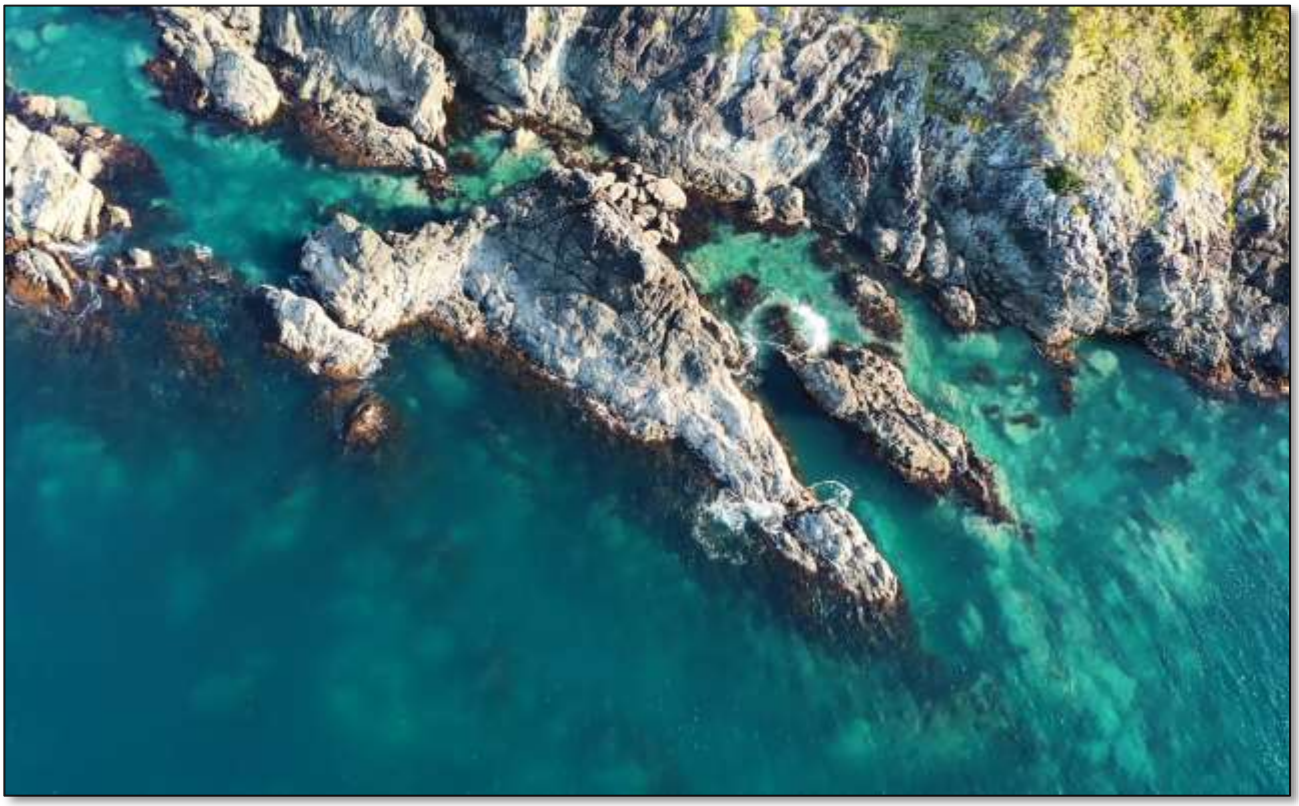
Marine habitats of Maitai Bay and the exposed coast of the Karikari Peninsula

Vince Kerr, Whetu Rutene, Oliver Bone, December, 2020



Cover Photo: *A drone captured view of the rugged reefs and kina barren off the outer point of the Merita Peninsula. Photo is a screen grab from the high definition video footage and trial work completed this year by the authors and the AUT research team of Dr Dan Breen and Graham Hinchcliff.*

For: Te Whānau Moana/Te Rorohuri by:

Vince Kerr[1] B.Sc., Whetu Rutene[2], and Oliver Bone[3] M.Sc.

[1,3]Mountains to Sea Conservation Trust Community Support Program

[2]Te Whānau Moana/Te Rorohuri

[1]Kerr and Associates Marine Ecological Consultants, Whangarei, email: vince@kerrandassoicates.co.nz

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Key Words: kina barrens, marine reserves, rāhui, habitat maps, tāmure (snapper), crayfish, Maitai Bay, Karikari Peninsula, biological zonation, algal communities, wave exposure

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Contents

1 Summary

Te Whānau Moana/Te Rorohuri hapū of Ngāti Kahu iwi are mana whenua of Karikari Peninsula and are those ultimately responsible for the lands, seas, environment and people residing there. For several decades now they have been concerned about the degradation of their fisheries resources, mainly through overfishing. The area in and around Maitai Bay is of particular concern. It is an important kāpata kai (seafood source) of Te Whānau Moana/Te Rorohuri. However, the camping ground currently managed by the Department of Conservation at Waikura, adjacent to Maitai, attracts large numbers of people and many recreational fishing boats. For over two decades, the seafood resources in the Bay have been increasingly depleted.

In 2017 Te Whānau Moana/Te Rorohuri laid a rāhui over the area to stop all fishing and taking of seafood in order to allow the area to recover. While the area started to recover, the hapū considered whether they should extend the rāhui from two years to five years. To help inform their decision they asked Vince Kerr of Mountains to Sea Conservation Trust to conduct a marine habitat survey to provide a snapshot view of the present state of the area. This report details findings of that survey.

A marine habitat map for the waters of Maitai Bay, the rāhui and surrounding area has been completed and is presented in a series of maps. The maps cover an area of 748 hectares extending from shore as far as 2.0 km and the 70m depth contour. The rāhui covers approximately 390 hectares in total area. Sixteen habitats were classified for these maps. The mapping approach follows a series of mapping studies that have been done in Northland dating back to 1973. The classification is consistent with the *Marine Protected Areas (MPA): Classification, Protection Standard and Implementation Guidelines* (DOC, 2008). The MPA classification 'shallow rocky reef' is further defined into its primary biological communities of 'shallow mixed weed', 'kina barrens' referring to kina *Evechinus chloroticus* and '*Ecklonia* forest' characterised by the dominant macro-algae *Ecklonia radiata*.[1]

The survey and mapping were focused on the rāhui area. In this area hapū included high-quality examples of exposed shallow rocky reef and shores, adjacent deep reefs and a diversity of soft sediment areas adjoining the reefs. Habitats are described in detail and illustrated with underwater imagery.

The high resolution of aerial imagery and mapping in this study made it possible to accurately delineate the boundaries of kina barrens as part of the shallow rocky reef habitats. This study calculated the extent of kina barrens as covering 39.9% of estimated historic area of high productivity *Ecklonia* forests extending to 20m depth. The interpretation and assumptions behind this calculation were informed by analysis of aerial images allowing a view of the underwater shallow habitats to depths varying from 10-20m dating back to 1944. In the mapped area kina barrens cover 49.4 hectares and represent 6.61% of the total mapped area.

[1] Urchin barren (kina barren) is the commonly used term internationally and in the scientific literature. However, the term most commonly used in New Zealand is kina barren. We use kina barren in place of urchin barren throughout this report aimed at a New Zealand audience.

Maitai Bay is the most northern location mapped at this level contributing to the body of work done in Northland to document the decline of shallow algal forests. Importantly, there is good aerial imagery of steep exposed shorelines showing the kina barrens well which is rare for this habitat. This project will facilitate an effective monitoring approach to track the recovery of the algal forest, which is one goal of the rāhui. This is an important local management goal. The methodology for tracking shallow reef algal heath and our ecological understanding has matured over two decades of work in Northland. We urge that this methodology in some form be considered as a fundamental and high priority state of the environment indicator for coastal northeast New Zealand, due to the high ecological values of these shallow reef algal forests. The efforts of the Mountains to Sea Conservation Trust team and the mana whenua of Maitai Bay has shown a convergence of values, goals and observations between short-term Western-based science investigation and long-term scientific knowledge derived from over a 1000 years of living there, sometimes referred to as mātauranga Māori, that has led to a practical and effective approach to the work undertaken. The successful partnership has come about simply from the fact that we both deeply care about the health and future of this special place and the people who live there.

2 Introduction

2.1 Te kaupapa provided by the hapū

Te Whānau Moana/Te Rorohuri are mana whenua (ultimate power and authority) of Karikari Peninsula where Maitai Bay is located. They have lived there for over 1000 years having arrived on Māmaru waka led by the ancestors Kahutianui and her husband, Te Parata, more than 50 generations ago. All areas around the peninsula are named by these and other early ancestors, including the renowned navigator Kupe. Maitai is the sacred pā site on the headland between Ōmahuri and Merita beaches. As Māmaru circumnavigated what was an island at that time, it stopped at Maitai and the whānau of Te Rorohuri set up their papa kāinga there (Mutu et al, 2017, pp.21-22).

The first Europeans arrived in the 1830s but did not remain (although they falsely claimed land that the Waitangi Tribunal has confirmed they had no right to). Europeans did not start arriving on the peninsula in significant numbers until the 1980s. Te Whānau Moana/Te Rorohuri started experiencing degradation of their fishing grounds around the same time (Mutu, 2012, p.115). Lands confiscated by the Crown in the 1960s at Waikura and Merita were being used as a camping ground that was taken over by the Department of Conservation in 1987. The land is scheduled to be returned to the hapū but in the meantime the camping ground attracts huge crowds during the summer months and is often overcrowded. Fishing was encouraged and has severely impacted on the marine environment of the Bay.

In December 2017 Te Whānau Moana/Te Rorohuri made the decision to lay down a rāhui that prevented fishing in Maitai Bay so that marine life there could recover. Only mana whenua can lay a rāhui and the process for carrying it out followed the ancient tikanga (law) of the hapū. There was extensive consultation first among all whānau who are mana whenua and then others who regularly visit the area. European/Pākehā administrative bodies, including relevant government bodies, were advised. The aims of the hapū were publicly stated as:[2]

bring balance back to our Moana (

restore the depleted areas (

restore Tapu, restore Mana (

implement a sustainability plan for future generations (

[2] In November 2016 Te Whanau Moana/Te Rorohuri published an information flyer for distribution to the community which stated the aims of the project as stated above. This flyer also had a map of the boundaries for the rāhui. This information was also given to media and posted on Facebook.

Figure 1 Location map of Karikari Peninsula, Maitai Bay and the area of marine habitats mapped in this study. The rāhui boundary is outlined in dark grey.

The Mountains to Sea Conservation Trust (MTSCT) based in Northland and home of the Experiencing Marine Reserves program has an active community support program aimed at helping local communities and hapū to develop conservation actions. The conservation support program is led by Vince Kerr, a founding trustee of MTSCT. In 2017 the MTSCT worked in the background to help with some mapping work and supply advice to members of the rāhui committee. The design of the boundaries for the initial rāhui proposal was a key issue. Support work continued in the form of establishing a monitoring program to track the ecological restoration resulting from the laying down of the rāhui (Kerr, 2018), (Kerr, Rutene and Bone, 2019) and (Bone, Rutene and Kerr, 2020). These reports are focused on reef fish communities and key indicator species like tāmure (snapper), butterfish, and maratea (red moki) (Matiu and Mutu 2003, pp.126-128) that are expected to respond dramatically to the rāhui and algal forest recovery.

2.2 A marine habitat map for Maitai Bay

Over the last three years in parallel with the fish monitoring work our team has been gathering habitat information about the rāhui area. We have spent hundreds of hours in the water observing the shallow reef areas. In the deeper areas we have been gathering sonar data, drop camera imagery and collecting historic and current aerial imagery to assist with the mapping process. We have also begun a process of comparing this current survey information with the knowledge and information that is held by the mana whenua hapū for the area. Traditional knowledge and the hapū's understanding about what we need to know has guided our survey effort. The Maitai Bay area and coast is extremely diverse in terms of habitat with many special features that are significant at small spatial scales and that collectively add up to making the area very important ecologically. Traditional knowledge and experience have been valuable to this project; 'special places' were well known and had specific stories and fishing strategies associated with them as part of the extensive and detailed scientific knowledge the hapū has of their territories (Matiu and Mutu 2003).

The habitat mapping presented in this report is intended to support the traditional knowledge and experience of this place. Looking to the future, we believe the habitat mapping will also be a vital tool to assist ecological restoration.

2.3 Kina barrens: a symptom of long-term localised overfishing and the urgent need for restoration of this key habitat and community

A key outcome of a fine scale habitat map is that it allows you to see in a very clear way the extent of loss of algal forest on shallow reefs. Ecological recovery of the algal forest and reefs and their associated biodiversity can be tracked and measured via the habitat mapping process.

