Subtidal and intertidal habitats of the North Coast of Waiheke Island, Hauraki Gulf

2013

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Client's Brief

- Source and review available bathymetric data, habitat data, aerial photos, and relevant Geographical Information System (GIS) information for the study area (the north coast of Waiheke Island including offshore areas out to approximately 3-4 km)
- Survey subtidal habitats using side scan and single beam sonar, video and still photography
- Reliable map of rocky reef at a scale of at least 1:5,000
- Provide a marine habitat GIS layer and source data for the area in GIS format
- Produce a report with summary, introduction, methods, habitat classification, maps, discussion and conclusions
- Discuss accuracy and validation issues and comment on biological assemblages in the area
- Provide georeferenced, single and side scan data and imagery, digital photos and video to describe representative habitats and species assemblages
- Provide recommendations for future research and education to inform planning for marine protected areas (MPAs) off the northern coast of Waiheke Island

Executive Summary

Marine habitats along the north coast of Waiheke Island, New Zealand were mapped using single and side scan sonar, underwater video and still photography. The study surveyed 60 km of coast from Matiatia to Hooks Bay and waters 4 km northwards to D'Urville and Horuhoru (Gannet) Rocks, a total area of over 130 km^2.

Data was analysed and stored in a Geographic Information System (GIS) with existing marine habitat data digitised from aerial photograph and bathymetric fair sheets by the Department of Conservation (DOC). This study significantly improved the spatial and descriptive definition of marine habitats mapped in previous surveys. Sampling focused most on broad physical categories for inshore areas and less on offshore areas. The spatial resolution of field surveys varied from an almost continuous coverage of side scan swath images within about 300m of the shoreline and islands, to single beam sonar lines at 1 km intervals in offshore areas.

Representative habitats and biological assemblages were then sampled using underwater video and still photography on SCUBA and by remote suspended camera. Species assemblages within some habitats were identified, however more detailed sampling will provide a more comprehensive assessment of biological diversity. Habitats mapped include:

- intertidal sand, gravel and boulder beaches and rocky shores mapped in previous DOC research but verified in this survey
- subtidal sand, mud, coarse sand, shelly gravel, gravel and cobble, and rocky reefs verified, corrected or mapped for the first time by this survey.

The report and maps should be used to promote community awareness of marine values, improve marine management, and establish marine reserves as the core of a restoration and marine spatial planning program for the Hauraki Gulf Marine Park. The data also provide a basis to help assess social, economic and cultural values. These include values for commercial and recreational activities and other less tangible spiritual and historic values.

The environmental complexity and diversity of habitats along the north coast of Waiheke suggests that the area is a good candidate site for marine protection. Like most marine ecosystems throughout New Zealand, the north coast of Waiheke is impacted by human activities. However, the presence of many key habitats, species and ecological processes indicate that area is resilient and will rapidly benefit from protection and better environmental management.

Status as a marine protected area will promote community and political awareness of the area's natural value and contribute substantially to community understanding of the benefits of conservation and the legacy we can provide to following generations.

This relatively safe, sheltered, and intact coastline provides good underwater visibility and habitat for school children, families and visitors to experience the underwater ecosystems of Waiheke Island. Community engagement, consultation and input will help determine the extent, location and nature of this protection and how it can be implemented effectively.

Introduction

Detailed marine habitat mapping in New Zealand began with subtidal maps of Mimiwhangata in Northland (Ballantine, Grace & Doak, 1973). Maps of marine habitats at Leigh (Ayling, 1981), the Mokohinau Islands (Creese, 1978), Paparahi (Grace 1981), Mimiwhangata (Kerr & Grace, 2005), Doubtless Bay (Grace & Kerr, 2005a), Tawharanui (Grace, unpublished), Taiharuru (Grace & Kerr, 2005a), Motukaroro (Kerr & Grace, 2006), and Northland's east coast (Kerr, 2010) refined and extended the use of these techniques. Technologies like multibeam and side scan sonar and underwater video have greatly increased our ability to undertake marine habitat mapping.

This project integrates new and existing data in a Geographic Information System (GIS) to map marine habitats off the north coast of Waiheke Island. The maps will help plan and implement marine reserves and other management in the area and provide an example for similar work at other locations. The habitat classification and methods aim to meet specifications in the Marine Protected Areas Classification, Protection Standard and Implementation Guidelines (MPA Guidelines) and other related government policy documents (Ministry of Fisheries & Department of Conservation, 2008).

An assumption is that physical habitat categories are useful and readily recognised surrogates for more complex spatial patterns in biodiversity, ecosystems, and ecological processes (reviewed by Costello, 2009). Biotic and physical parameters such as depth, substratum, and exposure are important drivers for ecological processes and species distributions (Connor et al., 2004; Kingsford & Battershill, 2003).

Physical parameters are often easier to map over large areas, are relatively stable in time, and can potentially include a wide range of lesser known species and processes. However, where biological data on species distributions and life processes are available, these provide more direct descriptions of patterns in biodiversity for the species concerned and also act as surrogates for other related species. This is important where relationships among categories of physical habitat and biodiversity are assumed rather than known and where biological interactions among species (e.g. dispersal, predation, competition, behaviour, symbiosis) determine species distributions and ecological processes. Ideally, broad-scale physical surrogates and available biological data can be combined using a range of spatial, statistical, and other modelling techniques (Breen 2007; Leathwick 2008).

The habitat maps here provide approximate descriptions of major, conspicuous patterns in marine biodiversity. Although basic, they are critical to our understanding of marine ecosystems and their protection throughout New Zealand. The maps also provide a foundation for more detailed ecological research and consideration of economic, social, cultural and spiritual values.

Methods

Location

The area mapped in this study extends along the northern shoreline of Waiheke Island from Matiatia Harbour in the west to Hooks Bay in the east and northwards to D'Urville Rocks and Horuhoru (Gannet) Rock (Figure 1). The survey was completed between the 1st and 7th April 2013.

Waiheke Island lies north east of central Auckland and is the largest of the Inner Hauraki Gulf Islands. The north coast of the island is relatively exposed to the north but sheltered by the mainland, Coromandel Peninsula, Great Barrier and other islands. The south coast of Waiheke Island lies adjacent to the Tamaki Strait, inshore islands, central and south eastern Auckland and several estuaries. The north coast differs from the south coast of the island being less turbid, with less sedimentation, greater underwater visibility and probably less pollution from sources on the mainland.

The island and surrounding waters are within the Hauraki Gulf Marine Park. The Marine Park includes many marine ecosystems, islands and catchment areas on land but provides little direct legislation to specifically protect ecosystems except through recommendations to agencies administering legislation for other resource management, fisheries, conservation and other issues.

Figure 1. Study area off the north coast of Waiheke Island, Hauraki Gulf, New Zealand.

Side scan and single beam sonar, video and photographic surveys

Field research for this investigation was carried out from a 4.2 m Mac boat powered by a 50 hp outboard with sonar transducers mounted on the transom either side of the boat's motor.

The side scan sonar used was a Humminbird 987-C SI. It has side scan and GPS capabilities as described below:

- side image coverage of 160 degrees @ -10 dB in 455 kHz with a maximum 200m swath at 30 m depth
- 2D single beam sonar to 780 m, 74 degrees @ -10dB at 50 kHz and 20 degrees @ -10 dB at 200 kHz
- 7" sunlight viewable colour display with 480V x 854H resolution TFT LCD screen
- dual frequency 50/200 kHz single beam sonar, side image sonar 262 kHz / 455kHz
- 750 watts RMS, 6,000 watts PtP (200 kHz) and 1,000 watts RMS, 8,000 watts PtP (50 kHz) Power Output, 63 m target separation
- dual microprocessors and four channel sonar transmitter/receiver
- full screen track-plotter, 3D track and split screen sonar/track with adjustable split
- accelerated Real Time Sonar™ operating at up to 40 times per second with signal displayed as sonar return intensity plotted against a vertical depth scale
- freeze frame to pauses the sonar scroll for detailed inspection

A Humminbird 947c 3D multi-beam and 2D single beam sonar was also used. The multi-beam unit was used primarily for rapid surveys and relied primarily on the single beam display. Colour images of substrate hardness were used to help interpret sediments and the plotter was used to set track lines. Specifications for the Humminbird 947c 3D were:

- GPS, track-plotter and general features as in the Humminbird 987c SI
- dual frequency 83/455 kHz in a 6 beam configuration
- depth capability in 3D to 75 m and in 2D to 330 m
- coverage of 74 degrees @ -10 dB in 83kHz & 53degrees @ -10 dB in 455 kHz
- 750 watts RMS, 6,000 watts PtP (200 kHz) and 1,000 watts RMS, 8,000 watts PtP (50 kHz) Power Output, 63 mm Target Separation
- accelerated Real Time Sonar™ operating at up to 40 times per second with signal displayed in window as sonar return intensity plotted against a vertical depth scale
- freeze frame pauses the sonar scroll for detailed inspection and selection of georeferenced targets

Surveys were conducted in three ways with different sampling intensities:

1. detailed inshore side scan tracks run at less than 7 knots along the shore line and around offshore reefs and islands
2. offshore side scan and single beam transects run at 12-20 knots along east-west axes at 1km intervals while recording apparent changes in habitat
3. representative suspended remote video and still photographs across a range of areas and acoustic categories and SCUBA dives at two locations

The first method recorded complete side scan swathes up to 100 m each side of the vessel with navigation and bathymetry data. A minimum of two side scan tracks were run along the entire shoreline and around offshore reefs between Matiatia and Hooks Bay. Where reefs extended further from shore, additional side scan tracks were recorded.

