Progress report: Motukaroro Island baseline marine investigations, BUV fish monitoring, subtidal and intertidal habitat mapping
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Vince Kerr[1] and Roger Grace[2]

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[2]**Roger Grace**
C/- PDC
Leigh, Auck. 1241, NZ
Phone: 09 422 6127
Email: gracer@xtra.co.nz

[1]**Vince Kerr**
PO Box 4267
Kamo, Whangarei, NZ
Phone: 09 435 1518
Email: vincek@igrin.co.nz

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Client's Brief

- Review information sources relating to historic research on marine natural features and ecology of the Motukaroro study site.
- Source and review available bathymetric data and historic aerial photos for the study site.
- Produce a current set of aerial photos for the shallow areas of the study area as required for mapping in digital format and suitable for geo-referencing in ArcGis.
- Carry out on-water survey where required using geographically referenced sonar, drop video, and diving methods to augment sub-tidal habitat information not obtainable from aerial photography. Data must be sufficient to map rocky reef edge at a scale of 1:5,000.
- Produce GIS habitat and biotype maps in collaboration with Information Services, Northland Conservancy.
- Design and carry out a monitoring program utilizing standardized methodologies as much as possible incorporating UVC (Underwater visual count) and BUV (Baited underwater video) abundance surveys for crayfish and reef fish.
- Provide a report for the project which includes an executive summary, introduction, methodology, habitat classification, map sets, discussion and conclusions. The report must: discuss accuracy and validity issues associated with the investigation and output of habitat maps. The report will include methodologies, results and discussion of the baseline fish and crayfish abundance monitoring.

Executive Summary

Marine biological investigations of Whangarei harbour were reviewed, specifically around Motukaroro Island. Inter-tidal and sub-tidal habitat mapping investigation, and collection of baseline abundance data of fish and crayfish populations were selected for initial investigation focus to enable future study of changes to habitats and organisms arising from the introduction of marine reserve designation.

A habitat investigation and mapping of the Motukaroro area was successfully carried out. The survey was done using a combination of drop video, side-scan and single beam sonar techniques. Aerial photographs were used to map shallow (< 10 m depth) habitats. A map of physical and biological habitats was produced at 1:4,000 scale covering an area of approximately 75 ha.
Major habitats recognised and described were:

- Inter-tidal habitats, including sandy beaches, gravel and boulder beaches, and solid rock shores. Mixed sand and rock.
- Sub-tidal habitats, including large areas of sand, gravel and cobble, as well as hard rock bottom. The rock substrates were occupied by biological assemblages forming a mainly depth-related sequence from shallow to deeper water, including shallow mixed weed, kina barrens, *Ecklonia* kelp forest, and deep reefs. Some of the more sheltered shallow rock areas were occupied by tangle-kelp forest. Significant areas of mixed rock and sediment substrates occurred at various depths and are important ecologically to this area.

Sonar surveys, snorkelling and scuba diving techniques were used to design experimental layout for baited underwater video (BUV) and underwater visual census (UVC) reef fish and crayfish

monitoring. Difficulties were encountered in the design of the UVC survey due to the small scale of the reefs in this area, as well as the lack of comparable reference sites outside of the reserve area. With some modification we feel worthwhile UVC monitoring could be undertaken but due to these limitations should not be the priority monitoring method. Completion of the first UVC census is scheduled for next summer (2007). BUV monitoring was successfully established and the results are analysed and presented in this report. The differences between reserve and reference sites are minimal and reflect that both are currently full access fishing areas. Fish levels overall are relatively low compared to studies completed in other areas. The design of the BUV survey sites attempted to establish sufficient replication in the reserve area and fished reference sites to allow for statistical analysis of change over time as the reserve is established. The small, diverse and dynamic nature of the site raises some challenges for using the standard BUV methodology at Motukaroro, however some of the remaining uncertainties can be tested statistically and practically with modifications of the monitoring design as the monitoring proceeds in the coming years.

It is recommended that the report and maps should be widely used to promote awareness within the community of the marine values of Motukaroro, and to foster involvement in the establishment of the Whangarei Harbour marine reserve.

Introduction

Motukaroro Island is situated near the mouth of the Whangarei Harbour. An area of some 25 ha is to be established by gazettal as a marine reserve in 2006. The area is characterised by shallow rocky reef extending out to soft sediments of shell debris and sand and course sands. The island has a deep hole off the western end extending down to 30m depth. The reserve area is affected by strong outgoing tidal currents carrying at times high silt loads, and strong incoming tides bringing oceanic water and a regular supply of coastal marine organisms to the island and surrounding reefs. Eddy currents created by tidal currents around the island have resulted in unique conditions. As a result the island’s habitats and species assemblages have been described as both unique and highly diverse. The history of biological investigation at this site is briefly reviewed in the next section. Motukaroro Island and its immediate vicinity is also a candidate site for biosecurity monitoring based on its future marine reserve status, diverse habitats and its proximity to the Marsden Point industrial complex.

This study has begun work to establish biological baseline information which can be used in the future to test the effects of marine reserve establishment at this site. In this first phase of work we have completed an inter-tidal and sub-tidal habitat map of the site as well as an initial study of baited underwater video monitoring, (BUV). We have also done preliminary investigations and design for underwater visual census (UVC) monitoring for reef fish and crayfish.

It is a well established scientific norm to collect as much baseline information in a monitoring program before an impact or manipulation experiment or management regime is established (Kingsford & Battershill, 1998). In this case the change or manipulation is the establishment of a fully protected marine reserve. Once pre-manipulation baseline data has been collected, monitoring for change over time and comparison with the pre-treatment baseline data is possible. In this case we have chosen to do an inter-tidal and sub-tidal habitat map to facilitate understanding of the spatial arrangement of habitats in the area. Habitat mapping greatly assists species monitoring design and allows measurement of change in habitats over time. Habitat maps can be re-surveyed and drawn at a future date which allows for changes over time to be quantified. (Kerr & Grace, 2005). In addition to the habitat study work we have chosen snapper and crayfish as key indicator species to monitor for changes in abundance over time. Previous studies have established that these species which are subject to intense recreational and commercial fishing pressure serve as effective indicator species to measure changes in community composition over time as a result of establishment of fully protected marine reserve areas (Denny et al. 2004, Willis 2001). It has also been established that these two species play key ecosystem roles as top predators in the shallow rocky reef habitats and thus a trophic cascade of habitat change can take place in relation to changes in their population abundance over time (Babcock et al. 1999, Kerr & Grace 2005, Shears & Babcock 2002, Shears et al. 2006).

Review of previous work

Early habitat mapping investigations were completed for the lower harbour area by Bioresearchers (1976) and followed by Mason and Ritchie (1979). In the mid 1980's the Northland harbour board (1984a, 1984b, 1986) carried out studies of marine values at Motukaroro and at other similar sites around the harbour entrance areas. These studies provide some basic rocky reef zonation information, and preliminary species lists. Limited studies were also done of soft sediments and soft sediment species assemblies in areas near Motukaroro. More recently rocky reef algal zonation and fish species assemblies were investigated by Brook, (2001, 2002).

These historic studies were reviewed and species lists combined and compiled in the Kamo High School Whangarei Harbour Marine Reserve Application (2002). During the process of evaluation of the marine reserve application, the Department of Conservation contracted NIWA to review all past biological investigation work for the Harbour. This report (Morrison 2003) is valuable in that it brings historic and recently (2003) unpublished NIWA work together in one report. This body of work is reviewed and updated in a northland wide review document (Morrison 2005), produced by NIWA which is useful to allow some basis to compare information on Whangarei Harbour to the rest of Northland.

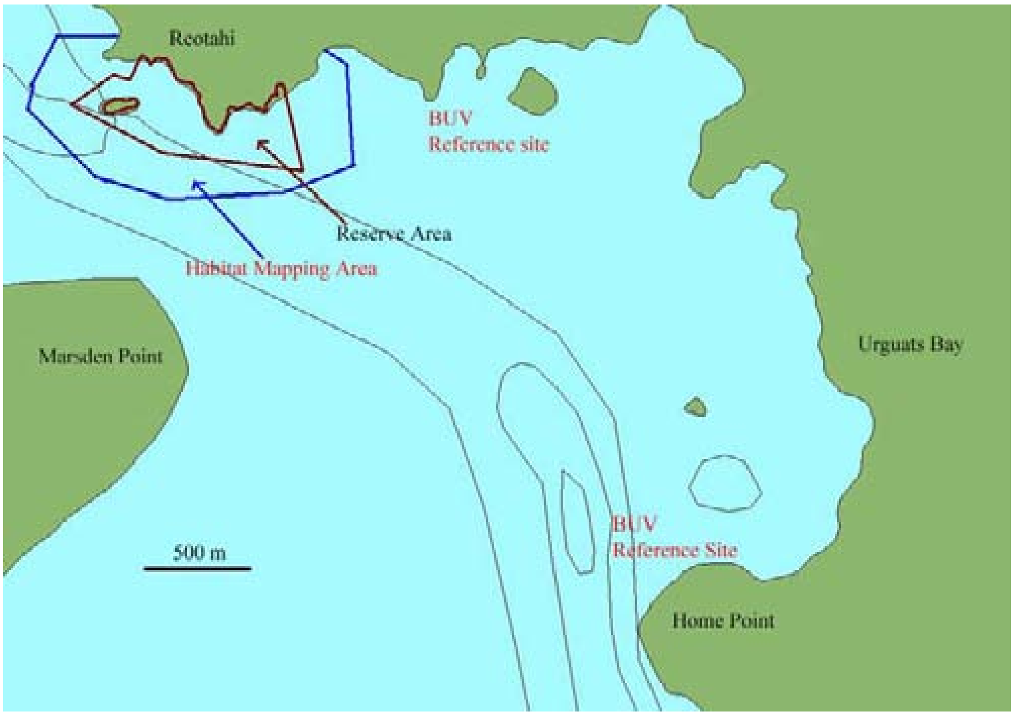

Figure 1. Motukaroro, Whangarei Harbour, showing the study area.

Methods

Habitat Classification and Mapping

The habitat classification used in this study is based on work by Ballantine et al. (1973), Ayling (1978), Ayling et al. (1981) and Grace (1981; 1983). The method adopted in this study closely follows the classification and methodology adopted in the Kerr and Grace Mimiwhangata habitat mapping report (2005). The authors completed further habitat mapping of Doubtless Bay (Grace & Kerr, 2006). The habitat descriptions generally use a combination of physical substrate characteristics and groupings of habitat-forming macro-algae. Qualitative habitat descriptors were used to enable rapid mapping of the study area using a combination of sonar and video methods, rapid sediment sampling, diving, and aerial photography.

Table 1 compares historic habitat classifications, ranging from the earliest work of Ballantine et al. (1973) at Mimiwhangata to a very recent classification (Shears et al. 2004), and includes the classification adopted for this study.

The Shears et al. (2004) study examined the degree of concordance between qualitative habitat descriptors and quantitative species data from various locations along the northeast coast. They concluded that qualitative habitat descriptors for rocky reefs do accurately define biologically distinct species assemblages and are therefore an efficient means of mapping subtidal rocky reef habitats. It is worth noting that Shears et al. (2004) describe five additional habitats on the shallow reef not used in this study: mixed algae, red foliose algae, turfing algae, *Caulerpa* mats and encrusting invertebrates. At Motukaroro, these habitats do not occur at spatial scales which can be mapped with the methods chosen for this study. Turfing algae would make up some of the habitat classified as ‘kina barrens’ in this study. The two algal types can not be distinguished from each other in aerial photos, which were used as the primary basis for mapping shallow areas.

Some of the historic classifications did not deal with inter-tidal or sediment-bottom habitats.

Table 1. Habitat classifications

Motukaroro (this report)	**Mimiwhangata** Kerr and Grace 2005	**Northeast NZ** Shears et al. 2004	**Hauraki Gulf** Grace 1983	**Paparahi** Grace 1981	**Leigh** Ayling 1978	**Mimiwhangata** Ballantine et al. 1973
Inter-tidal Habitats						
Sandy beaches	Sandy beach	Not considered	Not considered	Sandy beaches	No equivalent	Light-coloured sand beaches
Gravel beaches	Gravel beach	Not considered	Not considered	Gravel beaches	No equivalent	Dark-coloured sand beaches
Rocky shores	Rocky shore	Not considered	Not considered	Rocky shores	No equivalent	Solid rock shores
Mixed rock and sediments	Not present	Not considered	Not considered	Not present	Not present	Not present
Sub-tidal Habitats						
Sand or mud	Sand/mud	Not considered	Not considered	Sand (sand/mud)	Sand & gravel (in part)	Clean sand
Gravel or cobbles	Gravel/cobble	Not considered	Not considered	Gravel (gravel/cobbles)	Sand & gravel (in part)	Coarse gravelly sand, gravel
Gravel or cobbles	Gravel/cobble	Cobbles	Not considered	Cobbles	Cobbles (in part)	Coarse gravelly sand, gravel, cobbles
Shallow mixed weed	Shallow mixed weed	Shallow *Carpophyllum*	Shallow mixed weed	Shallow mixed weed	Shallow broken rock	Shallow exposed zone
Urchin (kina) barrens	Kina barrens	Urchin barrens	Rock flats	Rock flats	Rock flats	Medium-depth without kelp
Tangle-weed forest	Tangle-weed (kelp) forest	*Carpophyllum flexuosum* forest	Kelp forest (in part)	*Carpophyllum flexuosum* forest	Not present	Shallow sheltered zone
Ecklonia forest	*Ecklonia* forest	*Ecklonia* forest	Kelp forest (in part)	*Ecklonia* forest	*Ecklonia* forest	Medium-depth kelp bed
Deep reef	Deep reef	Not considered	Very deep reef	Not present	Sponge garden (in part)	Very deep reef
Mixed sand and rock	Deep reef mixed sand and rock (part)	Not considered	No equivalent	No equivalent	No equivalent	No equivalent

The habitat investigation surveyed the northern shore of the Whangarei harbour out to approximately the middle of the channel between Reotahi and Marsden Point and included approximately 2 kms of shoreline. The work was completed in stages between February and May 2006. Aerial photography was used to map habitats in shallow waters (< 12 m depth). In deeper waters sonar methods were used. In both cases video techniques and diving were used to ground-truth the resulting habitat classification. In association with the sonar surveys the soft bottom areas were investigated at randomly chosen sites with a simple rapid sediment sampler. A detailed description of the various methods and equipment used follows.

