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Tini a Tangaroa

Biogenic habitats on New Zealand's continental shelf. Part II: National field survey and analysis

New Zealand Aquatic Environment and Biodiversity Report No. 202

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

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Biogenic habitats are a key component of coastal and continental shelf ecosystems throughout the world, and the associated economic and social values that human society receives from those systems can be significant. A project to map and determine the biodiversity and significance of biogenic habitats in New Zealand was conducted in two steps. First to tap into the knowledge held by commercial fishers through Local Ecological Knowledge (LEK) interviews and a review of existing scientific literature; second, to conduct field surveys to sample and map the key biogenic areas identified through LEK, and other sources. This report describes the findings from the field surveys.

Two surveys to characterise biogenic habitats were undertaken from March to June 2011 using RV *Tangaroa*. The biogenic habitat locations ranged from Three King Islands down to Stewart Island, including off the northern Kaipara Harbour, the North Taranaki Bight, D'Urville Island, the North Canterbury Bight, the North Otago shelf, southern Foveaux Strait, areas off Gisborne, and Ranfurly Bank off East Cape. Overall, 35 sites within six geographic regions were visited.

Multibeam sonar was deployed at most sites, and underpinned the associated biological and seafloor sampling, which summed to 194 Deep Towed Imaging System (DTIS), 28 beam trawl, 35 rock dredge, and 124 sediment samples/deployments. A diverse range of seafloor types and ecological assemblages were encountered, including sponge gardens on both soft and hard seafloors, extensive chaetopterid tube-worm meadows, deep-water rhodolith beds and *Ecklonia radiata* (brown kelp) beds (a 'new' deep-water form), bryozoan thickets, hard and soft corals, sea urchin and sea pen fields on soft sediments, gorgonian fields, and crinoid fields.

The surveys produced a close correspondence between areas identified as biogenic habitats by the LEK process, and the empirical field observations. Biological collections returned over 1000 species (a conservative estimate), including 919 invertebrate species (95 new to science (10.3%), 13 new to New Zealand); 46 macro-algae (11 new to science (24%)), and 76 small fish species (10 described only to genus, 3 new species described; putatively 17% new species). Sponges were a particularly under-described group despite being important habitat formers, with 54 new species out of the 120 identified from the samples processed to date (43%).

Three regions were analysed in greater detail; two canyons along the North Taranaki Bight, the east coast South Island "*Hay Paddock*" and "*Wire-weed*" areas, and Ranfurly Bank, East Cape. The multibeam, DTIS, and biological samples from these three areas were processed, and in-depth descriptive and statistical analyses completed to describe the species assemblages, and their distribution relative to both remotely and directly measured physical variables. Non-heirarchichal k means clustering was used to identify faunal communities based on the sessile macrofauna observed in still images. Of the fourteen "habitat clusters" identified, some could be classed as biogenic habitats, with important sessile taxa including sponges, chaetopterid tube worms, red/brown/green macro-algae, bryozoans, gorgonians, corals, ascidians, and hydroids. The contribution of environmental factors derived from multibeam maps to the variation observed in the community structure was explored using distance based linear modelling (DISTLM). Typically, less than 10% of the total variation was explained by these metrics alone. Similar analysis of the fish communities observed, assessed at the scale of a DTIS transect were more successful, with variables such as depth, slope and rugosity explaining between 16–49% of variation. These data are summarised and discussed with respect to the known distributions of key habitat species and likely current day extent of such habitats on the continental shelf, the ecological values that these biogenic habitats provide, and likely threats and stresses.

In conclusion, the project has demonstrated the presence of widespread biogenic structure in New Zealand's coastal waters that hold high levels of biodiversity, and are likely to be important fish habitat, including nursery habitat. Biogenic habitats are generally considered as highly productive areas, important for ecosystem functioning and service provision. Further mapping will be required to understand their full extent and identify the more vulnerable locations that may require some level of protection from activities such as fishing, mining and extraction as well as externalities such as sedimentation and high nutrient runoff.

1. INTRODUCTION

1.1 Overview

The role of marine habitats in supporting sustainable fishery production is emerging as an important theme in Fisheries Management, and the development of Ecosystem Based Fisheries Management (EBFM) in many countries (Armstrong & Falk-Petersen 2008, Caddy 2014). Different habitat types vary in their complexity, represented by the heterogeneity in physical structure, which may be geological and/or of biological form. Evidence from a wide range of studies on different marine system components indicates that as habitat complexity increases, so does a given unit of area's value for biodiversity (species richness, abundance, age / length composition, provision of settlement surfaces, juvenile survivorship / growth, bentho-pelagic coupling, and base trophic production) (e.g. Heck & Wetstone 1977, Connell 1978, Luckhurst & Luckhurst 1978, Dean & Connell 1987, Connell & Jones 1991, Tupper & Boutilier 1995, Klitgaard 1995, Rooker at al. 1998, Charton & Ruzafa 1998, Lindholm et al. 1999, Cummings et al. 2001, Norkko et al. 2001, Buhl-Mortensen et al. 2010, Beazley et al. 2013, Caddy & Defeo 2003, Rogers et al. 2014). Biogenic habitats, i.e. those formed by living species that create emergent three-dimensional structure, have been shown to be especially important to many fish species (e.g. Luckhurst & Luckhurst 1978, Bell & Galzin 1984, Ebeling & Laur 1985, Roberts & Ormond 1987, Carr 1989, Connell & Jones 1991, Rooker et al. 1998, Heifetz 2002, Gratwike & Speight 2005, Abookire et al. 2007, Pérez-Matus & Shima 2010, Rabaut et al. 2010, Humphries et al. 2011, Baillon et al. 2012, Laman et al. 2015). More diverse assemblages have been shown to be more productive, sustainable, and / or more resilient (Millennium Ecosystem Assessment 2005, Worm et al. 2006, Sala & Knowlton 2006, Palumbi et al. 2008). Unfortunately, structurally complex habitats are becoming rarer in many parts of the world (Airoldi et al. 2008). For example, in Europe, less than 15% of the coastline is considered to remain in good condition, with near elimination of many productive and diverse coastal habitats (Airoldi & Beck 2007). Similarly, a comparison of 12 estuarine and coastal ecosystems in North America, Europe, and Australia found human impacts to have depleted 90% of formerly important species (including many habitat builders), destroyed 65% of seagrass and wetland habitat, degraded water quality, and accelerated species invasions (Lotze et al. 2006).

In New Zealand, biogenic habitats include coral and bryozoan reefs, sponge-dominated habitats, horse mussel, oyster, scallop and dog cockle beds, kelp forests, rhodolith beds, sea grass meadows, and tube worm fields. Many of these habitats have been shown to play important roles in maintaining biodiversity and healthy marine ecosystem functioning, (for a New Zealand review, see Morrison et al. 2014b) however there are many gaps in our knowledge. Similar to other parts of the world, the close proximity to land makes such habitats vulnerable to fishing (both direct and indirect), land-derived sedimentation, sediment dumping and spoil dispersal, pollution, invasive species and other human impacts (see Morrison et al. 2009, 2014b). Currently, our understanding of the extent and magnitude of biogenic habitats on the continental shelf is limited, making it difficult to manage threats to these resources without knowledge of their identity and spatial location. This lack of fundamental information was recognized in New Zealand's Biodiversity Strategy, which listed "*Identify, assess, map and rank the threats to New Zealands coastal and marine biodiversity*" as part of its Action Plan for coastal and marine ecosystems (Anon, 2000).

While scientific information on coastal shelf biogenic habitats is limited, a nation-wide pool of information exists, held by fishers, especially older/retired commercial fishers, who as resource users necessarily develop detailed knowledge of their fishing grounds. As part of this project, fifty commercial fishers from around New Zealand were interviewed about their knowledge of biogenic habitats (Jones et al. 2016).

Many of the sites described were memorable for the distinctive habitats/species that were caught as bycatch, sometimes in sufficient amounts to damage gear or make cleaning the net difficult, and were often given nicknames reflecting their physical appearance. This Local Ecological Knowledge (LEK) was translated into digitised maps of fisher-described habitats; a total of 496 areas were digitized along with a further 92 observations of sites that were not geo-referenced. Biogenic habitat categories made up 66% of the areas drawn on charts (327), with a further 15% classed as “Foul” or “Reef”. The most commonly mentioned biogenic habitats were corals (likely to include bryozoans), sponges, kelp, horse mussels and bryozoans. Many of the areas marked on charts were overlapping or spatially clustered: e.g. Cape Reinga/North Cape/Three Kings; East Cape; offshore North and South Taranaki Bight; Stewart Island / Foveaux Strait / Fiordland; and the Oamaru to Dunedin continental shelf.

When all fisher-drawn areas were overlaid, a total of 65 sites were identified around the country where up to nine fishers described the same or similar habitats. For nearly half of these sites (30), additional scientific information was identified which provided some level of corroborative evidence for the presence of biogenic habitat. From the 65 sites, 47 were proposed as “Key Sites” for consideration for field sampling.These include areas where some scientific surveys have already characterized biogenic habitats, (e.g. Separation Point, Otago Shelf and Foveaux Strait bryozoan assemblages, and sponge gardens of North Cape), and sites where more limited scientific data corroborated fisher information, but the spatial extent and/or the biological communities remained unquantified, (e.g. Canterbury “*wire-weed*” (tube worm fields), Ranfurly Bank)) and sites where only LEK information was identified (e.g. west coast North Island canyons, “*Coral Patch*” in the Hauraki Gulf).

1.2 Objectives

The overall objective of the project was to characterise and map the occurrence of significant areas of biogenic habitat forming hotspots and associated biodiversity in New Zealand’s near-shore coastal zone (about 5–150 m). Specific objectives included:

1. To collect and integrate existing knowledge on biogenic habitat-formers in the about 5–150 m depth zone of New Zealand’s continental shelf, from sources including structured fisher interviews, primary and grey literature, and other sources as available.
2. Using the findings of Objective 1, design and deploy a series of sampling voyages to selected locations, to map and characterise locations of significant biogenic structure (either still existing, or historical), and collect relevant biological samples (both through visual census, and physical collection).
3. Process and analyse the samples collected in Objective 2, to provide a hierarchical, quantitative description of the biogenic habitats and associated species encountered.
4. Using the findings from Objective 1–3, assess the present status, likely extent, ecological role, and threats to, biogenic habitat formers in the <5–150 m depth zone.

The results of Specific Objective 1 are described in the companion report, “Biogenic habitats on New Zealand’s continental shelf. Part I: Local Ecological Knowledge.” (Jones et al. 2016). The results from Objectives 2, 3 and the first part of Objective 4 are addressed in this report. The spatial modelling and risk assessment approach components that were originally part of Objective 4 have been deferred and are not covered in this report.

2. METHODS

2.1 Selection of locations for sampling.

As part of Specific Objective 1, information from fifty fisher interviews was collated along with available scientific studies to produce a list of "Key Sites" for consideration for empirical sampling (see table 20, Jones et al. 2016). With no formally adopted habitat classification framework for New Zealand, or agreed definition of what constituted "significant biogenic structure", a pragmatic working definition of a generic biogenic habitat, as suggested in Morrison et al. (2014a) was used:

> "*Biogenic habitats encompass both a) those living species that form emergent three-dimensional structure, that separate areas in which it occurs from surrounding lower vertical dimension seafloor habitats and b) non-living structure generated by living organisms, such as infaunal tubes and burrows*"

Species with the potential to form emergent three-dimensional structure include sponges, corals, bryozoans, bivalves, tubeworms, and algae, all of which were identified by fishers during the interviews. It is recognized that the presence of habitat-forming species does not automatically equate to the provision of significant habitat, but recollections by fishers of large, memorable amounts of these species in their catches was used as a proxy for the possible existence of "significant biogenic structure".

Key sites were defined as those being repeatedly and consistently described by multiple fishers, consistent with scientific information if available, and/or considered especially unusual and interesting (as arbitrarily defined by the report authors). During the course of the project, additional funding from other sources (OS2020 and MBIE) greatly increased the empirical sampling capacity originally envisaged for the project. Final selection from the 47 key sites was carried out in consultation with MPI, with prioritization according to a range of criteria including potential biological significance, and vulnerability of the fisher-located sites, as well as vessel logistics, and included the following areas (see Figure 1, page 19):

North Island
- North Cape and Cape Reinga
- Three Kings and Middlesex Bank
- Offshore North Taranaki Bight
- Mahia Peninsula to Ranfurly Bank (East Cape Region)

South Island
- Kaikoura to Cape Campbell area
- North Canterbury Bight
- Southland coast including off Otago Peninsula
- Southern area of Stewart Island
- Puyseger Bank area and adjacent coastline outside lower Fiordland (Chalky Inlet)

The first voyage onboard *RV Tangaroa* (23 March–6 April 2011) targeted the North Cape "*Rock garden*" and the North Taranaki shelf edge canyons (both identified through fisher interviews), as well as Middlesex Bank and the Three Kings Island group (the latter not identified by fishers, but an area of known high biodiversity and un-sampled biogenic habitat). Other sites were sampled *en route* to these locations (west of Cape Reinga, and west coast canyons), with shallow sites at Separation Point and D'Urville Island being included whilst sheltering from poor weather. The second voyage (10 May–4 June 2011) targeted the North Canterbury Bight, "*The Hay Paddock*" and Otago bryozoan fields on the Southland coast and East Cape region (all identified by fishers). Poor weather prevented sampling around southern Stewart Island, Puysegar Bank, and lower Fiordland, with alternative sites sampled as weather permitted (inside Foveaux Strait, east of Stewart Island and Mason Canyon). While the nominal depth cut-off for this programme was 150 m, this was extended to 200 m (and sometimes deeper on canyon edges) once the depth zones of some of the most interesting LEK targets become known from Objective 1 (Jones et al. 2016).

2.2 Field survey design and data collection approach

Within each target site, the aim was to locate and characterize representative portions of biogenic habitats using a combination of multibeam sonar, video transects, and physical sampling of sediments and macrofauna. Because of the extensive areas involved, it was not always possible to map the full extent of each habitat encountered. The focus was to confirm presence or absence of biogenic structure identified by the LEK process, and enable characterization of biogenic habitats seen during the surveys. Guided by the mapped fisher-drawn areas, combined with available bathymetry information, multibeam sonar was used to either: fully map the target where the target feature was certain and spatial dimensions allowed (e.g. canyon heads); or selected sub-areas within a larger area, or, as a series of transects, where the target was too large overall to be fully mapped and the location of the true biogenic habitats within the overall area was uncertain. In the latter case, initial transects were used to identify promising targets, and then finer scale areas 'filled in' (e.g., the "*wire-weed*" beds off the North Canterbury Bight and sub-sections of Ranfurly Bank).

Each multibeam-mapped area was allocated a site number and the bathymetry and back-scatter were scrutinized at sea to identify areas of interest that might contain or represent the biogenic habitat described, such as drop offs, rocky outcrops, or distinctive patterns in topography or seafloor hardness. DTIS transect stations were assigned to these features, along with other habitats (e.g. flatter, featureless areas) so as to cover as much suspected habitat variation and depth range as practical, to cross habitat boundaries where possible, and to provide reasonable levels of replication within a suspected habitat type. For each DTIS transect, a sediment sample using a Shipek grab was collected at an arbitrary location where bottom type allowed. Samples were retained for sediment grain analysis and organic content to provide an indication of the sediment types observed in the DTIS videos, and more broadly across regions. Biological sampling was conducted using a beam trawl on soft sediments and a seamount dredge on rough seafloors. These stations were assigned so that, where possible, at least one sample was taken of each suspected habitat type seen in the multibeam maps, providing a semi-quantitative sample and voucher specimens from a range of habitats.

Multibeam data were collected during daylight hours (06:00–18:00), and DTIS transects (along with biological sampling) were undertaken during the hours of darkness. This strategy was taken to optimize collection of information on fish species utilizing the habitats, as well as the habitat formers and associated invertebrate community. Previous studies have demonstrated that video sampling at night improved estimation of snapper population abundance and size structure (particularly juveniles) when they and other diurnally active species settled on the seafloor (Morrison & Carbines 2006, Compton et al. 2012). Additionally, a range of other nocturnally active species are active and more visible at night (Jones et al. 2010, Morrison et al. 2016).

The number of DTIS transects completed at night varied depending on water depth, the number of biological and sediment stations sampled, and whether steaming to the next area was required. On some occasions, the timing of arrival at a location did not allow for multibeam mapping to be carried out first, and DTIS transects were placed based on the fisher-drawn areas and existing charts alone. Decisions on how long to remain at any given location were made as a balance between how much un-sampled habitat variability was estimated to remain at that location, versus how much time was required to sample other proposed target locations, and weather conditions.

2.3 Onboard data collection

An outline of the shipboard data collection protocols is given here. Further detail is provided in Appendix 1. A hull-mounted Kongsberg EM302 echosounder was used to collect swath bathymetry, backscatter and water column data throughout the surveys. Realtime data acquisition was carried out using Seafloor Information Systems (SIS) software, and initial processing and cleaning of bathymetry and backscatter data for map production onboard was done with CARIS HIPS vV7.1.

Seabed photographic transects were carried out using NIWA's Deep Towed Imaging System (DTIS) to record data on seabed substrates, benthic invertebrates, algae, and demersal and benthic fish. Transect lengths varied from 15 to 90 minutes duration at a target speed of between 0.25 and 0.5 m s^{-1}. With DTIS at a target altitude of 2–3 m above the seabed, the foreground frame width for both video and still cameras was about 2 m. Thus, for a 1 h deployment, total seabed area imaged per transect ranged between 1800 m^2 and 3000 m^2. During deployments, the real-time video image was monitored by biologists and all conspicuous organisms and changes in substratum type were recorded as spatially referenced observations using the software Ocean Floor Observation protocol (OFOP, ofop@texel.com). This program automatically logs the time, spatial co-ordinates, depth, and a range of other parameters associated with each observation, every still photograph taken during the transect, and the start and end point of the video transect. High resolution (8 megapixel JPEG format) photos were taken at 15 second intervals along each transect.

Collection of benthic biological samples was carried out using a beam trawl (TB) on flat seafloor, and an epibenthic sled ('seamounts sled', SEL) on rougher seafloor including rocky reefs. Beam trawl tows were made for 20 minutes, while the epibenthic sled tows each covered 0.1 nautical miles. Each catch was fully weighed and sorted whenever possible. Rocks and larger-sized rubble were separated on deck, and biological material sorted. Smaller-sized rubble/mud/shell hash was put in bins, and sorted for biological material in the deck lab. Weights of the overall catch were derived from weighing each bin on motion-compensated 100 kg scales (or estimated from the number of cases multiplied by the average case weight).

All fauna were sorted to higher level taxonomic groups at sea (class, phylum), preserved appropriately (in ethanol, or formalin, or frozen, depending on taxon), and catalogued in the Specify database of the NIWA Invertebrate Collection (NIC). Objective 2 of the ZBD200801 project only allowed for the collection and identification of larger (over 5 cm) 'habitat-forming' organisms. Additional DOC staff and a student volunteer enabled sorting and collection of smaller specimens as appropriate from the biological material bought on board, and the pressing and preservation of macro-algae where present.

A Shipek sediment grab was used to collect a 0.04 m^2 sample of sediment at an arbitrary point along each DTIS transect. From this grab a 3 × 5 cm deep core was taken in the central least disturbed part of the sample if the grab was full. If the grab was less than a quarter full (common in some of the harder soft sediments such as gravel, and hard-packed fine sand) the full contents of the grab were taken. Where the seabed was too hard, no sample was collected.

2.4 Selection of core areas for post-voyage processing.

A substantial volume of samples, both digital and biological, was collected across the two combined *Tangaroa* voyages. These proved to be well in excess of what could be processed through this project. Some initial postprocessing of the multibeam data (basic bathmetry maps with obvious survey artefact removed), and analysis of the sediment samples was carried out for all sites under this project. For the biological samples and imagery data (video and stills), three core areas were prioritised for full analysis and write-up. In consultation with MPI, the following areas were chosen;

- North Taranaki shelf canyons. Very little is known about this region's seafloor habitats and species, but human activities such as seabed mining and drilling are expected to increase (MacDiarmid et al. 2014). Fishing activities target these canyon areas and the surrounds. Preliminary taxonomic browsing of the samples also indicated unusual sponge species assemblages. Therefore sites 13 and 14 ("*The Coral Canyon*" and "*The Well*") were analysed in full.
- East Coast South Island, the "*Hay Paddock*" and "*Wire-weed*" meadow areas. These habitats are largely 'new to science', although noted in several scientific studies (Carter & Carter 1985, Probert & Anderson 1986, Fenaughty & Bagley 1981) and verbally described by Graham (1969). They were identified from the LEK interviews (Jones et al. 2016) as being unique environments not seen elsewhere.
- Ranfurly Bank, East Cape. This area is poorly known, but suspected to hold high species and habitat diversity, from both LEK and science sources. Anecdotal accounts also suggest that it is coming under increasing fishing pressure as gear technology improves.

Biological samples for the remaining stations were processed and identified in a separate taxonomy project, with the exception of some sponges, and some groups for which no in-house expertise was available (e.g. anemones, gorgonians) (Schnabel et al. 2014).

Multibeam data processing

The multibeam and backscatter data were initially processed onboard the vessel in CARIS HIPS software to produce digital elevation models (DEM) of the survey areas gridded at 10 m using the CUBE surfacing tool. Post voyage, for the Core areas the CUBE process was rerun to produce a DEM of the survey areas gridded at 5 m. A 5×5 m nearest neighbour interpolation was then run to fill in any significant gaps in the resulting DEM. The bathymetry grid data for all sites were exported in BAG format (Bathymetry Attributed Grid) so they could be natively read in ESRI Arc Map v10, and used for final plot production for each site.

For the the core sites (North Taranaki canyons, East Coast South Island, and Ranfurly Bank) the Benthic Terrain Modeller (BTM) package for ArcGIS (Wright et al. 2012) was used to produce a number of derivative layers including slope (the maximum change in elevation between each cell and cells in its analysis neighbourhood, in degrees from horizontal), aspect (the azimuthal bearing of the steepest slope calculated for each cells neighbourhood), rugosity (the ratio of surface area to planar area, representing terrain complexity, or "bumpiness" of the seabed) and Bathymetric Position Index (BPI) data sets at two different nested scales. The latter is a second order derivative, from slope, and represents a measure of where a georeferenced location, with a defined elevation is relative to the overall landscape (Lundblad et al. 2006). Its derivation involves evaluating elevation differences between a focal point and the mean elevation of the surrounding cells, within a user-defined radius. Both rugosity and BPI are sensitive to the scale at which they are examined. As part of the BTM tool, a broadscale BPI layer is created, with a fine scale BPI layer generated using a smaller analysis neighbourhood. The BPI grids are usually defined by their scale factors, the outer radius in map units multiplied by the bathymetric data resolution. In the present study settings used in the Benthic Terrain Modeller extension to ArcGIS were: broadscale BPI inner radius = 5, outer radius = 25; fine scale BPI inner radius = 1, outer radius = 5. The two BPI data sets are then standardized, and in conjunction with slope and bathymetry, used to classify the seabed into a series of broadscale and finescale features. The original classifications were based on coral reef systems, but were developed to produce a standardized way of classifying other deepwater benthic environments (Lundblad et al. 2006). For this study, the categories were applied to the mapped areas and related to the features observed in each area, e.g. the continental shelf, canyon walls and canyon bottom for the North Taranaki canyons and the sides, rock ramparts and pinnacles of Ranfurly Bank. The broadscale classification sonsists of four zones (crests, depressions, flats, slopes) and the finer scale classification contains 13 structures (narrow depression, local depression on flat, lateral midslope depression, depression on crest, broad depression, broad flat, shelf, open slopes, local crest in depression, local crest on flat, lateral midslope crest, narrow crest, and steep slope). Descriptions of these categories is given below:

Zones:

1. Crests: High points in the terrain where there are positive bathymetric position index values greater than one standard deviation from the mean in the positive direction.
2. Depressions: Low points in the terrain where there are negative bathymetric position index values greater than one standard deviation from the mean in the negative direction
3. Flats: Flat points in the terrain where there are near zero bathymetric position index values that are within one standard deviation of the mean. Flats have a slope that is less than or equal to 5°.
4. Slopes: Sloping points in the terrain where there are near zero bathymetric position index values that are within one standard deviation of the mean. Slopes have a slope that is over 5°.

Structures:

1. Narrow depression: A depression where both fine and broad features within the terrain are lower than their surroundings.
2. Local depression on flat: A fine scale depression within a broader flat terrain.
3. Lateral midslope depression: fine scale depression that laterally incises a slope.
4. Depression on crest: A fine scale depression within a crested terrain.
5. Broad depression with an open bottom: A broad scale depression with a U-shape where any nested, fine scale features are flat or have constant slope.
6. Broad flat: A broad flat area where the terrain contains few, nested, fine scale features.
7. Shelf: A broad flat area where the terrain contains few, nested, fine scale features. A shelf is shallower than 22 m depth. (This depth value was based on 3-D visualization and the NOAA/NOS classification scheme (NWHI 2003)). The NOAA/NOS scheme defines a shelf as ending between 20 and 30 m depth.
8. Open slopes: A constant slope where the slope values are between 5° and 70° and there are few, nested, fine scale features within the broader terrain.
9. Local crest in depression: A fine scale crest within a broader depressed terrain.
10. Local crest on flat: A fine scale crest within a broader flat terrain.

11. Lateral midslope crest: A fine scale crest that laterally divides a slope. This often looks like a ledge in the middle of a slope.
12. Narrow crest: A crest where both fine and broad features within the terrain are higher than their surroundings.
13. Steep slope: An open slope with a slope value greater than 70°.

For selected multibeam derivative layers, mean values were calculated at the scale of the still image by creating a point layer of the still image positions in ArcGIS, and adding the grid cell value of all relevant multibeam derived layers as an attribute to the point layer. These values were averaged to produce a mean value at the DTIS station level.

DTIS imagery analysis

To capture the diversity of the biogenic habitats sampled, analysis focussed primarily on the high resolution still images taken at 15 second intervals, which allowed for a higher level of faunal identification than the video itself. The video was used to generate information on the fish assemblages and other large, ‘rarer’ benthic organisms not adequately sampled in the still images. This analysis was carried out only for the stations within the three core areas.

Reference libraries

A library of reference images was compiled for all distinctive animal and algal types visible in the DTIS seabed photographs, described as Operational Taxonomic Units (OTU). In contrast to physical specimens, it is often not possible to identify organisms seen in seabed video to species level because key characteristics of their body form may be obscured or be at an angle to the camera that renders them unclear. Thus, the actual taxonomic level which can be achieved varies between groups.

Representative images of each OTU were colour corrected, scaled using the lasers projected in the DTIS image frame, and cropped to the organism of interest. Specialist taxonomists for each taxonomic group then provided identification at the finest achievable taxonomic resolution. These identification images formed site-specific reference libraries used by the analysts as the primary reference for identification of organisms in the stills and video.

Still image analysis

To determine the number of images that could be analysed in the time available, the results of a pilot survey of similar image data (Bowden & Hewitt 2012) were used. From that pilot survey, and a brief look at the habitat heterogeneity, it was decided to analyse every fourth image, with additional images added to ensure coverage of rare / patchy habitats. At each site, image thumbnails were viewed to determine the overall habitat types (mud, bedrock, boulders, cobbles, sand, pebbles), and every fourth image was selected for analysis. If the image was of poor quality then the next image was selected. If this was still poor quality then the image prior to the fourth image was selected.

Data extraction from the still images was conducted using two software programs. Images were initially corrected for colour balance and lightened using the image manager, viewer and processing software *ACDSee*. Analysis was then carried out in *ImageJ* (http://rsbweb.nih.gov/ij/). The lasers (20 cm separation) were used to scale the image and calculated the seabed area sampled. The proportions of different substrate types in the image were measured by drawing polygons around the different areas. Substrates were classified by reference to a table of descriptors, ranging from bedrock to muddy sediments, and recorded as a proportion of the total image area.

Benthic epifauna were recorded as either a scaled area cover (per square metre) or count, determined by the ease with which individuals could be discriminated and counted (e.g., large sessile serpulid worms and emergent mobile worms were counted, whilst patches of chaetopterid worms were recorded as an area). The type and extent of bioturbation was recorded as either counts or area. The ROI (Regions of Interest) function in ImageJ was use to save the information recorded, allowing the analysts to go back to queries or unknown species later and edit information.

Video analysis

The Ocean Floor Observation Protocol (OFOP) software was used to synchronise digital video files with ship-board recorded position data, enabling DTIS transects to be re-run with the advantages of full-resolution and ability to pause, rewind, slow down, or speed up the replay. Using the taxon list and identification guides developed from the still images, DTIS transects were reviewed in full and the position and taxonomic identification of all fish and large conspicuous organisms recorded. Additional information on fish activity, location (in relation to surrounding benthic habitat) and size category were also recorded for future use.

Identification of biological samples

On return to shore, preserved specimens from the prioritized sites were distributed to specialist taxonomists at NIWA, Te Papa and abroad for identification. For most mega-faunal groups, identifications were made to species or genus level. Invertebrate data are presented in tables summarising the number of OTUs identified and toal catch weight by order. The fish samples collected, identified by Te Papa, are presented as species counts. A NIWA taxonomic project enabled almost all of the remaining invertebrate samples from the two voyages (apart form the sponge collection) to be processed (Schnabel et al. 2014).

Sediment analysis

Aliquots of sediment were subsampled for the following analyses: % total organic matter (TOM), % calcium carbonate (%$CaCO_3$) and grain size, both laser and sieved where material greater than 1.6 mm was present.

Grain-size analysis

Samples were analysed for particle grain size parameters using a Beckman Coulter LS 13 320 Dual Wavelength Laser Particle Sizer following established methods (e.g. McCave & Syvitski, 1991, McCave et al. 2006). A laser light source illuminates the suspended particles passing through a glass chamber. The light scattered by the particles is detected by silicon photo-detectors. The intensity of light on each detector, measured as a function of angle, is then subjected to mathematical analysis using a complex inversion matrix algorithm. The result is a particle size distribution, covering size ranges from 0.4 to 2000 μm, displayed as volume percent across more than 100 discrete size classes.

To achieve appropriate obscuration (a function of sample turbidity) approximately 0.5–1 cm^3 of sediment was initially dispersed in washing solution made of sodium hydrogen carbonate (4g/20L) and sodium carbonate anhydrous (1g/20L) and quickly sonicated for about 5 seconds in a 50 ml container. The sample was then washed through a 1.6 mm sieve into the laser-sizer's sample bath, containing approximately 1 L of tap water. Gravel-sized particles must be excluded from the sample, and so visual estimates of gravel components retained on the 1.6 mm sieve were recorded only. Where gravel components were observed, the sediment fraction greater than 63 μm was washed onto filters and oven dried at 60°C before weighing.

Granulometric analysis was achieved using GRADISTAT version 8.0 (Blott 2010), which calculates the standard granulometric statistics, textural descriptions and size fraction percentages, thus allowing details of the gravel component to be included with the laser-sizer results in determining the overall grain size distribution of each sample. Textural classifications and size ranges in millimetres and phi size classes used within GRADISTAT are given in Appendix 2, where gravel is defined as greater than 2 mm (or greater than -1 phi), sand as 63 µm – 2 mm (or 4 to -1 phi), and mud as less than 63 µm (or <4 phi).

Total organic matter

Total organic matter for the less than 2 mm fraction of each sample was derived using the Loss on Ignition method. Samples were wet weighed, then oven dried at 60°C overnight, crushed with a pestle and mortar, re-weighed and the dry weight recorded. The sample was then combusted in a McGregor Eurotherm furnace at 450°C for 2 hours, cooled in a desiccator, re-weighed and the combusted weight recorded. The % water was calculated from the wet and dry weights and was used to determine the weight of salt, which was deducted from the dry and combusted weights of sediment. Thus, the % total organic matter (TOM) was determined using the dry and combusted sediment weights less the weight of salt.

Calcium carbonate content

The carbonate content of dried powdered samples was determined via gasometric quantitative analysis after acidification (Jones & Kaiteris 1983), with a precision of ± 2%. Oven dried sediment was crushed using a pestle and mortar, then further dried for 2 hours at 100°C and cooled in a desiccator. Approximately 0.3 g was weighed before placing in a glass side-armed bomb. Carbonate gas was evolved from the sediment using 70% orthophosphoric acid under vacuum. These volumes were used to calculate the %$CaCO_3$ in each sample.

2.5 Data Analysis of Core Areas

The following analysis was carried out using data from the DTIS imagery and multibeam derivatives for the three core areas (North Taranaki canyons, East Coast South Island tubeworm habitats, and Ranfurly Bank).

Benthic community characterization of core areas

The epifaunal community data from DTIS still images were examined by calculating the proportional occurrence of key taxonomic groups (divided into sessile groups and mobile groups) at each of the distinct geographic locations (sites) sampled in the core areas. These data were then analysed to identify clusters in community composition across all areas sampled. A similar approach to that recently adopted for examination of Chatham Rise and Challenger Plateau benthic fauna was followed (Floerl et al. 2012). A number of different methods were explored for the initial dataset analysed, before deciding on the preferred approach. Both hierarchical and non-hierarchical clustering were initially investigated; hierarchical clustering was conducted within the CLUSTER routine in PRIMER version 6.1.11. Non-hierarchical clustering was conducted using K-means in the *vegan* and *cluster* libraries in the R software package (www.r-project.org).

In order to combine both count and area cover into one comparable data set, individual species data were initially standardised by their maximum across the dataset, and then samples were standardised to their respective totals. Clustering analysis was carried out on the complete faunal assemblage, a sub-set including only the sessile fauna (‘Habitat-formers’), and on the presence / absence of these two datasets.

The hierarchical approach used average linkage clustering on modified Gower distances (Anderson et al. 2006). There are no automated procedures for selecting the number of clusters, so arbitrary distance measures were chosen. The ability to partition data into groupings of high within-group similarity and between-group dissimilarity was assessed using Analysis of Similarities (ANOSIM) and Similarity Percentage Analysis (SIMPER) routines within Primer (Clarke 1993).

Non-hierarchical clustering was conducted on Gower (Gower 1971) and alternate Gower (Anderson et al. 2006) dissimilarity matrices of the standardised and presence/absence transformations of the full community and sessile fauna datasets using K-means partitioning routines in the *vegan* package. This method uses the algorithm of Hartigan & Wong (1979) to identify high-density regions in data, and partitions samples into *k* clusters (chosen *a priori*) so as to minimise the within group dispersion (spread) of the samples, the sum of within-groups sums-of-squares, and maximize the between-group dispersion (Borcard et al. 2011). For non-hierarchical clustering, a range of measures are available to select the number of clusters, and two commonly used approaches were used; the Calinski-Harabasz criterion (Calinski & Harabasz 1974) and Simple Structure Index (SSI) (Dolnicar et al. 1999). The Calinski-Harabasz criterion compares the among-group to within-group sum of squares of the partition and produces a pseudo-F statistic. In these analyses, it did not appear to perform well, consistently selecting either the minimum or close to the maximum available, possibly due to the variation in group sizes. The SSI combines the maximum difference of each variable between the clusters, the sizes of the most contrasting clusters, and the deviation of a variable in the cluster centres compared to its overall mean. These three elements are combined and normalized to give a value between 0 and 1, with higher values indicating the best partition in the least squares. The cascade-KM function was used to perform` multiple iterations (100) of the clustering analysis, creating a cascade of small to large values of *k*, with the SSI criterion estimated for each partition.

The community cluster grouping for each data set determined to be the optimum using these methods was explored further in PRIMER using ANOSIM and SIMPER. Where ANOSIM returned a significant global test ($P<0.05$), SIMPER was used to explore the dissimilarity among samples within a group and between groups and identify key contributing species. The community composition of these ‘habitat groups’ were quantified by comparing the frequency of occurrence of species from both sessile and mobile taxon groups.

Relating benthic community data to environmental variables

The relationships between the benthic community at core sites and multibeam-derived and other environmental metrics were examined using distance based linear modelling, with the DistLM method (Anderson 2001, McArdle & Anderson 2001) within *PERMANOVA+ for PRIMER* (Anderson et al. 2008). DISTLM partitions variation in a data cloud, as described by a resemblance matrix, according to a multiple regression model. Importantly, it supports the use of a number of different distance measures, including the Modified Gower similarity measure (considered most appropriate for the data analysed here, as a combination of abundance and % cover data), and can be used in backwards selection mode. While both Redundancy Analysis (RDA) and Canonical Correspondence Analysis (CCA) also partition variance in a data cloud according to a multiple regression model, these two analyses are confined to the use of Euclidean and chi-square distances respectively, which are not used quite so frequently in analyses of community data. Moreover, there is no software package other than DISTLM that allows for simple backwards selection of variables, despite this being preferable when interactions and some correlations exist between explanatory variables.

DISTLM was carried out using the full community dataset (stations with no species were excluded), and multibeam-derived continuous (slope, rugosity, reflectance, bathymetry), and categorical (BTM Zones and Structure) topographical variables, followed by the addition of categorical variables to discriminate between the different geographic sites examined within each core area. Finally, image-derived variables representing small scale patterns in substrate and benthic habitat were added. These included a categorical variable reflecting level of observed bioturbation (either low, medium or high), a continuous variable of the proportion of hard substrate observed in the image sample, and, in the case of the East coast South Island tubeworm habitats only, a categorical variable representing the ‘type’ of tubeworm bed. Backwards model selection was conducted using the AIC (Akaike Information Criterion), with forward selection used to identify the order of importance of explanatory variables, and their relative contribution to the explanatory power of the final model. The final model for each core area was visualized with a distance-based redundancy analysis (db-RDA) plot to provide the best two-dimensional visualization of the DISTLM results, with samples grouped by their community cluster, and vectors representing the explanatory variables being proportional to their contribution of that variable to the overall variation.

Fish community analysis from DTIS video counts

All fish observed on the DTIS video transect from the core areas were identified to the lowest taxonomic level possible. Total transect counts were scaled to numbers per 1000 m^2, using the estimated swept area of each transect. Swept area was estimated using a mean transect width, calculated from a subsample of width measurements taken from frame grabs for that transect, and transect distance. Transect distances varied according to duration (10–45 minutes), and tidal current direction and strength.

The fish communities observed were dominated overall by benthic-associated species such as sea perch, rattails and opal fishes, and reef-associated species such as pink maomao and butterfly perch. A number of pelagic species observed on camera were omitted from further community analysis since these species tended to be attracted to the DTIS lights themselves, or the potential prey attracted by the lights, and counts were usually not accurate due to high numbers (e.g., myctophids). A number of other categories were combined where it was not possible to consistently distinguish between species; e.g., bastard cod, red cod and rock cod were all combined; witch and other flatfish were combined into a single flatfish group; unidentified eel and worm eels were combined where the unidentified eels were not any other obvious species.

For each of the three core areas, a zero-adjusted Bray-Curtis dissimilarity matrix was computed from square root transformed fish density data at a transect level, providing moderate down-weighting of the contribution of numerically dominant species and allowing for rarer species to better contribute to the similarities calculated between samples (Clarke & Warwick, 2001). A similarity profile test (SIMPROF) determined if there were significant differences within the fish community multivariate structure (i.e., between stations), and unconstrained non-metric multidimensional scaling (nMDS) applied to visualize patterns in data in two dimensions. Where significant groupings were found, a similarity percentage test (SIMPER) was performed to evaluate the role of individual species in contributing to the group separations (Clarke & Warwick 2001, Clarke & Gorley 2006).

To assess the contribution of the environmental factors to the variation observed in the fish community structure, a non-parametric multivariate regression using distance-based redundancy analysis (db-RDA) was carried out. Possible explanatory variables were derived from the multibeam, CTD and sediment samples collected at each DTIS station. As the fish community sample was at the DTIS transect level, for the multibeam-derived variables, mean values of slope, rugosity and reflectance were calculated using the grid values selected for still images within that transect. From the DTIS-mounted CTD, average values of water depth, temperature, and salinity were estimated at the transect level. For most DTIS stations, a matched sediment grab sample was taken, except where the ground was too hard to use the grab. These samples provided values of the percentage of calcium carbonate, TOM, mud and sand for each DTIS station. In two Core areas (Taranaki Canyons and Ranfurly Bank), the ground was too hard for a grab sample to be retrieved on some transects. In these areas, calcium carbonate and TOM were not included as explanatory variables, and the percentage of mud and sand assumed to be zero, with a nominal value of 100% rock assigned. Some image-derived metrics were also generated. From all the DTIS stills images analysed within a transect, the summed area of hard substrate (bedrock, boulders, cobbles and pebbles combined) was expressed as a percentage of the total area analysed for each station. The amount of bioturbation observed at each station was represented by calculating the proportion of images classed as having medium or high levels of bioturbation (five or more burrows, tracks, faecal casts etc). To reflect the level of biogenic habitat observed on a transect, the proportion of images sampled within that transect that were assigned clusters classed as representing ‘high’ biogenic habitat was calculated. Clusters were assigned this category, based on presence of a biogenic habitat former, or having a sessile species diversity greater than 5. For the east coast South Island stations, another variable was created to directly reflect the coverage of selected tubeworm “types” in the sampled images within each station.

The multivariate multiple regression (DistLM routine) tested the significance of the contribution of the above variables by fitting a linear model based on the zero-adjusted Bray-Curtis dissimilarities from square root transformed fish density data using permutations. The contribution of each variable was first assessed, before the AIC selection criterion and BEST / STEP-WISE procedure were used to find a model that retained only variables with good explanatory power. The reduced model was visualized with a db-RDA plot with samples grouped by appropriate spatial location and vectors representing the explanatory variables being proportional to their contribution of that variable to the overall variation.

2.6 Synopsis Section

In the Synopsis section, the findings of objectives 2 and 3 are used to assess the present status, likely extent, ecological role and threats to the biogenic habitats described here. The strategy of the field sampling was to confirm presence and collect samples to enable characterization of locations of suspected biogenic habitat at multiple sites around New Zealand. Extensive mapping to ascertain the extent and boundaries of all these locations was not feasible. As such, the status and extent of the habitats identified during the *Tangaroa* voyages were assessed based only on a qualitative comparison of field observations from DTIS footage with the collated LEK data, and where available, additional scientific information available from other projects. This information was summarised into a table with comments on the level of correspondence between LEK and data collected. Where some or all of the fauna described by fishers from their past recollections of bycatch was seen in DTIS videos, this was noted as a good or a partial match. Where no evidence of the bycatch described by fishers was observed, this was noted as not matched, or indeterminate if the fisher descriptions implied a sparse or very patchy habitat that could have been missed.

The likely wider extent of the habitats identified at the Core sites was also assessed based on identification of key species contributing to the habitats observed, and documenting the known distribution of those individual species based on a number of sources including existing scientific literature, and NIWA's taxonomic datatbase (Specify). It is noted that the presence of habitat-forming species does not automatically equate to the provision of important habitat, but knowledge of the distribution of potential habitat formers provides some information on possible extent of that habitat.

The ecological role of the observed habitats is discussed based on the key sessile habitat-formers in the different locations, and a review of existing literature relating to the known functions of these key species. A particular focus of this project was the value of biogenic habitats in supporting fisheries production, specifically their potential role as fish nursery habitats. To formally define what are and what are not fish nurseries at the level of both habitat type, and specific spatial location, requires a detailed understanding of what proportion of overall recruitment is contributed by a given habitat or spatial location relative to all others (Beck et al. 2001, Dahlgren et al. 2006). In the absence of such detailed empirical knowledge, the presence (particularly in high abundance) of juvenile fish in samples (both imagery and physical samples), is discussed as a first proxy for fish nursery areas.

The main threats to biogenic habitats are likely to be fishing and land-based effects such as sedimentation (MPI, 2016). To provide a broad view of fishing impacts using fishing footprint as a proxy, the trawl intensity data from Baird et al. (2015) was used to allocate a fishing footprint to each of the fisher drawn habitat areas sampled during the two voyages. The fisher-drawn areas were overlaid with the fishing trawl intensity data in ArcGIS, and the average fishing footprint per 5 km^2 calculated (the same resolution provided by Baird et al. 2015), and averaged over the five years. Grid cells which fell over the boundaries of the fisher drawn area were prorated by the proportion of their area that fell within the area. No attempt was made to re-define the fisher-drawn areas using the multibeam or DTIS transects. The average fishing footprint per 5 km^2 (25 km^2) in each of the fisher drawn habitat areas was then expressed as a value within a range from 0 (no trawling) to 25 (all of the area was covered by a trawl at least once) (e.g. 10 would equal 40% of the area being fished, 20 would equal 80% of the area being fished). These values are presented in Table 65, alongside the qualitative ranking of the match between the DTIS observations and the original LEK descriptions (including comments on fishing impacts), and are used as a basis to assess areas of biogenic habitat that may have been removed or impacted by fishing activities since the recollections of the fishers. Caveats include: the fisher-drawn areas may be spatially imprecise (e.g., the Taranaki canyon biogenic habitats only occupy a small proportion of the fisher-drawn areas; other fisher-drawn areas extend over both trawlable and untrawlable ground), that the calculations of Baird only cover the 2007–2012 time period, and that other fishing methods such as dredging were not included.

The CLUES model (Catchment Land Use for Environmental Sustainability) is a GIS-based freshwater catchment model for assessing the effects of land use change on water quality variables (Woods et al. 2006). To provide a broadscale indication of land-based effects by region, the CLUES model was used to generate a visual representation of the total sediment yields from major rivers around the New Zealand coast. The potential impacts of both fishing and sedimentation on the biogenic habiats observed in this study are discussed in the context of the inferred fishing footprint and regional scale sediment load, and collated alongside published studies reporting the loss of biogenic habitat due to anthropogenic activities.

3. RESULTS

Across the two voyages, 45 sites were visited from Middlesex Bank in the north, to Stewart Island in the south (Figure 1), with 194 DTIS, 28 beam trawl, 35 rock dredge, and 124 sediment samples collected. The analysis of sediment samples from all stations is presented first, as these summary plots are referred to throughout the later sections. This is followed by a section providing summary descriptions of the sites sampled, grouped into geographic regions. For each region, a broadscale map is presented showing the digitized fisher-drawn (LEK) areas from Objective 1, with the multibeam-derived bathymetry maps, and sampling station positions overlaid. For details of the LEK areas, the reader is referred to Jones et al. (2016). For each site, a higher resolution bathymetry map where multibeam data were collected is also presented, and overlaid with the DTIS transects and location of other stations. Brief observational summaries are then provided for all of the sites surveyed, including a DTIS station table, and some representative DTIS images. The presentation order largely follows that of the voyage survey order, to provide a logical geographical narrative.

Following broadscale descriptions of all sites sampled during the voyages, the analysis of the data collected in three core areas is presented. A total of 20 biological samples (rock dredge and beam trawl) were processed, and 73 DTIS transects analysed; 15 stations at the North Taranaki canyon sites, 31 stations from the "Wire weed" and "Hay Paddock" areas on the east coast South Island, (includes 4 stations with video only, no stills), and 31 stations on Ranfurly Bank. In these sections, multibeam derived maps of bathymetry, slope, reflectivity and BTM zones and structures are presented and described. Summary tables and information from the biological samples collected is then presented. The analyses of the DTIS stills images are given, including occurrence of the main taxonomic groups within geographic locations (sites) and the results of the cluster analysis of invertebrate community level data (full data and sessile fauna only) across all the sites within each core area. The next section presents the distance based linear modelling (DISTLM) of the relationships between the invertebrate community and multibeam derived and other environmental variables. Finally, the fish community data are presented, including a summary of biological specimens collected, overall densities of all species or OTUs observed on the DTIS video at each geographic location within the core areas, a cluster analysis of the fish community data and DISTLM models exploring the influence of different environmental and biological (invertebrate community metrics) variables on the fish communities.

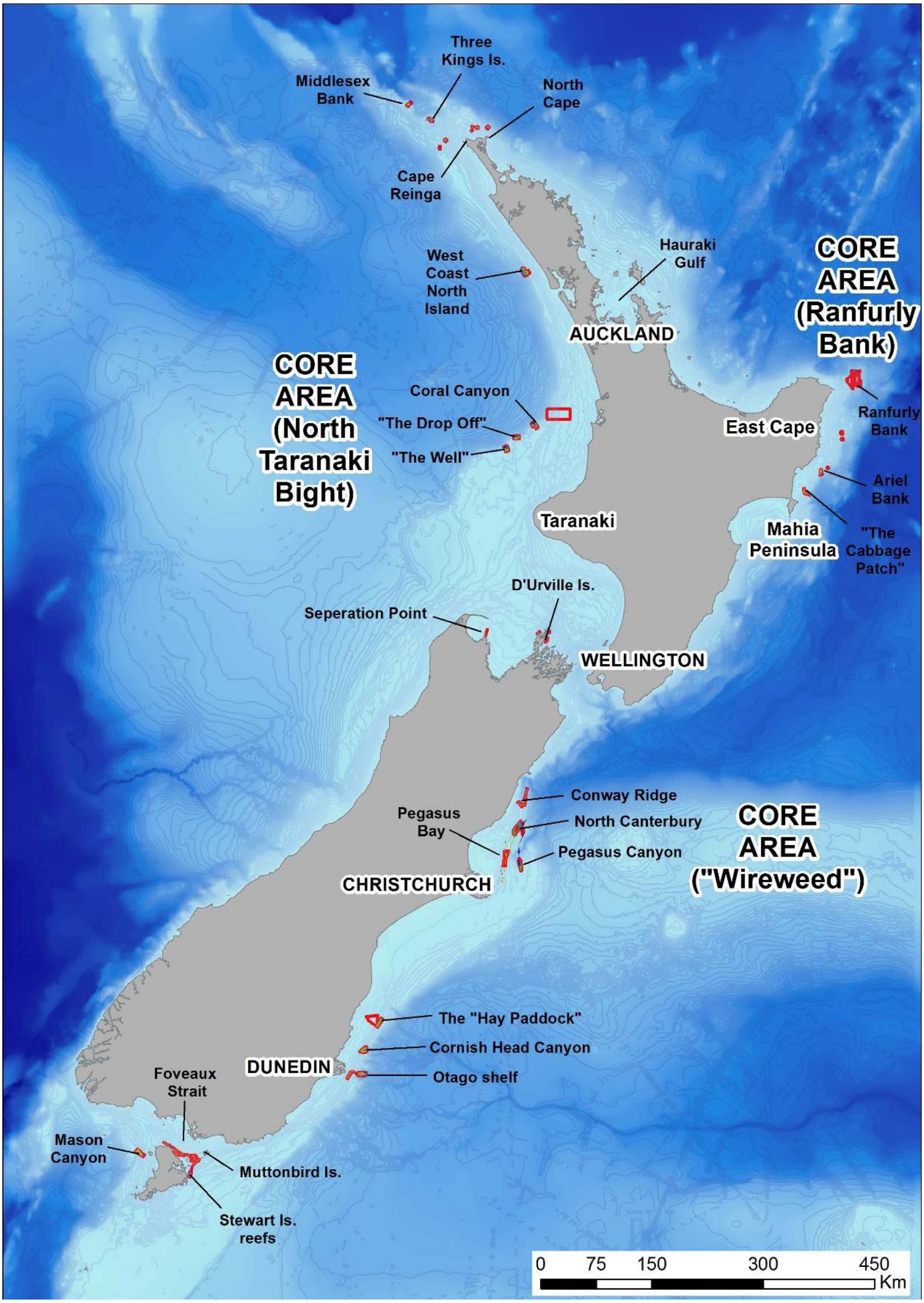


Figure 1: Map of survey locations around New Zealand. The three areas selected for detailed analysis (the ‘Core’ areas) are also shown.

3.1 Sediment analysis

One hundred and twenty-four sediment grab samples were collected across the two voyages (see later sections for spatial locations). Colour coding is used in these figures to help distinguish areas, noting that each voyage is coded independently of the other. For sediment grain size, two tertiary plots are given for each voyage: the first for Gravel:Sand:Mud and the second for Sand:Silt:Clay.

For the first voyage (Middlesex Bank to Tasman Bay), most of the far northern sites' sediments fell along the gravel to sand continuum, with little to no silt or clay being present (Figure 2). The west coast canyons, with the exception of three gravelly stations, were classed as sandy mud and muddy sand, with variable silt contributions, as were the two D'Urville Island sites. Calcium carbonate proportions were high in the far northern sites, especially at Middlesex Bank (over 80%), but were generally much lower for the west coast canyons and D'Urville Island sites (Figure 4). The percentage contribution of Total Organic Matter (TOM) was less variable across all of the sites sampled, and ranged from around one to five percent (Figure 5).

For the second voyage (East Cape to Stewart Island), a much wider range of sediment classes was sampled (Figure 3). Foveaux Strait, the Hay Paddock, Otago Shelf, Pegasus Canyon, and Ranfurly Bank tended to fall out as gravel to sand classes, with a small mud contribution, and no silt; while samples from the east coast North Island (Table Cape and Ariel Bank) varied widely with gravel, sand and mud contributions, as did some Ranfurly Bank sites. North Canterbury samples and the one Conway Ridge sample, tended towards the sand to mud continuum, with a large silt contribution.

Calcium carbonate proportions were higher for Foveaux Strait, the Otago Shelf, Cornish Head canyon, one Pegasus Bay site, and Ranfurly Bank; less so at the Hay Paddock, and relatively low at Conway Ridge, North Canterbury, Pegasus Bay, Table Cape and Ariel Bank (Figure 4). The percentage contribution of Total Organic Matter (TOM) was variable across sites within regions, but was generally higher at the North Canterbury, Table Cape, Ariel Bank, and Ranfurly Bank areas (averaging about 3 to 4 percent); and lower in the other areas (less than 2 percent) (Figure 5).

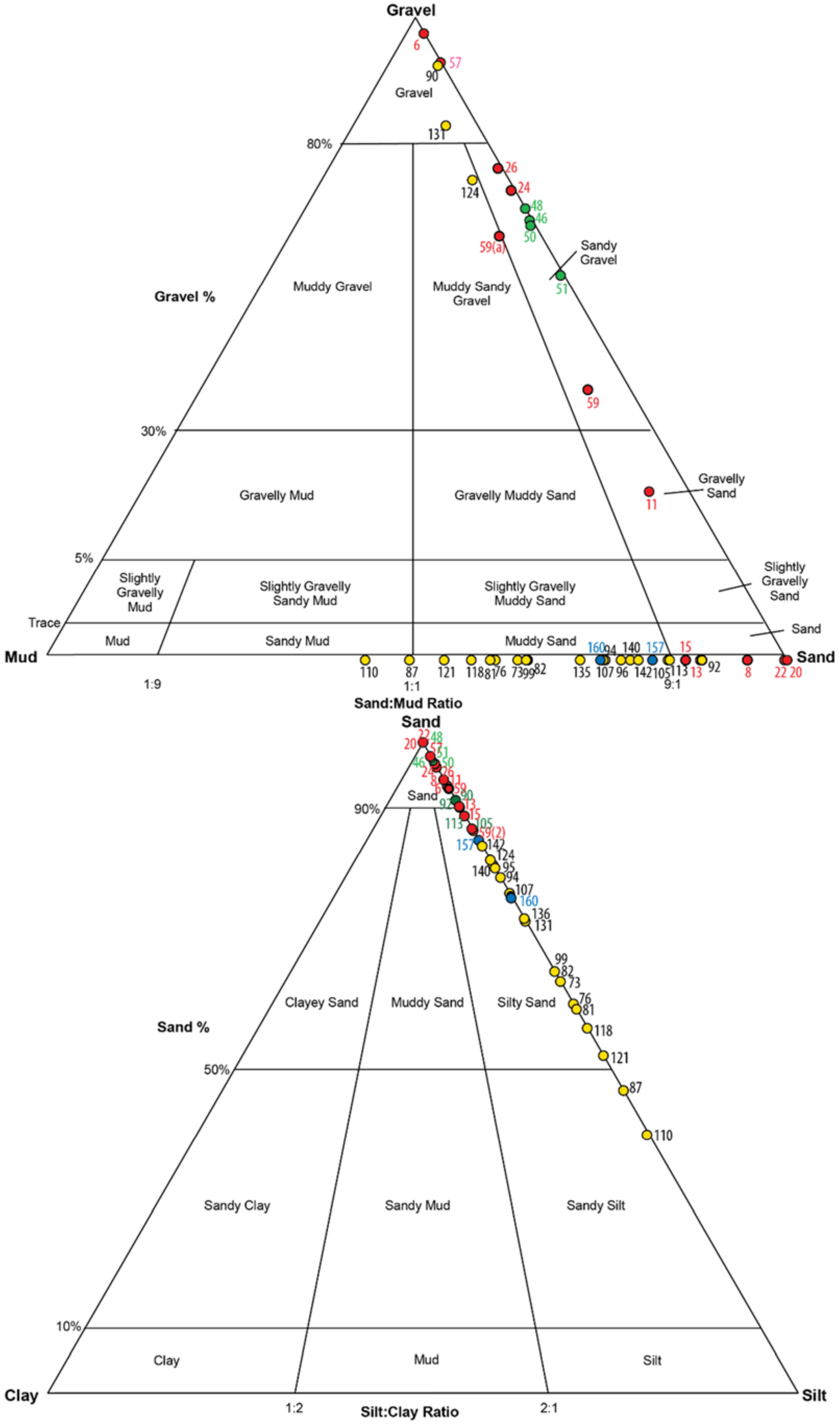


Figure 2: Sediment grain size analysis from the TAN1105 voyage. Top) Gravel/mud/sand plot, bottom) sand/clay/silt plot. Red, North Cape to Three Kings; green, Middlesex Bank; yellow, Three Holes and North Taranaki canyons canyons and shelf; blue, D’Urville Island. Labels are the station numbers.

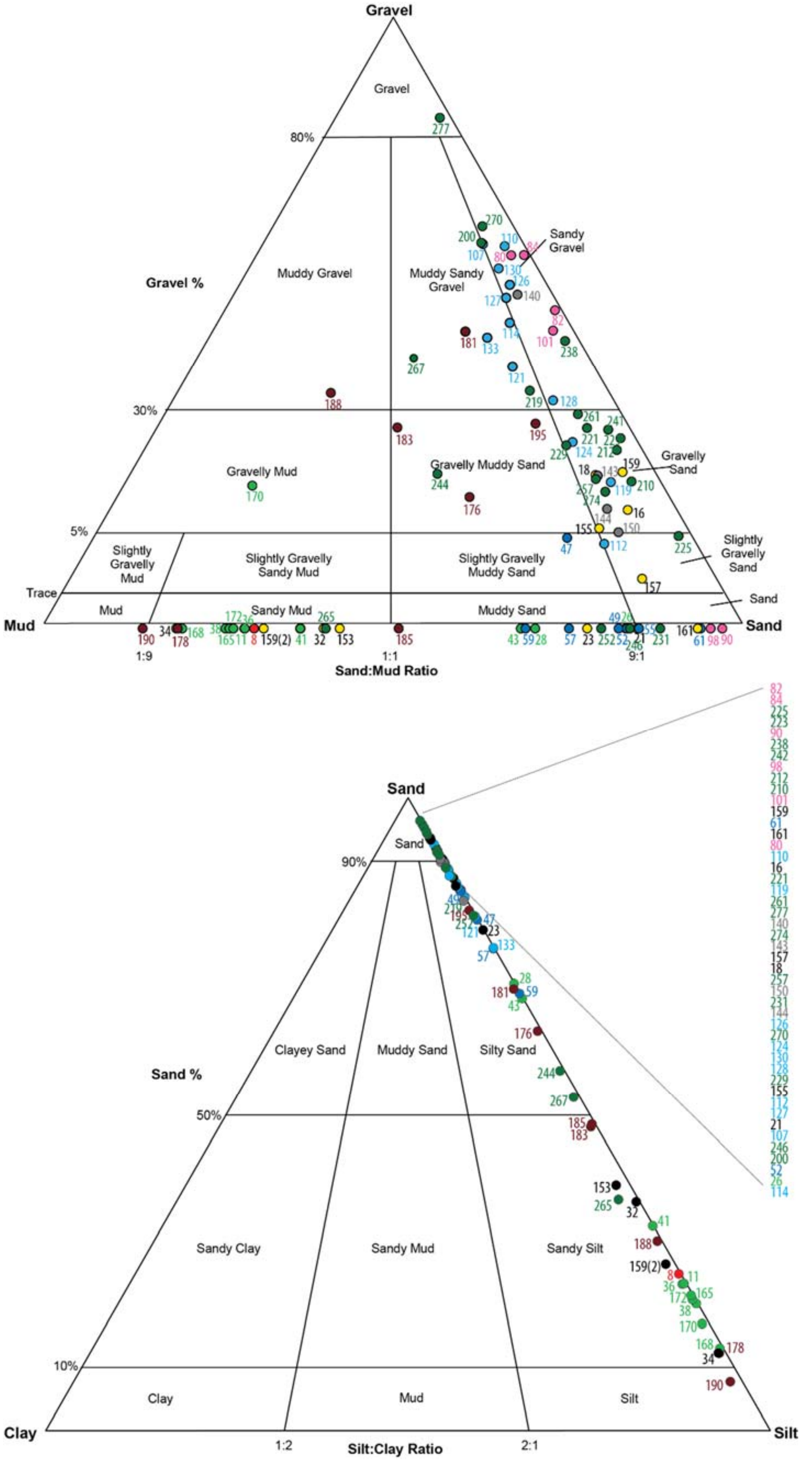


Figure 3: Sediment grain size analysis from the TAN1108 voyage. Top) Gravel/mud/sand plot, bottom) sand/clay/silt plot. Red, Conway Ridge; light green, North Canterbury; yellow, Pegasus Canyon; blue, Hay Paddock; pink, Foveaux Strait; light blue, Otago shelf; grey, Cornish Head canyon; brown, Table Cape and Ariel Bank; dark green, Ranfurly Bank. Labels are the station numbers.

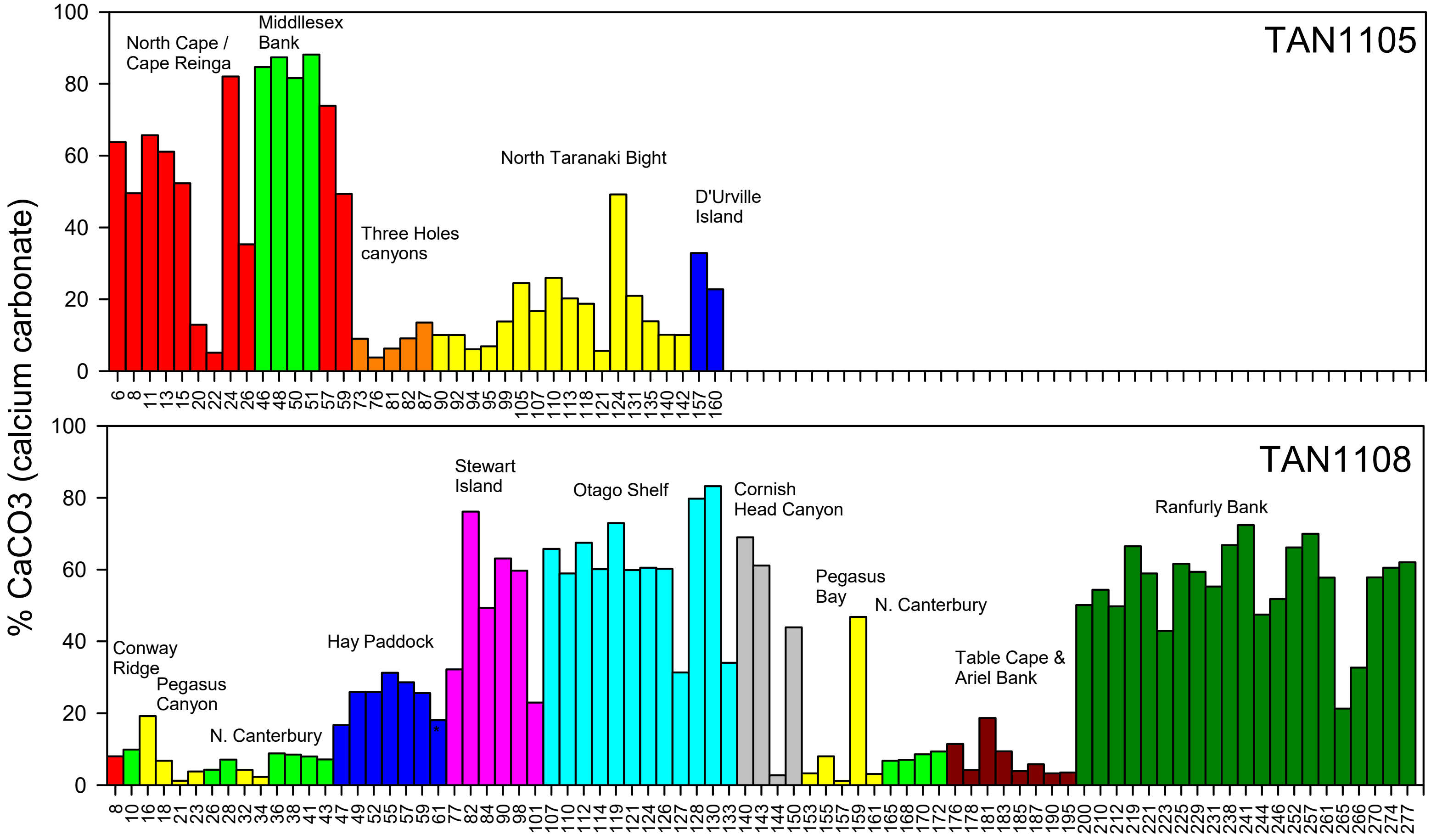


Figure 4: Percentage calcium carbonate ($CaCO_3$) for sediment samples from the two *Tangaroa* voyages. Labels are the station numbers, by voyage respectively. Core areas: North Taranaki Bight, North Canterbury, Pegasus Bay, Pegasus Canyon, Haypaddock ("wireweed" habitats), and Ranfurly Bank.

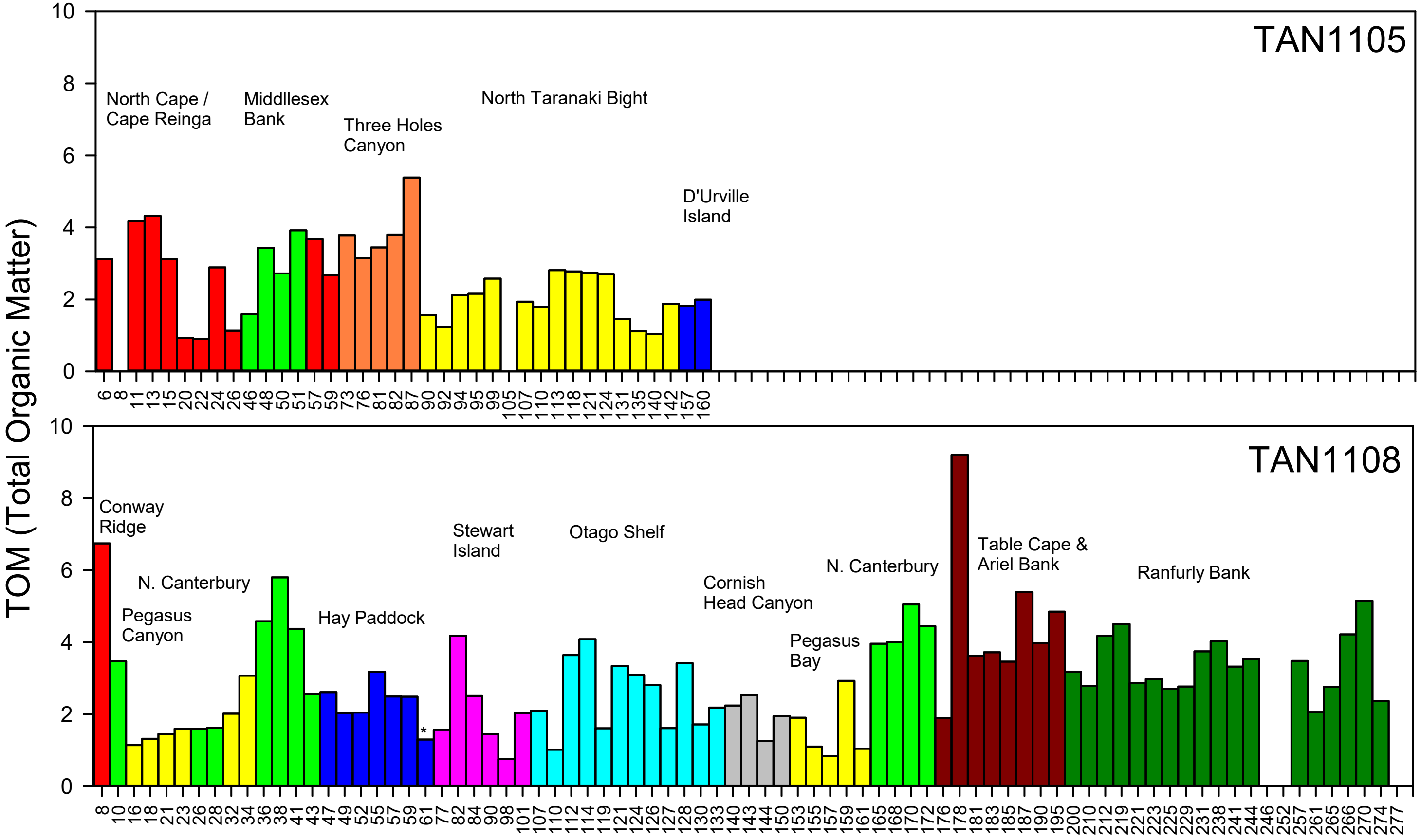


Figure 5: Total Organic Matter (TOM) for sediment samples from the two *Tangaroa* voyages. Labels are the station numbers, by voyage respectively. Core areas: North Taranaki Bight, North Canterbury, Pegasus Bay, Pegasus Canyon, Haypaddock ("wireweed" habitats), and Ranfurly Bank.

3.2 Regional Descriptions

Middlesex Bank to North Cape

Eight multibeam blocks, along with several additional DTIS/dredge tows outside these blocks, were completed in this region (Figure 6).

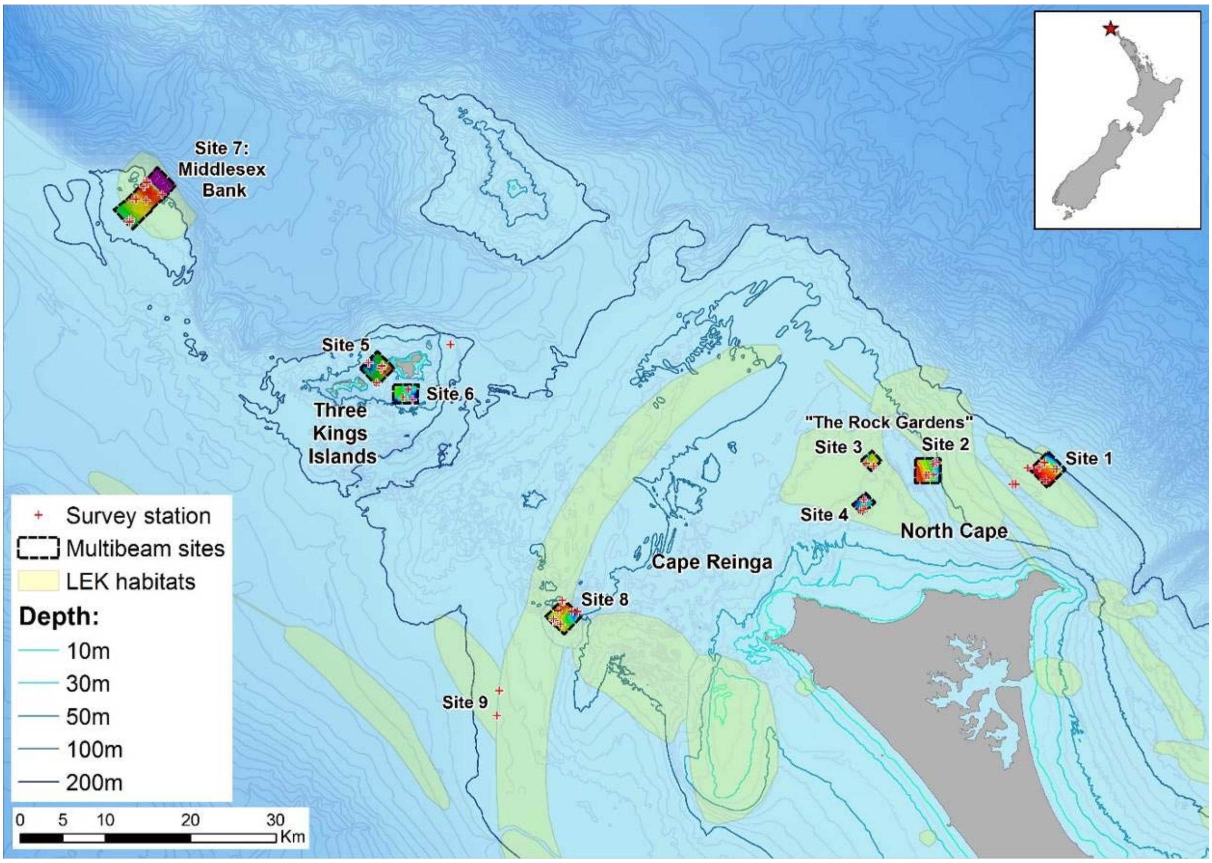


Figure 6: Middlesex Bank to North Cape survey region. Fisher-drawn areas (LEK habitats) shown as light yellow polygons.

Middlesex Bank (Site 7)

A rectangular multibeam block (25.7 km^2) was mapped across the bank crest, cutting through the only fisher-drawn area for the bank, which was noted for its coral habitat (Figure 6 and Figure 7). This block included the steep north-eastern drop-off (about 120 m down to 600 m depth), the crest of the bank at about 100 m water depth, and a gentle slope gradually increasing in depth to the south-east (maximum depth mapped about 180 m) (Figure 7). Four DTIS, two rock dredge, and one beam trawl stations were completed (Table 1). The four sediment samples collected were classified as sandy gravel (Figure 2), composed of more than 80% calcium carbonate (Figure 4), with a total organic matter (TOM) content of around 1% (Figure 5). The mapped block was a mixture of bed-rock outcrops, sandy gravel, and white carbonate sands. A rich epifauna was present, including black corals, gorgonians, bryozoans, and sponges (Figure 8). Fifty-seven sponge species were identified from the collections during a separate NIWA taxonomic project (COBR1408), 16 of which were new to science, as well as other rare sponges last sampled in a 1924 expedition; other notable finds included two new hydroid species (Schnabel et al. 2014).

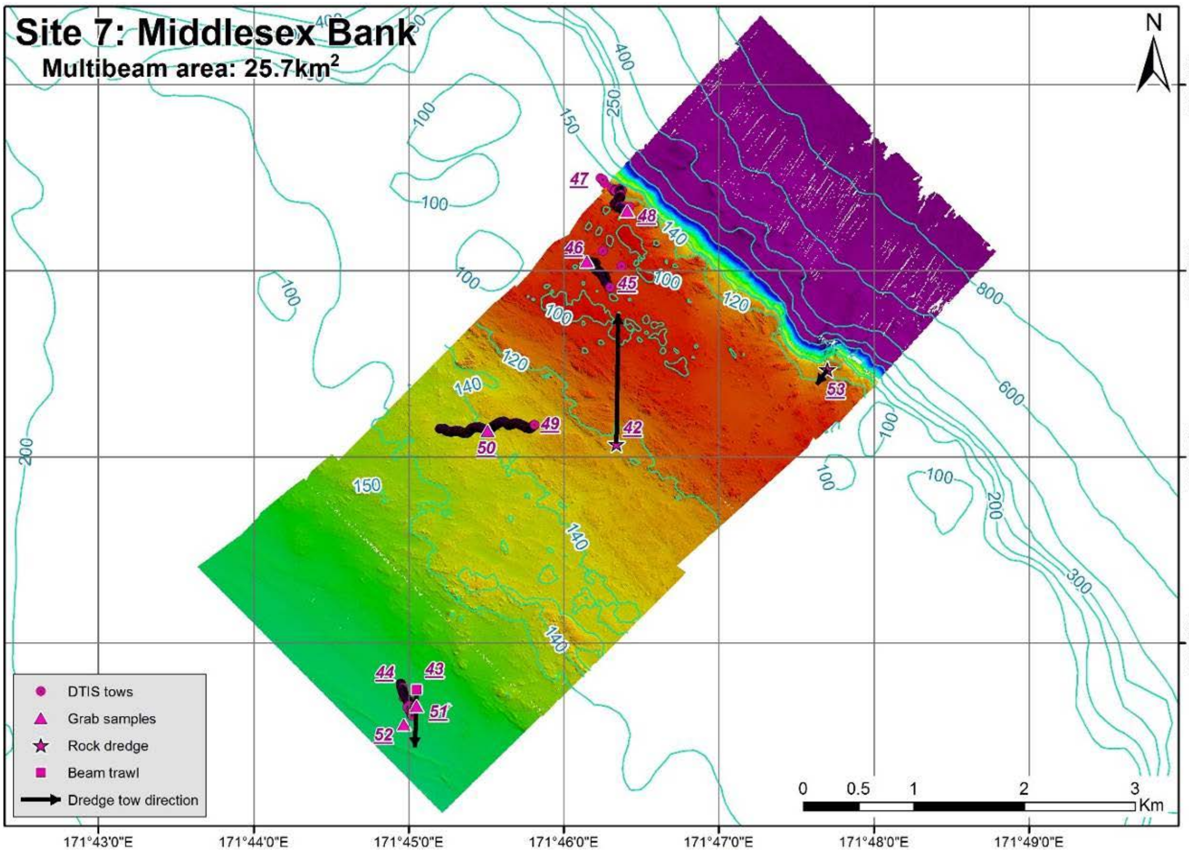


Figure 7: Middlesex Bank mapped bathymetry (Site 7). 4 DTIS, 2 rock dredge, 1 beam trawl, 5 sediment.

Table 1: DTIS stations for Middlesex Bank.

Stn.	Time (min)	Images	Depth (m)	General habitat
44	31	126	170	Sand/bed rock mix with black coral whips, bryozoans, sponges, gorgonians
45	31	128	95	Sand/bed rock mix with sponges and gorgonians, bryozoans
47	31	127	100–115	Sand / bed rock mix with sponge and gorgonians
49	61	254	125–135	Sand / bed rock mix with sponge, gorgonians and bryozoans

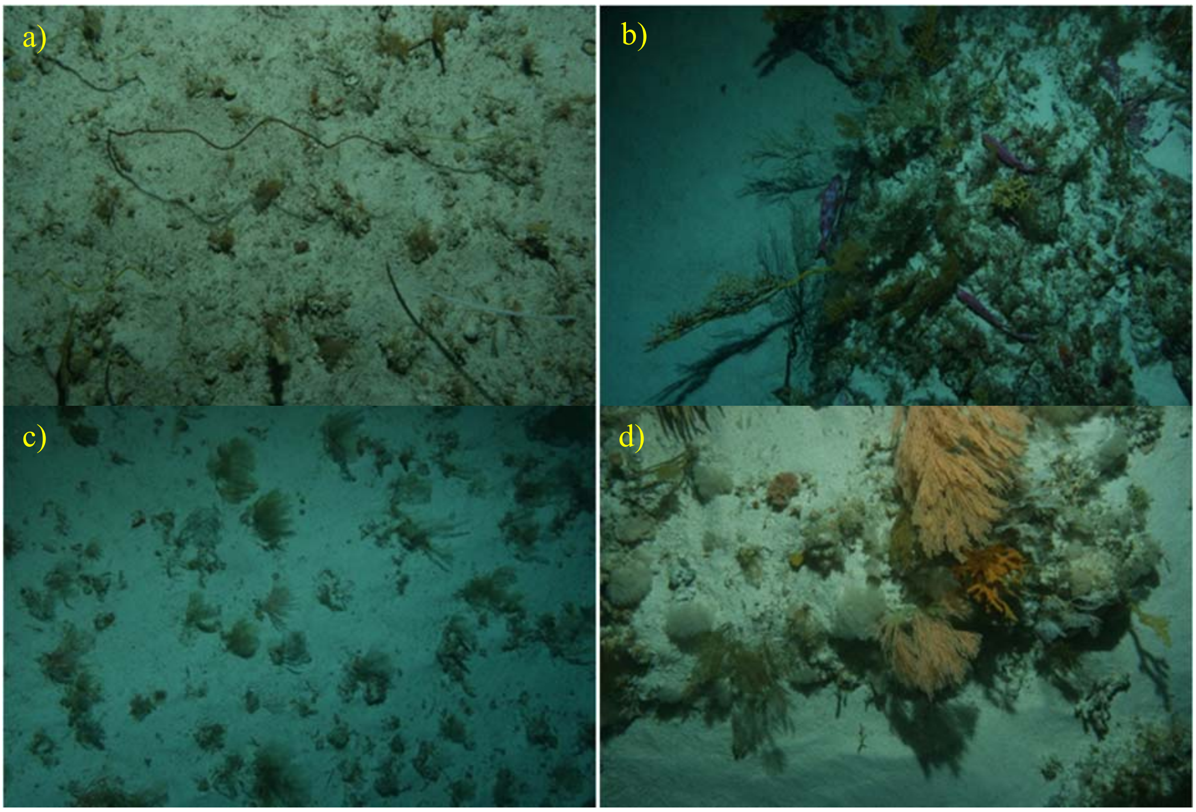


Figure 8: Middlesex Bank seafloor imagery: a) whip coral and sea-pen, b–d) gorgonians, sponges and hydroids. Fish are pink maomao. Image scale varies.

The Three Kings Islands (Sites 5, 6)

Two multi-beam blocks were completed (Figure 6), one between the two main islands (Figure 9a; Site 5, 9.7 km^2), and one south of Great King Island (Figure 9b; Site 7, 7.5 km^2). The first site consisted of a shallow approximately 50 m reef feature, connected by a reef ridge to Great King Island, and surrounded by deeper low-relief reef, which eventually graded into cobbles and sand at about 80–90 m water depth. A sand-fan feature was present on the eastern side of the block. Four DTIS transects and one rock dredge sample were collected, indicating mixtures of kelp on reef, larger form rhodolith beds on sand/cobbles, bryozoans, and turfing algae (Figure 10, Table 2). The second site, in 70 to 90 m water depth, was largely covered by low-relief bedrock and cobble fields, with some areas of coarse sand sediment overlays. Sponges, and in particular, dense but patchy bryozoan clumps, were the main habitat forming species present (Figure 11, Table 2). One exploratory rock dredge tow was also made north-east of Great King Island (Figure 6), and returned relic dead rhodoliths, with little attached epifauna (no biological samples taken). It is suspected that these rhodoliths date from an earlier time period when sea-levels were lower (Nelson & Hancock 1984), as the water depth (about 130 m) is probably too deep to support living rhodolith beds.

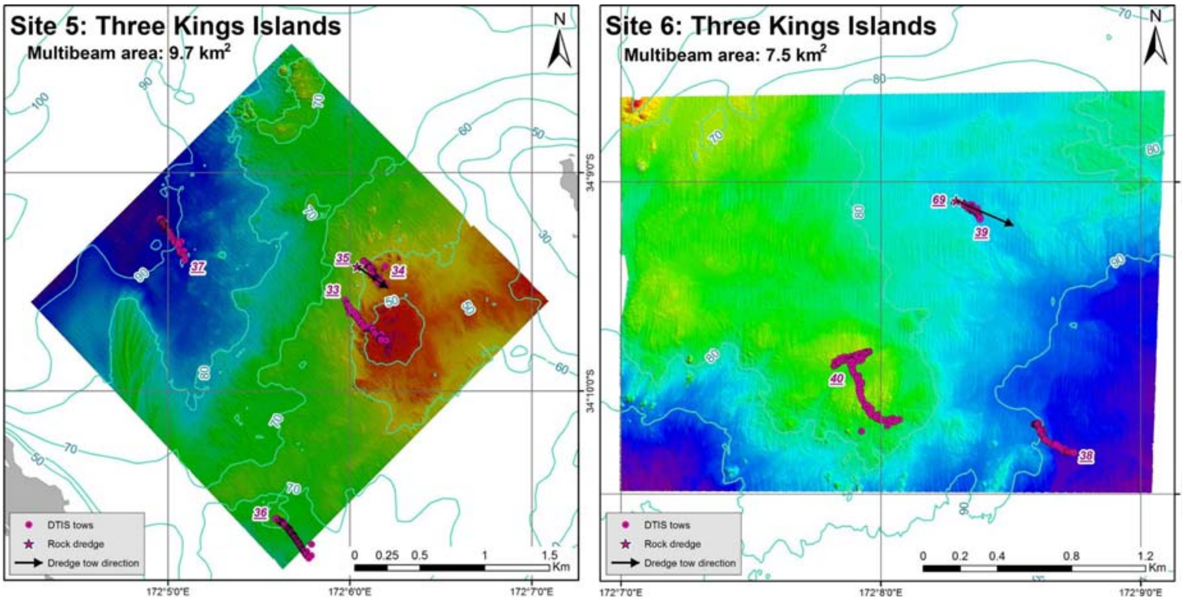


Figure 9: a) Three Kings Islands northern site (Site 5) mapped bathymetry, 4 DTIS, 1 rock dredge; b) Three Kings Islands southern site (Site 6) mapped bathymetry, 3 DTIS, 1 rock dredge. Scales differ.

Table 2: DTIS stations for the two Three Kings Islands multibeam blocks.

Station	Time (m)	Images	Depth (m)	General habitat
Northern site				
33	32	128	40–56	Kelp forest on bedrock, rhodolith habitat on sand
34	*c* 30		44–54	Kelp forest on bedrock, rhodolith habitat on sand
36	30	121	60–67	Rhodoliths, cobbles, sand, turfing algae, bryozoans, sponge
37	34	133	83–88	Cobbles/sand/bedrock. Turfing algae
Southern site				
38	31	126	84–87	Sand/bedrock and sponge reef
39	30	122	78	Sand/cobbles/bedrock, sponges, other reef species
40	60	246	68	Bedrock/sand, as above

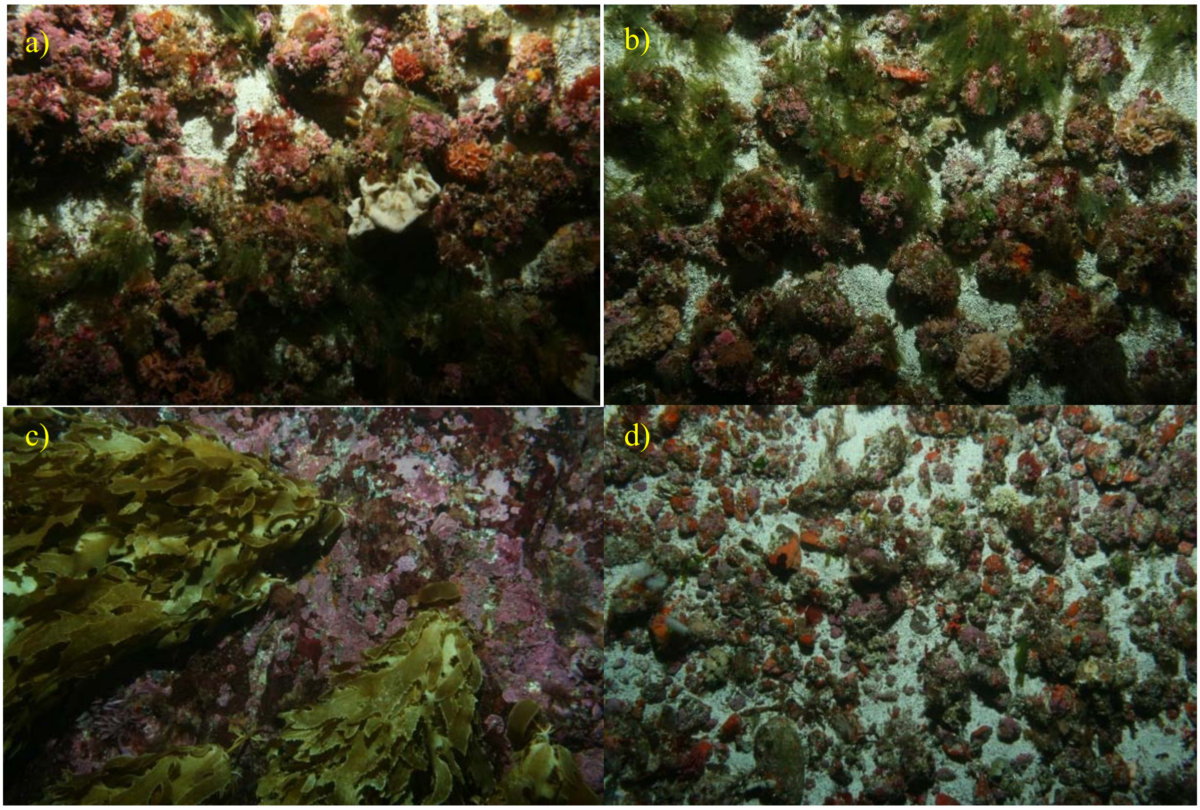


Figure 10: Three Kings Islands northern site seafloor imagery: a–b) rhodoliths on carbonate sand, hydroid 'trees' (green), and various bryozoans, c) kelp on rocky reef, d) cobbles with sponges and bryozoans on carbonate sand. Image scale varies.

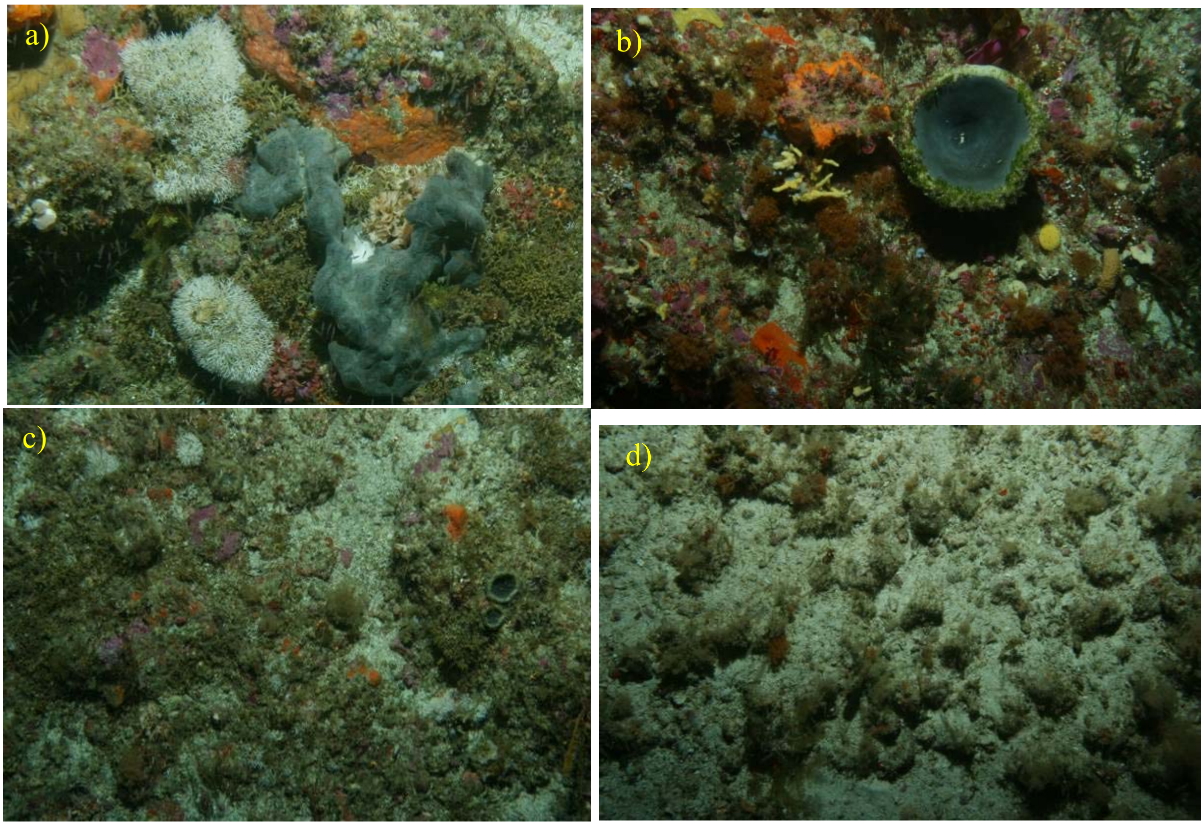


Figure 11: Three Kings Islands northern site seafloor imagery: a) bryozoan clumps and sponges, b) bryozoans and sponges, c–d) bryozoans and rubble. Image scales vary.

Cape Reinga west (Sites 8, 9)

One multibeam block was mapped and sampled (Site 8), along with two exploratory DTIS transects (no multi-beam) to the south-west (Site 9) (Figure 6), all overlapping fisher-drawn areas where a bycatch of sponges and gorgonians was described. The multibeam block (Site 8, 10.4 km^2) had 5 associated DTIS transects, 1 rock dredge, and 1 beam trawl (Figure 12, Table 3). The northern quadrant of this block contained bedrock reef, extending from about 100 m to 120 m water depth, and grading into coarse sands. Two discrete reef features were also present in the south, as well as the start of reef on the most eastern corner of the block. The rest of the block was occupied by gently sloping soft sediment channel between the northern and eastern reef areas, with a deeper channel (to 150–160 m) running between reef systems in the eastern block quadrant. These sediments were characterised as gravel/sandy gravel, with a high calcium carbonate content, and about 3–4% TOM (Figure 2, Figure 4, Figure 5). The shallower bedrock areas were characterised by relatively abundant cup and plate sponges, hydroids, corals; deeper reef had a higher number of plate-like sponges, and some especially dense corals on near-vertical faces near the start of Station 64 (Figure 13a–d). Two short DTIS tows in deeper water to the west (Site 9: 154–155 m water depth) to look for fisher-described corals returned coarse sand/gravel only (no samples taken), with scattered small sponges and ascidians (Figure 13e–f).

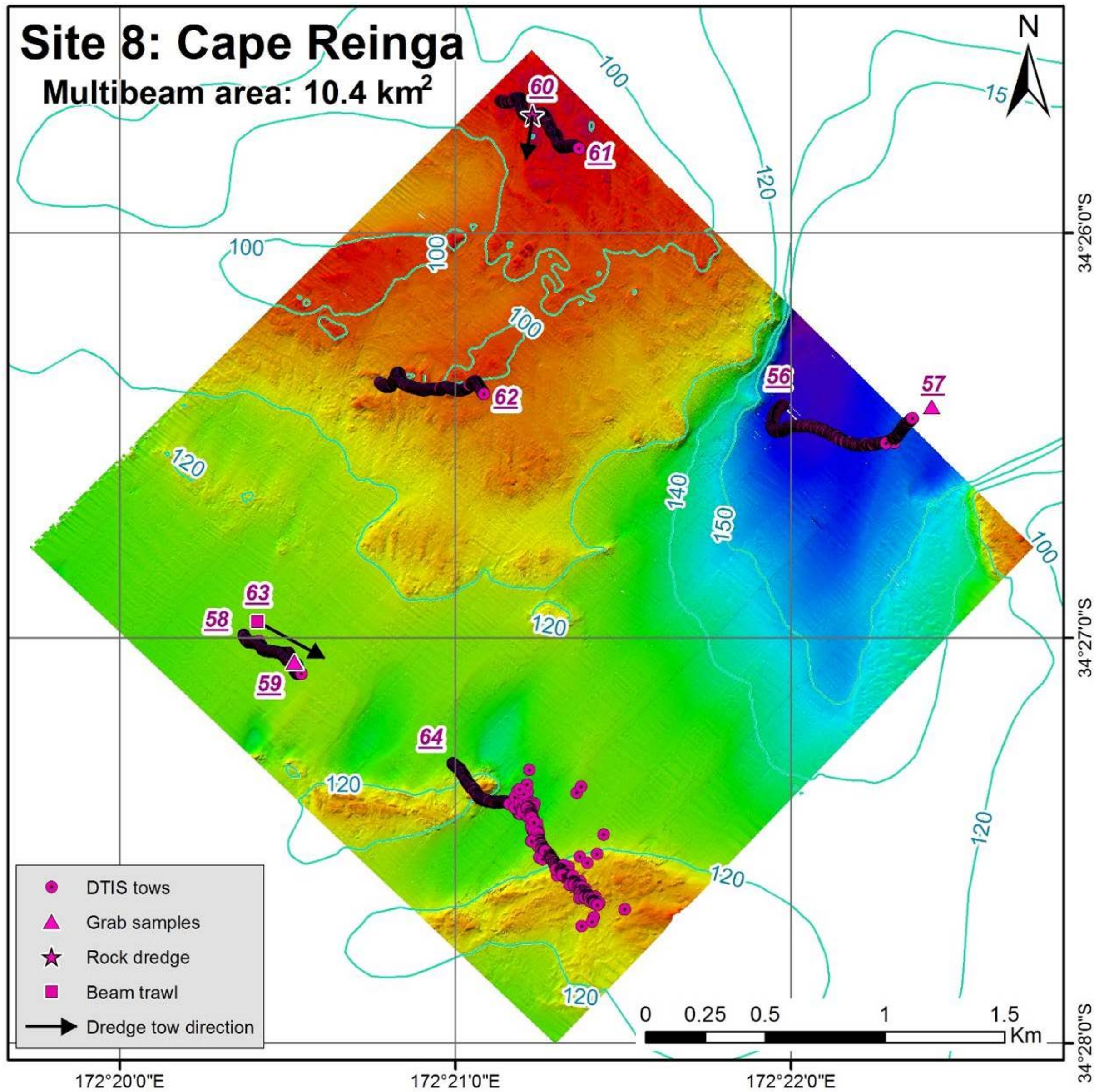


Figure 12: Cape Reinga west (Site 8) mapped bathymetry. 5 DTIS, 2 rock dredge, 1 beam trawl, 2 sediment.

Table 3: DTIS stations for Cape Reinga west (Sites 8 and 9).

Station	Time (min)	Images	Depth (m)	General habitat
Site 8				
56	25	103	150–160	Sand/shell hash and low relief habitat
58	38	152	116	Sand/shell hash and low relief habitat
61	31	125	88	High relief rocky reef sponge habitat
62	40	124	98	High relief rocky reef sponge habitat
64	66	261	100–120	High relief rocky reef sponge habitat, corals
Site 9				
65	15	61	154	Sand only
66	17	71	155	Sand only

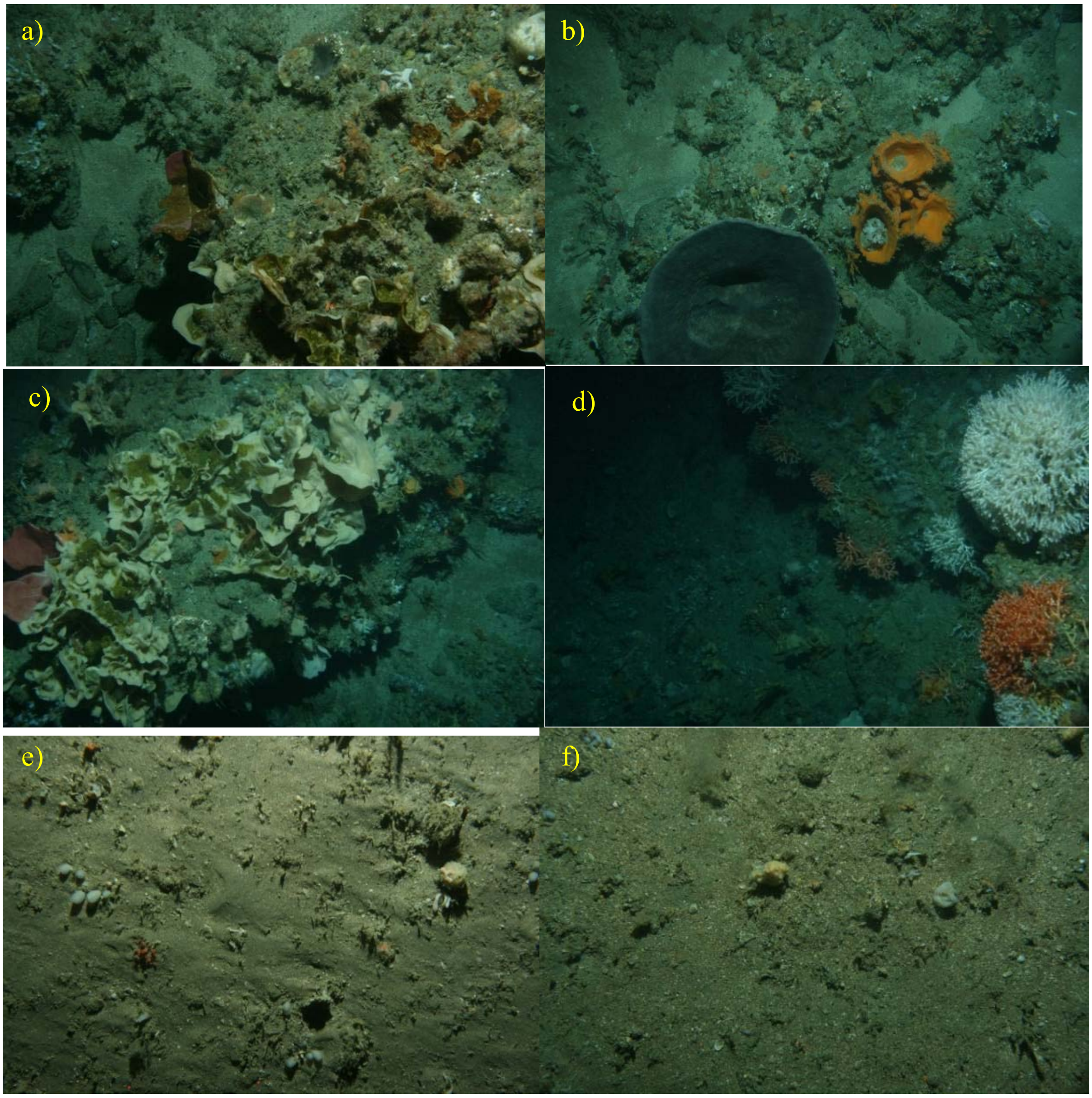


Figure 13: Cape Reinga west seafloor imagery for: Site 8, a–c) sponge cover on high relief rock, d) corals on steep rock wall; Site 9, e and f) sand/gravel sediment with scattered sponges and ascidians. Image scales vary.

North Cape (Sites 1–4)

Four multibeam blocks were mapped across a number of fisher-drawn areas, collectively called "The Rock Garden" (Figure 6). The areas mapped ranged from 3.4 km^2 to 10.4 km^2 in size (Figure 14). Site 1 (10.4 km^2, 135–200 m water depth) was placed across a broadly north-east sloping sand area, steepening on the north-east side, with some shell hash, and patches of very low relief/buried rock out-crops. These outcrops supported scattered finger and cup sponges, gorgonian fans, whip corals, and larger black coral trees (Table 4, Figure 15a, b). The sediments ranged from gravel through to sand, with a high calcium carbonate content, and 3–4% TOM (Figure 2, Figure 4, Figure 5). This habitat type also extended west of the Site 1 block, with an exploratory DTIS station three km to the east (Station 14, Table 4, Figure 14,) composed of the same seafloor type and epibenthos, suggesting a large area of this habitat type to be present. Site 2 (9.9 km^2, 80–100 m water depth) was placed over large east-west orientated soft sediment dune features, with the seafloor being dominated by hard-packed sand with a relatively low calcium carbonate content (about 5–10%), low TOM (less than 1%) (Figure 2,

Figure 4, Figure 5), and little to no epifauna observed (Figure 15c). Site 3 (3.8 km^2, 70–80 m water depth) was similar, with large ripple features, composed of sandy gravel, with variable calcium carbonate content (35–80%) and TOM content (1–3%) (Figure 2, Figure 4, Figure 5), again with little to no epibenthos observed (Table 4). Site 4 (3.4 km^2, 70–80 m water depth) was dominated by extensive low-relief rocky reef with variable soft sediment overlays, and supported dense, visually striking, and species-rich sponge, gorgonian, and bryozoan assemblages (Table 4, Figure 15d–f). Sea pens were also present in some parts of the DTIS transects.