The second method ran east-west transects at speeds between 12 and 20 knots while an observer recorded waypoints and changes in bathymetry, hardness and side scan imagery. Screen snapshots at these locations were recorded to an SD memory card and apparent changes in substrata were later investigated using remote suspended video and photography. This method is well suited to covering large areas of uniform sediment which occur in many offshore areas. The method has been developed over a decade of similar work in Northland and is described and illustrated in more detail in Kerr (2010a).

Side scan imagery, bathymetry and navigation were processed using the software package SonarTRX from Leraand Engineering Inc. For this initial mapping exercise, the side scan imagery was processed at a relatively low resolution resulting in a pixel dimension of .476 m x .476 m. This was adequate for mapping shallow rocky reef at a scale of around 1:1,000.

The third method suspended a camera to just above the seabed to video and photograph habitats in order to ground truth and interpret the sonar data. A Go-Pro Hero 3 camera was suspended below the vessel on a line with a series of floats attached above and a weight suspended below the camera on a 1 m line. Adjusting these weights and floats allowed the operator to ‘feel’ when the camera was suspended approximately 1m above the seabed. The arrangement allowed the camera to rotate and greatly increase the viewing area. Bouncing the system along the bottom for short distances also increased the area photographed.

The sonar imagery was used to identify locations to video, photograph and ground truth:

- major physical habitat types
- inconsistencies between the side scan and single beam sonar surveys
- areas where potential habitat boundaries were still not surveyed
- reefs and depth zones where major boundaries might occur, and
- other areas identified from aerial photography

The camera drops were arranged across depth profiles in each reference area for the purpose of identifying depth-dependent zonation patterns of biological communities as defined by Kerr & Grace (2005). In two locations, we used snorkel and SCUBA dives with underwater cameras to collect more detailed information. On these dive, a Go-Pro camera and a Canon G-12 camera in an Ikelite underwater housing were used.

Habitat Mapping

Sonar imagery, underwater video and photography, sediment data, aerial photography (Auckland Regional Council, 2008 & 2010) and the previous DOC habitat map were integrated in the ArcGIS 10.0 Geographic Information System software package (ESRI 2010). Using the DOC marine habitat map as a base, intertidal habitat polygons were checked for accuracy against the aerial photography and corrected where necessary.

Mapping of shallow, inshore areas was typically done at 1:1,000-1,500 scale. For sediments beyond inshore areas, islands and reefs, snapshots of side scan and single beam images at perceived boundaries together with existing sediment data (Land Information New Zealand Navigation Charts, Bardsley et al. 2008) and video and photo drops were used to interpolate broad categories of sediment.

The habitat classification shown in Table 1 is based on the New Zealand Marine Habitat Classification proposed by the Ministry of Fisheries and Department of Conservation (2008a). However, for this project, coarse sand, coarse shelly sand, coarse sandy shelly gravel, and gravel habitats were combined into one category as sediments were mapped at relatively coarse scales between 1:10,000 and 1:20,000. The depth, exposure and biogenic habitat categories recommended in the NZ Marine Habitat Classification were not applied to the mapped data but can be added with further analysis and data collection.

Results

Habitat Maps

Figure 2 provides an example of side scan imagery and Figure 3 shows a screen snapshot for an isolated reef south of D'Urville Rock marked on the chart at an approximate depth of 5m. This example was processed at a medium resolution with a pixel dimension of .076 m x .076 m.

Habitat maps derived from existing data, side scan sonar, single beam sonar, video and underwater photography are displayed in Appendix 1. Map 1 provides an overview of habitats in the entire study area (in total over 130 km^2).

Table 2 summarises the area of each habitat. Offshore sediment habitats make up most of the study area, but shallow rocky reefs and intertidal habitats are also significant features. Rocky shorelines dominate the coastal intertidal zone, interspersed with relatively small areas of sand or gravel beaches.

Maps 2 and 3 are finer scale versions of the habitat map depicted in Map 1. These maps represent the western and the eastern ends of the island respectively. While these maps summarise the major habitats in the study area, the digital GIS and side scan data provide more detailed views of reef structure and habitat within these boundaries.

Map 4 outlines sampling locations for different methods. For each point there is a coloured symbol representing the interpretation of the habitat classification. Overlaying this coloured dot there is a method symbol that shows what method was employed at this data point: SCUBA diving photography, ground truthing photo, single beam sonar screen grab, or side scan sonar screen grab.

Map 5 shows the additional sediment data from marine charts (Land Information New Zealand) and the New Zealand Combined Oceans Sediments database (Bardsley et al. 2008).

Map 6 displays the processed side scan imagery and the coverage of this layer of information.

Map 7 shows the sampling waypoints as in Map 4 with the addition of waypoint numbers. This map is included to allow reference to imagery or data held in the survey archive.

Maps 8 and 9 show the waypoints labelled at a finer scale for east and west sections respectively. These are included to help identify waypoints in areas where the waypoint numbers are difficult to read on Map 4.

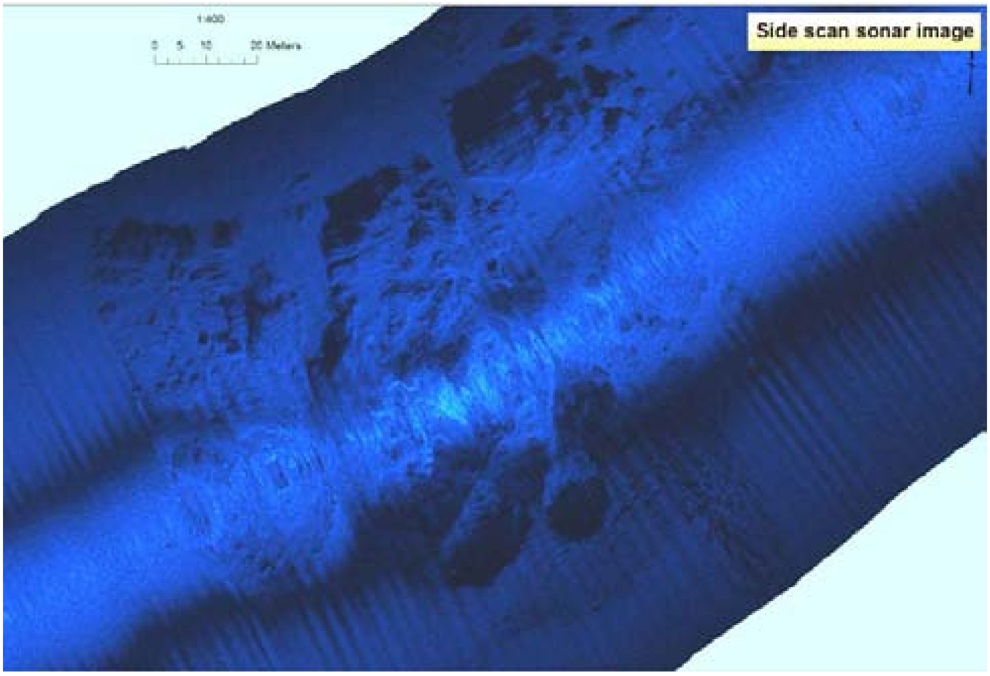

Figure 2. Example of side scan imagery processed at moderate resolution.

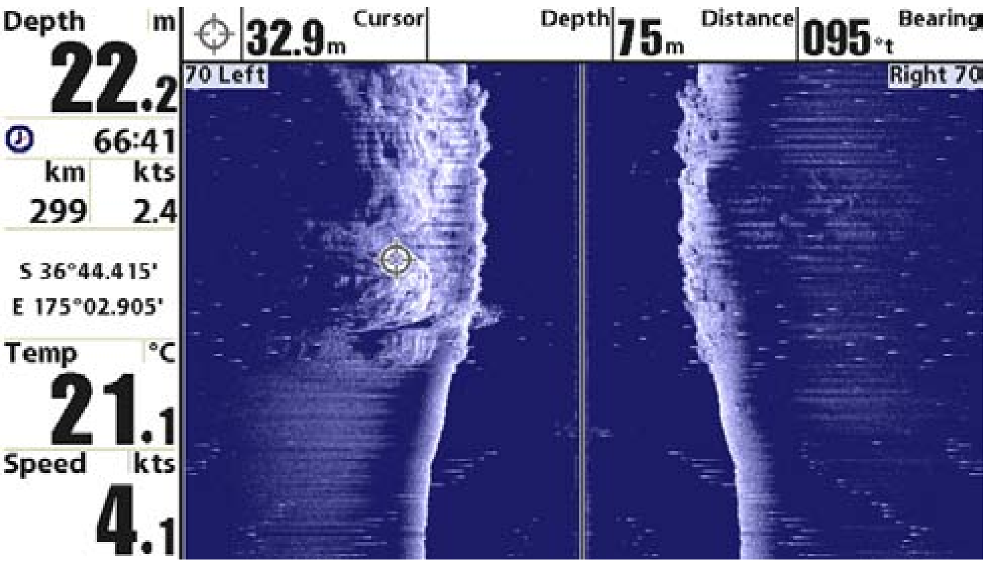

Figure 3. Example of side scan screen capture for the reef in Figure 2.

