Fisheries New Zealand
Tini a Tangaroa

Quantifying Benthic Biodiversity—Phase II: a factual voyage report from RV *Tangaroa* voyage TAN2004 to Campbell Plateau, 17 May–7 June 2020

New Zealand Aquatic Environment and Biodiversity Report No. 264

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Uncertainty about the environmental effects of activities associated with deep-sea resource use, including bottom trawling, is a continuing issue for New Zealand. Species-environment models, which use correlations between environmental variables and records of species' presence to predict distributions, are increasingly used to aid management of environmental risk in the deep sea. However, reliable quantitative data on the distribution and abundance of seabed fauna are limited in New Zealand waters. This situation has resulted in high levels of uncertainty associated with predictive models of communities and species distributions, which in turn have resulted in either precautionary management decisions in relation to proposed seabed resource use or management decisions being made without this information. Critical data for reducing uncertainty in such models includes quantitative baseline information on the distribution and abundance of benthic habitats, communities, and species.

In 2016, the Ministry for Primary Industries (now Fisheries New Zealand) initiated the *Quantifying Benthic Biodiversity* project with the objective of reducing uncertainty in species-environment model predictions for seabed invertebrate taxa across New Zealand's Exclusive Economic Zone (EEZ). This was to be achieved in three stages: collection of new, quantitative data in a series of dedicated photographic surveys; merging of these data with existing, high-quality photographic survey data; then using the combined dataset to generate improved distribution models. Following the successful completion of Phase I of this project, centred on Chatham Rise (ZBD2016-11), FNZ commissioned further work (ZBD2019-01) which extended the spatial extent of the new models to include another region of major fisheries importance: Campbell Plateau. This report is a summary of the second seabed photographic survey in the *Quantifying Benthic Biodiversity* project: TAN2004 to Campbell Plateau.

The survey was designed to acquire quantitative data about benthic habitats and fauna across Campbell Plateau, an oceanic plateau extending to the south of New Zealand's South Island, using a towed camera system with high-definition digital video and still image cameras. Photographic transects of approximately 1 km seabed distance were completed at 82 sites across Campbell Plateau, in depths from 83 m to 2062 m. The total seabed distance covered by photographic transects was 58.4 km (approximately 175 000 m^2 seabed area), with 86 hours of seabed video and 20 500 still images recorded, and more than 35 694 individual observations of fauna recorded to log files. Multibeam echosounder data and CTD data were also collected routinely throughout the voyage.

This report presents details of the activities, sequence of events, samples, and data collected during the survey, together with preliminary descriptions of seabed habitats and faunal distributions observed across the study area and representative images from each site. Data from the voyage will take several months to analyse in detail, yielding finer-level taxonomic identifications and more precise population density estimates than were possible at sea. Meticulous auditing and cross-checking will then be required before these data can be combined with those from earlier surveys on Campbell Plateau and data from Chatham Rise collected and compiled under Phase I of the *Quantifying Benthic Biodiversity* project (ZBD2016-11). When this analysis has been completed, the combined dataset will provide a spatially extensive, taxonomically detailed, and internally consistent resource enabling further study of deep-sea benthic faunal distributions across a broad area of New Zealand's Exclusive Economic Zone.

1. INTRODUCTION

Uncertainty about the environmental effects of deep-sea bottom trawling is an ongoing issue for New Zealand. The Marine Stewardship Council has identified benthic effects as a topic that needs to be better addressed for eco-certification of commercial fisheries, and public interest in the effects of bottom trawling has been heightened with increased awareness of impacts on marine ecosystems and important seabed habitats such as cold-water corals. To understand and manage the ecosystem impacts of bottom-contacting fishing and other seabed disturbances, it is essential to have reliable, quantitative information about the distribution and abundance of seabed (benthic) habitats, communities, and species. Because such information represents fundamental knowledge about biodiversity, it also contributes to government agencies meeting New Zealand's Biodiversity Strategy goals and commitments under international agreements, including the Convention on Biological Diversity Aichi Targets.

Empirical quantitative data about the distributions and abundances of benthic species are sparse for most of New Zealand's Exclusive Economic Zone (EEZ). This situation has resulted in increasing reliance on predictive 'species-environment' or 'habitat suitability' models to estimate the likelihood of occurrence of benthic taxa. Such models work by calculating complex, non-linear correlations between continuously mapped environmental variables and point-sampled taxon occurrence data. However, the paucity of suitable taxon occurrence data has generally resulted in high levels of uncertainty associated with predictions from such models, which in turn has led to lack of confidence in their outputs when proposed for use in environmental management decision-making.

In 2016, the Ministry for Primary Industries (now Fisheries New Zealand), working with NIWA, initiated a research programme to collect seabed data that would reduce uncertainty in predictive models of the distributions of seabed habitats and fauna throughout New Zealand's Exclusive Economic Zone (MPI project ZBD2016-11, *Quantifying Benthic Biodiversity to improve benthic habitat modelling potential*). A key goal of this initiative was to generate data layers that would inform development of a benthic risk assessment framework for bottom-dwelling organisms in relation to bottom-contacting fisheries. The first survey in this initiative was conducted in January 2017 (TAN1701, Bowden et al. 2017) and collected high-definition digital video and still image photographic transects at 142 sites across Chatham Rise using NIWA's Deep-Towed Imaging System (DTIS). Data on the occurrence of seabed fauna in these transects were used to assess the reliability of existing predictive distribution models on Chatham Rise (Bowden et al. 2021) and were subsequently combined with data from prior photographic surveys of Chatham Rise to inform development of new, fully quantitative models that have improved predictive ability (Bowden et al. 2019a, Bowden et al. 2019b).

At the completion of the Chatham Rise work (Phase I), Fisheries New Zealand commissioned further work (Phase II) under the *Quantifying Benthic Biodiversity* initiative (project ZBD2019-01) including a second photographic survey. This report is a summary of the second survey, TAN2004 to Campbell Plateau.

1.1 Objectives:

The overall objective of project ZBD2019-01 is "*to expand and develop initiatives to improve confidence in predictive models of seabed fauna and habitat distributions started under ZBD201611; 'Quantifying benthic biodiversity to improve benthic habitat modelling potential'*".

This objective is to be achieved via the following four specific objectives:

1. *Predict gradients in benthic faunal turnover across Campbell Plateau (CP) using relationships between faunal distributions and environmental gradients developed for Chatham Rise (CR) under ZBD2016-11;*

2. *Run a dedicated photographic survey of seabed habitats and fauna across CP, structured on the basis of predictions from (1);*

3. *Use quantitative data from the CP survey to assess the utility of existing CR models when applied to a neighbouring area of the EEZ;*

4. *Generate updated models with a spatial domain encompassing both regions by merging data from the CP survey with existing CR dataset.*

Specific Objective 1 was completed in early 2019, and the results will be incorporated in reporting for Specific Objective 3, where they will be assessed against results from the survey (TAN2004, Specific Objective 2). This report is a summary of sampling undertaken during voyage TAN2004 to address Specific Objective 2, including details of methods and chronology, with preliminary results in the form of seabed imagery, descriptions of substrata and fauna present in each photographic transect, tables of benthic taxa records, and plots of their distributions across the study area.

2. METHODS

2.1 Survey area

Campbell Plateau is a large submarine plateau extending to the south and southeast of New Zealand's South Island (Figure 1). Most of the plateau is in depths of 500–1000 m but, in places, shoals to less than 300 m, with the shallowest waters around the Snares Island, Auckland Island, and Campbell Island groups, and on Pukaki Rise in the east. On the western and southern boundaries of the plateau, the seabed descends steeply to depths greater than 3000 m. The sub-Antarctic Front associated with the northern boundary of the eastward-flowing Antarctic Circumpolar Current is deflected around the southern edge of the plateau, and the Sub-Tropical Front lies north of the Auckland Islands, where warmer subtropical waters entrained down the west coast of the South Island recurve to the north, forming the Southland Current, which transports nutrient-rich colder waters towards Chatham Rise in the north (Hayward et al. 2007, Hurlburt et al. 2008, Mackay et al. 2014, Nelson & Cooke 2001). Biological productivity is not as high on Campbell Plateau as on Chatham Rise but is elevated above levels in the surrounding ocean (Gutierrez-Rodriguez et al. 2020), and supports substantial fisheries for several species including: hoki (*Macruronus novaezealandiae*), hake (*Merluccius australis*), ling (*Genypterus blacodes*), arrow squid (*Nototodarus* spp.), southern blue whiting (*Micromesistius australis*), jack mackerel (*Trachurus* spp.), scampi (*Metanephrops challengeri*), orange roughy (*Hoplostethus atlanticus*), and oreos (Family Oreosomatidae) (Fisheries New Zealand 2019).

