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Biodiversity of the Kermadec Islands and offshore waters of the Kermadec Ridge: report of a coastal, marine mammal and deep-sea survey (TAN1612)

New Zealand Aquatic Environment and Biodiversity Report No. 179

Clark, M.R.; Trnski, T.; Constantine, R.; Aguirre, J.D.; Barker, J.; Betty, E.; Bowden, D.A.; Connell, A.; Duffy, C.; George, S.; Hannam, S.; Liggins, L..; Middleton, C.; Mills, S.; Pallentin, A.; Riekkola, L.; Sampey, A.; Sewell, M.; Spong, K.; Stewart, A.; Stewart, R.; Struthers, C.; van Oosterom, L.

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EXECUTIVE SUMMARY

Clark, M.R.; Trnski, T.; Constantine, R.; Aguirre, D.; Barker, J.; Betty, E.; Bowden, D.A.; Connell, A.; Duffy, C.; George, S.; Hannam, S.; Liggins, L..; Middleton, C.; Mills, S.; Pallentin, A.; Riekkola, L.; Sampey, A.; Sewell, M.; Spong, K.; Stewart, A.; Stewart, R.; Struthers, C.; van Oosterom, L. (2017). Biodiversity of the Kermadec Islands and offshore waters of the Kermadec Ridge: report of a coastal, marine mammal and deep-sea survey (TAN1612).

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A survey of the biodiversity of coastal and offshore waters around the Kermadec Islands was carried out from RV *Tangaroa* in October-November 2016. Seven agencies collaborated in developing a multidisciplinary research plan that centred around three objectives:

1) To describe and quantify the diversity of benthic invertebrate fauna and fish communities of the central Kermadec Islands and Ridge
2) To develop and expand marine mammal identification around the Kermadec Islands, and determine links to regional populations
3) To characterise the demographic and genetic connectivity of coastal populations and quantify morphological adaptation in shallow reef communities

The offshore biodiversity survey covered an area from Raoul Island in the north to Star of Bengal Bank in the south, and was structured around three transects to the east of Raoul Island, Macauley Island, and L'Esperance Rock, with a fourth partial survey of the Star of Bengal Bank, and opportunistic sampling off Havre Rock. Sampling stations were randomly distributed within seven depth strata from 50 to 3250 m, and included surface plankton, line fishing, vertical plankton, midwater and bottom trawl, deep-towed camera, epibenthic sled and beam trawl, fish trap, and CTD operations. These multiple gear types sampled a wide range of faunal types and sizes in different habitats, from the surface to the seafloor, and from shallow waters inshore to the abyssal plains east of the Kermadec Ridge. Combined with diving operations inshore at depths to 30 m, and marine mammal research around Raoul and Macauley Islands, there were 143 sampling events. These included 16 dive stations, 11 marine mammal small-boat trips, 36 deep-towed camera deployments, 27 epibenthic sled or beam trawl tows, and 19 plankton casts.

In total, 88 coastal and 166 offshore invertebrate species (or taxonomic groups) were provisionally identified, and 236 fish species. Many of these could not be identified onboard (especially the invertebrate taxa) and material will be sent to taxonomists throughout New Zealand and internationally. However, it is clear that there are many new records for the region, and for the New Zealand EEZ, as well as undescribed new species. For fish, initial examination has 60 new records for the Kermadec Ridge, 20 new records for the EEZ, and at least 3 new species. New habitat-related discoveries were also made, such as the observation of extensive rhodolith beds at Macauley Island, L'Esperance Rock and the Star of Bengal Bank-the first time these have been recorded from the northern Kermadec Ridge.

The benthic faunal composition and abundance was highly variable between transects, as the seafloor ranged from predominantly soft sediment on some transects, to lava flows and blocky pumice debris on others. Highest diversity and abundance was observed on hard seafloor features such as banks and small hills. The extensive photographic coverage will provide an important baseline dataset on seafloor habitats and the distribution of fish and invertebrate communities.

The coastal dive survey and marine mammal work built on time series of studies in the area. Extensive samples were collected by divers to continue genetic studies of echinoderms and corals, and biopsy samples of humpback whales and bottlenose dolphins, as well as fluke photographs of individual whales, extend existing data to help understand the breeding and feeding dynamics of whales passing the islands.

The report provides summary accounts of the sampling stations and catches, and includes preliminary analyses of some species distributions, and species lists for invertebrate and fish collections. Work is ongoing to confirm and update species identifications and more fully describe the biodiversity of the region to support the information requirements of the proposed Kermadec-Rangitahua Ocean Sanctuary.

The project has demonstrated that the combination of three different research objectives with multiple activities can be carried out efficiently and effectively. Results will be integrated into future survey plans that, given the near pristine conditions of the Kermadec Islands and Ridge, could be used to monitor natural changes over time and, as a natural baseline, aid our understanding of how humans are affecting the structure and function of marine life in areas closer to the New Zealand mainland.

RV *Tangaroa* surveying off L'Esperance Rock (photo C. Middleton).

1. INTRODUCTION

The New Zealand government has pronounced the 200 n.mile zone around the Kermadec Islands as a prospective protected area; the "Kermadec-Rangitahua Ocean Sanctuary". This region has been only lightly affected by human activities, has an established 12 n.mile Marine Protected Area around the main island groups, and hence contains a largely natural community of sub-tropical to temperate fauna. However, only a small proportion of the region has been explored, especially in offshore and deeper waters. This region also provides important habitat for migratory and resident marine mammals. Hence, to support improved knowledge of the proposed Sanctuary a multidisciplinary survey was carried out by a team onboard RV *Tangaroa* that would investigate biodiversity patterns of benthic and midwater fauna of the Kermadec region, extend knowledge of use of the area by marine mammal populations, and progress studies examining genetic connectivity and biogeography of coastal fauna among mainland New Zealand, the Kermadec Islands and the southwest Pacific region.

1.1 Objectives:

The main aims of the voyage were:

1) To describe and quantify the offshore diversity of benthic invertebrate fauna and fish communities of the central Kermadec Islands and Ridge, and determine the environmental variables influencing community composition.
2) To develop and expand marine mammal identification around the Kermadec Islands, and determine links to regional populations.
3) To characterise the coastal biodiversity, demographic and genetic connectivity of populations within the proposed Kermadec-Rangitahua Ocean Sanctuary and quantify morphological adaptation in shallow reef communities**.**

Background to these components is described below.

1.2 Objective 1: Benthic offshore biodiversity

Sampling of coastal waters (to 30 m depth) of the Kermadec Islands has been reasonably comprehensive (Trnski & Schlumpf, 2015, Duffy & Ahyong 2015) but research in deeper waters has been more sporadic and focussed on particular habitats. The majority of sampling in deepwater areas of the proposed Sanctuary has occurred on the seamounts along the back-arc west of the Kermadec Ridge (largely at depths shallower than 1000 m), and limited collections in the Kermadec Trench, between 6000 and 10 000 m . Figure 1 below shows the distribution of sampling where specimens are held in the NIWA Invertebrate Collection (from Clark et al. 2016).

The southern parts of the Kermadec Ridge and back-arc have been relatively well researched (Wysoczanski & Clark 2012), but Figure 1 shows clearly how clustered sampling has been around the islands and back-arc seamounts, with more limited knowledge of the deep-sea fauna over much of the Ridge itself and the adjacent abyssal plains. Hence, baseline information on biodiversity within the Sanctuary is limited, and currently there is a very restricted basis for describing what the area contributes to New Zealand's overall biodiversity, what is protected (within both the existing Marine Reserves, Benthic Protection Area, and in the proposed Kermadec-Rangitahua Ocean Sanctuary), and understanding how these faunal communities could change over time.

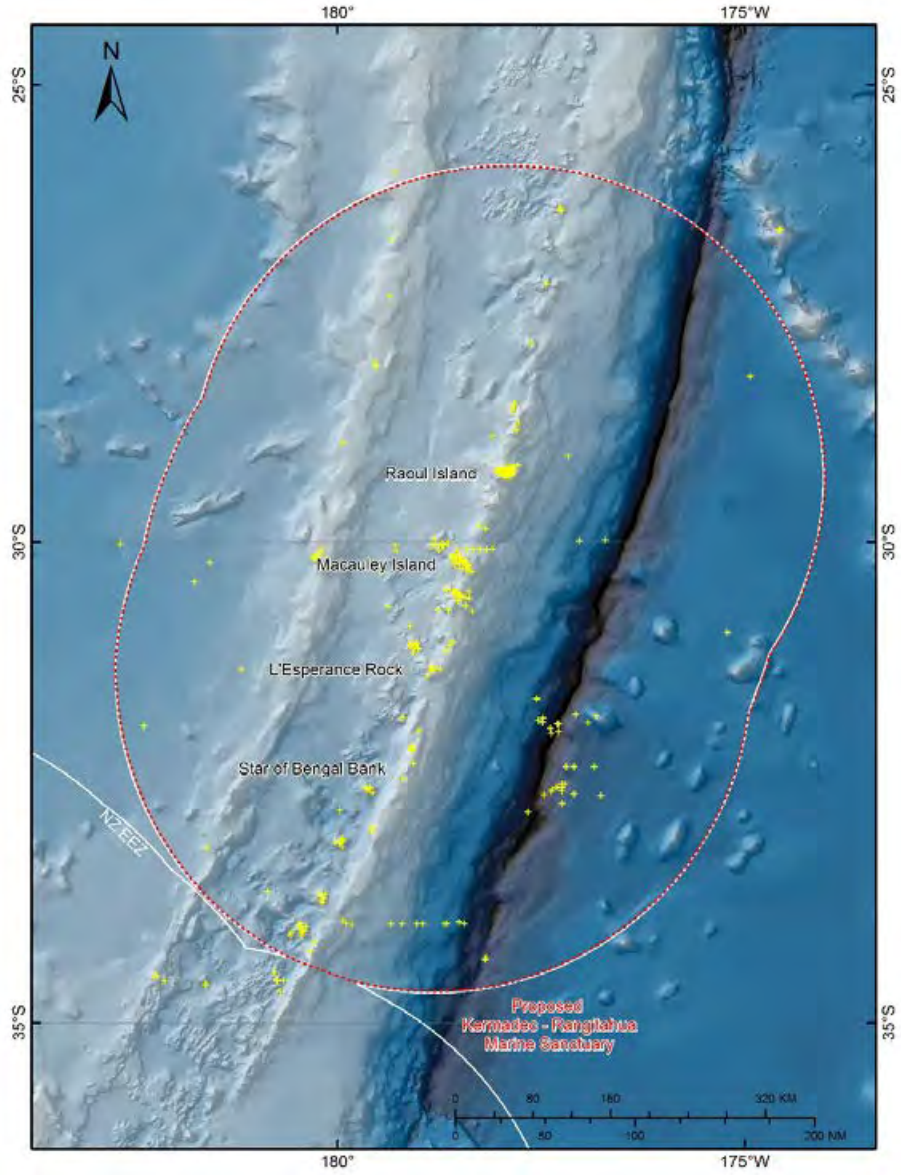


Figure 1: Distribution of samples held by the NIWA Invertebrate Collection in the area of the proposed Kermadec-Rangitahua Ocean Sanctuary (white, pre-2010, yellow 2010–2015).

1.3 Objective 2: Marine mammal research

There have been several species of oceanic and migratory whale and dolphin species recorded at the Kermadec Islands (Duffy & Ahyong 2015). The most notable are the humpback whales reported passing Raoul Island during mid-September to mid-November on their southern migration to Antarctic waters. These whales form part of the endangered Oceania humpback whale population and as such are of interest to one of the primary projects for the Southern Ocean Research Partnership–International Whaling Commission non-lethal whale research programme. This work built on research carried out in 2015 at the Kermadec Islands to determine the breeding grounds, migration paths and Antarctic feeding areas of humpback whales.

Bottlenose dolphins are listed as "Nationally Endangered" (Baker et al. 2016) because of a small population size and expected continued decline. However, the population status of bottlenose dolphins at the Kermadec Islands is uncertain. The relationship of Kermadec dolphins to those around New Zealand and throughout the Pacific Islands is important for establishing the extent of the populations, and will be progressed through biopsy and photo-identification studies.

1.4 Objective 3: Coastal biodiversity and connectivity

The geography and geology of the Kermadec region provide a unique opportunity to examine the processes underlying the accumulation and maintenance of biodiversity on young, small, isolated islands, straddling the transition zone between tropical and temperate seas. The community structure of shallow coastal assemblages of the Kermadec Islands has been relatively well studied (Schiel et al. 1986, Cole et al. 1992, Cole 2001, Gardner et al. 2006, Wicks et al. 2010, Eddy 2011, Duffy & Ayhong 2015, Francis & Duffy 2015, Richards & Liggins 2015); however, the eco-evolutionary context of the organisms living at the Kermadec Islands has received less attention – this includes quantifying the demographic and genetic connectivity of Kermadec Island populations with surrounding regions, and understanding the extent of, and the potential for, morphological change. Quantifying the demographic and genetic connectivity of populations at the Kermadec Islands with populations inhabiting mainland New Zealand and the greater Pacific region allows some perspective on the resilience and stability of Kermadec marine communities, including vulnerabilities to a changing climate. This requires the sampling of species already well represented in genetic surveys, data repositories, and tissue collections for New Zealand and neighbouring regions of the Pacific. Predominantly, these collections focus on shallow reef benthic species, but also include some deep-sea species where possible in order to build national collections and genetic resources for future research. The first step in calibrating the potential for adaptive evolutionary shifts in response to environmental and ecological change is gathering a detailed understanding of the degree of morphological divergence of populations at the Kermadec Islands from populations of these same species experiencing different environmental regimes.

Collections and surveys for the coastal objective complement existing studies at the Kermadec Islands as well as international collaborative projects (including: the Diversity of the Indo-Pacific Network, www.diversityindopacific.net; Coral Trait Database, https://coraltraits.org/; and the extensive depth-stratified collections of reef building corals held by collaborators at the Queensland Museum).

These three objectives are, to some extent, separate, as they investigate different components of marine communities in the Kermadec region. However, they are complementary in that they contribute different packets of information which together will significantly improve our understanding of biodiversity and ecosystem structure and function in the region, across multiple spatial scales and taxa.

The survey was carried out collaboratively by voyage participants from NIWA, Auckland Museum, University of Auckland, Massey University, National Museum of New Zealand Te Papa Tongarewa, Department of Conservation and The Pew Charitable Trusts.

2. METHODS

2.1 Survey area

The research survey took place in the central part of the Kermadec region, between latitudes 29° S and 33° S, spanning the Ridge between Raoul Island in the north, and the Star of Bengal Bank in the south (Figure 2).

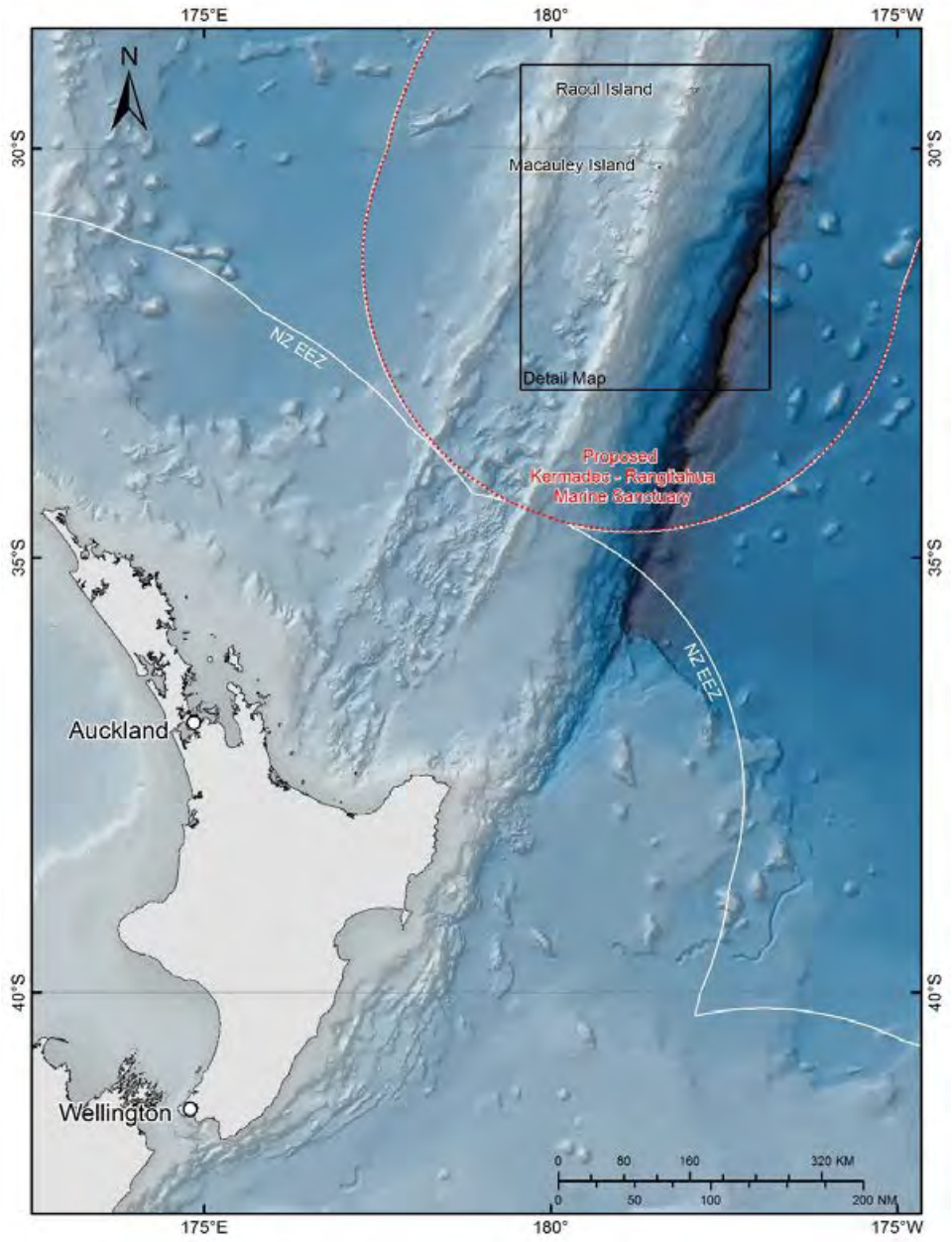


Figure 2: The general location of the Kermadec Ridge expedition (for more detail refer Figure 3).

2.2 Survey design

Offshore Biodiversity

Sampling at great depths is time-consuming, and survey design in deep-sea operations is often a compromise between sampling a smaller number of stations intensively (with replication at each site), and sampling more stations (e.g., more transects) with less replication. We adopted the latter approach here, because the need at this stage is to characterise the nature and composition of biodiversity in the area, rather than attempt to test specific hypotheses (e.g., latitudinal gradients) until more baseline information is gained. We followed the generic advice by Van de Meer (1997) who proposed that monitoring programmes were most effective when sampling more stations with less effort at each, but also incorporate the findings of Bijleveld et al. (2012) that random stations on a grid pattern was the best overall design to meet multiple objectives.

The original design comprised three transects, extending from 50 m to 3000 m depth on the eastern flank of the Kermadec Ridge, positioned off Raoul I., Macaulay I., and L'Esperance Rock. However,

due to good progress during the survey, an additional partial transect was added off the Star of Bengal Bank (see Figure 3).

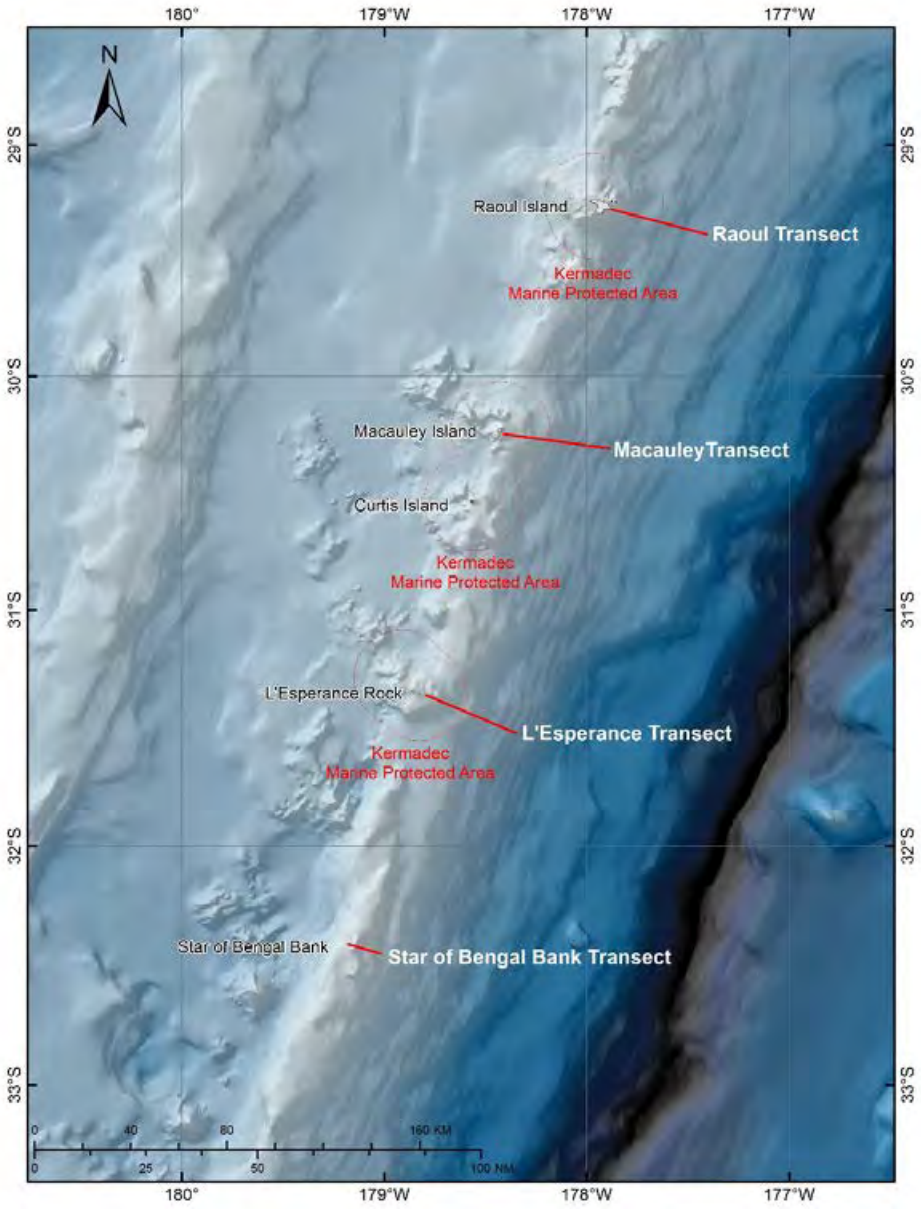


Figure 3: The survey area and location of transects for the offshore sampling.

Each transect was sampled within seven depth strata (except for Star of Bengal Bank with four), with sites selected at random depths within each stratum:

1) 50–250 m
2) 250–750 m
3) 750–1250 m
4) 1250–1750 m
5) 1750–2250 m
6) 2250–2750 m
7) 2750–3250 m

The survey design involved two gear types being deployed at each site along each transect (towed camera and epibenthic sled/beam trawl), with other gear types depending on time and their effectiveness (Table 1). At two sites on each transect a vertical plankton tow was carried out. At one site along each transect, a midwater fish trawl and a mesopelagic trawl were conducted, with a Conductivity-Temperature-Depth (CTD) cast to 2000 m. Surface plankton nets were deployed opportunistically.

Table 1: Planned distribution of gear type deployments on each transect, constituting the "core" survey design for offshore biodiversity research.

Central depth (m)	Camera	Sled/ beam	Fish trap	Plankton	Midwater trawl	Mesopelagic trawl	CTD
150	+	+		+			
500	+	+	+				
1000	+	+	+	+		+	
1500	+	+	+				
2000	+	+	+		+		+
2500	+	+					
3000	+	+					

Marine mammal sampling

Transit observations: Observers were on the bridge surveying for whales and dolphins between approximately 06:00 to 18:00 as the RV *Tangaroa* transited from Auckland to Raoul Island, between the island groups and on the return voyage to Wellington. The species identity and position (latitude and longitude) were noted and a photograph taken where possible to confirm species identity.

Coastal survey

The collection of materials from coastal areas was predominantly achieved by hand-collection while diving and from intertidal rock pools. Diving and intertidal operations were largely determined by weather conditions and sea state. Population genetic studies required that we collect approximately 50 individuals of each species from each location (i.e. Raoul Island, Macauley Island, L'Esperance Rock, Havre Rock). The collection of tissue for genetic analyses was non-lethal whenever possible (e.g. for reef building corals and the pencil urchin, *Phyllacanthus parvispinus*); however, for species where lethal collection was required, we minimised the impact on target species by spreading collection over stations within a location, and/or collecting no more than 33% of individuals from any patch of habitat within a station.

For collection of reef building corals and shallow-reef community composition photo quadrats, the sampling followed a depth stratified design with five strata (30 m, 25 m, 20 m, 15 m, 10 m and 5 m) at each station. Accordingly, quadrat surveys and collections were undertaken in regions of suitable substrate (rocky reef), bathymetry (30 m – 0 m, over a swimmable distance), and in locations where previous surveys had been undertaken to allow temporal comparisons. Samples of reef building corals were taken from the growing edge for plate forming species (e.g. *Astrea curta*) and from the outer branches of the branching species (e.g., *Pocillopora damnicornis*). Each sample covered less than 20% of the area of an individual coral colony.

Station recording

Each sampling event or survey operation at a particular site was logged as a separate station. This varied between activities, with individual stations consisting of each whale trip from the work boat, one or more dives at a certain location, or each deployment of a different gear type offshore. Full data on the times and positions of each deployment were logged in RV *Tangaroa*'s Trawl Coordinator system as well as a working onboard spreadsheet, error-checked for duration, distance, and direction, and transferred once ashore to the appropriate databases at NIWA, Wellington. More precise data on dives and whale operations were available from GPS computer dive logs and Automatic Identification System (AIS) tracking of the workboat respectively.

2.3 Sampling operations

Multibeam mapping

High quality multibeam data were available for parts of the transect lines planned for this voyage, from existing NIWA databases. However, deeper sections of transects off Raoul and Macaulay, and much of the lines off L'Esperance Rock had to be mapped during the survey, as did the additional area around

the Star of Bengal Bank. This utilised the Kongsberg EM302 system on *Tangaroa*. Mapping was generally run along the planned transects and back again to widen the swath. Vessel speed depended on the weather conditions, and was between 8 and 9.5 knots. Additional opportunistic bathymetric mapping was conducted on the transits to, between, and from the survey area, as well as along the inshore waters of Raoul Island, Macauley Island, L'Esperance and Havre Rocks.

Photographic transect survey

The camera gear used was NIWAs "Deep Towed Imaging System" (DTIS) (Figure 4) (Hill 2009) which has been proven on many surveys around New Zealand. DTIS is a battery-powered towed camera frame which records continuous high definition (HD) digital video and simultaneously takes high definition (10 megapixel) still images at 15 second intervals. Full resolution video and still images were recorded at the seabed and downloaded on return to the surface. A low-resolution video image was transmitted to the surface in real time enabling control of camera altitude and initial evaluation of seabed substratum types and biological assemblages. The seabed position of DTIS was monitored by an acoustic ultra-short baseline (USBL) transponder system and plotted in real time using the OFOP (Ocean Floor Observation Protocol) system. A Seabird CTD attached to the DTIS frame during each deployment collected additional environmental data for each station.

During all deployments, spatially-referenced observations on the occurrence of biological assemblages (at relatively coarse taxonomic resolution) and substratum types were recorded by observers using the OFOP system. These initial observations were logged directly to an onboard database. All data were subsequently transferred to the ship's server for storage.

DTIS transects were run using *Tangaroa*'s Dynamic Positioning System to maintain course and speed. This was successfully done using the main azimuth thruster, and minimising use of bow or stern thrusters. DTIS was towed for one hour at 0.5 knots, at a height of 2–3 m above the seafloor.

Figure 4: NIWA's towed camera system DTIS.

Fish and Invertebrate sampling

Sled/trawl sampling

Specimens were collected at each site with an epibenthic sled or a beam trawl depending on the nature of the seafloor seen on DTIS.

The NIWA "Seamount Sled" (Clark & Stewart 2016) (Figure 5) is designed to sample rough seafloor (and used extensively on seamounts around New Zealand as well as on soft seafloor), and catch macro- and mega-epifauna. It is most effective at sampling benthic invertebrates, but also samples small slow-moving fishes. The sled has a mouth opening of 1 m width, and 0.4 m height. It is towed at 1–1.5 knots, for 15 minutes. Position of the gear was determined by an acoustic transponder mounted on the side.

The NIWA beam trawl (4 m width by 0.3 m height) (Laubier & Monniet 1985) (Figure 5) can be used on soft and relatively smooth seafloor. It is towed at 1.5 knots and is effective at catching small-bodied or slow-moving demersal fish and a wide range of benthic invertebrates.

Figure 5: The NIWA seamount sled (left) and beam trawl (right).

Fish traps

The fish traps used during the survey were developed by Te Papa. They have dimensions of 1.8 m diameter × 0.7 m high, each weigh 120 kg, and are lined with 16 mm square mesh (Figure 6). They have three throats, with the door on the roof of the trap or the side. A smaller trap was placed inside to catch smaller fishes or invertebrates. The pots were baited with pilchards and mackerel to attract scavenging predators. They were attached to 10 mm rope, using a warp to depth ratio of about 1.5:1, with five windy buoys on the surface. The rope was weighted before the first buoy to ensure that excess rope was below the surface to reduce the risk of the vessel fouling the warp upon retrieval. These traps were deployed over the stern of the vessel, and retrieved through the amidships A frame using a pot-hauler. After deployment, they were left for periods of 4–6 hours soak time before retrieval.

