Orange Roughy Fishery Benthic Habitat Mapping ORH3B

Introduction

In recent years a range of predictive models have been developed to attempt to define habitat suitability for VME taxa such as corals. Examples of this include the Maximum Entropy "MaxEnt" and Boosted Regression Tree "BRT" models developed for the South Pacific Fisheries Management Organisation. One major problem with this approach is the need for ground truthing of the models, and dealing with zero data records. In the case of SPRFMO, some ground truthing was carried out by use of a research vessel (RV Tangaroa) with NIWAs Deep Towed Imaging System (DTIS) to collect substrate type. However this is a very expensive way to collect such data.

There is another way to approach the definition of bottom habitats, by using sonar technology to determine the type of habitat. The power of sonar is shown in Figure 1which is from the Indian Ocean, where the metal wires from a sea anchor attached to a sunken fishing vessel in 4000 m of water can be seen on the mud. This is the latest high frequency sonar imaging technology in use.

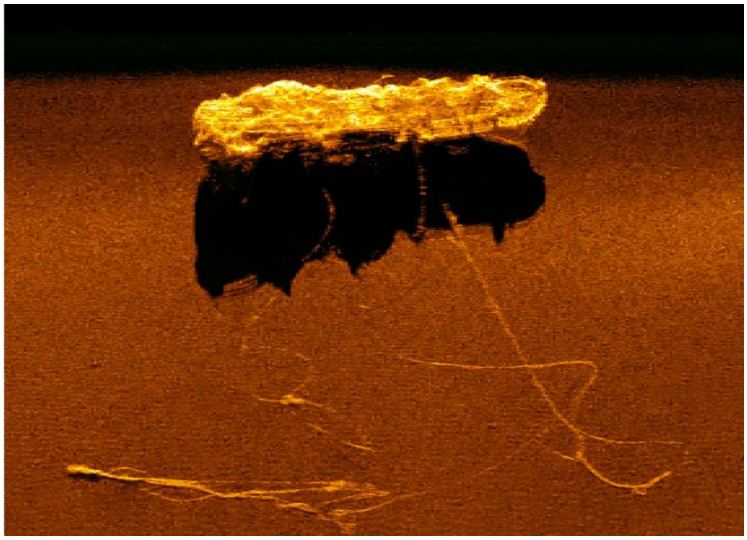

Figure 1 Sonar image of 42m Fishing Vessel on the bottom in 4000m

In 1994, a full sidescan sonar survey over orange roughy habitat on the Chatham Rise was carried out by the fishing industry ORH3B quota owners (The Orange Roughy Management Company). This survey was carried using the MR1 towed body system from the University of Hawaii Mapping Group, on the fishing vessel *FV Arrow*. This system provided a sidescan swath to almost 10 kilometres either side of the vessel, when steaming along the 1000 m contour. The objective of the survey was to identify the habitat between 800 and 1400 metres across the whole region, focussing on areas outside the historical fishery. The power of sidescan sonar technology is that it provides an opportunity to compare soft and hard bottom habitat such as sand/mud compared with rock and volcanic cones or lava flows.

Hawaii MR1

The HAWAII MR1 (HIG Acoustic Wide-Angle Imaging Instrument, Model Revision 1) seafloor imaging system is a wide swath side-scanning sonar instrument that acquires digital bathymetry and acoustic backscatter (sidescan sonar) in full ocean depths. It is a system that simultaneously acquires digital bathymetry (swath width > 3.4 times water depth) and sidescan sonar imagery (swath width > 7.5

times water depth). The system's sonar transducers are housed in a 5-meter-long vehicle that is towed beneath the surface mixed layer (80 to 100 m) at ship speeds of 3 to 10 knots. No hull mounted system can produce the quality of sidescan that good towed systems like MR1 acquire, partly due to differences in how the systems acquire and process the data, and partly due to the physical advantage that towed arrays have by being located below the mixed layer and far from ship noise and below the bubble layer.

MR1's high power and 11/12 kHz frequency enable sidescan swath widths up to 30 km.

Terminology used in this report

The terms "sidescan," "backscatter" and "reflectivity" are often used interchangeably, and incorrectly, when describing data collected by sidescan sonar. The correct definitions of these terms is as follows:

Sidescan is the correct term for the instrument that is used to collect the data.

Backscatter is the measure of the amplitude of a reflected acoustic signal bouncing off the seafloor (or riverbed, etc.). Backscatter results from the small (centimetre scale) reflective surfaces on the seafloor.
Reflectivity refers to the broader scale reflective properties of the seabed (i.e., the side of a hill, the flat region directly under a sonar system).

By juxtaposing successive sidescan pings, it is possible to make an image of seafloor textures in response to sound waves emanating from a particular sonar system (Figure 2). It is important to remember that the measured amplitude will vary as a function of wavelength; towed at the same altitude above the seafloor a 30 kHz sidescan sonar and a 12 kHz sidescan sonar will record different amplitudes.

One of the most common mistakes made by novices to sidescan sonar data interpretation is to assume that the magnitude of the return echo has a geological meaning; that is, that magnitudes in one range correspond to lava flows and magnitudes in another range correspond to coral reefs.

There have been significant efforts to quantify the data collected by various sidescan sonars and systematically characterize the seafloor surface, but these experiments have not been successful.

Nevertheless, the resulting imagery allows scientists to investigate the processes that contribute to seafloor creation and modification. One major advantage of the imagery from the Score 94 Chatham Rise survey is that it was collected with the same 12 kHz tow body used in similar orange roughy habitats in Namibia, South Africa, Eastern Indian Ocean, Western Indian Ocean, and in New Zealand; Challenger Plateau, the Subantartic, Macquarie Ridge. In all these regions there has been ground-truthing of the different reflectivity, by bottom trawling, bottom longlining, and cameras deployed on bottom trawls.

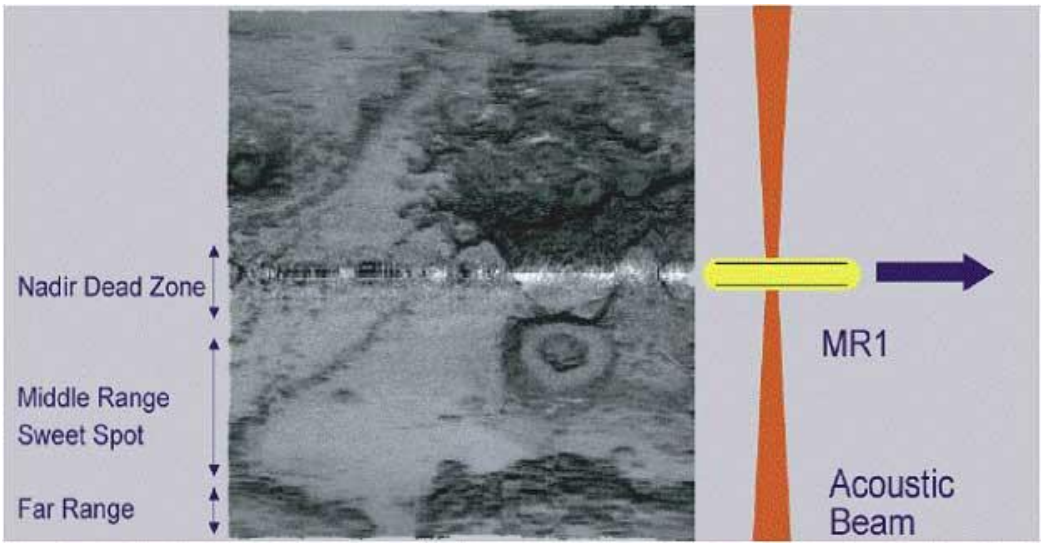

Figure 2- Swath of MR1 sidescan data showing round volcanic cones and tectonic lineations. The labels on the left side of the figure hard and easy parts of the sidescan data swath to interpret.

Interpretation of data

A sidescan sonar image cannot be correctly interpreted without some local knowledge. Prior to, and after the Score94 survey, all New Zealand orange roughy skippers were asked to provide lists of hills and any notes/records they had on habitat. In particular, Captain Mike Baker of the *fv Willwatch* provided his substantial knowledge of the fishery for the planning.

An example of where a skipper noted ROUGH bottom in 760 m depths, which matches the sidescan record, is shown in Figure 3. When a skipper noted rough bottom, they described it as rocky habitat that is difficult or impossible to fish on with a bottom trawl. Another guide was where FAST was noted, which is where the trawl has hit an obstruction (generally rock) and become stuck on the bottom. In this figure, the dark area marked rough does not have any significant elevation (position shown as red marker in Figure 4). However, it is between two hills each rising to 500 m from the sea surface.

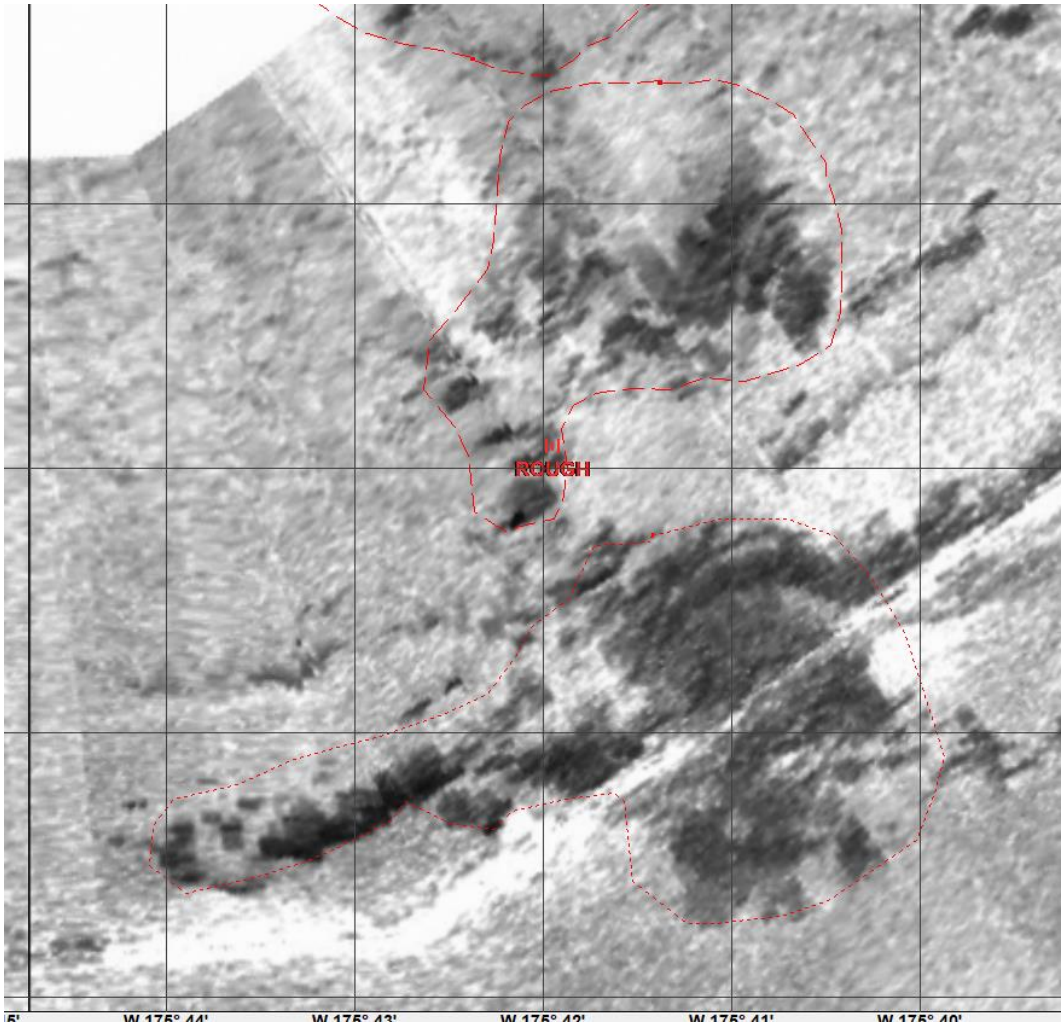

Figure 3 Sidescan image South Chatham Rise showing high reflective habitat

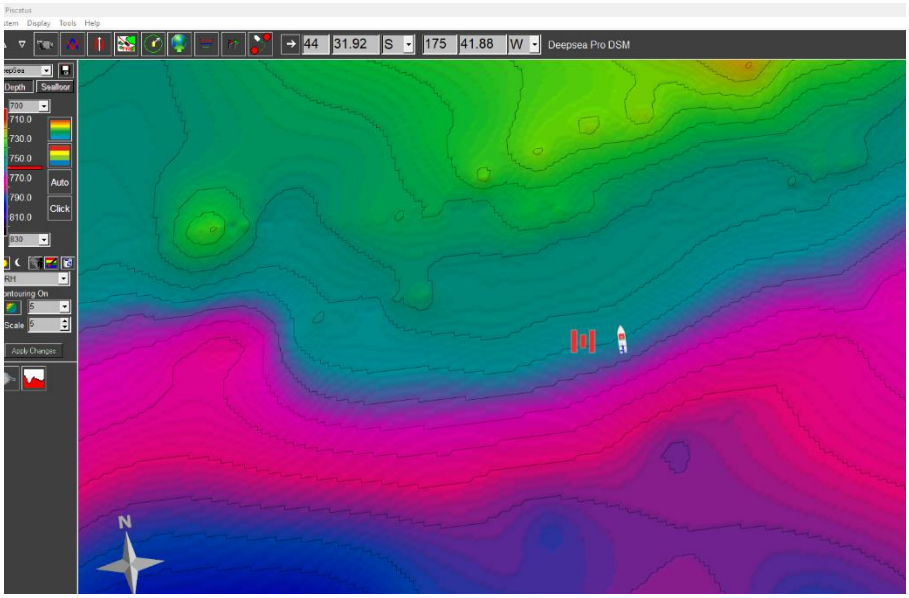

Figure 4 Bathymetry Map (Piscatus tm) of rough bottom on South Chatham Rise

Seaplotpro [tm] and Piscatus [tm]

These two fishing vessel bridge management programs developed in New Zealand work together on one computer with two screens, so that both bathymetry and vessel recordings can be viewed on either screen, as they 'talk' to each other. This provides the technology to look at a sidescan image on one screen and view the bathymetry in fine scale at exactly the same position on the other screen (Figure 5). This was an important component of this habitat assessment. It allowed the cross checking of all sidescan imagery that was available georeferenced.