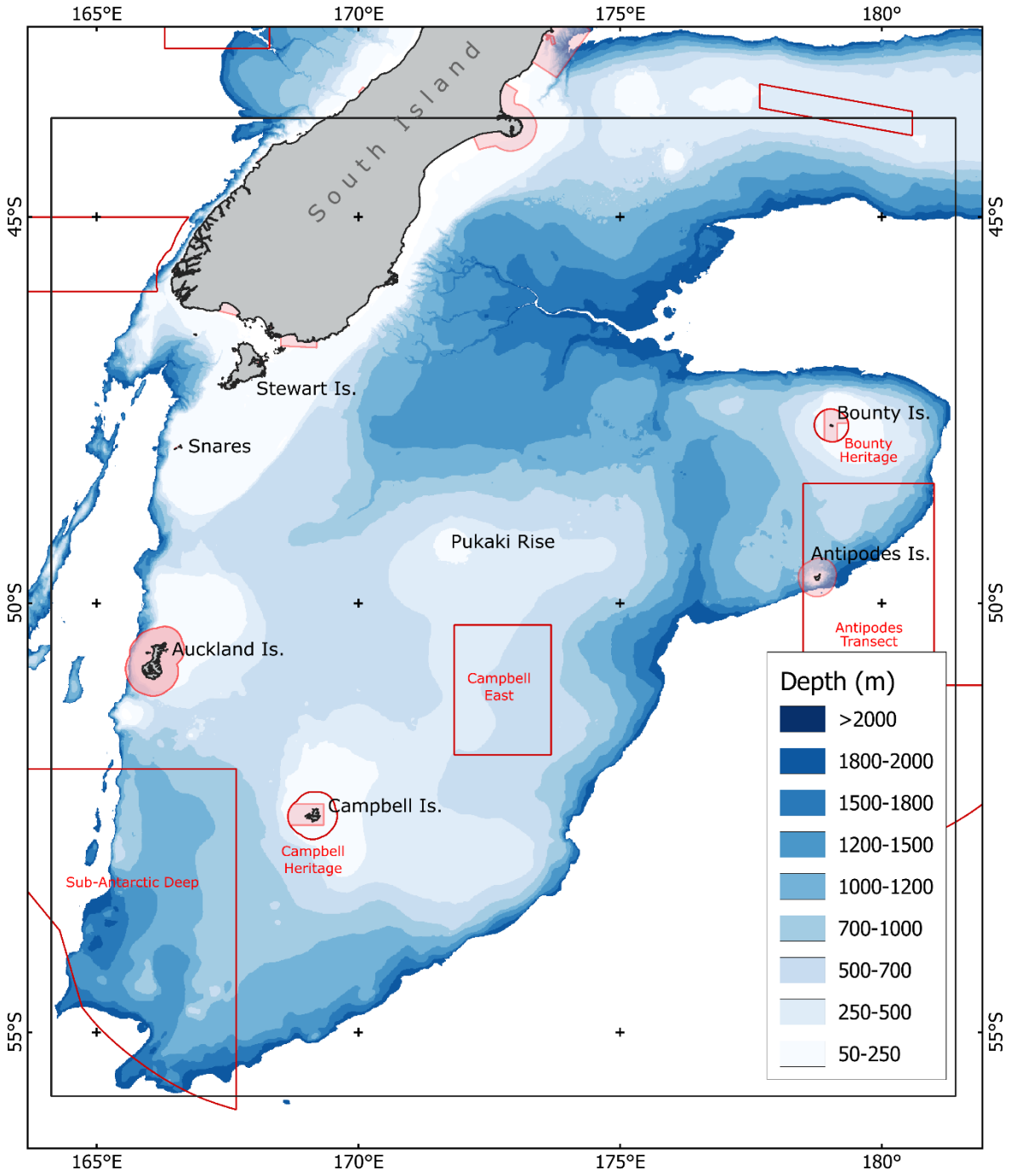

Figure 1: Campbell Plateau, New Zealand. Bathymetry, islands, and boundaries of Benthic Protection Areas (named open red polygons), and Marine Reserves (shaded red polygons). Outer black rectangle indicates maximum extent of the Environmental Protection Authority-approved seabed sampling area for TAN2004.

Seabed habitats have been impacted by bottom trawl fisheries in many regions of the Campbell Plateau. The combined and accumulated footprint of these fisheries shows a concentration of effort around the southern and eastern Stewart-Snares shelf, on the Auckland Islands Shelf, north and east of the Auckland Islands, and in some regions of deeper water at various longitudes between the two main shelf features (Figure 2).

New Zealand's *Fisheries (Benthic Protection Areas) Regulations 2007* currently define seven Benthic Protection Areas (BPAs) that lie at least partially within the EPA-approved seabed sampling area for

the survey (Figure 1); the use of bottom-contacting fish trawls and dredges within these BPAs is prohibited. In addition, Marine Reserves (established under the *Marine Reserves Act 1971*) also exist around the sub-Antarctic islands in the region; no fishing, disturbance, or removal of marine life is permitted in these areas. Of all these protected areas, however, only the Auckland Islands Marine Reserve and a very small portion of the Campbell East BPA lie within the survey area ultimately defined for TAN2004.

2.2 Survey design

Photographic seabed transects using a towed camera system was chosen as the most appropriate sampling method for this survey because it is non-destructive and enables collection of quantitative information about both seabed habitats and fauna simultaneously, at spatial scales ranging from centimetres to kilometres, while still allowing for efficient coverage of broad regions of seafloor.

The Campbell Plateau is too large an area to allow complete coverage in the survey time available without sacrificing too much vessel time to transits between sites. Therefore, the survey area was limited to the western and southern regions of the plateau, covering the steepest gradients of both benthic community change indicated in Gradient Forest analyses conducted for Specific Objective 1 of this project, and cumulative bottom-contacting fishing effort (Figure 2). The survey was planned to cover seabed depths from 50 to 2000 m, with a total of 80–100 sampling sites planned for in the initial design, distributed using a stratified, weighted-random design approach with ten classes from the Gradient Forest classification as strata. This design was modified after disruptions caused by the COVID-19 pandemic resulted in a substantial delay to the voyage departure and reduction of its duration from four weeks to three weeks, requiring the target number of survey sites to be reduced to 60–70.

There were four stages to the initial selection of random sampling sites.

1. Random placement of 10 sites per Gradient Forest (GF) classification stratum.
2. Random placement of additional sites across the entire survey extent, weighted by gradients in:
    a. model predictions of abundance for three individual taxa with contrasting distributions: the branching scleractinian coral *Goniocorella dumosa*, sea pens (Pennatulacea), and non-cidarid echinoids (Euechinoidea) (80 sites each)
    b. cumulative commercial bottom trawl intensity based on data layers produced by Baird & Mules (2021a, 2021b).
3. Elimination of neighbouring sites by spatial proximity, to reduce total number of sites to 5 per stratum, with extra sites for those strata that are represented by more than a single polygon. In this stage, allowance was also made for existing comparable seabed imagery available from Auckland Islands Shelf (TAN1602, Roberts et al. 2018).
4. Repetition of steps 1–3 to generate ‘A’ and ‘B’ sets of survey sites as contingency for at-sea operations.

Random allocations were made using the *random selection within subsets* tool in QGIS (for stage 1 above) and the function *sample* in R software (for stage 2). For stage 1, the number of sites allocated per stratum was equal across strata, regardless of differences in stratum size. This approach was used because stratum size is a reflection of the steepness of environmental gradients; more strata are defined across regions of strong gradients. Thus, a larger stratum may be expected to encompass less-pronounced environmental gradients and the total number of samples required to characterise a stratum may be similar regardless of size.