Figure 6: The fish trap.

Trawling

NIWAs "ratcatcher" trawl is a full wing trawl that samples a wide variety of fish and benthic invertebrates. It has a net opening of 25 m width and a headline height of 4 m. It is used on smooth and soft seafloor. It was fitted with a 40 mm mesh lengthener and 12 mm cod-end. Small plankton nets with 1 mm mesh were attached to the wings of the trawl when used in either midwater or bottom trawl mode. The trawl was only used on two occasions on the bottom when the seafloor appeared from the multibeam and DTIS data to be suitable.

Two trawl types were used in midwater on each transect:

a) Mesopelagic trawl. The standard NIWA trawl was shot to a depth of 1000 m, and then hauled obliquely to the surface at an ascent speed of 20 m per minute. Depth and hauling rate were derived from a Furuno CN22 net monitor unit on the headline.
b) Deep midwater trawl. The "Ratcatcher" bottom trawl was configured in a "midwater mode", retaining the 2000 m floats on the headline, but adding the mesopelagic trawl weights to the ends of the groundrope, and removing the normal 0.5 m bridle layback. It was towed for 60 minutes at 2.5 knots while being fished at 2000 m depth before hauling slowly (two-thirds normal speed) to reduce damage to specimens. Depth and position were determined from an acoustic transponder unit (the same as the seamount sled) attached to the headline. Although this is not a proper midwater trawl, it yielded good samples at depth, and helped solve logistical issues of taking separate midwater and bottom trawl gear.

Line fishing

When *Tangaroa* was in "stand-by" mode supporting dive or whale operations, several other activities were possible. These included shallow bathymetry recording (using *Tangaroa*'s multibeam echosounders), surface plankton casts, and line fishing from the *Tangaroa*. The latter was undertaken opportunistically to catch larger fish down to 300 m depth. Fishing shallower than about 100 m was not done to minimise any chance of catching the protected spotted black grouper, *Epinephelus daemelii*.

Plankton sampling

Plankton sampling was undertaken at two of the depth strata on each of the four transects (targeting about 200 m and 500 m) using a WP-2 type net (0.7 m diameter, 2 m length) with 200 µm mesh. These semi-vertical hauls sampled from a depth of approximately 70–80 m to the surface to quantify zooplankton in the euphotic zone, with a research focus on the meroplankton (larval stages of marine invertebrates and fish). Three replicate hauls were made at each station; two of these were fixed in 4% formalin, the remaining replicate was fixed in ethanol to allow future molecular analyses (e.g. DNA barcoding).

Opportunistic meroplankton sampling was also undertaken at Raoul and Macauley Island with a 0.5 m diameter, 1.0 m length, 100 µm mesh net deployed to a depth of 10 m.

Further opportunistic surface hauls were undertaken at three transects using a 1.8 × 1.1 m channel net with 800 µm mesh. The net was towed from *Tangaroa*'s A-frame and sampled the surface waters to a depth of 10–50 cm. Sample duration varied from 15 to 20 minutes with a towing speed of 1 knot.

Catch processing

Biological specimens recovered from the sled or trawls were sorted once on deck. Macro-invertebrates were identified to the lowest possible taxon, and data entered onto data log sheets and then entered into the NIWA "Specify" database. Fish were sorted, identified, and data were entered into an Excel spreadsheet file for later transfer to museum databases at Te Papa and Auckland Museum.

In addition to specimen collection and preservation, tissue samples were taken from a variety of invertebrate taxa and fish species for genetic studies, as part of existing research on connectivity and biogeography of the Kermadec region. This material was preserved in ethanol.

Unsieved sediment/rubble from several sled catches were bagged and frozen for studies on micro-molluscs by Te Papa and at Auckland Museum.

Fresh specimens were photographed where possible, and then labelled and preserved.

Specimens were distributed among the participating institutions with suitable collection facilities based on agreed distribution protocols. These were a combination of an equitable split of multiple specimens of each species/taxon, as well as scientific considerations (e.g., having specialist taxonomists actively working on taxa, depth of capture where existing collections had a coastal or offshore focus, and whether the species was already held in a collection). Invertebrates were shared by NIWA and Auckland Museum, and fish and algae by Te Papa and Auckland Museum. Some tissue samples were deposited

at University of Auckland (marine mammals) and Massey University (fishes and invertebrates) to support current research on population connectivity.

Environmental sampling

A small CTD unit was attached to DTIS, recording conductivity, temperature, and depth data for every camera transect. These data were downloaded after each DTIS tow, and conversion and derivation programmes run to produce final temperature, salinity and density values.

On the Raoul Island transect, a 12 bottle CTD-rosette unit was deployed to collect environmental data and water samples. Samples were collected at standard depths of 10, 50–100 (the approximate depth of the mixed layer), 250, 500, 750, 1000, 1100, 1200, 1300, 1400, 1500 and 2000 m. Samples were taken for alkalinity (1 l bottles) and dissolved inorganic carbon (250 ml bottles). Bottom temperature and dissolved oxygen were recorded at each sample depth on CTD log sheets.

Marine mammal sampling

Biopsy sampling: At Raoul and Macauley Islands dedicated small-boat surveys were conducted using the *Tangaroa*'s 'Work Boat' a 5.8 m Naiad with a 100 hp four-stroke engine. Small tissue biopsy samples were collected from humpback whales and bottlenose dolphins using a modified biopsy rifle system fitted with a 7 × 20 mm surgical steel cutting tip. These samples were processed in the laboratory onboard *Tangaroa* twice a day with the blubber separated from the epidermis, then frozen at -20°C for progesterone analysis, and the skin sub-sampled then fixed in 70% ethanol for genetics and diet analyses.

Photo-identification: Photographs were taken of the unique pattern of markings on the underside of the whales' flukes (Katona et al. 1979) and of the lateral side of the bottlenose dolphin dorsal fins (Würsig & Würsig 1977) for individual identification purposes. Photographs were primarily taken from the 'Work Boat' but the RV *Tangaroa* was also used when small boat operations were not possible and when in transit between islands. All photographs were quality controlled and the best images of each whale or dolphin were chosen to create catalogues of unique individuals for the voyage.

Acoustic recordings: A hydrophone at 48 kHz and Roland recorder were used to record whale vocalisations. Where weather conditions allowed, the hydrophone was deployed to a depth of 15 m to listen for whale song, if song was detected recordings were made for at least 20 minutes to capture an entire song cycle, or until the song was too weak to hear.

Dive sampling operations

Phylogenetic and population genetic collections: Target species were selected based on local abundance at the Kermadec Islands, complementarity with existing genetic data for the South West Pacific region (e.g. *Acanthaster planci*, Figure 7), existing tissue collections for surrounding regions (e.g. *Centrostephanus rodgersii* collections in mainland New Zealand), outstanding taxonomic questions (e.g. *Patiriella oliveri*), and opportunistic samples from other gear collections (e.g. *Chromis abyssicola*).

Reef building coral collections: Samples of reef building corals were hand collected from shallow reefs (0–30 m) surrounding Raoul Island, Macauley Island and L'Esperance Rock (Figure 7). At each depth stratum, one diver would search the reef for six to ten minutes and sample each coral species encountered. Samples were then placed in a bag, labelled with the depth, before moving to the next depth stratum. Once back in the onboard laboratory, we attached an individual identifier to each sample and removed a small tissue sample (less than 1 cm2) which was placed in a 2 ml tube filled with 100% ethanol. The remainder of the sample was then placed in ethanol for five minutes before being transferred into a 10% bleach solution for 24–48 hrs. The bleached coral skeletons were then left to dry for 48 hrs (Figure 7). The clean skeletons will be imaged using a scanning electron microscope and fine-scale morphological characters measured.

Shallow-reef community composition photo quadrats: The community composition of shallow reefs surrounding Raoul Island was examined using photo quadrats. At each depth stratum, one diver took photos of five haphazardly placed 0.25 m2 quadrats (Figure 7).

Shallow-reef in-situ temperature recorders: In-situ temperature recorders were deployed at Raoul Island, Macauley Island, Havre Rock and L'Esperance Rock. The first two sites involved replacement of existing loggers, while the latter two locations were new. The recorders (Hobo Pendant Loggers) were placed at 5–10 m depth by attaching the recorder to a stainless steel shackle embedded within 100 g of underwater epoxy wedged into a crack in the bedrock (Figure 7) or by attaching the recorder directly to existing infrastructure (e.g. the tsunami warning device at Boat Cove, Raoul Island). The recorders were formatted to record water temperature every 30 minutes for three years. Visual fish records: Four divers wore a head-mounted GoPro camera throughout diving operations, and the diver undertaking photo quadrats took photos of fishes during dives opportunistically, in order to generate verifiable fish species lists for each station.

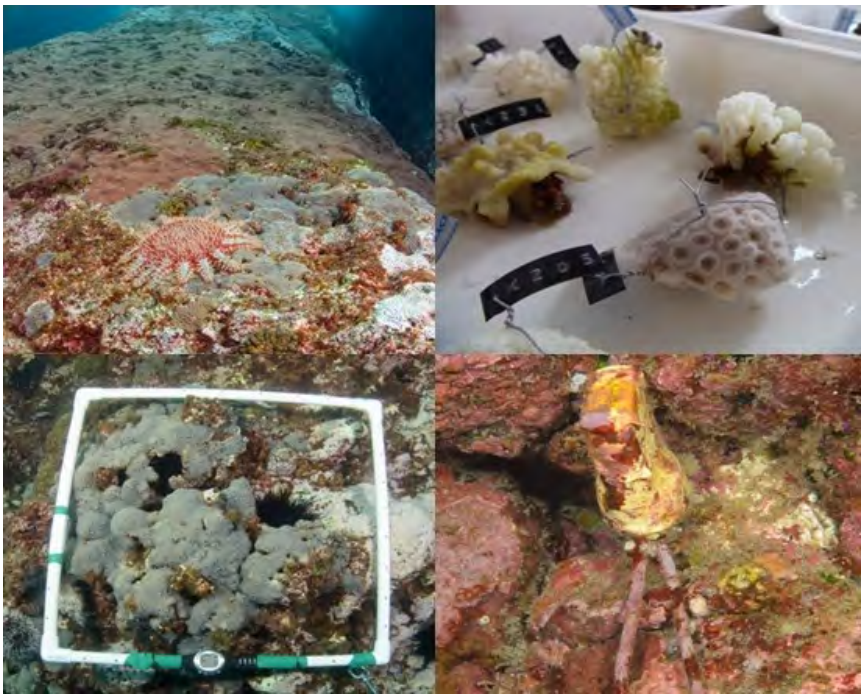


Figure 7: Clockwise from top-left: *Astrea curta, Pocillopora damnicornis,* an unknown species of reef building coral, and the corallivorous Crown of Thorns seastar (*Acanthaster planci*) at Napier Island, Raoul Island; Cleaned, dried and labelled coral skeletons; Temperature logger deployed at Macauley Island; Photo quadrats at North Meyer Island, Raoul Island (Photos: Crispin Middleton).

Outreach

Education and outreach were regarded as critical aspects of both the voyage and the whole project in the context of the public interest in the Kermadec region and the proposed Kermadec-Rangitahua Ocean Sanctuary.

An on-board professional videographer and photographer documented the voyage with videos and still images of vessel operations and samples, as well as carrying out interviews with most of the scientific staff onboard to record their research and views on the survey.

A voyage blog was operated by the Pew Charitable Trusts, with regular updates from the vessel to a website hosted by Auckland Museum. In addition, regular posts including videos and photographs were posted on NIWA's social media networks.

3. RESULTS

3.1 Voyage timetable and narrative

The voyage track from Auckland to the Kermadec Islands then returning to Wellington is shown in Figure 8. A daily summary of the work schedule is given in Table 2.

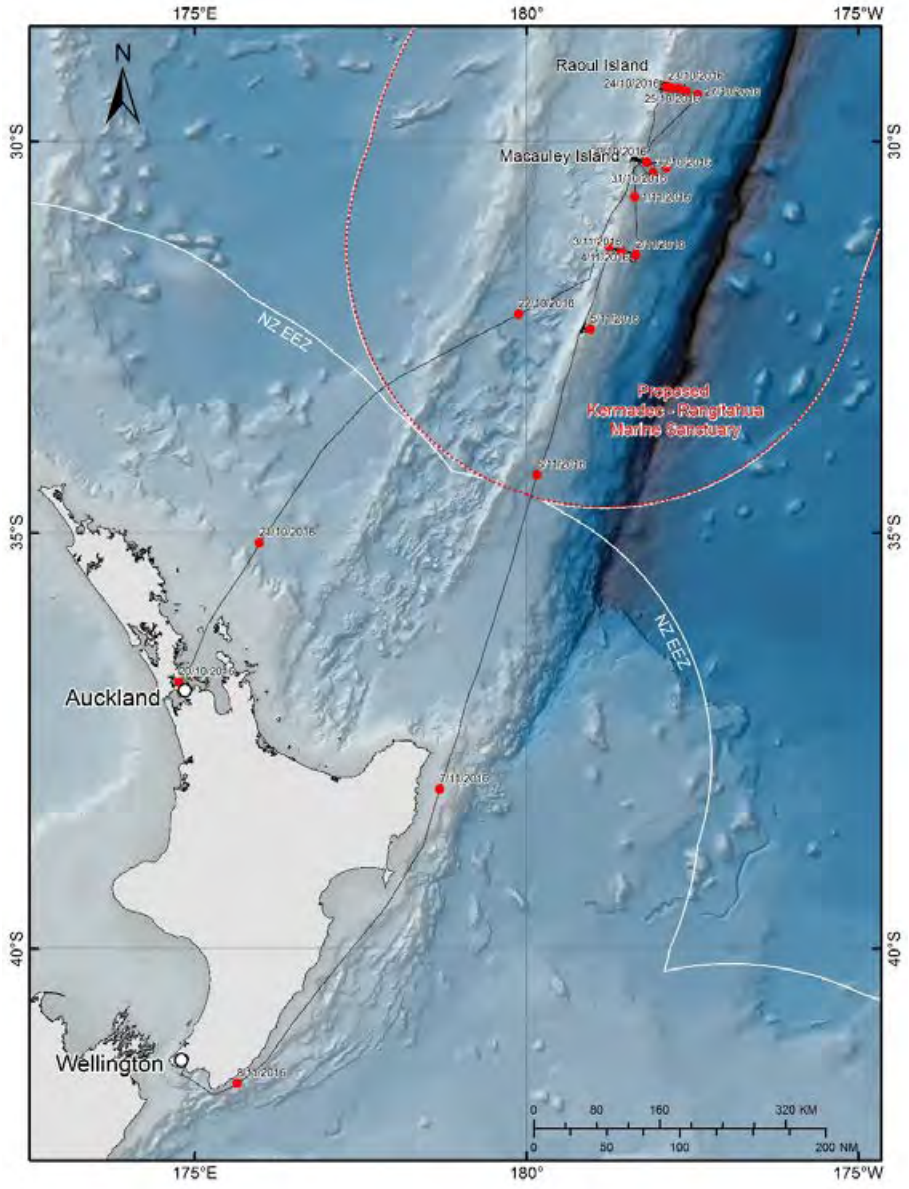


Figure 8: Track of *RV Tangaroa* during voyage TAN1612 (showing the route from Auckland northwards to Raoul Island, and then working southwards to the Star of Bengal Bank before returning to Wellington. Red dots indicate daily position at 1200 hrs.

3.2 Sampling

In total, there were 143 gear deployments or sampling events (Table 3). All station details are presented in Appendix 1, and locations are shown and described in greater detail in the following sections.

Table 2: Summary of daily activities during the survey.

Date	Activity
20 Oct	Blessing of Koha (turtle). Sail from Auckland 1300.
21 Oct	In transit to Kermadecs. Swath mapping.
22 Oct	In transit to Kermadecs. Stop off at Havre Rock, dive to deploy data-logger, collect samples. Resume transit steam and MBES mapping.
23 Oct	Arrive Raoul Island. Release Koha the turtle. DTIS test deployments (2), fish trap (1), whale trip (1), dives (2 sites), DTIS test shots (2, still giving some trouble), then DTIS transect stratum 1.
24 Oct	Raoul I. Sled (stratum 1), mesopelagic trawl shot (1000 m), DTIS transects (strata 2, 3), whale survey (2), dive survey (2 dives).
25 Oct	Raoul I. DTIS transects (strata 4, 5), beam trawl (stratum 4), fish trap (stratum 3), whale survey off north coast (2), intertidal collection, surface plankton (2), dive survey (2), vertical plankton sites (2), fish trap (stratum 4).
26 Oct	Raoul I. Beam trawl (stratum 3), fish trap (1), whale surveys (2), dive and rod-line ops, surface plankton (2), deep MWT (1700 m), start MBES to deep.
27 Oct	Raoul I. DTIS (stratum 7), fish trap (stratum 5), surface plankton tow, whale surveys (2), rod-line ops (4), CTD-rosette to 2000 m.
28 Oct	Complete sampling off Raoul Island, with DTIS (stratum 6) and beam trawl (str7). Transit to Macaulay I. Surface plankton (1), dives (1 site), DTIS (stratum 2), sled (stratum 2), oblique mesopelagic trawl shot.
29 Oct	Macauley I sampling: DTIS (4: strata 4, 1, 3, 5), beam trawls (3: strata 4, 1, 3), dives (2 sites, 3 dives), problem with workboat outboard, surface plankton (1), short whale hydrophone trip, deep MWT (2000 m).
30 Oct	Macauley I. Dive sites (2 sites), whale survey (1), DTIS (seamount feature, damaged). Vertical plankton casts (2), DTIS (stratum 2), sled (1), beam trawl (1).
31 Oct	Macauley I. DTIS transects (stratum 7, Plateau site, “Gnarly Knob”), beam trawl (stratum 7), sled (Plateau, 2 on hill outcrops). Weather OK for short whale survey, short period of line fishing. Bottom trawl on Plateau. Start transit to L’Esperance, swath mapping.
1 Nov	Complete transit to L’Esperance, swath map from 3000 m to the rock along the transect line. Conditions unsuitable for diving. Complete DTIS runs and sled sampling tows at strata 1 and 2, MBES out to 3000 m, and DTIS (stratum 7).
2 Nov	Esperance. Beam trawl (stratum 7), MBES into Rock. Dive operations, 4 dives. Some shallow MBES and line fishing. Vertical plankton sites (2), DTIS and sled combinations (stratum 3). Deep midwater tow (2000 m).
3 Nov	Esperance. DTIS transects (strata 4, 5, 6, 850 m ridge), mesopelagic trawl to 1000 m, sled shots on DTIS tow lines (2), bottom trawl shot on slope. Damage net. DTIS tow on shallow peak feature (stratum 1).
4 Nov	Esperance. Sled shallow peak. Complete transect at Esperance. Transit to Star of Bengal Bank. MBES lines to map feature. DTIS on summit (stratum 1), sled summit, fish trap, vertical plankton (1). DTIS (stratum 2).
5 Nov	Star of Bengal Bank. DTIS (strata 3, 4), beam trawls (3), vertical plankton tow (1), surface plankton (1), fish trap at 500 m. Short MBES lines. Finish survey 1300. Begin transit to Wellington.
6 Nov	Transit towards Wellington
7 Nov	Transit towards Wellington
8 Nov	Arrive Wellington.

Table 3: Count of stations and type of sampling events per transect and stratum. (RAOL=Raoul I., MACY=Macauley I., ESPC=L'Esperance Rock, HAVR=Havre Rock, STAR=Star of Bengal Bank) (shaded columns, non core transect sampling).

Area	Stratum	Depth range (m)	Camera	Sled/TB	Fish trap	Plankton	Midwater	Mesopelagic	CTD	Dive	Whale	Rod	Surface plankton	Bottom Trawl
RAOL	1	50–250	1	1		1								
	2	250–750	1	1	1									
	3	750–1250	1	1	1	1		1						
	4	1250–1750	1	1	1									
	5	1750–2250	1	1	1		1		1					
	6	2250–2750	1											
	7	2750–3250	1	1										
		Other	5							8	8	5	9	
MACY	1	50–250	4	3	1	1								
	2	250–750	1	1	1	1								
	3	750–1250	1	1				1						
	4	1250–1750	1	1										
	5	1750–2250	1	1			1							
	6	2250–2750	1	1										
	7	2750–3250	1	1										
		Other								5	3	3	2	1
ESPC	1	50–250	2	2		1								
	2	250–750	1	1		1								1
	3	750–1250	2	2				1						
	4	1250–1750	1	1										
	5	1750–2250	1				1							
	6	2250–2750	1											
	7	2750–3250	1	1										
		Other								2		1		
HAVR		Other								1		2		
STAR	1	50–250	2	2	1	1								
	2	250–750	1	1	1	1								
	3	750–1250	1	2										
	4	1250–1750	1										1	
Total			**36**	**27**	**8**	**8**	**3**	**3**	**1**	**16**	**11**	**11**	**12**	**2**

3.3 Offshore biodiversity

Photographic sampling

More than 30 hours of high definition video were recorded (1 hr per DTIS station), and almost 7500 still images were taken (240 frames per 1 hr of transect) (Table 4). Image quality for both video and stills was generally high, and the use of the *Tangaroa*'s Dynamic Positioning was an important element in this, as it controlled the speed of the ship and enabled a reasonably consistent height above the seafloor to be maintained. The relatively calm weather conditions through most of the survey also contributed to the success of this method.

Table 4: Summary of DTIS data. Duration of video and number of still images per region.

Region	Stations	Stills	Stills data size (GB)	Video elapsed (HH:MM:SS)	Video data size (GB)
Test deployments (Raoul Island)	4	201	1.04	00:45:44	8.47
Raoul Island	8	1 841	14.72	07:29:15	83.11
Macauley Island	10	2 314	23.00	09:30:08	105.41
L'Esperance Rock	9	2 098	21.06	08:15:18	91.60
Star of Bengal Bank	5	1 009	10.60	04:09:01	46.06
Total	**36**	**7 463**	**70.42**	**30:09:26**	**327.22**

Descriptions of faunal assemblages and substratum types were recorded in real time from DTIS camera transects and subsequently augmented by observations from high-resolution still images. In the next sections of the report, we document for each transect the sampling sites, descriptions of each video station, and selected images of the seafloor that give a representative indication of the observed communities.

Site description: Raoul Island

The location of sampling stations on the Raoul Island transect is shown in Figure 9.

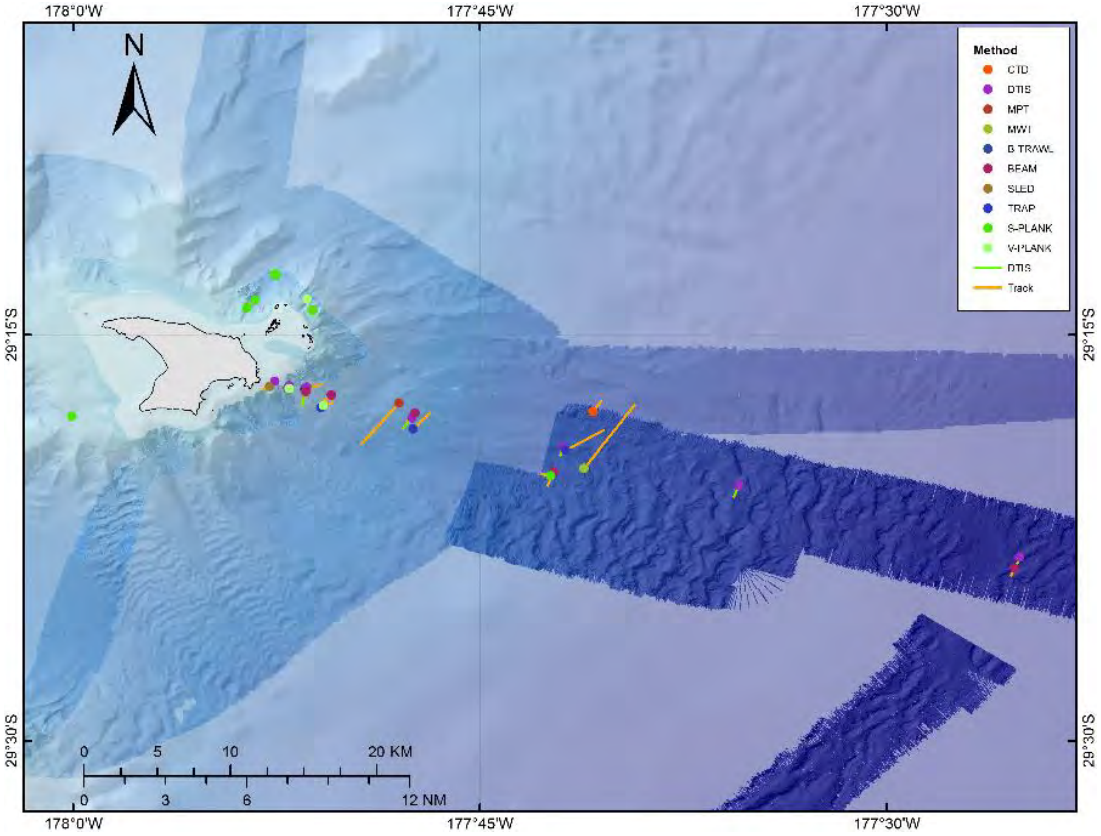


Figure 9: The distribution of sampling stations on the Raoul Island transect.

DTIS station descriptions

Station 015: Raoul stratum 001

Start depth: 98 m. Finish depth: 182 m

The tow began on the top of a ridge and ran down-slope, over predominantly sandy-gravel substrate. Sparse fauna included sponges and gastropods. Towards the middle of the station was a rocky outcrop, approaching another ridge, with black corals (whip corals), crinoids, sponges and stylasterids. Fish included scattered pink maomao. Further on were more extensive bedrock outcrops, and higher densities of invertebrate fauna, especially whip corals.

Station 017: Raoul stratum 002

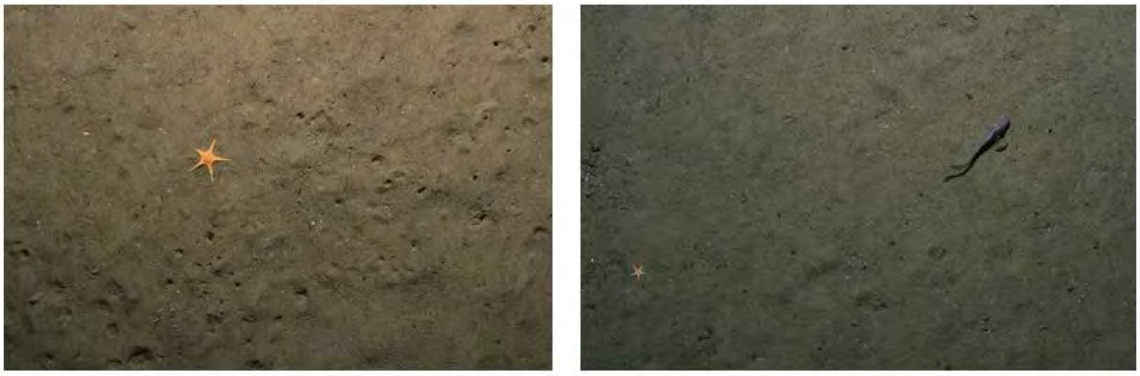
Start depth 493 m. Finish depth 635 m.

The substrate comprised largely muddy sediments, with gravels and some patches of cobbles. Fauna comprised echinoids, asteroids and holothuroids, with occasional sponges and stony corals on larger cobbles. Fish included scorpaenids, eels and rattails.

Station 025: Raoul, stratum 003

Start depth 809 m. Finish depth 787 m

DTIS line ran slowly upslope. Substrate was soft sediment, with many burrows, some tracks. There were scattered holothurians, asteroids, gastropods. There were occasional fish, but not many. From half-way through the tow, the bottom became harder, with some ridge structures, and shift to pebbles and gravel.

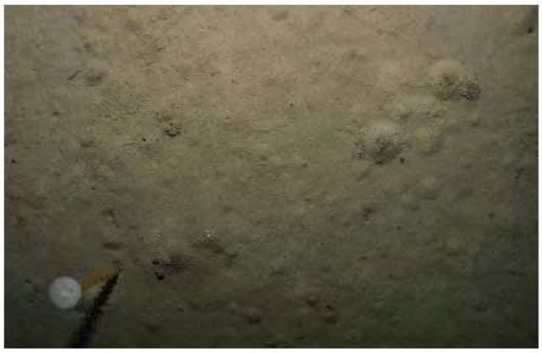


Station 029: Raoul, stratum 004

Start depth: 1334 m. Finish depth: 1326 m

Substrate comprised muddy sediment, with burrows, and pumice pieces. Sparse fauna, one large *Benthodytes* holothurian, a single brisingid starfish, and a few scattered fishes. The station was sampled with beam trawl #030.

Station 042: Raoul stratum 005
Start depth: 2092 m. Finish depth 2096 m
Soft sediment throughout the tow line, sandy mud with frequent burrows. Sparse fauna, scattered shrimps, with occasional fish (including rattails), holothurians, several lollipop sponges. Very flat bottom. The station was sampled with beam trawl #043.

Station 054: Raoul stratum 7
Start depth 3094 m. Finish depth 3104 m.
Substrate consisted of muddy sediment throughout most of the station, with some patches of gravel/pebbles and pumice cobbles. Fauna were sparse, with scattered fish, shrimps, lollipop sponges (*Hyalonema*?), some holothurians and large anemone.