In northern New Zealand large snapper and crayfish are the main predators of kina (Shears and Babcock, 2002). In their absence, the population density of kina can rise to ten-fold of normal densities resulting in the kina removing large areas of the algal forest. These areas often become a stable state of drastically reduced productivity and diversity. Shallow algal forests are connected to the life cycles of many coastal species and their productivity is significant across large distances via species dispersal and 'drift algae' fueling food webs. Maitai Bay has developed kina barrens over large parts of its shallow reefs, some persisting for decades. A stated goal of the rāhui is to restore the life of the rocky reefs. While it is not intended that Maitai Bay become a marine reserve, research in New Zealand on the recovery of algal forests has focused on the Leigh marine reserve where, after thirty years of full protection, the kina barren areas extensive in the 1970s reverted to healthy algal forests. This dramatic change ran in parallel with the predator species re-establishing in the marine reserve. The changes were documented at Leigh by comparing historic habitat maps to recent mapping efforts (Leleu and Remy-Zephir, 2012). Other habitat mapping studies in Northland that have mapped kina barrens are Doubtless Bay (Grace and Kerr, 2005); Mimiwhangata (Kerr and Grace, 2005); Bay of Islands (Kerr and Grace, 2015), (Kerr, 2016), (Booth, 2015, 2017) and Tāwharanui; (Grace, 2007 unpublished).

In 2017 a report (Kerr and Grace) estimating kina barren extent for the Northland East Coast was prepared for the Motiti Rohe Moana Trust in support of its landmark Environment and High Court cases aiming to restore shallow reef areas in its rohe.[3] This regional scale study marks a beginning of our attempts to document the size of the issue we face and the actual loss to biodiversity and productivity of what is arguably one the most valuable and important coastal habitats and communities. The 2017 report was based on all the previous Northland mapping work and showed that the current loss and decline is significant and alarming.

Overseas, a similar dynamic of overfishing leading to loss of algal forests has been reported in virtually every other country with extensive temperate shallow rocky reef and algal forest habitats (Ling, 2015), (Filbe and Wernberg 2015) and (Filbe and Scheibling, 2018). In New South Wales and Tasmania, the impact of intense localised fishing and establishment of kina barrens has been extensively documented including significant adverse ecological impacts and impacts to commercial reef-dwelling species like pāua *Haliotis iris* and shallow reef fish communities.

3 Methods

3.1 Classification and description of coastal marine habitats

Marine habitat mapping in the form that is practiced in this report had its birth in New Zealand in 1973 (Ballantine, Grace and Doak). In this first study at Mimiwhangata, Dr Bill Ballantine, Dr Roger Grace and Wade Doak were tasked with doing an ecological study and description of the marine area of Mimiwhangata by Lion Breweries, the then owner of Mimiwhangata station. They invented the approach and method of mapping based on the resources they could pull together, their extensive diving observations and a simple set of principles they derived. This pioneering work still stands as a useful guideline for marine habitat mapping today. The principles derived from the 1973 work stated that the map should represent the most significant and important ecological communities and physical boundaries that affect these biological communities (for example, hard and soft substrates and depth). The methods established in 1973 were further refined in the form of a habitat map of the Leigh marine reserve (Ayling, 1981) that Dr Bill Ballantine was also involved with. This early work formed the basis of the Northland mapping efforts completed by the Kerr and Grace team in the last two decades. All the Northland reports have method sections that discuss the evolution and project-specific details of how the mapping was carried out.[4]

[3] A collection of documents relating to the Motiti Rohe Moana Trust cases can be found here: https://www.howtokit.org.nz/case-studies/rma-processes/motiti-rohe-moana-trust.html.

[4] Several of the Northland mapping studies are listed in the Reference section of this report. A full downloadable archive of the work of the Kerr and Grace team can be found here: https://www.kerrandassociates.co.nz/completed-works.html.

Figure 2 below shows the list of habitats and their descriptions that were used in this map. Depth is broken down into three main zones that are primary drivers of the marine communities: the intertidal zone that is the area between low tide and high tide, the shallow zone where light can penetrate and support algal species and algal forests to grow, and a deep zone which is beyond 30m depth where low light levels can no longer support algal growth and encrusting invertebrates dominate the reef communities.

Figure 2 Key to habitat classification used in this project.

3.2 Habitat surveys

Each summer between 2017 and 2020, habitat information was recorded at the study site. Various methods were adopted to maximise efficiency of boat time and equipment available. The methods also varied according to the depths targeted and the equipment available. For shallow areas down to approximately 20m, depth analysis of aerial imagery was the main resource used. This analysis was tested with diving notes and sonar and drop camera imagery. For the deeper areas beyond 20m depth, sonar data was collected and drop camera imagery was used to assist interpretation of the sonar data. Each of these methods is further described below.

3.3 Aerial imagery

Obtaining aerial photography which allows for viewing into the water to depths of 20m is a considerable challenge in Northland. There is a long list of factors which all must be ‘right’ on the day. Fortunately, as part of the various projects undertaken by the Kerr and Grace team, high-quality aerial images of the Maitai Bay area were taken in 2005 and 2009. In addition, ‘historic’ images were found that were at least partially useable taken in 1944 and 1983. The most recent imagery was sourced from Google Earth and provided reasonable coverage of the shallow areas from 2019. The Google Earth imagery is satellite based and lacks the resolution for fine scale mapping of the 2005 and 2009 imagery but is still useful as a check to gauge changes that have occurred from 2009 to the present. There was also some 2019 imagery taken as part of an ongoing drone research project aimed at updating and improving the aerial imagery required for mapping shallow marine features. The drone project is collaboration between the authors, Te Whānau Moana/Te Rorohuri and an AUT research team. The initial trial imagery from the drone field work only covered a small portion of the mapped area but was high-quality and resolution and provided another check on the current status of the algal forest and the overall mapping process.

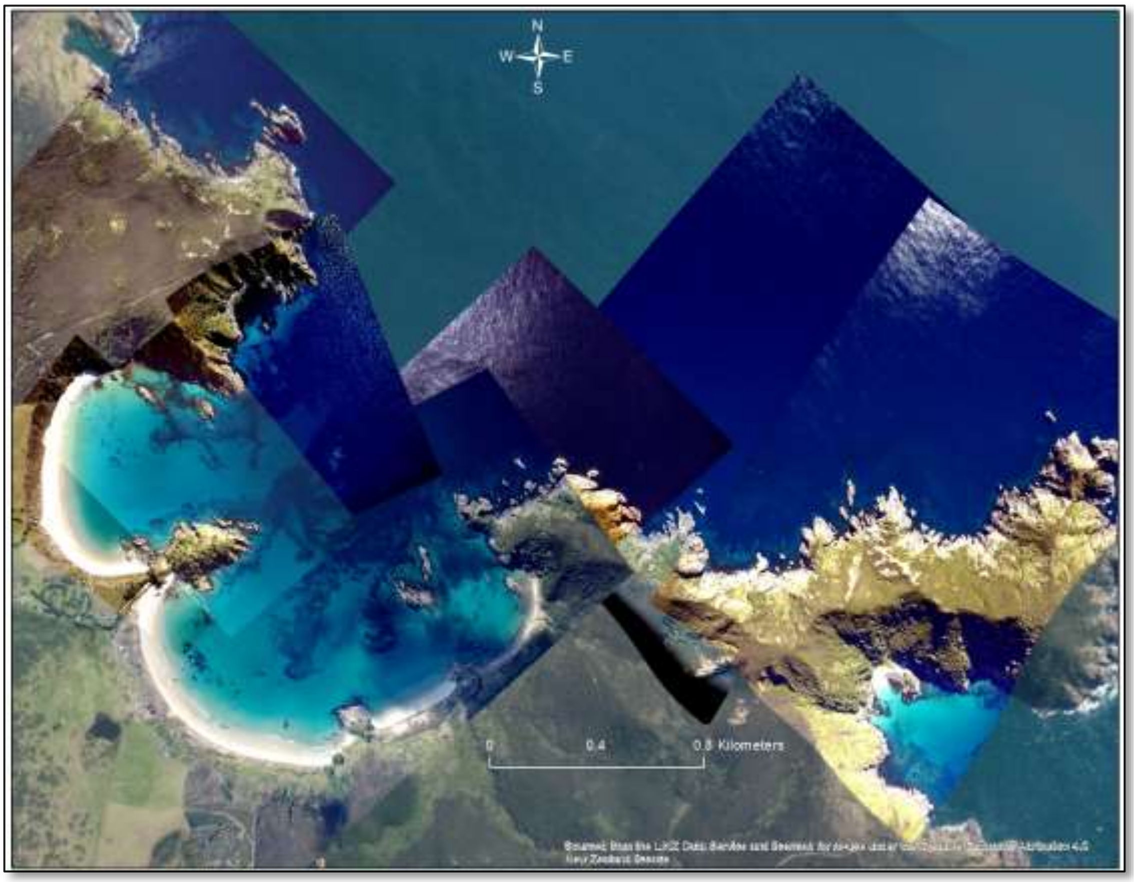

Figure 3 An example of the 2009 aerial images used in the mapping process.

3.4 Drop camera surveys

The drop camera system used in the survey utilised a GoPro Hero 4 Silver camera mounted on a drop apparatus with lighting supplied by two 1,200 lumen Sola video flood lights. The GoPro drop camera was set to take high-resolution still photos at 10 second intervals. The design of the drop camera apparatus allowed for some rotation of the system when it was positioned on the bottom to allow for photos to be taken at different angles. Also, photos were automatically taken as the apparatus was approaching and leaving the seabed. See Figure 4 below.

At each drop site, time, GPS position and depth were recorded and photographs or video footage archived for later interpretation. Locations of the drop camera survey sites are shown on the Figure 5 map along with the sonar survey tracks (see next section).

Target points for the drop camera survey were determined by locating specific locations of interest in the GIS map layers where interpretation of the sonar data could be tested. The areas targeted were:

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

Figure 4 GoPro drop camera system.

3.5 Sonar survey

The Sonar survey was conducted using a 4.3m Mac boat equipped with a Humminbird helix 9" mega side imaging sounder and chart plotter. The unit has the capability to record the various sonar data streams that it collects and processes. This allows for post-processing and analysis with third party software, *Reefmaster*. For this survey, notes on substrate interpretation and habitat change boundaries and waypoints were taken in real time. In post-processing, field notes were compared with the various views of the sonar data that can be produced in the third party software, *Reefmaster*. From the analysis, habitat change points were determined and recorded as GPS points to be used in the end mapping process in a GIS project. The sonar interpretation can reliably differentiate between major habitat or substrate boundaries such as a change from sand to solid rocky reef. The interpretation becomes more difficult and less reliable when there are mixtures of ‘hard and soft’ substrates such as shell mixed with sand, various gravel and cobble mixtures with sand and patch reefs. The drop camera ground-truthing is designed to help with these limitations of the sonar interpretation.

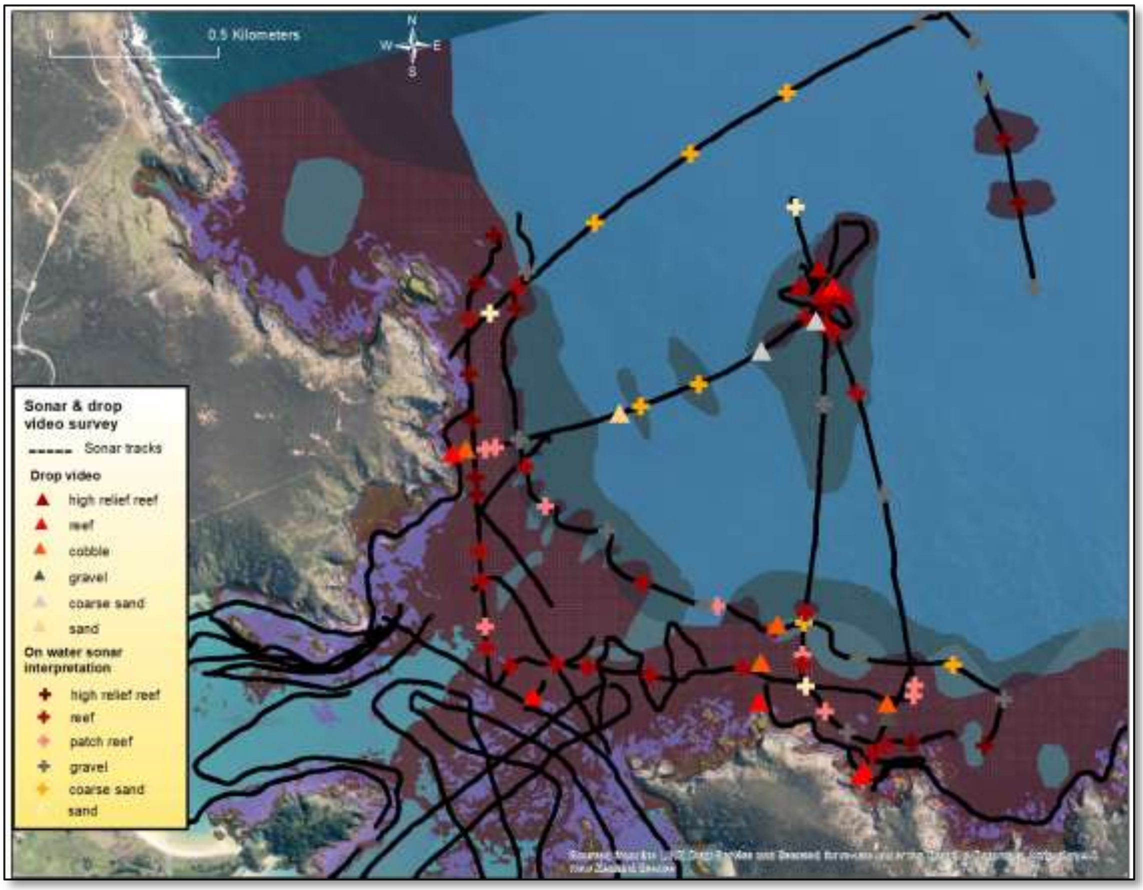

Figure 5 Map of sonar tracks and drop camera survey locations.