Survey vessel

All work in this investigation was carried out from a 4.2 m Mac boat powered with a 50 hp outboard. The sonar equipment described below is mounted in the boat and transducers for both machines are mounted on the bottom edge of the transom either side of the motor.

Side-scan sonar

The side-scan unit used was a Humminbird 987-C SI. The unit has side-scan GIS capability as described in the following specification:

- Side Image Coverage area (max 200 m swath 0-30 m depth) of the bottom, 160 degrees @-10 dB in 455 kHz.
- 2D conventional sonar depth capability 780 m,74 degrees @ -10 dB in 50 kHz & 20 degrees @ -10 dB in 200 kHz.
- 7" sunlight viewable colour display with 480V x 854H resolution TFT LCD screen technology (allows easy screen capture w/ digital camera, i.e. no flicker).
- Dual frequency 50/200 kHz sonar conventional 2D 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 triple channel sonar transmitter/receiver.
- Full screen track-plotter, 3D track and split screen sonar/track with adjustable split.
- Programmable view presets access important screens with one touch.
- Plug & Play Compatibility and PC Connection.
- Accelerated Real Time Sonar™ operates at up to 40 times per second to instantly capture the action under the boat. Signal displayed in window as actual sonar return intensity plotted against a vertical depth scale.
- Freeze Frame pauses the sonar scroll for detailed inspection of the screen.
- Totally automatic operation or totally manual operation with upper and lower range control.
- One-touch Zoom with 2 x, 4 x, 6 x, and 8 x zoom levels.
- Adjustable chart speed.

Multibeam 3D sonar

A second sonar unit utilised for the project was a Humminbird 947c 3D unit. This machine has a multi-beam arrangement and produces a 3D swath image on its screen. It also has conventional 2D sonar images and the Humminbird ‘real time sonar’ window display. This second system was used as a check on the interpretation of the side-scan unit and was especially helpful in the interpretation of soft sediments. It was a further advantage to have the track-plotter capability on this second machine so that the side-scan unit was totally free for side-scan imaging.

- Same GPS, track-plotter and general features as the Humminbird 987c SI unit described above.
- Dual frequency 83/455 kHz arranged in a 6 beam configuration.
- Depth capability 3D 75 m, 2D 330 m.
- Area of coverage 74 degrees @ -10 dB in 83 kHz & 53 degrees @ -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™ operates at up to 40 times per second to instantly capture the action under the boat. Signal displayed in window as actual sonar return intensity plotted against a vertical depth scale.
- Freeze Frame pauses the sonar scroll for detailed inspection and selection of georeferenced target points via cursor control.

GPS and Georeferencing data collection

For all point and track information in the study a Garmin 12 GPS unit was used. The position accuracy of this unit given by the manufacturer is 15 m. Our own checks of the unit by returning to known points indicated an accuracy of 5-7 m. At the end of each day data was downloaded into a PC laptop into Fugawi 3.4 software for processing to Excel spreadsheets. The track-plotter function in the Humminbird 947c unit was used for basic navigation and the setting up of target points for sonar and video drop positions.

Rapid Sediment Sampler

As a quick field check on interpretation of soft sediment characteristics from the sonar image, a sediment sampling system was devised based on a method used on old sailing ships. In the old days depths were sounded using a lead weight and measured line. A sample of the bottom material was collected during soundings by smearing tallow on the bottom of the lead sounding weight, a small sample of the sediment sticking to the tallow when the weight hit the bottom. We copied the technique by using a lead weight smeared with margarine, dropping the weight to the bottom and retrieving it quickly using a casting rod and reel. This minimised sampling time but enabled retrieval of sufficient sedimentary material to characterise the substrate type. Example photographs of the sampler and sediment samples collected can be seen in (Grace & Kerr 2005).

Drop video equipment

The video drop apparatus was a Sony TRV6e mini DV camera mounted in a simple, robust housing built from a recycled scuba cylinder and Plexiglas sheet material. The housing was arranged with a bottom weight attached to a one metre line attached to the bottom edge of the housing. Another line was attached to the top edge of the housing extending upwards to a series of floats starting at one metre above the housing (Fig. 3). By adjusting the attachment points of the weights and floats we were able to arrive at an arrangement that allowed us to 'feel' when the unit hit the bottom. We would then let out 3-5 m of slack in the line. The unit would then hang vertically from the floats with the camera approximately one metre above the bottom. We found that the arrangement would naturally rotate the housing in a circle or semi-circle, effectively panning the camera and greatly increasing the viewing area. We also devised a method of bouncing the unit along the bottom for short distances which also increased the area photographed. The housing unit had no external camera controls. The camera was simply turned on, set on automatic focus and exposure, placed in the housing and deployed. A remote on/off device was used to place the camera on standby while on the surface between drops. Using this system drops could be made with a minimum of time and effort, allowing many drops during a field work session. At each drop site, time, GPS position and depth were recorded. Depth measurements were tide corrected in post analysis and added to other bathymetry information for the final mapping interpretative work.

Side-scan sonar, drop video survey method

Following initial analysis of bathymetry and aerial photos, areas of potential reef were marked on a work map. A system of parallel survey lines was then planned, the lines extending beyond the potential reef areas to try to ensure reef edges were detected and to pick up any outlying patch reefs nearby. The lines were approximately 50m apart in the initial survey. The survey lines were as much as possible oriented in north-south and east-west directions to aid interpretation/georeferencing of sonar images. By necessity the survey was adjusted in the field to suit the underwater topography, with most effort being focused in complex areas.

At each point along the survey track, where the substrate/habitat classification was judged to have changed, the coordinates of the point were recorded. Depth measurements were not manually recorded with each waypoint record but are available if needed in post analysis as they are constantly recorded on to the side scan images which are saved as still-grabs or on video record. The boat's travel track was recorded for all survey lines. The lines and 'change points' are illustrated in the 'Sonar data points, tracks and video drop points map' (see map section). The data for all survey points is included in Appendix 4. This subjective classification interpretation was informed by diving experience in some of the areas, and by previous experience and testing with the sonar equipment. Where rock structures were visible, representative areas were classified by measuring the sonar 'shadows' cast by the vertical structure. This gives a relatively accurate calibration of vertical features. (Fish and Carr 1990). Classification of the side-scan image and sonar imagery was ground-truthed with drop video, scuba and snorkel dives, and rapid sediment sampling technique during the course of the investigation to ensure the interpretation of the sonar images was accurate. As a further check in the system, side-scan screen still images and video of areas of particular interest were captured in digital formats and archived on DVD backup disks as MPEG2 video and jpg format still photos. The screen image has a window for latitude and longitude coordinates and the video has a lineal time-code so that any point on the survey run can be located and checked or further analysed. The video archive also has a sound track which records the waypoint calls that are made during the survey and any other verbal comment. The classification used for the initial sonar survey was as follows:

1. high relief rocky reef with vertical structures > 3m
2. low relief rock reef
3. mixed reef and soft sediments
4. gravel/cobble
5. sand/mud

Following the initial survey work, results were brought into an ArcView GIS system and mapped. The initial survey yields an approximate reef edge. Analyses of the initial survey maps indicated further sonar survey lines to be run as required to fill gaps in the interpretation and resolve outstanding issues. In this survey we designed the sonar runs at 50m wide spacings. As a result we had no gaps in the image coverage and in complex areas we did additional runs which increased image overlaps aiding accurate interpretations. Given the small spatial area and extent of side scan coverage we expect that the interpretation of the underwater features in the areas of greater than 10m depths would be similar to the precision of the GPS location equipment, (approximately 5-10m), plus an additional factor of approximately 10m for interpretation error making a possible maximum total error of approximately 20m. In shallow areas where fine resolution was possible from the aerial photos, precision came down to less than 10m and is governed by the georeferencing accuracy of the aerial photos which we estimate is between 5 and 10m.

From the mapped sonar survey information a drop video survey was designed. The video survey target points were selected to identify and /or ground truth sonar interpretations of:

1. all the major physical habitat types
2. inconsistent interpretations between the side-scan and single beam sonar surveys
3. areas where it was likely habitat boundaries were still not covered
4. reef areas and depth zones where major biological boundaries were likely to occur
5. areas to ground-truth the analysis of aerial photography

This survey served the function of checking the sonar interpretation in replicate areas.

Secondly, video drops were arranged across depth profiles in each reference area for the purpose of identifying depth dependent zonation patterns of biological communities. At some locations, in order to gather more detailed information than the video drop produces, we used snorkel swims and scuba dives. The data for the video drops are included in Appendix 4.

Aerial Photography

Available aerial photographs were assembled and reviewed. Previous photo series taken for Motukaroro held by the Northland Regional Council (NRC) and the Department of Conservation were not sufficiently useful for mapping sub-tidal structures and habitats. On May 19, 2006 conditions were adequate for aerial photography and a new set of photographs were taken according to the specifications described below. The photos were georeferenced with the use of the NRC 2003 aerial photos and Image Analyst and ArcView GIS software, (Northland Conservancy GIS team).

Aerial Photography Planning Details

Hardware, camera settings, and other technical details were as follows:

Camera:	Nikon D70 digital SLR
Lens:	17-70 mm zoom lens
Focus:	Fixed on infinity
Sensitivity:	Digital ISO equivalent 200
Shutter priority:	1/250 second
File type(s):	Fine resolution jpeg at 6MB file size
Download time:	3 seconds per image
CF card size:	1 GB
Images per card:	About 150

Plane:	Piper with camera port in floor
Height:	3,000 ft (& some were flown at 1,500 ft)
Speed:	120 mph
Picture length:	170 - 340 m on ground, parallel to flight path
Picture width:	250 - 490 m on ground, across flight path
Picture centres:	500 m intervals on the ground
Picture overlap:	20-50m across photo (variable)
Flight plan:	Flight east from Onerahi, starting just east of Parua Bay follow coast making several passes over the Reotahi and Urquats Bay area. Return flight to Onerahi.

Bathymetry Data Correction to Chart Data

Bathymetry lines for the survey area were captured in the GIS software from the *Land Information NZ Approaches to Marsden Point Chart.* Depth interval contour lines indicating chart datum, 3m, 5m, 10m,15m, 20m, 25m and 30m were used in the mapping exercise to identify location of biological zones in relation to depth. We plotted the drop video points and depths after correcting for tide difference and added them to the chart based bathymetry information. In this study we didn’t find it necessary to extract the side scan sonar based depth information to carry out the habitat mapping process.

Side Scan Still Image Analysis

In order to refine the accuracy of reef margin location and to do more detailed checks on the sonar interpretation we took a series of overlapping still image grabs of the sonar screen image during the sonar survey. We timed the taking of the still images so that the images would overlap. Using *Photoshop* software on a PC the images were spliced together on a lineal distance scale or track. Each photo had an accurate point at the top of the image which is the boat's location at the time the screen image was taken. This position location appears on the screen image. Using this technique we were able to generate a lineal track of sonar image. This technique was useful in mapping reef edges and detail of structures and was used in conjunction with the drop video, diving and georeferenced aerial photo resources for the mapping process.

Habitat Mapping

Sonar, video and all ground-truthing information were brought together in a series of GIS layers. Georeferenced (May 2006) aerial photographs were adjusted for light/dark balance and contrast in a graphics programme to provide maximum visibility of underwater structures. The photos were then added as a further layer in a GIS system. A series of work maps were created from all the line and point data, which was overlaid on the aerial photo layer. In the shallow areas (less than 10m depth), aerial photographs allowed resolution of detail to + or - 5m. In areas deeper than 10m the distance between the sonar images combined with the video points determined the accuracy of the sonar-derived habitat polygons. In this survey nearly all sonar image tracks were overlapping, so the accuracy of interpretation of detail is similar to the GPS accuracy of +or -10m. Another potential component of error is in the side scan interpretation of the changes of substrate. The challenge here is the interpretation, where often there is a mixed transition between substrates which necessitates a subjective decision. In areas where this is a problem we review the side scan imagery in post processing to further test the initial interpretation. For the purposes of this survey this aspect of the work introduces a further potential error of up to 10m which represents a substrate or habitat transition zone. Thus adding the two error components we estimate that our accuracy in waters deeper than 10m does not exceed 20m. A third error component was also investigated in this survey which was the spatial accuracy of the side scan image itself. In preparing the screen shots of the side scan for this study we were able to check the accuracy of the lineal (direction of boat travel) dimension of the image by georeferencing the sequences of images assembled in *Photoshop* software. Once these images were georeferenced as a GIS layer we were able to see the degree of error in the lineal dimension of each image. This error was very small or negligible and well below the 10m accuracy of the GPS location equipment. Using this same procedure we were also able to check the accuracy of the horizontal dimension (perpendicular to the boat). For this survey we had a number of side scan image sequences that were taken along the shoreline where we could see various detail in the GIS aerial photo layer which we could compare to the same detail on the side scan image. We also had the actual track of boat as a GIS layer which fixed the boat position and centre of the side scan image. We found in these checks that the horizontal dimension accuracy was well within the 10m accuracy of the location equipment, supporting our assessment of the 20m overall precision estimate for the habitat polygons in the waters over 10m depth. Our sonar equipment does not come with an image accuracy rating. Therefore while our work is an indication of accuracy of the images derived, it can not be concluded that it always performs in all conditions and depth ranges with the precision that we have estimated. In the final mapping exercise all the information was assessed collectively to make the best possible approximations of the habitat polygons which were drawn free-hand on hard copy work maps (1:4,000 scale). The hand-drawn habitat polygons on the work map were then digitised through a combination of scanning and computer drawing methods and transferred to the GIS system to produce the final habitat map.

Depth boundaries of the various habitats defined were determined by a combination of drop video, scuba diving, snorkelling and knowledge of similar habitats. Beyond the depth at which detail was visible on aerial photographs (10m), biological habitat lines were located by interpolation along depth contours derived from the digitised bathymetry. In shallow water where good detail was available from aerial photographs, habitat boundaries were drawn directly on aerial photo prints as described above.

An A3 size map of the habitat study area is included as Map 2 in the back of the report.

Baited underwater video (BUV) monitoring

Seventeen stations were designed and positioned to carry out BUV monitoring for carnivorous fish species. The layout consisted of eight sites within the marine reserve area and nine sites outside the reserve area. The outside sites or 'fished reference sites' are intended to provide a means of comparison over time between the fished state and the reserve sites that will cease to be fished upon establishment of the reserve. Care was taken to locate reference sites with similar current, bottom substrate and depth to the reserve sites. Typically the sites selected are soft sediment bottoms immediately adjacent to rocky reefs. A location map of the BUV sites appears in Figure 2 below. GPS coordinates and notes of the BUV sites are included in Appendix 1.