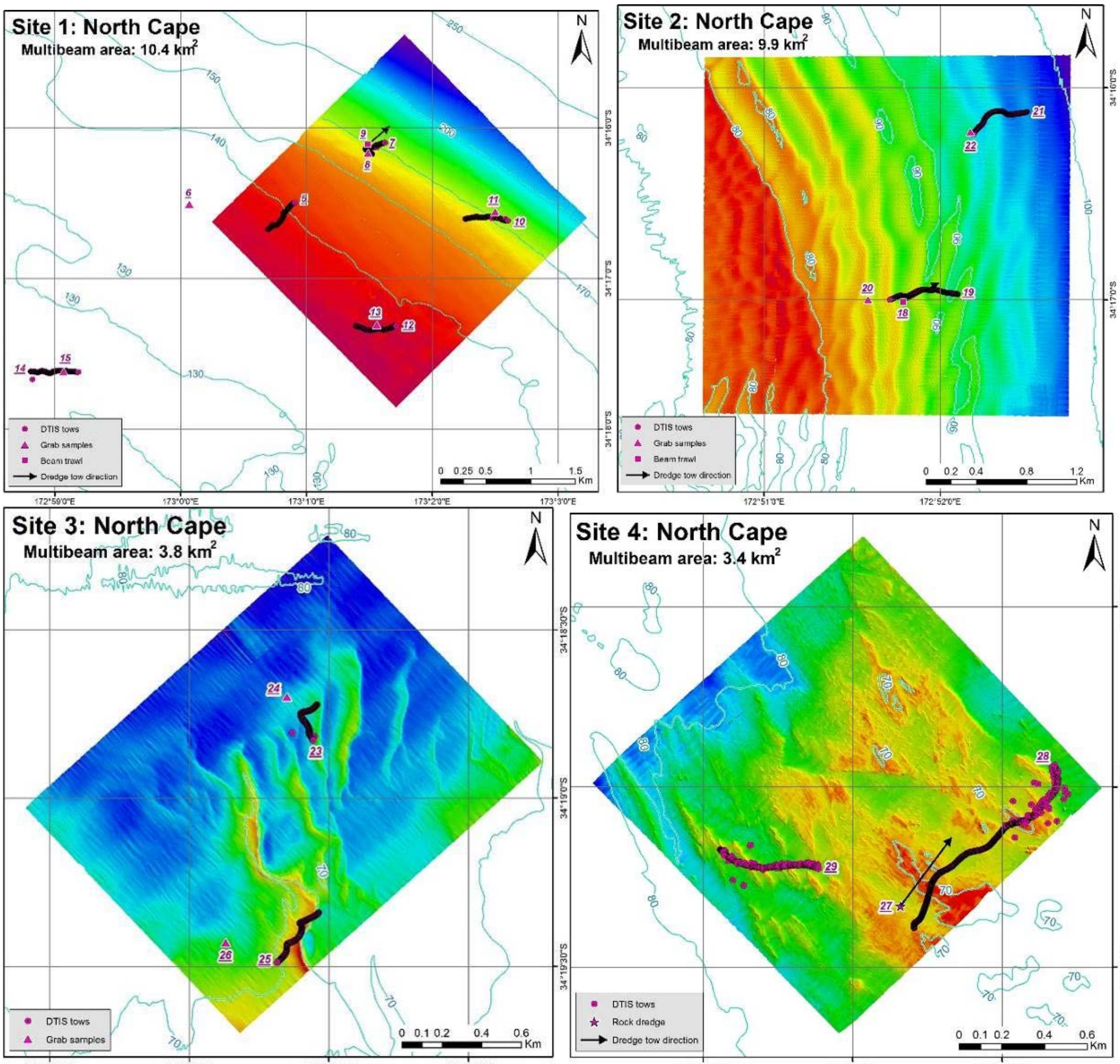


Figure 14: North Cape seafloor bathymetry (Sites 1–4).

Table 4: DTIS stations for North Cape sites.

Station	Time (min)	Images	Depth (m)	Habitat type
Site 1				
5	32	127	136	Sponge, gorgonians, soft corals, pink maomao
7	32	125	165	Sponge, gorgonians, soft corals, pink maomao
10	31	130	170	Sponge, black coral, gorgonians, soft corals, pink maomao
12	30	124	135	Sand and burrows, with patches sponge and gorgonians
14	34	126	120	Mixed sand and bedrock with sponge and gorgonians
Site 2				
19	33	128	81	Sand
21	31	124	90	Sand
Site 3				
23	33	127	71	Sand
25	4	20	62	Sand
Site 4				
28	60	252	66	Sand/reef with black coral, sponge, sea pens
29	31	125	68	Sand/reef with black coral, sponge, sea pens

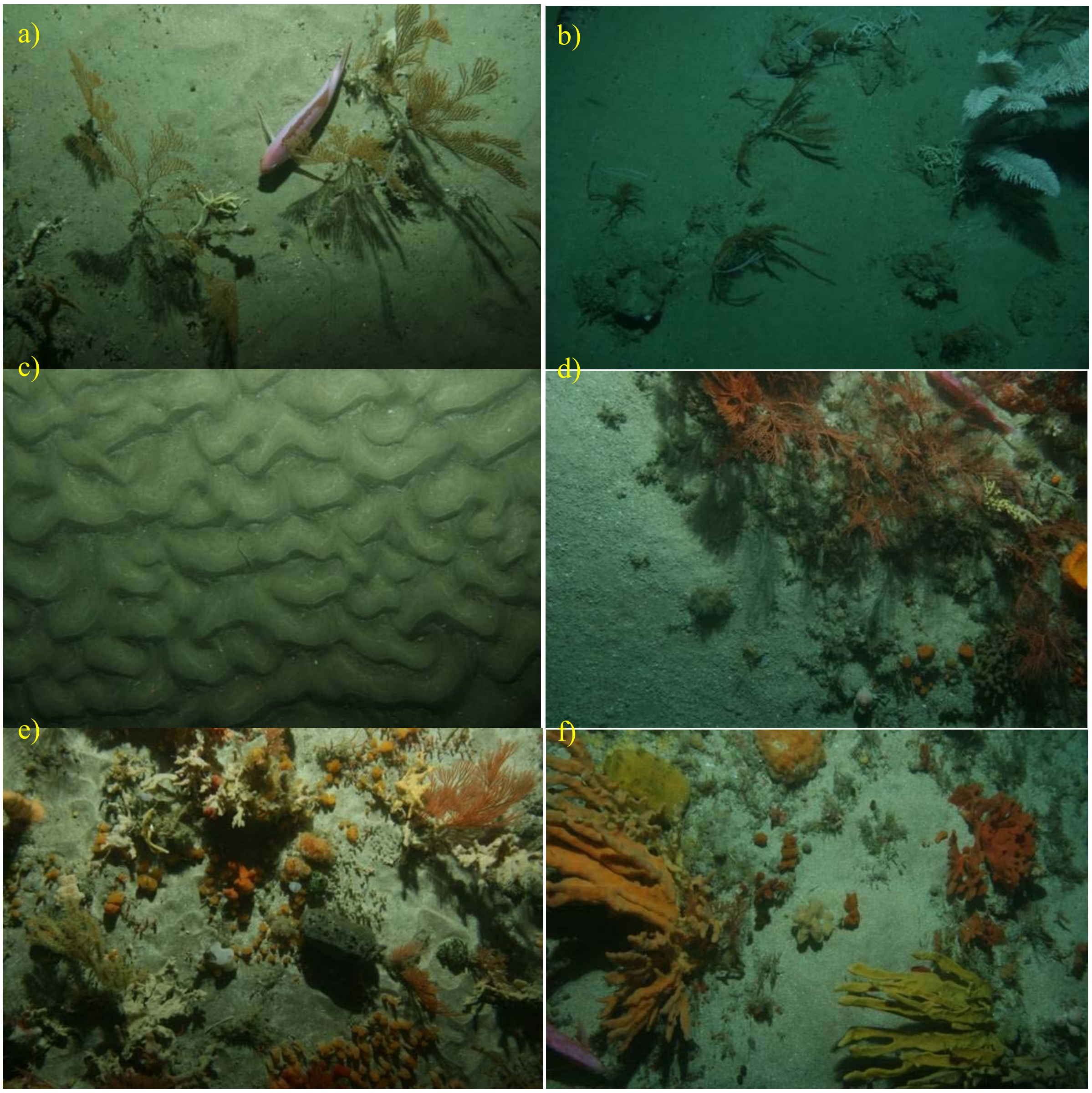


Figure 15: North Cape area seafloor imagery. Sites 1, a) gorgonian and sponge with pink maomao, b) gorgonians, sponge, black coral tree; Site 2, c) bare rippled sand; Site 4, d–f) gorgonian, sponge, and bryozoan assemblages.

West Coast North Island – Kaipara and North Taranaki Bight canyon heads

Five locations were investigated, with four of these being multi-beamed, and one examined using exploratory DTIS transects only (Figure 16).

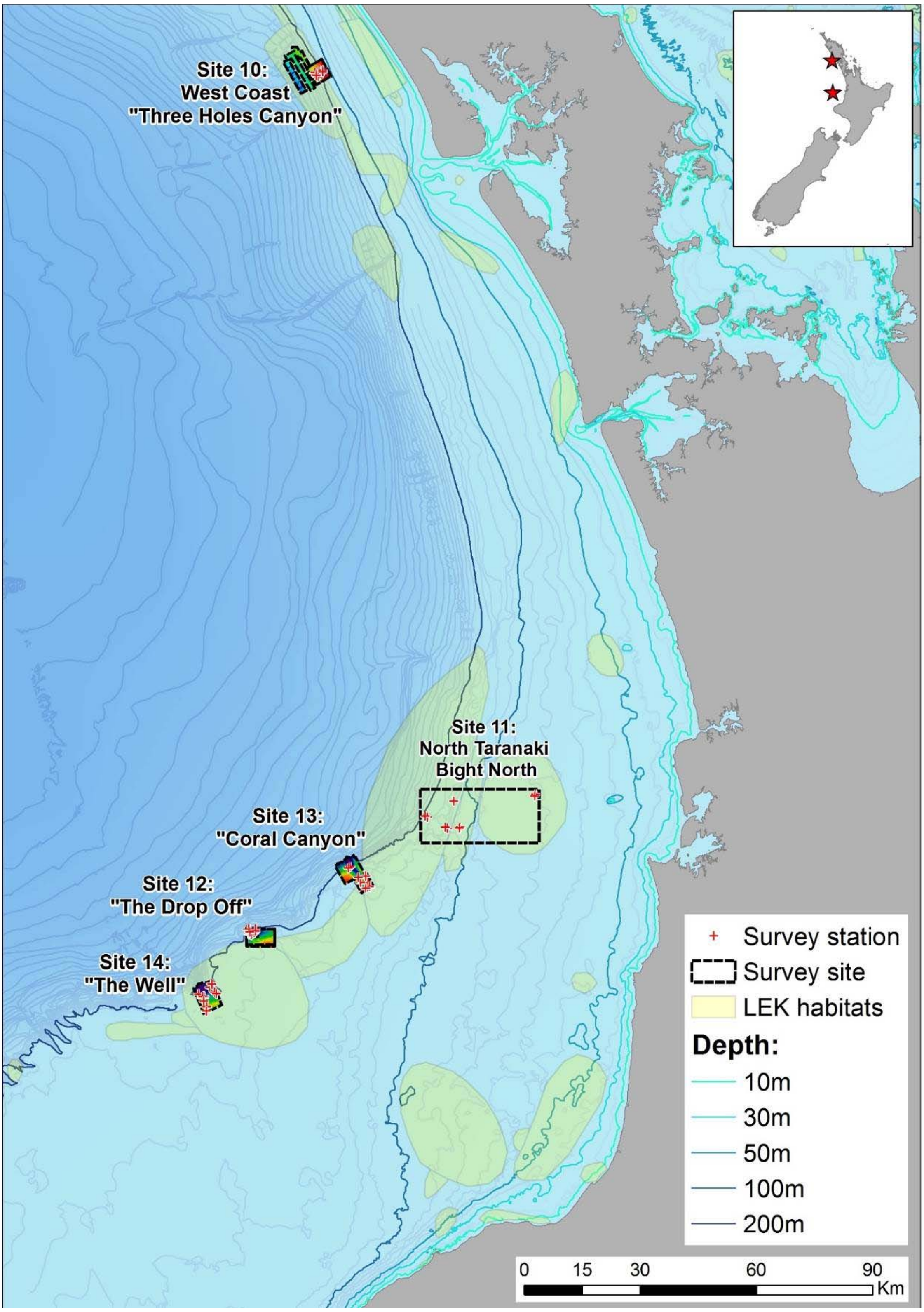


Figure 16: West Coast North Island locations. Fisher-drawn areas (LEK habitats) are shown as light yellow polygons.

“Three Holes Canyon” (Site 10)

These canyons were identified by a number of fishers, and were targeted for tarakihi, with a bycatch of sponge and coral described. One multibeam block (25.7 km^2) was completed over the southern-most, shallowest canyon head, with eight associated DTIS tows, two rock dredges, and one beam trawl station (Figure 17a). Given the absence of multibeam data for this entire region, this mapped area was extended out to cover an additional 42.9 km^2, improving our geophysical understanding of the wider canyon system (Figure 17b). DTIS transects were run up or down the slopes of the canyon head, targeting both the general area, and discrete, visually distinctive areas of backscatter on the flanks of the canyon, which were observed on the video to be patches of carbonate rubble.

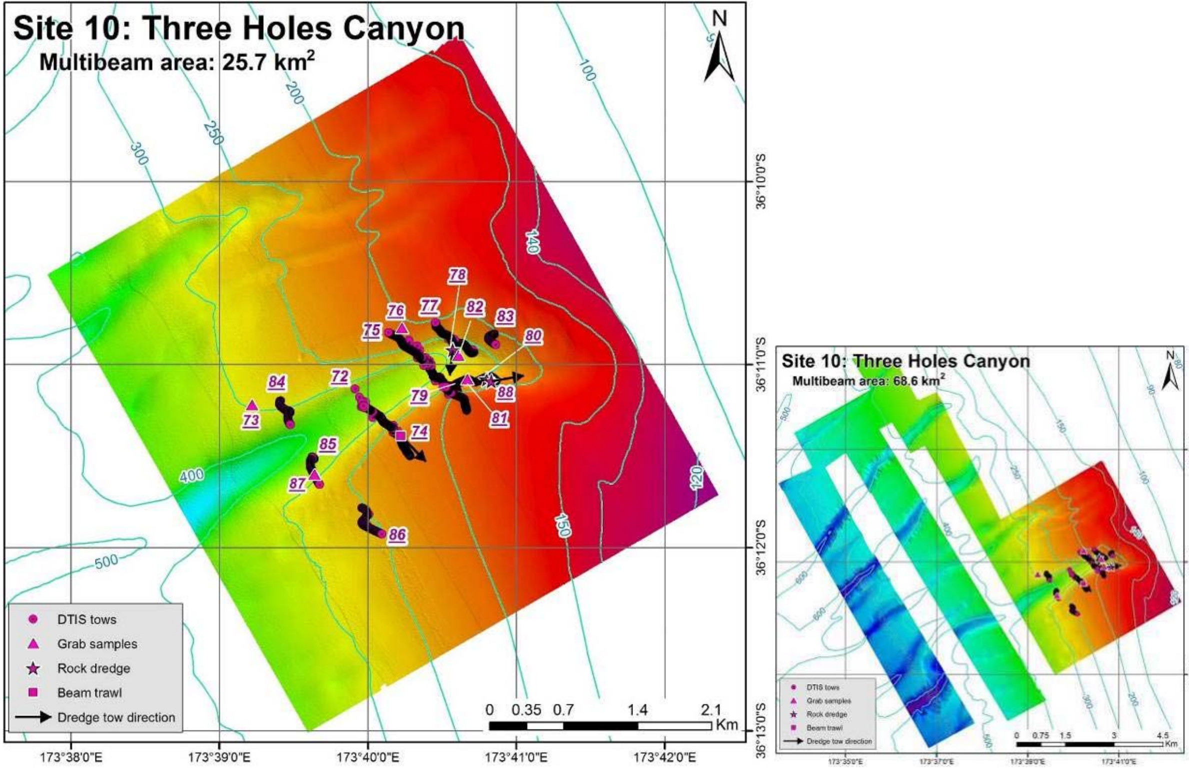


Figure 17: “*Three Holes Canyon*” (Kaipara canyons); a) the wider canyon system extending out off the shelf (mapped to about 600 m water depth); b) area of biological sampling, head of shallowest canyon. 8 DTIS, 2 rock dredge, 1 beam trawl, 5 sediment samples.

Sea pen ‘fields’ were a dominant epifaunal species across most of the soft sediment area surveyed (Table 5, Figure 18a), while sea urchins appeared on soft sediments on the canyon floor only (280–344 m water depth), reaching relatively high densities (several per square metre) (Table 5, Figure 18b). Discrete patches of low-lying rubble were encountered along the canyon sides, the cylindrical shape resembling petrified wood, as well as some bedrock/boulders. On examination at the surface, many were hollow in the centre, and may be biogenic carbonates formed by geological cold-water seeps when sea levels were lower (J. Mountjoy, geologist NIWA, pers. comm.). Anemones, small sponges, brachiopods, and some corals were present on these low relief reefs, but not at high densities (Table 5, Figure 18 c–f). The overall extent of these carbonate reef patches relative to the surrounding soft sediment areas of the canyon was small, and consisted of several discrete patches present along both canyon flanks (visually estimated from backscatter). Sediment samples were classed as muddy sand/silty sand, with a low calcium carbonate content (less than 10%), and higher TOM (3–4%) (Figure 2, Figure 4, Figure 5).

Table 5: DTIS stations for "*Three Holes Canyon*" (Kaipara canyons) multi-beam block.

Station	Time (min)	Images	Depth (m)	General habitat
72	62	252	200–344	Soft mud, sea pens and sea urchins
75	63	252	180–200	Soft mud, fewer sea pens, some rubble (log shaped) with growth
77	30	242	200–240	Soft mud with cobble / boulder outcrops with sponge and anemones
79	33	240	210–220	Muddy sediment some bed rock with sponge, anemones, cup corals
83	10	42	200–220	Sand / shell hash with sea pens and quill worms
84	17	68	280–360	Softer mud with some rubble, sea pens, urchins
85	18	74	260–325	Soft muddy sediment, sea pens, urchins, some anemones, burrows
86	17	70	240	Soft muddy sediment, sea pens, urchins, some anemone

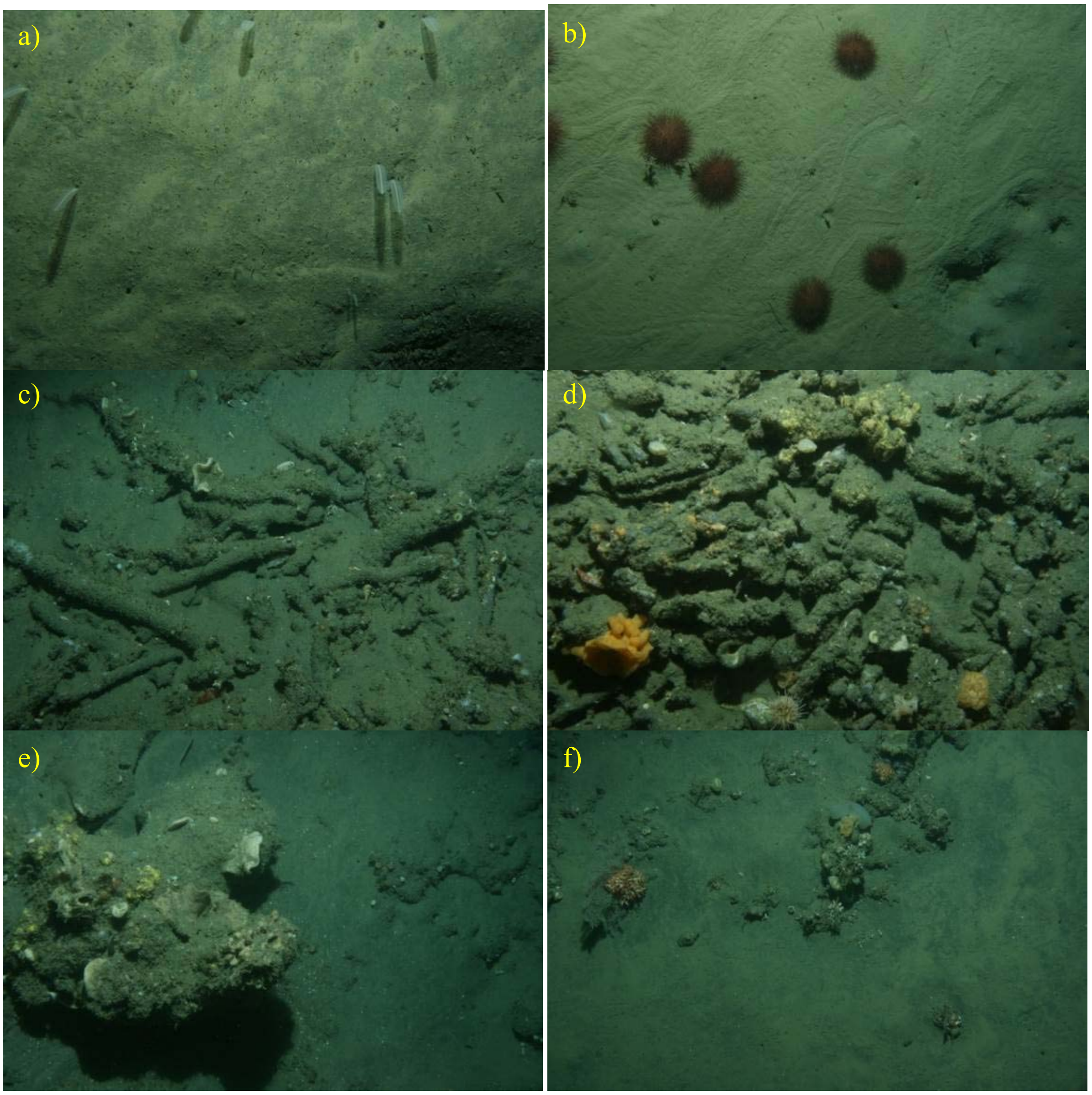


Figure 18: "*Three Holes Canyon*" (Kaipara canyons) seafloor imagery: a) sea pen 'field', b) sea urchins on canyon floor, c–d), carbonate cylinders with sponges, brachiopods, and anemones, e–f) boulder/rock outcrops, with sponges and coral.

North Taranaki Bight “North block” (Site 11)

Five exploratory DTIS transects were deployed across three large fisher-drawn areas in the northern North Taranaki Bight (Figure 19), described as areas of foul (deepest area), tube worms, and shells (possibly dog cockles) (Figure 16). In the most northerly area, the seafloor was composed of rippled sand; stations to the west in deeper waters had muddy seafloor sediments, with some rock outcrops seen in the furthest offshore DTIS station (98) (Table 6, Figure 20). Sediment samples were composed of classes of sand / muddy sand / silty sand, with low calcium carbonate content, and an average TOM of about 2% (Figure 2, Figure 4, Figure 5). Although the DTIS transects were very small relative to the spatial extents of the fisher-drawn areas, the descriptions were partially verified by the small patches of foul on the deeper transect.

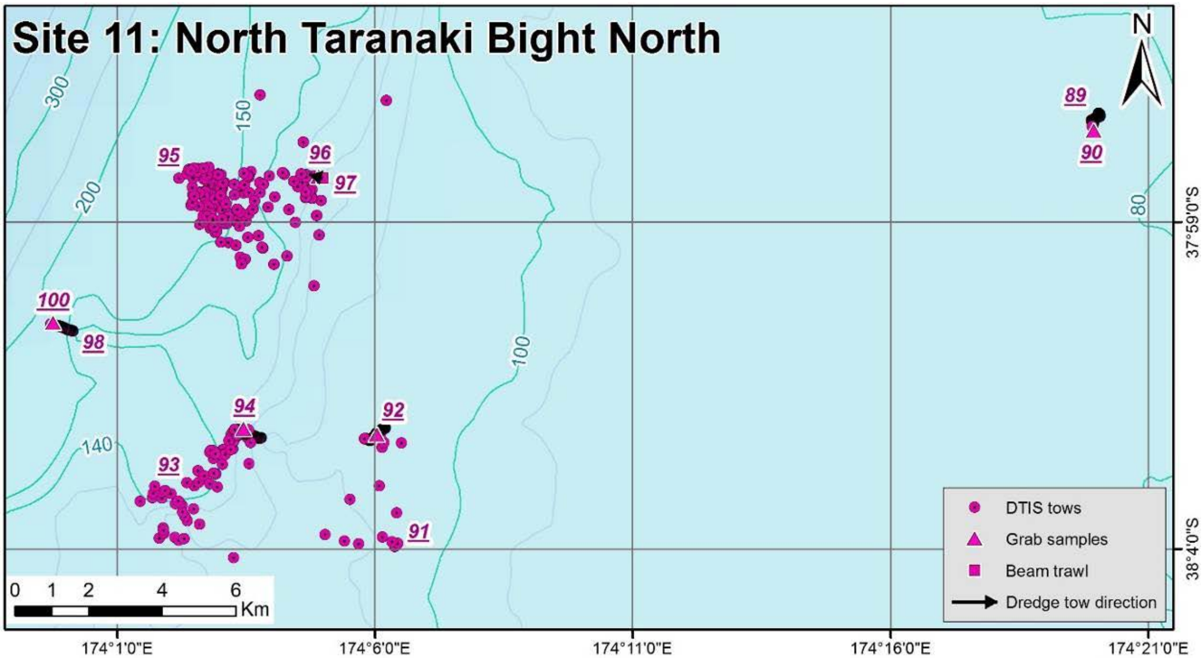


Figure 19: North Taranaki Bight “North Block” DTIS stations. The scatter of image points is due to positional errors in the DTIS system that have not been corrected using splines. No multibeam was collected.

Table 6: DTIS stations for “North” site, North Taranaki Bight.

Station	Time (min)	Images	Depth (m)	General habitat
89	30	125	77	Rippled sand and sparse shell hash, occasional sea pen, quill worms
91	32	131	97	Rippled sand and shell hash, several eel species common
93	31	128	110	Sand / shell hash / mud
95	32	128	114	Muddy sediment, some burrows
98	31	123	150–160	Muddy sediment with some small bedrock outcrops

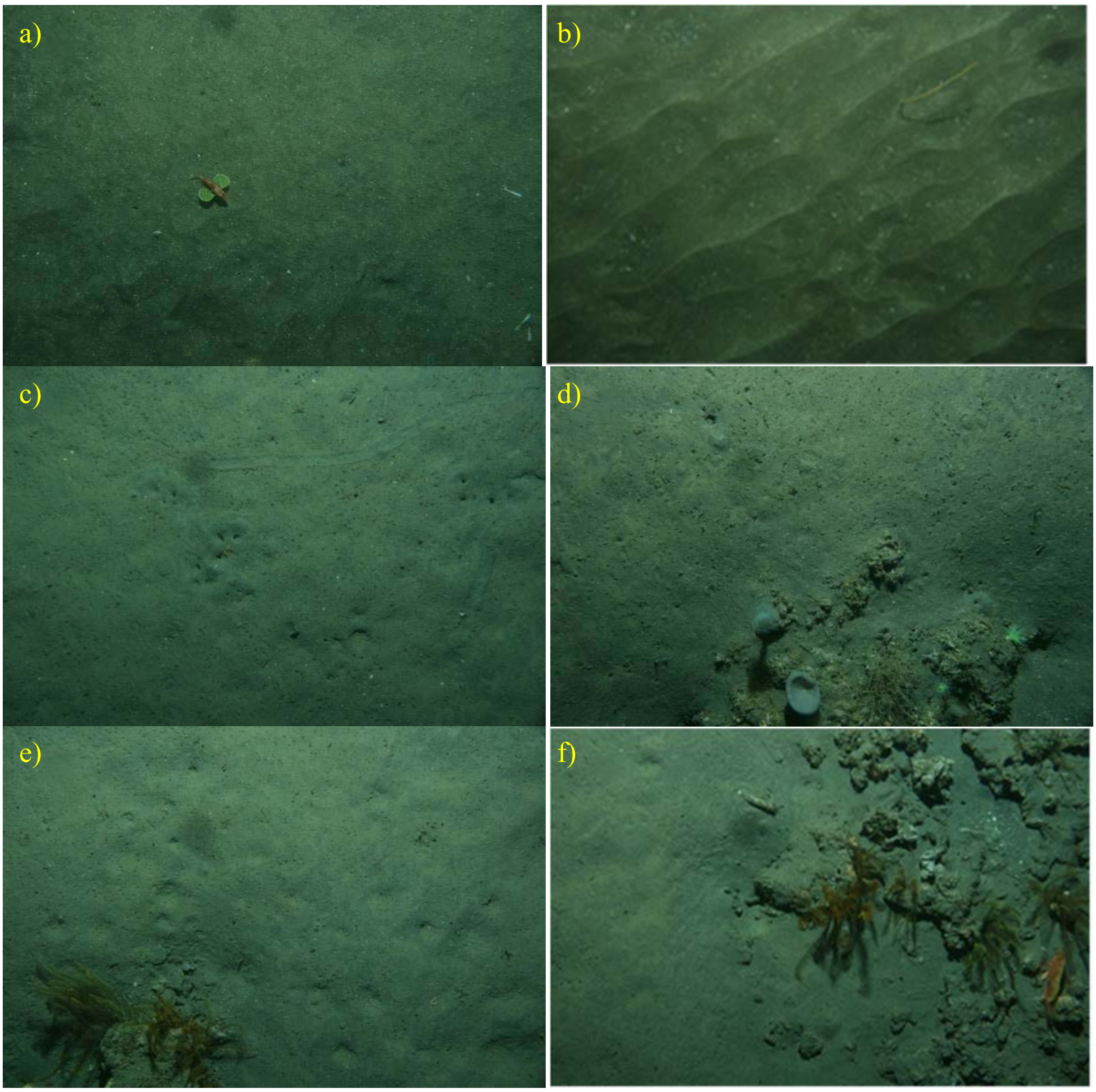


Figure 20: North Taranaki Bight "North Site" seafloor imagery: a) flat sand with small gurnard, b) rippled sand with sea-pen, b) soft sediment with burrow structures, d–f) small rock outcrops with cup sponges, anemones, crinoids, tubeworms/bryozoans, and a butterfly perch.

The "Coral Canyon" – North Taranaki Bight (Site 13)

This narrow canyon was identified by fishers as an area containing big coral trees, and was long-lined for hapuka, school shark, grouper, bluenose and other species. A multibeam block of 48.9 km^2 was mapped, inclusive of the top of the canyon out to and beyond the edge of the shelf (Figure 21). Seven DTIS and one rock dredge station were sampled (Table 7). The continental shelf area around the canyon was composed of muddy sediments, with some occasional sea-pens. Around the edges of the canyon were patches of bedrock, and the rubble reef 'log' forms, as seen further north at the "*Three Holes Canyon*". Associated hard substrate species included crinoids, anemones, sponges including small vivid blue 'rock' sponges (*Reidispongia coerulea*), and whip corals (Figure 22). Sediment analysis returned muddy sandy gravel (with 50% calcium carbonate) for one site on the rubble area, and muddy sand for the other two sites, with 5–20% calcium carbonate; all three stations had less than 3% TOM (Figure 2, Figure 4, Figure 5). The deepest station (126) was at 500 m, conosisting of muddy sediment with occasional sea pens, squat lobsters, and some exposed bed-rock. This canyon was selected as one of the core areas for analysis, and is reported on in significantly more detail in the core analysis section (Section 4.1).

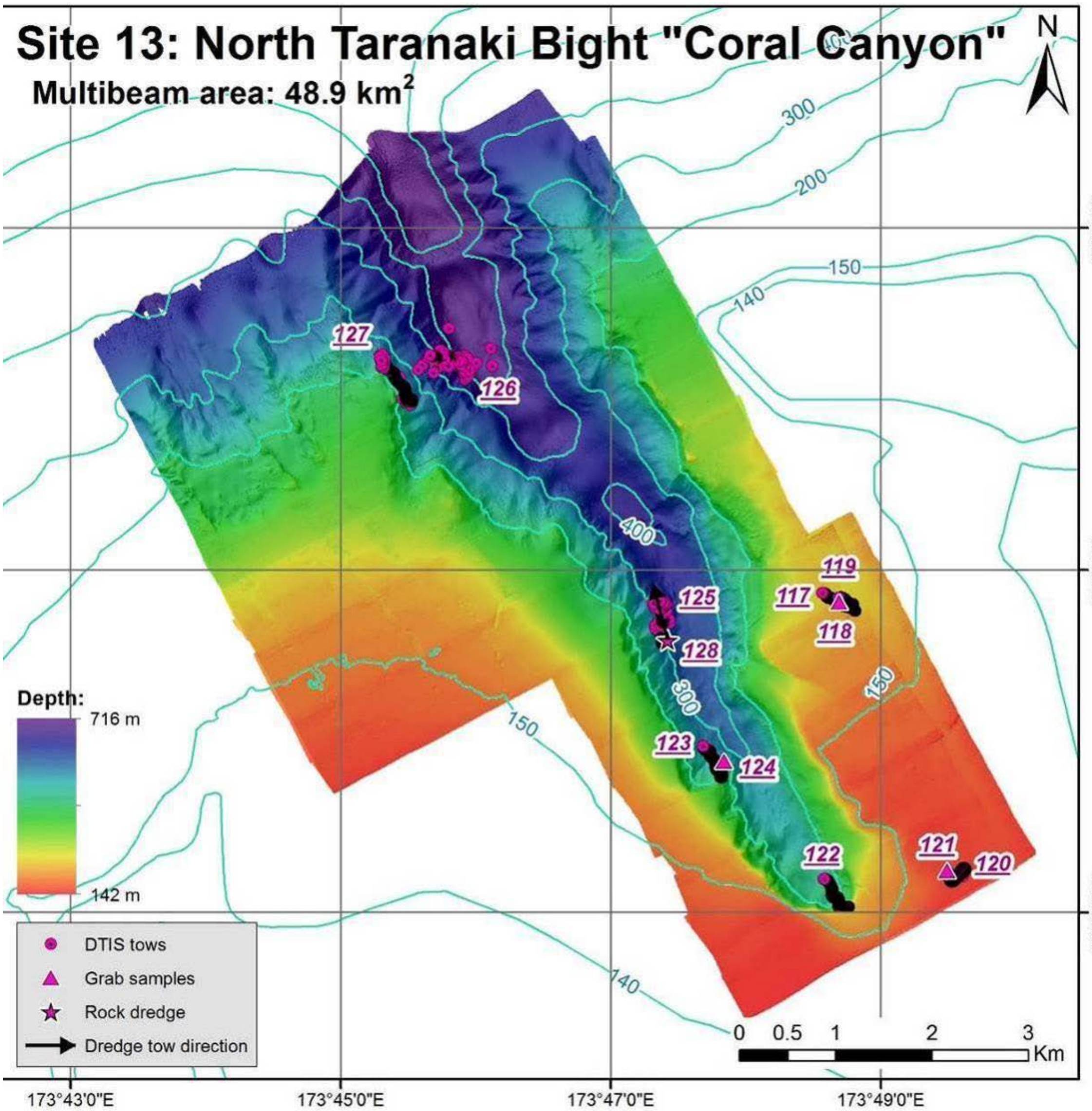


Figure 21: "*Coral Canyon*", North Taranaki Bight. 7 DTIS, 1 rock dredge, 3 sediment samples.

Table 7: DTIS stations for the "*Coral Canyon*", North Taranaki Bight.

Station	Time (min)	Images	Depth (m)	General habitat
117	31	126	146	Muddy sediment, burrows, sea pens
119	14	47	148	Muddy sediment, some bedrock with sponges and soft corals
120	28	79	140	Muddy sediment, some bedrock with sponges and soft corals
122	32	126	146	Muddy sediment / cobbles / bedrock, burrows, sea pens, sponge
123	31	128	173	Muddy sediment / bedrock, with black coral and anemones
125	32	126	265	Muddy sediment / bedrock , sea pens, sponge, anemones, gorgonians, hydroids, tube worm masses, crinoids
126	32	128	507	Muddy sediment, burrows, sea pens, squat lobsters, small foul
127	34	142	257	Muddy sediment / bedrock, with whip-like black coral on soft and anemones, crinoids, sponge on the hard substrate

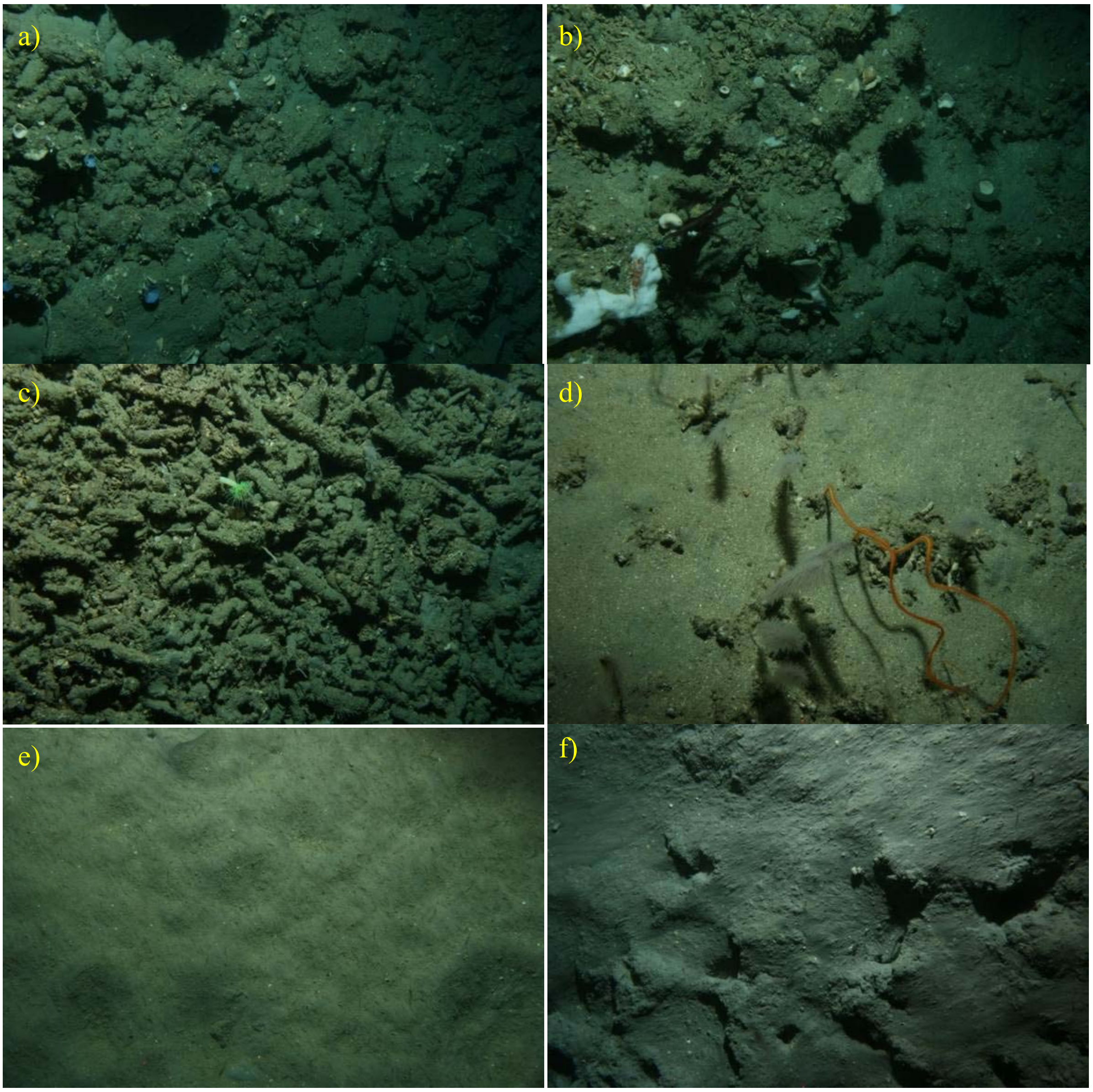


Figure 22: "*Coral Canyon*", North Taranaki Bight, seafloor imagery: a–c) rubble with sponges (including blue rock sponge *Reidispongia coerulea*), bryozoans, carbonate debris, anemones, sea-perch, d) whip coral and sea-pens, e–f) soft sediments.

"The Drop Off", North Taranaki Bight (Site 12)

A feature known as "*The Drop Off*" was mapped in a 6.8 km^2 block (Figure 23), covering an irregular extension of the shelf off into deeper water. This area contains three overlapping fisher-drawn areas (Figure 16), containing unusual rocks (with swiss-cheese holes, others described as concrete-like pillars), "*lacey corals*", and sponges. From a flat shelf of 160 m water depth, the seafloor gently sloped down to 200 m depth, before increasing in slope off to deeper waters. Three DTIS, one rock dredge, and one beam trawl station were sampled. The sediments were analysed as muddy sand, with about 20% calcium carbonate, and 2–3% TOM (Figure 2, Figure 4, Figure 5), along with small areas of exposed bed-rock. Associated with the bedrock were black corals, crinoids, small chaetopterids (tube-worms) and other rock encrusting / burrowing fauna (Table 8, Figure 24). 'Swiss cheese' rocks (sandstone with animal boring holes) were recovered from the rock sled.

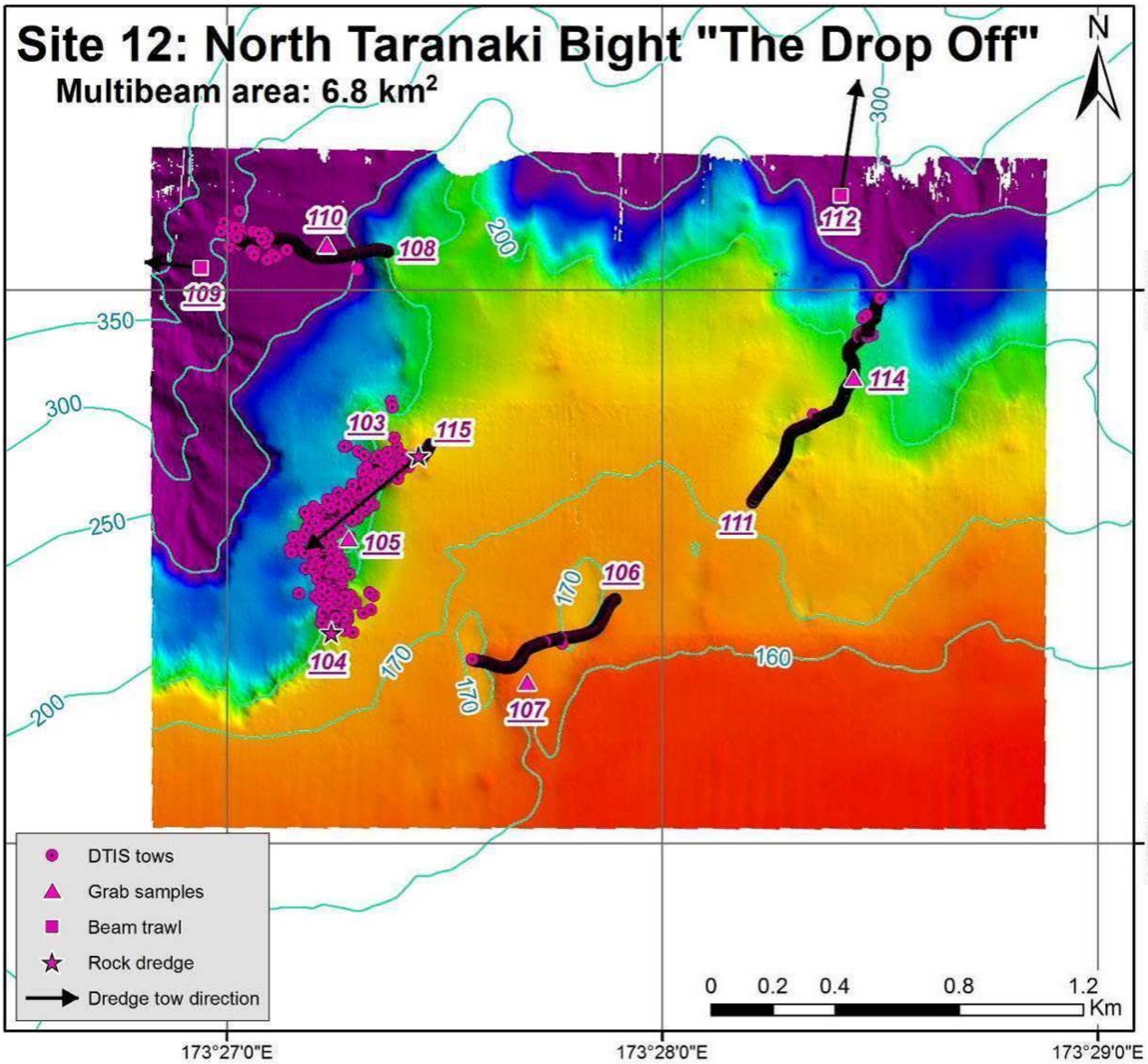


Figure 23: "*The Drop Off*", North Taranaki Bight. 3 DTIS, 2 rock dredge, 1 beam trawl, 4 sediment samples. The scatter of image points on some DTIS tows is due to positional errors in the DTIS system that have not been corrected using splines.

Table 8: DTIS stations for the "*The Drop Off*", North Taranaki Bight.

Station	Time (min)	Images	Depth (m)	General habitat
103	62	251	181	Muddy sediment / bedrock rubble, anemones, hydroids, sea pens, black coral, crinoids
106	35	138	162	Mainly muddy sediment, but one section over bedrock with sponge, crinoids, others
108	29	116	192	Starts off on bedrock and then onto muddy sediment. Fauna as above. Observed 'prawn killers' (*Ibacus* sp.) and eels
111	62	253	161	Muddy sediment with sea pens, anemones, burrows, some black coral

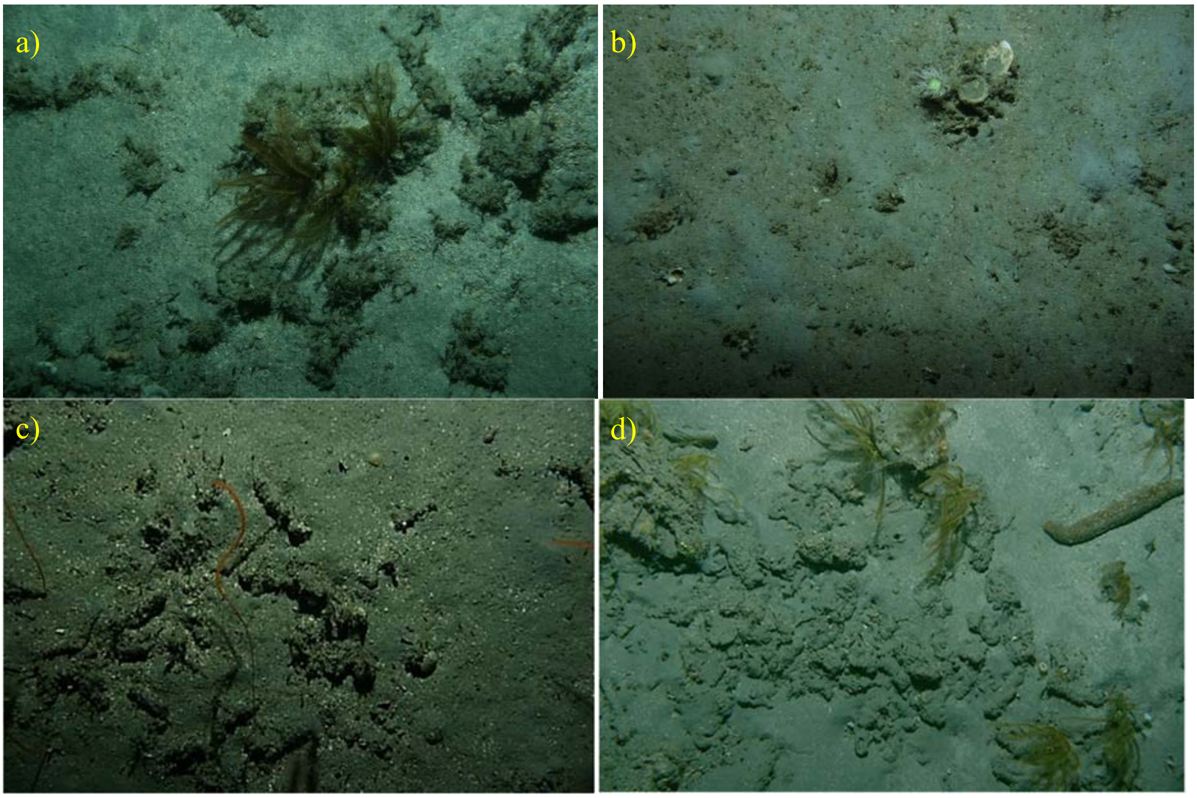


Figure 24: "*The Drop Off*", North Taranaki Bight, seafloor imagery: a–d) rubble with crinoids, tubeworms, anemones, whip corals, cup corals, and a sea cucumber.

"The Well", North Taranaki Bight (Site 14)

A multi-beam block of 39.1 km^2 was mapped covering the top of a dendritic canyon head, and an associated 'basin' area on the edge of the shelf (Figure 25). This basin started at about 200 m water depth, with the adjacent shelf being relatively flat, but with a slight rise feature along the southern part of the block. Seven DTIS transects were carried out, as well as two rock dredge, and one beam trawl tows. One sediment sample on the canyon flank was classed as gravel with over 20% calcium carbonate, while the other samples were classed as muddy sand, with less than 15% calcium carbonate; all had 1–2% TOM. Most of the seafloor was composed of muddy sands, with patches of broken reef/rubble reef around the top of the basin drop-off region. These patch reefs supported a fauna that included sponges, anemones, crinoids, whip corals, and brittle stars, while sea pens were present in some soft sediment areas (Table 9, Figure 26). This canyon is covered in much more detail in the core area analysis section of this report.

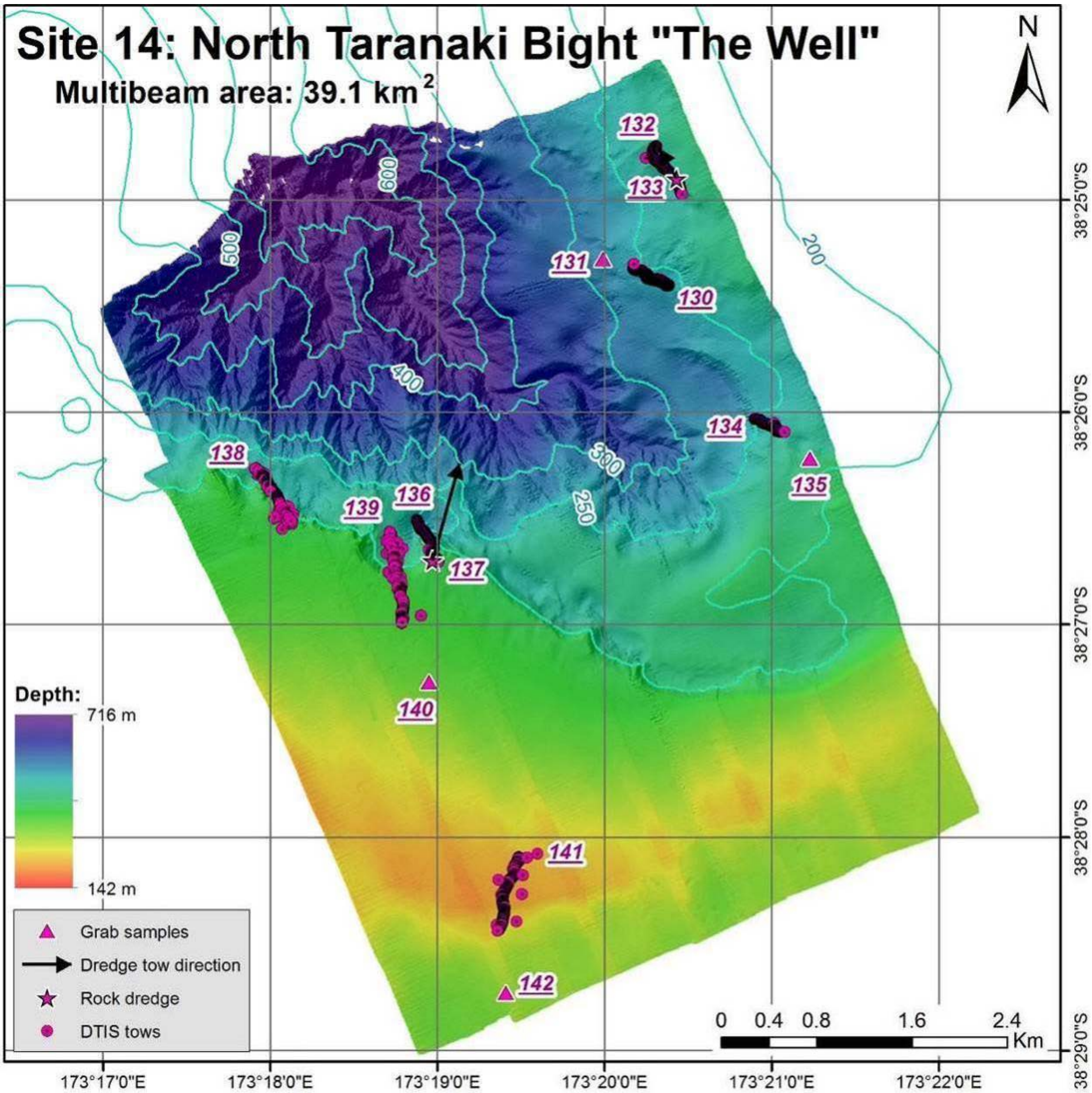


Figure 25: "*The Well*", North Taranaki Bight. 7 DTIS, 2 rock dredge, 3 sediment samples.

Table 9: DTIS stations for the "*The Well*", North Taranaki Bight.

Station	Time (min)	Images	Depth (m)	General habitat
130	34	142	257	Muddy sediment / bedrock, sea pens, sponge, black coral
132	29	116	214	Muddy sediment / bedrock, sea pens, sponge, black coral
134	31	125	245	Sand / muddy sediment with sea pens and quills
136	33	127	240	Sand / bedrock, with fauna as above
138	31	124	242	Sand / bedrock with black corals, sponges, cup corals, crinoids, anemones, sea perch
139	32	126	210	Sand / muddy sediment, sea pens, burrows, black corals, sponge, crinoids, Scleractinia corals
141	30	122	145	Sand / shell hash with sea pens, anemones, burrows.

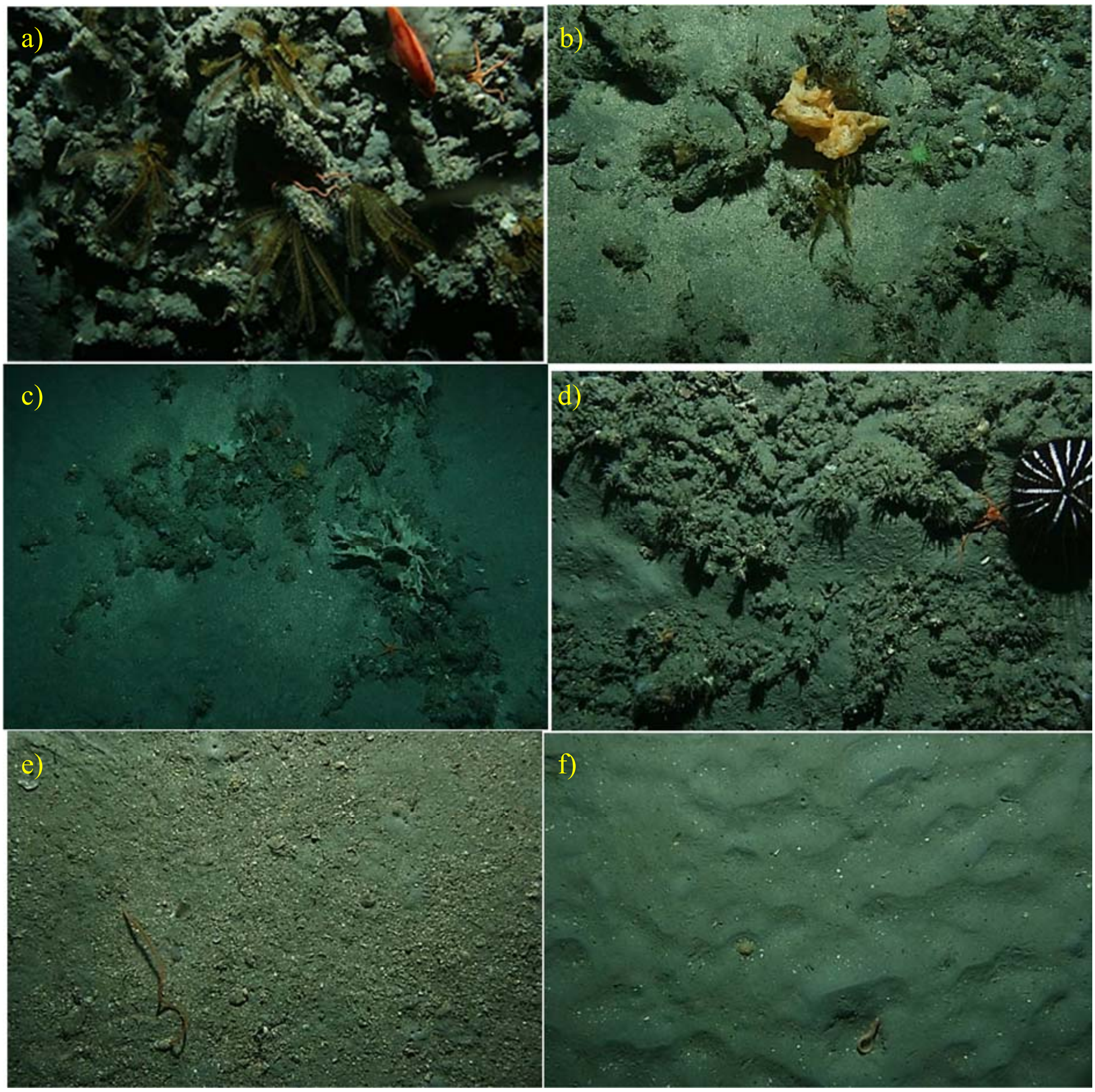


Figure 26: "The Well", North Taranaki Bight Seafloor imagery: a) carbonate rubble with crinoids, ophiuroids, orange perch, b) rubble with glass sponge, anemone, crinoids, c) rubble with various sponges species, d) rubble with tubeworms, O'Tanter sea urchin, ophiuroid, e) gravel with whip coral, f) shelf ripped sand with small fish.

Golden and Tasman Bays / D'Urville Island

This area was not one of the target regions for the survey, but severe storm conditions on the exposed coast necessitated seeking shelter, and so sampling was undertaken close to sheltered shores at Separation Point, and around D'Urville Island (Figure 27). Fisher-drawn LEK areas at these sites described "coral" (identified as bryozoan) and sponge bycatch.

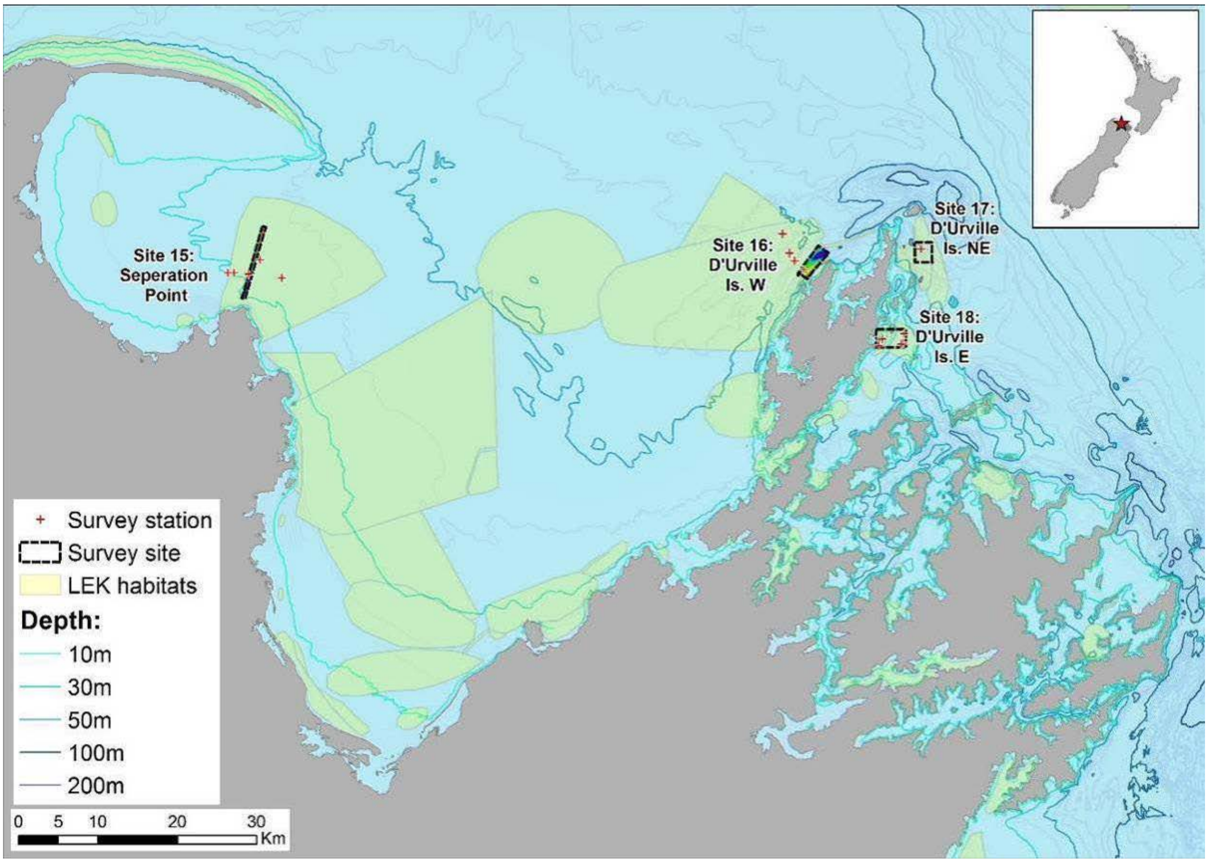


Figure 27: Tasman/Golden Bay/D'Urville Island sites. Fisher-drawn areas (LEK habitst) are shown as light yellow polygons

Separation Point (Site 15)

A multibeam transect of four parallel ship runs (Figure 28, 4.3 km^2) was mapped off Separation Point, within the bryozoan ('coral') beds area closed to power fishing. The outer start point and transect orientation were based on the habitat zone descriptions of Grange et al. (2003). No biological samples were taken inside the closed zone, as the legal regulations around scientific sampling (re disturbance of the seafloor) were unknown at the time of sampling. Three short DTIS transects were deployed (Table 10), but the underwater visibility was very poor. While most of the DTIS imagery was over mud, some bottom biogenic structure was sighted, composed of dead shell, bryozoans, sponges and indeterminate debris (Figure 29). One beam trawl tow was collected outside of the western boundary of the closed area; and was retrieved full of mud. The multibeam imagery showed a complex patch mosaic of fine scale depth variation, which was associated with variation in bottom hardness as seen in the unprocessed back-scatter (close-up images of Figure 29). These patterns were possibly a result of the patches of shell debris/bryozoan patches present, although some may be buried under a mud veneer. Unfortunately, most of the DTIS transects fell outside the multibeam area, in the hunt for better water visibility, however seafloor observations at the start of station 143 did indicate bryozoans and shell debris that matched a patch of harder seafloor as observed on the multibeam map (Figure 29, lower middle image). These data strongly suggest that the bryozoan 'field/s' of the

Separation Point closed area can be mapped to high resolution using multi-beam sonar. No sediment samples were collected.

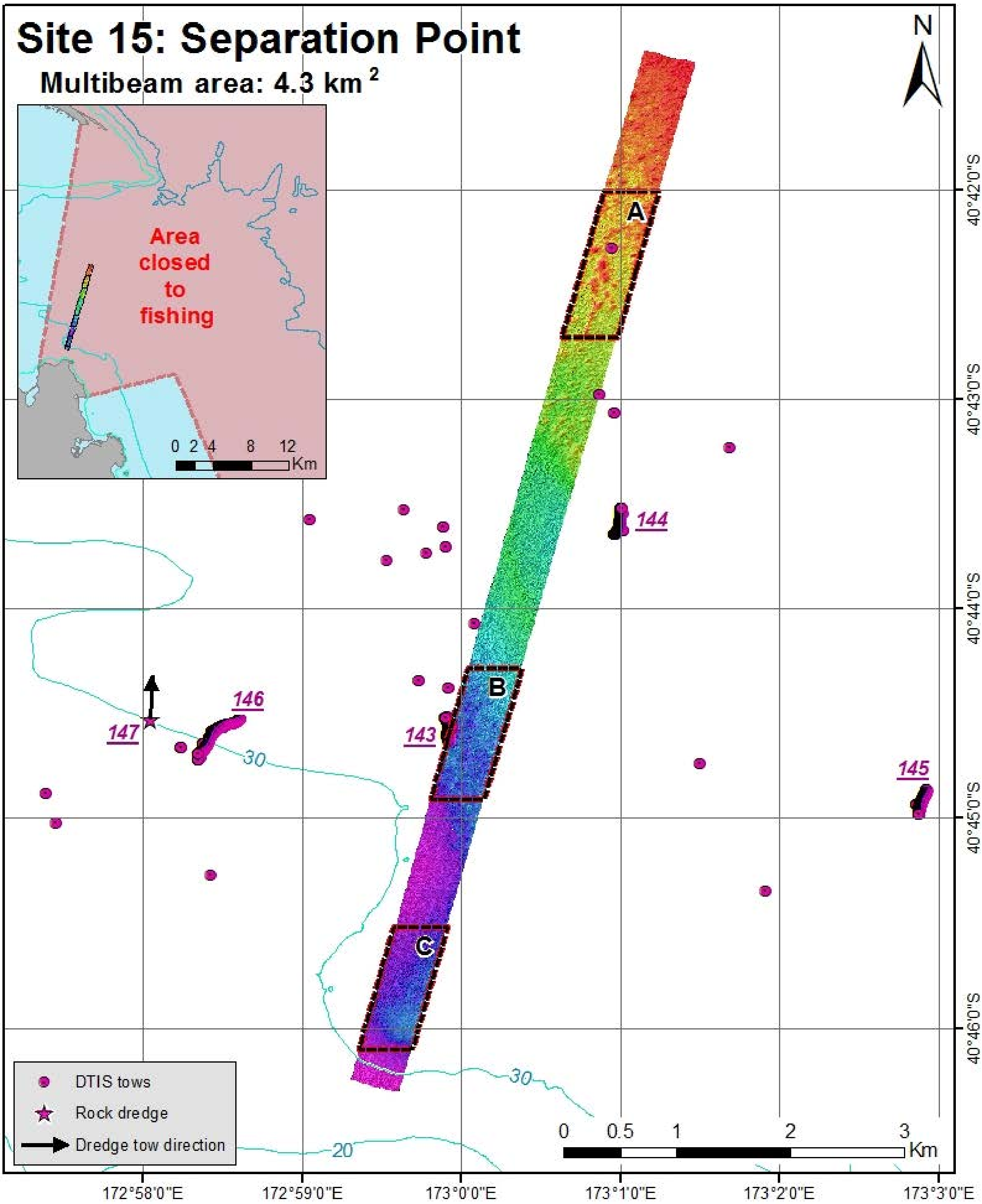


Figure 28: Separation Point multibeam transect. 4 DTIS, 1 beam trawl samples. The single dots are errors in the GPS positioning that have not yet been corrected by splining. Sections A to C are shown in higher resolution in the next figure.

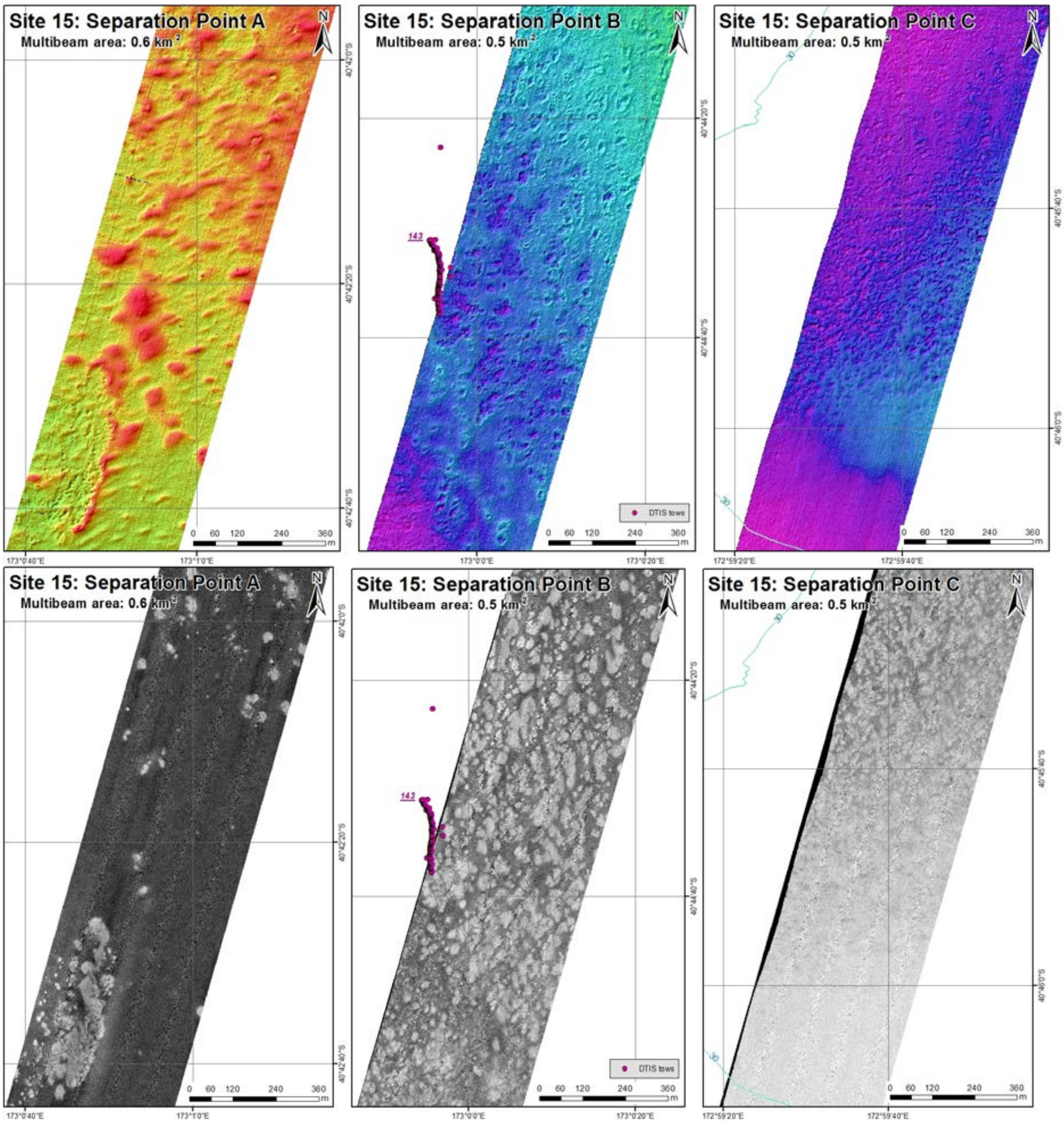


Figure 29: Close-ups of three multibeam sections from the Separation Point multibeam transect. Upper row bathymetry; lower row un-processed back-scatter, the whiter the colour, the more reflective (harder) the seafloor. Sub-sections A and B are thought to show bryozoan mounds with surrounding muddy soft sediments, while sub-section C is likely to be grading into harder packed sands in its southern part. Some of these (putative) structures may be buried under a thin veneer of mud.

Table 10: DTIS stations for Separation Point.

Station	Time (min)	Images	Depth (m)	General habitat
143	10	41	30	Mainly mud; shell and indeterminate debris, some bryozoans at start. Very poor water clarity
144	10	41	30	Mainly mud, some whelks/hermit crabs, dog cockle shell, indeterminate debris. Poor water clarity
145	10	42	30	Mainly mud, with numerous epifaunal trails. Poor water clarity
146	30	133	30	Mainly mud, some dead shell patches towards the end of the tow. Poor water clarity

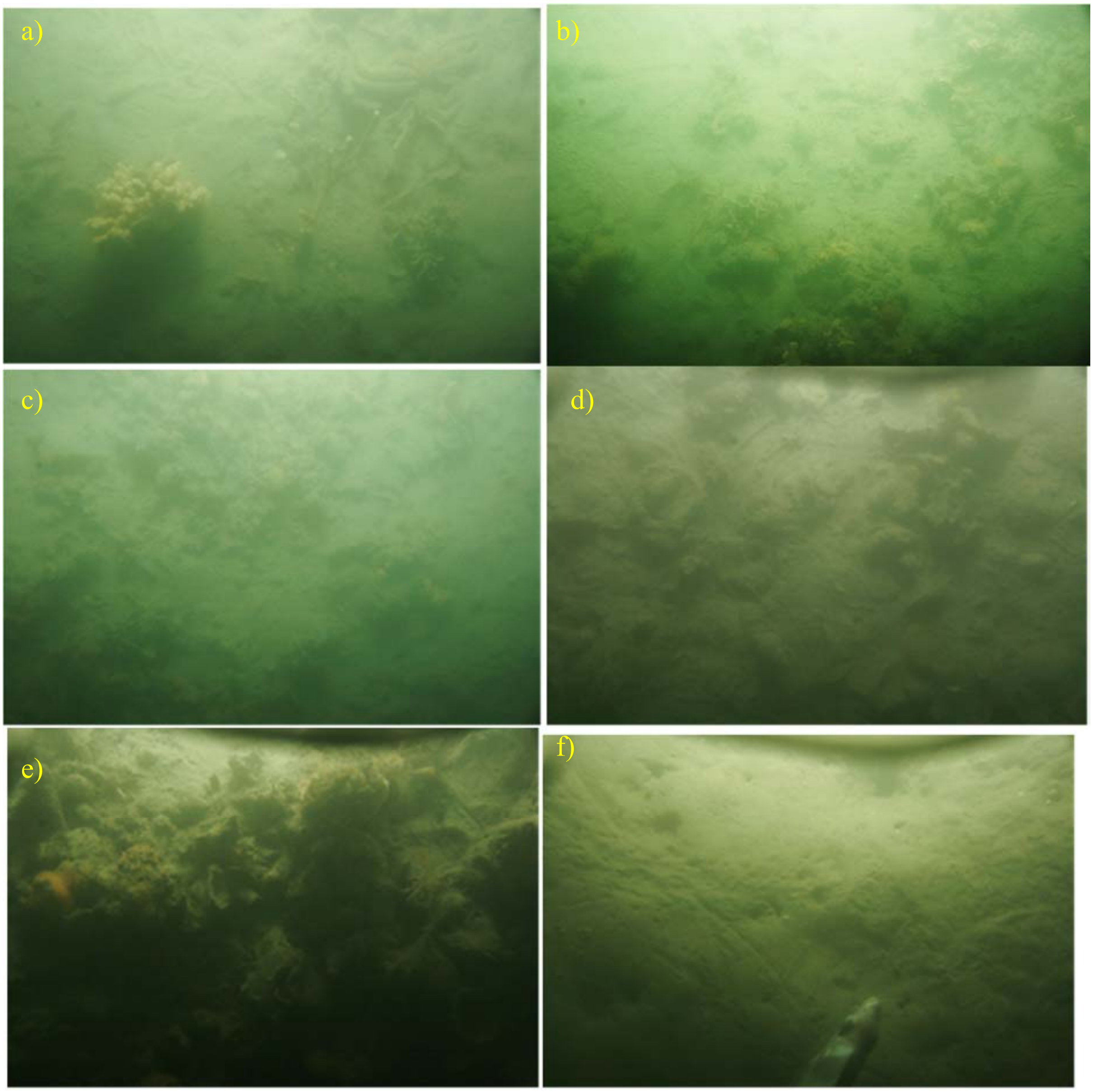


Figure 30: Separation Point seafloor imagery; a) sponge/bryozoan on probable horse mussel, finger sponge, grey finger sponge, eleven-armed starfish, bryozoans, shell debris, b–c) bryozoans/sponges on shell debris, d) dead dog cockles, whelk/hermit crab, e) bryozoans on shell rubble mound, f) muddy seafloor with tracks, tarakihi.

West of D'Urville Island, Tasman Bay (Site 16)

An area just west of D'Urville Island was investigated, as it once contained significant bryozoan ('coral') habitat (Mace 1981 Saxton 1980a, b), and four fisher-drawn areas describing "coral" bycatch overlap here (Figure 27). A 6.2 km^2 multibeam block (Figure 31) found a large current scour hole in the northern half, flatter seafloor in the south, flanked on the south-east side by sand ripples and the start of reef. One DTIS station was completed in the multibeam block, as well as three exploratory DTIS stations to the north-west looking for bryozoans. The DTIS transect inside the block showed a seafloor of dead shells (dog cockles, geoducs) and coarse sands, grading into cobbles in the second half of the transect (Table 11). Sparse epifauna included low-relief sponges, holothurians, gastropods, and echinoderms (Figure 32a–d). The three DTIS stations further offshore found rippled sand with some shell hash, and little to no epifauna (Table 11, Figure 32e, f). No biological or sediment samples were collected.

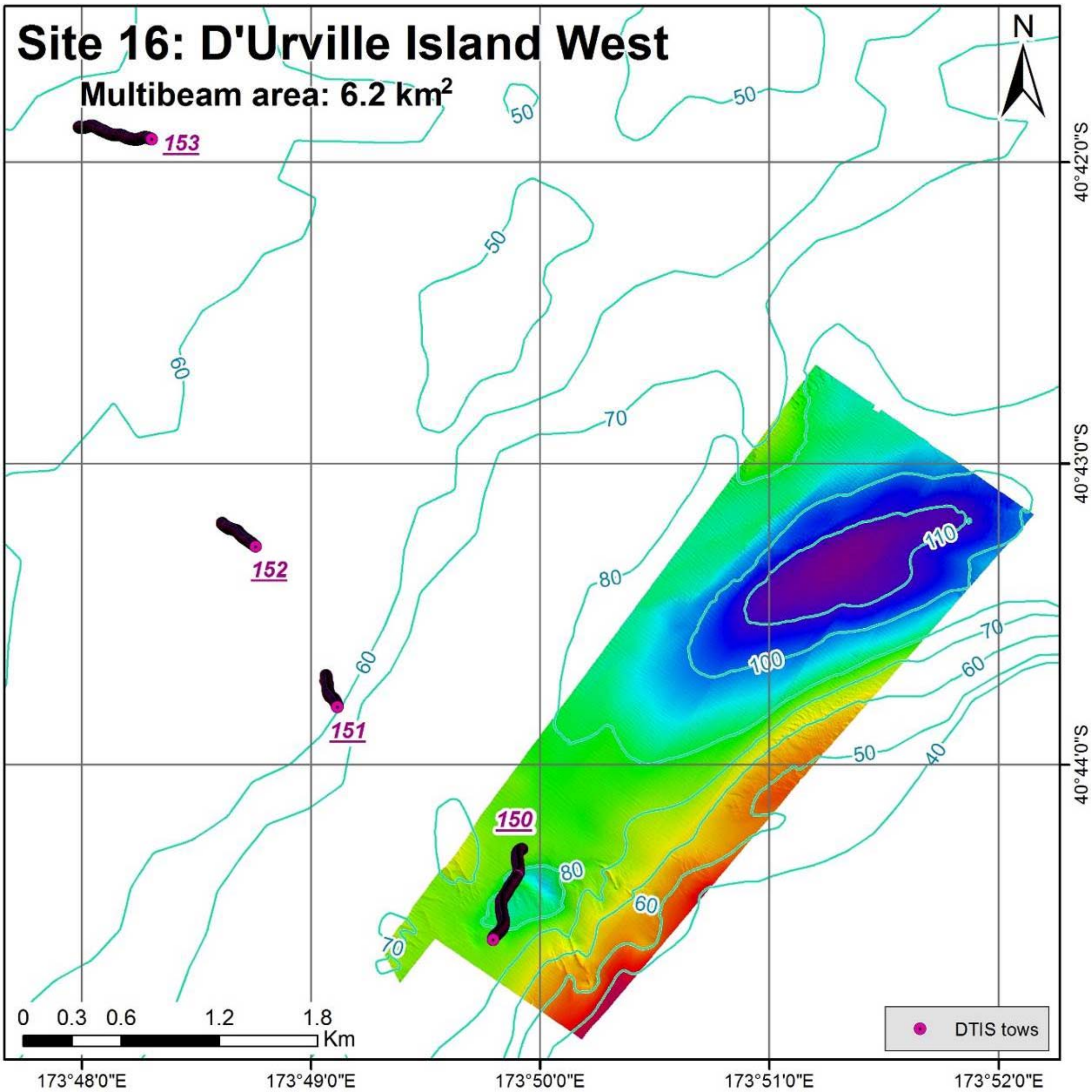


Figure 31: Western D'Urville Island, Tasman Bay.

Table 11: DTIS stations for the western side of D'Urville Island, Tasman Bay.

Station	Time (min)	Images	Depth (m)	General habitat
150	24	95	67	Sand/shell hash, shell armoured seafloor, cobbles towards end, some low relief epifauna
151	11	47	54	Rippled sand and some shell hash
152	12	49	53	Rippled sand and some shell hash
153	15	63	60	Rippled sand and some shell hash

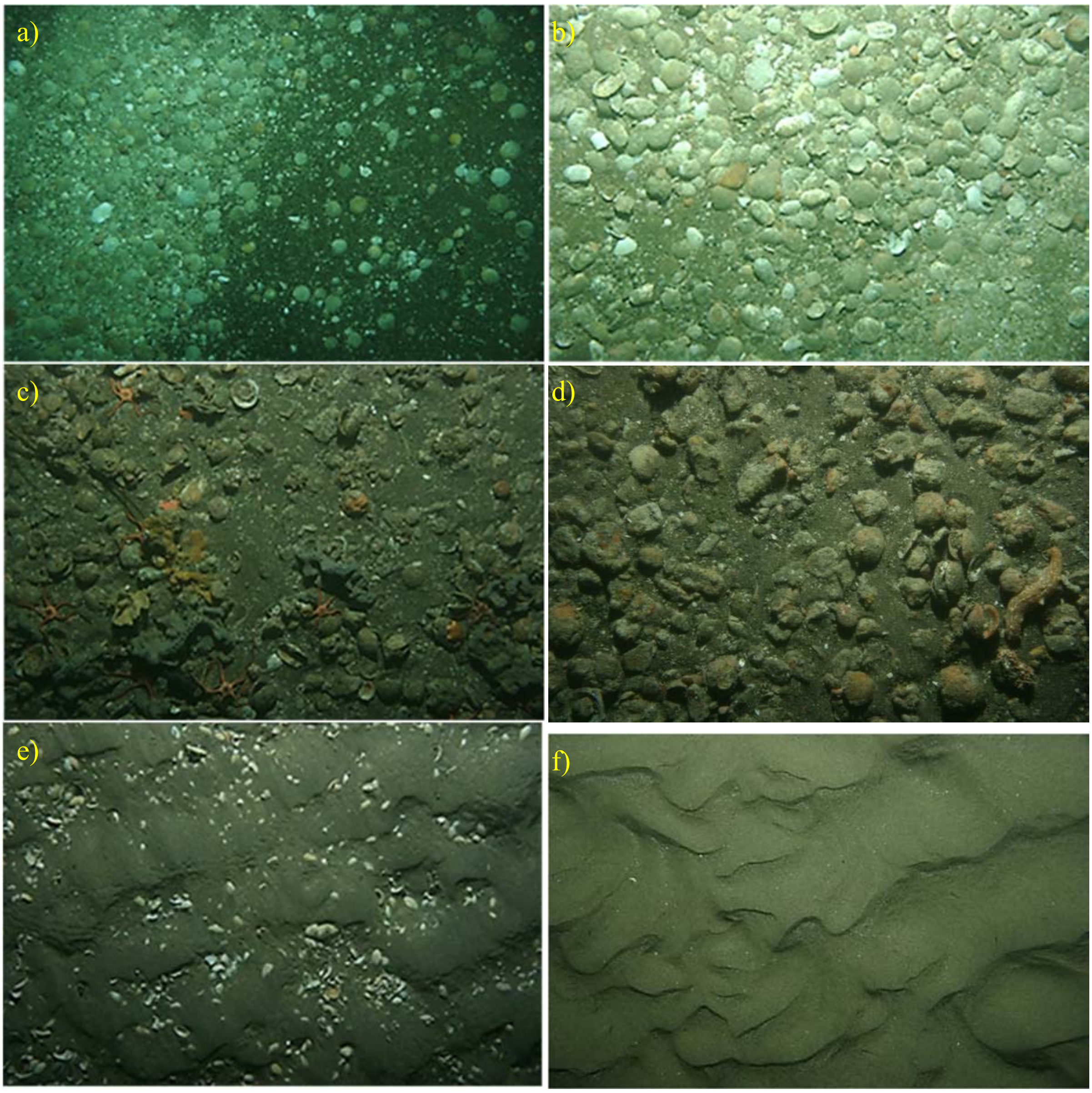


Figure 32: Western D'Urville Island, Tasman Bay seafloor imagery: a-b) Station 150 seafloor, starts with variable amounts of dead shell (dog cockles/geoducs) on sand and gravel, changes to c-d), cobbles and sand, with generally sparse epifauna (sponges, encrusting bryozoan *Cellaporaria agglutinans*, ophiuroids, starfish, and sea-cumbers; e-f) offshore 3 DTIS transects returned rippled sand, with variable components of small shells.

North-east of D'Urville Island, outer Marlborough Sounds (Site 17)

One DTIS station was undertaken north-east of D'Urville Island targeting two fisher-drawn areas identified historically (pre-1980s) as "*coral rubble*" (Figure 27, Site 17, no multibeam). The 20 minute tow observed only rippled sand, with some sparse small, low-lying sponges (Table 12, Figure 33). No biological or sediment samples were taken.

Table 12: DTIS station for north-eastern D'Urville Island, outer Marlborough Sounds.

Station	Time (min)	Images	Depth (m)	General habitat
154	20	81	35	Rippled sand, occasional sponge, hermit crab

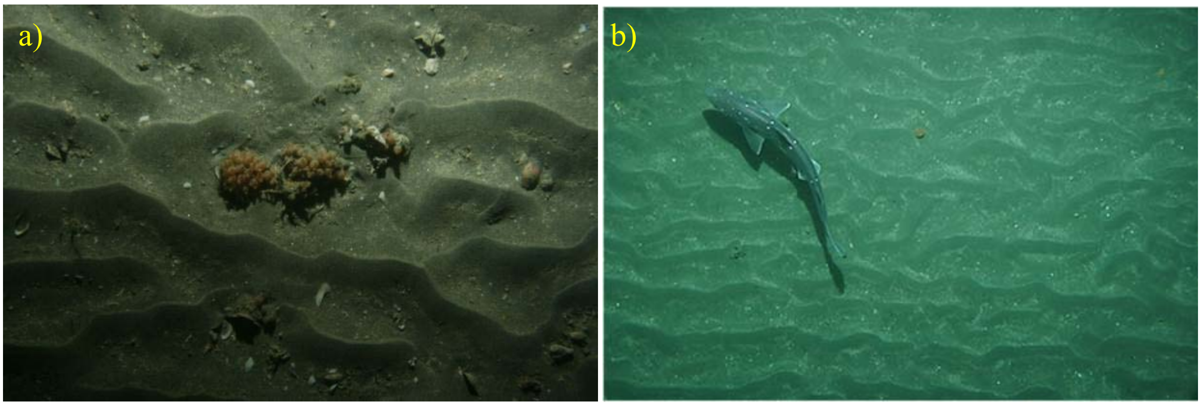


Figure 33: North-west D'Urville Island, outer Marlborough Sounds, seafloor imagery: a) rippled sand with sponge epifauna (one of only a few epifauna seen), b) southern spiny dogfish (*Squalus acanthias*) on rippled sand.

East of D'Urville Island (Site 18)

The area off Simpsons and Half-way points contained three fisher-drawn areas, all described as "*coral*" (bryozoans). Two multibeam blocks covering a combined area of 6.5 km^2 were mapped covering water depths of 10–40 m, but mainly between 10 to 20 metres (Figure 34). Three DTIS stations and one beam trawl tow were completed (Table 13). The seafloor was composed of flat sand, covered with very high numbers of turret shells and dead bivalve shells. The two sediment samples were classed as muddy sand, with 20–30% calcium carbonate, and less than 2% TOM (Figure 2, Figure 4, Figure 5). Biogenic features included low-relief patches of mixed sponge species, and occasional horse mussels with attached epifauna. Other species present included holothurians, ophiuroids, and starfish (Figure 35). A number of resting blue cod (mainly sub-adults/adults) were observed, usually up against biogenic structures. There was no evidence of any significant bryozoan habitat being present.

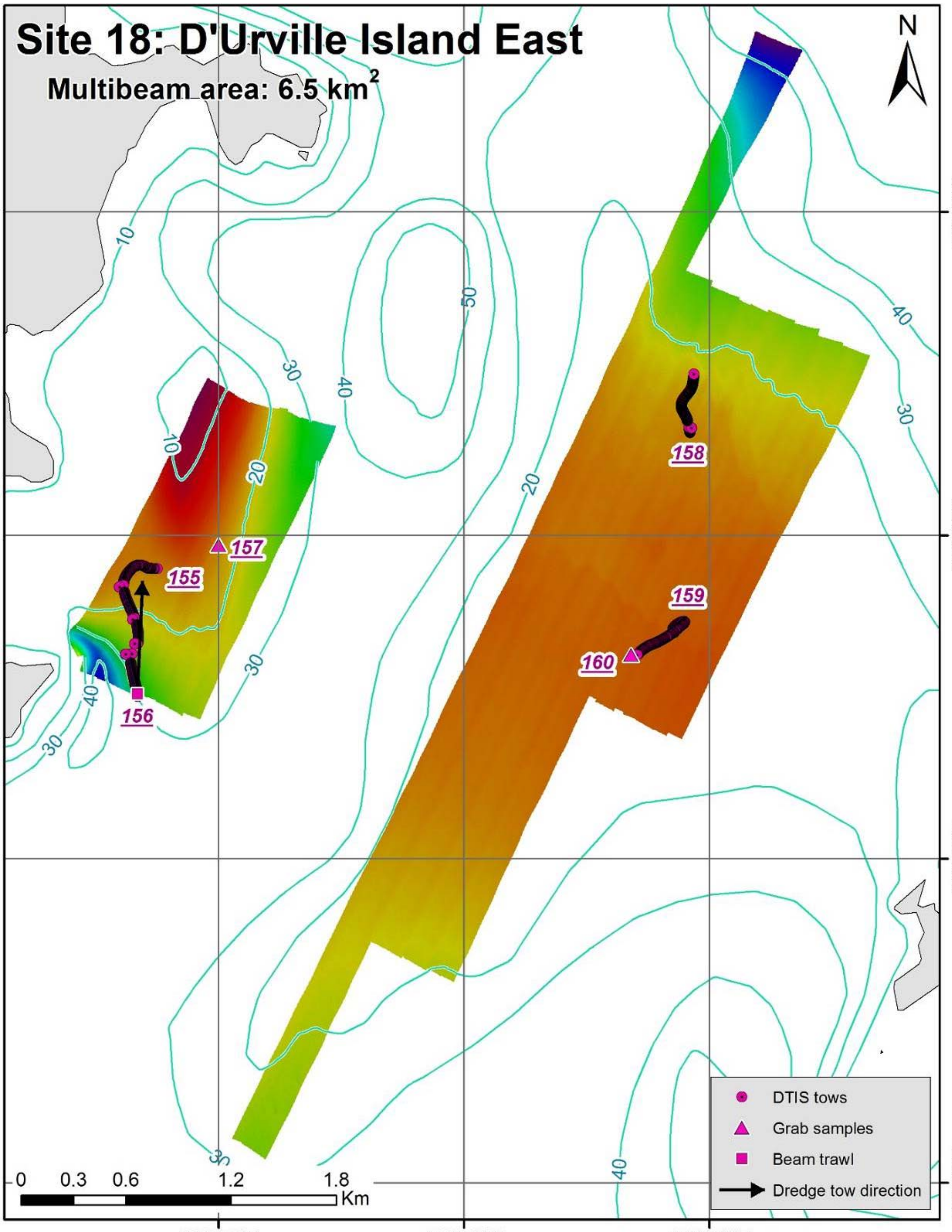


Figure 34: D'Urville Island, Marlborough Sounds. 3 DTIS, 1 beam trawl, 2 sediment samples.

Table 13: DTIS stations east of D'Urville Island, Marlborough Sounds.

Station	Time (min)	Images	Depth (m)	General habitat
155	36	172	35	Sand, screw shells, sponge, hermit crabs, holothurians, brittle stars, anemones, dead bivalve shells
158	20	82	25	As above
159	20	81	25	As above

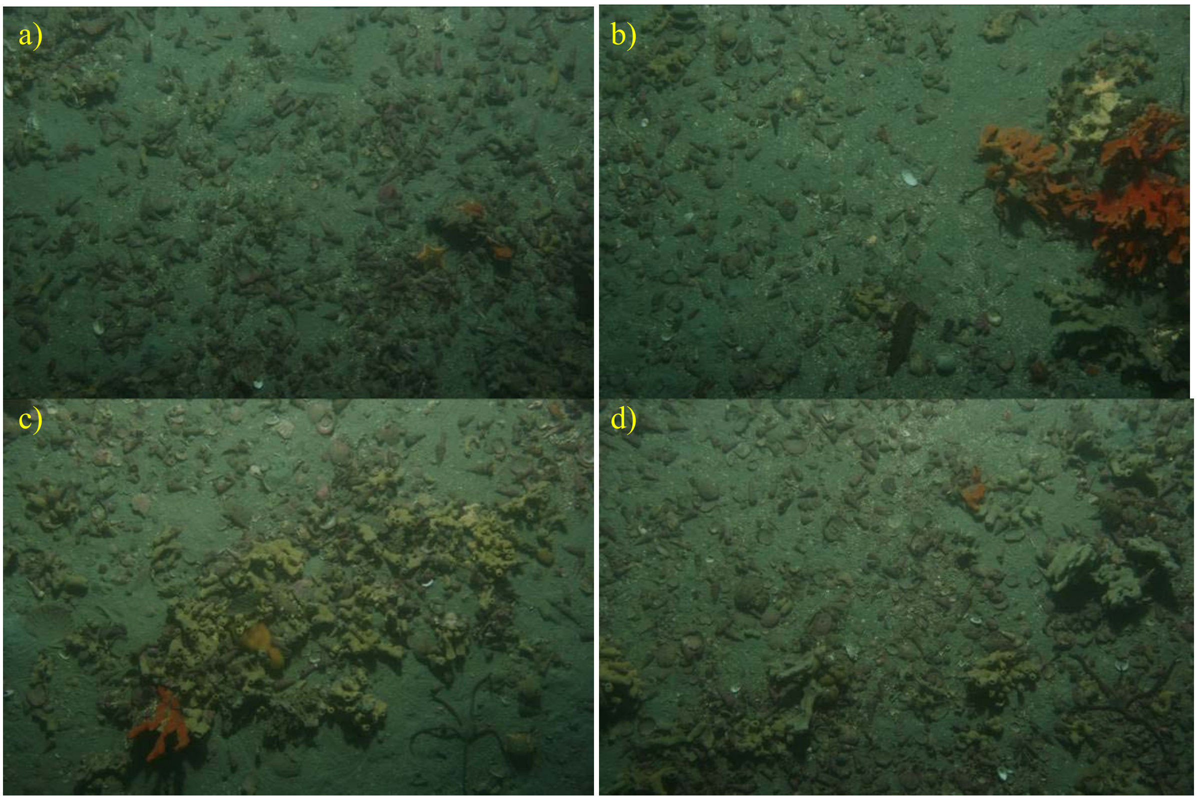


Figure 35: Eastern D'Urville Island, Marlborough Sounds, seafloor imagery: a) dominant seafloor cover of Turret shells (*Maoricolpus roseus*) which occurred across the area, b–d) patches of mixed species sponges, as well as starfish, ophiuroids, and holothurians.

Kaikoura to Banks Peninsula region

This region encompassed the Conway Ridge, which helps define part of the Kaikoura Canyon, and the North Canterbury Bight (Figure 36).

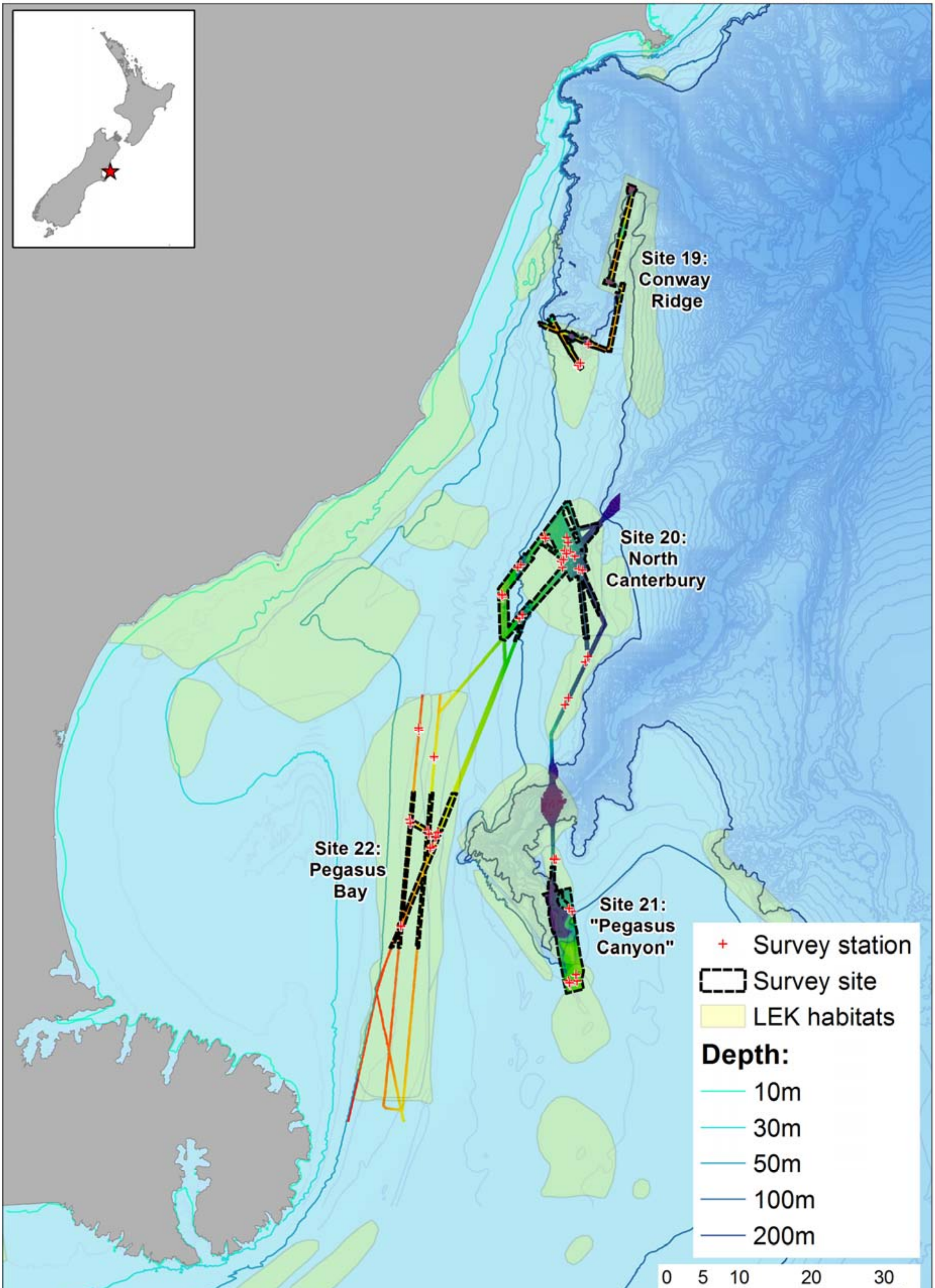


Figure 36: Kaikoura to Banks Peninsula region. Fisher-drawn areas shown as light yellow polygons.

Conway Ridge (Site 19)

Given the target size, multibeam transects were run across two fisher-drawn areas, one along the Conway Ridge described as an area of coral bycatch, and one at the southern end of the Kaikoura Canyon noted for sponges; as well as covering areas where rocky reef was thought likely to be present (canyon edges) (Figure 36). Twenty-five km^2 of seafloor was mapped (Figure 37). Only one DTIS transect was completed (Figure 37), before the still camera failed. The decision was made to leave this area and work on rectifying the camera issues while steaming south. For the one DTIS tow made, the seafloor was composed of muddy sand, with patches of rock holding ‘stick-like’ sponge species, along with other epifauna such as cup corals, ascidians, bryozoans, and holothurians observed (Figure 38a). The sponges were also seen on the soft sediment, possibly attached to rock and other objects buried beneath the sediment (Figure 38b). The one sediment sample collected was classified as sandy mud, with less than 10% calcium carbonate content, but with one of the highest TOM values recorded across both surveys, at about 6.8% (Figure 3, Figure 4, Figure 5).

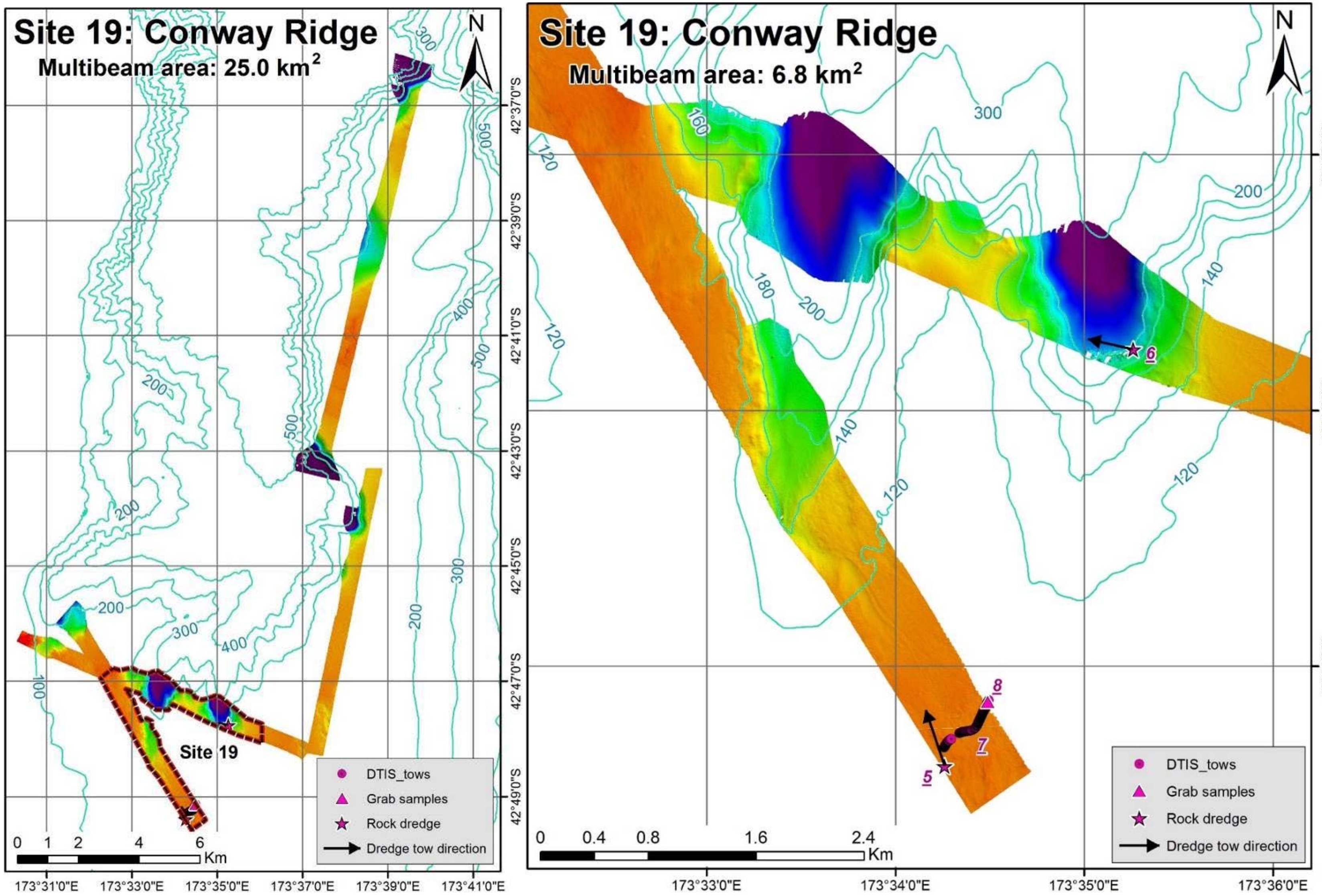


Figure 37: Seafloor bathymetry for multibeam along the Conway Ridge, and the southern edge of Kaikoura Canyon. The right side image is a closer view of the dotted polygon extent marked up in the left image.