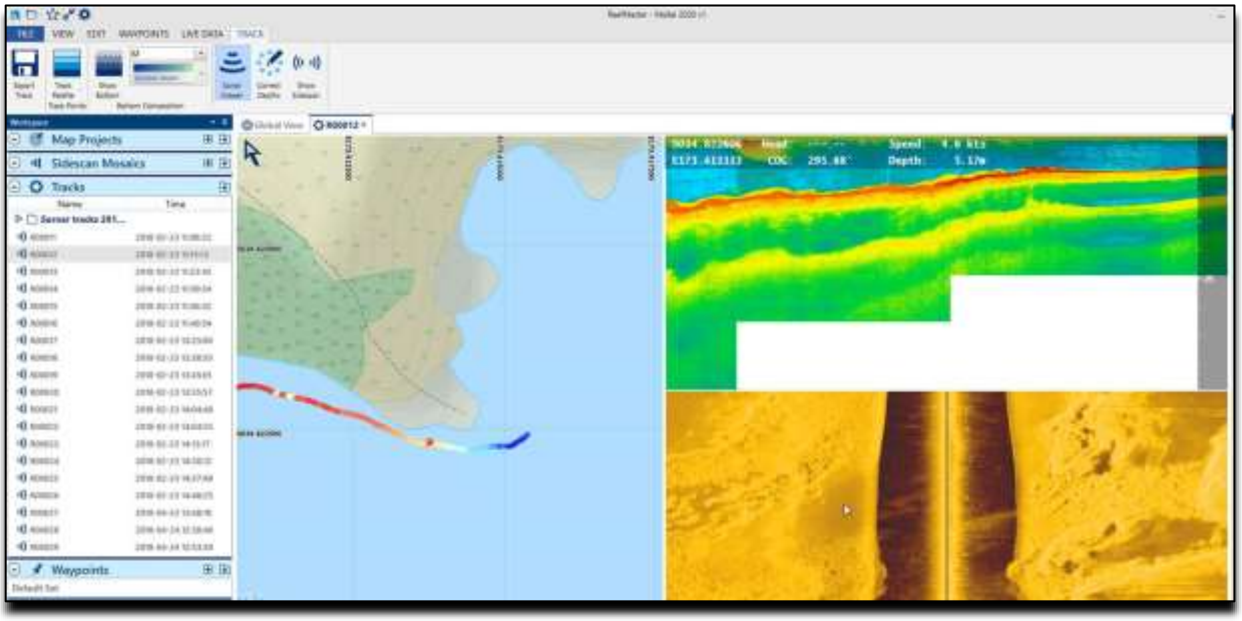

Figure 6 A screen shot from the *Reefmaster* shot showing sonar views used in interpretation of the sea floor substrates.

3.6 Snorkel and scuba dives

In the shallow reef areas, habitat interpretations were supported by notes on depth and algal communities from a series of snorkel and scuba dives completed in the area by the monitoring team. The three methods we are currently using in the fish monitoring work: BUV (baited underwater video), timed swim (snorkel-based) and fish diversity dives (SCUBA), all contribute specific information on habitats and habitat boundaries in the project area. The timed swim survey, which is carried out along most of the coastline of the rāhui area, is repeated numerous times during the summer period leading to hundreds of hours of observation time each year. On all survey days we make habitat notes as we go, and in most cases a camera is taken along with divers to record unusual events, biodiversity or habitat information. From this past work we have built up a significant photo archive of sites representing all the main habitats of the rāhui area. Where there was uncertainty in the aerial imagery interpretation these resources were reviewed.

3.7 Determination of exposure (wave energy)

Exposure to wind, wave energy and currents is known to influence the development of biological communities. *The Marine Protected Areas Implementation Guideline* identifies exposure as important in defining marine habitats for the purpose of its classification system. The guideline defines 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. This theoretical approach was combined with diver observations of the species make-up and depth of the shallow mixed weed zone. The shallow mixed weed zone is the first band of algal species below the low tide line that is dominated by kelp species that are tolerant of wave disturbance. At fine scales, observing the species of kelp present is an effective way to judge the degree of exposure to wave energy. The characteristics of the shallow mixed weed zone are explained further and illustrated in Results section below.

3.8 Habitat mapping process

To support the habitat mapping process, an ArcGIS (graphical information system) 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 to support interpretation.

An aerial image base map (LINZ NZ Imagery 2015) was used for the project to 'georeference' aerial images from the Kerr and Grace 2005/2009 archive and Google Earth. In ArcGIS there is a range of tools available and transformations that allow for this georeferencing process to reach a high-level of accuracy. The base map layer from LINZ has an accuracy within 1m. Typically, the georeferencing process in ArcGIS can result in imagery being georeferenced to 1-5m accuracy.

Polygons of the habitat classification were then hand-digitised at scales ranging from 1:1,500 in the deep areas, to a range of 1:500 to 1:1,000 for the shallow areas.

Using the LINZ imagery base map layer, a visual estimate was mapped of the Mean High Water Level and the Mean Low Water Level and classified by physical habitat (gravel, cobble, rock or sand) within the intertidal zone. In the shallow waters where the aerial photo provided visibility extending down to the seabed, habitat zones were drawn over the aerial photo layer. Where the aerial photo could not be reliably interpreted because of light angles or steep slopes, the depth of habitat zones were estimated by depth and the sonar data and drop camera imagery. After completion of the initial interpretation, the mapped habitat layers were tested against the overlay of the field ground-truthing information. Where uncertainty remained, field notes and photo archives were examined.

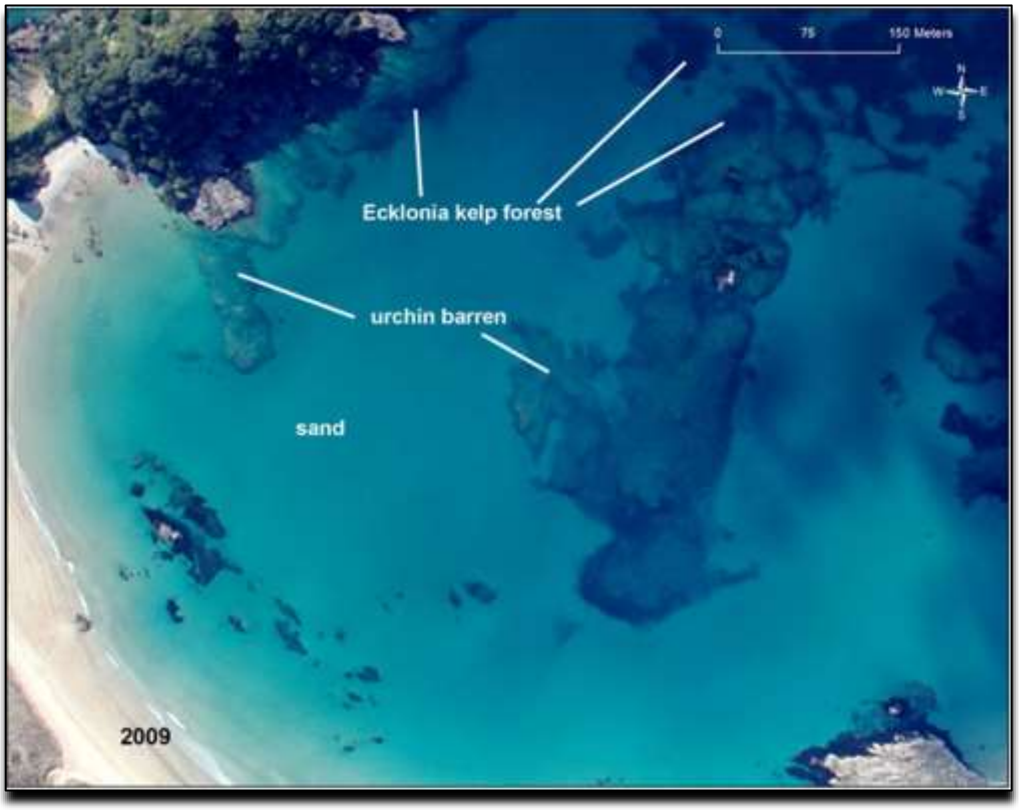

Figure 4 An example of the aerial photo layer used for the mapping process with examples of kina barrens and *Ecklonia* forest indicated.

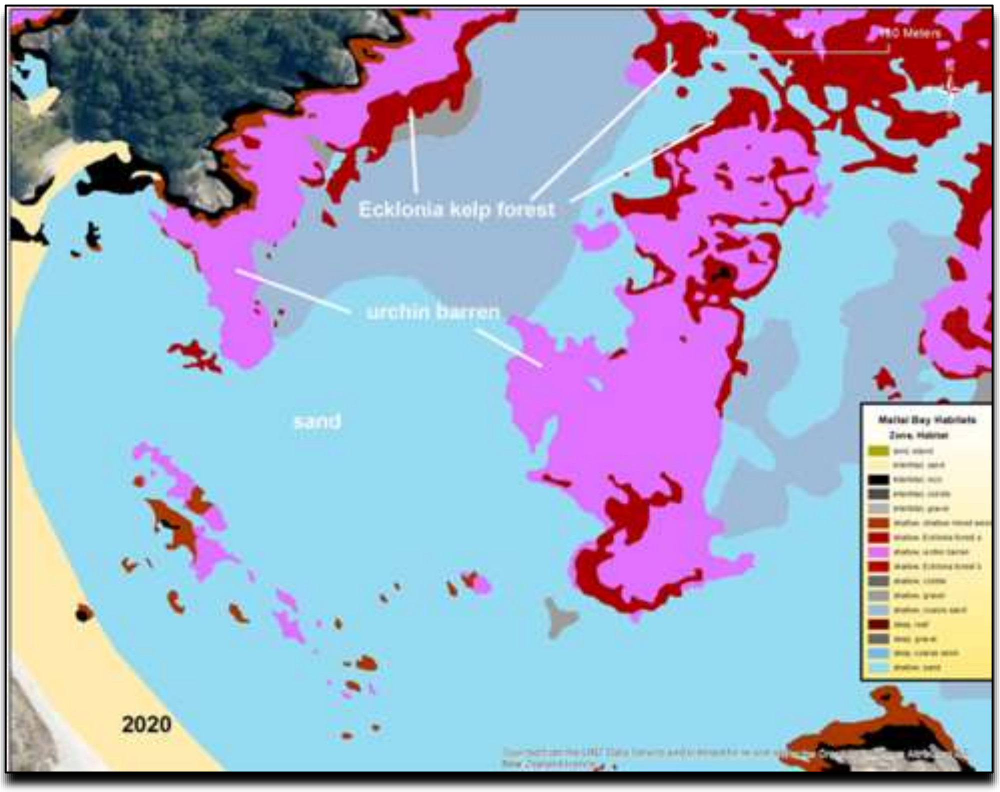

Figure 5 Completed habitat polygons drawn over the top of the aerial photo layer.

Figure 4 above shows an example of the quality and resolution of the aerial photography used. In this example you can clearly see the major substrata boundaries: a sandy beach, shallow sand area, shallow rocky reefs, and various biological communities. Algal species and forest appear as dark areas and kina barrens appear as light bare-looking rocky areas. Figure 5 above shows a section of the habitat map drawn from the aerial photo layer in Figure 4 showing the habitat interpretation of the colour differences seen in the imagery. Where conditions for aerial photography interpretation were suitable this allowed fine scale mapping to extend seaward, typically to a depth of 20m.

4 Results

4.1 The habitat maps

The habitat maps of this report were prepared in a GIS project as a data layer of polygons and associated attributes describing the habitats of each polygon. The habitat polygons are assigned a colour which is shown in each map key.

Detailed maps for this project can be viewed in a map book in Appendix 1. Map 1 (see Figure 9 below) shows the habitats of the survey area along with a map key that identifies the colours assigned to the various habitats.