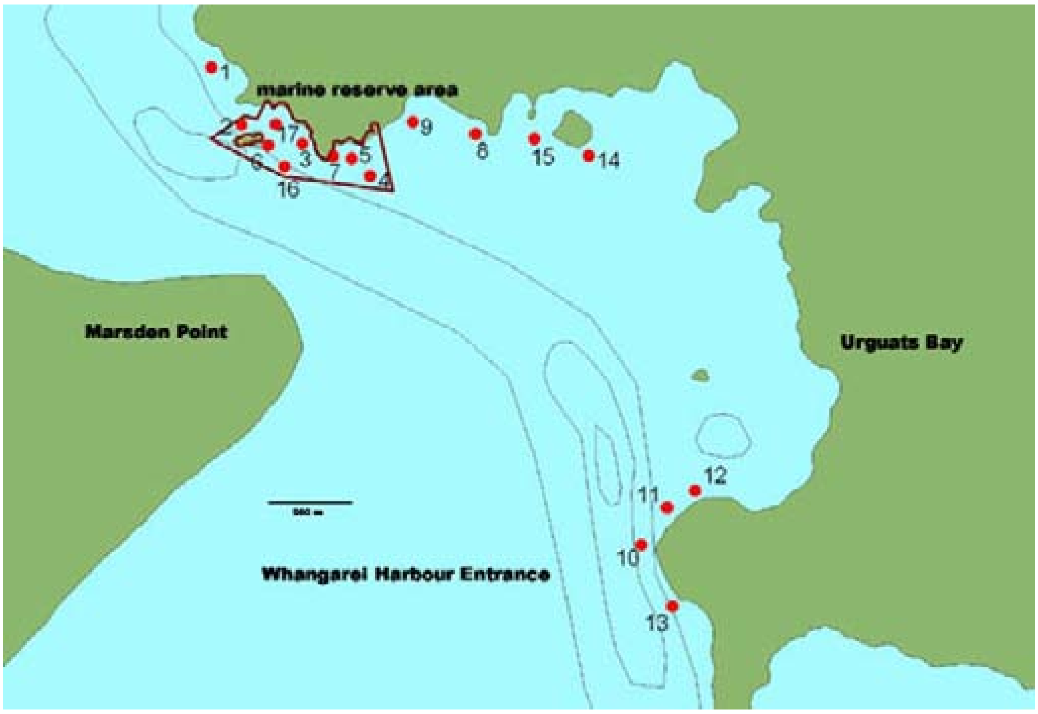

Figure 2. BUV monitoring sites

The BUV method used followed the protocols of Willis and Babcock (2000) with some modifications. It consists of a weighted steel bar forming the base of unit attached by ropes to a video contained in a water-housing. The video housing and camera is the same unit described earlier in the drop camera section. As a result of a series of calibration tests a Raynox .3X clip-on wide angle lens was added to the video camera system to achieve the minimum vertical focal length which would result in a field of vision area of 1.43m^2 at the level of the base bar, i.e. at the bottom substrate level. The video unit is held tensioned in the vertical dimension by a rope to a float and then the whole unit is tethered to a surface with a floating buoy. A bait jar containing approximately 4 pilchards (300g), *Sardinops neopilchardus* is attached to the base of the apparatus. The apparatus is pictured here in Figure 3 below. The BUV was deployed from the research vessel. At each site the video was recorded for 30 min from the time the video assembly reached bottom.

Figure 3. BUV apparatus

Post field analysis of the video tapes was done on a PC with *ArcSoft Showbiz* video editing software and DVD backup tapes were made of all drops. Video sequences for each site were played back on the PC with a real-time counter. The maximum number of each species of fish observed was recorded during each 30-minute sequence. Only fish visible at any one time were counted to avoid counting the same fish twice. For each species at the time in the tape where the maximum count was taken the size of these individual fish were recorded. This was done from the still image at the maximum count point of the video, and in addition the tape was moved back and forth a few frames so that individual fish could be observed in slightly different positions which made estimation of size easier. Estimation of size was done by comparing two scales available in the image. One was the 10cm markers on the bar base of the apparatus and the other was the 9cm width of the bait container. A judgement had to be made in each case as to where the fish was in the vertical dimension which affects the perception of length against a fixed point such as the bottom bar, i.e. the closer the fish is in the vertical dimension to the camera the longer it will appear in relation to the measured bottom bar. With a little practice it is possible to be certain that the fish being measured is at the 'bottom' position or the level of the bait container top or even higher. Measurements were only made of those fish present when the count of the maximum number of fish of a given species in a sequence was made. While this means that some fish moving in and out of the field of view may not have been measured, it also avoids repeated measurements of the same individuals. It is likely that this approach results in more conservative abundance estimates in high density areas than low density areas, and therefore observed relative differences between sites are also likely to be conservative.

Figure 4. Drop video apparatus

Figure 5. Sonar equipment and research boat

Results

Habitat map

The habitat maps included at the end of this report (Map 2 Motukaroro Habitat Map) represent the summation of all the information assembled in this investigation. The total area mapped is approximately 75ha. The mapped area includes shorelines and seabed features landwards of a 2km stretch of the shoreline at Reotahi. The habitat classification used is shown in Table 1. Table 2 below details the area of each habitat occupied within the mapped area, as well as the percentage of the mapped area covered by each habitat. Table 3 details the areas of each habitat within the Motukaroro marine reserve area as well as the percentage each habitat is of the total reserve area.

Table 2. Motukaroro entire survey area habitat areas.

Hectares	Percentage of Habitats	Inter-tidal Habitats
0.235	0.32%	sand
1.812	2.44%	mixed sand and rock
0.374	0.50%	rock
		Sub-tidal Habitats
64.504	86.87%	sand/mud
0.364	0.49%	cobble
2.847	3.83%	shallow mixed weed
0.182	0.25%	tangle weed forest
0.034	0.05%	urchin barrens
0.81	1.09%	Ecklonia forest
2.48	3.34%	mixed rock sand
0.029	0.04%	coralline turf
0.41	0.55%	deep reef
0.171	0.23%	mixed sand and rock deep reef
74.252	100.00%	Total

Table 3. Motukaroro marine reserve area habitat areas

Hectares	Percentage of Habitats	Inter-tidal Habitats
0.175	0.69%	sand
0.972	3.80%	mixed sand and rock
0.296	1.16%	rock
		Sub-tidal Habitats
19.140	74.92%	sand/mud
0.364	1.42%	cobble
2.094	8.20%	shallow mixed weed
0.182	0.71%	tangle weed forest
0.034	0.13%	urchin barrens
0.750	2.94%	Ecklonia forest
1.229	4.81%	mixed rock sand
0.029	0.11%	coralline turf
0.150	0.59%	deep reef
0.131	0.51%	mixed sand and rock deep reef
25.546	100.00%	Total

By far the greatest part (87 %) of the total survey and mapped area is occupied by sand/mud and gravels. Rock and sediment mixes comprise 6 % of the mapped area, with 6.3 % being solid rock habitats. For the area within the marine reserve boundary the soft sediments comprise 77 % of the area. In the marine reserve the mixed rock and sand habitats comprise 9.13% of the area and the various habitats on rock substrates make up 13.72 % of the area. The rock and rock-sediment mixes thus make up only a small proportion of the Motukaroro seabed, but have a disproportionately large ecological importance because of their high topographical complexity and consequently high biological diversity.

Inter-tidal habitats occupy only 3.3 % of the total mapped area, but are interestingly the only habitats seen by the vast majority of people.
A composite image of the aerial photography used for the habitat mapping exercise is included at the end of this report as Map 3.

Habitat descriptions

Intertidal habitats.

Sandy beaches

There are very limited areas of sandy beaches in the Motukaroro area. Biologically the sandy beaches support little life with low species abundance and diversity compared to the other habitats. Apart from sand hoppers on the drift line, marine life consists of several species of worms and tiny crustaceans on the middle or lower parts of the beaches.

Gravel and cobble beaches

Many of the beaches in the area consist of gravel and pebbles, or gravel with sandy areas at certain tidal levels. There are small gravel beaches in coves on the rocky shores on the mainland. This habitat is hostile to macro-invertebrates since even in very light wave action the movement of gravel and pebbles causes mechanical damage to organisms living there.

Rocky shores

A high proportion of the mainland and Motukaroro shoreline consists of hard rock of volcanic origin. 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 and Miller 1973). Some of the more familiar forms of marine life are rock oysters *Crassotrea gigas* on the most sheltered shores, and barnacles. The southern side of Motukaroro Island has a very interesting uniformly sloping inter-tidal rock reef which shows classic inter-tidal zonation.

Mixed rock and sand

In the Motukaroro area this is a common habitat and is therefore included in our habitat classification. This habitat is a result of the mass wasting and erosion that has taken place in the surrounding hills of volcanic origin. In this habitat many specialised niche opportunities are created in and around the stones and boulders for a wide range of marine invertebrates. During high tides these invertebrates are a potential feeding opportunity for predatory fish. During low tide periods wader bird species, most notably oyster catchers, can be seen foraging in the rocks and boulders.

Sub-tidal habitats.

Sand and soft sediments (depth range 0-30m)

The soft sediments of the Motukaroro area are very varied across spatial scales. They range from fine sands to coarse sand shell mixes. Frequently the sandy environments are strewn with small rocks and boulders which do much to add to the diversity of these habitats. In the course of our survey work we saw scattered individuals of a number of invertebrate species which are characteristic of this habitat. These organisms were: the morning star shell *Tawera spissa*, a bivalve shellfish 20 to 25mm in length, horse mussel *Atrina zelandica*, scallop *Pecten novaezealandiae*, sand dollar, *Fellaster zealandiae*, eleven armed starfish, *Coscinasterias calamaria*, and the common octopus *Pinnoctopus cordiformis*.

Gravel or cobbles (depth range 0-30m)

Under normal conditions a cobble bottom is fairly stable. In the Motukaroro area these cobble areas are often strewn with larger stones or boulders thus making 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 however is a precarious existence as even in the semi-sheltered situation of the Motukaroro area there may be very strong currents due to large tides at times, as well as significant wave action caused by surface winds on the harbour which particularly affect shallow areas. A wide range of invertebrates and fish life frequents these areas.

Shallow mixed weed (depth range 0-5)

This habitat occurs on rocky reefs between low water and about 5 m depth. Typically the rocky substrate is often very broken and dissected, with tumbled boulders, ridges and crevices. Several species of large brown algae are visually dominant. The flapjack kelp *Carpophyllum maschalocarpum* appears occasionally as a thin layer at the top of the zone. Small plants of common kelp *Ecklonia radiata* occur throughout this zone and at times dominate especially in the high current areas. In a very patchy distribution tangle weed kelp *Carpophyllum flexuosum* is quite dominant in the zone, while in other areas the tangle weed plants are in a mixed distribution with *Ecklonia radiata.* 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 occur in this habitat.

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

At Motukaroro areas big enough to map as kina barrens are rare. This is probably because the habitat is not ideal for kina with the high suspended silt loads that regularly occur. 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'), in some areas with coralline turfing algae as well. In a few areas small plants of the brown seaweeds such as *Carpophyllum flexuosum* form patches within the predominantly coralline paint-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 the grazing by urchins that maintains 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 the home of 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 10cm or more in diameter.

Tangle-weed forest (depth range 1-10 m)

In the most sheltered areas of rock substrate, a thick, almost impenetrable tangled forest of the brown seaweed *Carpophyllum flexuosum* occurs. Individual plants may reach a height of over 3m. With increasing wave exposure and/or current, it intergrades with *Ecklonia* forest. This habitat usually gives way to *Carpophyllum maschalocarpum* and a narrow strip of the shallow mixed weed zone towards low tide. The seaweed and the rock substrate of this sheltered zone are nearly always covered with a thin layer of fine silt, settled out from the water, which may be relatively turbid. 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.

Ecklonia forest (depth range 1-10m)

Ecklonia forest is characterised by dominance of the large brown laminarian kelp *Ecklonia radiata*. This seaweed attaches to the rock surface by a branched holdfast, and has a single cylindrical stalk or stipe, on top of which is a bushy top or lamina. The density of the plants varies considerably, with perhaps 5 plants per metre in 'thin' beds, often in deeper water, and about 50 plants per metre in dense, usually shallower, beds. The length of the stipe also varies, apparently with depth, from about 20 cm in adult plants in shallow slightly turbulent water, to about 80-100 cm in some deeper sites.

The canopy of the *Ecklonia* forest greatly reduces the light intensity on the rock surface beneath, which provides more favourable conditions for small encrusting animals such as bryozoans, hydroids, sponges and ascidians. The holdfasts of *Ecklonia* provide a crevice-like habitat for a rich diversity of life. In many areas the rocky bottom occupied by *Ecklonia* forest is of low relief, but where a high relief rocky substrate occurs within this zone, *Ecklonia* plants are usually found on the tops of the rocks, but not on their more shaded vertical sides, which typically are covered in a rich variety of encrusting animal life. As light levels diminish with increasing depth, sponges of numerous types become increasingly common within the thinning *Ecklonia* forest.

The *Ecklonia* forest zone usually occupies the rocky reefs between the urchin barren zone and the sandy seafloor, generally in a depth range of 4-29m. At Motukaroro *Ecklonia* is commonly part of the shallow mixed weed zones. Typically in areas of high current the shallow mixed weed zone makes way to a solid stand of *Ecklonia radiata* which in turn typically starts to thin out beyond about 8m depth and disappears beyond 10-12 meters. In the Motukaroro area it is common for the sponge community to be well developed under the *Ecklonia* canopy right up to the shallow mixed weed zone, thus the boundaries of these biotypes are very much overlapping.

Deep reef (depth greater than 10m)

On the rocky bottom deeper than 10m there is insufficient light to support the large brown seaweeds found in shallower water. Sponge species become the dominant life form on the deep reef. Representative sponges recorded at Motukaroro are: the massive grey sponge *Ancorina alata,* the orange branching sponge, *Raspailia* sp., a yellow branching sponge, *Iophon sp*. a massive yellow sponge, *Polymastia granulosa*, and the orange golf ball sponge, *Tethya aurantium*. The deeper areas off the Motukaroro Island reef have especially diverse and vigorous sponge communities. As previously mentioned an unusual feature of the sponge dominated encrusting communities at Motukaroro is the tendency for the community to extend well up into shallow water growing vigorously as a sub canopy community with the larger brown kelp species. The degree to which this is common at Motukaroro is unusual and points to the very special nature of the place. Drawing 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.