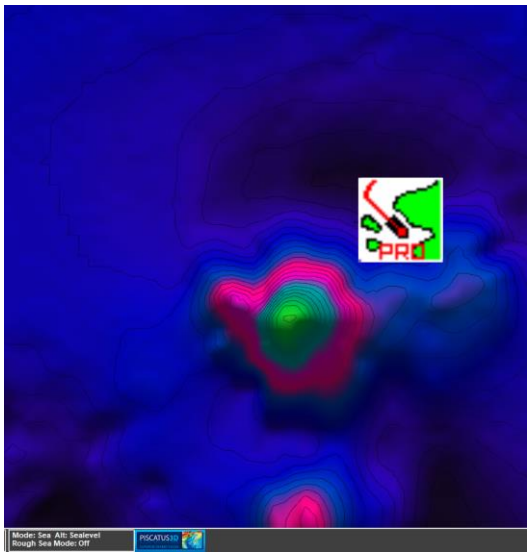

Figure 5 Piscatus bathymetry with position of cursor on Seaplotpro

Analysis of Habitat Capable of supporting Corals

The process followed was to view the processed sidescan images on Seaplotpro, with georeferencing, and to draw boundaries around the areas of high reflective data, cross referencing with the bathymetric data on Piscatus. These were also compared with the original sidescan images which used the full swath available from the MR1 system, but were not georeferenced images. This was important to clarify the full extent of the rocky habitat in various areas. The final processed records did not include far range data. An example of this process is shown in Figure 2 where the processed data on the left did not include the full swath data shown on the right. The rocky habitat extends well to the north. The defined area shown in red is the best estimate available. It is likely an underestimate, because the far field data also suggests more hard habitat to the west. Enhanced processing of the raw data from Score94 could improve this interpretation.

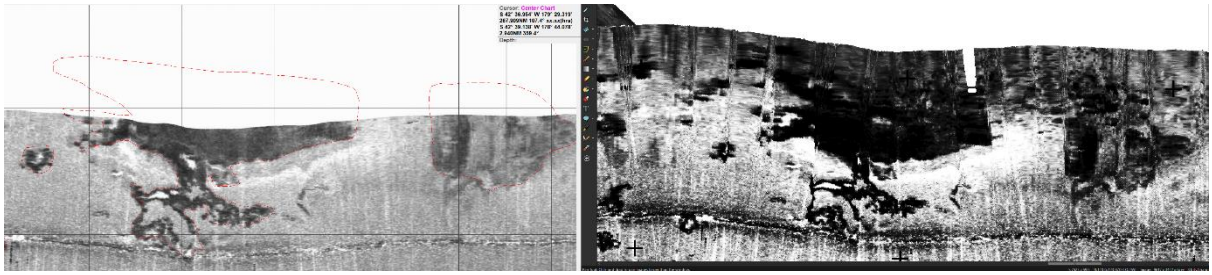

Figure 6 Sidescan coverage from processed data compared with far range data

To use the sidescan swath data to demark high reflective habitat indicative of rocky habitat that can support corals, it is necessary to take account of the trackline and which way you are looking at the backscatter return. Bathymetry data must also be taken into account, to detect whether the feature is going up (a UTF) or down into a canyon or hole.

Not all areas of the Chatham Rise had sidescan coverage, and known UTFs were plotted using bathymetry data. In particular this dealt with the knolls on the South Chatham Rise.

Habitat Areal Assessment Approach

Polygon areas were mapped in planar scale, i.e flat. Although each knoll or UTF is often a cone with larger total area than the base area, for habitat impact assessment it is the base area that is needed. For all the fished area assessments in SPRFMO and SIOFA, when trawl impact data on knolls or seamounts are analysed, the actual footprint measured is also planar (difference in latitude and longitude start and finish positions). Lines were split on the 180^{o} line to allow polygon processing, and on the QMA boundary for NWCR.

The line points from Seaplotpro were exported and converted to DMS xyz data and imported into ArcGIS Pro. The points were then converted to lines then polygons and exported to ArcMap shapefile format. The ArcGIS Pro project was maintained, to provide for future analysis work, as this GIS system holds much more precise data than is stored in the shapefile format. This allows modification of points, and recalculation of areas.

Data Sources

The Score94 survey was led by Professor Charles Helsley, Director of the Hawaii Institute of Geophysics, and Graham Patchell of the Orange Roughy Management Company. Cruise notes and records of geological and habitat observations taken during the cruise were used in this analysis.

From the Score94 survey, a total of 18 charts were produced for the initial report (Figure 7). These charts were stored as tif images, not as geotiff images. They are available from the Score94>Arrow94>Imagery folder. A subset of charts with the far field data excluded, are Charts 1-21 are in portable grey map format (.pgm). The parameter files for these charts are in proprietary format of Seabed Mapping International Limited and stored under Score94>Arrow94.

Cruise reports and data files supplied by various skippers to the Score94 team were a key source of information for the analysis.

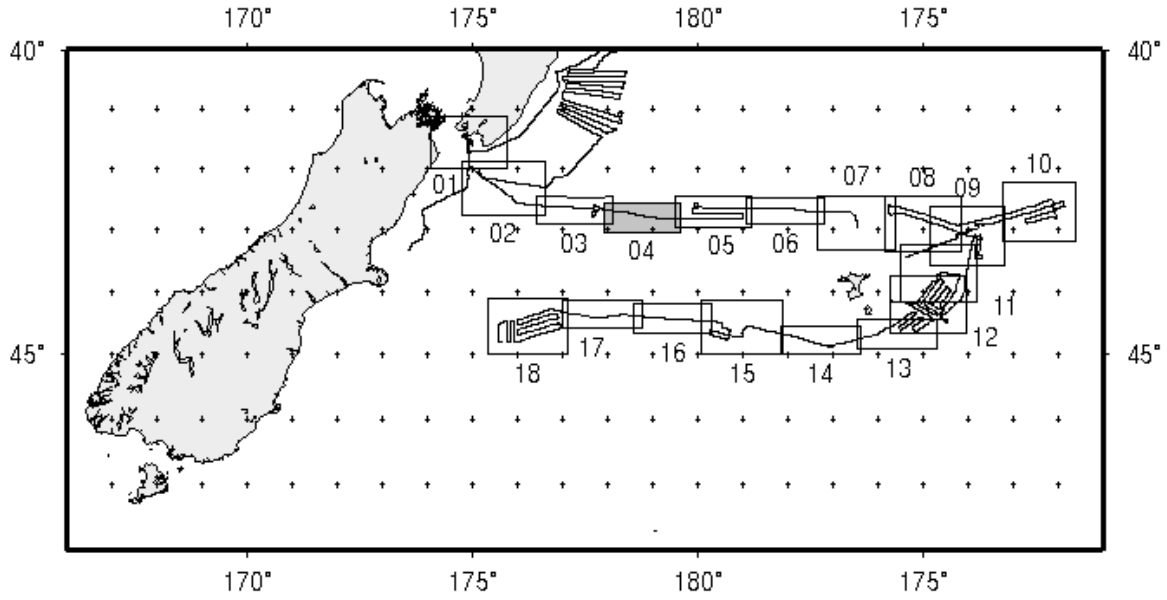

Figure 7 Score94 Survey Tracks and Chart numbers

Northwest Chatham Rise (Chart 4)

This region contains the Graveyard complex of knolls which rise 200m off the surrounding seafloor. The Morgue feature (Figure 8) has a long ridge which extends to the south and is covered with coral according to a NIWA study. In this case, using bathymetry of the actual feature to establish potential habitat would underestimate the area. Off to the west is an area of hard bottom in 1200 metres that has little elevation (10-20 metres).

The Graveyard Volcano has a crater in the centre. There are numerous small features rising 50 m high, surrounding the main volcano. The full extent of the high reflectivity in the whole area is shown in the sidescan image (Figure 9), and the whole structure should be considered potential coral habitat.

To fully understand the rocky habitat on these two features, the trawl corridors that have been successfully fished are important (Figure 10). On Morgue it is not possible to trawl to the west because of the rocky habitat in this area noted by skippers, and it is the same for trawling north or south. This feature was originally proposed for closure to fishing because 100% of the fished area had been fished.

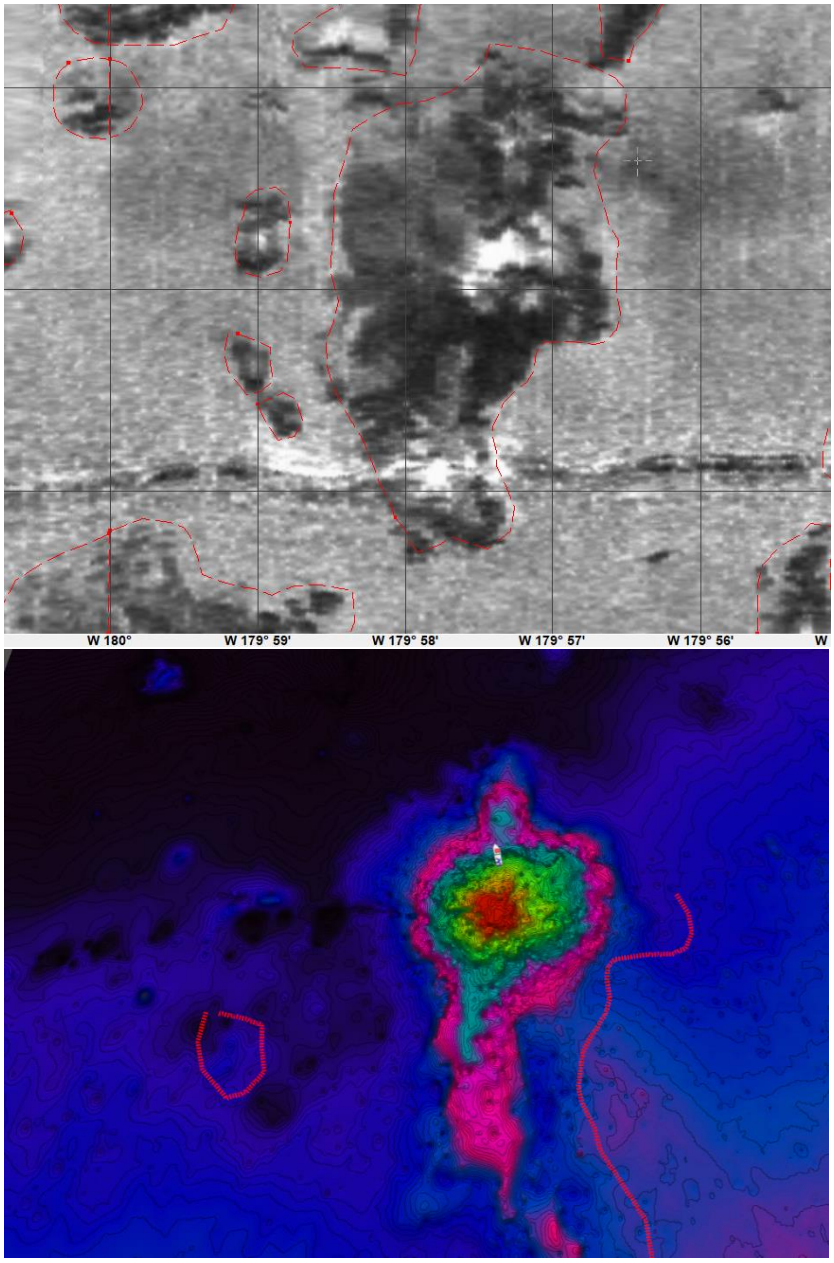

Figure 8 Sidescan and bathymetry of the Morgue knoll.