Station 063: Raoul stratum 0006
Start depth: 2492 m. Finish depth 2501 m.
The towline was relatively flat, with muddy sediment and pebble-cobble sized pumice. A bedrock scarp crossed part-way through. Tracks, burrows, rings of burrows, pits and mounds were common. Fauna comprised shrimps and holothurians throughout, with scattered anemones and sponges. Several fish were observed, including a deep-sea halosaur, and several lizard fish.


Site description: Macauley Island

The location of sampling stations on the Macauley Island transect is shown in Figure 10.

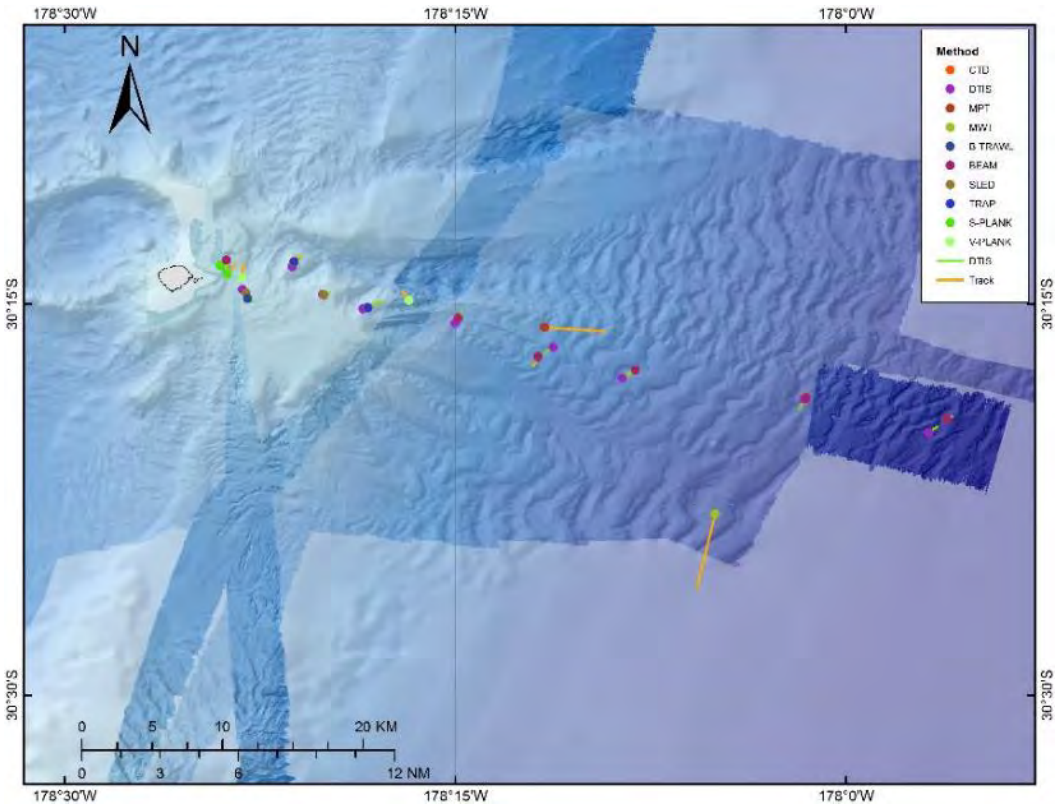


Figure 10: The distribution of sampling stations on the Macauley Island transect.

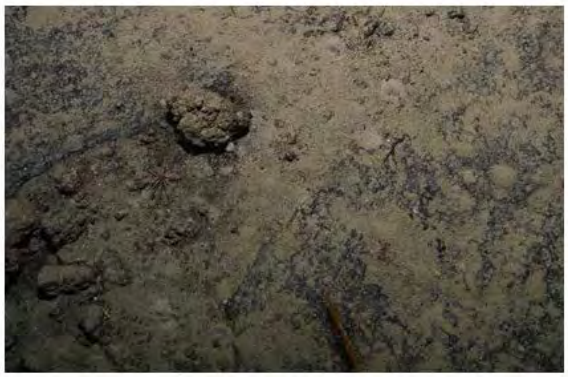
DTIS station descriptions

Station 067: Macauley stratum 0002

Start depth 314 m. Finish depth 460 m.

Substrate was mainly smooth bedrock, with some patches of more lumpy lava flows. From the start of the station down to about 350 m fauna was predominantly dense stalked crinoids. Below that were more scattered crinoids, gorgonians, glass sponges, and echinoids. In places small stylasterids were abundant. Below 400 m fauna were sparse, comprising mainly scattered glass sponges. At 451 m there was a large orange gorgonian.

Station 070: Macauley stratum 0004
Start depth 1444 m. Finish depth 1465 m.
The substrate along much of the station was smooth muddy sediments, with cobble-pebble-gravel sized pumice. Bedrock outcrops occurred about two-thirds of the way through. Fauna included shrimps, holothurians, lizard fish, rattails, and a few scattered sponges.

Station 074: Macauley stratum 0001
Start depth 71 m. Finish depth 103 m.
The towline comprised current-swept sand and gravel. Algae was observed at the start to about 85 m, and after that the seafloor appeared relatively barren.


Station 078: Macauley stratum 0003
Start depth: 987 m. Finish depth: 970 m
Substrate comprised muddy sediment with pumice cobbles and pebbles throughout the length of the station. The bottom was relatively flat, but from about two-thirds along there were lumpy cobble patches. Fauna were sparse, with scattered asteroids, echinoids, glass sponges, brisingids and holothurians. Burrows and tracks were common, but not abundant, in the soft sediment.


Station 080: Macauley stratum 0005

Start depth 1828 m. Finish depth 1826 m.

The seafloor comprised soft muddy sediment with scattered pumice cobbles and pebbles. For the first part there were patches of dense pumice, thinning out along the station line. Few fauna, some scattered fish, shrimps, echinoids, and brisingids.


Station 083: Seamount feature ENE of Macauley I.

Start depth: 170 m. Finish depth: 322 m.

The station started on the summit of the hill, with sand and gravel, and bedrock outcrops with gorgonian corals. Rough bottom then mixed cobble/pebble substrate becoming gravelly with depth. Gorgonian corals and sponges were common throughout, particularly around the summit region.


Station 092: Macauley stratum 0006

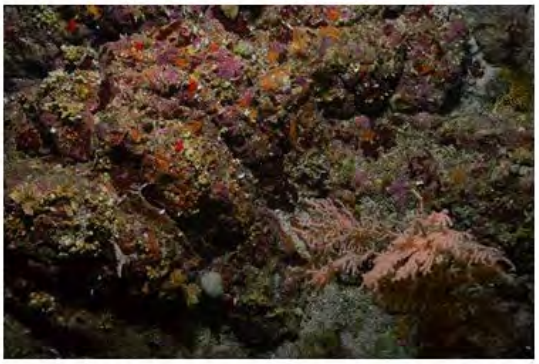
Start depth 2370 m. Finish depth 2415 m.

There was a gradual slope along the station. The first half of the tow revealed soft mud with pumice cobbles and pebbles, changing into more pebble pavement. Half-way through was a patch of exposed bedrock and boulders, over a depth range of 2400–2410 m. Beyond that, substrate became soft sediment-cobbles-pebbles again. The first half was judged suitable for beam trawling.


Station 094: Macauley stratum 0007.
Start depth: 2801 m. Finish depth: 2811 m.
Muddy sediments with pumice, gravel, and cobbles occurred throughout most of this transect, with a steep 20-30 m drop-off at 43 mins. Fauna were sparse: stalked crinoids, holothuroids, and hexactinellid sponges.


Station 096: Macauley, "Plateau" site
Start depth: 137 m. Finish depth: 135 m
The plateau had mixed substrate comprising bedrock, with boulders and cobbles in places, with encrusting red algae. There were occasional solitary sponges, asteroids, and scattered whip corals, and abundant pink maomao towards the end of the station.


Station 100: Macauley, "Gnarly knob" site
Start depth: 151 m. Finish depth: 185 m
At the start there was exposed bedrock, with encrusting sponges, gorgonians, black corals, soft coral, and solitary sponges. Around 160 m the substrate became mixed bedrock and sandy gravel, with gorgonian and black corals, as well as pink maomao. Towards the end the bottom was a mix of bedrock and gravel rubble, with echinoids, occasional black corals, soft corals and cup corals.




Site description: L'Esperance Rock

The locations of sampling stations on the Esperance transect are shown in Figure 11.

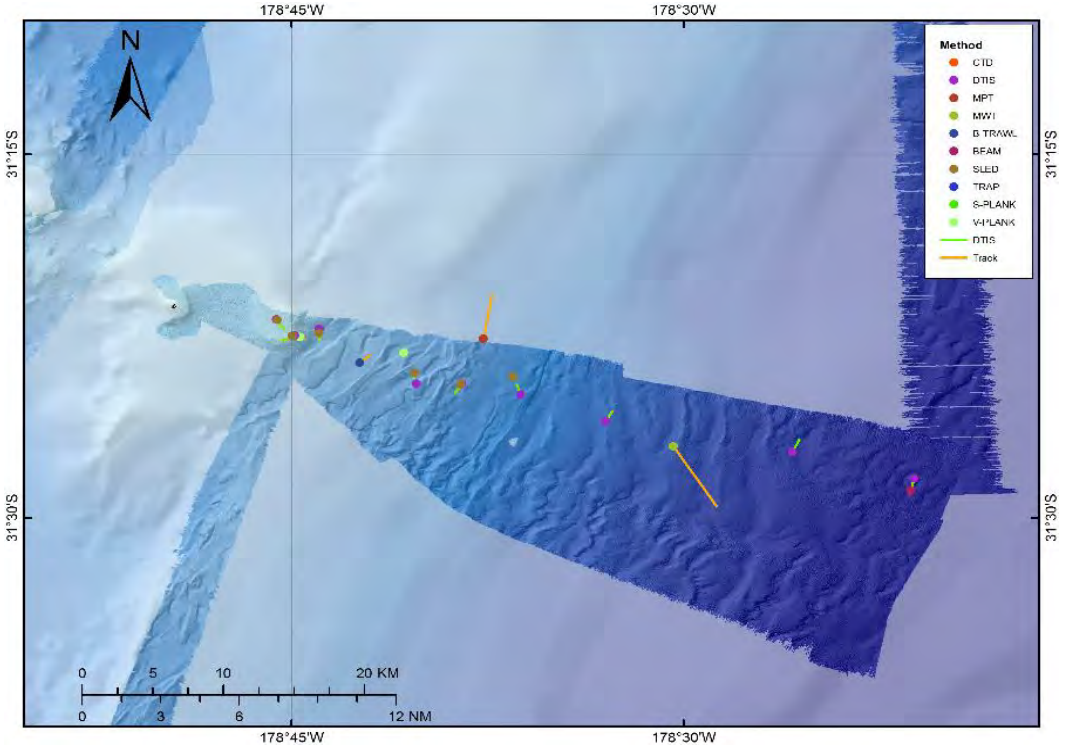


Figure 11: The distribution of sampling stations on the Esperance transect.

DTIS station descriptions

Station 105: Esperance stratum 0001
Start depth: 98 m. Finish depth: 118 m.
The station ran from the top of an outcrop feature (98 m on summit) with boulder bedrock, dense gorgonians, and lots of fish, especially pink maomao. Rocks were encrusted with red algae, some anemones, and black spiral corals. Dropping off the outcrop, the seafloor was covered in pebble-sized rhodoliths. On the video they looked like rock pebbles encrusted with red and green algae. There were also encrusting yellow sponges, black whip corals, and holothurians as the substrate became more open with patches of muddy-sandy sediments. Overall this was a diverse station.

Station 107: Esperance stratum 0002.
Start depth: 503 m. Finish depth: 552 m.
There was muddy sediment at the start, with gravel patches and the occasional rocky outcrop and boulders. This transitioned to relatively low bedrock with cobble and pebble patches, and black sand interspaces. There were few animals, scattered anemones, echinoid, and gastropods.


Station 109: Esperance stratum 0007.
Start depth: 3079 m. Finish depth 3098 m.
Along most of the towline the substrate was bedrock, with mud overlay and cobbles and pebbles. Fauna were sparse, with scattered anemones and shrimps. A single-spicule sponge was seen early on. Towards the end were some stalked sponges and holothurians.


Station 116: Esperance stratum 0003
Start depth: 1086 m. Finish depth: 1092 m
Muddy sediment overlying patches of bedrock, with boulders, cobbles and pebbles. This mixed composition continued throughout the station. Fauna were sparse, some rattails, urchin tests, and the occasional holothurian and jellyfish. Outcrops of bedrock were more frequent towards the end.


Station 119: Esperance stratum 0004
Start depth: 1371 m. Finish depth: 1336 m
This station ran over slowly shallowing seafloor. Rugged seabed of boulders, cobbles, bedrock and overlying sediments. Sparse fauna. Some gorgonian and black corals.


Station 122: Esperance stratum 0005
Start depth: 1817 m. Finish depth: 1798 m
This station featured rugged seabed of boulders, cobbles, bedrock and overlying sediments. Sparse fauna. Some gorgonian and antipatharian corals, sponges, crinoids, and holothurioids. Also burrows in deeper sediment patches.


Station 123: Esperance stratum 0006
Start depth: 2646 m. Finish depth: 2661 m.
Very flat seafloor, slightly deepening over the station. Mixed substrate of bedrock-cobbles-pebbles with sandy-muddy overlay along the length of the towline. Very sparse fauna, several fish (including halosaur), occasional echiuran worms, and glass sponges.


Station 124: Esperance, 850 m Ridge

Start depth: 835 m. Finish depth: 898 m.

The tow started on the summit of the "850 m" ridge, and towed down the NW flank of the feature. Substrate was bedrock with a muddy overlay and cobbles on the top, and then hard basaltic bedrock down the flanks. There were scattered *Metallogorgia*, gorgonian corals, glass sponges, crinoids and anemones. The substrate was more broken and boulder-cobble as we towed into the valley at the base of the ridge.

Station 127: Esperance, 76 m hill

Start depth: 86 m. Finish depth: 95 m

The station started with bouldery bedrock, with sponges, gorgonian corals, soft corals, black whip corals and encrusting algae, which continued coming down the flank of the hill to about 98 m. Frequently-oserved fish included pink maomao and several large bass. The middle section of the station was dominated by rhodolith beds, with black whip corals, sponges and gorgonians, with some pink maomao, kingfish, and a ray.

Site description: Star of Bengal Bank

The location of sampling stations on the Star of Bengal Bank transect is shown in Figure 12. This transect was additional to the original survey design, and enabled by good progress through the survey. This meant time was able to be spent on a partial transect on the largely unsampled bank, which was spaced about the same as the distance between the northern transects. Hence it strengthened the scientific design with a greater geographic spread.

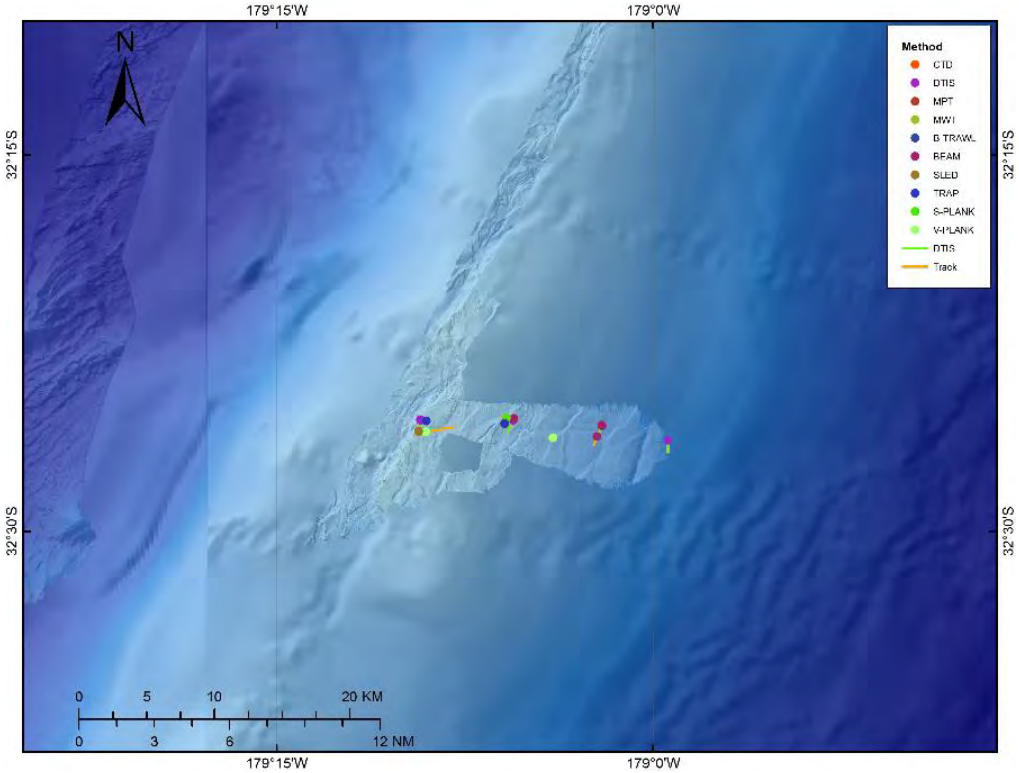


Figure 12: The distribution of sampling stations on Star of Bengal Bank.

DTIS station descriptions

Station 129: Star of Bengal Bank stratum 0001

Start depth: 140 m. Finish depth: 145 m.

Bouldery bedrock at start, encrusted with algae, demosponges, gorgonian corals, many bass. Lost images after 4 minutes. Aborted tow.

Station 130: Star of Bengal Bank stratum 0001
Start depth: 139 m. Finish depth 179 m.
Substrate over the length of the towline was bedrock, boulder in the early stages near the summit, but softer substrate in the summit depression, and bedrock with sediment overlay over the latter stages. Near the summit were many bass. Off the summit on the 145–150 m plateau were extensive rhodolith beds. Gorgonian corals, demosponges, and possibly soft corals were common near the summit, and again in the last third of the station. Tam-O'Shanter urchins were prominent in places.


Station 135: Star of Bengal Bank stratum 0002
Start depth: 499 m. Finish depth: 523 m.
Relatively flat bottom along the length of this station. Initially sand and gravel, changing to sand and pebbles half-way through, and then sand with ripples. Scattered fauna included anemones, galatheids, asteroids, holothurians, and a bass. A carpet shark was on the high resolution video.


Station 136: Star of Bengal Bank, stratum 0003.
Start depth: 949 m. Finish depth: 951 m
Substrate was predominantly muddy soft sediment, with borrows and track marks. The seafloor was very flat and featureless. Fauna included an orange roughy and several sharks, tripod fish, holothurians, asteroids and shrimps.


Station 142: Star of Bengal Bank, stratum 0004.
Start depth: 1263 m. Finish depth: 1308 m.
The station was similar to the 950 m site. Mud/sand sediments predominate, with pronounced sand ripples in places. Fauna were sparse, with scattered taxa including asteroids, glass sponges and gorgonian corals on isolated cobbles, with some rattails and shrimps.


Transect substrate and faunal distributions

The predominant substrate observed in DTIS imagery varied considerably among transects, and also within them by depth (Table 5). Soft sediments dominated all depths at Raoul Island except for the shallowest stratum where gravels were common. In contrast, substrate was more mixed at the other three transects, with bedrock-boulders-cobbles important especially off Macauley Island and L'Esperance Rock. At Star of Bengal Bank hard substrate was predominant in shallow waters, with muddy sediments dominating in the deep. Rhodolith beds were common in the shallower areas off Macauley Island, L'Esperance Rock and Star of Bengal Bank.

Table 5: Counts of substrate type (as a percentage of total count per station) by Transect, Stratum and Station from OFOP records. RAOL = Raoul Island, MACY = Macauley Island, ESPC = L'Esperance Rock, STAR = Star of Bengal Bank.

Transect	Stratum (m)	Station	Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Mud	Shell hash	Rhodolith
RAOL	50–250	15	9	5	1	7	47	26	0	4	0
	250–750	17	1	2	5	2	17	3	66	4	0
	750–1250	25	0	0	1	4	4	31	60	0	0
	1250–1750	29	0	0	2	0	6	0	86	6	0
	1750–2250	42	0	0	4	0	0	11	83	0	0
	2250–2750	63	1	1	17	1	0	0	79	0	0
	2750–3250	54	0	0	7	6	28	0	59	0	0
MACY	50–250	74	0	1	3	8	37	35	0	8	8
	50–250	83	36	3	13	10	26	11	0	0	0
	50–250	96	3	10	23	6	39	10	3	7	0
	50–250	100	33	1	0	18	37	2	7	2	0
	250–750	67	97	0	0	0	3	0	0	0	0
	750–1250	78	0	1	32	8	0	0	58	0	0
	1250–1750	70	2	1	19	9	6	0	63	0	0
	1750–2250	80	1	0	27	16	2	0	54	0	0
	2250–2750	92	2	2	20	46	1	0	29	0	0
	2750–3250	94	4	3	6	21	12	0	53	0	0
ESPC	50–250	105	16	7	17	39	5	7	9	0	0
	50–250	127	19	15	6	1	9	37	1	0	12
	250–750	107	22	11	29	11	4	9	14	0	0
	750–1250	124	34	17	25	15	1	0	8	0	0
	750–1250	116	6	14	33	6	0	0	41	0	0
	1250–1750	119	4	28	22	10	12	0	25	0	0
	1750–2250	122	1	25	15	11	22	0	26	0	0
	2250–2750	123	3	14	38	29	0	0	16	0	0
	2750–3250	109	23	9	28	15	0	1	24	0	0
STAR	50–250	129	62	23	8	0	0	0	8	0	0
	50–250	130	25	5	2	46	2	8	2	0	10
	250–750	135	0	0	0	11	37	50	2	0	0
	750–1250	136	0	0	0	0	7	2	91	0	0
	1250–1750	142	0	0	5	3	1	21	71	0	0

Faunal counts also varied considerably between transects and stations (Table 6). These counts are from the low-resolution direct video feed, but give a rough guide to where certain fauna were abundant and dominated communities.

Table 6: Counts of algae and invertebrate faunal types by station for Raoul Island transect (RAOL), Macauley Island transect (MACY), Esperance Rock transect (ESPC) and Star of Bengal Bank transect (STAR).

				RAOL							MACY									
Phylum	**Class**	**Order**	**Taxon label**	**15**	**17**	**25**	**29**	**42**	**54**	**63**	**67**	**70**	**74**	**78**	**80**	**83**	**92**	**94**	**96**	**100**
Algae			Algae (erect)	0	0	0	0	0	0	0	0	0	59	0	0	0	0	0	1	1
Arthropoda	Malacostraca	Decapoda	Crustacean (lobster)	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
			Crustacean (crab)	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Crustacean (pagurid)	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
			Crustacean (shrimp)	10	2	1	12	38	2	76	1	24	0	0	4	1	15	7	0	1
Cnidaria	Anthozoa	Actiniaria	Anemones	0	0	0	0	0	4	4	3	3	4	0	0	0	1	2	0	0
		Alcyonacea	Alcyonacea	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4
		Antipatharia	Antipatharia	17	0	0	4	0	0	1	0	1	0	0	0	53	0	0	41	92
			Bathypathes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Gorgonacea	Gorgonacea	263	4	1	4	1	0	4	129	9	0	5	3	156	1	0	3	138
			Isididae	0	1	0	1	0	0	1	4	0	0	0	0	31	0	0	0	0
			Chrysogorgiidae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pennatulacea	Pennatulacea	0	0	5	2	1	0	0	3	1	0	2	0	0	0	0	1	0
		Scleractinia	cup corals	0	0	0	0	0	0	0	1	5	0	0	0	0	0	0	0	8
		Zoantharia	*Epizoanthus* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Zoanthidea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Scyphozoa		Medusa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Echinodermata	Asteroidea		Asteroid	4	33	34	1	1	1	0	0	2	7	19	0	1	1	1	3	0
		Brisingida	Brisingidae	0	0	0	1	0	0	1	0	0	0	1	2	0	2	0	0	0
	Crinoidea	Bourgueticrinida	Crinoidea (stalked)	3	0	0	0	0	0	0	694	1	0	0	0	0	0	17	0	0
		Comatulida	Crinoidea (motile)	11	0	0	2	0	0	1	6	1	0	1	0	3	0	0	0	0
	Echinoidea	Cidaroida	Cidaridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Echinoida	Echinoid	3	15	1	0	0	0	0	14	2	5	2	3	0	1	0	0	4
		Echinothurioida	Echinothuriidae	0	37	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	Holothuroidea		Holothurian	0	53	13	7	9	29	18	0	8	0	7	5	0	13	10	0	1
		Elasipodida	*Enypniastes eximia*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
	Ophiuroidea		Ophiuroid	0	1	1	1	0	0	1	10	2	1	0	0	0	0	1	0	0
Echiura			Echiura	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hyrozoa	Hydrozoa	Anthoathecatae	Stylasteridae	11	4	0	0	0	0	0	382	0	0	3	0	20	0	0	0	0
Mollusca	Cephalopoda	Octopoda	Mollusc (octopod)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Gastropoda		Mollusc (gastropod)	19	5	6	2	1	0	0	5	0	0	3	0	3	0	0	5	1
Porifera	Demospongiae		Sponge (demospongiae)	242	47	11	10	2	4	3	12	7	3	1	0	10	0	1	38	20
	Hexactinellida		Sponge (hexactinellidae)	0	1	0	0	4	47	8	108	6	0	15	5	8	4	30	1	1

				ESPC									STAR				
Phylum	**Class**	**Order**	**Taxon label**	**105**	**107**	**109**	**116**	**119**	**122**	**123**	**124**	**127**	**129**	**130**	**135**	**136**	**142**
Algae			Algae (erect)	475	0	0	0	0	0	0	0	149	7	234	0	0	0
Arthropoda	Malacostraca	Decapoda	Crustacean (lobster)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Crustacean (crab)	0	0	1	0	0	0	0	0	0	0	0	0	0	0
			Crustacean (pagurid)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Crustacean (shrimp)	0	1	7	6	2	13	5	0	0	0	0	4	5	26
		Ascidiacea	Ascidians (solitary)	0	0	0	1	0	0	0	0	0	0	14	0	0	0
Cnidaria	Anthozoa	Actiniaria	Anemones	2	6	27	3	1	7	0	3	2	0	1	1	0	0
		Alcyonacea	Alcyonacea	0	0	0	0	0	0	0	2	10	0	75	0	0	0
		Antipatharia	Antipatharia	88	0	0	0	9	1	0	1	57	0	89	0	0	0
			Bathypathes	0	0	0	0	2	3	0	0	0	0	0	0	0	0
		Gorgonacea	Gorgonacea	25	1	0	5	2	8	0	15	85	3	151	0	1	3
			Isididae	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Chrysogorgiidae	0	0	0	0	5	1	0	4	0	0	0	0	0	0
		Pennatulacea	Pennatulacea	0	0	0	2	0	0	0	0	0	0	1	0	3	2
		Scleractinia	cup corals	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Zoantharia	*Epizoanthus* sp.	0	0	0	0	0	1	0	0	0	0	0	1	0	0
			Zoanthidea	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Scyphozoa		Medusa	0	0	0	7	0	0	4	0	0	0	0	0	0	0
Echinodermata	Asteroidea		Asteroid	4	4	0	3	2	0	1	4	1	0	3	9	4	9
		Brisingida	Brisingidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Crinoidea	Bourgueticrinida	Crinoidea (stalked)	0	0	0	1	0	0	0	0	0	0	0	0	0	0
		Comatulida	Crinoidea (motile)	0	0	0	9	1	3	1	2	0	0	1	0	0	0
	Echinoidea	Cidaroida	Cidaridae	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		Echinoida	Echinoid	2	1	0	34	0	0	0	1	3	0	24	2	3	0
		Echinothurioida	Echinothuriidae	0	0	0	0	0	0	0	0	0	0	0	2	0	0
	Holothuroidea		Holothurian	67	1	3	8	3	2	2	0	0	0	0	1	12	2
		Elasipodida	*Enypniastes eximia*	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Ophiuroidea		Ophiuroid	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Echiura			Echiura	0	0	1	0	0	0	11	0	0	0	0	0	0	0
Hyrozoa	Hydrozoa	Anthoathecatae	Stylasteridae	0	0	0	0	0	0	0	0	5	0	244	0	0	0
Mollusca	Cephalopoda	Octopoda	Mollusc (octopod)	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Gastropoda		Mollusc (gastropod)	0	13	0	1	0	0	0	1	0	0	1	9	1	0
Porifera	Demospongiae		Sponge (demospongiae)	52	1	0	0	0	0	0	0	8	9	205	4	0	0
	Hexactinellida		Sponge (hexactinellidae)	2	1	5	2	5	14	4	2	3	3	2	0	1	5

The variability of many faunal groups between offshore transects is highlighted for several examples of common or abundant taxa in Figures 13 to 18 below.

For example, algae were not observed at Raoul at all, but occurred on the innermost transect at Macauley. They were abundant where associated with rhodolith beds on the hard substrate features inshore at both L'Esperance Rock and Star of Bengal Bank (Figure 13).