Table 14: DTIS tows for Conway Ridge, North Canterbury region.

Station	Time (min)	Images	Depth (m)	General habitat
7	3	12	87	Muddy sand with rocks, stick sponges. Stills camera failed

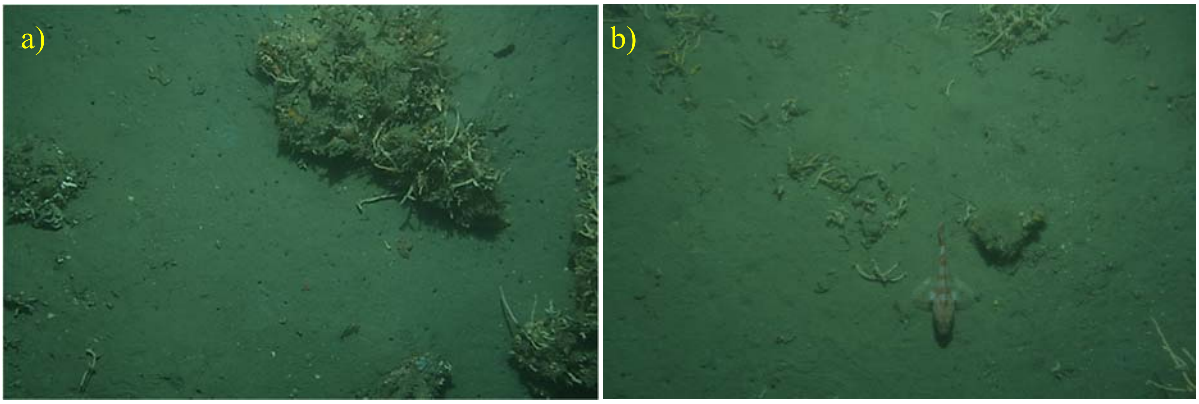


Figure 38: Conway Ridge seafloor imagery: a) rock with 'stick' sponges, cup coral, holothurians, b) sponges and sea perch. Limited stills as stills camera failed.

North Canterbury, Pegasus Canyon and Pegasus Bay "Wire-weed" areas (Sites 20, 21 and 22)

This area contained a number of fisher-drawn areas (Figure 36), variously described as "*wire-weed*", along with patches of foul. Eight of these were targeted across two separate time periods in voyage TAN1108 (Figure 39). Initial multibeam mapping commenced at the Site 20 area (most northern area), returning a distinctive hummocked surface thought to indicate the presence of 'wire-weed' (identified as polychaete meadows by DTIS and beam trawl). Given the large combined extent of the fisher-drawn areas, transects were then extended, looking for the same hummocked signature. At Site 21, a larger rectangular block was mapped, and towards the end of the survey time in this region, Site 20 was 'filled in' as much as possible between its initial transects, to gain a better multibeam coverage for BTM analysis. Additional transects were also extended out to the south-west and south-east, looking for the boundaries of the wire-weed area. Twenty-two DTIS transects were carried out, along with four beam trawl tows; the still camera failed on four of the DTIS deployments (Table 15). Polychaete meadows (the '*wire-weed*') were the dominant biogenic habitat in this region, but with large variations in tube densities and heights above the sediment, as well as large expanses of bare sediment. Associated with the polychaete meadows was a diverse invertebrate fauna, which varied across areas, and included sponges, ascidians, bryozoans, anemones, holothurians, gastropods, and crabs (Figure 40). Sea perch (especially juveniles) were relatively abundant in some areas, and juvenile tarakihi and ling were also observed. This area is analysed in greater detail in the core analysis Section 4.2, including higher resolution multibeam maps of sites 20, 21 and 22.

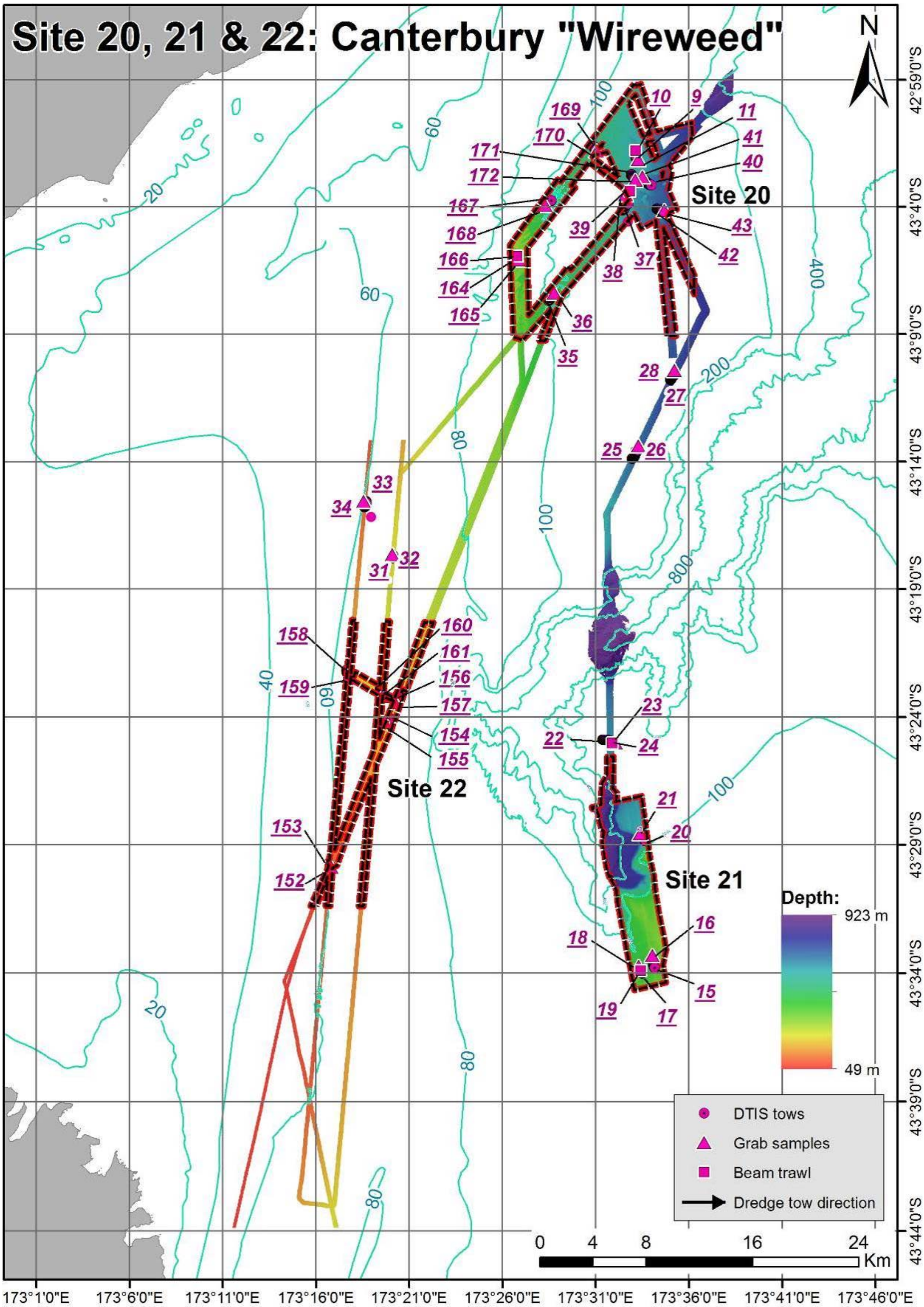


Figure 39: Wire-weed area, North Canterbury Bight. 22 DTIS, 4 beam trawl samples.

Table 15: DTIS stations for the North Canterbury Bight 'wire-weed' areas.

Stn	Time (min)	Images	Depth (m)	General habitat
Site 20: North Canterbury				
9	37	111	109	Muddy sediment, dense tube worm patches, very little attached biota
25	30	124	117	Muddy sediment with very short tube worms visible, gastropods, burrows
27	30	121	121	Muddy sediment with very short tube worms visible, gastropods, burrows
35	42	161	91	Muddy sediment with patches of tube worms, some sponges and fish.
37	30	101	106	No flash, no stills captured. Dense tube worm beds, sponges and fish
40	37	0	116	No flash, no stills captured. Dense tube worm beds, sponges and fish
42	31	0	111	No flash, no stills captured. Patches of tube worm beds
164	32	128	79	Low visibility, patchy tube worm clumps interspersed with bare sediment.
167	31	127	92	Patchy tube worm clumps on muddy sediment with sponges, trawl tracks visible.
169	32	126	100	Patchy tubeworms on muddy sediment with areas of shell hash, trawl tracks visible.
171	33	125	106	Dense tube worms, sponges, holothurians on muddy sediment
Site 21: Pegasus Canyon				
15	30	122	85	Coarse sand, shell hash, low bryozoan clumps, majid crabs, gastropods. Small patches of short/buried tube worms
17	32	132	87	As above
20	30	123	108	As above, but more buried tube worm patches
22	30	120	115	Muddy sediment with patches of dense tube worm, and sponges.
31	20	0	65	No flash, no stills captured Muddy sediment, low visibility, no tubeworms visible
33	21	0	54	No flash, no stills captured. Muddy sediment, low visibility, some buried tube worms?
Site 22: Pegasus Bay				
152	30	121	55	Muddy sediment, low visibility, buried tube worm patches, horse mussels
154	32	128	65	Muddy sediment and shell hash, buried tube worms, small bryozoan clumps, hermit crabs
156	31	126	67	Muddy sediment and shell hash, mixture of buried and more visible tube worms. No laser, stills not analysed.
158	32	127	60	Muddy sediment, patches of tube worms, varied density, anemones and ascidians.
160	31	125	65	Muddy sediment, sparse, buried tube worms. Lots of gastropods / hermit crabs

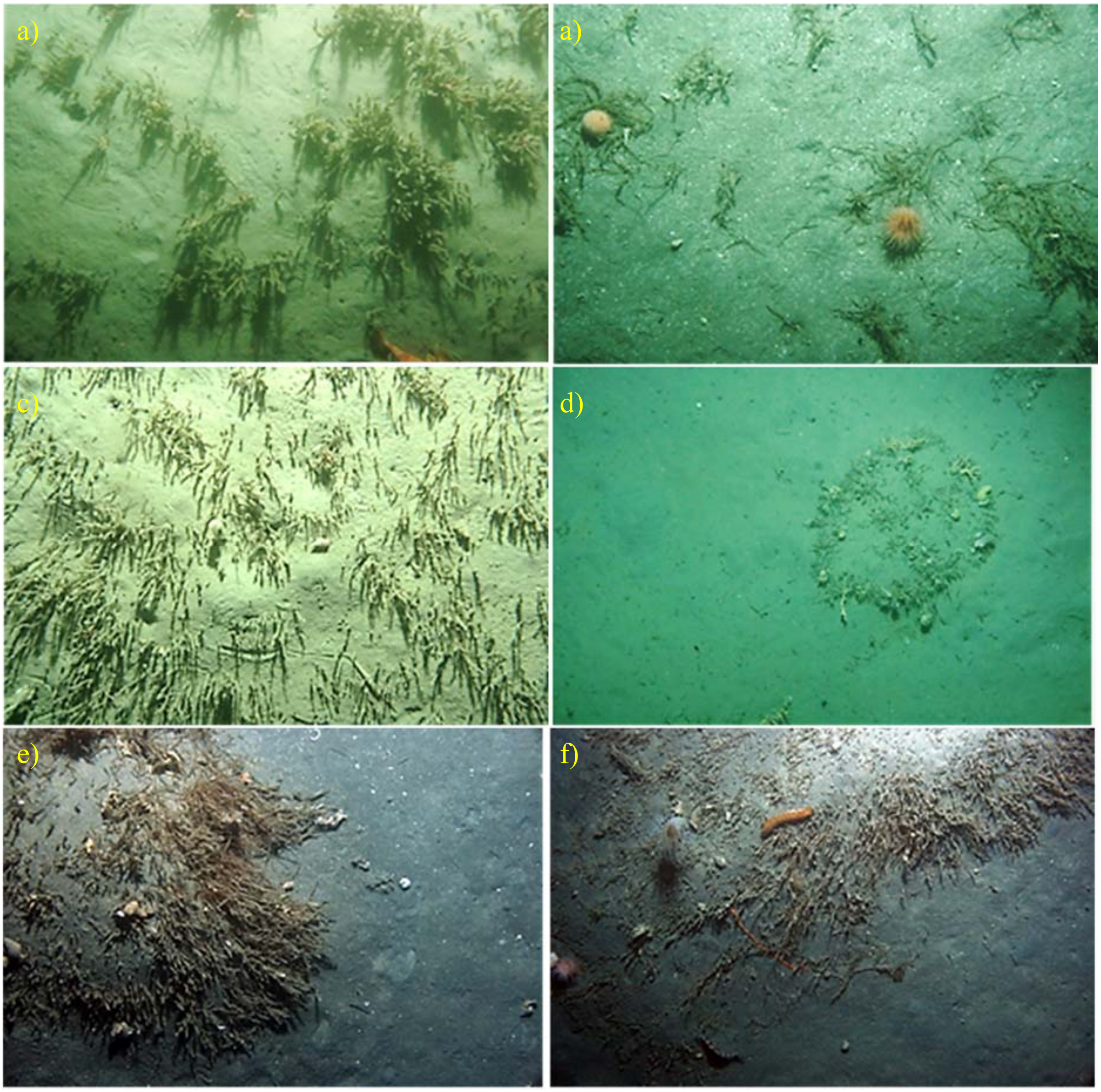


Figure 40: Wire-weed, North Canterbury Bight (large bare muddy expanses are also present): a–c) wire-weed over flat expanses, d–f) fine scale mounts with diverse associated epifauna, including sponges, ascidians, anemones, holothurians, and nemertean worms. Note that the hummocks seen on the multibeam maps are at larger spatial scales that the fine scale mounts shown here.

The Otago region

This region contained a relatively large number of fisher fisher-drawn areas. Targeted locations were: the feature known as the 'Hay Paddock' (like "*straw*"), and to a lesser degree the sea cucumber/sea tulip areas inshore of this; Cornish Head (Karitane) Canyon with bryozoans ("*coral*") and sponges, the Otago Shelf bryozoan thickets, and one of the Otago shelf queen scallop grounds (Figure 41). Three DTIS tows were also completed off Blueskin Bay while sheltering from storm conditions; these were largely sandy seafloor with little epifauna or other features, and are not discussed further.

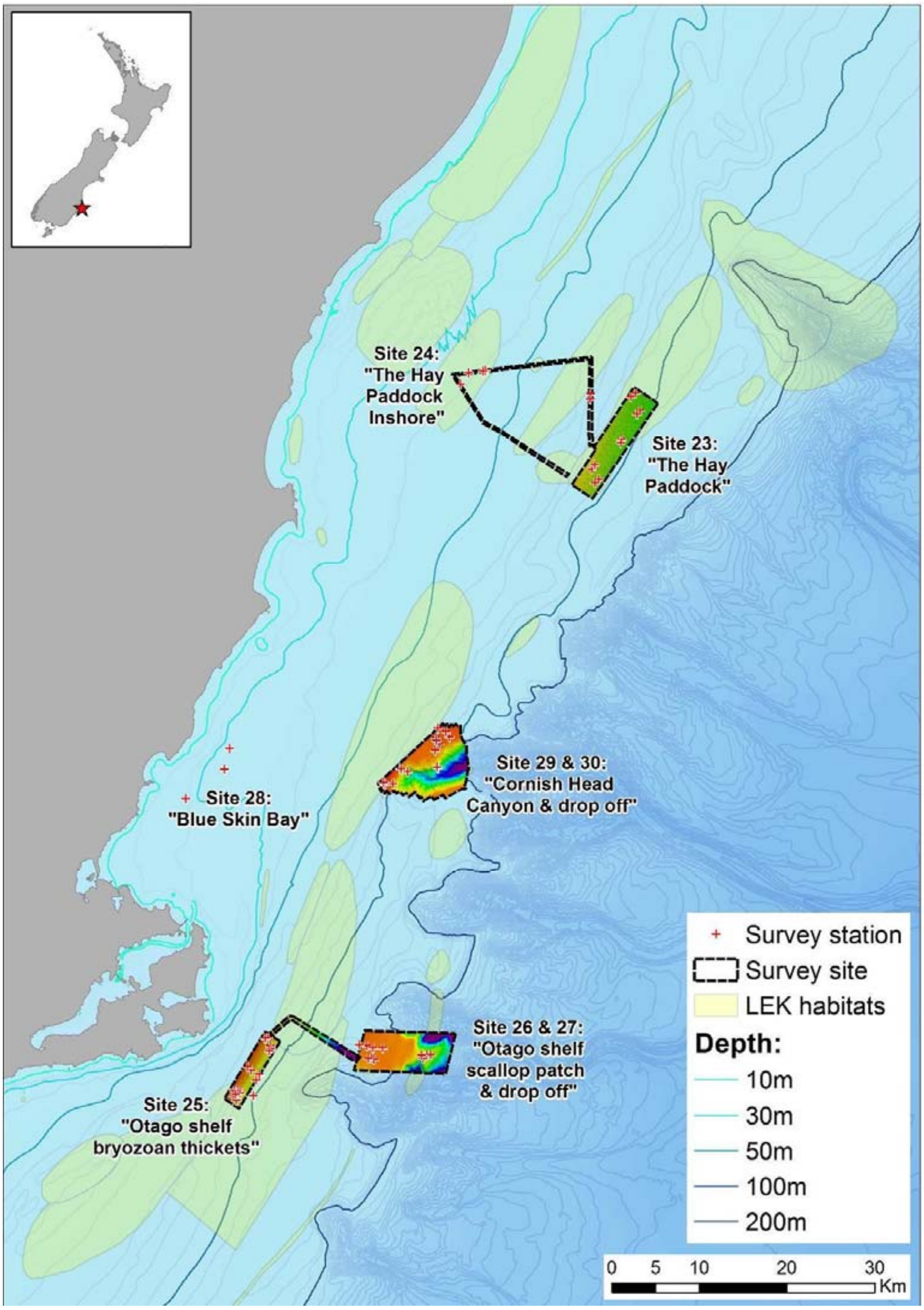


Figure 41: Otago Shelf region. Fisher-drawn areas (LEK habitats) are shown as light yellow polygons.

The “Hay Paddock” (Site 23)

Two fisher-drawn areas delineate a site known to fishers as the “*Hay Paddock*”. A 36.3 km^2 block was mapped where the two areas over-lapped (Figure 41). Five DTIS and one beam trawl station were completed within this block (Table 16, Figure 42), as well as an exploratory DTIS station to the west, over a Vooren (1975) trawl station (J08/41/69). Sediments were classified as slightly gravelly muddy sand / muddy sand / sand, across the five stations sampled (Figure 3, Figure 4, Figure 5), with 20–30% calcium carbonate, and 2–3% TOM. The dominant epifauna were sponge species, at times very dense, growing on polychaete (wire-weed) tubes. The associated assemblage included at least a dozen ascidian species, nudibranchs (including *Archidoris wellingtonensis*), large anemones, holothurians, and starfish (Figure 43). Fish seen included large adult red cod, sea-perch, blue-cod, and snipe-fish. For Station 58 (matching the Vooren 1975 trawl station start point), the seafloor was classed as muddy sand, and held scattered live horse mussels, with almost all supporting one or more wandering anemones, as well as often associated larger ophiuroids (Figure 43e, f). Vooren (1975) noted that a 1 hour trawl here caught 1145 tarakihi, with the associated field note of “*Immense quantity of sponge, with many starfish, molluscs, worms, etc*". That station’s given start was inshore of the Fisher-drawn areas (Figure 41), at 65 m water depth; but the direction of tow, end position, and depth were not given (NB: there was probably positional error at the time, the start position given falls on the 70 m contour using present-day bathymetry). The Hay Paddock multi-beam block spanned around the 82 to 110 m depth contour. Vooren’s account closely matches the Hay Paddock’s biological assemblage, but it cannot be ascertained from the data available whether his account shows the inner extent of the Hay Paddock to have contracted since 1969, or whether he simply towed seaward and encountered it in the latter part of his trawl tow. The fauna found here at the Hay Paddock site are described in greater detail in section 4.2.

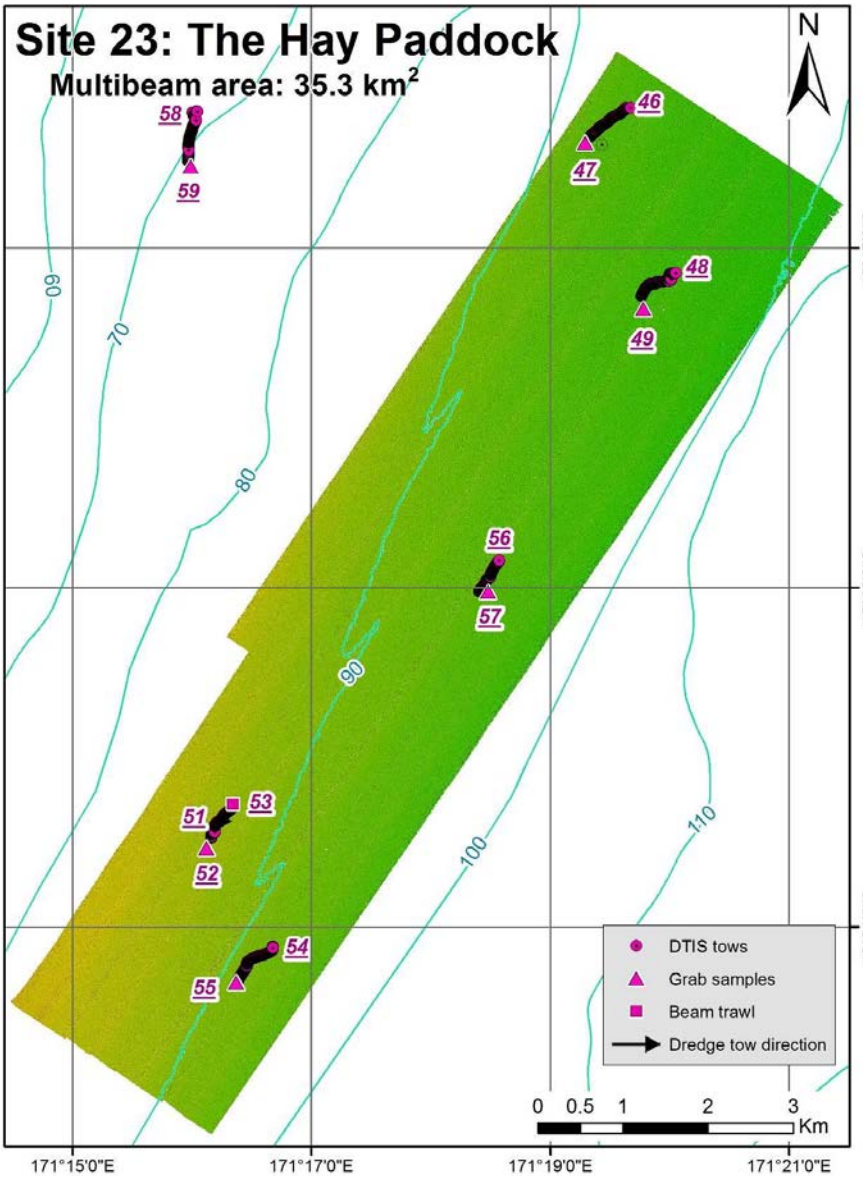


Figure 42: The Hay Paddock (north Otago Shelf) bathymetry: 5 DTIS, 1 beam trawl, 6 sediment samples. 1 exploratory DTIS (Station 58) and sediment sample to the west on a Vooren (1975) trawl station.

Table 16: DTIS stations for the Hay Paddock, northern Otago shelf. *, Vooren (1975) station.

Stn.	Time (min)	Images	Depth (m)	General habitat
46	30	125	88	Muddy sediment, tube worm clumps with sponge epifauna and others
48	34	131	92	Muddy sediment, tube worm clumps with sponge epifauna, ascidians, anemones, sea perch
51	30	122	86	Muddy sediment, tube worm clumps with sponge epifauna and others
54	33	131	85	Muddy sediment, tube worm clumps with sponge epifauna and others
56	30	122	88	Muddy sediment, tube worm clumps with sponge epifauna and others
58*	34	131	70	Muddy sediment, occasional horse mussels and anemones

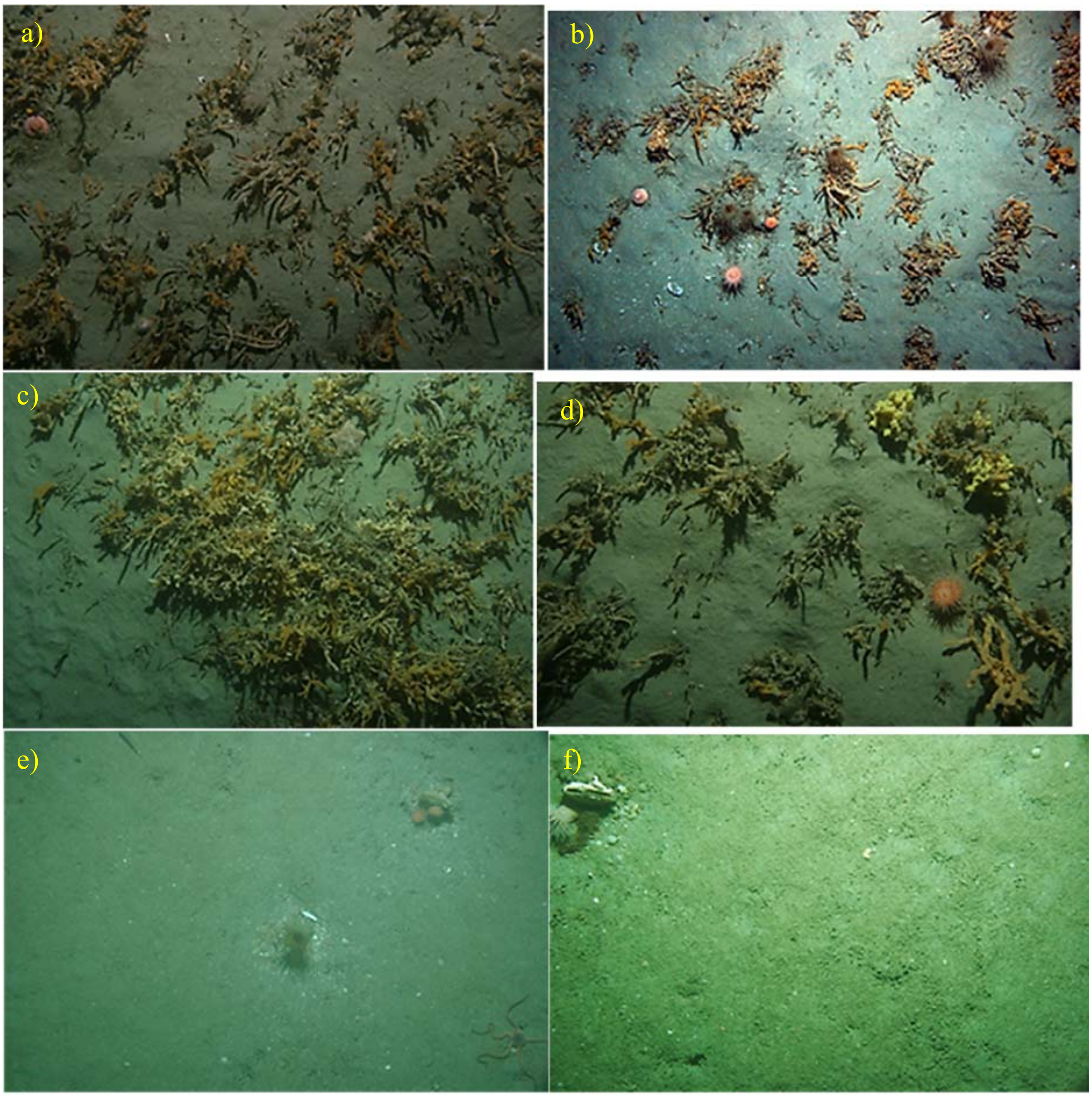


Figure 43: Hay Paddock, northern Otago shelf, seafloor imagery: a–d) wire-weed with associated sponge assemblage, anemones, ascidians, and starfish, e–f) inshore Station 58 images, including horse mussels and wandering anemones, holothurians, ophiuroid, and squat lobsters (sheltering under the others).

Inshore of the Hay Paddock (Site 24)

A multibeam transect (10.2 km^2 extent) was run inshore of the Hay Paddock area, crossing fisher-drawn areas for sea cucumbers and sea tulips respectively (Figure 41). Areas of patchy low-relief rocky reef were readily apparent on the multi-beam imagery. Three DTIS stations were completed, targeting the reef features (Table 17, Figure 44). The seafloor was composed of low broken reef and rock/cobble areas, interposed with soft sediments that ranged from bare rippled sands, through shell debris, to large coarse gravels (red-coloured). The one sediment sample collected was assessed as sand, with about 20% calcium carbonate, and less than 2% TOM (Figure 3, Figure 4, Figure 5). Some of the soft sediments appeared to be structured as larger sediment waves. Often abundant ‘sponge gardens’ were associated with the harder reef areas, including both mound (e.g., *Polymastia croceus*) and finger forms, along with bryozoans, ophiuroids, and holothurians (Figure 45). Non-geniculate coralline algae cover was also present across some boulders and cobbles in the area. Fish observed including blue cod, leatherjackets, orange wrasse, southern pigfish, and barracouta (in the water column).

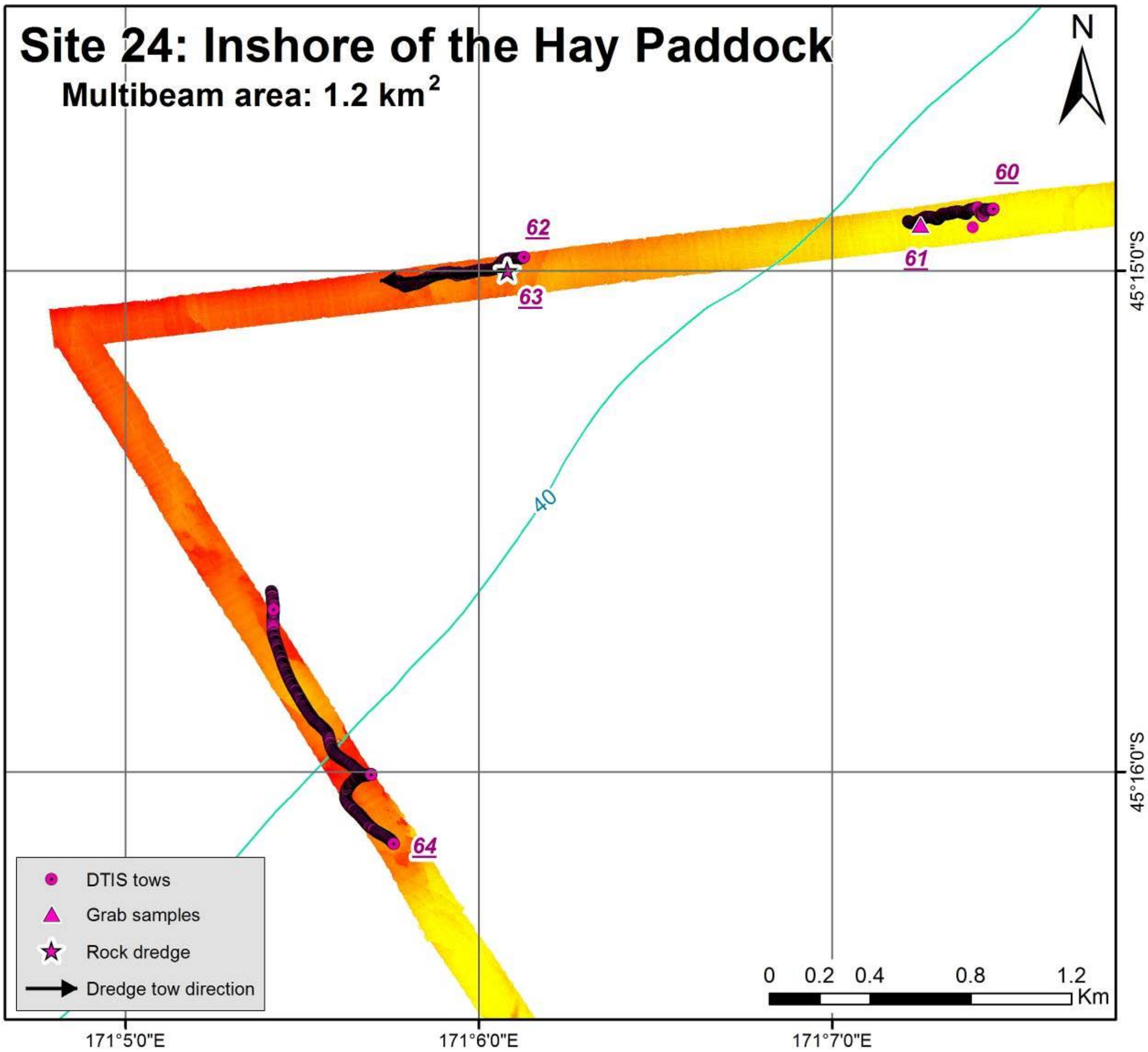


Figure 44: Inshore of the Hay Paddock, (northern Otago Shelf). 3 DTIS, 1 rock dredge, and 1 sediment sample.

Table 17: DTIS stations inshore of the Hay Paddock, northern Otago Shelf.

Stn	Time (min)	Images	Depth (m)	General habitat
60	29	121	36	Sand / shell hash, bryozoans
62	33	130	33	Sand / shell hash / bedrock ledges, sponge beds, bryozoans
64	62	260	32	Sand / shell hash / bedrock ledges, sponge beds, bryozoans

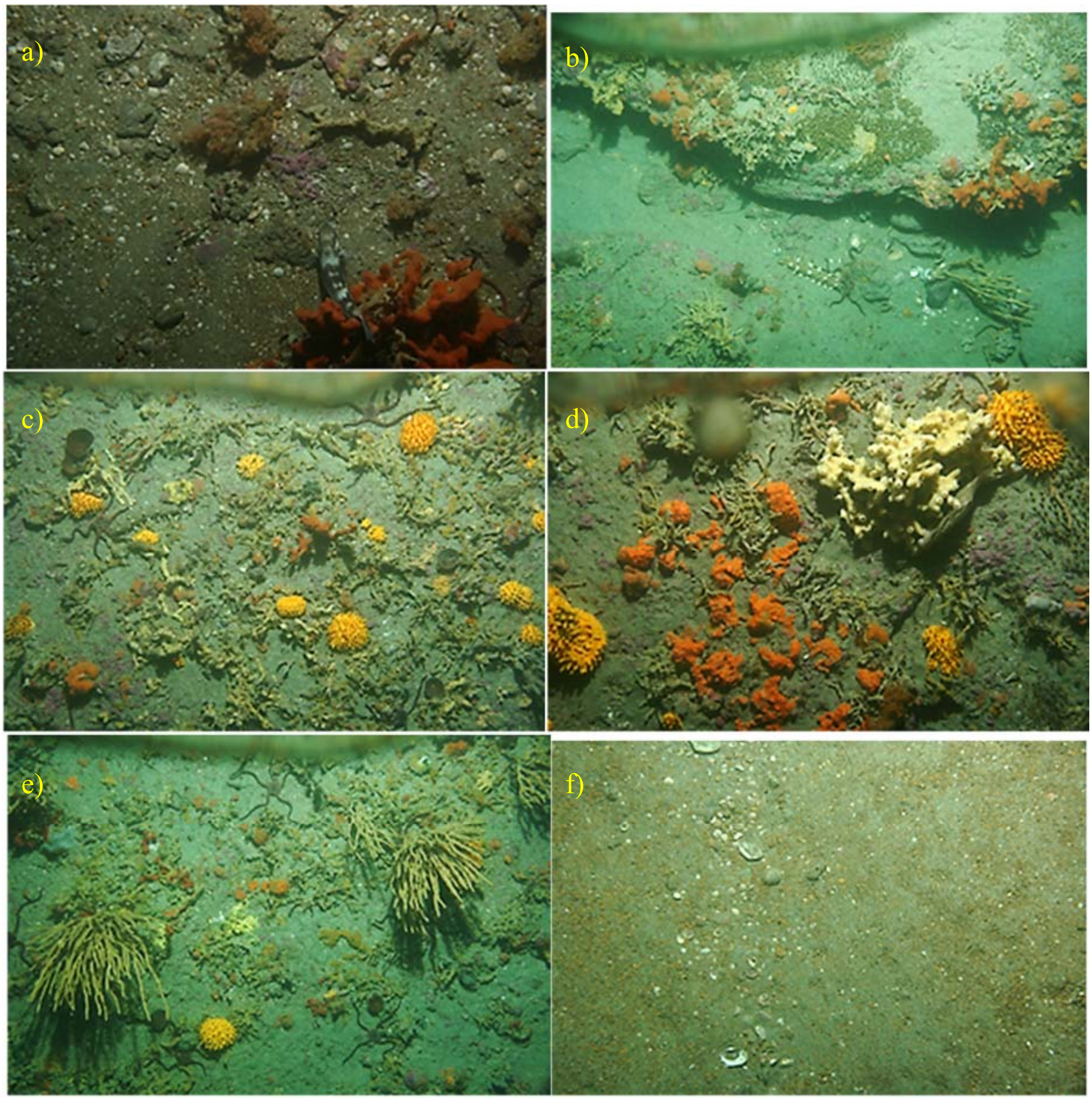


Figure 45: Area inshore of the Hay Paddock, within a LEK sea tulip area. a) rubble, sponge, sleeping blue cod, bryozoans, ophiuroid, b) low rock ledge with sponges, saw-shell, holothurian, c–e) sponge flats, with sleeping pigfish against fawn sponge in (d), f) coarse gravel interspersed with low reefs. Bright yellow sponges are *Polymastia croceus*.

Cornish Head (Karitane) Canyon (Sites 29 and 30)

Fisher-drawn areas of bryozoans (described as snow-flakes) were located along the northern canyon side, as well as a large area of sponges just north of this on the flat continental shelf (Figure 41). To target these, the canyon head was multibeam mapped, as well as an area of shelf on the northern side, collectively covering 46.7 km^2 (Figure 46). Eight DTIS stations were completed: three of these were relatively short exploratory tows of ten minutes (Table 18). One beam trawl and one rock dredge station were also sampled. Two of the DTIS tows (Stations 146, 147) ran over the canyon edge, and revealed a drop-off composed of large ledges and very big boulders/bedrock, interspersed with coarse sediments and dead shell debris (Figure 47). A notable biogenic feature at the shelf/canyon edge at Station 146 was the presence of large *Hippomenella vellicata* bryozoan colonies, with a number of large rock lobsters associated with them in over 200 m water depth. A range of sponges, bryozoans, and anemones covered the rock surfaces, although habitat types varied greatly over short distances, and not all rock surfaces supported epifauna. A crab (probably *Leptomithrax longipes*) (Figure 47a) was found in notable groups, roaming over both rocks and soft sediment areas, while small squat lobsters (*Munida gregaria*) were also commonly observed over rock with epifauna, and coarse debris (Figure 47f, g respectively).

On the adjacent continental shelf flat, DTIS stations in the southern area revealed a seafloor of muddy sands, along with the presence of tube-worms (putatively wire-weed), and sponge assemblages (Figure 48a–c) that appeared very similar to the Hay Paddock, 40 kilometres to the north-east. Observations from DTIS stations in the northern area showed a seafloor of sand/fine shell/gravels, with the presence of many bryozoan colonies, and tubeworms as at the southern stations. Other epifauna includes sponges and ascidians (Figure 48d–f), this area looked similar in appearance to the bryozoan fields off Otago Peninsula (see following section). Both these assemblage types were patchy at the multiple tens of metres scale, and were interspersed with areas of bare sediments (wire-weed and sponges), and sediment with shell and other debris (wire-weed and bryozoan) respectively. Sediment samples were classed as sandy gravel / gravelly sand, with 45–70% calcium carbonate (one outlier at under 3%), with 1–2% TOM (Figure 3, Figure 4, Figure 5).

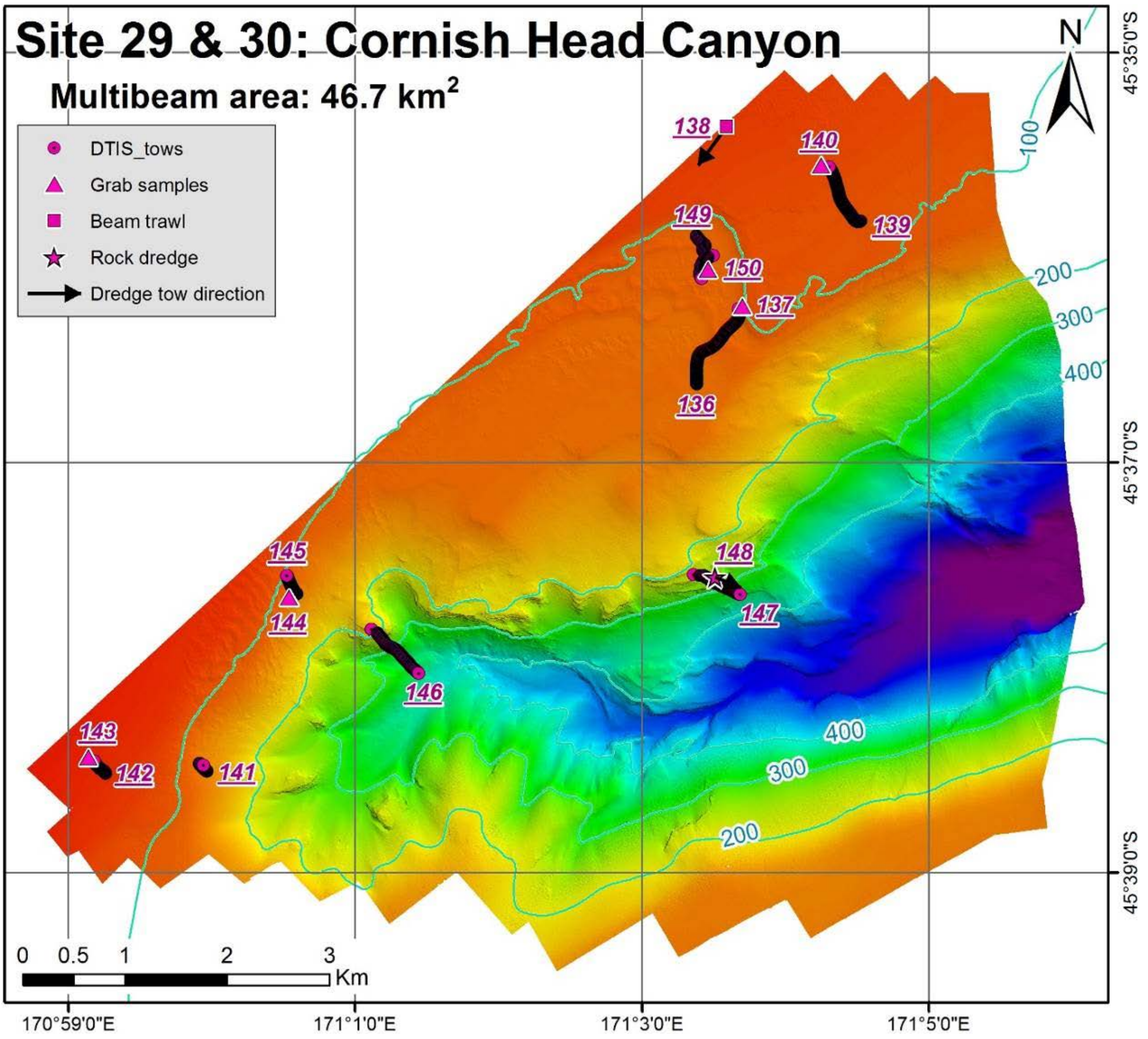


Figure 46: Cornish Head Canyon (northern Otago Shelf) bathymetry: 8 DTIS, 1 beam, 1 rock dredge, 5 sediment samples.

Table 18: DTIS stations from Cornish Head Canyon, northern Otago Shelf.

Stn.	Time (min)	Images	Depth (m)	General habitat
136	31	125	108	Muddy sediment with shell hash / bryozoan fragments, tube worms (same species as wire-weed?), horse mussels, brown finger sponge
139	33	128	93	Similar to above, less tubeworm, gravellier (very small spired gastropods), more bryozoan colonies towards end
141	10	40	115	Sand / shell hash, occasional patch of tube worm / sponge
142	10	41	70	Sand / shell hash, occasional patch of tube worm / sponge
145	10	42	116	Similar to 136 and 139, a number of stills similar to Hay Paddock
146	33	131	170–350	Along the drop off. Bedrock with large bryozoan colonies at edge, some sponge, lots of crabs, then to mud
147	32	129	200–325	Shell hash, sponge, anemones, bedrock with low encrusting sponges, dead shell. Very variable over short distances.
149	31	123	103	Similar to 136 and 139, many Hay Paddock like patches

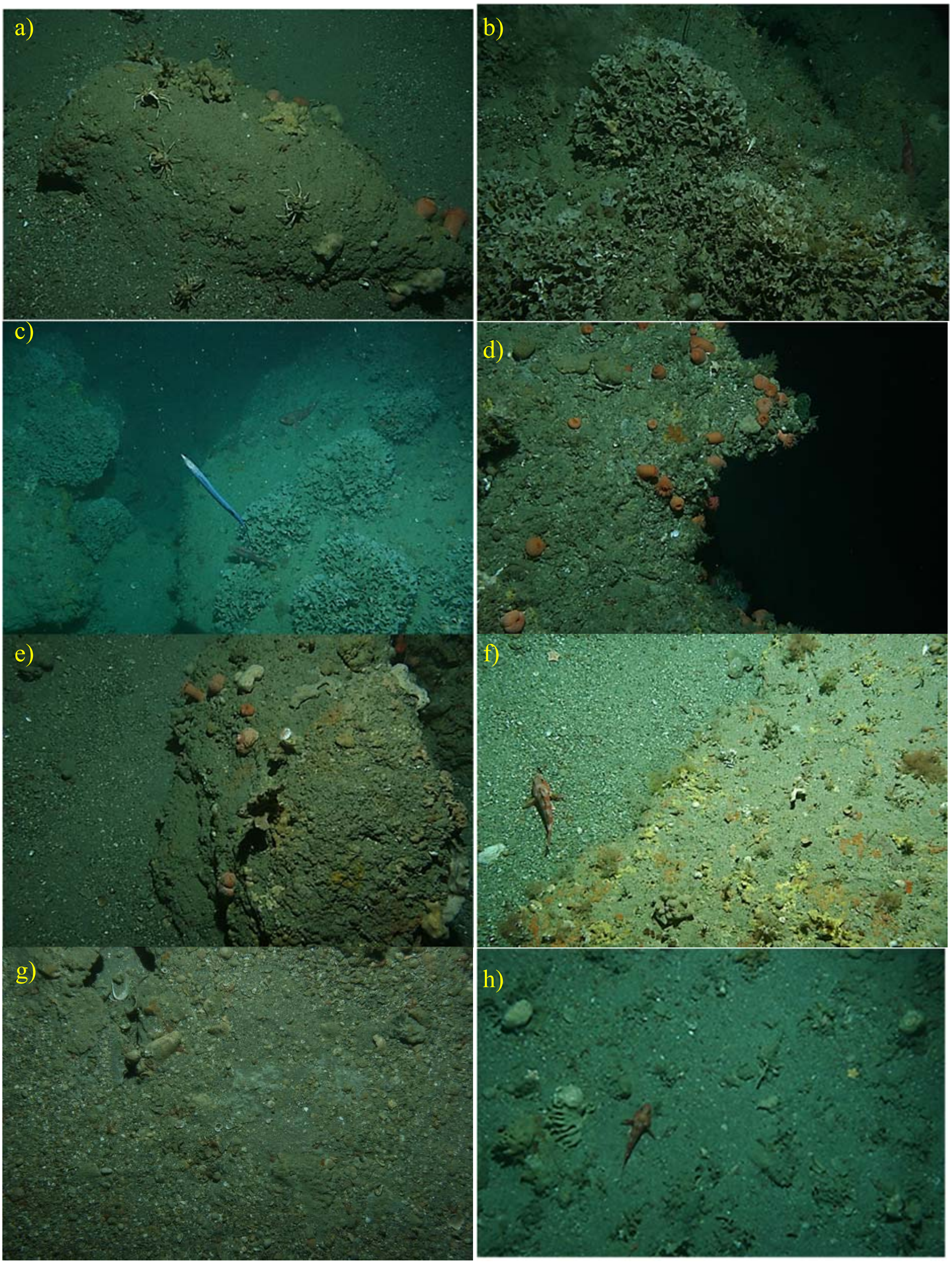


Figure 47: Cornish Head Canyon, North Otago, seafloor imagery. Canyon drop-off, stations 146, 147: a) boulder with crabs (probably *Leptomithrax longipes*) and sponges, b–c) large bryozoan (*Hippomenella vellicata*) colonies, rock lobster behind top colony in (b), d) one of rock ledge series, with anemones, sponges, and bryozoans, e–f) sponge and bryozoan assemblages on rock, including a number of sheltering squat lobsters on (f), g–h) coarse sand/gravel/shells interspersed with the rock areas.

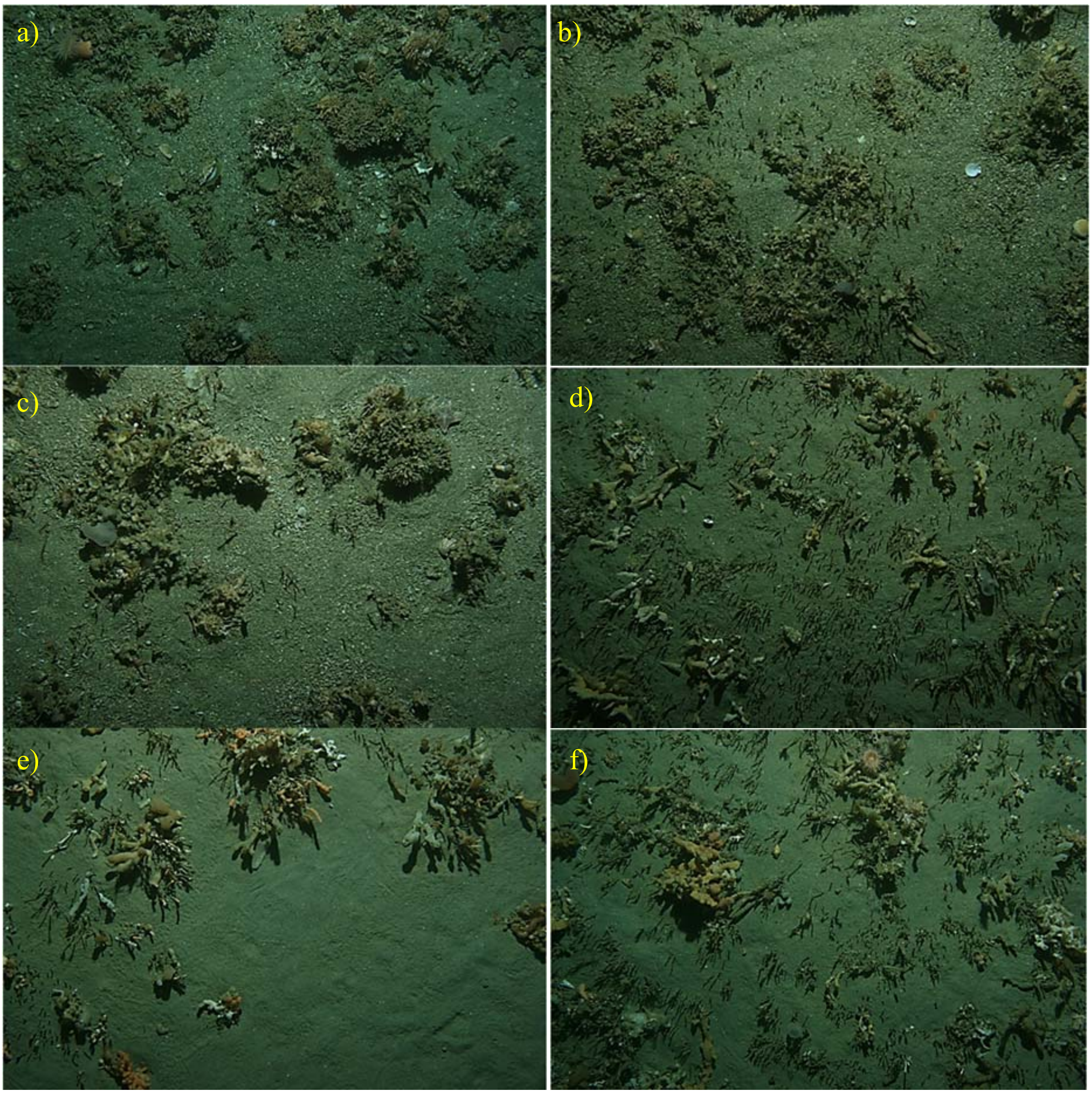


Figure 48: Cornish Head Canyon, North Otago, seafloor imagery: Shelf next to canyon: a–c) bryozoan colonies, polychaete tubes, d–f) sponges and ascidians, polychaete tubes.

Otago Shelf bryozoan thickets (Site 25)

A 15.4 km^2 block was mapped within the fisher-drawn areas described as bryozoan beds, targeting a higher abundance/diversity area as broadly seen in the benthic dredge data of Batson & Probert (2000). Six DTIS stations were completed (Table 19, Figure 49), of which five stations fell on areas of significant bryozoan clump cover, while the sixth (Station 109) ran along the very edge of the block, and was dominated by gravel and shell hash. Sediment samples were assessed as muddy sandy gravel / sandy gravel / slightly gravelly sand, with 60–80 % calcium carbonate (excepting Station 133, at 35%), and variable TOM, from 1 to 4% (Figure 3, Figure 4, Figure 5). There was a diverse but patchy cover of bryozoan species along with sponge and ascidians, interspersed with gravel and coarse sediment patches (Figure 50). Tube-worms (believed to be the same "wire-weed" species) were common (difficult to see on the images here due to scale). These gravels are relic river sediments from an earlier geological period when sea levels were lower (Carter et al. 1985). Many mobile invertebrate species, especially ophiuroids (snake and feather stars) were also present, while numbers of juvenile (0+) blue cod and southern pigfish were seen on DTIS, as well as captured in the beam trawl samples.

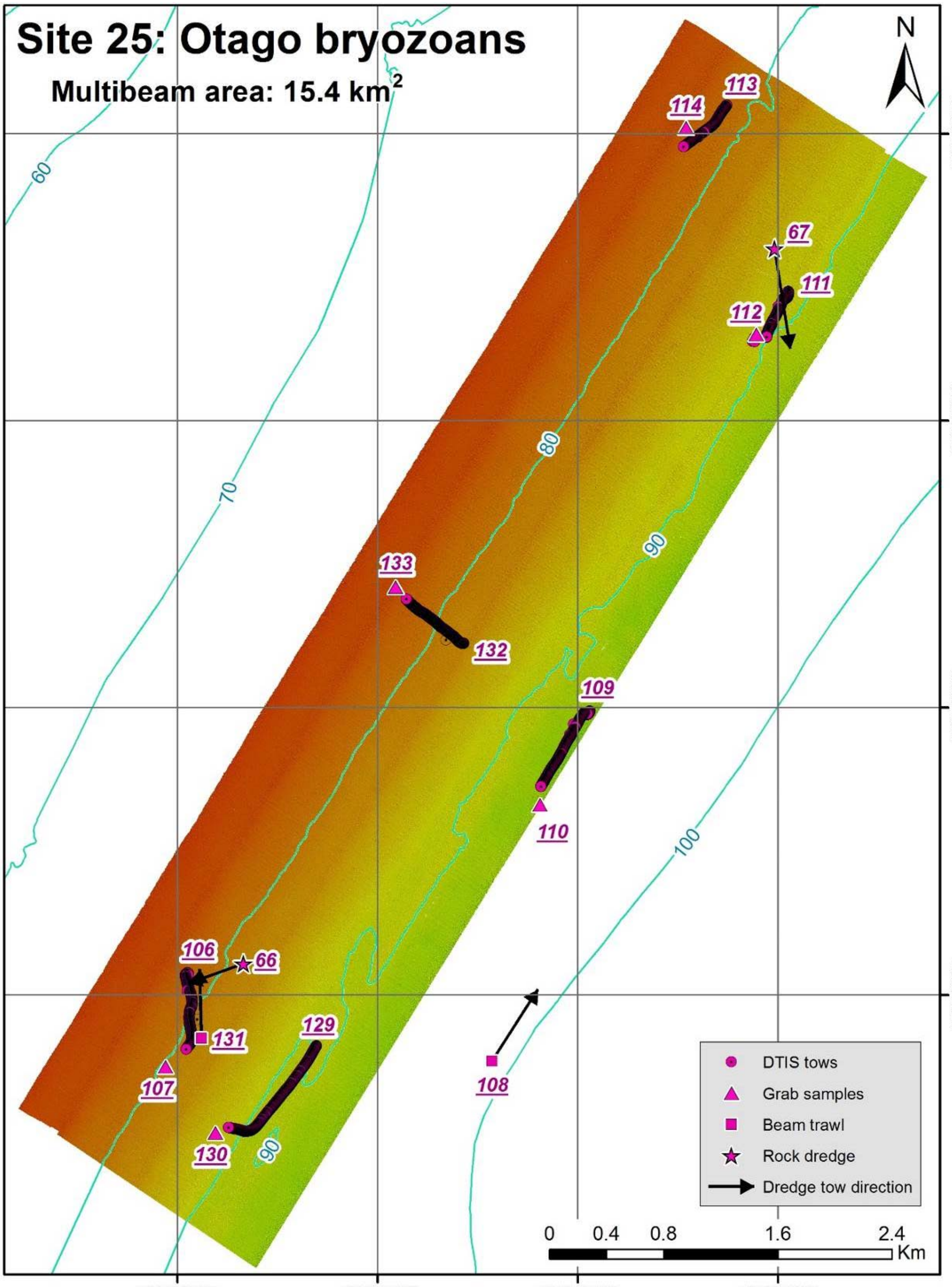


Figure 49: Central Otago Shelf, bryozoan fields, bathymetry.

Table 19: DTIS stations for the mapped bryozoan area, central Otago Shelf.

Station	Time (min)	Images	Depth (m)	General habitat
106	30	121	70	Bryozoan thickets on sand / shell hash, asteroids, brittle stars, sponge
109	33	131	86	Sand, shell hash, pebbles, asteroids, echinoids, sponge, horse mussels
111	30	121	82	Similar to station 106
113	33	131	73	Similar to station 106
129	32	128	84	Sand / gravel, shell hash; bryozoans, sponges, holothurians, asteroids, ascidians
132	31	126	77	As above

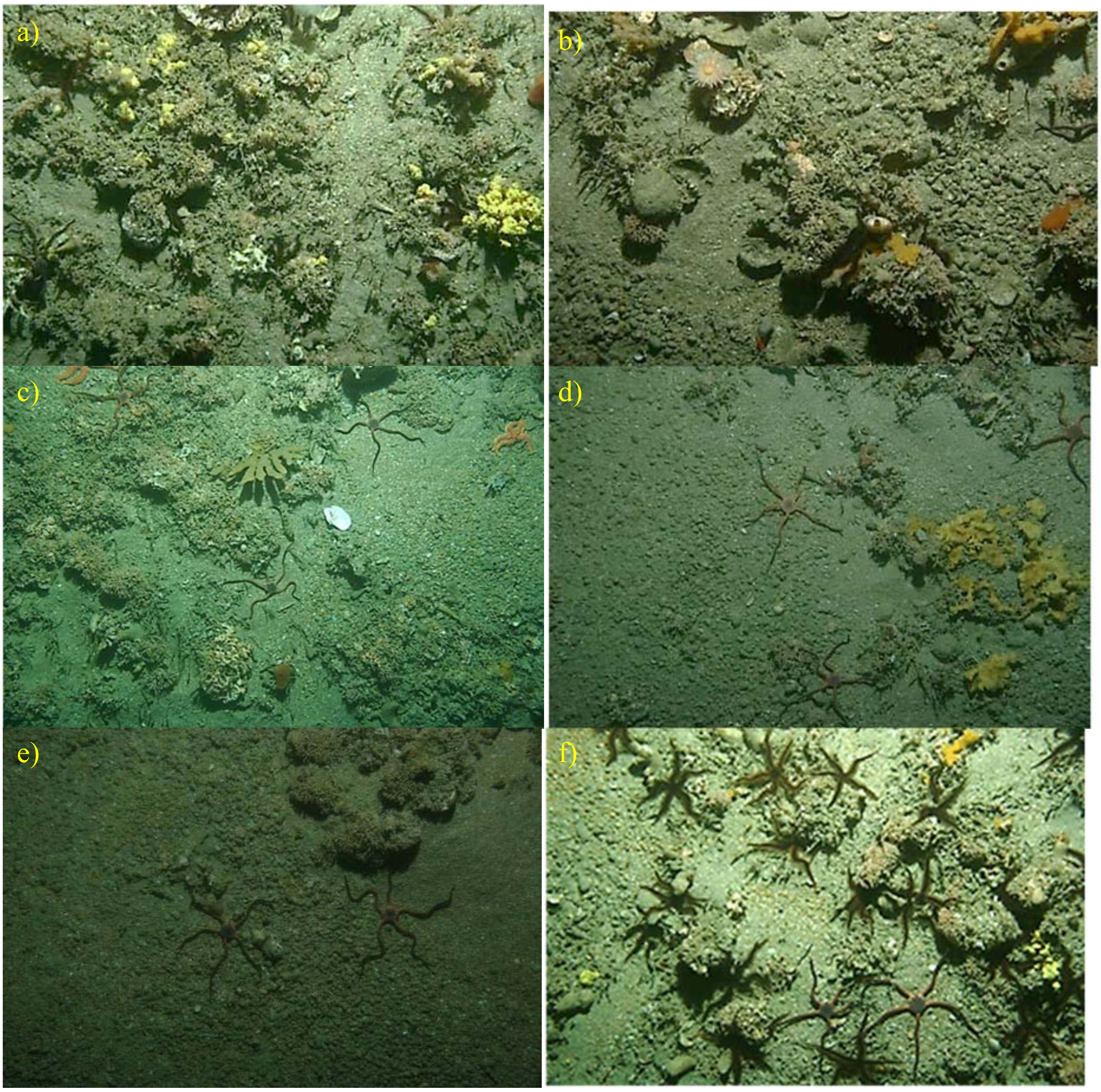


Figure 50: Central Otago Shelf seafloor imagery. a–f) various bryozoan colonies, tubeworms, sponges, starfish, ophiuroids, and ascidians. There is a sleeping juvenile blue cod at the centre of image (c). Physical sediments range from coarse sands to pebble drifts.

Otago Shelf queen scallop grounds (Sites 26 and 27)

A block (40.6 km^2) was mapped over a fisher-drawn area for a queen scallop fishing ground, as well as a deeper water fisher-drawn area described as sponge bycatch. This block extended from the shelf flat (about 130 m), out along a ‘peninsula’ extending east, falling to 200 m depth, and then a further extension to 400 m, before dropping off as the continental slope (Figure 51).

Five DTIS stations were completed (Table 20). For the two deeper stations, sediment was classed as gravelly sand/muddy sandy gravel, with 60–70% calcium carbonate, and 2–3.5% TOM (Figure 3, Figure 4, Figure 5). Observations from the DTIS indicated that different bryozoan species were present compared to those of the shallower stations (including a “white spiky clump” form) in association with patches of shell/bryozoan debris, surrounded by bare sediments. Other epifauna included yellow curved tubes, thought to be tube-worms (red heads observed on several with DTIS transects) (Figure 52a–b). At the shallower stations, the seafloor was composed of sands, shell hash, and variable amounts of dead scallop shells. Sediment samples were classed as sandy gravel/gravelly sand, with 35–80% calcium carbonate, and 2–4% TOM (Figure 3, Figure 4, Figure 5). Bryozoans, shelly rubble, along with large patches of yellow ‘stringy’ sponges in some places were observed on these shallower transects (Figure 52c–d). Live queen scallops were distributed across the area, but not at consistently high densities (e.g., >1 m^{-2}) (Figure 52e–f). Other mobile invertebrate fauna included crabs and squat lobsters.

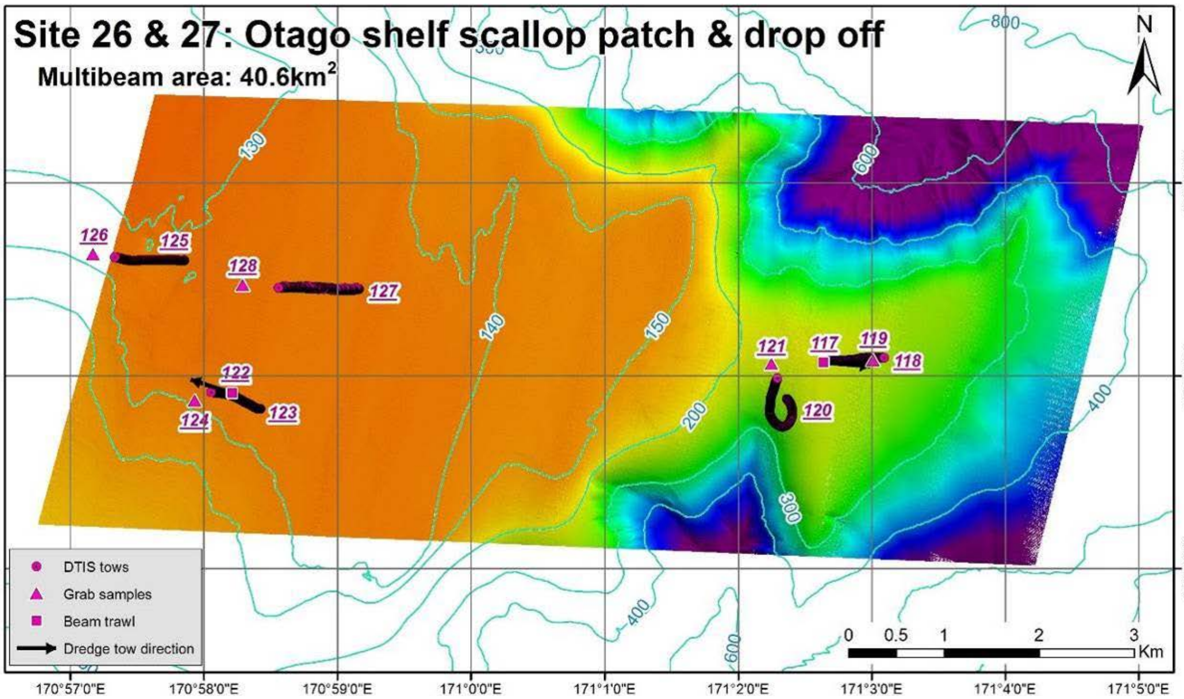


Figure 51: Mid Otago Shelf – queen scallop fishery ground, and deeper water sponge habitat. 5 DTIS, 2 beam trawl, 5 sediment samples.

Table 20: DTIS stations for the queen scallop fishery grounds, mid Otago Shelf.

Stn	Time (min)	Images	Depth (m)	General habitat
118	31	121	198	Sand/mud, shell hash, small bryozoan clumps, unid. yellow fragments
120	33	129	220	Sand/mud, shell hash, small bryozoan clumps, sponge
123	31	126	133	Sand / shell hash/gravel, sponge, scallops, asteroids, bryozoans, echinoids
125	32	127	128	Sand / shell hash/gravel, sponge, scallops, asteroids, bryozoans, anemones
127	33	135	130	Sand / shell hash/gravel, sponge, scallops, asteroids, bryozoans, crabs

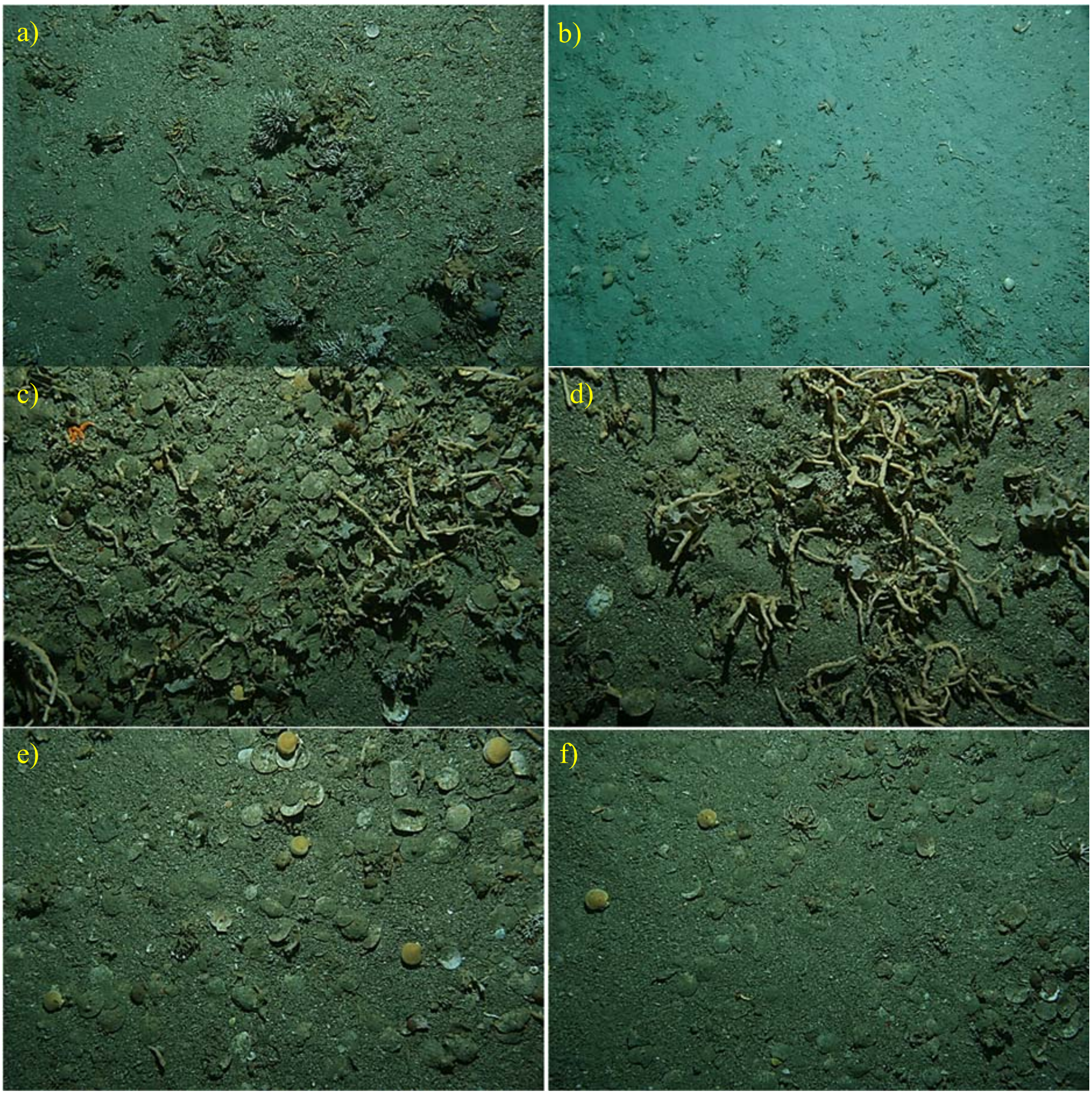


Figure 52: Mid-Otago shelf seafloor imagery: a–b) deeper stations, variable bryozoan and rubble cover, live and dead yellow surface-living tube-worms (*Spirobranchus latiscapus*), bare sediments; c–d) shallower station patches of yellow 'stick' sponges, bryozoan and shell debris, e–f), shallower stations live queen scallops on coarse sediment and dead scallop shell, along with squat lobsters *Munida gregaria* and crabs.

Southland region

A number of fisher-drawn areas were located in Foveaux Strait and around Stewart Island. During a period of storm conditions, *Tangaroa* sheltered in the lee of Stewart Island, surveying a reef feature south-east from Paterson Inlet (Site 31), and undertaking transects in the southern part of Foveaux Strait (Sites 32 and 33) where several fisher-drawn polygons and scientific observations described biogenic habitat including bryozoans and sponges. Once weather conditions eased, the canyon-head of Mason Canyon, due west of Codfish Island (Site 34), was also surveyed.

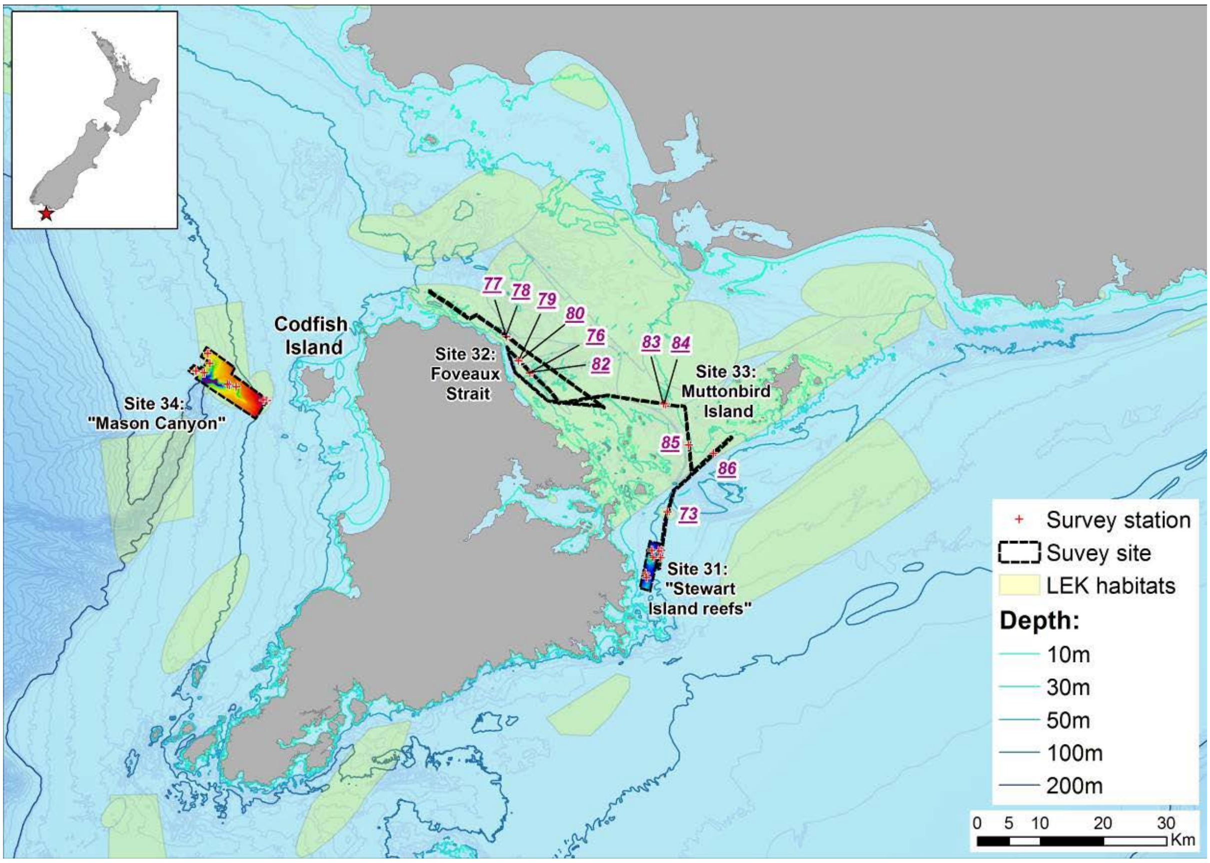


Figure 53: Southland survey locations. Fisher-drawn areas (LEK habitats) shown as light yellow polygons.

East Stewart Island reef (Site 31)

An area of rocky reef east of Stewart Island was mapped, in a search for remnant protected patches of the biogenic habitat mix known to fishers as 'mulloch' (see Figure 53). An area of 10.7 km^2 was mapped, including a large central area of patch reef in 30 to 50 m water depth, and another reef system's eastern point in the southern part (Figure 54a). Six DTIS stations were completed (Table 21), but no biological samples were collected. The seafloor around the reef system was flat rippled to hummocked sand with no apparent fauna, while the reefs themselves were a mixture of solid elevated bedrock, and patchy reef and cobbles intermixed with sand around the reef boundary areas. The one sediment sample taken was classified as sand, with 60% calcium carbonate, and 1.5% TOM (Figure 3, Figure 4, Figure 5). Brown kelps were present in the shallowest depths, as well as some non-geniculate coralline algae cover over broader depths. Invertebrates such as bryozoans (especially soft lightly-calcified bushy species), sponges, and ascidians dominated the deeper reef extents (Figure 55), but no mulloch was observed. The mobile sand floor observed around the reefs probably made the presence of mulloch quite unlikely.

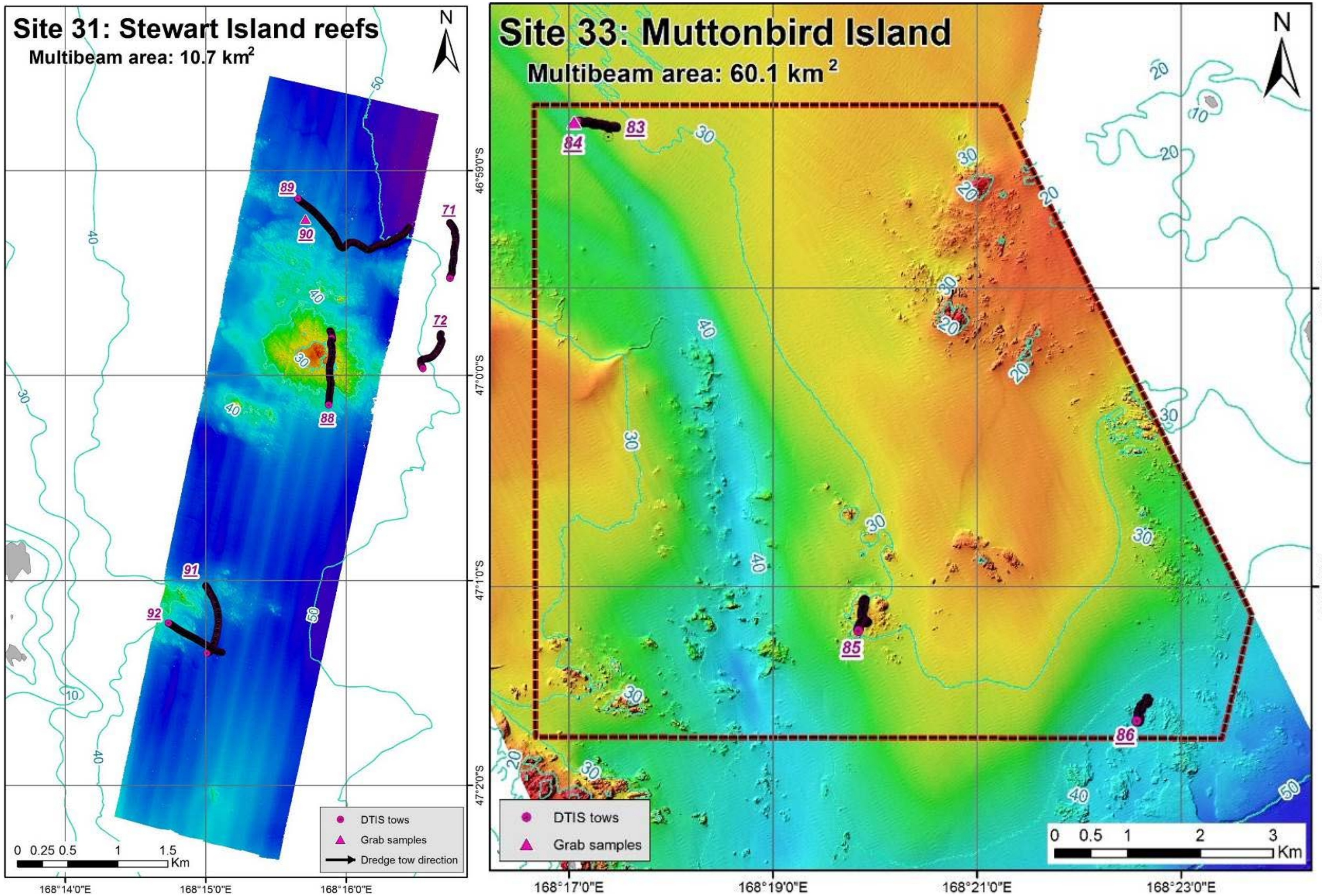


Figure 54: a) Reef south-east of Paterson Inlet, Stewart Island, seafloor bathymetry. 6 DTIS, 1 sediment sample; b) Mutton-bird Islands, stations 85 and 86. Also shown is soft sediment Stations 83, 84 from next section (LINZ multibeam imagery used as backdrop). Note that the two maps are not displayed at the same scale.

Table 21: DTIS stations for the south-east Stewart Island reef site, Southland.

Station	Time (min)	Images	Depth (m)	General habitat
71	30	122	48	Rippled sand, then onto bedrock, reef outcrop, sponge, bryozoan
72	25	94	48	As above
88	40	162	34	Bedrock, sand, brown and red algae, coralline, sponge, bryozoan
89	62	250	45	Bedrock, sand, sponges, ascidians, bryozoans
91	26	129	38	Bedrock, sand, sponges, ascidians, bryozoans
92	30	122	42	Bedrock, sand, sponges, ascidians, bryozoans

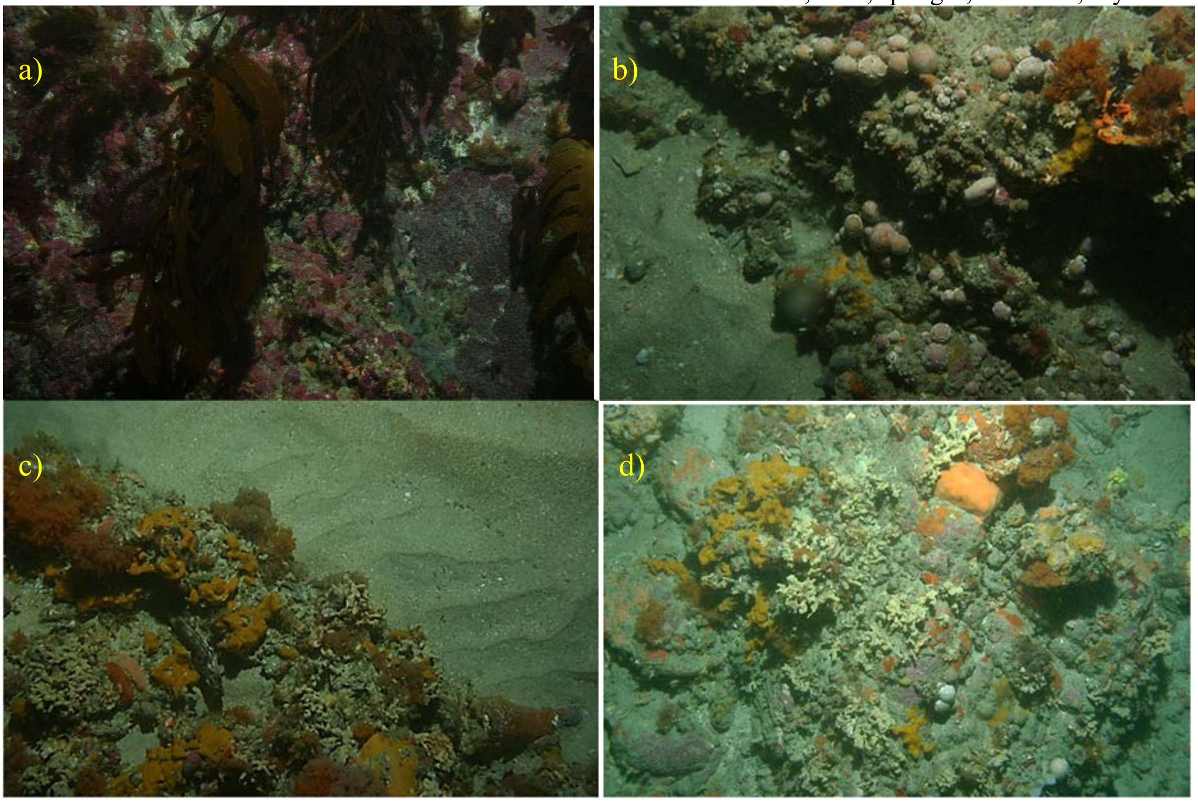


Figure 55: South-east Stewart Island reef site, Southland, seafloor imagery: a) brown macro-algae and corallines at the top of the reef system; b–d) various covers of bryozoans, sponges, and ascidians.

The Mutton-Bird Islands and southern Foveaux Strait (Sites 32 and 33)

Foveaux Strait itself was too large an area to map, and so multibeam transects were placed to cover seafloor features based on previous extensive multibeam mapping of the area, along with chart information. While fisher-drawn areas were present, they were at too large a scale to be of value in selecting transect targets. Two broad areas were covered, the rocky patch reefs in the south-east (referred to as the Mutton-Bird Island area), and the soft sediment areas adjacent to Stewart Island. Collectively 20.6 km^2 of multibeam transect area was mapped (Figure 53). Two DTIS tows were completed in the Mutton-Bird Island area targeting reefs, with three more DTIS tows targeting soft sediment systems along the eastern side of Stewart Island, as well as two rock dredge samples (Table 22, Figure 53, Figure 54b, Figure 56).

For the Mutton-Bird Island area, Stations 85 and 86 crossed over large patch reefs formed of bedrock and cobbles, covered by a diverse and abundant epifauna of sponges, bryozoan, and ascidians, as well as coralline and red algae (Figure 57a–d). The bottom of the reefs were bounded by cobbles, which had little epifauna but often crustose corallines, and appeared to be regularly covered/abraded by sand. Fish observed included blue cod.

The western soft sediment sites (Stations 78, 79, 81) were dominated by seafloors of dead bivalve shells. Sediments were analysed as sandy gravel, with 75% calcium carbonate, and 4% TOM (Figure 3, Figure 4, Figure 5), with small components of sponge, bryozoans and red algae species. Station 83 had a seafloor of sand with shell hash, with a variable cover of coralline algae encrusted shell, brittle stars, red algae, and some sea tulips (Figure 57e–h). Live epifauna from the rock dredge samples were heavily dominated by several mussel species and dredge oysters (mostly below legal size), suggesting a very filter-feeding bivalve dominated system. The force of the current was such that coarse sand and small shell fragments were observed being moved with the current on some of the DTIS footage.

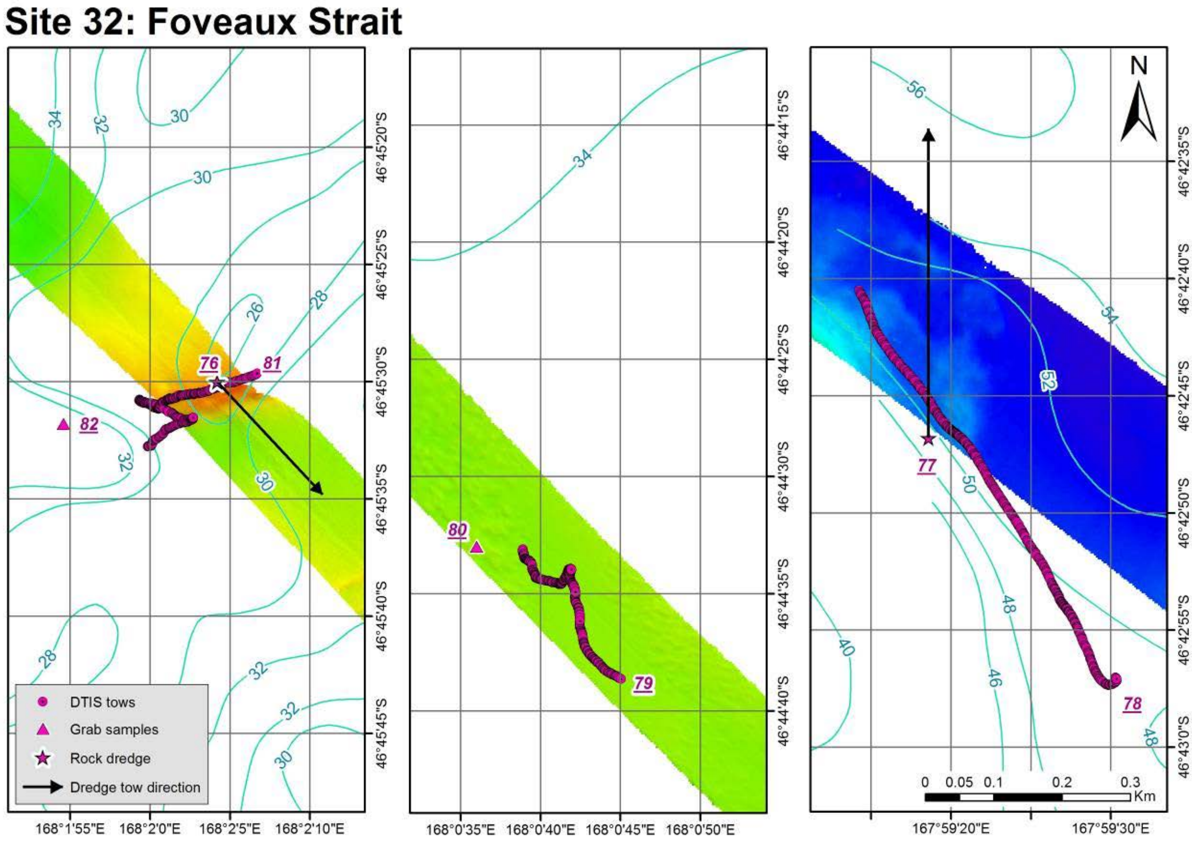


Figure 56 Eastern Stewart Island multibeam transects. The ridge-like features in (a) and (b) are large sand/shell hash waves, and do not contain any reef components; (c) contains some low relief reef. Stations 83 and 84 are shown on Figure 54b to maximise map resolutions. 3 DTIS, 2 rock dredge, 2 sediment samples.

Table 22: DTIS stations for southern and western Foveaux Strait, Southland.

Station	Time (m)	Images	Depth (m)	General habitat
Mutton-Bird Islands				
85	37	134	26	Cobbles and bedrock, sponge, bryozoan, coralline algae
86	30	122	35	Bedrock, cobbles, crustose coralline algae, sponges, bryozoans
Soft sediment				
73	30	122	51	Rippled sand
78	22	95	45	Shell hash, some rock at start, brittle stars, sponges, bryozoans, sponges
79	19	76	76	Sand / shell hash, bryozoans, brittle stars, algae
81	22	95	20–25	Sand and fine shell hash
83	30	121	27	Sand and shell hash, brittle stars, gastropods, algae, sea tulips

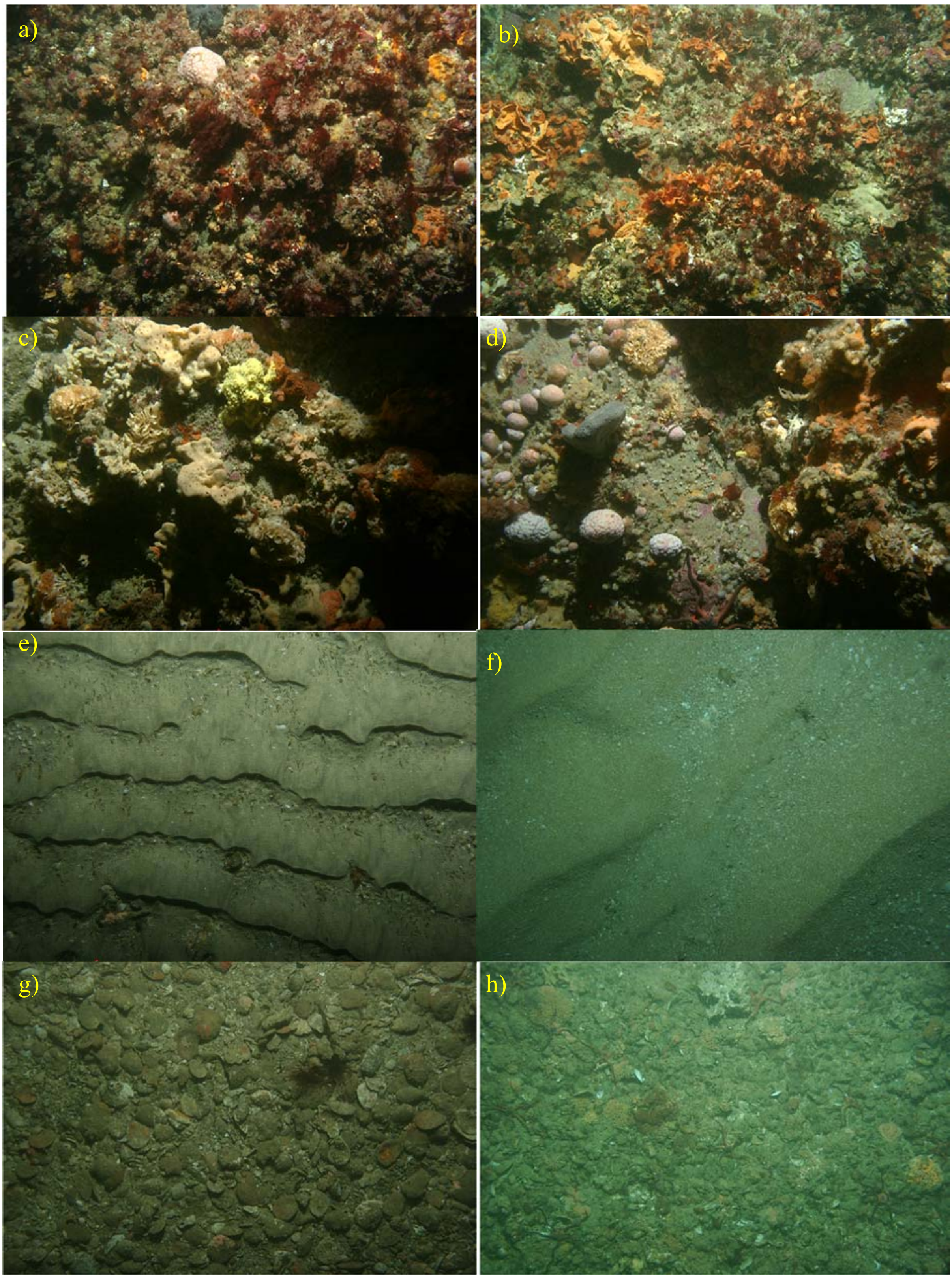


Figure 57: Mutton Bird Islands (a–d) and southern Foveaux Strait soft sediment sites (e–h): and soft sediment sites seafloor imagery: a) red algae and bryozoans; b) bryozoans and red algae; c) bryozoans and sponges; d) sponges, ascidians, bryozoans, crab, and ophiuroid; e) rippled sand with shell; f) rippled shell gravel; g) dead shell, h) dead shell with bryozoans (*Cintopora elegans*), sponges, and ophiuroids.

Mason Canyon, west of Codfish Island, Southland (Site 34)

This canyon was described by one fisher as the site where he caught a black coral tree the size of an apple tree, as well as being full of bryozoans and "*cow's horns*", while another also noted the canyon as an area of coral bycatch. A multibeam block of 42.3 km^2 was mapped, covering the two arms of the canyon head, and the immediate surrounding continental shelf, to a minimum depth of 80 m (Figure 58). Seafloor sediments were sandy on the shelf, becoming muddier going into the canyon. A sediment sample taken at the most north-eastern block corner was analysed as sand, with 60% calcium carbonate, and 0.8% TOM; while a sample taken on the canyon's western edge was assessed as sandy gravel, with 20% calcium carbonate, and 2% TOM (Figure 3, Figure 4, Figure 5). Extensive low relief bedrock was present along the western flank of the canyon, along with small patch areas along the north side of the eastern arm. A sharp serrated ridge feature was observed in the deeper mapped part of the canyon, but was not ground-truthed. Seven DTIS stations were completed, along with two rock sled stations (Table 23). The deeper bedrock along the eastern arm supported an assemblage of glass and other sponges (including distinctive 'stick' sponges), ascidians, and large solitary tubeworms (Figure 59a–b). On the slightly shallower reef areas on the western flank of the canyon many small colourful sponge species, occasional black coral trees with associated ophiuroids, and bryozoans were observed, with 'stick' sponges being far less prevalent (Figure 59c–f). The bare sediment areas were largely rippled hard packed sand and mud seafloors, with little or no epifauna observed.

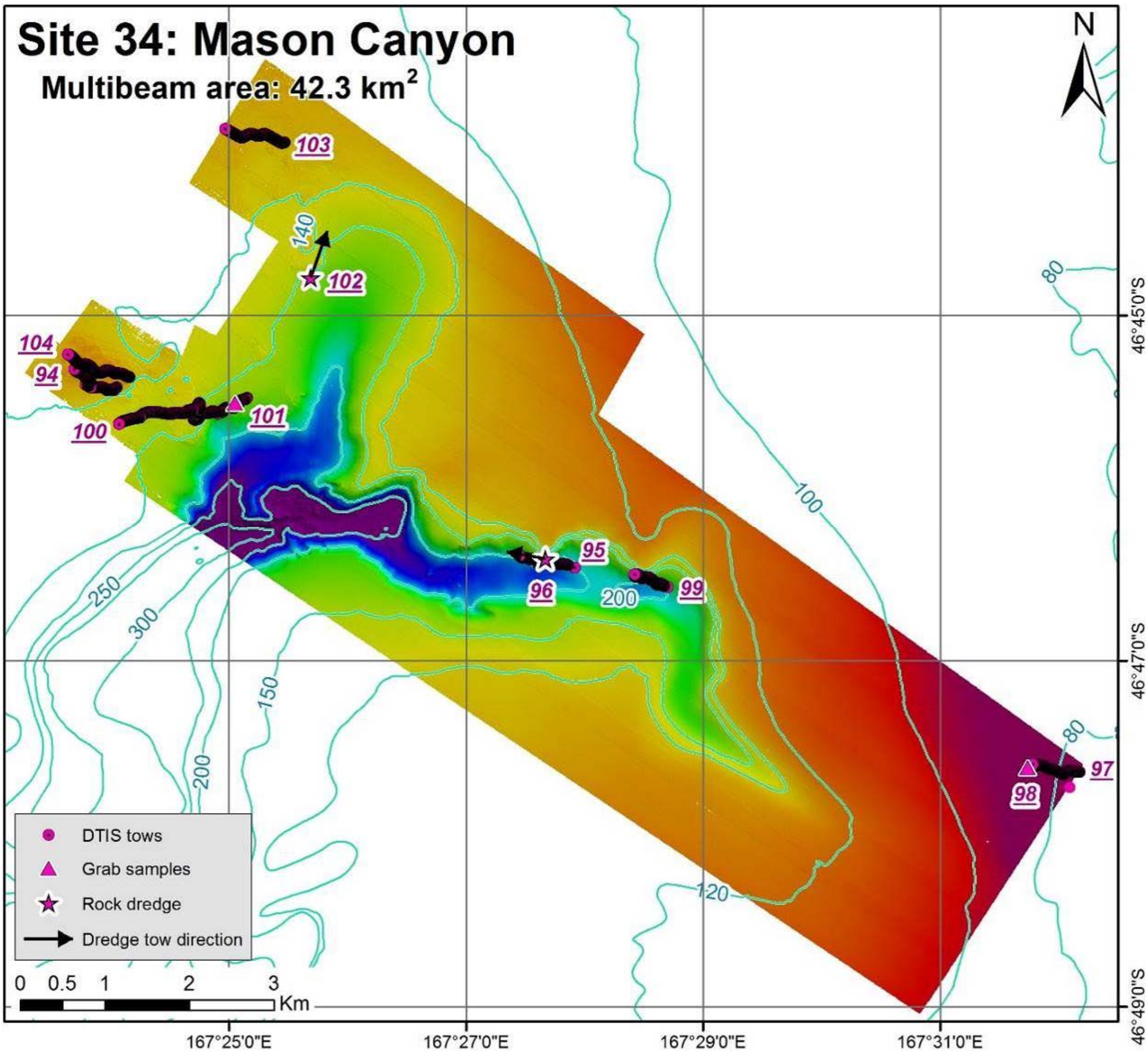


Figure 58: Mason Canyon, west of Codfish Island, Southland. 7 DTIS, 2 rock sled samples.

Table 23: DTIS stations for Mason Canyon, west of Codfish Island, Southland.