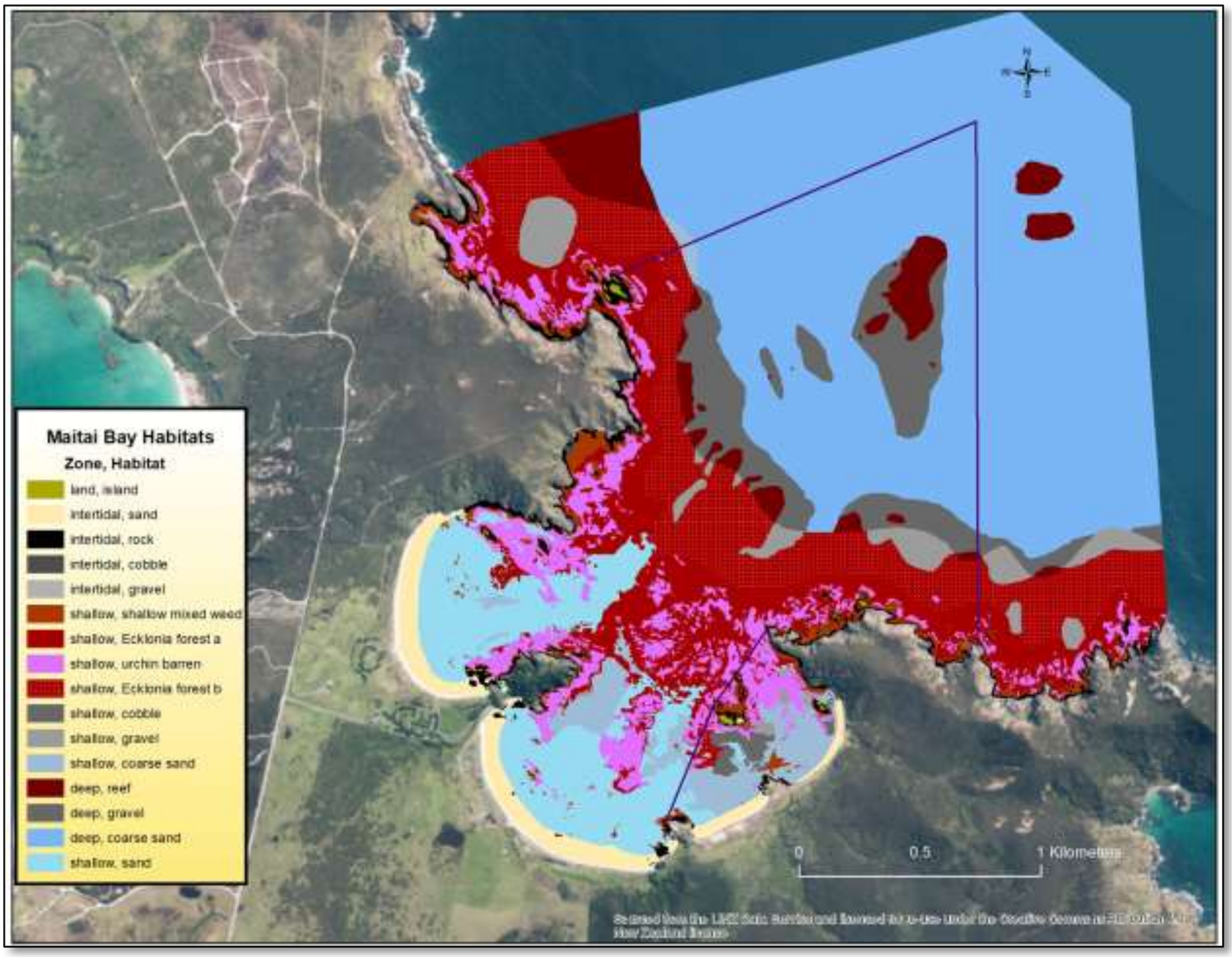

Figure 9 The completed habitat map.

4.2 Habitat area calculations

Table 1 below lists the spatial areas and percentage coverage of each of the 16 habitats mapped in this project. Shallow habitats are defined as extending to 30m depth and make up a total area of 322 hectares of the total mapped area that is 748 hectares. The rāhui area within the total mapped area is 390 hectares in size including intertidal, shallow and deep habitats.

Table 1

Habitat	Zone	Substrate	Hectares	Percentage of mapped area
island	land	land	0.76	0.10%
sand	intertidal	sand	17.26	2.31%
rock	intertidal	rock	14.66	1.96%

gravel	intertidal	gravel	0.72	0.10%
cobble	intertidal	cobble	0.56	0.08%
shallow mixed weed	shallow	reef	15.20	2.03%
kina barren	shallow	reef	49.44	6.61%
Ecklonia forest a	shallow	reef	74.32	9.94%
Ecklonia forest b	shallow	reef	76.47	10.22%
gravel	shallow	gravel	19.59	2.62%
cobble	shallow	cobble	3.23	0.43%
sand	shallow	sand	62.59	8.37%
coarse sand	shallow	coarse sand	21.52	2.88%
reef	deep	reef	28.97	3.87%
gravel	deep	gravel	42.46	5.68%
coarse sand	deep	coarse sand	320.17	42.81%
Total			**748**	100%

Maitai Bay has a significant area of shallow rocky reef habitat made up of shallow mixed weed and kina barrens and *Ecklonia* forest. The shallow mixed weed makes up 15.2 hectares of this total. *Ecklonia* forest is the major habitat and in total occupies 151 hectares.

Soft sediments are mixed between the coarse gravelly sands and fine sands, each also have shell components in places. Generally, on this coast the soft sediment areas are more gravelly and shelly towards the shoreline and transition in deeper areas to sandier substrates, that in some areas appear in combination with gravel cobble, scattered rock and shell mixtures.

4.3 Biological community zonation and the importance of depth

Boundaries of marine communities on shorelines have traditionally been defined in relation to height above and below tide levels. When combined with exposure or wave energy these two physical factors have a great influence on how communities are composed. In this project, we did not attempt to characterise the intertidal habitats beyond their most basic physical drivers. However, within this band where the tide comes in and out and wave energy is often high, there is great variation in community structure and significant vertical zonation of species on the shore in relation to the low tide mark.

Below low tide, a primary factor affecting the make-up of biological communities is depth. Depth affects light penetration and the impact of wave energy. The first zone descending from low tide level may be referred to as the shallow mixed weed zone. This zone varies in its depth range from less than 2m in the very sheltered locations to a depth of 8m in the most exposed areas. This difference is created by differing wave energy and the impact that has on these algae species. In this zone there are groups of algae dominating the community, that are specially adapted to the physical demands of wave energy and the degree of wave energy affecting each location.

The next zone, descending downwards, is typically an algal forest dominated by the large brown algae *Ecklonia radiata* that forms a dense canopy up to 2m in height. There is a great diversity of less dominant algae and encrusting invertebrates associated with this habitat.

Within the potential *Ecklonia* forest zone there is an important sub-type commonly referred to as kina barrens in New Zealand. In kina barrens, kina abundance is typically greater than 4 individuals/m^2 and the *Ecklonia* forest is grazed out, leaving largely bare rock with a much-impoverished encrusting invertebrate community compared to the *Ecklonia* forest community.

In this project we completed two drop camera transects on the outer coast. We photographed the bottom community at various depths ranging from 10m to over 30m and found that the *Ecklonia* forest progressively thinned out beyond 20m depth and was virtually absent at depths beyond 30m.

We were fortunate to have high-quality aerial imagery that allowed us to map kina barrens out to their apparent limit at approximately 15 - 20m depth. We expect that the reason kina barrens typically do not appear below 20m depth is because the nature of the algal forest changes significantly beyond 20m depth. Essentially, light intensity, especially red light, is reduced dramatically below 20m depth and at 33-35m depth there is not enough light penetration for the macro-algae species to grow. The result of this light penetration factor is that the algae productivity is greatly reduced as compared to the shallower part of the habitat at depths less than 20m. It appears that this factor affects kina behaviour, density and their ability to create the shift to the kina barren state. Supporting this interpretation are our observations from the drop camera and the aerial imagery we evaluated.

The 20m and 30m depth lines pictured in Figure 10 below were derived from chart bathymetry and soundings recorded in our sonar survey track data.

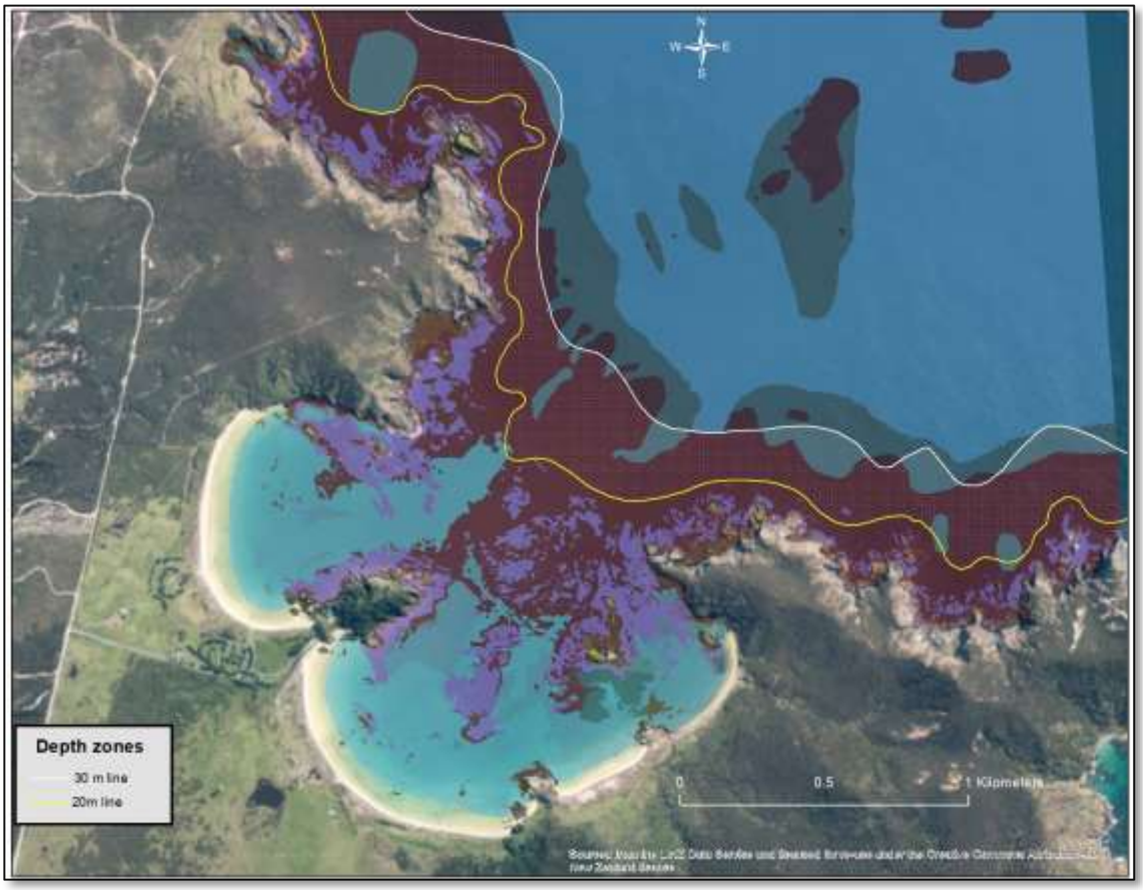

Figure 10 The habitat map showing significant depth level zones for biological zonation indicated by the white line (30m) and yellow line (20m), affecting the *Ecklonia* forest and deep reef communities.

To allow us to analyse more carefully the effect of depth on kina barrens and the algal forest we decided to represent the shallow *Ecklonia* forest as two sub-habitats that we labelled *Ecklonia* forest a (defined as extending to 20m depth) and *Ecklonia* forest b (defined as extending between 20 and 30m depth levels). These two sub-zones or habitats could also be described as high-productivity *Ecklonia* forest and low-productivity *Ecklonia* forest. The importance of this analysis is that we can now calculate the proportion of high-productivity *Ecklonia* forest that has been lost to kina barrens. Table 2 below shows the results of comparing the extent of the kina barrens compared to the two sub-habitats of high and low-productivity *Ecklonia* zones. To calculate the current percentage loss of *Ecklonia* forest, we have taken the current area of kina barrens and added the current *Ecklonia* forest, to give us an estimated historic area of *Ecklonia* forest. We believe this is a reliable estimate of the natural state and extent of the *Ecklonia* forest. This assumption is supported by studies of historic aerial imagery and is illustrated and discussed further in Section 4.5 below. In the mapped area, 39.9% of the historically estimated highly-productive area of *Ecklonia* forest (extending to 20m depth) has been lost to kina barrens. Of the total historically estimated *Ecklonia* forest (extending to 30m depth), 24.7% has been lost to kina barrens.

Table 2 Analysis of the extent of kina barrens compared to two depth zones of the shallow *Ecklonia* forest: *Ecklonia* forest a to 20m depth, and *Ecklonia* forest b to 20-30m depth.

Extent of *Ecklonia* forest and kina barren areas	
Total current *Ecklonia* forest area	150 hectares
Total current kina barren area	49.4 hectares
Percentage of total mapped area currently in *Ecklonia* forest (areas a & b, to 30m depth)	20.2%
Estimated area of historic *Ecklonia* forest area (areas a & b, to 30m depth)	200 hectares
Kina barren area as a percentage of total historically estimated *Ecklonia* forest (areas a & b, to 30m depth)	24.7%
Kina barren area as a percentage of historically estimated high-productivity *Ecklonia* forest (area a, to 20m depth)	39.9%

4.4 The importance of exposure and wave energy

Maitai Bay and its adjacent coast have a highly localised range of wave exposure and wave energy impacts on the shore and reef communities. Karikari Peninsula generally is highly exposed to north, northeast, east and to a lesser degree southeast swells and strong driving winds. Large swell events strike the outer or exposed coast with great intensity and depending on their angle also enter the bay with somewhat decreased but still significant energy in large swell events. Te Whānau Moana/Te Rorohuri describes shoulder-high waves crashing on the inner beaches of the bay during extreme events. For the shallow reef areas this infrequent but heavy wave energy has a dramatic impact on the shallow mixed weed zone and the shallower parts of the *Ecklonia* forest habitat. In shallow areas, wave energy can damage and break the larger kelp species. Where wave energy is a factor, wave energy resistant algal species make up the shallow weed zone to deeper levels and the *Ecklonia* forest begins at a deeper level. This effect of exposure on the shallow mixed weed zone and the upper limit of the *Ecklonia* forest is illustrated in the habitat descriptions below (see Sections 4.6 to 4.10 below).