Figure 6. Representative photos from the deep reef sponge community at Motukaroro

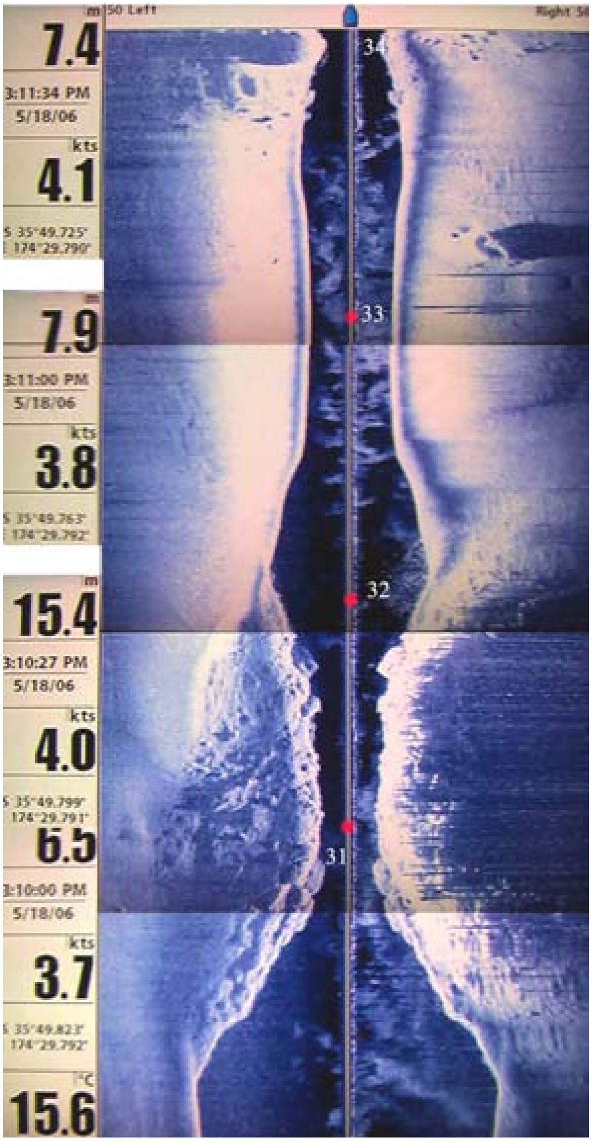

Figure 7. Representative sonar images. This image is a composite of a series of screen shots on a survey line from sonar points 31-34 (refer Map Section Map 1). This track runs from south to north just past the west end of Motukaroro Island. The distance from data point 31 to point 34 is 181 m.

Mixed sand and rock (depth range 0-10m algal communities on patch reefs, and 10-30m sponge encrusting invertebrate communities on patch reefs and boulders)

This habitat type occurs in transition zones between reef and sediment as well as in areas comprised of a patchy mixture of rock and sediment habitats. There are extensive areas of this habitat at Motukaroro. This ecologically important habitat is the preferred habitat of some species and is part of the habitat of the juvenile life stage of some reef species (for example, goatfish, juvenile snapper and blue cod). It is usually the place where species that shelter on reefs but feed in the sediments (like rock lobsters) forage most intensely. The habitat covers those areas where there is a mixture of small patches of rock scattered amongst sandy areas, but each is of such small extent that it is not possible to map them on the scale used for this survey.

Coralline Turf

This habitat is characterised by a low dense encrusting cover of calcified algae of the *Corallina* genus. Occasional patches of this habitat occur in the shallow reefs areas of Motukaroro. Most of these patches are too small in area to map, however there was one significant area of this habitat mapped in this survey. It is a long thin band of coralline turf in shallow water near the middle of the reserve area. Coralline turf forms a dense mat cover which is an important biogenic habitat. A wide diversity of invertebrates can be found in these habitats.

BUV reef fish monitoring

Thirty minute BUV drops were completed at 17 sites in and nearby to the Motukaroro reserve area. Maximum counts were made for each species for each site. The maximum count was defined as the greatest number of a species occurring in the field of vision of the camera during the 30 minute interval. The field of vision of the camera was 1.43 m^2 at the level of the bottom bar. Seven species were found in the 17 BUV drops: Spotty *Notolabrus celiodotus,* snapper P*agrus auratus,* trevally P*seudocarnyx dentex,* goatfish *Upeneichthys lineatus*, leatherjacket *Parika scaber,* blue cod *Parapercis colias* and john dory *Zues faber.* Results of these counts for each species are shown in Table 4 below.

Table 4. BUV fish counts Note: The sites inside the reserve area are shaded grey and are arranged from left to right in relation to their actual west to east position.

Fish/ Drop #	**1**	**2**	**6**	**17**	**16**	**3**	**7**	**5**	**4**	**9**	**8**	**15**	**14**	**12**	**11**	**10**	**13**
Spotty			4			1	1	3			1					3	
Snapper	3	3	3	2	2	5	5	3	2	3		2	2	9			
Trevally	3	13	19	18			11	9	1					3			
Goatfish								1								2	
Leatherjacket			1		1			2							2	4	1
Blue cod																2	
John Dory							1										
unidentified																3	
Total	6	16	27	20	3	6	18	18	3	3	1	2	2	12	2	14	1

One way to view this data is to calculate the number of sites that had each species present. Once this is done it is also possible to compare results from within the reserve area to the reference site areas. This result is depicted in Figure 8 below. (Note: Standard error calculations for the reserve and non-reserve replicate drops for spotty, snapper and trevally are indicated in Figure 12 below). For the three species that appear in the survey in the greatest numbers (spotty, trevally and snapper), there is an apparent difference between inside the reserve area and the outside reference sites. Spotty and snapper occur almost twice as frequently in the reserve as outside and trevally occurs three times as often. Snapper were present at 100% of the reserve sites and at only 56% of the reference sites. This aspect of the result suggests that the area around Motukaroro is in some way especially attractive to these species. Differences in frequency of presence/absence of the other four species, goatfish, blue cod, john dory and leatherjacket are hard to interpret and are unlikely to be significant. The actual numbers of these species observed were very low and the apparent differences between inside the reserve and outside are not great. There was only one legal size snapper counted in all the BUV drops making the separate analysis of legal and sub-legal size snapper impractical at this point.

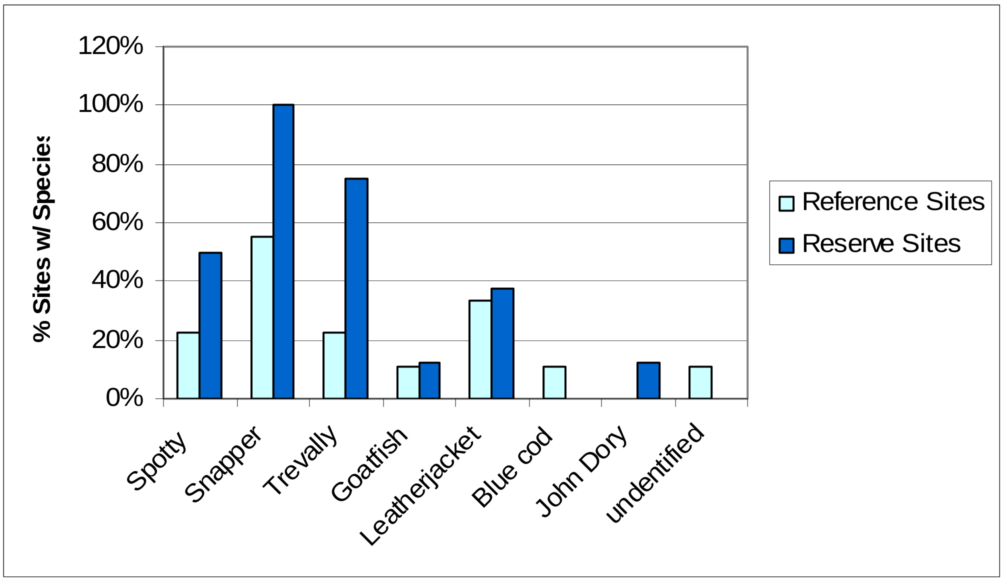

Figure 8. Frequency of species present at reserve and reference sites
Note: unidentified corresponds to a small fish on one BUV drop that could not be identified.

In another treatment of the data the total of the maximum counts for all species observed was calculated for each BUV site. The results of this treatment are presented in Figure 9. Two observations can be made. The total number of combined fish species shows that overall there are significantly more fish in the reserve area. However as can be seen from the graph there is considerable variation in numbers between the sites in the reserve and also between the reference sites. This variation will be explored further with evaluation of the results by species.

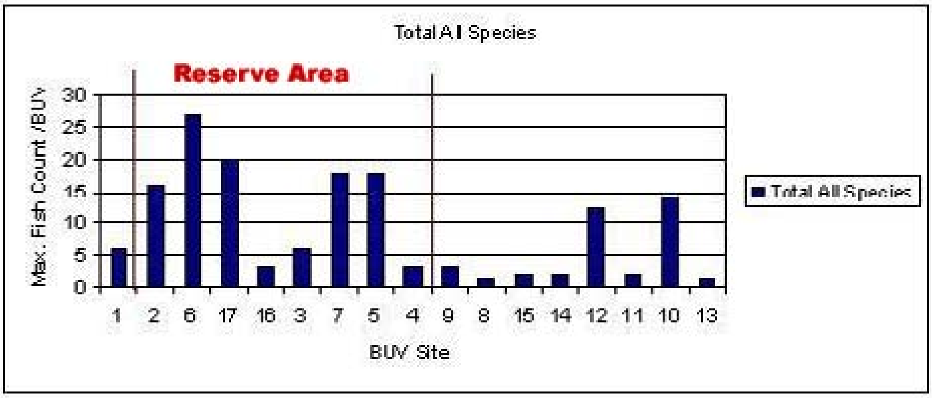

Figure 9. Maximum fish counts all species combined.
Note: the BUV drop sites between the vertical red lines are in the reserve area.

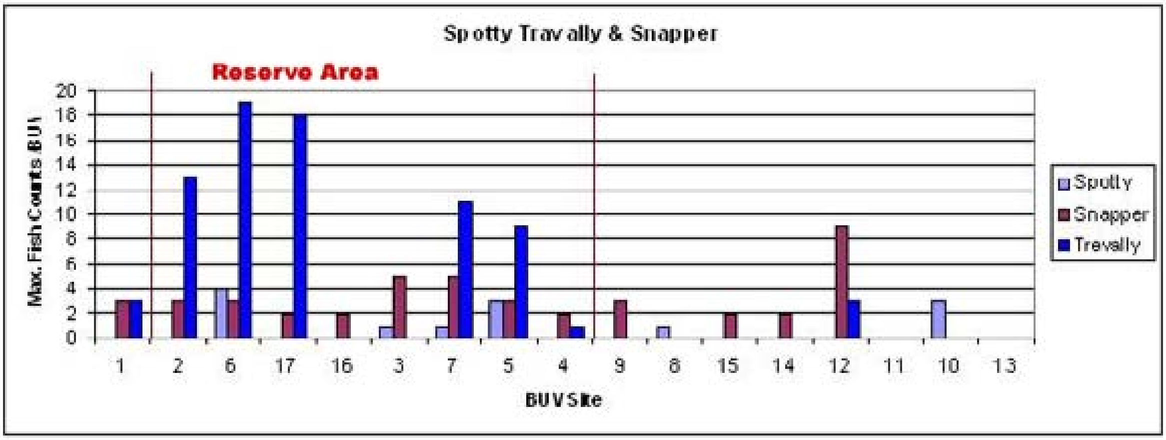

Figure 10. Maximum counts for spotty, trevally and snapper for all BUV sites.
Note: the BUV drop sites between the vertical red lines are in the reserve area.

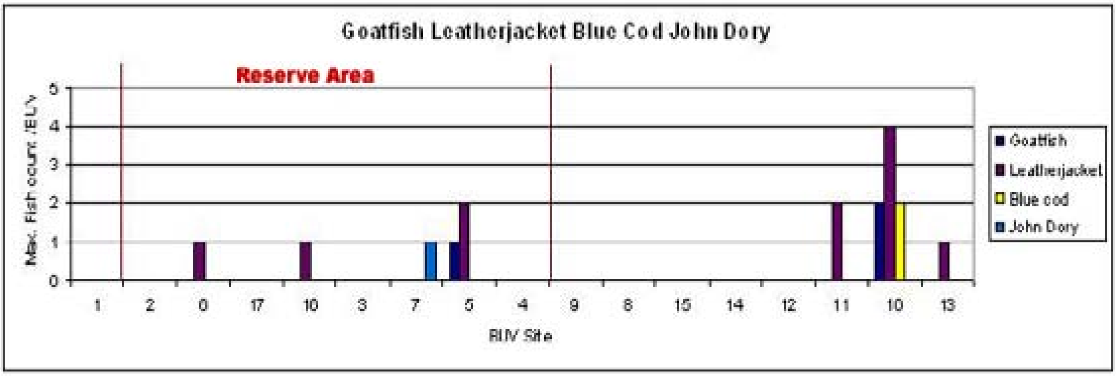

Figure 11. Maximum counts for goatfish, leatherjacket, blue cod and john dory for all BUV sites.
Note: the BUV drop sites between the vertical red lines are in the reserve area.

In order to test the usefulness of this data and the degree to which the reserve area and the reference site area can be compared we pooled the maximum count data for each species into two groups: the reserve group and the reference site group. Grouped in this way the BUV site become two sets of replicates with n=8 for the reserve area and n=9 for the reference sites. We then calculated a mean value for the maximum counts for snapper, trevally and spotty. This is presented in Figure 12 below along with standard error bars which indicate the variation between the replicate BUV drops within the two groups.

When the data is viewed in this way for spotty and snapper, while the means are higher in the reserve than outside, the difference is less than the standard error. This can be taken to mean that either the difference between in and out is not significant or there is too much variation between the replicate BUVs to indicate difference between in and out, i.e. more replicates are required. For trevally the absolute mean values are quite divergent. However the apparent difference between inside and outside must be considered along with the variation error between samples, expressed as error bars (standard error or 95 % confidence level), which are large in this case. This means that the variation between sites within each group is nearly as large as the overall difference between inside and outside groups. Accordingly much of the difference between the two groups can be accounted for as sampling variation. The results do however suggest there is a difference between inside and outside for trevally, but again the large error bar especially for the reserve group suggests that there is a tendency towards a patchy distribution of trevally and that the number of replicates used is minimal for this species.