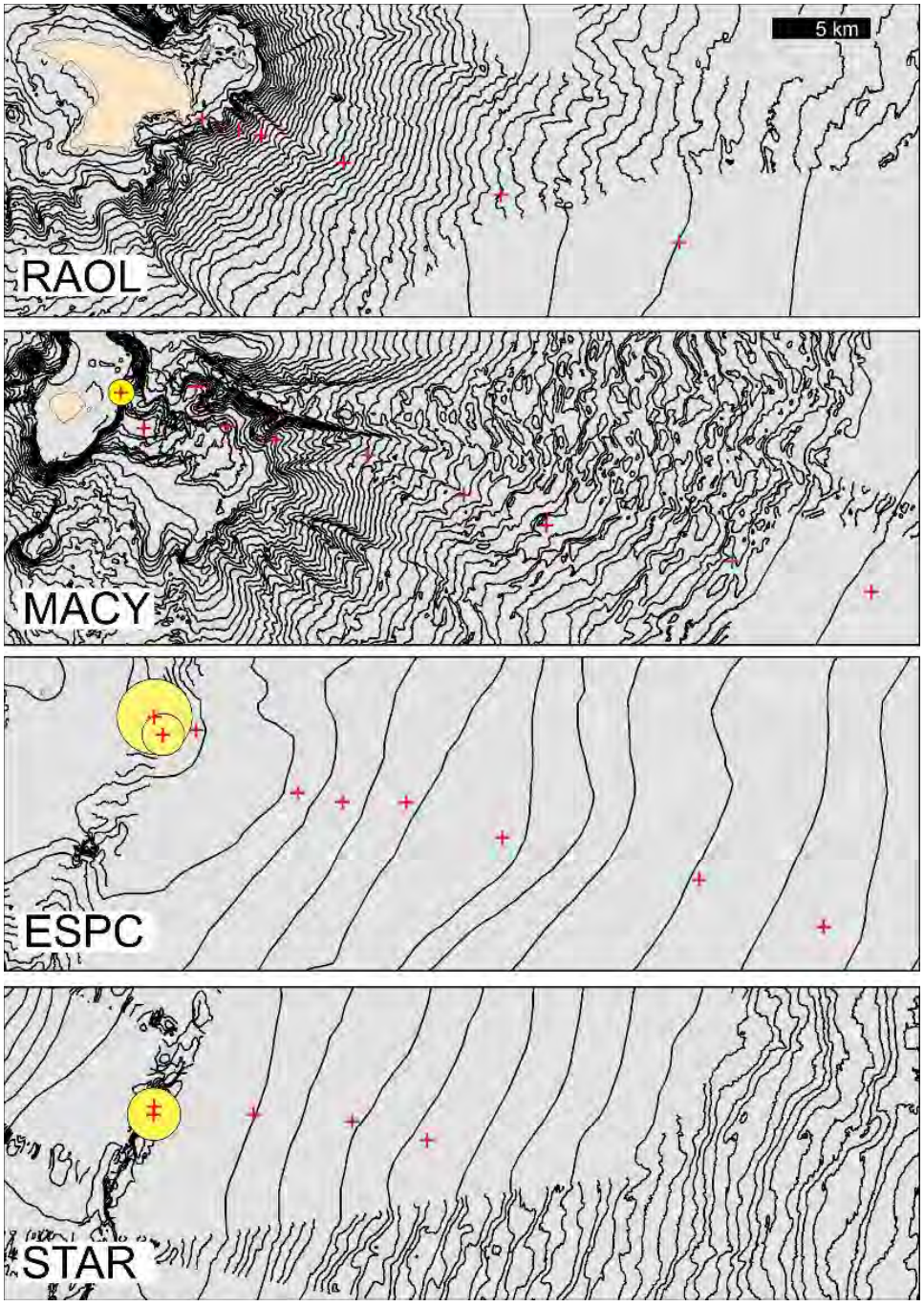


Figure 13: The distribution of algae in DTIS tows (circle sized proportional to counts, same scale across Figures 13–18) by transect. Red crosses are the centre of DTIS stations, black lines are depth contours (new MBES not added).

Black corals (mainly a thin spiral-shaped species) were also distributed inshore on all transects (Figure 14). They were abundant on the rocky features off L'Esperance Rock and Star of Bengal Bank, as well as off Macauley Island on the small topographic rises along the flanks of the inshore plateau.

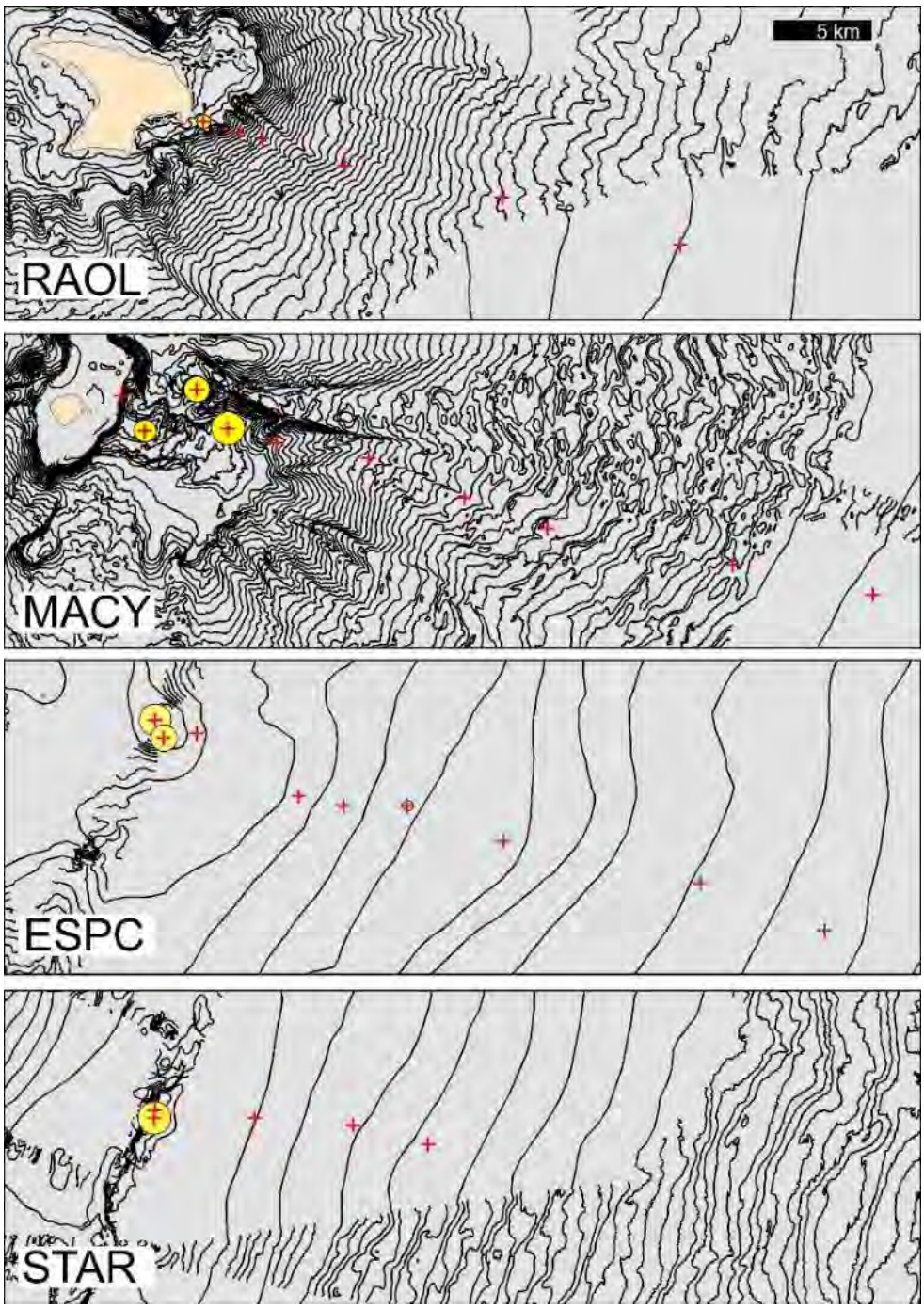


Figure 14: The distribution of black corals in DTIS tows (circle sized proportional to counts, same scale across Figures 13–18) by transect. Red crosses are the centre of DTIS stations, black lines are depth contours (new MBES not added).

Stalked crinoids were a striking taxon at a single station off Macauley Island, at a depth of about 350 m (Figure 15). Reasons for the localised distribution are unknown, although they are known to occur also on the western side of the island along the rim of the caldera.

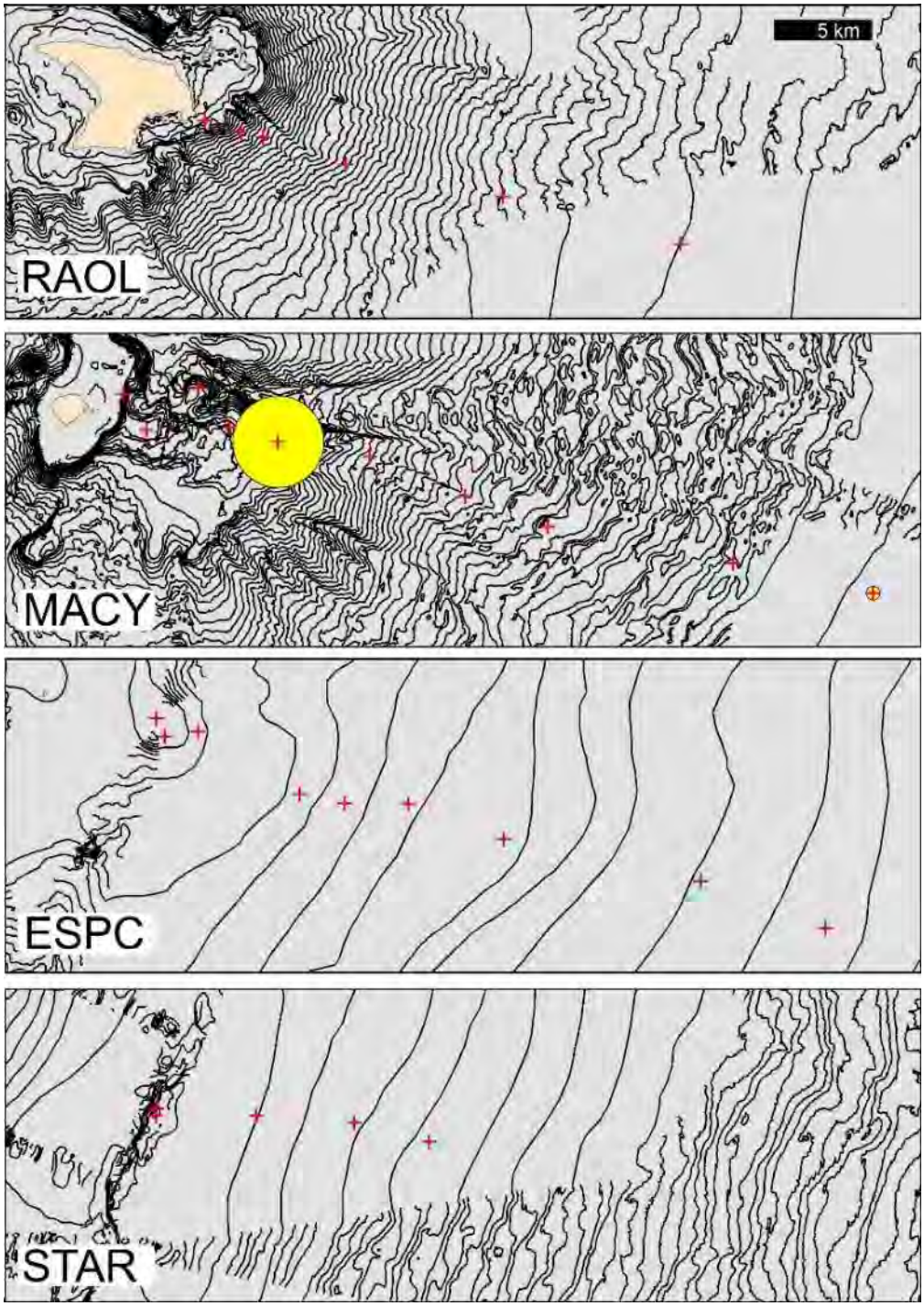


Figure 15: The distribution of stalked crinoids in DTIS tows (circle sized proportional to counts, same scale across Figures 13–18) by transect. Red crosses are the centre of DTIS stations, black lines are depth contours (new MBES not added).

Gorgonian corals occurred in small numbers across the depth range on hard substrate. However, they were most abundant in the shallowest strata off Raoul Island, L'Esperance Rock, and Star of Bengal Bank. They extended deeper off Macauley Island. (Figure 16).

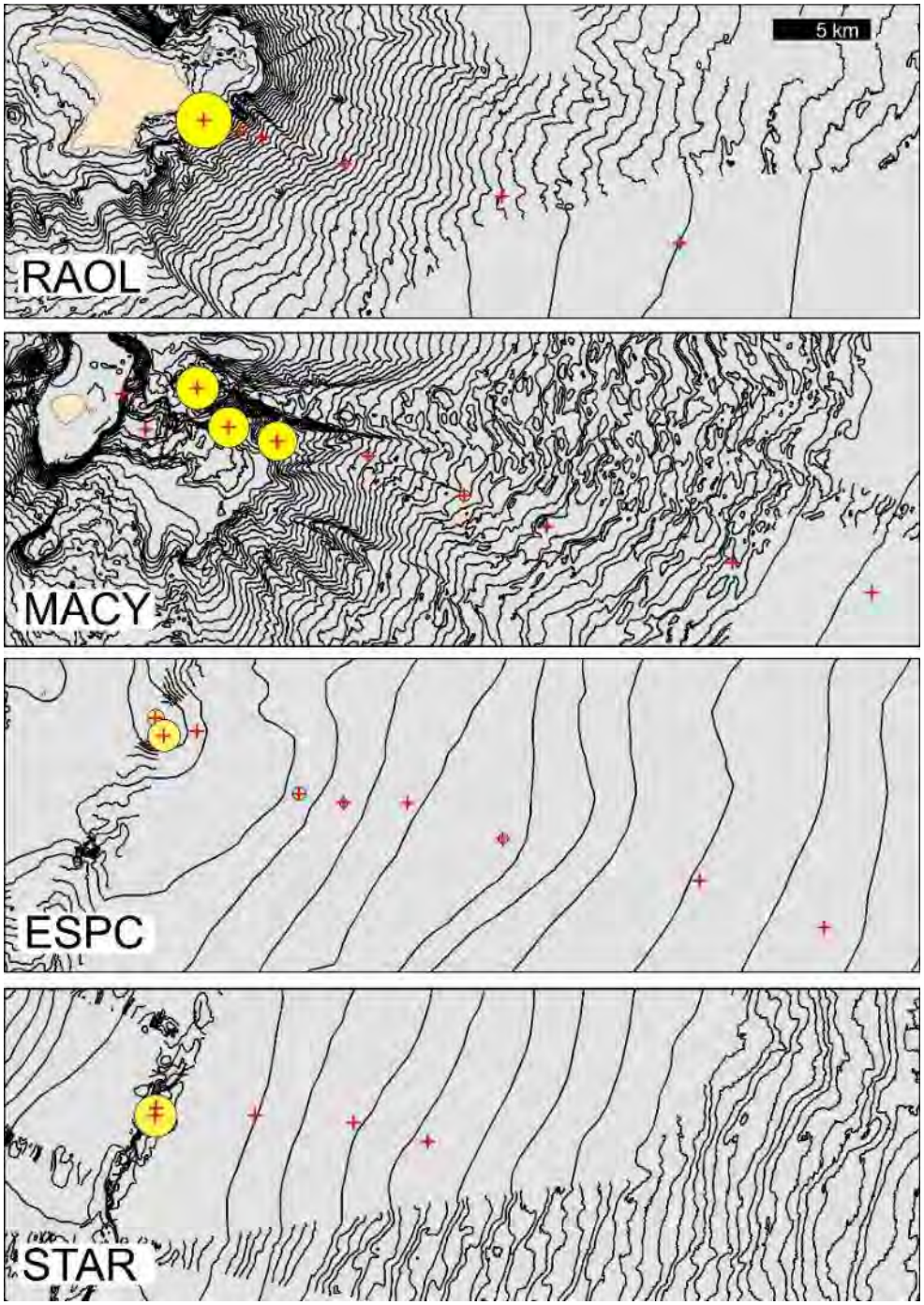


Figure 16: The distribution of gorgonian corals in DTIS tows (circle sized proportional to counts, same scale across Figures 13–18) by transect. Red crosses are the centre of DTIS stations, black lines are depth contours (new MBES not added).

Holothurian echinoderms (sea cucumbers) were amongst the most widely distributed taxa, although in low numbers. Often associated with soft sediment in deeper waters, they occurred across almost all substrates and all depths (Figure 17).

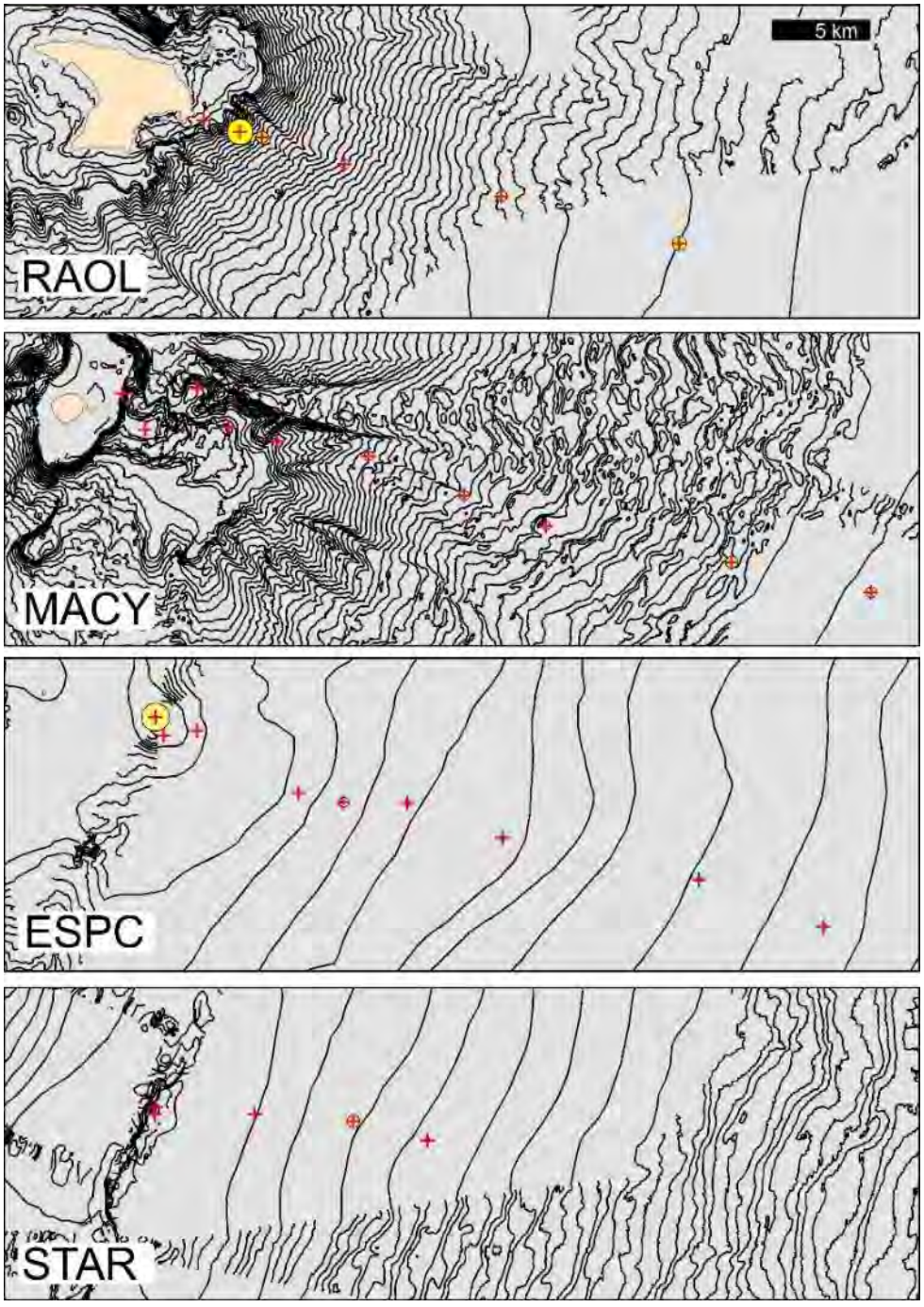


Figure 17: The distribution of holothurian echinoderms in DTIS tows (circle sized proportional to counts, same scale across Figures 13–18) by transect. Red crosses are the centre of DTIS stations, black lines are depth contours (new MBES not added).

Glass sponges (Hexactinellida) were patchily distributed. They were scattered in low numbers in the deeper stations off Raoul Island and L'Esperance Rock, but were more abundant across a range of depths on the hard substrate commonly found along the Macauley transect (Figure 18).

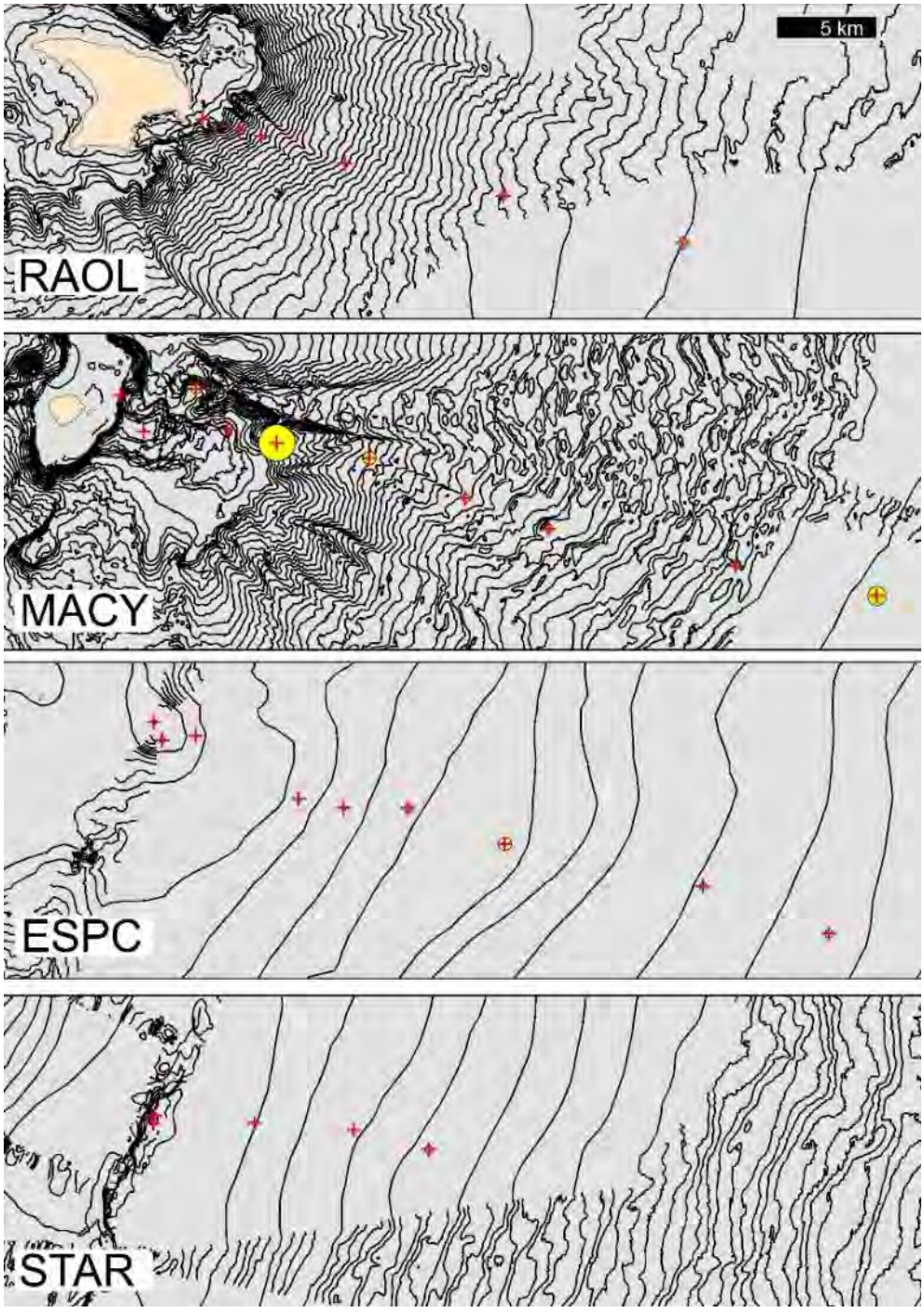


Figure 18: The distribution of glass sponges in DTIS tows (circle sized proportional to counts, same scale across Figures 13–18) by transect. Red crosses are the centre of DTIS stations, black lines are depth contours (new MBES not added).

3.4 Specimen collections

Invertebrates

A total of 1241 invertebrate "lots" were catalogued during the survey, including those collected from coastal hand collections and divers, plankton tows, hand nets, fish traps, sleds and trawls. The numbers of specimens by taxon are summarised in the following three tables:

- specimens collected from offshore gear, grouped by transect (Table 7),
- specimens collected by hand in shallow water by divers or from the shallow subtidal/intertidal zone (Table 8), and
- specimens collected by plankton net or dip net in the water column (Table 9).

A total of 166 operational taxon units (OTUs) were identified from 14 phyla from offshore deployments, with the largest number of specimens collected from the Macauley Island transect (Table 7).

A total of 311 invertebrate lots were collected in shallow water by divers or by hand from the shallow subtidal/intertidal zone representing 88 OTUs from 10 phyla (Table 8).

A total of 41 invertebrate lots were catalogued from plankton net or dip net deployments on the voyage (refer to Section 3.9 Plankton Sampling). Table 9 outlines the total number of samples from each transect, and the 15 taxa provisionally identified from them.

Invertebrates from the various sampling gears were sorted to the lowest level possible onboard, however many lots contain mixed species, so the collections will yield a larger number of species upon post-voyage identification by taxonomic experts.

Invertebrate specimens from the shallow coastal and deep water transects have been preserved in ethanol, formalin or frozen as appropriate for the taxon group, and catalogued into the NIWA Invertebrate Collection (NIC) and Auckland War Memorial Museum Marine Collections (AIM). Following taxonomic identification by experts voucher specimens of all invertebrate taxa will be split equally between NIC and AIM. These samples represent exciting new collections for both NIC and AIM, which are lacking comprehensive samples collected from shallow and deep waters respectively in this region.

Table 7: List of taxa and number of specimens collected from deep-sea gear (epibenthic sled, fishtrap, midwater and bottom trawl, mesopelagic trawl and beam trawl).