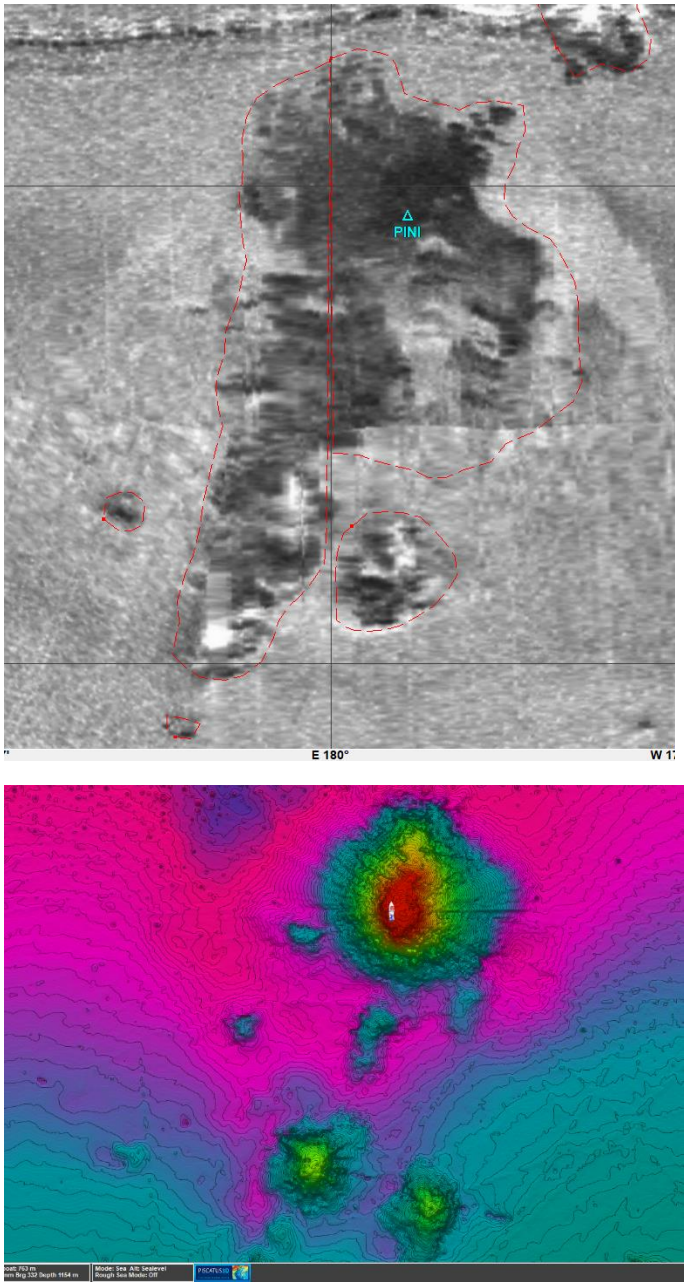

Figure 9 The Graveyard Volcano Sidescan and bathymetry

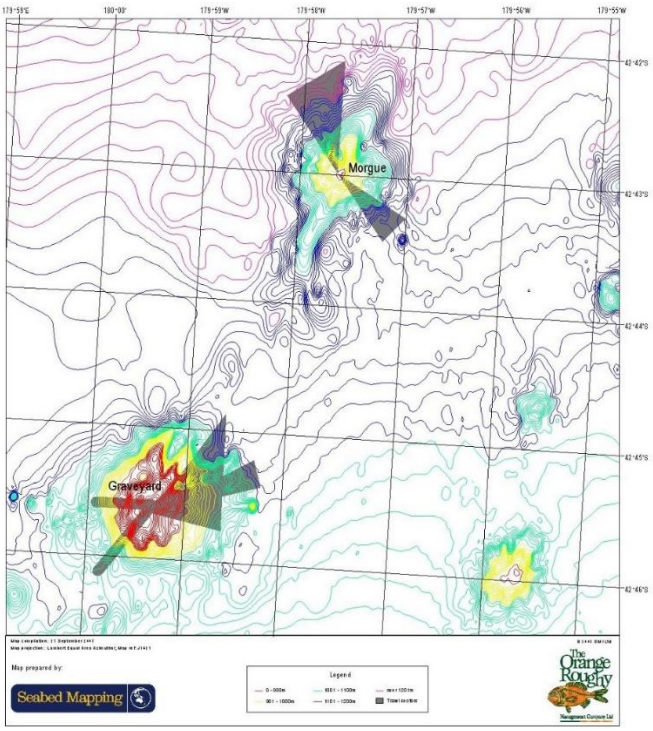

Figure 10 Fished Areas on Graveyard and Morgue

ESCR Region- North Chatham Rise

The East and South Chatham Rise rocky habitat area starts with Rekohu (Figure 11) on the North Chatham Rise where a new orange roughy spawning stock was discovered in 2011. This region was identified during Score94 as being hard rolling habitat likely to contain orange roughy according to Professor Helsley, as the backscatter record printed out real time. The region includes a 50 m high 'brick' well known by fishers as an obstruction to avoid when trawling. The region continues eastwards to cover the region where what is now termed the Old Plume region around 177 10E. The habitat region southern extent is close to the 1000 m contour line. During the early 1990s this region was fished extensively with bottom trawling from vessels such as the Akebono maru 73, which were successfully fishing deeper than the New Zealand fleet earlier in the season.

Also in this region is the 'Crack' or ' Mt Muck', all of which is included as potential habitat. This feature was just inside of the sidescan sonar survey, and bathymetry has been used to define the area (Figure 12). There are much more precise bathymetric data for this feature held by NIWA, and also significant video footage of the bottom habitat from AOS surveys carried out by Deepwater Group.

Most of this region is covered with soft sediment. There is extensive coverage of the 800-1000 m depth range from 177 W to 179 W with AOS bottom trawl videos which show sediment and little else. No standing corals have ever been identified in the video footage by the author of this report, who has viewed all the footage.

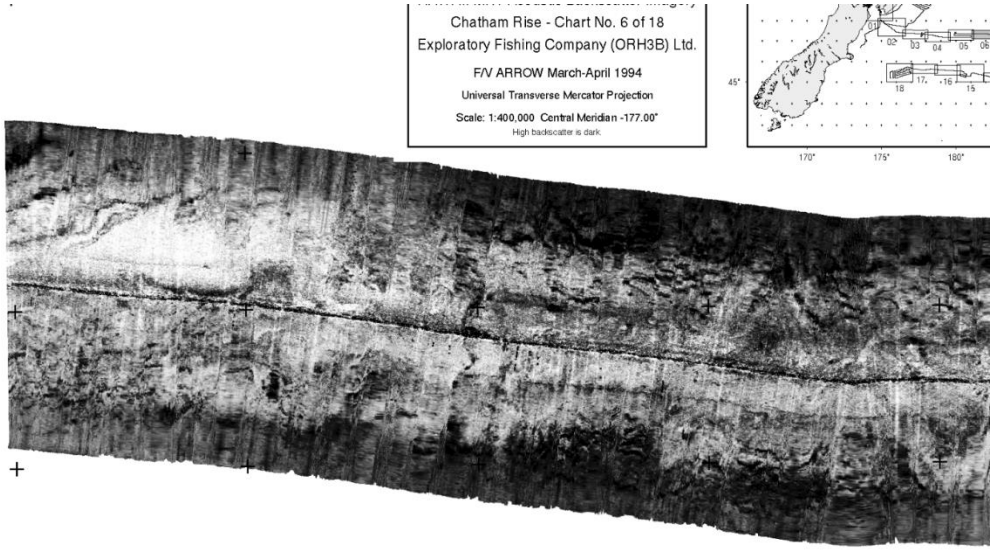

Figure 11 Rekohu to Old Plume Region sidescan

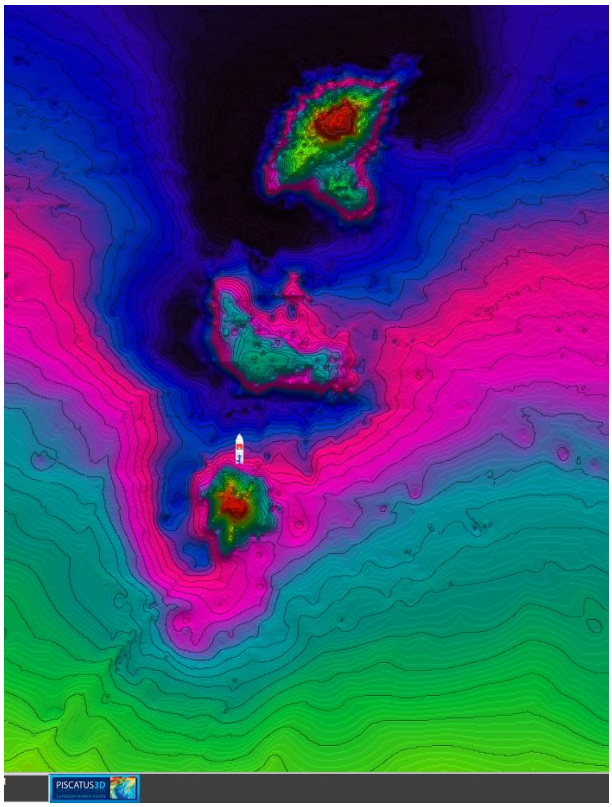

Figure 12 Bathymetry of the Crack

ESCR Region NE Chatham Rise

Most of the northeast Chatham Rise knolls were covered with sidescan sonar. Many of the knolls were well known by fishers, but additional deeper ones were located. One knoll that rose to 1183 metres was included in the habitat analysis as it was potentially 200 m high (Figure 13). There was an area of hard reflective data to the west, which showed strongly on the full swath image. The Piscatus

bathymetry indicates rising bottom here, but more detailed data would be useful. The area was included as habitat.

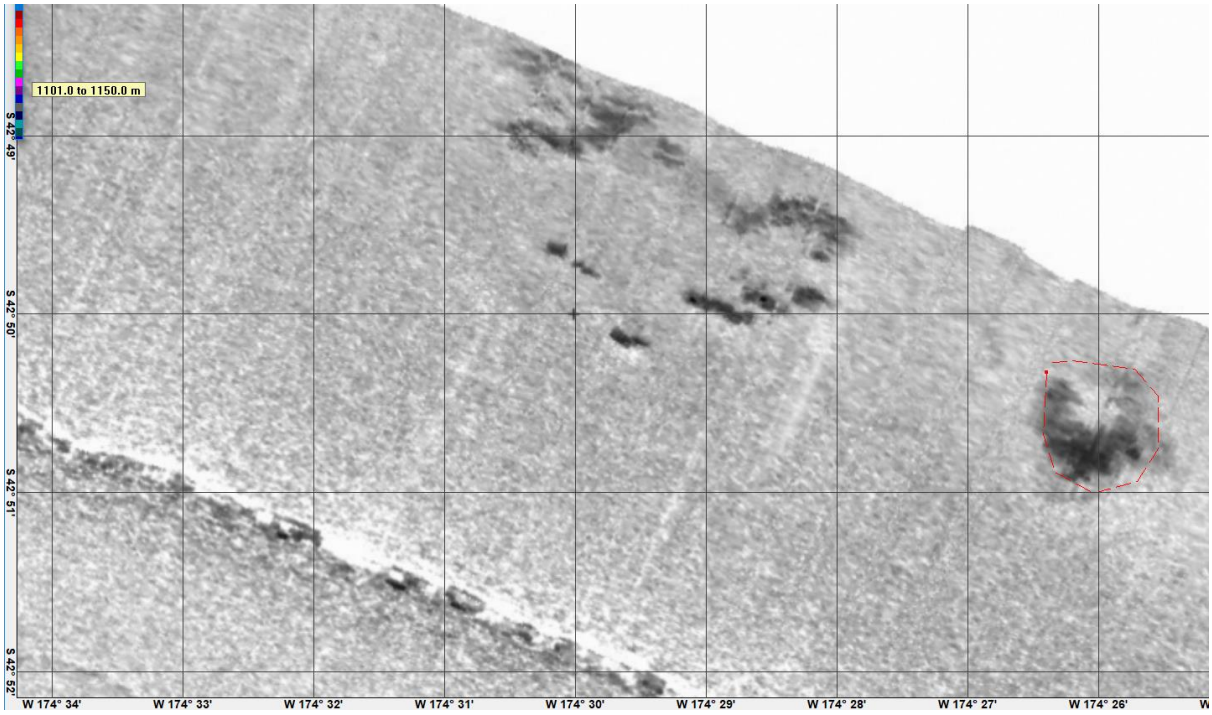

Figure 13 Deep knoll on NE Chatham Rise

There were other deeper knolls rising out of 1600 metres to 1363 m identified as rocky habitat and included in the analysis. One of these is shown in Figure 14, and is 2.6nmx 1.6 nm in area, making it bigger than the Morgue knoll. There is no evidence of this knoll ever being fished, which is likely because of the depth at the top.