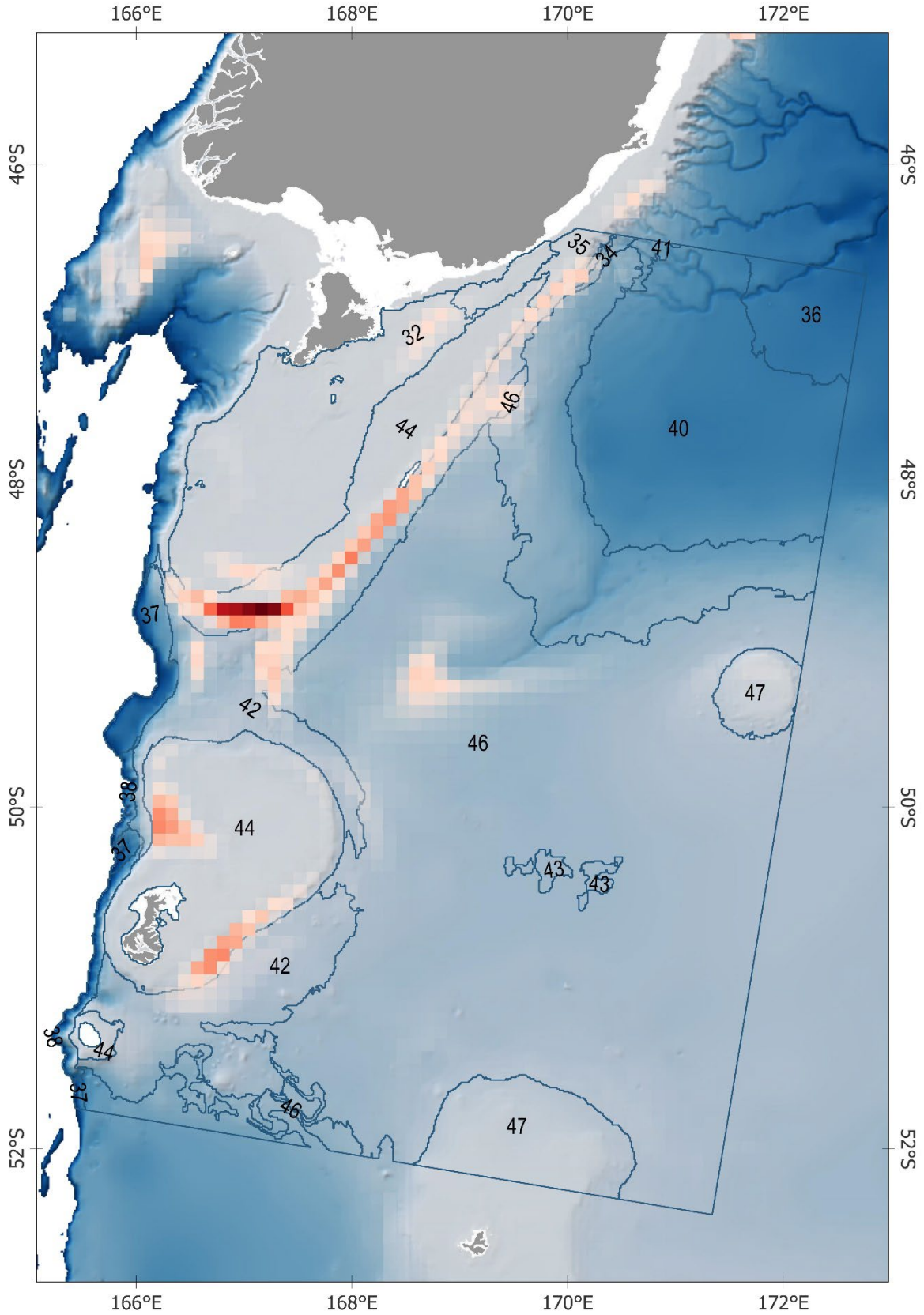

Figure 2: **The Campbell Plateau survey area showing boundaries of the Gradient Forest classes used for sampling stratification, underlying bathymetry, and aggregated bottom trawling swept area (ha swept per 25 km^2 of seafloor, re-gridded to 10 x 10 km cells) from all deep-water and inshore vessels reporting coordinates for individual trawls, for the 1989–90 to 2017–18 fishing years. Maximum value (darkest cell) = 520 024 ha.**

2.3 Sampling

Towed camera system

NIWA's Deep Towed Imaging System (DTIS, Hill 2009) was the primary sampling tool for the voyage (Figure 3). This is the same system used in all Ocean Survey 20/20 benthic surveys since 2007 (Bowden. 2011, Bowden et al. 2013, Nodder 2007a, Nodder 2007b), all of NIWA's Seamounts and Vulnerable Deep-Sea Communities research programme surveys (Bowden et al. 2016, Clark et al. 2010), and the Chatham Rise photographic survey carried out under Phase I of this research programme (ZBD2016-11, Bowden et al. 2017). As such its use on this voyage enabled substantial additions to be made to an already extensive benthic dataset, in a matching format.

DTIS is a battery-powered towed camera frame deployed on a single-conductor CTD cable with real-time video feed and control of camera and light functions via a G.SHDSL modem link (Hill 2009). In its current configuration, DTIS records continuous high definition digital video (Sony HDRPJ760P, HD1080p), with high resolution digital still images (Nikon D3200 DSLR, 24-megapixel JPEG) captured simultaneously at 15-second intervals throughout the transect. Video lighting is from two 80-Watt LED floodlight units (Sealite Sphere 5100, Deep Sea Power & Light Inc.), and stills lighting is from 2 x 330Ws strobe units (Develogic Gmbh).

DTIS transects were run for one hour at 0.6 knots (~1 km seabed distance), at a target altitude of 2–3 m above the seafloor, using RV *Tangaroa*'s Dynamic Positioning system (DP) to maintain precise control of course and speed over the ground. Full resolution video and still images were recorded at the seabed and downloaded on return to the surface. The low-resolution video image transmitted to the surface in real time enabled control of camera altitude and initial evaluation of seabed substratum types and fauna. The seabed position of DTIS was monitored by an acoustic ultra-short baseline (USBL) transponder system (Kongsberg HiPAP) and plotted in real time using Ocean Floor Observation Protocol software (OFOP, http://www.ofop-by-sams.eu/). A Seabird CTD unit attached to the DTIS frame during each deployment recorded water column data (conductivity, temperature, and depth) that were also downloaded on deck.

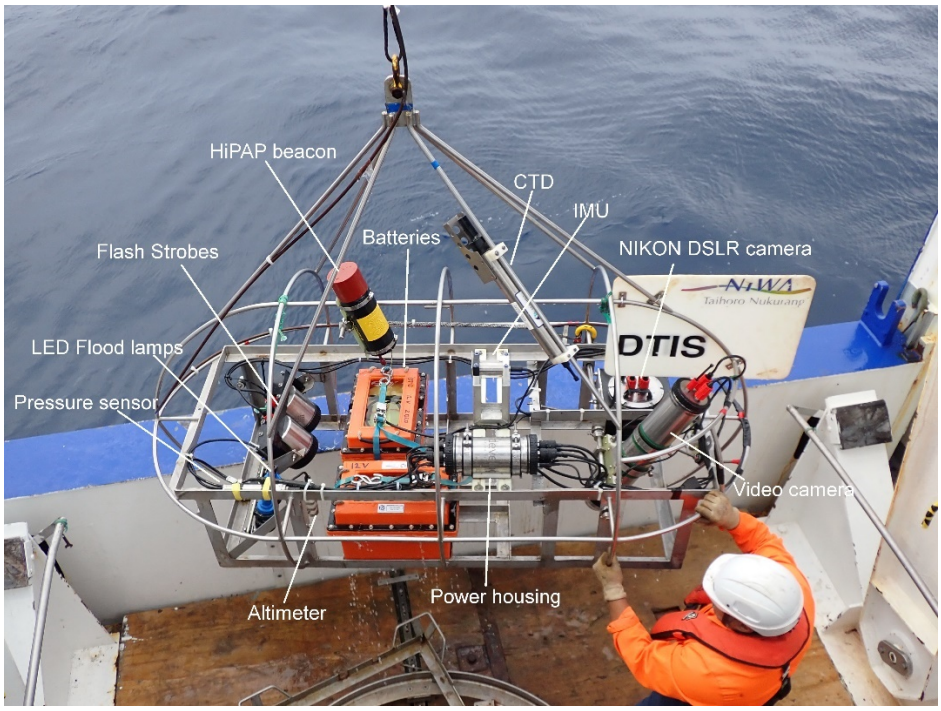

Figure 3: NIWA's Deep Towed Imaging System (DTIS) in the configuration used during the voyage.

Observations of seabed substrata and individual benthic and demersal fauna, including fishes were recorded using OFOP throughout all camera deployments. These observations were made from the lower-resolution real-time DTIS video feed using standard procedures with three science staff: one watching the screen and calling observations; one entering these observations in OFOP; and the third monitoring technical parameters of DTIS and communicating with the bridge officer and the winch driver to ensure consistent direction, speed, and altitude.

DTIS video was saved as high definition (HD1080p) *.MTS files to a dedicated hard disc drive (DTIS HDD) and to the ship's server. Video files were saved with camera-original numerical file names defining date and time of capture as year, month, day, hours, minutes, seconds (YYYMMDDHHMMSS). Still images were downloaded from DTIS immediately on recovery of the vehicle and voyage-specific file names and metadata were written using the 'batch edit' tools in ACDSee Pro. A full duplicate set of the DTIS images was then created and geo-referenced information was written to the EXIF data fields of each image individually (Latitude and Longitude as DTIS USBL position harvested from the ship's Data Acquisition System via the OFOP protocol files) using NIWA's custom 'Geotagger' tool (developed by Santiago Herrera, Vijay Paul, and Brent Wood). All images were then saved to the ship's server and backed up to the DTIS HDD. All OFOP log files were checked for completeness of navigational data and accuracy and consistency of seabed observations after each deployment and saved to the ship's server. Ashore, all video, image, OFOP log files, and CTD data were uploaded to NIWA's secure archive servers.

After each DTIS transect, observation log files and high-resolution still images were evaluated for the existence of *sensitive environments*, as defined by Schedule 6 of the Exclusive Economic Zone and Continental Shelf (Environmental Effects - Permitted Activities) Regulations (2013) under the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012. Although detailed density estimates for benthic taxa associated with such habitats were not made at sea, sites where there was consensus among the survey team that thresholds indicating sensitive environments were likely to have been exceeded were noted and reported to both Fisheries New Zealand and the Environmental Protection Agency (EPA).

Multibeam echosounder

RV *Tangaroa*'s multibeam echosounders (MBES; Kongsberg EM302 and EM2040) were used to map seafloor topography during transits between survey sites and at all sampling sites, so that detailed bathymetric maps were available for safe deployment of DTIS. Sound velocity profiles were harvested routinely from the DTIS CTD data (using Sound Speed Manager (https://www.hydroffice.org/soundspeed/main). All MBES data collected were processed and cleaned at sea using QPS QIMERA (version 2.1.1), and maps were generated using ESRI ArcGIS Pro (version 2.4.3).