Phylum	Class	Order	Taxon name	Raoul Island	Macauley Island	L'Esperance	Star of Bengal Bank	Total
			Invertebrata (encrusting mixed species on rocks)	195	1	1		**197**
Annelida			Annelida			1		**1**
	Oligochaeta	Euhirudinea	Hirudinidae		1			**1**
	Polychaeta		Polychaeta	62	99	6		**167**
		Phyllodocida	Polynoidae	3				**3**
		Sabellida	Serpulidae	3		30		**33**
		Spionida	?Chaetopteridae			40		**40**
Arthropoda			Crustacea			2		**2**
	Malacostraca	Amphipoda	Amphipoda	19	6			**25**
			Hyperiidae	15	12	6		**33**
			Phronima	6	23			**29**
		Decapoda	?*Systellaspis*	1				**1**
			Acanthephyra			3		**3**
			Alpheidae		6			**6**
			Aristeus			1		**1**
			Brachyura	3	60	17	1	**81**
			Caridea	1				**1**
			Decapoda	108	293	19		**420**
			Galatheoidea	28	50	24	1	**112**
			Glyphocrangonidae	1				**1**
			Haliporoides sibogae	8				**8**

Phylum	Class	Order	Taxon name	Raoul Island	Macauley Island	L'Esperance	Star of Bengal Bank	Total
			Lyreidus			1		**1**
			Majidae		1			**1**
			Notostomus			1		**1**
			Notostomus auriculatus		1			**1**
			Oplophorus		10	13		**23**
			Oplophorus spinosus			10		**10**
			Paguridae		28			**28**
			Paguroidea	23	19	15		**57**
			Pilumnidae		1			**1**
			Platymaia maoria	1				**1**
			Polycheles		1			**1**
			Polychelidae	12	2			**14**
			Scyllaridae		1			**1**
			Sergestes	23	28	12		**63**
			Systellaspis		4			**4**
			Systellaspis debilis	1				**1**
			Xanthidae		30			**30**
		Euphausiacea	Euphausiacea	3	370	55		**428**
		Isopoda	Aegidae		1			**1**
			Isopoda	1				**1**
		Lophogastrida (Mysidacea)	*Gnathophausia ingens*			4		**4**
			Lophogastrida (Mysidacea)	1	4	3		**8**
		Stomatopoda	Stomatopoda		6			**6**

Phylum	Class	Order	Taxon name	Raoul Island	Macauley Island	L'Esperance	Star of Bengal Bank	Total
			Cirripedia	2	46	25	5	**78**
			Copepoda		1			**1**
	Ostracoda		Ostracoda	1				**1**
	Pycnogonida		Pycnogonida		2			**2**
Brachiopoda			Brachiopoda	3	18	2		**23**
Bryozoa			Bryozoa	3	98	7	1	**109**
			Bryozoa multiple		9			**9**
	Gymnolaemata	Cheilostomata	*Steginoporella*		5			**5**
Chaetognatha			Chaetognatha	1				**1**
Chordata	Ascidiacea [Tunicates]		Ascidiacea [Tunicates]		9	5		**14**
	Thaliacea [Salps]		Thaliacea [Salps]	82	149	29	4	**264**
		Pyrosomida	?*Pyrosoma*		9			**9**
			Pyrosoma		1	1		**2**
		Salpida	Salpidae		3			**3**
Cnidaria			Cnidaria	1				**1**
	Anthozoa	Actiniaria	Actinernidae		5			**5**
			Actiniaria	4	6	1		**11**
		Alcyonacea	Acanthogorgiidae	2	55			**57**
			Alcyonacea		26	15		**41**
			Alcyoniidae		1	1		**2**
			Anthomastus		1	1		**2**
			Chrysogorgia		2			**2**
			Chrysogorgiidae	2	4	3		**9**
			Coralliidae		3		1	**4**

Phylum	Class	Order	Taxon name	Raoul Island	Macauley Island	L'Esperance	Star of Bengal Bank	Total
			Ellisellidae		10			**10**
			Isididae	4	4	1		**9**
			Metallogorgia	1	3			**4**
			Plexauridae	7	40	21	5	**73**
			Primnoidae	3	8	1	3	**15**
			Radicipes	1				**1**
		Antipatharia	Antipatharia	14	203	8	8	**233**
			Bathypathes		2			**2**
		Corallimorpharia	?Corallimorpharia				1	**1**
		Gorgonacea (Alcyonacea undet.)	Gorgonacea	1	8		1	**10**
		Pennatulacea	Pennatulacea		6			**6**
		Scleractinia	?Caryophylliidae		1			**1**
			?Fungiidae		1	8		**9**
			Caryophylliidae	4	1			**5**
			Flabellidae	1				**1**
			Flabellum	1	1			**2**
			Madrepora oculata	3				**3**
			Scleractinia	10	108	20		**138**
			Stephanocyathus		1			**1**
		Zoantharia	Epizoanthidae		2			**2**
			Epizoanthus	25				**25**
			Epizoanthus paguriphilus	9				**9**
			Zoantharia		1			**1**

Phylum	Class	Order	Taxon name	Raoul Island	Macauley Island	L'Esperance	Star of Bengal Bank	Total
	Hydrozoa		Hydrozoa	6	75	10	1	**92**
		Anthoathecata	Stylasteridae	6	38	2	1	**47**
	Scyphozoa		Scyphozoa	3	15	36		**54**
		Coronatae	*Atolla*	11				**11**
Ctenophora			?Ctenophora	2				**2**
Echinodermata	Asteroidea		Asteroidea	21	7	4		**32**
		Brisingida	?Brisingidae	1				**1**
			Brisingida		5			**5**
		Notomyotida	Benthopecten	3				**3**
		Paxillosida	Astropectinidae		1			**1**
			Luidia		1			**1**
		Spinulosida	*Henricia*			1		**1**
		Valvatida	Asterinidae		6			**6**
			Lithosoma		1			**1**
	Crinoidea		Crinoidea	2	12	4	1	**19**
		Isocrinida	Isocrinidae		6			**6**
	Echinoidea		Echinoidea	43	12	6		**61**
		Cidaroida	?*Phyllacanthus*			2		**2**
		Clypeasteroida	Clypeasteroida		11	1		**12**
		Diadematoida	Diadematidae		1			**1**
		Echinothurioida	Echinothurioida	49	1		1	**51**
	Holothuroidea		Holothuroidea	135	12			**147**
	Holothuroidea (Class)	Elasipodida	?*Benthodytes*		1			**1**
			Benthodytes		1			**1**

Phylum	Class	Order	Taxon name	Raoul Island	Macauley Island	L'Esperance	Star of Bengal Bank	Total
	Ophiuroidea		Ophiuroidea	491	139	49	4	**683**
		Euryalida	*Asteroporpa* *Asteroporpa australiensis*				1	**1**
			Euryalida		2			**2**
		Ophiurida	*Ophiernus vallincola*		5			**5**
			Ophiochitonidae			2		**2**
			Ophiomyxidae		1			**1**
			Ophiophycis			1		**1**
			Ophiopsammus assimilis		1			**1**
			Ophiothrix *Acanthophiothrix lepidus*		58	3		**61**
			Ophiurida		19			**20**
Hemichordata			Hemichordata		2			**2**
Mollusca			?Mollusca			1		**1**
			Mollusca	7	7	1		**15**
			Mollusca multiple		16			**16**
	Bivalvia		Bivalvia	26	92	29	2	**149**
	Cephalopoda		Cephalopoda	1				**1**
		Myopsida	*Sepioteuthis*		2			**2**
		Octopoda	Argonautidae	1				**1**
			Octopoda		4			**4**
		Oegopsida	?*Todarodes*	3				**3**
			Cranchiidae	2	3	1		**6**
			Histioteuthidae			4		**4**
			Histioteuthis		3			**3**

Phylum	Class	Order	Taxon name	Raoul Island	Macauley Island	L'Esperance	Star of Bengal Bank	Total
			Nototodarus		4			**4**
			Todarodes	1				**1**
		Sepiida	Sepiidae		4			**4**
			Spirula spirula		2	1		**3**
		Teuthida	Teuthida	56	39	46		**141**
	Gastropoda		Gastropoda	4	44	13	2	**63**
	Gastropoda Caenogastropoda	Littorinimorpha	Ranellidae			1		**1**
	Gastropoda Opisthobranchia	Cephalaspidea	Cephalaspidea		1			**1**
			Philine	3				**3**
		Nudibranchia	Nudibranchia			1		**1**
		Thecosomata	Thecosomata (pteropods)	4	9	41		**54**
	Gastropoda Prosobranchia	Mesogastropoda	Siliquariidae		5			**5**
		Neogastropoda	Conidae	1				**1**
	Scaphopoda		Scaphopoda	1		2		**3**
	Solenogastres		*Solenogastres*		1			**1**
Platyhelminthes			Platyhelminthes		2			**2**
Porifera			Porifera	23	58	26	12	**119**
	Demospongiae		Demospongiae		24			**24**
		Hadromerida	*Tethya*			1		**1**
		Lithistid Demospongiae	Lithistid Demospongiae	2				**2**
	Hexactinellida		Hexactinellida	2	3			**5**
		Amphidiscosida	Amphidiscosida		2			**2**

Phylum	Class	Order	Taxon name	Raoul Island	Macauley Island	L'Esperance	Star of Bengal Bank	Total
		Hexactinosida	*Auloplax*		1			**1**
			Farreidae		11	2		**13**
			Lefroyella		1			**1**
		Lyssacinosida	Euplectellidae		7			**7**
Sipuncula			Sipuncula		2	2		**4**
Total				**1613**	**2690**	**706**	**56**	**5065**

Table 8: List of taxa and number of specimens collected by divers using SCUBA or by hand at Raoul, Meyer, Havre, Macauley and L'Esperance.

Phylum	Class	Order	Taxon Name	Raoul (SCUBA)	Meyer (Hand)	Meyer (SCUBA)	Macauley (SCUBA)	Havre (SCUBA)	L'Esperance (SCUBA)	Total
			Invertebrata (mixed encrusting fauna on rocks)	4		176		1		**181**
Annelida	Polychaeta		Polychaeta	9	5	17	1	10	1	**43**
		Sabellida	Serpulidae					2		**2**
Arthropoda	Malacostraca	Amphipoda	Amphipoda			16	3	100	1	**120**
			Caprellidae			1		5		**6**
		Decapoda	Alpheidae			3		20		**23**
			Brachyura	1		8	6		2	**17**
			Decapoda			8	109		66	**183**
			Diogenidae	1						**1**
			Grapsidae					2		**2**
			Lysmata					1		**1**
			Majidae	3				1		**4**
			Paguroidea	6		5	5	10	17	**43**
			Pilumnidae	1						**1**
			Porcellanidae	2						**2**
			Stenopus	1		2				**3**
			Trapezia	1						**1**
			Xanthidae	2						**2**
		Tanaidacea	Tanaidacea	2		2				**4**
	Maxillopoda		Cirripedia		16			5	2	**23**
		Sessilia	*Megabalanus*					3		**3**

Phylum	Class	Order	Taxon Name	Raoul (SCUBA)	Meyer (Hand)	Meyer (SCUBA)	Macauley (SCUBA)	Havre (SCUBA)	L'Esperance (SCUBA)	Total
Bryozoa			Bryozoa			2		10	1	**13**
Chordata	Ascidiacea [Tunicates]		Ascidiacea [Tunicates]	7		6	8	2		**23**
		Pleurogona Stolidobranchia	*Pyura*				2			**2**
	Thaliacea [Salps]		Thaliacea [Salps]	1						**1**
Cnidaria	Anthozoa	Actiniaria	*Actinia tenebrosa*		10					**10**
			Actiniaria	5	19	10	1	6	6	**47**
		Alcyonacea	Alcyonacea	1		3				**4**
			Clavulariidae						1	**1**
		Corallimorpharia	Corynactis	20						**20**
		Gorgonacea (now Alcyonacea))	Gorgonacea	2						**2**
		Scleractinia	*Astrea curta*	5		10	2			**17**
			Goniastrea favulus	6		2	3			**11**
			Hydnophora pilosa	17		4	2			**23**
			Montipora capricornis	4		1	1			**6**
			Montipora spongoides	8		2	2			**12**
			Pocillopora				1			**1**
			Pocillopora damnicornis	9		5	39			**53**
			Scleractinia			8	5			**13**
			Turbinaria frondens	13		1	7			**21**
			Unknown sp. 1	7			24		9	**40**

Phylum	Class	Order	Taxon Name	Raoul (SCUBA)	Meyer (Hand)	Meyer (SCUBA)	Macauley (SCUBA)	Havre (SCUBA)	L'Esperance (SCUBA)	Total
			Unknown sp. 2	1			2			**3**
			Unknown sp. 3	3		2	2			**7**
			Unknown sp. 4				2			**2**
		Zoantharia	Zoantharia		12		4			**16**
	Hydrozoa		Hydrozoa			1	2	11		**14**
	Scyphozoa	Stauromedusae	Stauromedusae				1			**1**
Echinodermata	Asteroidea		Asteroidea			5				**5**
		Forcipulatida	*Astrostole*						2	**2**
			Astrostole rodolphi	2		5	1			**8**
		Valvatida	*Acanthaster planci*	3			14			**17**
			Asterinidae				6	1		**7**
			Leiaster	1		1				**2**
			Leiaster speciosus					1		**1**
			Patiriella				60			**60**
			Petricia	2				1		**3**
	Echinoidea		Echinoidea			1				**1**
		Camarodonta	*Echinometra mathaei*		1					**1**
			Heliocidaris tuberculata	1		39	53	5	27	**125**
			Tripneustes gratilla				51	5	9	**65**
		Cidaroida	*Phyllacanthus parvispinus*	28		4	32	1	1	**66**
		Diadematoida	*Centrostephanus rodgersii*				50	40	51	**141**

Phylum	Class	Order	Taxon Name	Raoul (SCUBA)	Meyer (Hand)	Meyer (SCUBA)	Macauley (SCUBA)	Havre (SCUBA)	L'Esperance (SCUBA)	Total
			Diadema	3						**3**
			Diadema palmeri			2				**2**
	Ophiuroidea		Ophiuroidea			1	7			**8**
		Ophiurida	*Clarkcoma bollonsi*					1		**1**
			Ophionereididae			3				**3**
			Ophionereis	1						**1**
			Ophiotrichidae	2						**2**
			Ophiurida					3		**3**
Mollusca			Mollusca	2	2		5	6		**15**
	Bivalvia	Mytiloida	*Modiolus areolatus*		4					**4**
			Mytilidae		3					**3**
		Ostreoida	*Ostrea*		3					**3**
	Gastropoda		Gastropoda	21	2	3	9	30	4	**69**
		Aplysioidea	Aplysioidea			1	2			**3**
	Gastropoda Neritimorpha	Cycloneritimorpha	*Nerita*		10					**10**
	Gastropoda Opisthobranchia	Anaspidea	Aplysiidae			2				**2**
		Notaspidea	Pleurobranchidae			1			3	**4**
		Nudibranchia	Nudibranchia			4	1			**5**
	Gastropoda Patellogastropoda	Patellogastropoda order unassigned	*Scutellastra kermadecensis*		4		34			**38**
	Gastropoda Prosobranchia	Neogastropoda	Conidae	4						**4**
			Muricidae		4					**4**

Phylum	Class	Order	Taxon Name	Raoul (SCUBA)	Meyer (Hand)	Meyer (SCUBA)	Macauley (SCUBA)	Havre (SCUBA)	L'Esperance (SCUBA)	Total
		Vetigastropoda	Trochidae	1			1			**2**
	Polyplacophora		Polyplacophora	2		2		3	3	**10**
Nemertea			Nemertea	1						**1**
Porifera			Porifera	3		2	1	6		**12**
Sipuncula			Sipuncula		19		2			**21**
Total				**219**	**114**	**371**	**563**	**292**	**206**	**1765**

Table 9: List of taxa and number of specimens collected by plankton net sampling.

Phylum	Class	Order	Taxon name	Raoul	Macauley	L'Esperance	Star of Bengal	Total
Annelida	Polychaeta		Polychaeta	1				**1**
Arthropoda	Malacostraca	Decapoda	Brachyura	2				**2**
			Decapoda	2				**2**
		Isopoda	Isopoda	1				**1**
	Maxillopoda		Copepoda	2				**2**
Chaetognatha			Chaetognatha	2				**2**
Chordata	Thaliacea [Salps]		Thaliacea [Salps]	3				**3**
Cnidaria	Scyphozoa		Scyphozoa	2				**2**
Ctenophora			Ctenophora	1				**1**
Echinodermata	Holothuroidea		Holothuroidea	1				**1**
Foraminifera			Foraminifera	1				**1**
Mollusca	Cephalopoda	Oegopsida	Cranchiidae	1				**1**
	Gastropoda Opisthobranchia	Nudibranchia	*Glaucus atlanticus*	1				**1**
			Nudibranchia	1				**1**
		Thecosomata (pteropods)	Thecosomata (pteropods)	1	1			**2**
Sipuncula			Sipuncula			1		**1**
Zooplankton			General Zooplankton sample	8	3	4	2	**17**
Total				**30**	**4**	**5**	**2**	**41**

Algae

Thirty nine lots of algae were collected from Havre Rock, Raoul Island and its surrounding islets, Macauley Island and L'Esperance Rock between the surface and 160 m depth. A summary table of the number of specimens collected from each station is given below (Table 10).

Table 10: Total number of algae specimens, depth and gear method used to collect them

Station	Taxon	No. of specimens	Place name	Depth (m)	Gear
1	Mixed algae spp.	21	Havre Rock	0–25	Diver with SCUBA
9	Algae	1	Northern side North Meyer Island	0–30	Diver with SCUBA
16	Coralline algae	2	Raoul Island Transect (50-250 m site)	117–160	Sled, epibenthic
19	*Sargassum* (drift)	1	Raoul Island	surface	surface scoop net
20	*Codium*	3	North of Napier Island	0–30	Diver with SCUBA
32	Mixed algae spp.	4	Meyer Islands	0–5	Collected by hand
37	Mixed algae spp.	28	NW side of North Meyer Island	0–16	Diver with SCUBA
48	Mixed algae spp.	4	Boat Cove, Raoul Island	0–9	Diver with SCUBA
66	Mixed algae spp.	7	Off Annexation Point, Macauley Island	0–24	Diver with SCUBA
77	Mixed algae spp.	15	Macauley Island Transect	72–101	Trawl, beam
73	Algae sp.	1	NE coast Macauley Island	0–28	Diver with SCUBA
84	Mixed algae spp.	43	Off SE coast, SW of Haszard Islet, Macauley Island	0–21	Diver with SCUBA
97	Mixed algae spp. (incl. rhodoliths)	2	Maculey Island Transect	125–136	Sled, epibenthic
106	Mixed algae spp. (incl. rhodoliths)	14	L'Esperance Rock Transect	90–109	Sled, epibenthic
111	*Sargassum*	1	NE side of L'Esperance Rock	0–31	Diver with SCUBA
128	Mixed algae spp. (including rhodoliths)	230	L'Esperance Rock	97–97	Sled, epibenthic

Fishes

Offshore collections of fish specimens were made using line fishing, epibenthic sled, beam trawl, mesopelagic trawl, midwater trawl, bottom trawl and fish trap. There were a total of 56 stations using these methods, and fishes were collected in 38 (68%) of these. All of these methods collected fishes but only the mesopelagic and midwater/bottom trawls collected fishes at each deployment.

A total of 2033 specimens in 737 specimen lots were collected consisting of 236 taxa in 97 families (Table 11). An additional 390 specimens in 17 lots representing 14 species were transferred to Dr Kendall Clements, University of Auckland (271 specimens from the family Myctophidae) and Dr Libby Liggins, Massey University (119 specimens of *Chromis abyssicola*). Most specimens were identified to species, although some remain identified only to genus or family until further examination is made following the voyage.

Muscle tissue subsamples were preserved in 100% ethanol from almost all species collected. A total of 398 tissue samples were retained representing 176 species. These have been deposited principally at Te Papa Tongarewa with a smaller subset of 52 tissues deposited at the Auckland Museum.

Photographs were captured of 215 freshly collected specimens representing 141 species (a total of 1045 images). These images are archived at Te Papa Tongarewa with copies of images of Auckland Museum specimens deposited at Auckland Museum.

Table 11: Summary of fishes collected. For each family or subfamily the number of taxa, new records for the Kermadec Ridge (KR) and the EEZ (NZ), probable new species to be described, and the number of species recorded in each depth stratum is recorded. Collections using the midwater sampling methods of mesopelagic and midwater trawls assume capture from 100 to 1000 m depth and 100 to 2000 m depth, respectively.

					Benthic Sampling							Midwater sampling	
Family/Subfamily	No. taxa	New record, KR	New record, NZ	New species	<50 m	50–250 m	250–750 m	750–1250 m	1250–1750 m	1750–2250 m	2250–2750 m	100–1000 m	100–2000 m
Scyliorhinidae	2	1					2						
Triakidae	1					1							
Squalidae	2					1	1						
Dalatiidae	1	1					1						
Etmopteridae	1	1					1						
Somniosidae	2	2						1					1
Chlopsidae	1	1					1						
Muraenidae	1					1							
Nettastomatidae	1									1			
Congridae	1	1				1							
Synaphobranchidae	3	1					1	2	1	1			
Serrovomeridae	1											1	1
Nemichthyidae	5	1										3	4
Eurypharyngidae	1	1											1
Cyematidae	1	1											1
Halosauridae	1	1								1			
Argentinidae	1											1	
Bathylagidae	2	1	1							1			2
Opisthoproctidae	1	1								1			
Microstomatidae	1	1										1	
Gonostomatidae	10	2	1									6	7
Photichthyidae	3											3	2
Sternoptychidae	11	1	1				1	1	1			9	7
Melanostomiinae	10	3	1									9	3
Malacosteinae	1											1	1
Chauliodontinae	1											1	1

Family/Subfamily	No. taxa	New record, KR	New record, NZ	New species	Benthic Sampling							Midwater sampling	
					<50 m	50–250 m	250–750 m	750–1250 m	1250–1750 m	1750–2250 m	2250–2750 m	100–1000 m	100–2000 m
Stomiinae	1							1		1		1	1
Idiacanthinae	1											1	1
Alepocephalidae	5	1	3							2			3
Aulopidae	1					1							
Synodontidae	2		1			2							
Neoscopelidae	2	2					2						
Myctophidae	41	4	2				1	1	2	1		29	19
Ipnopidae	1							1					
Notosudidae	3											2	1
Paralepididae	4	2										3	2
Omosudidae	1												1
Scopelarchidae	2	1											2
Rondeletiidae	1	1											1
Gobiesocidae	1				1								
Chaunacidae	4	2	1				2	1	1	1			
Ogcocephalidae	1						1						
Melanocetidae	1												1
Oneirodidae	1	1											1
Ceratiidae	2	1											2
Linophrynidae	2		1									1	1
Moridae	5	1				1	2	1				2	
Melanonidae	2	1								1		1	2
Ophidiidae	1	1				1							
Carapidae	1												1
Macrouridae	12	7					3	8	1	1			2
Bathygadidae	2								2				
Scomberesocidae	1						1						
Stephanoberycidae	1	1								1			
Melamphaidae	7	2										3	7
Diretmidae	1											1	
Trachichthyidae	3	1				2	1					1	

					Benthic Sampling							Midwater sampling	
Family/Subfamily	**No. taxa**	**New record, KR**	**New record, NZ**	**New species**	**<50 m**	**50–250 m**	**250–750 m**	**750–1250 m**	**1250–1750 m**	**1750–2250 m**	**2250–2750 m**	**100–1000 m**	**100–2000 m**
Anoplogastridae	1											1	1
Berycidae	1					1	1						
Bramidae	1		1										1
Monocentridae	1					1							
Holocentridae	1					1							
Zeniontidae	1					1							
Zeidae	1	1				1							
Oreosomatidae	1	1							1				
Macroramphosidae	1					1							
Syngnathidae	1		1	1		1							
Sebastidae	1						1						
Scorpaenidae	6		1	1		6	1						
Setarchidae	1												1
Tetrarogidae	1					1							
Plectrogenium	1						1						
Triglidae	2					2							
Polyprionidae	1						1						
Serranidae	3		1	1		2	1						
Callanthiidae	1					1							
Epigonidae	1											1	
Acropomatidae	1	1				1							
Carangidae	2				1	1							
Emmelichthyidae	1		1			1							
Lutjanidae	1					1							
Mullidae	1					1							
Microcanthidae	1					1							
Chaetodontidae	1					1							
Pomacentridae	2				1	1							
Cheilodactylidae	1					1							
Opisthognathidae	1					1							
Labridae	2					2							

					Benthic Sampling							Midwater sampling	
Family/Subfamily	**No. taxa**	**New record, KR**	**New record, NZ**	**New species**	**<50 m**	**50–250 m**	**250–750 m**	**750–1250 m**	**1250–1750 m**	**1750–2250 m**	**2250–2750 m**	**100–1000 m**	**100–2000 m**
Pinguipedidae	1	1				1							
Uranoscopidae	1		1			1							
Chiasmodontidae	4	4								1		2	2
Callionymidae	1					1							
Gempylidae	3		2			2						1	1
Trichuridae	1	1										1	
Nomeidae	1					1						1	1
Soleidae	1				1								
Monacanthidae	3				1	3							
Ostraciidae	1	1				1							
Tetraodontidae	2					2							1
Totals	**240**	**60**	**20**	**3**	**5**	**54**	**27**	**17**	**9**	**14**	**0**	**87**	**87**

A small selection of rocks, mainly pumice, were saved from various stations along the Raoul, Macauley and L'Esperance transects and were deposited at NIWA, Auckland Museum and Te Papa Tongarewa.

3.5 Notes on selected taxa

Fishes

Prior to this voyage, 479 species in 120 families were known from the northern Kermadec Ridge area (Duffy & Ahyong 2015). Of the species collected during this voyage, 80 were new records of fish species for the Kermadec Ridge, of which 20 were new records for the EEZ. Nearly every fish specimen caught was retained into the collection of either the Museum of New Zealand or the Auckland Museum: a total of 1000 specimens in 405 lots have been registered into the Museum of New Zealand National Fish Collection and 1039 specimens in 333 lots into the Auckland Museum. Specimens of species that are well represented in collections and were collected by rod and line or in fish traps were released alive.

The 60 species that are new records for the Kermadec Ridge are northern range extensions of species that occur around mainland New Zealand (Roberts et al. 2015). These include the kitefin shark (Dalatiidae), lanternshark (*Etmopterus* sp.), six species of lantern fishes (Myctophidae), a redmouth whalefish (*Rondeletia* sp.), two species of coffin fishes (Chaunacidae), a prickly anglerfish (*Ceratias* sp.), eight species of rattails (Macrouridae), two species of roughies (Trachichthyidae), an oreo (*Allocyttus* sp.), a splitfin (*Synagrops* sp.), a sandperch (*Parapercis* sp.), four species of swallowers (Chiasmodontidae), and a box fish (*Kentacapros* sp.)

Twenty species are new records for New Zealand, and several were known just outside of the EEZ prior to this voyage and were assumed to also occur in NZ waters. Species that are now confirmed from the EEZ include three species of slickheads (Alepocephalidae), a lizard fish (*Synodus* sp.), two species of lantern fish (Myctophidae), a recently-described coffin fish (Chaunacidae), a deep-sea angler (*Linophryne* sp.), a redbait (*Emmelichthys* sp.), a stargazer (*Uranoscopus* sp.) and a gemfish (*Diplospinus* sp.)

A number of taxa were collected that may represent new species: the first seahorse to be recorded from the area (*Hippocampus* sp.), a scorpion fish (*Scorpaena* sp.), an anthiine perch (*Plectranthias* sp.). These will undergo further analysis to determine their status and, if new, described in the peer-reviewed literature.

Several species that were considered rare from the area were collected, some in large numbers. An undescribed species of Kermadec smooth hound, *Mustelus* sp., was known from only five specimens; we collected an additional five specimens that are now available to more fully characterise and describe the species. The putative new species of carpet shark *Cephaloscyllium* cf. *variegatum* was observed with DTIS on the Star of Bengal Bank, and two mature males were caught in the last fish trap deployment. There is only one record of false morays (Chlopsidae) in New Zealand, and this is based on a larva; we collected the first non-larval specimen. The bobtail snipe eel, *Cyema atrum*, is the deepest known-pelagic eel and was known in New Zealand only from the larval stage; we collected the first adult specimen to be collected in New Zealand waters. Also collected was the first voucher material to be deposited in New Zealand collections of the waspfish, *Ocosia apia* (Poss & Eschmeyer, 1975). A specimen of the Kermadec scaly gurnard, *Lepidotrigla robinsi*, was caught. This species was only known from the four specimens collected in 1973 to describe the species (Richards, 1997). Sixty-nine specimens of the pineapple fish, *Monocentris japonicus*, were collected at one site (Station 104); this nocturnal species is rarely found and usually only as single individuals.

Chondrichthyan distributions

The Galapagos shark, *Carcharhinus galapagensis*, was observed at all dive stations and a female about 1.5 m TL was taken in a bottom trawl in 112–120 m depth at Station 104 (returned alive to the water). Although a limited number of captures and observations of deep water sharks and rays were made

during the expedition, with the exception of *Squalus* spp., most taxa observed below 200 m depth represent new records for the northern Kermadec Ridge. The northern spiny dogfish (*Squalus griffini*) was distributed from Star of Bengal Bank to Raoul Island and occurred in similar numbers to Kermadec spiny dogfish (*Squalus raoulensis*) and Kermadec smoothhound (*Mustelus* n.sp.) at Macauley Island (Station 104). The Kermadec spiny dogfish and Kermadec smoothhound were not observed or collected south of Macauley Island, although *S. raoulensis* was collected off Curtis and Cheeseman Islands in 2011 (Trnski et al. 2015). *Cephaloscyllium* cf. *variegatum* has previously been reported from Star of Bengal Bank, Bay of Plenty and West Norfolk Ridge (Roberts et al. 2015). Further research is required to confirm if the specimens from Star of Bengal Bank are conspecific with those collected from these other locations. This species was not collected or observed further north than Star of Bengal Bank.

A single, large short tailed stingray, *Dasyatis brevicaudata*, was taken at Station 104 (returned alive to the water). This species has previously been recorded from Macauley and Raoul Islands but appears to be uncommon at the Kermadecs. Four skates (Rajidae 1 sp.; Arhynchobatidae 2 spp.) were observed on the DTIS at Raoul Island and L'Esperance Rock but as no specimens were collected, and no vouchers from the Kermadec Ridge are held in museum collections the identification of these species could not be confirmed.

No chimaeras (Chimaeridae, Rhinochimaeridae) were observed or caught during the expedition, suggesting that this group may be rare on the north Kermadec Ridge, or that the main sampling methods (DTIS, beam trawl) used in this survey do not sample these species well. Nominal records of dark ghost shark, *Hydrolagus novaezealandiae*, reported in fisheries data for the region require confirmation (Duffy & Ahyong 2015).

Gaps in fauna and collecting of fish species

Several families and subfamilies that were expected to be caught based on previous expeditions to the region were not taken. These included: the star eaters (Stomiidae, subfamily Astronesthinae), cucumberfishes (Paraulopidae), manefishes (Caristiidae) and gapers (Champsodontidae). Rattails (Macrouridae) were collected in small numbers and in low diversity.

The DTIS captured frequent images of a small, black benthic fish with large golden reflective eyes, possibly the black deepsea lizardfish, *Bathysauropsis gracilis*. Despite several sled and beam trawl deployments in the stratum, none were caught. Other taxa recorded only from DTIS included flatfishes, and several rattail species.

Rhodolith beds

Extensive rhodolith beds were observed and sampled at Macauley Island, L'Esperance Rock and Star of Bengal Bank. This is the first time that this habitat type has been reported from the northern Kermadec Ridge. DTIS imagery suggests that these can cover large areas of shallow seafloor to a depth of 150 m.

Ophiuroidea-brittle stars

The Ophiuroidea are ubiquitous in shallow and deepsea habitats, and on this survey were one of the most numerous invertebrate taxa collected. Ophiuroids were found at multiple depths across Raoul, Macauley, L'Esperance and Star of Bengal Bank transects. This survey has been valuable in extending knowledge of their known distributions. For example, a single specimen of *Ophiopsammus assimilis* (Bell, 1888) was collected from 125–136 m on the Macauley Island transect. This specimen (Figure 19) is strikingly patterned with small white and purple spots on the dorsal surface, and a strong banding pattern on the arms which has not been noted in other live specimens collected around the North of New Zealand. This specimen represents an extension of the known range for this species to the Kermadec Islands.

Figure 19: *Ophiopsammus assimilis* (Bell, 1888) collected from off Macauley Island.