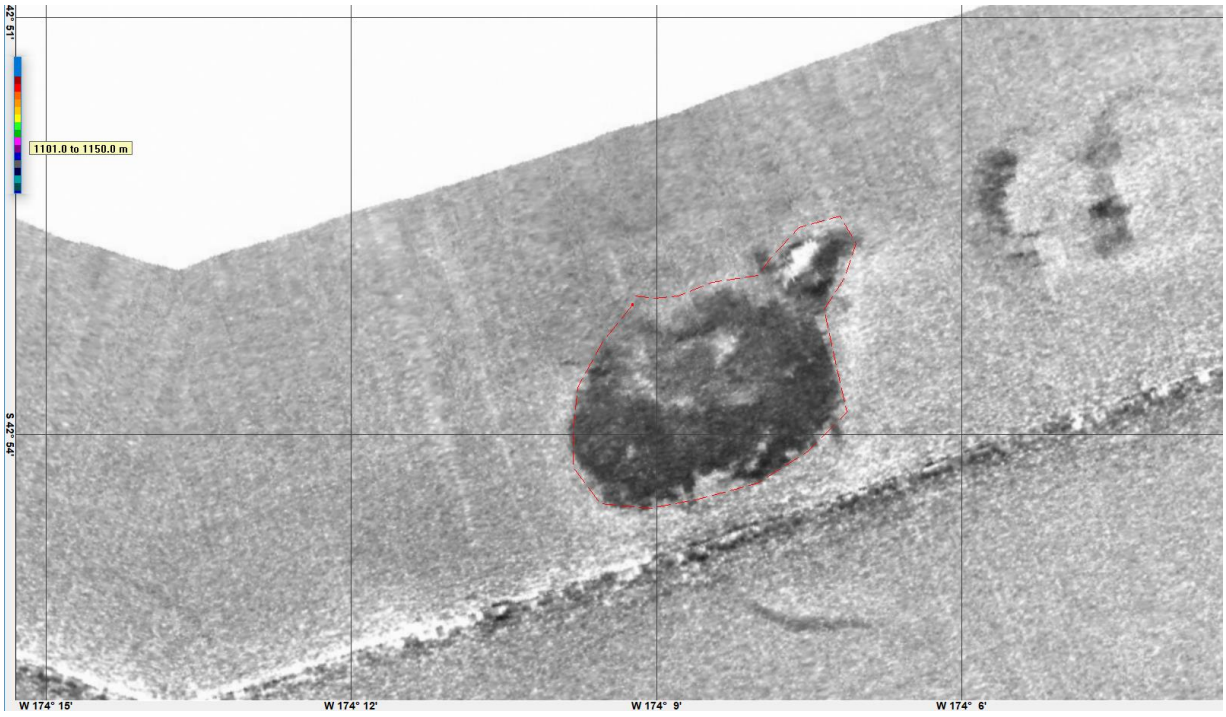

Figure 14 Large unfished knoll on NE Chatham Rise

To the northeast of this knoll is an area originally called Dreamtime which is a series of 3 knolls that rise from 2000 metres up to 1240 metres. These knolls were just outside of the sidescan survey which had identified extensive hard reflective data in 1600-2000 m depths (Figure 15), which was deeper than the depth range in this analysis. However, Geosat data also suggested elevated habitat to the north of this. The habitat was subsequently reported by fishers as being very difficult to fish, with many fast trawl shots which can be taken very strong evidence of hard rocky bottom. Orange roughy were caught here.

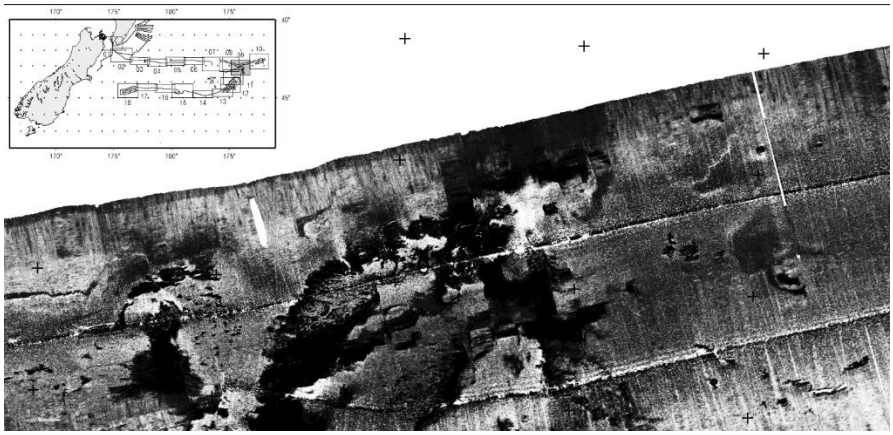

Figure 15 Sidescan sonar image of area between Arrow Plateau and NE hills

Arrow Plateau (Chart 10)

The Arrow Plateau is separated from the Northeast Chatham Rise by 1600-1800 metre water depths. During the survey the geologists on board were confident they were identifying lava flows in the real time sidescan imagery being monitored on each transect.

The plateau has a large volcanic lava coverage and a number of volcanoes. This rugged volcanic field is in 1300-1500 metres, and the two main cones rise to about 1000 metres (Krakatoa and Ho Whyte). Other cones include Saigon Sal at 1232m, Raffles at 1370m, China Beach at 1439m, Tokyo Rose at 1270m, Ho Chi Min at 1236, Kowloon at 1309m, and Kai Tak at 1212m. All these named features will have been fished on. There are also others with tops of 1356 to 1526m that do not appear to have been fished.

The imagery is shown in Figure 16 , with the dark reflectivity showing the volcanic rock. This image had not been processed with suitable georeferencing. The areas were estimated from comparison between bathymetry for each area and the approximate position of the dark reflectivity, and the known cone position.

A fishery for orange roughy occurred on these two cones (Figure 17), but a few fish have also been caught on the 'soft' bottom by RV Tangaroa in 1600 m using a bottom trawl (Dr Don Robertson pers com.)

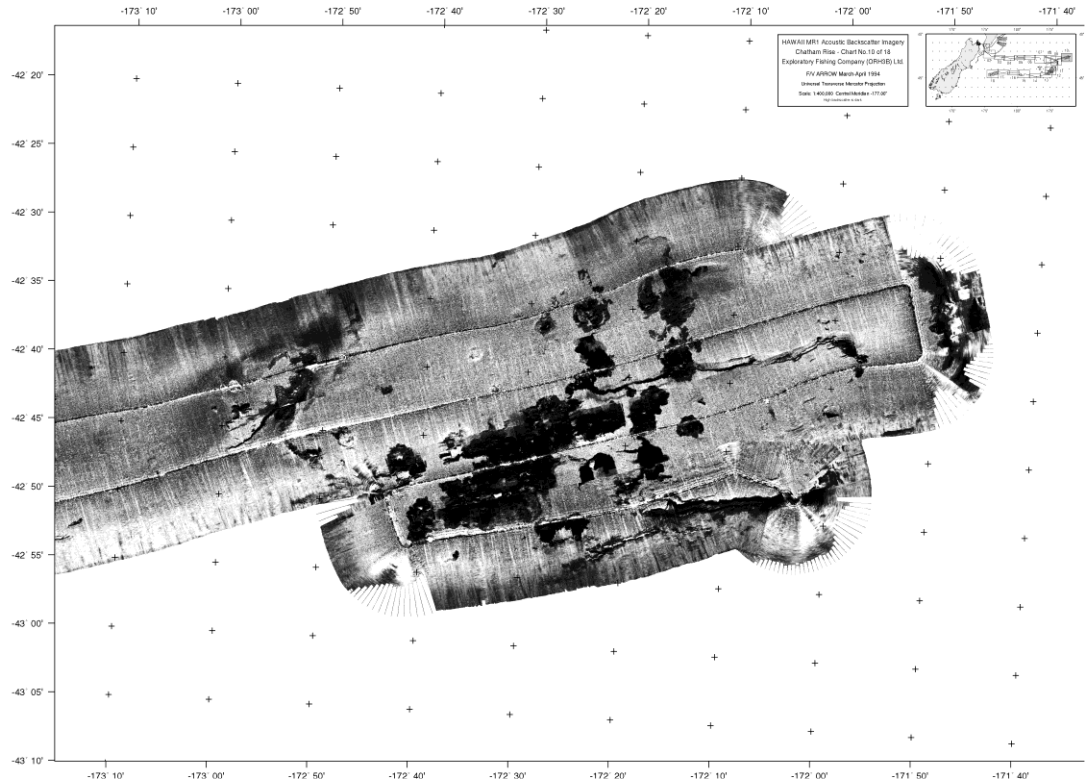

Figure 16 Arrow Plateau Sidescan Image full swath

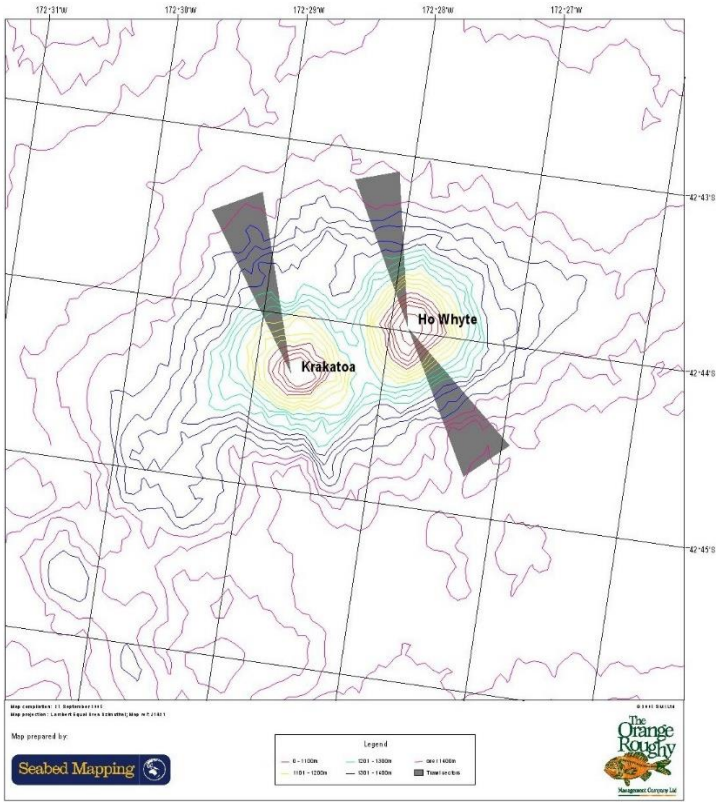

Figure 17 Skippers evaluation of Trawl Path on Arrow Plateau volcanos

Andes-Chief Complex (Charts 11-12)

This complex of knolls to the east of the Chatham Islands was completely sidescan surveyed during Score94, even though most of the knolls were known in this area. This was carried out to ensure full habitat knowledge of this important region for the orange roughy fishery.

The region is complex with many steep gullies and steep cliff faces falling into deep water off the top of flat plateaus, as well as numerous volcanic knolls of different size. Large parts of this region are unfishable because of this complex topography. In Figure 18, the rocky/volcanic habitat is surrounded by sedimented bottom in 1000-1200 metres. There has been a significant orange roughy fishery in this region for many years. It is one region where there have been significant coral interactions with bottom trawls. Analysis of this region is important because a large part of the habitat between 500 and 1600 metres bottom depth cannot be fished with bottom trawl.

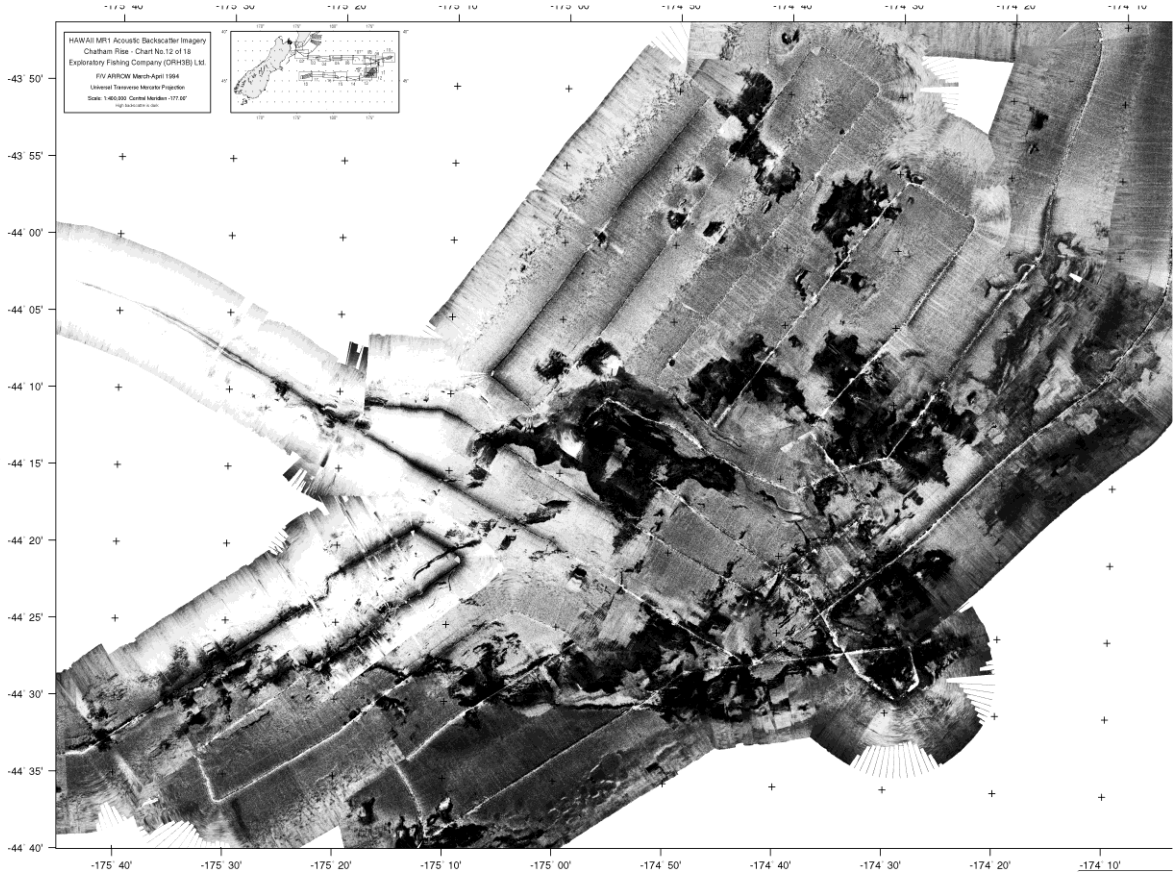

Figure 18 Andes-Chief Complex Sidescan coverage

For example, the region in Figure 19 to the south of the canyon and west of the Andes is a large area of strong reflectivity surrounding two knolls that rise up to 200-260 metres from the base depth around 800 metres. It is the large rocky area surrounding these steep and shallow knolls, in depths of 700-800 metres, and on the northern slopes down to 1100 metres where there are small pinnacles rising 30-50 metres high that are highly likely to be coral habitat not impacted by the fishery. In early voyages this hard bottom area was noted as 'FOUL'. The difference in reflectivity between soft and hard bottom is clearly shown in this area.

