. *Ecklonia radiata* and flapjack kelp, *Carpophyllum flexuosum* appear as scattered remnants in the kina barren zone. At 5 m depth a thin band of healthy *Ecklonia* forest remains, extending to the reef edge at about 6 m depth where the substrate changes to sand.

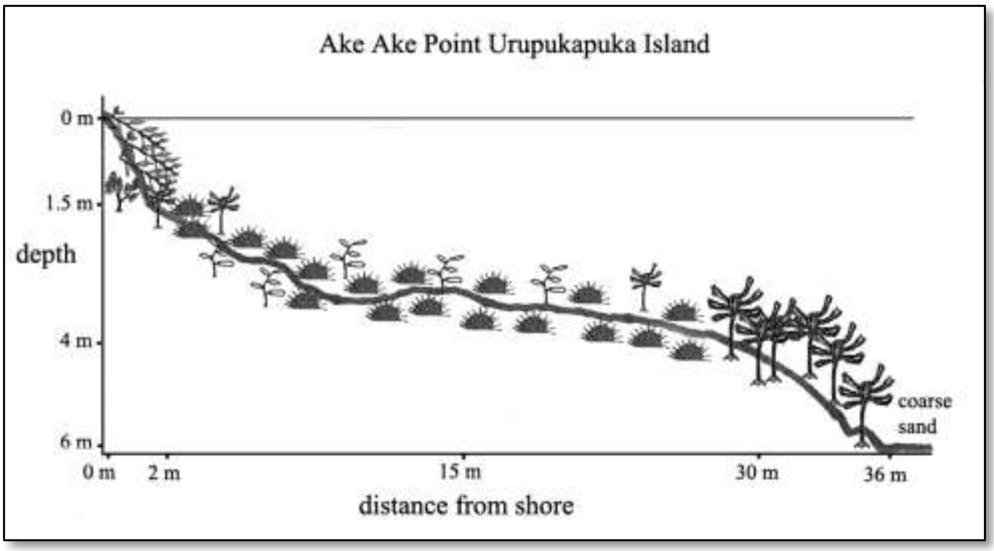

Figure 12 Profile 3, Akeake Point, Urupukapuka Island reef profile showing common indicator species depth and distance offshore (see fig. 6)

The second sheltered site on the southwestern corner of Okahu Island is shown in Figure 6 and Figure 14. This sheltered shore actually includes the boundary between medium and low exposure. The site shows a higher diversity of algal species and the depth of the shallow mixed weed zone extends to 3 m in places compared to 1.5 m at Akeake Point. The kina barrens at this site were not as extensive either. Here they occurred in bands across the depths of 3-4 m and 6-7 m. Also at this site, the *Ecklonia radiata* stands with *Carpophyllum plumosum* and *Carpophyllum flexuosum* present were denser and healthier than at Ake Ake Point. The reef edge occurred at 10 m depth and 90 m off shore, compared with a reef edge at 6 m depth and 36 m offshore from Ake Ake Point.

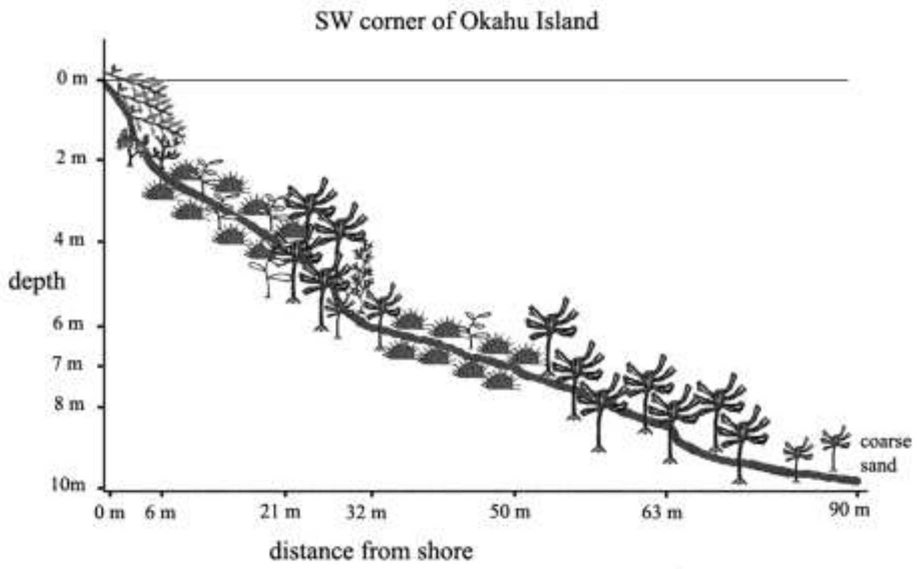

Figure 13 Profile 4 Southwest corner of Okahu Island reef profile showing common indicator species depth and distance offshore (see fig.6)

Algal species

In addition to the notes taken on indicator species at the profile sites a more comprehensive list of algal species was recorded. This list appears in Appendix 1 and includes 10 species of red algae, 15 species of brown algae, and 4 species of green algae. This list was a result of limited survey effort at only four sites indicating that there is potentially a much larger diversity of algal species in these habitats.

Intertidal shore habitats

Intertidal habitats mapped in this study included sand beach, gravel beach, cobble beach, rock platform, and mangrove. The extent of these areas can be seen in Maps 1-8. And the areas and percentages of these occurring within the study area and within the intertidal zone are shown in Table 3 and 4. Few observations of biodiversity within the intertidal zone were recorded in this study but Gibb (2014) provides excellent photographic examples and a geological discussion of most of these habitats.