Transitional communities

Several shallow reef taxa meet their northern or southern latitudinal limit across the islands of the Kermadec Archipelago. For several species we were able to sample these edge-of-range populations, in order to determine the likelihood of the species extending their ranges in future. For instance, reef building coral diversity drops dramatically from Macauley Island to L'Esperance Rock. Some elements of the shallow reef community remained surprisingly consistent throughout the archipelago despite the evident changes in coral and algal cover (from Raoul to Havre, respectively), in particular the three urchin species *Tripneustes gratilla*, *Centrostephanus rodgersii* and *Heliocidaris tuberculata*.

3.6 Specimen photographs

Many of the specimens caught were photographed soon after capture in order to record their natural colouration. Examples of some of these are given in Figures 20 and 21 for invertebrates and fishes respectively.

Figure 20: Specimen images. Clockwise from top left. Sieve pore of a *Regradrella* tubular hexactinellid sponge from Macauley Island at 1430 m; A pelagic nudibranch *Glaucus sp*. from a surface plankton tow off Raoul Island; *Histioteuthis spp*. squid from a meso-pelagic trawl to 1000 m off L'Esperance Rock; Shallow water Scleractinia (stony cup corals) from a cave off Annexation Point, Macauley Island at 24 m; An unidentified colourful echinoid from 72 m deep off Macauley Island; *Trapezia* sp. crab associated with the shallow water stony coral *Pocillopora damicornis* from Macauley Island; An extremely spiny ophiuroid, *Ophiothrix Acanthophiothrix lepidus* de Loriol, 1893, collected from 191 m off Macauley Island; Collection of 1 to 3 cm Rhodoliths from L'Esperance area in 97 m [Photos by Rob Stewart, Mary Sewell and Sadie Mills].

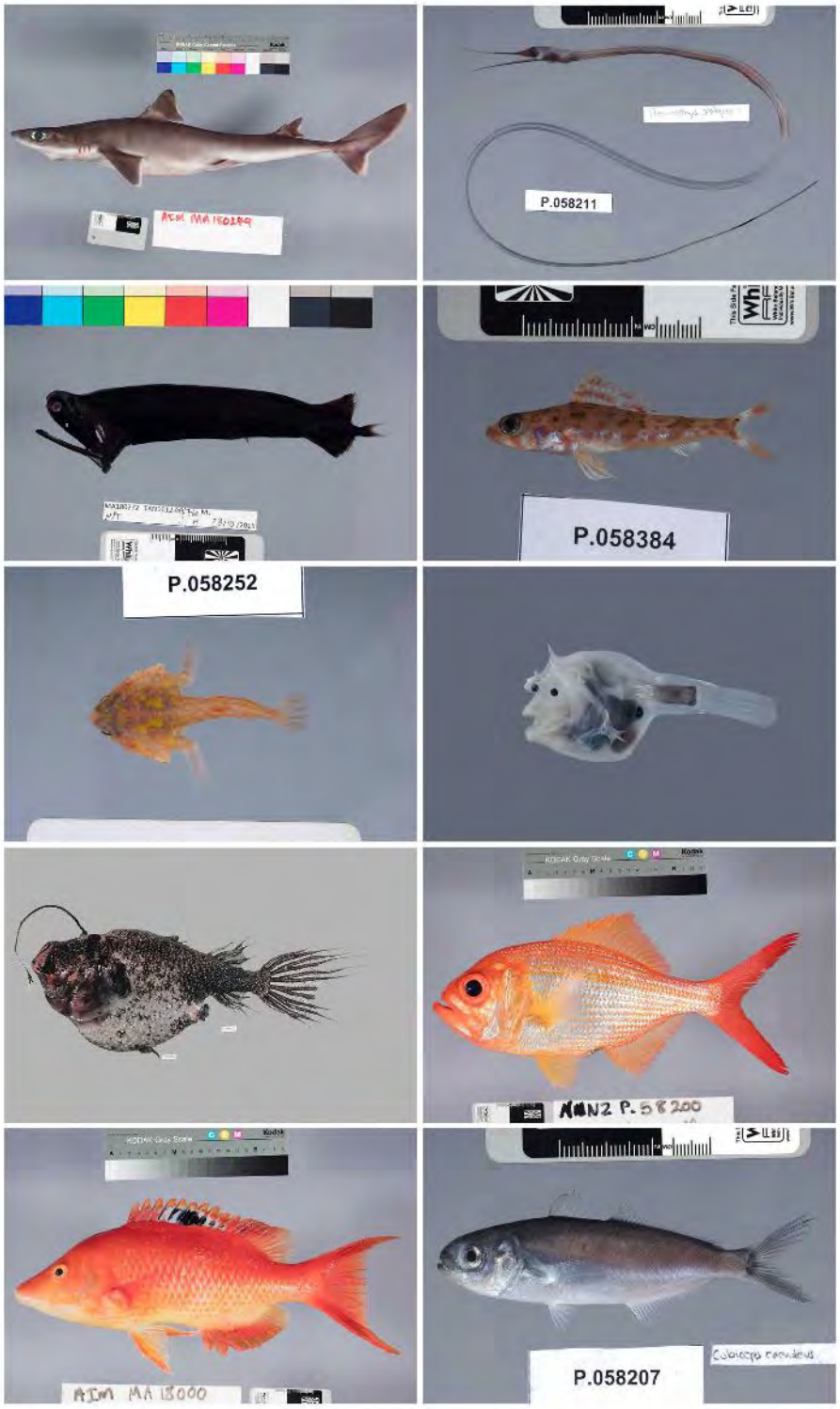


Figure 21: Examples of specimen photography of fishes caught during TAN1612. From top left to right: Kermadec spiny dogfish (*Squalus raoulensis*), stn 060, 260 m; Pale snipe eel (*Nemichthys scolopaceus*), stn 120, 150–1000 m; Southern stoplight loosejaw (*Malacosteus australis*), stn 069, 150–1000 m; Flaming flagfin (*Hime pyrhistion*), stn 077, 150 m; Arrowhead batfish (*Malthopsis parva*), stn 028, 500 m; Phantom angler (*Haplophryne mollis*), stn 081, 2000 m; Southern seadevil (*Ceratias tentaculatus*), stn 053, 150–2000 m; Golden snapper (*Centroberyx affinis*), stn 002, 180 m; Red pigfish (*Bodianus unimaculatus*), stn 007, 70 m; Blue cubehead (*Cubiceps caeruleus*), stn 018, 150–1000 m. (Photos: C. Struthers, NMNZ Te Papa Tongarewa).

3.7 Plankton sampling

A total of 24 zooplankton samples were collected (four transects, two depth stations, three replicates) and eight opportunistic samples (Stations 10, 11, 21, 22, 33, 34, 51, 65). Detailed quantification of the zooplankton community awaits analysis, but preliminary observations suggest that there is a diverse zooplankton community on the Kermadec Ridge including copepods, chaetognaths, appendicularians and pteropods. Larval forms identified in opportunistic tows or during preservation of samples include crab zoea, larval fish, molluscan trochophore, and metamorphosed sipuncula. The presence of large amounts of algal material in plankton samples collected from the Star of Bengal Bank was notable, as this had been absent at the other locations.

Surface plankton net samples were not sorted on board and will be analysed following the voyage. The Raoul Island transect channel net sample was taken at dawn in 2050–2070 m depth over 0.36 n miles (Station 056). This was dominated by pelagic nudibranchs *Glauca* and *Fiona* and also contained small preflexion stage fish larvae and copepods. The Macauley Island sample was taken at night in 129–133 m depth. This contained two *Physalia* and small invertebrate plankton. The Star of Bengal Bank sample was taken at night in 440–446 m depth and among the identifiable contents were larvae of the saury, *Scomberesox saurus*.

3.8 Environmental sampling

Only a single cast of the CTD-rosette was carried out, off Raoul Island. Eleven of the 12 bottles fired. Samples were collected at standard depths of 10, about 50–100 (the approximate depth of the mixed layer), 250, 750, 1000, 1100, 1200, 1300, 1400, 1500 and 2000 m. The 500 m sample was unsuccessful. Water samples were taken for alkalinity and dissolved inorganic carbon and will be worked up by NIWA as part of ongoing ocean acidification research.

Temperature, depth, and conductivity data were collected for every DTIS deployment. These data will be worked up separately, but exploratory analyses show general similarity in T-S plots between transects (Figure 22).

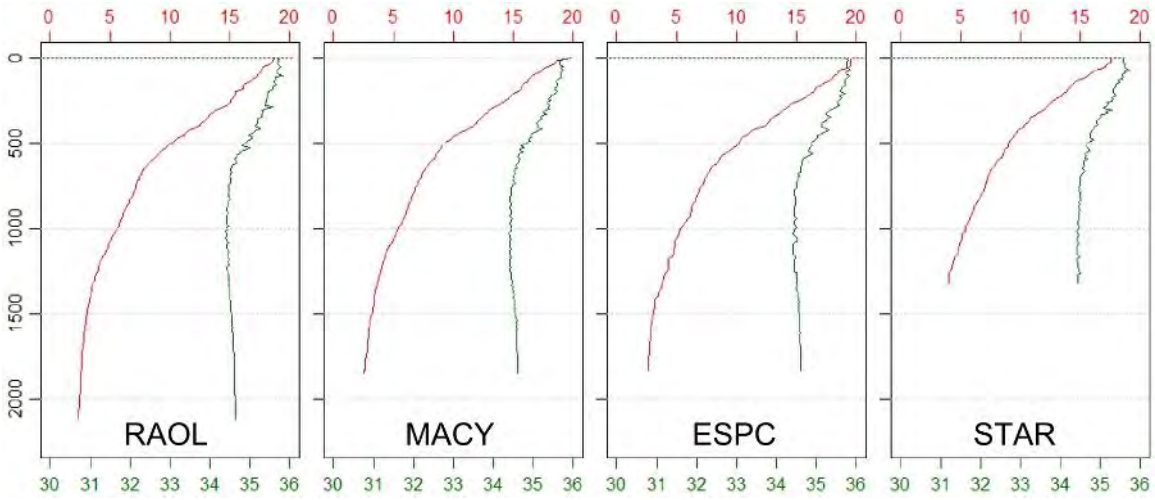


Figure 22: An example of temperature (top axis) – salinity (bottom axis) plots against depth for mid-depth stations from each transect (Raoul-Macauley-Esperance-Star of Bengal)

3.9 Marine mammal observations

Transit observations

There were 14 sightings of cetaceans during the ship transit from Auckland to Raoul Island including one group of striped dolphins (*Stenella coeruleoalba*), one sei whale (*Balaenoptera borealis*), two humpback whales, nine unidentified rorquals and one unidentified whale (Table 12). There were no sightings of cetaceans *en route* between the Kermadec Island groups, and one sighting of common dolphins *(Dephinus delphis*) on the return to Wellington south of East Cape (Figure 23).

Table 12: Cetacean sightings and species identity, where known, between Auckland and Raoul Island.

Date	Latitude	Longitude	Species
21-Oct-16	34.05017 S	176.8486 E	Striped dolphin
21-Oct-16	33.67083 S	177.2510 E	Rorqual
21-Oct-16	33.29467 S	177.6737 E	Rorqual
21-Oct-16	33.25850 S	177.7163 E	Rorqual
21-Oct-16	33.17750 S	177.8467 E	Rorqual
21-Oct-16	33.17750 S	177.8840 E	Rorqual
21-Oct-16	33.12973 S	177.9286 E	Rorqual
21-Oct-16	33.11233 S	177.9578 E	Sei whale
21-Oct-16	33.09183 S	177.9945 E	Rorqual
21-Oct-16	32.92753 S	178.3475 E	Rorqual
22-Oct-16	31.29883 S	178.9183 W	Humpback whale
22-Oct-16	30.66617 S	178.5052 W	Rorqual
22-Oct-16	30.65720 S	178.5019 W	Rorqual
22-Oct-16	30.63872 S	178.4958 W	Humpback whale, Common dolphin

Raoul and Macauley Island observations

A total of seven non-systematic surveys were conducted from the *Tangaroa*'s Work Boat, five at Raoul Island and two at Macauley Island, for a total of 28 hrs on-water (25:47 hrs at Raoul and 2:24 hrs at Macauley). Research was primarily focused on the north and west of the island where there were known aggregations of whales (Constantine 2016) (Figure 24). Data were collected on 48 groups of humpback whales with a cumulative total of 134 whales sighted including 26 mother-calf pairs (Figure 25, Table 13).

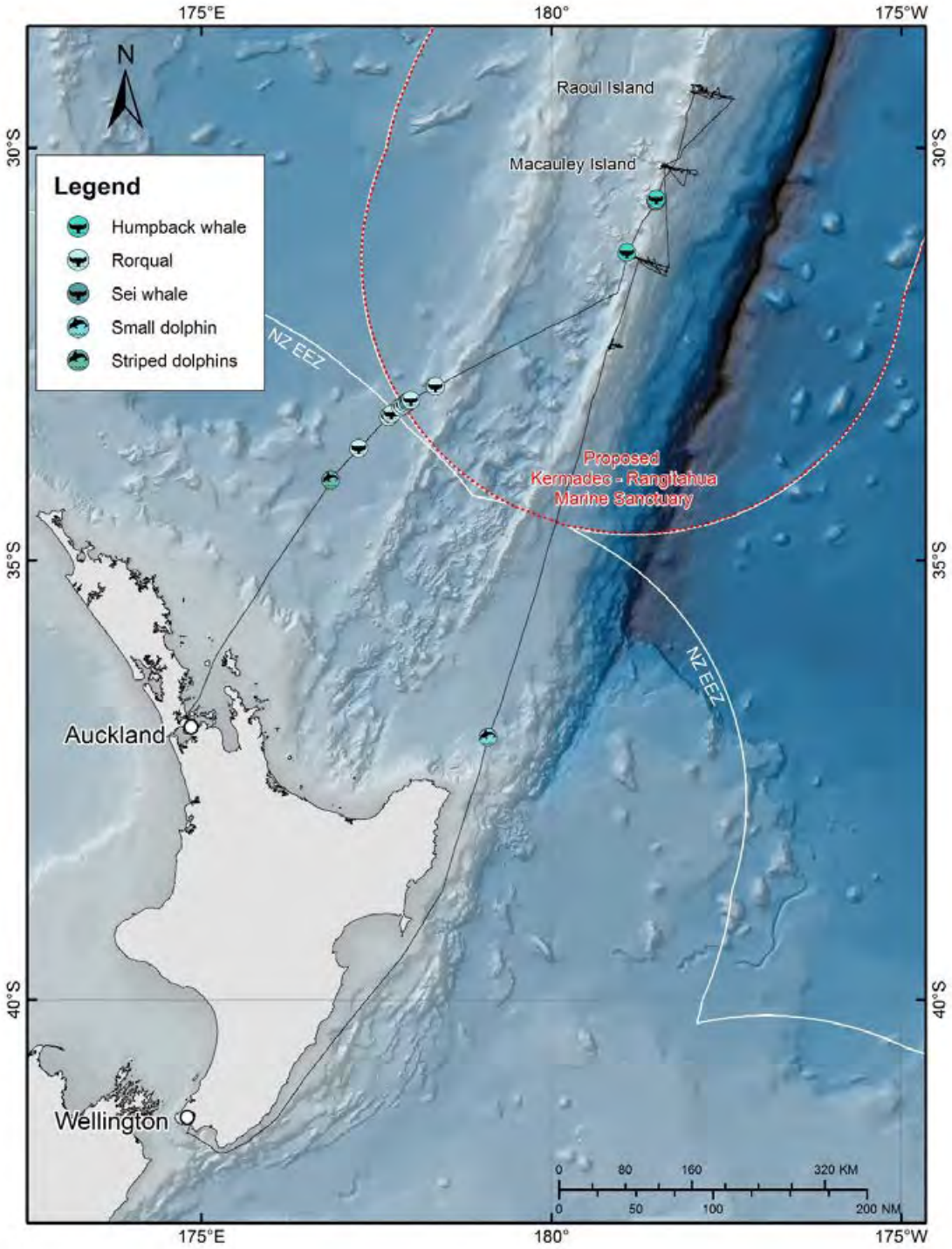


Figure 23: Distribution of marine mammal sightings in transit from Auckland to the Kermadec Islands, between the islands, and the return to Wellington.

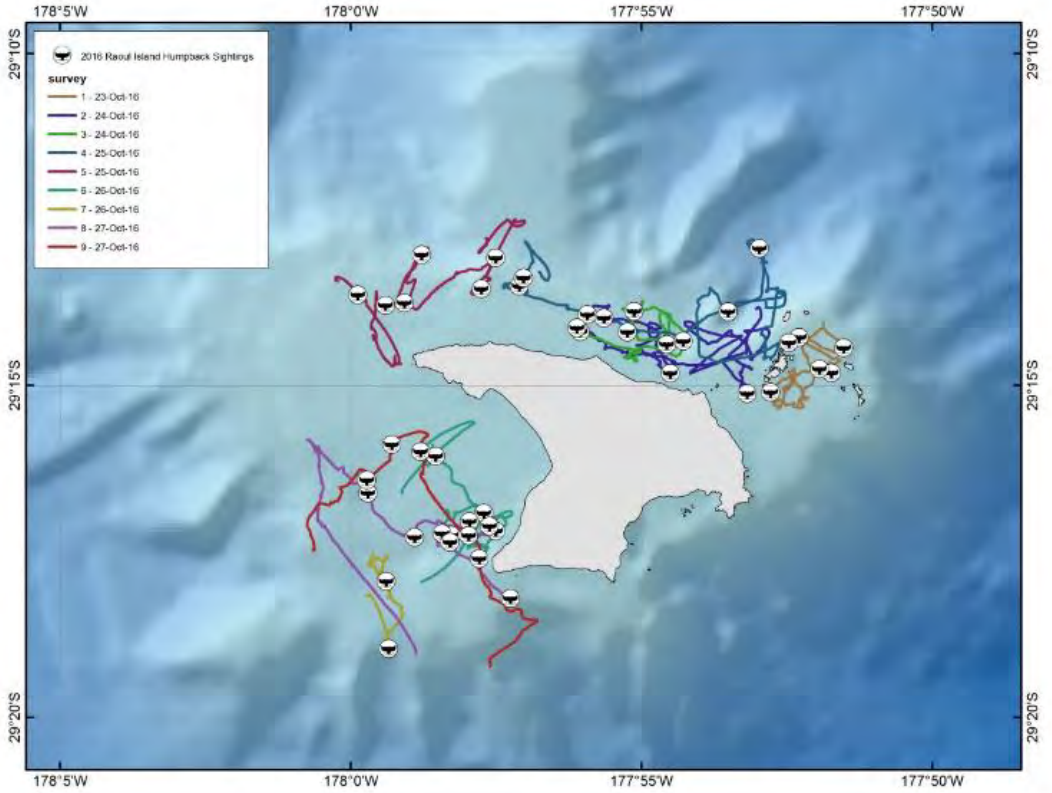


Figure 24: Map of the nine survey tracks from the Work Boat undertaken at Raoul Island. The location of humpback whale groups are denoted by the whale tail symbol.

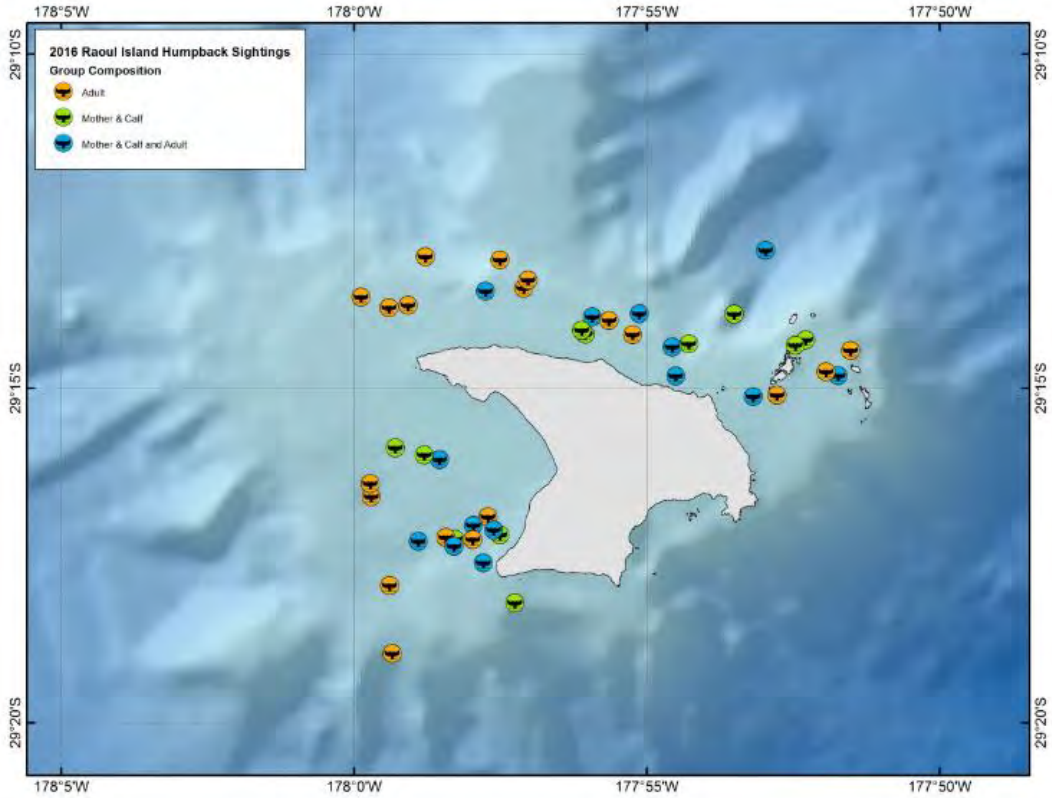


Figure 25: Location of humpback whale groups broken down by group composition at Raoul Island.

A total of 34 tissue samples were collected and 61 fluke identification photos from individual whales were added to the Kermadec Island catalogue (Appendix 2). There were five whales with both a tissue sample and fluke identification photo. Three whales were sighted on two separate days with a maximum of two days between sightings. No whales from Raoul Island were re-sighted at Macauley Island. Approximately 1.5 hours of whale song was recorded primarily from three recording events at Raoul Island and one at Macauley Island. All tissue samples, the photo-identification catalogue and acoustic recordings will be analysed further and matched to existing databases from Oceania, mainland New Zealand, Australia and Antarctica as part of the Southern Ocean Research Partnership collaborative project.

Data were collected from the small boat surveys on seven groups of bottlenose dolphins, five at Raoul Island, two at Macauley Island as well as one group of dolphins photographed from the RV *Tangaroa* at L'Esperance Rock. There were an estimated cumulative total of 134 dolphins (92 at Raoul and 42 at Macauley) including three calves and 15 juveniles. A total of seven tissue biopsy samples were taken and will be added to the two samples currently curated in the New Zealand Cetacean Tissue Archive. The photo-identification catalogue contains 71 individually identified bottlenose dolphins from the Kermadec Islands; 50 from Raoul Island, 19 from Macauley Island and two from L'Esperance. Preliminary analysis of dolphins photo-identified at Raoul Island has revealed matches to previous surveys conducted by the University of Auckland in August 2012 and September – October 2015.

Table 13: Summary of data collected during the small-boat surveys for humpback whale and bottlenose dolphins at Raoul and Macauley Islands, and L'Esperance Rock.

Whales	**No. Groups**	**Cumulative no. whales**	**Adults**	**Calves**	**Biopsy**	**Sloughed skin**	**No. Photo-ID**
Raoul Is.	45	126	94	26	23	9	49
Macauley Is.	3	8	6	2	n/a	2	12
Dolphins	**No. Groups**	**Cumulative no. dolphins**	**Adults**	**Calves/ Juveniles**	**Biopsy**	**Sloughed skin**	**No. Photo-ID**
Raoul Is.	5	92	80	1/11	7	n/a	50
Macauley Is.	2	42	36	2/4	n/a	n/a	19
L'Esperance	2	40	-	-	n/a	n/a	2

3.10 Coastal biodiversity

Phylogenetic and population genetic collections

A total of 35 person dives at 16 stations focused on biodiversity collections, lasting a total of 24.3 hours. The maximum depths of these dives was 25 m, but on average they were no deeper than 18 m. Phylogenetic and genetic collections were made at Havre Rock, Raoul Island, Macauley Island, and L'Esperance Rock from 24 species (Table 14). Genetic collections from nine species will be used for phylogenetic/taxonomic analyses. For six species, collections were made from all three of the planned regions (i.e. Raoul Island, Macauley Island, and L'Esperance Rock), and will be suitable for investigating population connectivity among the islands of the Kermadec Archipelago. Several species will also be used to understand connectivity of the Kermadec populations with populations of mainland New Zealand (four species) and other regions of the Pacific (17 species).

Table 14: Summary of genetic collections made for population genetic (PopGen), phylogenetic and taxonomic (Phylo) objectives. Methods of collection include: L, lethal; NL, not lethal; and *,opportunistic. Genetic samples taken at each station (bold numbers) and totals per location (P, tissue collections exist from previous collections).

			Stations															Totals			
Species	**Objective**	**Method**	**9**	**20**	**32**	**35**	**37**	**45**	**48**	**66**	**73**	**84**	**85**	**104**	**106**	**111**	**113**	**1**	**Raoul**	**Macauley**	**L'Esperance**	**Havre**
Centrostephanus rodgersii	PopGen	L								24	26	1				40	11	38	P	51	51	38
Tripneustes gratilla	PopGen	NL/L								28	20	2				2	7	5	P	50	9	5
Heliocidaris tuberculata	PopGen	L		14			38			50						5	22	5	52	50	27	5
Phyllacanthus parvispinus	PopGen	NL		1			4	2	25	6	18		8		2	1		1	32	32	4	1
Diadema sp.	Phylo	NL		3			2												5			
Echinometra mathaei	PopGen	L			1														P,1			
Acanthaster planci	PopGen	NL						2		2	8		4						P,2	14		
Patiriella oliveri	Phylo	NL/L											46							46		
Scutellastra kermadecensis	PopGen	NL								2			32						P	34		
Pyura sp.	Phylo	L											2							2		
Decapoda sp.	Phylo/ PopGen	L					52			108							66		52	108	66	
Chromis abyssicola	PopGen	L												119						119		
Actinia tenebrosa	PopGen	L			10														P,10			
Goniastrea favulus	PopGen	NL	2	2		2		3			2	1							P,9	3		
Pocillopora damincornis	PopGen	NL	5	2		4		4		7	26	6							P,15	39		
Turbinaria frondens	PopGen	NL	4	5		8		4		3	2	2							P,21	7		

			Stations															Totals			
Species	**Objective**	**Method**	**9**	**20**	**32**	**35**	**37**	**45**	**48**	**66**	**73**	**84**	**85**	**104**	**106**	**111**	**113**	**1**	**Raoul**	**Macauley**	**L'Esperance**	**Havre**
Hydnophora pilosa	PopGen	NL	5	9		11		5		1		1							P,30	2		
Astrea curta	PopGen	NL	4	5		1		4		1		1							P,14	2		
Montipora capricornis	PopGen	NL	4			1		3			1								P,8	1		
Montipora spongoides	PopGen	NL	3	3		5		2			1	1							P,13	2		
Scleractinia sp. 1	PopGen Phylo/ PopGen	NL		1		1		5			16	1				9			P,7	17	9	
Scleractinia sp. 2	PopGen Phylo/ PopGen	NL		2								2							P,2	2		
Scleractinia sp. 3	PopGen Phylo/ PopGen	NL	3	1						2									P,4	2		
Scleractinia sp. 4	PopGen	NL								1		1									2	

Reef building coral collections

Sixteen dives focused on coral collections and photo quadrats with a maximum depth of about 30 m, totalling 10.6 hours. Reef building corals were found at all locations except Havre Rock. Species diversity was very low at L'Esperance Rock (one species), but were comparable between Macauley and Raoul islands. The distribution of each reef building coral species over the 0–30 m depth interval and any morphological changes along this gradient will be analysed.

Shallow-reef community composition photo quadrats

The percentage cover of the major groups occupying hard substrates (e.g. corals, algae and sponges) will be quantified using image analysis software (i.e. imageJ). Changes in the prevalence of these major space-occupying groups will then be compared with data collected by Brooks (1999) and Gardner et al. (2006) from similar areas to examine temporal changes in community composition.

Shallow-reef in-situ temperature recorders

Loggers were deployed during biodiversity collection dives at Havre Rock (one logger) and L'Esperance Rock (two loggers). Loggers were deployed during an earlier survey in 2015 at Raoul, Macauley and Cheeseman islands, and three of these loggers were retrieved and replaced with new loggers: Caves and Lava Dykes at Macauley Island (two loggers), and Boat Cove at Raoul Island (one logger). A summary of logger deployments is provided in Table 15.