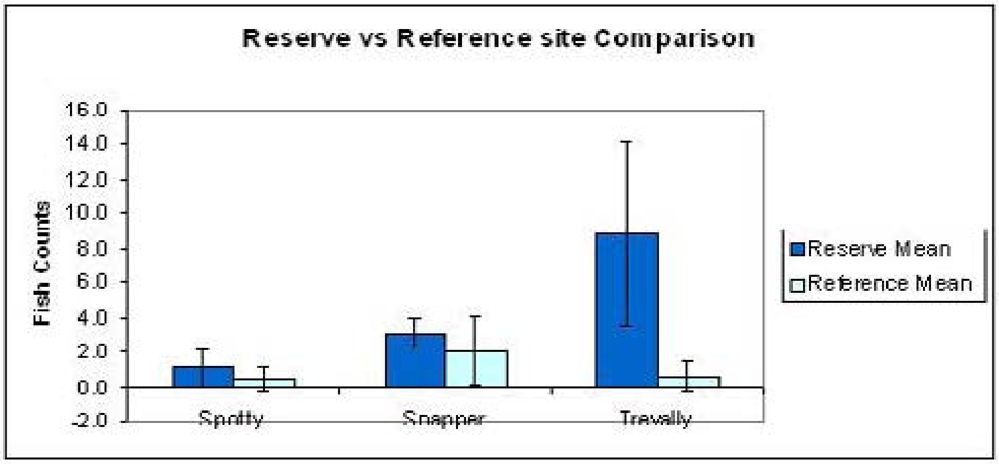

Figure 12. Comparison of mean maximum counts snapper, trevally and grouped as reserve verses reference sites

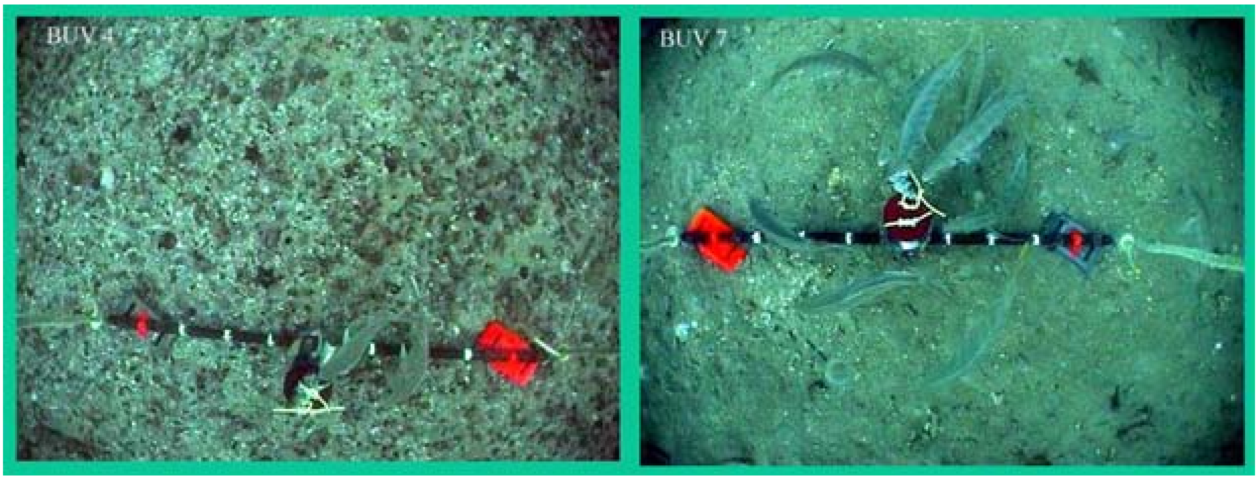

Figure 13. Representative photos from BUV monitoring

For the four species occurring in small numbers, goatfish, leatherjacket, blue cod and john dory, the distribution is too patchy and numbers too low to allow for the calculation of sensible mean values in and out of the reserve, or to measure variation within the two groups. At these low levels of occurrence more replicate BUV drops would be required to assess difference between inside and outside.

Returning to Figure 12 it is worth examining the results of snapper in the context of the longer term purpose of this monitoring program. It is possible based on previous studies, that in the years to come following the establishment of the reserve, density of exploited species will increase over time in relation to densities in nearby 'fished' reference sites. While there is some question about this at the Motukaroro reserve because of the very small size, this possibly remains the most important monitoring question. It is also clear that changes in snapper abundance will potentially be one of the best indicators of the reserve effect and thus should be a central focus of the monitoring. In our BUV design snapper occurred at all reserve BUV sites. The standard error calculated for the reserve mean of 3.1 fish/BUV was 0.9. This degree of variation is acceptable for statistical treatments of the data, indicating that the BUV design should be workable for assessment of change over time for this species. For the reference sites the mean of 2.1 fish/BUV and standard error of 1.9 is not as encouraging. Snapper were present in only 56% of reference area BUV drops. If snapper numbers appearing at the reference sites remains this low it is logical to conclude that more replicates will be required to calculate mean values for the reference group sites with sufficiently low variation error to allow for meaningful comparison to the reserve group of BUV sites.

BUV fish size data

Size data was collected for all species at the time in each BUV of the maximum count for each species. The size data by species for each BUV drop is detailed in Appendix 2 of this report. Overall the size of the fish is small with the vast majority of fish appearing falling into size classes that would be considered juveniles for that species. Snapper ranged in size between 9 and 28cm with only three fish in total being estimated to equal to or exceeding 27cm, the size for legal take. Trevally ranged from 19 to 37cm in size and spotty ranged from 11 to 27cm. The other four species leatherjacket, blue cod, goatfish and john dory exhibited a similar pattern of predominately small fish and no large individuals present. This pattern of young fish dominating the population is typical of fished areas, and is also a typical feature of harbour habitats known for their importance as nurseries and refuges for juvenile stages of these species (Morrison 2005). Comparison of size data following reserve establishment is expected to produce a key indicator of reserve effect change over time. As a general rule, in reserves studied to date, the increase in biomass over time after reserve establishment is greater than the increase in abundance. For this purpose then it would appear that this data will form a worthwhile baseline to measure changes in biomass of these species, at the least for snapper.

Discussion

The habitat map of Motukaroro produced in this study is intended as a tool for managers, iwi and community groups interested in examining the marine environment of Motukaroro. Habitat maps are especially useful in assisting the design of baseline change over time monitoring or research studies. While we can put forward questions about the effect of establishing a reserve at Motukaroro now, it is likely that there will be changes that occur that no one has predicted. This has been the pattern of past reserves and is an indication of how complex marine systems are and how little we know about these systems in an ‘unfished state’. For this reason baseline work, like habitat mapping and aerial photography coupled with population monitoring of key exploited species, allows for a great deal of flexibility for future enquiries.

Habitat map

Limitations of the study

There were some limitations to our methods which should be noted. The precision changed with depth, reflecting the methods used, being greatest in shallow areas and decreasing as the depth increased. We suggest this is appropriate in that significant biological boundaries occur across much smaller scales in shallow waters and tend to become further apart as depth increases.

In depths less than 10m the accuracy of the mapping was determined by the interpretation of aerial photography which in most areas afforded resolution of detail down to 3-5m. Overall accuracy was limited by georeferencing error (i.e. approx 10 m). In this survey, in waters deeper than 10m, we were able to achieve nearly 100% survey coverage and in most cases had overlapping sonar images to work with. As a result, in terms of the physical habitats, we expect that the accuracy of our habitat lines is within 20m, which accounts for GPS error and interpretation of the sonar and a small error (estimated to be 10m) which we have not fully quantified generated by the sonar equipment in the lateral dimensions of the sonar image.

There are other limitations of the habitat map that are a combination of the special characteristics of the Motukaroro site. Divisions between biological zones which are normally depth dependent and quite distinct in Northland are typically variable or overlapping at Motukaroro. In the shallow mixed zone there is a high degree of patchiness in the combination of the algal species. The pattern of variation is often very localised and difficult to map at the scales we were working at. We also found that the deep sponge community overlapped with the algal forests more at Motukaroro than is typically observed at other sites. This boundary varied to a degree between parts of the study area. These variations can probably be explained by the effects of currents and eddies which are strong in places and quite variable across very small distances due to the complex topography of the coast in the study area. These localised currents influence silting and light penetration significantly. These factors in turn have a defining influence on biological zonation especially of algal species.

BUV fish monitoring

Overall the results of the BUV monitoring appear to fulfil the objectives set down for the study with some concerns that can be addressed in subsequent years of monitoring which we will further discuss here. For the most significant carnivorous fish species snapper, the results indicate that the number of replicates and placement inside the reserve should provide the ability to do change over time statistical analysis and yield worthwhile results. This is assuming that there is significant change over time as a result of the establishment of the marine reserve. However the layout and number of replicates in the 'reference' site areas is not as clearly sufficient even though there were nine sites compared to the eight within the reserve. The main problem is that the various habitat characteristics of the Motukaroro area are not easily replicated by moving either up or down the harbour. We tried to pay particular attention to current and depth and proximate reef structures in this regard, but the choice of sites is limited. In one sense this supports the argument to have more replicates in the reference areas. The other aspect of this problem is that the fish numbers we measured at the reference sites were quite low with a number of zero counts affecting the analysis of results. This is a chronic problem in marine reserve studies as the organism that is studied may be so depleted outside the reserve area that 'fished reference sites' become difficult to identify. Reviewing the initial data with these two considerations in mind it seems sensible to expand the number of replicate BUV drops of the reference sites. In the layout of reference sites it is possible to view them as two distinct groups: one group described as the shore to the East - around High Island and between High Island and the reserve, the other group described as the shoreline of Home Point. If expanded it would probably be necessary to have 8-10 replicates for each reference area. This approach would afford the possibility of using more powerful statistical analysis on the data. The current number of replicates for the reserve area should be regarded as the bare minimum to be practically useful. Increasing the number of replicates from 8 to 12 or 15 would greatly increase the statistical power of the analysis based on the data in this years monitoring. While future efforts are most likely to be focused on snapper, increasing the number of replicate BUV drops as described here would also solve some of the problems of assessing change in the other species that appear in smaller numbers and/or appear in a more patchy distribution.

There are two other limitations of this BUV study which warrant discussion. Previous to this study the BUV methodology has been used for open coast applications. It is possible that in the estuarine situation, the time of tide when the BUV drop is deployed is a more important factor in influencing the number of fish present than it would be in an open cost situation where typically tide stage has been ignored. There are two possible ways to deal with this added uncertainty. The first is to test the method for changes over a tide cycle. This is a specific research project on its own and would be valuable to this study and other estuarine BUV studies. The second is to set a standard tide stage to do the BUV drops - say 1 hour either side of high tide and do all drops in this way. In the current study we carried out the survey over three days and did not standardise the tide stage. The second limitation is the spatial proximity of drop sites. In previous studies an effort was made to have a minimum of 500m between BUV drop sites. This spatial separation is designed to eliminate possible interactions between fish attracted in numbers to one BUV drop simply shifting on mass to the next proximate BUV drop and thus skewing the data. In this study because of the extremely small scale of the reserve and the non-fished reference sites this degree of spatial separation is not achievable. No sites were less than 100m from one another but about a third are between 100-200m apart with the others being 200-300m from the next closest site. The degree to which this spatial limitation affected the current survey data is unknown. Given that it would be very difficult to quantify this effect the practical solution appears to be to adopt a protocol which requires that sites with less than 500m spatial separation must be done with a certain amount of time lag or possibly on different days. The exact rule to use here needs to be determined and tested in a practical manner alongside the protocol adopted to deal with the stage of tide factor and is therefore appropriate to resolve as part of the next round of monitoring. It needs to be noted that adoption of the protocols discussed above will increase the time and therefore the cost of this work.

One of the distinct advantages of using a standardised method like BUV monitoring is to have the ability to compare results with other locations, management treatments and research programs. Table 5 below is a summary of mean snapper densities in BUV surveys conducted by the Auckland University research team. The comparable result for our study is indicated in Figure 12. In our study there were not enough legal-size snapper to calculate a mean so we can take this value as zero, and the mean for sub-legal sized snapper was just over 2 fish/BUV drop. Taken in a straight forward comparison our result is at a similar level as Mimiwhangata, but well below the other study sites. While this comparison is interesting caution must be taken in interpreting what it means because as a harbour site Motukaroro differs substantially from the Auckland University study sites which are coastal or offshore island sites. Taking this into account the snapper densities at Motukaroro appear to be comparatively low. This comparison will be useful over time if not in terms of absolute values then in terms of relative change over time in relation to differing management treatments of the sites, especially if we see large changes in the monitoring data over time.

Table 5. Mean snapper densities in BUV surveys at Poor Knights, Cape Brett, Mokohinau Islands and Mimiwhangata from: (Denny & Babcock 2004)

Mean number of snapper, *Pagrus auratus*, per BUV (+/- s.e. in brackets) at the Poor Knights, Cape Brett, Mokohinau Islands, and Mimiwhangata. The first 3 areas show data from autumn 2001; Mimiwhangata data is from autumn 2002.

	2001(autumn)			2002 (autumn)
Snapper	Poor Knights	Cape Brett	Mokes	Mimiwhangata
all	19.6 (2)	10.53 (3.7)	6.6 (0.8)	4.4 (0.9)
legal (>270mm)	13.5 (1.3)	0.9 (0.3)	0.7 (0.2)	0.3 (0.1)
sublegal (<270mm)	3.9 (0.5)	9.13 (1.2)	5.86 (0.8)	3.83 (0.9)

A bit of good news for future work has arisen from the field work this year. As part of our work this year we re-designed the BUV apparatus as pictured in Figure 3. Previous systems were designed around large steel tripod frames. The new design worked extremely well, even in some rather difficult current and visibility situations encountered in this study. While these are simple changes the new arrangement is a lot easier to use and cheaper to build than previous versions of the BUV apparatus. Some of the improvement was made possible by the use of a wide angle lens on the video camera which allowed us to shorten the vertical dimension of the apparatus considerably. This in turn allows for faster handling and a better result in reduced visibility conditions. The present system lends itself to a method where two BUVs are deployed simultaneously tethered to buoys allowing the boat and crew to move alternately between BUV units, reducing the field time by a significant factor. Another advantage of the new system is that we can use the same camera and housing that we use for the drop video habitat ground truthing work. Also the cost of building a second unit with this design would be low.