Shallow mixed weed

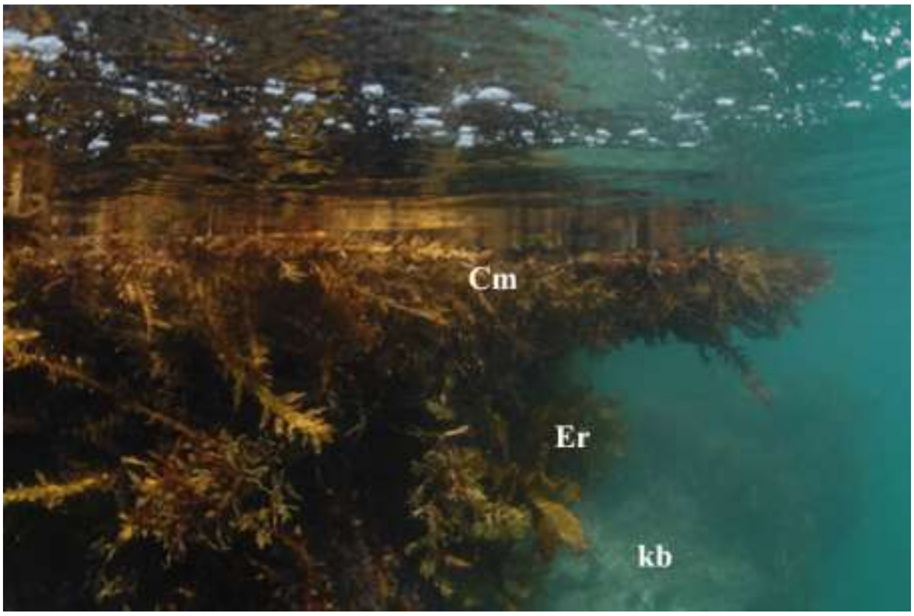

Figure 14 Shallow mixed weed habitat at Akeake Point (Profile 3) on the western shore of Urupukapuka Island. Carpophyllum maschalocarpum (Cm), Ecklonia radiata (Er), kina barren (kb)

The photo above from Akeake Point is a typical example of shallow mixed weed where exposure is low. At these sites, this habitat is reduced to a couple of metres of depth, sometimes less. *Carpophyllum maschalocarpum* forms a dense band at the top of the zone, with *Ecklonia radiata* appearing at the bottom of the band. Note in the right-hand lower quarter you can see the top of the kina barren which extends up to about 1 m depth in some areas on this reef.

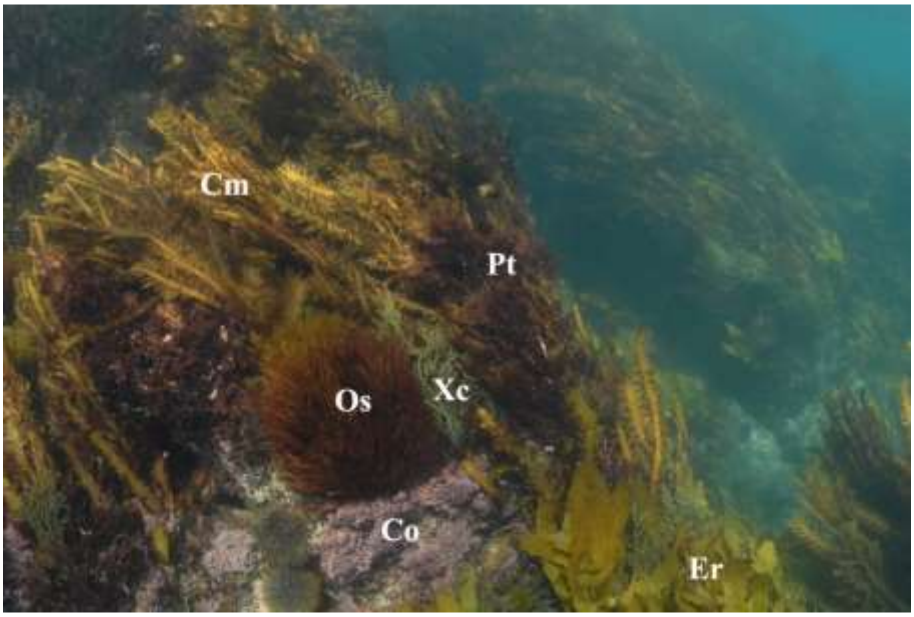

Figure 15 Shallow mixed weed habitat on the western shore of Okahu Island near Profile 4. Carpophyllum maschalocarpum (Cm), Pterocladia lucida (Pt), Osmundaria colensoi (Os), Corallina officinalis (Co), Ecklonia radiata (Er), Xiphora chondrophylla (Xc)

The site in the photograph above is typical of moderate exposure. Here *Carpophyllum maschalocarpum* forms a top band, often several metres depth. In the middle of the photograph, two common red algae, *Pterocladia lucida* and *Osmundaria colensoi*, are visible. The more purple of these is the *Pterocladia*. Below the *Osmundaria*, a smaller pink encrusting turf algae, *Corallina officinalis*, can be seen At the bottom centre left, the large-bladed brown algae is *Ecklonia radiata*. Intermixed with it is another common brown algae *Xiphora chondrophylla* with a more stringy, light brown appearance.