Stn.	Time (min)	Images	Depth (m)	General habitat
94	31	126	121	Mud sediment / bedrock, sponge, black coral, sea and butterfly perch
95	31	127	195	Mud sediment, finger sponge, tube worms, black corals
97	31	121	75–85	Rippled sand
99	30	120	178	Muddy sediment / bedrock, sponges, tube worms, cup corals
100	62	250	151	Muddy sediment / bedrock, sponge, hydroids, tube worms, black coral, bryozoans
103	30	130	130	Muddy sediment / bedrock, sponge, hydroids, tube worms, black coral, bryozoans
104	35	121	130	Muddy sediment / bedrock, sponge, hydroids, tube worms, black coral, bryozoans

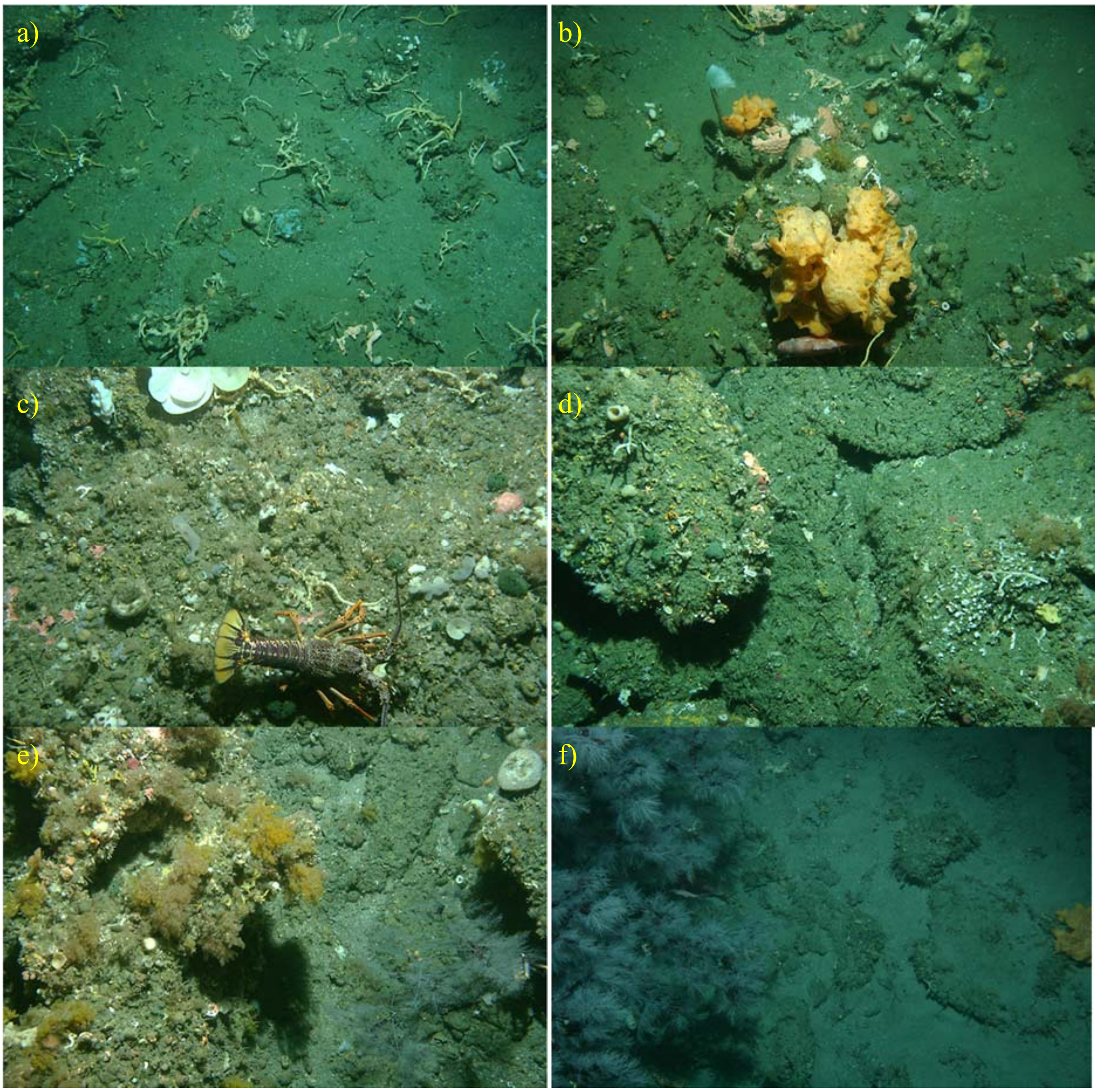


Figure 59: Mason Canyon seafloor imagery: a–b) reef on north side of eastern canyon arm, glass sponges, 'stick' sponges, other sponges, holothurians; c–d) shallower reef west flank of canyon, many small encrusting sponge species, crayfish; e) encrusting sponges, bryozoans, black coral with ophiuroids; f) larger black coral trees with ophiuroids, sheltering fish, glass coral.

East Cape region

Sites in this region included the "Cabbage Patch" north of Mahia Peninsula, up to Ranfurly Bank off East Cape, including Ariel Bank off Gisborne (Figure 60).

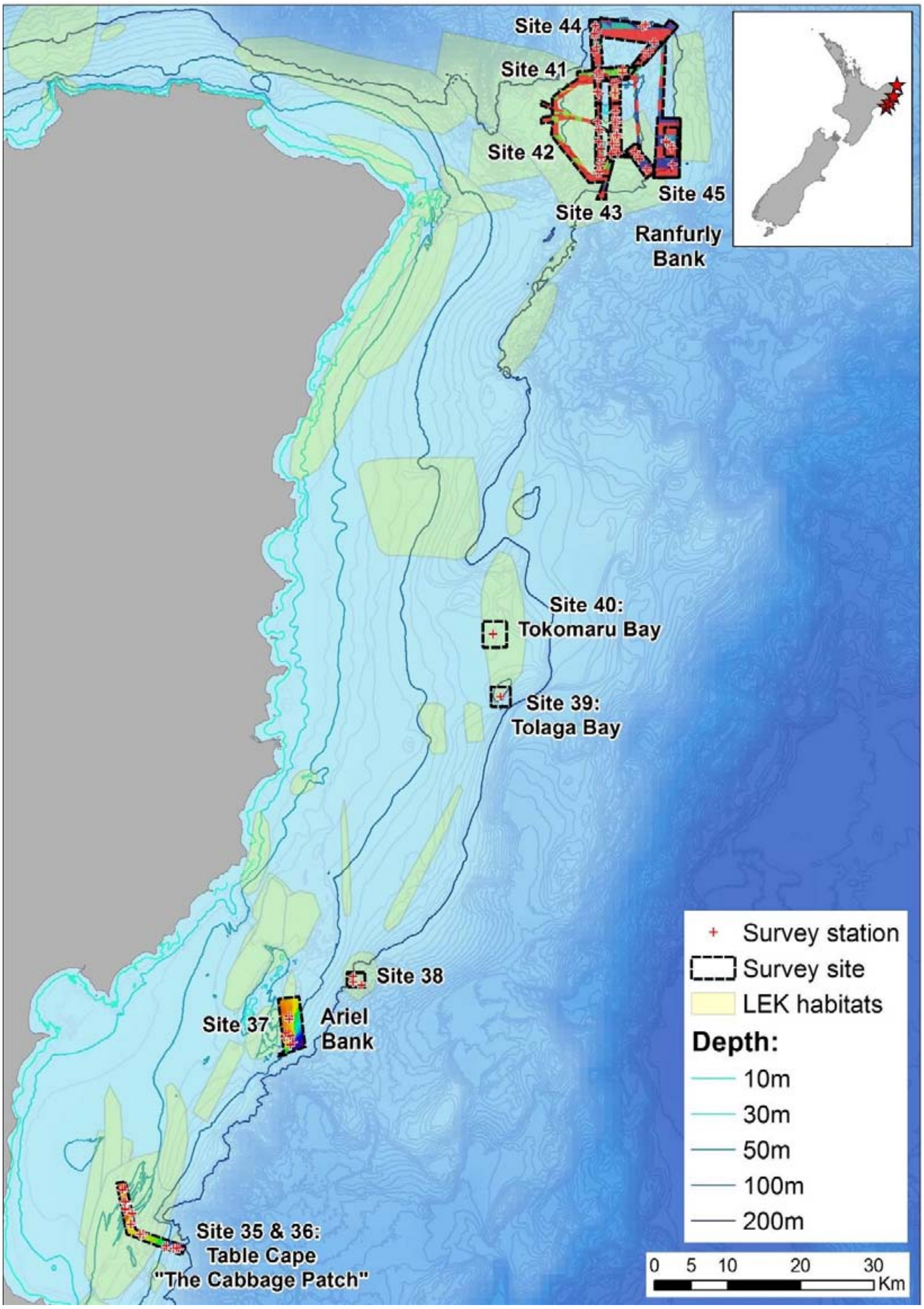


Figure 60: East Cape to Mahia Peninsula region. Fisher-drawn areas (LEK habitats) shown in light yellow.

Table Cape (Sites 35 and 36)

A number of fisher-drawn areas were located along this coast, including a site known as "*The Cabbage Patch*". As the area was quite large, existing broader scale resolution Navy multibeam data was used to select features to target. This resulted in a 'jointed' multibeam transect (18.8 km^2) extending from around 50 to 200 m depth. In shallower water a faulted syncline reef series with interspersed overlying soft sediments was apparent, with deeper reef ridges surrounded by sediments also mapped, including a feature thought to be a moki spawning spot by one fisher (Figure 61). Eight DTIS and two rock dredge samples were collected. The seafloor was found to be composed of low rock ridges alternating with soft sediment flats, with apparent heavy sedimentation of the seafloor, and poor water column visibility in general. The epibenthos was generally quite modest, with more diverse and abundant assemblages seen only on the the highest elevations of the overall reef system, covered by stations 180 and 191 (Table 24, Figure 61). These included bryozoans, finger and other sponges, and coralline algae (Figure 62a–e). In the deeper parts of these stations, and the surrounding stations in deeper water and/or where the reef ridges were much less pronounced, the fauna was very sparse and species limited (Table 24, Figure 62f–h). Collectively, these patterns imply a system degraded by sedimentation, with 'healthier', though still probably impacted remnants occurring only on the parts of the reef most elevated from the surrounding sediment flats. Tarakihi were observed settled on the seafloor, while juvenile frostfish were seen in the water column at the inner stations, consistent with the East Cape region being a spawning ground (Robertson 1978).

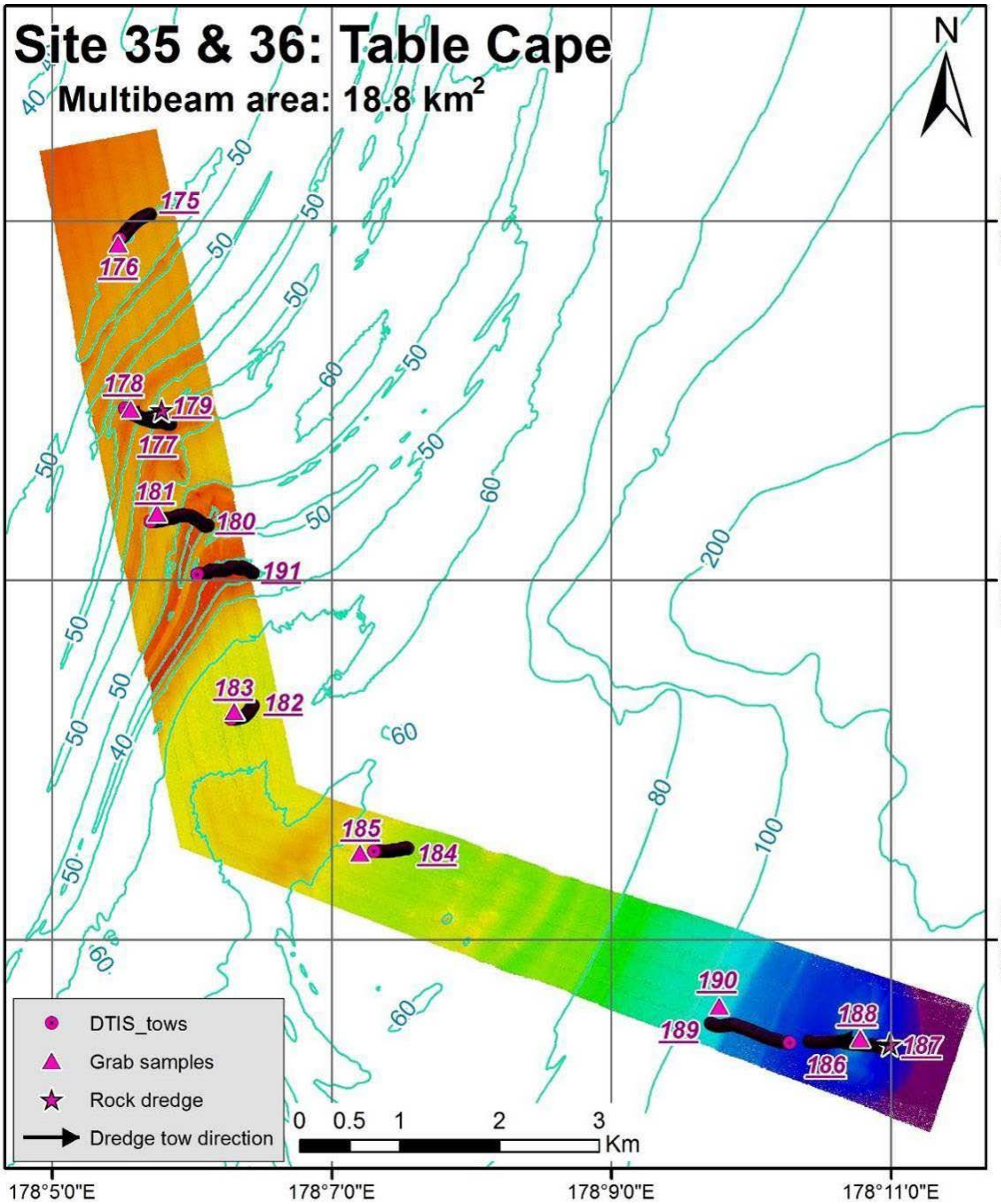


Figure 61: Table Cape, off Mahia Peninsula. 8 DTIS, 2 rock dredge, 7 sediment samples.

Table 24: DTIS stations for Table Cape ("*Cabbage Patch*"), Mahia Peninsula.

Stn.	Time (min)	Images	Depth (m)	General habitat
175	31	125	45	Rippled sand, occ. cobble / bedrock with sponge, very sedimented
177	31	127	36–42	Rippled sand, some ledges, very sediment smothered
180	32	125	40–47	Bedrock with sparse sponge, bryozoans, coralline algae, ledges
182	16	63	58	Sand, mud, live cup corals attached to some hard objects
184	16	64	60	Mainly sand, some rock outcrops
186	31	125	114–123	As above, some sea pens
189	32	128	100–116	Sand, mud
191	34	136	36	Low relief bedrock, sponge, heavily sedimented

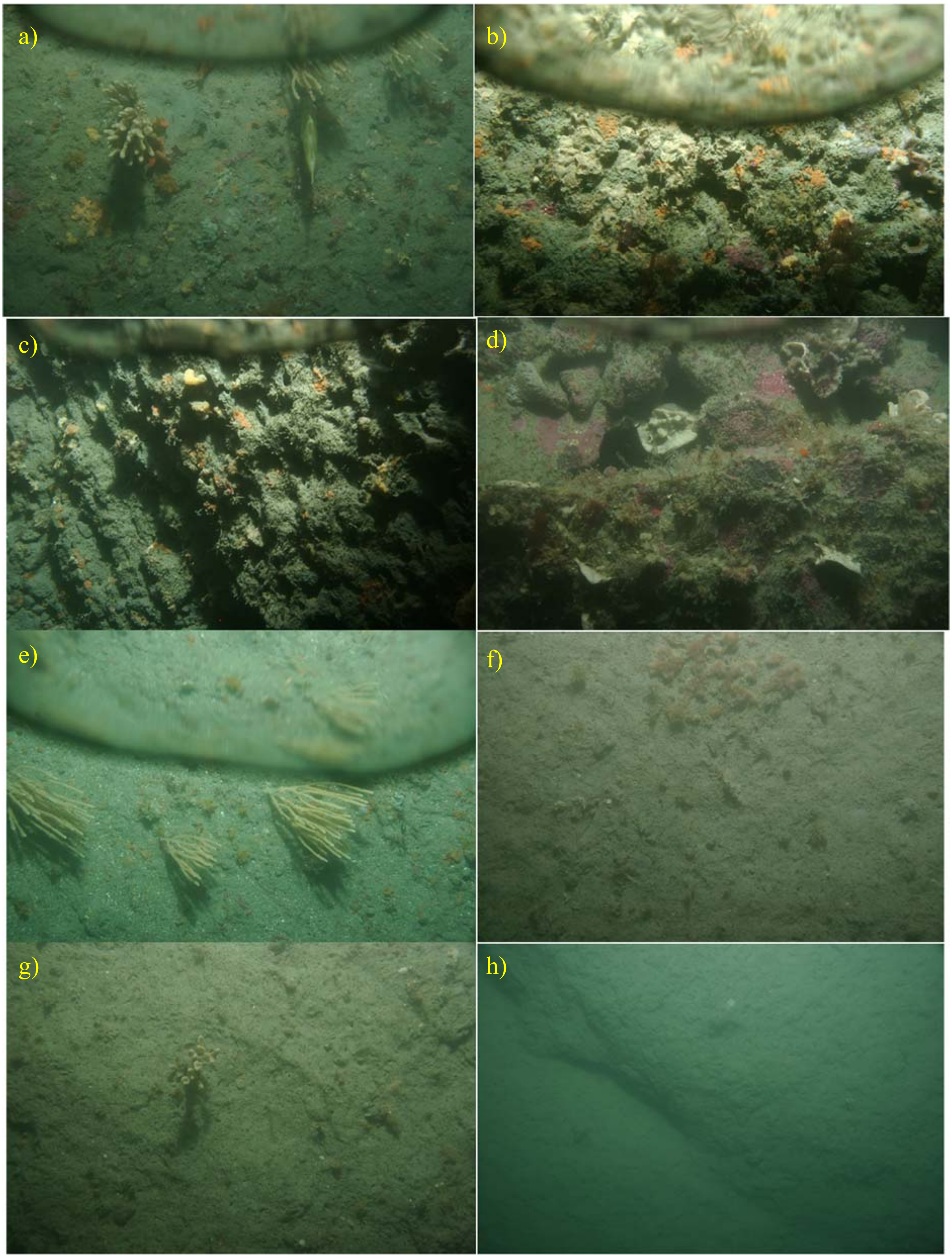


Figure 62: Table Cape, off Mahia Peninsula, seafloor imagery (there is an air-bubble artefact in some images): a) sponges with sleeping leather-jacket; b–c) bryozoans and sponges; d) sponges, bryozoans, coralline algae; e) finger sponge and bryozoans; f) sponge on sedimented rock flat; g) sponge on sedimented rock flat; h) bare sedimented rock flat.

Eastern Ariel Bank (Site 37)

An area identified by fishers as a site of coral bycatch was mapped by multibeam (22.9 km^2), covering the eastern side of Ariel Bank (Figure 60, Figure 63). Water depths ranged from about 50 m on the bank, down to about 140 m in the south-eastern block corner. A reef feature was apparent as a broad promotory extending to the east, while north of this was a broader gently sloping flat, with the slope increasing more steeply at the 80 m depth contour. Four DTIS stations (Table 25) and one rock dredge station were completed. The southern reef areas (Stations 194, 196, 198) were composed of low bedrock often veenered in irregular rock/cobbles and sediments, with some low-relief outcrops. To the north, Station 198 was similar but with a greater proportion of flat bedrock habitat. Station 194 showed pronounced sedimentation and relatively high water turbidity compared to other stations (Figure 64). The rock in these transects appeared to be a soft mudstone prone to breakage, with some fractured slabs observed on video. Much of the smaller material observed was not embedded, making it suseptible to being moved around during storms, with the general impression that the reef was erosion-prone. In general, biogenic habitats were patchy and relatively sparse, with most of the larger epibenthos present on areas of raised bedrock, or the tops of larger rocks. These included large grey sponges, and modest patches of smaller encrusting sponges and bryozoans, while clumps of brachiopods and some cup corals were present at greater depths in Station 194. Sparse kelp (*Ecklonia radiata*) and patches of *Caulpra* sp. were found in the shallowest parts of Stations 198 and Station 199, with coralline algae widely present in these shallower areas (Figure 64). Station 194 generally held less epibenthos than the other stations, probably attributable to the higher sedimentation level, and loose rubble/lack of elevated bedrock. Large trevally were observed to follow the DTIS foraging at Stations 194 and 196, along with large numbers of small pelagic fish (myctophids) feeding in the water column. Pink maomao were also present in modest numbers; this was the furthest south this warm temperate species was observed.

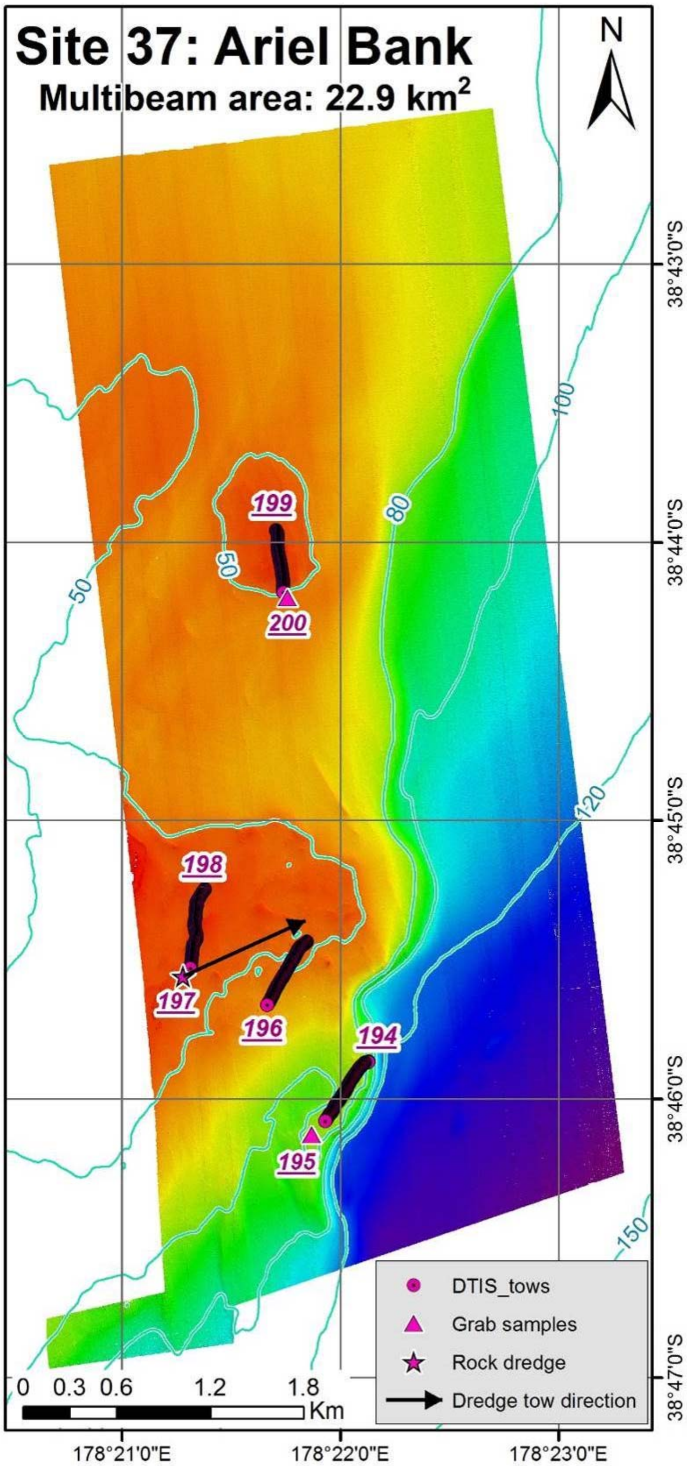


Figure 63: Eastern side of Ariel Bank. 4 DTIS, 1 rock dredge, 2 sediment samples.

Table 25: DTIS stations for eastern Ariel Bank, East Cape region.

Stn.	Time (min)	Images	Depth (m)	General habitat
194	31	126	80	Sedimented reef, brachiopods, small sponges and bryozoans
196	32	128	50	Better visibility, bedrock, sponges, coralline algae
198	32	130	45	Gravel, bedrock, sponge on reef, coralline and brown algae
199	30	122	50	Bedrock, gravel, sponge on reef, some large cup sponges, brown and green algae

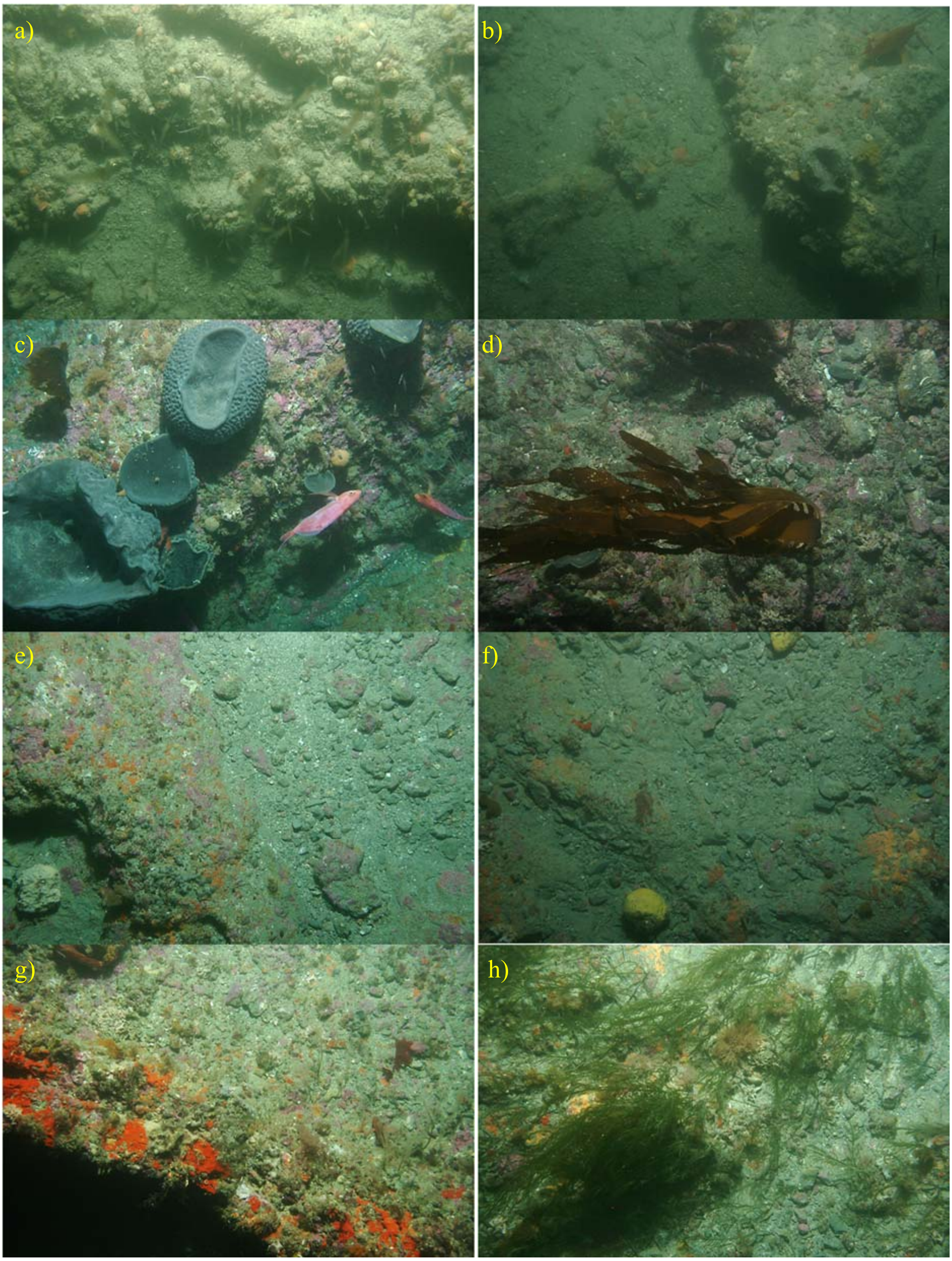


Figure 64: Ariel Bank seafloor imagery: a–b) sedimented reef at Station 194, with brachiopods, cup corals, sponges, and bryozoans; c) large grey cup sponges and pink maomao; d) *E. radiata* and corallines; e–g) low reef and rubble with sponges and corallines; h) *Caulerpa* sp.

East coast "White straw" (tube-worm) areas (Site 38, 39 and 40)

Two fisher-drawn areas located along this coast were described as places where "white straw" was picked up in trawls. This was thought to be either similar or the same species of chaetopterid tube worms as those in the Canterbury region, or possibly a species of sea pen (Figure 60). Three beam trawl stations (depth range 175–307 m) were sampled in the most southerly site (38) searching for this by-catch species. While sea-pens were found, they did not match the fisher's description. No multibeam mapping or DTIS sampling was done. Further north, another larger fisher-drawn area was sampled at two locations. At Site 39, a multibeam transect was placed in a north-south direction across an unusual large raised mound feature, as seen on the nautical charts (multibeam not shown due to its very long linear scale), followed by a single DTIS station along a section of this transect (Table 26), with water depth ranging from 47 to 61 metres. The DTIS imagery revealed a hard seafloor, largely covered with small irregular rocks and coarse sediments (Figure 65d), with some patches of larger rocks, and bare bedrock (very limited). The epibenthos was generally modest; small patchily distributed encrusting species, with few larger forms. Small red macro-algae and coralline algae were present in the shallower transect section, but no kelp was seen. Fish were rare, but included leatherjacket, and small Seranidae (unidentified). A single beam trawl sample was collected about 10 km to the north over soft mud sediments in the same fisher-drawn area (Site 40, Figure 60), with sea pens sampled, but no tube-worms.

Table 26: DTIS station for Site 39.

Stn.	Time (min)	Images	Depth (m)	General habitat
204	31	127	80	Coarse sedimented reef, brachiopods, small sponges and bryozoans

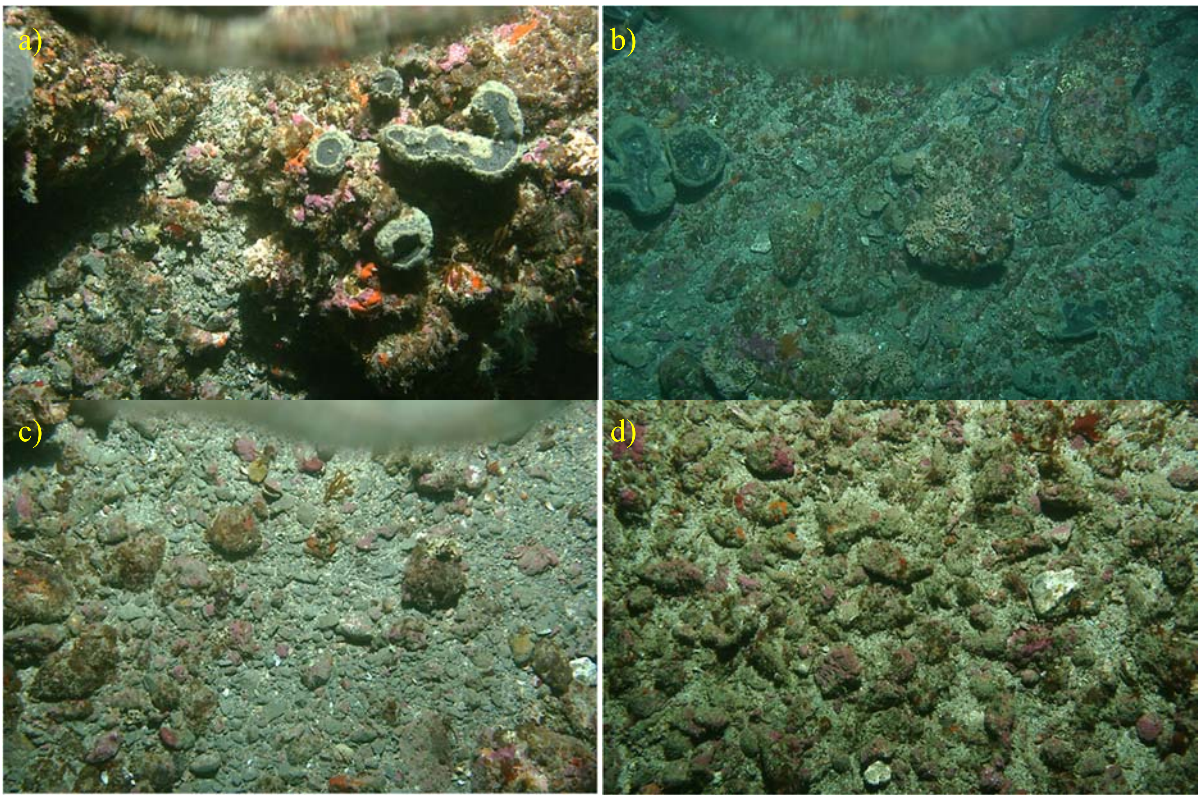


Figure 65: Site 39 seafloor imagery (some images contain an air bubble artefact): a–b) bedrock at start of feature, with sponges, bryozoans, hydroids; c–d) irregular rocks/cobbles with coarse sediment, and variable epibenthic cover of sponges, ascidians, and coralline algae.

Ranfurly Bank (Sites 41 – 45)

This large offshore bank feature was noted by fishers as an area of foul which had not traditionally been trawled, but was being "opened up" to trawling more recently (Figure 60). A long rectangular fisher-drawn area located along the eastern side of the bank in 200–400 m water depth was described as an area of sponge and black coral by-catch. A smaller area on the western side of the bank, also in 200–400 m water depth in a bathymetric 'notch' feature was also thought to have similar habitat. Given the large size of Ranfurly Bank, and its relatively shallow average depths limiting multibeam swathe width, a series of 'wide' transects were mapped, with discrete blocks 'filled in' to target putative reef and other features identified from initial transects and available nautical charts, such as the low relief wall buttresses seen on the multibeam on the northern bank side (Site 41). Thirty one DTIS (Table 27), four beam trawl and five rock dredge stations were sampled (Figure 66). A wide of range of seafloor types were observed, including gentle rock flat slopes, steep bedrock drop-offs and walls, gravels, sands, and muds. There was clear evidence of significant sediment transport in the shallower areas (bare bedrock being uncovered, as well as biogenic assemblages being buried by advancing sediments), as well as actual in-situ breakages of the presumably soft sandstone edges in some places. Biogenic habitats were species diverse, including large deep-water *Ecklonia radiata* forests (3 m high single blade morphology), many species of foliose and turfing red algae, sponges including some large basin forms, bryozoans, hydroids, gorgonian and crinoid 'fields', corals, and sea pens (e.g., Figure 67). This area is analysed in much greater detail in the core analysis section of this report (Section 4.3).

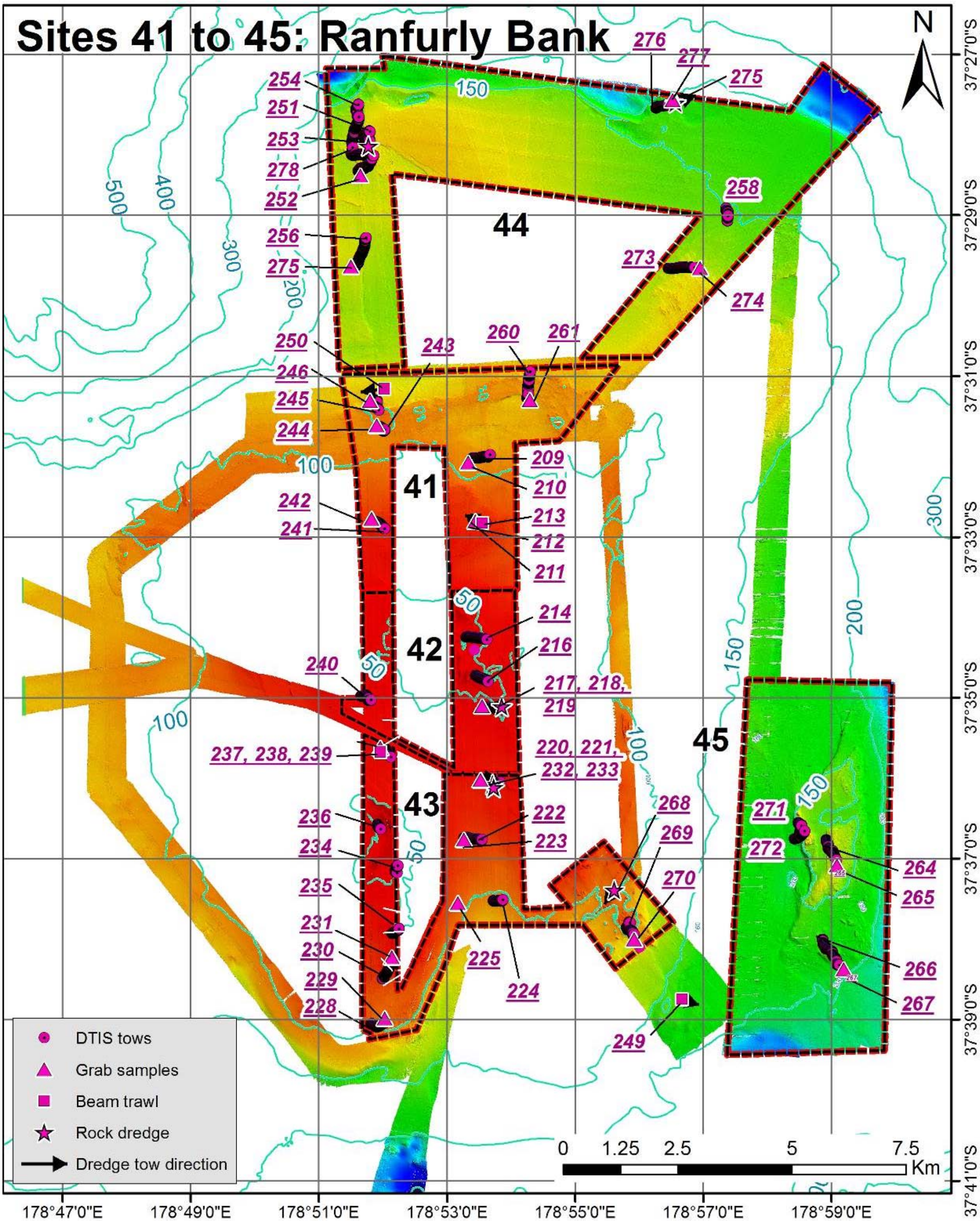


Figure 66: Multibeam mapped area for Ranfurly Bank. The labelled sub-areas are referred to in a later section of this report.

Table 27: DTIS transects for Ranfurly Bank, separated into five broad areas.

Station	Time	Images	Depth	General habitat
Central area (37–50 m)				
214	31	125	44	Sand and gravel overlay, with low relief sponge, hydroids, algae and then kelp
216	27	109	37	Bed rock / boulders and sand, Kelp forest, dense in places
218	32	125	49	Bedrock / sand overlay, turfing red and brown algae, sponge
234	15	62	42	Sand / brown algae, turfing algae, sponges
235	15	64	42	Rippled sand, brown algae, sponges, turfing.
236	10	43	40	Sand bedrock, coralline algae, kelp
240	15	62	40–50	Kelp, sand and bedrock with sponge and turfing
Northern slope (50–110 m)				
209	31	125	98	Sand shell hash, quill worms, drift weed, sea pens, fish
211	32	127	67	Sand, bedrock, drift weed, sponge, turfing
241	15	61	70	Sand, boulders, bedrock, sponge, turfing, coralline algae
243	16	60	94	Sand overlying bedrock, bryozoans, hydroids, sponges
245	17	70	90–106	Sand, gravel overlying bedrock, bryozoans, hydroids, sponges
260	32	129	107–110	Sand, gravel, crinoids, bryozoans, sea pens
Outer northern slope and outcrops (100–160 m)				
251	62	252	120	Bedrock with sponges, gorgonians, black corals lots of pink mao-mao
254	35	155	100–130	Sand/ cobbles with gorgonians, sponges, bedrock outcrops
256	31	131	120	Sand/ cobbles with gorgonians, sponges, soft coral
258	21	83	140	Sand, shell hash, sea pens
273	32	127	122	Sand, low relief bedrock, crinoids, sea pens, sponges
276	17	69	150–160	Dog cockle bed, sand, bedrock, sponges, lots of kingfish attracted
278	31	125	109	Bedrock outcrops, gorgonians, sponges, black coral, pink mao-mao
South/central slope (56–100 m)				
220	32	129	60	Sand / gravel with cobbles, sponge, hydroids. Bedrock with sponge and coralline
222	30	120	78	Rippled sand, non-rippled sand, sea pens, hydroids
224	33	132	97	Rippled sand, occasional cobble
228	32	126	92	Sand / gravel / silty? sea pens
230	32	128	74	Sand / gravel, sponge, bryozoan, hydroid
237	23	91	56	Sand / gravel, coralline algae, cobbles with sponge, bryozoans, hydroids
269	30	125	84–100	Sand/gravel, reef outcrop with cup and encrusting sponges, etc
East deep rock bank (120–180 m)				
264	31	124	120–130	Sand with sea pens + bedrock (wall?) with smeary sponge, crinoids
266	49	220	160–180	Similar to above, with small crinoids on sand areas
271	20	48	120–130	Sand sediment, crinoids
272	10	40	160–170	Sand sediment, crinoids

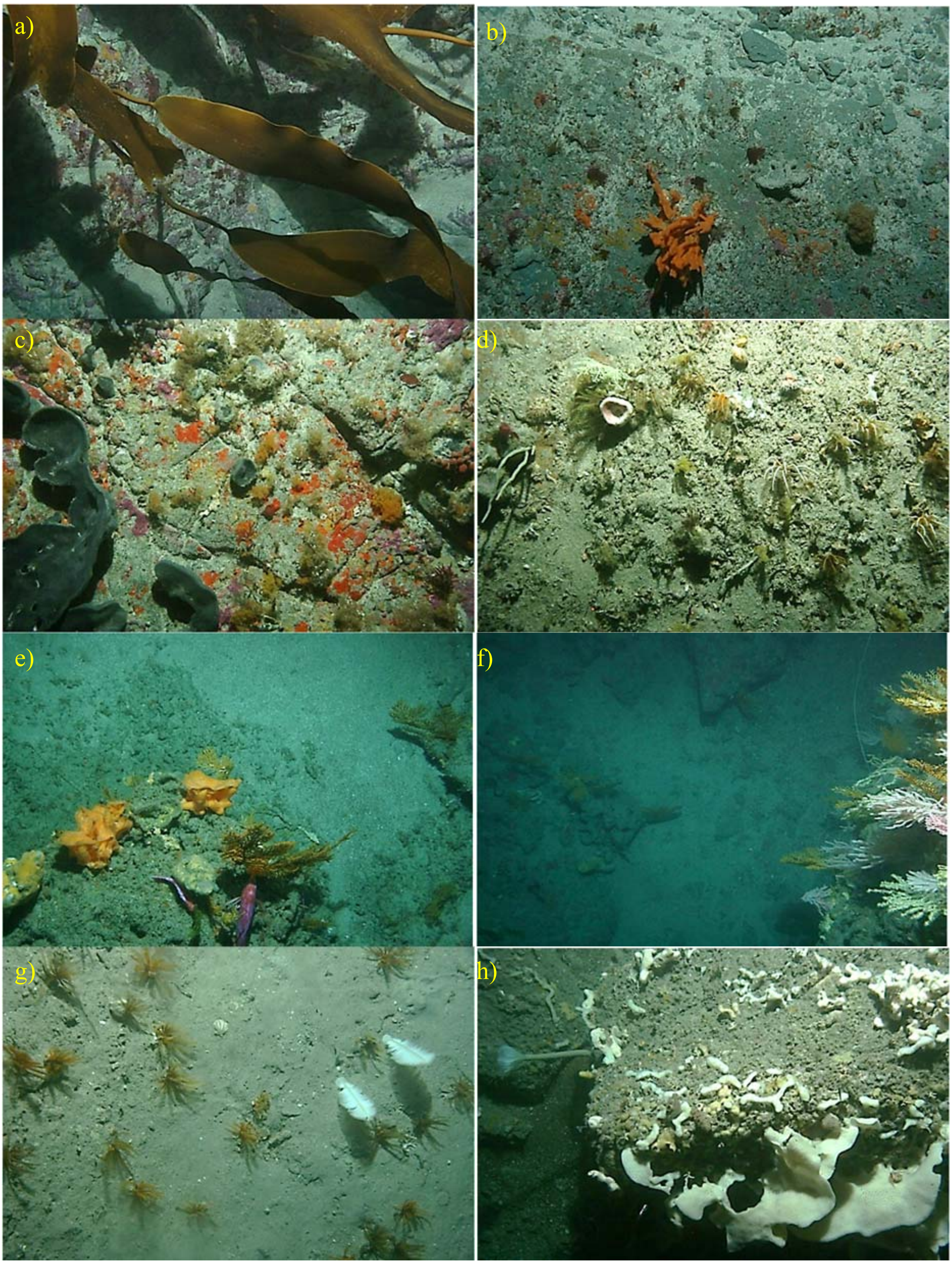


Figure 67: Seafloor habitats on Ranfurly Bank. NB: Only a sub-set of the high diversity present is shown here. a) *E. radiata* deep-water form; b) sponges on eroding mud-stone; c) sponges and bryozoans on bed-rock; d) crinoids and sponges on rubble; e) glass sponges and gorgonians; f) hard corals on wall; note lost rope below in background; g) crinoids and sea-feathers; h) deeper water sponges, and tubeworm.

4. ANALYSIS OF CORE AREAS

In this section, the analysis of multibeam, biological samples and DTIS imagery for the selected core areas is presented in more detail. Each section follows the same order. Multibeam sonar derived maps (bathymetry, slope, reflectivity, BTM zones/structures) are presented and discussed, including reference to the bathymetry/station position figures given in the earlier general section. The invertebrate (and macro-algae for Ranfurly Bank) biological sampling (beam trawl/rock dredge) is presented next, with general trends and highlights outlined. The analysis of the DTIS still images follows next, providing a description of the invertebrate macrofauna (and macroalgae for Ranfurly) species observed, and how they cluster into assemblage groupings. The relationships between the biological assemblages and the remote sensing derivative data (depth, slope, rugosity, reflectivity, BTM zones/structures) and other potential explanatory variables (e.g. depth, latitude, visual bottom structure), are then quantified and explored. Finally, the diversity and abundance of the fish fauna collected in the biological samples (beam trawl, rock dredge), and observed on the DTIS videos is presented.

4.1 North Taranaki shelf edge canyons (Sites 13 and 14)

Two of the four sites surveyed in north Taranaki were analysed in greater detail: the canyon heads labelled as “The Well”, and “Coral Canyon” (Sites 13 and 14, Figure 16, Figure 21, Figure 23). Both were described by fishers as locations where corals and sponges were found, with the fisher-drawn areas encompassing the canyon heads and surrounding continental shelf edge (see Jones et al. 2016). A total of 15 DTIS transects, three biological samples and seven sediment samples were analysed from the two sites.

Multibeam mapping and topographic features of North Taranaki canyons

The Coral Canyon is a long linear incision canyon, extending around 7.9 km into the edge of the continental shelf, with a low outer sill feature (500 m water depth) coincident with the adjacent shelf edge (Figure 68). It is 2.2 km wide at the shelf mouth, about 1.5 km at its mid-point, and narrows to about 500 m wide in its most upper reach. Its sides slope fairly uniformly to its floor, with many smaller gullies running down its sides. Depth along the canyon bottom increases from about 200 m to more than 600 m adjacent to the shelf break. Areas of carbonate rubble/foul occur patchily along the canyon edges. Derived maps of rugosity and slope confirm this structure, with the map of slope also highlighting some low linear bed-forms on the adjacent shelf, on the western side (Figure 68). Benthic Terrain Mapper (BTM) zones showed a simple pattern of flat (continental shelf), depression (canyon bottom), slopes (canyon wall), and crests (edges of the canyon; continuous on the eastern side, broken on the western side) (Figure 69). BTM structures showed similar patterns, nested within the broader zones, including narrow crests along much of the canyon edge, and lateral mid-slope crests and depressions (Figure 69). A narrow depression was also present semi-continuously along the lower western edge of the canyon, and to a lesser extent on the lower eastern edge. As the primary water depth targets of the survey were less than 200 m, most DTIS and biological sampling targeted the shelf, crests, and sides of the canyon (Figure 21).

The Well was a more diffuse canyon structure than the Coral Canyon, with a multi-armed dendritic canyon head extending up into an associated broad bowl area (Figure 68). The eastern edge of this 4 km wide bowl area was not captured by the multi-beam mapping. The BTM rugosity and slope maps showed the same features, with some additional low relief linear bed-forms at the kilometres scale being picked up on the shelf by the slope plot (Figure 68b, c). The BTM zones were similar in their distribution to the Coral Canyon, although the crest areas were more complicated, and the slopes much more widespread (Figure 69c). The BTM structures were also more complicated, given the more ‘dendritic’ nature of the canyon intrusion up to the shelf edge (Figure 69d). The canyon proper (300–600+ m water depth, as mapped) was well below the target depths of the survey, and sampling was restricted to the edges of the bowl area (Figure 23).

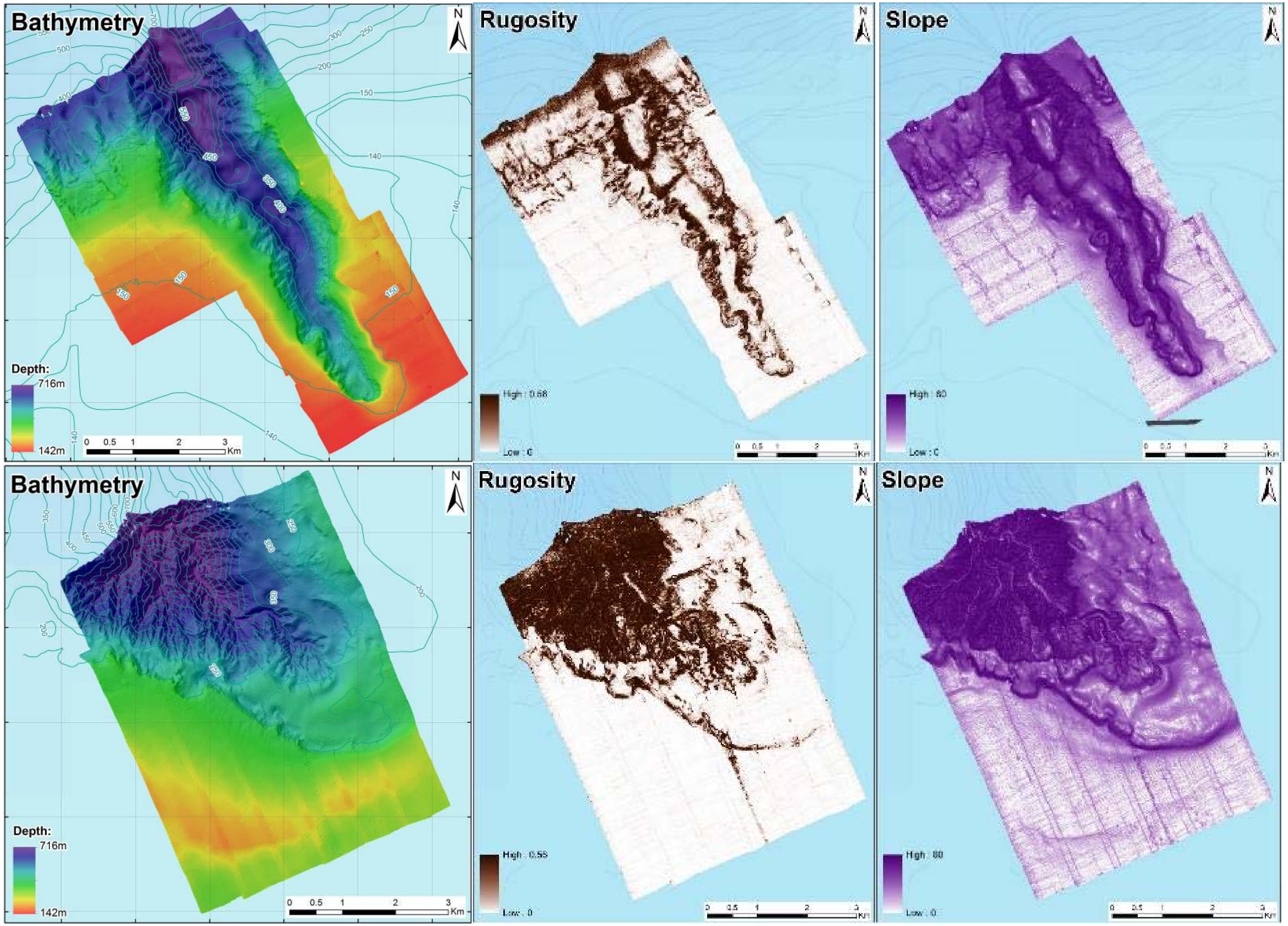


Figure 68: Maps of bathymetry, rugosity, and slope for: top row, The Coral Canyon (Site 13); bottom row, The Well (Site 14), North Taranaki Bight.

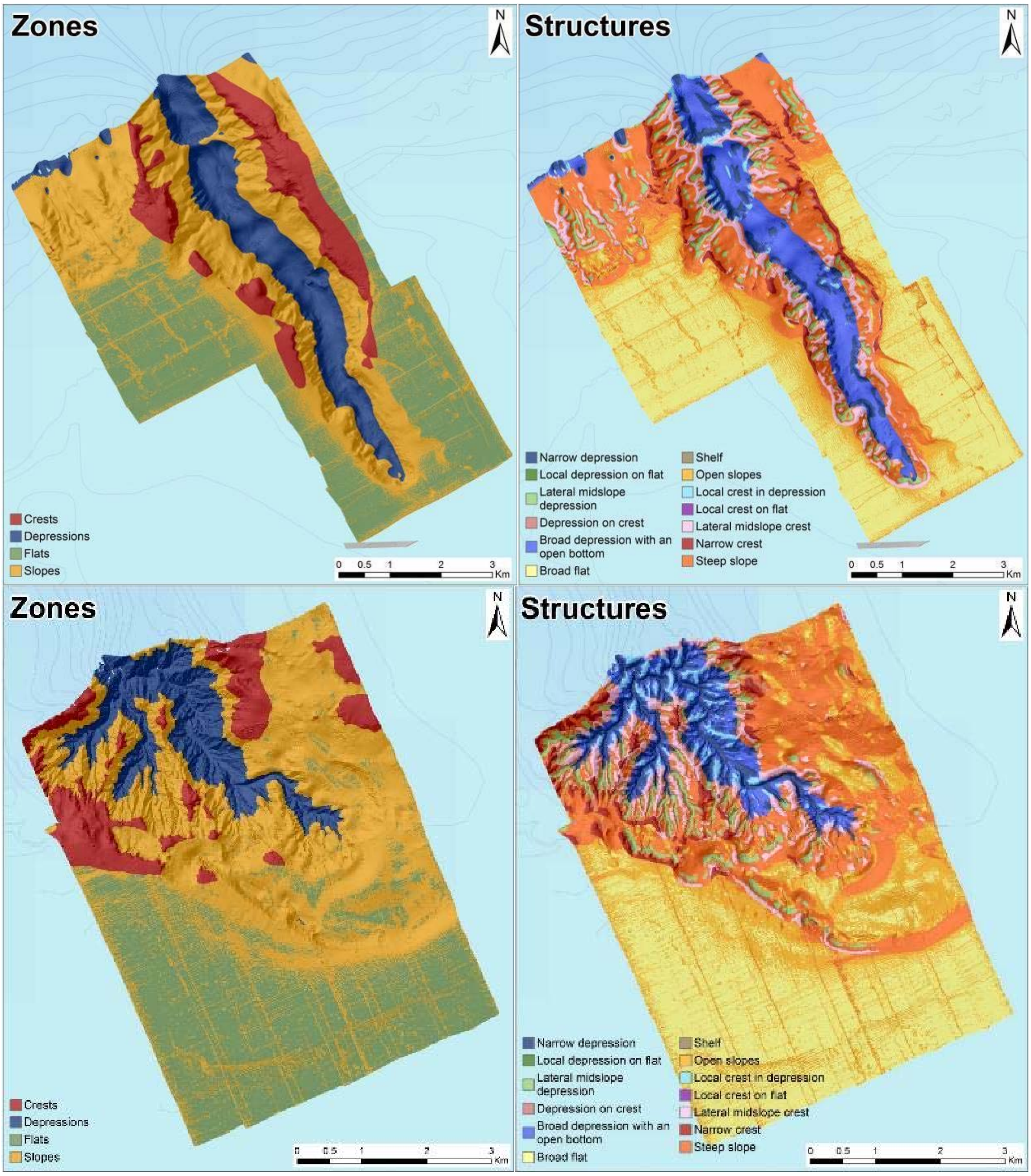


Figure 69: BTM zone and structure maps for: top, The Coral Canyon (Site 13); and bottom, The Well (Site 14), North Taranaki Bight. For definitions of the Zones and Structures, see Section 2.4.

Invertebrate diversity from biological sampling of north Taranaki canyons

Two (175–240 m) epibenthic sled samples were collected at The Well, and one (250–330 m) at the Coral Canyon (Table 28). These samples were characterized by unusual 'holey'/'swiss-cheese' rocks (as described by fishers), often encrusted with tube worms, which were identified as the rock-dwelling chaetopterid *Spiochaetopterus spiochaetopterus* C. Sponges were a significant catch component, with 30 species identified, 9 being new to science. Most species collected were also identified in the DTIS imagery, including the grey bracket sponges *Psammocinia amodes* and *P. hawere*, the lithistid 'cup and ear' sponges *Aciculites pulchra, Pleroma menoui*, the bright blue and white cup *Reidispongia coerulea*, the haplosclerid *Xestospongia coralloides*, and two distinctive orange hexactinellids (glass sponges), *Symplectella rowi* and *Rossella ijimai*. The latter is the first re-collection of this species since

Dendy's 1924 Terra Nova collection (MK, pers. obs.). Bryozoans were less diverse, including *Cellaria tenuirostris* (also on DTIS images), *Caberea solida, Stephanollona scintillan,* and *Reteporella malleatia*. A variety of cnidarians were collected: the 'whip coral' *Stichopathes variabilis*, the 'bottle brush coral' *Stylopathes cf. tenuispina*, a possible new soft coral from the Anthothelidae family, two cup coral species (*Caryophyllia profunda* and a second new species), small pieces of the reef-building stony coral *Goniocorella dumosa*, the common deep-water sea pen *Anthoptilum grandiflorum*, and nine hydroid species. Mobile species included decapods, crinoids, and ophiuroids. A number of decapod species, also likely to have been observed on DTIS, included the squat lobsters *Munidopsis papanui* and *Phylladiorhynchus pusillus*, and the crab *Bellidilia cheesmani.* Eight species of ophiuroid were identified, with *Ophiopsammus assimilis* being the most numerous. Crinoids sampled from The Well were all identified as *Comanthus novaezealandiae.* The scallop *Talochlamys gemmulata* was present in the epibenthic dredge samples, and observed on DTIS images, sometimes in large numbers.

Table 28: Biological rock dredge samples from The Well (Site 14) and The Coral Canyon (Site 13), giving the number of species/Operational Taxonomic Units (OTU's) and total weight by Order. The number of samples for each area are given in brackets.

			Coral Canyon (1)		The Well (2)	
Phylum	Class	Order	OTU count	Weight (g)	OTU count	Weight (g)
Annelida	Polychaeta	Amphinomida	1	<1		
		Eunicida	1	<1	1	2
		Phyllodocida	1	<1	1	2
		Sabellida	1	<1	2	8
		Spionida	1	27	1	32
		Terebellida			1	7
	Total		5	27	6	51
Arthropoda	Malacostraca	Decapoda	9	30	11	30
Brachiopoda	Articulata	Terebratulida	2	67	1	3
Bryozoa	Gymnolaemata	Cheilostomata	5	25	7	28
	Stenolaemata	Cyclostomata			1	4
	Total		5	25	8	32
Chordata	Ascidiacea	Enterogona Phlebobranchia	1	15	2	10
Cnidaria	Anthozoa	Actinaria			1	2
		Alcyonacea	1	1		
		Antipatharia			2	35
		Pennatulacea	1	8		
		Scleractinia	2	40	2	7
	Hydrozoa	Leptothecata	2	8	9	86
	Total		6	57	15	131
Echinodermata	Asteroidea	Forcipulatida	2	20	1	3
	Crinoidea	Articulata			1	6
	Echinoidea	Clypeasteroida			1	1
	Holothuroidea	Dendrochirotida			1	2
	Ophiuroidea	Euryalinida			1	1
		Ophiurida	2	13	6	22

	Total		4	33	11	35
Mollusca	Bivalvia	Arcoida	1	1	1	11
		Limoida			1	1
		Ostreoida	1	4	1	8
		Veneroida	1	40	1	31
	Gastropoda	Cephalaspidea			1	2
	Opisthobranchia	Nudibranchia			1	1
	Polyplacophora	Acanthochitonida	1	1		
	Scaphopoda		1	1		
	Total		5	47	5	54
Porifera	Calcarea	Clathrinida			1	3
	Demospongiae	Astrophorida	1	128	2	2
		Dictyoceratida	2	559	2	21
		Hadromerida	2	115	1	7
		Halichondrida	2	64	3	10
		Haplosclerida	2	35	2	2
		Lithistid	3	233	1	2
		Poecilosclerida			2	11
	Hexactinellida	Lyssacinosida	1	25	1	2
	Total		13	1 159	16	61

Invertebrate assemblages observed in DTIS imagery from the north Taranaki canyons.

Across the two canyons, 485 still images were analysed from 15 DTIS transects (every fourth consecutive image, as well as a number of extra images selected to improve the data coverage of patchy hard substrate). The number of operational taxonomic units (OTUs) identified in images includes some groups that were not consistently visually distinguishable from each other/or not definitely different species, e.g., some colonial ascidians, galatheid crabs, crinoids, bryozoans, and sponges. Such groups were combined as appropriate, resulting in 85 final OTUs (Appendix 3). The sessile fauna of both canyons was dominated by sponges, bryozoans, ascidians, and stony corals (Figure 70). Sponges (present in around 40% and 30% of images respectively) were abundant over the carbonate rubble fields and bedrock outcrops, which occur in patches along the canyon edge and slope. Species observed included the ‘cup and ear sponges’ *Pleroma* and *Aciculites* spp., the large grey plates and bowls of *Psammocinia* spp., digitate sponges such as the Arenoscleridae, Axinellidae and Raspailiidae, and encrusting patches of *Darwinella* and/or *Petrosia* sp. 6 (orange and yellow coloured). At the Coral Canyon, the distinctive blue and white lithistid cup sponge *Reidispongia coerulea* was particularly numerous at some stations, as was the (previously rare) orange *Rossella ijimai*. At the Well, both *R. ijimai* and the similar *Symplectella rowi* were abundant on rocky outcrops, along with the ragged white fans identified as either *Calyx* n. sp. 5, or *Xestospongia coralloides* as well as *Poecillastra laminaris*. Clumps of ‘twiggy’ bryozoans, in some cases identifiable as *Cellaria tenuirostris*, were observed on rocky substrate in both canyons, along with small delicate white lacy fans identified as a Phidoloporidae species (possibly *Phidolopora avicularis*). On soft sediment areas, bugulid bryozoans were occasionally present. Ascidians were hard to identify, and most observations were of colonial encrusting forms grouped into an unidentified aplousobranch or didemnid categories. At the Coral Canyon, distinctive orange *Synoicum otagoensis* were occasionally observed, and on soft sediment, white ‘lollipops’ identified as *Culeolus* sp. were numerous at one station. The stony corals category included mainly cup corals (*Caryophyllia profunda*), along with several small outcrops of the coral

Goniocorella dumosa from the deepest Coral Canyon station (station 126, 280–330 m, Figure 71a), and an unidentified bright yellow coral thought to possibly be a *Dendrophylliia* species (M. Kitahara, pers. comm.) (Figure 71b).

Other sessile fauna observed included sea pens on soft sediment, and fields of bright orange whip corals (Gorgonacea) and white bottle brush corals (Antipatharia) in areas of mixed soft sediment and cobble rubble. The former were identified in images as possibly *Ellisellidae* spp. or *Lepidisis* spp., although only *Stichopathes variabilis* was identified in dredge samples. Similarly, the bottle brush corals were thought to resemble a species of *Cladopathidae*, but samples collected were *Stylopathes cf. tenuispina*. Also observed were scallops (*Talochlamys gemmulata)*, serpulid and sabellid worms, brachiopods and hydroids.

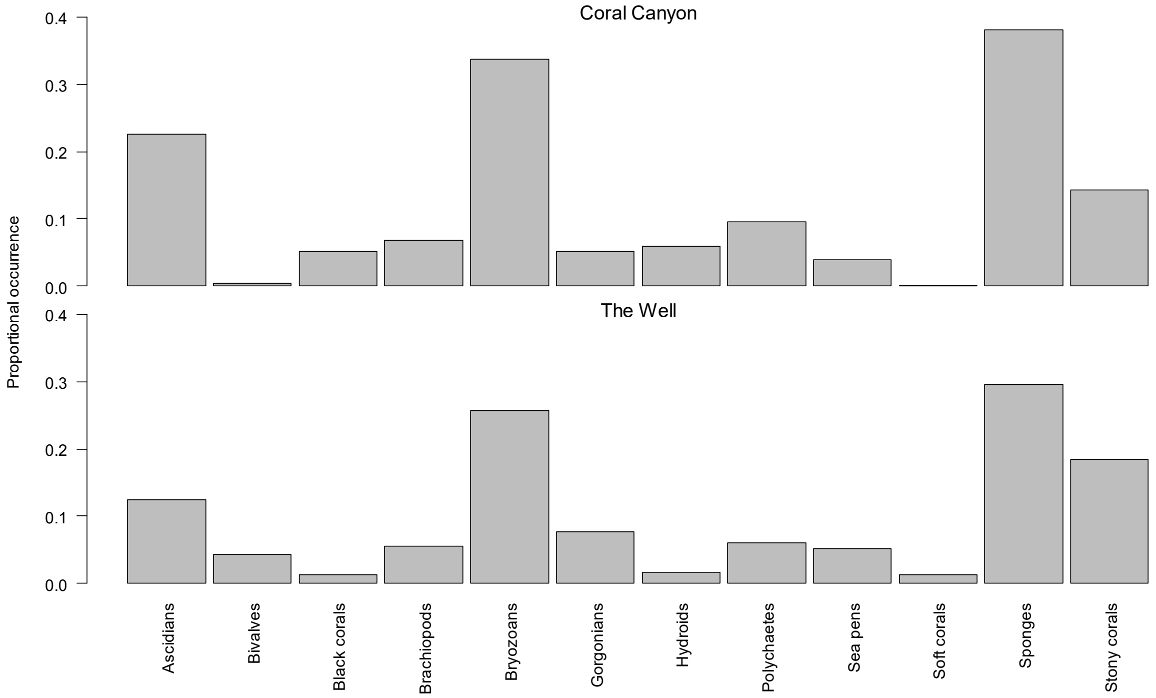


Figure 70: Proportional occurrence in images for key sessile taxonomic groups for the North Taranaki canyons (Site 13: Coral Canyon, and Site 14: The Well).

Figure 71: Example fauna observed at the North Taranaki canyons. a) Small deep water coral outcrop of *Goniocorella dumosa* (Station 126, the Coral Canyon). Note also the columnar carbonate structures, including one standing upright with a hollow centre, as well as rocks with a swiss-cheese like appearance. b) unidentified cup coral, possibly *Dendrophylliia* species. c) Scorpaenid fish amongst high abundances of crinoids (*Comanthus novaezealandiae*), ophiuroids, and glass sponges (orange, *Symplectella rowi*).

Mobile fauna showed a greater degree of variation between the two canyons. Anemones, brittle stars, crabs and crinoids were some of the most often observed fauna at both sites, but squat lobsters, natant decapods and gastropods were more prevalent in the Coral Canyon, whilst asteroids were more often observed at the Well (Figure 72). Anemones were not identified to species, the brittle stars observed were thought to be either *Ophiomyxa brevirima* or

Ophiopsammus assimilis, and crabs observed were mainly the distinctive orange *Bellidilia cheesmani*, found in the soft sediment areas. Crinoids, thought to be *Comanthus novaezealandiae*, were particularly numerous in rubble areas at some stations at The Well (Figure 71c), whilst at the Coral canyon, unidentified squat lobsters were observed in burrows over soft sediment areas. Gastropods observed were mainly scaphopods, but with a few other species such as *Penion jeakingsi* and *Austrofusus glans*.

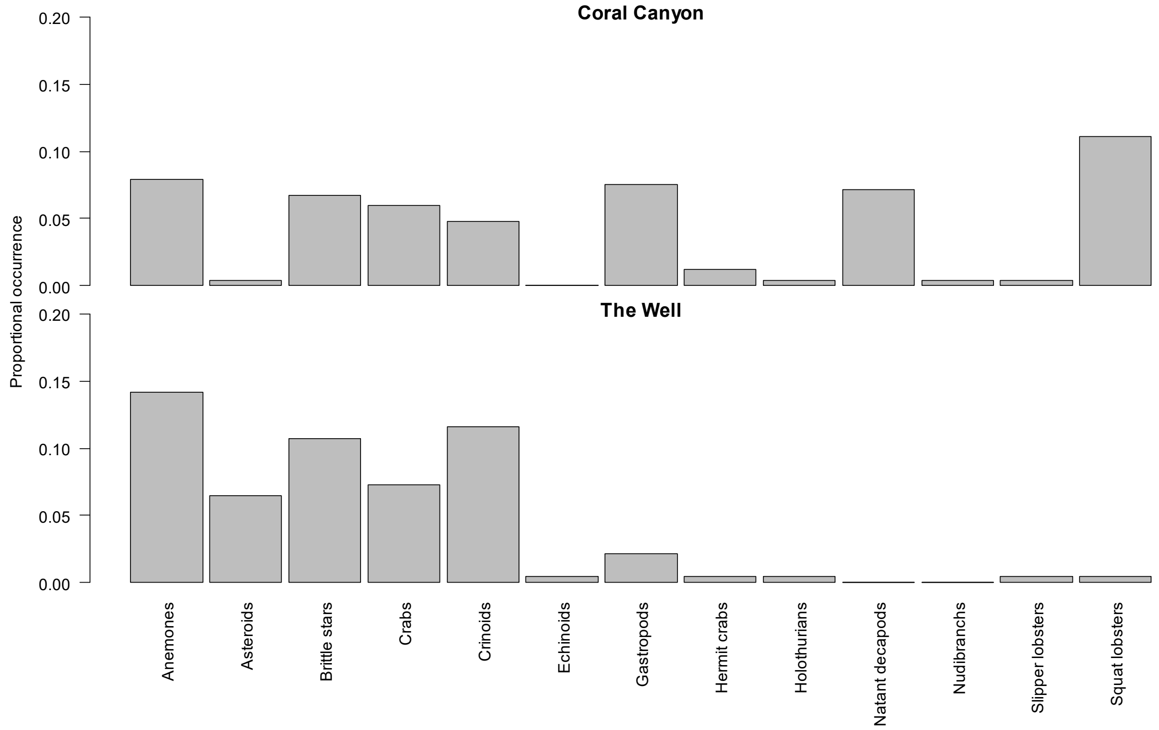


Figure 72: Proportional occurrence in images for key mobile taxonomic groups for the North Taranaki canyons (Site 13: Coral Canyon, and Site 14: The Well).

Non-hierarchical cluster analysis of benthic fauna observed in DTIS images from the North Taranaki canyons

All fauna

For analysis of the full community data set (sessile and mobile OTUs) from the two canyons, 172 images without fauna were dropped, leaving 313 image samples. A k-means cluster analysis on the alternate Gower dissimilarity matrix of standardized data returned between 3–5 groupings, with SSI values ranging from 0.244 to 0.300 (Table 29, Figure 73). After 100 iterations with k set between 2 and 20 groups, the 3 cluster grouping was selected as optimal using the cascade-KM function (Figure 74). ANOSIM identified significant differences between the clusters for both 3 and 5 groups (Table 29), but two of the pairwise comparisons were not significant in the 5 cluster grouping.

Table 29: Summary of non-hierarchical cluster analysis of biological community data observed in images from the north Taranaki canyons. SSI criterion, BTSS/TSS ratio and global R values from ANOSIM tests are presented for two different data sets (full community and sessile-only fauna) and for different clustering scenarios considered.

Data matrix	No of Clusters	SSI value*	BTSS/TSS	ANOSIM
Full community	3	0.244/0.244	80.8%	R=0.105 (P=0.001)
	4	0.299	82.6%	R= -0.164 (P>0.05)
	5	0.300	83.4%	R=0.146 (P=0.001)
Sessile community	3	0.197/0.244	73.6%	R=0.064 (P=0.001)
	4	0.295	76.2%	R=0.113 (P=0.001)
	5	0.294	77.5%	R=0.013 (P>0.05)
	6	0.268	81.5%	R=0.082 (P=0.001)

*SSI values from cascade-KM/single k-means partitioning routines.

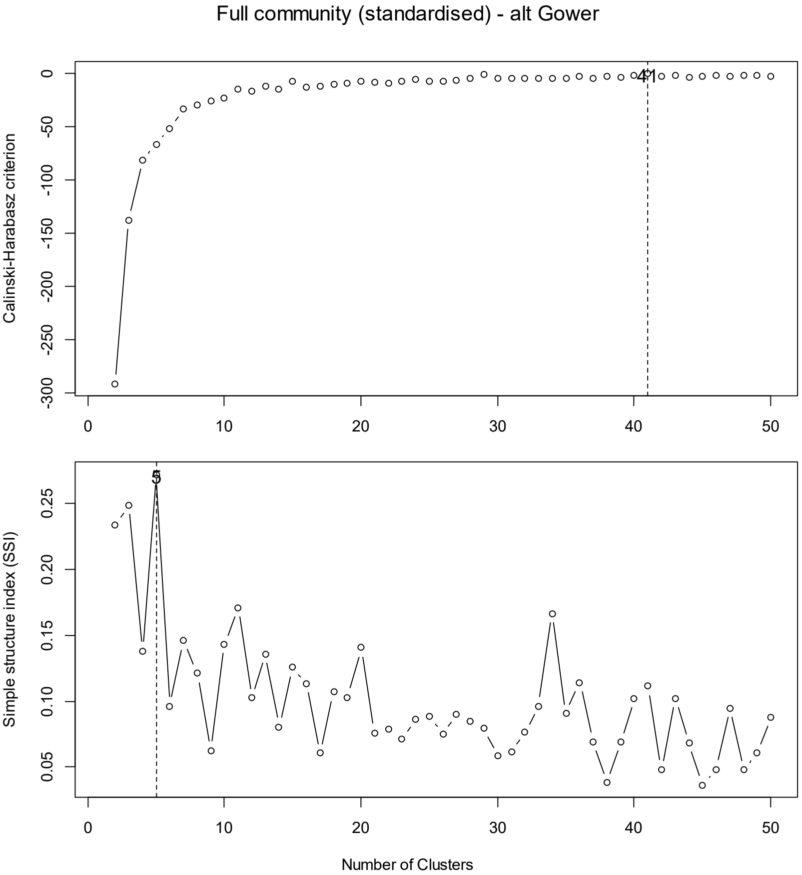


Figure 73: k-means cluster analysis of full community biota observed in images from the north Taranaki canyons, with the number of groups giving optimum values for the Calinski-Harabasz criterion (upper), and Simple Structure Index (SSI) (lower).

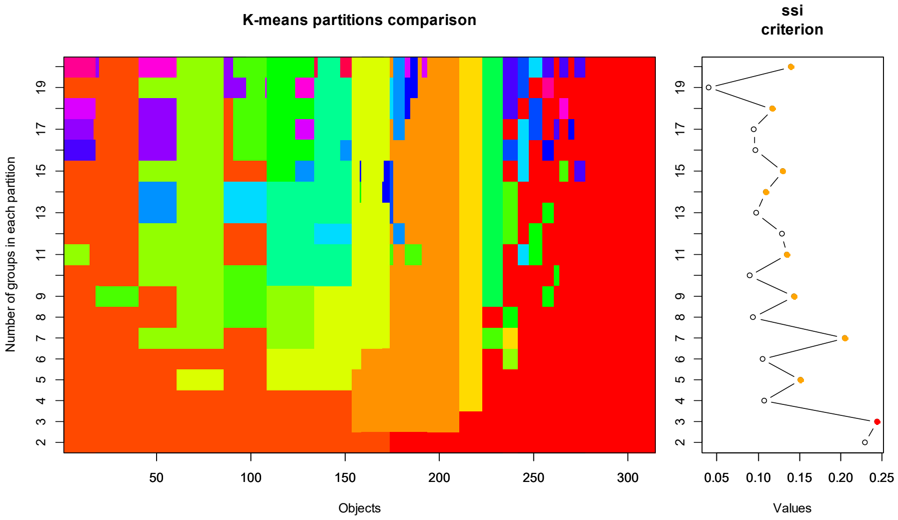


Figure 74: k-means cascade plot of cluster analysis using full community biota observed in images from the north Taranaki canyons. The group each 'object' (image) was assigned to for each partition is plotted (left), and the associated SSI criterion after 100 iterations (right). The maximum SSI criterion value is indicated in red.

Sessile fauna only

Using only the sessile OTUs (n=55) reduced the number of images from the two canyons for classification to 249 (down from 313 for all fauna). The k-means cluster analysis on the alternate Gower dissimilarity matrix of standardized sessile community data returned from 3–6 groupings, with SSI value ranging from 0.197 to 0.295 (Table 29, Figure 75). After 100 iterations with k set between two and twenty groups, the three cluster grouping was selected as optimal using the cascade-KM function (Figure 76). ANOSIM identified significant global differences between three, four and six groupings (Table 29), but with two or more non-significant pairwise comparisons found in groupings greater than three.

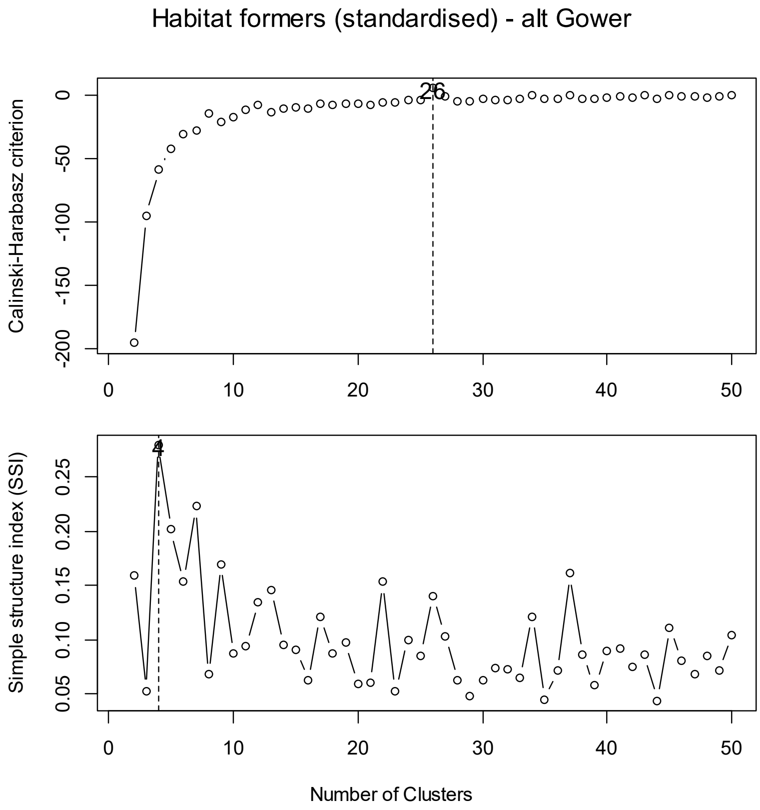


Figure 75: k-means cluster analysis of sessile community biota observed in images from the north Taranaki canyons, with the number of groups giving optimum values for the Calinski-Harabasz criterion (upper) and Simple Structure Index (SSI) (lower).

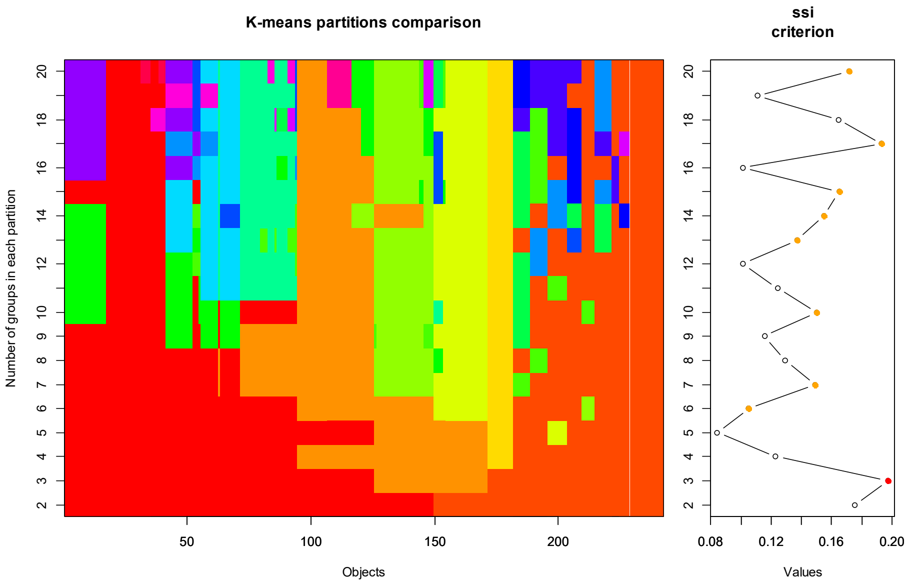


Figure 76: k-means cascade plot of cluster analysis using sessile community data set from the north Taranaki canyons, showing the group each ‘object’ (image sample) was assigned to for each partition (left), and the associated SSI criterion after 100 iterations (right). The maximum SSI criterion value is indicated in red.

The three cluster grouping based on sessile-only fauna was selected as the final grouping level, along with an additional default Cluster '0', for images devoid of fauna. A non-metric MDS ordination of the sessile fauna samples indicated considerable overlap in community composition between both the two canyon sites, and between the clusters generated using k-means (Figure 77). The three clusters separated out as soft sediment only (Cluster 2), mixed soft and hard substrate (Cluster 1), and rubble/rock habitat types (Cluster 3). The main contributing OTUs/species to each of these assemblages (as defined by SIMPER) are given in Table 30. The relative occurrence of high level taxonomic groups is given in Figure 78. Clusters 1 and 3 were similar to each other, having sponges in 80–100% of their images, along with 'bryozoan clumps' (unidentified branching turf on rocks), *Phidoloporidae* (a small white lacy bryozoan), ascidians, cup corals, and anemones. The scallop *Talochlamys gemmulata* occurred in 10% of Cluster 1 images, with fewer occurrences in Cluster 3, and was absent from Cluster 2. Images grouped in Cluster 2 had fewer occurrences of most sessile species, with the exceptions of slightly more occurrences of hydroids, whip corals, and sea pens (Table 30).

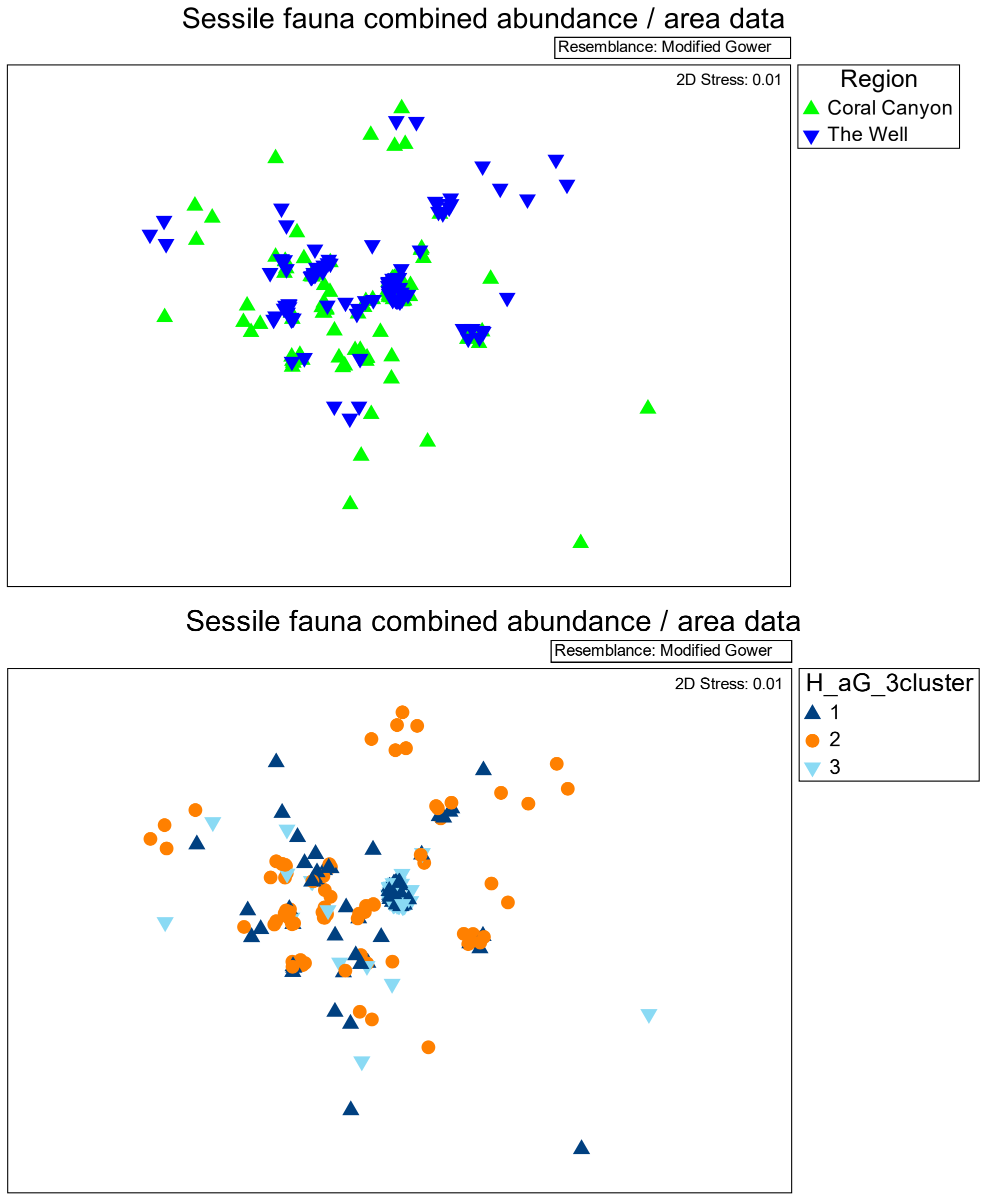


Figure 77: MDS plot of north Taranaki canyons sessile fauna data: labelled by canyon (top); labelled by three final clusters selected (bottom).

Table 30: Dominant contributing species for the three faunal assemblages from the north Taranaki canyons, identified by non-hierarchical clustering, identified by SIMPER.

Cluster 0: Bare sediment: no sessile fauna.

Images	Coral Canyon	The Well	Main contributing species/OTUs	Av. Value	% Cont	Cumu . %
242	116	126		–	–	–

Cluster 1: Occurring over mixed sediment types (both soft and hard) with low levels of sessile fauna such as bryozoan turf, cup corals, sparse sponges on rubble / rock, and whip corals, sea pens in sediment. Mean species richness 4.13 ± 0.91 (s.d).

Images	Coral Canyon	The Well	Main contributing species/OTUs	Av. Value	% Cont.	Cumu. %
80	39	41	Bryozoan clumps (unid)	0.20	15.73	15.73
			Caryophyllia profunda (cup coral)	0.10	8.00	23.73
			Kophobelemnon (sea pen)	0.04	7.83	31.56
			Psammocinia spp. combined (sponge)	0.03	4.86	36.42
			Bottle brush coral ?*Cladopathidae* sp. (Antipatharia)	0.03	4.68	41.10
			Aplousobranchia (ascidian)	0.03	4.61	45.71
			Brachiopoda	0.04	3.85	49.56
			Whip coral ?*Ellisellidae* sp. (Gorgonacea)	0.03	3.54	53.10
			Synoicum otagoensis (ascidian)	0.02	3.30	56.40
			Pleroma and *Aciculites* spp. (sponges)	0.04	3.13	59.53
			Phidoloporidae (lace bryozoan)	0.06	2.56	62.09
			Cryptolaria (hydroid)	0.02	2.49	64.58

Cluster 2: Bare sediment with occasional sessile fauna such as sea pens, whip corals, hydroids. Mean species richness 1.18 ± 0.39.

Images	Coral Canyon	The Well	Main contributing species/OTUs	Av. Value	% Cont.	Cumu. %
88	39	44	Whip coral ?*Ellisellidae* sp. (Gorgonacea)	0.13	12.42	12.42
			Culeolus sp. (ascidian)	0.10	9.96	22.38
			Nemertesia elongata (hydroid)	0.09	9.17	31.55
			Kophobelemnon (sea pen)	0.09	8.97	40.52
			Pennatulacea (unid.)	0.08	8.84	49.36
			Bryozoan clumps (unid)	0.07	6.75	56.11
			Aplousobranchia (ascidian)	0.06	6.54	62.65
			Caryophyllia profunda (cup coral)	0.05	5.25	67.90
			Darwinella sp. /*Petrosia* n. sp. 6 (sponge)	0.04	4.02	71.92

Cluster 3: Sponge community on rubble / rock. Mean species richness 7.76 ± 1.67.

Images	Coral Canyon	The Well	Main contributing species/OTUs	Av. Value	% Cont.	Cumu. %
81	58	23	Sabellidae (polychaete worm) (unid.)	0.05	5.76	5.76
			Reidispongia coerulea (sponge)	0.05	5.27	11.03
			Tethya and *Suberities* spp. (sponge)	0.05	5.14	16.17
			Rossella ijimai (sponge)	0.03	4.95	21.12
			Caryophyllia profunda (cup coral)	0.06	4.36	25.48
			Bottle brush coral ?*Cladopathidae* sp. (Antipatharia)	0.03	4.15	29.63
			Psammocinia spp. combined (sponge)	0.04	3.80	33.43
			Darwinella sp. /*Petrosia* n. sp. 6 (sponge)	0.04	3.66	37.09
			Cryptolaria (hydroid)	0.01	3.40	40.49
			Pleroma and *Aciculites* spp. (sponge)	0.06	2.98	43.47
			Leucetta lancifer (sponge)	0.02	2.63	46.10
			Petrosia n sp. 5 (sponge)	0.03	2.50	48.60
			Aplousobranchia (ascidian)	0.02	2.49	51.09

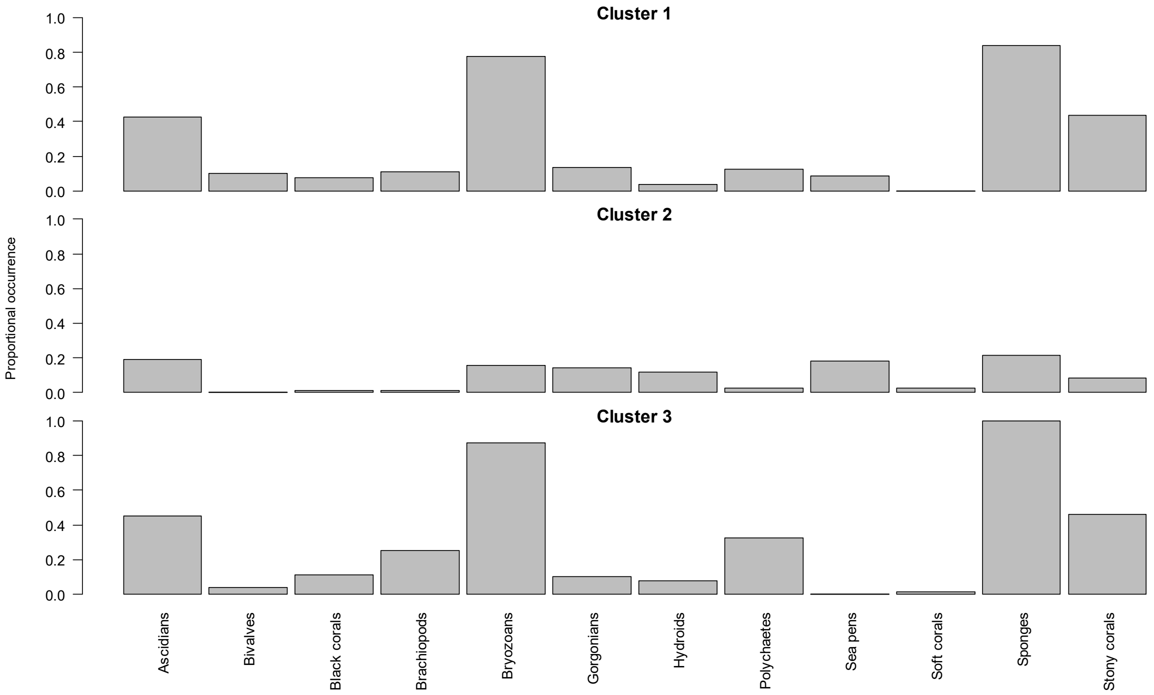


Figure 78: Proportional occurrence of different sessile species groups, across the three faunal clusters as identified by non-hierarchical clustering of invertebrate faunal data from DTIS imagery of the north Taranaki canyons.

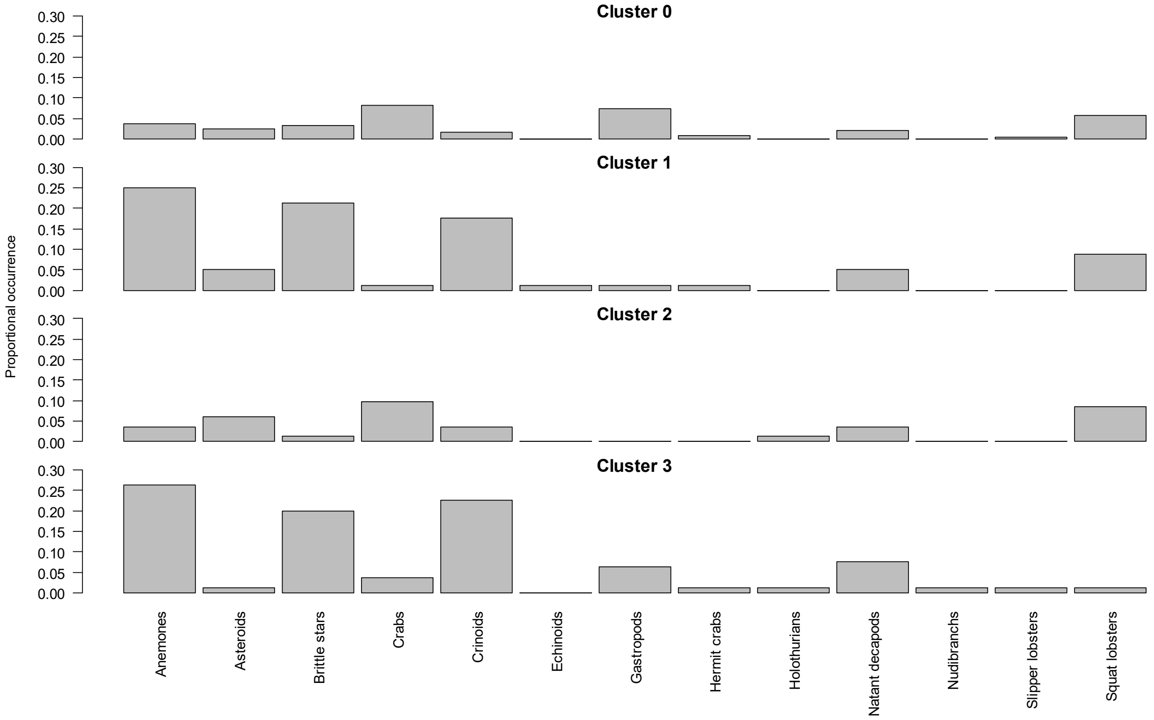


Figure 79: Proportional occurrence of different mobile species groups, assigned across the three faunal clusters identified by non-hierarchical clustering of invertebrate faunal data from DTIS imagery of the north Taranaki canyons and bare sediment (cluster 0).

For the mobile fauna (Figure 79), the dominant groups across Clusters 1 and 3 were anemones, crinoids, and ophiuroids (principally *Ophiopsammus assimilis*), which were observed in 15–

25% of images. In images classified as either bare sediment (Cluster 0) or Cluster 2 (largely soft sediment areas), mobile fauna was sparser, with the crab *B. cheesmani* and squat lobsters (either *Phylladiorhynchus pusillus* or *Munidopsis papanui*) the most frequently observed fauna.

Table 31 presents the frequency of occurrence and average scaled cover of the dominant sponge species in each cluster. Cluster 3 (rock/rubble) had the highest species richness and percentage occurrence of sponges, with 26 species. The top five sponges in Cluster 3 occurred in 30 – 65% of images, whilst occurrence of sponge species was less than 25% of images in Cluster 1 and less than 10% in Cluster 2. Even in Cluster 3, sponge cover was very low, with a maximum cover of 0.01 m^{-2}. Three sponge groups occurred in the top five species across all three clusters; encrusting sponges, the finger sponges (e.g. *Raspailia*, *Axinella* spp.), and 'cup and ear sponges' (*Pleroma/Aciculites* spp.). Other species were present in several groups, but more common in one, e.g. *Symplectella rowi* and *Leucetta lancifer* in Cluster 1, (also found in less than 25% of images in Cluster 3), and *Rossella ijimai* in Cluster 2, (also found in 11.2% of images in Cluster 3). Figure 80 and Figure 81 give examples of some of the fauna observed in images from different clusters.

Table 31: Percentage occurrence across images, and average cover per standardised square metre, of the dominant habitat-forming sponge species identified from DTIS imagery of the north Taranaki canyons.

Cluster	Species richness	Key species	% occ.	Average cover per m^2
0	0		–	–
1	20	Encrusting sponge (*Darwinella* sp.)	24.7	0.0011
		Symplectella rowi	24.7	0.0015
		Finger sponges (*Raspailia*, *Axinella* spp.)	24.7	0.0009
		Pleroma/*Aciculites* spp.	20.1	0.0038
		Leucetta lancifer	11.0	0.0001
2	8	Finger sponges (*Raspailia*, *Axinella* spp.)	8.4	0.0002
		Encrusting sponge (*Darwinella* sp.)	4.8	0.0001
		Pleroma/*Aciculites* spp.	2.4	0.0002
		Rossella ijimai	2.4	0.0000
3	26	*Pleroma*/*Aciculites* spp.	65.0	0.0108
		Finger sponges (*Raspailia*, *Axinella* sp.)	60.0	0.0023
		Encrusting sponge (*Darwinella* sp.)	51.2	0.0045
		Psammocinia sp.	40.0	0.0014
		Reidispongia coerulea	33.7	0.0021

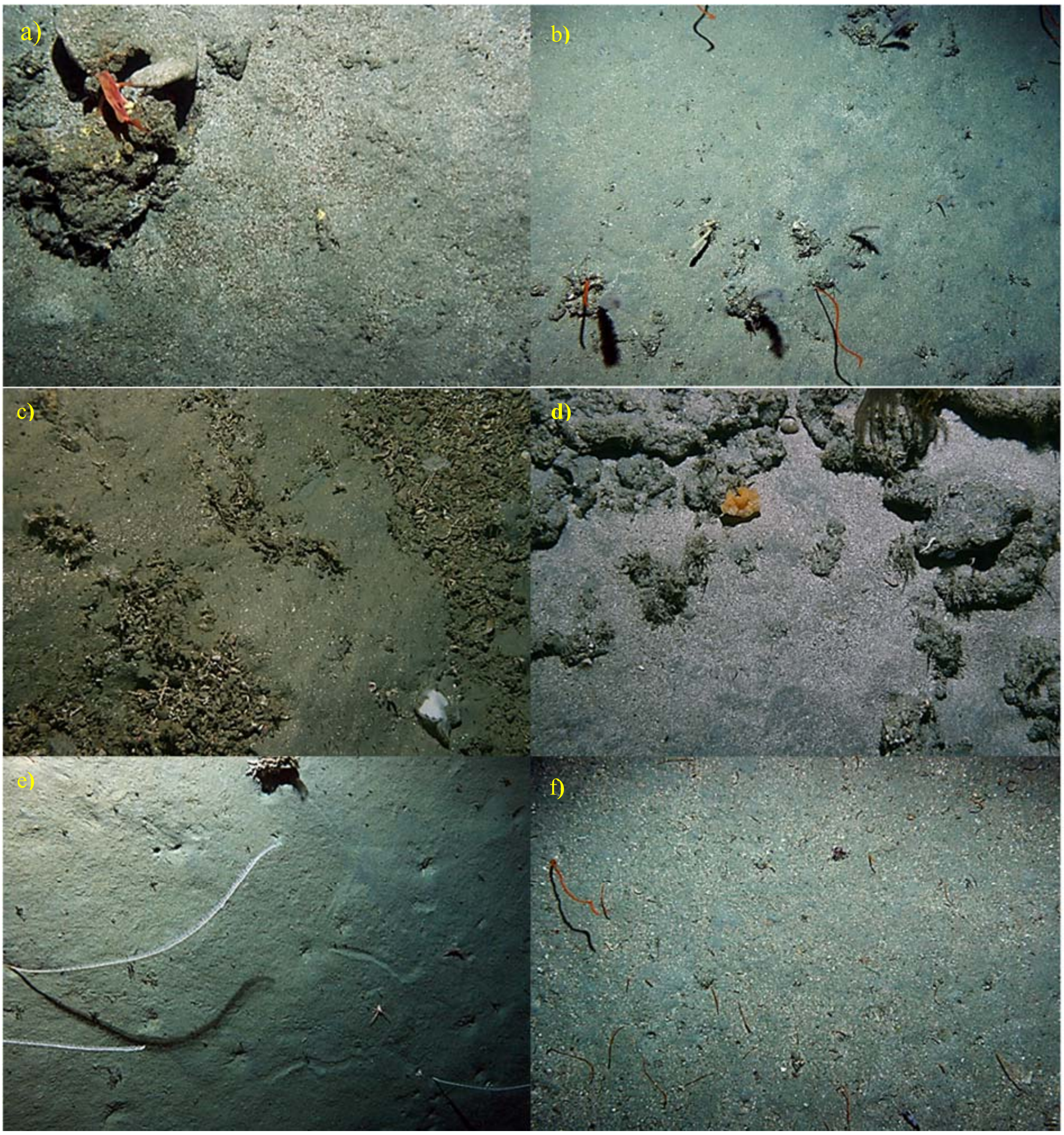


Figure 80: Benthic fauna observed at the north Taranaki canyons. Cluster 1: a) encrusting sponges and ascidians on small rocky outcrops; b) broken cobble patches with (orange) whip and (white) bottle brush corals in soft sediment; c) mainly dead coral rubble, and the sponge *Poecillastra laminaris* (white); d) rock rubble with lace bryozoans, cup corals and the glass sponge *Symplectella rowi* (orange). Cluster 2: e–f) bare sediment with sea pens, whip corals and other sparse fauna.

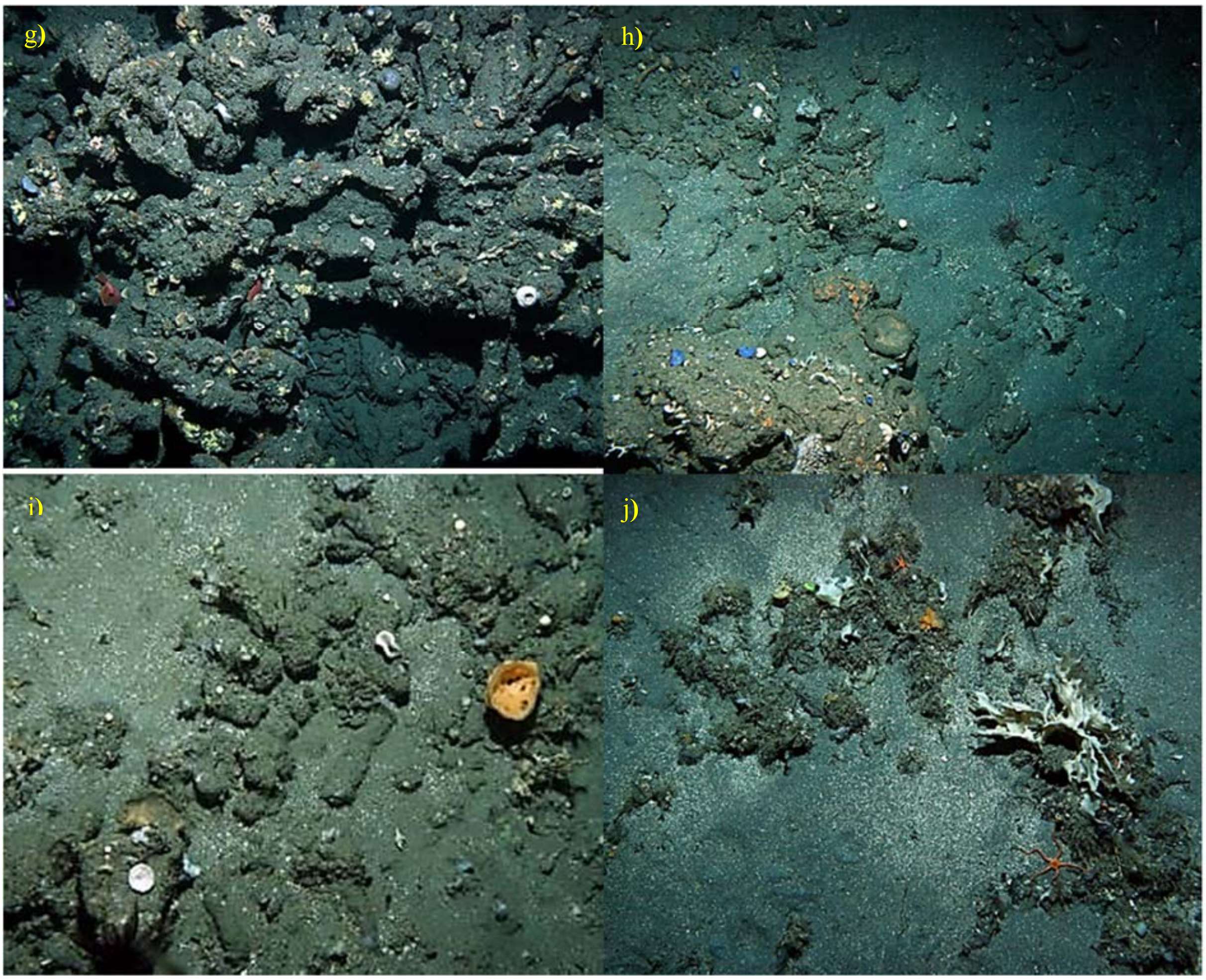


Figure 81: Benthic fauna observed at the north Taranaki canyons. Cluster 3: g) rocky outcrops with diverse sponge fauna, including *Petrosia* n sp. 6 (yellow encrusting), *Pleuroma turbinatum* (white cup), and *Aciculites pulchra* (tan ears); h) *Reidispongia coerulea* (blue and white cups), *Pleroma menoui* (furry edged ear), *Psammocinia* cf. *verrucosa* (grey plate) and *Darwinella* sp. (encrusting orange); i) rubble patches with *Rossella ijimai* (orange); j) *Calyx* sp. 5/*Xestospongia coralloides* (white jagged fan), and a small *Symplectella rowi* (orange).