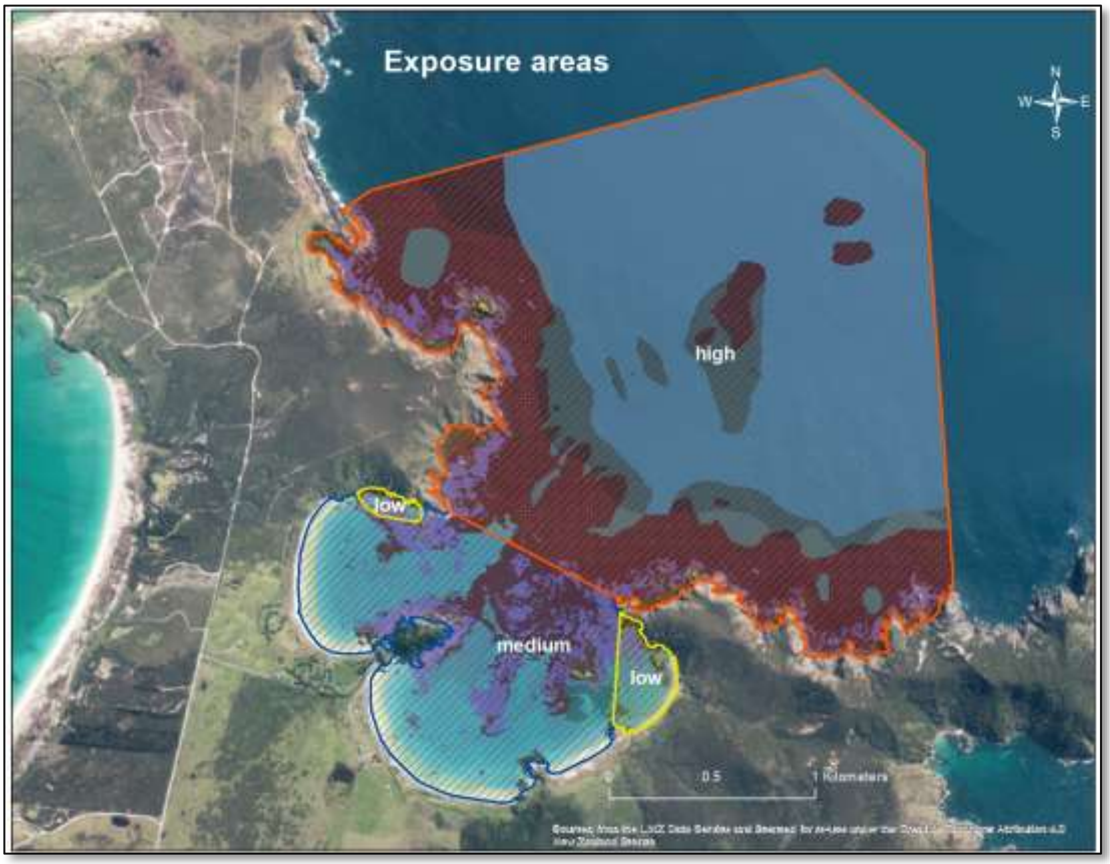

Figure 11 A three-level view of exposure and wave energy in the habitat map area.

4.5 Historic analysis of algal forest decline

Analysis of historic aerial imagery can be an effective way to track the long-term changes that lead to the formation of stable kina barrens. It is essential that we have a 'natural condition baseline' to inform our understanding of the ecology and the accurate mapping of these shallow habitats.

The first known attempt in New Zealand to track the decline of algal forests over time was made as part of the Mimiwhangata mapping project (Kerr and Grace, 2005). The authors of that report were able to source good quality aerial imagery of Mimiwhangata from 1950. They also had the 1973 habitat map as well as high-quality aerial imagery from 2005 and extensive diver experience and data. Below is a quote from the 2005 report which mirrors what we can now see with our study of Maitai Bay's history of algal forest decline at the expense of the kina barrens' expansion.

"This time series illustrates the long-term trend of decline in algal forest cover of the 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 that exists today. This suggests that there has been a continuous gradual decline in algal forest cover since 1950."

In the Bay of Islands, Dr John Booth (2005), working for the conservation group *Fish Forever*, used a similar approach to the Mimiwhangata work tracking algal forest loss over decades using historic aerial imagery. His results showed a similar pattern of extensive loss over similar time periods to Mimiwhangata.

To begin the process of establishing this natural condition baseline, we have included in this report an example of mapping and analysis of one small area in Maitai Bay. We searched for historic aerial imagery and found a set of images from 1944 which were taken at low tide and on a day that conditions favoured a view into the water of the bay down to about 12-15m for most of the shallow part of Maitai Bay. These images can shed light on the decline/restoration process we are studying.

In the two images below (Figure 12 1944 and 2009 imagery), you can clearly see boundaries between reef and soft sediments. Shallow mixed weed habitats along with *Ecklonia* forest are also easily seen once you get used to the interpretation of the images. In both images the algal forest areas are outlined with a thin white line. The mapped area used to calculate the extent of algal forest is outlined similarly with a thin white line. In both images the darker areas indicate algal cover. Bare rocky reef areas indicated by the lighter coloured reef are kina barrens.

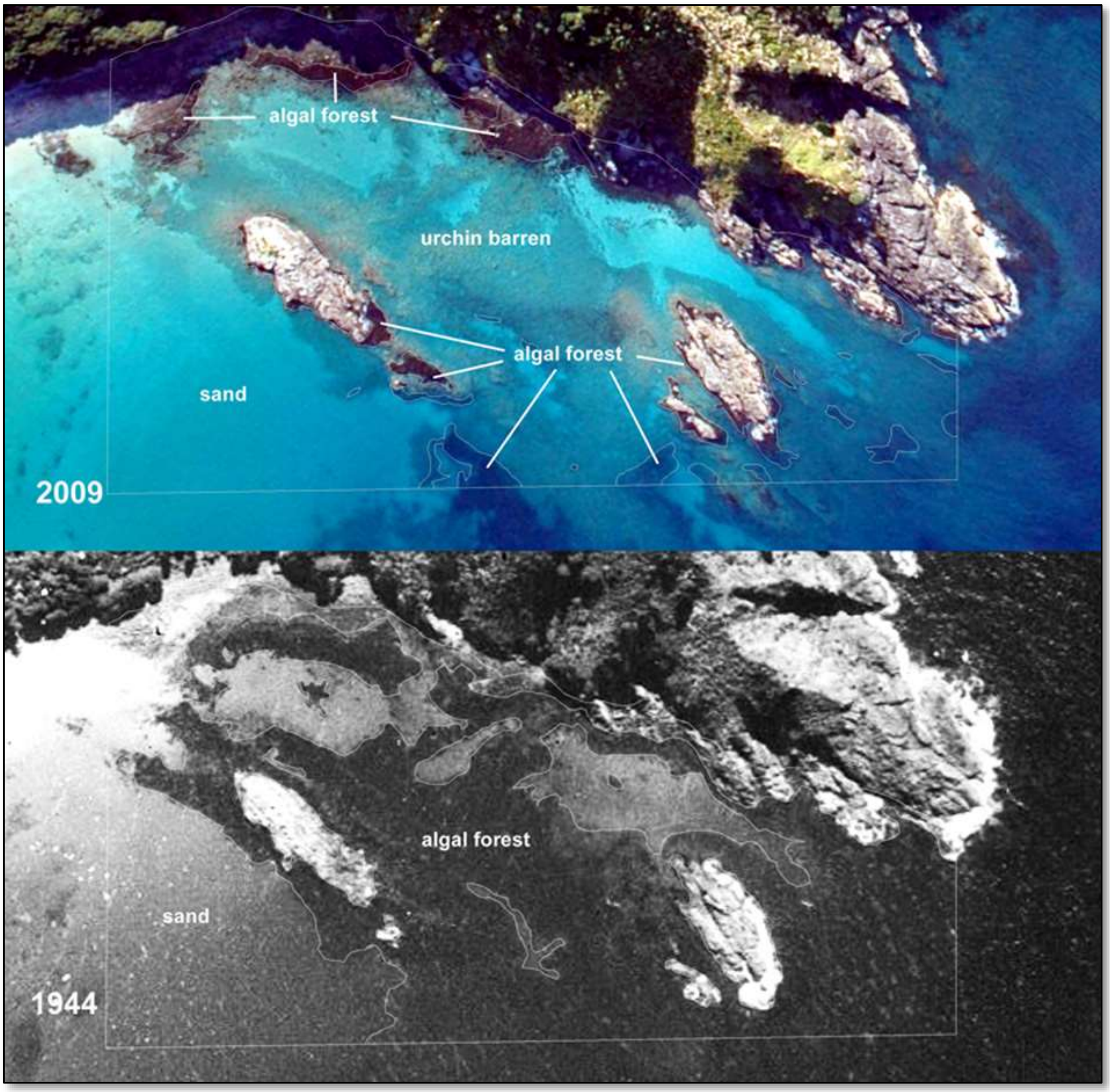

Figure 12 Comparison of 1944 and 2009 aerial imagery and kina barren expansion over time. Location: the Waikura area at the north side of Maitai Bay

In Table 3 below the calculated areas of the algal forest are shown. These results quantify at least for this one localised area the obvious loss of algal forest that is seen in the imagery. The change amounts to a loss of 73% of the original algal forest at this site.

This analysis of one area in Maitai Bay is preliminary and in future could be greatly expanded. From the studies at Mimiwhangata and Bay of Islands, we expect that these results are typical of the shallow areas of the inner part of Maitai Bay. These 1944 images and the condition of the algal forest are helpful in showing us the areas where the natural condition was indeed dense algal forest.

This is a check on the assumption that kina barrens are areas that were once stable algal forests. The images of 1944 illustrate to us a ‘restoration goal’ in regards the shallow algal forests.

Table 3 Area calculations for the trial mapped area for the 1944 to 2009 comparison

Comparison of algal forest cover 1944 -2090	
Trial area mapped	7.71 ha
1944 algal forest cover	4.58 ha
2009 algal forest cover	0.61 ha

4.6 Shallow mixed weed habitat

The shallow mixed weed zone or habitat is distinct from the general *Ecklonia* forest. It occurs along virtually all rocky shorelines. It is distinct due to the fact that it can withstand the physical forces of wave energy striking shallow water and the shore. It is typically composed of a diversity of large brown and red algae species that are valuable ecologically. These species vary along with the degree of wave energy. Currently under immense pressure from kina grazing, the shallow mixed weed forest is an important zone slowing the spread of kina barrens because most of the algal species that occupy this zone are not as palatable or preferred by kina as the dominant kelp of the deeper areas, *Ecklonia radiata*. Unfortunately, as the areas of kina barrens increases, kina begin to graze up into the shallow mixed weed zone. This condition can be seen in many of the worst affected areas in the shallow parts of Maitai Bay. In extreme cases the shallow mixed weed zone can also over time disappear, replaced by kina barrens.

One of the most important differences between the shallow mixed weed communities is the degree of exposure. In sheltered areas, the depth range varies between approximately 1.5-3m as compared to 4-8m depth observed on the exposed coast. This difference is a result of the effect of the variation in wave energy experienced by these algal communities.

On the exposed shores, the algal community is especially resilient to the high wave energy. The upper levels of this zone are dominated by the brown algae species *Xiphophora chondrophylla*, *Carpophyllum maschalocarpum* and *Carpophyllum augustifolium*. The latter is the species that dominates in the most exposed areas of the shoreline. Another indicator of surge and high wave energy is the brown kelp *Lessonia variegata*. This species thrives in the most extreme exposure areas, for example: pinnacles rising to the surface, the extreme outer seaward shores of headlands, or guts which magnify wave energy. Towards the bottom of the shallow mixed weed zone at 4-8m there is often a mixture of the common red algae *Pterocladia lucida* and the deep red coloured *Osmundaria colensoi*. *Carpophyllum maschalocarpum* and *Carpophyllum plumosum* feature in the lower reaches of the shallow mixed weed. In addition to this list of common species, there is also a diversity of small red algae species falling into the main groups of encrusting calcareous species, such as *Corallina officinalis* and many small foliose species. 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.

In the more sheltered areas, the shallow mixed weed has a slightly different group of seaweed species that dominate the community. The main species at the shallowest part of the zone is *Carpophyllum maschalocarpum.* There is also *Xiphora chondrophylla* and at times the common red algae *Pterocladia lucida* (the species collected for agar). Towards the bottom of the zone, *Ecklonia radiata* becomes common and then at the deep boundary of the zone *Ecklonia radiata* dominates forming a dense canopy. In this transition zone, there are often a number of encrusting and foliose red algae species and the other large brown algae species *Carpophyllum plumosum* and *Sargassum sinclairii* may be seen.