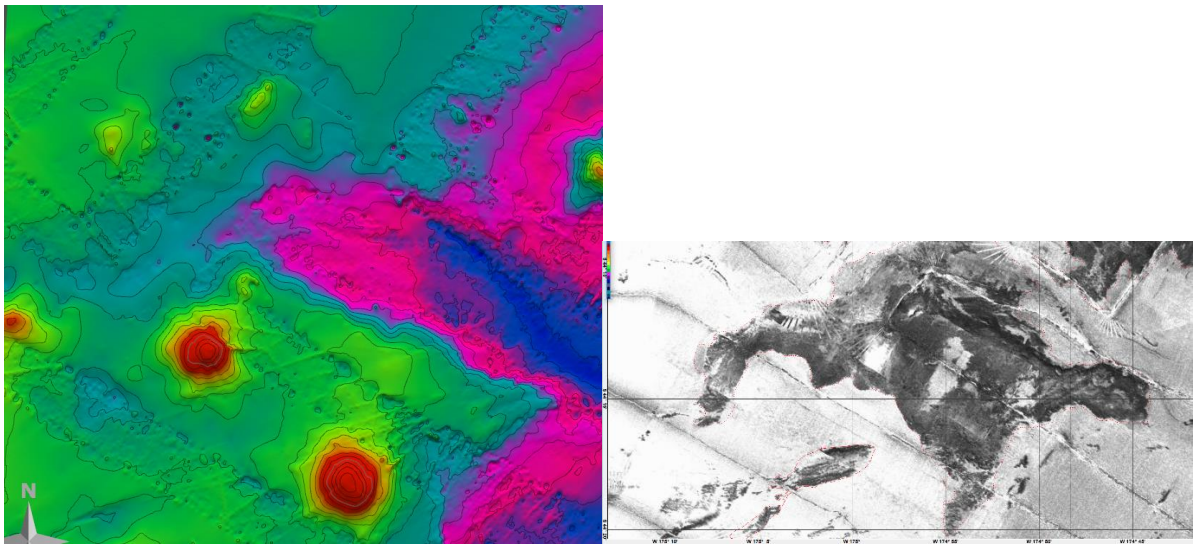

Figure 19 Sidescan and Bathymetry of 100 square miles of rocky habitat west of the Andes

The Andes area, with knolls known by such names as Possum and Opossum, Richie, Cotopaxi, Chile, has extensive rocky habitat suitable for corals. The region is complex, with limited trawl paths available (Figure 20), because of the topography (Figure 21).

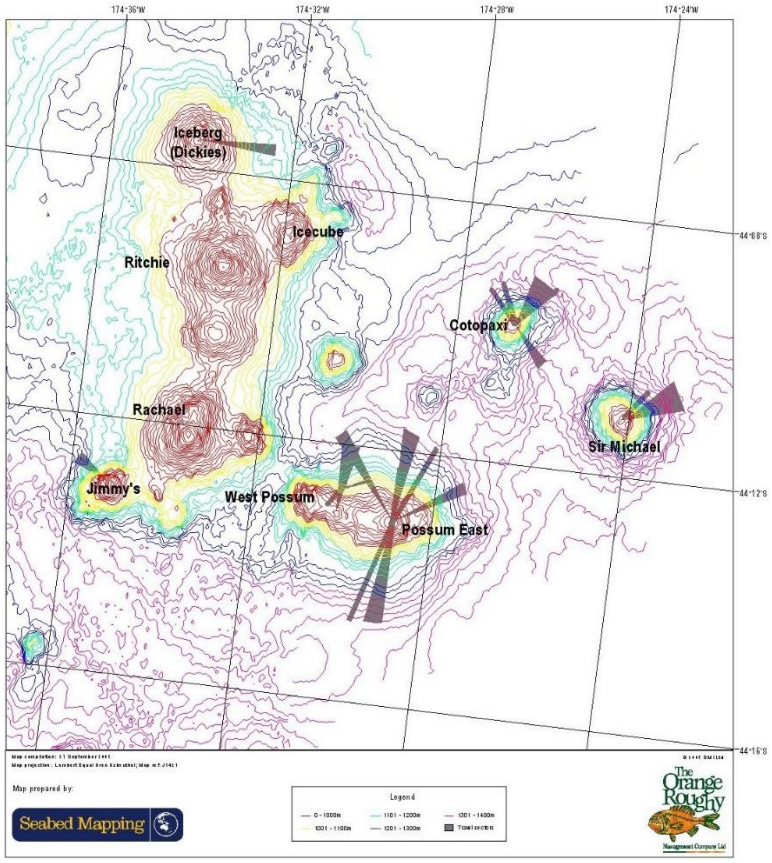

Figure 20 Skippers Evaluation of Trawl Paths on Andes

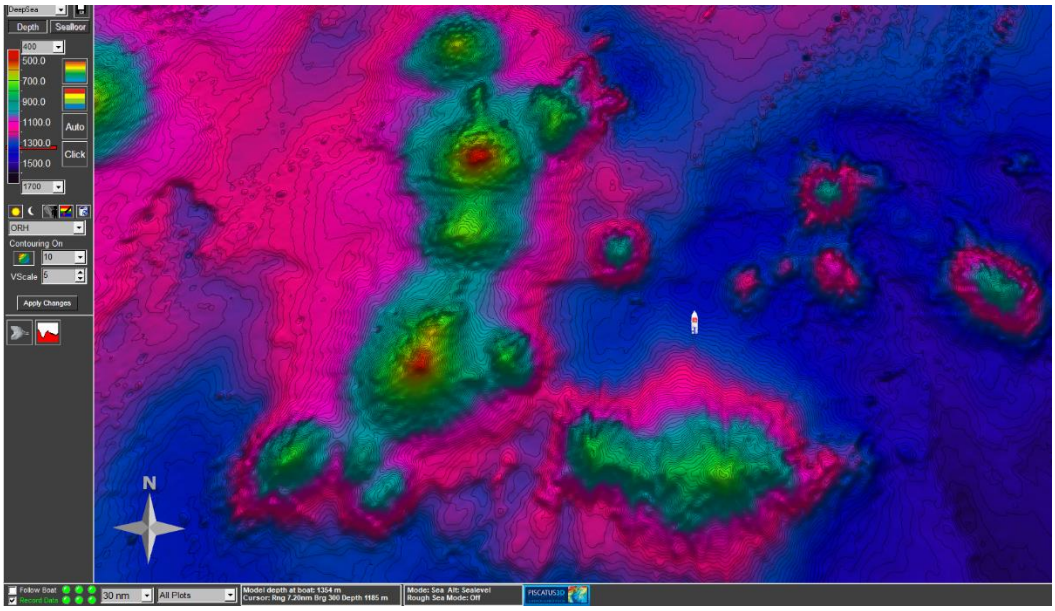

Figure 21 Bathymetry of the Andes Complex

To the northeast of Andes there is an area detected on sidescan that is much more reflective than the surrounding area, extending from 1300 m to 1500 m (Figure 22). The backscatter appears similar to that seen at Rekohu on the north Chatham Rise. This area is worth further study, with examination of any trawl shots carried out here. Additional bathymetry outside of Score94 would also aid analysis. It is not known as a trawling ground to the author's knowledge.

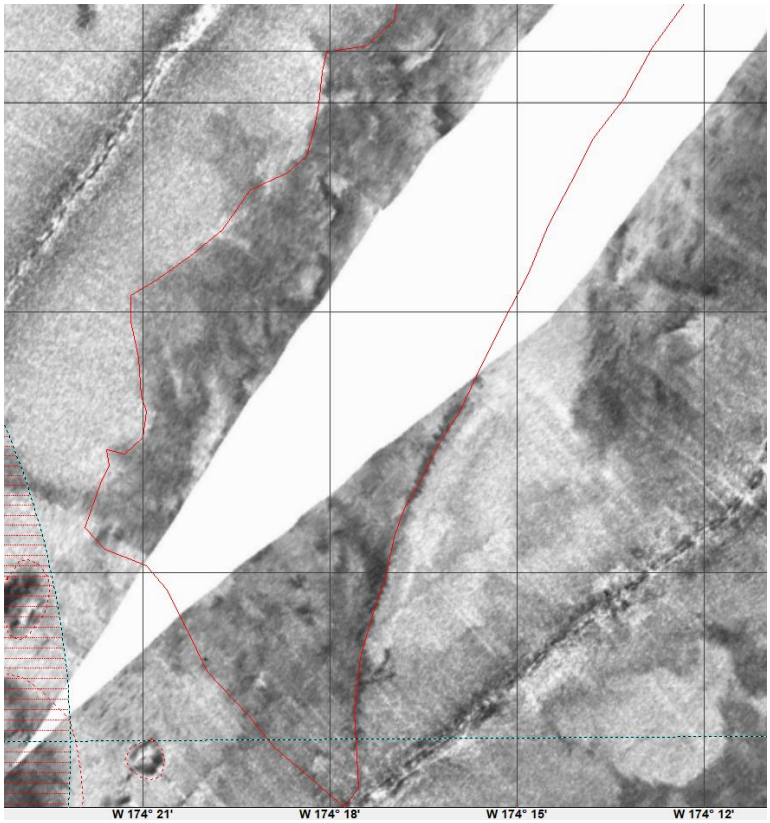

Figure 22 Northeast of Andes habitat identified on sidescan

South of Andes towards the Chief area is a region of deeper water in 1600-1800 m that has higher reflectivity (Figure 23), and two knolls marked in yellow on the image at the top right. There is no bathymetry available for these knolls which appear to rise to under 1600 metres. Further south there is a seamount that rises from 2600 metres to 1579 metres. Both these regions have been included in the potential habitat area. One rationale for this is that it is on the eastern edge of the Chatham Rise, and on the Louisville Ridge the 2014 VME survey noted that corals were more abundant in deeper depths than in New Zealand, with black coral found at 1426m and other corals deeper (Figure 24).