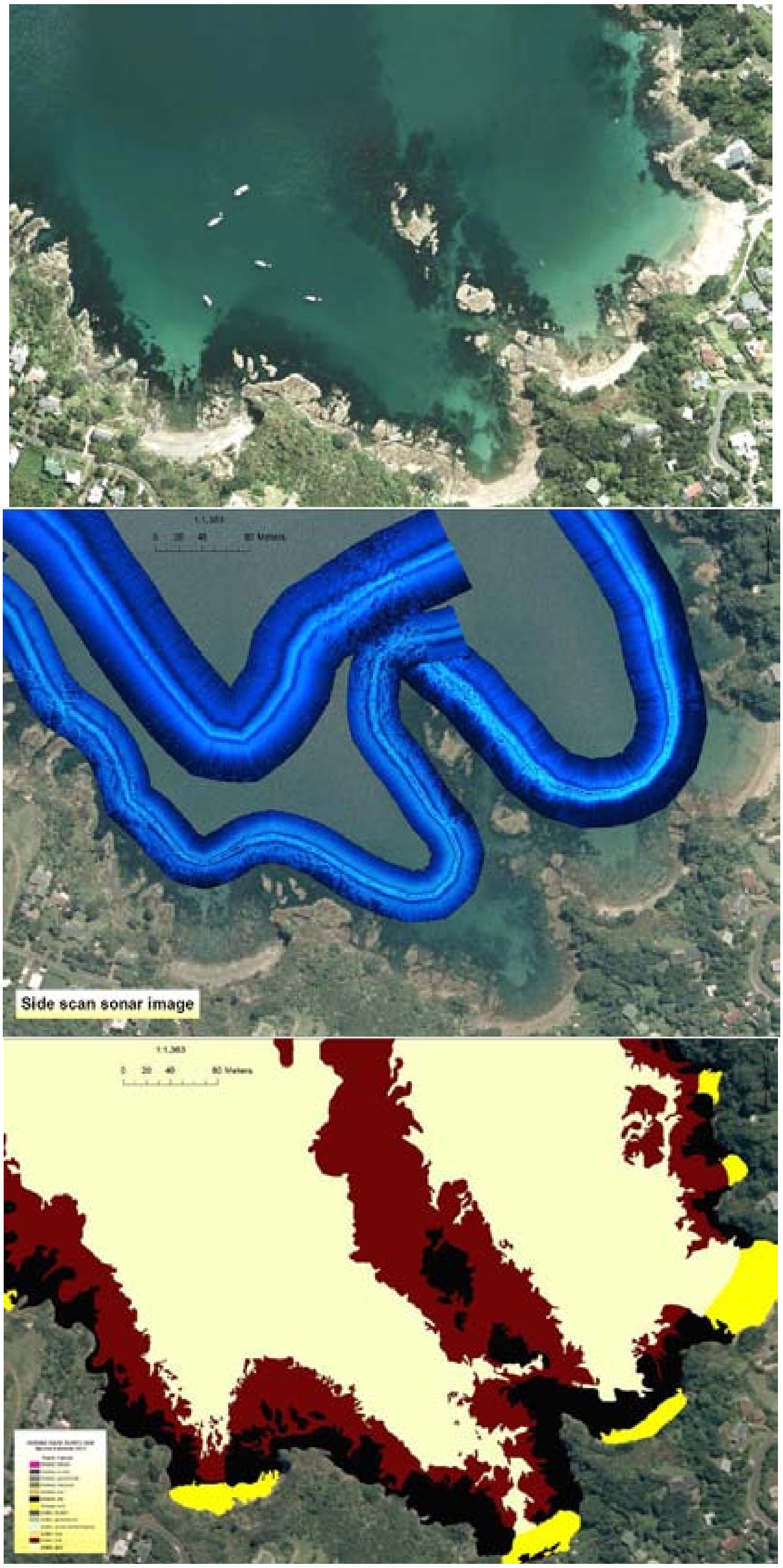

Figure 4. Aerial photograph (Auckland Council, top), side scan swath (centre) and GIS habitat map for Hekerua Bay.

Table 2. Area (hectares) of habitats mapped in the study area.

Habitat		Hectares
Intertidal	Boulder	3.47
Intertidal	Gravel/Cobble	12.70
Intertidal	Rock	100.61
Intertidal	Sand	47.01
Subtidal	Boulder	1.19
Subtidal	Coarse Sand/Shell/Gravel	4,966.04
Subtidal	Gravel/Cobble	4.16
Subtidal	Mud	7,506.25
Subtidal	Rock	275.65
Subtidal	Sand	929.73
Total Mapping Area		**13,846.81**

Habitat Descriptions

Intertidal sandy beaches

There are a number of sandy beaches on the north coast of Waiheke Island, including Oneroa, Palm, Onetangi and several smaller beaches along a predominantly rocky coast. Tuatua, *Paphies subtriangulata* and sand dollars were observed on Oneroa Beach during this survey and wash-ups of other invertebrates have been recorded from previous years.

Figure 7. Sandy beach habitat at Oneroa.

Intertidal gravel beaches

Many smaller beaches in the area consist of gravel and pebbles, or gravel with sandy areas at certain tidal levels particularly in coves within the rocky shores on the north coast of Waiheke Island. This habitat may be hostile to macro-invertebrates since movement of gravel and pebbles even in very light wave action causes mechanical damage to organisms living there. There are also a few boulder beaches, particularly on shores near Thumb Point.

Figure 8. Gravel and cobble beach.

Rocky shores

The rocky shores of Waiheke Island are derived mainly from greywacke sandstones and argillite formed in the Jurassic era. The shoreline is highly eroded by wind and waves exposing a complex mixture of rocky substrates resulting from the folding and shifting of the land. Areas of softer rock erode faster than the more durable types, leading to a very complex shoreline. Marine life on these rocky shores is rich and varied. The details of distribution and types of animals and plants present are controlled mainly by tidal level and the degree of exposure to wave action (Morton & Miller, 1973).

There is a considerable range of exposure to wave action along the highly indented coastline from Matiatia Bay to Hook Bay. The semi-exposed nature of this coast is complicated by the presence of numerous embayments separated by projecting headlands. There is a correspondingly wide range of patterns of marine life.

Examples of the more familiar forms of marine life are rock oysters on the most sheltered shores and surf barnacles on the more exposed rocky points and headlands. There are also examples of rocky shores where the major patterns of life are further modified by shade, sand scour, standing water in rock pools, and freshwater run-off. Small colonies of green lipped mussels *Perna canaliculus* occur on many of the rocky shores.

Figure 9. Rocky shores at Thompson’s Point, Waiheke Island.

Subtidal habitats

Fine sand and mud sediments

The soft sediments of north Waiheke vary across spatial scales. They range from clean fine sands close to shore to mixes of sand and mud further out and become predominantly muddy offshore at a distance beyond 2 km. Exceptions include areas to the west and east of the island where channel currents appear to have a major influence on the level of silt and mud that is deposited. In these areas the soft sediment is more typically coarse shelly sand or gravel. In places the sandy environments are strewn with small rocks and boulders add to the diversity of these habitats.

Coarse sandy shelly gravels

This habitat type is very common in the survey area and has significant importance for marine biodiversity. In general, the presence of this habitat suggests that the deposition rate of silt is relatively low compared to the large areas of mud habitat in the Hauraki Gulf. These habitats are usually correlated with areas of higher current. Waiheke Island has significant channel areas to the west and the east which coincide with the areas where we found large examples of this habitat.

The presence of these currents is significant biologically, as they carry many types of food for benthic invertebrates and pelagic fish species. These substrates also offer a range of possibilities for benthic organisms, from the very small invertebrates and bivalves that prefer sand substrates to the large gravels that can become encrusted with algal species or macro-invertebrates like sponges. All of this biodiversity attracts other marine organisms that either feed on or find shelter in these structurally diverse habitats.

Where these sediment habitats lie adjacent to reefs they form a valuable combination with many species crossing regularly to feed or shelter between the two environments. In the small sample of sites we photographed, we saw very good examples of dog cockle *Tucetona laticostata* and scallop beds *Pecten novae zealandiae*.

Figure 10. Example of coarse sandy shelly gravel habitat, five scallops are visible.

Figure 11. Coarse sandy shelly gravel and dog cockle bed

Gravel and cobbles (depth range 0-30 m)

Under normal conditions, a cobble bottom is fairly stable. In the Waiheke Island area, these cobble areas are often strewn with larger stones or boulders which make the habitat more diversified. The semi-stable nature of this habitat enables some types of faster-growing seaweeds (often red algae) to survive on the more stable rocks. This is, however, a precarious existence as even in the semi-sheltered Waiheke Island habitats there may be significant wave action caused by wind and storm swells, particularly in shallow areas. A wide range of invertebrates and fish life frequent these areas.

Rocky reefs

For this study we have combined the various shallow reef habitats into one classification representing the physical subtidal habitat 'rock'. While this forms a useful base to work from, it does little to describe the important biological communities that naturally occur within shallow rocky reef habitats. We did however make observations to document the zonation of these communities at several sites along the coast. What follows is description of the zonation and characteristics of these communities or species assemblages within shallow rocky reef habitats.

Communities and species assemblages within rocky reef habitats

Light, wave energy and depth are major influences on the biological communities that occupy shallow rocky reef habitats. When marine scientists first studied subtidal ecology of shallow reef environments with the use of SCUBA it was not long before consistent patterns emerged, demonstrating how these environmental factors control reef communities.

The Hauraki Gulf provides an especially good example. As you travel from the inner Gulf to the outer, there is a consistent gradient for both light penetration (related to water clarity) and wave exposure. This relationship is illustrated in Figure 12 below. Along a continuum of zones between the inner and outer Gulf, the reefs off the north coast of Waiheke Island sit roughly in a similar position to those of the Tiritiri Channel. Biological communities and benthic species assemblages within this zone are described below.