Kina barrens

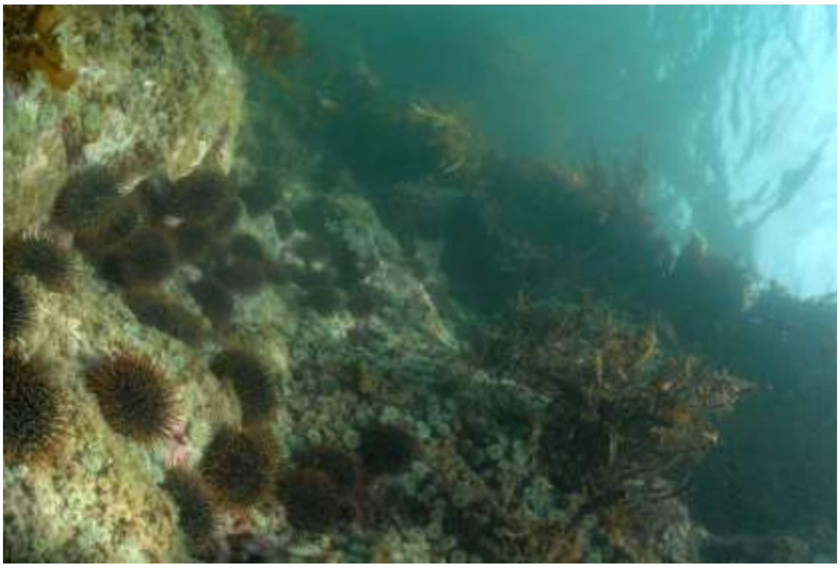

Figure 16 Kina barren habitat at Akeake Point on western shore of Urupukapuka Island near Profile 3

This photograph from Akeake Point is typical of the kina barrens on the sheltered shores of the islands in this area. In this scene, the kina density is high and macro-algal cover is largely absent with little recruitment of young *Ecklonia* kelp plants.

Table 5 shows the areas in each exposure zone of the three habitats of the shallow reefs; the percentage coverage of kina barrens of the entire shallow reef system is also shown. The area calculations in Table 5 are for the entire habitat survey area of this study. The worst affected exposure zone is the low exposure areas, where kina barrens have expanded to cover 43.5% of the shallow reef area, a greater area than any other habitat. The medium exposed areas have 10.3% of the reef in kina barrens and the percentage is only 1.0% for the exposed areas. Over all exposure areas kina barrens cover averages 9.5% of the shallow reef area.

Shallow rocky reef habitats in survey area (in hectares)					
Exposure	**Shallow mixed weed**	**Kina barren**	**Ecklonia forest**	**Exposure zone total**	**Kina barren percentage of total exposure zone area**
High	8.0	1.0	92.8	101.8	**1.0%**
Medium	3.8	5.9	47.2	56.8	**10.3%**
Low	3.6	10.3	9.9	23.8	**43.5%**
All exposures totals	15.3	17.3	149.9	182.4	**9.5%**

Table 5 Total spatial extents within the habitat survey area of shallow rocky reef habitats and the percentage total now occupied by kina barrens.

Ecklonia forests

Figure 17 Ecklonia forest habitat on the exposed coast at approximately 12 m depth.

Figure 18 Under the canopy of the Ecklonia kelp forest.

Figures 18 & 19 represent a typical view of healthy *Ecklonia* kelp forest. This is a very productive habitat and should be seen as one of our most valuable coastal habitats. There are many fish species that live specifically in this habitat, either browsing on kelp or feeding off the many invertebrates that live there.

The understorey of the kelp forest is an especially valuable ecosystem in its own right. It is a low light environment in which the canopy provides enough shelter from wave energy to favour a wide range of encrusting invertebrates like sponges, sea squirts, anemones, and hydroids which make their living as filter feeders in high current areas.

The base of the kelp plants, called the holdfast, is another special feature of this habitat. It is highly complex in terms of cracks and crevices formed and this provides safety and shelter for an extensive list of invertebrates and small fish (Anderson, 2005 and Smith, 1990).

The kelp forest also plays an important role in our coastal fishery for many pelagic fish species as a temporary nursery. These fish species make the transition from plankton-based larvae to large schooling fish in this nursery environment. Snapper *Pagrus auratus* and trevally *Caranx lutescens* can be seen in the summer and autumn months as tiny 10-20 mm fish hiding in the kelp. Later on in their life cycle as adult fish these pelagic fish return to the reef either on temporary feeding visits or as long-staying reef residents. As adults these species take on the role of primary predators on the reef and fulfil a fundamentally important ecological role.

Coralline algal turfs - shallow rocky reef

Figure 19 A lush bed of coralline red algal turf habitat, exposed coast

Shallow rocky reef coralline turf, as depicted in Figure 20, was not mapped in this study. However, it is a common algal community which was seen in small patches or mixed in as an understorey in the kelp forest. The description is included here because it is a common component of the shallow mixed weed and Ecklonia habitats on the exposed coast, but does not appear typically in areas large enough to map at the scale we worked at. A coralline algal turf habitat (Figure 20) is typically made up of a number of specialised red algal species that have the ability to calcify part of their structure to withstand high wave energy situations and resist grazing. *Corallina officinalis* (see Figure 16), is the most common of this red algae sub-group. This habitat is described by Shears (2004) as an important habitat on northern shallow rocky reefs.

Soft sediments

A wide array of sizes and proportions of sand, gravel, cobble, and shell occurred in different sediments. Often these variations occurred over small spatial scales, sometimes within the view of a single video drop. As documented in a geology report for this area (Gibb, 2012), there have been many forces at work in this area to create so much substrate diversity across small spatial scales. Geological history has delivered a great diversity of parent materials. Dynamic forces of wind, current, and wave energy and significant historic sea level change have influenced the mixing of the area's soft sediments over time.