3. RESULTS

3.1 Voyage summary and timetable

After a 41-hour transit from Wellington, sampling operations took place at sea over an 18-day period from 19 May to 5 June 2020. Sampling commenced offshore of the south Otago coastline at site A34, in GF classification stratum 28, then zig-zagged between successive sites roughly following an anti-clockwise direction to the Stewart-Snares shelf, south down to and around the Auckland Islands, and then back northward on the eastern side of the survey area, ending at site A69 in GF classification stratum 36 in the Great South Basin (Figure 4, Table 1).

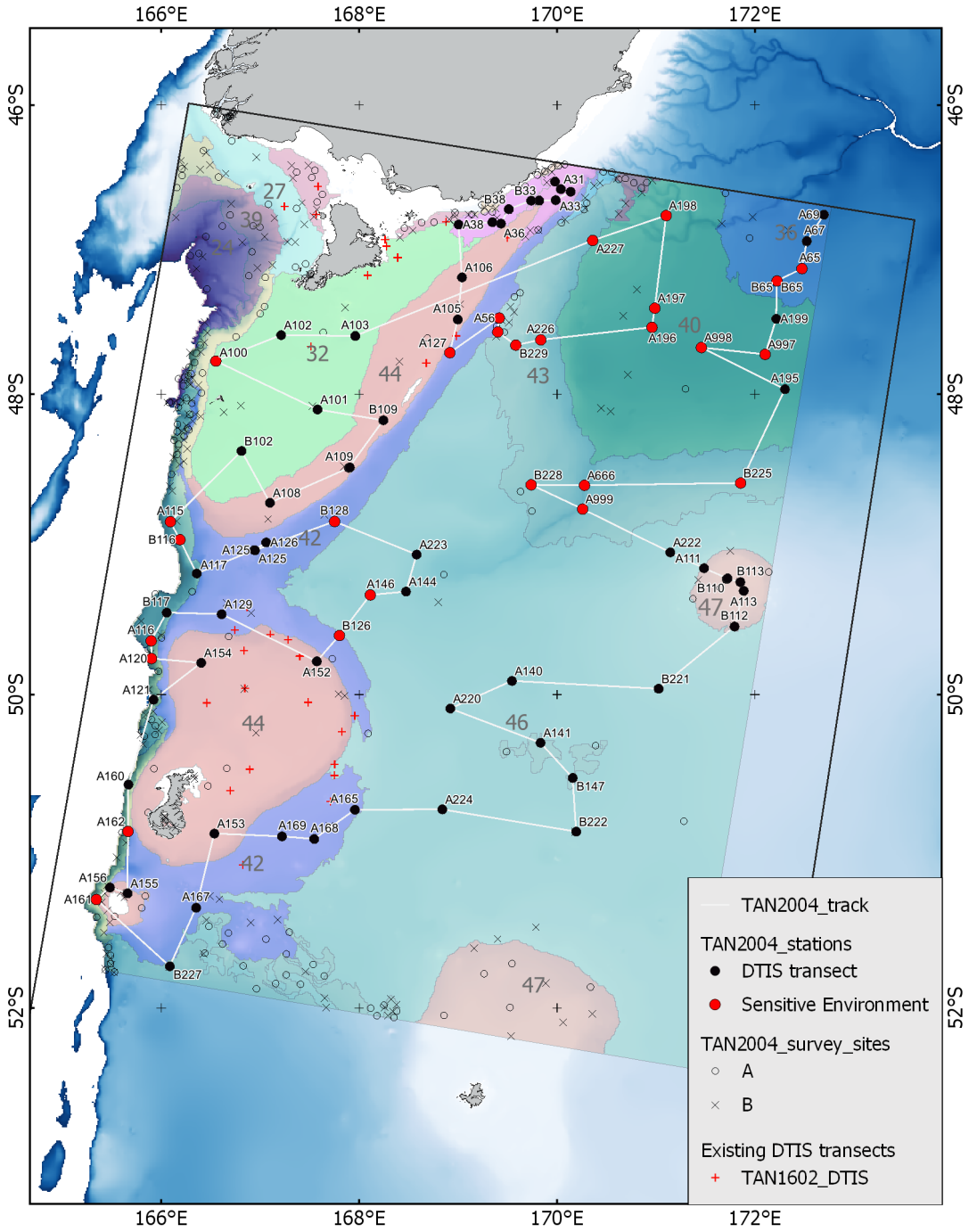

Figure 4: **Sampled sites (TAN2004_stations, labelled with site codes) and track of RV *Tangaroa* during voyage TAN2004. Sites at which fauna indicative of sensitive environments were recorded during DTIS camera transects are indicated as red dots. See Appendix 1 – Station Records and Appendix 3 – Site summaries for details of deployments, fauna and substrata, and representative images. Also indicated on the map are: the Gradient Forest survey strata (coloured polygons with stratum/class numbers); the full set of pre-defined, random-stratified sites from which survey sites were selected at sea (TAN2004_survey_sites), and existing DTIS stations recorded during voyage TAN1602, from which comparable imagery and data are available. Black rectangle indicates boundary of original planned extent of survey (4-week survey).**

Table 1: Voyage TAN2004, 17 May–7 June 2020, summary log of voyage progress. DTIS; Deep-Towed Imaging System; times are NZDT. Refer to Figure 4 for site locations and ship's track and Appendix 1 – Station records for station details.

Date	Activity
16 May	Mobilisation, Aotea Wharf, Wellington.
17 May	0900 h Depart Aotea Wharf, Wellington. Headed southward into a light southerly.
17–19 May	Transit to northern boundary of study area. Excellent weather conditions for the entire transect but passage slowed by several hours due to adverse currents, especially around Banks Peninsula.
19 May	0220 h arrive at site A34, off Nugget Point on south Otago coast. Run MBES survey followed by DTIS transect within swathed area. Completed 7 MBES/DTIS stations in shallow water (100–120 m); strata 35 and 28.
20 May	Completed 6 MBES/DTIS stations in northern strata, eastern Stewart-Snares shelf (strata 28, 42, 44).
21 May	Completed 5 MBES/DTIS stations in northern strata (strata 40, 43, 46).
22 May	Completed 3 MBES/DTIS stations in northern strata (strata 40, 43). Slow speed on long transit into strong wind and heavy swell resulted in a loss of 8 h survey time.
23 May	Completed 3 MBES/DTIS stations on Stewart-Snares shelf (stratum 32).
24 May	Completed 5 MBES/DTIS stations on Stewart-Snares shelf strata (strata 32, 44).
25 May	Completed 5 MBES/DTIS stations in strata 32, 37, 42 south of Stewart-Snares shelf.
26 May	Completed 5 MBES/DTIS stations in strata 42, 46 south of Stewart-Snares shelf.
27 May	Completed 6 MBES/DTIS stations in strata 37, 42, 44, 46 north of Auckland Islands Shelf.
28 May	Completed 4 MBES/DTIS stations in strata 38, 44 western flank of Auckland Islands Shelf.
29 May	Completed 6 MBES/DTIS stations in strata 38, 42, 43, 44 south of Auckland Islands.
30 May	Completed 5 MBES/DTIS stations in strata 42, 44, 46 east of Auckland Islands.
31 May	Completed 4 MBES/DTIS stations in strata 43, 46 northeast of Auckland Islands; after 14 days at sea, on-board COVID-19 restrictions eased for the remainder of the survey.
1 June	Completed 5 MBES/DTIS stations in strata 46 and 47 on and around Pukaki Rise.
2 June	Completed 6 MBES/DTIS stations in strata 43, 46, 47 around Pukaki Rise; MBES mapping of granite mound at shallowest point of the rise and added an extra DTIS station to investigate.
3 June	Completed 4 MBES/DTIS stations in strata 40 & 43 north of Pukaki Rise.
4 June	Completed 3 MBES/DTIS stations in strata 36 & 40 north of Pukaki Rise. Lost about 15 hours survey time due to heavy seas.
5 June	Completed 4 MBES/DTIS stations in stratum 36 north of Pukaki Rise. Lost 4 hours survey time due to weather. Conducted class-requirement DP trials. 1700 h commence transit to Wellington.
6 June	Transit to Wellington.
7 June	0700 h Alongside Aotea Wharf, Wellington.

In total, 82 sites were surveyed using MBES and DTIS. No other seabed sampling methods were used. At each survey site, one seabed DTIS transect of one-hour duration was recorded, with four additional deployments being made for operational reasons: repeat of Site A109 because the first attempt was abandoned after 13 minutes due to adverse currents; repeat of Site A125 after the DTIS video camera stopped recording; a second transect at Site B110 due to the varied and interesting terrain on the summit of the Pukaki Rise; and a repeat of Site B65 after large swells initially prevented safe operation of the DTIS. The target number of sites was achieved in all survey strata except for stratum 47; sites in the southern subarea of this stratum were not attempted due to stormy weather forecast for this area and, although extra sites were added in the northern subarea, only 5 of the 6 sites were completed. However,

additional time at the end of the survey allowed 4 transects to be completed in GF classification stratum 36, a lower priority, deep stratum in the northeast of the survey area (Table 2).