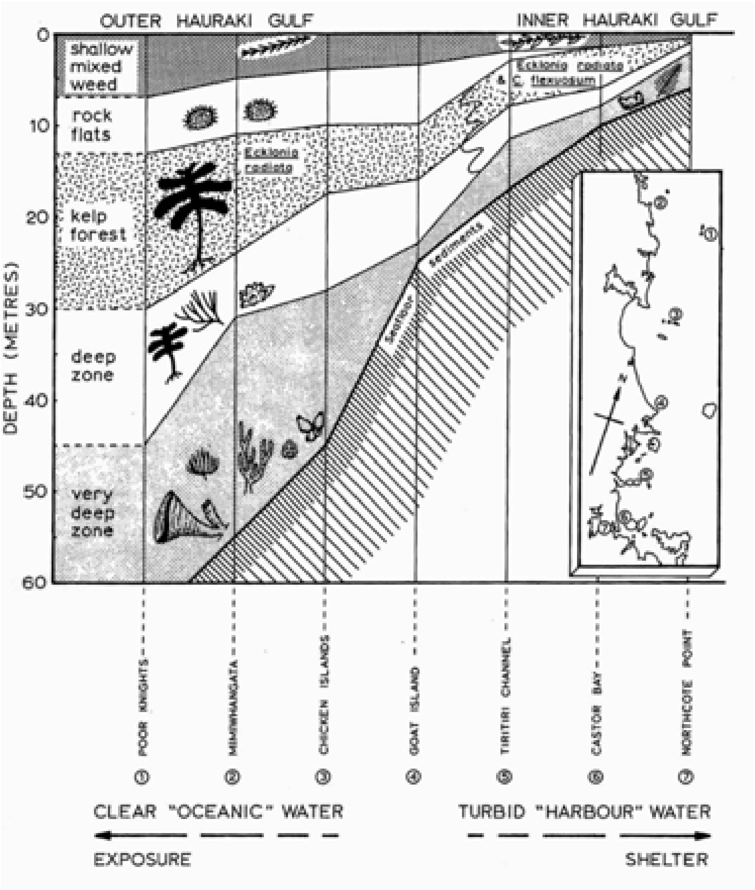

Figure 12. Zonation of rocky reefs in the Hauraki Gulf (from Grace, 1983)

Shallow mixed weed (depth range 0-5 m)

This habitat occurs on rocky reefs between low water to about 2-5 m depth. At more locally exposed sites this habitat extends deeper than in more sheltered sites, due to the difference in wave energy. Typically the rocky substrate is very broken and dissected, with tumbled boulders, ridges and crevices. Several species of large brown algae are visually dominant. The flapjack kelp *Carpophyllum maschalocarpum* is common as a thin layer at the top of the zone along with *Xiphophora chondrophylla*. Small plants of common kelp *Ecklonia radiata* occur occasionally through this zone, typically where wave energy is higher. Tangle weed kelp *Carpophyllum flexulosum* appears in a scattered distribution, usually below the thick band of *Carpophyllum maschalocarpum.* Other occasionally occurring kelp species are *Carpophyllum plumosum* and the red algae *Pterocladia lucida*. The sea-urchin or kina *Evechinus chloroticus* is common in this habitat, usually nestled in holes, crevices, and depressions. Here it often feeds on seaweed which has been torn off the rocks by heavy wave action. A wide variety of grazing molluscs also occurs in this habitat.

Figure 13. Shallow mixed weed

Urchin (kina) barrens (depth range 3-10 m)

This rocky habitat is characterised by a lack of large brown algae, the rock surface appearing bare and relatively barren. Upon close inspection, nearly the whole rock surface is covered in a thin film of mauve to pink coloured encrusting coralline seaweed (coralline 'paint'), and in some areas with coralline turfing algae. In a few areas, small plants of the brown seaweeds such as *Carpophyllum flexulosum* form patches within predominantly coralline covered rocks.

The most conspicuous animal in this habitat is the sea urchin or kina, which is often present at a density of 5-10 m^2 but may be much denser in places. It is grazing by urchins which maintain the habitat in its relatively barren state. Sea urchins scrape the rock surface, removing recently settled algae and encrusting animals before they have a chance to grow. Sea urchins may also graze directly on large attached algae. This is relatively uncommon but, when it does occur, can lead to an extension of the kina-grazed zone into formerly algal-covered areas. This zone is also home to a number of small grazing molluscs, such as limpets and chitons. The most spectacular grazing mollusc here is the large Cook's turban shell *Cookia sulcata*, a rough-surfaced gastropod 10 cm or more in diameter.

Urchin barrens were once thought to be part of the natural zonation of shallow rocky reefs. However, experience with long-term recovery of kelp forests in marine reserves has revealed that urchin barrens result from removal of its key predators, which are large crayfish and snapper, as a result of high and persistent fishing pressure (Babcock et al. 1999).

Figure 14. Urchin (kina) barrens

Tangle-weed forest (depth range 3-14 m)

The brown tangle weed kelp *Carpophyllum flexuosum* is the predominant algal species stretching down the reef below the shallow mixed weed zone, forming a continuous kelp forest. It has a rather upright unruly growth habit leading to its common name. Individual plants may reach a height of over 3 m, but are typically much smaller on the Waiheke Island coast. The canopy of the tangle weed forest greatly reduces the light intensity on the rock surface beneath, which provides more favourable conditions for small encrusting animals such as bryozoans, hydroids, sponges, and ascidians. The holdfasts of the tangle weed kelp provide a crevice-like habitat supporting a rich diversity of species. Where there is locally increased wave exposure and/or current, there is a mixing with *Ecklonia radiata*.

Tangle weed kelp forests are typical of semi-sheltered coastlines and are tolerant of a moderate level of silt deposition. The seaweed and the rock substrate of this semi-sheltered zone can be seen covered with a thin layer of fine silt, settled out from the water column, which may be relatively turbid at times. This detritus provides food for a range of specialized detritus and deposit feeders, such as the sea cucumber *Stichopus mollis,* found on the rocks and in crevices beneath the weed canopy.

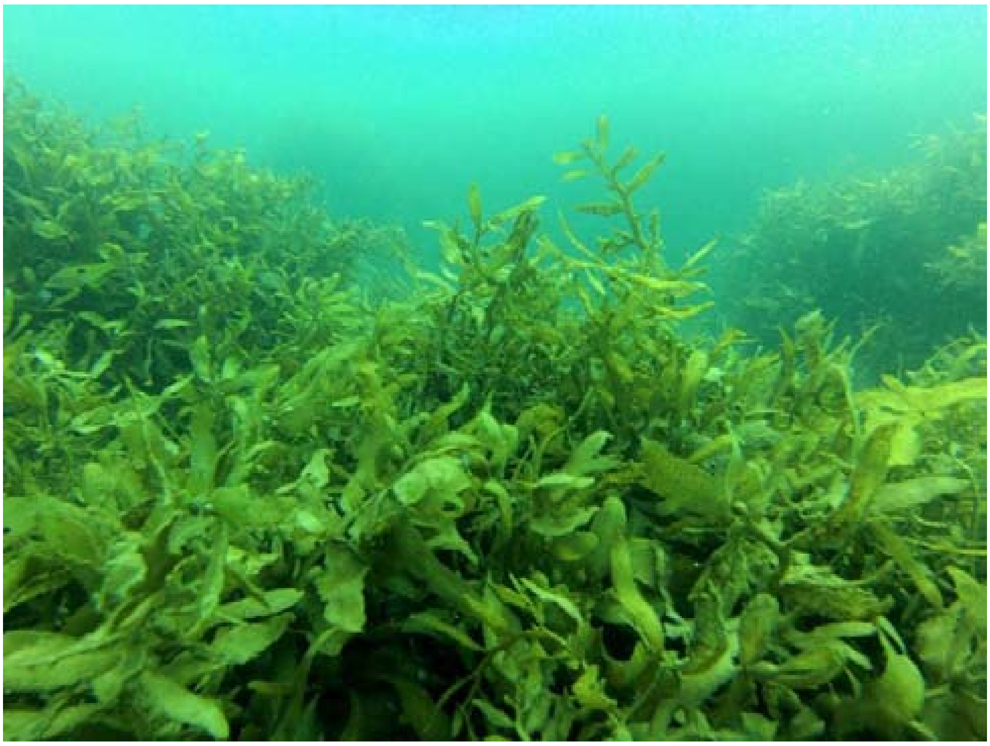

Figure 15. Tangle weed forest

Deep reef (depth greater than 14-20 m)

On the rocky bottom, at depths greater than about 14-20 m, there is insufficient light to support the large brown seaweeds found in shallower water. This depth marks the transition to a biological community based on filter-feeding invertebrates which we refer to as the deep reef. Typically, sponge species become the dominant life form on the deep reef. Representative sponges observed in the survey were the massive grey sponge *Ancorina alata,* a yellow branching sponge *Raspailia sp*., a massive yellow sponge *Polymastia granulosa,* and the orange golf ball sponge *Tethya aurantium*.

Determining distinct habitat or biotype lines at a certain depth contour is problematic because there is so much overlap in communities. However drawing the lines at an approximate depth contour is helpful to illustrate that there is a transition zone. In this survey all the reefs that we dived or dropped cameras on ran out to soft sediments at about 15 m maximum depth and were in transition from tangle weed kelp forest thinning out to a sponge-dominated deep reef community. The deep reef classification does not appear on our habitat map because most areas in the survey area deep enough to form a true deep reef habitat were classified as soft sediments.

Figure 16. Photo from Thompson's Point at 15m depth at transition from tangle weed forest to deep reef sponge garden habitat. Sponge is yellow finger sponge, *Raspailia sp.*

Discussion

Potential Uses of this Mapping Resource

This first version of the mapping resource should be viewed and used as a work in progress. The data layers and the interpretation approach adopted can be improved upon in the future. Ideally, the classification should be extended to further define physical soft bottom substrates and identify significant biological communities. An adaptive approach to the GIS database design has been adopted to allow updates to be made readily as new information becomes available.

The map can be useful to many forms of marine planning, including resource management, fisheries and aquaculture planning management, and the design of future scientific research. However, this project was specifically designed to assist the Waiheke Island community in designing marine protected areas. To that end this information fulfils the basic information requirements to relate any proposal to criteria suggested in the New Zealand Marine Protected Area Strategy. It is now possible to evaluate any proposal at the national, the Northeast Bioregion, or the Hauraki Gulf planning scale (Ministry of Fisheries & Department of Conservation, 2008).