Figure 13 These images are taken at the shoreline of one of the small islands off the north end of Maitai Bay (Waikura). (Left) two important species of the shallow mixed weed forest: the darker brown kelp is *Carpophyllum maschallacarpum* and the bright yellow green kelp is *Lessonia variegatum.* (Right) a view of a shallow mixed weed zone comprising several species with some *Ecklonia radiata* appearing towards the bottom of the zone. The rich green algae at the right bottom of the image is *Caulerpa geminata* (often called sea rimu). This is a semi sheltered location with the depth of the shallow weed zone extending to about 3m, bordered by kina barren below. Both images are showing evidence of kina grazing affecting the algal forest.

Figure 14 Two examples of the shallow mixed weed zone on an exposed shoreline near Takini Point. The main species at the top of the zone is *Carpophyllum maschalocarpum*. Towards the bottom of the zone *Ecklonia radiata* starts to appear. *Ecklonia* forest can be seen below at greater depth. In this location, the depth range of the shallow mixed weed zone extends to 6-8m due to greater wave energy. At the center of the right image a butterfish can be seen. This species only lives in healthy shallow algal forest.

4.7 Kina barrens

Kina barrens are defined as areas of rocky reef where kinas have overgrazed the kelp species to an extent where they can no longer persist on that part of the reef. In Northland generally and in Maitai Bay, the worst affected areas are shallow areas with low exposure to wave energy. Another factor is the nature of the terrain. Large continuous smooth or flat reefs are often the worst affected. Where the natural predators of kina, large snapper and crayfish, are eliminated the kina numbers can increase to 5-10 fold the density of the natural level. Kina also have a specific behaviour that they employ in certain situations, called a 'feeding front'. When this occurs, the kina gather together in large numbers and move along the reef in dense line and literally mow the kelp plants down. Several kina chewing on the base of an *Ecklonia* stem are capable of chopping it off at its base. The felled kelp plant is then surrounded by the kina as they devour the softer leaf parts of the plant. Once the algal forest is felled the high kina numbers easily control any new recruits of the kelp species that attempt to grow in the kina barren area. The end result is the kina barren becomes established as a long-term and stable habitat. In the case of Maitai Bay, the worst affected areas have been kina barrens for decades. Typically, once a kina barren is well established the kina numbers reduce somewhat due to the scarcity of food. Often an impoverished community of encrusting invertebrates and turf algae establish along with seasonal algal species which grow on the kina barren for just a few months and then disappear again. As the age of the kina barren increases typically the kina slowly expand the kina barren upwards attacking the shallow mixed weed zone and downwards eating away at the deep edge of the *Ecklonia* forest until the kina barren reaches the edge of the reef or a lower limit which appears to be about 20m depth at Maitai Bay.


Figure 15 (Left) a view of the reef near the visitor car park, where the kina barren has reduced the shallow mixed weed zone to a small strip along the intertidal line and reaches in some places all the way down to the sand edge of the reef at about 10m depth. In other places, a thin band of *Ecklonia* forest remains along the deep edge of the reef. (Right) this reef is the semi-exposed shore at Takini Point and shows the kina barren encroaching upwards into the shallow mixed weed zone.


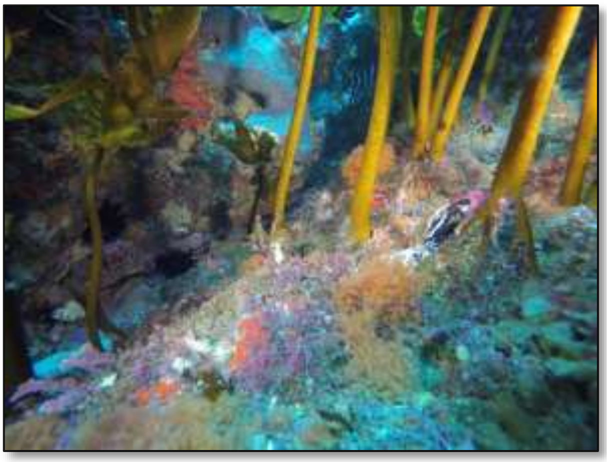

Figure 16 (Left) a group of kina devouring a fallen kelp plant. (Right) this is a view of the lush encrusting algae and invertebrate community that live under the canopy of a healthy shallow *Ecklonia* forest. Virtually this entire community is removed once the kina barren is established. This *Ecklonia* forest understory habitat is an extremely rich and productive ecosystem which is critical for the life stages of many marine organisms including most of the fish species we recognise as recreationally and commercially important.

4.8 *Ecklonia radiata* algal forest

On the exposed shores, the *Ecklonia* forest extends from about 8m depth to around 30m depth, or to the edge of the reef if that occurs at less than 30m. In the more sheltered areas, this transition takes place at 1.5 to 3m. In most cases, the *Ecklonia* forest appears to be monotypic. In places, the *Ecklonia* 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 dominating the reef surface. As you travel down the reef slope, some of the common sponges begin to appear. The grey sponge *Ancorina alata* is often the first to be seen.

The understorey of the algal forest is an especially valuable ecosystem in its own right. Its low-light environment in which the canopy provides shelter from wave energy favours a wide range of encrusting invertebrates like sponges, sea squirts, anemones and hydroids, that make their living as filter feeders thriving 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 by the convoluted base structure. The holdfast provides safety and shelter for an extensive list of invertebrates and small fish (Smith, 1990 and Anderson, 2005). As many as 100 marine species have been found in just one *Ecklonia* holdfast.

The algal forest also plays an important role in our coastal fishery for many pelagic fish species as a temporary nursery. This is especially noticeable at Maitai Bay with the influx of juvenile fish species in the summer months. These fish species make the transition from planktonic larvae to large schooling fish in this nursery environment and importantly escape predators. Tāmure (snapper *Pagrus auratus*) and araara (trevally *Caranx lutescens*) can be seen in the summer and autumn months as tiny 10-20mm fish hiding in the kelp. Later on in their lifecycle, 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.

As the *Ecklonia* forest extends to deeper depths beyond 20m depth there is a noticeable thinning of the forest and the individual plants take on a more spindly appearance. This thinning effect continues to the 30m depth level where the kelp plants can be meters apart. Typically, beyond 33-35m depth the *Ecklonia* kelp is completely absent and the habitat becomes dominated by a diverse community of filter feeding encrusting invertebrate species and the grazers and predators associated with this community.

Figure 17 (Left) a typical view taken of a healthy shallow *Ecklonia* forest at approximately 10-12m depth on the southern exposed shore, illustrating how dense the canopy is at this optimum depth for the species. (Right) in this image the reef is changing from a broken rock and solid reef to a cobble substrate at approximately 18m depth; the canopy is thinning out at this depth.

Figure 18 (Left) a typical view of the *Ecklonia* forest at 20m depth showing the canopy dramatically thinned as compared to the shallower part of the reef. (Right) at 20m depth the sponge community is starting to be well established amongst the *Ecklonia* plants; several different sponge species are present in this image.

4.9 Deep reefs

Beyond 30m depth, on the offshore reefs light levels become too dim to support growth of the kelp species. Replacing the seaweeds is a wide array of encrusting invertebrates that form the basis of the deep reef community. Primarily these species make their living as filter feeders, but there are many other organisms that feed on these encrusting invertebrates or the species attracted to the reef for shelter. The interaction of currents with these reefs plays a major role; the more vertical the reef, the more it creates eddies or upwellings in the currents. Eddies and upwellings are very important and productive for filter feeding invertebrates and planktivorous fish species. These encrusting invertebrate communities form a complex three-dimensional structure on the surface of the reef.

All of Maitai Bay is less than 30m depth. Directly out from the bay and along the two adjacent coastlines, the shoreline reefs extend out to 30m depth where the slope of the reef flattens considerably and the solid reef tends to change to gravels, cobble and broken rock or patch reefs. There are no large areas of ‘deep reef’ extending outwards into the offshore area. The 30m plus reefs present are transitional in nature and do not appear to have the spectacular sponge gardens that would be seen at greater depths of 40-70m. Leaving these inner areas of deep reefs, going offshore the terrain is quite flat. Bottom substrates vary from sand to sand/gravel/shell mixes, cobble and areas of broken rock.

4.9.1 The Pinnacle

About 1.2 km offshore from Maitai Bay the bottom depth is 40-50 m and rising out of this flat soft sediment is an impressive pinnacle and surrounding reef. At its highest point it extends just above the low tide level. The Pinnacle is included within the rāhui boundary. In places the Pinnacle rises in a nearly vertical manner for some 40m. In the upper zones of the Pinnacle there is a wide shallow mixed weed zone extending downwards 10-12m. Below that in places *Ecklonia* can be seen but it is typically sparse not dense as found in more sheltered locations. Wave energy at the Pinnacle would be extreme at times affecting the algal forests for their entire depth. Below 30m, the encrusting sponge communities become more and more prominent. The Pinnacle is home to large numbers of plankton feeding fish that school there and benefit from the upwelling and strong currents caused by the Pinnacle. These dramatic structures often are very attractive to pelagic predator species such as kahawai *Arripis trutta* and kingfish *Seriola lalandi*. On one of the days we were surveying there was a large kingfish school present at the Pinnacle.

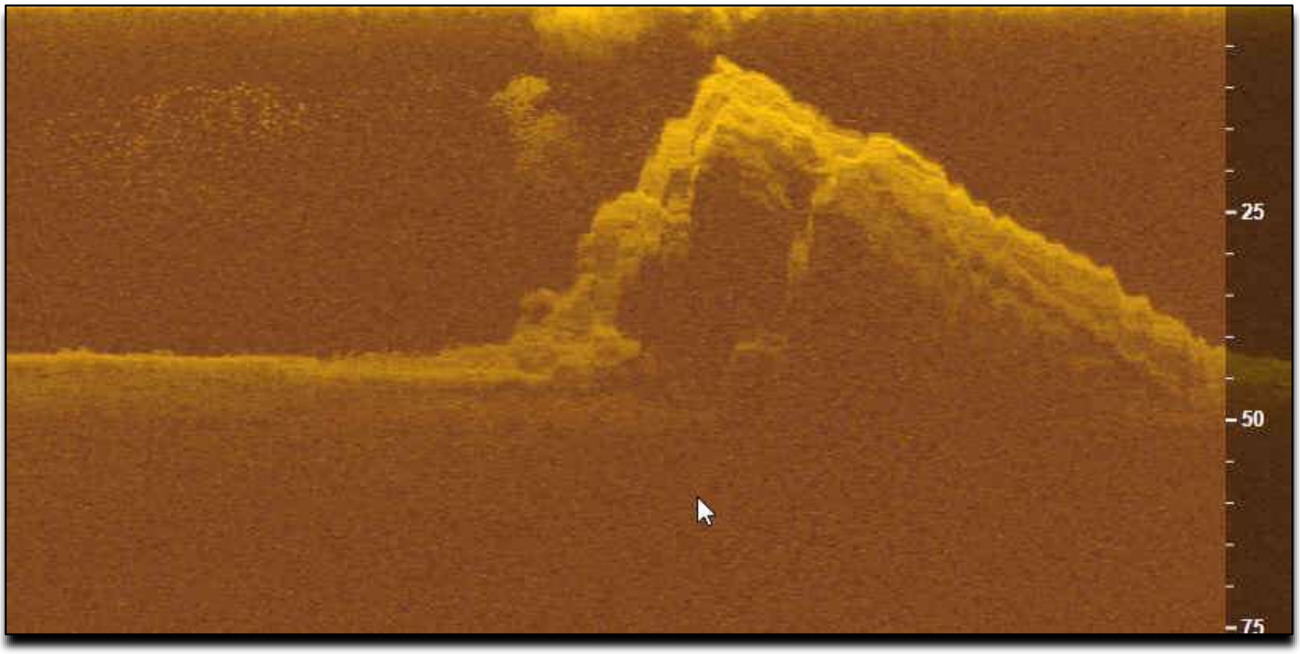

Figure 19 This is a sonar side profile view of one of the steep faces of the Pinnacle (notice the scale of depth on the right hand side). Directly above the Pinnacle, the white fluffy area on the surface is air bubbles, the other two white spotty areas that are in 10-30m depth water are schools of fish. The one closest to the Pinnacle is a mixture of two-spot demoiselle *Chromis dispilus* and blue mao mao *Scorpis violacea*. The school further away from the Pinnacle is kingfish.

Figure 20 The Pinnacle viewed from a different direction. In this view you can see a rather fuzzy effect on the top of the reef; this is algal forest. There are air bubbles on the surface and two schools of fish visible to the right of the top of the Pinnacle.

Figure 21 (Left) a drop camera image taken at about 35m depth looking down the slope of the Pinnacle. At this level there is a well-developed community of encrusting invertebrates covering the rocky surface of the reef. (Right) a drop camera image of the kingfish schooling at the Pinnacle on one of the survey days.

4.9.2 The outer reef

Traveling another 0.7 km further offshore to the northeast there is another prominent reef system within our mapped area, but not within the rāhui boundary. This deep reef structure as far as we know has no local name and rises from a relatively flat soft sediment bottom at 65m depth. The reef is two irregular shaped humps rising approximately 16m off the ocean floor. We only did sonar survey of this reef for mapping purposes and did not drop video cameras. We expect that there could be very rich deep reef communities on these reefs. They could be expected to be a 'special place' for a range of fish species. There are school fish showing in the sonar image below seen as faint dots or cloud hovering over the reefs.