Recommendations

1. The information and maps in this report should be promoted widely as awareness tools within the community.

2. Further refinement of some of the habitat map and descriptions in the Motukaroro area would be desirable from a science perspective due to the uniqueness of the area. This work could include acquisition of additional images of the various habitats to help with presentations and other work within the community.

3. Opportunities exist to fill in the key information gaps identified, particularly soft sediment faunas, sponge and encrusting invertebrate community taxonomy.

4. Design layout of the BUV monitoring should be reviewed in the context of the discussion above regarding the increase in the number of replicates and the protocols addressing the issues around stage of tide and spatial separation of the BUV sites.

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Map Section

Map 1 Sonar data points, tracks and video drop points

Map 2 Motukaroro habitat map

Map 3 2006 Motukaroro aerial photo composite image

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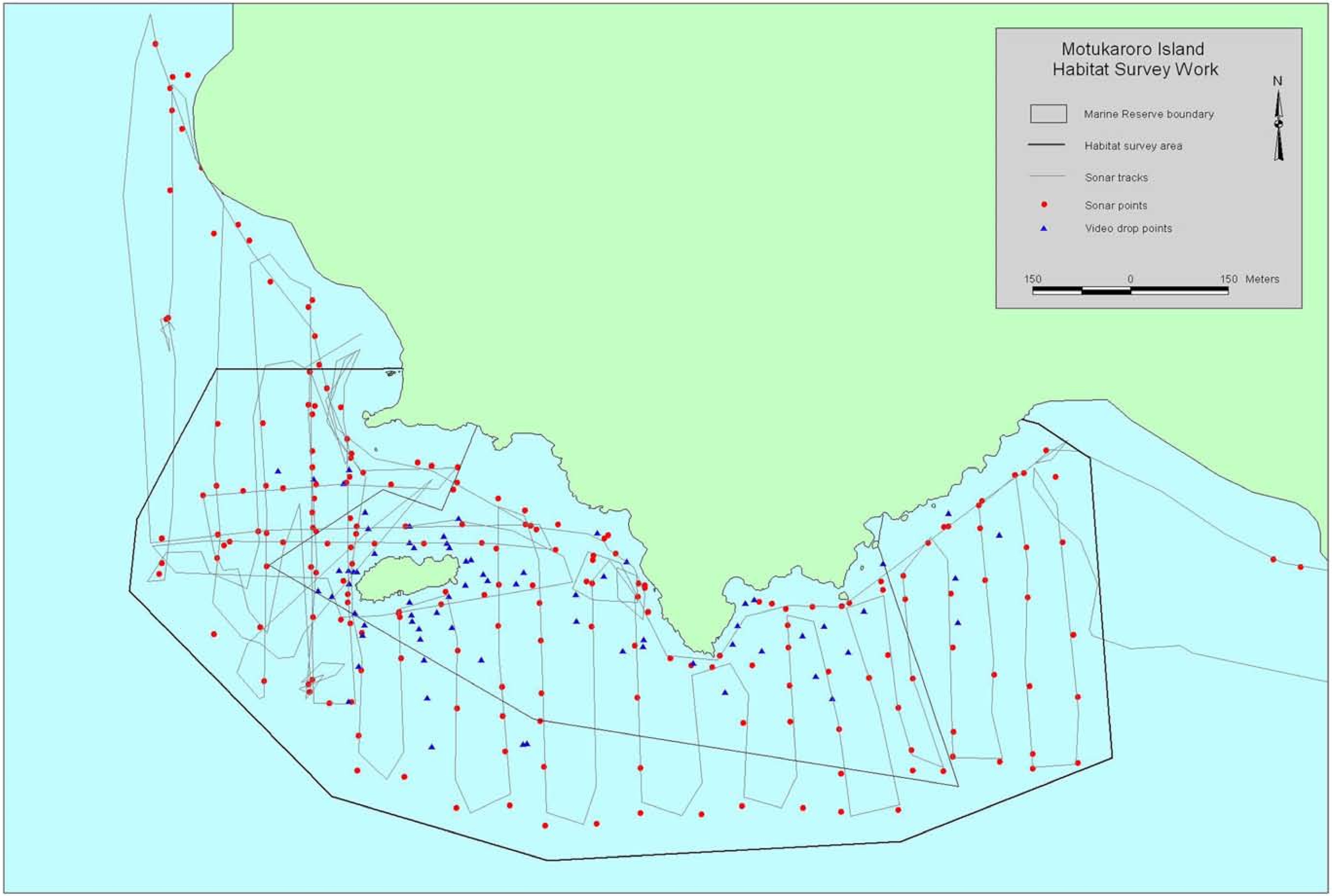
Appendix 1. BUV points

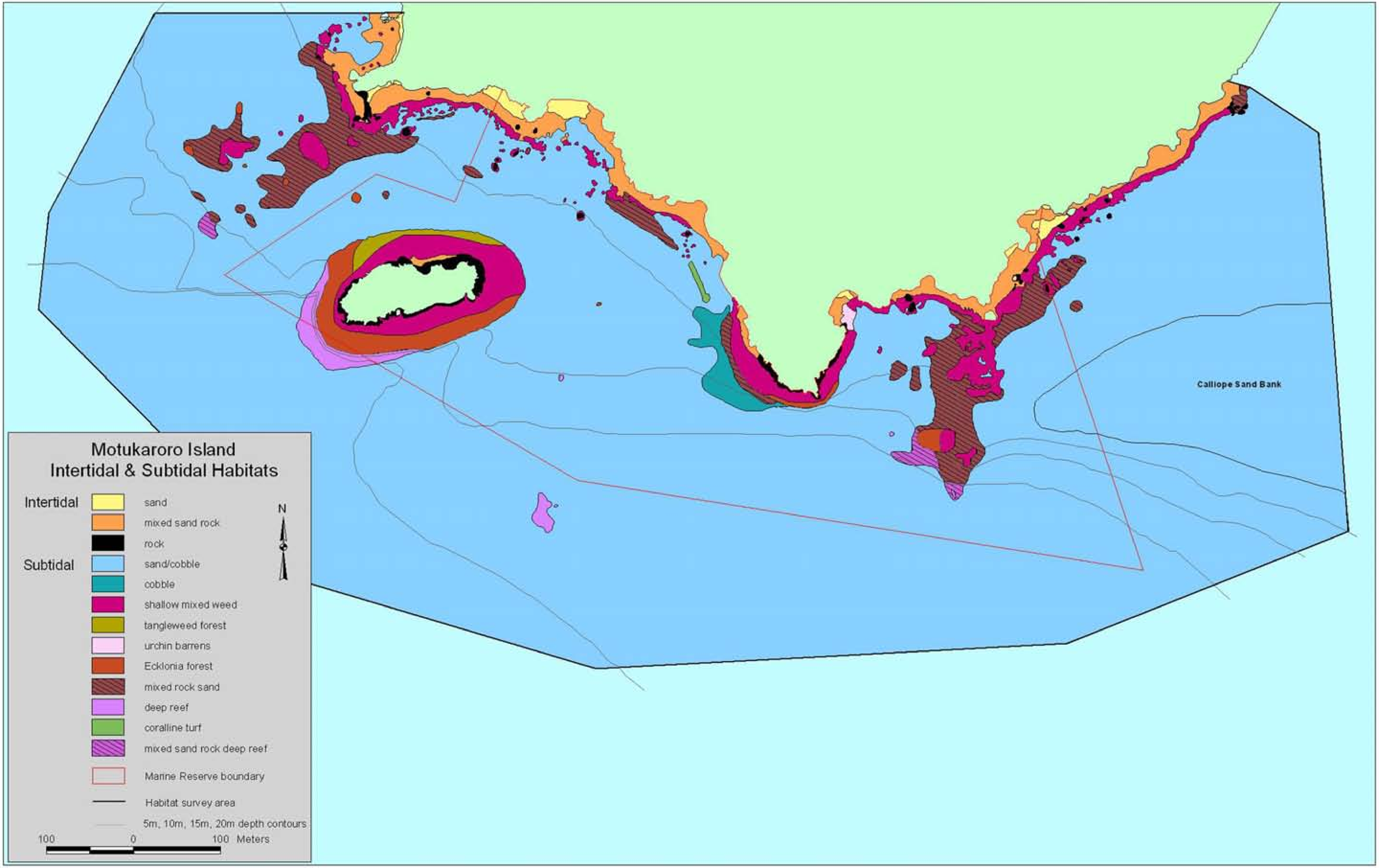
Appendix 2. BUV fish size data

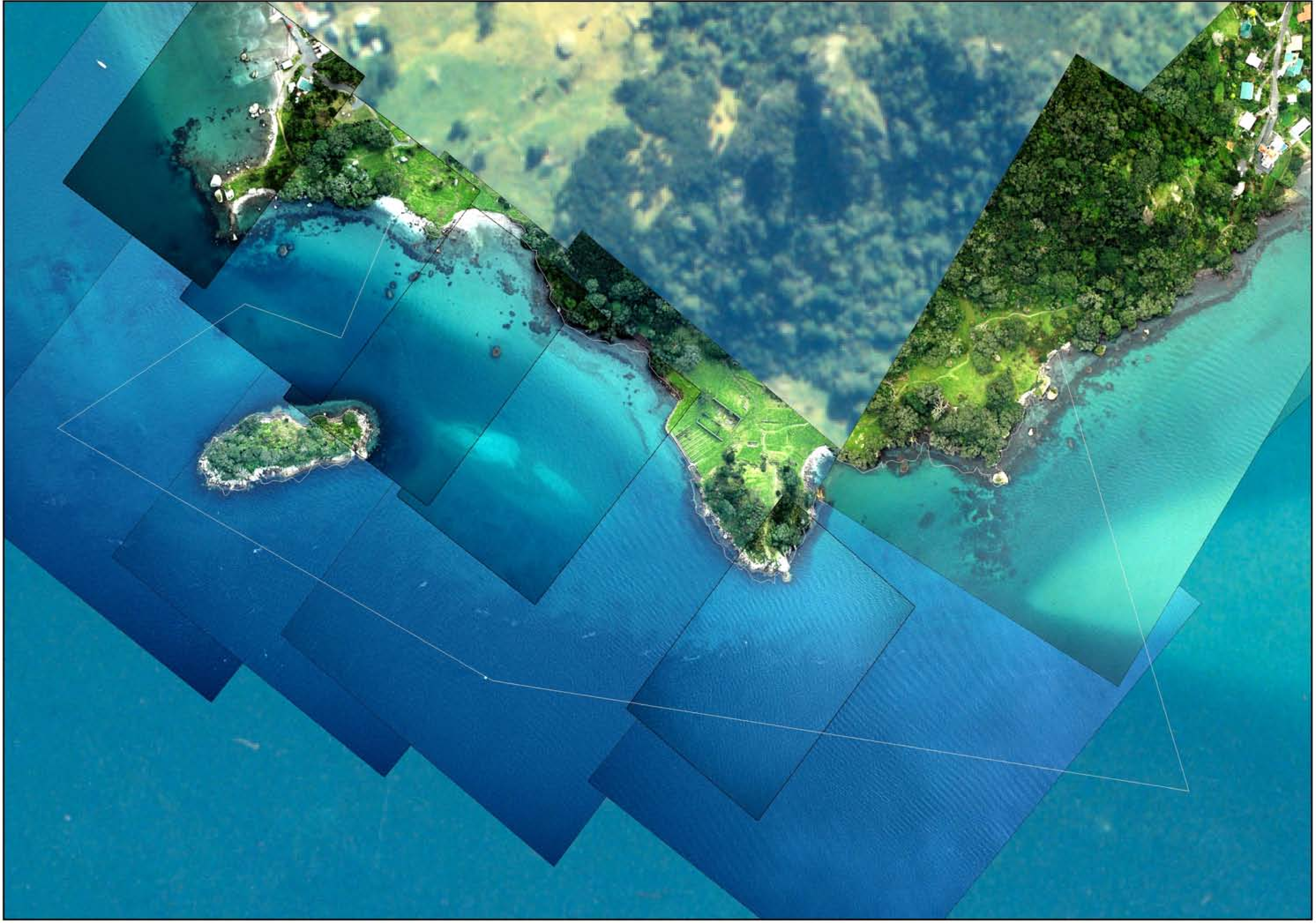
Appendix 3 BUV size data

Appendix 4 Sonar data points



Motukaroro Island
Habitat Survey Work
Marine Reserve boundary
Habitat survey area
Sonar tracks
Sonar points
Video drop points
N
150
0
150 Meters


Calliope Sand Bank
Motukaroro Island
Intertidal & Subtidal Habitats
Intertidal
sand
mixed sand rock
rock
Subtidal
sand/cobble
cobble
shallow mixed weed
tangleweed forest
urchin barrens
Ecklonia forest
mixed rock sand
deep reef
coralline turf
mixed sand rock deep reef
Marine Reserve boundary
Habitat survey area
5m, 10m, 15m, 20m depth contours
N
100
0
100 Meters



Appendix 1. BUV data points

Wpt	Lat	Long	Eastings	Northings	Time	Uncorrected depth m.	Habitat	Date	Notes
1	-35.8264	174.4949	2645723	6596044	1407	8.1	s	31.5.06	Seechi disk (SD)4.8m. Current 1 kn. Fine sand.
2	-35.82941	174.497	2645901	6595706	1500	5.2	s	31.5.06	Too much current for SD. Current c.1.5kn. Coarse sand.
3	-35.83033	174.501	2646259	6595598	1545	6.7	s	31.5.06	SD 3.8m. Current 0.5kn. Coarse sand.
4	-35.832	174.5054	2646656	6595406	1109	17.6	s	1.6.06	end of rising tide. Current c. 0.5kn at start. SD 7.9m.
5	-35.83109	174.5042	2646548	6595509	1150	9.0	s	1.6.06	Sand with rocks nearby. First of falling tide.Current c.0.5-1 kn.Temp c. 15.1C.
6	-35.83046	174.4987	2646057	6595588	1230	9.0	s	1.6.06	Sand. Falling tide. Current c. 0.5kn.
7	-35.83098	174.503	2646440	6595523	1400	6.0	s	1.6.06	Sand. 1/2 Falling tide. Current < 0.5kn.SD 6.0m
8	-35.82967	174.5122	2647275	6595653	1440	9.0	s	1.6.06	Sand. 1/2 Falling tide. Current < 0.5kn.SD 7.4m. Temp 15.3C
9	-35.8291	174.5081	2646906	6595723	1025	4.1	s	2.6.06	Current < 0.5kn. Viz greater than 4.0m. Approaching HW.Sand/ Temp 15.0C
10	-35.85127	174.5235	2648252	6593238	1112	15.5	s	2.6.06	Current C.0.5kn. Close to HW.Viz c.6+m. Coarse sand.Photo of *Ecklonia* brought up.
11	-35.84929	174.5251	2648402	6593455	1202	9.5	s	2.6.06	Current c.0.5kn.First of dropping tide. Sand.Viz c. 6+m.
12	-35.84836	174.5269	2648566	6593556	1238	7.0	s	2.6.06	Current c. 1.0kn. Tide dropping. Viz 6+m.Coarse sand.
13	-35.85449	174.5255	2648432	6592877	1322	6.5	s	2.6.06	Current nil. Coarse sand. 15.2C. Viz greater than 6m.
14	-35.8307	174.5196	2647941	6595527	1411	9.5	s	2.6.06	Current less than 0.5kn.Viz c, 6+m.Probably coarse sand.
15	-35.82984	174.5161	2647624	6595628	1455	7.5	s	2.6.06	Probably coarse sand. Current less than 0.5m. Viz c. 6m.
16	-35.83157	174.4998	2646150	6595463	1536	16.1	s	2.6.06	Viz c.3m? Current c.1kn. Sand. Heading toward low tide.
17	-35.82934	174.4992	2646100	6595711	1616	7.0	s	2.6.06	Coarse sand. Viz c.6m. Current c.1.0kn. Toward low water.