Figure 20 An example of a mixed habitat showing gravel and cobble substrates

Algal turf beds – soft sediment (biogenic habitat)

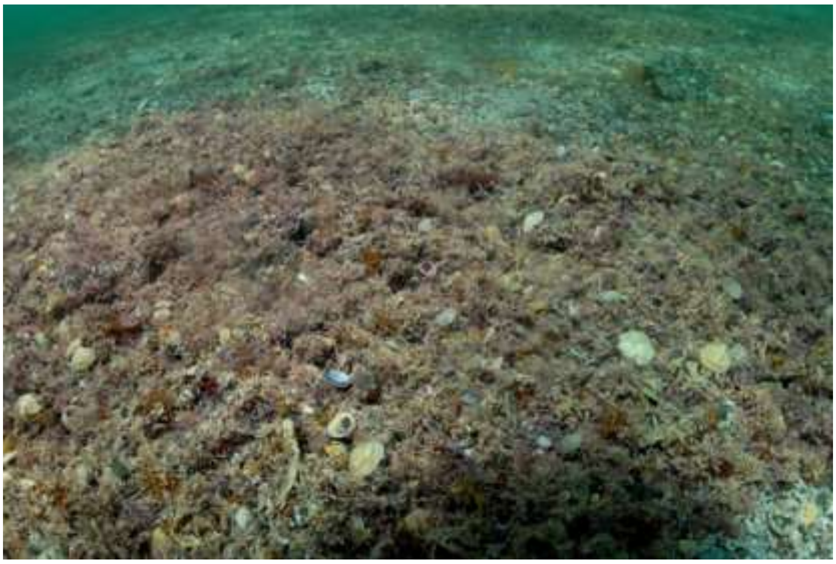

Figure 21 Algal turf habitat growing on a coarse sand, shell, and gravel substrate typical of the Okahu Channel bottom

Algal turf beds (Figure 22) cover large areas in the channels between the islands of the survey area. They are typically associated with substrata containing either gravel or shell or a mixture of shell and gravel as in the photograph above. The algae are typically an assembly of small foliose red algae species but have other algal species associated as well, contributing to the turf bed habitat. Although not observed in this study, others have reported patchy beds of rimurimu *Caulerpa spps*. in the deeper parts of the channel between Motukiekie and Urupukapuka (Chris Richmond and Victoria Froude, pers. comm.). Associated with these beds are calcareous red algae called rhodoliths. These algae take a porous open-structured golfball shape. They can be intermixed with the algal turf bed or form dense beds themselves. We identified scattered individual rhodoliths amongst the algal turf in some locations but did not collect samples. Others have reported small patches of rhodolith beds in the channel between Motukiekie and Urupukapuka (Chris Richmond and Victoria Froude, pers comm). In a 1981 study (Hayward et al.) rhodolith beds were described off the southwest corner of Urupukapuka Island. More recently, two nearby rhodolith beds have been described in detail (Nelson 2012). These beds are located approximately 4 km to the southwest of our survey area at Kahuwhera Bay near the mainland and Te Miko Reef which lies in the channel between Moturua and Motuarohia Islands. These known sites, with the exception of Kahuwhera Bay, have habitats similar to the sheltered shallow channels and soft sediment areas in our survey area. Kahuwhera Bay bottom sediments are more affected by fine sediments than any of the habitats in the study area.

The algal turf beds are referred to as biogenic, meaning that they create a habitat for themselves and other organisms to live in. One of the shellfish species we found to be associated with the algal turf beds in Okahu Channel was the morning star shell, *Tawera spissa.* There were large patches of dense beds of this shellfish in much of the channel. Figure 23 shows a bed of *Tawera* exposed by the diver whipping his hand over the bottom, blowing away the finer sediments normally covering the shell bed.

It should be noted that this is a habitat that can change with the effects of storm conditions and from a mapping point of view it occurs often in association with streaks of fine sand and gravel substrates.

Figure 22 An uncovered bed of morning star shells, Tawera spissa found in the Okahu Channel

Seagrass, *Zostera capricorni* (biogenic habitat)

Figure 23 Small mounds and patches of seagrass, Zostera capricorni photographed in the Okahu Channel

Seagrass beds form a significant habitat in sheltered shallow areas within the survey area. Large beds cover much of the area of the two bays (Otiao and Paradise) on the western shore of Urupukapuka Island. These habitats are important to many marine invertebrates and fish and are important nursery habitats for a range of coastal fish species early in their life cycle (Turner and Swartz 2006). The seagrass beds in this area are exceptional examples of subtidal beds, now rare in New Zealand.

Figure 25 Seagrass bed in Otiao Bay, western side of Urupukapuka Island, providing a home for large numbers of juvenile spotty, length approximately 16 mm