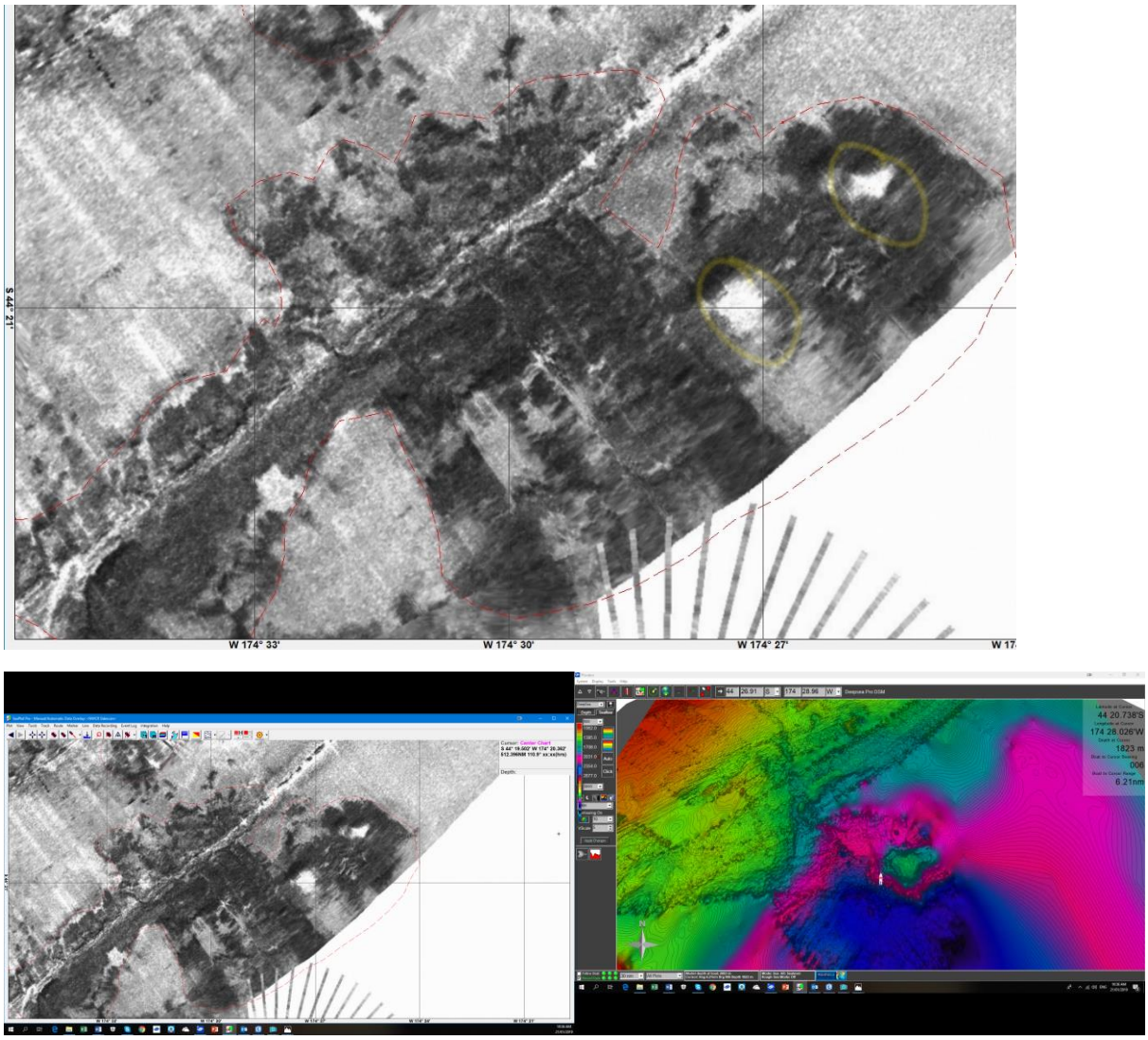

Figure 23 Rocky Habitat Eastern Edge of the Chatham Rise

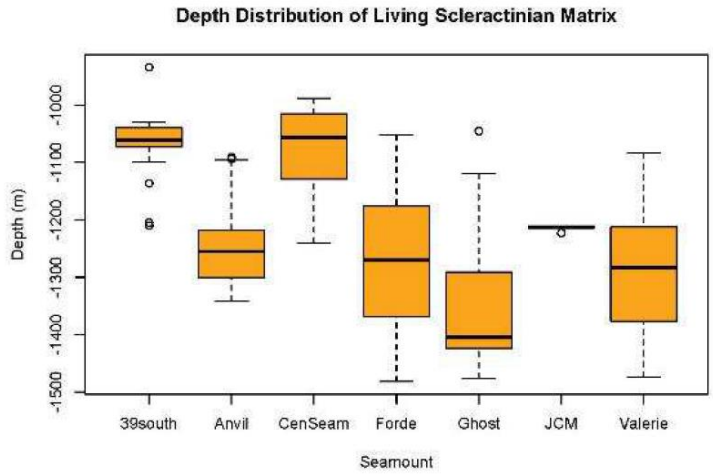

Figure 24 Depth Distribution of Living Corals on some Louisville seamounts

In the southwest part of this area (Figure 18) there is more rocky habitat (Figure 25). There is an 857m peak here that has been fished, but the other areas marked in yellow are simply called 'Rocks'. The darker area on the right of the image is a steep slope rather than clear rocky habitat. The 70 m drop along this line could potentially be coral habitat, but it is not clearly defined.

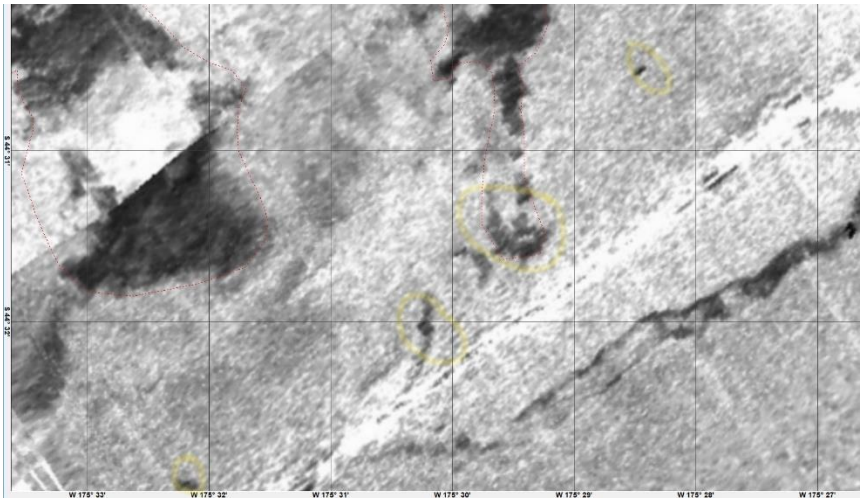

Figure 25 Acute and Chong feature to the northwest of Chief

The Big Chief complex, containing Flinstone, Teepee, Tomahawk, and other features, (Figure 26) covers an area slightly smaller than the Andes. This area has been extensively fished for many years. The sidescan imagery shows the rocky habitat extends well beyond the slopes of the knolls. This is important for habitat delineation and assessment. Big Chief is a place where a fine scale fished area assessment should verify that significant parts of the likely coral habitat have never been fished.

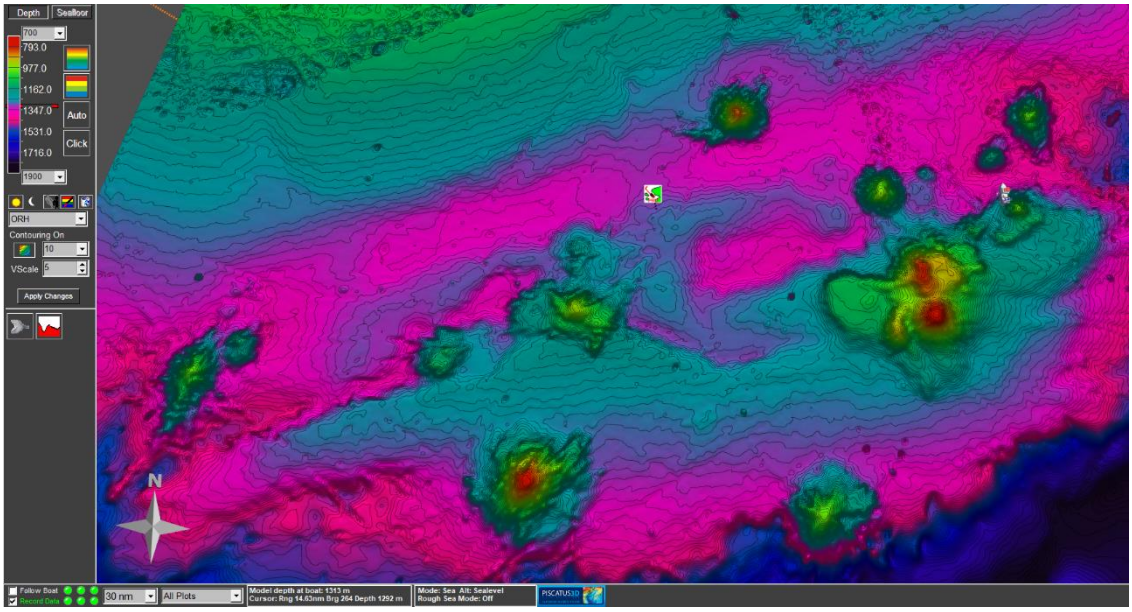

Figure 26 Big Chief to Mangrove Bathymetry

South Chatham Rise

The sidescan survey ran south of the known hills such as Hegerville. The bathymetry of these features has been used in this analysis for assessment of rocky habitat. However, Score94 discovered new features such as Chuckies, and areas of rocky habitat that were not part of the known fishery. In Figure 27 there is an area of high reflectivity which was noted by skippers as "Rough". There is a cone rising to 491 m south of this, with an area of elevated habitat (20-30 m) that runs to the southwest. All this was included as potential habitat. There are other small high reflective features on this image, but no bathymetry is available to support inclusion.

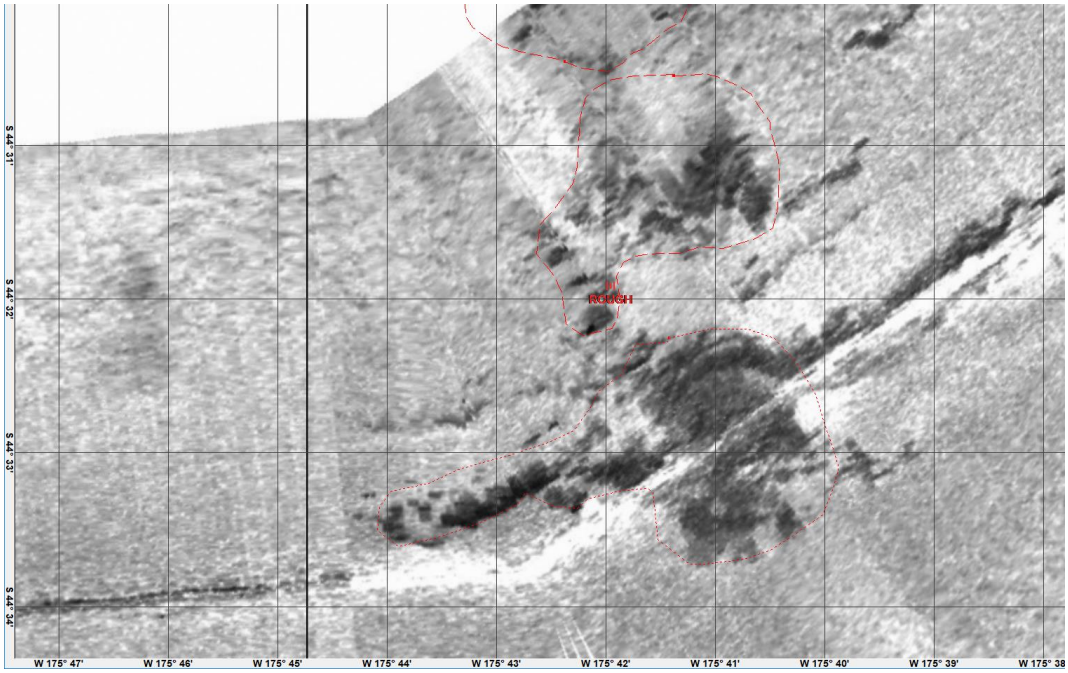

Figure 27 Sidescan imagery of likely coral habitat on the South Rise

Further west of this, just to the east of Paranoia, is an area with several regions of higher reflectivity. In the north, the area is larger than shown on the processed image (Figure 28), and the full extent has been estimated from the images for Page 11-13 of Score94 and also the bathymetry. On the south side of the image there are two knolls indicated, which come out of 1300 m depths to an unknown height.

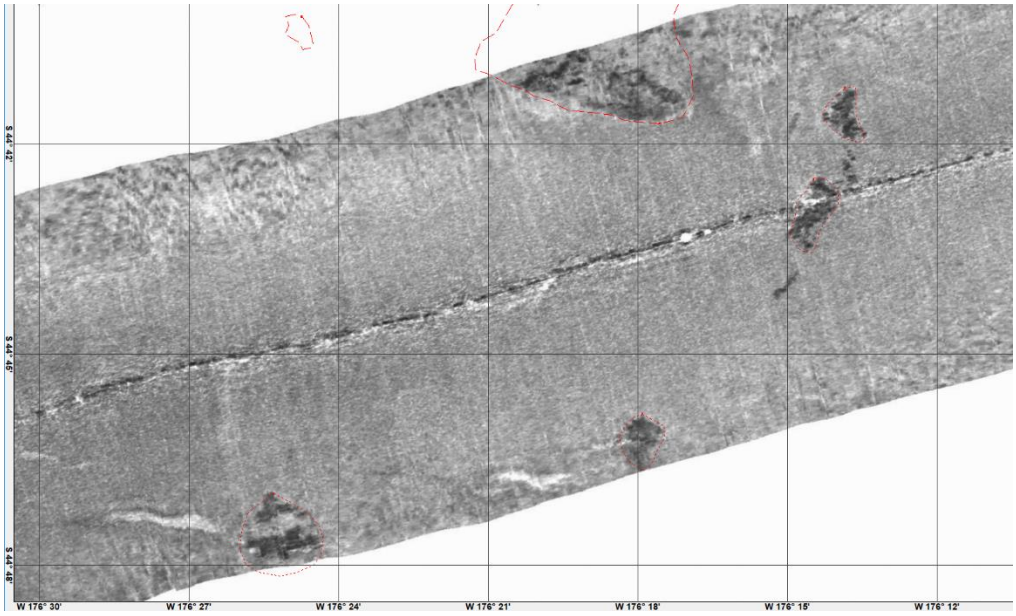

Figure 28 Rocky areas east of Paranoia on South Chatham Rise

The feature known as Chuckies (after the HMRG Cruise Chief), shows an interesting difference to all the knolls in the Andes-Chief area, because there is no indication of high reflectivity around the knoll. Hence the only potential habitat identified, was the actual volcano (there is a crater in the centre) which is 2 nm in diameter (Figure 29).