Relationships between benthic community data, remote sensing and other potential explanatory variables for the north Taranaki canyons.

Relationships between the invertebrate benthic communities observed at the two canyon sites and environmental variables were examined using distance based linear modelling (DISTLM). The explanatory power of the variables was examined in a step-wise procedure, starting with topographical metrics derived from the multibeam data only, and increasing the number of variables to include a geographic category (Site), followed by image-derived variables that related to the substrate; levels of bioturbation in soft sediment, and proportion of hard substrate observed in the images. Table 32 summarises the outputs from the models, showing the explanatory power of each of the terms used in isolation (marginal proportion), as well as what proportion is explained as variables are added sequentially, after accounting for the effects of the variables already selected in the model (sequential proportion). Using only the multibeam-derived topographic variables (depth, slope, reflectance, zones and structures), the explained proportion of total variance was modest. Reflectance explained 4.3% of the variation, followed by depth (1.7%), and slope (1.2%); cumulatively these three variables explained 7.3% of the variation, with neither of the BTM-derived categorical variables being retained in the model.

The addition of a canyon identifier term improved the model's performance only slightly, increasing the overall proportion of variance explained to 7.8%.

Table 32: Summary of step-wise DISTLM models fitted to the north Taranaki canyons full community data. Explanatory terms used are listed in the first column. Marginal proportion (proportion explained by the term in isolation) is given for all terms in the second column, with sequential proportions for each model given in following columns. The total cumulative proportion explained by each model is also given, along with improvement made as terms are added. (-) indicates a term is not included in that model, (ns) indicates a term was included, but dropped from the final model.

Term		MB only	MB + Region	MB + Region + Bioturbation	MB + Region + Bioturbation + % Hard subst.
	Marginal prop.				Sequential prop.
% hard substrate	0.129	–	–	–	0.129 (1)
Depth	0.018	0.017 (2)	0.017 (2)	0.018 (3)	0.019 (2)
Bioturbation	0.064	–	–	0.064 (1)	0.021 (3)
Region	0.012	–	0.008 (4)	0.006 (5)	0.009 (4)
Reflectance	0.043	0.043 (1)	0.041 (1)	0.024 (2)	ns
Rugosity	0.017	ns	ns	ns	ns
Slope	0.025	0.012 (3)	0.013 (3)	0.015 (4)	ns
Structure	0.050	ns	ns	ns	ns
Zone	0.020	ns	ns	ns	ns
Cumulative prop.		0.073	0.078	0.127	0.177
Improvement			0.005	0.049	0.050

The addition of a visual score for soft sediment bioturbation activity improved the model fit, with this variable becoming the most important (6.4%); followed by reflectance (2.4%), depth (1.8%), slope (1.5%), and region (0.6%). Adding the remaining image-derived term for proportion of hard substrate in samples resulted in a final model which retained both the hard substrate (12.9%) and bioturbation (2.1%) terms, along with depth (1.9%) and region (0.9%), explaining a total of almost 18% of the variance. The dbRDA plot showed that the proportion of hard substrate in the sample was the strongest explanatory variable along the primary axis; samples with greater areas of hard substrate fell to the right (mainly Cluster 1 and 3 images), while samples with higher proportions of soft sediment fell to the left (mainly Cluster 2 or 0 images) (Figure 82). The influence of depth was along the secondary axis, with samples from deeper stations falling to the top of the plot.

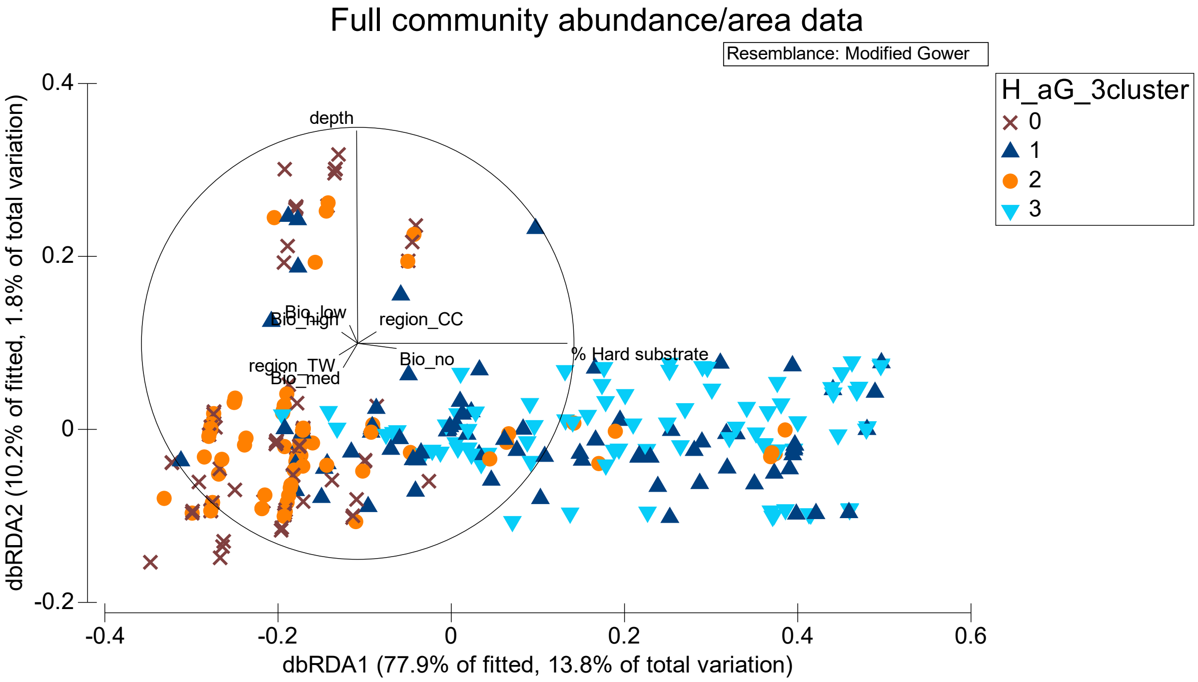


Figure 82: dbRDA plot of north Taranaki canyons full community data, for multibeam-derived variables (bathymetry, slope, and reflectance), canyon (CC, The Coral Canyon (Site 13); TW, The Well (Site 14)), and level of biogenic complexity (none, low, medium, high) and seafloor hardness, as measured from the still images.

The same process was repeated using the sessile fauna data only, with the final model retaining the percentage of hard substrate as the primary explanatory term, followed by Region (canyon), depth and reflectance; the total amount of variation in the data explained by the model was just over 11% (Table 33, Figure 83).

Table 33: Summary of step-wise DISTLM models fitted to the north Taranaki canyons sessile community data. Explanatory terms used are listed in the first column. Marginal proportion (proportion explained by the term in isolation) is given for all terms in the first column, with sequential proportions for each model given in following columns. The total cumulative proportion explained by each model is also given, along with improvement made as terms are added. (-) indicates a term is not included in that model, (ns) indicates a term was included, but dropped from the final model.

Term	Marginal Prop.	MB only	MB + Region	MB + Region + Bioturbation	MB + Region + Bioturbation + % Hard subst.
		Sequential prop.			
% Hard substrate	0.079	–	–	–	0.079 (1)
Region	0.019	–	0.017 (2)	0.017 (2)	0.016 (2)
Depth	0.009	0.009 (3)	0.008 (3)	0.009 (4)	0.010 (3)
Reflectance	0.034	0.034 (1)	0.034 (1)	0.034 (1)	0.008 (4)
Bioturbation	0.043	–	–	0.008 (3)	ns
Slope	0.017	0.009 (2)	0.009 (4)	ns	ns
Rugosity	0.009	ns	ns	ns	ns
Zone	0.025	ns	ns	ns	ns
Structure	0.053	–	ns	ns	ns
Cumulative prop.		0.052	0.067	0.067	0.114
Improvement			0.015	0	0.047

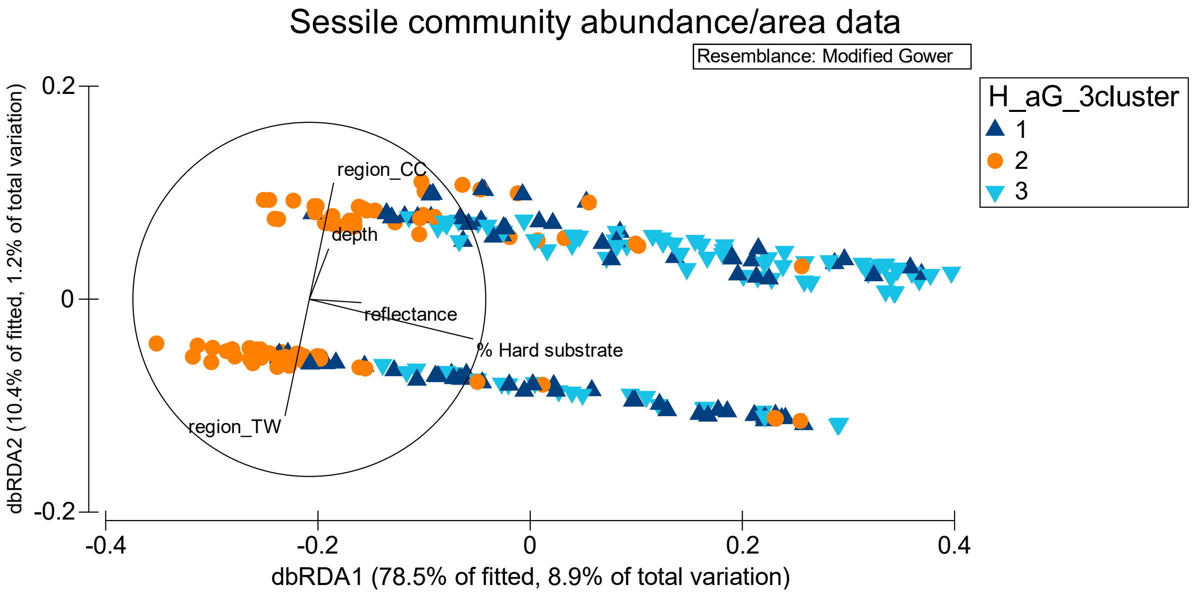


Figure 83: dbRDA plot of north Taranaki canyons sessile community data only, for multibeam-derived variables (bathymetry, slope, and reflectance), canyon (CC, Coral Canyon (Site 13); TW, The Well (Site 14)), level of biogenic complexity (none, low, medium, high), and seafloor hardness as measured from the still images.

Fish diversity and abundance in the north Taranaki canyons

Biological samples (beam trawl and rock dredge)

Seventeen species of fish were identified from samples of the wider north Taranaki area, including the two Taranaki canyons, and two adjacent areas (Site 11: North shelf, and Site 12: The Drop Off) (Table 34). These included two rare species, the luminescent cod *Physiculus luminosa* (Paulin 1983), and the Fiordland brotula *Fiordichthys slartibartfasti* (Paulin 1995); and a paratype of a new pearlfish species, *Echiodon prionodon* (Parmentier 2012).

Table 34: Fish species captured by epibenthic sled and beam trawl in the north Taranaki canyons. [1]Rare species, [2]paratype of new species. Numbers in brackets are number of sample tows. Two adjacent non-core areas, North shelf and The Drop Off, are also included for local regional species completeness.

Species		Coral Canyon (1)	North (shelf) (1)	The Drop Off (4)	The Well (2)	Total
Witch	*Arnoglossus scapha*		5			5
Cucumber fish	*Paraulopus nigripinnis*		5			5
Butterfly perch	*Caesioperca lepidoptera*			4	1	5
Southern bastard cod	*Pseudophycis barbata*		3			3
Bastard cod	*Pseudophycis* sp.			3		3
Spot-tail perchlet	*Plectranthias maculicauda*				3	3
Fiordland brotula[1]	*Fiordichthys slartibartfasti*	2				2
Sea perch	*Helicolenus* spp.			2		2
Yellow weaver	*Parapercis gilliesi*			2		2
Orange perch	*Lepidoperca aurantia*				2	2
Scaly gurnard	*Lepidotrigla brachyoptera*		1			1
Splendid perch	*Callanthias australis*			1		1
Rattail	*Coelorinchus melanobranchus*			1		1

Species		Coral Canyon (1)	North (shelf) (1)	The Drop Off (4)	The Well (2)	Total
Silver dory	*Cyttus novaezealandiae*			1		1
Hagfish	*Eptatretus cirrhatus*			1		1
Red-banded weever	*Parapercis binivirgata*			1		1
Luminescent cod[1]	*Physiculus luminosa*			1		1
Pearlfish[2]	*Echiodon prionodon*				1	1
Species richness		1	4	10	4	18
Total catch		2	14	17	7	40

DTIS (video)

At the Coral Canyon, the eight DTIS tows collectively recorded 507 fish (excluding small pelagic fish such as myctophids), varying from 38 to 131 individuals per tow. Eighteen species were identified, along with three OTUs to genus (jack mackerels, opal-fish and bellows-fish) and a further five to family level (Table 35). Small-bodied Seranidae and Sebastidae dominated the small fish assemblage, with butterfly perch and sea perch being the most commonly observed species (densities up a maximum of 157 per 1000 m^2 for butterfly perch). Macrourids (rattails) were observed at all stations. Eight of the 18 DTIS fish species were also identified in the biological samples from this region (sea perch, butterfly perch, orange perch, splendid perch, southern bastard cod, yellow weaver, cucumber fish and hagfish).

At the Well, the seven DTIS tows collectively recorded 341 fish, varying from 17 to 91 individuals per tow. Eighteen species were observed (12 in common with the Coral Canyon), along with two OTUs to genus (jack mackerels, opal-fish), and two to family level (rattails, scorpion fish) (Table 35). Rattails were the most commonly observed OTU, followed by orange perch and cucumber fish. Overall densities of Seranidae species and Helicolenus sp. were lower than at the Coral Canyon, whilst densities of soft-sediment associated species, such as rattails and cucumber fish were higher.

Table 35: Fish densities per 1000 m^2 estimated from DTIS video, at the Coral Canyon and The Well, north Taranaki. The top five most abundant species for each area are shaded. Density is given with an associated standard error. Ind.; individuals.

Common name	Scientific name	The Coral Canyon			The Well		
		Density	Range	Ind.	Density	Range	Ind.
Butterfly perch	*Caesioperca lepidoptera*	39.68 ± 21.73	0–157	141	2.74 ± 1.93	0–13.2	15
Rattails	Macrouridae	9.86 ± 2.33	0–19	57	18.07 ± 7.97	0–56.8	110
Sea perch	*Helicolenus percoides*	21.39 ± 4.35	0–37	104	5.89 ± 3.25	0–20.6	34
Orange perch	*Lepidoperca aurantia*	5.03 ± 3.81	0–31	32	13.57 ± 5.56	0–32.3	76
Cucumber fish	*Paraulopus nigripinnis*	2.59 ± 0.77	0–5.5	16	10.62 ± 3.70	3.18–32.1	50
Jack mackerel spp.	*Trachurus* spp.	8.44 ± 5.71	0–45	35	1.51 ± 1.51	0–10.6	10
Scorpion fish	Scorpaenidae	2.96 ± 1.83	0–14	20	1.83 ± 1.29	0–8.82	10
Splendid perch	*Callanthias australis*	3.41 ± 2.95	0–24	9	0.56 ± 0.42	0–2.94	3
Southern bastard cod	*Pseudophycis barbata*	2.54 ± 1.38	0–10	11	0.29 ± 0.11	0–1.01	2

Common name	Scientific name	The Coral Canyon			The Well		
Long fin worm eel	*Scolechenchelys breviceps*	2.75 ± 1.45	0–12	14	–	–	–
Eel	(Unid.)	1.18 ± 0.58	0–3.4	5	0.61 ± 0.61	0–4.24	4
Red band-fish	*Cepola aotea*	–	–	–	1.67 ± 1.67	0–11.7	11
Common roughy	*Paratrachichthys trailli*	0.88 ± 0.48	0–3.4	4	0.56 ± 0.27	0–1.48	3
Hagfish	*Eptatretus cirrhatus*	1.10 ± 0.95	0–7.7	7	0.15 ± 0.15	0–1.06	1
Opalfish	*Hemerocoetes* spp.	1.09 ± 0.42	0–2.5	6	0.14 ± 0.14	0–0.99	1
Half-banded perch	*Hypoplectrodes* sp.	0.50 ± 0.37	0–2.9	3	0.21 ± 0.21	0–1.48	1
Codling	Moridae	0.64 ± 0.42	0–2.9	4	–	–	–
Stargazer	Uranoscopidae	0.61 ± 0.33	0–2.5	4	–	–	–
Silver conger eel	*Gnathophis habenatus*	0.31 ± 0.20	0–1.3	2	0.30 ± 0.30	0–2.12	2
Carpet shark	*C. isabellum*	0.15 ± 0.15	0–1.2	1	0.46 ± 0.32	0–2.14	2
Bellows fish	*Centriscops* spp.	0.55 ± 0.55	0–4.4	4	–	–	–
Tarakihi	*Nemadactylus macropterus*	0.26 ± 0.26	0–2.1	1	0.21 ± 0.21	0–1.48	1
Shark	(Unid.)	0.30 ± 0.20	0–1.3	2	–	–	–
Scaly gurnard	*Lepidotrigla brachyoptera*	0.26 ± 0.26	0–2.1	1	–	–	–
Flatfish	(Unid.)	0.26 ± 0.26	0–2.1	1	–	–	–
Barracouta	*Thyristes atun*	0.26 ± 0.26	0–2.1	1	–	–	–
Spotted gurnard	*Pterygotrigla picta*	0.21 ± 0.21	0–1.7	1	–	–	–
Yellow weaver	*Parapercis gillespi*	0.21 ± 0.21	0–1.7	1	–	–	–
Red-banded perch	*Hypoplectrodes huntii*	–	–	–	0.21 ± 0.21	0–1.47	1
Dark ghost shark	*Hydrolagus novaezealandiae*	–	–	–	0.21 ± 0.21	0–1.47	1
Rock cod	*Lotella rhacinus*	–	–	–	0.21 ± 0.21	0–1.47	1
Pink maomao	*Caprodon longimanus*	0.16 ± 0.16	0–1.3	1	–	–	–
Oreo	Oreosomatidae	0.14 ± 0.14	0–1.1	1	–	–	–
Painted moki	*Cheilodactylus ephippium*	–	–	–	0.14 ± 0.14	0–1.01	1
Smooth skate	*Dipturus inominatus*	–	–	–	0.14 ± 0.14	0–0.99	1
Unidentified fish				18			13
Lantern-fish	Myctophidae			1103			39
Species/OTU richness				29			23

Most of the common perch species (butterfly, orange and sea perch) were estimated to be between 10–20 cm total length from the DTIS videos, with some estimated to be more than 20 cm, and for sea perch, a large proportion of the fish observed were juveniles (less than 10 cm) (Figure 84).

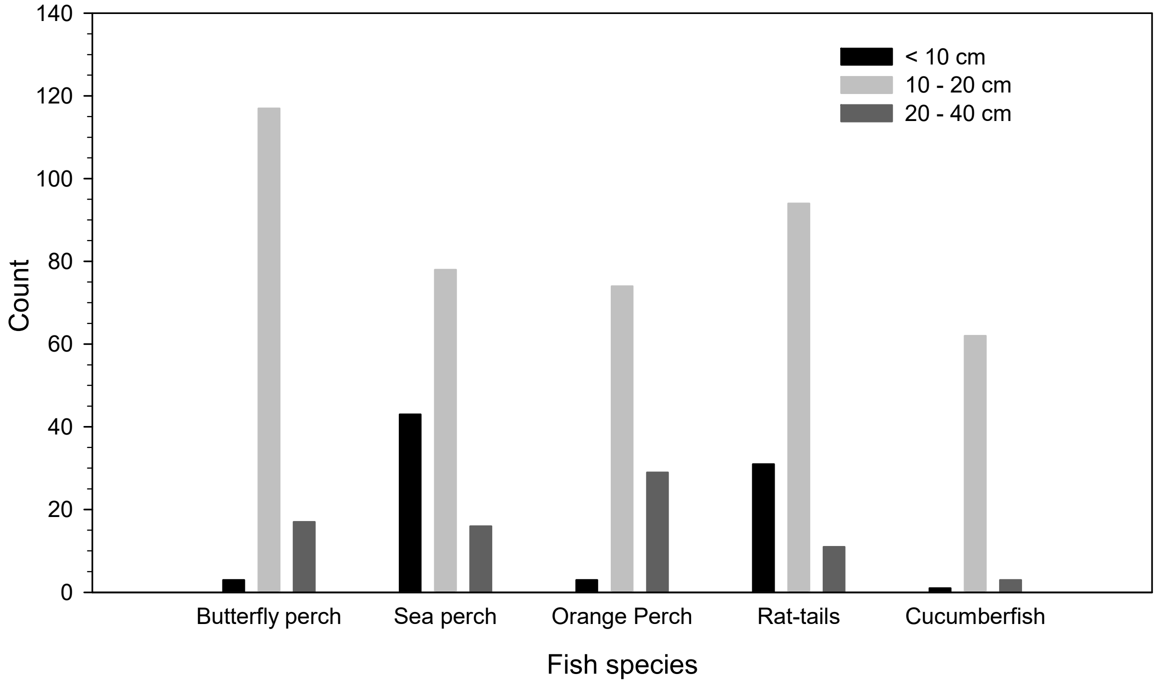


Figure 84: Size class abundances of the five numerically dominant fish species/OTUs observed by DTIS at the Coral Canyon and The Well, north Taranaki, combined.

When station-level fish densities (DTIS video) from both canyons were combined, a cluster analysis with a SIMPROF permutation test of the group-average Bray-Curtis similarity matrix showed that only two discrete groups could be distinguished at the 35–40 % similarity level (P=0.05), with one of these groups consisting of just two stations (Figure 85). This separation was mainly driven by the absence/low numbers of species such as butterfly perch, orange perch and sea perch in these two stations, along with higher numbers of cucumber fish (Station 134) and red band fish (Station 141). The occurrence of the latter two species reflects that these two stations, located on the inner northern slope of The Well, were largely over soft sediment and did not sample significant rocky rubble habitat. For the larger main group, the average Bray-Curtis similarity between all pairs of stations was 43%, dominated by contributions from rattails (27.6%) and sea perch (23.4%), along with lesser contributions from butterfly perch, orange perch and cucumber fish. A MDS representation of the same species fish community data suggested some degree of separation between the two canyon sites, although an ANOSIM indicated no significant difference (R = 0.294, P >0.05).

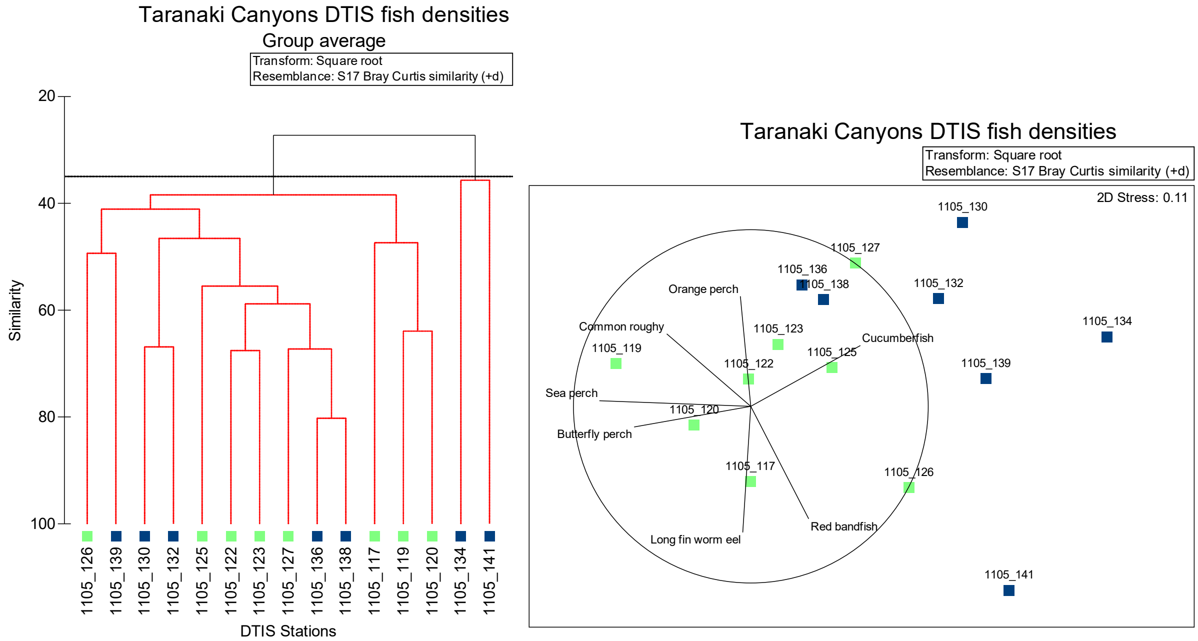


Figure 85: left) cluster analysis dendrogram showing two groups identified by SIMPROF from the north Taranaki canyon fish assemblage. Dotted red lines connect stations that did not show significant differences in community structure. The horizontal black line indicates 35% similarity. Right) Two-dimensional MDS of the Taranaki Canyons DTIS stations, based on a zero-adjusted Bray-Curtis dissimilarity matrix from square root transformed fish densities. Pearson Correlation coefficients (> 0.6) of key fish species are overlaid. Labels indicate voyage and station; blue squares The Well, green squares The Coral Canyon.

A step-wise distance-based linear model (DISTLM) applied to the DTIS fish community data was used to examine the relationship between a number of environmental and benthic habitat-related variables, using the AIC criterion to select the optimal number of terms included. Of the multibeam variables, reflectance alone explained 15.8% of the total variation in the data, but was not included in the final model (Table 36). When a canyon identifier was added, this replaced reflectance as the primary term, with slope and reflectance adding another 11% each, increasing the variation explained to just over 40%. Adding in terms to account for substrate (based on grab samples) and mean water temperature (from the DTIS CTD) did not improve the model, but including image-derived variables reflecting levels of hard substrate, bioturbation and occurrence of ‘high’ biogenic habitat (Clusters 1 and 3), resulted in the latter two terms replacing region and reflectance to give an optimal model which accounted for 46% of the total variation (Table 36, Figure 86).

Table 36: Summary of step-wise DISTLM models fitted to the north Taranaki canyons DTIS fish density data. Explanatory terms used are listed in the first column. Marginal proportion (proportion explained by the term in isolation) is given for all terms in the first column, with sequential proportions for each model given in following columns. The total cumulative proportion explained by each model is also given, along with improvement made as terms are added. (-) indicates that a term is not included in that model, (ns) indicates that a term was included, but dropped from the final model.

Term	Marginal Prop.	MB only	MB + Region	MB + Region + Substrate+ Water temp	MB + Region + Substrate+ Water temp + % Hard subst.+ Bioturbation+ % Biogenic habitat
					Sequential prop.
Bioturbation level	0.192	-	-	-	0.192 (1)
% High Biogenic Habitat	0.144	-	-	-	0.180 (2)
Mean Slope	0.088	ns	0.111(3)	0.111(3)	0.088 (3)
Mean Rugosity	0.037	ns	ns	ns	ns
Mean Reflectance	0.158	0.158 (1)	0.114(2)	0.114(2)	ns
Mean Depth	0.076	ns	ns	ns	ns
Region	0.188	-	0.188(1)	0.188(1)	ns
Substrate	0.354	-	-	ns	ns
Mean Water Temp	0.088	-	-	ns	ns
% Hard substrate	0.146	-	-	-	ns
Cumulative prop.		0.158	0.414	0.414	0.460
Improvement			0.256	0	0.046

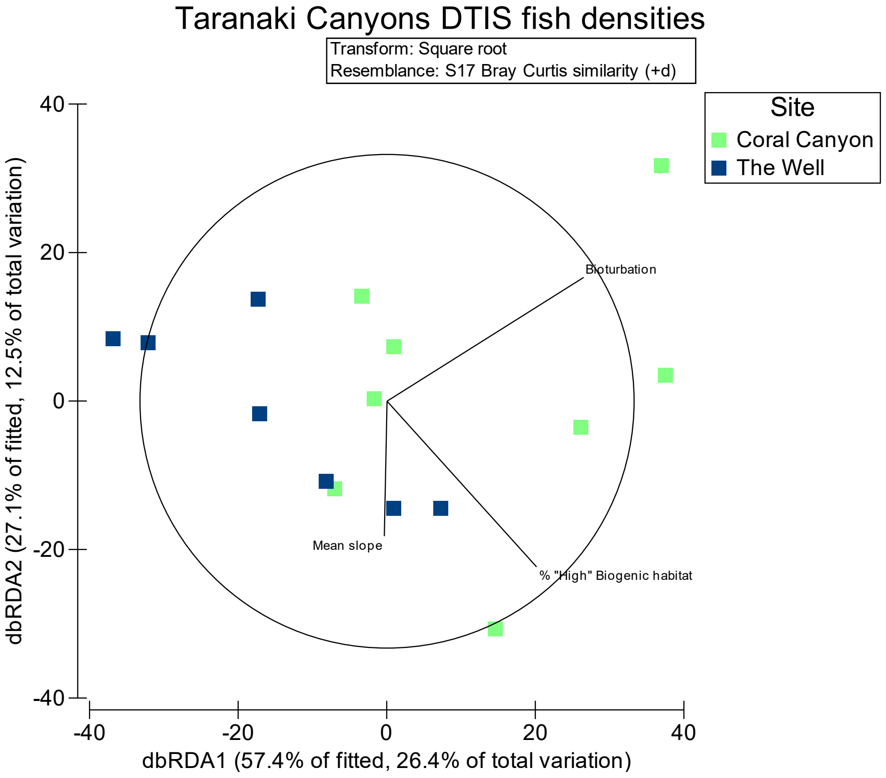


Figure 86: Distance-based redundancy analysis (dbRDA) plot to illustrate the DISTLM model based on the DTIS station fish densities and fitted selected variables with their vector (strength and direction of effect on the ordination plot) displayed. The axis legends include the percentage variation explained by the fitted model and total variation for the first two axes.

4.2 East Coast South Island: North Canterbury Bight, and Hay Paddock

Four sites were identified during the field survey as containing similar biogenic habitat (chaetopterid polychaete meadows), and were grouped together for analysis. Site 20, 21 and 22 were in the North Canterbury Bight, each corresponding to one or more fisher-drawn LEK "*wire-weed*" areas (see Figure 39). The fourth site, (site 23) was located 275 km to the south on the north Otago Shelf. This site overlaid a location known by fishers as the "*The Hay Paddock*", due to the large amount of '*straw-like'* material bought up on trawl gears (Figure 41, Figure 42). Both the "*wire-weed*" and the "*straw*" in these areas refer to chaetopterid worm tubes, and "*wire-weed*" is used as a generic term in this section to refer to all areas. A toal of 28 DTIS transects, 5 biological samples (beam trawls), and 28 sediment samples were collected across the four sites.

Multibeam mapping and topographic features of east coast South Island "wire-weed" beds

Much of the 73.9 km^2 of mapped seafloor at the most northerly site 20, North Canterbury (NC), was composed of mounds, dunes and flat features, occurring as a mosaic, with depth differentials of about 4–6 m over tens to hundreds of metres scale (Figure 87). Large isolated mounds were seen on the eastern side of the block. Examination of slope and rugosity metrics reinforced the patterns of depth variations over small spatial scales, and confirmed that the bathymetric structuring was also distinctive in derived metrics; ranging from a mottled appearance to consistent heavy shading (Figure 87). The derived landscapes of zones and structures also clearly picked up these features as crests, flats, and depressions of various types and scales, including the mounds to the east (classified as 'crests') (Figure 87). There was some indication from DTIS transects crossing these features, that the chaetopterid tubeworm patches were associated with the raised structures.

For the shallower Pegasus Bay (PB) (site 22), transects across four very large overlapping fisher-drawn areas (Figure 39) returned a largely uniform and flat depth gradient with little structuring (Figure 87). However, the multibeam bathymetry revealed the presence of noticeable ‘ripplings’ on the seafloor at some spots, which were targeted with DTIS, and confirmed as wire-weed habitat (Figure 39; larger patch around Stations 156 to 161; much smaller patch around Station 152). These were also apparent on the derived rugosity and slope maps, as mottled/darker areas (Figure 87), similar to that seen at NC. Multibeam artefacts were present on some southern segments of individual transects (bar-code like stripes), and were easily recognisable as such. The BTM zones and structures maps did not detect these small-scale patches (Figure 87).

Site 21 was located on the eastern upper side/end of the Pegasus Canyon (PC) (Figure 39). Sampling here targeted a broad fisher-drawn area around the top of the canyon. The shelf edge was relatively flat, but with some large-scale pocking in the southern part of the mapped block (Figure 88). Four DTIS tows targeted general bottom features (flat areas, and the edge of the shelf drop-off), as no obvious wire-weed like features were apparent from the field multi-beam map. Several of these DTIS tows subsequently revealed small scattered wire-weed patches, often only 1 to 2 m across, with associated mounding at the vertical scale of tens of centimetres. These were at a spatial scale below that which multibeam data could detect, given that the native (‘pixel’) resolution is 25 m^2 (5 × 5 m). Multibeam data derived maps of slope and rugosity indicate some areas of ‘speckling’ that may represent further areas of mounds, (e.g. the inverse crescent shaped area at the top-end of Figure 88 rugosity, 3 km long, 1.9 km^2 extent), but no DTIS ground-truth data are available. The BTM maps of zones and structures did not distinguish these areas from flat and slope forms (Figure 88). Artefacts were also very obvious in the rugosity coverage in the form of a lattice pattern, and were easily identified as such (Figure 88, rugosity).

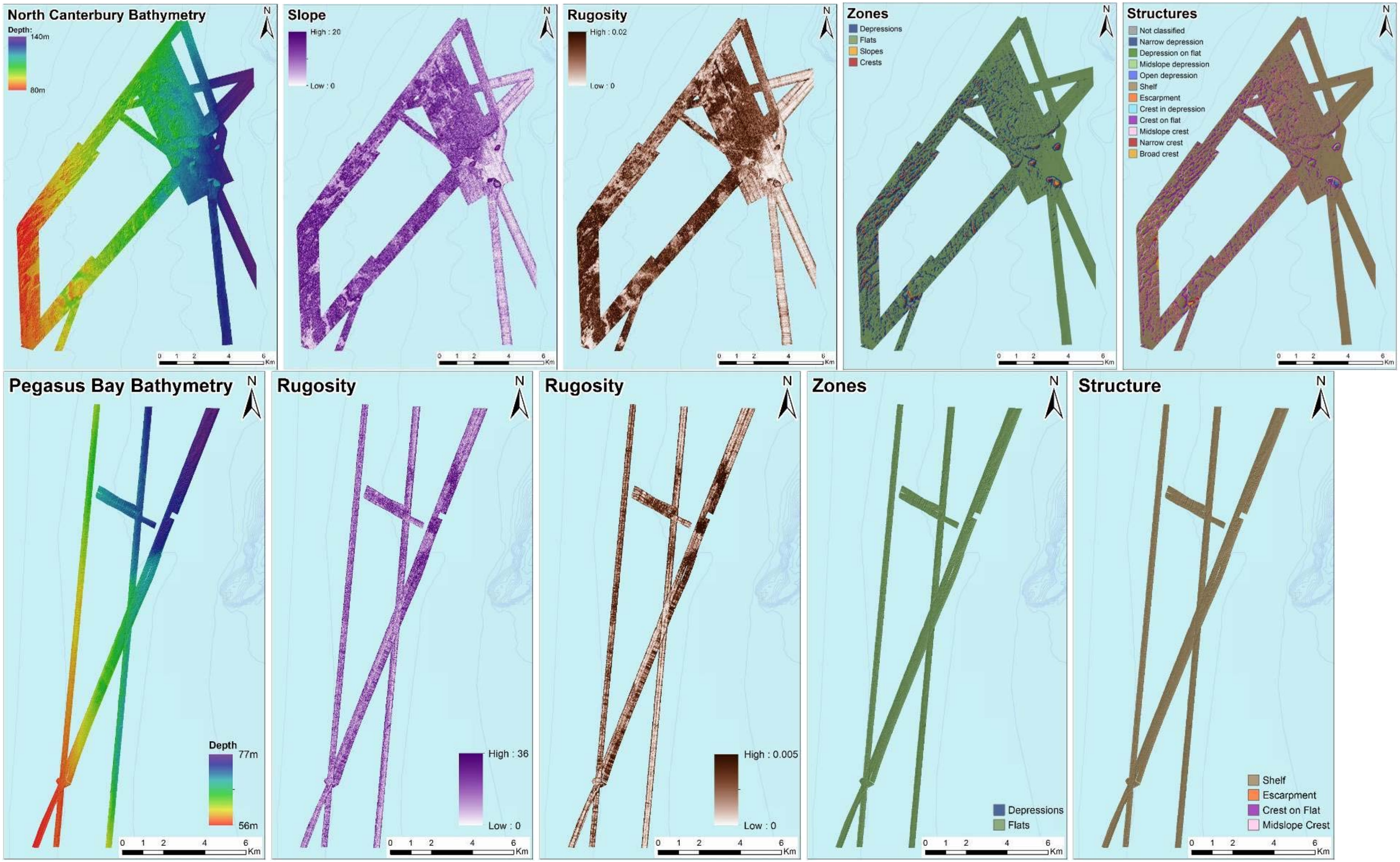


Figure 87: Multi-beam data derived maps for bathymetry, slope, rugosity, BTM zones, and BTM structures for two sites from the east coast South Island "wireweed" Sites: top panel, Site 20, "North Canterbury"; bottom, Site 22, 'Pegasus Bay'.

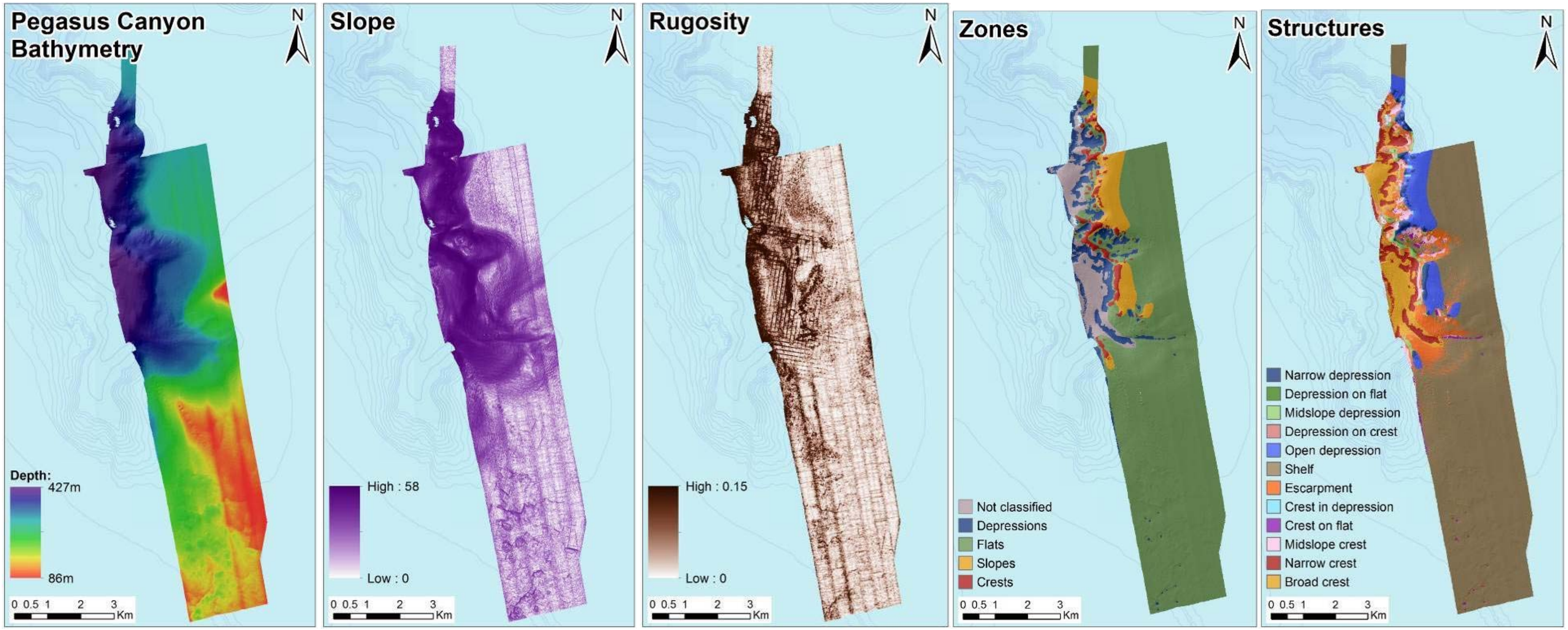


Figure 88: Multi-beam data derived maps for bathymetry, slope, rugosity, BTM zones, and BTM structures for Site 21, “Pegasus Canyon”, from the east coast South island “wireweed” sites.

Invertebrate diversity from biological sampling in the east coast South Island “wire-weed” beds

Three beam trawl samples were collected from site 20 (NC) (79–109 m water depth; Figure 39). Chaetopterid (Spionida) worms were the dominant catch component (see Figure 89, Table 37), followed by holothurians (mainly *Australostichopus mollis*). The chaetopterid worms were initially assumed to be *Phyllochaetopterus socialis* but have subsequently been re-assigned to three new, undescribed species. The dominant species (based on the beam trawl catches) is *Spiochaetopterus spiochaetopterus* A with tubes around 400mm in length and 2-3mm in diameter. A smaller number of two other species were also collected; *Spiochaetopterus spiochaetopterus* B, which has a near “*hair thickness*” tube, and *Phyllochaetopterus phyllochaetopterus* A, with a thicker tube than *Spiochaetopterus* A (G. Read, taxonomist, pers. comm., see Figure 89). Aside from these species, the annelid worms were the most diverse group, with 26 species recorded (including some observed by DTIS such as *Chloeia inermis* and *Megalomma suspiciens*). A high decapod crustacean diversity was also recorded (18 OTUs), including six hermit crab species, the most common being *Lophopagurus foresti* (n=100) and three spider crab species, the most common being *Thacanophrys filholi* (n=181), and *Leptomithrax longipes* (n=164). These relatively high numbers may have resulted from sampling dense aggregations of these species, as observed in one DTIS tow, where the estimated density from one still image was 45 m^{-2}. Other diverse groups included gastropods, bivalves and ascidians, the latter including species recognizable in DTIS images, such as *Cnemidocarpa bicornuta* (n=88) and *C. stewartensis* (n=44), orange *Didemnum sp.*, and *Diplosoam velatum*. Large numbers of *Pyura trita* (n=196) and *P. suteri* (n=90) were also collected. Anemones were abundant, but were not identified to species level due to a shortage of taxonomic expertise for this group, apart from one specimen of *Phellia aucklandia*. Eight species of sponge were recorded, with the most abundant being the golden-coloured tubular *Callyspongia* n. sp. 2 and 11, and the digitate *Dactylia palmata*. A small number of bryozoans were collected, mainly small erect forms encrusting chaetopterid tubes, including *Cellaria tenuirostris* and a new *Galeopsis* species. In addition to decapods and holothurians, other mobile species included echinoderms (e.g. *Odontaster benhami, Sclerasterias mollis*, *Goniocidaris umbraculum*), molluscs (e.g. the gastropods *Calliostoma granti*, *Buccinulum pertinax*, and *Fusitriton laudandus*), and the nudibranch *Chromodoris aureomarginata.*

Figure 89: a) unprocessed beam trawl sample from North Canterbury (NC) (Site 20) containing large volume of wire-weed along with spiny sea dragons, sea perch, yellow weaver, holothurians, starfish, anemones, and gastropods; b) wire-weed after sorting; c) dominant wire-weed species Spiochaetopterus spiochaetopterus A; d) much less common wire-weed species *Phyllochaetopterus phyllochaetopterus* A

No biological samples were collected from the shallow Pegasus Bay area (Site 22).

Two beam trawl samples were collected from the southern and northern end of Pegasus Canyon (Site 21, 86 to 115 m; Figure 39). A similar fauna to that found at North Canterbury was recorded, including the chaetopterid worm *Spiochaetopterus spiochaetopterus* A, as well as large numbers of holothurians (*Australostichopus mollis*, n=59), ascidians (*Synoicum occidentalis,* n=182), decapods (*Leptomithrax longipes*, n=22; *Thacanophrys filholi*, n=19) and anemones (n=74) (Table 37). Bryozoans were more numerous that further north, including the habitat-formers *Celleporina grandis, Hippomenella vellicata, Cinctipora elegans* and *Idmidronea*. The most common sponge was the digitate *Iophon minor* (over 100 small pieces, 860 g), along with *Callyspongia* n. sp. 2.

A single beam trawl sample at the Hay Paddock (Site 23, 80 m, Figure 42) collected *Spiochaetopterus spiochaetopterus* A (over 9 kg), the holothurian *Australostichopus mollis*, and a variety of sponges; including the digitate *Crella incrustans*, the distinctive yellow conulose *Acanthodendrilla*, and 10 new, undescribed species. Bryozoans included *Caberea rostrate, Hornera foliacea* and *Idmidronea*, and ascidians the colonial *Diplosoma velatum* and the solitary *Cnemidocarpa bicornuta*. In addition to holothurians, the mobile fauna included large numbers of decapods (n=398), mainly *Munida gregaria*, and 12 other species, including the nudibranch *Chromodoris aureomarginata.*

Table 37: Biological beam trawl samples from wire-weed sites along the east coast of the South Island, giving the number of species/Operational Taxonomic Units (OTU's) and total weight by Order. The number of samples for each area are given in brackets. No samples were taken at Pegasus Bay.

			North Canterbury (3)		Pegasus Canyon (2)		Hay Paddock (1)	
Phylum	Class	Order	OTU count	Weight (g)	OTU count	Weight (g)	OTU count	Weight (g)
Annelida	Oligochaeta	Euhirudinea	–	–	1	5	–	–
	Polychaeta	Amphinomida	1	5	–	–	–	–
		Eunicida	3	105	2	27	2	40
		Phyllodocida	9	53	5	15	3	5
		Sabellida	4	92	4	53	–	–
		Scolecida	3	<1	–	–	1	<1
		Spionida	3	39 722	1	605	1	9 462
		Terebellida	3	<1	–	–	–	–
	Total		9	39 977	13	705	7	9 507
Arthropoda	Malacostraca	Amphipoda	–	–	1	1	–	–
		Decapoda	18	4 028	10	1 562	13	1 278
	Maxillopoda	Sessilia	–	–	1	5	–	–
	Pycnogonida	Pantopoda	1	4	–	–	–	–
	Total		19	4 032	12	1 568	13	1 278
Bryozoa	Gymnolaemata	Cheilostomata	5	11	2	420	1	<1
	Stenolaemata	Cyclostomata	2	<1	2	400	5	61
	Total		7	11	4	820	6	61
Chordata	Ascidiacea	Aplousobranchia	7	359	3	4 115	3	358
		Phlebobranchia	1	12	–	–	–	–
		Stolidobranchia	5	2 973	3	290	2	1 085
	Thaliacea		–	–	1	4	–	–
	Total		13	3 344	7	4 409	5	1 443
Cnidaria	Anthozoa	Actiniaria	3	5 529	3	5 043	1	754
		Alcyonacea	–	–	1	5	–	–
	Hydrozoa	Leptothecata	4	13	3	16	5	60
	Total		7	5 542	7	5 064	6	814
Echinodermata	Asteroidea	Forcipulatida	1	1 788	2	550	–	–
		Paxillosida			1	210	–	–
		Valvatida	1	160	1	31	1	200
	Echinoidea	Cidaroida	1	622	1	5	–	–
		Temnopleuroida	1	10	1	135	–	–
	Holothuroidea	Apodida	–	–	–	–	1	20
		Aspidochirotida	1	20 473	1	6 754	1	8 800
		Dendrochirotida	2	61	2	16	–	–
	Ophiuroidea	Ophiurida	1	10	1	5	1	8
	Total		8	23 124	10	7 706	4	9 028
Echiura			1	40				
Mollusca	Bivalvia	Myoida	1	1	–	–	–	–
		Mytiloida	1	5	–	–	–	–
		Nuculoidea	1	11	–	–	–	–
		Ostreoida	4	57	3	336	3	30
		Pterioida	1	<1	–	–	–	–
		Veneroida	4	32	–	–	1	10

			North Canterbury (3)		Pegasus Canyon (2)		Hay Paddock (1)	
	Cephalopoda	Octopoda	1	2 550	–	–	–	–
	Gastropoda Caenogastropoda	Littorinimorpha	1	290	1	105	–	–
	Gastropoda Opisthobranchia	Notaspidea	1	<1	–	–	–	–
		Nudibranchia	5	1 220	2	45	4	2 257
	Gastropoda Prosobranchia	Mesogastropoda	4	94	1	12	2	80
		Neogastropoda	6	436	4	38	–	–
		Vetigastropoda	4	308	2	90	–	–
	Total		34	5 004	13	626	11	2 377
Porifera	Demospongiae	Chondrosida	1	29	–	–	–	–
		Dendroceratida	–	–	–	–	5	450
		Dictyoceratida	–	–	1	115	1	<1
		Hadromerida	–	–	–	–	1	3
		Halichondrida	–	–	–	–	2	147
		Haplosclerida	4	5 804	2	285	5	575
		Poecilosclerida	3	216	2	890	4	3 050
	Total		8	6 049	5	1 290	18	4 225
Priapulida	Priapulida		1	5	–	–	–	–
Sipuncula	Sipunculidea		1	1	1	1	–	–
Total			126	87 146	72	22 189	70	2 873

Invertebrate assemblages observed in DTIS imagery from the east coast South Island “wire-weed” sites

Of the 28 DTIS transects from the North Canterbury, Pegasus Canyon, Pegasus Bay, and Hay Paddock sites, still images were unavailable from seven stations due to equipment failure (flash or lasers) (Table 15). From the remaining 21 stations, 671 still images were analysed. This number included every fourth still, with some additional images selected where patches of biogenic habitat were undersampled. The final number of OTUs was 81, following the merging of some groups due to difficulties in consistently visually distinguishing between them (e.g., some sponge and bryozoan species, hermit crabs and anemones). A full OTU list is given in Appendix 4, along with their sessile (a proxy for being a ‘habitat-former’), or mobile group assignment.

An overview of what sessile groups were present and in what percentage occurrence is given in Figure 90. Sessile polychaetes, dominated by chaetopterid tube worms (wire-weed), were recorded in 60–90% of the images from North Canterbury, Pegasus Canyon and the Hay Paddock; and in around 50% of images from Pegasus Bay. The appearance of tubes varied (discussed further below). Aside from chaetopterid tubeworms, ascidians, bryozoans and sponges were important sessile macrofauna. Sponges and ascidians were more frequently observed at the Hay Paddock and North Canterbury; while bryozoans were more frequently observed in Pegasus Bay and Pegasus Canyon (Figure 90).

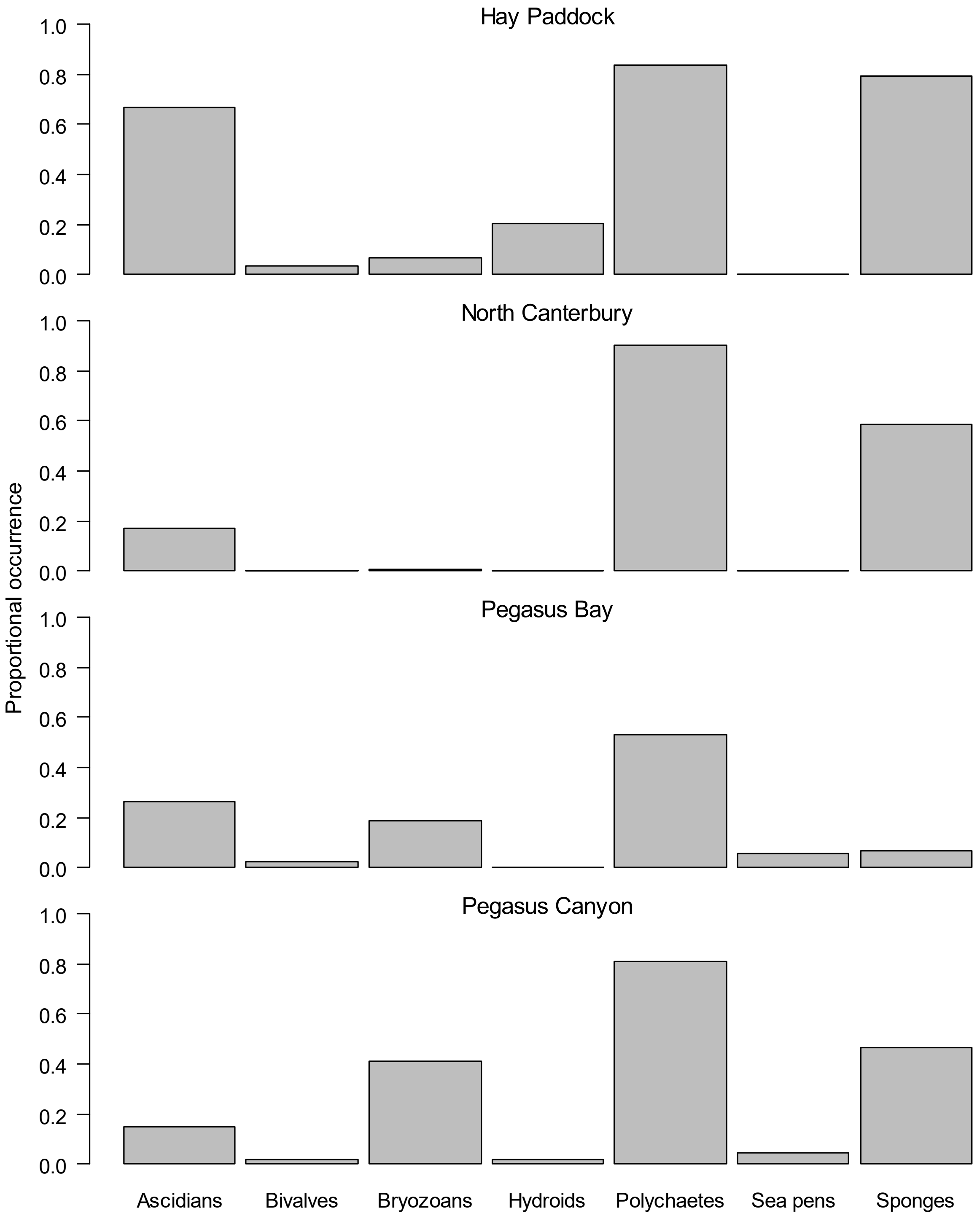


Figure 90: Proportional occurrence in images of key sessile (proxy for habitat-forming) taxonomic groups for the Hay Paddock, North Canterbury, Pegasus Bay, and Pegasus Canyon sites, east coast South Island.

Of the mobile fauna recorded, crabs (mainly hermit crabs), gastropods, and anemones were significant components in all areas (Figure 91). Squat lobsters (probably *Munida gregaria*) were observed in over 60% of images from the Hay Paddock, and holothurians in nearly 20%. Echinoids (likely *Goniocidaris umbraculum*) were more frequently present in images from North Canterbury, asteroids were also more common at this site and at Pegasus Canyon, with the mobile fauna being generally sparser at Pegasus Bay stations (Figure 91).

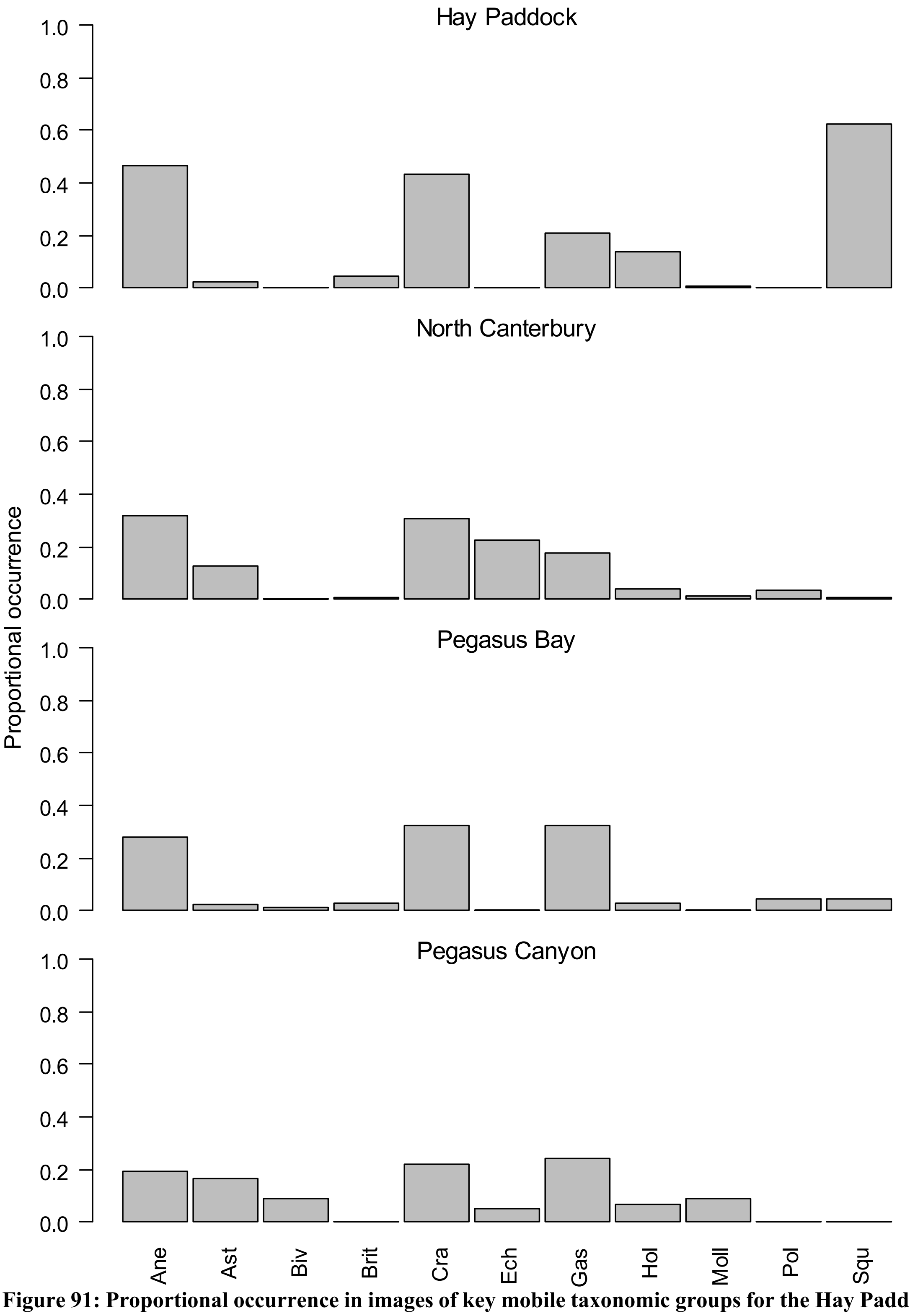


Figure 91: Proportional occurrence in images of key mobile taxonomic groups for the Hay Paddock, North Canterbury, Pegasus Bay and Pegasus Canyon sites, east coast South Island. Ane=Anemones, Ast = Asteroids, Biv = Bivalves, Brit = Brittle stars, Cra = Crabs, Ech = Echinoids, Gas = Gastropods, Hol = holothurians, Moll =Molluscs, Pol = Polychaetes, Squ = Squat lobsters.

The appearance of the chaetopterid worm tubes observed in still images varied; in some transects, the worm tubes appeared to be largely buried in the sediment, whist in others, they were more visible above the surface (up to 8–10 cm in length). In some places, worm tubes were 'clumped' together, sometimes forming extensive 'meadows'. In other areas, worm tubes appeared sparse, or were observed as singletons. Tubeworm abundance was quantified as an area coverage, with the variations in appearance captured using categories as outlined in Table 38 and examples in Figure 92. In all of the biological samples collected across the wire-weed sites, *Spiochaetopterus spiochaetopterus* A, was always the dominant (or only) species identified. A small number of the other two species (*Phyllochaetopterus phyllochaetopterus A*, *Spiochaetopterus spiochaetopterus B*) were found at North Canterbury. Given the taxonomic identifications (confirmed after completion of image analysis), and lack of clear ability to assign visual categories to different species, it was assumed that *S. spiochaetopterus* A was the main tubeworm observed in all areas, and all analysis based on the premise of there being one dominant species. Within the North Canterbury and Hay Paddock areas, tubeworms were observed in around 80–90% of images, and were categorized mainly as long (more emergent), clumped, and in either medium or high density beds (Figure 93). Within the Pegasus Bay and Pegasus Canyon areas, tubeworms were less abundant, but still observed in 55% and 65% of images respectively. In these areas, the worm tubes were categorized mainly as 'short' (more buried) and 'sparse', with fewer images sampling denser 'clumped' beds.

Table 38: Descriptive categories used to class Chaetopterid tubeworm beds observed in images from east coast South Island sites.

Chaetopterid tubeworm Categories	Description
Short, low density, clumped Short, low density, sparse	Tubes nominally protruding <2.5 cm above sediment. Up to 10 individuals per 0.2 m^2. Either clumped or sparse.
Short, medium density, clumped Short, medium density, sparse	Tubes nominally protruding <2.5 cm above sediment. Around 11–50 individuals per 0.2 m^2. Either clumped or sparse.
Short, high density, clumped Short, high density, sparse	Tubes nominally protruding <2.5 cm above sediment. Greater than 50 individuals per 0.2 m^2. Either clumped or sparse.
Long, low density, sparse Long, low density, clumped	Tube length above sediment >2.5 cm, up to 10 individuals per 0.2 m^2. Either clumped or sparse.
Long, medium density, clumped	Around 11–50 individuals per 0.2 m^2. Only clumped distribution observed.
Long, high density, clumped	Greater than 50 individuals per 0.2 m^2. Only clumped distribution observed.

Figure 92: Variation in chaetopterid tube worm appearance from east coast South Island sites. a) short, medium–high density, clumped (Station 156); b) short, low density, sparse (Station 25); c) long, medium–high density, clumped (Station 9); d, e) long, medium, clumped (Station 169); f) long, high, clumped (Station 156); g) long, high, clumped; h) long, medium, clumped.

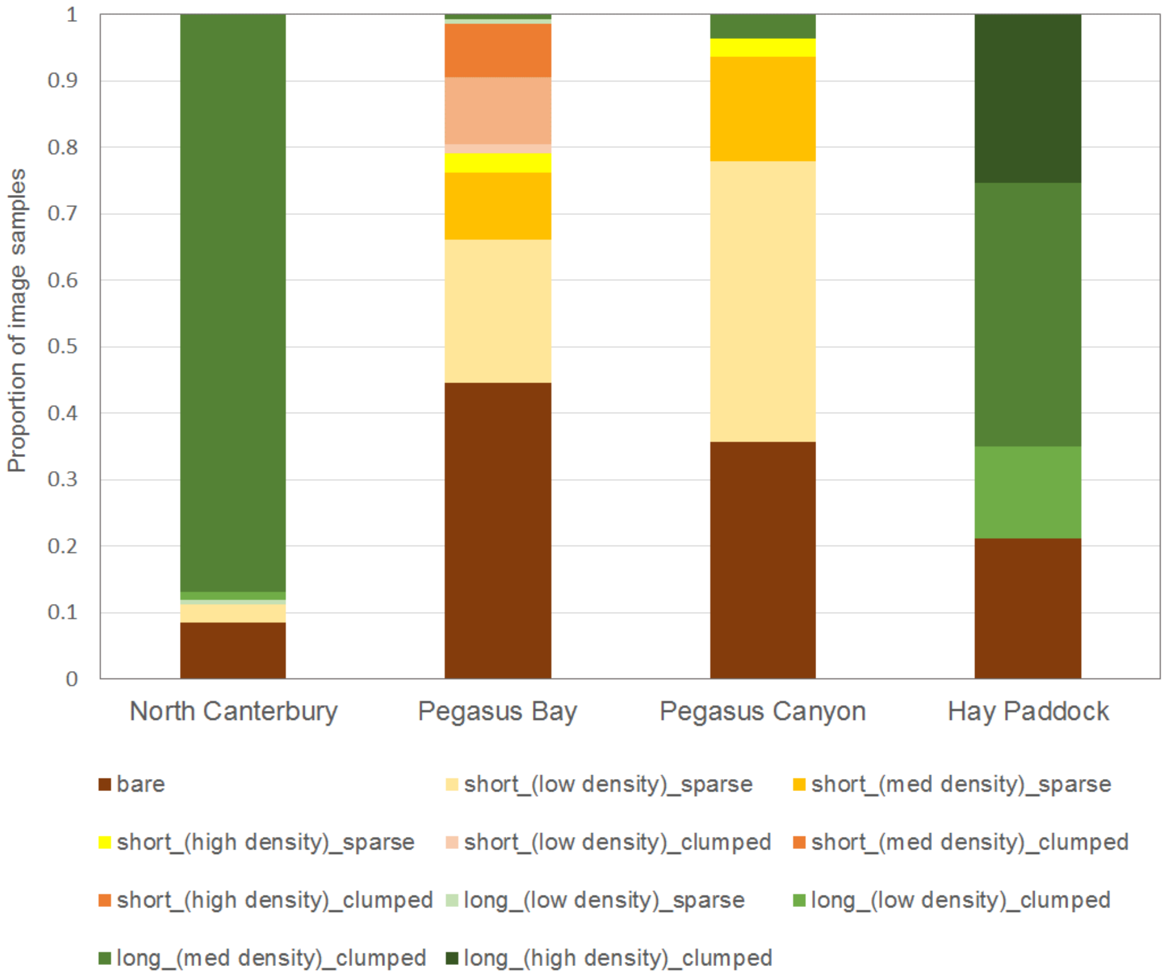


Figure 93: Variation in dominant chaetopterid tube worm categories, summed across images, for the four sites sampled from the east coast South Island.

Non-hierarchical cluster analysis of benthic fauna observed from the east coast South Island "wire-weed" sites.

Non-hierarchical cluster analysis was carried out using both the full community and sessile fauna datasets from all four sites combined.

Full community data

For the full community data, 12 images were excluded as they were devoid of fauna. K-means cluster analysis (with *k* set to between 1 and 50) on the alternate Gower dissimilarity matrix of standardized data gave clustering results varying from 8 to 26 groupings, with SSI values ranging from 0.26 to 0.335. The SSI indices and BTSS/TSS ratios were highest for 12 and 14 groups (Table 39, Figure 94). Using the cascade-KM function, clustering analysis was performed for *k* = 2–20, along with the SSI criterion. For the full community data set, 12 and 14 partitions again gave the highest values of SSI after 100 iterations (number of random starting configurations for each value of *k*), with group, or cluster membership ranging from 7 to 104 samples (Figure 95). ANOSIM identified significant differences between the clusters for both 12 and 14 groups, but the global R value was higher for 12 groups). However, around a third of all pair-wise comparisons between groups were not significant.

Table 39: Summary of non-hierarchical cluster analysis of biological community data observed from the east coast South Island "wire-weed" sites. SSI criterion, BTSS/TSS ratio and global R values from ANOSIM tests are presented for the three different data sets and for different partition scenarios considered.

Data matrix	No of Clusters	SSI value*	BTSS/TSS	ANOSIM
Full community	8	0.154 / 0.275	88.9%	R = 0.064, P=0.001
	10	0.193 / 0.278	89.6%	R = 0.005, P=0.222
	12	0.267 / 0.324	90.1%	R = 0.127, P=0.001
	14	0.257 / 0.335	90.6%	R = 0.084, P=0.001
Sessile community	7	0.198 / 0.357	90.0%	R=0.362, P=0.001
	8	0.271 / 0.352	92.7%	R=0.411, P=0.001
	9	0.269 / 0.348	91.1%	R=0.413, P=0.001
	10	0.279 / 0.312	93.8%	R=0.456, P=0.001
Sessile community P/A	5	0.295 / 0.340	77.2%	R = 0.621, P=0.001
	8	0.292 / 0.389	83.2%	R = 0.713, P=0.001

*SSI values from cascadeKM/single k-means partitioning routines.

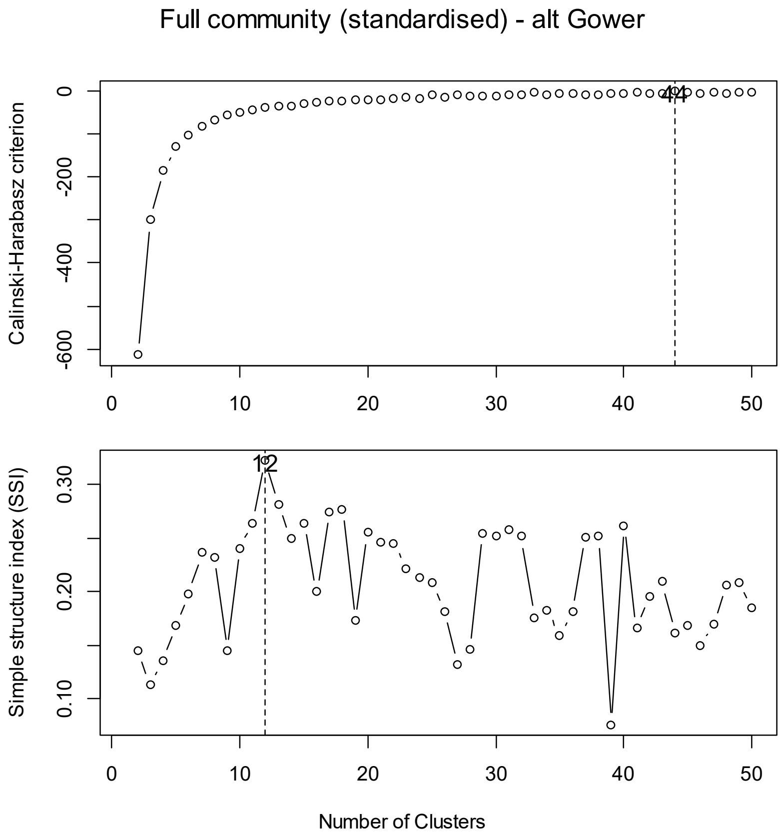


Figure 94: Results of k-means cluster analysis of full community biota observed in DTIS images from the east coast South Island "wire-weed" sites, with the number of groups giving optimum values for the Calinski-Harabasz criterion (upper) and Simple Structure Index (SSI) (lower).

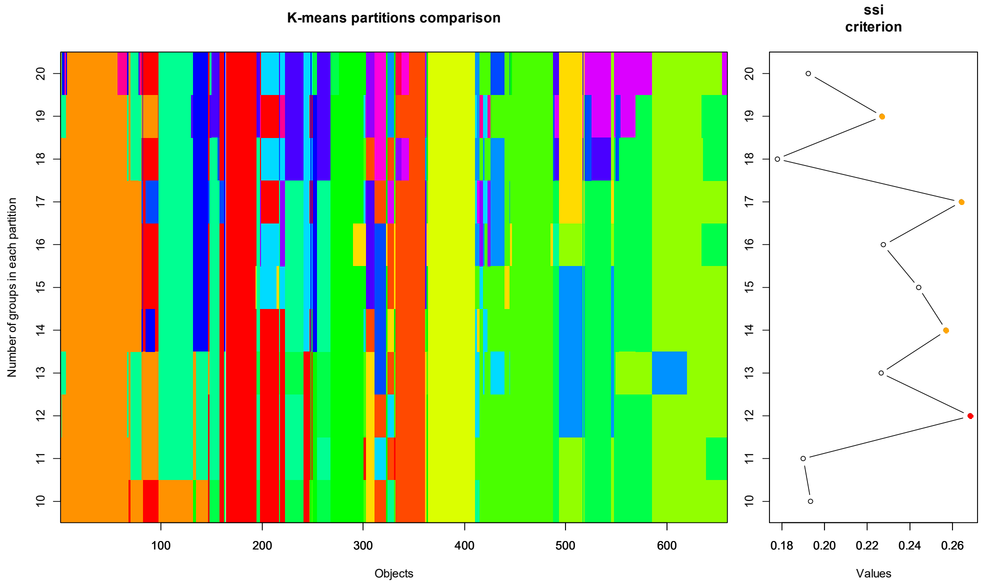


Figure 95: k-means cascade plot of cluster analysis of the full community dataset from the east coast South Island "wire-weed" sites, showing the group each 'object' (image sample) was assigned to for each partition (left), and the associated SSI criterion (right). The maximum SSI criterion value is indicated in red.

Sessile (habitat-formers) data

Forty-two out of the overall 81 OTUs were classed as sessile fauna, including ascidians, sponges, bryozoans, the horse mussel *Atrina zelandia*, hydroids, and serpulid and chaetopterid worms. Using these sessile OTUs only, 79 images were dropped from the data-set as they did not contain any sessile fauna. The k-means cluster analysis on the alternate Gower dissimilarity matrix of standardized sessile community data gave results varying from 6–10 groups, all with SSI values of > 0.30 (Table 39, Figure 96). Using the cascade-KM function, set between two and twenty groups, the optimum number of groups was estimated at 10, with an SSI of 0.28 (Figure 97). ANOSIM identified significant global differences between 7, 8, 9 and 10 groupings, but with increasing numbers of non-significant pairwise comparisons. Cluster analysis was also run on presence/absence sessile data. Clusters of between five and nine were identified, with maximum SSI values for five and eight. The cascade-KM routine identified five groups as optimal, and ANOSIM returned significant differences between all groups (Table 39).

Given the aim of describing biogenic habitats, we chose the sessile fauna abundance/cover dataset as the most appropriate to process further with analysis. After exploration of the species data using SIMPER, a seven cluster grouping was selected as optimal. Figure 98 shows the non-metric MDS plot of the sessile fauna only data set, labelled by site/the seven clusters, although the high stress value indicates this plot needs to be viewed cautiously.

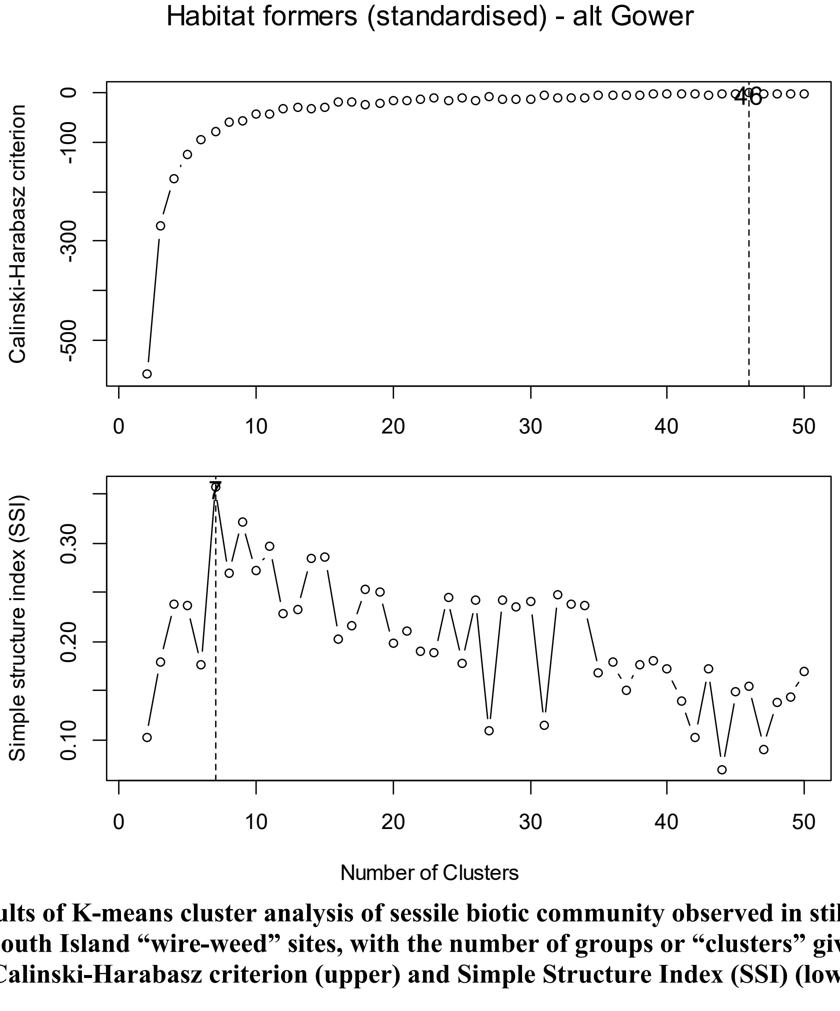


Figure 96: Results of K-means cluster analysis of sessile biotic community observed in still images from the east coast South Island “wire-weed” sites, with the number of groups or “clusters” giving optimum values for the Calinski-Harabasz criterion (upper) and Simple Structure Index (SSI) (lower).

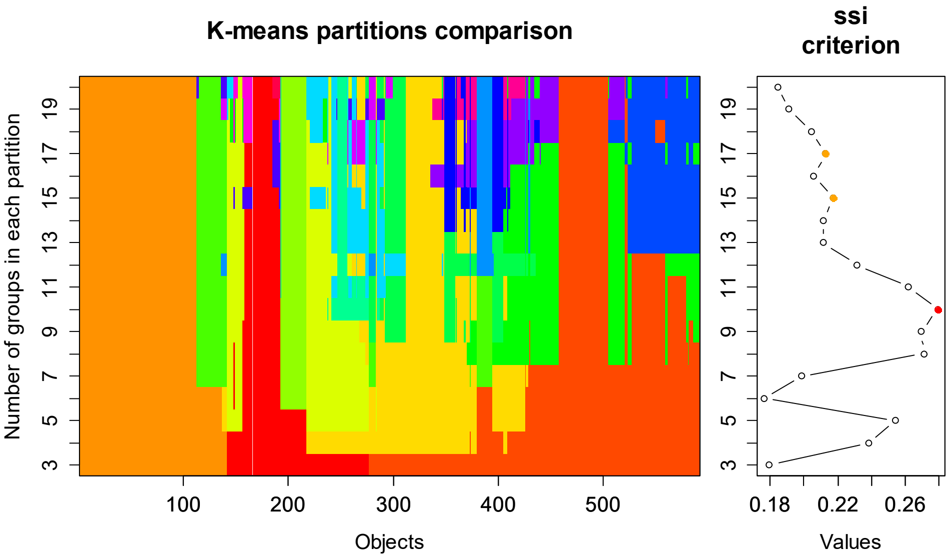


Figure 97: K-means cascade plot of cluster analysis of sessile biotic community observed from the east coast South Island "wire-weed" sites showing the group each 'object' (image sample) was assigned to for each partition (left) and the associated SSI criterion (right). The maximum SSI criterion value is indicated in red.

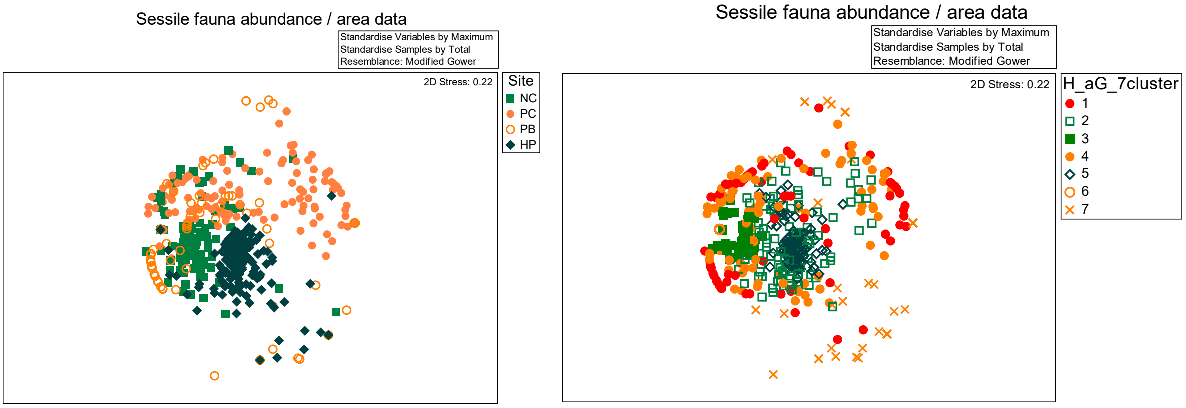


Figure 98: MDS plot of all image samples from the east coast South Island "wire-weed" sites identified by site (left): North Canterbury (NC), Pegasus Canyon (PC), Pegasus Bay (PB) and Hay Paddock (HP), and by sessile community clusters (right).

The percentage occurrence of key taxonomic groups within these seven community clusters is given in Figure 99. Tubeworms were present in over 80% of the images within Clusters 1 to 6, and 26% in Cluster 7. The dominant tube-worm 'type' varied (Figure 100), along with the frequency of occurrence and diversity of key associated sessile faunal groups (sponges, ascidians, and bryozoans) (Figure 99).

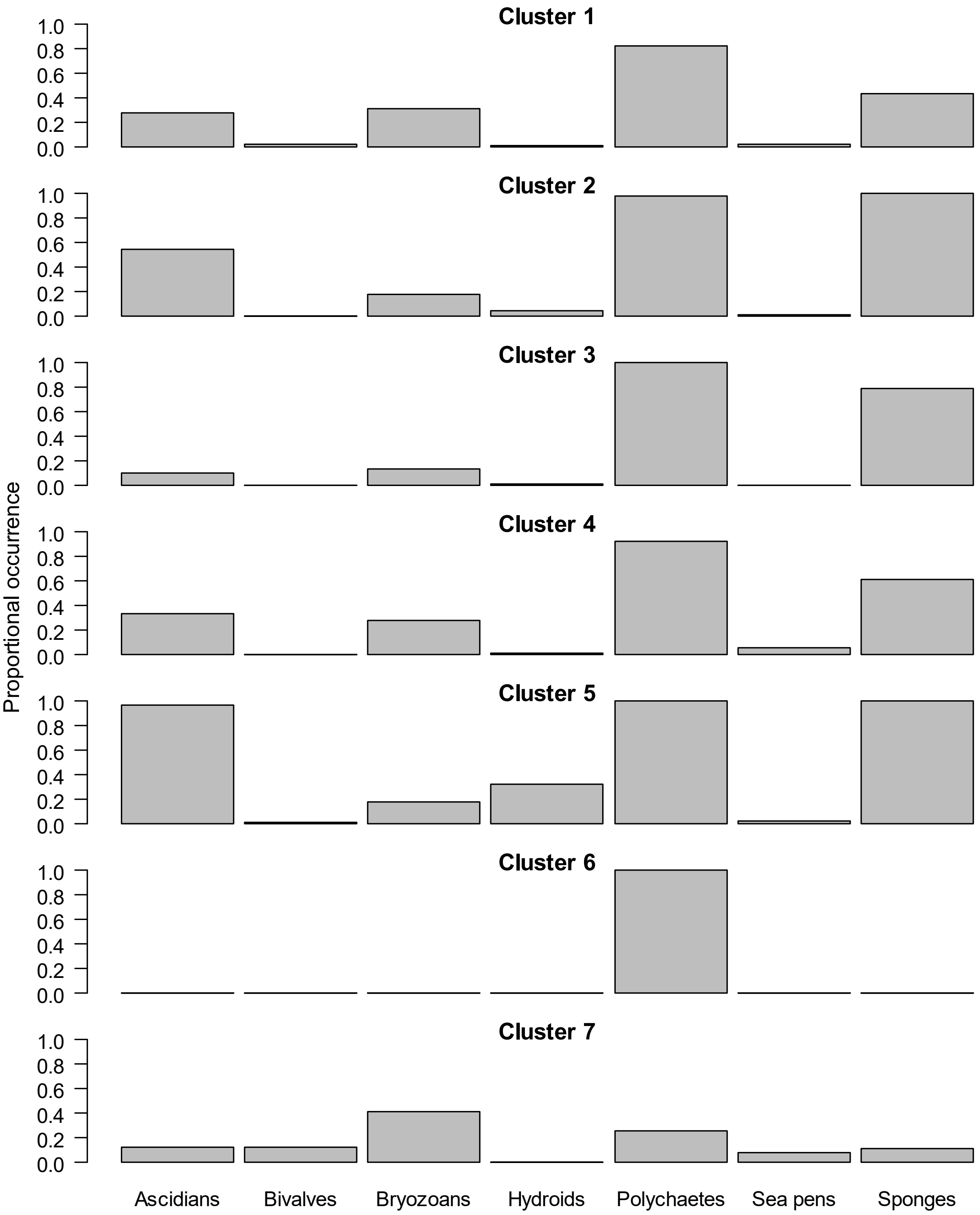


Figure 99: Proportional occurrence of different sessile taxonomic groups, assigned across the seven faunal clusters identified by non-hierarchical clustering of community data from east coast South Island "wire-weed" sites.

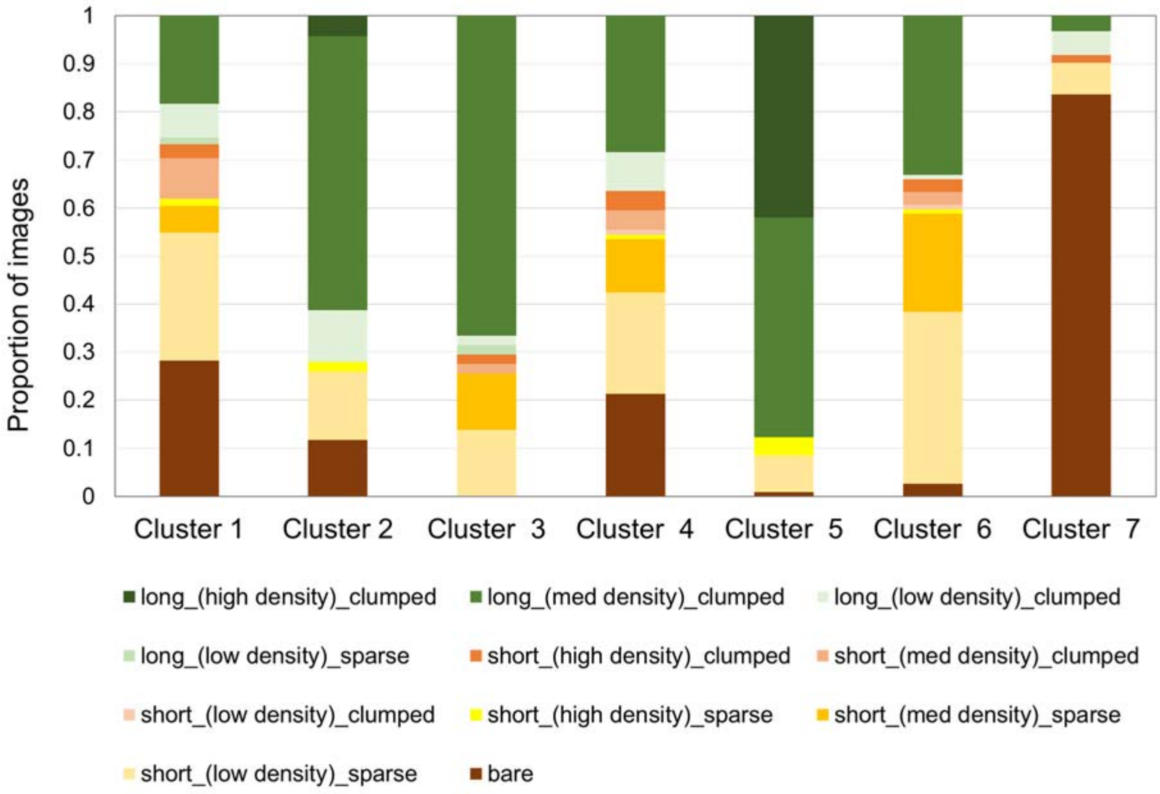


Figure 100: Variation in dominant chaetopterid tube worm category assigned to images within each of the seven sessile-fauna clusters identified from the east coast South Island "wire-weed" sites.

Most cluster types were found at all four sites, but certain clusters were more common in particular areas (Table 40). For example, Clusters 3 and 5 were mainly from North Canterbury and the Hay Paddock respectively, and were dominated by the more emergent (longer), clumped form of worm tubes, and their associated distinguishing fauna. Clusters 2 and 5 were characterized by higher species richness (4.9, 8.2 per image respectively), with sponges present in all, or almost all samples, and a mixture of ascidians (both solitary *Cnemidocarpa* sp., and orange colonial *Didemnidae* sp.) observed in 55 and 96% of images respectively. In general, variations in OTU identities and coverage for tube-worms, sponges and ascidians were the main cluster separators. Cluster 6 was defined by the almost complete dominance of tub-worms with no other significant fauna, while Cluster 7 had relatively few tube-worms, and was defined by the presence of mixed bryozoans, horse mussels, and the solitary ascidian *Cnemidocarpa* sp. (Table 40). Some species images are given in Figure **101**.

Table 40: Dominant contributing species for each cluster, as identified by SIMPER, from the east coast South Island "wire-weed" sites. The number of images assigned to each cluster (by area) is also given.

Habitat cluster 0: Bare sediment, no sessile fauna.

Images	NC	PB	PC	HP	Main species	Av. Value	% Cont.	Cum. %
79	25	12	40	2		–	–	–

Cluster 1: chaetopterid worms present in around 70% of images, mainly 'short', i.e., buried worm tubes, with the median proportional cover being low (<10%). More common at Pegasus Bay and Pegasus Canyon stations. Other sessile species contributing to the within group similarity included the unidentified 'grey ball' ascidian, serpulid and sabellid worms, and small bryozoan clumps with encrusting sponges. Mean species richness: 2.1 ± 0.05.

Images	NC	PB	PC	HP	Main species	Av. Value	% Cont.	Cum. %
71	12	21	27	11	ASC 70 (unidentified ascidian)	12.8	14.1	14.1
					Megalomma suspiciens (sabellid polychaete)	11.6	12.8	26.9
					Bryozoan mixed sp.	12.5	11.5	38.4
					Euryspongia sp. 5 (sponge)	4.7	6.4	44.8
					Protula bispiralis (serpulid polychaete)	4.32	5.5	50.3

Cluster 2: chaetopterid worm beds present in 88% of images, mostly classed as long and clumped. Median proportional cover was around 20%. Other contributing species included ascidians, serpulid worms and a distinctive red sponge (*Raspailia* sp. / *Crella incrustans*) encrusting the worm tubes. Mean species richness: 4.9 ± 0.09.

Images	NC	PB	PC	HP	Main species	Av. Value	% Cont.	Cum. %
93	27	2	25	39	*Cnemidocarpa* sp. (solitary ascidian)	11.6	15.6	15.6
					Didemnidae orange (colonial ascidian)	5.9	10.1	25.8
					Chaetopteridae (tubeworms)	18.9	9.9	35.7
					Raspailia sp. / *Crella incrustans* (sponge)	4.2	5.9	41.6
					Protula bispiralis (serpulid polychaete)	2.9	5.4	47.0
					Euryspongia sp. 5 (sponge)	4.8	5.2	52.2

Cluster 3: chaetopterid worm beds present in all images, most described as long and clumped, with the highest median proportional coverage (>40%). Mainly found at North Canterbury. Sponges dominated the other contributing species, including encrusting finger and palmate sponges such as *Callyspongia* n. sp. 2, 11 and 12, *Chondropsis* n. sp. 2, *Raspailia* sp. / *Crella incrustans* (red form) and *Leucettusa tubulifera*, as well as solitary ascidians (*Cnemidocarpa* sp.). Mean species richness: 2.3 ± 0.07.

Images	NC	PB	PC	HP	Main species	Av. Value	% Cont.	Cum. %
51	35	7	8	1	Chaetopteridae (tubeworms)	86.4	31.4	31.4
					Callyspongia n. sp. 2, 11 and *Chondropsis* n. sp. 2 (sponges)	4.3	12.7	44
					Raspailia sp. / *Crella incrustans* (sponge)	1.7	9.0	53.1
					Callyspongia n. sp. 12 (sponge)	0.9	5.8	58.9

Cluster 4: more common at Pegasus Canyon, 80% of images had tubeworms, with median proportional coverage of around 30%, but most were categorized as short and sparse. Apart from chaetopterid worms, solitary ascidians and sabellid worms contributed to within group similarity, along with encrusting sponges typically associated with mixed bryozoan clumps (*Euryspongia* sp. 5 and *Halichondria* cf sp.). Mean species richness: 2.9 ± 0.07.

Images	NC	PB	PC	HP	Main species	Av. Value	% Cont.	Cum. %

99	22	19	45	13	Chaetopteridae (tubeworms)	29.6	13.5	13.5
					ASC 70 (unidentified ascidian)	6.7	7.9	21.4
					Megalomma suspiciens (sabellid polychaete)	7.0	6.8	28.2
					Cnemidocarpa sp. (solitary ascidian)	5.1	6.2	34.4
					Euryspongia sp. 5 (encrusting sponge)	4.8	5.5	39.8
					Euthyroides jellyae (bryozoan)	2.9	5.3	45.2
					Halichondria cf sp. (encrusting sponge)	3.8	5	50.2

Cluster 5: This class was largely found at the Hay Paddock, with tubeworms observed in almost all images (median coverage of around 30%), and dominated by long, clumped forms which were ‘encrusted’ with a diverse variety of colonial ascidians and finger sponges, including the distinctive ‘orange, scrappy’ *Hymeniacidon perleve*. The feathery hydroid, *Crateritheca* sp., also contributed to within group similarity. Mean species richness: 8.2 ± 0.14.

Images	NC	PB	PC	HP	Main species	Av. Value	% Cont.	Cum. %
105	2	–	18	85	*Crateritheca* sp.	8.2	12.6	12.6
					Cnemidocarpa sp. (solitary ascidian)	9.7	10.1	22.6
					Didemnidae orange (colonial ascidian)	3.9	8.6	31.2
					Callyspongia n. sp. 2 and 11 (and *Chondropsis* n. sp. 2) (encrusting sponge)	9.7	7.0	38.2
					Chaetopteridae (tubeworms)	13.1	6.8	44.9
					Hymeniacidon perleve (encrusting sponge)	3.2	4.9	49.8

Cluster 6: Images in this class, observed most commonly at Pegasus canyon and North Canterbury, contained tubeworm cover in 97% of samples, mostly the short, buried type, with a median coverage of around 20%, but with few other sessile, encrusting species observed. Mean species richness: 1.

Images	NC	PB	PC	HP	Main species	Av. Value	% Cont.	Cum. %
112	39	23	48	2	*Chaetopteridae* (tubeworms)	100	100	100

Cluster 7: Chaetopterid tubeworms were absent from over 80% of images in this class, found mainly at Pegasus Canyon and Pegasus Bay sites. Small clumps of mixed bryozoans (including species such as *Celleporaria agglutinans, Cellaria immersa, Adeonellopsis sp., Cinctipora elegans*), horse mussels, and solitary ascidians contributed a combined 50% to the within group similarity, with serpulid polychaetes and a small unidentified orange sea pen also observed in a number of images. Mean species richness: 1.2 ± 0.05.

Images	NC	PB	PC	HP	Main species	Av. Value	% Cont.	Cum. %
61	4	27	17	13	Bryozoan mixed *sp.*	40.7	30.7	30.7
					Atrina zelandia (horse mussel)	13.1	14.6	45.4
					Cnemidocarpa sp. (solitary ascidian)	8.1	9.4	54.8

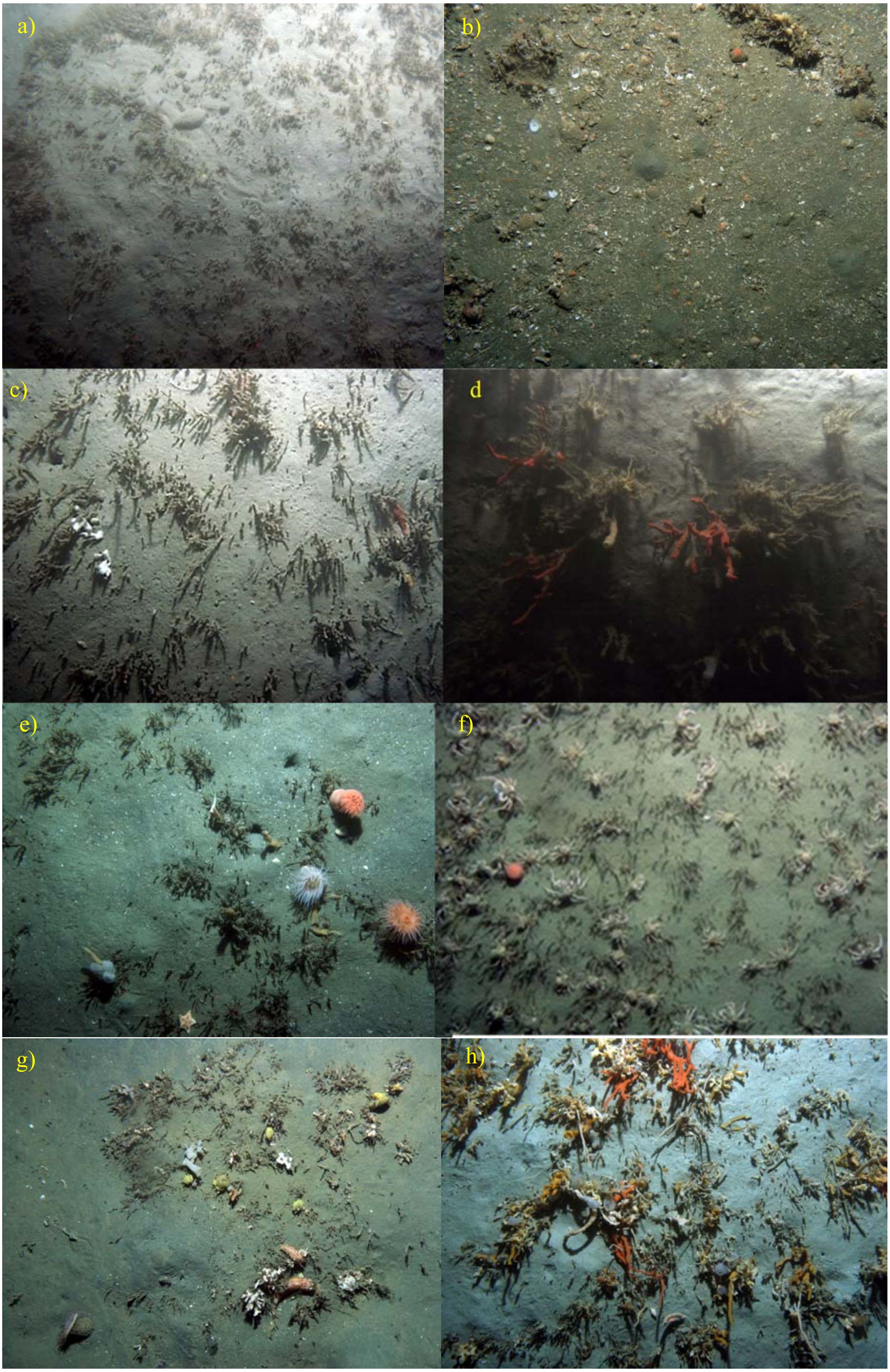

a)
b)
c)
d
e)
f)
g)
h)

Figure 101: Examples of epifauna observed in images from the east coast South Island "wire-weed" sites (a) Cluster 4 type habitat with short (buried) chaetopterid tube worms and unidentified ascidian (ASC 70), Pegasus Bay. (b) Cluster 1 type assemblage with mixed bryozoan species encrusted with *Euryspongia* sp. 5, Pegasus Canyon. (c) & (d) Cluster 3 type habitats at North Canterbury: long tube worms with encrusting sponges: *Raspailia sp.* / *Crella incrustans* (red) and *Leucettusa tubulifera* (white), *Chondropsis* n. sp. 2 (thin strongyles) or *Callyspongia (Callyspongia)* n. sp. 2. Examples of mobile fauna, North Canterbury; e) wandering anemones amongst clumped tubeworms with encrusting sponges, (f) dense aggregation of spider crabs *Leptomithrax longipes. (g)* sea cucumber, yellow weaver on Cluster 5-type patch of tubeworms at Pegasus Canyon with mixed sponges including *Callyspongia stellata* (white), and yellow ascidians (?*Synoicum occidentalis*). (h) Cluster 5 type habitat at the Haypaddock with tubeworms heavily encrusted with diverse sponges. Examples: (i) *Hymeniacidon perleve* (foliose/palmate peach sponge in centre), *Callyspongia* n. sp. 12 (palmate, upper right), and *Chondropsis* n sp. 7 (thin spaghetti-like sponge, to the lower right of *H. perleve*), ?*Crella incrustans* (darker orange digitate sponges). (j) *Acanthodendrilla* n. sp. 3 (yellow spiky mass) (k) *Crella* n. sp. 3 (knotty spaghetti mass) (l) *Haliclona* n. sp. 18 (fat spaghetti strings).

Twenty sponge OTUs were present in the tubeworm habitats (Table 41). The most frequently observed sponge OTU overall, and in Clusters 1 to 4, was a group of three putatively new species; *Callyspongia* n. sp. 2, 11, and *Chondropsis* n. sp. 2. These golden or cream-coloured tubular sponges, with either single or multiple oscules, were also sampled in the beam trawls from North Canterbury (all species) and Hay Paddock (*Callyspongia sp.* only).

Another yellow/orange digitate sponge OTU, thought to be either *Iophon cf. minor*, *Crella incrustans*, and/or *Paraesperella* sp. was also widespread, and in the top three species for Clusters 2, 3, 4, 5 and 7. Other relatively common 'finger' sponges included the palmate *Callyspongia* n. sp. 12, the more foliose *Hymeniacidon perleve* and *Halisarca dujardini*, and the ‘spaghetti-like’ *Chondropsis* n. sp. 7. Other distinctive encrusting sponge species included *Euryspongia* sp. 5, described as “*soft, sticky and mushy*”; and the pinkish coloured *Tedania* sp. and *Dysidea* sp., which were observed more frequently in Clusters 1 and 4, where they were often encrusting either chaetopterid tubes or small clumps of bryozoans.

Table 41: Percentage occurrence of dominant sponge species, and average cover per standardised square metre in images grouped by the seven sessile faunal clusters identified from the east coast South Island “wire-weed” sites.