Deep reefs

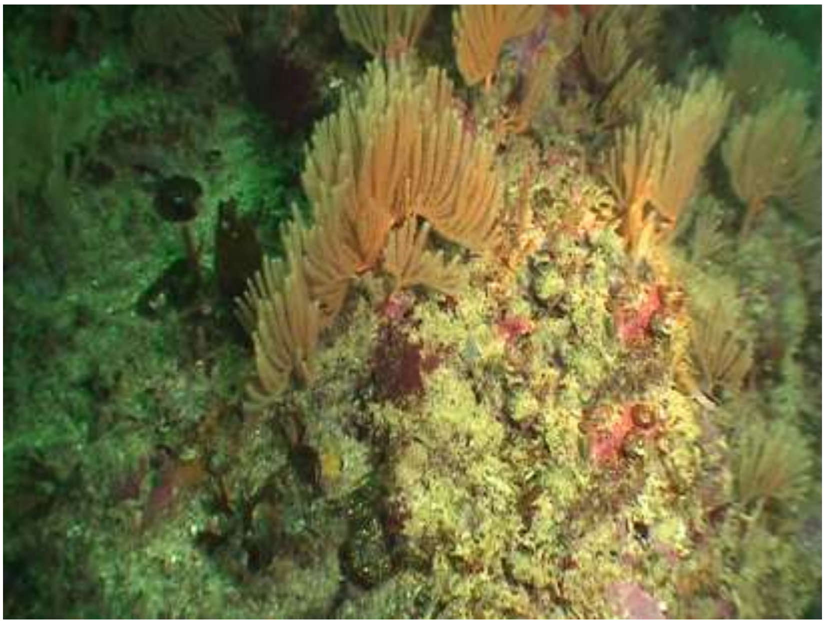

Figure 24 A deep reef scene taken from drop video footage off Okahu Island at 34 m depth

Beyond 30 m, on the reefs to the north and northeast on the seaward side of Okahu, Waewaetorea, and Urupukapuka Islands, the kelp forests thin out and disappear as light levels become too dim to support them. As shown in Figure 26 the pink *Primnoides sp. g*orgonian fans are commonly seen at these depths. Alongside the elegant gorgonian fans is a wide variety of filter feeding encrusting invertebrates made up of sponges, bryozoans, hydrozoans, ascidians, and many other groups. These encrusting communities form a complex three-dimensional structure providing food and shelter to a great diversity of marine life.

Deep soft sediment areas

Surrounding the deep reefs offshore to the north and east of the islands are extensive areas of soft bottom sediments, made up of deep gravelly coarse sand (268 ha), mud (15 ha), and fine sand (5 ha). These habitats when viewed from above, as we did with our drop video camera, often look devoid of life but in fact they are home to extremely diverse and important invertebrate communities living within the substrate. A study of rock lobster, *Jasus edwardsii*, at Leigh showed that the soft bottom habitats adjacent to rocky reefs are key feeding areas for this species regularly foraging as far as 2 kms from the reef edge on shellfish (Kelly 2001). In our study we were not able to sample the species of these benthic communities, however previous work of Morley and Hayward (1999) described the diversity of molluscan fauna in the Bay of Islands as the most diverse in New Zealand for an area of this size. 551 mollusca species were found in that study.

Otiao Bay Estuary, Urupukapuka Island - a special place

At the head of Otiao Bay on the western shore of Urupukapuka a small stream comes down from a valley and the hills behind to form an estuarine environment where it meets the waters of the Bay (Figure 27). This little estuary is very well sheltered and joins a seagrass bed and the relatively clean sand bottom of Otiao Bay. At the head of this little estuary is a small patch of mangrove habitat. It is very unusual to have mangrove habitat associated with an offshore island. Even more unusual is to see a mangrove habitat connected in an ecological sequence to a healthy subtidal seagrass bed. On one afternoon when rough weather and rain forced us to stay at anchor in the bay, one of our divers Roger Grace went for an investigation/photography dive at high tide in this little estuary. Figures 28 and 29 offer a glimpse of the importance such a small habitat can hold as a nursery area for fish species. The two species observed in large numbers in their juvenile stage were spotty (*Notolabrus celidotus*) and parore (*Girella tricuspidata*).

Figure 25 The small estuary at the head of Otiao Bay, habitat map on left and OS 20/20 aerial photograph on right. Habitats on left are dark green: intertidal mangrove, pale beige: intertidal sand, black: intertidal rock platform, red: subtidal shallow mixed weed, pink: kina barren, light green: subtidal seagrass. Note the seagrass habitat in the aerial photograph, seen here as dark blotches on the sand bottom.

Figure 26 A very young juvenile parore estimated length 12 mm, swimming in the mangrove area of the Otiao Bay estuary

Figure 27 Juvenile spotty amongst the shallow mixed weed close to the entrance to the Otiao Bay estuary, estimated length 25-30 mm

Fish communities

On this survey, the main focus of diving and video investigations was to provide habitat descriptions and ground truthing information for the mapping. However, we took notes of fish species encountered throughout the survey on an opportunistic basis. With the complexity of habitats and currents found in the survey area, it can be expected that fish diversity would be high. Our counts supported this totalling 54 species over the entire survey. By comparison Nicholson and Roberts (1980) recorded 57 species at 15 sites around Urupukapuka Island. Our fish species list is included in this report as Appendix 2.

The fish survey effort indicates that these islands are hotspots for subtropical species. We recorded subtropical and tropical species, usually associated with offshore islands like the Poor Knights Islands, including notch head marblefish (*Aplodactylus etheridgi*), spotted goatfish (*Parupeneus fraterculus*), giant boarfish (*Paristiopterus labiosus*), orange wrasse (*Pseudolabrus luculentus*), crimson cleaner (*Suezichthys aylingi*), and painted moki (*Cheilodactylus ephippium*). The more common southern species, blue moki (*Latridopsis ciliaris*), was also recorded.

Figure 28 An orange wrasse seen at the northwest corner of Okahu Island. This fish is in a transitional phase changing from female to male.