Table 15: Summary of temperature logger deployment date, location and attachment method, and recovery date for loggers retrieved during TAN 1612

Logger no.	Start Date	Recovery Date	Location	Depth	Position
	1/11/2015		Raoul Is, Fishing Rock, behind stainless steel plate of tsunami warning system	3.2 m	29.251150°S 177.903919°W
	1/11/2015	26/10/2016	Raoul Is, Boat Cove, behind stainless steel plate of tsunami warning system	6.0 m	29.279872°S 177.894374°W
	26/10/2016		Raoul Is, Boat Cove, behind stainless steel plate of tsunami warning system	6.0 m	29.279872°S 177.894374°W
10621166	1/11/2015	29/10/2016	Macauley Is, NW side about 100m W of Lava Point, between two lava flows	7.4 m	30° 13.516'S 178°25.540'W
	29/10/2016		Macauley Is, NW side about 100m W of Lava Point, between two lava flows	7.4 m	30° 13.516'S 178°25.540'W
10621159	1/11/2015	30/10/2016	Macauley Is, N side in front of the big cave	7.6 m	30° 13.819'S 178°25.119'W
	30/10/2016		Macauley Is, N side in front of the big cave	7.6 m	30° 13.819'S 178°25.119'W
10621200	1/11/2015		Cheeseman Is, behind big boulder on W side	8.4 m	30° 32.033'S 178°34.161'W
10621151	1/11/2015		Cheeseman Is, seaward side of the boulder on N side	8.1 m	30° 32.021'S 178°34.142'W
	2/11/2016		l'Esperance Rock, N side	12 m	31°21.219'S 178°49.468'W
	2/11/2016		l'Esperance Rock, W side	8.0 m	31°21.272'S 178°49.563'W
	22/10/2016		Havre Rock	12 m	31°17.259'S 178°54.809'W

Visual fish records

A total of 316 photos and 53 videos were taken by divers to generate fish species lists at each station. From the photos alone, there were 47 coastal fish species recorded throughout the voyage. Once the species records have been confirmed from the video footage, resulting species lists per location will be compared with existing distributional knowledge for the fish species. Photos and screen grabs will be used to support confirmation of new species records for the Kermadec region to be reported in a subsequent publication.

Algae

A representative collection of subtidal coastal algae was made at North Meyer Island (Station 037). Opportunistic hand collections of selected taxa (*Codium* spp., Dictyotales, *Sargassum*) were made at Raoul Island, Macauley Island and Havre Rock, and a single hand collection of vesiculate brown, filamentous red and filamentous green algae was made from the low intertidal zone at Meyer Islands. In addition four collections of rhodoliths and attached macroalgae were obtained from epibenthic sled and beam trawl stations from 70–120 m depth at Macauley I. and L'Esperance Rock. Rhodolith beds were also observed in DTIS footage from the Star of Bengal Bank.

Dinoflagellates were extracted from macroalgae collected at Macauley Island and L'Esperance Rock. These were supported in seawater and GeO_2/F2 solution for the duration of the voyage for culturing by Lesley Rhodes (Cawthron Institute). Voucher specimens and a genetic sample were retained for each alga from which a dinoflagellate extraction was undertaken.

Fish collections

Sampling of inshore fishes has been undertaken in detail before this survey (e.g., Trnski et al. 2015, Francis & Duffy 2015), but several opportunistic samples were taken: two specimens of an undescribed, endemic clingfish, *Aspasmogaster* sp., one kingfish, *Seriola lalandi*, the first voucher specimen of *Chromis vanderbilti*, a Bahamonde sole, *Aseraggodes bahamondi*, and one specimen of the dark vent leatherjacket, *Thamnaconus analis*. These specimens were taken by hand while diving except for the kingfish which was collected by line fishing.

3.11 Bathymetry

Some of the survey area had been mapped prior to the voyage, but additional data gathering was necessary on most of the sampling transects to assist with deciding on suitable sampling methods. Additionally, opportunistic seafloor mapping was conducted whenever other sampling operations allowed, extending the knowledge about the bathymetry in this region significantly.

During the survey, including transits, more than 9000 km^2 of Multibeam Echosounder (MBES) data were collected. The bathymetry, seafloor backscatter and water column backscatter signals were processed for all data, but the water column backscatter only screened for major features such as gas plumes. The transit lines were run at speeds of up to 12 knots and were of reduced quality.

The necessary Sound Velocity Profiles (SVP) were derived from CTD data collected during the DTIS deployments.

Bathymetry data and backscatter were processed using CARIS HIPS 9.1.8 and QPS FMGT 7.6 respectively. Data from both software packages were exported into ESRI compatible formats. Using ESRI ArcGIS, data were then imported into File Geo Data Bases (FGDB) for generation of map exports into the OFOP software used in DTIS operations, and maps for this report.

Previous MBES data in the survey area consisted largely of survey data collected by NIWA. These data were collected as part of geological research into the Kermadec Arc volcanism on earlier *Tangaroa* research surveys TAN0205, TAN0411, and TAN0706. The present survey repeated some of the coverage of these surveys because of survey constraints (crossing previously mapped areas on transit), but in general attempts were made to navigate the ship in such a way as to increase existing multibeam data coverage. Several transits examined shoals marked on the nautical charts of the area. As a result shoals marked on NZ22/INT635 on positions 33°10'S/179°27'W (57 m) and 32°28'S/179°09'W (48 m) can be assumed to not exist.

3.12 Communications and outreach

During the voyage blog entries were written on a two-daily basis by Amelia Connell, on behalf of the expedition team. These were not a detailed or official record of the survey, but comprised a description of various activities and observations on board, accompanied by images.

Blog 1: Easing into the Kermadec Ridge Expedition

Blog 2: Releasing Koha the turtle at Raoul Island

Blog 3: Raoul Island whales

Blog 4: It's a bit fishy up here in the Kermadecs

Blog 5: From shallows: moving from the familiar shores of Raoul Island to lesser known higher latitude Islands

Blog 6: There be dragons!

Blog 7: Caught on camera

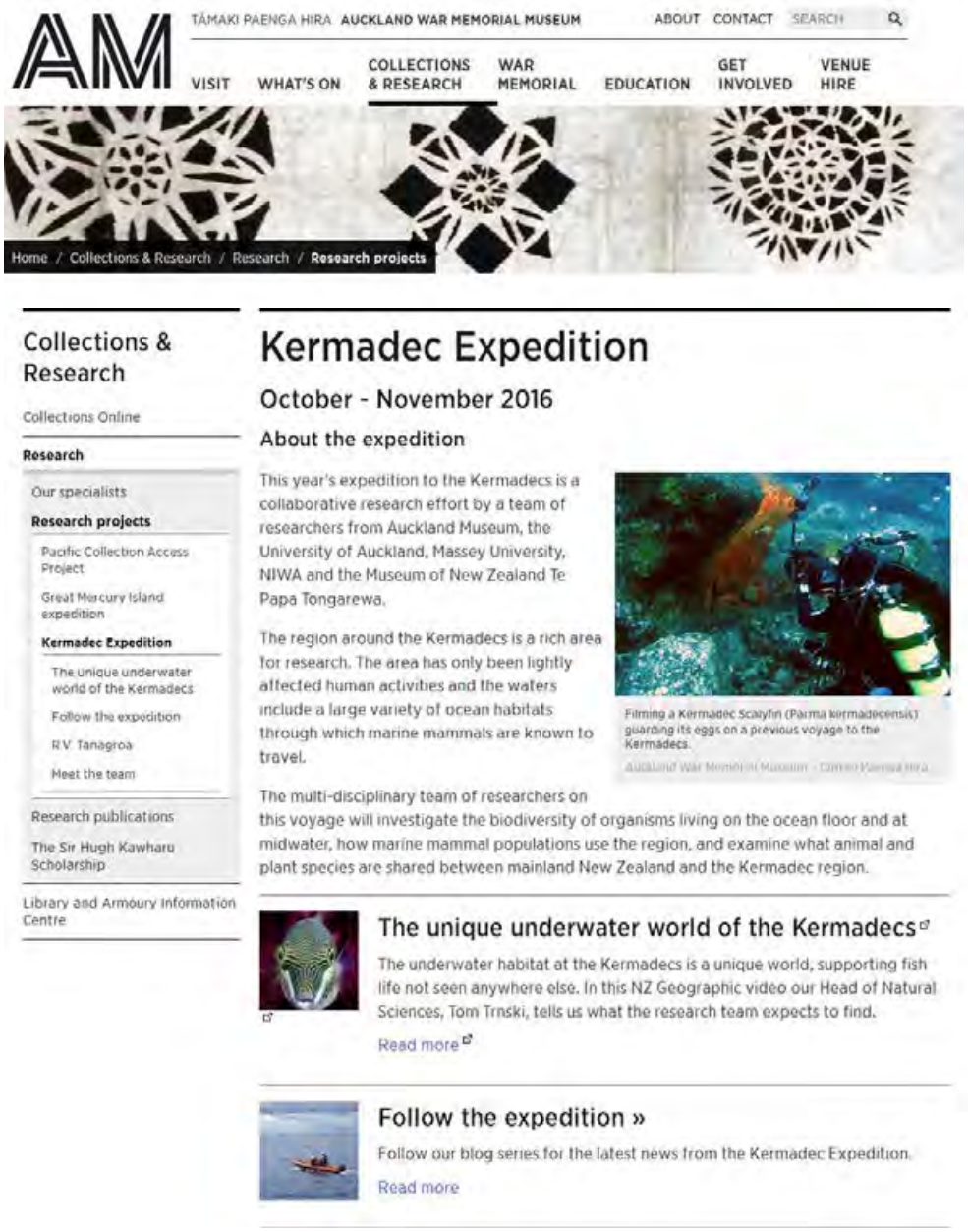
Blog 8: It's a small world after all

Blog 9: On the road again

See the complete blogs on the following webpage: www.aucklandmuseum.com/kermadec-expedition (as shown below).

Daily images of the general activities and different samples caught were provided to NIWA for sharing on social media by NIWA and other participating institutions. Images were captured by both Hamish McCormick and Amelia Connell.

Eleven short video interviews, with scientists on board about their areas of expertise, were conducted by Hamish McCormick. These videos are housed on the NIWA webpage (at: www.niwa.co.nz/news-publications/videos and www.facebook.com/nzniwa) and available for use by the participating institutes on social media.



Koha release

Vessels do not often head north to the Kermadec Islands. Hence, when it was known this survey would take place, Kelly Tarlton's asked if we could transport a hawksbill turtle that had been washed ashore two years ago on the west coast of Northland, and had been slowly recovering in their care. This is a northern species, and its chance of survival is better if returned to Kermadec waters.

Below is repeated the excerpt from the daily blog on the release of Koha:

Blog link: http://www.aucklandmuseum.com/about-us/blog/2016/releasing-koha-the-turtle-at-raoul-island

"We have had a special voyager on the trip with us – Koha the hawksbill turtle, who has been waiting patiently for our arrival at Raoul Island.

A release time for Koha was set for about 10am. When this time came around Koha was loaded back into its special transport box (which is a bit smaller and more movable than the one it's spent most of the trip in). From the deck of *Tangaroa* the box and turtle were loaded into the smaller boat and then lowered over the side. The release team then headed close to Raoul Island so that upon release Koha could see land and orientate itself, rather than potentially getting lost in the open ocean.

The release was successful, with Koha swimming down from the surface to sit on the bottom for a little while, and then after several minutes hanging out on the bottom it took off, happy to be back in the wild again.

We had become accustomed to having Koha on board, so it was a little sad to say good bye – but it is definitely for the best, and we're happy that we could successfully release Koha at Raoul Island."

Accompanying image: Koha's final swim in the tank on the deck of *Tangaroa*. (Photo Amelia Connell).

4. DISCUSSION

The survey achieved its objectives and was successful for all participants in the multi-agency research team. There was a highly successful integration of coastal to deep-sea work surveying multiple ecosystem components, from the smallest to largest marine organisms, and surface to benthic environments.

The offshore transect and coastal sampling revealed highly variable habitats between the environments. The DTIS footage showed substantial, and unexpected, differences in substrate type and biodiversity richness and abundance between the different depth strata, and between transects. Typically the soft sediment or pumice boulder habitats were low in diversity and faunal abundance, with high faunal densities associated with hard seafloor features such as banks and raised hill-type features in shallower waters.

The samples will take many months and longer to work up and arrive at definitive identifications to define the level of increase in known or estimated biodiversity of the Kermadec region. Nevertheless, the observations made by the experienced team onboard of numerous new records for New Zealand as well as the Kermadec area, together with species that are likely to be new to science, emphasise that there is still a lot to learn about the region. The wide range of habitat types, and species with subtropical to temperate affinities, offshore as well as close to the islands, confirm the potential biogeographic importance of the region, and one of the objectives of the proposed Kermadec-Rangitahua Ocean Sanctuary, to protect a wide variety of communities and biodiversity.

The survey built on time series datasets for the region, in particular for the coastal dive surveys and marine mammal research. Visiting three regions within the Kermadec Archipelago enabled the research teams to collect sufficient samples for population genetic assessments of echinoderms and corals and to progress determination of levels of connectivity between the island groups of Raoul, Macauley and L'Esperance Rock. These coastal habitats were highly variable and this was reflected in the biodiversity observed at each group. Retrieval of data-loggers deployed in 2015 and attachment of new loggers to the coastal sediment will support a future fine-scale analysis of environmental change throughout the Kermadecs. This information will be critical when assessing the effects of climate change on the region.

The biopsy samples for DNA finger-printing and fluke photographs of individual whales are substantial additions to the 2015 Raoul Island voyage data and will increase our understanding of the breeding ground origins of whales passing the Kermadec Islands. Despite there being only a short time available for small-boat operations at Macauley Island, we were able to ascertain that this is a place where whales aggregate, albeit in lower numbers than seen at Raoul Island. Bottlenose dolphins were sighted at Raoul Island, Macauley Island and L'Esperance Rock. All sightings were of *Tursiops truncatus*, the large form of bottlenose dolphin seen around mainland New Zealand. Preliminary analysis of the Raoul Island dolphins indicates some form of residency, either seasonally or year-round and this warrants further exploration to determine whether the other island groups have similar residency patterns.

The offshore survey covered areas on the eastern side of the Ridge that have not previously been explored. The variety of benthic gear types used, as well as sampling surface and midwater environments, added much new knowledge of biodiversity. However, it has also established baseline data on habitat types and faunal communities along transects that can be monitored in future. In addition to the coastal research, the deep-sea stations provide a network of sites that can

be used to measure natural changes in populations well away from human impacts common around the coasts of mainland New Zealand.

The survey increased our topographic knowledge of the region, with a large area swath mapped, including shallow areas close to the islands, to the north of Macaulay Island and L'Esperance Rock. This work was undertaken during the near-shore coastal dive and whale survey work and proved to be an efficient use of time that will allow safer navigation around the islands in future.

The DTIS coverage and supporting sampling tows were completed largely as planned. The use of DTIS footage to inform where and what type of sampling tow was most appropriate proved valuable in maximising the returns from a limited sampling time. In almost all cases, the species collected during tows largely reflected the fauna seen in the footage. This benign survey method is an important research tool, particularly in the Marine Protected Areas covered in this project.

Due to the success of the multidisciplinary study, a partial transect was added off the Star of Bengal Bank. While the other areas are inside the existing MPA boundaries, the Star of Bengal Bank is in the EEZ, but included in the area proposed for the Ocean Sanctuary. This region is a sub-sea feature renowned for the presence of large kingfish, bass and hapuku but other forms of biodiversity were largely unknown and the area was poorly mapped. The addition of this region to the survey was very worthwhile and provides additional baseline information on faunal communities that would be protected.

This Kermadec survey was the first time dive operations were conducted from the RV *Tangaroa*. The use of a small (5.8 m) research vessel worked seamlessly for both dive and marine mammal surveys due to the experience of the research teams and the vessel crew. There are no doubts that this kind of research, when well planned and equipped, can be successfully undertaken on the *Tangaroa*, and expand these types of multi-disciplinary surveys to other remote coastal areas and offshore islands.

Finally, this project showed that the combination of three very different research objectives with multiple activities was able to be carried out efficiently and effectively and this work should, in the authors' opinions, be repeated in the future now that we have a robust baseline established.

4.1 Future work

Short term

This report summarises the fieldwork but there are several aspects that will be continued by the research team. There are new species records to be worked up, and confirmation by the fish and invertebrate groups of uncertain species identifications. This will involve collaboration with a number of local and international experts. Many of the samples were preserved to allow population genetics, molecular identification and phylogeographic studies to be undertaken. Some of these data will form part of geographical studies on species colonisation, distribution and population structure within and outside New Zealand. The topographical data will be cleaned and curated as part of the Land Information New Zealand nautical mapping data. The DTIS data will be reviewed to resolve species identification and determine species assemblages.

Longer term

There have been several Kermadec marine voyages over the last five years, primarily led by the Auckland Museum and University of Auckland, focusing on coastal dive and whale surveys. This has led to a valuable time series developing for several sites throughout the archipelago. It is

important, in the authors' opinions, that we continue the coastal dive surveys, environmental monitoring, nearshore whale and dolphin research and develop further the offshore time series for monitoring natural changes in the largely un-impacted Kermadec marine environment.

Little is known about the bathymetry and topography of the shallow waters around the Kermadec Islands, with no detailed surveys having been conducted. Existing survey data are of exploratory quality and density, and were collected in two surveys in 1845 and 1955. Detailed, high quality shallow water multibeam surveys around Raoul, Macauley, L'Esperance and Havre will be beneficial for navigation purposes but also for understanding the geography of this region and elucidating the environmental variables that may influence community structure throughout the region.

The science team on Tangaroa (photo: H. McCormick)

5. ACKNOWLEDGMENTS

The officers and crew of the RV *Tangaroa* did an excellent job supporting the myriad of activities taking place during the survey. Deployment of new equipment, additional survey types, and rough seafloor provided numerous challenges, but all were dealt with effectively.

The support of members of the Marine Funding Advisory Research Group was instrumental in enabling the survey to take place. The survey was organised at relatively short notice, and we appreciate efforts made by the Department of Conservation and Ministry for Primary Industries to expedite the necessary permits for sampling inside Marine Protected Areas and Benthic Protection Areas. NIWA management and Te Ohu Kai Moana are also acknowledged for their help. The general support of Ngati Kuri and Te Aupouri for research in the Kermadec region, as well as with Ngati Whatua o Orakei the blessing of Koha in preparation for release, is greatly appreciated.

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APPENDIX 1

TAN1612 sampling station summary. See text for method information. Perf = gear performance, depths (s_dep, f_dep) in m, Time is NZST.

Stn	Transect	Date	Method	Strat	Time	lat_d	lat_min	lon_d	lon_min		s_dep	f_dep	n.mile	dir	Perf	Comments
1	Havre	22-Oct	DIVE	NA	918	31	17.23	178	55.06	w	0	25	0.00	NA	Y	Dive on Havre Rock, deploy temperature probe, urchin and coral collection
2	Havre	22-Oct	ROD	NA	910	31	17.42	178	54.97	w	300	308	0.00	211	Y	Three rods deployed. 7 fish.
3	Raoul	23-Oct	DTIS	NA	29	29	16.97	177	52.09	w	187	233	0.10	210	Y	DTIS test off Raoul Island
4	Raoul	23-Oct	TRAP	2	152	29	17.02	177	51.46	w	500	510	0.00	71	Y	Fish trap deployed at 500 m. 3kg rocks, some corals, large Squalus griffini.
5	Raoul	23-Oct	DTIS	NA	434	29	16.93	177	52.05	w	183	192	0.10	217	Y	DTIS test off Raoul Island: HiPAP error
6	Raoul	23-Oct	WHALE	NA	621	29	15.39	177	52.43	w	0	0	0.00	101	Y	Survey in Eastern Anchorage area inside Meyer and Herald Is. Many hump-backed whales. 4 biopsy samples.
7	Raoul	23-Oct	ROD	NA	855	29	15.83	177	51.87	w	30	42	0.00	36	Y	Rod fishing, 1 kingfish.
8	Raoul	23-Oct	KOHA	NA	947	29	15.57	177	53.68	w	0	0	0.00	NA	Y	Release of Koha the hawksbill turtle
9	Raoul	23-Oct	DIVE	NA	1145	29	14.99	177	53.74	w	0	30	0.00	NA	Y	Northern side North Meyer Island. Corals collected.
10	Raoul	23-Oct	S-PLANK	NA	1155	29	13.72	177	53.28	w	0	1	0.00	226	Y	Rectangular net, 0-0.5M. Test. Some salps and arrow worms.
11	Raoul	23-Oct	S-PLANK	NA	1223	29	14.01	177	53.59	w	0	2	0.00	196	Y	Test of surface plankton cone net.
12	Raoul	23-Oct	DIVE	NA	1300	29	14.95	177	53.65	w	0	14	0.00	120	Y	Dive off Egeria Rock. Strong current limits dive.
13	Raoul	23-Oct	DTIS	NA	1753	29	16.93	177	52.07	w	174	181	0.04	204	Y	DTIS test off Raoul Island
14	Raoul	23-Oct	DTIS	NA	1933	29	16.94	177	52.05	w	201	190	0.02	204	Y	DTIS test off Raoul Island
15	Raoul	23-Oct	DTIS	1	2120	29	16.72	177	52.56	w	98	182	0.52	229	Y	Flat gravelly substrata with some rough patches, becoming bedrock. Small sponges, spiral gorgonians common on rocks.
16	Raoul	23-Oct	SLED	1	2306	29	16.91	177	52.76	w	117	160	0.26	236	Y	Small catch, pumice, pebbles, shell, pagurid crab, small gorgonians.
17	Raoul	24-Oct	DTIS	2	121	29	16.94	177	51.39	w	493	635	0.64	192	Y	Flat mud/sand/gravel substrata with some boulders. Echinoids, asteroids, holothuroids, some small sponges, small stony coral colonies on isolated small boulders. No HiPAP data recorded.Still images mostly no flash.
18	Raoul	24-Oct	MPT	3	423	29	17.52	177	47.98	w	1000	90	1.98	219	Y	Oblique mesopelagic haul. Myctophids, dragonfish, 0.76kg. 4.5kg inverts, including 3 large squid.
19	Raoul	24-Oct	WHALE	NA	647	29	13.87	177	53.02	w	0	0	0.00	260	0	4 humpack whale biopsies, 2 dolphins. Off DOC station
20	Raoul	24-Oct	DIVE	NA	1157	29	13.87	177	52.49	w	0	30	0.00	NA	Y	Napier I. 2 dives in small inlet clear of currents. Crown of thorns starfish impact band, with good faunal coverage above and below.
21	Raoul	24-Oct	S-PLANK	NA	1146	29	12.80	177	52.51	w	10	0	0.00	NA	Y	Surface vertical drop, scraped side of ship so repeat.
22	Raoul	24-Oct	S-PLANK	NA	1150	29	12.76	177	52.56	w	10	0	0.00	270	Y	Surface vertical haul 0-10 m.
23	Raoul	24-Oct	WHALE	NA	1410	29	14.32	177	54.60	w	0	0	0.00	61	Y	Very successful trip, 6 whale biopsies.

Stn	Transect	Date	Method	Strat	Time	lat_d	lat_min	lon_d	lon_min		s_dep	f_dep	n.mile	dir	Perf	Comments
24	Raoul	24-Oct	DTIS	NA	1746	29	16.88	177	52.04	w	197	182	0.05	221	Y	DTIS test after further adjustments. Good performance
25	Raoul	24-Oct	DTIS	3	1848	29	17.23	177	50.47	w	809	787	0.51	222	Y	DP run to SW. Flat soft bottom, scattered holothurians, asteroids, gastropods. Target for beam trawl.
26	Raoul	24-Oct	TRAP	3	2028	29	17.69	177	50.87	w	770	800	0.00	64	Y	Ribaldo, 4 basketwork eels, catshark.
27	Raoul	24-Oct	BEAM	3	2135	29	17.22	177	50.48	w	780	770	0.37	219	Y	Small clean catch; holothuroids, galatheids, asteroids and fishes (RAT, CHX)
28	Raoul	24-Oct	BEAM	2	2247	29	17.10	177	51.42	w	499	615	0.50	197	Y	DP run to SW. Flat soft sediment with dark patches. Sparse fauna; 1 large brisingid, 1 Benthodytes holothuroid, some small sponges and benthic fish.
29	Raoul	25-Oct	DTIS	4	120	29	18.08	177	47.50	w	1335	1328	0.52	218	Y	DP run to SW. Flat soft sediment with dark patches. Sparse fauna; 1 large brisingid, 1 Benthodytes holothuroid, some small sponges and benthic fish.
30	Raoul	25-Oct	BEAM	4	412	29	17.89	177	47.39	w	1311	1320	0.46	220	Y	Small clean catch, pumice, shrimps, prawn killers, asteroids, isidid coral. Rat tails and possibly a new species of coffin fish.
31	Raoul	25-Oct	WHALE	NA	712	29	13.71	177	52.91	w	0	0	0.00	278	Y	Whale biopsy sampling. 1 whale, 1 dolphin, hydrophones, fluke photos
32	Raoul	25-Oct	SHORE	NA	803	29	14.64	177	52.66	w	0	0	0.00	NA	Y	Intertidal sampling on N. Meyer Island
33	Raoul	25-Oct	S-PLANK	NA	1140	29	14.11	177	51.15	w	10	0	0.00	270	Y	Surface plankton net, vertical shot to 10 m
34	Raoul	25-Oct	S-PLANK	NA	1144	29	14.09	177	51.18	w	10	0	0.00	NA	Y	Surface plankton net, vertical shot to 10 m
35	Raoul	25-Oct	DIVE	NA	1150	29	14.68	177	51.56	w	0	30	0.00	NA	Y	2 divers at Dayrell Island.
36	Raoul	25-Oct	V-PLANK	NA	1221	29	13.69	177	51.37	w	30	0	0.00	270	Y	Test of vertical plankton net.
37	Raoul	25-Oct	DIVE	NA	1300	29	14.61	177	52.75	w	0	16	0.00	NA	Y	3 divers on NW side of North Meyer Island.
38	Raoul	25-Oct	WHALE	NA	1437	29	12.78	177	57.72	w	0	0	0.00	253	Y	Working area along northern side of island.
39	Raoul	25-Oct	V-PLANK	1	1756	29	16.99	177	52.04	w	100	0	0.00	355	Y	Vertical plankton tows. 3 replicates. To 100 m
40	Raoul	25-Oct	V-PLANK	3	1837	29	17.61	177	50.77	w	100	0	0.00	2	Y	Vertical plankton tows. 3 replicates. To 100 m
41	Raoul	25-Oct	TRAP	4	1930	29	18.48	177	47.46	w	1333	1399	0.00	42	Y	Fish trap deployed at 1340 m. 1 fish, 1 shrimp.
42	Raoul	25-Oct	DTIS	5	2127	29	19.14	177	41.93	w	2092	2096	0.34	196	Y	Soft sediment, scattered holothurians, shrimps, lollipop sponge. Very flat seafloor.
43	Raoul	26-Oct	BEAM	5	52	29	20.06	177	42.26	w	2087	2090	0.60	203	Y	106kg pumice rock, mixed invertebrates including large anemone, gorgonians, and galatheids. Large basketwork eel.
44	Raoul	26-Oct	WHALE	NA	738	29	18.03	177	58.87	w	52	49	0.00	351	Y	Whale biopsy sampling Denham Bay, 2 whales, some dart failures.
45	Raoul	26-Oct	DIVE	NA	1150	29	17.80	177	54.87	w	0	32	0.00	139	Y	Dougall Rock. 2 divers down.
46	Raoul	26-Oct	ROD	NA	1154	29	18.28	177	54.42	w	192	286	0.00	335	Y	Ruby snapper, king tarakihi.
47	Raoul	26-Oct	ROD	NA	1258	29	18.45	177	54.46	w	265	164	0.00	315	Y	*Mustelus* sp. Taken at 225 m
48	Raoul	26-Oct	DIVE	NA	1300	29	16.82	177	53.73	w	0	9	0.00	NA	Y	Boat Cove, 3 divers down. Replace temperature logger.

Stn	Transect	Date	Method	Strat	Time	lat_d	lat_min	lon_d	lon_min		s_dep	f_dep	n.mile	dir	Perf	Comments
49	Raoul	26-Oct	WHALE	NA	1438	29	18.07	177	59.36	w	0	0	0.00	251	Y	Denham Bay. 3 whale, 3 dolphin biopsies
50	Raoul	26-Oct	NET	NA	1130	29	18.30	177	54.60	w	0	0	0.00	NA	Y	Scoop net on surface. Portuguese man-o-war
51	Raoul	26-Oct	S-PLANK	NA	1521	29	18.02	178	0.05	w	10	0	0.00	NA	Y	Surface plankton net, vertical shot to 10 m
52	Raoul	26-Oct	ROD	NA	1541	29	17.96	178	0.04	w	138	131	0.00	127	Y	Denham Bay. Red pigfish, spotted gurnard.
53	Raoul	26-Oct	MWT	5	1925	29	19.94	177	41.16	w	1700	1700	2.89	35	Y	Ratcatcher in midwater, 2400 m above bottom. 13kg prickly anglerfish, 4 kg mixed mesopelagic fishes, whalefish, 1 kg shrimps.
54	Raoul	27-Oct	DTIS	7	100	29	23.22	177	25.09	w	3098	3105	0.50	199	Y	Flat muddy sediment with high density of gravel/pebble sized pumice. Sparse fauna: 'lollipop' sponges, holothuroids, anemones, rat tails and other fishes.
55	Raoul	27-Oct	TRAP	5	424	29	19.26	177	41.84	w	2210	2210	0.00	59	Y	No fish catch, one prawn.
56	Raoul	27-Oct	S-PLANK	5	502	29	20.20	177	42.38	w	0	0	0.36	280	Y	Surface plankton sample (2x1 net). Salps; copepods; predatory nudibranchs; annelids; odd 'fish-shaped' nudibranchs with two tentacles.
57	Raoul	27-Oct	WHALE	NA	642	29	19.06	177	56.43	w	0	0	0.00	270	Y	Whale biopsy work in Denham Bay/Smith Bluff
58	Raoul	27-Oct	ROD	NA	758	29	19.11	177	58.89	w	163	183	0.00	186	Y	King tarakihi, scorpionfish, trevally, spotted goatfish, mado.
59	Raoul	27-Oct	WHALE	NA	1419	29	17.49	178	0.66	w	0	0	0.00	123	Y	2 whale biopsies, plus skin samples, fluke photos. Frequently breaching juvenile.
60	Raoul	27-Oct	ROD	NA	1450	29	17.39	178	0.81	w	148	288	0.00	204	Y	*Centroberyx*, *Squalus raoulensis*
61	Raoul	27-Oct	ROD	NA	1915	29	18.10	177	40.84	w	1	1	0.00	90	Y	Todarodes squid caught while hauling pot.
62	Raoul	27-Oct	CTD	5	2115	29	17.59	177	40.80	w	2170	0	0.00	59	Y	CTD to 2100 m. 11 bottles fired, water samples taken.
63	Raoul	28-Oct	DTIS	6	5	29	20.55	177	35.44	w	2492	2501	0.50	201	Y	Level muddy sediments with areas of pumice cobbles. Fauna more abundant than at 3000 m; shrimps, holothuroids, sponges, fish incuding *Bathysauropsis* sp., halosaur.
64	Raoul	28-Oct	BEAM	7	431	29	23.62	177	25.28	w	3112	3108	0.33	202	Y	200 kg pumice cobbles and pebbles, many small ophiuroids, some holothuroids, a few crustaceans. Most specimens damaged by rocks.
65	Macauley	28-Oct	S-PLANK	NA	1314	30	13.52	178	24.02	w	10	0	0.00	344	Y	Surface plankton net to 10 m.
66	Macauley	28-Oct	DIVE	NA	1327	30	13.40	178	25.38	w	0	24	0.00	NA	Y	Divers off Annexation Point. Good collections of urchins and corals. Spotted grouper near site.
67	Macauley	28-Oct	DTIS	2	1648	30	15.17	178	18.54	w	314	460	0.65	65	Y	Hard bottom, dense stalked crinoids at start, thinning deeper to scattered gorgonians, stylasterid patches, and glass sponges. Few fish.
68	Macauley	28-Oct	SLED	2	1832	30	15.12	178	18.37	w	340	390	0.20	63	Y	Sled along section of DTIS tow. Small catch (3kg total) stalked crinoids, gorgonians, stylasterids.
69	Macauley	28-Oct	MPT	3	2110	30	15.89	178	11.56	w	1000	100	2.03	94	Y	Good catch of mesopelagic fish, large *Diretmus*. Invertebrates included some striking squids.