Cluster	Species Richness	Key species	% occurrence	Average cover per m^2
All	20	*Callyspongia* n. sp. 2, 11 / *Chondropsis* n. sp. 2	32.3	0.0067
		Iophon cf. minor / *Crella incrustans* / *Paraesperella* sp.	26.9	0.0050
		Hymeniacidon perleve	16.9	0.0020
		Haliclona n. sp. 18	14.2	0.0016
		Halisarca dujardini and *Chondropsis* n. sp. 7	13.2	0.0006
0	0	–	–	–
1	14	*Callyspongia* n. sp. 2, 11 / *Chondropsis* n. sp. 2	8.5	0.0017
		Callyspongia n. sp. 12	5.6	0.0002
		Tedania sp. / *Dysidea* sp.	5.6	0.0002
2	16	*Callyspongia* n. sp. 2, 11 / *Chondropsis* n. sp. 2	53.8	0.0065
		Iophon cf. minor / *Crella incrustans* / *Paraesperella* sp. 2	50.5	0.0044
		Hymeniacidon perleve	31.2	0.0027
3	9	*Callyspongia* n. sp. 2, 11 / *Chondropsis* n. sp. 2	56.9	0.0014
		Iophon cf. minor / *Crella incrustans* / *Paraesperella* sp.	15.7	0.0005
		Raspailia sp. / *Crella incrustans*	9.8	0.0001
4	15	*Callyspongia* n. sp. 2, 11 / *Chondropsis* n. sp. 2	21.2	0.0021
		Iophon cf. minor / *Crella incrustans* / *Paraesperella* sp.	14.1	0.0006
		Euryspongia sp. 5	13.1	0.0003
5	19	*Iophon cf. minor* / *Crella incrustans* / *Paraesperella* sp.	81.9	0.0233
		Callyspongia n. sp. 2, 11 / *Chondropsis* n. sp. 2	80.0	0.0283
		Hymeniacidon perleve	60.9	0.0086
6	0	–	–	–
7	6	*Halisarca dujardini* and *Chondropsis* n. sp. 7	3.3	0.003
		Iophon cf. minor / *Crella incrustans* / *Paraesperella* sp.	1.6	0.0001
		Xestospongia corallodies	1.6	0.0001

Mobile fauna

The occurrence of key mobile faunal groups in image samples within each of the seven clusters is presented in Figure 102. Crabs (dominated by hermit crabs) and anemones were observed in around 20 to 50% of images, across all clusters. Squat lobsters (probably *Munida gregaria*) were particularly abundant in Cluster 5 (counted in 60% of images) and, to a lesser extent, Cluster 2. Gastropods were observed in between 15–30% of images, and were dominated by the whelks *Austrofusus glans* and *Fusitriton laudandus,* and the turret shell, *Maoricolpus roseus.*

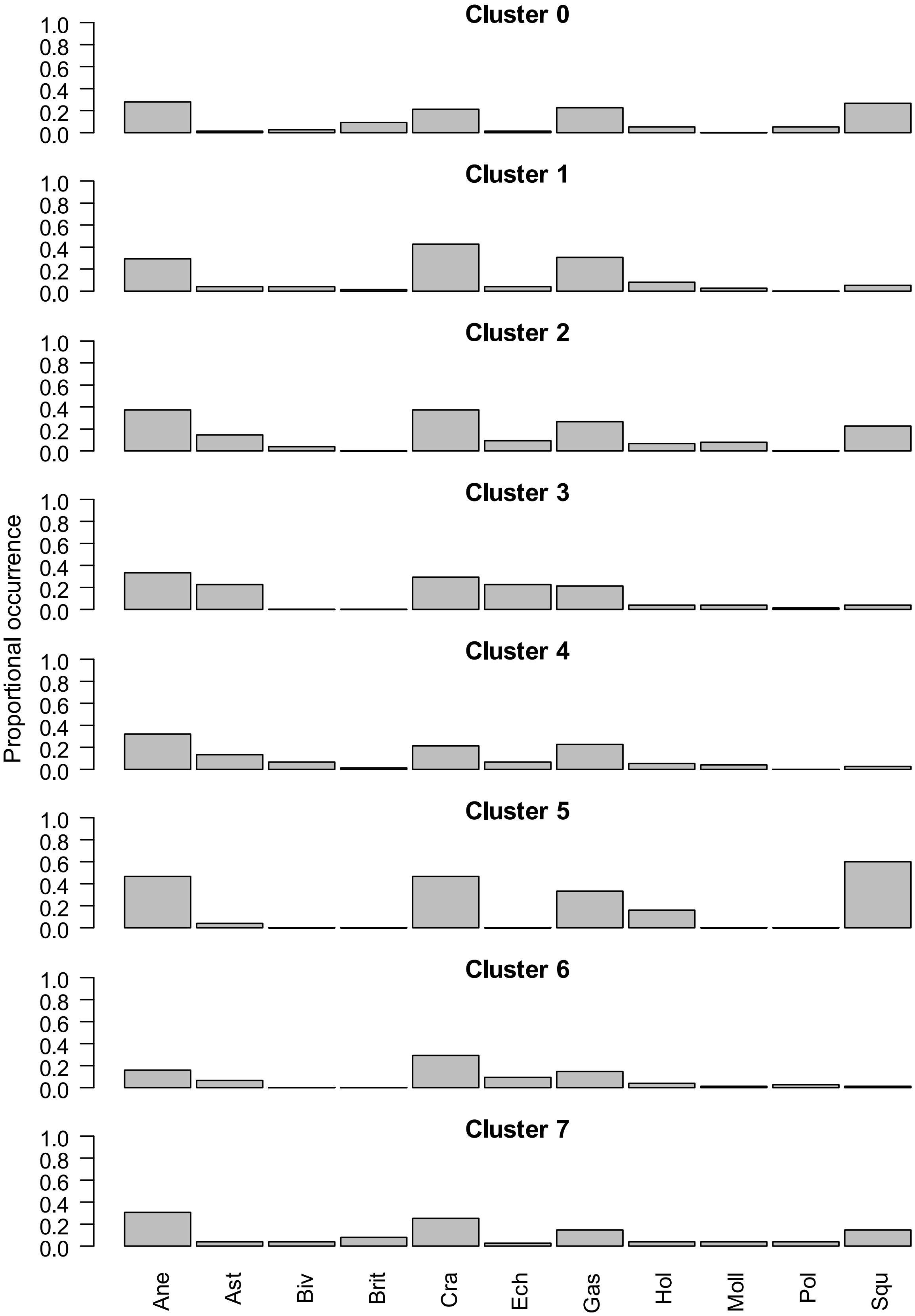


Figure 102: Proportional occurrence of different mobile taxonomic groups, assigned across the seven sessile faunal clusters, and bare sediment (Cluster=0) identified by non-hierarchical clustering from the east coast South Island "wire-weed" sites, and bare substrate (Habitat Cluster 0). Ane=Anemones, Ast = Asteroids, Biv = Bivalves, Brit = Brittle stars, Cra = Crabs, Ech = Echinoids, Gas = Gastropods, Hol = holothurians, Moll =Molluscs, Pol = Polychaetes, Squ = Squat lobsters.

Relationships between benthic community, remote sensing and other potential explanatory variables for east coast South Island “wire-weed” sites.

Multibeam-derived metrics were generated for the North Canterbury, Pegasus Canyon and Pegasus Bay areas, but not the Hay Paddock. Some DTIS transects partially fell outside the multibeam coverage; those images without underlying multibeam data were not used in the analysis.

Full community

DISTLM results using the full community dataset (sessile and mobile species combined) and multibeam derived variables alone showed that the best fit was obtained using three of the five predictor variables (depth, zone and rugosity), although even combined, these explained only 6.6% of the total variation in the data, with the first two axes accounting for just over 6% (Table 42). Depth was the most important of these predictor variables, explaining 4.7% of the variation along the first axis of the distance-based redundancy analysis, whilst BTM zone (1.3%) and BTM rugosity (1%) were both correlated with the second axis. The BTM zone categories 1 and 4 equated to low relief depressions and crests respectively, and were in the same direction of affect as rugosity in the ordination plot, whilst the effect of the zone 2 category, reflecting flatter areas, was in the opposite direction. This separation of relatively more undulating terrain from flatter areas might have been expected to separate out samples classed as denser tubeworm habitat, e.g. Clusters 2, 3 or 5, but this was not apparent in the dbRDA. Including a categorical variable to identify the three regional sites sampled, resulted in zone and rugosity being left out, and gave a modest improvement, explaining just over 11% of the total variation across three axes (Table 42). By including bioturbation level and tubeworm type categorical variables derived from the images, the final model retained tubeworm type (14.4%), region (2.7%) and depth (0.7%), to give the optimum model which explained nearly 18% of the total variation in the full community data (Table 42, Figure 103). In the ordination plot, the tubeworm type categories were approximately correlated with the regional categories; North Canterbury and ‘long clumped’ vectors acting in a similar direction, whilst vectors for Pegasus Canyon and ‘bare’, and the ‘short’ tubeworm categories and Pegasus Bay were in approximately similar orientations.

Table 42: Summary of step-wise DISTLM models fitted to the east coast South Island full community data. Explanatory terms used are listed in the first column. Marginal proportion (proportion explained by the term in isolation) is given for all terms in the second column, with sequential proportions for each model given in following columns. The total cumulative proportion explained by each model is also given, along with the improvement made as terms are added. (-) indicates that a term is not included in that model, (ns) indicates that a term was included, but dropped from the final model.

Term	Marginal Prop.	Multibeam only	Multibeam + Site	Multibeam + Site + Tubeworm Type+ Bioturbation
				Sequential Prop.
Tubeworm Type	0.144	–	–	0.144 (1)
Site	0.047	–	0.047 (2)	0.027 (2)
Depth	0.047	0.047 (1)	0.047 (1)	0.007 (3)
Slope	0.010	ns	ns	Ns
Rugosity	0.010	0.010 (2)	ns	Ns
Zone	0.013	0.009 (3)	ns	Ns
Structure	0.023	ns	ns	Ns
Bioturbation	0.020	–	–	Ns
Cumulative Prop.		0.0659	0.111	0.178
Improvement			0.0451	0.067

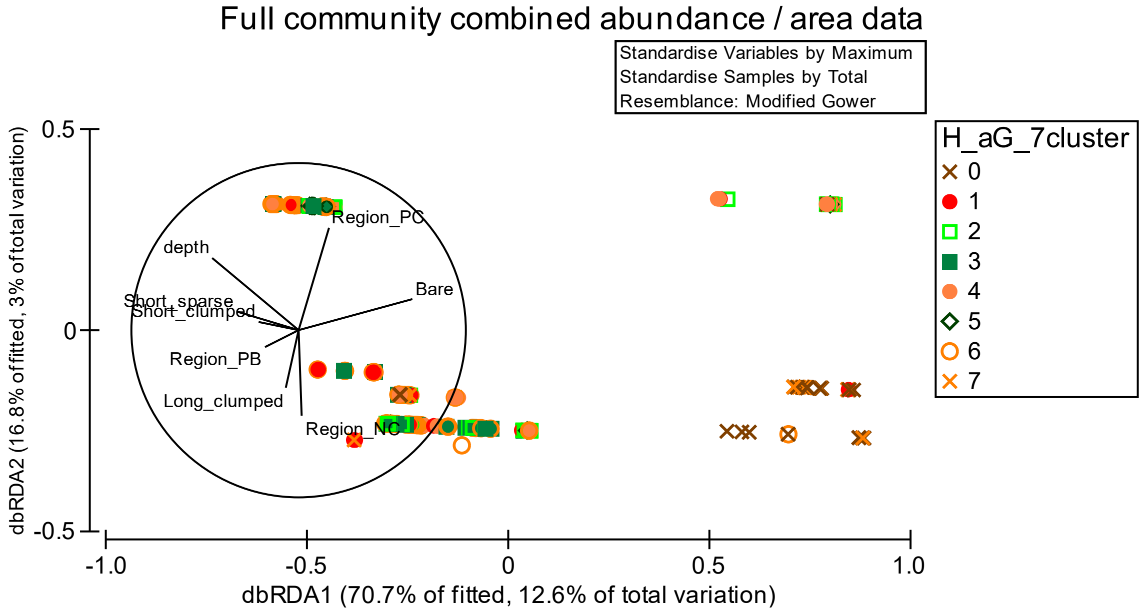


Figure 103: Distance-based redundancy analysis (dbRDA) plot to illustrate the DISTLM model based on the east coast South Island full community data set and fitted multibeam, site identifier (PC = Pegasus Canyon, PB = Pegasus Bay, NC = North Canterbury), and biological variables (Tube types: bare, short_sparse, short_clumped and long_clumped). The axis legends include the percentage variation explained by the fitted model and total variation for the first two axes. Image samples are labelled according to the cluster groupings defined using the sessile-only database.

Sessile fauna only

The same process was repeated using the sessile-only community data (i.e. images devoid of sessile fauna excluded). Using only the multibeam-derived variables, the three continuous terms were retained in the model, but explanatory power was low (just over 7%), with depth followed by rugosity being the strongest predictors (Table 43). These two predictors were retained in the model which included a regional categorical variable, increasing the amount of variation explained to 21.3%. Adding in categorical terms relating to the levels of bioturbation in the sediment, and the dominant tube worm morphology, gave a final model which included the same variables as for the previous model (tube worm type, region and depth), and explained nearly 29% of the total variation in the sessile community data (Table 43, Figure 104).

Table 43: Summary of step-wise DISTLM models fitted to the east coast South Island sessile community data. Explanatory terms used are listed in the first column. Marginal proportion (proportion explained by the term in isolation) is given for all terms in the second column, with sequential proportions for each model given in following columns. The total cumulative proportion explained by each model is also given, along with the improvement made as terms are added. (-) indicates a term is not included in that model, (ns) indicates a term was included, but dropped from the final model.

Term	Marginal Prop.	MB only	MB + Site	MB + Site + Bioturbation + Tubeworm Type.
		Sequential Prop.		
Tubeworm type	0.261	–	–	0.261 (1)
Site	0.071	–	0.071 (1)	0.017 (2)
Depth	0.048	0.048 (1)	0.138 (2)	0.011 (3)
Rugosity	0.019	0.019 (2)	0.004 (3)	ns
Slope	0.019	0.006 (3)	ns	ns
Structure	0.033	ns	ns	ns
Zone	0.024	ns	ns	ns
Bioturbation	0.038	–	–	ns
Cumulative prop.		0.074	0.213	0.289
Improvement			0.139	0.076

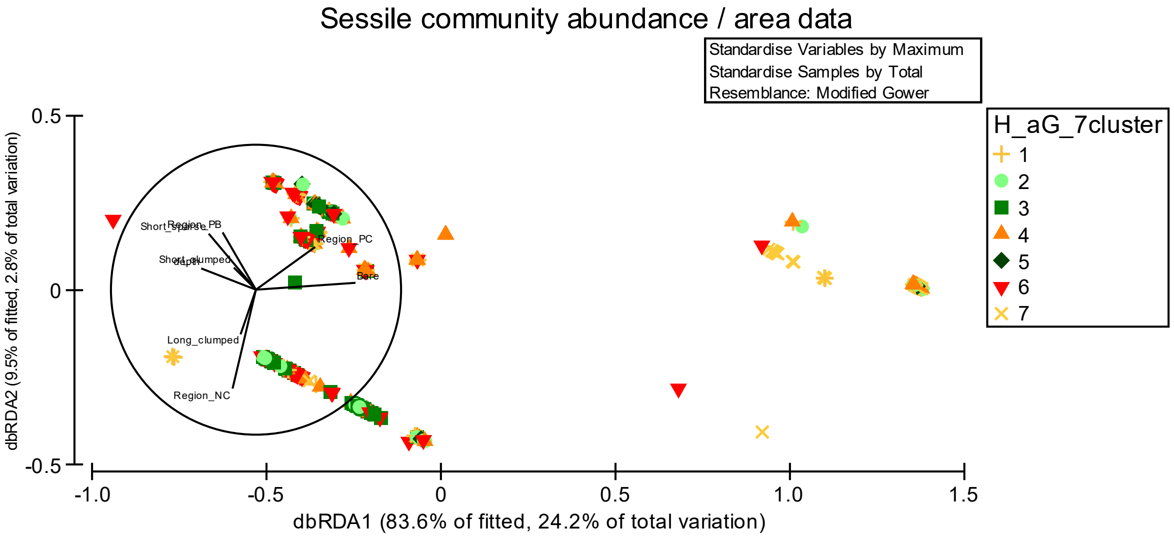


Figure 104: Distance-based redundancy analysis (dbRDA) plot to illustrate the DISTLM model based on the east coast South Island sessile community data and fitted multibeam, site identifier (PC = Pegasus Canyon, PB = Pegasus Bay, NC = North Canterbury), and biological variables (Tube types: bare, short_sparse, short_clumped and long_clumped). The axis legends include the percentage variation explained by the fitted model and total variation for the first two axes. Image samples are labelled according to the cluster groupings defined using the sessile-only database.

Fish diversity and abundance observed at east coast South Island "wire-weed" sites.

Biological samples (beam trawl)

Eighteen species of fish were identified from North Canterbury (Table 44), including a specimen of a new triplefin species (*Ruanoho* n. sp.) previously only recorded off the upper eastern North Island coast in 2009. Sea perch (*Helicolenus percoides*) were the most abundant fish caught at North Canterbury stations, ranging in length from 32–235 mm, followed by at least two species (*Hemerocoetes macrophthalmus* and *H. pauciradiatus*) of opal-fishes (some specimens not identified to species), ranging in length from 52–182 mm. A number of elasmobranch egg cases were also recorded (not identified to species). At Pegasus Canyon, 10 species were identified, including two species not seen at North Canterbury (hoki and the Chatham Rise deep-water triplefin), with opal-fish (*H. macrophthalmus* and *H. monopterygius*) being the most abundant species caught at these stations (length range 122–190 mm) (Table 44). Small fish caught at the Hay Paddock included a number of species common to the wire-weed habitats further north, such as sea perch, opal-fish, red cod, and spiny sea dragon, as well as an additional species of triplefin (yellow and black triplefin, *Forsterygion flavonigrum*), capro dory, and lemon sole (Table 44). Egg cases (from carpet sharks and rough skate) were also collected.

Table 44: Fish species captured by beam trawl at three of the east coast South Island "wire-weed" sites along the east coast of the South Island. Numbers in brackets are number of sample tows. *[1], New, undescribed species.

Species common name	Scientific name	North Canterbury (3)	Pegasus Canyon (2)	The Hay Paddock (1)	Total
Sea perch	*Helicolenus percoides*	320	11	4	335
Opalfish	*Hemerocoetes macrophthalmus*, *H. monopterygius*, *H. pauciradiatus, others?*	21	37	1	59
Witch	*Arnoglossus scapha*	10	4	1	15
Spiny sea dragon	*Solegnathus spinosissimus*	12	–	2	14
Red cod	*Pseudophycis bachus*	2	5	1	8
Crested bellows fish	*Notopogon lilliei*	7	–	–	7
Yellow and black triplefin	*Forsterygion flavonigrum*	–	–	4	4
Ocellate triplefin	*Apopterygion oculus*	1	1	1	3
Sea horse	*Hippocampus abdominalis*	3	–	–	3
Chatham deep-water triplefin	*Matanui bathytaton*	–	3	–	3
Red scorpion-fish	*Scorpaena papillosa*	3	–	–	3
Southern pigfish	*Congiopodus leucopaecilus*	2	–	–	2
Ling	*Genypterus blacodes*	1	1	–	2
Electric ray	*Torpedo fairchildi*	–	2	–	2
Triplefin	Tripterygiidae	2	–	–	2
Capro dory	*Cyttus novaezealandiae*	–	–	1	1
Dragonet	*Foetorepus cf. phasis*	1	–	–	1
Giant stargazer	*Kathetostoma giganteum*	1	–	–	1
Hoki	*Macruronus novaezelandiae*	–	1	–	1
Yellow weaver	*Parapercis gilliesi*	1	–	–	1
Lemon sole	*Pelotretis flavilatus*	–	–	1	1
Triplefin*[1]	*Ruanoho* n. sp.	1	–	–	1
Species richness		18	10	9	23
Total catch		388	65	16	469

The only fish caught in substantial numbers were sea perch. Juveniles dominated the catches, with possibly three juvenile cohorts visible (Figure 105). Size at maturity has been estimated at between 15–20 cm for females and 19–25 cm for males, and around 5–7 years old (Paul & Francis 2002). Few fish in this older size range were sampled.

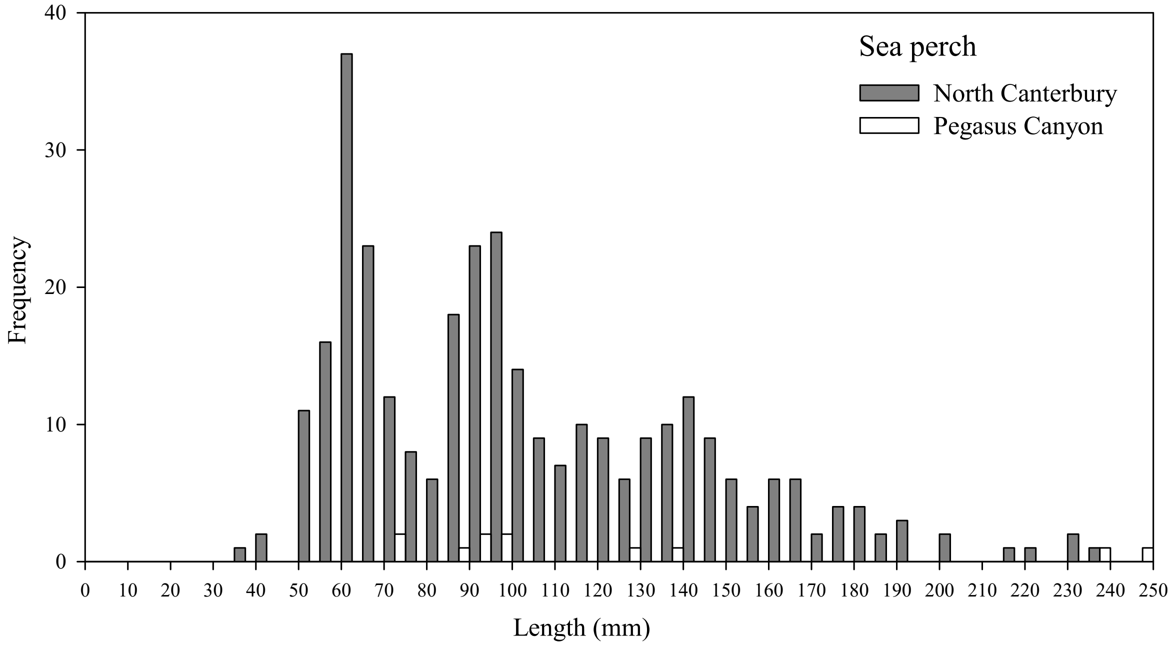


Figure 105: Sea perch length frequency distribution from beam trawl samples at two east coast South Island "wire-weed" sites; North Canterbury and Pegasus Canyon.

DTIS (video)

Video was analysed from 22 DTIS stations in the Canterbury Bight, and six stations at the Hay Paddock. Fish counts were aggregated at the transect level, and are presented as numbers of fish per 1000 m^2 (Table 45). Overall, 22 individual species were identified from the four regions, along with 4 broader OTUs (Macrouridae / 'rattails', unidentified eels (possibly a snake or worm eel species such as *Scolechenchelys breviceps*), rays, and flatfish). From 12 to 16 species (up to 17 OTUs) were identified within each region, with the highest number at the Hay Paddock, and the lowest in Pegasus Bay. The highest fish densities were observed in the North Canterbury area, with over 1000 fish seen (excluding small pelagic fish such as myctophids), dominated by large numbers of sea perch, with densities of up to 176 individuals per 1000 m^2 (Table 45). The next most commonly observed species was tarakihi, followed by crested bellows fish and southern bastard cod. Of note, wire-weed is also called 'tarakihi-weed' by some fishers, as this species is often caught in association with it.

At the shallower sites in Pegasus Bay, visibility was poor at a number of stations and fish densities were lower, but may have been underestimated (Table 45). Far fewer sea perch were counted, with cucumber fish, opal-fish and scaly gurnard the most commonly observed species. The maximum density for a species was around 50 fish per 1000 m^2 for cucumber fish on one transect. In the deeper waters around the Pegasus Canyon, opal-fish and rattails were the most abundant fish counted, with densities of up to 33 individuals per 1000 m. Further south at the Hay Paddock, overall fish densities were low compared to North Canterbury, with sea perch being the dominant species, followed by cucumber-fish and crested bellow-fish (Table 45).

Table 45: Fish densities per 1000 m^2 estimated from DTIS video transects from east coast South Island “wireweed” sites. The top five species for each areas are shaded. Density is given with an associated standard error. Ind.; individuals. *, fisheries species.

		North Canterbury			Pegasus Bay			Pegasus Canyon			Hay Paddock		
Common name	Scientific name	Density	Range	Ind.	Density	Range	Ind.	Density	Range	Ind.	Density	Range	Ind.
Sea perch*	*Helicolenus percoides*	126.28 ± 10.15	90.1–175.7	846	3.72 ± 1.82	0–10.8	15	2.34 ± 1.62	0–10.2	15	27.94 ± 9.79	6.6–71.8	117
Opalfish	*Hemerocoetes* spp.	0.32 ± 0.21	0–1.4	3	8.36 ± 3.42	2.2–27.7	33	17.71 ± 4.77	0–32.7	100	–	–	–
Cucumber-fish	*Paraulopus nigripinnis*	1.48 ± 0.61	0–5.5	9	10.1 ± 7.1	0–51.80	46	1.30 ± 0.90	0–5.7	7	11.54 ± 6.32	0–39.4	51
Rattail	Macrouridae	–	–	–	0.31 ± 0.31	0–2.2	1	20.2 ± 3.78	10.7–3.6	122	–	–	–
Southern bastard cod	*Pseudophycis barbata*	2.82 ± 0.86	0–7.2	19	2.29 ± 1.31	0–8.9	6	2.93 ± 2.01	0–12.5	15	8.27 ± 3.97	0–25.4	35
Crested bellows fish	*Notopogon lilliei*	3.07 ± 1.06	0–7.6	21	–	–	–	0.38 ± 0.38	0–2.3	2	10.08 ± 4.46	0–27.4	41
Scaly gurnard	*Lepidotrigla brachyoptera*	0.99 ± 0.42	0–3.0	6	7.86 ± 3.21	0–23.02	31	0.36 ± 0.36	0–2.4	2	2.74 ± 1.44	0–9.2	12
Tarakihi*	*Nemadactylus macropterus*	5.66 ± 1.38	0–10.4	41	2.2 ± 2.2	0–15.4	10	0.63 ± 0.63	0–3.8	4	3.15 ± 1.08	0–7.8	13
Barracouta*	*Thyrsites atun*	0.19 ± 0.19	0–1.8	1	7.26 ± 4.85	0–35.4	29	–	–	–	–	–	–
Flatfish (unid)		1.30 ± 0.52	0–3.5	7	3.33 ± 1.41	0–10.8	14	–	–	–	1.33 ± 0.84	0–4.1	6
Trevally*	*Caranx georgianus*	0.60 ± 0.60	0–4.8	2	0.46 ± 0.46	0–3.2	2	0.43 ± 0.43	0–2.6	2	2.06 ± 1.20	0–7.9	9
Spiny sea-dragon	*Solegnathus spinosissimus*	1.79 ± 0.50	0–3.5	13	–	–	–	–	–	–	1.58 ± 0.75	0–5.0	6
Witch	*Arnoglossus scapha*	0.43 ± 0.23	0–1.8	3	0.91 ± 0.91	0–6.4	4	0.16 ± 0.16	0–0.9	1	2.10 ± 0.82	0–5.0	8
Ling*	*Genypterus blacodes*	1.64 ± 0.77	0–7.0	9	0.45 ± 0.29	0–1.6	2	–	–	–	0.69 ± 0.48	0–2.8	3
Carpet shark	*Cephaloscyllium isabellum*	–	–	–	0.21 ± 0.21	0–1.4	1	–	–	–	1.55 ± 0.57	0–3.4	6
Blue cod*	*Parapercis colias*	–	–	–	–	–	–	0.46 ± 0.29	0–1.5	4	1.25 ± 0.44	0–2.7	5
Red gurnard*	*Chelidonichthys kumu*	0.14 ± 0.14	0–1.1	1	1.17 ± 0.94	0–6.7	4	–	–	–	0.22 ± 0.22	0–1.3	1
Eels (unid)		0.60 ± 0.60	0–4.8	2	0.52 ± 0.35	0–0.2	2	–	–	–	–	–	–
Rough skate*	*Dipturus nasutus*	–	–	–	–	–	–	0.08 ± 0.08	0–0.5	1	0.22 ± 0.22	0–1.3	1
Pigfish	*Bodianus unimaculatus*	–	–	–	–	–	–	–	–	–	0.23 ± 0.23	0–1.4	1
Scarlet wrasse	*Pseudolabrus miles*	–	–	–	–	–	–	–	–	–	0.23 ± 0.23	0–1.4	1
Rays (unid)		0.22 ± 0.22	0–1.8	1	–	–	–	–	–	–	–	–	–
Yellow weaver	*Parapercis gilliesi*	0.12 ± 0.12	0–1.1	1	–	–	–	0.08 ± 0.08	0–0.5	1	–	–	–
Silver conger eel	*Gnathophis habenatus*	–	–	–	–	–	–	0.19 ± 0.19	0–1.2	1	–	–	–
Unidentified fish				21			45			7			4
Species/OTU richness				17			15			14			17

A cluster analysis of the group-average Bray-Curtis similarity matrix and similarity profile (SIMPROF) test of the combined fish community dataset from all four regions (excluding pelagic species), found that the 35–40% similarity level, four groups were identified as significantly different from each other (at p=0.05 level) (Figure 106a). Cluster A held all of the Pegasus Canyon stations, and two from Pegasus Bay. Cluster D held only Pegasus Bay stations, while Cluster C contained only two stations from the Hay Paddock. Cluster B was a mixture of North Canterbury and Hay Paddock stations. An MDS of the same data showed similar separations, and contributing species (Figure 106b).

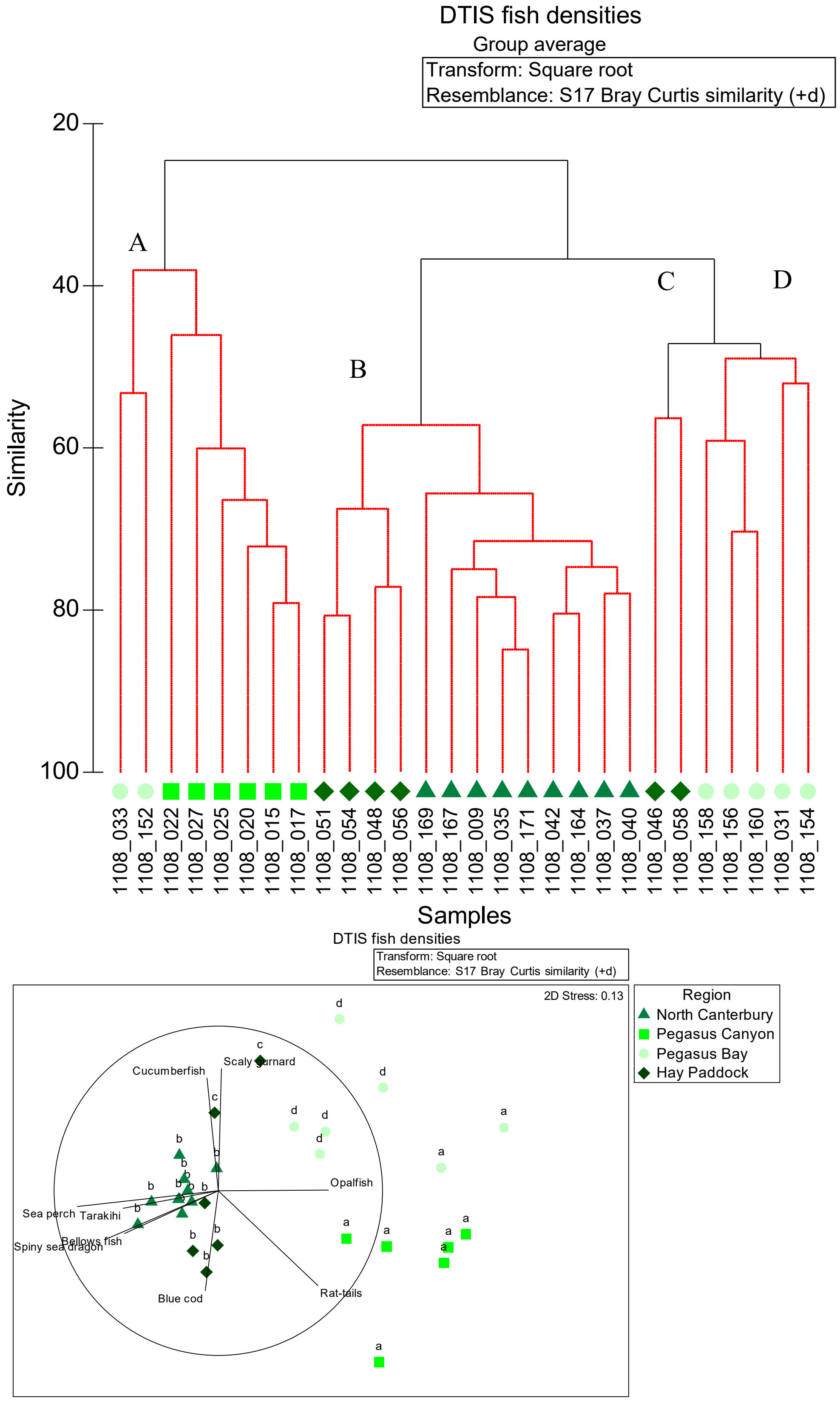


Figure 106: a) Dendrogram from cluster analysis of the zero-adjusted group-average Bray-Curtis similarity matrix from east coast South Island "wire-weed" fish communities observed from DTIS, showing groups identified by SIMPROF. Red lines indicate stations that did not show statistical differences in multivariate community structure. Right) MDS of the fish communities observed from DTIS stations, based on a zero-adjusted Bray-Curtis dissimilarity matrix from square root transformed fish densities. Pearson Correlation coefficients (> 0.5) of key fish species have been overlaid.

The key fish species contributing to the similarity between stations within each of the four groups are given in Table 46. A limited number of species drove the group separations.

Table 46: Dominant contributing species for the four fish community groups found at east coast South Island "wire-weed" sites, defined by SIMPROF, as identified by SIMPER.

Group A: average similarity = 43.77

Stations	NC	PB	PC	HP	Main species	Av. abundance	Av. similarity	% Cont.	Cum. %
8	–	2	6	–	Rattails	3.06	20.10	45.91	45.91
					Opalfish	2.78	18.89	43.16	89.07
					Bastard codling	0.84	2.30	5.25	94.32

Group B: average similarity = 63.09

Stations	NC	PB	PC	HP	Main species	Av. abundance	Av. similarity	% Cont.	Cum. %
13	9	–	–	4	Sea perch	7.66	34.42	54.56	54.56
					Tarakihi	1.69	6.90	10.94	65.50
					Bellows fish	1.64	5.04	7.99	73.49
					Flatfish	1.17	4.07	6.45	79.95
					Bastard codling	1.34	4.02	6.38	86.32
					Spiny sea dragon	1.05	3.92	6.22	92.54

Group C: average similarity = 53.66

Stations	NC	PB	PC	HP	Main species	Av. abundance	Av. similarity	% Cont.	Cum. %
2	–	–	–	2	Cucumber fish	4.56	23.75	44.26	44.26
					Sea perch	3.33	13.07	24.36	68.62
					Scaly gurnard	2.16	10.99	20.49	89.11
					Bastard codling	2.68	5.85	10.89	100

Group D: average similarity = 50.12

Stations	NC	PB	PC	HP	Main species	Av. abundance	Av. similarity	% Cont.	Cum. %
5	–	5	–	–	Scaly gurnard	2.69	13.58	27.10	27.10
					Opalfish	2.69	13.42	26.78	53.88
					Cucumber fish	2.54	8.00	15.95	69.84
					Flatfish	1.85	7.27	14.5	84.34
					Sea perch	1.58	4.46	8.89	93.23

A step-wise distance-based linear model (DistLM) was used to explore the relationship between the fish community data and the multibeam and other environmental variables. A full step-wise procedure including all regions and all stations was not possible, as multibeam-derived metrics were only available for the three Canterbury sites (20, 21 and 22) and image-derived variables were not available for seven DTIS stations within these sites. Table 47 summarises the variables explored and their explanatory power. Using multibeam-derived metrics alone, depth and rugosity were able to explain nearly 50% of the total variation in the fish community data. Where a regional category was included in the model, it was the main explanatory term (62.9%), with variables relating to the substrate type (% mud content and levels of bioturbation) and the presence of biogenic habitat types increasing the explanatory power to over 70% of the total model variation. The dbRDA plot of the DISTLM model indicates that the effect of % mud content in the sediment was acting along the primary axis, with stations to the left having higher mud content (North Canterbury) and those to the right having a lower content (Pegasus Canyon) (Figure 107). The variable reflecting the proportion of 'high' biogenic habitat presence (images classed as sessile Clusters 2, 3, 5 and 6), acted mainly along the secondary axis, with stations at the top of the plot having a higher proportion of biogenic habitat. Excluding the regional category, but including all other terms resulted in depth and rugosity being retained, with % Total Organic Matter (TOM) becoming the main explanatory variable along the primary axis, with stations from North Canterbury having higher %TOM and higher average rugosity values than stations from the other two sites. Removing the regional identifier reduced the explanatory power of the model to just under 60% of the total variation.

Table 47: Summary of step-wise DISTLM models fitted to the DTIS station fish densities observed at selected east coast South Island DTIS stations. Explanatory terms used are listed in the first column. Marginal proportion (proportion explained by the term in isolation) is given for all terms in the second column, with sequential proportions for each model given in following columns. The total cumulative proportion explained by each model, along with the improvement made as terms are added is also provided. (-) indicates a term is not included in that model, (ns) indicates a term was included, but dropped from the final model. MB, multibeam.

Term		MB only	MB + Site	MB + Site + Substrate	MB + Site + Substrate+ Bioturbation	MB + Site + Substrate + Bioturbation+ % Biogenic habitat	MB + Substrate + Bioturbation + % Biogenic habitat
	Marginal Prop.						Sequential prop.
% TOM	0.391	–	–	ns	ns	ns	0.391 (1)
Mean depth	0.118	0.118 (2)	ns	ns	ns	ns	0.120 (2)
Mean rugosity	0.377	0.377 (1)	ns	ns	ns	ns	0.078 (3)
Site	0.629	–	0.629 (1)	0.629 (1)	0.629 (1)	0.629 (1)	–
% Mud	0.383	–	–	0.052 (2)	0.052 (2)	0.052 (2)	ns
Bioturbation	0.033	–	–	–	0.040 (3)	ns	ns
% Biogenic	0.178	–	–	–	–	0.046 (3)	ns
Mean slope	0.361	ns	ns	ns	ns	ns	ns
% Sand	0.368	–	–	ns	ns	ns	ns
% $CaCO_3$	0.032	–	–	ns	ns	ns	ns
% Tubeworm	0.351	–	–	–	–	ns	ns
Cumulative prop.		0.494	0.629	0.681	0.721	0.727	0.588
Improvement			0.135	0.052	0.04	0.006	-0.139

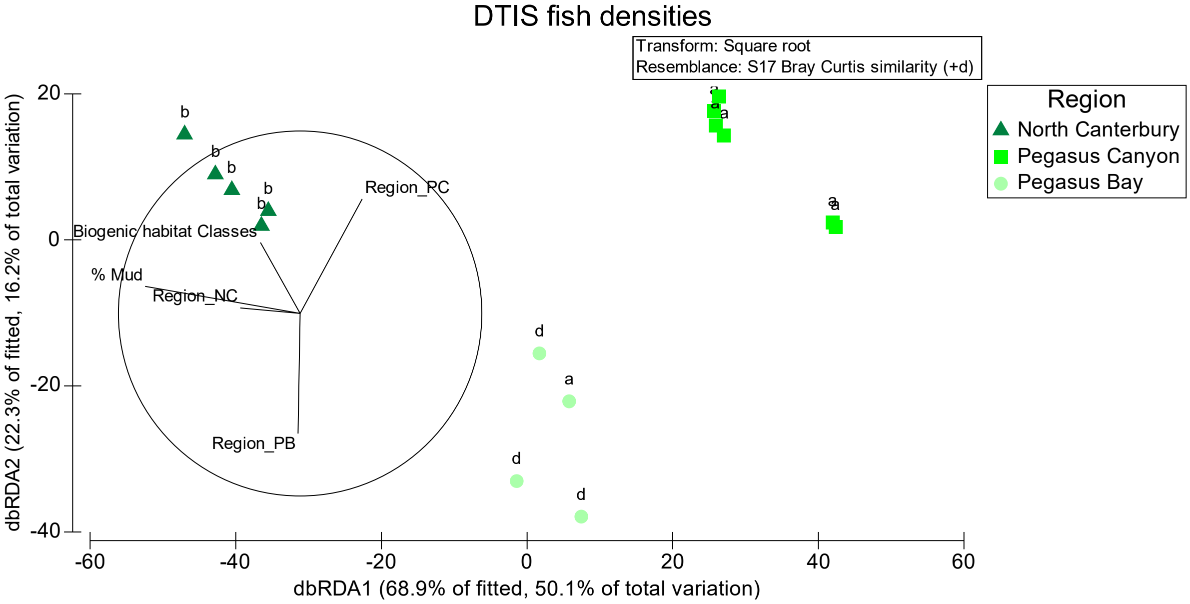


Figure 107: Distance based redundancy analysis (dbRDA) plot of the DistLM model based on a zero-adjusted Bray-Curtis dissimilarity matrix from square root transformed fish densities from three of the east coast South Island "wire-weed" sites, with PCA overlay of fitted explanatory variables, displaying strength and direction of effect on the ordination plot. The axis legends include the percentage variation explained by the fitted model and total variation for the first two axes. Image samples are labelled by Region, and by the allocated grouping from SIMPROF.

4.3 Ranfurly Bank

Ranfurly Bank was identified by a number of fishers as an area of foul with some areas noted for their sponge and coral bycatch. Due to its large size and relatively shallow depths, which constrained the multibeam swathe width, the bank was initially mapped in a series of transects, with selected areas mapped in more detail to cover as much of the variation thought to occur on the bank as possible (Figure 108). The mapped areas were grouped into five sites: Site 41, northern slopes (50–110 m), including low relief 'walls'; Site 42, central shallow (<50 m); Site 43, central/southern slopes (50–110 m); Site 44, outer northern slopes and outcrops (>100 m); and Site 45, eastern deep rock bank and surrounds (120–180 m). Across these sites, a total of thirty-one DTIS tows, four beam trawl and five rock dredge stations, and twenty-three sediment grabs were collected (Figure 66). For ease of description, these samples are divided amongst five Sites.

Multibeam mapping and topographic features of Ranfurly Bank

Ranfurly Bank is a broadly rectangular 'mega-feature' (Figure **60**) off East Cape, connected to the Cape by a shallow broad bank on part of its western side, and dropping off into deeper waters on its other sides. The core area of the bank is roughly square and sits in less than 100 m water depth, surrounded by a more rectangular (north–south) area of 100–200 m deep area, which also includes the bank to the mainland (about 105–127 m depth). Outside this, the bank steepens from 200 m to 500 m water depth around its other three sides, and then extends as a gentler slope out from 500 to 1000 m, especially to the east. Our focus was on the area of the bank 200 m or less in depth. The shallowest areas of the bank, as shown on nautical chart NZ55, were two central 'pinnacle' features, rising to 14.8 m and 21.5 m respectively, and composed of surrounding shallow areas which merged with the deeper main bank at around 40 to 50 m. The multibeam transects passed just to the west of the more southern pinnacle, and to either side of the northern pinnacle (Figure 108; Figure 109, Site 42, Site 43). This central area of the bank was composed of extensive low relief bedrock platforms, as well as veneers of coarse sediments, with evidence from DTIS that these veneers were mobile (exposed bare rock uncovering from sediment, faunal assemblages being engulfed by sediment), as well as fractured rock sheets in some places. The rock itself was composed of a grey mudstone. To the north of this shallower area, a low rock rampart ran east-west across the bank at about 100 m water depth, before the bank gently sloped from about 120 to 150 m water depth, with some sharper ridge features in the north-west corner of the survey block (Figure 108; Figure 109, Site 41, Site 44). To the south, there were also some rock ramparts although these were much less defined, and then the bank sloped away more steeply to 150 m. An extension of bed-rock was evident on the south-east corner of this block (Figure 108; Figure 109, Site 43) To the east, less multibeam was collected, but the pattern also appeared to be some low bed-rock 'walls', and then a gentle slope off to 150 m. To the west the seafloor gently sloped off to around 100 m, where it merged with the connecting bank to the mainland (Figure 108). A deeper water rock stack feature (about 140–200 m) was also mapped to the lower east of the main block, and returned a bedrock feature about 60 m high, with lower relief rock with sediment veneers to the east and south, grading into surrounding deeper soft sediment flats (Figure 110). Some of the slopes of the features qualified as cliffs, as evidenced by DTIS footage. On the northern side of the Ranfurly Bank survey block, a large area from 120 to 200 m was mapped, and returned extensive sloping flats, with some 'ripple' feature in the central north. An area of rubble was also located to the mid north-east (Figure 108; Figure 109, Site 44). Derived rugosity and slope measures, and the BTM zones and structures, also highlighted these landscape features across the multibeam mapped block; in particular picking up the central reef areas, the rock ‘walls’, the deeper water pinnacles, and the areas of rubble (Figure 108, Figure 110) (see also Figure 66).

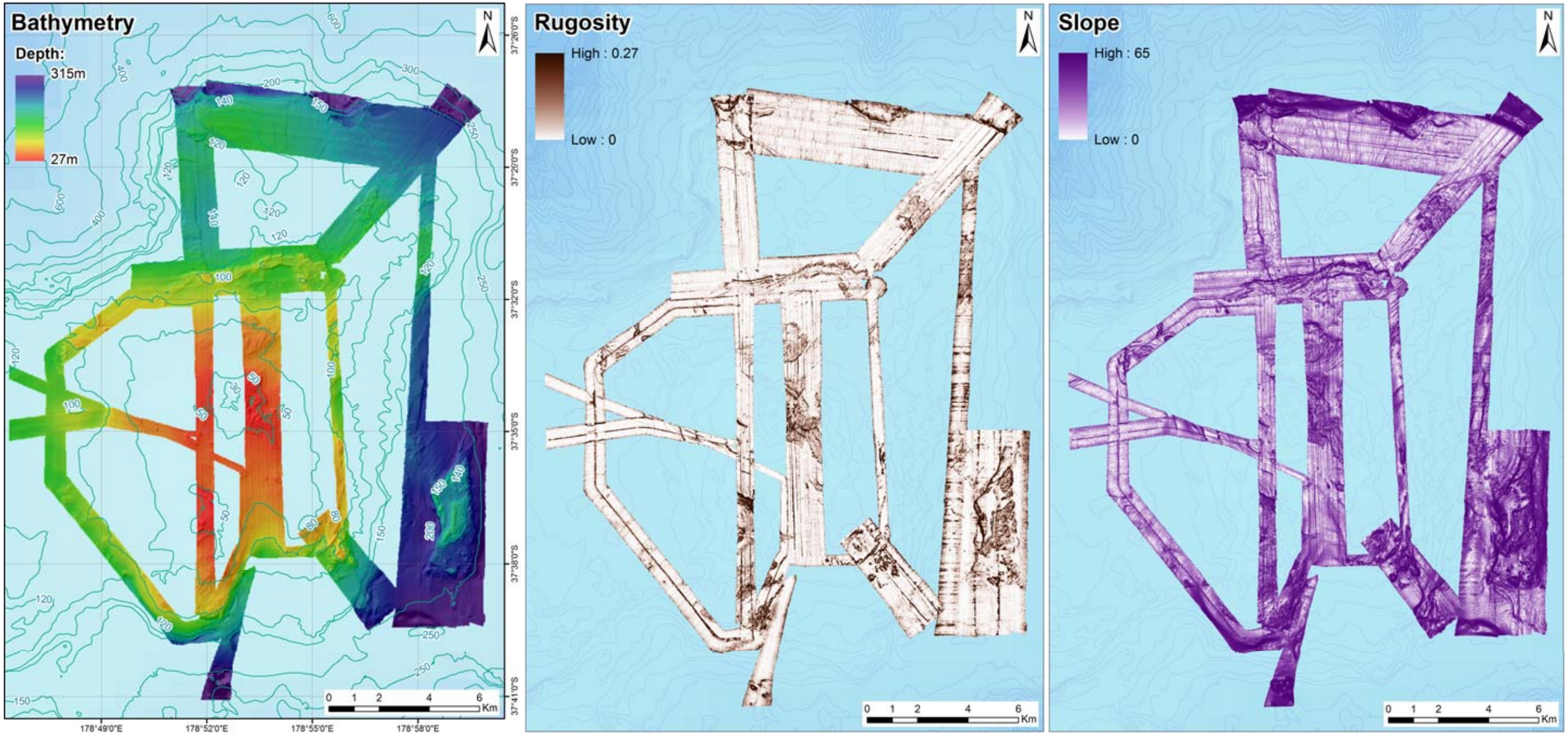


Figure 108: Multi-beam data derived maps for bathymetry, rugosity, and slope for Ranfurly Bank (Sites 41–45 combined).

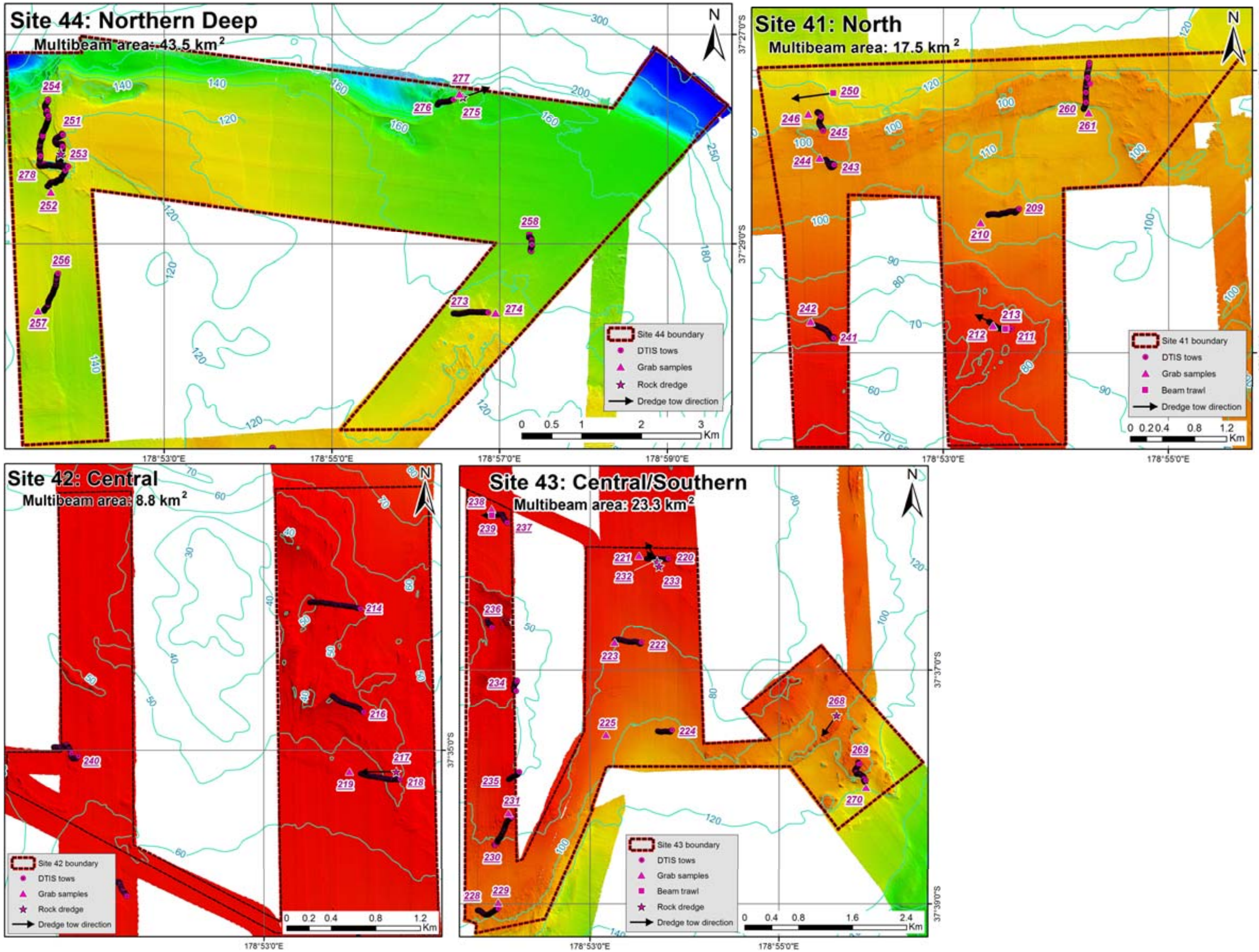


Figure 109: Bathymetry and stations for Sites 41, 42, 43, and 44 at Ranfurly Bank. For a broader scale map of how the divisions relate, see Figure 66.

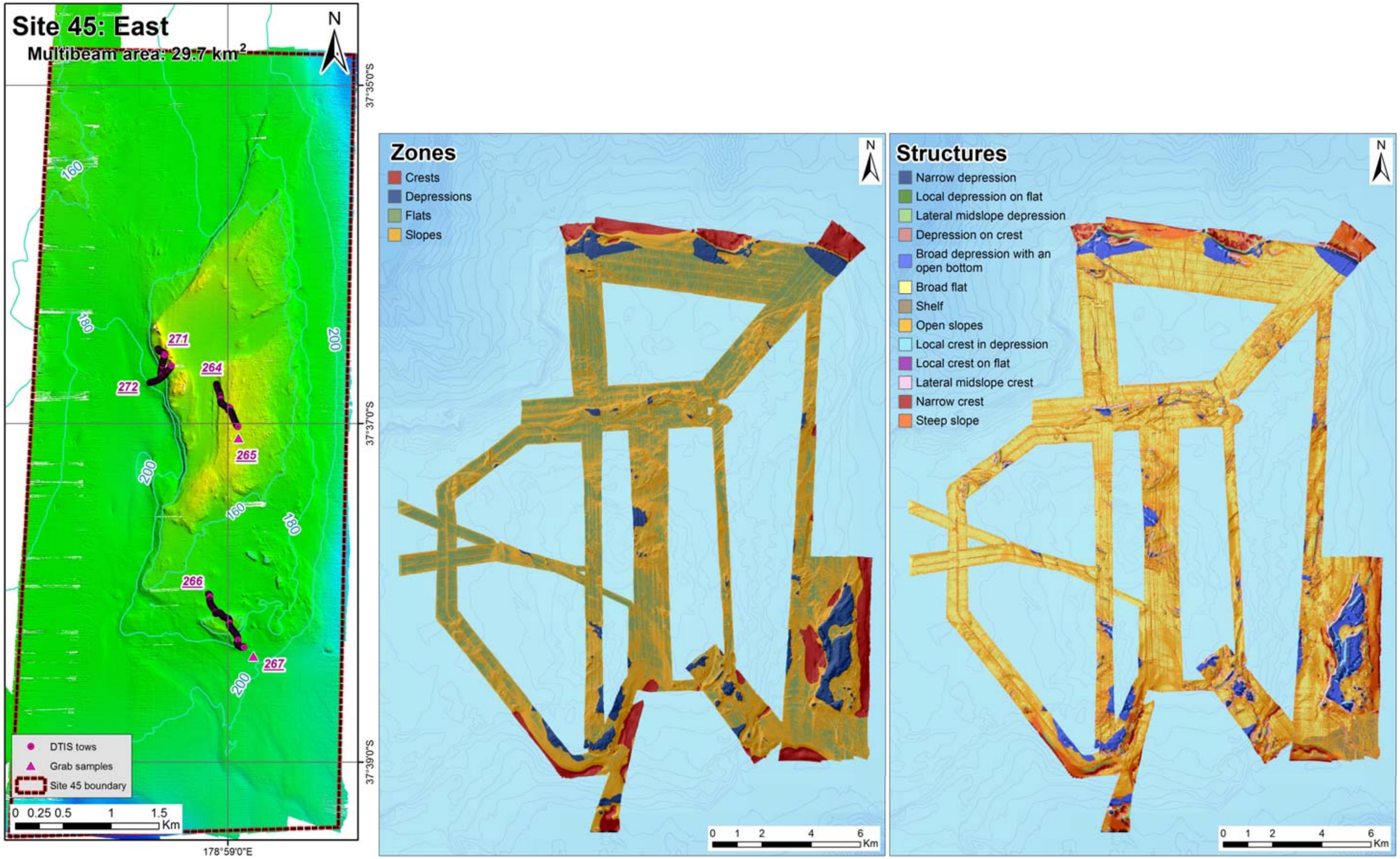


Figure 110: a) bathymetry and stations for Site 45 (see Figure 66 for its location on Ranfurly Bank); b) BTM zones and structures for Ranfurly Bank. For a definition of feature categories, see methods Section 2.5.

Invertebrate and algal diversity from biological sampling on Ranfurly Bank

Ten stations were sampled (four beam trawls, six rock dredges), covering the 40–160 m depth range. Sponges dominated by weight, with 67 species identified, of which up to 28 are likely to be new species (MK, pers. comm.). High species diversity was also observed amongst the bryozoans, with 81 species recorded, including many epizoic species. Hydroids were abundant with 20 species identified, the most common being *Crateritheca insignis* (n=155), *Crateritheca zelandica* (n=148), *Lytocarpia incise* (n=130), and *Nemertesia elongate* (n=101). Crinoids were abundant, with *Comanthus novaezealandiae* and *Argyrometra mortenseni* identified, along with a new species of *Comatulida.* Ophiuroids were also numerous, associated with sponges, bryozoans, and gorgonian corals. The most common species collected were *Ophiactis resiliens* and *Macrophiothrix oliveri.* Two new records of tropical species in New Zealand waters were also collected, *Ophiobyrsa intorta* and *Ophiotreta valenciennesi.* A tropical holothurian *Holothuria integua*, rare in New Zealand, was collected from two of the deeper stations to the north (and appeared common on DTIS video). Dog cockles (*Tucetona laticostata*) were the most commonly collected bivalve. More detail is provided on what was collected in the different areas below.

Macro-algae

Algae were collected at six stations, from depths of 40 to 110 m (Table 48). The highest diversity was seen in the red algae, with a number of specimens likely to represent new species (at least 6). From the Halymeniaceae family, a new genus (*Galene* D'Archino & Zuccarello) has been proposed (D'Archino et al. 2014), which includes an undescribed species, *Galene* sp., based on the samples found only at Ranfurly and probably observed on DTIS (identified as ALG 01). Also likely to be included in this OTU was the delicate, membranous *Phycodrys adamsiae* (recently described from Bay of Plenty and Ranfurly Bank specimens, Lin & Nelson 2010), and possibly an undescribed species of *Euptilota.* From the Rhodymeniaceae family, *Rhodymenia hancockii*, along with a new species from this genus, and a possible new genus from the Rhodomeniales Order, were most likely identified as either ALG 03 (bushy) or 05 (branching) in DTIS images, along with the *Plocamium sp.* and the new genus from the Kallymeniaceae family. Rhodoliths and non-geniculate coralline algae were collected at five stations (including a grab sample) on the central bank and mid slopes, but could not be identified to species without molecular sequencing.

Drift kelp was sampled at two stations (213, 217), with nearly 20 kg recovered from the shallowest site. Attached *Ecklonia radiata* was sampled down to 70 m, and observed in photos at depths of up to 105 m on the northern slope of the bank. Dense beds were recorded along some transects, with stipe densities of between 30–40 m^{-2}, and single thalli estimated at more than 1.5 m length. The morphology of specimens growing on Ranfurly Bank is different to that of shallower-dwelling specimens, with linear, flattened blades missing the lateral lobes found in shallower specimens (Nelson et al. 2015), and estimated heights of up to about 3 m. The green algae *Caulerpa flexilis* was collected at two stations, and was observed on a number of DTIS tows forming dense mats of intertwined stolons in places.

Table 48: Macro-algae identified from Ranfurly Bank.

Phylum	Class	Order	Genus / Species	Stations	Depth range
Rhodophyta	Florideophyceae	Halymeniales	*Galene* sp. (Family: Halymeniaceae)	213 (mid-slopes)	60–70
		Rhodomeniales	New genus?	217, 239 (shallow and mid-slopes)	42–70
			Rhodymenia sp. (Family Rhodymeniaceae)	217, 213 (shallow and mid-slopes)	42–70
			Rhodymenia hancockii (Family: Halymeniaceae)	213, 233 (mid-slopes)	60–70
		Ceramiales	*Euptilota* sp. nov. (Family: Callithamniaceae)	213, 217 (shallow and mid-slopes)	42–70
			Phycodrys adamsiae (Family: Delesseriaceae)	213, 239 (mid-slopes)	56–70
		Plocamiales	*Plocamium sp.* (Family: Plocamiaceae)	217, 239 (shallow and mid-slopes)	42–70
		Gigartinales	New genus? (Family: Kallymeniaceae)	217 (shallow)	42–48
		Corallinales	Rhodoliths	215, 217, 233 (shallow and mid-slopes)	42–60
		Corallinales	Nongeniculate coralline algae	213, 239 (mid-slopes)	56–70
Ochrophyta	Phaeophyceae	Laminariales	Drift kelp (Unid.) (Family *Lessoniaceae*)	213 (mid-slopes)	60–70
			Ecklonia radiata (Family Lessoniaceae)	213, 217 (shallow and mid-slopes)	42–70
Chlorophyta	Ulvophyceae	Bryopsidales	*Caulerpa flexilis* (Family: Caulerpaceae)	213, 217 (shallow and mid-slopes)	42–70

Invertebrates

Central (<50 m water depth) – Site 42

The number of species and sample weight by taxonomic Order for samples from shallow and mid-slope depths on Ranfurly Bank is given in Table 49. Twenty-eight species of bryozoans were identified in the single biological sample (one rock dredge) collected from less than 50 m depth. These included species observed on DTIS: such as the finger-shaped *Steginoporella neozelanica* (n=60, weight=106 g); 'fluffy curling' catenicellids such as *Cornuticella taurine*, *Cribricellina cribraria*, *Orthoscuticella innominate* and *Pterocella scutella;* and fenestrate ('lacy') species such as the magenta-coloured *Iodictyum yaldwyni* and a new species of *Triphyllozoon*. The latter is the first record of this tropical genus in New Zealand. Also present was the feathery branching *Bicellariella ciliate*, and 'twiggy' branching Cellariidae such as *Cellaria immerse* and *Cellaria tenuirostris*. The larger non-encrusting bryozoans often formed habitat for smaller epizootic bryozoan species. A large volume of dead bryozoan 'hash' was also sampled, including nearly 9 kg of dead *Celleporaria agglutinans*.

A number of sponges seen in the DTIS images were sampled, including *Aaptos rosacea* (pinky grey balls), *Polymastia crocea* (yellow lump), *Acanthella dendyi* (erect red, lumpy), *Ciocalypta cf. polymastia* (yellow lumpy encrusting), *Dragmacidon austral* (red encrusting), *Desmacidon mamillatum* (erect plate/finger), *Latrunculia Biannulata duckworthi* (grey lump), *Raspailia (Raspaxilla) topsenti* (erect finger), and *Dictyodendrilla* n. sp. 2 (yellow encrusting).

Mid slopes (50 to 110 m) – Sites 41 and 43.

Five samples (two beam trawl, three epibenthic sled) were collected between 50–110 m on the northern and southern slopes of the main bank (Table 49). These mid-depth samples contained the highest diversity of bryozoans seen (74 species), with many soft curling catenicellids such as *Cornuticella taurine, Cribricellina cribraria*, *Orthoscuticella innominate*, *Pterocella scutella*, as well as other “bushy” forms such as *Amathia wilsoni*, and the newly described endemic *Amathia zealandica*, and *Amathia gracei*, so far only recorded from Ranfurly Bank (Gordon & Spencer-Jones 2013). A number of lacey “cornflake” bryozoans were also collected including *Iodictyum yaldwyni,* and the first record of the tropical genus *Triphyllozoon.* A diverse sponge fauna (47 species) included large amounts of the purple cup sponge *Ecionemia alata* and pink coloured *Petrosia hebes*, as well as *Acanthella dendyi*, and three new species yet to be described. Nineteen species of hydroids were recorded, with large numbers of *Crateritheca zelandica*, *C. insignis* and *Lytocarpia incise*. A number of anthozoans were also sampled; the pink soft coral *Rhodelinda gardineri*, and two confirmed new genera and species in the families Alcyoniidae and Clavulariidae, including a distinctive red finger-like species with white polyps, likely to be the same as the many observed on DTIS (‘unid. soft coral 2’). Of the mobile fauna, large numbers of crinoids (*Argyrometra mortenseni* and *Comanthus novaezealandiae*) were collected at some stations, along with several hundred *Ophiactis resiliens.*

Table 49: Biological samples from the shallow (less than 50 m) and mid-slope (50–110 m) depths on Ranfurly Bank (Sites 41, 42, 43) summed at Order level, split by gear type. The number of samples for each area/gear type are given in brackets; N., number of species/OTUs; Wt., (weight in grams).

			Shallow (< 50 m)		Slope (50–110 m)				All
			Beam (1)		Sled (2)		Beam (3)		
Phylum	Class	Order	N.	Wt.	N.	Wt.	N.	Wt.	N.
Annelida	Polychaeta	Amphinomida	–	–	1	<1	–	–	1
		Eunicida	1	<1	2	40	–	–	2
		Phyllodocida	4	10	6	32	1	5	7
		Sabellida	1	<1	5	20	1	<1	5
		Spionida	–	–	1	<1	–	–	1
		Terebellida	–	–	–	–	1	12	1
Total			6	10	15	92	3	17	18
Arthropoda	Malacostraca	Amphipoda	–	–	–	–	1	<1	1
		Decapoda	1	3	15	295	11	189	22
		Isopoda	–	–	1	1	–	–	1
		Stomatopoda	–	–	–	–	1	32	1
	Maxillopoda	Pedunculata	–	–	–	–	1	10	1
		Sessilia	–	–	1	3	–	–	1
	Pycnogonida	Pantopoda	–	–	–	–	1	2	1
Total			1	3	17	299	15	233	28
Brachiopoda	Articulata	Terebratulida	1	3	1	264	4	87	4
Bryozoa	Gymnolaemata	Cheilostomata	27	427	32	460	50	1 765	57
		Ctenostomata	–	–	1	3	4	190	4
	Stenolaemata	Cyclostomata	1	<1	8	<1	12	125	13
Total			28	427	41	463	66	2 080	74
Chordata	Ascidiacea	Enterogona (Aplousobranchia)	2	30	3	172	4	307	7
		Pleurogona (Stolidobranchia)	–	–	1	143	2	146	3
Total			2	30	4	315	6	453	10
Cnidaria	Anthozoa	Alcyonacea	1	35	1	15	3	36	3
		Antipatharia	–	–	–	–	1	1	1
		Gorgonacea	–	–	2	7	–	–	2
		Scleractinia	–	–	2	63	–	–	2
		Zoantharia	–	–	1	20	–	–	1
	Hydrozoa	Anthoathecata	–	–	–	–	1	1	1
		Leptothecata	4	46	11	246	17	1 559	18

			Shallow (< 50 m)				Slope (50–110 m)		All
Total			5	81	17	351	22	1 597	28
Echinodermata	Crinoidea	Articulata			1	1 109	2	111	2
	Echinoidea	Clypeasteroida	1	70	1	15	2	16	2
	Ophiuroidea	Euryalinida [Phyrynophiurida]	–	–	1	<1	–	–	1
		Ophiurida	3	8	9	375	7	82	12
Total			4	78	12	1499	11	209	17
Mollusca	Bivalvia	Arcoida	1	44	2	115	–	–	2
		Mytiloida	–	–	1	37	–	–	1
		Myoida	1	4	–	–	–	–	–
		Ostreoida	–	–	1	1	–	–	1
		Veneroida	3	10	3	21	–	–	3
	Gastropoda (Caenogastropoda)	Littorinimorpha					1	2	1
	Gastropoda (Opisthobranchia)	Cephalaspidea	1	21			1	10	1
	Gastropoda (Prosobranchia)	Mesogastropoda			4	72			4
		Neogastropoda	4	11	4	36	1	1	5
		Vetigastropoda			3	25			1
	Polyplacophora	Acanthochitonida			4	43			4
Total			10	90	23	356	3	13	26
Nemertea					1	<1			1
Porifera	Demospongiae	Astrophorida			6	142 792	4	13 184	8
		Dendroceratida	1	31	1	5	1	25	2
		Dictyoceratida	1	140	7	25185	1	394	7
		Hadromerida	2	2 009	1	880	2	103	3
		Halichondrida	3	377	2	35	6	1 467	7
		Haplosclerida	2	189	6	36596	4	3 223	8
		Poecilosclerida	3	857	6	1 162	7	2 853	10
		Spirophorida			1	20	1	20	2
Total			12	3 603	30	206675	26	21269	47

Deep slopes and outcrops (>110 m) – Sites 44 and 45

Three deeper stations (one beam trawl, two rock dredge) were sampled on Ranfurly Bank and adjacent rock outcrops (Table 50). A station on the southern slope, towards the eastern outcrop, caught a large number of the small crinoid *Argyrometra mortenseni* (n=387), along with two sea pen species; *Acanthoptilum grandiflorum,* a common widespread species, and *A. longifolium,* only recently described and presumed endemic to New Zealand. Far fewer bryozoans were found here compared to the shallower stations, and only two species of sponge; the haplosclerid *Haliclona (Gellius) regia*, and the large finger sponge *Desmacidon mamillatum*. Some dead bryozoan and shell hash was caught, along with drift kelp and some red and green macro-algae. Around the northern outcrops, two epibenthic sled samples brought on board many rocks, sandy rubble, possible relict rhodoliths and shell hash, along with gorgonian fans, black coral, and sponges. Up to eight gorgonian OTUs were identified, but none beyond genus level, as there is no comprehensive taxonomic treatise for deep-sea gorgonians in the wider southwest Pacific. Most specimens were from the Plexauridae family, from four different genus' (*Paracis*, *Swiftia*, *Villogorgia*, *Scleracis*), with the Primnoidae and Acanthogorgiidae families also represented. Many gorgonians had commensally associated ophiuroids attached, mainly *Astroceras elegans* and *Asteroporpa australiensis*. A white 'carnation coral' *Dendronephthya* found in these samples has only been recorded on four previous occasions; three from the Norfolk Island region and one from Ranfurly Bank in 1975

(D. Tracey, NIWA, pers. comm.). Bushy colonies identified as *Antipathella* sp. (one a possible new species), and spiral whip corals identified as *Stichopathes* sp., were also collected. The spionid worm sampled here was the rock-dwelling *Spiochaetopterus spiochaetopterus-C*; as opposed to *Spiochaetopterus spiochaetopterus-A*, which was sampled at shallower stations.

Table 50: Biological samples from deeper Ranfurly Bank (> 150 m) (Sites 44 and 45), summed at Order level, split by gear type. The number of samples for each area/gear type are given in brackets; N., number of species/OTUs; Wt., weight.

Phylum	Class	Order	East (>150 m) Beam (1)		North (>150 m) Sled (2)	
			N.	Wt. (g)	N.	Wt. (g)
Annelida	Polychaeta	Eunicida			2	4
		Phyllodocida	2	9		
		Sabellida	1	5	1	<1
		Spionida	1	<1	1	1
		Terebellida	1	1	1	<1
Total			5	15	5	5
Arthropoda	Malacostraca	Decapoda	6	76	12	47
		Isopoda			1	1
		Stomatopoda	1	20	1	10
	Pycnogonida	Pantopoda	1	1		
Total			8	97	14	58
Brachiopoda	Articulata	Terebratulida			1	2
Bryozoa	Gymnolaemata	Cheilostomata	8	42	2	3
Chordata	Ascidiacea [Tunicates]	Enterogona (Aplousobranchia)	3	43		
Cnidaria	Anthozoa	Alcyonacea			1	35
		Antipatharia			2	65
		Gorgonacea			8	2 081
		Pennatulacea	2	102		
	Hydrozoa	Leptothecata	6	37	3	23
Total			8	139	14	2 204
Echinodermata	Crinoidea	Articulata	2	207		
		Comatulida	1	1		
	Echinoidea	Echinothurioida			1	130
	Holothuroidea	Aspidochirotida			1	628
		Dendrochirotida	1	35	1	15
	Ophiuroidea	Euryalinida			2	16
		Ophiurida			7	74
Total			4	243	12	863
Mollusca	Bivalvia	Ostreoida	1	20		
		Veneroida			2	14
	Gastropoda (Caenogastropoda)	Littorinimorpha			3	87
	Gastropoda (Opisthobranchia)	Opisthobranchia			1	1
	Cephalopoda	Octopoda	1	10		
Total			2	30	6	102

Phylum	Class	Order	East (>150 m)		North (>150 m)	
Porifera	Demospongiae	Astrophorida			6	3 152
		Dictyoceratida			2	244
		Hadromerida			1	32
		Halichondrida			3	798
		Haplosclerida	1	98	1	72
		Poecilosclerida	1	90	2	1 478
	Hexactinellida	Lyssacinosida			1	30
Total			2	188	16	5 806
Priapulida	Priapulida				1	25

Invertebrate assemblages from DTIS imagery from Ranfurly Bank

Thirty-one DTIS stations were surveyed between 40 to 160 m water depths, grouped into four different areas, according to depth and location: Central Shallow, a cluster of stations on the top of the bank at depths less than 50 m (Site 42); Central Mid Depth, stations down the northern and southern slopes between 50–110 m (Sites 41 and 43); Eastern Deep Outcrop (Site 45) and Northern Deep Outcrops (Site 44), stations respectively to the east and north of Ranfurly Bank proper targeting rocky outcrops (over 100 m). Seven hundred and eighty-five images were analysed from these stations, with 73 devoid of biota being excluded, leaving 712 samples. The final OTU number was 132 (Appendix 5), after a number of species groups were combined where they could not reliably be visually differentiated from each other in images, e.g., some red algae, species of 'catenicellids' (soft bushy) bryozoans, yellow and orange gorgonian sea fans, and a number of sponge groupings.

The invertebrate fauna were classed as either sessile (with macro-algae also included) or mobile (Figure 111, Figure 112). The sessile fauna from the shallow bank stations was dominated by algae and sponges, recorded in 98% and 84% of images respectively (Figure 111). Algae observed included *Ecklonia radiata* stands as well as low relief red algal turf, *Caulerpa flexilis* patches, and non-geniculate coralline algae encrusting hard substrates. The red algae were grouped into four different categories (blades, feathery, stringy, bushy), with a number of the species collected in the biological samples included in these visual groups (Appendix 5). Sponges were found beneath the kelp forests, and on the open flats, where they occurred alongside soft curling catenicellid bryozoans, soft corals (e.g., the unidentified red finger-like coral), and hydroids. The most frequently observed sponges included *Dragmacidon austral* and *Poecilosclerid* sp. (orange encrusting), *Chondropsis* cf. *n sp.* 5 (grey stringy) and *Ecionemia alata* (large grey cup), along with occasional *Axinella n. sp.* 10 (red lumpy), *Latrunculia duckworthi* (grey rock) and *Crella incrustans* (bumpy orange). Very few mobile fauna were recorded at these shallow stations (Figure 112), being single records of an anemone, an asteroid and a holothurian (identified as the rare *H. integra*).

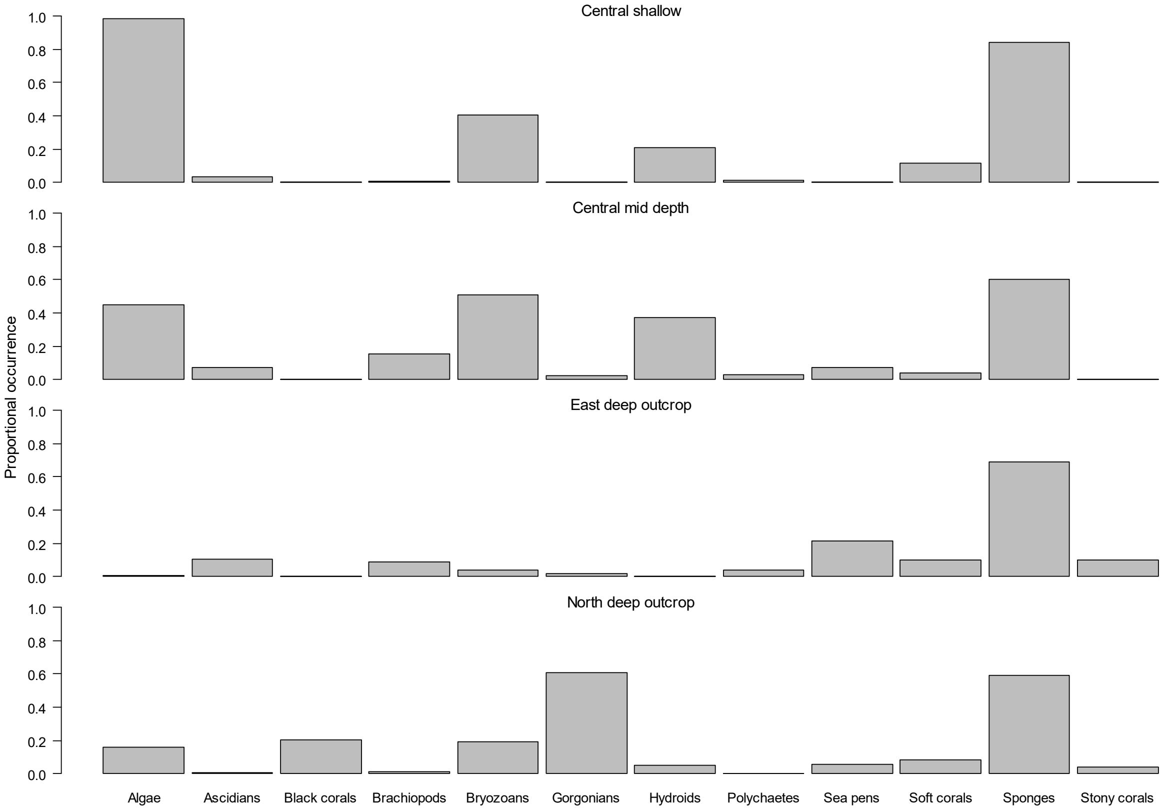


Figure 111: Proportional occurrence in images of key sessile faunal groups from sites across Ranfurly Bank: Site 42; Central Shallow, a group of stations on the top of the bank at depths less than 50 m. Sites 41 and 43; Central Mid Depth, stations down the northern and southern slopes between 50–110 m. Site 45; Eastern Deep Outcrop, and Site 44; Northern Deep Outcrops, stations respectively to the east and north of Ranfurly Bank proper, targeting rocky outcrops.

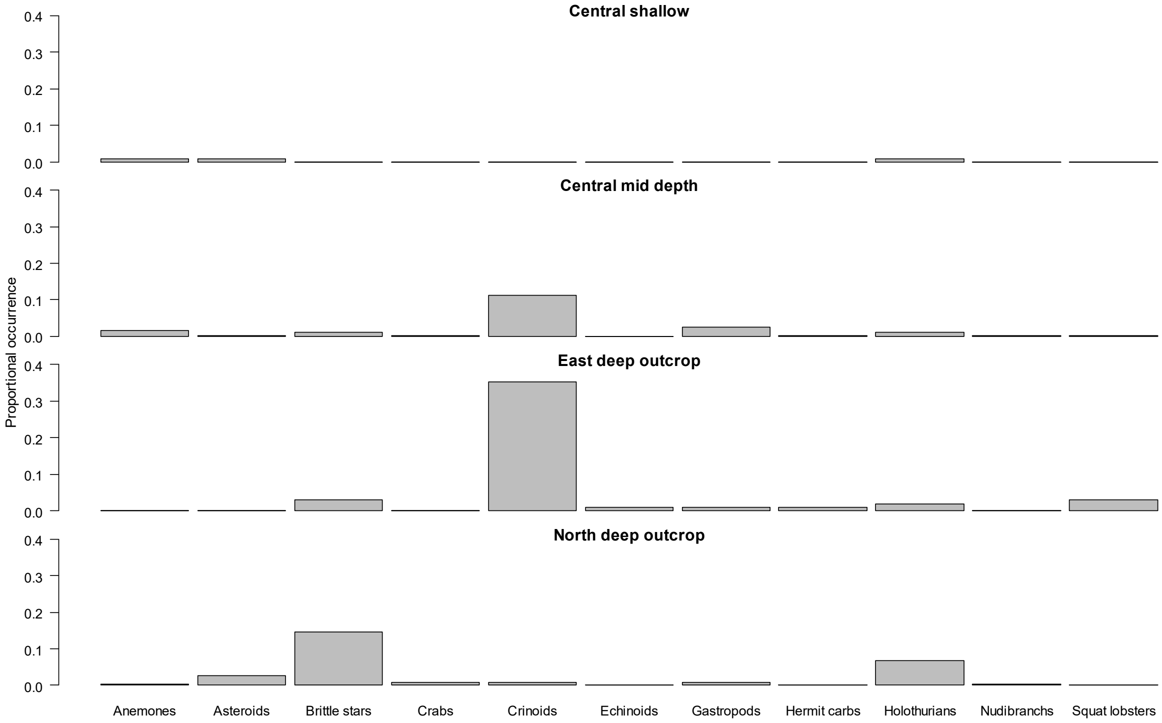


Figure 112: Proportional occurrence in image samples of key mobile faunal groups from sites across Ranfurly Bank. Areas as described in Figure 111 caption.

Similar sessile faunal groups were observed at the mid-depth stations (50–110 m), although algae were less abundant, made up mainly of encrusting non-geniculate coralline, red blades and bushy categories, as well as occasional sparse stand of *Ecklonia radiata* (Figure 111) Bryozoans and hydroids were more common than at the shallower stations. Bryozoans were mainly 'soft curling' bushy species (e.g., *Catenicellidae: cf. Cribricellina & Cornuticella, Amathia wilsoni*), which were grouped together into a single OTU, the distinctive finger-like *Steginoporella neozelanica*, and lacy 'cornflake' bryozoans ranging in colour from whitish/pale pinky purple to a deep brick red. These cornflake bryozoans were also grouped into a single OTU, which included some identified as *Hippomenella vellicata*, and others thought to be *Iodictyum yaldwyni* (pale purple coloured), *Reteporella* sp., and the closely related new tropical species *Triphyllozoon sp.* (darker brick red). Common sponges included orange encrusting species (*Ecionemia alata, Crella incrustans, Raspailia* sp., *Dactylia palmate* and *Acanthella dendyi*) as well as occasional *Stelleta crater, Petrosia hebes,* and *Polymastia crocea.* Mobile fauna included occasional gastropods, ophiuroids and holothurians, as well as moderate densities of crinoids (*Comanthus novaezealandiae* and *Argyrometra mortenseni*) at one station (Station 269) (Figure 112).

Stations located on and around the deeper eastern rocky outcrop had a less diverse sessile fauna, dominated by a distinctive sponge fauna encrusting the rocky faces, including *Coscinoderma* n. sp. 2, and *Sarcotragus sp.* (both white ragged), *Psammocinia* n. sp. 1, and *Xestospongia coralloides* (both white bulbous), *Iophon* n. sp. 4, or *Topsentia* cf n. sp. 4 (both orange and yellow encrusting) and the ball-like *Dictyoceratida* sp. /*Spongia* n. sp. 3 with its distinctive apical oscules. Sea pens were also relatively common in the soft sediments adjacent to the outcrops. At these stations, crinoids were observed in 35% of image samples, sometimes in very high densities, approaching 100 m^{-2}.

The deep stations targeting rocky outcrops to the north were dominated by gorgonian sea fans (observed in 60% of images), mainly orange and yellow-coloured plexaurids, along with less common primnoid sea fans (bright white) and occasional *Plumigorgia* spp. (*Ifalukellidae*?). Ophiuroids were often observed amongst the arms of the gorgonians, and these were the most common mobile invertebrate fauna, followed by holothurians and asteroids. The sponge fauna was diverse. Large cup sponges such as *Stelletta columna* and *Ancorina stalagmoides*, often encrusted with orange/yellow *Desmacella dendyi*, were common, along with the creamy white finger-like *Coscinoderma* species, and cream plate-like Haplosclerid sp. / *Haliclona* (*Gellius*) *regia*. Other species observed included *Symptella rowi*, *Axynyssa sp.* (?), *Topsentia* sp., *Psammocinia beresfordae*, *Raspailia* n sp. 6 / *Axinella* sp., and *Xestospongia coralloides*. Patches of the rare white carnation coral, *Dendronephthya* sp., were observed on multiple transects, as well as a number of black corals; *Parantipathes* spp. (pink), *Stichopathes* spp. (spiral) and *Antipathella* spp. (branching). Other sessile fauna included encrusting non-geniculate coralline algae and low numbers of catenicellid bryozoans, along with small lacy bryozoans, including the distinctive green *Bitectipora retepora*.

Non-hierarchical cluster analysis of benthic fauna observed at Ranfurly Bank

Full community

Using the full community data set from Ranfurly Bank (712 image samples), k-means cluster analysis on the alternate Gower dissimilarity matrix of standardized full community data gave clustering results varying from 3–11 groupings, with SSI values ranging from 0.22–0.25 (Table 51). The SSI index was highest for 6 groups (Figure 113). Using the cascade-KM function, a cascade of partitions (groupings) of between two and twenty were calculated, along with the

SSI criterion for clustering quality. For the full community data set, four partitions gave the highest value of SSI after 100 iterations (number of random starting configurations for each value of K) (Figure 114). ANOSIM identified significant differences between the clusters for both four and six groups, but the global R value was higher for six groups (global R=0.262, P=0.001). All but one of the pairwise comparisons were significant, with R values varying between 0.11–0.999.

Table 51: Summary of non-heirarchichal cluster analysis of biological community data from all sites at Ranfurly Bank. SSI criterion, BTSS/TSS ratio and global R values from ANOSIM tests are presented for the three different data sets and for different partition scenarios considered.

Data matrix	No of Clusters	SSI value*	BTSS/TSS	ANOSIM
Full community	6	0.139 / 0.25	18.6%	R = 0.262, P=0.001
	4	0.175 / 0.22	8.4%	R = 0.151, P=0.001
Sessile Community	4	0.228/ 0.23	81.6%	R = 0.358, P=0.001
	5	0.115/ 0.25	84.5%	R =0.051, P=0.001
	6	0.126/ 0.27	87.6%	R = 0.083, P=0.001
Sessile P/A	23	0.196	89.3%	R = -0.046

*SSI values from cascadeKM/single Kmeans partitioning routines.

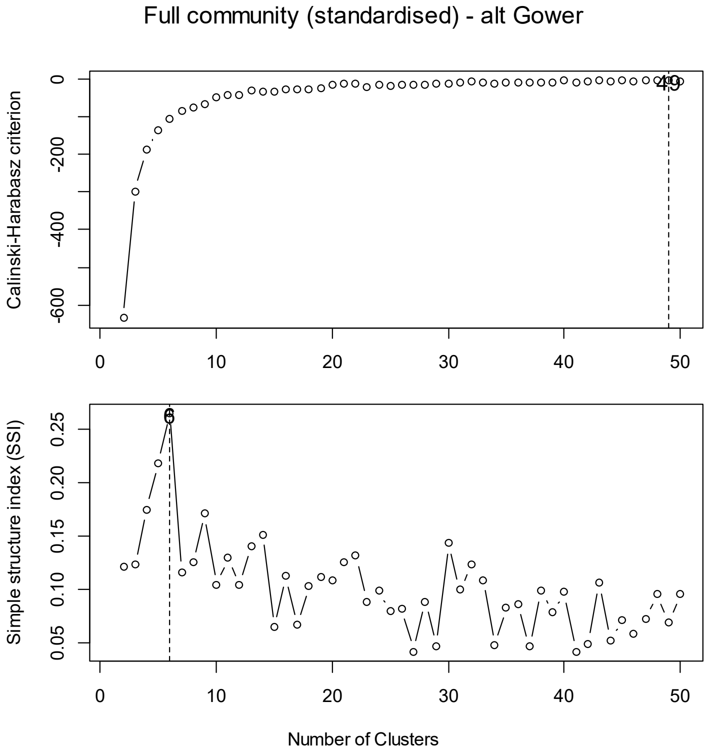


Figure 113: K-means Cluster analysis of full community biota from Ranfurly Bank, with the number of groups giving optimum values for the Calinski-Harabasz criterion (upper) and Simple Structure Index (SSI) (lower).

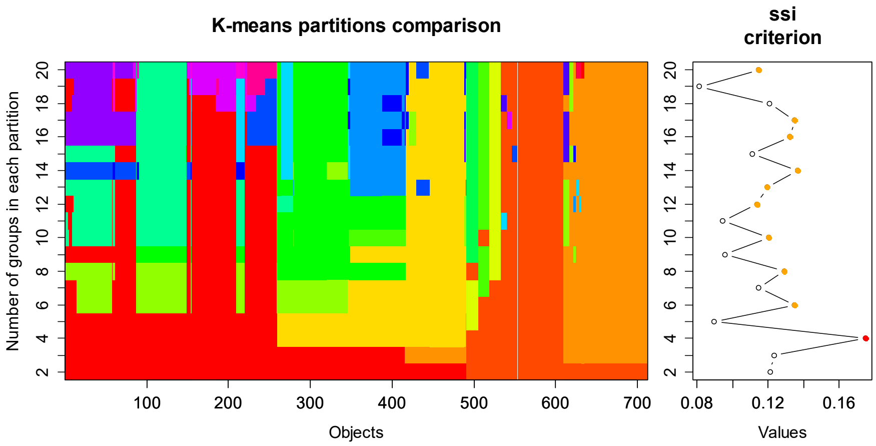


Figure 114: k-means cascade plot of cluster analysis of the full community dataset from Ranfurly Bank showing the group each "object" (image sample) was assigned to for each partition (left), and the associated SSI criterion (right). The maximum SSI criterion value is indicated in red.

Sessile fauna only

Using only the sessile fauna reduced the data matrix to 103 OTUs and 680 images. k-means cluster analysis on the alternate Gower dissimilarity matrix of standardized sessile fauna community data gave results varying from three to eight groupings, with the highest SSI value (0.27) for 6 clusters (Table 51, Figure 115). Using the cascade-KM function, four groupings gave the highest value of SSI (0.23) (Table 51, Figure 116). ANOSIM identified significant differences between the clusters for four, five and six groups, but the global R value was highest with four groupings (global R=0.358, P=0.001), with all pairwise comparisons also being significant (0.074–0.684).

K-means cluster analysis of the sessile fauna presence/absence data consistently returned an optimum number of groups as more than 35 (n=10) and the KM-cascade routine produced an optimum number of groups with a relatively low peak SSI value (0.195). ANOSIM results indicated that these numbers of groups were not significantly different from each other.

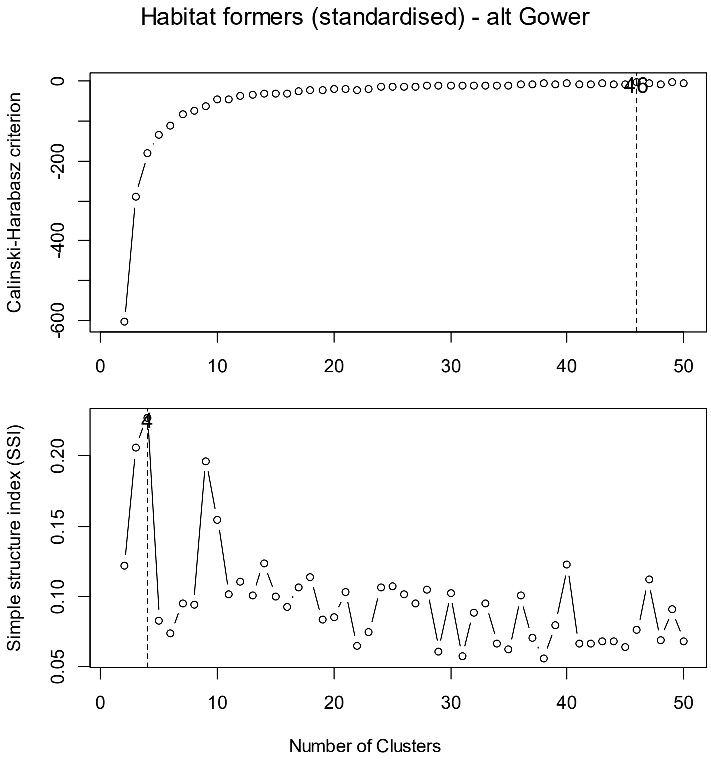


Figure 115: K-means cluster analysis of sessile biota from Ranfurly Bank (all sites combined), with the number of groups giving optimum values for the Calinski-Harabasz criterion (upper) and Simple Structure Index (SSI) (lower).

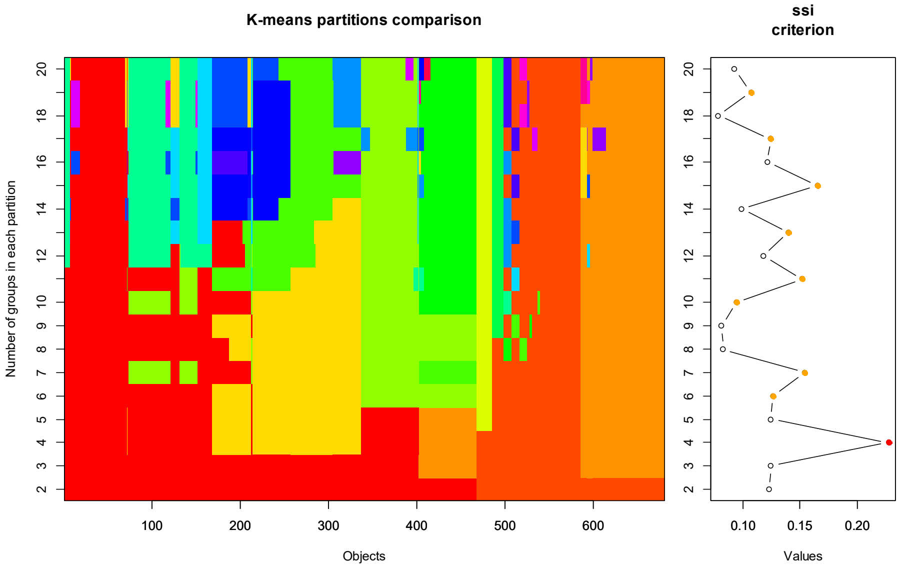


Figure 116: k-means cascade plot of cluster analysis of the sessile community dataset from Ranfurly Bank showing the group each "object" (image sample) was assigned to for each partition (left), and the associated SSI criterion (right). The maximum SSI criterion value is indicated in red.

After exploration of the species data using SIMPER, the sessile fauna four cluster grouping was selected. This clustering produced relatively high values of SSI, BTSS/TSS ratio, and global R values, with all pairwise comparisons being significant. An MDS plot of the sessile fauna only data set, labelled by site and by the four clusters, is given in Figure 117. The high stress value indicates that this is not a very useful representation of the data, and there is considerable overlap between sites, and cluster groupings.

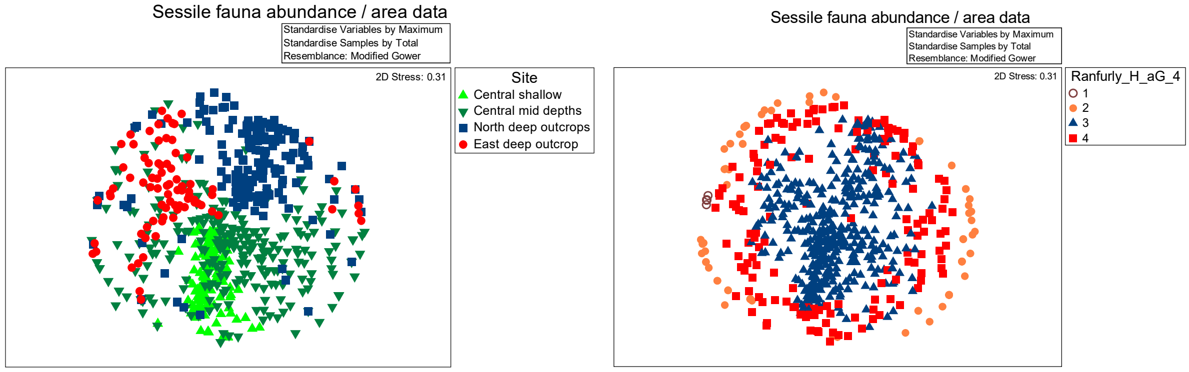


Figure 117: MDS plots of Ranfurly bank image samples identified by: a) Site (left); and b) sessile fauna cluster (right).

The main species/OTUs contributing to within group similarity for the four cluster classes are given in Table 52. Clusters 1 and 2 represent mainly bare, low diversity areas (Figure 118); Cluster 3 represents all the higher diversity images, including areas of *Ecklonia* forests, 'fields' of low relief catenicellid bryozoans, red algae and sponges, as well as deeper sponge and/or gorgonian sea fan dominated rocky reef outcrops (Figure 119); while Cluster 4 includes mixed hard and soft substrate with a slightly higher diversity of sessile fauna, such as plexaurid sea fans and small encrusting sponges (Figure 120).

Table 52: Dominant contributing species for the four faunal assemblages identified from Ranfurly Bank biota (all sites combined) by non-hierarchical clustering, as identified by SIMPER.

Cluster 0: Bare substrate (mainly sand), no sessile fauna.

Images	Central Shallow	Central Mid	East	North	Main species	Av.	% Cont.	Cumu. %
104	2	44	18	40		–	–	–

Cluster 1: Bare soft sediment with sea pens. Mean species richness: 1 (± 0).

Images	Central Shallow	Central Mid	East	North	Main species	Av.	% Cont.	Cumu. %
18	0	11	2	5	Unidentified pink sea pen	100	100	100

Cluster 2: Mainly bare soft substrate, occasional cobble or boulder, with small area of encrusting coralline algae, orange sponge, low relief red algae or plexaurid sea fan. Mean species richness: 1 (± 0).

Images	Central Shallow	Central Mid	East	North	Main species	Av.	% Cont.	Cumu. %
101	13	46	14	28	Coralline algae	13	11.97	11.97
					Brachiopod (unid.)	9	8.67	20.64
					Plexaurid sea fan (gorgonian)	9	8.67	29.31
					Encrusting orange sponge	8	7.79	37.10
					Nemertesia elongate (hydroid)	6	5.97	43.07
					ALG 04 (red bushy algae)	4	4.06	47.13
					Unidentified white sea pen	4	4.06	51.19

Cluster 3: Mixed hard and soft substrate with diverse fauna; soft curling catenicellid bryozoans and red algae, hydroids, *Caulerpa* mats and patches of the carnation coral (*Neptheidae* spp.), along with key sponges such as *Acanthella dendyi* (mid slopes) and *Coscinoderma* sp. 2 (eastern outcrop stations). Mean species richness: 6.65 (± 2.33).

Images	Central Shallow	Central Mid	East	North	Main species	Av.	% Cont.	Cumu. %
401	111	150	44	49	Catenicellid bryozoans	5.68	6.30	6.30
					ALG 03 (red feathery algae)	3.48	4.62	10.92
					Plexaurid sea fan (gorgonian)	4.44	3.82	14.74
					Hippomenella vellicata (bryozoan)	2.39	3.26	18.00
					Coscinoderma sp. 2 (sponge)	2.74	2.93	20.93
					Crateritheca sp. (hydroid)	2.86	2.85	23.78
					Acanthella dendyi (sponge)	2.31	2.69	26.47
					ALG 04 (red bushy algae)	3.35	2.29	28.76
					Xestospongia corallodies (sponge)	1.95	2.23	30.99
					Neptheidae spp. (soft coral)	2.12	2.14	33.13
					Caulerpa flexilis (green algae)	1.60	2.09	35.22
					Haplosclerid 1 (sponge)	1.85	1.96	37.18
					ALG 02 (red stringy algae)	2.13	1.92	39.10
					Axinella sp. 8 (sponge)	1.34	1.78	40.88

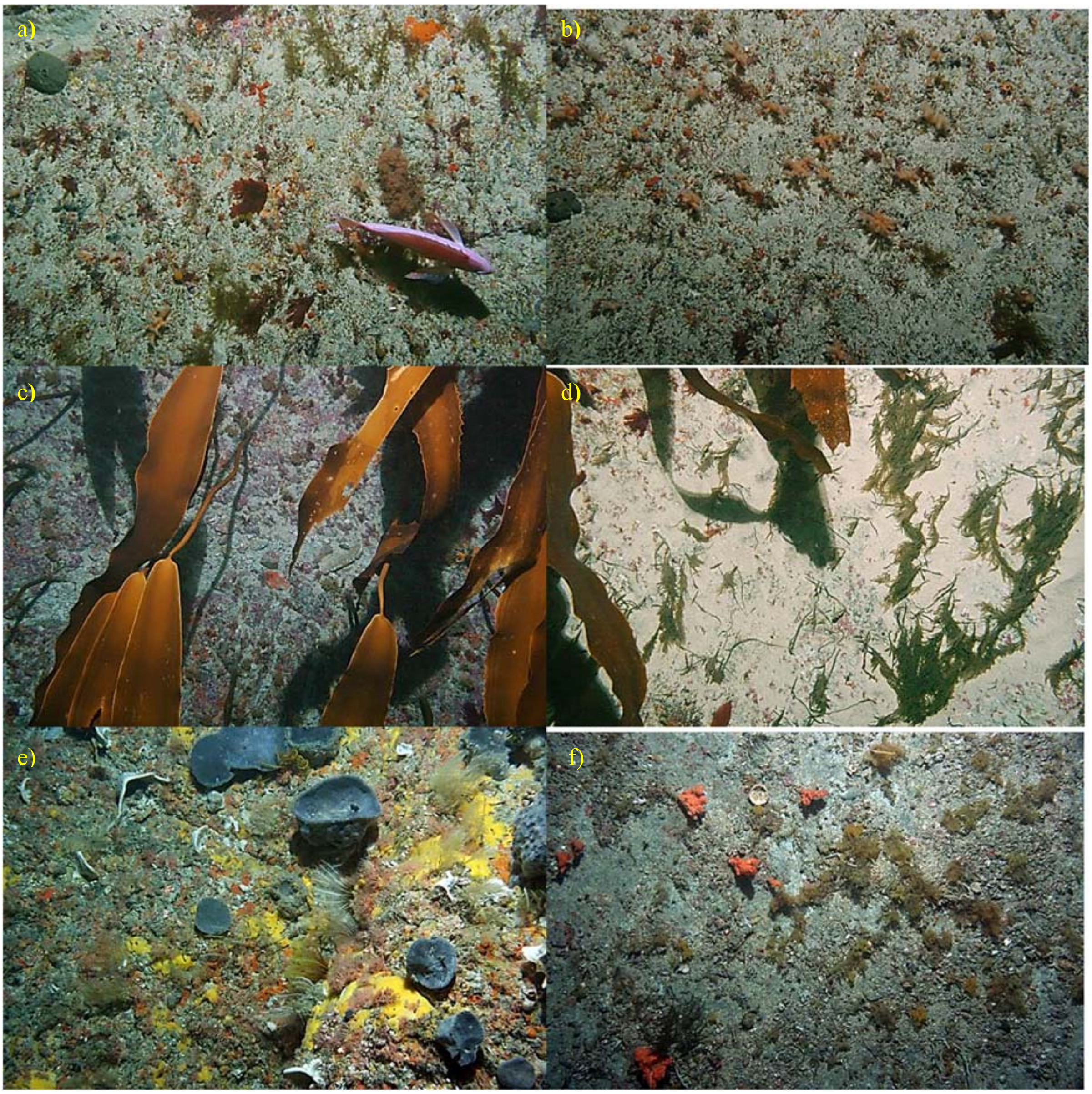
Cluster 4: Largely similar to Cluster 2, but with slightly higher diversity and abundance of similar fauna. Mean species richness: 2.41 (± 0.51)

Images	Central Shallow	Central Mid	East	North	Species	Av.	% Cont.	Cumu. %
161	14	71	24	52	Plexaurid sea fan (gorgonian)	6.82	5.04	5.04
					Nemertesia elongata (hydroid)	4.04	4.40	9.44
					Unidentified pink sea pen	3.87	4.25	13.69
					Catenicellid bryozoans	3.65	4.17	17.86
					Hippomenella vellicata (bryozoan)	3.15	3.77	21.63
					Iophon sp. 4 / *Topsentia* sp. 4 (sponge)	3.40	3.54	25.17
					Neptheidae spp. (soft coral)	3.45	3.32	28.49
					Pseudobranchiomma grandis (sabellid)	2.23	3.14	31.63
					Encrusting orange sponge	4.86	2.90	34.53
					Stichopathes sp. (whip coral)	3.02	2.81	37.34
					Crateritheca (hydroid)	2.70	2.79	40.13
					Brachiopod	2.64	2.61	42.74
					Axinella sp. 8 (sponge)	2.08	2.40	45.14
					Haplosclerid 1 (sponge)	3.19	2.25	47.39
					Alcyoniina unid. 3 (soft coral)	2.22	2.23	49.62
					Ecklonia radiata (kelp)	2.78	2.21	51.83

The percentage occurrence of key taxonomic groups within these four habitat clusters is given for sessile fauna in Figure 121 and mobile fauna in Figure 122. Cluster 1 consisted of only 18 samples, with pink sea pens being the only sessile fauna observed. Cluster 2 images had a low percentage occurrence of a wide variety of sessile fauna, with sponges and algae being recorded with the highest frequency (about 20%). The occurrence of key sessile fauna groups was slightly higher in Cluster 4, whilst Cluster 3 had much higher occurrences of sessile fauna, particularly algae, sponges and bryozoans. Mobile fauna was dominated by crinoids in Clusters 1, 2 and 4, with brittle stars the most frequently observed mobile species in Cluster 3. Echinoids and gastropods were most often observed in Cluster 1, whilst holothurians were observed mainly in Clusters 2 and 3.