It needs to be stressed that systematic MPA planning for the coastal zone is in its infancy in New Zealand, and the author suggests that careful attention be given to international best practice in terms of design guidelines. The authors has prepared practical guidelines for community groups (Kerr 2010a) which attempt to cover some of the important internationally accepted design criteria and principles that are not yet fully expressed in our 'official' government documents.

Important tasks in the MPA planning process can now be progressed. An analysis of habitat areas can be made. This information can be used to complete a gap analysis of current protection mechanisms locally and regionally. This can lead to goal setting and identification and prioritisation of recommended areas, leading eventually to the establishment of an effective network of MPAs, with a core of highly protected areas around Waiheke Island that contribute to the emerging regional and national networks.

Looking to the future, this habitat map and the related GIS and photographic resources, sonar imagery and field data can form the basis of a MPA design process which has the potential to effectively engage and inform the community and decision-makers in the considerable challenges that lie ahead.

Overseas experience demonstrates that the use of habitat maps and targeted information layers can greatly aid the broader MPA public participation process (Breen 2007, Fernandes et al. 2005, 2009; Kerrigan et al. 2010; Beck et al., 2009; Wahle et al., 2009; Bernstein et al., 2004). It enables the engagement of participants in a formative process that is objective, transparent, and can be portrayed in a readily understood visual format. Having the ability to assess cost and benefit analyses for alternative design options can help to facilitate solutions and compromises among diverse stakeholder interests. Sound information, and tools to communicate this information, does not replace well-run community participation processes and governance. However, they are clearly an important tool in helping to meet these challenges.

Limitations of the Study

There were some limitations to our methods which should be noted. The precision changed with depth, being greatest in shallow areas but decreasing as depth increased. This is at least partly due to efficiently targeting the significant biological boundaries that occur in shallow water.

In depths of less than 10 m the accuracy of the mapping was determined by the interpretation of aerial photography, which in most areas afforded resolution of detail down to 3-5 m. We were able to record nearly 100% side scan coverage to approximately 15 m in depth. As a result, for inshore physical habitats, we expect that the spatial accuracy of our habitat lines is well within 20 m. This estimate accounts for GPS error, interpretation of the sonar, and a small error generated by the sonar equipment and processing in the lateral dimensions of the sonar image (mainly due to running curved alongshore lines).

Precision for the large areas of sediment mapped by the rapid survey method can be expressed in terms of distance between the sonar tracks. This varied across the survey area from 0.5-1.6 km. There are, therefore, large areas where there is little or no information. However, other evidence from sediment charts (Bardsley et al. 2008) and fair sheet bathymetry suggests that these areas of sediment are continuous and rarely interrupted by isolated rocky reefs. More detailed surveys may confirm or update these areas with new information.

In general terms, our view is that our methods and ground truthing were adequate to support the interpretation required for this mapping exercise. However we encourage readers and researchers to access the maps and data archives and review or refine the maps with additional detail in the future.

Recommendations

1. The information and maps in this report should be used widely in the Waiheke Island community to promote an awareness of the value of marine habitats off the northern shores of Waiheke Island.
2. The report and maps should be used to promote discussion within the community of future directions and options for marine management, including establishment of marine reserves as the central core of any restoration and on-going management programme. Core marine reserves are likely to support all other local marine management initiatives.
3. Refinement of some of the habitats in this habitat map would be desirable and helpful. Higher resolution aerial photos and field surveys, would allow for detailed mapping of the important shallow reef biological communities and species assemblages.
4. These would allow greater discrimination of important areas for protection and management and would also enable analysis of changes over time and the effect of ecological and human processes. This information would be expected to show the restoration over time of kelp forest and associated biodiversity within the boundaries of an established marine reserve.
5. The opportunity exists to establish key sites where more detailed mapping could be completed based on the current map base and GIS data. This could be accompanied by a programme of regular monitoring of habitats and species, ideally involving members of the local community in an on-going programme.

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We thank Bill Ballantine and Wade Doak, along with co-author Roger Grace, who in 1973 at Mimiwhangata pioneered the methods, used in this study and showed us why marine habitat maps were useful. Without the foresight and effort of the Waiheke Island-based Friends of the Hauraki Gulf group, this study could not have happened. Their positive support throughout the project was highly appreciated. I wish them every success with their project. Dan Breen helped us with the field work, reviewed the report and provided advice throughout the project. Dan’s review of the report manuscript added substantial value to the end result and is much appreciated. The GIS component of this work was supported by the Mountains to Sea Conservation Trust, which is an ESRI Conservation Grant holder, and by Torre Leraand of Leraand Engineering Inc., Hawaii, who has provided the Sonar TRX processing software as a conservation support grant. Torre has also assisted with technical advice on the processing of the side scan imagery. Special thanks are due to Linda Simpson who accompanied us on one of our diving days and provided us with accommodation, meals and company for our stay on the island. Jessica and Arla Kerr ably assisted us in proof reading and editing this manuscript.

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Appendix 1. Maps of marine habitats, data locations, side scan images and waypoints.

Map 1 Marine habitats of Waiheke Island
Map 2 Marine habitats of Waiheke Island west section
Map 3 Marine habitats of Waiheke Island east section
Map 4 Methods and data points
Map 5 Existing sediment data
Map 6 Side scan sonar imagery
Map 7 Methods with labelled waypoints
Map 8 Waypoints labeled west section
Map 9 Waypoints labeled east section