There were no gear-related failures during the voyage that resulted in any significant loss of survey time and the weather, sea-state, and reliability of the DTIS systems were such that there was no need to deploy other sampling equipment. Approximately 8 hours of survey time were lost due to adverse sea conditions that substantially reduced vessel speeds on a long transit between sites on 22 May, and operations were suspended for a total of 19 hours on June 4 and June 5 due to heavy seas affecting DTIS operations. See Appendix 1 – Station Records for full deployment details.

Table 2: Target and completed number of photographic transect sites in each Gradient Forest classification stratum. See Figure 2 for strata locations.

	Stratum												
	28	32	35	36	37	38	40	42	43	44	46	47	Total
Target number of sites	5	5	5	0	5	5	5	9	10	10	8	6	73
Completed number of sites	5	5	5	4	5	5	7	10	10	10	11	5	82

The total seabed distance covered in DTIS transects was 58.4 km (approximately 175 000 m^2 seabed area, based on a nominal video frame width of 3.0 m), with 86 hours of seabed video and 20 500 still images recorded, and more than 35 694 individual observations of fauna (Appendix 2 – DTIS Video Taxa) recorded in OFOP log files. For this report, initial summaries of at-sea OFOP observation data are shown to describe the distributions of substrata (Figure 5) and selected taxa (Figures 6 to 13) across the study area, and, for a subset of sites (every tenth site), representative seabed images and a brief text description of substrata and fauna are presented in Appendix 3 – Site Summaries.

3.2 Benthic substrata and fauna

Substrata

Observations of seabed substrata recorded in eight general categories (bedrock, boulders, cobbles, gravel, sand, muddy sediment, shell-hash, and coral-rubble) during camera transects provide an outline map of how substrata vary across the study area (Figure 5), and the site summary pages in Appendix 3 include text summaries of substratum type from the OFOP log files together with representative images from the DTIS still image camera.

The prevailing substrate type across much of the survey area was muddy sediment. At many sites no other substrate type was observed, particularly in deeper eastern regions of the area away from the shelves surrounding Stewart and Snares islands, the Auckland Islands, and the Pukaki Rise. Substrata in these shallower locations were far more heterogeneous, with combinations of sand, gravel, mud, and shell hash at many sites. Hard substrate (bedrock and boulders) formed substantial parts of the substrate in only a few distinct locations. Deeper sites along the western edge of the Campbell Plateau included areas of often rough and steep, boulder strewn bedrock terrain amongst flatter sand/gravel seabed. Two of the shallower transects around the Pukaki Rise weaved in amongst the exposed rock surfaces of granite mounds that characterised the peak region of this feature. Coral rubble was recorded in a substantial proportion of the transect at Site B113 on the top of Pukaki Rise.

Benthic invertebrate fauna

A total of 35 694 individual observations of benthic invertebrate fauna were made during DTIS video transects and recorded in OFOP log files, providing a quantitative record of common faunal groupings seen on the seabed. Because these observations are made from the lower resolution real-time video image feed at sea, identifications are mostly at coarse taxonomic level (Phylum, Class, Order), but density estimates of these and particularly of distinctive fauna such as scampi (*Metanephrops challengeri*) or the queen scallop *Zygochlamys delicatula* are likely to be reliable.

Across all sites, 55 benthic invertebrate taxa were recorded, representing 10 phyla (Appendix 2 – DTIS Video Taxa). Densities of taxa that were observed in the highest numbers are shown in Figure 6 to Figure 13. Taxa recorded at highest overall abundances (top 15%) comprised three echinoderm classes (Echinoidea, Ophiuroidea, and Asteroidea), two sponge classes (Demospongiae and Hexactinellida), two hexacoral groups (Actiniaria and Ceriantharia), 'giant' foraminiferans (Xenophyophoroidea), and bryozoans (Phylum Bryozoa). Taxa with the widest distributions across the survey area (highest site-occupancy) were Actiniaria, Asteroidea, Demospongiae, Echinoidea, Holothuroidea, and Gastropoda, all of which were present at 55 or more of the 82 sites sampled across the survey area, whereas six taxa were recorded at only a single site and three taxa were recorded only as a single individual.

Sensitive environments were recorded at 27 sites (Figure 4); all were defined by densities of xenophyophores exceeding 1 specimen per m^2 at some point during the transect.

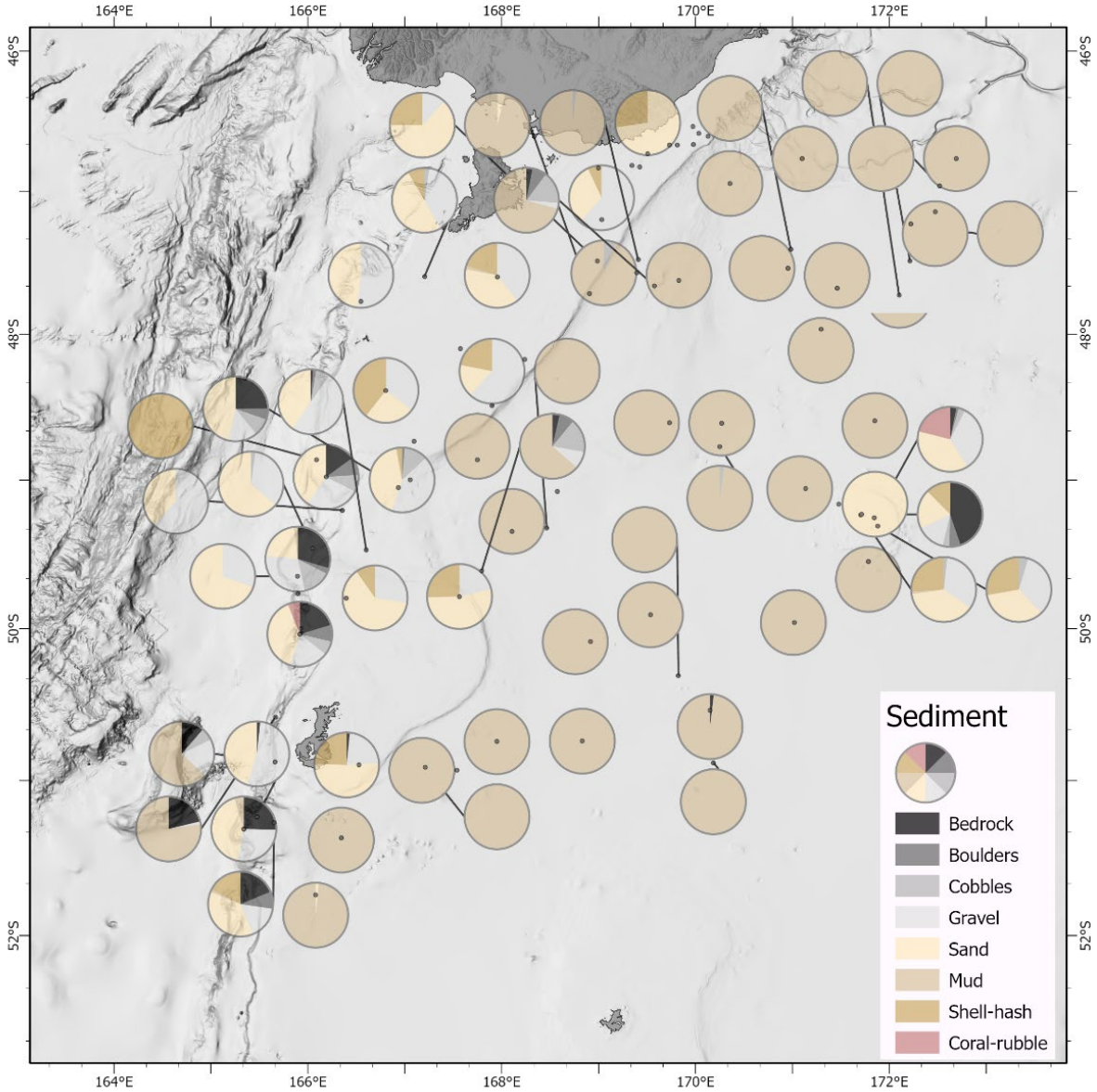

Figure 5: Seabed substrata as proportions of towed camera transect length in eight general categories: bedrock, boulders, cobbles, gravel, sand, muddy sediment, shell-hash, and coral-rubble. Data are at-sea observations forward-filled at 1 s intervals through each transect and expressed as proportion of the full transect (after exclusion of any sections where the seabed was obscured in the video image).