Discussion

Potential uses of this mapping resource

This mapping resource should be viewed and used as a work in progress. The data layers and the interpretation can be improved upon in the future. Ideally, the classification should be extended to further define physical soft bottom substrates and significant biological communities. The GIS based approach has been adopted to allow updates to be made readily as new information becomes available. This project was specifically designed to fulfil the basic information requirements to evaluate a proposal for marine protection using criteria suggested in the New Zealand MPA Guidelines (DOC & MFish, 2008). Specifically, the map of habitat types enables depiction and calculation of the extent to which the proposed marine protected areas in question might be representative of the full range of habitat types in this locality. site. Overseas experience demonstrates that the use of habitat maps and targeted information layers can greatly aid the broader MPA public participation process (Breen, 2007, and Bernstein et al., 2004). The map can also be useful to many forms of marine planning, including resource management, fisheries investigations, the design of future scientific research and marine education generally.

Habitat diversity and quality

The Waewaetorea area that was subject to this survey is deserving of protection status under the Marine Reserves Act 1971, which will also contribute to the government’s initiatives under the Marine Protected Area Policy, the Resource Management Act 1991 and other national legislation and policies. The diversity and quality of the habitats within this relatively small area is remarkable. The values found here should be considered equal to the most unique and outstanding sites in Northland and throughout New Zealand. The exposed coastline of the islands could also be considered representative of this habitat in Northland and a very high quality example.

There are many contributing and interacting factors: oceanographic influences, significant examples of rare subtropical species, geological influences, diverse substrates, complex topography, and the full range of exposure conditions represented.

Where to from now? Destruction of shallow reef kelp forest by kina.

A significant feature of the habitat maps in this study is the documentation of extensive kina barrens occurring on the sheltered and moderately sheltered shallow coastal reefs of these islands. Current thinking among marine ecologists, both here and overseas, describes kina (urchin) barrens as a condition of trophic change brought about by chronic removal of kina's primary predators, large crayfish (*Jasus edwardsii*) and large snapper (*Pagrus auratus*), through fishing (Shears, 2002, Shears et al., 2004). The kina (urchin) barren effect has been documented elsewhere in Northland at Doubtless Bay (Grace and Kerr, 2005) and Mimiwhangata (Kerr and Grace, 2005). The Mimiwhangata example analysed 1950 aerial photographs along with a verbal history of the kelp forests provided by kaumatua of the local hapu. At Mimiwhangata the kaumatua stated with confidence that the current condition of extensive kina barren areas was not known prior to about 1960-1970 or mentioned in their tribal knowledge handed down from elders. The Mimiwhangata report illustrated dramatic decline of the kelp forests over wide areas, starting sometime in the 1960s or 1970s. Returning to the Bay of Islands, in an essay prepared for Fish Forever, a Bay of Islands scale view of kina barren expansion is presented (Booth, 2015). Historic aerial photos used for the analysis show a similar trend to what was found at Mimiwhangata. A dramatic time series of aerial photos of Akeake Point is featured in the essay previously referred to illustrating the slow degradation of the reef.

Our results present evidence of significant decline of kelp forests due to kina barren establishment and persistence. By any measure our results should be a cause for concern. Tasmanian reports on the ecological significance of kina barrens (Ling et. al.) 2008, 2009 have demonstrated dramatic increases in kina barrens associated with their shallow rocky reefs and cited significant biodiversity and economic loss as a result. In a recent study by Ling and others (2015), a global summary of the threat is presented. This study concludes that there is a consistent pattern established on temperate rocky reefs globally following that observed in Tasmania. The Tasmanian results also showed that a 'regime shift' to kina or urchin barrens as they are referred to internationally is typically irreversible in the face of continued fishing pressure and greatly reduces the overall resilience of the reefs to the impacts of climate change. We should be aware that the kina barren example, as dramatic as it is, may be just one easily spotted symptom of ecological decline. There may well be other serious examples of ecological decline that we are not seeing because we are not yet looking in the right place or manner.

Directly contrasting with this story of decline is the story of recovery that has been documented at marine reserves at Goat Island (Leleu et al., 2012) and in Tasmania (Ling et al., 2009). The fieldwork for the Leleu study work was completed in 2006. In this study the historic habitat map done at the Leigh Marine Reserve in 1981 (Ayling) was compared to a new survey and map. The result showed that the large areas of kina barren (44 ha) in 1981 had virtually completely restored to healthy *Ecklonia* forest, with only 4.5 ha of kina barren documented in 2012. The Leleu survey also found that the boundary areas immediately outside the reserve continued to have large kina barren zones. A similar result of kelp restoration resulting from long-term full protection from fishing has been observed by the authors at Tawharanui, but is not yet documented.

It also appears from this study that kina barrens may also be influenced by exposure to wave energy, however more research is required to confirm this. While reduced predation of kina is well established as a primary cause of long-term kina barren formation, there is uncertainty as to the relative importance of a list of other factors that also affect the dynamic relationship between the algal forest and kina as its primary browser. These factors include:

- reef slope and topology which may affect the impact of wave energy on kina;
- the abundance of crevices and other refugia for kina;
- effects of sedimentation;
- storm damage and recovery of kelp forest ;
- kina and kelp disease outbreaks.

The pattern of greater kina barren coverage in more sheltered areas does seem to repeat itself in the Bay of Islands generally, based on our observations and those of Booth (2014). Generally, exposed areas appear to have less kina barrens, however there are notable exceptions. Just 1.5 km from our survey area to the southwest along Urupukapuka Island’s exposed west southwest coast there are extensive kina barrens established. At Mimiwhangata there were extensive kina barrens in some places on the exposed coast as well as areas virtually free of kina barrens. At Mimiwhangata in sheltered areas there were generally extensive areas of kina barren consistent with this study.