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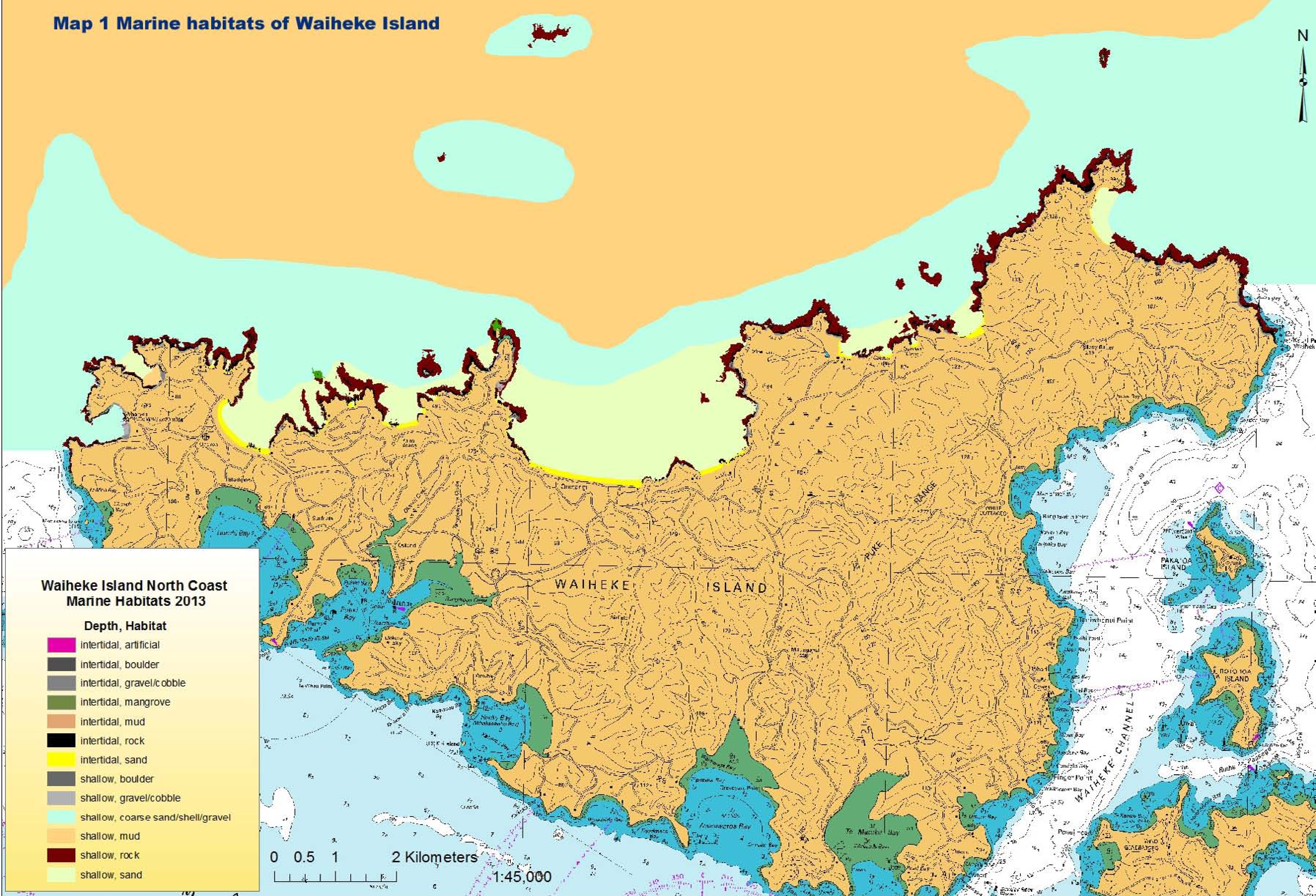
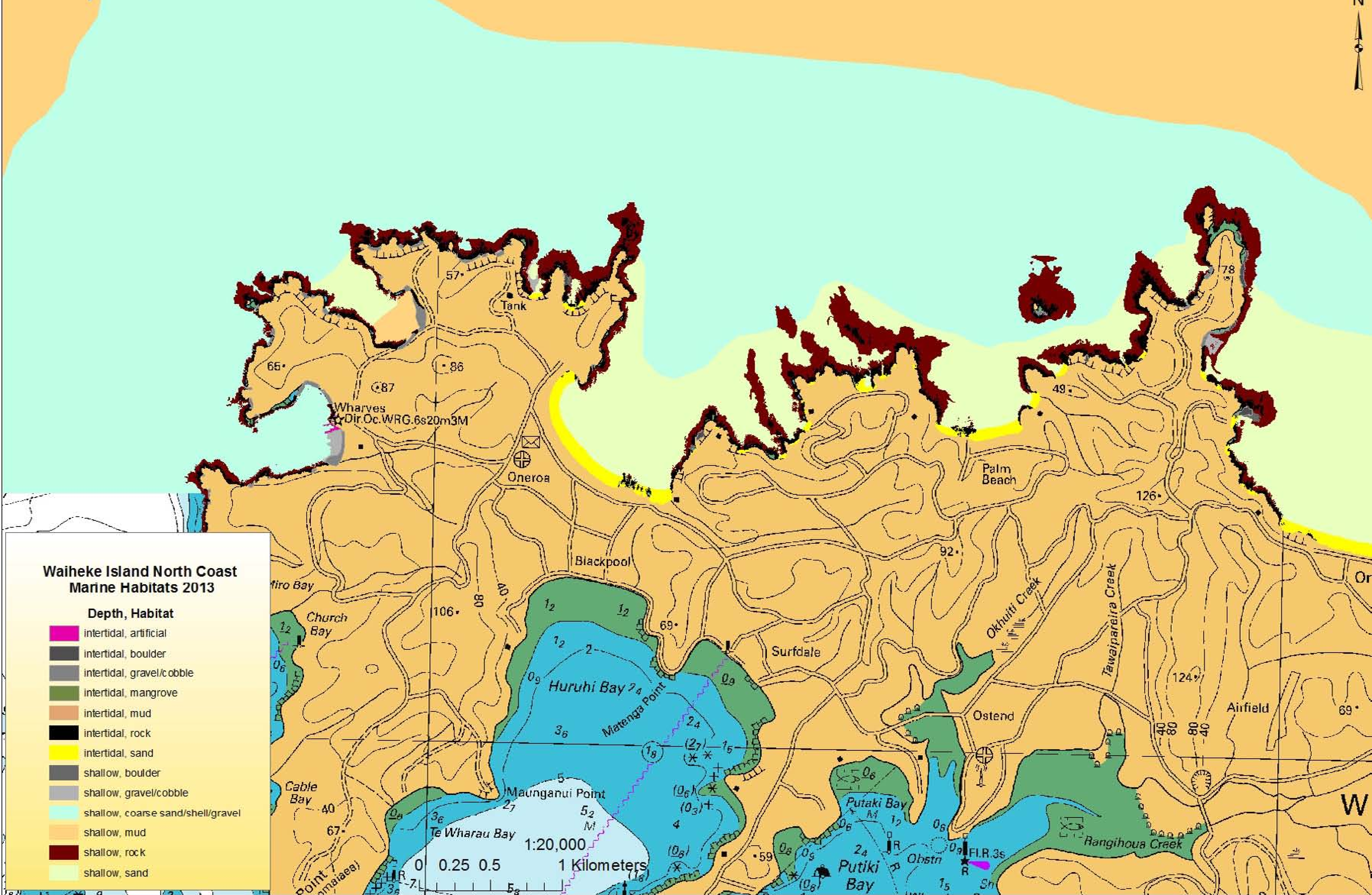
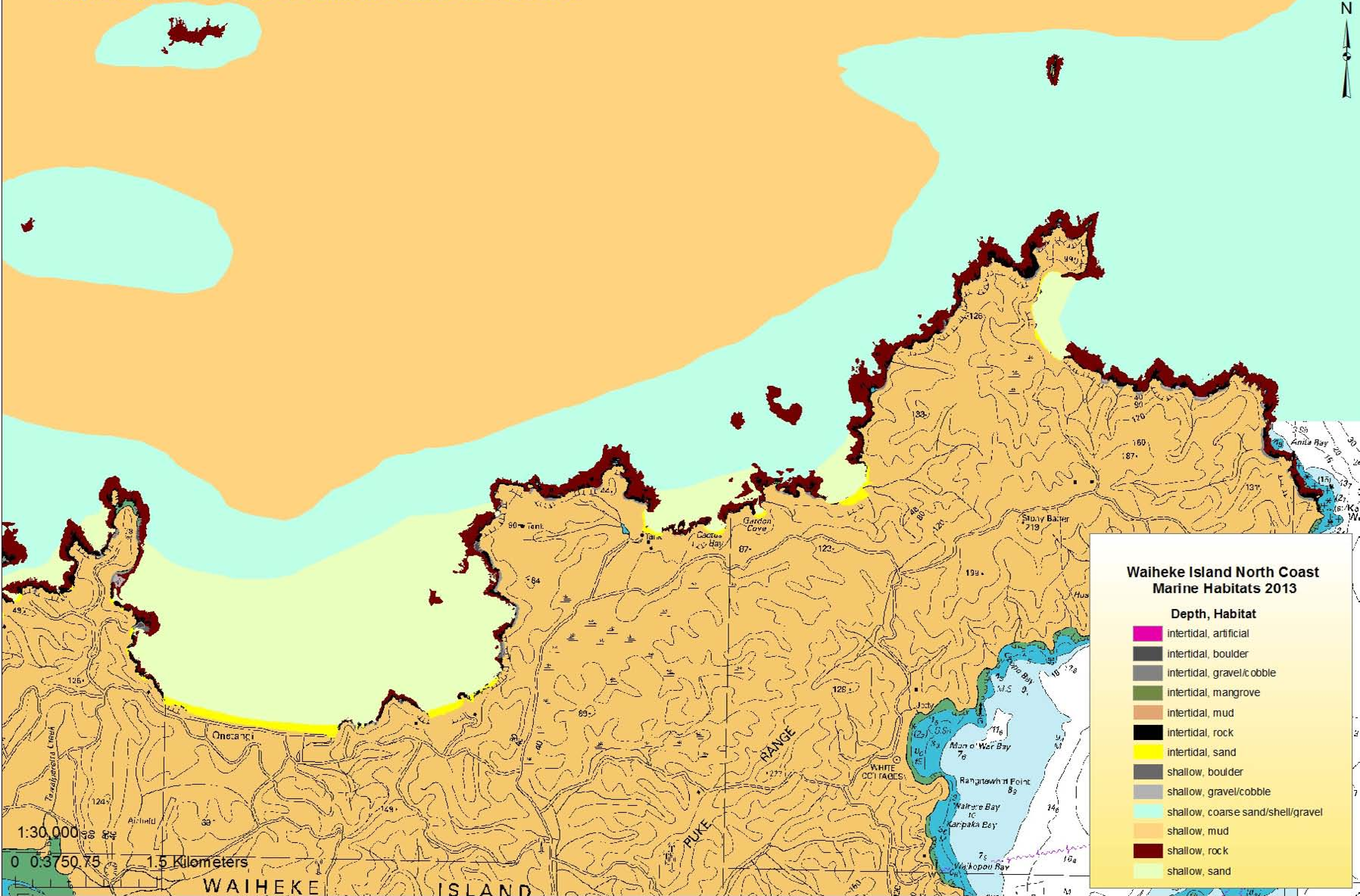
Map 1 Marine habitats of Waiheke Island