Figure 22 A sonar profile view of the two reefs that make up the outer reef (note the depth scale on the right hand side and a faint view of fish schools hovering over the top of the reefs).

4.10 Soft sediments

The soft sediments in the Maitai Bay area are diverse ranging from fine sand to mixtures of coarser sand, gravel and shell. Unfortunately, the mapping of these soft sediment areas was the lowest priority of our mapping program. To do this habitat justice, mapping at fine scale would require more sonar and drop camera ground-truthing. However, we did complete enough work to reliably establish the major reef/soft sediment boundaries and explore the range of soft sediment types that are common in the area. Without doubt, the offshore area has had a dynamic geological history with vast amounts of rock worn from the rocky outcrops of the peninsula’s coast by intense wave action. This has led to many variations of gravel, broken rock and cobble mixing with the drifting sands in the areas near shore. Adding to this mix over time, a lot of shell material has been added to the substrates from the various invertebrate species that live there. To add to this complex geological history, the coastal sands are in motion with the influence of storm events and the strong currents that sweep the area.

The large variation of soft sediments and relative clean nature (free of silt) in this area would be expected to support a large diversity of benthic species inhabiting these soft sediment areas. The ecological contribution of these soft sediment areas should not be underestimated, especially when they are associated with reef areas.

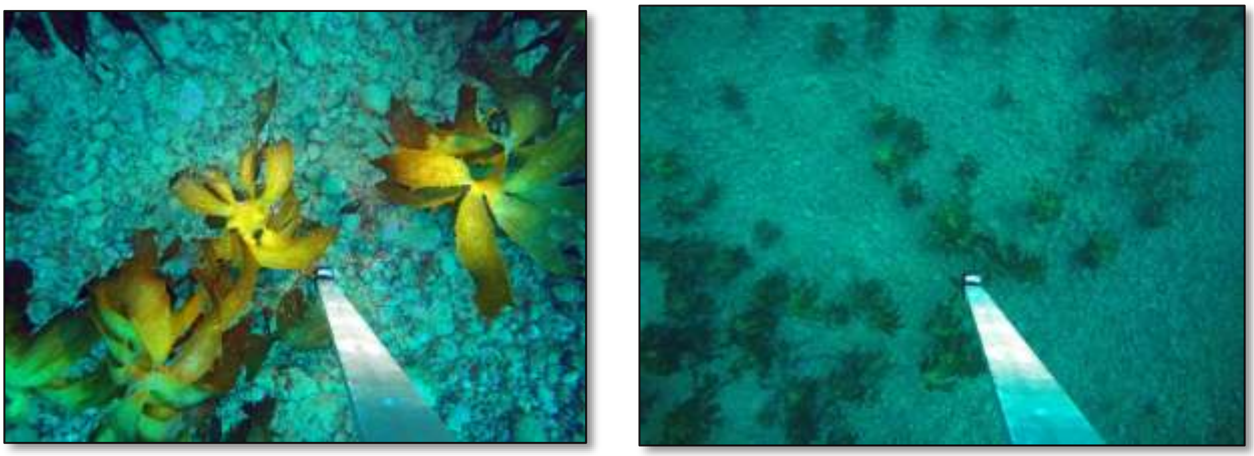

Figure 23 Two views of a coarse gravel/cobble sand mixed soft sediment habitat. This location is at about 28m depth and is offshore from the exposed southern coast. Here the *Ecklonia* forest is very thin and is reaching its lower depth limit.

Figure 24 (Right) a drop camera image showing a small patch reef area with a mixture of rock outcrops and coarse sand substrate. These patch reef areas are common in the Maitai Bay area on the edges of the solid reefs. (Left) an example of coarse sand and shell soft sediment substrate, a common soft sediment habitat in the Maitai Bay area.

5 Discussion

5.1 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. The classification could be expanded further to differentiate soft-bottom substrates and achieve greater definition of significant biological communities. The GIS-based approach allows updates to be made readily as new information becomes available. The map can be useful to many forms of marine protection planning, including resource management, fisheries research, the design of future scientific research and marine education generally. Importantly for the rāhui, we are now able to better see what the full restoration of the ecology of Maitai Bay could look like. The mapping system will be a useful tool in tracking the progress of the recovery of the shallow algal forests.

5.2 Habitat diversity and quality

The Maitai Bay area and Karikari Peninsula are well known for the diversity and quality of their marine environments. The diversity of the habitats within this relatively small area is remarkable. Subtle changes in wave exposure combine with the full range of reef types including cobble, broken rock, patch reef and solid reef slopes of widely varying topography. A unique feature of the bay's habitat complexity is the interaction between soft sediments and reefs. There is a lot of 'reef edge'. Every reef is close to a soft sediment area and every soft sediment area is close to a reef. All this adds up to create a unique suite of habitats all working together as a system. We are only beginning to unravel this story of how marine species use this special environment. We are aware that as the restoration of the algal forest within the rāhui proceeds, there will be many changes in species and their behaviours. At this early stage in the project a special feature that stands out is that the bay is an extremely busy nursery over the summer months for juvenile fish species and notably sub-tropical reef fish. Observations of this special nature of the bay have been recorded in our monitoring reports and may be a focus in future work that Te Whānau Moana/Te Rorohuri may consider. The ecological values found in the Maitai Bay area should be considered equal to the most unique and outstanding sites in Northland and throughout New Zealand. The exposed coastline offshore reefs and pinnacles and the semi-sheltered shallow habitats within Maitai Bay could be considered representative and very high-quality examples of these habitats in Northland.

5.3 Limitations of the study

In the shallow areas extending to 20m depth, mapping precision was determined by the resolution and geo-referencing accuracy of the LINZ base map and the Kerr and Grace 2005/2009 aerial photography, estimated at 3-5m or better. We attempted to draw significant biological boundaries at scales down to 1:700. At this scale, drawing errors typically would be well within the georeferencing error of 5m.

For the offshore areas, positional accuracy of the sonar tracks and drop camera locations and resultant mapping accuracy would be in less than 5m. 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. Some substrata interpretations can be confounded due to the mixing of gravels, cobble, and heavy shell. Some of these shell gravel or shell cobble mixes can give similar sonar returns to some to flat reef and patch reef. Our drop camera imagery assisted this interpretation greatly, although this was point data spread over wide areas. This limitation may have resulted in some erroneous interpretations between the coarse sand, gravel and patch reef. In the deep soft sediment areas, the spatial distribution of our sonar track lines varied, resulting in a variable reliability of the interpretation and as a result the habitat boundaries drawn. For example, there could be patches of deep reef that we simply missed. A finer definition of these offshore large soft sediment areas can be improved in future studies.

5.4 The kina barren threat

Our results culminating in the habitat map present compelling evidence of significant decline of algal forests due to kina barren expansion and persistence over decades. The shallow areas of Maitai Bay represent one of the worst cases of kina barren expansion studied so far in Northland, based on the proportion of the shallow reef affected (Kerr and Grace 2017).

The results are consistent with other studies completed in Northland over the last two decades. By any measure these results along with the obvious ecological significance of the shallow reefs should be a cause for concern. 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 showed that a 'regime shift' to kina barrens is typically extensive and irreversible in the face of continued fishing pressure and greatly reduces the overall resilience of the reefs to the impacts of climate change.

Since the 1960s, Maitai Bay and its beautiful shallow reefs have been much-loved by fishers and spear fishermen, at great cost to the marine communities and habitats of the bay. These past decades have coincided with the development of industrial fishing and an explosion of recreation fishing interest, access to powerful personal boats and advanced fishing gear. During this period, Te Whānau Moana/Te Rorohuri have been alienated from any role of management at the local level of their precious resources. All these factors working in unison have created a classic example of the 'Tragedy of the Commons'.

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. In the ocean all is connected.

5.5 A suggestion for a way forward

Directly contrasting with this story of decline is the story of recovery that has been documented at the marine reserve at Goat Island (Leleu et al., 2012) and in Tasmania (Ling et al., 2009). A similar result of kelp restoration resulting from 40 years of long-term full protection from fishing has been observed by the authors at Tāwharanui. In recent years, Tāwharanui was made a marine reserve. The irony of our present situation is that this is one disturbing environmental problem we can easily fix. The ocean is by nature extremely well equipped to 'heal' itself. We do not have to do anything other than eliminate or control ecologically unsound or harmful human disturbance. In this case, the harm is localised, prolonged over-fishing. Just as we would take steps with urgency to protect our native forests and streams, we can now turn to the ocean and create a new relationship.

The aim of the rāhui at Maitai is to allow the kaimoana that has fed the whānau for generations to recover so that Te Whānau Moana/Te Rorohuri's kāpata kai is refilled. The suggestion of a marine reserve in the area is simply a suggestion – and something that Te Whānau Moana/Te Rorohuri will take into consideration as they make decisions surrounding the rāhui.

Figure 25 Te Whānau Moana/Te Rorohuri rāhui committee members and the Pou the hapū erected at Maitai Bay as part of the process of laying down the rāhui. *(Top row standing from left, Kataraina Rhind, Ruby Anne Reihana, Mal Hekeua bottom row seated from left, Hazely Windelborn, Whetu Rutene.)*

6 Acknowledgements by Vince Kerr

There are many who have contributed to this project, the great relationship with Te Whānau Moana/Te Rorohuri, and the end result, a map of the habitats. There are the many marine ecologists who have dedicated themselves to the learning about our ocean in Northland and New Zealand. Drs Bill Ballantine and my former workmate Roger Grace reside at the top of the list. Sadly, they have now passed on but are with me always with this work. For twenty years they guided my education in this field of work that they largely invented. They would have been thrilled to finally see this work completed at Maitai Bay. Roger in fact took some of the aerial images we used in the mapping with his steady hand leaning out of a freezing small airplane with its door missing. My first scuba dive in Maitai Bay was of course also done with Roger at my side.

The Mountains to Sea Conservation Trust has as always been in constant support and added immensely to the project with their marine education work in the area helping bringing the local people to the bay and into the water. Foundation North and the Pacific Development and Conservation Trust have provided essential funding for our monitoring work. We applaud their vision in support of this work.

The inspiration, enthusiasm and commitment of the Te Whānau Moana/Te Rorohuri rāhui committee members continues to lead the way for this great project. Their vision is clear and although they are small in number and resources, their resilience and strength remains solid. It is the ultimate privilege for me to work on a project like this alongside them. We all owe a great debt to what these people are doing.

I love habitat mapping, I love doing marine ecology, but nothing beats a perfect morning simply looking out over Maitai Bay. V. Kerr 2020 (photo Diane Kerr)

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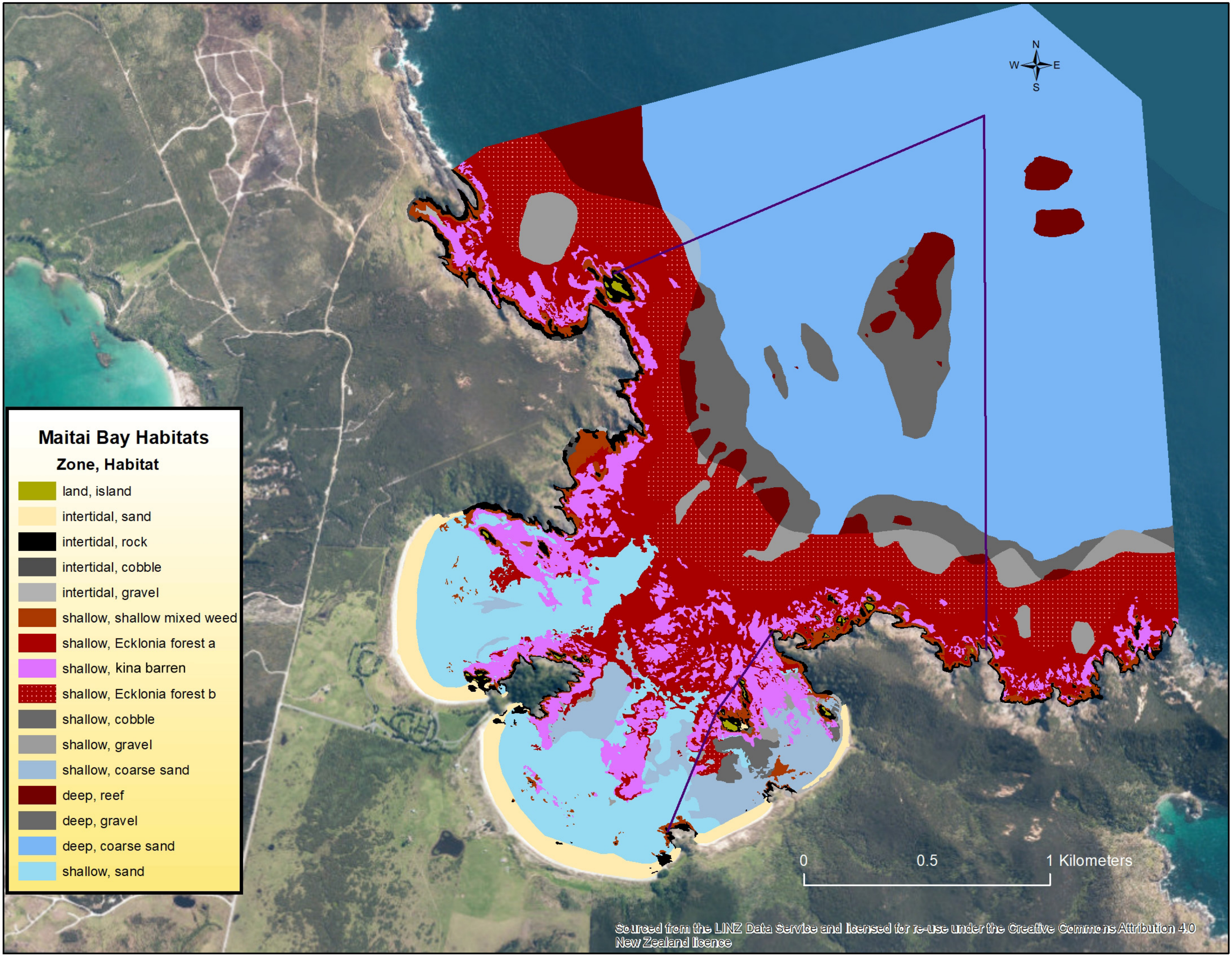
8 Appendix 1 Map book of Maitai Bay marine habitats