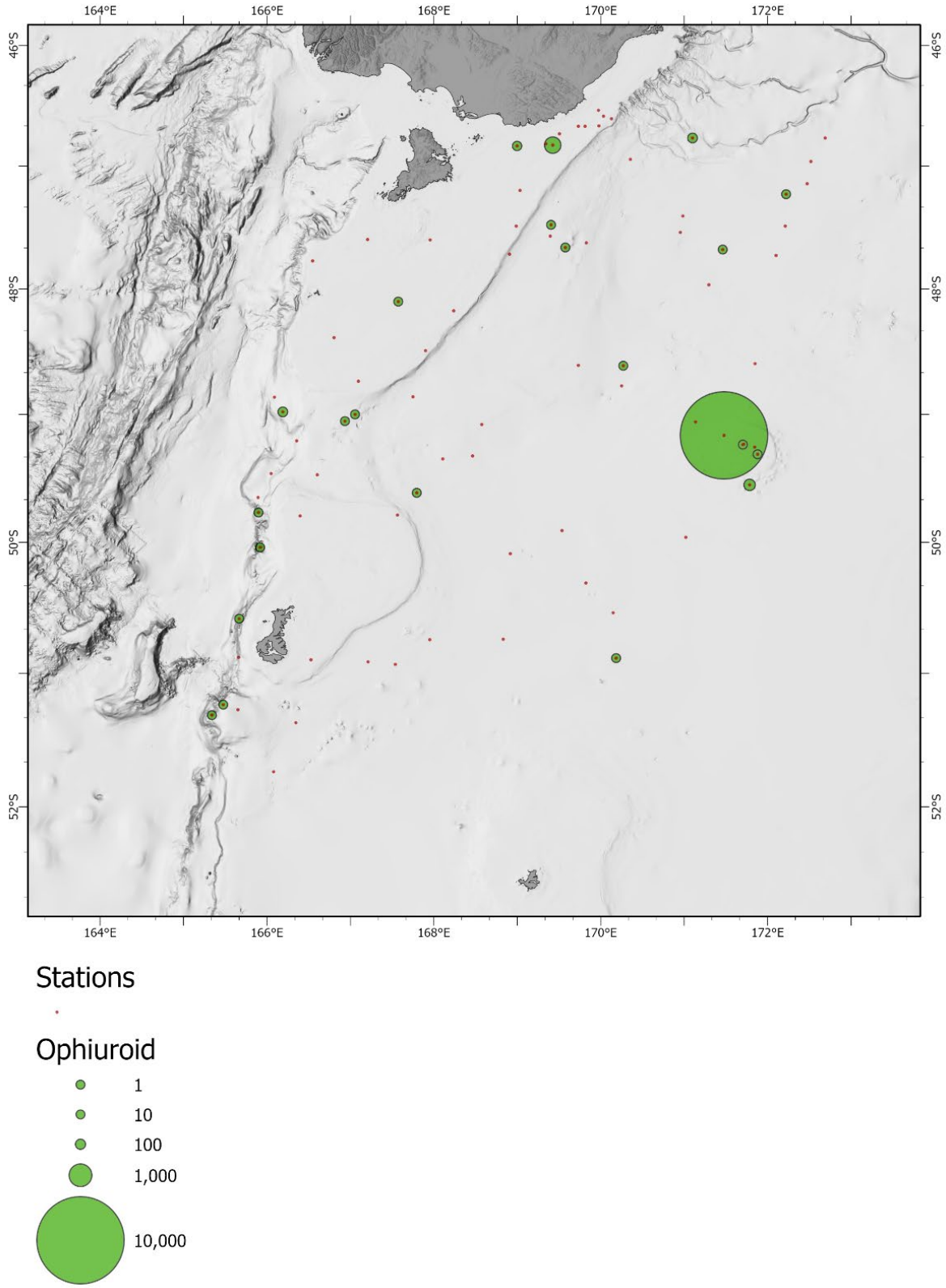

Figure 6: Occurrence and relative densities of Ophiuroidea across the study area. Data are counts of individuals observed in real time during DTIS video transects and the radius of expanding bubble symbols is proportional to number of individuals per transect (approximately 3000 m^2 seabed area).

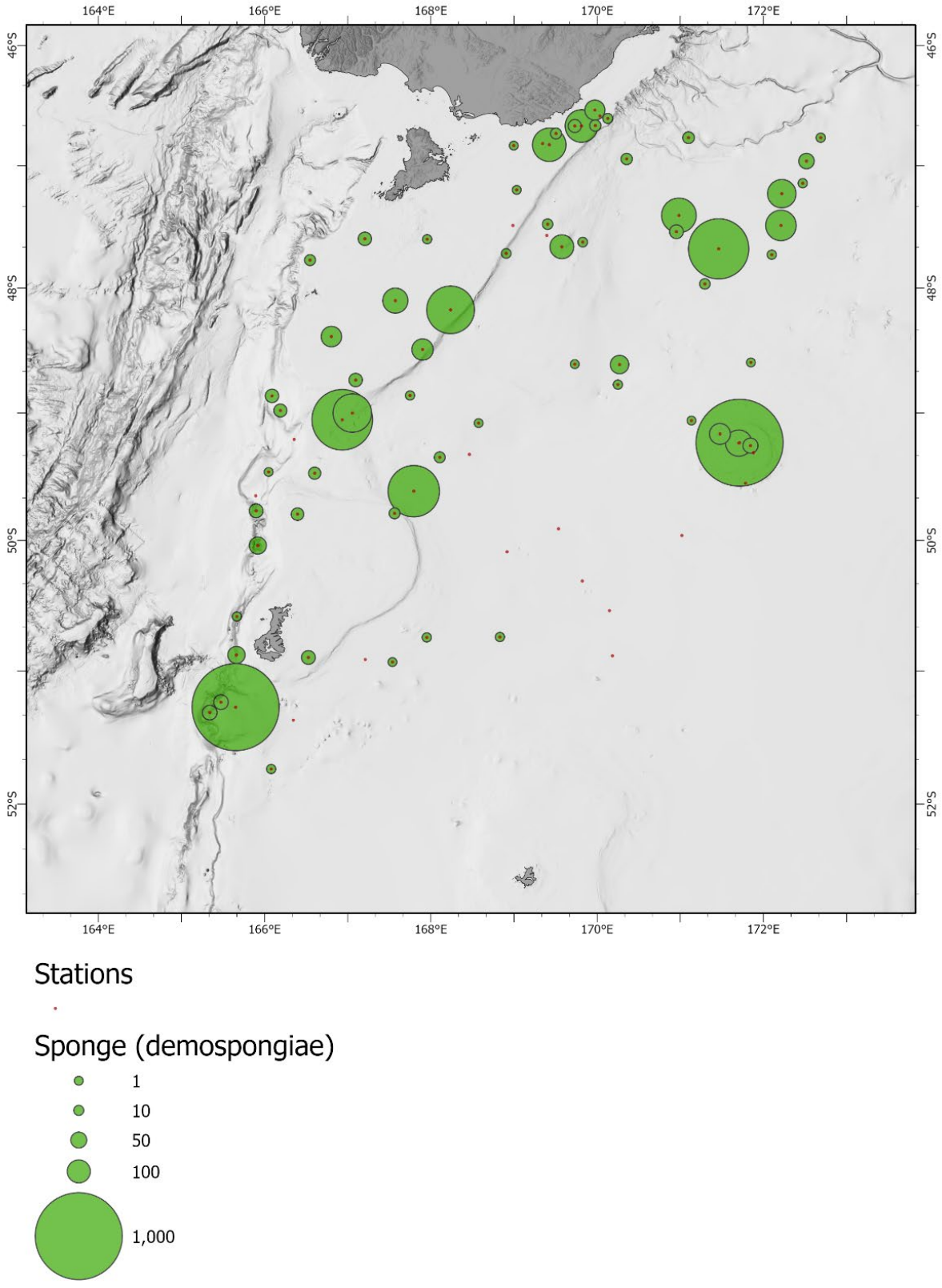

Figure 7: Occurrence and relative densities of Demospongiae (demosponge sponges) across the study area. Details as in Figure 6.