The most frequently observed species, and their spatial cover, are given for non-sponge groups in Table 53, and sponges in Table 54, by cluster.

Figure 118: Example images of sessile community clusters found at Ranfurly Bank. Cluster 1, a–b) bare soft substrate with small unidentified pink sea pen; Cluster 2, c–f) mainly bare substrate with encrusting coralline algae, occasional plexaurid sea fan or sponge (pink sponge *Petrosia hebes*).


a)
b)
c)
d)
e)
f)

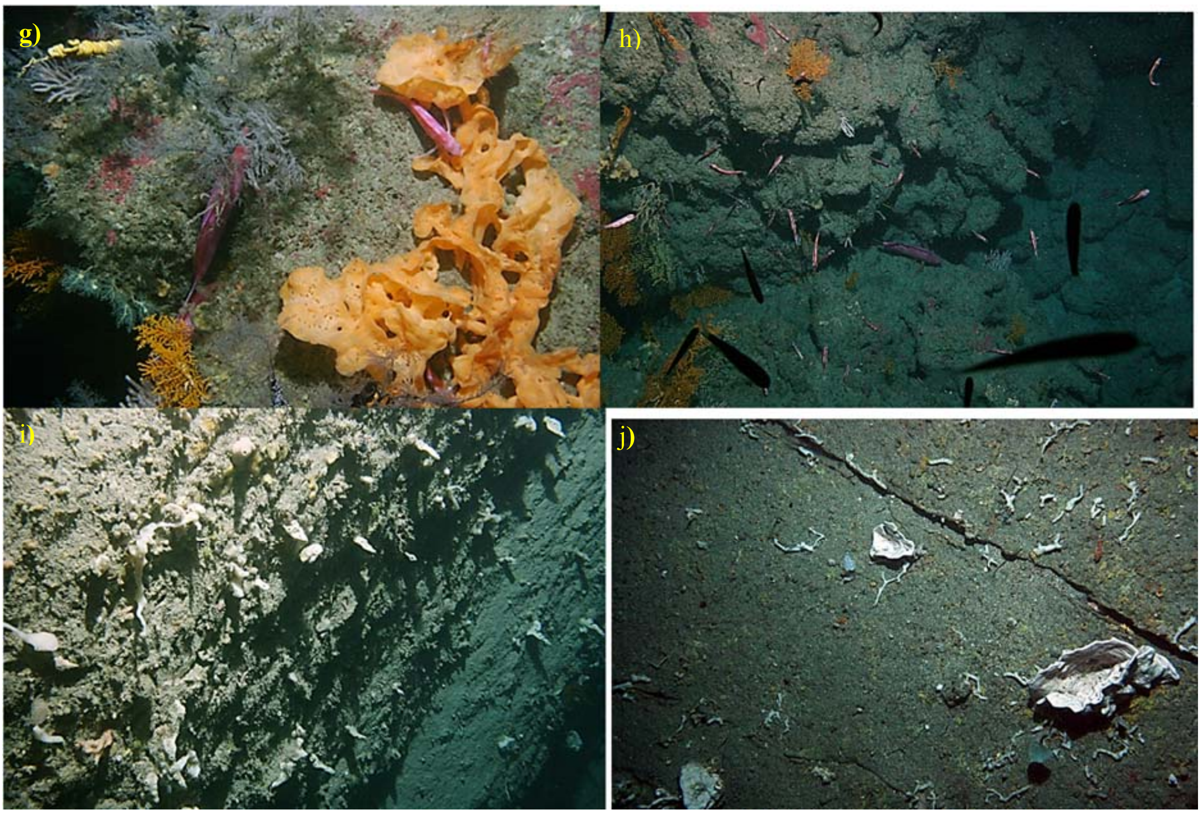


Figure 119: Example images of sessile community clusters found at Ranfurly Bank. Cluster 3 examples: a–b) areas of low relief red algal, catenicellid bryozoans and soft coral fields with occasional sponge, e.g. grey *Latrunculia duckworthi*; c–d) *Ecklonia radiata* beds with similar understorey of species, *Caulerpa flexilis* mats, all found on the upper slopes and top of the bank; e–f) at greater depths, reef outcrops dominated by sponges such as the grey *Ecionemia alata* and white fans of *Xestospongia corallodies* (e), and catenicellid bryozoans; with flats covered in catenicellid bryozoans and sponges such as *Acanthella dendyi*; g–h) deep northern rocky outcrops with sponges (*Symptella rowi*), black corals (g), plexaurid and primnoid sea fans (h); i–j), sponge and ascidian-encrusted rock faces of the eastern outcrop (sponges including *Xestospongia corallodies* and *Coscinoderma.* sp. 2).

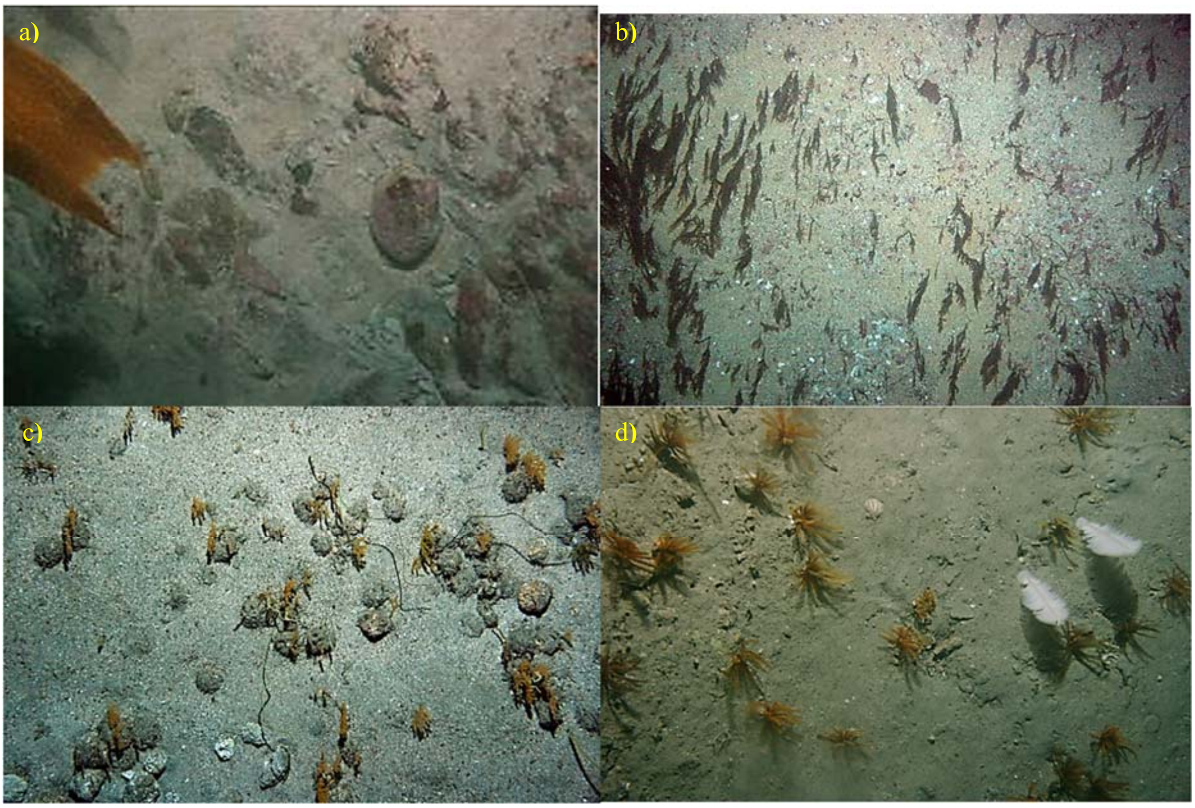


Figure 120: Example images of sessile community clusters found at Ranfurly Bank. Cluster 4 images. a) Top of bank bare sand with boulders encrusted with coralline algae, sparse *Ecklonia radiata*, and *Caulerpa flexilis*; c) deeper northern station with bare substrate, relict rhodoliths (?), plexaurid sea fans, whip coral *Stichopathes* sp., and unidentified haplosclerid sponge; d) deep eastern outcrop area, rubble and soft sediment substrate with crinoids and sea pens.

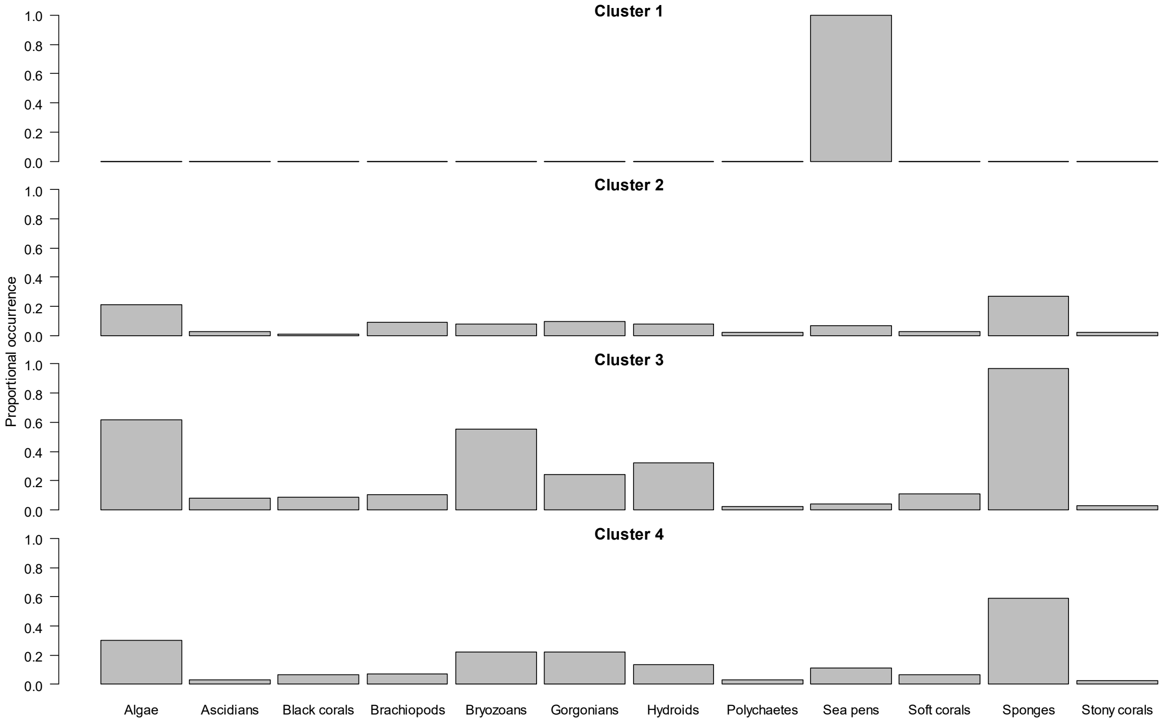


Figure 121: Proportional occurrence of different sessile species groups, assigned across the four faunal clusters identified in community data from Ranfurly Bank by non-hierarchical clustering.

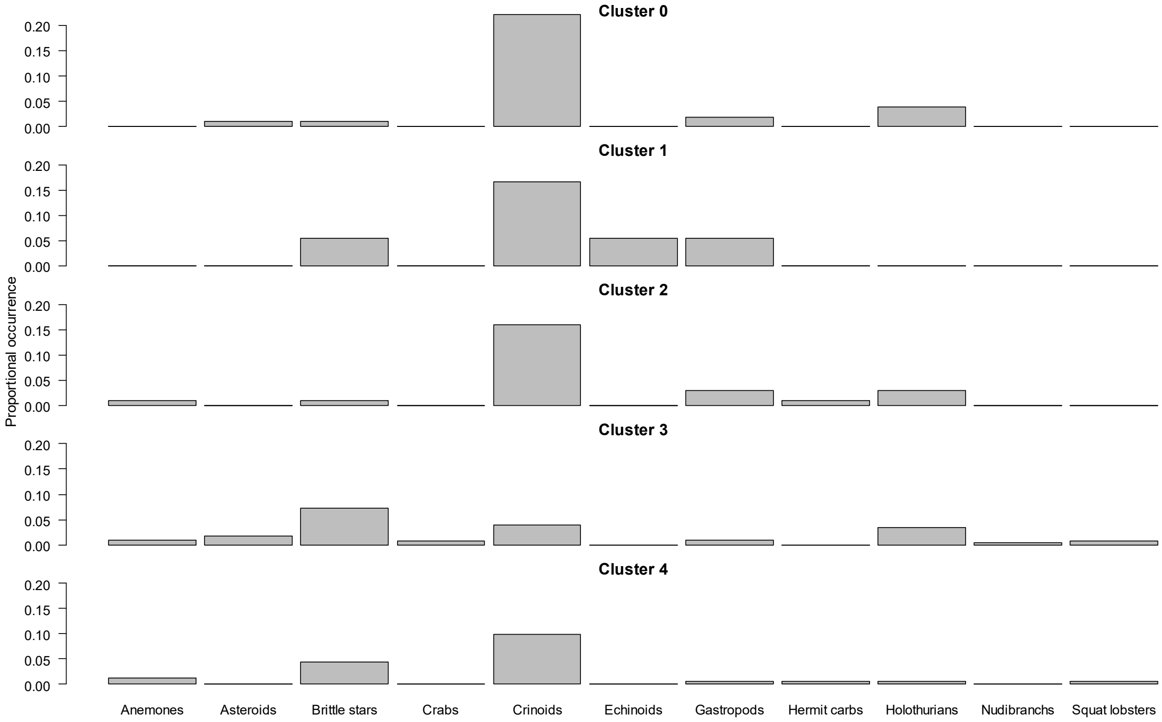


Figure 122: Proportional occurrence of different mobile species groups, assigned across the four faunal clusters identified in community data from Ranfurly Bank by non-hierarchical clustering.

Table 53: Percentage occurrence across images, and average cover (*E. radiata*) or count per standardised square metre of some key sessile species from Ranfurly Bank.

Cluster	Species Richness	Key species (algae, bryozoans, cnidarians and hydroids)	% occ.	Average count*/cover per m^2
0	–	–	–	–
1	1	Pink sea pen (unidentified)	100	1
2	19	Encrusting coralline algae	12.87	0.0397
		Plexaurid sea fans	8.90	0.1453
		Nemertesia elongate (Hydroid)	5.94	0.0667
		Red bushy algae	3.96	0.00004
		Catenicellid bryozoans	2.97	0.00006
3	36	Encrusting coralline algae	58.60	0.1083
		Catenicellid bryozoans	39.40	0.0148
		Red algae (blades)	28.17	0.0030
		Red algae (bushy)	23.94	0.0037
		Plexaurid sea fans	23.44	0.7339
		Ecklonia radiata	20.69	*1.9720
4	31	Encrusting coralline algae	22.36	0.0273
		Plexaurid sea fans	18.63	0.548
		Catenicellid bryozoans	10.56	0.0016
		Ecklonia radiata	9.94	*1.0075
		Nemertesia elongate (Hydroid)	6.83	0.0987

Table 54: Percentage occurrence across images, and average cover per standardised square metre of the dominant sponge species from Ranfurly Bank.

Cluster	Species Richness	Key species	% occ.	Average cover per m^2
0	–	–	–	–
1	–	No sponges	–	–
2	15	*Dragmacidon austral / Poecilosclerid* sp. (encrusting orange)	7.90	0.0001
		Iophon sp. 4/*Topsentia* sp. 4 (encrusting yellow)	2.97	0.0001
		Coscinoderma sp. 2 (white ragged)	1.90	0.000004
3	56	*Dragmacidon austral / Poecilosclerid* sp. (encrusting orange)	60.85	0.0204
		Iophon sp. 4 / *Topsentia* sp. 4 (encrusting yellow)	17.71	0.0026
		Stelletta columna (cup)	15.71	0.0022
		Coscinoderma sp. 2 (white ragged)	13.72	0.0026
		Xestospongia corallodies (white fans)	12.96	0.0017
4	30	*Dragmacidon austral / Poecilosclerid* sp. (encrusting orange)	27.33	0.0024
		Haplosclerid sp. 1 (white digitate)	9.32	0.0006
		Iophon sp. 4 / *Topsentia* sp. 4 (encrusting yellow)	8.07	0.0009
		Coscinoderma sp. 2 (white ragged)	4.35	0.0004
		Raspailia sp. 6 / *Axinella* sp. 12 (finger)	3.11	0.0007

Relationships between benthic community data and remote sensing and other potential explanatory variables for Ranfurly Bank

Full community

The relationship between the benthic communities observed at Ranfurly Bank and environmental variables was examined using distance based linear modelling (DistLM). Multibeam coverage was not available for all stations, so some were dropped from further analysis, along with any species recorded only at those stations. This left a total of 599 images. The DistLM analysis using the full community dataset (sessile and mobile species combined) and multibeam-derived variables (both continuous and categorical) gave a best fit model which included depth, structures, reflectance and slope, although even combined, these explained only 9.1% of the total variation in the data, with the first two axes accounting for just over 7% (Table 55). The most important variable contributing to the first axis of the dbRDA plot was depth, whilst slope, reflectance and the different structure categories were more correlated with the second axis, particularly the structure 9 category ('local crest in a depression') (Figure 123).

Table 55: Summary of step-wise DistLM models fitted to Ranfurly Bank full community data. Explanatory terms used are listed in the first column. Marginal proportion (proportion explained by the term in isolation) is given for all terms in the second column, with sequential proportions for each model given in following columns. The total cumulative proportion explained by each model is also given, along with the improvement made as terms are added. (-) indicates that a term is not included in that model, (ns) indicates a term was included, but dropped from the final model. MB, multibeam.

Term		MB only	MB + Site	MB + Site + Bioturbation + % Hard subst.	MB + Bioturbation + % Hard subst.
	Marginal Prop.	Sequential Prop.			
Site	0.060	–	0.060 (1)	0.059 (1)	–
Depth	0.051	0.051 (1)	0.085 (2)	0.025 (2)	0.051 (1)
Structure	0.037	0.034 (2)	ns	ns	0.034 (2)
% Hard substrate	0.008	–	–	0.005 (3)	0.005 (3)
Reflectance	0.004	0.003 (3)	ns	ns	0.004 (4)
Slope	0.004	0.003 (4)	ns	ns	–
Bioturbation	0.001	–	–	ns	ns
Zone	0.013	ns	ns	ns	ns
Rugosity	0.003	ns	ns	ns	ns
Cumulative prop.		0.091	0.085	0.089	0.093
Improvement			-0.006	-0.002	0.004

The addition of a categorical site identifier that split the samples into northern deep outcrops (Site 44), eastern outcrop (Site 45) and the central bank stations (Sites 41, 42 and 43) replaced all multibeam-derived variables except depth, producing the most parsimonious model with the lowest AIC value, but did not result in an improvement in the amount of total variation explained by the model. Including the image-derived variables relating to levels of bioturbation activity and % hard substrate, resulted in a model that included Site, depth and % hard substrate, but again, did not increase the amount of variation explained compared to the initial model (a total of 8.9%). Excluding the Site category gave a final combination of depth, structure category, % hard substrate, and reflectance, which combined accounted for 9.3% of the total variation, with depth being the most important explanatory variable.

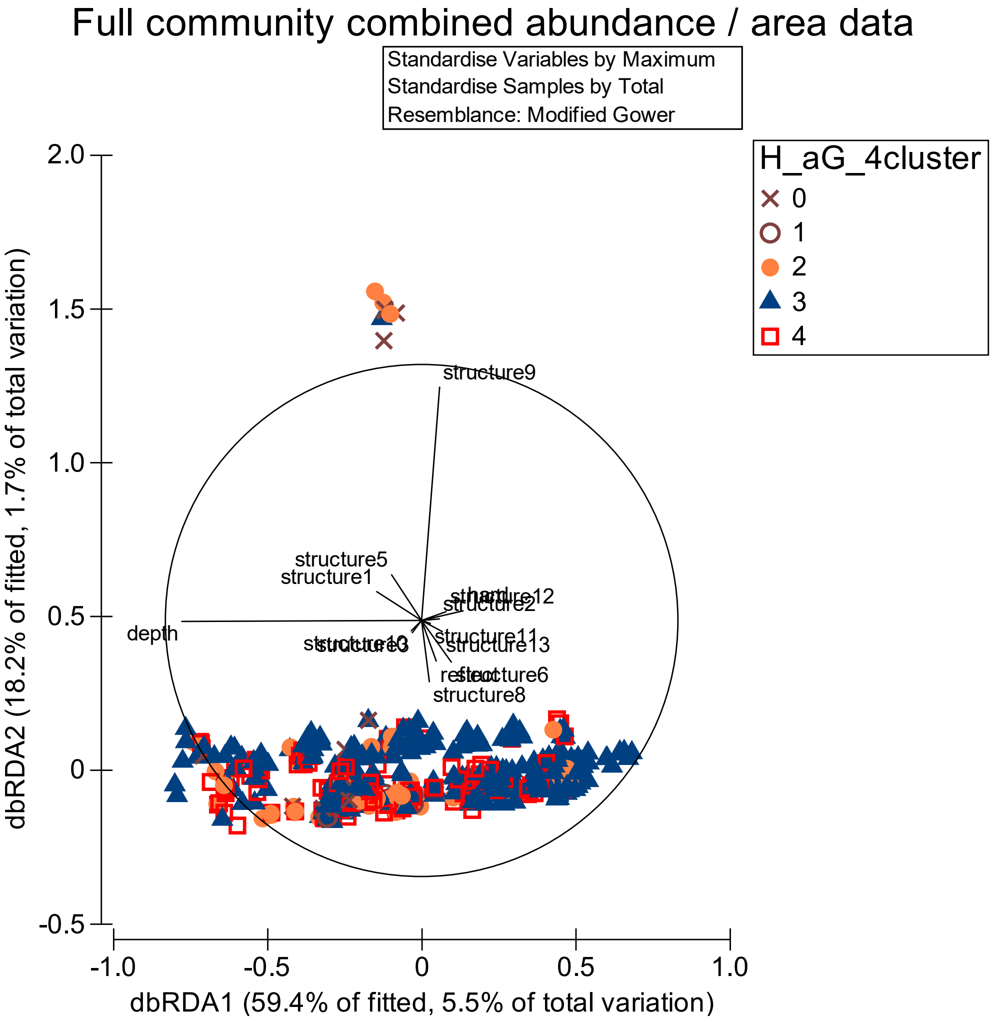


Figure 123: Distance based redundancy analysis (dbRDA) plot of the DistLM model based on a Modified Gower similarity matrix of full community standardised abundance and area data from Ranfurly Bank, with PCA overlay of fitted multibeam and image-derived variables, displaying strength and direction of effect on the ordination plot. The axis legends include the percentage variation explained by the fitted model and total variation for the first two axes. Image samples are labelled according to the cluster groupings defined using the sessile-only database (H_aG_4cluster). For definition of Structure categories, refer to Multibeam data processing section on page 8.

Sessile fauna only

Using only the sessile fauna data did not increase the explanatory power of the model; depth, zone, reflectance and slope together accounted for 6.8% of variation, when multibeam-only variables were used (Table 56). Depth was the main explanatory term along the primary axis, with shallow stations from the top of the bank clustered to the right and the deeper stations to the north and east found to the left of the plot (Figure 124). Separation of samples along the vertical axis was driven by classification of most images as either ‘depressions’ (Zone 2) or a mixture of ‘slopes’ (Zone 4), and ‘flats’. Of these terms, only depth was retained once region was included, the latter becoming the main explanatory variable and increasing the total variation explained by 1.4% (Table 56). Including the image-derived variables relating to proportion of hard (% Hard substrate) and soft (Bioturbation levels) substrate increased the explanatory power slightly with the hard substrate term adding 0.3%. Excluding the Site category resulted in 5 other variables, depth, % hard substrate, zone, reflectance and slope, being selected, but did not improve the explanatory power (just over 7% of the total variation, Table 56).

Table 56: Summary of step-wise DISTLM models fitted to the Ranfurly bank sessile community data. Explanatory terms used are listed in the first column. Marginal proportion (proportion explained by the term in isolation) is given for all terms in the second column, with sequential proportions for each model given in following columns. The total cumulative proportion explained by each model is also given, along with the improvement made as terms are added. (-) indicates a term is not included in that model, (ns) indicates a term was included, but dropped from the final model.

		MB only	MB + Site	MB + Site+ Bioturbation+ % Hard subst.	MB + Bioturbation + % Hard subst.
Term	Marginal Prop.	Sequential Prop.			
Site	0.060	–	0.060 (1)	0.060 (1)	–
Depth	0.049	0.049 (1)	0.022 (2)	0.022 (2)	0.049 (1)
% Hard substrate	0.005	–	–	0.003 (3)	0.052 (2)
Zone	0.021	0.012 (2)	ns	ns	0.065 (3)
Reflectance	0.002	0.004 (3)	ns	ns	0.069 (4)
Slope	0.006	0.003 (4)	ns	ns	0.072 (5)
Rugosity	0.003	ns	ns	ns	ns
Structure	0.035	ns	ns	ns	ns
Cumulative Prop.		0.068	0.082	0.085	0.072
Improvement			0.014	0.003	-0.013

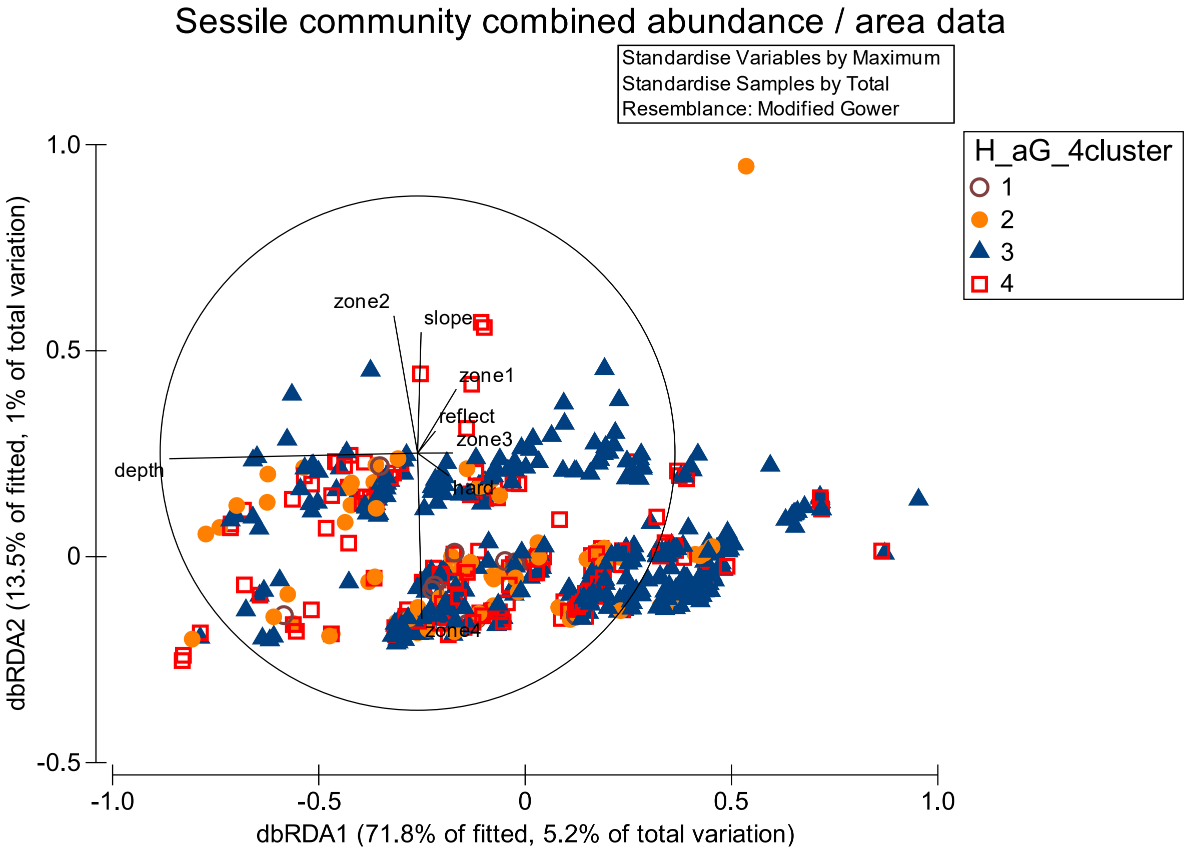


Figure 124: Distance based redundancy analysis (dbRDA) plot of the DistLM model based on a Modified Gower similarity matrix of sessile community standardised abundance and area data from Ranfurly Bank, with PCA overlay of fitted multibeam and image-derived factors, displaying strength and direction of effect on the ordination plot. The axis legends include the percentage variation explained by the fitted model and

total variation for the first two axes. Image samples are labelled according to the cluster groupings defined using the sessile-only database (H_aG_4cluster).

Fish diversity and abundance observed on Ranfurly Bank

A small number of fish were sampled in the beam trawl and epibenthic sled. Red scorpion fish were most frequently caught, and were present at all depths. The second most common species was initially identified as the redbanded weever, *Parapercis binivirgata*, but subsequently found to be a new sand perch (weever) species, now known as the black-fin sea perch, *Parapercis nigrodorsalis* (Johnson et al. 2014). Also included in the total of 16 species were two species rare to the New Zealand mainland; the luminescent cod and the red little gurnard perch (Table 57).

Table 57: Fish species captured by epibenthic sled and beam trawl on Ranfurly Bank. Numbers in brackets are number of sample tows. [1] Holotype and paratypes of new species, [2] rare species.

Species		Central Shallow <50 m (1)	Central Mid (50–110 m) (5)	East >100 m (1)	North >100 m (2)	Total
Red scorpion fish	*Scorpaena papillosa*	1	15	–	1	17
Black fin sand perch [1]	*Parapercis nigrodorsalis*	–	10	–	–	10
Redbanded weever	*Parapercis binivirgata*	–	1	–	1	2
Northern bastard cod	*Pseudophycis breviuscula*	–	4	–	–	4
Southern bastard cod	*Pseudophycis barbata*	–	2	–	–	–
Leatherjacket	*Parika scaber*	–	5	–	–	5
Spot-tail perchlet	*Plectranthias maculicauda*	–	3	1	1	5
Red little gurnard perch [2]	*Maxillicosta raoulensis*	–	3	–	–	3
Sea perch	*Helicolenus* spp.	–	1	–	1	2
Rock fish	*Acanthoclinus cf. matti*	–	1	–	–	1
Pink maomao	*Caprodon longimanus*	–	1	–	–	1
Crimson wrasse	*Suezichthys aylingi*	–	1	–	–	1
Crested flounder	*Lophonectes gallus*	–	1	–	–	1
Spiny sea dragon	*Solegnathus spinosissimus*	–	1	–	–	1
Hector's lantern fish	*Lampanyctodes hectoris*	–	–	–	1	1
Luminescent cod [2]	*Physiculus luminosa*	–	–	–	1	1
Total		1	48	2	6	57

The most common fish observed on DTIS tows at Ranfurly Bank were pink maomao, with just over 1000 fish counted (Table 58). They were particularly abundant around the deep rocky outcrops to the north of the main bank, but also the most common species observed at the shallower stations at less than 50 m depth. Sea perch were not observed at the shallow stations, but were abundant deeper than 50 m. Morid cods, including bastard codling were also commonly observed at the deeper stations. Over the softer sediment areas, cucumber fish and silver conger eels were frequently observed.

Table 58: Fish densities per 1000 m^2 estimated from DTIS videos on Ranfurly Bank. The top five species for each area are shaded. Density is given with an associated standard error. Ind.; individuals. *, fisheries species.

		Central shallow (<50 m)			Central mid (50–110 m)			East deep (> 100 m)			North deep (> 100 m)		
Species	Scientific name	Density	Range	Ind.	Density	Range	Ind.	Density	Range	Ind.	Density	Range	Ind.
Pink maomao	*Caprodon longimanus*	13.6 ± 4.50	2–28.9	76	10.75 ± 4.63	0–54.4	112	4.48 ± 2.25	0–10.1	20	92.94 ± 68.37	0.8–494.6	793
Cucumberfish	*Paraulopus nigripinnis*	–	–	–	0.22 ± 0.16	0–1.9	2	9.32 ± 2.16	3.6–14.1	37	0.07 ± 0.07	0–0.5	1
Sea perch*	*Helicolenus percoides*	–	–	–	0.36 ± 0.20	0–1.9	3	5.03 ± 3.02	0–12.1	26	3.33 ± 1.66	0–12.6	33
Kingfish*	*Seriola lalandi*	1.36 ± 1.36	0–9.5	7	0.96 ± 0.75	0–9.8	8	2.73 ± 2.73	0–10.9	6	3.40 ± 2.75	0–19.5	28
Eels	Unid.	–	–	–	1.30 ± 0.49	0–5.4	14	1.76 ± 0.89	0–4.2	4	0.39 ± 0.28	0–1.9	3
Silver conger eel	*Gnathophis habenatus*	–	–	–	1.25 ± 0.61	0–7.1	14	0.17 ± 0.17	0–0.7	1	2.01 ± 0.72	0–5.6	21
Morid cod	Moridae	–	–	–	1.14 ± 0.72	0–7.9	12	–	–	–	1.79 ± 0.88	0–6.7	12
Northern bastard cod	*Pseudophycis barbata*	–	–	–	0.08 ± 0.08	0–1	1	1.18 ± 0.97	0–4	5	1.1 ± 0.58	0–3.4	14
Leatherjacket*	*Meuschenia scaber*	2.0 ± 0.53	0–3.1	11	0.20 ± 0.10	0–1	3	–	–	–	–	–	–
Tarakihi*	*Nemadactylus macropterus*	–	–	–	0.15 ± 0.15	0–1.9	1	0.88 ± 0.38	0–1.8	3	0.28 ± 0.18	0–1.1	2
Crested bellows fish	*Notopogon lilliei*	–	–	–	–	–	–	0.71 ± 0.44	0–1.8	2	0.49 ± 0.49	0–3.4	2
Scorpionfish	Scorpaenidae	–	–	–	0.08 ± 0.08	0–1	1	–	–	–	0.96 ± 0.36	0–2.3	10
Opalfish	*Hemerocoetes spp.*	–	–	–	–	–	–	–	–	–	0.75 ± 0.48	0–3.4	4
Porae*	*Nemadactylu douglassi*	0.66 ± 0.51	0–3.6	4	–	–	–	–	–	–	–	–	–
Rock cod	*Pseudophycis bachus*	–	–	–	–	–	–	0.52 ± 0.52	0–2	1	–	–	–
Slender roughy	*Optivus elongatus*	–	–	–	–	–	–	–	–	–	0.44 ± 0.33	0–2.3	4
Blue warehou*	*Seriolella brama*	–	–	–	–	–	–	–	–	–	0.40 ± 0.32	0–2.3	3
Mottled moray	*Gymnothorax prionodon*	–	–	–	0.23 ± 0.16	0–1.9	2	–	–	–	0.16 ± 0.16	0–1.1	1
Single-spot demoiselle	*Chromis hypsilepsis*	0.34 ± 0.22	0–1.4	2	–	–	–	–	–	–	–	–	–
Goat fish	*Parupeneus lineatus*	0.30 ± 0.30	0–2.1	1	–	–	–	–	–	–	–	–	–
Spotted gurnard	*Pterygotrigla picta*	–	–	–	0.15 ± 0.15	0–1.9	1	–	–	–	0.11 ± 0.11	0–0.8	1
Blue moki*	*Latridopsis ciliaris*	0.15 ± 0.15	0–1	1	0.09 ± 0.09	0–1.1	1	–	–	–	–	–	–
Spiny dogfish*	*Squalus acanthias*	–	–	–	0.23 ± 0.23	0–3.0	3	–	–	–	–	–	–
Rig*	*Mustelus lenticulatus*	–	–	–	0.19 ± 0.19	0–2.4	3	–	–	–	–	–	–
Jack mackerel*	*Trachurus* spp.	–	–	–	0.17 ± 0.17	0–2.2	2	–	–	–	–	–	–
Butterfly perch	*Caesioperca lepidoptera*	–	–	–	–	–	–	0.17 ± 0.17	0–0.17	1	–	–	–
? Frostfish*	*Lepidopus caudatus*	–	–	–	–	–	–	0.17 ± 0.17	0–0.7	1	–	–	–
Northern splendid perch	*Callianthias australis*	–	–	–	–	–	–	–	–	–	0.16 ± 0.16	0–1.1	1
Blue cod*	*Parapercis colias*	–	–	–	–	–	–	–	–	–	0.16 ± 0.16	0–1.1	1
Sandfish	*Gonorynchus forsteri*	0.14 ± 0.14	0–0.9	1	–	–	–	–	–	–	–	–	–
Conger eel	Congridae	–	–	–	0.06 ± 0.06	0–1.8	1	–	–	–	0.07 ± 0.07	0–0.5	1
? Lizardfish	Synodontidae	–	–	–	0.08 ± 0.08	0–1.9	1	–	–	–	–	–	–
Unidentified Fish				5			30			7			15

The results of cluster analysis of the group-average Bray-Curtis similarity matrix and similarity profile (SIMPROF) test are shown in Figure 125. SIMPROF identified five groupings in the fish community data (P=0.05) at between 35–50% similarity. Exploration of the species contributing to the within group similarity using SIMPER indicated that differences were driven by species such as long fin worm eels, silver conger eels, and cucumber fish, found in higher abundance at stations which included areas of soft substrate (SIMPROF groups a and d), and species such as pink maomao and leatherjacket found at the shallower sites (simprof group b), and morid cods and scorpion fish occurring alongside pink maomao at deeper stations (groups e and c). An MDS of the stations is given in Figure 126.

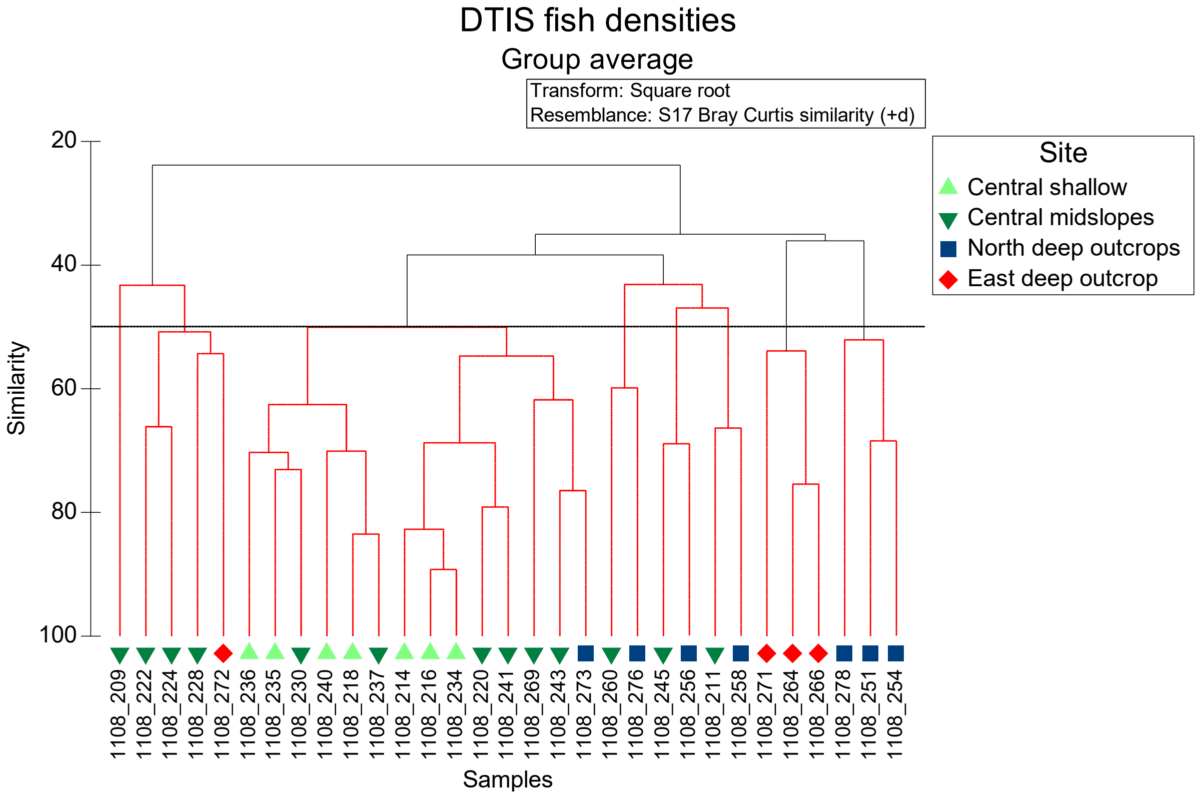


Figure 125: Dendrogram from cluster analysis of the group-average Bray-Curtis similarity matrix from Ranfurly bank fish community showing five groups identified by SIMPROF. Dotted red lines connect stations that did not show significant differences in community structure. The horizontal line represents 50% similarity. Stations are labelled by the sites targeted on the bank (central midslopes = 2 sites).

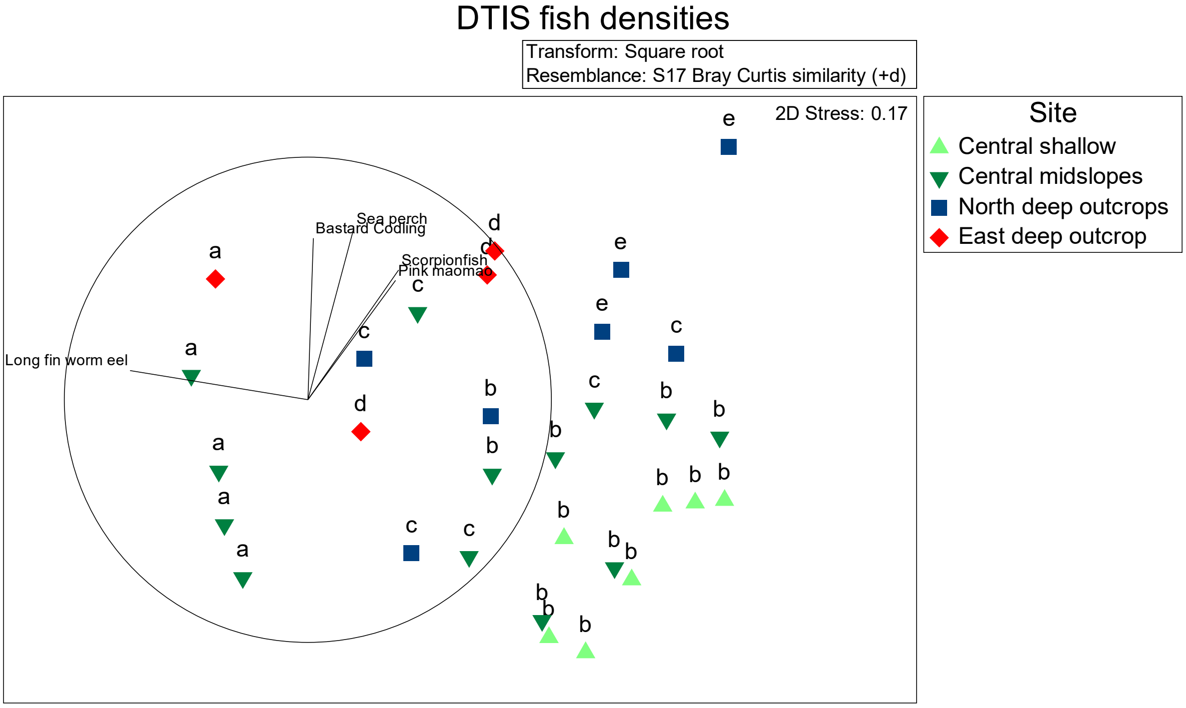


Figure 126: MDS of Ranfurly Bank fish communities observed at different DTIS stations, based on a zero-adjusted Bray-Curtis dissimilarity matrix from square root transformed fish densities. Pearson correlation coefficients (> 0.6) of key fish species have been overlaid.

A step-wise distance-based linear model (DistLM) applied to the DTIS fish community data was used to examine the relationship between environmental and benthic habitat-related variables, using the AIC criterion to select the optimal number of terms included (Table 59). Using multibeam-derived terms of average station depth, slope and rugosity (reflectance was not available for five stations, so was omitted), explained 25% of the total variation in the fish community data, with rugosity being non-significant. Adding in a categorical term for the four sites (central shallow, central mid-slopes, northern deep outcrops and eastern deep outcrop) improved the explanatory power of the model by nearly 18%. Adding average water temperature (CTD), and % hard substrate (image-derived) produced a model explaining over 50% of the total variation, with all terms retained except rugosity and % hard substrate. Excluding the site categorical term, reduced the overall explanatory power and the number of variables, leaving both the % of ‘High’ biogenic habitats (Clusters 3 and 4) and depth as the main explanatory terms, followed by slope (Figure 127).

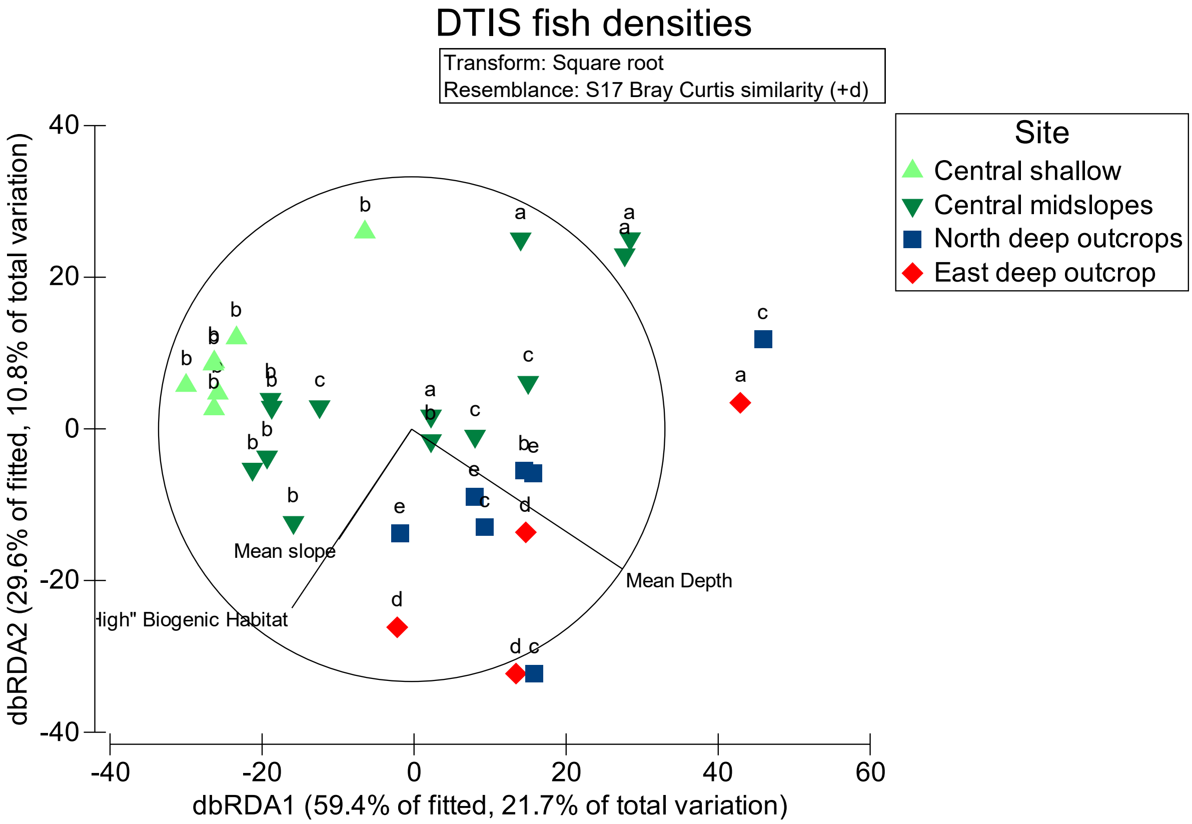


Figure 127: Distance based redundancy analysis (dbRDA) plot of the DistLM model based on a zero-adjusted Bray-Curtis dissimilarity matrix from square root transformed fish densities from Ranfurly Bank, with PCA overlay of fitted explanatory variables, displaying strength and direction of effect on the ordination plot. The axis legends include the percentage variation explained by the fitted model and total variation for the first two axes. Image samples are labelled by Region (excluded from the model), and by the allocated grouping from SIMPROF.

Table 59: Summary of step-wise DistLM models fitted to the DTIS station fish densities on Ranfurly Bank. Explanatory terms used are listed in the first column. Marginal proportion (proportion explained by the term in isolation) is given for all terms in the second column, with sequential proportions for each model given in following columns. The total cumulative proportion explained by each model, along with the improvement made as terms are added is also provided. (-) indicates a term is not included in that model, (ns) indicates a term was included, but dropped from the final model. MB, multibeam.

Term		MB only	MB + Site	MB + Site + Water temp + % Hard subst.+ % Biogenic habitat	MB + Water temp + % Hard subst.+ % Biogenic habitat
	Marginal Prop.	Sequential prop.			
% Biogenic Habitat	0.188	-	-	0.125 (2)	0.188 (1)
Mean Depth	0.181	0.181 (1)	0.063 (2)	0.033 (4)	0.121 (2)
Mean Slope	0.069	0.071 (2)	0.051 (3)	0.031 (5)	0.055 (3)
Site	0.314	-	0.314 (1)	0.314 (1)	-
Mean Water Temp	0.102	-	-	0.042 (3)	ns
Mean Rugosity	0.039	ns	ns	ns	ns
% Hard substrate	0.046	-	-	ns	ns
Cumulative prop.		0.252	0.428	0.545	0.364
Improvement			0.176	0.117	-0.181

5. BROADER SCALE SYNOPSIS

5.1 Nature and extent of the biogenic habitats observed.

The two surveys collectively revealed a broad and rich array of biogenic habitats and associated biodiversity, many of which were not previously identified in the New Zealand science literature. These included assemblages of sponges, corals, tube-worms, deep water macro-algae, rhodoliths/maerl, ascidians and crinoids. In the three core areas studied in detail, the key habitat formers for each area were quite distinct from each other, and are summarized below, along with an assessment of their likely extent based on the observations collected, and other information, both anecdotal and scientific.

North Taranaki Bight canyons (The Well, The Coral Canyon)

Biogenic habitat (aside from sea pens) was largely restricted to low outcrops of bedrock and carbonate rubble fields on the flanks of the canyons. Three habitat assemblages were identified; 1) soft sediments with occasional sessile fauna such as sea pens, whip corals, hydroids; 2) mixed sediment types (carbonate rubble interspersed with soft sediment) with low levels of sessile fauna such as bryozoan turf, cup corals, sparse sponges on rubble / rock, and whip corals and sea pens in sediment; and 3) a diverse sponge community on rubble / rock, with sabellid worms, cup corals, hydroids and bryozoans also present. Many of the sponges in this third assemblage are new to science, along with others previously considered rare (see following taxonomy section). Proportional coverage of the rock habitats was low, with most species being small-bodied, but nevertheless these organisms provided significant additional biological complexity to these rocky seafloors.

Amongst the most abundant species of sponge identified were the lithistid (rock-dwelling) sponges *Pleroma* spp. and *Aciculites pulchra*, and the distinctive blue and white *Reidispongia coerulea.* Lithistid sponges, including the species observed in this study, are known to dominate the sponge fauna on a range of diverse shelf edge, bank and seamount habitats from 140 m to around 1000 m in the Southwest Pacific, reported in association with highly diverse communities, including hydroids, soft corals, bryozoans and ascidians (Kelly 2000). Table 60 summarises the individual species distributions which collectively includes New Caledonia, Norfolk Ridge, Kermadec Ridge, Three Kings Ridge, and northern New Zealand. Around New Zealand, specimens have been collected from both east and west northland coast (e.g. Pandora Bank, and the outer Bay of Islands), in the Bay of Plenty (e.g. White Island and Rungapapa Knoll), and eastern edge of the Challenger plateau (Kelly 2000; Kelly 2007; Schlacher-Hoenlinger et al. 2005). Visually similar habitat assemblages to the canyon sites analysed in this study were also present at a third Taranaki Bight site on the shelf break (The Drop-off), and to the north at Three-Holes Canyon (off north Kaipara Harbour) (see West Coast North Island section). These four canyons/shelf edge locations spanned 250 km along the west coast North Island continental shelf, effectively filling in the gap between Pandora Bank in the north and the Challenger Plateau. Several distinctive, endemic hexactinellid glass sponges were also observed at these canyon sites; *Rossella ijimai*, previously known only from North Cape and recently identified off Great Barrier Island (Lee et al. 2015), and *Symplectella rowi,* reported from North Cape, east northland, the Bay of Plenty, the north east coast of the South Island, Fiordland and around Stewart Island (Kelly et al. 2009), and identified in this study at Middlesex Bank, Cape Reinga, North Cape, Ranfurly Bank and Mason Canyon. The lithistid sponges are believed to be “relict” sponges, with a much more restricted current distribution compared to the fossil record for these genera. Key factors likely to determine the distribution of all sponges are the availability of hard substrate, water temperature, ocean currents, and the availability of silica (Kelly 2007).

Table 60: Key sponge species recorded at North Taranaki Bight, and their known distribution, based on existing scientific literature, and NIWA's Specify databases. Depth ranges are given from existing information, and from this study specifically.

	Species	Depth range (m)	Occurrence
Lithistid sponges	*Pleroma menoui* Lévi & Lévi, 1983	179–1131	South Fiji Basin; Norfolk Ridge south of New Caledonia; western continental slope of Northland; west of Three Kings Ridge; Colville Ridge; Wanganella Bank; Raukumara Plain, northern Bay of Plenty; Kermadec Ridge; Cavalli Seamounts; west of White Island and Tuatoru Knoll, Bay of Plenty (Kelly 2007)
		200–330	From this study: North Taranaki Bight canyons and likely observed on DTIS at west coast canyons, Northland
	Pleroma turbinatum Sollas, 1888	230–860	Fiji Islands; Norfolk Ridge south of New Caledonia; Lord Howe Seamount Chain; Norfolk Ridge south of Norfolk Island; northern slopes of Challenger Plateau; west of White Island, Bay of Plenty (Kelly 2007)
		200–330	From this study: North Taranaki Bight canyons
	Aciulites pulchra Dendy, 1924	80–1050	Endemic to New Zealand, found on West Norfolk Ridge; southern Three Kings Ridge; Louisville Seamount Chain; Kermadec Ridge; western continental slope, Northland; west of Pandora Bank; North Cape; Cavalli Seamount; outer Bay of Islands; Ngunguru Bay, Northland; off Tutukaka; Rungapapa, Tumokemoke, Mahina, and Tuatoru Knolls, west of White Island, and Mayor Island, Bay of Plenty; east of Gisborne; south of East Cape; Mahia Peninsula
		180 – 330	From this study: North Taranaki Bight canyons and west coast canyons, Northland.
	Reidispongia coerulea Lévi & Lévi, 1988	141–1132	Éponge Seamount, south New Caledonian slope of Norfolk Ridge; Eastern edge of the Challenger Plateau; west of White Island and Rungapapa Knoll, Bay of Plenty; South Kermadec Ridge.
		250 – 330	From this study: North Taranaki Bight canyons
Hexactinellid sponges	*Symplectella rowi* Dendy, 1924	5–240	Endemic to New Zealand, found around North Cape, east Northland, Bay of Plenty, Cook Strait and northeast coast of the South Island, Fiordland and around Stewart Island (Kelly et al. 2009)
		100–200	From this study: North Cape, Middlesex Bank, Cape Reinga, west coast canyons, Northland, North Taranaki Bight canyons, Conway Ridge, Mason Canyon, Ranfurly Bank
	Rossella ijimai Dendy, 1924	90–130	First described from North Cape (*Terra Nova* Expedition, 1910) and subsequently from the outer Hauraki Gulf (Rakitu Island, Great Barrier Island) (Lee et al. 2015)
		160–330	From this study: North Taranaki canyons

Chaetopterid tubeworm habitats of the east coast South Island.

At the North Canterbury and Haypaddock sites, extensive chaetopterid polychaete tubeworm "meadows" provided an attachment surface for a number of sessile phyla as observed in the images and confirmed by the specimens collected. Mobile fauna, including fish, crabs, squat lobsters, holothurians and anemones were also observed in close association with the tubeworm beds, presumably making use of the habitat for shelter, and foraging.

The densities and proportional length of tube visible above the surface varied spatially, from dense and "long" (8–10 cm) tubes in the northern Canterbury Bight, to "short" and sparse tubes in parts of the Pegasus Bay and Canyon, with a high degree of variability throughout (see Figure 92). Based on the taxonomic identification of the samples, the dominant species making up the meadows in all areas sampled was one of three previously undescribed species, *Spiochaetopterus spiochaetopterus* A, with two other species also collected in much smaller quantities from North Canterbury only (*Spiochaetopterus spiochaetopterus* B, and *Phyllochaetopteris phyllochaetopterus* A). It is believed that these species have been previously identified as *Phyllochaetopteris socialis* along this coast (Graham 1962; Probert & Anderson 1986).

Attached fauna included a number of tubular, palmate and digitate sponges (e.g. *Chondropsis* and *Callyspongia* species, and *Crella incrustans*), along with both solitary and colonial ascidian species, serpulidworms, and bryozoans in coarser sediments, eg around Pegasus Canyon (see Figure 101). A further 120 km south, at the Hay Paddock location, the associated community of sponges was even more diverse, along with abundant ascidians, hydroids and bryozoans (see Table 40 and Table 41). Seven "habitat clusters" were identified from image samples of the sessile faunal community across all these sites. These groups reflected the differing occurences of emergent or buried tubeworms, and composition of secondary habitat formers such as sponges, ascidians, bivalves, bryozoans, hydroids, and sea pens (see Table 38 and Table 40). Clusters two, three and five were characterized by tube worms that were relatively more emergent from the sediment (categorized as "long and clumped"). Image samples classed as cluster three, found mainly at North Canterbury, were characterized by a lower diversity of associated assemblage of sponges, with an average species richness of 2.3 (± 0.07). Image samples classed as clusters two (found across multiple sites) and five (mainly at the Haypaddock) had higher species richness (average of 4.9 (± 0.09) and 8.2 (± 0.14) respectively, including ascidians, serpulids and hydoids. Images classed as Cluster 6 represented tubeworm patches with no associated fauna, and Cluster 7 consisted largely of image samples where tubeworms were absent, but small clumps of bryozoans with encusting sponges and horse mussels were observed (see Table 40).

A chaetopterid tubeworm and sponge habitat assemblage that appeared to be visually indistinguishable from the Hay Paddock was observed at the head of Karitane ("Cornish Head") Canyon, 40 km south of the Haypaddock (Figure 48). In addition, chaetopterid tubeworms are known to be an important component species in the Otago bryozoan fields, where, as with the Hay Paddock, it is thought to provide a recruitment surface for bryozoans and help establish/maintain the bryozoan fields (Anna Wood, University of Otago, pers. comm.). A slightly less developed tubeworm/bryozoan assemblage was also seen to the inshore of Karitane Canyon (in addition to the Hay Paddock-like assemblage seen there) (Figure 48).

In the North Canterbury area, the tubeworm "meadows" occurred over an area of distinctive ridges and gullies that were evident in the multibeam maps. This region has been previously characterized as an early Holocene mud blanket, separating a zone of modern mud deposition to the south in Pegasus Bay, from the sand and gravel dominated shelf to the north (Carter & Carter 1985). The ridge and gully zone (estimated to be 255 km^2), largely confined to the mud blanket, was reported to most likely be the result of a mass failure of sediments on the continental shelf. The authors noted that the presence of dense chaetopterid tubeworm meadows had stabalized the distinctive topography from erosion by currents. Fenaughty & Bagley (1981) reported "*huge tracts of polychaetes refered to by some fishermen as "tarakihi weed"* from the Conway Ridge area, approximately 30 km north of the North Canterbury site, and one of the fishers interviewed described "wireweed" found near Wellington, and off Cape Campbell (150 km to the north of the North Canterbury site). In the outer Marlborough Sounds, Escourt (1967) noted the presence of *Phyllochaetopteris socialis* at 14 sites with muddy seafloors, although there was no description of the density. Davidson et al. (2017) also recorded a *Spiochaetopterus* sp. from shallow water (less than 20 m) in Port Underwood more recently, noting the association of sponges and red algae, and its possible widespread occurrence.

The NIWA Invertebrate Collection's *Specify* database was interrogated for records of chaetopterid worms (see Table 61). The database contains records which date from the early 1950s, and include NZOI records, and registered records from MPI funded fisheries trawl surveys, observer data, NIWA-led biodiversity surveys, and other fieldwork collections. Chaetopterid records are widely distributed around New Zealand from all depths, but most are not identified to species. From within this family, the genus *Chaetopterus* has been recorded mainly in shallow waters around north eastern New Zealand and from the Marlborough Sounds. Records from the genus *Phyllochaetopterus* exist from all around the North Island, and off the northern South Island (including Malborough Sounds, and both east and west coasts). *Spiochaetopterus* records also occur all around the North Island, and from both the east and west coasts of the South Island. The "wireweed" worms, *Spiochaetopterus spiochaetopterus* A and B, and *Phyllochaetopterus phyllochaetopterus* A, have been identified in samples from deeper (over 500 m) soft sediments on seamounts and in canyons along the Hikurangi margin (Wairarapa coast), and in the Bay of Plenty. In addition, *P. phyllochaetopterus* A has been collected from more than 300 m depth off the Kaipara harbour. From voyages described in this report, these worms were collected from the soft sediments sampled south east of Ranfurly Bank, and near Ariel bank during, although dense meadows were not observed on DTIS transects at these sites. Together, these findings indicate that the species identified from the "wireweed" habitats occur along a latitudinal range extending from at least the Bay of Plenty down to Otago, and over a wide depth range from about 50 to 1000 m. Within this range, they have been observed to be a key contributor to a range of distinctive soft sediment biogenic habitats in certain localized areas at shelf depths along the east coast of the South Island. Closely related, or the same species form similar biogenic habitats in shallow waters (less than 50 m) in parts of the Malborough Sounds.

Table 61: Key putative chaetopterid species recorded from the Canterbury and "Haypaddock" tubeworm sites, and their known distribution, based on NIWA's Specify databases. Depth ranges are given based on existing information.

Species	Depth range (m)	Occurrence
Spiochaetopterus spiochaetopterus A	70–1300	From this study: North Canterbury, Pegasus Bay, Haypaddock, Otago shelf (bryozoan thickets and outer shelf and drop-off), Ariel bank and Ranfurly Bank Also recorded from: Hikurangi margin, Tauranga and White Island canyons, Bay of Plenty (NIWA Specify database)
Spiochaetopterus spiochaetopterus B	100–750	From this study: North Canterbury Also recorded from: Hikurangi margin (NIWA Specify database)
Phyllochaetopterus phyllochaetopterus A	80–1200	From this study: North Canterbury, and Ranfurly Bank Also recorded from: Bay of Plenty canyon sites (NIWA Specify database)

Ranfurly Bank

The third core area surveyed, Ranfurly Bank, was a mixture of different habitat types and depth zones. With a strong sub-tropical influence from the East Auckland Current (EAC), it was more similar to the Three Kings Islands and surrounding banks than the rest of New Zealand. The upper part of the bank was shallow enough to be in the euphotic zone, (receive sufficient sunlight for photosynthesis) and so supported a diverse assemblage of macro-algae species, including kelp, corallines and rhodoliths. Four "habitat clusters" were statistically identified on the bank: 1) sparse sea pens on soft sediment; 2) soft substrate, occasional cobble or boulder, with encrusting coralline algae, encrusting orange sponge, low relief red algae or plexaurid sea fans; 3) mixed hard and soft substrate with diverse fauna; soft curling catenicellid bryozoans and red algae, hydroids, *Caulerpa* mats and patches of the carnation coral (*Neptheidae* spp.), along with key sponges such as *Acanthella dendyi* (mid slopes) and *Coscinoderma* sp. 2 (eastern outcrop stations), and 4) similar to Cluster 2, but with slightly higher diversity and abundance of similar fauna. These assemblages were quite different from those of the other core areas, and included a number of additional new species, as well as tropical species previously considered rare or absent from New Zealand waters, e.g., a number of *Neptheidae* (soft coral) and gorgonian species.

While the statistical analysis grouped most of the more complex biogenic habitats together, it was clear that finer scale assemblages were present, and spatially separated across the bank (see sections on algal and invertebrate samples p164, and DTIS imagery descriptions, p169, and Figure 118 – 120). Large *Ecklonia radiata* forests were restricted to the top of the bank, along with mixtures of red algae and the green alga *Caulerpa flexilis* down to about 90 m water depth (e.g. Figure 119 c, d). Areas of 'sponge gardens' occurred in the 50–100 m+ depth zone, with *Ecionemia alata*, *Petrosia hebes*, *Raspailia* sp and *Acanthella dendyi* amongst the most commonly observed species (Figure 119 e, f). Other species observed included meadows of "soft curling" catenicellid bryozoans, hydroids and occasional soft corals (e.g. Figure 119 a,b).

Beyond 100 m, gorgonian fields and hard corals were found along with sponges on the rocky outcrops in the north-western part of the survey area (e.g. Figure 119 g,h) and a distinctive sponge species assemblage on the deeper southern-eastern reef area was dominated by *Coscinoderma* sp. 2 (Figure 119 i,j), with sea-pen and crinoid fields in deeper mixed rubble and soft sediments (Figure 120 d).

Ranfurly Bank's very clear oceanic waters, shallow depths, and distance from the mainland (including being probably clear of land-based sediment delivery), may make it a relatively unique area, with possible similarities to other offshore banks around New Zealand including the wider Three Kings Islands bank region. Deepwater macroalgae were a prominent feature on the top of the bank. Although widespread in shallower coastal waters, this was the first time *E. radiata* was observed at such depths, and in the distinctive deep-water form. This occurrence represents an important depth extension for this habitat. *E. radiata* was also observed, but in its foliose form, at around 50 m at the Three Kings sites surveyed in this project, and is reported from the Kermadec Islands also (less than 40 m water) by Nelson et al. (2015). *Caulerpa flexilis* was also observed to 70 m depth at Ranfurly bank, and reported from depths over 90 m from the Three Kings and central New Zealand (38.1–43.0°S) by Nelson et al. (2015).

A total of 78 bryozoan species were recorded from Ranfurly Bank samples, but most were hard to identify to species in the DTIS images. The most easily recognizable bryozoans were the erect branching catenicellids that appeared as soft, curling orange-brown bushes around 10–20 cm high, sometimes in high densities on rocks and gravel substrate (Figure 119). Other distinctive species included brownish-orange unbranched fingers of *Steginoporella neozealanica* (Busk, 1861), and fenestrate "lacey" types such as *Hippomenella velicata*, often bright red in colour, the purple or magenta-coloured *Iodictyum yaldwyni* and pink-coloured *Triphyllozoon* n. sp. (grouped as *H. velicata* in image analysis). The catenicellid bryozoans were the most frequently observed bryozoan contributing to the overall occurrence of this group in images (40 – 50% on the central bank in 50 – 110 m depth – Figure 111). The catenicellid OTU was made up of a number of different species, some of which are commonly found around New Zealand in certain habitats. These species are known to thrive in areas of relatively high current flow, particularly around islands, under rock walls, in straits and shelf edges (D. Gordon, pers. comm.).

Table 62 lists some of the species identified in Ranfurly Bank samples, along with the other sites where they were collected within this project, and records from other scientific sources. *Amathia wilsoni,* idenitifed from Ranfurly Bank samples and in still images, was not collected elsewhere in this project, but is reported from Three Kings, all round the North Island, and Fiordland, from shallow depths to around 80 m (Gordon & Spencer-Jones, 2013; Gordon & Mills, 2016). Another, previously unknown species, (*Amathia gracei* n. sp.) is only known from Ranfurly, and is assumed to be endemic, along with *Amathia zealandica* n. sp., which was also found at Ranfurly, and has previously been collected from Spirit's Bay (Gordon & Spencer-Jones, 2013). *Orthoscuticella ventricosa* was the most commonly identified bryozoan species in the Ranfurly samples, but was not recorded elsewhere in this study. A number of closely related, and / or similar-looking "bushy" species, such as O. *innominate,* O. *margaritacea, Cornuticella taurina, Cribricellina cribraria* and *Pterocella scutella,* were found at other locations during the study, including offshore banks to the far north (Three Kings, Middlesex), further south along the east coast of the North Island (Ariel bank and Table Cape), and the southern tip of New Zealand (Mason Canyon and Foveaux Strait). Many of these species are known to have a wide distribution around New Zealand, with some also recorded from south-east Australia (see Table 62). However, there is little empirical information available on levels of abundance within the known distribution. Beaumont et al. (2013) described a wormfield habitat (*Euchone* sp.) on sandy substrate in 30 – 50 m depth on the Patea shoals, South Taranaki Bight, characterized by, among other species, orange catenicellid bryozoans, but noted that densities were low (1–15 individuals per 300 m transect). Species identified from these samples included *Costaticella bicuspis*, *Orthoscuticella fissurata; O. innominate, O. margaritacea,* and *Pterocella scutella* (J. Beaumont, pers comm.).

The distinctive fenestrate, or "lacey" bryozoans also identifiable on images included the "cornflake coral", *Hippomenella vellicata*, which is known to form, (or previously formed) relatively large colonies (up to 30 cm high) at Torrent Bay, Separation Point and the Otago shelf (Grange et al. 2003; Batson & Probert, 2000). Most observations at Ranfurly were of smaller (less than 5 cm) colonies, although larger (10–20 cm) colonies were occasionally observed. This species is one of 11 known habitat-forming bryozoans in New Zealand for which habitat suitability models have been generated using Maxent software by Wood et al. (2013). All 11 species were identified from at least some areas sampled in this project, with 6 identified from Ranfurly Bank samples specifically; *Hippomenella vellicate*, along with *Cellaria immersa, Cellaria tenuirostris, Celleporaria agglutinans*, *Diaperoecia purpurascens,* and *Galeopsis porcellanicus*. Wood et al. (2013) found that most species were associated with shelf depths, relatively shallow mixed layer depths, and intermediate to high current speeds. Stable substrate and low levels of sedimentation were also important. The species distribution models correctly predicted some, but not all known areas where each individual species dominate either on their own or with other habitat-forming species. It was acknowledged that building models that can distinguish between habitat suitable for byrozoans that can form habitat, and areas where bryozoan-generated habitat occurs was not straightforward. As a proxy, the authors identified areas where conditions were suitable for the highest number of species, infering that there is a higher chance of bryozoans generating habitat in these places. They determined that hot spots were areas suitable for 8+ species, and these included Greater Cook Strait, off Banks Peninsula, Mernoo Bank, Pusegur bank and Foveaux Strait. Areas identified as suitable for 4–5 species included around northern North Island, Hauraki Gulf, west of Taranaki, and North Taranaki Bight. The East Cape, including Ranfurly was largely omitted from the individual models due to lack of sufficient environmental data, but, given the results of this project, should fall somewhere between this lower diversity group and the hot spot areas. Although the most abundant bryozoan species observed on Ranfurly may not be classed as habitat-forming, both the bushy catenicellids and the fenestrate forms described above were found to host many epiziotic species; e.g. 18 species have been associated with *Iodictyum yaldwyni* (Schnabel et al. 2014), and the full diversity of this assemblage is likely to be underestimated, with 28 species identified in a single rock dredge sample.

Table 62: Key bryozoan species identified from Ranfurly Bank, and their known distribution, based on existing scientific literature, OBIS and NIWA's Specify databases. Depth ranges are given from existing information, and from this study specifically.

Type	Species	Depth range (m)	Other areas
"Fluffy" low bushes	*Cribricellina cribraria* (Busk, 1852) *(up to 10cm)*	30 – 180	This study: Three Kings, Middlesex Bank, Ranfurly Bank, Table Cape, The Haypaddock, Mason Canyon.
		15 – 250	Also recorded from: Three Kings, Colville Channel, Napier, Wellington, Cook Strait, Kaikoura, Otago, Fiordland, western Foveaux Strait, Snares Platform, Puysegur Bank, Campbell Island also Queensland, NSW, Victoria and Tasmania, South Australia (Gordon, 1989; Smith & Gordon 2011).
	Cornuticella taurina (Busk, 1852)	40 – 86	This study: Ranfurly Bank, Ariel Bank and Table Cape.
		15 – 250	Also recorded from: all around South Island, including Cook Strait and Fiordland. Also recorded from Three Kings, South Taranaki Bight, and from southeastern Australia and S. Africa (Gordon & Mills, 2016 and Specify database).
	Orthoscuticella ventricosa (Busk)	50 – 160	Ranfurly Bank only
		46 – 549	Also recorded from: Kermadec Ridge, Three Kings, Hauraki Gulf, Napier, Cook Strait, Chatham Rise, Otago, Foveaux Strait and Fiordland. Also Victoria, Bass Strait, south eastern Australia (Gordon, 1984; Gordon 1989).
	Orthoscuticella margaritacea (Busk)	30 – 110	This study: Three Kings, Ranfurly Bank, the Haypaddock, Foveaux Strait.
		24 - 164	Also recorded from: Three Kings, South Taranaki Bight, Chatham Islands, western approaches to Foveaux Strait, also Victoria, and Tasmania (Gordon, 1989, Specify database).
	Orthoscuticella innominate Gordon, 1989	40 – 160	This study: Ranfurly Bank, Mason Canyon.
		15 – 300	Also recorded from: all round New Zealand, from Three Kings to Stewart Island as well as Bass Strait and Victoria (Gordon & Mills, 2016).
	Catenicella constans (Powell, 1967)	30 – 110	This study: Middlesex Bank, Ranfurly Bank, Ariel Bank, the Haypaddock.
		10 – 20	Also recorded from: Hauraki Gulf (Specify database).
	Pterocella scutella (Hutton, 1880) (up to 6cm)	20–160	This study: Three Kings, Middlesex Bank, Ranfurly Bank, Ariel Bank, D'Urville Island, Foveaux Strait, Mason Canyon.

Type	Species	Depth range (m)	Other areas
		15 – 220	Also recorded all round New Zealand, from Three Kings to Stewart Island as well as Bass Strait and Victoria, Australia (Gordon & Mills, 2016).
	Amathia wilsoni Kirkpatrick, 1888	50 – 70	This study: Ranfurly Bank only.
		5 – 85	Also recorded from: Three Kings, North Island (including Bay of Islands and Poor Knights Islands), Fiordland, Victoria and NSW, Australia (Gordon & Mills, 2016).
Fenestrate, “Lacey” forms	*Iodictyum yaldwyni* Powell, 1967	40 – 170	This study: Three Kings, Middlesex Bank, Ranfurly Bank, Cape Reinga.
			Also recorded from: Three Kings, North Cape, Cape Reinga, east northland (Nelson & Hancock, 1984, OBIS).
	Hippomenella vellicata (Hutton, 1873)	50 – 220	In this study: Three Kings, Middlesex Bank, North Cape, west coast canyons (N. Island), Ranfurly Bank, Conway Ridge, Pegasus Canyon, Otago coast.
		25 – 350	Also recorded from: Kermadec Ridge, Three Kings, Hauraki Gulf, Cook Strait, South taranaki bight, Tasman Bay, Separation Point, Chatham Rise, Otago shelf, western approaches to Foveaux Strait, Fiordland, and also New Caledonia (Gordon, 1989; Smith & Gordon, 2011, OBIS).
“Twiggy” branching forms	*Cellaria immersa* (Tenison Woods, 1880) (up to 6cm high)	40 – 215	In this study: Conway Ridge, Otago shelf including shelf edge and Karitane (Cornish Head) Canyon, Table Cape and Ranfurly Bank.
		15 - 220	Also recorded from: all around the South Island including Cook Strait, Tasman Bay, Kaikoura, Chatham Rise, Otago shelf, Foveaux Strait, Fiordland, Campbell Plateau, Puysegur Bank, Snares platform, as well as New South wales, Australia (Smith & Gordon, 2011; Gordon & Mills, 2016).
	Cellaria tenuirostris (Busk, 1852).	40 – 330	In this study: Three Kings, Cape Reinga, North Cape, North Taranaki Bight, Ranfurly, Ariel Bank, North Canterbury, Mason Canyon.
		20 – 220	Also recorded from: all around New Zealand, including the Kermadec Ridge, Hauraki Gulf, Cook Strait, Chatham Islands, as well as southeastern Australia, and Japan (Gordon & Mills, 2016; Gordon 1984).

Plexaurid and primnoid gorgonian fans dominated the deeper rocky outcrops on the north of the bank along with sponges (Figure 111 and Figure 119). None of the samples collected could be identified beyond genera (no New Zealand taxonomist is currently working on this group), so limited conclusions can be drawn about distribution. However, gorgonian fans from these families were only collected from northern North Island sites within this project; North Cape, Cape Reinga, Three Kings and Middlesex Bank, over a depth range of 50 – 170 m. From the Specify database, two thirds of the 367 records were from water depths of more than 300 m down to nearly 2000 m, widely distributed around the offshore banks, ridges and plateaus around New Zealand. The shallower records were concentrated mainly around the North Cape / Three Kings region, and the seamounts and knolls around White Island, Bay of Plenty, with a small number of records from the shelf edge south of Ranfurly, off the west coast of the South Island and Fiordland.

Other areas

For the non-Core sites and regions surveyed, although no formal analysis was undertaken, it was clear from the imagery that a wide range of habitats exist at the national scale on the continental shelf. Most of the species assemblages were quite distinctive from each other across these larger spatial scales (e.g. deeper water rhodolith beds and bryozoan fields at the Three Kings Islands; sponge assemblages off Cape Reinga; large gorgonian fields off North Cape; bivalve and ascidian assemblages in Foveaux Strait on soft and hard seafloors respectively). Some species assemblages are likely to be quite area-limited, e.g., at the top of the North Island, where a strong subtropical EAC influence is present, in association with clear oceanic waters and isolation from land-based sedimentation. Habitats such as the deep-water rhodolith beds at the Three Kings Islands, and the deep-water *Ecklonia radiata* beds at Ranfurly Bank, both of which require very clear waters to grow at depth, may not occur in such abundance (or at all) elsewhere in New Zealand.

5.2 Ecological roles

Biogenic habitats are valuable for a range of ecological roles and functions, including enhanced primary and secondary production, bentho-pelagic coupling, habitat provision, enhanced biodiversity, and juvenile fish nursery functions (e.g., Heck & Wetstone 1977, Connell 1978, Luckhurst & Luckhurst 1978, Dean & Connell 1987, Connell & Jones 1991, Tupper & Boutilier 1995, Klitgaard 1995, Rooker at al. 1998, Charton & Ruzafa 1998, Lindholm et al. 1999, Cummings et al. 2001, Norkko et al. 2001, Buhl-Mortensen et al. 2010, Beazley et al. 2013, Caddy & Defeo 2003, Rogers et al. 2014; see Morrison et al. 2014a for a review of New Zealand fisheries functions).

Primary production

Macro-algae are a dominant primary producer on shallow water temperate reefs (Schiel & Foster 1986, Steneck et al. 2002, Connell & Irving 2008, Wilson et al. 2014), but only recently is their occurrence and importance in deeper water starting to be recognised (e.g., Graham et al. 2007, Leichter et al. 2008, McGonigle et al. 2011, Joher et al. 2012; Hurrey et al. 2013). Deep water (more than 30 m) macro-algae were found at a number of locations in the field surveys, including: *Lessonia* down to 54 m water depth, rhodolith beds to 67 m, and turfing algae to 87 m at the Three Kings Islands (Figure 10) (all depths represent lower depth observed on DTIS, rather than the potential true depth limit at a given site); brown macroalgae (*E. radiata*) to 45 m, and coralline algae and *Caulerpa* sp. to 50 m at Ariel Bank (off Gisborne) (Figure 64); and *E. radiata* in extensive tall beds from 45–74 m, rhodoliths to 60 m, and red turfing algal species and *Caulerpa flexilis* (green algae) to 70 m at Ranfurly Bank. The deep-water *E. radiata* were very different in morphology from the shallower water form, occurring as very long elongated single blades, up to 3 m in length, originating from a stipe (Figure 67). We are not aware of any previous reports of this deep-water growth form. Overall, the shallower bank area of Ranfurly Bank (down to 50 m) was dominated by algae (including corallines) and sponges.

For most of the other areas and regions surveyed, sampling was too great a depth and/or water clarity limits to support macro-algae, including the Cape Reinga area (more than 61 m), west coast of the North Island (more than 70 m), North Canterbury (more than 70 m), and Mason Canyon (more than 75 m). However, coralline algae were seen inshore of the Hay Paddock site off Otago on reef habitats in 32 to 36 m water depth (Figure 45), and in 35 m water depth in Foveaux Strait (Figure 55).

Collectively, these findings demonstrate that deeper water macro-algal biogenic habitats are much more widespread around New Zealand than previously realised, particularly in areas with hard seafloor (reef, dead shell) and very clear water quality. As such, in certain localized areas, they may provide significant primary production, as well as providing habitat and food for other organisms (see also Nelson et al. 2015).

Bentho-pelagic coupling and secondary production

Most of the animal taxa encountered were filter-feeders (e.g., sponges, bryozoans, gorgonians, corals, crinoids, ascidians, polychaetes, and hydroids). Collectively, these assemblages are likely to provide significant trophic coupling of the pelagic water column with the benthic seafloor, through their filtering of the water to capture prey (phytoplankton and zooplankton), incorporation of digested material into their tissues, and voiding of waste material (Cryer et al. 2004).

Rich and diverse filter feeding assemblages were found on most deeper water rocky reef habitats that were sampled, especially below the euphotic zone where macro-algae were no longer present. The exceptions were where sedimentation loads appeared to be high, such as Table Cape off Mahia Peninsula, (Figure 62), or wave forces to be very strong, e.g. the top of Ranfurly Bank (Figure 120a). These filter feeding assemblages included: dense bryozoan patches/fields at the Three Kings Islands (Figure 11), mixed gorgonian, bryozoan, black coral and sponge fields at Middlesex Bank and off North Cape (Figure 8, Figure 15); crinoid fields on eastern Ranfurly Bank (Figure 120); diverse sponge ‘gardens’ offshore of Spirits Bay (Figure 15), at the Taranaki Canyons (Figure 22), Ranfurly Bank (Figure 119), and off Oamaru (Figure 45); and high densities of ascidians and bryozoans on deeper reef areas in eastern Foveaux Strait (Figure 55, Figure 57).

Significant epibenthic filter-feeding assemblages were also found on softer sediments, including shell and gravels, in some areas. These assemblages included: bryozoan fields off Separation Point (Nelson) (Figure 30), and the Otago coast (including Cornish Head Canyon) (Figure 48); “wire-weed” (polychaete worm) meadows in the North Canterbury Bight, along with associated ascidian and other secondary species (Figure 40); dense turret shell populations off eastern D’Urville Island (Figure 35); and the impressive sponge assemblage on fine sands (recruiting onto chaetopterid tubes) off Oamaru known as the Hay Paddock (Figure 43).

Also of particular note, pink maomao and to lesser extent butterfly perch, were a consistently dominant component of the deeper reef fish faunas, as observed by the towed video; for maomao from Middlesex Bank down to Ariel Bank on the eastern North Island coast, and for butterfly perch more patchily but at the national scale. Both are essentially herbivorous species, and given their high abundance (and relatively large body size for pink maomao) may be important contributors to nutrient and energy linkages between the water column and the seafloor. Such roles have been demonstrated for shallower water systems between fish and corals, and fish and kelps.

Enhanced Biodiversity

Over 1000 species were physically sampled and identified from the survey, including both habitat-formers (defined as sessile species such as sponges, bryozoans, brachiopods, bivalves, gorgonians, corals, crinoids, ascidians, polychaetes, and hydroids) and more mobile groups, such as crabs, cnidarians (sea anemones), echinoderms, gastropods, molluscs, holothurians, and squat lobsters, as well as fish. Notable single species 'aggregations' included extensive soft sediment urchins (?*Spatangus multispinus*) fields at 200 m water depth on the floor of the Three-Holes Canyon off the Kaipara Harbour (Figure 18b), and dense patches of spider crabs (*Leptomithrax longipes*) within chaetopterid tubeworm habitat areas (Figure **101**h).

In two of the three Core areas, the species richness of habitat clusters increased with higher proportions of hard seafloor cover. For the Taranaki canyons Core area, the average richness of sessile species on soft sediment was 1.18 ± 0.39 (s.d.) per image, increasing to 4.13 ± 0.91 over mixed soft and hard seafloors, and reaching 7.76 ± 1.67 on rubble/rock seafloor, while associated mobile species also increased. The fish species were assessed more broadly into a soft sediment and a hard sediment assemblage, with the dominant deep reef species being sea perch, butterfly perch, common roughy, and orange perch, while the soft sediments were dominated by rattails (genus level OTU), cucumber fish, red band-fish, and long-fin worm eels. Many of these species are seldom encountered in research or commercial catches, being small and/or strongly associated with reefs (foul ground). A number of rare species were also sampled.

Across the chaetopterid tubeworm Core area sites of North Canterbury, Pegasus Bay and Pegasus Canyon, the species richness within the six "habitat clusters" most commonly assigned to images from these areas ranged from 1 (essentially low form, semi-buried tubeworms with few other sessile habitat formers), up to 4.9 ± 0.09 for a cluster containing more emergent forms, with three other assemblage clusters falling between these values. One of these classes was defined by a relatively low tubeworm contribution, but was dominated by mixed bryozoans, horse mussels, and the solitary ascidian *Cnemidocarpa* sp., with a low species richness of 1.2 ± 0.05. The highest species richness occurred in a seventh cluster class found largely in the Hay Paddock area, with an average of 8.2 ± 0.14, dominated by colonial ascidians and finger sponges attached to chaetopterid tube worms. Across these tubeworm habitats in general, sponges were a dominant co-occurring habitat former species, with 20 OTUs contributing, of which half were new species. As such, these habitats represent an important 'new' assemblage (biotope) and potentially require associated management policies. A relatively diverse range of mobile invertebrate taxa were also associated with these habitat formers, dominated by anemones, gastropods, crabs, and, at the Haypaddock, squat lobsters (probably *Munida gregaria*). The fish associated with the tubeworm areas clustered into four species assemblages, with a limited number of species driving the group separations. Geographical location was a strong driver (potentially as a proxy) in the clustering, with depth and sediment type (% mud and % TOM) all found to explain significant amounts of variation in the assemblages using the DISTLM approach.

For the Core area of Ranfurly Bank, four broad assemblage groupings were identified statistically. Two of these assemblages were soft sediments with a single pink sea pen species (sessile species richness 1), and soft sediments with occasional cobble or boulder (richness 1 ± 0, but with seven contributing OTUs including small areas of encrusting coralline algae, orange sponge, low relief red algae or plexaurid sea fans. The remaining two assemblages were associated with mixed hard and soft substrate, and a much more diverse habitat forming species richness (2.41 ± 0.51, and 6.65 ± 2.33). Visual differences in the flora and fauna were apparent within these two assemblages across the bank, but these were not able to be effectively defined with the statistical approach used. The mobile fauna was also diverse across these two latter assemblages, in particular around anemones, brittle-stars, crinoids, gastropods and holothurians. Many species, especially the sponges, were new to science, or previously rare or unknown in New Zealand waters due to their more tropical water mass affiliations. The fish assemblages also contained a number of rare or new species. Pink maomao were the most common fish observed on DTIS video, with over 1000 individuals counted. Five fish assemblage groupings were identified at the DTIS tow level, which correlated with depth and spatial position on the bank. The dominant species after pink maomao were cucumber fish, sea perch, kingfish, eel species, silver conger eels, morid cod, northern bastard cod, and tarakihi.

Fish nursery areas

Across the sites surveyed, four species stood out: sea perch, blue cod, ling, and tarakihi; although only the first two were seen in any abundance. We note that the sampled areas were too deep and/or too far south for the juveniles of other common coastal species, e.g., snapper, trevally, and kahawai (Morrison et al. 2014b, c).

Sea perch (Helicolenus spp.)

Sea perch were observed nationally across most sites which held foul ground or epifaunally structured soft sediments. From the Core areas analyzed juveniles, defined as fish less than 15 cm length, (Paul & Francis, 2002) were seen in relatively high numbers at the North Taranaki canyons (Figure 84) and the North Canterbury chaetopterid tubeworm site (Figure 128e). At North Taranaki, the domimant size class on DTIS imagery were fish of 10–20 cm length, followed by smaller fish of less than 10 cm length. Only low numbers of larger fish over 20 cm were seen. Overall densities observed on DTIS videos were highest at the Coral Canyon (21.39 ±4.35 per 1000 m^2), compared to The Well (5.89 ±4.35 per 1000 m^2).

At North Canterbury, sufficient fish were sampled by beam trawl to allow a more precise examination of length frequencies (Figure 105). Three size modes were apparent between 50 to 155 mm (below sexual maturity), with an average density (all sizes) of 126.28 ± 10.15 per 1000 m^2. Larger, older fish were present, but at much lower numbers. Given these densities, the chaetopterid tubeworms and associated epifaunal assemblage can probably be viewed as a nursery habitat. Using just the North Canterbury fisher-drawn areas as an approximate spatial extent (286.3 km^2), the total number of fish would be 36.1 ± 2.9 million (all fish sizes). This area was being actively trawled during the survey (vessels fishing close nearby, and net bobbin 'lanes' on the seafloor), but the target species were unknown. It is not known if juvenile sea perch remain in the same area as older fish, or disperse to other adult habitats (Morrison et al. 2014b). Paul & Francis (2002) compared length frequency distributions from trawl surveys in different regions, and although confounded across different vessels, cod end mesh size, and depth ranges, noted the presence of a slight juvenile size mode (13–15 cm) in the summer east coast South Island survey series. Hurst et al. (2000) also reported large catch rates for juveniles in the general Pegasus Bay area (up to 2.0 t km^{-2}).

Ling (Genypterus blacodes)

Juvenile ling (less than 70 cm in length) were also seen at the North Canterbury site associated with the tubeworm patches, but at lower densities (Figure 128e). The dominant size class observed on DTIS video was 20–40cm (n = 10, with one fish less than 20 cm, one fish over 40 cm also recorded), with an estimated density of 1.64 ± 0.77 individuals per 1000 m^2, representing 469.5 ± 222 thousand individuals, if scaled to the same area. A small number of juvenile ling were also observed on the Otago bryozoan fields. Little is known about the distribution of juvenile ling below 40 cm, the length at which they appear in trawl survey data (Annala et al. 1999). Hurst et al. (2000) reported that 0+ juveniles have been recorded from shallow inshore areas, but that most occur from 200–500 m water depth, with the main areas including the Bay of Plenty, and central east coasts of the North and South Islands. The largest South Island research trawl catch rates (up to 1.5 t.km^{-2}) were on the shelf in Canterbury Bight (Hurst et al. 2000). The numbers seen in the present survey were modest, and do not, on their own qualify as evidence for a nursery, but do indicate that tubeworm and bryozoan habitats have value to juvenile ling. Very small ling, less than 30 cm in size, remain unknown in terms of their habitat requirements.

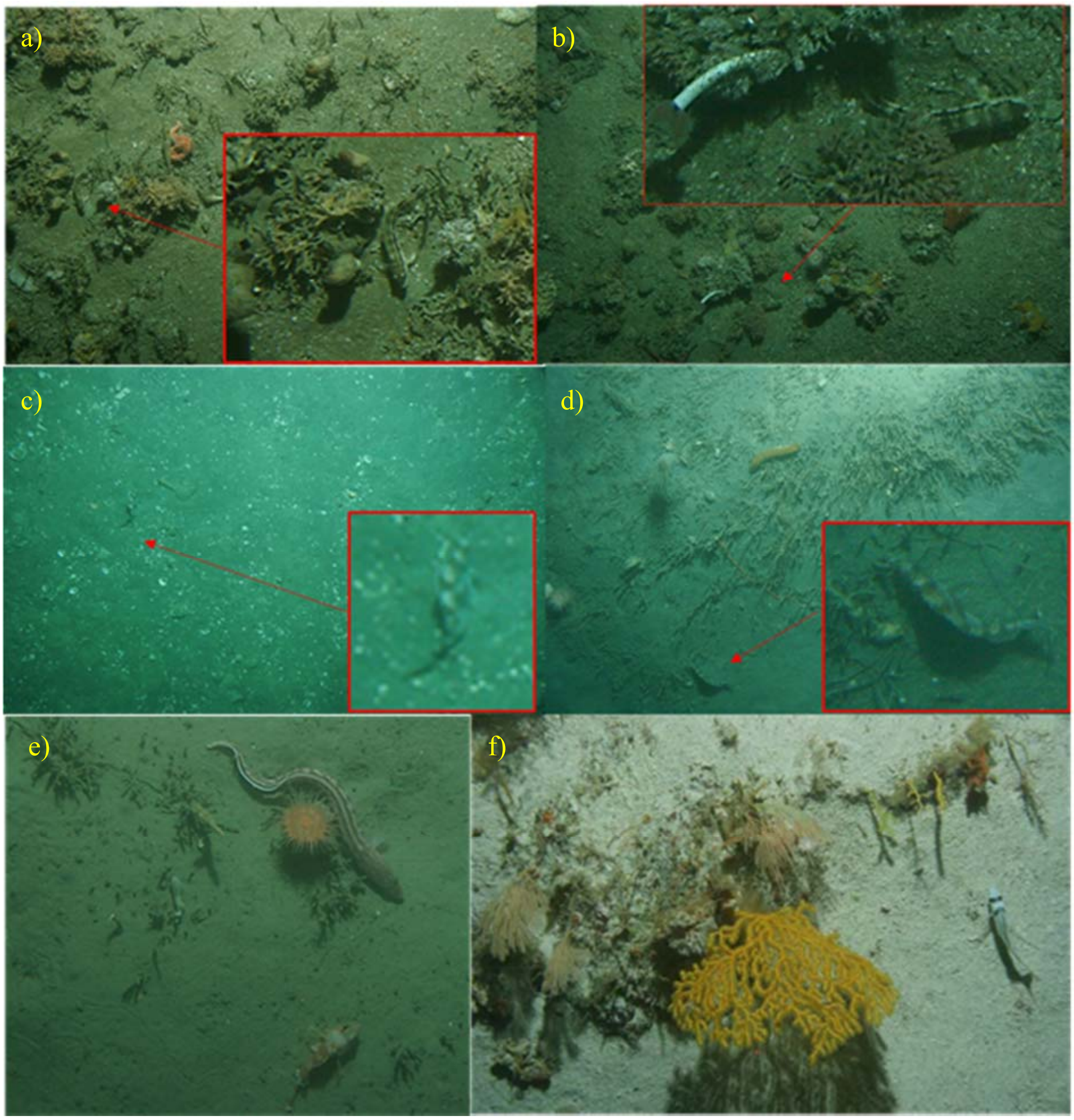


Figure 128: Examples of juvenile fish seen with DTIS: a–b) juvenile blue cod (12–15 cm) in bryozoan assemblages, Otago Shelf; c–d) juvenile pigfish or tarakihi, and tarakihi respectively (8–10 cm), inner wire-weed area, Pegasus Bay, North Canterbury Bight; e) juvenile ling (about 35 cm) and juvenile sea perch (about 15 cm), wire-weed, North Canterbury Bight; f) juvenile tarakihi (about 20 cm), possibly a king tarakihi, North Cape.

Blue cod (Parapercis colias)

As with sea perch, sub-adult and adult blue cod were seen across a number of areas sampled, both in association with reef/foul, and epifaunally structured soft sediments. From the Core areas, a single blue cod was observed at Ranfurly, and low numbers (5 or less) counted at Pegasus Canyon and the Haypaddock. Juveniles (under 20 cm) were much less common, and were only seen on the Otago bryozoan fields, in close proximity to bryozoan colonies and other fauna such as sponges (Figure 128a–b). These fish were too small and cryptic to reliably make out on video, and the best observations came from the DTIS stills. Fish were measured in a sample of stills (n = 19), and ranged from 12 to 33cm with nine fish estimated to be less than 20cm in length. A total of 35 blue cod, including juveniles, were also captured in two associated beam trawl tows. Length ranged from 5.7–38 cm, with most fish (31) measured at less than 20 cm, and an overall median length of 12.3 cm. Based on these observations, and observations of the presence of juvenile blue cod by others (Batson & Probert 2000, Jones 2006) the Otago bryozoan fields are probably a nursery habitat for this species. It is unknown whether these juveniles stay resident or move elsewhere with increasing age and size. There is a blue cod pot fishery over the bryozoan beds in this region. Of note, very similar bryozoan habitats (though less dense and developed; Figure 48) seen in the northern part of the Cornish Head Canyon block did not hold juvenile blue cod, suggesting variation in habitat use at larger spatial scales.

Tarakihi (Nemadactylus macropterus)

Based on past observations of juvenile tarakihi (under 25cm) being strongly associated with biogenic seafloor structure (Vooren 1975, various observations recorded in Morrison et al. 2014a), it was expected that this species would be seen in abundance at some South Island sites. Tarakihi abundance estimated from DTIS video was highest at North Canterbury (5.66 ± 1.38 per 1000 m^2, n = 45), with more than half the fish observed being estimated at less than 20 cm. A small number were observed in still images, and estimated to be less than 10 cm in the shallowest tubeworm area on the North Canterbury Bight (Figure 128c–d), along with one captured by beam trawl. Work at a 'known' nursery habitat of bryozoan fields at Separation Point (Vooren 1975, Mace 1981) was severely limited by very poor water visibility at the time of the survey. Further south at the Hay Paddock, a Vooren (1975) trawl station (10 November 1969) reported a large catch of juvenile tarakihi and associated biogenic by-catch, just inshore of the Hay Paddock. This station was re-sampled with a DTIS tow in 2011, but no tarakihi were seen, and the only biogenic structure present was low density scattered horse mussels, with associated wandering anemones (Station 158, Figure 42). A low density of tarakihi were observed on other DTIS tows at the Haypaddock (n = 13), but all but one was estimated to be greater than 20 cm in length.

Tarakihi differ from many other species in that they have a long larval and post-larval pelagic 'paper-fish' phase of 9–10 months drifting in offshore waters (Bruce et al. 2001), before metamorphosing into juveniles and settling at around 7–9 cm (Vooren 1972). Given our poor knowledge of the early post-settlement life history of tarakihi, it is possible that sampling may have been at the wrong time of year to detect juveniles on these habitats, or that the juveniles are not associated with the habitats surveyed, or that they are present, but poorly sampled using the towed video method. Initial work with a smaller Dropped Underwater Video (DUV) for snapper used far less powerful lights (Morrison & Carbines 2006, Compton et al. 2012) than DTIS, and subsequent surveys with DUV and DTIS in the shallow waters of the Bay of Islands suggested some avoidance of the DTIS by snapper, although some technical and seasonal confounding issues were also present (Jones et al. 2010). Given the above, more targeted work would be required to quantify what and where juvenile tarakihi habitats are located.

5.3 Taxonomic advances

All taxonomic samples were processed, excepting a number of sponge 'lots', and some groups for which there are few/no specialists in New Zealand, and for which overseas collaborators were not available. The invertebrate taxonomic findings are covered in greater detail in an associated NIWA report (Schnabel et al. 2014); a brief summary and highlights are presented here, as well as information on macroalgae and fish. We note that for the species reported as 'new to science', a proportion of those species have been collected previously, but have not yet been formally described and named (although virtually all of the sponges are entirely new).

For the invertebrates, 919 species were identified, including 95 new, undescribed species (10.3%), and 13 species not previously recorded from New Zealand (Table 63, Table 64, Figure

129). These are conservative estimates, as not all groups and specimens have yet been fully identified. Using sponges (54 new species) as an example for biogenic habitat formers; at Middlesex Bank 57 species were identified, 16 of which were new to science, along with a new genus for New Zealand. Two species had not been re-collected since their discovery in 1924 at this bank, while five other species were rare with only one to two specimens having ever been collected. Seven sponge species were collected from Three-Holes Canyon (off the northern Kaipara Harbour), one of these was new to science: another was only the second specimen collected since this species was described in 1980; and almost certainly a new species as the original was described from South Africa (MK, pers. obs.). The offshore North Taranaki Bight canyons were distinctive for their relatively high density of species previously considered very rare. Of particular note was the re-discovery of the shallow water glass sponge *Rossella ijimai*, previously only known from North Cape. Moreover, the lithistid sponges *Reidispongia coerulea*, *Pleroma menoui*, *P. turbinatum*, and *Aciculites pulchra* were very distinctive and common in the area. Thirty sponge species were identified overall, nine of which were new to science. Of these, the most noteworthy were two twiggy, tree-like species of the genus *Axinella*, a thin fan-like sponge in the genus *Calyx* (Figure 129h), and new species of *Stryphnus* and *Latrunculia*. This latter find was particularly exciting as it was thought that all species were known for New Zealand. From the east coast South Island “wire-weed” areas, 25 species were identified, seven of which were new to science; the new species were thin strappy digitate poecilosclerid species typical of the fauna associated with the polychaete meadows (e.g., Figure 129f). At Ranfurly Bank, sponges were also a dominant contributor of biogenic habitats; 65 species were identified, 13 of which were new to science. Of these new species, the most noteworthy were two new species of *Geodia*, a new species of *Stelletta*, and a new species of *Spongia* (e.g., Figure 129g). Collectively, these 54 new sponge species demonstrate how modestly the continental shelf has been explored (45% of all sponge species sampled were new to science). Biological sampling intensity during the two voyages was relatively low for any given site or area. In addition, just over 50% of the sponges collected have now been identified, with 327 samples remaining, primarily from North Cape, Three Kings, Cape Reinga, Ariel Bank, Hay Paddock (inshore area), Cornish Head, and Mason Canyon. Given this, it is almost certain that a number of additional continental shelf sponge species remain to be discovered and described.

For macro-algae, 46 species were identified, of which 11 were new to science (24%) (Table 63, Table 64). Five new genera were also created from the specimens collected (e.g. *Galene*, see Figure 129i). There were a further 24 unknown specimens, which include the non-geniculate corallines, and other material unable to be identified within the resources available, and/or too fragmentary to take further. A notable find was the occurrence of the kelp *Ecklonia radiata* in deeper water (attached to 74 m; drift to 104 m) at Ranfurly Bank. These plants were very different morphologically from the shallow water form, forming single fronds up to three metres long. Genetic work confirmed these to be the same species as in shallower waters. These data show that algae are much more common and diverse in deeper areas on the shelf than previously believed, with most of the macroalgae material collected from deeper waters in this programme now incorporated into a paper emphasising this point (Nelson et al. 2015).