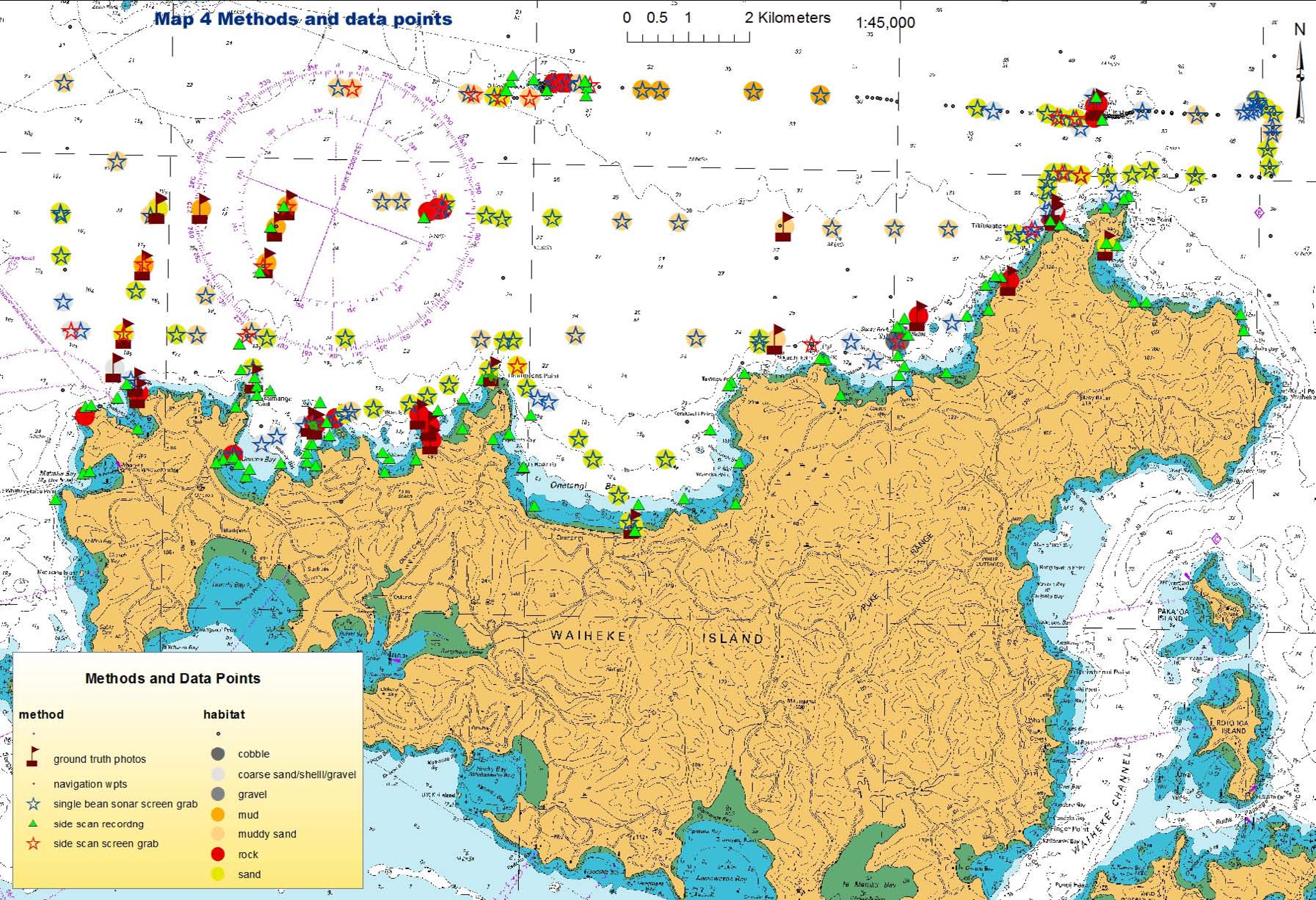


Map 2 Marine habitats of Waiheke Island west section

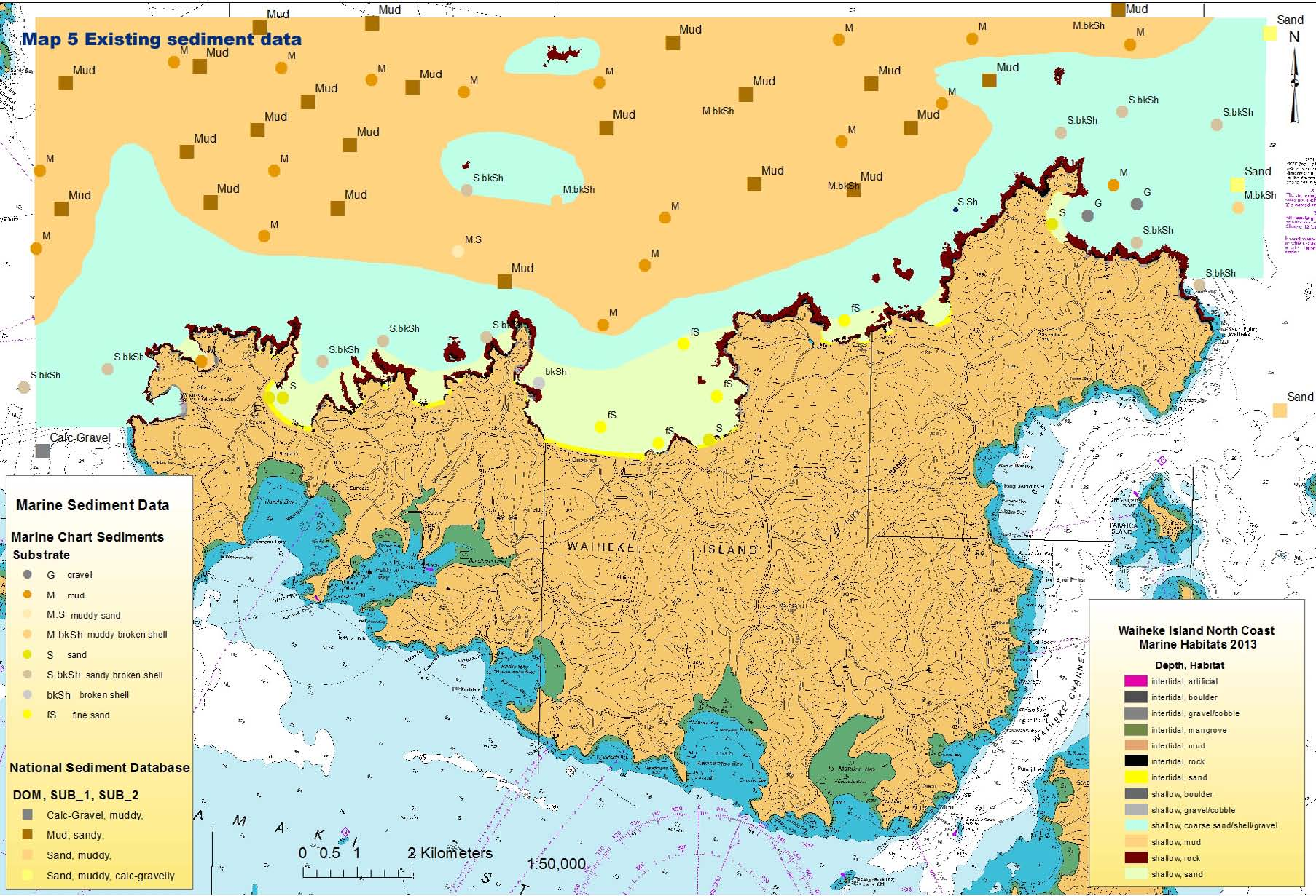


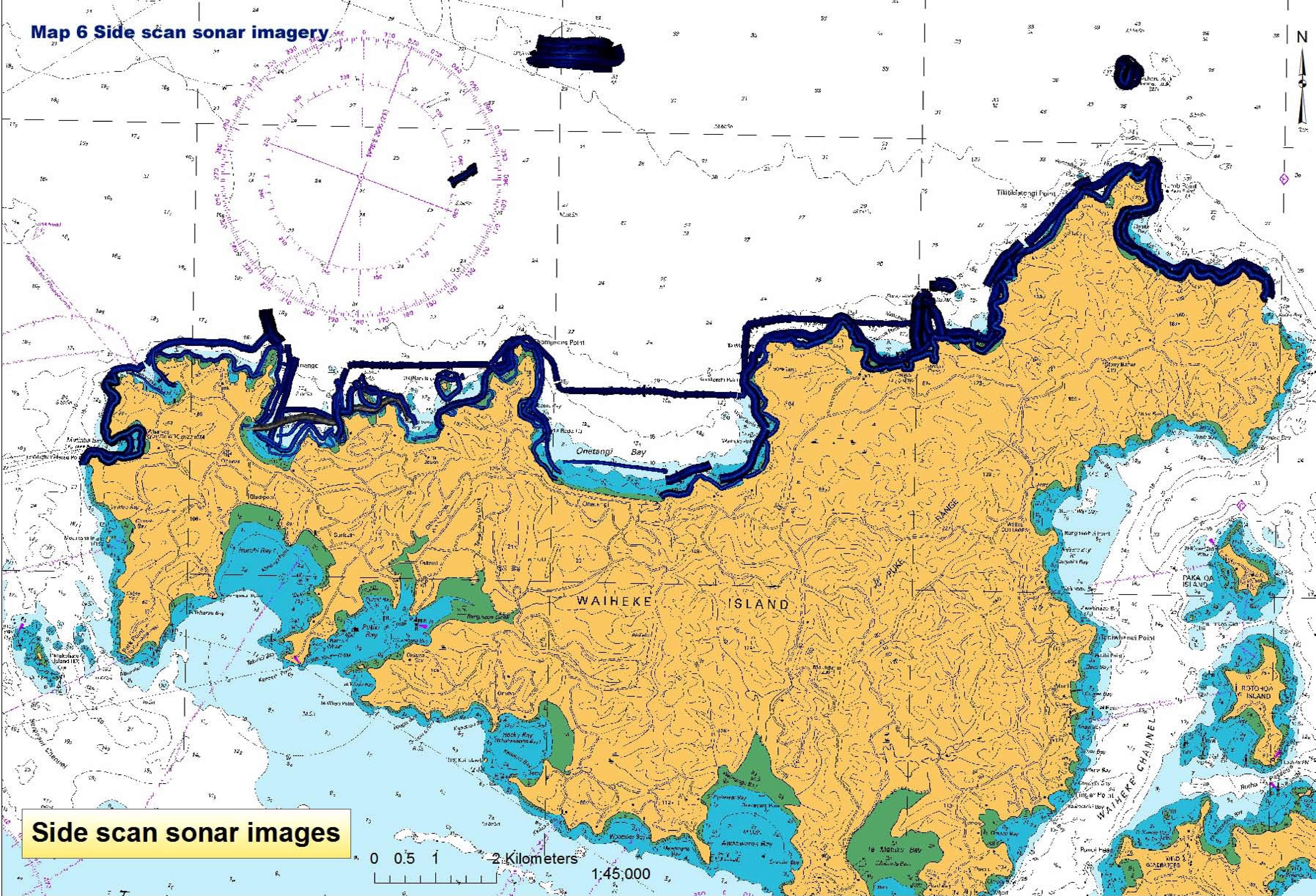
Map 3 Marine habitats of Waiheke Island east section