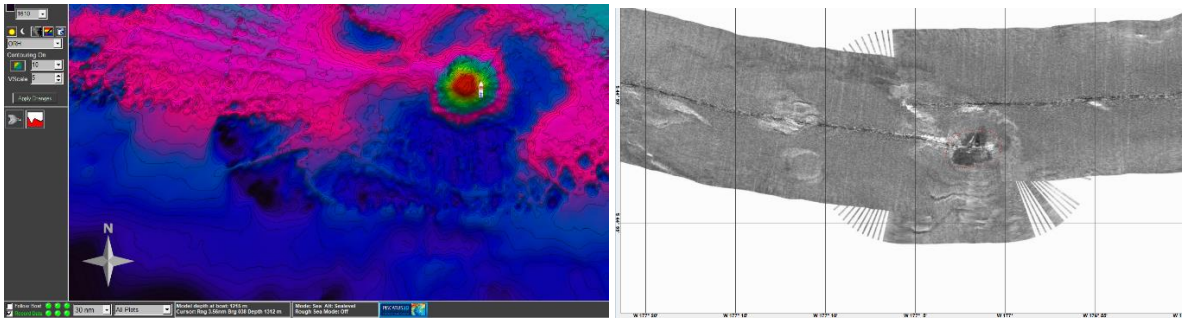

Figure 29 Bathymetry and sidescan image of Chuckies

This pattern seemed to occur further east along the South Rise with an area of higher reflectivity showing, but not as strong as expected for rocky habitat. The sonar was looking at a sharply rising slope here, according to the bathymetry map (Figure 30). A “Rock” and “Pimple” recorded by skippers and seen in the bathymetry from this region were included (marked in white circle). The sidescan area was not included in the habitat assessment, but it could be if further information was made available

from the fishery about what they find in the slope which extends from 900 m down to 1100 m southwest of the rock and pimple. There are also clear 40-60 metre sinkholes in the area, which were also identified further west in the sidescan imagery.

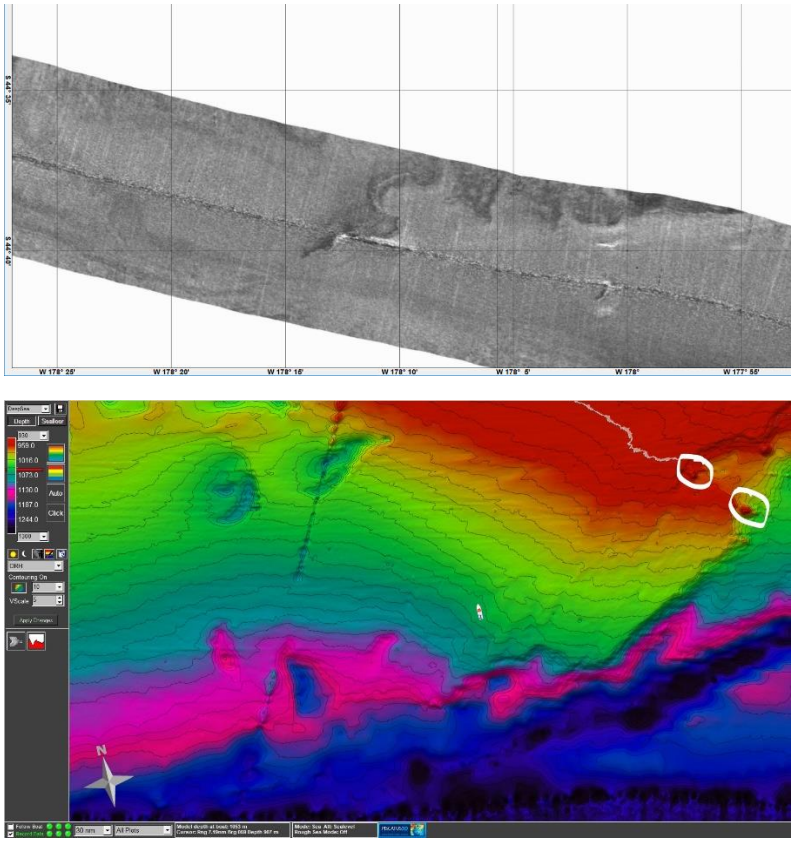

Figure 30 Sidescan and Bathymetry from South Chatham Rise 178 W.

The large region of Mt Kiso was included in the analysis (Figure 31). Fifteen miles to the northwest of Kiso is a large area of rocky habitat in 400-500 metres. This had been recorded as rocky and foul by skippers. It has been included in the analysis as potentially the area extends all the way to Mt Kiso. More detailed bathymetry from the hoki fleet would assist in a fuller analysis of the region.

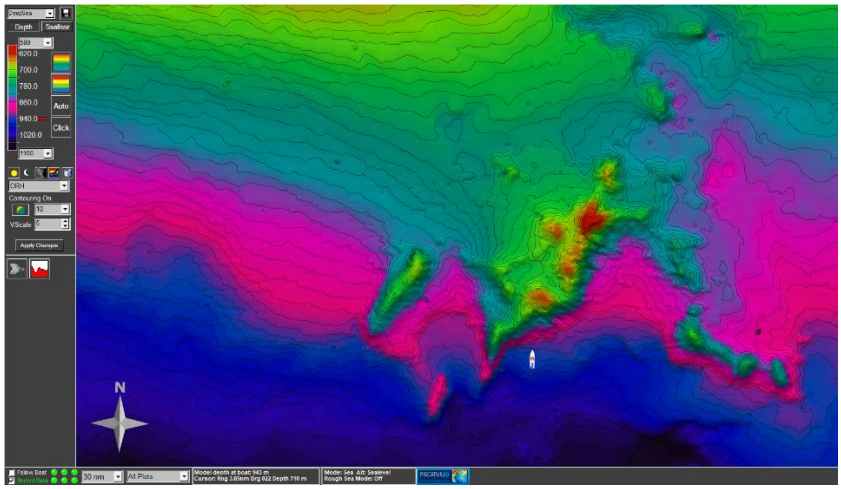

Figure 31 Bathymetry of Mt Kiso on the South Rise

Further west of Mt Kiso is an area identified by skippers as “Rough Bottom” and shows up on the full beam sidescan image with dark backscatter (Figure 32). The depth of the region is 950 to 1050 metres.

Figure 32 Full Sidescan image showing rough bottom area around 179 40 W

Mt Nelson was one of the first orange roughy hills fished on the South Chatham Rise (Figure 33). Only the actual hill at 179° 52’ E is included in the area analysis. This was not covered by Score94 and there is no additional information currently available on the habitat surrounding this hill that would allow expansion of the habitat here.

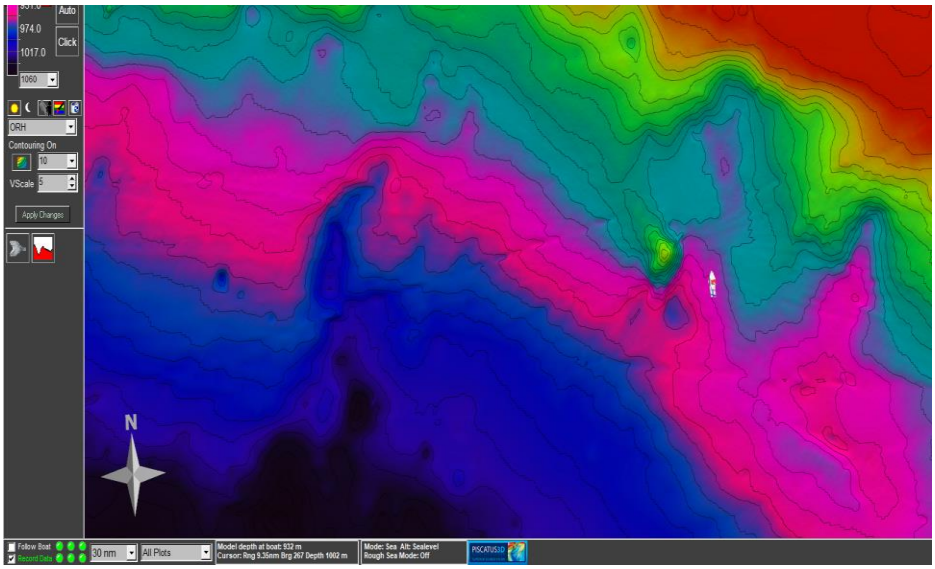

Figure 33 Mt Nelson bathymetry

Continuing west to south of a known hill called Condoms (which was not included in the analysis by mistake) was an area of rocky habitat identified by sidescan sonar. The extent of this habitat shows more clearly on the full swath, starting from 1250 metres and shoaling to the north. More bathymetry on this region to Mt Nelson could extend this likely coral habitat. This is the last potential coral habitat identified, until 100 miles further west.

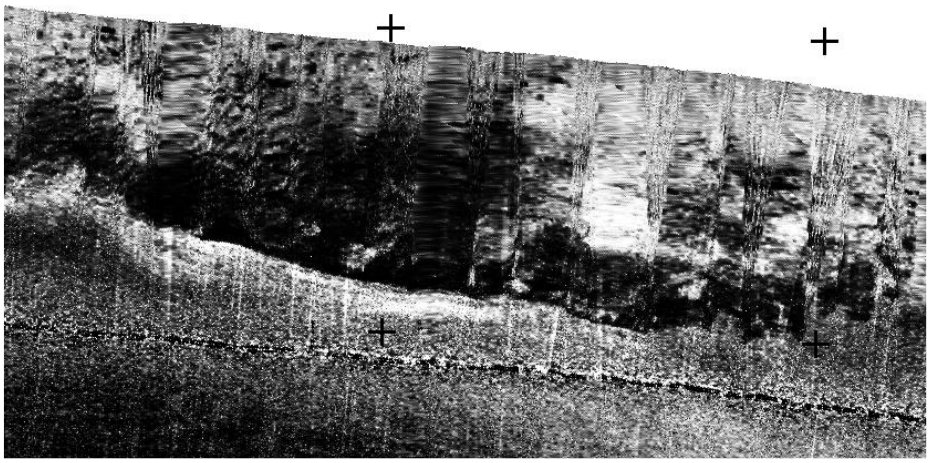

Figure 34 Full Sidescan imagery of rocky habitat around 179° 20' E on the South Chatham Rise

The Southwest Chatham Rise

This complex region south of Veryan Bank is traditionally regarded as an oreo dory fishery. However, during the 1990's there was an orange roughy summer fishery on hill such as Jungle Jim and U2. In 1994 an industry winter survey here identified spawning orange roughy. The region has a large number of small knolls, 30-50 m high, scattered amongst much larger knolls and holes. An example of this is shown in Figure 35 where the hole is marked in white, and a small knoll (30 m high) in yellow. There are two larger knolls bounded in red in the lower right corner of the image, one of these rising to 660 metres and is 4 square miles in area. There are other small knolls not marked up, as the sheer number of them to evaluate would need much better bathymetry.

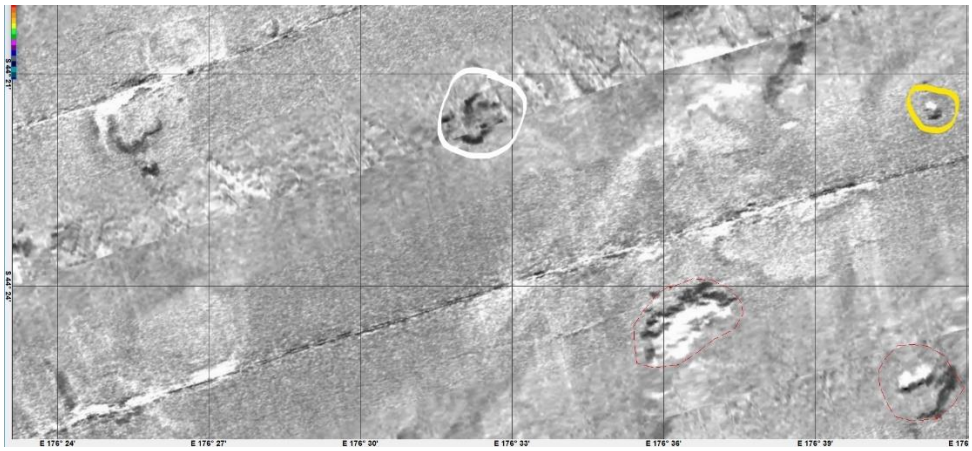

Figure 35 Sidescan sonar image on the Southwest Chatham Rise showing knolls and holes

Jungle Jim is shown in Figure 36, and rocky outcrops are apparent to the north and southwest of the main knoll. There is also strong reflection on the south side of JJ which may make it difficult to trawl north to south.