Small fish collected by the beam trawl and rock sledge were also diverse, with 76 species being collected, of which 10 remain identified to genus level only, and three species since being formally described including using voyage material; putatively 17% are new species (Table 63). Of note was the capture of new specimens of an undescribed deep-water triplefin species (*Ruanoho* sp.) (Figure 129b). This species was first seen in 2009 during biological sampling off the upper east Northland coast for the OS2020 Bay of Islands programme; TAN1108 survey specimens collected from the North Canterbury Bight and west of Stewart Island now extend its known range to the full extent of mainland New Zealand, and provide important new material for its formal description. Other highlights included a new weever species (Figure 129b, the black-fin sea-perch, *Parapercis nigrodorsalis*) from Ranfurly Bank, specimens used as the holotype, and paratypes; and only the third specimen caught to date of a new pearlfish species (*Echiodon prionodon*), from the North Taranaki Bight, used as a paratype in its formal taxonomic description. Rare/uncommon species included the goby *Modicus minimus*, the luminescent cod *Physiculus luminosa*, the bythitid *Fiordichthys slartibartfasti*, the scorpaenid *Scorpaena onaria*, the serranid *Lepidoperca tasmanica*, the labrid *Suezichthys aylingi*, and the scorpaenid *Maxillicosta raoulensis* (three specimens from Ranfurly Bank, previously only reported from the Kermadecs Islands).

Table 63: Summary of taxonomic identifications, by groups. [1], lowest level of ID, either genus or species; [2], to family level only; **, for fish these are specimens unidentified beyond Genus level at present; [4], eel *Leptocephalus* sp.

Phylum	Taxon	Total species [1]	New records for NZ	New species [3]	Papers using material
Porifera		120	–	54	Kelly & Sim-Smith (2012) Sim-Smith & Kelly (2015), Kelly & Sim-Smith (in prep)
Cnidaria	Hydrozoa	38	–	5	
	Stylasteridae	5	–	1	
	Actiniaria	1	–	–	
	Alcyonacea	24	1	8	
	Antipatharia	5	–	–	
	Pennatulacea	3	–	–	
	Scleractinia	10	1	–	
Bryozoa		359	4	17	Gordon & Spencer-Jones (2013) Di Martino et al. (2016) Gordon et al. (2017)
Arthropoda	Amphipoda	10	2	1	
	Isopoda	–	4[2]	–	
	Decapoda (shrimp)	24	–	(3?)	
	Decapoda (crabs)	61	1	(3?)	
	Stomatopoda	3	1	2	Ahyong (2012)
	Pycnogonida	4	–	–	
Echinodermata	Asteroidea	20	–	–	
	Crinoidea	4	–	–	
	Echinoidea	16	–	–	
	Holothuroidea	8	–	1	Davey & Whitfield (2013)
	Ophiuroidea	34	–	–	Mills & O'Hara (2013)
Ascidiacea		41	(2?)	–	
Mollusca		124	–	–	
Hemichordata		1	–	–	
Total (invertebrates)		919	13	95	
Macro-algae	Rhodophyta (reds)	37	–	9	D'Archino et al. (2014)

Phylum	Taxon	Total species [1]	New records for NZ	New species [3]	Papers using material
	Ochrophyta (browns)	3	–	–	
	Chlorophyta (greens)	6	–	2	
Total (algae)		46	–	11 **	
Fish	Argentinidae	1	–	–	
	Aulopidae	1	–	1	Gomon et al. (2013)
	Bothidae	3	–	1	
	Bythitidae	1	–	–	
	Callanthiidae	1	–	–	
	Callionymidae	1	–	–	
	Carapidae	1	–	1	Paramentier (2012)
	Chimaeridae	1	–	–	
	Congiopodidae	1	–	–	
	Congridae	2	–	1[4]	
	Creediidae	2	–	1	
	Gobiesocidae	1	–	–	
	Hoplichthyidae	2	–	1	
	Labridae	3	–	1	
	Macroramphosidae	2	–	–	
	Macrouridae	5	–	1	
	Merlucciidae	1	–	–	
	Monacanthidae	1	–	–	
	Moridae	4	–	–	
	Myctophidae	1	–	–	
	Neosebastidae	1	–	–	
	Ogcocephalidae	–	–	1	
	Ophidiidae	1	–	–	
	Paraulopidae	1	–	–	
	Percophidae	5	–	1	
	Pinguipedidae	2	–	1	Johnson et al. (2014)
	Plesiopidae	4	–	1	
	Pleuronectidae	2	–	–	
	Rajidae	1	–	–	
	Scorpaenidae	3	–	1	
	Scyliorhinidae	1	–	–	
	Serranidae	6	–	–	
	Syngnathidae	2	–	–	
	Torpedinidae	1	–	–	
	Trachichthyidae	1	–	–	
	Triglidae	1	–	–	
	Tripterygiidae	5	–	1	
	Uranoscopidae	1	–	–	

Phylum	Taxon	Total species [1]	New records for NZ	New species [3]	Papers using material
	Zeidae	1	–	–	
Total (fish)		76		10**	

Table 64: Papers and monographs produced using voyage material as of December 2014.

Johnson et al. (2014)	New weaver described, the black-fin sea-perch (*Parapercis nigrodorsalis*). Holotype from Ranfurly Bank (TAN1108), as well as 5 paratypes (one for genetics)
Gordon & Spencer-Jones (2013)	Two new species of ctenostome bryozoans described: *Amathia gracei* (holotype, Ranfurly Bank); *Amathia zealandica* ('other material', Ranfurly Bank)
Di Martino et al. (2016)	A new genus and species of Bryozoa described from Middlesex Bank, *Powellitheca labiosa* (TAN1105, holotype and two paratypes)
Gordon et al. (2017)	Examined material, Bryozoa, *Steginoporella* spp. from various sites on Ranfurly Bank, Table Cape and Ariel Bank (TAN1108), Three Kings Islands, Middlesex Bank, and North Cape (TAN1105)
Mills & O'Hara (2013)	All ophiuroids from both voyages, as well as BoI OS2020 samples, used to describe ophiuroids of biogenic habitats on the continental shelf of New Zealand
Ahyong (2012)	Stomatopoda memoir (mantis shrimps): New genus (Colubrisquilla, paratype for new species *Colubrisquilla dempsey* (Tokomaru Bay, only record outside Chatham Rise); paratype for new species *Heterosquilla koning* (Rock Garden, North Cape)
Davey & Whitfield (2013)	New species of holothurian, *Psolidium ramum*. Holotype. Only one specimen, sampled at Three-Holes Canyon, North Kaipara
Cairns (2012)	Primnoidae (Anthozoa: Alcyonacea) Memoir – one new genus and species from Middlesex Bank, *Narelloides crinitus*. Paratype, TAN1105
Kelly & Sim-Smith (2012)	Review of *Ancorina*, *Stryphnus*, and *Ecionemia* (Demospongiae, Astrophorida, Ancorinidae) – One paratype of new species *Stryphnus spelunca;* examined material of new species *Stryphnus ariena* (TAN1105, "The Drop off", North Taranaki Bight), & *Stryphnus levis* (northern Ranfurly Bank (TAN1108); Examined material of existing but redescribed species *Ecionemia alata* and *Ancorina stalagmoides* from Ranfurly Bank and Ariel Bank
Sim-Smith & Kelly (2015)	Geodiidae (Porifera: Geodiidae) Memoir. Holotype specimens for three new species of Geodia have come from these surveys (Three Holes canyon and Ranfurly bank) as well as material for the re-examination of a further three known species (Three Kings and Taranaki Bight).
Kelly & Sim-Smith (in prep)	Revision of the *Latrunculia* species of New Zealand: of five new species, one is from the North Taranaki Bight region
D'Archino et al. (2014)	New genera red algae (Galene). *Galene profundae* (selected specimens, Three Kings Islands and eastern D'Urville Island); *Galene* sp., Ranfurly Bank and Ariel Bank (TAN1108) only specimens to have been collected, further collections required
Nelson et al. (2015)	Review of deep-water algae in New Zealand; specimens, and images (from Ranfurly Bank) incorporated.
Gomon et al. (2013)	New fish species, Flaming Flagfin *Hime pyrhistion* ('other material').
Paramentier (2012)	New species of pearlfish (*Echiodon prionodon*); paratype from North Taranaki Bight, one of only three specimens in total to have been collected.
Marshall et al. (2018)	Paratype of new species *Penion lineatus*, from the Three Kings Islands (TAN1105)

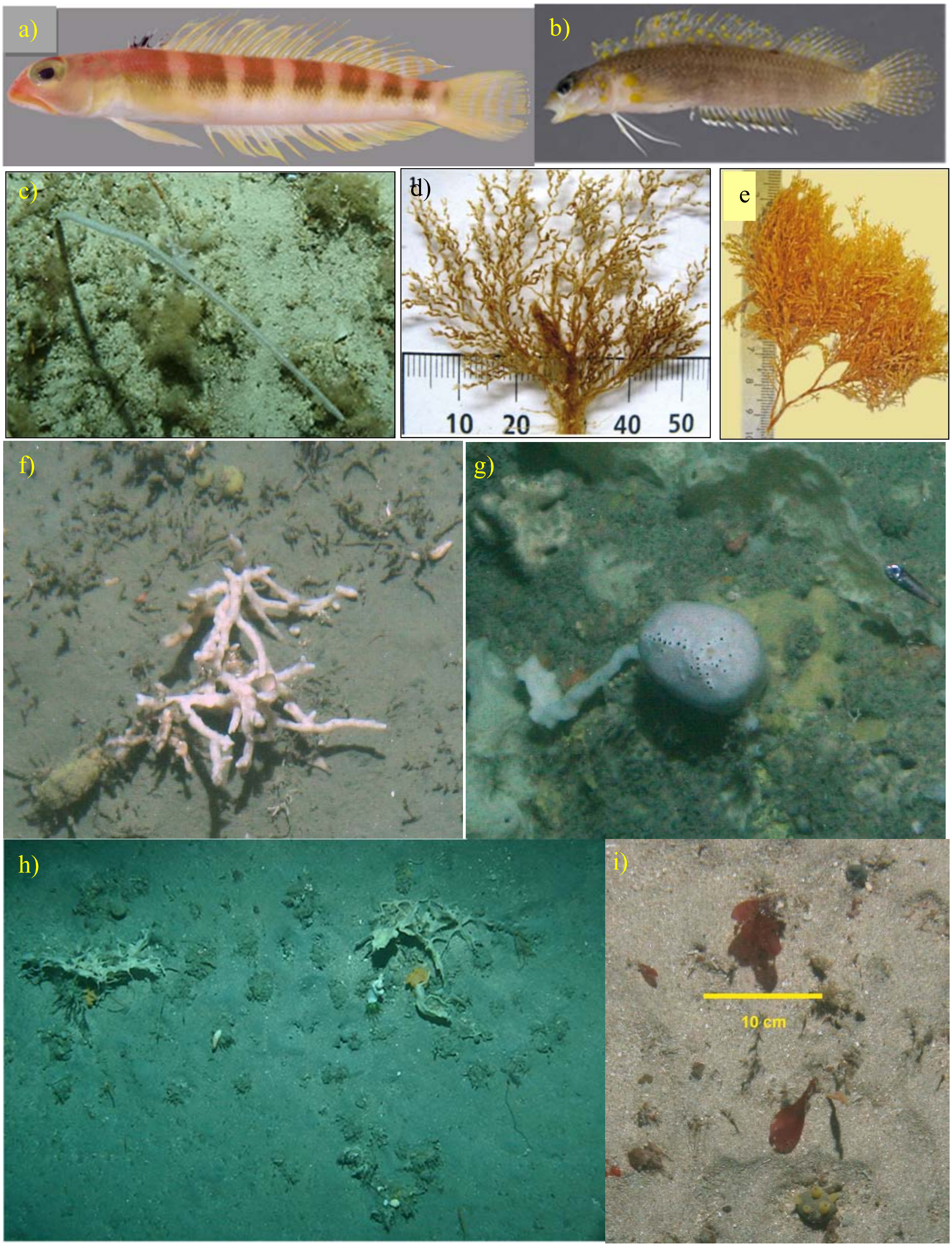


Figure 129: Examples of new species described using specimens from TAN1105 and TAN1108, see Table 64 for details; a) black-fin sand-perch *Parapercis nigrodorsalis* (Johnson et al. 2014) (Ranfurly Bank); b) *Ruanoho* sp. (triple fin, not yet described) (North Canterbury); c) coral *Narelloides crinitus* (Cairns 2012) (Middlesex Bank); d–e) bryozoans *Amathia gracei*, *Amathia zealandica* (Gordon & Spencer-Jones (2013) (Ranfurly Bank); f) sponge *Chondropsis* n. sp. 7 (Hay Paddock); g) *Spongia* n sp. 3 (Ranfurly Bank); h) *Calyx* n. sp. 5 (North Taranaki); i) red alga *Galene profunda* (D'Archino et al. 2014) (Ranfurly Bank).

5.1 Correspondence between LEK and *Tangaroa* voyage observations and results.

The data collected in this project was not sufficient to quantitatively ascertain the status of any of the habitats encountered. In most cases, the historical spatial information provided by the fishers was at a relatively large scale, and it was outside of the scope of the voyages to ascertain the extent and boundaries of each putative biogenic habitat. Rather the voyages aimed to confirm presence or absence of suspected biogenic habitat at multiple locations around New Zealand. The correspondence between what fishers reported in Local Ecological Knowledge (LEK) interviews and what was observed during the two voyage surveys was assessed qualitatively by comparing their descriptions with observations from the DTIS videos and samples collected. Table 65 lists 28 geographic locations which were sampled on the voyage. These locations consist of multiple fisher-drawn areas, with one or more scientific sampling "sites" that overlapped these areas. At 20 of these locations (71%), the empirical samples and observations of biogenic habitat were considered to match the historic fisher descriptions of their bycatch. For example, the diverse assemblages of sponges, gorgonians, corals and bryozoans observed at Midlesex bank, and a number of the sites around North Cape and Cape Reinga region matched well with fisher descriptions of these areas, as did the results from sampling canyon features off the west coast from Kaipara harbour and North Taranaki, to Mason Canyon off Stewart Island. Along the east coast of the North Island, the reefs described by fishers at Table Cape and Ariel Bank were also corroborated by the observations from DTIS, and the existence of "wireweed" (tubeworms) off the east coast of the South Island was confirmed at multiple sites.

Whilst the presence of these habitats was confirmed, the full extent, and the impacts of any fishing activity to date cannot be assessed based on the data reported. The fisher knowledge itself came from interaction of fishing gear with these habitats, i.e. the occurrence in their trawl nets of unwanted bycatch. In many instances, this knowledge was used to avoid further interaction. This was often the case with retired fishers, whose nets were less robust than modern trawls, e.g. retired skippers talked about avoiding the Canterbury tubeworm beds ("wireweed") for fear of clogging up their nets with mud, and areas of rough terrain associated with reefs such as Ariel Bank and Table Cape, where gear might be lost altogether. However, in some instances, those interviewed suggested that newer, heavier, more robst gear had allowed habitats to be impacted more recently, e.g. Ranfurly Bank, and the Canterbury "wireweed" areas, where fishers reported only 30% of the largest area in Pegasus Bay remained (Jones et al. 2016).

In other cases, those interviewed believed that the habitats they recalled had been eliminated by ongoing fishing activity. These sites are included in the eight locations where the historic biogenic habitat described by fishers was not corroborated by scientific sampling. For example, at site 2, to the north of North Cape, a 9.9 km^2 block was mapped that overlapped several much larger fisher-drawn areas (over 200 km^2) known as "the Rock Garden", where a bycatch of coral and sponges was recalled by fishers. Those anecdotal accounts also noted that there had been heavy fishing in the area, with one fisher describing the coral as "*trashed*", but clear fishing tows through the habitat were known to exist. The multibeam mapping suggested a large dune feature, the DTIS transects observed only hard packed sand, and it is likely that this site simply covered part of the area reported as clear fishing paths compared to the other mapped sites further east and west (sites 1 and 4), where patches of low relief reef with diverse sessile assemblages were observed (Middlesex Bank to North Cape section, p.24). Previous surveys closer inshore, and out to the east, and south east of North Cape have also recorded heterogeneous substrates ranging from sand and muddy sediments to bedrock and boulders that supported a diverse assemblage of sessile invertebrates dominated by sponges (Bowden et al. 2010). From these observations, it is clear that deep reefs exist in this area, but are patchy, and the extent to which fishing may have impacted them cannot be ascertained from the information collected.

Around D'Urville Island, multiple fishers described three areas of "coral" (bryozoan reefs) that had existed decades ago, and were likened to the bryozoan reefs off Separation Point (Jones et al. 2016). For all these areas, the fisher descriptions also included comments about the coral being hard to fish, having to be "*broken in*", and causing net damage. In the scientific literature, Saxton (1980a) reported on fisher knowledge he had collected describing a coral bed off the western side of D'Urville Island that "*appears to be relatively untouched*". He also noted that not enough research had been done, and that the "*coral trawlermen*" who had fished the Separation Point coral, were interested in exploiting this area. A large number of bryozoan species, including *Celleporaria agglutinans* (the Separation Point bryozoan) have been reported from two stations in this area (Bradstock & Gordon 1983; Gordon 1989), with these authors also citing commercial fishermens reports and their own unpublished observations of bryozoans in the outer Marlborough Sounds. Sampling at these locations on the subsequent *Tangaroa* voyages found no evidence to match the historic fisher descriptions of bryozoan reefs, although areas of gravel and shell hash appeared to support low-relief sponge and encrusting *C. agglutinans* (Figure 32). Given the anecdotal comments made by the fishers themselves, and historic accounts of trawl damage in this area (Saxton 1980a, b; Grange at al. 2003), it seems likely that there could have been significant elimination of bryozoan habitat, although the DTIS observations were extremely limited compared to the size of the fisher-drawn areas. A more recent multibeam mapping survey of this region provided little evidence to suggest extensive bryozoan reefs similar to those observed at Separation Point were still present, but no samples or imagery was collected to confirm this (Neil et al. 2015).

Another area off Oamaru was reported to historically contain "Kaeo beds", (sea tulips) which the fishers reported were no longer present. Our limited sampling at this site found no evidence of sea tulips, effectively corroborating the absence of this habitat in this area. No comments were made as to the cause of this disappearance, although these species are thought to be somewhat ephemeral in nature. In three other locations, scientific sampling was extremely limited compared to the size of the fisher-drawn areas, and the lack of corroboration with fisher descriptions was just as likely to be due to missing the habitat / organisms described as any other reason. To the west of Cape Reinga fishers had reported coral and sponge bycatch in a narrow depth band several hundred kilometres around the coast. Scientific sampling was limited to two DTIS tows, without the benefit of being guided by multibeam mapping, and found only bare sand substrate. It is likely that these deeper reefs are patchy in nature and easily missed. Along the east coast of the North Island, fishers reported what was potentially thought to be sea tulip or tube worm beds. Sampling did not reveal evidence of either of these in any great density, but this may be due to the limited sampling, or sparse, patchy nature of the occurrence of these organisms.

Overall, the snapshot of scientific data collected during the *Tangaroa* voyages suggested that many of the biogenic habitats described, such as deep reefs on both low lying and more prominent hard substrate (ie reefs and offshore banks), and tubeworm fields on soft substrate were still present to some extent in many areas. At some sites there were signs of habitat deterioration or reduction, e.g. the inshore Pegasus Bay site, where tubeworm habitat was sparser and fishers believed it was reduced in extent (Figure 92 and Table 65). In other areas, the absence of fisher-described habitat suggested possible elimination, e.g. the D'Urville Island bryozoan beds, but generally, the data presented were insufficient to draw clear conclusions about historical changes in extent.

Table 65: Historic biogenic habitat locations and descriptions from fisher LEK survey contrasted with empirical field survey observations. Location is given as the geographic name, the scientific Site identifier, and the regional map figure in this report, followed in brackets by the relevant LEK map figure number in lower case, and fisher-drawn area ID number(s), as given in Jones et al. (2016) (Fisher-drawn areas in this report are only given as generic backgrounds). Fisher LEK descriptions/comments are summarized, along with field survey observations (2011), and the relevant report figure/s which illustrate them. The Comparison column provides a qualitative assessment of degree to which empirical observations match the historic biogenic habitat descriptions. The trawl fishing footprint values are calculated from Baird et al. (2015) data, see Synopsis Methods section; values represent total km^2 swept by trawl per 25 km^2 grid (5 × 5 km), as averaged across each fisher-drawn area (minimum value 0, no trawling; maximum value 25, all of seafloor is trawled). Multiple values are given where multiple areas were drawn at a site.

Location	Fisher LEK description/comments	Field survey observations	Comparison	Trawl fishing footprint by fisher drawn area)
Middlesex Bank: Site 7, Figure 6 (figure 4; #1)	#1, picked up a lot of coloured coral on lines – oranges, reds, pinky-red. Mentions 'ferns' also. 90–500 m	Lots of whip corals, gorgonians, hydroids, sponges. (Figure 8)	**Good matches**, including descriptions of gorgonians. (e.g., orange, pink, and "fern-like" description).	Outside Baird et al. (2015) data coverage
West of Cape Reinga: Site 9, Figure 6 (figure 4; #2, #10)	#2, sponge garden, sponges heavier; #10 'staghorn coral' area	Coarse sand/gravel with scattered small sponges and ascidians. (Figure 13 e–f.)	**Not matched**. Very large fisher-drawn areas, no multibeam collected, and very limited sampling.	2.65 3.10
West of Cape Reinga: Site 8, Figure 6 (figure 4; #2 and #11)	#2, sponge garden, sponges heavier; #11 corals, sand area	Larger (heavier) sponges on reef areas, stony corals on vertical faces. (Figure 13a–d)	**Good matches** at the site sampled which overlaps both #10 and the much larger area #2	2.65 0.44
North of North Cape: Site 1, Figure 6 (figure 4; #7, #8)	#7, coral, black coral; #8, coral and sponge.	Sponge, gorgonians, soft corals, black coral, on mixed bed-rock patches and carbonate sands. Figure 15 a–b.	**Good matches.** Diverse and patchily abundant (small rock outcrops) epifauna.	9.81 12.31

Location	Fisher LEK description/comments	Field survey observations	Comparison	Trawl fishing footprint by fisher drawn area)
North of North Cape: Site 2, Figure 6 (figure 4; #3, #4, #6)	#3 all the coral here trashed, #4 Coral and sponge, but areas fished hard for tarakihi, #6 area of coral and sponge (noted bright yellow and grey sponges) with some "workable" fishing tows	Hard packed rippled sand with little or no epifauna	**Indeterminate**. Fishers described clear tows through areas of coral, # 6 was very large.	12.31; 12.94; 18.21
North of North Cape: Site 3, Site 4, Figure 6 (figure 4; #5)	#5. sponges, lacy sponges with fibreglass	Site 3 sand, Site 4 sand with diverse fauna patch reefs with gorgonians, sponges, bryozoans. (Figure 15 d–f).	**Good matches** in some but not all areas sampled – large area. No glass sponges seen, but are known from the region.	3.09
Off north Kaipara Harbour, "The Canyons": Site 10¸ Figure 16 (figure 10; #11)	Fishes up and down canyon walls, rock and boulders, coral and sponges, light black pumice. Describes light black pumice that can be encrusted with organisms. Mentions feathery sparse trees <10 cm high, possibly bryozoans. Also elephants ear sponges 2–3 foot size and corals	Some bed rock outcrops, carbonate rubble patches, corals, sponges, bryozoans. Rocks have pocked appearance from boring organisms, encrusted, may be the 'light black pumice'. Figure 18 a–f.	**Good matches** for fauna and seafloor. Elephant's ear sponges may be a grey bracket sponge, Psammocinia spp. or "lithistid "cup and ear" sponges (*Pleroma* and *Aciculites* spp).	5.06
North Taranaki Bight: Site 11, Figure 16 (figure 11; #2, #3, #4)	#2 and #3, tubeworms and sometimes sea-pens; #4, large beds of gatherer shells	DTIS station/s in each area – no gatherer shells or large tubeworms seen, sea pens present, and small low patch reefs in #2. (Figure 20 a–f.)	**Some matches**. Very large areas, no multibeam, limited sampling.	10.43; 20.26; 1.80

Location	Fisher LEK description/comments	Field survey observations	Comparison	Trawl fishing footprint by fisher drawn area)
North Taranaki Bight, The Coral Canyon: Site 13, Figure 16 (figure 11; #2, #5, #6).	#2, foul ground, possibly some pinnacles; #5, coral on south face of canyon wall; #6, concrete-like pillars, up to 1.5 m long, around 12–15 cm diameter, either the central core or that bits break off in square -shaped pieces. Not encrusted with anything. Bring up elephant's ear sponges, grey, look like *Ancorina*	Mainly targeted #5, with overlap into #2 and #6. Patches of foul ground that match #2, Carbonate rubble includes components that clearly match #6 as 'concrete-like pillars', whip and black corals present. (Figure 22, Figure 71, and Figure 81.)	**Good matches** especially for geology and sponges. #5 fished to 500 m, larger corals may be deeper. Elephant's ear sponges likely to be either grey bracket sponge, *Psammocinia* spp. or "lithistid "cup and ear" sponges (*Pleroma* and *Aciculites* spp).	10.43; 0.80; 17.20
North Taranaki Bight, the Drop-off: Site 12, Figure 16 (figure 11; #6, #7, #8)	#6, as above; #7, Described isolated papa like rocks like "swiss cheese" with holes in them, all in same direction, "lacy" corals growing on these. Surrounding area muddy; #8 area of foul but had tows through, occasional yellow sponges and weed.	Bedrock and carbonate rubble patches along the shelf edge, sponges, bryozoans (probably the lacy corals), some black coral, (Figure 24).	**Good matches** for rock descriptions and fauna. The weed mentioned was probably drift algae, area is too deep for macro-algae	17.20; 20.06; 13.06
North Taranaki Bight, The Well: Site 14, Figure 16 (figure 11; #6, #8)	#6, #8, as above	Bedrock and carbonate rubble patches, sponges, bryozoans (probably the lacy corals), some black coral. (Figure 26, Figure 71, Figure 81)	**Good matches** for rock descriptions and fauna	17.20; 13.06

Location	Fisher LEK description/comments	Field survey observations	Comparison	Trawl fishing footprint by fisher drawn area)
Western D'Urville Island: Site 16, Figure 27 (figure 21; #9–#12)	#9, corals, sandy coloured finger like sponges; #10, light coral rubble; #11, coral rubble, rough; #12, coral area on rough bottom, associated plentiful leatherjackets and 'charity' tarakihi (25–30 cm).	Sand, shell, and cobble seafloors, little epifauna. (Figure 32).	**Not matched**. This area was historically reported to hold bryozoan fields (Saxton 1980a, Bradstock & Gordon 1983). The fisher LEK observations date from the 1970s, with comments indicating that the habitat was believed to have been eliminated by fishing since then.	19.64; 20.40; 16.53; 17.37
North-eastern D'Urville Island: Site 17, Figure 27 (figure 22; #1, #2)	#1, hard corals, described as similar to Separation Point before 1982; #2, coral rubble, 1970–1983.	Rippled sand, occasional sponge, hermit crab. (Figure 33).	**Not matched**. Thought to have existed previously, but eliminated by fishing according to fisher's observations. One DTIS station only, no multibeam	12.29; 11.30
Eastern D'Urville Island: Site 18, Figure 27 (figure 22; #4, #5, #6)	#4, Heavy coral, more like Separation Point, specifically at Wharaeatea Bay entrance (before 1982); #5, huge dredges full of rubbish (coral rubble) (1970–83 period), only fished one time; #6, coral rubble, 30 bins of juvenile blue cod once when experimenting with cod-end liners. Always good cod area but well known area to rip your nets. Cod good here when jellies (salp chains) are in bloom. 1960s–70s infrequently	Sand, screw shells, sponge, hermit crabs, holothurians, brittle stars, anemones, dead bivalve shells. No significant bryozoan colonies / coral rubble. Some sleeping sub-adult to adult blue cod (Figure 35).	**Not matched**. Fishers indicated that they believed the bryozoan habitats were eliminated by fishing.	19.16; 17.37; 17.39

Location	Fisher LEK description/comments	Field survey observations	Comparison	Trawl fishing footprint by fisher drawn area)
Conway Ridge: Site 19, Figure 36. (figure 14; #5, #6, #8).	#5, large branched corals; #6, sections of papa rock, can only tow one way often lots of 'bits and pieces' attached to rock such as sponges; #8, this rock area not fished intentionally but when it, quite a lot of funny-looking orange cylinder / cup / glass like sponges. Soft. Bit of coraly stuff. Also a lot of sea cucumbers.	Gear failures resulted in only one DTIS and two rock dredge tows at Site 19. Stick-like sponges observed, along with cup corals, bryozoans and holothurians. Multibeam transects showed areas of foul along the eastern Conway Ridge, which could support the 'large branched corals' of polygon #5. (Figure 38).	**Good matches**, despite very limited sampling of fisher-drawn area # 8.	15.82
North Canterbury Bight, "wire-weed" areas: Sites 20, 21, 22, Figure 36 (figure 14 #12, #14, #15, #19, #20, # 21, #24)	#12, patches of wire-weed; #14 and #15, described as wiry algae, but confirmed from material on boat deck as polychaete tubes by interviewers; #19, worm cases patch (fisher thought them to be algae); #20, main wire-weed area, called the 'weed-line', was thought to be algae; #21, wire-weed patches; #22, weed 6–8 inches long, fine, like grass with a smooth, non slimey texture, pale white-brown in colour and about two mm diameter. Older fishers fished around it as could not fish into it; but in recent times the larger trawlers now directly fish it.	Chaetopterid tube worm patches matching the "wire-weed" description were observed in all of the fisher-drawn areas sampled, though limited and patchy in some (#19, #20, #21 and #24) Variety of species associated with the tubeworms included sponges, ascidians, bryozoans, and holothurians (Figure 40, Figure 92, Figure 101)	**Good matches**. Fishers believed it has been reduced in extent from its historical coverage, particularly in areas #19, #20 and #21 (Site 22). Trawlers present during survey, and fishing gear marks were seen on some DTIS transects.	20.95; 16.42; 16.43; 23.65; 22.50; 22.12; 13.99
North Otago, The Hay Paddock: Site 23, Figure 41 (figure 16; #13, #17).	#13, 'weed', found in pockets further inshore also; #17, The Hay Paddock. Also called tarakihi weed. A pale yellow colour. Straw-like with kinks. Came up like clumps of hay. It is still there today but not in such huge amounts. It may grow on humps of substrate.	Muddy sediment, chaetopterid tube worm clumps with diverse and abundant sponge epifauna and others. (Figure 43, Figure 92, Figure 101).	**Good matches** to fisher descriptions.	17.08; 13.78

Location	Fisher LEK description/comments	Field survey observations	Comparison	Trawl fishing footprint by fisher drawn area)
North Otago, inshore of the Hay Paddock: Site 24, Figure 41 (figure 16; #11)	#11, historic sea tulip bed, was always cyclic but now doesn't come back at all. However, sea tulip beds were noted to be coming back further inshore.	Sand / shell hash / bedrock ledges, sponge beds, bryozoans (Figure 45). Did not sample shallower areas where they were reported to have come back.	**Not matched, i.e.** lack of sea tulips in this area matched fisher's comments, but hard substrates for them to attach to were present.	17.71
North Otago, Cornish Head Canyon (Karitane canyon): Sites 29 and 30, Figure 41 (figure 16; #19, #21, #22, #23, #24)	#19, area where brown sponges were commonly dredged up. Not necessarily beds, rather areas where drift sponges collected. The tarakihi caught here were 'just of size'; #21, shell hash; #22, cornflakes (bryozoans) along canyon flank, can tow right up to the cornflakes patch but too rough on nets to go through. This area is mainly set netted; #23 and #24 a reef where tarakihi were found	Sponges found on the shelf in the north, very similar to the Hay Paddock (Figure 48), includes brown sponges, some shell hash areas (bryozoan fragments and numerous small gastropods). Bryozoan fields found in the south, and along canyon edge (the latter 'cornflake' species, see Figure 47 b–c). #24, rough ground visible in multibeam imagery, DTIS station just to east confirms rock outcrops present (Figure 46).	**Good matches** to fisher descriptions.	11.06; 12.24; 2.82; 2.72
Otago Shelf bryozoan thickets: Site 25, Figure 41 (figure 16; #36, #41)	#36 and #41, shell hash and bryozoan thickets	This site was chosen largely based on the dredge data of Batson & Probert (2000), to build on existing science knowledge. (Figure 50)	**Good matches** to fisher descriptions.	0.46
Otago Shelf scallop patch and drop-off: Site 26 and 27, Figure 41 (figure 16; #33, #34)	#33, elephant ears, large sponges named due to size and shape rather than colour. Thinks yellow; #34, scallop beds dredged all along the drop-off, early 1990s	Deeper area (#33); sand/mud, shell hash, small bryozoan clumps, limited sponges, but no elephant-ears type sponges obsv. (Figure 52 a–b). Shallower areas (#34); sand / shell hash/gravel, yellow "stick" sponges, scallops, asteroids, bryozoans, anemones (Figure 52 c–f).	**Some matches** to fisher descriptions of shallow beds, but deeper sponges not seen.	0.06; 0.38

Location	Fisher LEK description/comments	Field survey observations	Comparison	Trawl fishing footprint by fisher drawn area)
Foveaux Strait: Site 32, Figure 53 (figure 17; #9)	#9, Bryozoan rich area, large amounts of dead oyster shell.	In general, sand/shell hash (oyster shell), some bryozoans, brittle stars, algae. (Figure 57 e–h).	**Some matches** to fisher descriptions of oyster shell, bryozoans present but patchy, no bryozoan reefs.	20.09
Mason Canyon: Site 34, Figure 53 (figure 17; #10, #12, #13)	#10, foul; #12, very large black coral tree caught, patches of coral rubble bought up; #13, trench full of bryozoans and "cow's horns".	Muddy sediment, with bedrock outcrops supporting sponge, hydroids, tube worms, black coral, and bryozoans. (Figure 59).	**Good matches** in general and spatially, although bryozoans not a dominant group.	9.13; 0.00; 23.74
Table Cape, off Mahia Peninsula: Sites 35 and 36, Figure 60 (figure 8; #19, #21, #22, #23)	#19, a clear tow called "The Tunnels" through the foul, lots of coral, couldn't tow at the top as would come fast; #21, rough area, avoided; #22, grey sponges like elephant's feet, twisted very fragile coral, stony cup corals and fans (from flip-chart); #23, offshore ledge, moki spawning ground.	Bedrock with some attached sponges, cup corals, large areas of soft sediment, and regular emergent ridges from the underlying rock synclines. Raised reef feature at #23 location. (Figure 62).	**Good matches** in general, some grey sponges, but area heavily sedimented, with richest epifauna on shallowest ridges, presumably raised above suspended and deposited sediment issue.	24.76; 24.76; 24.31; 9.78
Eastern Ariel Bank: Site 37, Figure 60 (figure 8; #15, #17)	#15, steep sided reef. Would get blue moki. In some areas could tow up to the top of the bank and would pick up slabs of flat papa rock with coral bushes growing on them. Doesn't show on sounder but could get hooked up; #17, moki spawning grounds outside Ariel Reef	Bedrock, gravel, sponge on reef, some large cup sponges, brown and green algae; more sedimented in deeper part of block. Some of rock type (papa) matches, but possibly harder bed rock type also. (Figure 64).	**Good matches** in general, although bryozoans ('corals') not common.	22.51; 22.64
White straw/ tube-worms: Site 38, Figure 60 (figure 8; #16)	#16, white straw, described as yellow white in colour, 1-2ft long and slimey. Believed to be either tube-worms, or possibly sea pens.	Sea-pens found, but did not appear to match the fisher's description. No DTIS imagery collected.	**Indeterminate**. May have missed - limited sampling compared to size of area marked by fisher.	2.21

Location	Fisher LEK description/comments	Field survey observations	Comparison	Trawl fishing footprint by fisher drawn area)
Possible tubeworms: Site 39 and 40, Figure 60 (figure 8; #3)	#3 Could tow along here and get tube worms	DTIS transect on a raised feature at southern end of area marked by fisher was a large rock 'barrow' with low relief sponges, hydroids and coralline algae (Figure 65). A single beam trawl tow 10 km north returned only sea pens.	**Indeterminate**. Soft sediment sampling was minimal and the exact nature of the tubeworms is also unclear.	1.72
Ranfurly Bank: Site 41, 42, 43, 45, Figure 60 (figure 7; #6, #7, # 8, #10	#6 a large area of foul ground, believed to be tarakihi breeding ground, would avoid. #7 catches coral and black coral, and #10, gets yellow sponges	Most of multibeam and DTIS sampling on central area inside #6; observed *Ecklonia* forest, bryozoans, diverse sponges (including yellow *Polymastia crocea*). Sampling at the southern end of #7 observed white sponges and crinoids, no corals, but corals and gorgonians observed on deeper slopes and outcrops to the north (Figure 67, Figure 118, Figure 119, Figure 120).	**Good matches** in general, sampling limited given size of fisher-drawn areas.	2.72; 4.11; 3.54; 11.83

5.2 Large scale threats to biogenic habitats

While climate change and ocean acidification may arguably be the greatest potential threats of all for biogenic habitats, they are not manageable in the sense of being able to put local to regional scale spatial management regimes into place to address them. The two greatest spatially manageable threats to biogenic habitats on the continental shelf are commercial fishing and sedimentation (Ministry for Primary Industries, 2016).

Commercial fishing

The observational and 'one-off survey' nature of this programme means that fishing and sedimentation influences cannot be directly evaluated for their impact and scale of effect. Nevertheless, the data collected can help frame their likely impacts and scale, and direct future research efforts. Evidence of fishing and human presence was recorded at a number of sites, and included lost ropes, fishing line, and anchors, as well as net bobbin seafloor path marks at the North Canterbury wire-weed site (Figure 130, Figure 131). At the North Taranaki Bight canyons, solitary rock slabs were also observed by DTIS out on bare sand seafloors, and it is assumed that these were bought to the surface by fishing gears, and then thrown back over the side, to land some distance away from the rubble fields from which they came.

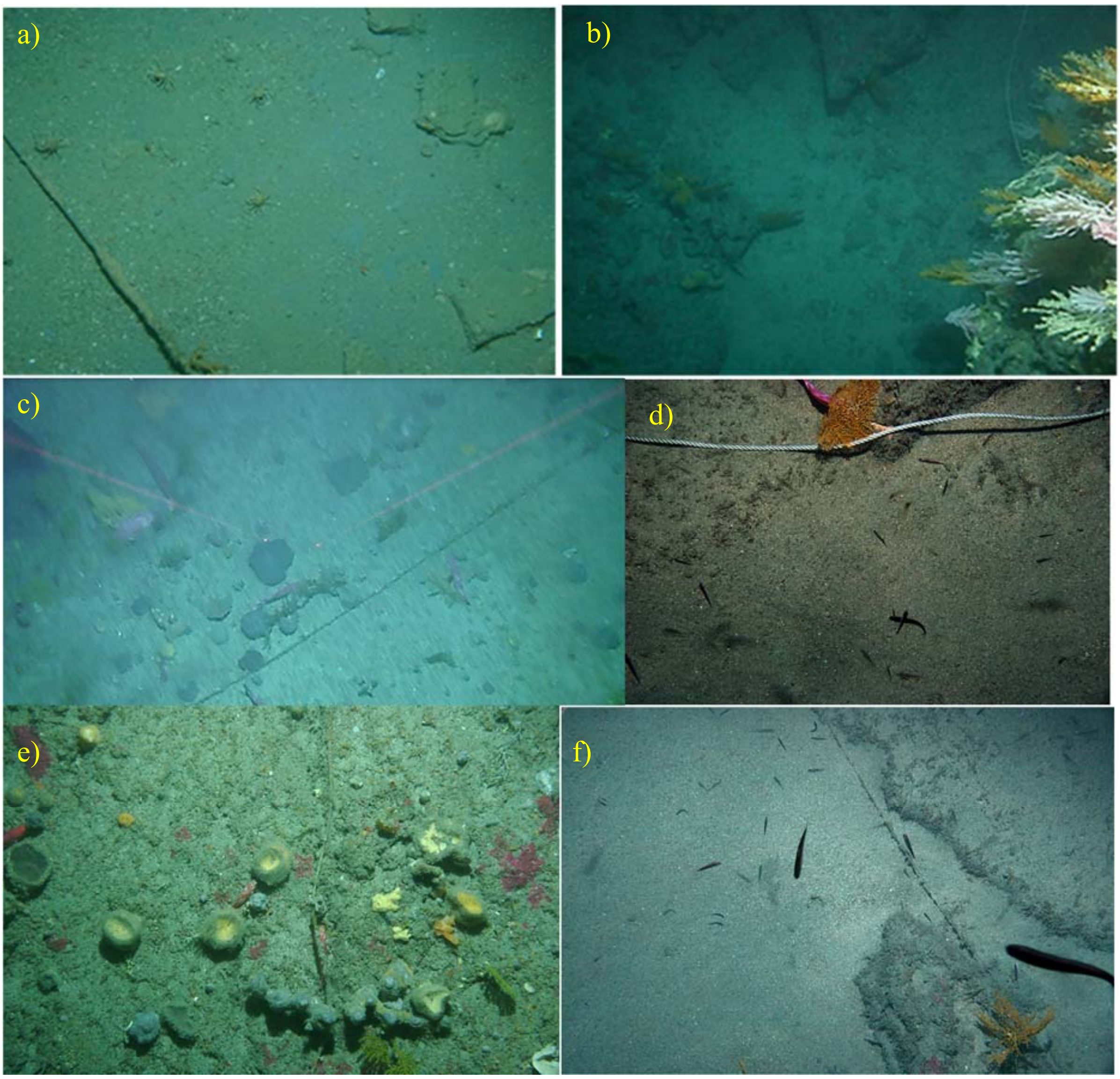


Figure 130: Examples of lost fishing gear from DTIS imagery: a) sponge encrusted rope from down the slope of Cornish Head Canyon, Station 146 (see Figure 46), an area of ledges and large boulders; b–e) Station 146, Site 44 at Ranfurly Bank (see Figure 66), steep rock outcrops with very diverse and abundant large epifauna, surrounded by coarse sediment flats; b–d) (different) ropes around the rock structures; e) encrusted cord on rock with sponges and gorgonians; f) encrusted monofilament line.

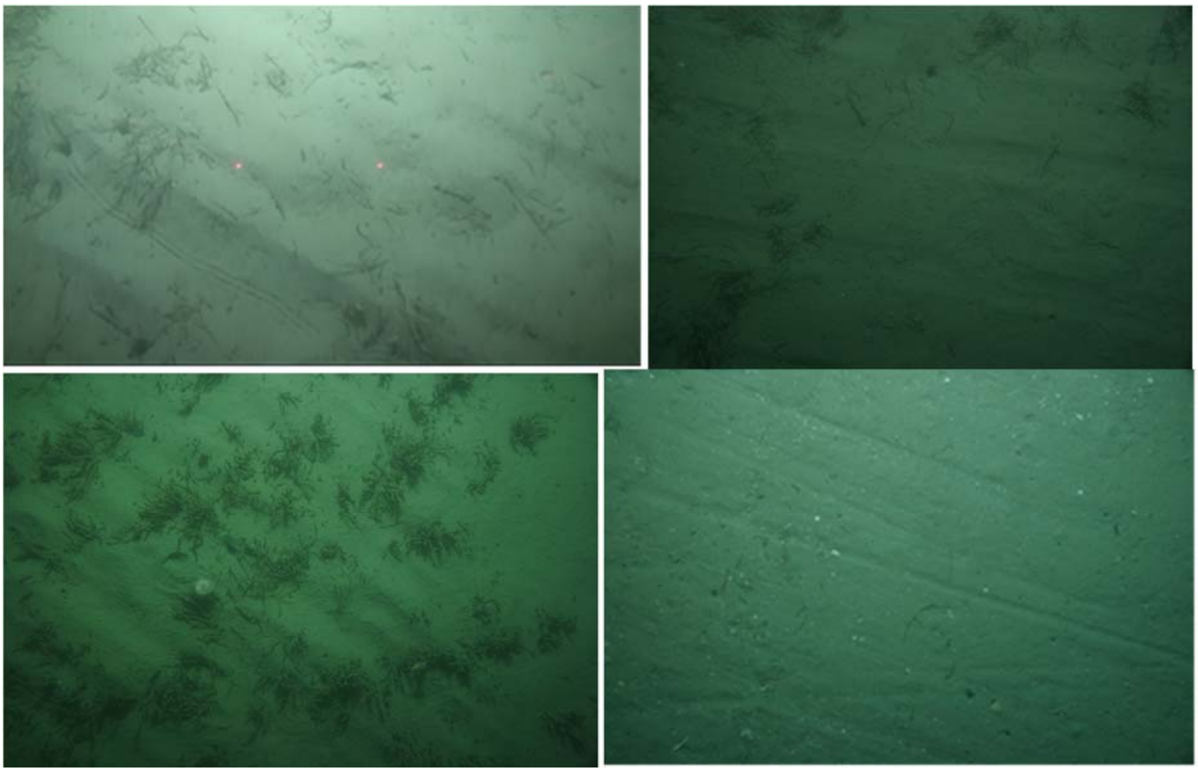


Figure 131: Trawl gear marks on the seafloor, Stations 167 and 169, wire-weed area, North Canterbury Bight. Each is a different ‘trawl event’ which has been crossed by the DTIS transect.

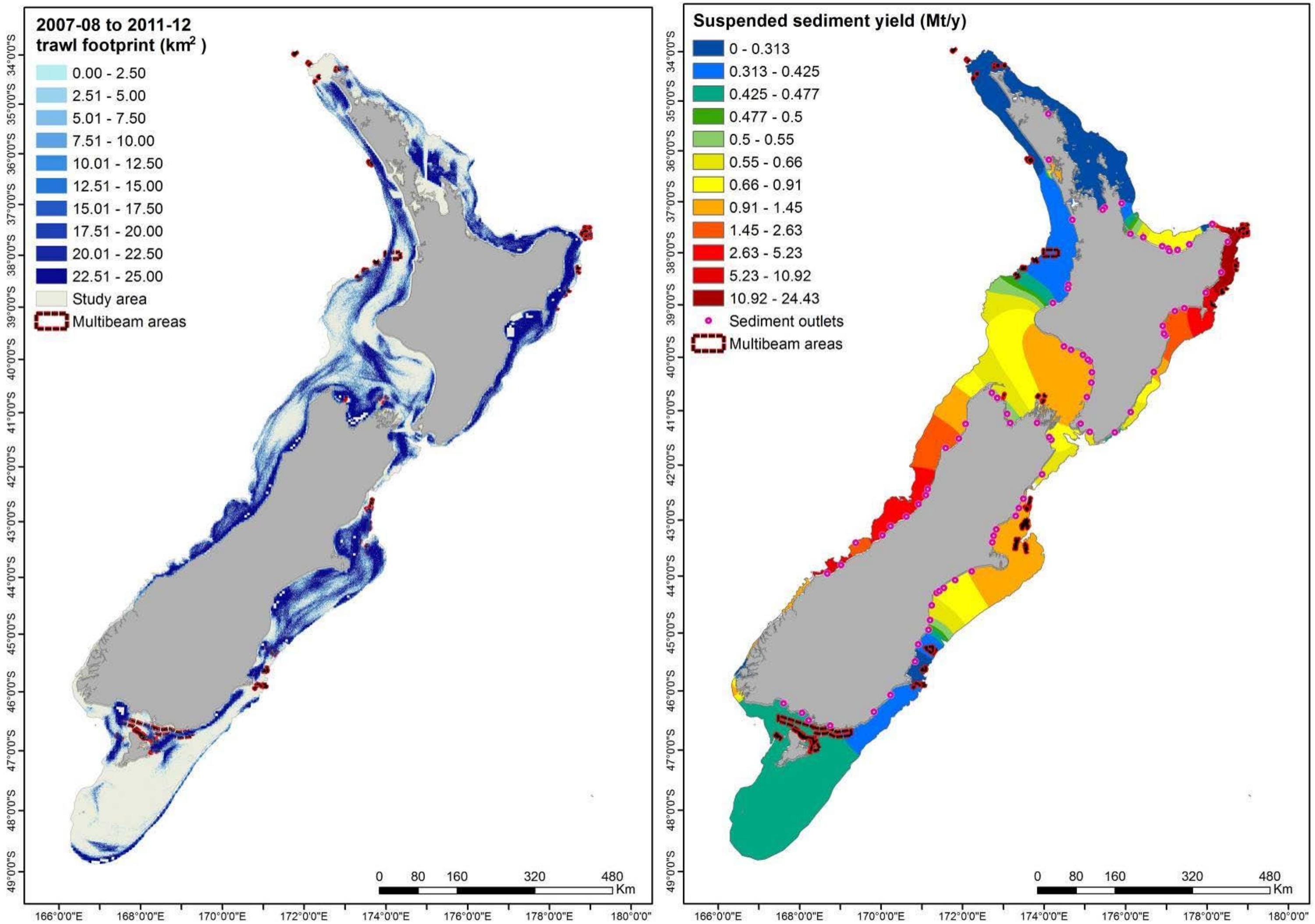


Figure 132: left) Total 5-y trawl cell-based footprint for 2007–08 to 2011–12 combined [trawl footprint for bottom trawl and midwater trawl within 1 metre of seafloor for vessels reporting on TCERs and TCEPRs during 2007–08 to 2011–12 – presented in 5×5 km cells for depths down to 250 m (Baird et al. 2015). Visual representation of total sediment yields from major rivers along the New Zealand coast; sediment yield estimates are from the CLUES model, released from key rivers (red dots). Contours are simple diffusion surfaces along the coastline and are for visualisation purposes only, they are not quantitative spatial surfaces.

Total commercial fishing extractions (fish catch) are capped by the QMS (allowing for natural stock variability), but where fishers can fish is less constrained, and spatial effort may shift as fish abundances move, and/or market and other factors change. Historical experience has shown that as fishing gear technology improves, previously inaccessible habitats may be opened up to fishing, e.g., the use of 'flown' gear over the bryozoan beds in Golden/Tasman Bays in the 1960/70s (Grange et al. 2003), and the extension of fishing up onto Ranfurly Bank (Jones et al. 2016). The improvement in spatial positioning using GPS, and other technology such as net monitors, since the 1990s has also greatly reduced the 'halo' habitat protection zones features such as rocky reefs provide, as fishers can fish much closer to (and sometimes over) such features through knowing exactly where their gears are in relation to such fishing hazards (Multiple Anon. fishers, pers. comms. to MM). This issue is also potentially accelerated as very detailed multibeam seafloor maps become available.

It was apparent that most of the sites that we surveyed had been trawled within the five-year period (2008–2012) covered by the trawl footprint data (25 being the maximum possible value, and indicating that the entire seafloor had been passed over by a trawl at least once in the five-year period). Most of the 'more open' areas received relatively high trawling footprints in the 10 (40%) to 25 (100%) intensity range, e.g. the fisher drawn polygons of the North Taranaki Bight (10.43–20.26; but also 0.80–1.80), D'Urville Island (11.30–20.40), Conway Ridge (15.82), North Canterbury (13.99–23.65), Hay Paddock (13.78–17.08) and inshore of the Hay Paddock (17.71), Mason Canyon (9.13–23.74, but also 0.00), Table Cape (9.78–24.76), and Ariel Bank (22.51–22.64). Relatively high trawl intensity was also seen in the southern Foveaux Strait area (20.09), which also receives significant oyster dredging intensity as part of the Foveaux Strait dredge oyster fishery (not included in the Baird et al. 2015 data). The only site with no trawling at all was fisher polygon #17 at Mason Canyon, west of Stewart Island. This polygon fell over extensive rocky reef on the flats adjacent to the canyon, and over the steep canyon sides, and appeared untrawlable.

We note that the trawl footprint values given are average 25 km^2 grid values over the fisher drawn areas, and do not necessarily imply that finer scale biogenic habitat patches within these areas were fished at this intensity. For instance, it seems unlikely that the seafloor assemblages observed with the core Hay Paddock area would exist if trawled at the average level given above for the overall fisher-drawn area; while foul ground at locations such as at Conway Ridge, Table Cape, and Ariel Bank appear untrawlable given their topography.

Lower relative effort was seen around the North Cape area (0.44–12.31). In this area, fishermen described 'known trawl tow paths' which avoid the extensive foul grounds. Intermediate trawl intensity was seen on the edge of the shelf off the Kaipara Harbour (5.06). For the Otago shelf bryozoans, fishing effort was relatively low (0.46), while further offshore, the deeper sponge and queen scallop area also had lower values (0.06 and 0.38 respectively). For the deeper areas, a dredge fishery for queen scallops operates, and as with Foveaux Strait, the use of this method is not captured in the Baird et al. (2015) values.

We suggest that the impact on biogenic habitats from commercial fishing has been, and continues to be significant, as an ongoing human activity that covers much of the continental shelf (e.g.Table 66). This impact may also include the ongoing 'suppression' of regeneration of some historically extensive biogenic areas, assuming that the conditions imposed by fishing are reversible once fishing ceases (e.g. as shown for sponges on the north-west Australian continental shelf, Sainsbury 1988, 1991, Sainsbury et al. 1988). For example, the bryozoan fields of the South Taranaki Bight, while still present, are thought to be degraded by ongoing trawling, and do not show the fully developed bryozoan individuals and assemblage that would expected without ongoing disturbance (Beaumont et al. 2013). For regions such as the inner to mid Hauraki Gulf, trawling (along with land-based impacts) has occurred for around 100 years, meaning that it is difficult to even establish what the seafloor once looked like (Dayton et al. 1998).

There are few specific protections for marine biogenic habitats in New Zealand in water depths between 30 to 200 m. Explicit shallow water reef examples include small marine reserves in Fiordland to protect “China Shops”, rocky wall sites that support visually impressive invertebrate assemblages (Willis et al. 2010), and red coral at “The Gap” in Doubtful Sound (Millar et al. 2004); and a small area of mixed bedrock and soft sediment in Spirits Bay which supports diverse epifaunal assemblages (Cryer et al. 2000). The only explicit soft sediment example is Separation Point, closed to any form of bottom contact commercial fishing since 1980, to protect its bryozoan beds suspected juvenile fish nursery role (Saxton 1980a, b). While a number of other (small) marine reserves are in place around the New Zealand coast, none have been placed to explicitly protect biogenic habitats, and there is an appreciable bias towards shallow (less than 30 m depth) rocky reef habitats.

Sedimentation

As living organisms, biogenic habitats are also vulnerable to degradation and loss from sedimentation impacts. Morrison et al. (2009) reviewed the impacts of land-based activities on coastal fisheries and associated biodiversity (e.g., biogenic habitats). They found wide-spread though patchily documented evidence of significant impacts from sedimentation, including the modification or loss of important fish nursery habitats, especially those composed of habitat-forming (biogenic) species. Eutrophication was also noted as a potentially serious problem in the future (e.g., in the Firth of Thames, Hauraki Gulf, Zeldis 2008). Figure 132 provides a broad visualisation of the annual suspended sediment yields into the marine environment around New Zealand. Some of the highest sediment yields occur around Mahia Peninsula to East Cape; and during the second *Tangaroa* survey, heavily sedimented reefs were seen along that coast in 50–100 m water depth, with associated poor water visibility and relatively poor epibenthic species assemblages, relative to adjacent more elevated reef stations (Figure 62, Figure 64).

Another region noted to have a similar sedimentation gradient, albeit putatively less intense, is the East Northland coast from north of Tutukaka through to North Cape (50–200 m depth zone). Sampling in the Bay of Islands OS2020 programme noted (putatively) strong impacts of sedimentation on the more southern deeper reef areas including less epibenthic diversity, while in the far north, lower apparent sedimentation was coincident with a higher epibenthic diversity. Notably, the land-mass in that far north coastal area (e.g., Great Exhibition Bay, Rangaunu Bay) has small catchments with large extents of ‘sandy’ land-forms, no major rivers, and contains relatively pristine estuaries (e.g., Parengarenga, Rangaunu) with extensive subtidal seagrass meadows supporting high biodiversity and fish nursery values (Morrison et al. 2014c, M. Lowe & MM, unpubl. data). Similarly, less degraded estuaries and coastal zones (with respect to sedimentation) occur at the far southern end of mainland New Zealand, including the Bluff/Awarua estuary, Foveaux Strait, and Stewart Island (including Paterson Inlet, Pegasus Inlet and others). As with upper East Northland, these areas do not have major river systems.

Broadly speaking, the regions of higher biogenic habitat extent and complexity, as identified from the LEK (Jones et al., 2016) and the field programme reported on here, tended to occur in areas less likely to be affected by land-derived sedimentation and more distant from large river influences, e.g., Middlesex Bank/Three Kings Islands/Cape Reinga/North Cape; offshore North Taranaki Bight, Ranfurly Bank; Otago Shelf including the Hay Paddock; and the Foveaux Strait region. A ‘central mainland’ exception was the North Canterbury Bight wire-weed (polychaete) meadows, although the shallower, less dense, more buried tube wire-weed patches may have been impacted by sedimentation. The cumulative weight of existing scientific evidence makes it apparent that sedimentation is a substantial and fundamental ongoing threat to biogenic habitats around much of mainland New Zealand, with little evidence to suggest that present day sediment yields will reduce going into the future. There is also likely to be an ongoing sedimentation interaction with bulk fishing methods, as towed gears such as trawls and dredges re-suspend fine seafloor sediments.

Table 66: Records and estimates of biogenic habitat loss, and possible impacts, on New Zealand's coast and continental shelf. Not all possible species are included, estuaries are excluded (see Morrison et al. 2014a for latter). New observations from this programme are listed as bolded text under 'Known or inferred causes'.

Biogenic habitat	Location	Estimated loss	Known or inferred causes	Reference
Green-lipped mussels	Inner Hauraki Gulf	1920s–1960s, about 500 km^2 lost (now functionally extinct)	Known: Commercial dredge fishery	Reid (1969), Greenway (1969), Morrison et al. (2002, 2003)
	Pelorus Sound, Marlborough	350 ha subtidally (conservative estimate), 1960s	Known: Commercial dredge fishery	Sean Handley, NIWA Nelson, unpubl. data
Bryozoan beds/reefs	Separation Point	1960s to 1980; 140 km^2 to 56 km^2	Known: Trawl fishing impacts **Heavy sedimentation and poor water visibility observed on DTIS**	Grange et al. (2003)
	Torrent Bay	1970s, 300 km^2 to none	Known: Trawl fishing impacts	Saxton (1980a)
	D'Urville Island	1970s, extent unclear. None found in 2014.	Known: Scallop dredging impacts **No bryozoan beds found (4 stations)**	Saxton (1980a), LEK - Jones et al. 2016
	Foveaux Strait	1960s to present, 800 km^2	Known: Oyster dredging, probable earlier additional losses, possibly also bottom trawl impacts. **No bryozoan/oyster reefs or 'mulloch' found**	Cranfield et al. (2003), but see Michael (2007)
Horse mussels	Hauraki Gulf	Unknown, suspected to be significant.	Inferred: Trawl fishery for about 100 years. Anecdotal accounts of conditioning of horse mussel areas for fishing using wire warps and/or water filled rollers. Also known to be sensitive to sedimentation.	Ellis et al. (2002), Morrison et al. (2009, 2014a), anon. comm. to MM

Biogenic habitat	Location	Estimated loss	Known or inferred causes	Reference
	Marlborough Sounds	Unknown, suspected to be significant	Inferred: Hay (1990) noted that fishers commonly "*flatten areas of horse mussels to render the bottom terrain more suitable for dredging and trawling in future years*". He suggested that significant horse mussel habitat on the outer Marlborough Sounds, inside the Sounds (e.g., Ketu Bay), and inside Croiselles Harbour had probably been eliminated by commercial trawling and dredging **No/few horse mussels seen during limited sampling on east side of D'Urville Island**	Hay (1990)
Wire-weed meadows	North Canterbury Bight	Unknown, but LEK fishers thought main extent in Pegasus Bay used to be much larger; with one estimating only about 30% remained.	Inferred: Suggestions of fishing around the habitat edges over time reducing extent. **Limited patches of tubeworms (mostly buied beneath the sediment) found in Pegasus Bay, where fishers indicated the main area used to be. Fishing gear marks (bobbins) seen at several sites. Some suggestion that sedimentation may be impacting on the shallower, southern extents of this habitat.**	LEK - Jones et al. 2016
	'Hay Paddock' off Oamaru (could also be classed as sponge garden)	Unknown, LEK fishers thought it still existed but "*not in such huge amounts*".	Inferred: Bottom fishing. **Stations had semi-continuous biogenic habitat cover, no sign of disturbance (stations in central areas of polygons, away from edges which may be more amenable to being fished with regard to by-catch levels).**	LEK - Jones et al. 2016
Sponge gardens	Spirits Bay, Northland	Unknown. 12 km^2 strata reported with high by-catch, but probably extends outside the area. Habitat map generated suggests one square kilometre area of sand with underlying bedrock held the greatest diversity	Known: Scallop dredging, possibly also trawling **Closed area not sampled, but putatively similar habitats sampled to the north and north-east.**	Cryer et al. (2000), Tuck & Hewitt (2011)

Biogenic habitat	Location	Estimated loss	Known or inferred causes	Reference
Sea pens	West Coast South Island (‘tarakihi weed’)	Unknown but suspected to be significant declines since the 1970s.	Inferred: Bottom fishing. Remnants though to occur around the edges of canyons and drop-offs where it tended to be denser and associated with rougher terrain and boulders, such as Cooks Canyon and the Hokitika Trench.	LEK - Jones et al. 2016
“*Sponge-weed*”, exact identity unclear	South Taranaki Bight	1970s over 5300 km^2, now about 181 km^2 (Fisher-drawn areas only)	Inferred: It is not clear whether this is sponge or algae, or both (in different areas). Whatever it is, it was once widespread and considered to be a binder and stabiliser of soft sediments; today it is largely gone, attributed to fishing by the retired fishers interviewed.	LEK - Jones et al. 2016

Morrison et al. (2014a) reviewed the evidence for linkages between biogenic habitats and fisheries species, including information on changes in biogenic habitat extents over time. That information is included and extended on in Table 66, along with new observations from the LEK component of this programme (Jones et al. 2016). The available scientific literature has documented significant loss of areas of biogenic habitat within living memory from fishing and sedimentation impacts (e.g., Greenway 1969, Reid 1969, Saxton 1980a, b, Cranfield et al. 2003), as well as suspected large earlier undocumented losses from human development of fishing and land-based industries (especially agriculture) (Morrison et al. 2009). Prior to this current programme, most of the (scant) empirical knowledge available from shelf habitats was collected over small discrete areas of the shelf, e.g., bryozoans of the Otago Shelf (Batson & Probert 2000, Wood & Probert 2013, Wood et al. 2012, 2013), mixed sponge, bryozoan and other biogenic habitat invertebrates off Spirits Bay (Cryer et al. 2000, Tuck & Hewitt 2011, 2013), and general shelf rocky reefs (50–200 m) along the upper East Northland coast (Bowden et al. 2010, Morrison et al. 2010b). The only real time series available is from Spirits Bay, which started in 1999, and has been sampled twice since (Cryer et al. 2000, Tuck & Hewitt 2013). These follow-up monitoring surveys have reported that the effects of fishing were detectable 7–9 years later in some areas, with some sensitive species of sponges and hydroids considered to have a poor probability of recovery from disturbance.

The examples documented elsewhere in the literature demonstrate that the cumulative effects of sedimentation and fishing on biogenic shelf habitats have been profound in some areas. The results from this project have recorded the persistence, to some extent at least, of less well known biogenic habitats on the continental shelf. The full extent of these habitats was not ascertained, but in some instances, the anecdotal information gathered, combined with field observations, indicate that degradation may have taken place, but further observations are required before drawing any clear conclusions about the actual causes.

5.3 The power of multibeam sonar to detect and map biogenic habitats

Multibeam sonar was an essential mapping tool for the field sampling. It was especially useful in situations where the critical targets were small and unknown, e.g. the bedrock/carbonate rubble habitats of canyon heads (e.g., Three-holes canyon (west coast North Island), North Taranaki canyons, Mason Canyon), and the reef/cobble/rubble components of Ranfurly Bank and eastern Foveaux Strait. Multibeam also mapped some soft sediment biogenic habitat structures, including the Separation Point bryozoan fields, and the North Canterbury Bight wire-weed areas. Without such maps, DTIS and biological sampling would have been largely blind, and missed many of the key habitats.

At the finer scale of ecological assemblages, success in providing derived metrics (e.g. slope, rugosity, zones, and structures) as potential explanatory factors in statistical models was more variable. For the North Taranaki Bight, using the full community assemblage (both sessile and mobile), and multibeam-derived metrics only, reflectance, slope and depth explained 7.3% of the variation, with rugosity dropped from the model. When geographic and DTIS image-derived variables were included, 17.7% of the overall variability could be explained through a combined model of % hard substrate, depth, bioturbation, and region, with depth accounting for 1.9%. The substrate and bioturbation variables, estimated directly from DTIS imagery, and the site variable (i.e., Canyon identity) had little predictive use at larger spatial scales. The most biogenic-habitat diverse clusters were those on rock and rubble, and rock and rubble intermixed with soft sediments. These harder seafloors were visually identifiable on the multibeam imagery, in particular on the back-scatter. The latter was only used in this report as unprocessed 'reflectance' but has been successfully used elsewhere as a powerful substrate characterisation tool (e.g. Brown & Blondel 2009, Le Bas & Huvenne 2009, McGonigle et al. 2009, Brown et al. 2011). Another useful tool may be sub-surface profiling to measure the thickness of sediment veneers; this could address some of the issues with the "*rock and rubble intermixed with soft sediments*" habitat cluster not being consistently detected and defined as such. Scale mismatch between the images (less than 1 m scale) and the multibeam data (minimum pixel 25 m^2) also remain a challenge.

For the North Canterbury, Pegasus Bay and Pegasus Canyon wire-weed habitats, using the full community assemblage (both sessile and mobile) and multibeam-derived metrics only, depth, rugosity and zone explained 6.6% of the variation, with slope and structure dropped from the model. When geographic and DTIS image-derived variables were included, 17.8% of the overall variability could be explained through a combined model of tubeworm type, site, and depth, with tube-worm type accounting for 14.4%. The bioturbation variable, estimated directly from DTIS imagery, and the site variable (i.e. location) had little predictive use. Tube-worm type (14.4%) is a variable directly measured from DTIS stills, and so is not a remote sensing variable; nor is region. However, these estimates relate to the overall epifaunal assemblage, rather than explicitly mapping wire-weed itself as a habitat former. The biological variability also probably incorporates fishing impact gradients (e.g., differential elimination of epifauna, which seems likely given the DTIS observations). In the North Canterbury region, the multibeam could detect the distinctive seafloor bed-form features where wire-weed meadows were found, although this topography is originally of geological origin (Carter and Carter 1985). In contrast, at the Hay Paddock, no features were detected, but extensive meadows were observed there also. It is possible that multibeam sonar can be developed further as a mapping tool for wire-weed habitat areal extents (down to some lower density threshold), although the associated faunal assemblages will still require direct sampling.

At Ranfurly Bank, using the full community assemblage (both sessile and mobile) and multibeam-derived metrics only, depth, structure, reflectance, and slope explained 9.1% of the variation, with zone and rugosity dropped from the model. When geographic and DTIS image-derived variables were included, 9.3% of the overall variability could be explained through a combined model of depth, structure, %hard substrate and reflectance, with %hard substrate depth accounting for less than 1.0%. The bioturbation variables, estimated directly from DTIS imagery, had little predictive value. As with the North Taranaki Bight canyons, future analysis of the backscatter data may better define some of the physical bottom types. Variable coarse sediment veneers were a dominant feature of the bank, and future use of sub-surface profiling may better distinguish different sediment depths, with respect to the ability of epifaunal assemblages to utilise shallow buried rock flats (e.g., sponge gardens).

Other habitats outside of the three core areas remain to be assessed. However, the multibeam transect from Separation Point over bryozoan bed showed visually strong structuring in both bathymetry and unprocessed back-scatter data (Figure 28, Figure 29), suggesting a mosaic of bryozoan patches over mud (Grange et al. 2003), and that multibeam may be a powerful mapping tool in this situation. At locations where bryozoan fields occurred on harder substrates (pebbles, carbonate gravels, e.g., on the Otago shelf) the differentiation was far less clear, but future backscatter processing holds promise. Other soft sediment habitat types that remain to be assessed include deeper water rhodolith beds (e.g., Three Kings Islands) and shallower water species, and possibly kelps (e.g., Ranfurly Bank *E. radiata* beds); as well as other biogenic habitats not sampled in this programme such as bryozoan 'reef' structures (Cranfield et al.

1999), and ‘dense’ horse mussel (Hay 1990), green-lipped mussel (Morrison et al. 2010a), dog cockle (Beaumont et al. 2013), and *Tawera spissa* (Taylor & Morrison 2008) bivalve beds.

At the national scale, New Zealand’s continental shelf remains largely unmapped by remote sensing technologies. Figure 133 shows the spatial extent of all multibeam coverage as held in NIWA’s master multi-beam database, and the percentage of seafloor mapped, by 50 m depth bands. In total, 19.96% of the continental shelf has been multibeam mapped, although the level of resolution within that 19.96% varies widely, depending on the multibeam system used. The 0–50 m zone has the lowest mapped coverage, at 10.7% of its 63 880 km^2 extent, while the highest coverage is for the 101–150 m zone, at 28.9% of 63 872 km^2 (Figure 133). Nationally, the coverage is heavily skewed towards the east coast, with virtually no mapping on the west coast of either island; and for the east coast, most of the mapped areas occur along the north-eastern coast, the lower eastern North Island, Foveaux Strait, and south of Stewart Island. These figures and plots are inclusive of the multibeam sonar mapping done in this programme.

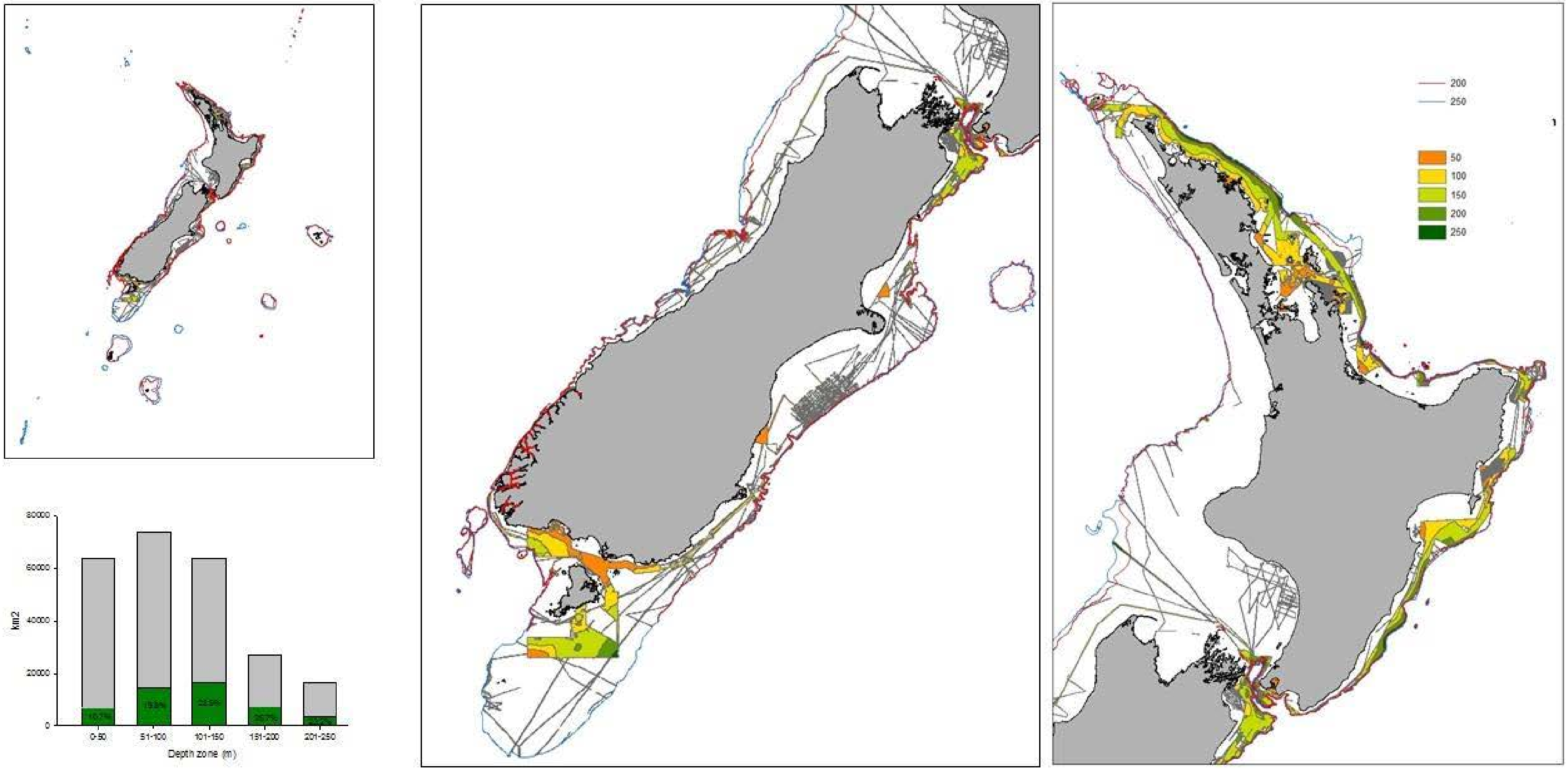


Figure 133: Multibeam sonar mapped coverage for New Zealand's mainland continental shelf, inclusive of all multibeam systems deployed, as logged in NIWA's master multibeam database (including the programme reported on here). 200 and 250 m depth contours are shown, as well as mapped areas in 50 m coloured depth bands, 0–250 m range. Bar plot shows the total areal shelf extent in 50 m bands (grey bars), and the proportion multibeam mapped (green bars). Upper left image shows offshore islands and banks <250 m in New Zealand's Exclusive Economic Zone (EEZ), including the Chatham Islands; no multibeam mapping has been undertaken in these regions.

6. FINAL CONCLUDING REMARKS

The data and observations reported here demonstrate that New Zealand's continental shelf supports a diverse range of habitats and species, many of which have not yet been formally described by science. Our initial sampling indicates that the North Cape region, including offshore Middlesex Bank, and Three Kings, the upper extents of canyons along the west coast North Island, the tubeworm habitats of the Canterbury and northern Otago coast, and Ranfurly Bank are likely to be significant regional and national biodiversity hotspots. The data collected have been used to characterise a number of these habitats, in terms of invertebrate species composition, richness, and associated fish communities, over localized spatial scales, depth ranges and substrate. Key species, or putative speices have been identified in each area, and information on the distribution of those species collated. With about 10% of all species sampled (over 1000) being new/undescribed, from a relatively low intensity sampling effort across New Zealand's continental shelf estate (not including large regions such as the west coast South Island), it is obvious that a great deal remains to be revealed and documented.

The observational knowledge of commercial fishers was invaluable in helping to identify and locate these habitat areas. The high rate of matches between LEK and scientific sampling demonstrated the accuracy of their observations. It was also apparent that they held a deep knowledge of fish behaviours and population dynamics, including spawning and migrations/movements, not always documented in the scientific literature.

As marine spatial planning (MSP) and Ecosystem Based (Fisheries) Management (EBFM) mature and evolve in the New Zealand context, we suggest that targeted research is required to demonstrate the role of habitats and environment in underpinning ecosystem health and sustainable fisheries production, along with cause and effect changes. It will also be important to explore how to operationally manage spatially explicit information regarding biogenic habitats. Approaches to halting contemporary declines in biogenic habitats should be explored. Reversing historic losses through mitigation of stressors to allow natural 'regeneration', as well as possibly initiating some (pragmatic) restoration efforts could be considered (e.g. Matheson & Wadhwa 2012; McLeod et al. 2012). The research findings presented in this report provide a substantial step forward in helping inform such efforts, and provide the foundation on which to build a comprehensive understanding of New Zealand's continental shelf habitats, environments, and species.

7. ACKNOWLEDGEMENTS

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9. APPENDICES

Appendix 1: Shipboard data collection methods in full

Navigation

The primary positioning system used was the position derived from the forward Applanix POS/MV GPS Antenna, differentially corrected by the Fugro SeaStar XP Wide Area Differential GPS (WADGPS) service. The differential corrections consist of pseudo-range corrections generated by the Fugro SeaStar XP WADGPS system. These corrections were uplinked through a Fugro monitoring station and received on board the vessel via the Pacific Ocean Region (POR) satellite. Analysis of the system accuracies and survey conditions indicate the positioning accuracy of Order 1 horizontal accuracy standards were met or exceeded.

Multibeam acoustic data

A hull-mounted Kongsberg EM302 multibeam echo sounder, centred on 30 kHz was used to collect swath bathymetry, backscatter and water column data throughout the survey. The multibeam was operated to obtain the maximum swath width with a maximum beam angle of 65°/65°, while in shallower water close to the coast the beam angle was further widened to the maximum swath width of the system (140°). At each site survey lines were spaced to give an overlap of about 20%. As swathe width increases with water depth, a constraint at locations with wider depth ranges was the need to do parallel swathes along depth contours, so that swathe widths remained consistent within each pass.

Any unmeasured change in sound speed through the water column is unpredictable and can potentially result in significant depth and positioning errors. This error source was mitigated by continual monitoring of the bathymetry data for evidence of sound speed artefacts during sounding operations. The surface sound speed was continuously measured and used to calculate departure angles at the transducer and was also used as an indicator of sound speed changes throughout the water column.

Sound Velocity Profiles (SVP) were collected at the start of each multibeam day, and whenever a change in velocity was observed to adjust for velocity errors. Vessel heave and attitude were provided by an Applanix POS/MV 320 motion sensor on RV *Tangaroa*. The POS/MV generates attitude data in three axes. Measurements of roll, pitch, and heading are accurate to 0.02º or better (manufacturer's specifications) regardless of the vessel's latitude. Heave measurements supplied by POS/MV maintain an accuracy of 5% of the measured vertical displacement or ±5 cm (whichever is the larger) for movements that have a period up to 20 seconds (manufacturer's specifications).

Real-time data acquisition from the multibeam sonar was carried out using Seafloor Information System (SIS) software. SIS was used to display the previous sounding coverage as well as the current sounding coverage and to provide planning and navigation for the data acquisition and bridge personnel. Raw data files were then exported into CARIS HIPS V7.1 for initial processing and cleaning with the Swath Editor. Several field-sheets were created to cover each survey target, as the high data density and small spatial resolution of the data resulted in high data volumes. Within each field sheet, the bathymetry data were gridded into a Bathymetry Associated with Statistical Error (BASE) surface at a 10 m-grid resolution using the Combined Uncertainty Bathymetric Estimation (CUBE) tool and final cleaning completed using the CARIS Subset Editor for production of maps during the voyage.

Backscatter data were processed in CARIS HIPS and overlaid onto the bathymetry to produce intensity maps of the survey sites. These maps represent a proxy for seafloor hardness and softness; the backscatter signal is a function of reflection from the sea floor, which depends on the substrate and topographic irregularity of the seabed.

Water column data were collected on all multibeam survey lines concurrently with the bathymetry. These data were logged to a separate file for later examination in CARIS HIPS and/or Fledermaus Midwater. All data collected by RV *Tangaroa* were backed up at the end of each line to an on-board mass storage device and then transferred to NIWA Greta Point on the vessel's return. Survey datum for the bathymetry data is Mean Sea Level (MSL).

Towed video sampling

Seabed photographic transects were carried out using NIWA's Deep Towed Imaging System (DTIS) (Figure 134). This is a self-powered (lead-acid batteries) camera array carrying a high definition digital video camera (Sony 1080i format) angled 45° forwards, and a vertically oriented still image camera (Canon EOS 35010 mp SLR). For these voyages, an additional forward facing self-contained video camera (Seacorder, Tritech) was also added to observe fish ahead of the moving frame. Video lighting was from halogen floodlights (250 W total) and still lighting was from a cluster of three Canon strobes. Each camera had an associated pair of parallel red lasers spaced 20 cm apart which projected onto the seabed within the image frame and thus allowed for the measurement of seabed area viewed, and the sizes of organisms within the image. Onboard sensors measured depth, altitude (height above the seabed), roll, pitch, and heading. The seabed position of the DTIS was recorded in real time using an ultra-short-baseline (USBL) acoustic tracking system (Simrad HPR 410). A CTD (conductivity, temperature, and depth) sensor was also deployed attached to the DTIS frame.

DTIS was deployed on a single-conductor CTD wire from the research ship. Continuous high definition video was recorded to miniDV tape in the camera vehicle, while a novel telecommunications link allowed low-resolution real-time colour video to be viewed during operation. This facility enabled observation of the seabed and control of camera altitude via a winch. Still images were taken automatically at 15 s intervals and recorded to flash memory in the camera.

After each deployment, video footage was backed up in uncompressed *.avi format to a dedicated computer hard drive (HDD). Still images were downloaded to HDD and re-named with voyage, station, and sequential number information. Metadata, including project name, laser spacing details, NIWA contact address, and camera configuration were appended to IPTC and EXIF fields in each image. Camera-original HD video tapes were labelled and stored in the video archive in the Brodie Building, NIWA, Greta point, Wellington, while working *.avi files were archived on NIWA's National Voyages server space. Still images were backed-up to archive space on NIWA's National Voyages server and uploaded to NIWA's digital media library, *Atlas*.

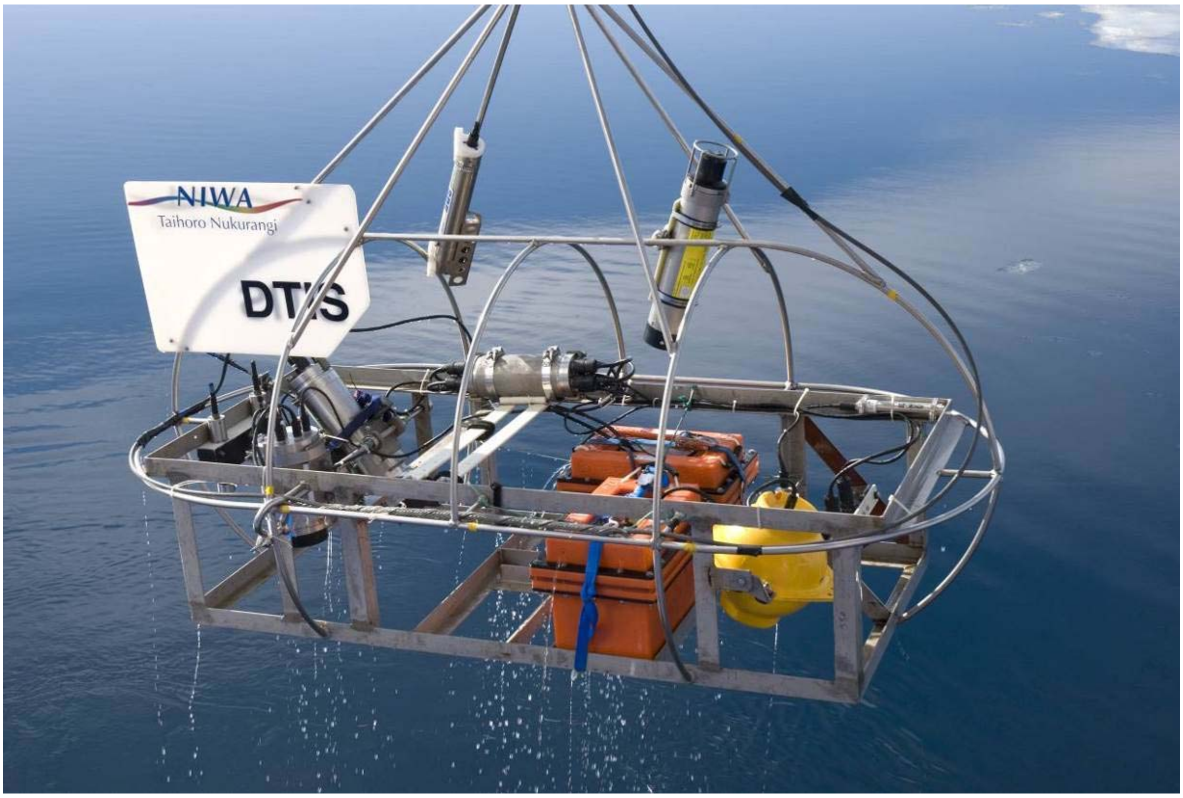
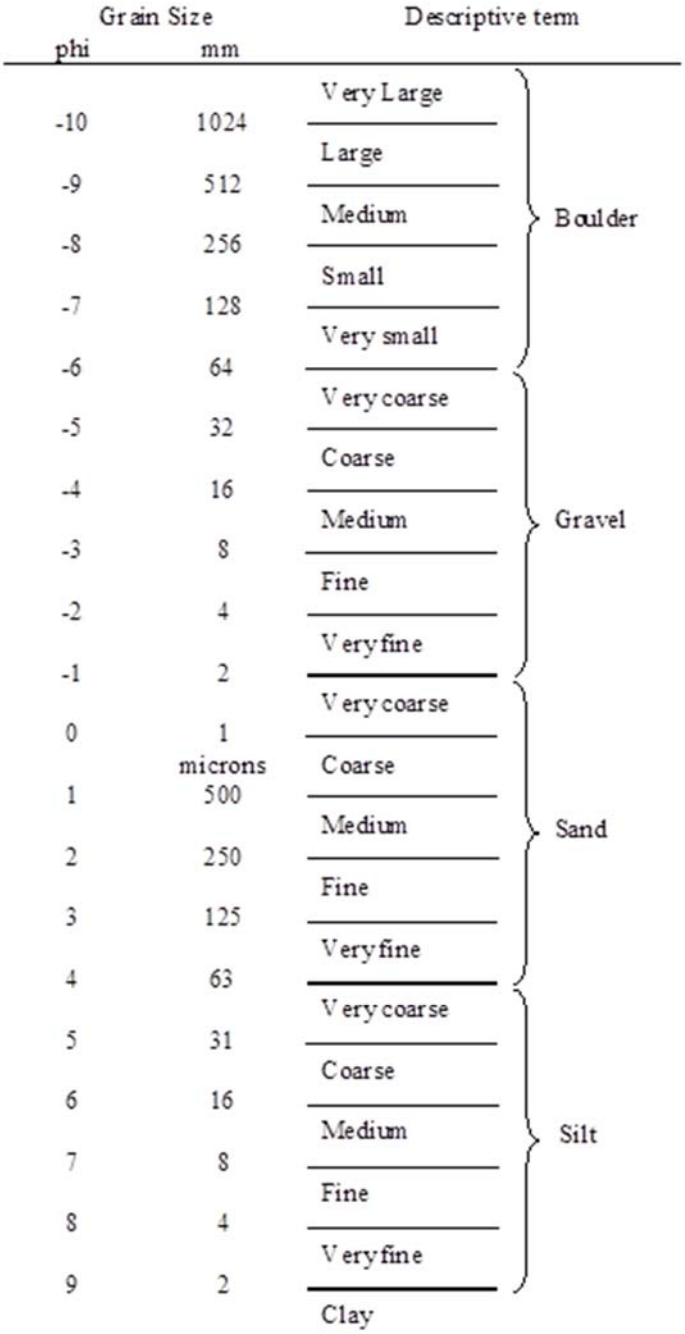


Figure 134: NIWA's Deep Towed Imaging System (DTIS). (Source: Dave Bowden, NIWA)

Biological data collection

A 4 m wide beam trawl (TB) was used on flat sea floor habitats. This net is designed to sample mega-faunal benthic invertebrates and small benthic fish. The net mouth is formed by a wooden beam held at about 500 mm above the substratum by steel runners at either side, while the net is made of 25 mm mesh throughout. The ground rope length was 5 m, and it was towed off 4 m long bridles. For rougher seafloor an epibenthic sled ('seamounts sled', SEL) was deployed. This is a small sled developed for sampling mega-epifauna primarily on rough terrain. It has a mouth opening of 1.4 m by 0.5 m, with a net of 25 mm mesh inside a chafing cover of 100 mm mesh. For general sampling of mega- and larger macro-epibenthos, the sled is very reliable and effective on a wide range of seabed types at any depth. Beam trawl tows were made for 20 minutes, while the epibenthic sled tows each covered 0.1 nautical miles.

Appendix 2: Sediment size: size scale adopted in GRADISTAT



Grain Size phi	Grain Size mm	Descriptive term	
		Very Large	Boulder
-10	1024		
		Large	
-9	512		
		Medium	
-8	256		
		Small	
-7	128		
		Very small	
-6	64		
		Very coarse	Gravel
-5	32		
		Coarse	
-4	16		
		Medium	
-3	8		
		Fine	
-2	4		
		Very fine	
-1	2		
		Very coarse	Sand
0	1		
	microns	Coarse	
1	500		
		Medium	
2	250		
		Fine	
3	125		
		Very fine	
4	63		
		Very coarse	Silt
5	31		
		Coarse	
6	16		
		Medium	
7	8		
		Fine	
8	4		
		Very fine	
9	2		
		Clay	

Appendix 3: OTUs used in Taranaki Canyons still image analysis.

Listed are taxon, abundance measure used, Sessile/mobile classification, OTU label/description, and further description where available (e.g. full species names; if multiple species).

Taxon	Type	Mobile/ Sessile	OTU label and description
Alcyonacea	Count	Sessile	Alcyoniidae small ball. Unid.
			Alcyoniidae fat finger. Unid.
Anemones	Count	Mobile	Ceriantharia. Unid.
			Actinostolidae – green – Unid.
			Actinostolidae – maroon – Unid.
			Actinostolidae – orange – Unid.
Antipatharia	Count	Sessile	Antipatharia – bottle: brush coral ?Cladopathidae sp. or *Stylopathes* cf. *tenuispina*
			Antipatharia – branching. Unid.
Ascidians	Area	Sessile	Didemnid sp.
			Diplosoma sp.
			Culeolus sp.
			Synoicum otagoensis
			Aplousobranchia
			Solitary ascidian
Asteroidea	Count	Mobile	*Sclerasterias mollis*
Bivalves	Count	Mobile	*Talochlamys gemmulata*
Brachiopoda	Count	Sessile	Brachiopoda
Bryozoans	Area	Sessile	*Adeonellopsis* sp.
			Phidoloporidae
			Bryozoan clumps. Unid
			Bryozoan fan-like. Unid.
			Bugulidae (?)
Crinoids	Count	Mobile	*Comanthus novaezealandiae*
Crustacea	Count	Mobile	Paguridae – Diogenidae/ Paguridae (*Paguristes subpilosus*, *Porcellanopagurus filholi* identified from samples)
			Bellidilia cheesmani
			Neopilumniplax
			Natant decapod 1
			Natant decapod 2
			Natant decapod 3
			Munida sp. (Galatheidae - likely *Phylladiorhynchus pusillus*)
			Ibacus alticrenatus
			Natant decapod 4
Echinoids	Count	Mobile	*Araeosoma thetidis*
Gastropods	Count	Mobile	Scaphopoda
Gastropods			*Charonia lampas*
Gastropods			*Penion jeakingsi*
Gastropods			*Austrofusus glans*
Gastropods			*Coluzea spiralis*

Taxon	**Type**	**Mobile/ Sessile**	**OTU label and description**
Gastropods			*Semicassis pyrum*
Gorgonacea	Count	Sessile	Whip coral (?Ellisellidae) - ?Ellisellidae spp. or *Stichopathes variabilis* - library images identified as gorgonian but none in sample, only Stichopathes – whip coral with orange polyps
			Whip coral spp. (?Lepidisis)
Holothurians	Count	Mobile	*Holothuria integua*
Hydroids	Count	Sessile	Cryptolaria
			Nemertesia elongata
			Symplectoscyphus
Nudibranch	Count	Mobile	Nudibranchia
Ophiuroidea	Count	Mobile	*Ophiopsammus assimilis*
			Ophiuroid – stripy legs – *Ophiomyxa brevirima* or *Ophiopsammus assimilis*
			Ophiuroid on coral. Unid.
Pennatulacea	Count	Sessile	?Kophobelemnon spp.
			Pennatulacea. Unid.
Polychaetes	Count	Sessile	Sabellidae. Unid.
			Protula bispiralis
Porifera	Area	Sessile	*Leucetta lancifer*
			Psammocinia modes and *P. hawere* combined
			Geodia vestifigera
			Raspailia sp. 6, *Axinella* sp. 10, and *Arensclera* sp. 3.
			Pararhaphoxya pulchra
			Xestospongia coralloides & *Calyx* n. sp. 5
			Pleuroma turbinatum, *P. menoui*, *Aciculites pulchra*
			Symplectella rowi
			Petrosia n. sp. 5
			Petrosia n. sp. 6 & *Darwinella* spp.
			Rossella ijimai
			Stryphnus ariena
			Reidispongia coerulea
			Poecillastra laminaris
			Ceratopsion cuneiformis
			Tethya cf. *expansa* & *Suberites* n. sp. 2
			Psammocinia cf. *verrucosa*
			Sarcotragus n. sp. 1
			Xestospongia coralloides red
			Stryphnus spelunca
			Axinyssa n. sp. 2
			Ircinia sp.
			Encrusting sponge. Unid.
			Styletta columna
			Finger sponge. Unid.
			Chalinidae sp.
			Dictyoceratida sp.
Salp	Count	Mobile	Salp

Taxon	Type	Mobile/ Sessile	OTU label and description
Scleractinia	Count	Sessile	*Caryophyllia profunda*
			Goniocorella dumosa
			Desmophyllum dianthus
			?Dendrophylliidae

Appendix 4: OTUs used in East Coast South Island still image analysis.

Listed are taxon, abundance measure used, Sessile/ mobile classification, OTU description, and further description where available (e.g. full species names; if multiple species).

Class	Measure	Category	Label
Anemones	Count	mobile	Ceriantharia
			Actinostolidae
Ascidians	Area	Sessile	*Diplosoma velatum* (transparent)
			Didemnidae (orange)
			Diplosoma velatum (orange)
			Aplousobranch sp. 6 (purple)
			Synoicum occidentalis (occasionally *Pyura*) (yellow)
			Small grey ball. Unid.
	Count	Sessile	Cnemidocarpa spp. (including *C. bicornuta*, *C. stewartensis*, *Molgula* sp.)
Asteroids	Count	mobile	*Sclerasterias mollis*
			Odontaster benhami
			Proserpinaster neozelandicus
			Pentagonaster pulchellus
			Diplodontias miliaris
Bivalves	Count	mobile	*Zygochlamys delicatula*
	Count	Sessile	*Atrina zelandia*
Bryozoan	Area	Sessile	*Euthyroides jellyae* (white frilly)
			Bryozoan mixed spp. (*Celleporaria agglutinans*, *Cellaria immersa*, *Adeonellopsis* sp., *Cinctipora elegans*)
			Steginoporella neozelanica
Crabs	Count	mobile	*Leptomithrax longipes*
			Majidae 02 (Notomithrax?)
			Lyreidus tridentatus
			Crab. Unid. 04
			Crab. Unid. 05
			Paguridae (includes *Paguristes subpilosus* & *Diacanthrus* sp.
Squat lobsters	Count	mobile	Galatheidae
Decapod	Count	mobile	Natant decapod. Unid.
Echinoids	Count	mobile	Goniocidaris sp.
			Pseudechinus huttoni
Gastropods	Count	mobile	*Fusitriton laudandus*
			Maoricolpus roseus
			Cominella nassoides
			Coluzea mariae

Class	Measure	Category	Label
			Austrofusus glans
			Calliostoma granti
			Sassia palmeri
			Penion cuvierianus
			Philine angasi
			Alcithoe wilsonae
			Iredalina mirabilis
			Glaphyrina plicata
Holothurians	Count	mobile	*Australostichopus mollis*
			Holothuria integua
			Holothurian. Unid.
			Molpadia
Hydroid	Count	Sessile	*Nemertesia elongata*
			Crateritheca sp.
Mollusca	Count	mobile	Scaphopoda
Ophiuroidea	Count	mobile	*Ophiopsammus maculata*
Polychaetes	Count	mobile	Nemertean worm. Unid.
			Worm. Unid.
			Chloeia inemis
	Count	Sessile	*Protula bispiralis*
			Megalomma suspiciens
			Serpulidae 04
	Area	Sessile	Polychaete tubes. Unid.
			Chaetopteridae: Spiochaetopterus sp. A and B
Scleractinia	Count	Sessile	Caryophyllidae
Sea pens	Count	Sessile	PTU 01 white. Unid.
			PTU 04 white. Unid.
			PTU orange 05. Unid.
Porifera	Area	Sessile	*Callyspongia* n. sp. 12 (pink finger)
			Callyspongia n. sp. 2 & 11 (& *Chondropsis* n. sp. 2)
			Callyspongia (*Callyspongia*) *stellata* (white transparent)
			Iophon cf. *minor*, *Crella incrustans*, *Paraesperella* sp. 2
			Tedania sp. and *Dysidea* sp. (pale pink)
			Crella n. sp. 3 (dirty white snot)
			Halisarca dujardini & *Chondropsis* n. sp. (orange cream finger)
			Hymeniacidon perleve (orange scrappy)
			Acanthodendrilla n. sp. 3
			Dactylia palmata (cream branching finger)
			Xestospongia corallodies (holey grey)
			Haliclona (*Gellius*) *regia* (cream plate)
			Leucettusa tubulifera (thick white finger)
			Raspailia sp. or *Crella incrustans* red form (red finger)
			Paraesperella sp. (greyish pink)
			Haliclona n sp. 18 (grey spaghetti)
			Sponge or ascidian 81. Unid. (greyish pink)

Class	Measure	Category	Label
			Psammoclemma n sp. 6? (red/brown encrusting)
			Euryspongia sp. 5 (grey green soft encrusting)
			Halichondria cf sp. (pale peach encrusting)

Appendix 5: OTUs used in Ranfurly Bank still image analysis.

Listed are taxon, abundance measure used, Sessile/ mobile classification, OTU description, and further description where available (e.g. full species names; if multiple species).

Class	Measure	Category	Label
Algae	Area	Sessile	Cryptonemia sp. / *Ectophora depressa* / *Phycodrys adamsiae* / *Galene* sp. (really not clear which to list)
			Rhodymenia sp. red string
			Coralline algae
			03 - Euptilota sp. (red feathery)
			Unid. (Red bushy)
			Caulerpa flexilis
	Count	Sessile	*Ecklonia radiata*
Anemones	Count	mobile	Ceriantharia
			Actinostolidae
Antipatheria	Count	Sessile	Parantipathes sp. (pink)
			Parantipathes sp. (white)
			Stichopathes sp.
			Antipatheria sp.
			Cladopathidae
Ascidians	Area	Sessile	*Diplosoma velatum*
			Diplosoma velatum (orange)
			Didemnidae (orange)
	Count	mobile	Styellid ascidian
Asteroids	Count	mobile	Ophidiasteridae
			Diplodontias miliaris
			Asterodiscides truncatus
			Asteroid unid.
Bivalves	Count	mobile	*Zygochlamys delicatula*
Brachiopoda	Count	Sessile	Brachiopod
Bryozoans	Area	Sessile	Buguloid bryozoan
			Catenicellid bryozoan (incl. cf. *Cribricellina*, *Amathia wilsoni* & cf *Cornuticalla*)
			Steginoporella neozelanica
			Hippomenella vellicata (includes pale pink, to brick red cornflakes. Identified by D. Gordon as *Triphyllozoon* sp. and also potentially, *Iodictyum yaldwyni*, ?*Reteporella* sp.)
			Bitectipora retepora
			Bryozoan lacy. Unid.
			Bryozoan. Unid.
Crabs	Count	mobile	Majidae
			Crab. Unid. 5
			Crab. Unid. 6
			Hermit crab. Unid.
Crinoids	Count	mobile	*Comanthus novaezealandiae*
			Argyrometra mortenseni
			Comatulida. Unid. orange 3
Echinoids	Count	mobile	Goniocidaris
Gastropods	Count	mobile	*Maoricolpus roseus*

Class	Measure	Category	Label
			Austrofusus glans
			Calliostoma granti
			Penion cuvierianus
			Alcithoe wilsonae
Gorgonacea	Count	Sessile	Plexaurid sea fan (includes orange and yellow)
			Neptheidae (cream / white fan-like)
			Primnoid sea fan (bright white)
			Plumigorgia spp. (Ifalukellidae?)
			Gorgonacea. Unid.
Holothurians	Count	mobile	*Australostichopus mollis*
			Holothuria integua
Hydroid	Count	Sessile	*Nemertesia elongata*
			Crateritheca
			Lytocarpia incisa
			Aglaopheniidae sp. A
			Aglaopheniidae sp. B
Nudibranch	Count	mobile	Nudibranch
Ophiuroidea	Count	mobile	Ophiuroid. Unid.
			Ophiuroid striped. Unid.
			Astroceras elegans
			Astrobrachion constrictum
Polychaetes	Count	Sessile	*Megalomma suspiciens*
			Pseudobranchiomma grandis
			Serpulid Unid. 4
Porifera	Area	Sessile	*Iophon minor* / *Crella incrustans*
			Tedania sp.
			Acanthella sp. 2
			Topsentia sp. 4
			Acanthodendrilla sp. 3
			Psammocinia beresfordae
			Acanthella dendyi
			Raspailia sp. 6 /*Axinella* sp. 12
			Raspailia flaccida
			Raspalia topsenti
			Spirastrella sp. 1
			Polymastia hirsuta
			Chondropsis sp. 5
			Ciocalypta polymastia
			Polymastia crocea
			Dactylia palmata
			Ecionemia alata / *Stelletta maori* / *Ancorina stalagmoides Ecionemia alata*/Ancorina
			Coscinoderma sp. 2
			Dragmacidon austral / Poecilosclerid sp. (encrusting orange)
			Psammoclema sp. 4 / *Dictyodendrilla* sp. 2
			? *Crella* cf *incrustans*
			Iophon sp. 4/ *Topsentia* sp. 4
			Xestospongia corallodies
			Dendrilla rosea
			Pterosia hebes
			Stelletta. columna
			Desmacella dendyi
			A stalagmoides encr. D. dendyi

Class	**Measure**	**Category**	**Label**
			Leucettusa lancifer
			Desmacidon mamillatum
			Haplosclerid 1
			Haplosclerid 2
			Hexactinellida
			Haliclona regia
			Symptella rowi
			Tetilla australis
			Coscinoderma sp. 2
			Callyspongia sp. 17
			Polymastia / Suberitidae sp.
			Psammocinia sp. 1
			Sarcotragus sp. 1/Psammocinia sp. 1
			Sarcotragus sp.
			Penares sp. 1
			Petrosia sp. 7
			Dictyoceratida sp. / Spongia sp. 3
			Sponge sp. 3
			Stelletta sp. 14
			Polymastia massilis
			Callyspongia latituba
			Polymastia aurantium
			Grey tubular. Unid. (similar to *Haliclona* n sp. 18)
			Psammoclemma n sp. 6? (red-brown encrusting)
			Latrunculia duckworthi
			Aaptos rosacea
			Axinella sp. 8
			Heterofibria gorgonocephalus
Polychaetes	Count	Sessile	Sabellidae. Unid.
Scleractinia	Count	Sessile	Caryophyllidae
Sea pens	Count	Sessile	White sea pen. Unid.
			Pink sea pen. Unid.
			White feather sea pen. Unid.
			Brown sea pen. Unid.
Soft corals	Count	Sessile	Neptheidae spp. (?Dendronephthya)
			Alcyoniina Unid. 2 (orange branched)
			Alcyoniina Unid. 3 (small orange finger)
Squat lobsters	Count	mobile	Galatheidae
Stylasteridae	Count	Sessile	Stylasteridae. Unid.