The current habitat map will allow future studies to assess the advance or decline of kina barrens in the study area. In the event of a marine reserve being established, the study will also provide a valuable baseline to assess the effects of protection on kina barrens and kelp recovery.

Limitations of the study

In the shallow areas, mapping precision was determined by the resolution and geo-referencing accuracy of the OS 20/20 aerial photography, estimated at 3-5 m or better. We attempted to draw significant biological boundaries at scales down to 1:1,000. At this scale, drawing errors typically would be within 5 m.

For the offshore areas, information layers were variable in spatial accuracy. The precision of the OS 20/20 sonar data layers was high at 2 m resolution. Accuracy of our ground-truthing waypoints contributed small potential errors (up to approximately 15 m).

A more significant potential for error results from our qualitative interpretation of the sonar data. In the case of determining the edge of rocky reefs where there is elevation variation of several metres, the sonar data depicts this edge clearly. However, where the reef becomes flat and broken as with patch reefs interpretations can become difficult. The 'backscatter' sonar return image layer assists in this interpretation but some substrata interpretations can be confounded due to the mixing of gravels, cobble, and heavy shell in areas which give similar backscatter returns to rock reef. Our ground-truthing data assisted this interpretation greatly, although this was point data spread over wide areas. This limitation may have underestimated the area of flat and patch reef occurring on the edges of some of the reefs.

In the many areas of sediment the analysis of scuba, drop video and sonar backscatter suggested that there was a great deal of substrate complexity. For example, streaks of gravel, shell, and gravel areas mixed with sand and cobbles in the channel areas are typically a fine scale mosaic of all these mixtures. Mapping these variations is problematic. Also there are likely to be dynamic changes in these mixed sediments from storms. Interpretation of these maps should take into account the potentially mobile nature of these sediments.

This complexity is a significant feature of the area. There is likely to be an associated change in community structure with these changes in substrata. Partially because of this, for the sake of current objectives we chose to simplify the classification and lump the mosaic of sand/gravel/shell substrates together in one habitat which we named gravelly coarse sand.

This does not reflect the fine scale significance of the shell and gravel components. The sonar data were not able to differentiate between shell components and gravel components although these habitats could be distinguished by video and scuba observations. Given the heterogeneous nature of these habitats further mapping would be justified but would require additional field sampling to ensure complete coverage.

Within the biological communities we mapped there is uncertainty with boundaries for algal turf beds. Interpretation of the aerial photography was based on field observations and we used all the available data to determine boundaries.

However there were two issues confounding the mapping. First, in some cases gravel beds can be mistaken in the aerial photograph interpretation for algal turf beds especially where gravel may or may not support algal turf. Secondly, the quality of aerial photograph interpretation gradually diminishes with depth. For deeper areas we had to rely more on scuba, drop video and sonar observations to assign boundaries. As a result the precision for the mapped area of algal turf habitat area ranges from less than 10 m in shallow areas to as much as 100 m potentially at the outer extent of the depth range. It is also likely that this habitat is susceptible to dynamic change as result of storm conditions rearranging the substrates the algae are colonising. In summary the area represented as algal turf habitat is a complex mosaic of substrates, varying in grain size and shell composition where patches of algal turf are colonising and forming biogenic communities when conditions suit their growth and establishment.

Recommendations

In the course of this survey, the authors were impressed by the special nature of this area, the array of marine habitats and dynamic environmental factors at play within the survey area in the Bay of Islands. Without doubt, the area is an ideal candidate for protection.

There are many valuable scientific investigations that could be done here in future. To the Bay of Islands community and all government agencies involved, we recommend supporting future efforts in monitoring and research. In this special area there are ideal opportunities to gain more knowledge which can guide management and marine protection planning for this coast. We suggest further work should:

1) Maintain the commitment to, and continue to work towards the establishment of the highest level of marine protection available for this area. The kina barrens of the Waewaetorea Island area have been present for two-three decades and show no signs of decreasing. We suggest this is posing an unacceptable ecological risk for such a special and valuable marine site. Marine reserves provide us with an alternative to long-term ecological decline and a place to learn about what is natural in our marine environment.

2) Support further investigations into the special nature of habitats and biodiversity in the Waewaetorea survey area. Fish, algal communities, benthic invertebrate

communities, and deep reef encrusting invertebrate communities are all good candidates for future investigations.

3) Pursue research and monitoring opportunities to build on our knowledge of the ecology of the Northland coast and address questions relating to the ecological decline that is observed in the shallow rocky reefs. In particular:

- Establish a set of representative rocky reef study areas situated along the Northland coast.
- Create a programme that reviews the spatial implications of various forms of fishing and their specific impacts on shallow rocky reefs. The specific impacts of fishing intensity at the local or reef scale must be quantified for its ecological impact role to be understood.
- Support ongoing study of the restoration of kelp forests in New Zealand marine reserves; this offers a ‘control’ to evaluate the impacts of fishing at local scales.

Acknowledgements

The authors would like to acknowledge the visionary work being carried out by the Te Rawhiti hapu, Ngati Kuta and Patukeha, the Guardians of the Bay of Islands and DOC in the restoration of the terrestrial ecosystems of these islands. This pioneering work should be seen as encouragement to treat adjacent marine habitats as high priority areas for study and consideration for protection.

Imagine these islands and their surrounding waters as a fully restored and protected sequence of habitats and ecosystems, extending from the deep reefs offshore to the stunning shallow reef habitats, and then up the shore to the coastal forests above.