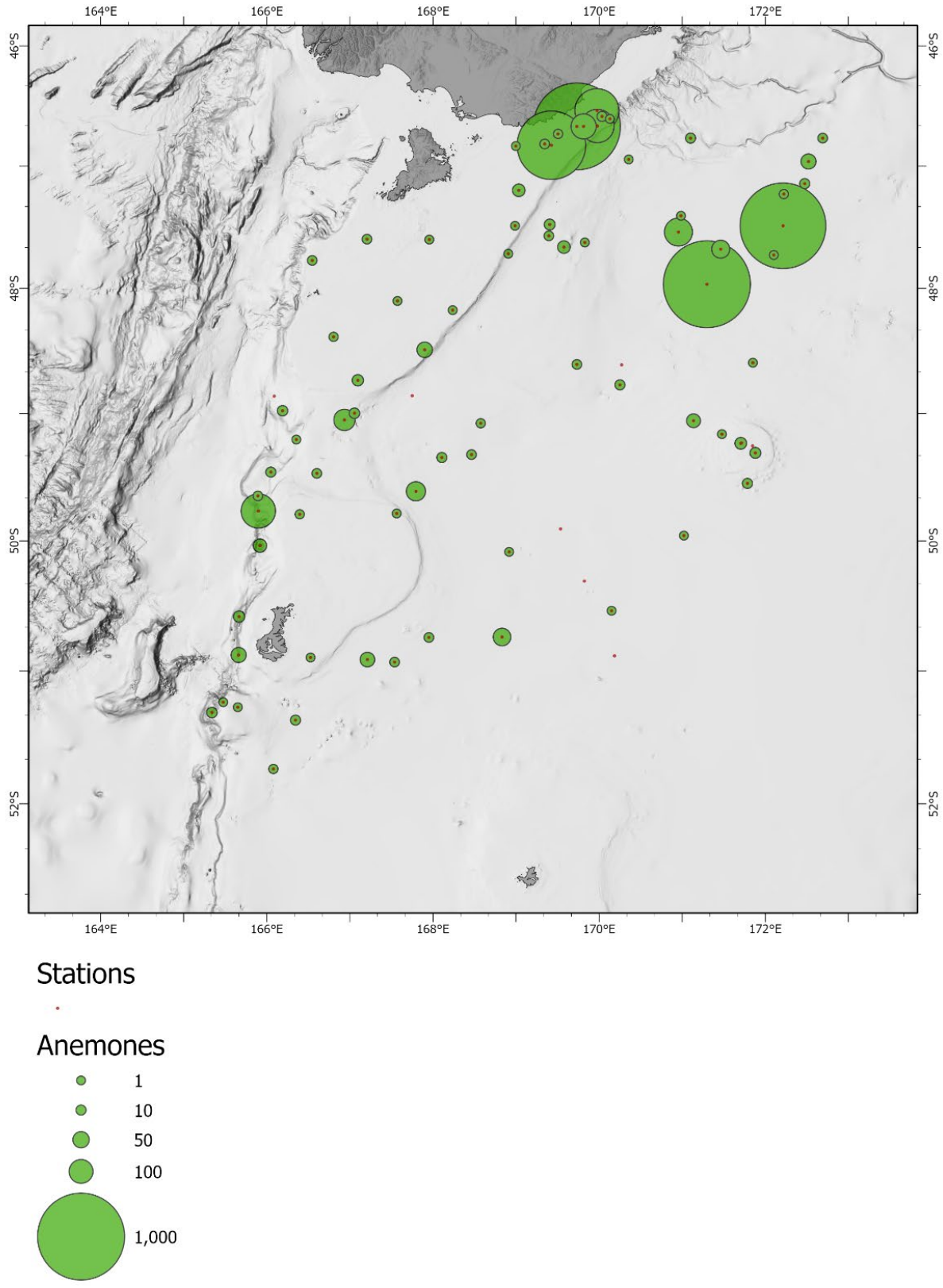

Figure 8: Occurrence and relative densities of anemones (Actiniaria) across the study area. Details as in Figure 6.

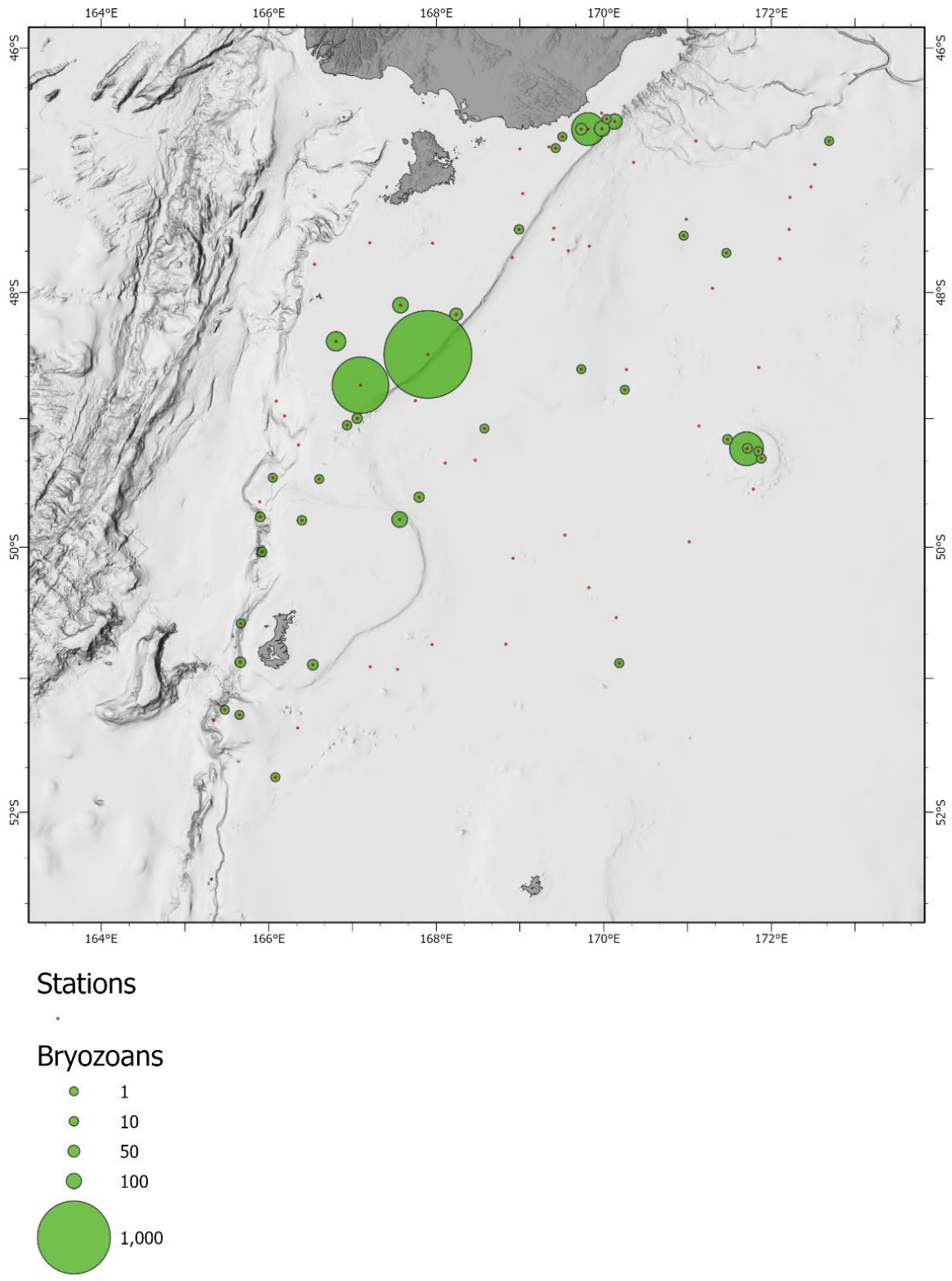

Figure 9: Occurrence and relative densities of bryozoans (Bryozoa) across the study area. Details as in Figure 6.

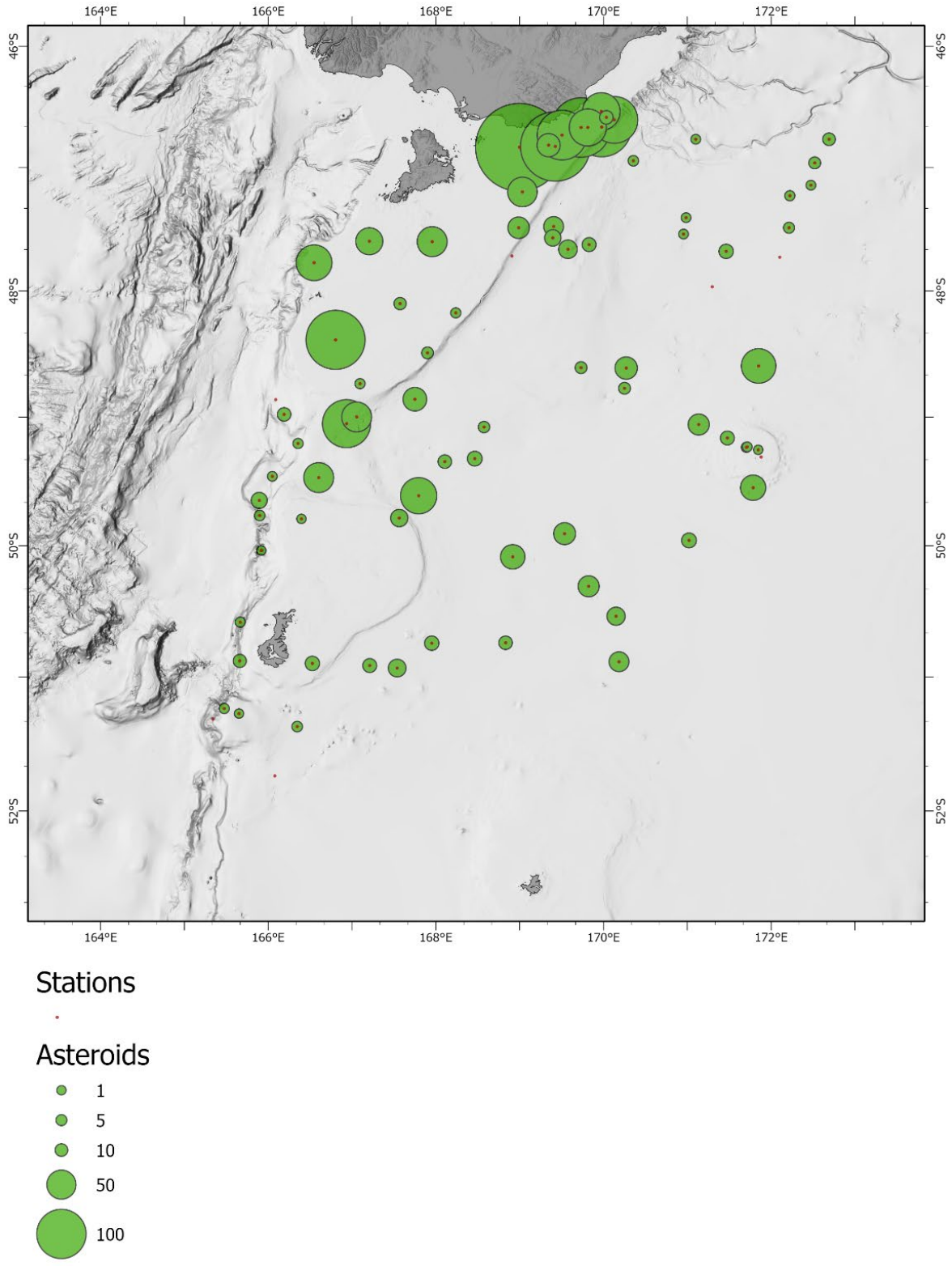

Figure 10: Occurrence and relative densities of asteroids (Asteroidea) across the study area. Details as in Figure 6.