Maitai Bay Habitats
Zone, Habitat
land, island
intertidal, sand
intertidal, rock
intertidal, cobble
intertidal, gravel
shallow, shallow mixed weed
shallow, Ecklonia forest a
shallow, kina barren
shallow, Ecklonia forest b
shallow, cobble
shallow, gravel
shallow, coarse sand
deep, reef
deep, gravel
deep, coarse sand
shallow, sand
N
W
E
S
0
0.5
1 Kilometers
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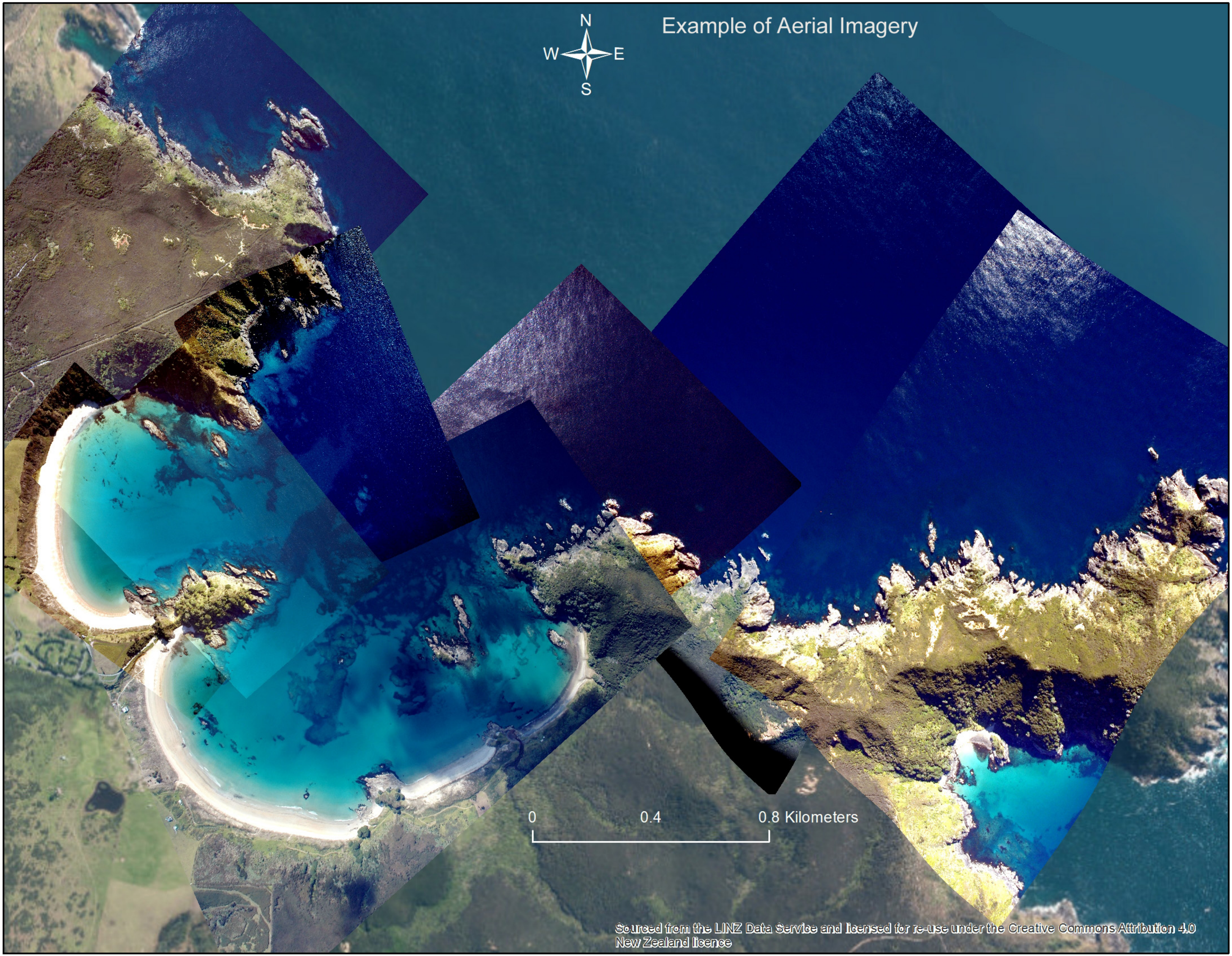
Example of Aerial Imagery
N
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0
0.4
0.8 Kilometers
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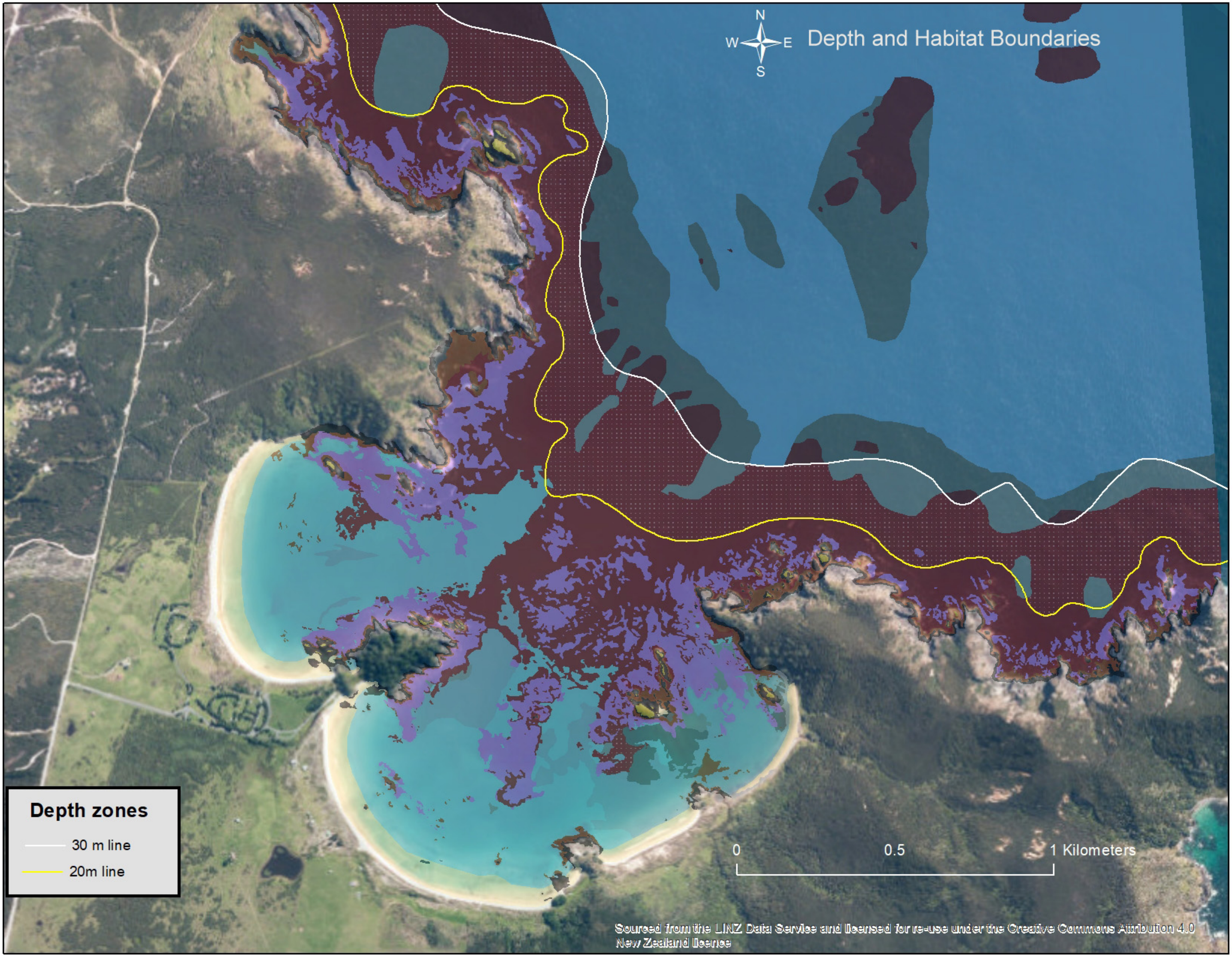
N
W
E
S
Depth and Habitat Boundaries
Depth zones
30 m line
20m line
0
0.5
1 Kilometers
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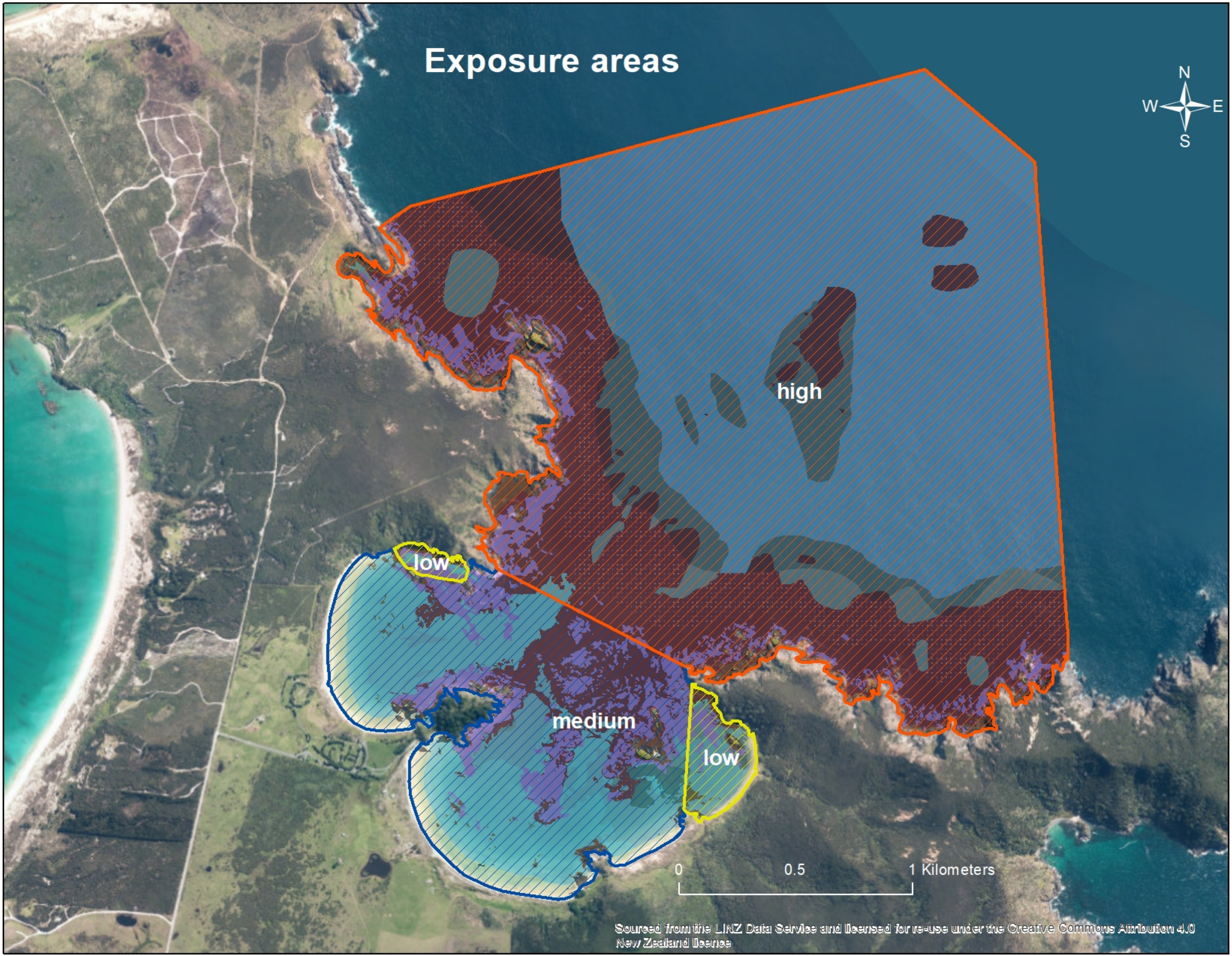

Exposure areas
N
W
E
S
high
low
medium
low
0
0.5
1 Kilometers
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