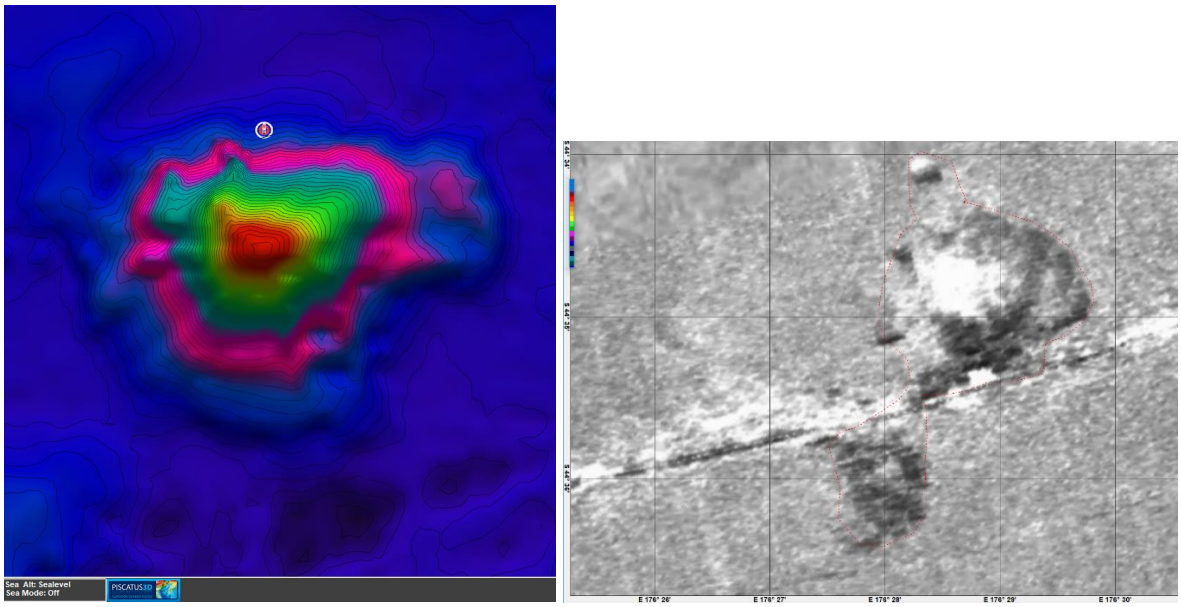

Figure 36 Bathymetry and sidescan image of Jungle Jim

The region around U2 shows an extensive rocky habitat. The sidescan images had been cropped and overlaid across U2 which makes it difficult to interpret (Figure 37). There is also an unnamed knoll on Figure 38 right top corner which rises to about 667 metres from 990 metres and is about 4 square miles in area.

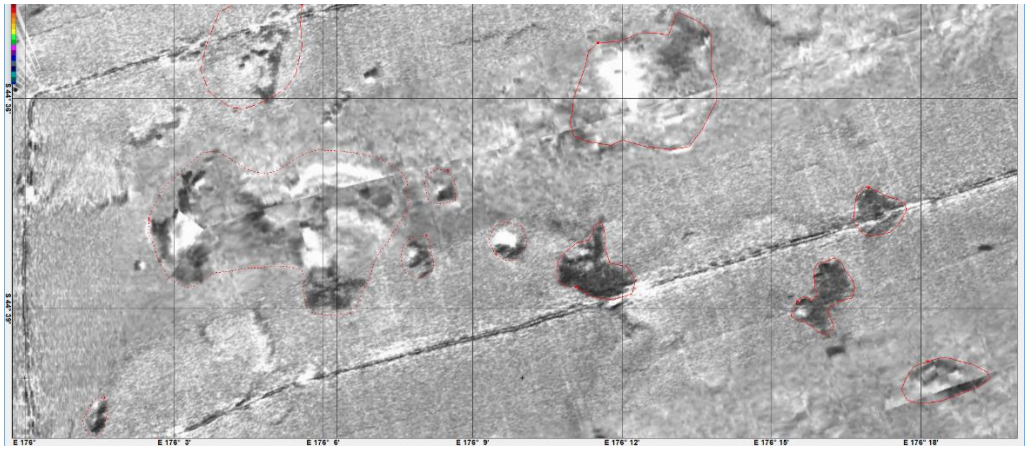

Figure 37 Sidescan sonar image of U2, Sally and unnamed hill at 176 11E

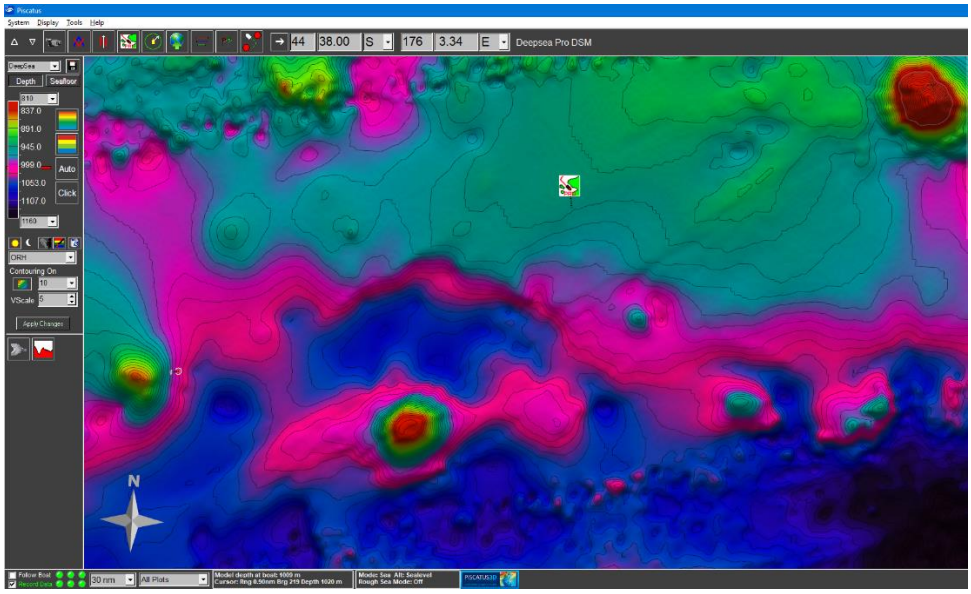

Figure 38 Bathymetry of U2 region

Further to the southwest Score94 identified another region of high reflectivity from knolls, surrounded by moats (Figure 39). In the habitat mapping of these features, the moat was not included. There were also a number of small isolated knolls without bathymetry and they were also not included.

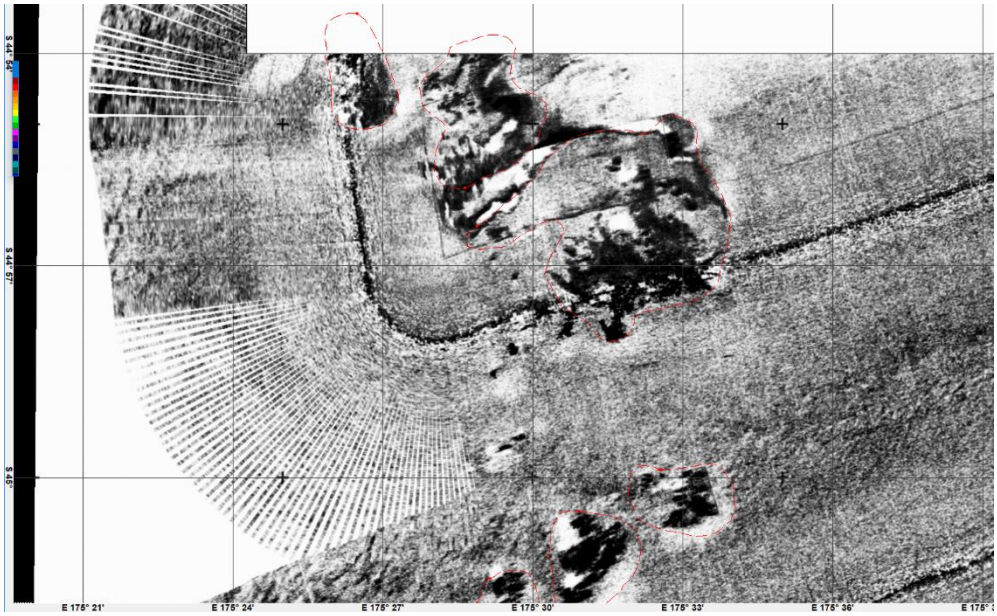

Figure 39 Sidescan sonar image of Southwest Chatham Rise knolls, southwest of U2

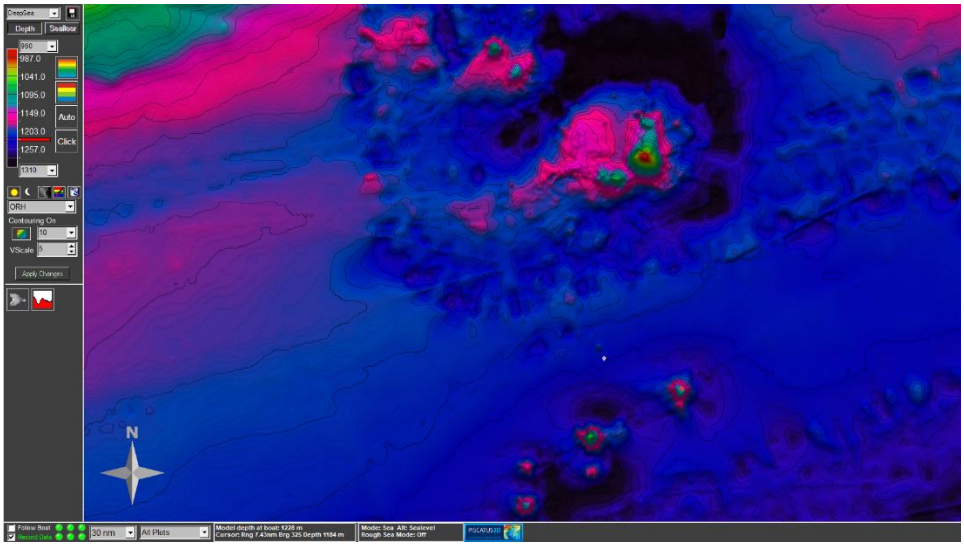

Figure 40 Southwest Chatham Rise knolls unnamed.

Habitat Summary

The features were converted to polygons (Figure 41) across the whole region. In total there were 279 polygons produced. These polygons represent the predicted rocky habitat in the region that is able to support corals (Figure 42).

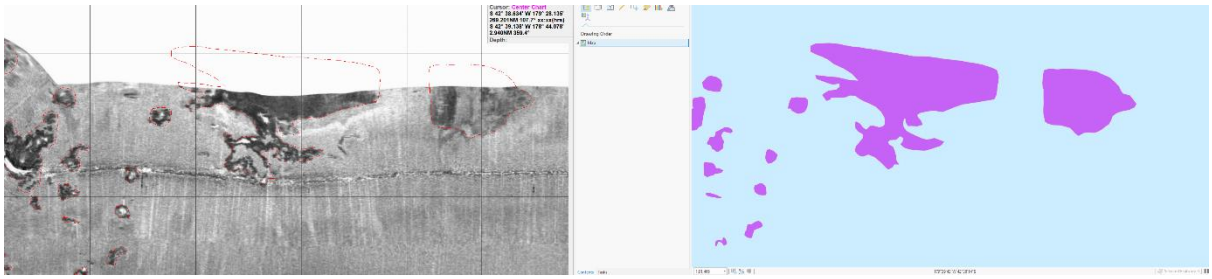

Figure 41 Feature to polygon comparison

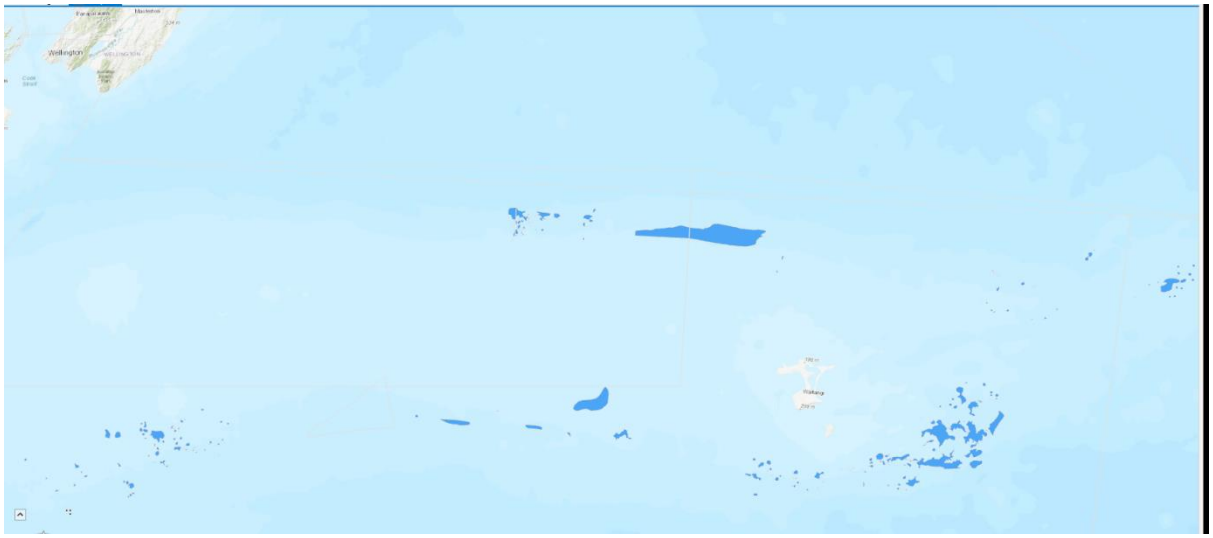

Figure 42 ORH3B Chatham Rise Predicted Rocky Habitat

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