Appendix 2. BUV size data

Note: Fish size, head to fork of tail estimate, in cm

BUV Drop Number	**1**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	22	22	20																
Trevally	22	22	22																
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	**2**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	20	18	19																
Trevally	32	32	24	24	27	26	26	20	26	26	20	28	25						
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	**3**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty	23																		
Snapper	28	27	22	18	19														
Trevally																			
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	**4**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	21	27																	
Trevally	37																		
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	**5**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty	12	20	17																
Snapper	20	22	17																
Trevally	30	30	33	25	21	21	20	22	19										
Goatfish	23																		
Leatherjacket	29	22																	
Blue cod																			

BUV Drop Number	**6**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty	27	18	20	22															
Snapper	25	25	22																
Trevally	32	36	32	32	33	34	34	36	29	33	34	30	31	30	32	27	27	29	33
Goatfish																			
Leatherjacket	32																		
Blue cod																			

BUV Drop Number	**7**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty	14																		
Snapper	25	20	24	20	18														
Trevally	35	28	30	33	32	28	27	30	28	29	29								
Goatfish																			
Leatherjacket																			
Blue cod																			
John Dory	36																		

BUV Drop Number	**8**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty	11																		
Snapper																			
Trevally																			
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	**9**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	12	10	12																
Trevally																			
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	**10**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty	24	26	20																
Snapper																			
Trevally																			
Goatfish	22	17																	
Leatherjacket	29	27	28	28															
Blue cod	27	18																	
unidentified	10	10	10																

BUV Drop Number	**11**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper																			
Trevally																			
Goatfish																			
Leatherjacket	29	27																	
Blue cod																			

BUV Drop Number	**12**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	22	23	23	23	22	24	21	21	20										
Trevally	20	20	19																
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	**13**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper																			
Trevally																			
Goatfish																			
Leatherjacket	30																		
Blue cod																			

BUV Drop Number	**14**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	12	9																	
Trevally																			
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	**15**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	12	12																	
Trevally																			
Goatfish																			
Leatherjacket																			
Blue cod																			

BUV Drop Number	**16**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	15	18																	
Trevally																			
Goatfish																			
Leatherjacket	30																		
Blue cod																			

BUV Drop Number	**17**																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fish Specie																			
Spotty																			
Snapper	22	20																	
Trevally	32	32	32	34	30	33	28	27	28	34	37	37	36	32	24	35	33	29	
Goatfish																			
Leatherjacket																			
Blue cod																			

Appendix 4 Sonar data points

Wpt	Lat	Long	Eastings	Northings	Data Type	Habitat	Notes
1	-35.8300156	174.4933337	2645571	6595645	sonar	s	
2	-35.826636	174.4933552	2645580	6596020	sonar	s	
3	-35.8266575	174.4933337	2645578	6596018	sonar	s	
4	-35.8248765	174.4933552	2645583	6596215	sonar	r	
5	-35.8237822	174.4933605	2645586	6596337	sonar	r	
6	-35.8233101	174.4933659	2645587	6596389	sonar	s	
7	-35.8232779	174.4936341	2645611	6596392	sonar		photo
8	-35.8248872	174.4942725	2645666	6596213	sonar		photo
9	-35.8254612	174.4941062	2645650	6596149	sonar	s	
10	-35.8280844	174.4942349	2645656	6595858	sonar	s	
11	-35.8289374	174.4942242	2645654	6595763	sonar	r	
12	-35.8299352	174.4942671	2645655	6595653	sonar	s	
13	-35.8309866	174.4942296	2645650	6595536	sonar		photo
14	-35.8308793	174.4950074	2645721	6595547	sonar		photo
15	-35.831625	174.4950932	2645727	6595464	sonar		photo
16	-35.8300371	174.495104	2645731	6595640	sonar	r	
17	-35.8295811	174.4950932	2645731	6595691	sonar	r	high relief
18	-35.8289266	174.4950664	2645730	6595763	sonar	sr	
19	-35.828063	174.4949967	2645725	6595859	sonar		photo
20	-35.8255524	174.4947177	2645705	6596138	sonar	edge	roch on right
21	-35.8263571	174.4958013	2645801	6596047	sonar	s	
22	-35.8279396	174.4958335	2645801	6595872	sonar	r	
23	-35.8286531	174.495855	2645801	6595792	sonar	sr	edge
24	-35.8292807	174.4958603	2645801	6595723	sonar	sr	edge big rock
25	-35.8300371	174.4958603	2645799	6595639	sonar	sr	edge big rock
26	-35.8307291	174.4959086	2645802	6595562	sonar	sr	edge big rock
27	-35.8317537	174.4958711	2645797	6595448	sonar	sr	edge big rock
28	-35.8319146	174.4962037	2645827	6595430	sonar	sr	edge big rock
29	-35.8318878	174.4965792	2645861	6595432	sonar	sr	edge big rock
30	-35.8307988	174.4965416	2645859	6595553	sonar	sr	edge big rock
31	-35.8304019	174.496488	2645855	6595597	sonar	edge sr	
32	-35.8297581	174.4965255	2645860	6595669	sonar	edge sr	
33	-35.8293504	174.4965094	2645859	6595714	sonar	edge sr	
34	-35.8287818	174.4964826	2645858	6595777	sonar	edge sr	
35	-35.8282722	174.4964236	2645854	6595834	sonar		photo
36	-35.8285297	174.4964987	2645860	6595805	sonar	r	
37	-35.8278269	174.4963163	2645845	6595883	sonar	r	onright side
38	-35.8287121	174.4967187	2645879	6595784	sonar	r	
39	-35.8286048	174.4978666	2645983	6595794	sonar		photo
40	-35.8286209	174.4983065	2646023	6595792	sonar		photo
41	-35.828932	174.4982368	2646016	6595758	sonar	s	
42	-35.8288784	174.49718	2645921	6595765	sonar	edge	
43	-35.8288676	174.4964343	2645853	6595768	sonar		photo
44	-35.8288945	174.4959194	2645807	6595765	sonar		photo
45	-35.8289481	174.4953561	2645756	6595760	sonar	sr	
46	-35.8290018	174.4946855	2645695	6595756	sonar	sr	
47	-35.8290661	174.494015	2645634	6595749	sonar	sr	
48	-35.8297635	174.4943851	2645666	6595672	sonar		photo
49	-35.8315928	174.495914	2645801	6595466	sonar		photo
50	-35.8316518	174.4958496	2645795	6595460	sonar	s	

51	-35.8301175	174.4959515	2645807	6595630	sonar	r	
52	-35.8295382	174.4959301	2645807	6595694	sonar	r	
53	-35.8290876	174.4958872	2645804	6595744	sonar		photo
54	-35.8284439	174.4958496	2645801	6595816	sonar	cob	
55	-35.8278001	174.4957692	2645795	6595887	sonar		photo
56	-35.8273495	174.4957799	2645797	6595937	sonar		photo
57	-35.8272476	174.4959462	2645812	6595948	sonar		photo
58	-35.8278162	174.4958764	2645805	6595885	sonar		photo
59	-35.8287121	174.4967133	2645879	6595784	sonar		photo
60	-35.829565	174.496606	2645868	6595690	sonar		photo
61	-35.8299781	174.4965524	2645862	6595644	sonar		photo
62	-35.8305092	174.4964933	2645855	6595585	sonar		photo
63	-35.8309329	174.4967455	2645877	6595538	sonar		photo
64	-35.8314479	174.4967401	2645876	6595481	sonar		photo
65	-35.8323438	174.4967187	2645872	6595381	sonar		photo
66	-35.8328266	174.4967079	2645870	6595328	sonar		photo
67	-35.8329017	174.4975072	2645942	6595318	sonar		photo
68	-35.8312763	174.4974107	2645937	6595499	sonar		photo
69	-35.8307076	174.4973731	2645935	6595562	sonar	s	
70	-35.8306325	174.4973624	2645934	6595570	sonar		photo
71	-35.8303429	174.4981456	2646005	6595601	sonar		photo
72	-35.8311529	174.4983602	2646023	6595511	sonar	r	
73	-35.8319468	174.4983655	2646022	6595423	sonar	s	
74	-35.8333201	174.4983816	2646021	6595270	sonar	s	
75	-35.8332718	174.4992882	2646103	6595274	sonar	s	
76	-35.8325262	174.4992024	2646096	6595357	sonar	r	
77	-35.8320434	174.4991487	2646092	6595411	sonar	r	
78	-35.8316357	174.4991273	2646091	6595456	sonar	r	
79	-35.8307988	174.4990361	2646085	6595549	sonar	sr	
80	-35.8302356	174.4990361	2646086	6595612	sonar	sr	
81	-35.8297367	174.4989824	2646082	6595667	sonar	sr	
82	-35.8290447	174.4989985	2646085	6595744	sonar		photo
83	-35.8292002	174.4994599	2646126	6595726	sonar		photo
84	-35.8294685	174.4996691	2646144	6595696	sonar		photo
85	-35.830477	174.4997281	2646148	6595584	sonar	sr	
86	-35.8309866	174.4997656	2646150	6595527	sonar	s	
87	-35.8317161	174.4997871	2646151	6595446	sonar	s	
88	-35.8321024	174.4997817	2646149	6595403	sonar	sr	
89	-35.8327354	174.4998568	2646155	6595333	sonar	sr	
90	-35.8335454	174.4998998	2646157	6595243	sonar	s	
91	-35.8335079	174.5007742	2646236	6595246	sonar	s	
92	-35.8307827	174.500624	2646228	6595548	sonar	r	
93	-35.8301873	174.500624	2646229	6595614	sonar	r	
94	-35.8298654	174.5006293	2646230	6595650	sonar	r	
95	-35.829801	174.5006347	2646231	6595657	sonar		photo
96	-35.8301819	174.5014018	2646300	6595614	sonar		photo
97	-35.8310349	174.5013589	2646294	6595519	sonar	sr	
98	-35.8317537	174.5014232	2646298	6595439	sonar	r	
99	-35.83273	174.5014984	2646303	6595331	sonar	s	
100	-35.8333523	174.5015091	2646303	6595262	sonar	s	
101	-35.8333469	174.502539	2646396	6595261	sonar	s	
102	-35.8312924	174.5023191	2646380	6595489	sonar	s	edge
103	-35.8312763	174.5033598	2646474	6595489	sonar	r	
104	-35.8320863	174.503215	2646460	6595400	sonar	sr	
105	-35.8332289	174.5032257	2646458	6595273	sonar	s	

106	-35.8332396	174.5042557	2646551	6595270	sonar	s	
107	-35.8320541	174.5040196	2646532	6595402	sonar	r	?
108	-35.8315498	174.5039874	2646531	6595458	sonar	cob	
109	-35.8310241	174.5039606	2646529	6595516	sonar	cob	
110	-35.8307237	174.5039445	2646528	6595550	sonar	cob	
111	-35.8304931	174.5039016	2646525	6595575	sonar	cob	
112	-35.8304662	174.5043522	2646566	6595578	sonar	cob	
113	-35.8313514	174.5046419	2646590	6595479	sonar	sr	
114	-35.8321399	174.5048511	2646607	6595391	sonar	sr	
115	-35.8327515	174.504894	2646610	6595323	sonar	sr	
116	-35.8332826	174.5049101	2646610	6595264	sonar	s	
117	-35.833245	174.505865	2646697	6595267	sonar	s	
118	-35.8314265	174.5053339	2646652	6595469	sonar	s	
119	-35.8304019	174.5049745	2646622	6595584	sonar	r	
120	-35.8302087	174.5055485	2646674	6595604	sonar		photo
121	-35.83111	174.5056397	2646681	6595504	sonar	s	
122	-35.8318288	174.5058328	2646697	6595424	sonar	s	
123	-35.8324082	174.5060688	2646717	6595359	sonar	s	
124	-35.8326925	174.506101	2646719	6595328	sonar	s	
125	-35.8326925	174.5066214	2646766	6595327	sonar	s	
126	-35.8314265	174.5060688	2646719	6595468	sonar	s	
127	-35.8303321	174.5059294	2646708	6595590	sonar	s	
128	-35.8300049	174.5058811	2646705	6595626	sonar	r	
129	-35.829329	174.506557	2646767	6595700	sonar		photo
130	-35.8302517	174.5066965	2646778	6595598	sonar	sr	
131	-35.8309866	174.506734	2646780	6595516	sonar	s	
132	-35.8321453	174.5067716	2646781	6595387	sonar	s	
133	-35.832494	174.5067716	2646780	6595349	sonar	s	
134	-35.8325476	174.5075655	2646852	6595341	sonar	s	
135	-35.8313514	174.5074475	2646844	6595474	sonar	s	
136	-35.8300478	174.5072651	2646830	6595619	sonar	s	
137	-35.8293397	174.5071632	2646822	6595698	sonar	s	
138	-35.8290232	174.507131	2646820	6595733	sonar	s	
139	-35.8285672	174.5078874	2646889	6595783	sonar	s	
140	-35.8295865	174.5079571	2646893	6595669	sonar	s	
141	-35.8302731	174.5079893	2646895	6595593	sonar	s	
142	-35.8315016	174.5080483	2646898	6595457	sonar	s	
143	-35.832435	174.5081288	2646903	6595353	sonar	s	
144	-35.8326442	174.5081341	2646903	6595330	sonar	s	
145	-35.832553	174.5088959	2646972	6595339	sonar	s	
146	-35.8316357	174.5088744	2646972	6595440	sonar	s	
147	-35.8307881	174.5087832	2646965	6595535	sonar	s	
148	-35.829506	174.5085579	2646948	6595677	sonar		photo
149	-35.8286048	174.5084292	2646938	6595777	sonar		photo
150	-35.8303107	174.5198447	2647966	6595570	sonar		photo
151	-35.830257	174.5196247	2647946	6595576	sonar		photo
152	-35.8292914	174.514786	2647511	6595691	sonar		photo
153	-35.8294255	174.514153	2647453	6595677	sonar		photo
154	-35.8296401	174.5137292	2647414	6595654	sonar		photo
155	-35.8297957	174.5126027	2647312	6595639	sonar		photo
156	-35.8296938	174.5121467	2647271	6595651	sonar		photo
157	-35.8282507	174.5082629	2646923	6595817	sonar		photo
158	-35.8285941	174.5077479	2646876	6595780	sonar		photo
159	-35.8289588	174.5071846	2646825	6595740	sonar		photo
160	-35.8293183	174.5066321	2646774	6595701	sonar		photo