Stn	Transect	Date	Method	Strat	Time	lat_d	lat_min	lon_d	lon_min		s_dep	f_dep	n.mile	dir	Perf	Comments
70	Macauley	28-Oct	DTIS	4	2359	30	16.64	178	11.23	w	1444	1465	0.40	234	Y	Smooth muddy sediments with pumice cobbles, bedrock at 2/3 of full distance. Holothuroids, shrimps, sponges on sediments, primnoid, antipatharian, and other corals on outcrop.
71	Macauley	29-Oct	BEAM	4	221	30	17.01	178	11.82	w	1431	1426	0.44	204	Y	Diverse catch of primnoid, antipatharian, and other corals, sponges, holothuroids, ophiuroids, brisingid, crustaceans. 63kg of pumice rock.
72	Macauley	29-Oct	S-PLANK	NA	416	30	13.85	178	23.75	w	1	1	0.00	32	Y	Surface tow with 2 x 1 net. Salps, pteropods, some fish larvae.
73	Macauley	29-Oct	DIVE	NA	534	30	13.41	178	23.93	w	0	28	0.00	NA	Y	NE coast Macauley I., two dives.
74	Macauley	29-Oct	DTIS	1	643	30	13.30	178	23.79	w	71	103	0.50	182	Y	Current-swept coarse sand, gravel, and shell hash, sparse macroalgae at start, then few visible organisms in live video.
75	Macauley	29-Oct	WHALE	NA	828	30	13.64	178	23.72	w	0	0	0.00	35	Y	One dive completed (logger recovery) but work boat engine failure caused abandonment of second dive. Work boat towed in by rescue boat
76	Macauley	29-Oct	DIVE	NA	851	30	13.52	178	25.54	w	0	24	0.00	NA	Y	One dive completed (logger recovery) but work boat engine failure caused abandonment of second dive. Work boat towed in by rescue boat
77	Macauley	29-Oct	BEAM	1	912	30	13.30	178	23.79	w	72	101	0.38	181	Y	15 minute tow along DTIS line, 38kg catch. Diverse and abundant fauna and flora in shell hash and gravel. Kermadec scorpionfish, gurnard, wasp fish, puffer fish, sandperch. Invertebrates included crabs, gastropods, asteroids, urchins and stomatopods.
78	Macauley	29-Oct	DTIS	3	1300	30	15.73	178	15.01	w	987	970	0.50	28	Y	Flat bottom, mainly soft muddy sediment but patches of lumpy pumice cobbles and pebbles. Scattered asteroids, echinoids, glass sponges, holothurians. Target first part of transect with TB 079
79	Macauley	29-Oct	BEAM	3	1450	30	15.53	178	14.88	w	982	978	0.31	210	Y	340kg kg pumice rubble. Diverse catch (2.5kg) of invertebrates, crabs, galatheids, gorgonians, ophiuroids, vase sponge, basketwork eel, rattail,
80	Macauley	29-Oct	DTIS	5	1651	30	17.83	178	8.59	w	1828	1826	0.38	53	Y	Flat bottom, muddy substrate with pumice cobbles and pebbles. Sparse fauna, holothurians, echinoids, brisingid, some fish.
81	Macauley	29-Oct	BEAM	5	1933	30	17.53	178	8.09	w	1826	1823	0.29	231	Y	Tow down DTIS line, 15 mins. 370kg pumice rubble, 3kg of fish and invertebrates including large anemone, Chrysogorgia, sponges, shrimps.
82	Macauley	29-Oct	MWT	5	2351	30	23.04	178	5.02	w	1962	1992	2.80	192	Y	Small, diverse catch. 11kg of mesopelagic fishes (several new records for the EEZ), salps, prawns, shrimps, and mysids

Stn	Transect	Date	Method	Strat	Time	lat_d	lat_min	lon_d	lon_min		s_dep	f_dep	n.mile	dir	Perf	Comments
83	Macauley	30-Oct	DTIS	1	352	30	13.56	178	21.26	w	174	323	0.50	36	Y	Transect NNE from summit of small seamount feature. Rugged outcropping on summit with gorgonian corals. Came fast under overhang but pulled clear. Continued down slope over mixed rock, sand, gravel, substrata with gorgonians. DTIS frame badly damaged.
84	Macauley	30-Oct	DIVE	NA	535	30	14.42	178	25.43	w	0	21	0.00	NA	Y	Off SE coast, SW of Haszard Islet. Gravelly substrate.
85	Macauley	30-Oct	DIVE	NA	825	30	13.82	178	25.12	w	0	12	0.00	NA	Y	NE coast off Lava Cascade. Large blocky substrate. Coral collections.
86	Macauley	30-Oct	WHALE	NA	1127	30	12.42	178	24.22	w	0	0	0.00	114	Y	Western side of island. Fluke photographs, skin slough samples, hydrophone recording.
87	Macauley	30-Oct	ROD	NA	1218	30	13.79	178	23.69	w	136	140	0.00	15	Y	Squalus raoulensis (2).
88	Macauley	30-Oct	ROD	NA	1252	30	14.36	178	23.83	w	112	141	0.00	18	Y	Golden snapper
89	Macauley	30-Oct	V-PLANK	1	1340	30	13.98	178	23.19	w	100	0	0.00	4	Y	Vertical plankton net haul from 100 m. 3 replicates. Bottom depth 170 m
90	Macauley	30-Oct	SLED	NA	1511	30	13.39	178	21.21	w	195	287	0.28	9	Y	Diverse catch of invertebrates: primnoid and bamboo corals, crabs, ophiuroids. Few fish.
91	Macauley	30-Oct	V-PLANK	2	1559	30	14.85	178	16.78	w	100	0	0.00	325	Y	Vertical plankton net haul from 100 m. 3 replicates. Bottom depth 700 m
92	Macauley	30-Oct	DTIS	6	1851	30	18.65	178	1.59	w	2374	2415	0.44	204	Y	Tow south along transect, muddy sediment with pumice cobbles and pebbles, bedrock in central region. Holothurians, scattered sponges and shrimps, brisingids. First section target for TB093.
93	Macauley	30-Oct	BEAM	6	2202	30	18.58	178	1.53	w	2368	2400	0.22	206	Y	Small catch of invertebrates.
94	Macauley	31-Oct	DTIS	7	129	30	19.93	177	56.81	w	2815	2855	0.40	49	Y	Level muddy sediments with pumice pebbles and cobbles. Precipitous bedrock scarp dropping down 20-30 m after 43 min, then back to muddy sediment and pumice. Sparse fauna: stalked crinoids, holothuroids, sponges, shrimps.
95	Macauley	31-Oct	BEAM	7	448	30	19.41	177	56.12	w	2821	2806	0.24	56	N	No sample in net, no sign that it contacted the seabed despite all signs (scope, time, winch tension).
96	Macauley	31-Oct	DTIS	1	839	30	14.43	178	23.17	w	143	139	0.59	143	Y	Plateau site. Mixed substrate along transect, patches of boulder-cobble interspersed with gravel and sand. Encrusting red algae on rocks.
97	Macauley	31-Oct	SLED	1	1040	30	14.56	178	23.04	w	125	136	0.40	147	Y	Target first part of DTIS 96. 285kg rocks.1.5kg diverse invertebrates, corals, crustaceans.
98	Macauley	31-Oct	TRAP	NA	1140	30	13.36	178	21.19	w	191	248	0.00	352	Y	2 fish (tarakihi, Bodianus), 4 brittle stars.
99	Macauley	31-Oct	TRAP	NA	1240	30	15.13	178	18.35	w	345	377	0.00	325	0	1 fish. Small perch, plus stalked crinoid and black swimming crinoid.
100	Macauley	31-Oct	DTIS	1	1335	30	14.62	178	20.09	w	151	185	0.24	73	Y	Gnarly knob, 140 m depth. Boulders and bedrock at summit, many yellow gorgonians and whip-like black corals.
101	Macauley	31-Oct	WHALE	NA	1450	30	13.16	178	24.15	w	0	0	0.00	334	Y	Hydrophone recording, 1 skin sample, fluke photographs.

Stn	Transect	Date	Method	Strat	Time	lat_d	lat_min	lon_d	lon_min		s_dep	f_dep	n.mile	dir	Perf	Comments
102	Macauley	31-Oct	ROD	NA	1514	30	12.80	178	24.38	w	46	61	0.00	339	Y	2 mado, 1 pink maomao
103	Macauley	31-Oct	SLED	1	1813	30	14.64	178	20.05	w	144	147	0.12	81	N	Sled on Gnarly knob. Came fast. Breakaways gone, pull out backwards. Good catch of gorgonians, black coral, a rare scorpaenid.
104	Macauley	31-Oct	B-TRAWL	NA	2019	30	14.78	178	22.98	w	125	135	0.47	328	Y	Excellent catch of fish: Galapagos shark, *Squalus raoulensis*, many scorpaenids, John dory, stingray.
105	Esperance	1-Nov	DTIS	1	1100	31	21.81	178	45.58	w	98	118	0.50	151	Y	Top of rocky outcrop down onto plateau. Bouldery at start, gorgonians and black coral, pink maomao.
106	Esperance	1-Nov	SLED	1	1249	31	21.83	178	45.55	w	90	109	0.16	148	Y	Sled on first section of DTIS 105. 85kg of rhodoliths. Diverse catch (5kg) of gorgonians, large plexaurid, black corals, soft coral, urchins.
107	Esperance	1-Nov	DTIS	2	1349	31	22.20	178	43.93	w	503	552	0.48	181	Y	Sandy sediment at start, then becoming more cobbly and bedrock with black sand interspaces. Few fauna, scattered echinoids, anemones.
108	Esperance	1-Nov	SLED	2	1543	31	22.37	178	43.94	w	506	502	0.19	196	Y	Filled sled with pumicy rocks and rubble (260kg). Small catch of galatheids, shrimp, small pufferfish, ophiuroids.
109	Esperance	1-Nov	DTIS	7	2103	31	28.37	178	21.19	w	3079	3098	0.35	190	Y	Bedrock with cobbles, mud overlay. Scattered anemones, occasional sponges, shrimps and holothurians.
110	Esperance	2-Nov	BEAM	7	56	31	28.87	178	21.31	w	3099	3103	0.23	194	Y	Net filled with ca. 5 tonnes of pumice rock. No fauna found in 100 kg subsample from cod end or seen elsewhere through net.
111	Esperance	2-Nov	DIVE	NA	550	31	21.22	178	49.47	w	0	31	0.00	NA	Y	NE side of L'Esperance Rock
112	Esperance	2-Nov	ROD	NA	824	31	20.55	178	49.47	w	124	124	0.00	NA	Y	Three rods deployed. 5 fish. Golden snapper, scorpaenid, king tarakihi, kingfish.
113	Esperance	2-Nov	DIVE	NA	917	31	21.27	178	49.56	w	0	19	0.00	NA	Y	Good echinoid collections
114	Esperance	2-Nov	V-PLANK	1	1220	31	22.54	178	44.68	w	100	0	0.00	108	Y	Vertical plankton cast (3 replicates) over 200 m depth.
115	Esperance	2-Nov	V-PLANK	2	1314	31	23.18	178	40.72	w	100	0	0.00	136	Y	Vertical plankton cast (3 replicates) over 700 m depth.
116	Esperance	2-Nov	DTIS	3	1511	31	24.48	178	38.49	w	1086	1092	0.46	212	Y	Bedrock with cobbles, mud overlay. Sparse fauna-rattails, urchin tests, jellyfish, holothurians.
117	Esperance	2-Nov	SLED	3	1729	31	24.49	178	38.54	w	1074	1079	0.25	27	Y	Tow towards end of DTIS line. 490 kg rocks, 500g invertebrates.
118	Esperance	2-Nov	MWT	5	2054	31	27.04	178	30.39	w	2001	2006	2.89	150	Y	MWT over 2200 m bottom. 4 kg mesopelagic fish and squid, including hatchetfish, myctophids, a slickhean, gulperfish and *Squalogadus* rattail.
119	Esperance	3-Nov	DTIS	4	105	31	24.91	178	36.23	w	1373	1338	0.50	342	Y	Rugged seabed of boulders, cobbles, bedrock and sediments. Sparse fauna.
120	Esperance	3-Nov	MPT	3	341	31	22.61	178	37.66	w	1000	110	1.85	9	Y	Small diverse catch of mesopelagic fishes and squids.
121	Esperance	3-Nov	SLED	4	606	31	24.17	178	36.53	w	1335	1330	0.20	5	Y	460kg pumice. 2 metallogorgia stalks, 1 intact gorgonian, 3 ophiuroids

Stn	Transect	Date	Method	Strat	Time	lat_d	lat_min	lon_d	lon_min		s_dep	f_dep	n.mile	dir	Perf	Comments
122	Esperance	3-Nov	DTIS	5	811	31	26.01	178	32.98	w	1817	1798	0.50	27	Y	Rugged seabed of boulders, cobbles, bedrock and sediments. Sparse fauna. Some gorgonian and antipatharian corals, sponges, crinoids, and holothuroids. Also burrows in deeper sediment patches.
123	Esperance	3-Nov	DTIS	6	1135	31	27.28	178	25.84	w	2646	2661	0.45	25	Y	Flat transect, mix of bedrock-boulders-cobbles with muddy overlay.Sparse fauna, occasional echiurans.
124	Esperance	3-Nov	DTIS	NA	1600	31	24.46	178	40.22	w	835	898	0.16	341	Y	Summit at 830 m, basalt bedrock near top, pumice at base. Scattered corals, anemones, glass sponge, crinoids.
125	Esperance	3-Nov	SLED	NA	1722	31	24.02	178	40.29	w	840	900	0.12	319	Y	175kg pumice. Small catch invertebrates-corals, crinoid, shrimps.
126	Esperance	3-Nov	B-TRAWL	NA	1957	31	23.60	178	42.39	w	670	667	0.47	47	N	5t boulder jamming cod-end. Sharks (seal, cat, and Lucifer-type) and 4 silver roughy. Inverts included large lamp shell.
127	Esperance	3-Nov	DTIS	NA	2247	31	22.47	178	44.88	w	86	95	0.50	243	Y	Rocky outcrops with gorgonians, black corals, macroalgae and fishes, interspersed with areas of sand with rhodolith beds.
128	Esperance	4-Nov	SLED	NA	121	31	22.49	178	44.97	w	97	97	0.08	234	Y	Tow along DTIS line. Came fast at end and parted one breakaway. Small catch of rhodoliths and a gorgonian coral.
129	Star of Bengal	4-Nov	DTIS	1	1253	32	25.55	179	9.27	w	148	150	0.04	180	N	Bouldery bedrock at summit, gorgonians, stylasterids, sponges, encrusting algae. Image failure, hauled after 4 minutes.
130	Star of Bengal	4-Nov	DTIS	1	1313	32	25.57	179	9.27	w	139	179	0.49	185	Y	Bedrock-bouldery at start, last half flat bedrock. Encrusting algae, rhodoliths, demosponges, gorginaians, stylasterids. Bass common.
131	Star of Bengal	4-Nov	TRAP	1	1442	32	25.60	179	9.03	w	156	161	0.00	12	Y	Three hours soaktime. 3 *Squalus griffini*. Released after weighing.
132	Star of Bengal	4-Nov	V-PLANK	1	1457	32	26.03	179	9.05	w	100	0	0.00	79	Y	3 replicate vertical tows to 100 m. Over 200 m bottom.
133	Star of Bengal	4-Nov	SLED	1	1819	32	26.00	179	9.34	w	159	162	0.16	161	N	Gear not on bottom. No catch.
134	Star of Bengal	4-Nov	SLED	1	1855	32	26.03	179	9.34	w	185	158	0.20	27	Y	3kg clean invertebrate catch. Gorgonian and stylasterid corals, echinoid. Representative of DTIS tow.
135	Star of Bengal	4-Nov	DTIS	2	2008	32	25.57	179	5.57	w	499	523	0.51	200	Y	Sand and gravel or pebbly sand substrate along the transect. Sparse fauna, some scattered anemones, galatheid, asteroids. Bass.
136	Star of Bengal	4-Nov	DTIS	3	2246	32	25.80	179	2.02	w	949	941	0.45	200	Y	Level fine sediments with scattered gravels. Tripod fish, ratails, holothuroids, asteroids, all at low densities.
137	Star of Bengal	5-Nov	BEAM	3	57	32	25.77	179	2.03	w	944	941	0.47	198	N	No sample. Trawl upside-down on recovery.
138	Star of Bengal	5-Nov	BEAM	2	226	32	25.50	179	5.54	w	479	524	0.42	200	Y	A few grams of gravel, no fauna. Deployment good.

Stn	Transect	Date	Method	Strat	Time	lat_d	lat_min	lon_d	lon_min		s_dep	f_dep	n.mile	dir	Perf	Comments
139	Star of Bengal	5-Nov	S-PLANK	NA	314	32	25.48	179	5.83	w	1	1	0.15	218	Y	Surface plankton tow with 2x1 net.
140	Star of Bengal	5-Nov	TRAP	2	335	32	25.70	179	5.92	w	468	468	0.00	342	Y	Two male carpet sharks.
141	Star of Bengal	5-Nov	BEAM	3	453	32	26.22	179	2.22	w	948	940	0.00	200	Y	No benthic fauna, 3 mesopelagic fish. Deployment good.
142	Star of Bengal	5-Nov	DTIS	4	645	32	26.37	178	59.40	w	1269	1308	0.50	179	Y	Level sand or muddy sand sediments. Very sparse fauna; shrimps, asteroids, holothuroids, small rat tails, oreos.
143	Star of Bengal	5-Nov	V-PLANK	2	859	32	26.27	179	3.98	w	100	0	0.00	70	Y	3 replicate vertical tows to 100 m. Over 700 m bottom.

APPENDIX 2.

Summary of humpback whale individuals with a fluke photograph and/or tissue sample from Raoul Island and Macauley Island. Photographs were taken opportunistically from the RV *Tangaroa* when the small-boat operations were underway.

Date	Group composition		Vessel	Latitude S	Longitude W	Fluke Photo	Tissue sample
	adults	calves					SS=sloughed skin
23-Oct-16	1	1	Work Boat	-29.237870	-177.87154	Y	-
23-Oct-16	2	0	Work Boat	-29.240520	-177.85880	Y	-
23-Oct-16	-	-	Tangaroa	-29.240520	-177.85880	Y	-
23-Oct-16	-	-	Tangaroa	-29.221617	-177.87717	Y	-
23-Oct-16	2	0	Tangaroa	-29.221617	-177.87717	Y	-
23-Oct-16	-	-	Tangaroa	-29.237870	-177.87154	Y	-
23-Oct-16	2	1	Work Boat	-29.24678	-177.86233	-	Mno16KI001-SS
23-Oct-16	2	0	Work Boat	-29.24588	-177.86577	-	Mno16KI002
23-Oct-16	2	0	Work Boat	-29.24588	-177.86577	-	Mno16KI003-SS
24-Oct-16	4	1	Work Boat	-29.232180	-177.93228	Y	Mno16KI007
24-Oct-16	4	1	Work Boat	-29.232180	-177.93228	Y	Mno16KI006
24-Oct-16	2	1	Work Boat	-29.231400	-177.91885	Y	Mno16KI009
24-Oct-16	1	1	Work Boat	-29.238850	-177.90480	Y	Mno16KI010
24-Oct-16	2	1	Work Boat	-29.23967	-177.90948	Y	-
24-Oct-16	2	2	Work Boat	-29.25203	-177.88644	-	Mno16KI004
24-Oct-16	1	1	Work Boat	-29.23649	-177.93425	-	Mno16KI005
24-Oct-16	4	1	Work Boat	-29.24689	-177.90851	-	Mno16KI008
24-Oct-16	1	1	Work Boat	-29.23554	-177.93529	-	Mno16KI011
24-Oct-16	6	0	Work Boat	-29.23301	-177.92757	-	Mno16KI012
24-Oct-16	6	0	Work Boat	-29.23301	-177.92757	-	Mno16KI013
24-Oct-16	6	0	Work Boat	-29.23301	-177.92757	-	Mno16KI014
25-Oct-16	3	1	Work Boat	-29.21559	-177.88297	Y	-
25-Oct-16	4	0	Work Boat	-29.225	-177.95177	Y	-
25-Oct-16	2	0	Work Boat	-29.22301	-177.95055	Y	-
25-Oct-16	1	0	Work Boat	-29.21796	-177.9585	Y	-
25-Oct-16	4	1	Work Boat	-29.22573	-177.96269	Y	-

Date	Group composition		Vessel	Latitude S	Longitude W	Fluke Photo	Tissue sample
	adults	calves					SS=sloughed skin
25-Oct-16	4	1	Work Boat	-29.22573	-177.96269	Y	-
25-Oct-16	4	0	Work Boat	-29.2299	-177.99013	Y	-
25-Oct-16	-	-	Tangaroa	-29.2299	-177.99013	Y	-
25-Oct-16	4	0	Work Boat	-29.2299	-177.99013	Y	-
25-Oct-16	4	1	Work Boat	-29.22573	-177.96269	Y	-
25-Oct-16	-	-	Tangaroa	-29.22573	-177.96269	Y	-
25-Oct-16	4	1	Work Boat	-29.22573	-177.96269	Y	-
25-Oct-16	2	0	Work Boat	-29.22925	-177.98466	Y	-
25-Oct-16	-	-	Tangaroa	-29.22925	-177.98466	Y	-
25-Oct-16	2	0	Work Boat	-29.2172	-177.97972	Y	-
25-Oct-16	4	0	Work Boat	-29.225	-177.95177	-	Mno16KI015
25-Oct-16	2	0	Work Boat	-29.22925	-177.98466	-	Mno16KI016-SS
25-Oct-16	4	1	Work Boat	-29.22573	-177.96269	-	Mno16KI017
26-Oct-16	2	1	Work Boat	-29.28525	-177.96637	Y	-
26-Oct-16	1	1	Work Boat	-29.282	-177.96196	Y	-
26-Oct-16	3	0	Work Boat	-29.282	-177.96196	Y	-
26-Oct-16	3	0	Work Boat	-29.282	-177.96196	Y	-
26-Oct-16	2	1	Work Boat	-29.28525	-177.96637	Y	-
26-Oct-16	1	1	Work Boat	-29.28759	-177.97130	Y	-
26-Oct-16	1	0	Work Boat	-29.28713	-177.97394	Y	-
26-Oct-16	2	0	Work Boat	-29.3161	-177.98918	Y	-
26-Oct-16	6	0	Work Boat	-29.2991	-177.98993	Y	-
26-Oct-16	6	0	Work Boat	-29.2991	-177.98993	Y	-
26-Oct-16	-	-	Tangaroa	-29.28713	-177.97394	Y	-
26-Oct-16	-	-	Tangaroa	-29.28713	-177.97394	Y	-
26-Oct-16	-	-	Tangaroa	-29.28713	-177.97394	Y	-
26-Oct-16	-	-	Tangaroa	-29.28713	-177.97394	Y	-
26-Oct-16	6	0	Work Boat	-29.2991	-177.98993	Y	-
26-Oct-16	-	-	Tangaroa	-29.28525	-177.96637	Y	-
26-Oct-16	2	1	Work Boat	-29.28525	-177.96637	Y	-

Date	Group composition		Vessel	Latitude S	Longitude W	Fluke Photo	Tissue sample
	adults	calves					SS=sloughed skin
26-Oct-16	1	1	Work Boat	-29.28653	-177.95851	-	Mno16KI018
26-Oct-16	1	1	Work Boat	-29.28653	-177.95851	-	Mno16KI019
26-Oct-16	1	1	Work Boat	-29.282	-177.96196	-	Mno16KI020-SS
26-Oct-16	2	1	Work Boat	-29.26774	-177.97572	-	Mno16KI021
26-Oct-16	6	0	Work Boat	-29.2991	-177.98993	-	Mno16KI022-SS
26-Oct-16	6	0	Work Boat	-29.2991	-177.98993	-	Mno16KI023
26-Oct-16	6	0	Work Boat	-29.2991	-177.98993	-	Mno16KI024
27-Oct-16	2	1	Work Boat	-29.29346	-177.96326	Y	-
27-Oct-16	1	1	Work Boat	-29.30345	-177.95432	Y	-
27-Oct-16	3	1	Work Boat	-29.28936	-177.97157	Y	-
27-Oct-16	4	0	Work Boat	-29.277	-177.99518	Y	-
27-Oct-16	2	1	Work Boat	-29.28416	-177.96606	Y	-
27-Oct-16	1	0	Work Boat	-29.28769	-177.96629	Y	-
27-Oct-16	3	1	Work Boat	-29.28807	-177.98174	Y	Mno16KI026
27-Oct-16	4	0	Work Boat	-29.277	-177.99518	Y	-
27-Oct-16	-	-	Tangaroa	-29.28807	-177.98174	Y	-
27-Oct-16	-	-	Tangaroa	-29.28807	-177.98174	Y	-
27-Oct-16	-	-	Tangaroa	-29.28807	-177.98174	Y	-
27-Oct-16	2	1	Work Boat	-29.29346	-177.96326	Y	-
27-Oct-16	-	-	Tangaroa	-29.277	-177.99518	Y	-
27-Oct-16	3	1	Work Boat	-29.28936	-177.97157	-	Mno16KI025-SS
27-Oct-16	3	1	Work Boat	-29.28807	-177.98174	-	Mno16KI027
27-Oct-16	2	0	Work Boat	-29.2737	-177.99542	-	Mno16KI028-SS
27-Oct-16	1	1	Work Boat	-29.26481	-177.98827	-	Mno16KI029
27-Oct-16	1	1	Work Boat	-29.26658	-177.98009	-	Mno16KI030-SS
27-Oct-16	2	1	Work Boat	-29.29346	-177.96326	-	Mno16KI031-SS
27-Oct-16	2	1	Work Boat	-29.29346	-177.96326	-	Mno16KI032
28-Oct-16	1	-	Tangaroa	-30.231	-178.39667	Y	-
28-Oct-16	2	0	Tangaroa	-30.21440333	-178.41327	Y	-
28-Oct-16	2	0	Tangaroa	-30.21440333	-178.41327	Y	-

Date	Group composition		Vessel	Latitude S	Longitude W	Fluke Photo	Tissue sample
	adults	calves					SS=sloughed skin
29-Oct-16	-	-	Tangaroa	-30.228	-178.39667	Y	-
29-Oct-16	-	-	Tangaroa	-30.228	-178.39667	Y	-
29-Oct-16	3	1	Tangaroa	-30.22258333	-178.39724	Y	-
30-Oct-16	2	0	Tangaroa	-30.25390833	-178.42405	Y	-
30-Oct-16	2	0	Tangaroa	-30.24818667	-178.41789	Y	-
30-Oct-16	3	1	Tangaroa	-30.2442	-178.41645	Y	-
30-Oct-16	2	0	Tangaroa	-30.22083333	-178.41533	Y	-
30-Oct-16	2	0	Tangaroa	-30.21261667	-178.41625	Y	-
30-Oct-16	-	-	Tangaroa	-30.21261667	-178.41625	Y	-
30-Oct-16	3	1	Work Boat	-30.22316	-178.40131	-	Mno16KI033-SS
31-Oct-16	1	1	Tangaroa	-30.23916667	-178.38567	Y	-
31-Oct-16	3	1	Tangaroa	-30.215695	-178.41401	Y	-
31-Oct-16	2	0	Work Boat	-30.20727	-178.41783	-	Mno16KI034-SS