Special thanks go to John Booth, Chris Richmond, Vicky Froude, and Dan Breen who all contributed with reviews of this report. Catherine Langford and Jessica Kerr assisted with proof reading. We thank Joe Moretti who ably contributed his time on our dive team. Lastly this survey was supported and made possible by the volunteer efforts of our skipper Dean Wright and the use of his launch Arethusa. Arethusa continues to serve as an ideal inshore survey vessel for our work. She is about to enter her second century as a work boat in New Zealand waters, an impressive feat.

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Appendix 1 Algal species

Name

red algal species
Pterocladia lucida
Hummbrella hydra
Haliptilon rosea
Liagora harveyana
Melanthalia abscissa
Cheilosporum sagitatum
Plocamium sp.
Osmundaria colensoi
Corallina officinalis
Gigartina circumcincta

brown algal species
Carpophyllum augustifolium
Lessonia variegata
Xiphora chondrophylla
Carpophyllum maschalocarpum
Carpophyllum plumosum
Ecklonia radiata
Carpophyllum flexuosum
Halopteris funicularis
Zonaria turneriana
Carpomitra costata
Landsbergia quercifolia
Colpomenia sinuosa
Sargassum sinclairii
Glossophora kunthii
Cystophora torulosa

green algal species
Caulerpa geminata
Codium convolutum
Codium gracile
Ulva lactuca

Appendix 2 Fish species

Waewaetorea Island marine reserve proposal areas fish list from Kerr & Grace survey 2012-2014

Aplodactylidae

Aplodactylus meandratus (marblefish)

Aplodactylus arctidens (notch-head marblefish)

Aplodactylus etheridgi (notch-headed marblefish)

Arripididae

Arripis trutta (kahawai)

Berycidae

Centroberyx affinis (golden snapper)

Hoplostethus elongatus (slender roughy)

Carangidae

Caranx lutescens (trevally)

Decapterus koheru (koheru)

Seriola lalandi (kingfish)

Trachurus novaezelandiae (jack mackerel)

Carcharhinidae

Carcharhinus brachyurus (bronze whaler)

Cheilodactylidae

Cheilodactylus spectabilis (red moki)

Cheilodactylus ephippium (painted moki)

Cheilodactylus douglasi (porae)

Chironemidae

Chironemus marmoratus (kelpfish/hiwihiwi)

Congridae

Conger verreauxi (common conger eel)

Dasyatidae

Dasyatis brevicaudata (short-tailed stingray)

Dasyatis thetidis (long-tailed stingray);

Diodontidae

Allomycterus jaculiferus (porcupine fish)

Gobiidae

Favonigobius exquisitus (exquisite goby or sand goby)

Hemiramphidae

(Hyporhamphus ihi (Piper)

Kyphosidae

Kyphosus sydneyanus (silver drummer)

Girella tricuspidata (parore)

Labridae

Bodianus unimaculatus (red pigfish)

Coris sandageri (sandagers wrasse)

Notolabrus celidotus (spotty)

Notolabrus fucicola (banded wrasse)

Pseudolabrus miles (scarlet wrasse)

Pseudolabrus luculentus (orange wrasse)

Suezichthys aylingi (crimson cleanerfish)

Latridae

Latridopsis ciliaris (blue moki)

Microcanthidae

Atypichthys latus (mado)

Monacanthidae

Parika scaber (leatherjacket)

Mugilidae

Aldrichetta forsteri (yellow-eyed mullet)

Mugil cephalus (grey mullet)

Mullidae

Parupeneus fraterculus (black-spot goatfish, sub-tropical)

Upeneichthys porosus (red mullet/goatfish)

Muraenidae

Gymnothorax prasinus (yellow moray eel)

Myliobatidae

Myliobatus tenuicaudatus (eagle ray)

Pentacerotidae

Paristiopteris labiosis (giant boarfish)

Odacidae

Coridodax pullus (butterfish)

Pempheridae

Pempheris adspersus (bigeye)

Pomacentridae

Parma alboscapularis (black angelfish)

Chromis dispilis (two spot demoiselle)

Scorpaenidae

Scorpaena cardinalis (granddaddy hapuku or northern scorpionfish)

Scorpidae

Scorpis lineolatus (sweep)

Scorpis violaceus (blue maomao)

Serranidae

Ellerkeldia huntii (redbanded perch)
Caesioperca lepidoptera (butterfly perch)

Sparidae

Pagrus auratus (snapper)

Tripterygiidae

Fosterygion malcomi (mottled triplefin)

Fosterygion varium (variable triplefin)

Obliquichthys maryannae (oblique swimming triplefin)

Zeidae

Zeus japonicus (john dory)

Note: Several other sub-tropical and/or Australia species also make appearances in the Bay of Islands, some seasonally and others for the duration of their post-larval lives. Although not observed during this survey others recorded in summer 2014 the presence of schools of the tropical blue knifefish (*Labracoglossa nitida*) on the headlands and high current areas of the mapped area and similar sites on Cape Brett (eg Oke Bay, Maunganui Bay in summer 2014), (Chris Richmond, pers. Comm.)

Appendix 3 Map book

Map 1 Waewaetorea proposal area habitat map

Map 2 Substrate map

Map 3 Exposure classification map

Map 4 Okahu Island area habitat map

Map 5 Waewaetorea Island area habitat map

Map 6 Urupukapuka Island north coast habitat map

Map 7 Urupukapuka Island west coast habitat map

Map 8 Motukiekie Island area map

Map 9 Aerial photograph Akeake Point 1:3,000 scale

Map 10 Aerial photograph Akeake Point 1:7,000 scale