161	-35.8295489	174.5062995	2646743	6595676	sonar		photo
162	-35.8300907	174.5055109	2646671	6595617	sonar		photo
163	-35.8304501	174.5048565	2646611	6595579	sonar		photo
164	-35.8304287	174.5036709	2646504	6595583	sonar		photo
165	-35.8304072	174.5034456	2646484	6595586	sonar		photo
166	-35.8311636	174.5028019	2646424	6595503	sonar		photo
167	-35.8313192	174.5026732	2646412	6595486	sonar		photo
168	-35.8312065	174.5019543	2646348	6595499	sonar		photo
169	-35.8303643	174.5014018	2646299	6595594	sonar		photo
170	-35.8297742	174.5010048	2646265	6595660	sonar		photo
171	-35.829565	174.5008063	2646247	6595683	sonar		photo
172	-35.8302034	174.5015198	2646310	6595611	sonar		photo
173	-35.8305789	174.5015681	2646314	6595570	sonar		recrding piles
174	-35.8302409	174.5015144	2646310	6595607	sonar		photo
175	-35.8295221	174.5008707	2646253	6595688	sonar		photo
176	-35.8294148	174.4995618	2646135	6595702	sonar		photo
177	-35.8288355	174.4982958	2646022	6595768	sonar		photo
178	-35.8285726	174.4976252	2645962	6595798	sonar		photo
179	-35.8284707	174.4965094	2645861	6595812	sonar		photo
180	-35.8275748	174.4960749	2645823	6595912	sonar		photo
181	-35.8268506	174.4958496	2645805	6595992	sonar		photo
182	-35.826459	174.4957316	2645795	6596036	sonar		photo
183	-35.8261211	174.4950879	2645737	6596075	sonar		photo
184	-35.8253432	174.4945192	2645687	6596162	sonar		photo
185	-35.8245546	174.4938916	2645632	6596250	sonar		photo
186	-35.8240343	174.4935429	2645602	6596309	sonar		photo
187	-35.823471	174.493323	2645583	6596371	sonar		photo
188	-35.8228649	174.4930709	2645561	6596439	sonar		photo
189	-35.8296079	174.4942671	2645656	6595689	sonar		photo
190	-35.8295543	174.4949484	2645718	6595694	sonar		photo
191	-35.8294953	174.4958818	2645802	6595699	sonar		photo
192	-35.8294685	174.4966167	2645869	6595701	sonar		photo
193	-35.8294577	174.4974482	2645944	6595701	sonar		photo
194	-35.8294148	174.4983977	2646030	6595704	sonar		photo
195	-35.8293934	174.499476	2646127	6595704	sonar		photo
196	-35.8293934	174.5000285	2646177	6595704	sonar		photo
197	-35.829742	174.4999909	2646173	6595665	sonar		photo
198	-35.8296616	174.4987357	2646060	6595676	sonar		photo
199	-35.829683	174.4977647	2645972	6595675	sonar		photo
200	-35.8296938	174.4969279	2645896	6595675	sonar		photo
201	-35.8297045	174.4961232	2645824	6595675	sonar		photo
202	-35.8296991	174.4953776	2645756	6595677	sonar		photo
203	-35.8297045	174.4944763	2645675	6595678	sonar		photo
204	-35.8296777	174.4933283	2645571	6595683	sonar		photo
205	-35.8301712	174.4932962	2645567	6595628	sonar		photo
206	-35.8302141	174.4964075	2645848	6595618	sonar		photo
207	-35.8307506	174.4963807	2645845	6595559	sonar		photo
208	-35.830654	174.497357	2645933	6595568	sonar		photo
209	-35.8305145	174.4980705	2645998	6595582	sonar		photo
210	-35.8303804	174.4988	2646064	6595596	sonar		photo
211	-35.8302356	174.4996154	2646138	6595611	sonar		photo
212	-35.8301658	174.500522	2646220	6595617	sonar		photo

Appendix4. Drop video data points

Wpt	Lat	Long	East	North	Time	Depth	Corrected Depth	Habitat	Notes
213	-35.829409	174.5075	2646852	6595690	9:30 AM	3.5	1.21	s	sand
214	-35.83001	174.50677	2646785	6595624	9:37 AM	4.8	2.55	s	sand, small ripples
215	-35.830622	174.50683	2646789	6595556	9:44 AM	1	-1.2	s	sand
216	-35.82912	174.50664	2646775	6595723	9:50 AM	1.8	-0.36	si	sand, micro algal, film. (diatoms?)
217	-35.829828	174.50555	2646675	6595646	9:56 AM	2.5	0.39	smw	Eckl. on rock, mostly sand. Eckl.+ few C. flex.
218	-35.830493	174.50523	2646645	6595573	10:02 AM	6.3	4.23	s	sand
219	-35.831062	174.50498	2646621	6595510	10:09 AM	6.1	4.09	r	red edge, coarse sand, Eckl., sponges.
220	-35.83141	174.50444	2646572	6595473	10:15 AM	7.5	5.54	sr	Eckl. + C. flex. Sand patches
221	-35.831711	174.50472	2646597	6595439	10:22 AM	12	10.1	s	sand, scattered shells, Patiriella
222	-35.830853	174.5042	2646551	6595535	10:29 AM	6.3	4.46	sr	sand, few rock with Eckl.
223	-35.830708	174.50456	2646584	6595550	10:35 AM	4.5	2.71	smw	Eckl. + C. flex.
224	-35.830359	174.50338	2646478	6595591	10:42 AM	1.3	-0.43	si	sand
225	-35.830418	174.50323	2646464	6595585	10:49 AM	1.5	-0.16	si	sand
226	-35.830724	174.5031	2646452	6595551	10:55 AM	3	1.39	s	sand, possible Caulerpa field.
227	-35.830976	174.50303	2646445	6595523	11:02 AM	5.2	3.65	s	sand
228	-35.831072	174.50352	2646489	6595512	11:09 AM	7.8	6.32	s	sand
229	-35.831646	174.50291	2646433	6595449	11:15 AM	10.7	9.27	s	gravelly sand
230	-35.831244	174.50236	2646384	6595494	11:21 AM	6.2	4.83	rcf	C. flex. Forest
231	-35.830166	174.49886	2646070	6595620	11:28 AM	7.9	6.59	sr	Eckl. forest, sand patches, sponges
232	-35.830482	174.49753	2645950	6595587	11:34 AM	5.4	4.14	sr	Eckl. sand ?areas
233	-35.830659	174.49758	2645953	6595567	11:40 AM	10.7	9.5	rdl	Deep reef. Sponges. Low rock
234	-35.83074	174.49759	2645954	6595558	11:47 AM	16.2	15.06	rdl	Deep reef, sponges, low rock
235	-35.830847	174.49772	2645965	6595546	11:54 AM	18.4	17.32	cob	cobbly, deep reef, rather dark
236	-35.830987	174.49774	2645967	6595530	11:02 AM	16	14.45	sg	shell gravel, big ripples
237	-35.831282	174.49781	2645973	6595498	11:10 AM	15.5	14.03	sg	shell gravel, big ripples
238	-35.831797	174.49788	2645978	6595440	11:18 AM	15.7	14.3	sg	shell gravel, ripples

Wpt	Lat	Long	East	North	Time	Depth	Corrected Depth	Habitat	Notes
239	-35.832473	174.49796	2645984	6595365	11:26 AM	18.8	17.47	sg	shell gravel,
240	-35.832419	174.4995	2646124	6595369	11:34 AM	17.8	16.54	sg	shell gravel, small bits of rock
241	-35.832403	174.49957	2646130	6595370	11:44 AM	18.9	17.73	sg	shell gravel, big ripples
242	-35.831872	174.49654	2645857	6595434	11:52 AM	21.2	20.1	sg	cobbly, probably shell gravel (ss interp. Sand)
243	-35.831378	174.4967	2645873	6595489	12:01 PM	23.3	22.28	s	too dark (ss interp. Sand)
244	-35.830949	174.49677	2645879	6595536	12:09 PM	27.5	26.54	rdl	too dark (ss interp. Rock)
245	-35.83081	174.49678	2645881	6595552	12:17 PM	20.3	19.4	rdl	probably deep reef (ssinterp. Rock)
246	-35.830649	174.49662	2645867	6595570	12:25 PM	10.5	9.66	re	Ecklonia+ C. flex. Reef
247	-35.830241	174.49651	2645858	6595615	12:33 PM	9.1	8.32	rdh	deep reef , good sponges with Eckl. Higher down wall
248	-35.830075	174.49664	2645870	6595633	12:41 PM	6.8	6.07	rdh	deep reef, good sponges, few Eckl.
249	-35.83008	174.49658	2645865	6595633	12:50 PM	2.4	1.73	re	Eckl. Forest
250	-35.830064	174.4965	2645857	6595635	1:01 PM	13.5	12.89	rdl	deep reef, lowish rock
251	-35.830064	174.49635	2645843	6595635	1:40 PM	15.5	15.05	rdl	deep reef with sandy patches
252	-35.830348	174.496	2645811	6595604	1:48 PM	21.2	20.77	sg	probably shell gravel-too dark
253	-35.830429	174.49623	2645832	6595595	1:56 AM	24.4	24.2	sg	too dark (ss interp no rock)
254	-35.829823	174.49694	2645897	6595661	1:04 PM	7	6.41	sr	Eckl. + sand patches
255	-35.829479	174.49682	2645887	6595699	2:12 PM	9.5	9.1	s	shelly sand
256	-35.829249	174.49676	2645882	6595725	2:20 PM	6.8	6.4	sr	shell gravel + rock patches with Eckl.
257	-35.828868	174.49639	2645849	6595768	2:28 PM	5.8	5.39	re	Eckl. Forest. Sand nearby
258	-35.828669	174.49648	2645858	6595790	2:36 PM	6	5.58	sr	rocks with Eckl. + sand. Mixed even.
259	-35.828809	174.49588	2645804	6595775	2:44 PM	7.8	7.37	sr	mixed rock + sand, some Eckl.
260	-35.828701	174.49528	2645749	6595788	2:52 PM	4.9	4.45	sr	rocks with Eckl. + sand. Mixed even.
261	-35.829731	174.4976	2645957	6595670	3:00 PM	1.5	1.03	re	Eckl.
262	-35.829656	174.49752	2645950	6595678	3:08 PM	3.5	3	re	Eckl.
263	-35.829431	174.49751	2645950	6595703	3:16 PM	7.6	7.07	s	shelly sand, possible Atrina?
264	-35.829726	174.49821	2646012	6595670	3:24 PM	3	2.43	rcf	C. flex. forest

Wpt	Lat	Long	East	North	Time	Depth	Corrected Depth	Habitat	Notes
265	-35.829662	174.49816	2646008	6595677	3:32 PM	5.5	4.89	re	Eckl. Forest
266	-35.829565	174.49811	2646003	6595688	3:40 PM	8.8	8.14	sr	mixed Eckl. On rock, +sand
267	-35.829318	174.49834	2646025	6595715	3:48 PM	4.1	3.39	s	cobbly sand? Small weeds
268	-35.829898	174.49849	2646037	6595650	3:56 PM	2	1.24	rsmw	mixed C. flex & Ecklonia
269	-35.829876	174.49857	2646045	6595652	3:02 PM	4.3	3.82	re	Eckl. Strong current, near reef edge,
270	-35.830085	174.49878	2646063	6595629	3:10 PM	6.8	6.29	re	Eckl. Current
271	-35.830236	174.49848	2646036	6595613	3:18 PM	2.6	2.06	re	Eckl. Sponges under, sweep & juv. Blue maomao.
272	-35.830397	174.49822	2646011	6595595	3:27 PM	6.1	5.51	re	sparse Eckl. Sponges under
273	-35.830616	174.49801	2645992	6595571	3:35 PM	15.5	14.87	rdl	sponge garden. Low rock with some sediment
274	-35.83082	174.49827	2646015	6595548	3:43 PM	12.1	11.43	sg	shell gravel
275	-35.831266	174.49878	2646060	6595498	3:51 PM	14.7	13.98	sg	shell gravel
276	-35.830048	174.49947	2646125	6595632	3:59 PM	4	3.22	s	sand
277	-35.830198	174.49934	2646113	6595615	4:06 PM	3.7	2.87	s	shelly sand
278	-35.830338	174.50036	2646205	6595598	4:15 PM	4.2	3.31	s	sand
279	-35.830697	174.50037	2646206	6595558	4:23 PM	7.3	6.34	s	sand, ripples
280	-35.831105	174.50117	2646277	6595512	4:31 PM	14.7	13.68		(ssinterp. Something)
281	-35.830949	174.50152	2646309	6595529	4:40 PM	17.6	16.5	sr	mixed rock + sediment,C. flex.forest)
282	-35.831035	174.50151	2646308	6595519	4:50 PM	10.3	9.12	sr	mixed rocck + sediment
283	-35.829865	174.5012	2646282	6595649	5:20 PM	1.5	0.05	s	(s/s interp. Seagrass?)
284	-35.830069	174.50082	2646247	6595627	5:06 PM	5.1	3.77	sr	mixed rock + sediment)
285	-35.829479	174.50071	2646238	6595693	5:30 PM	1.3	-0.24	sr	(s/sinterp. Mixed rock +sediment, cobble/gravel + some algae)