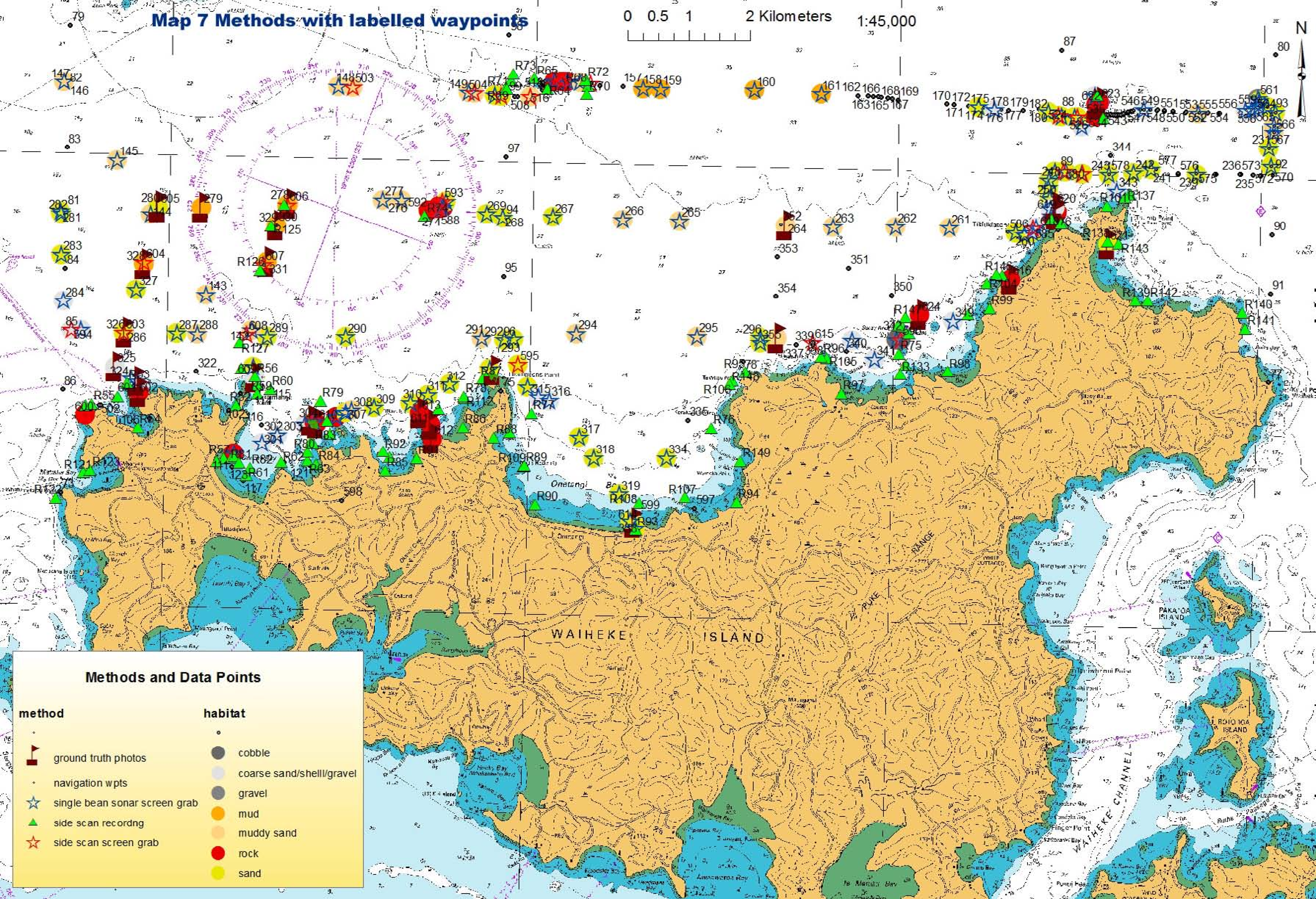


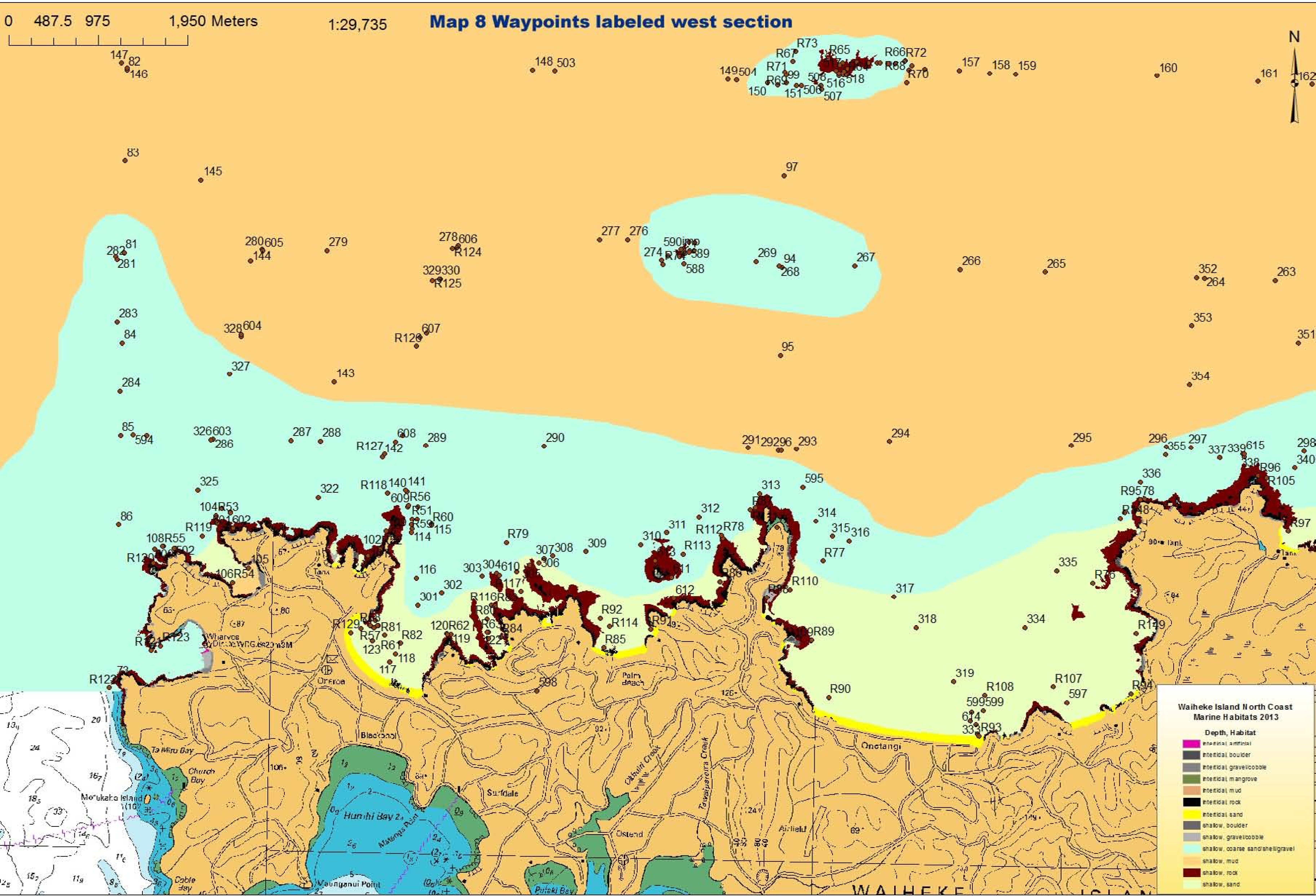
Map 4 Methods and data points
0 0.5 1 2 Kilometers
1:45,000
N
WAIHEKE ISLAND
Onetangi Bay
Methods and Data Points
method
ground truth photos
navigation wpts
single bean sonar screen grab
side scan recordng
side scan screen grab
habitat
cobble
coarse sand/shelll/gravel
gravel
mud
muddy sand
rock
sand


Map 5 Existing sediment data
N
WAIHEKE ISLAND
Calc-Gravel
Mud
M
Sand
M.bkSh
S.bkSh
M.S
S.Sh
G
S
fS
bkSh
PAKATOA ISLAND
WAIHEKE CHANNEL
0 0.5 1 2 Kilometers
1:50,000
Marine Sediment Data
Marine Chart Sediments
Substrate
G gravel
M mud
M.S muddy sand
M.bkSh muddy broken shell
S sand
S.bkSh sandy broken shell
bkSh broken shell
fS fine sand
National Sediment Database
DOM, SUB_1, SUB_2
Calc-Gravel, muddy,
Mud, sandy,
Sand, muddy,
Sand, muddy, calc-gravelly
Waiheke Island North Coast Marine Habitats 2013
Depth, Habitat
intertidal, artificial
intertidal, boulder
intertidal, gravel/cobble
intertidal, mangrove
intertidal, mud
intertidal, rock
intertidal, sand
shallow, boulder
shallow, gravel/cobble
shallow, coarse sand/shell/gravel
shallow, mud
shallow, rock
shallow, sand



Map 6 Side scan sonar imagery
N
Onetangi Bay
WAIHEKE
ISLAND
PUKE RANGE
WAIHEKE CHANNEL
PAKATOA ISLAND
ROTOROA ISLAND
Tikitikiatongi Point
Side scan sonar images
0 0.5 1 2 Kilometers
1:45,000


Map 7 Methods with labelled waypoints
0 0.5 1 2 Kilometers
1:45,000
N
WAIHEKE ISLAND
Onetangi
WAIHEKE CHANNEL
PAKATOA ISLAND
ROTOROA ISLAND
Methods and Data Points
method
ground truth photos
navigation wpts
single bean sonar screen grab
side scan recordng
side scan screen grab
habitat
cobble
coarse sand/shelll/gravel
gravel
mud
muddy sand
rock
sand



Map 8 Waypoints labeled west section
0 487.5 975 1,950 Meters
1:29,735
N
Waiheke Island North Coast
Marine Habitats 2013
Depth, Habitat
intertidal, artificial
intertidal, boulder
intertidal, gravel/cobble
intertidal, mangrove
intertidal, mud
intertidal, rock
intertidal, sand
shallow, boulder
shallow, gravel/cobble
shallow, coarse sand/shell/gravel
shallow, mud
shallow, rock
shallow, sand
Onetangi
Palm Beach
Surfdale
Oneroa
Blackpool
Church Bay
Owhanake
Cable Bay
Motukaha Island
Humbi Bay
Matiatia Point
Ostend
Airfield
Putiki Bay
Maunganui Point
Ta Miro Bay
Wharves
Oneroa
WAIHEKE

Map 9 Waypoints labeled east section