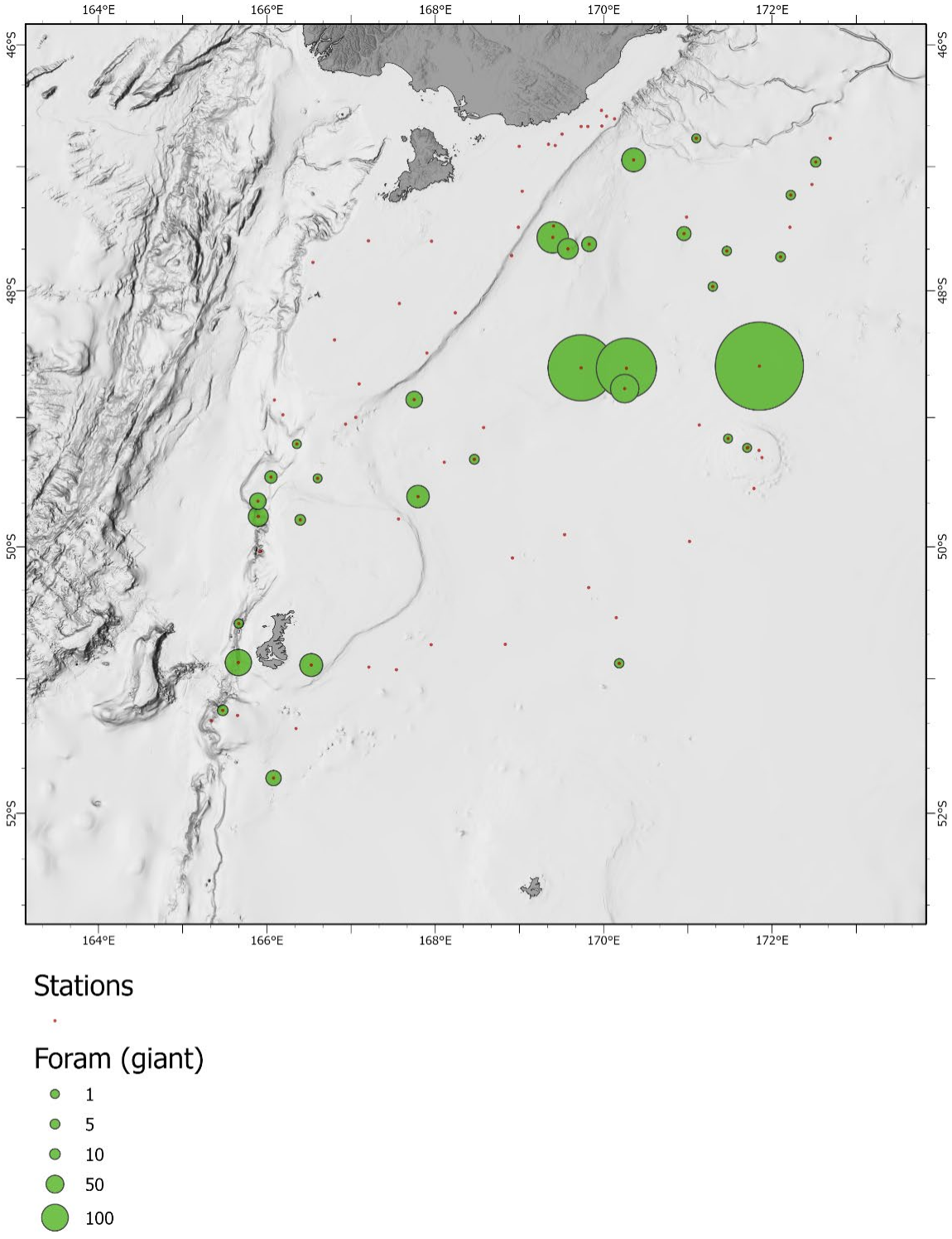

Figure 11: Occurrence and relative densities of giant foraminifera (Xenophyophora) across the study area. Details as in Figure 6.

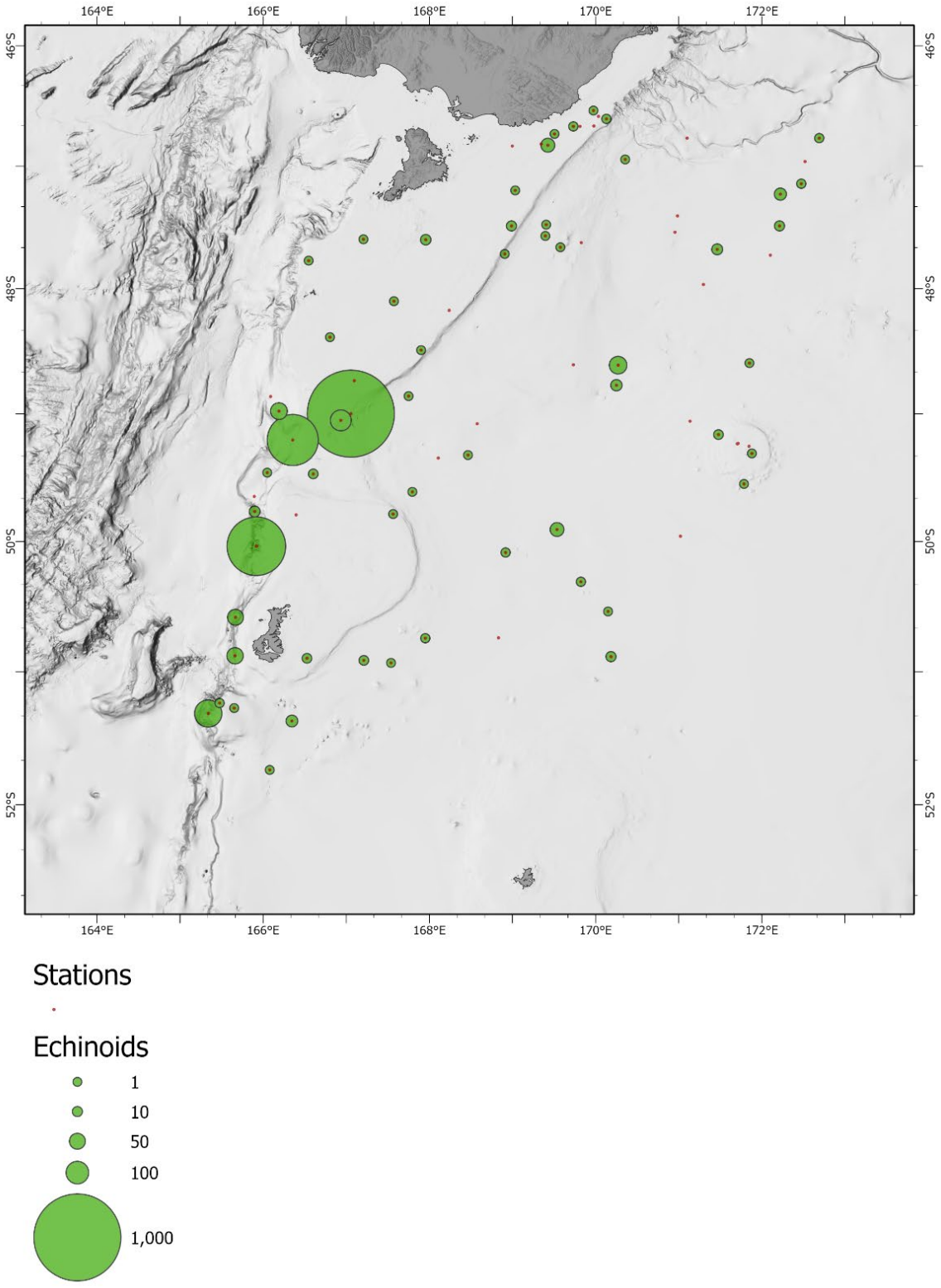

Figure 12: Occurrence and relative densities of echinoids (Echinoidea) across the study area. Details as in Figure 6.

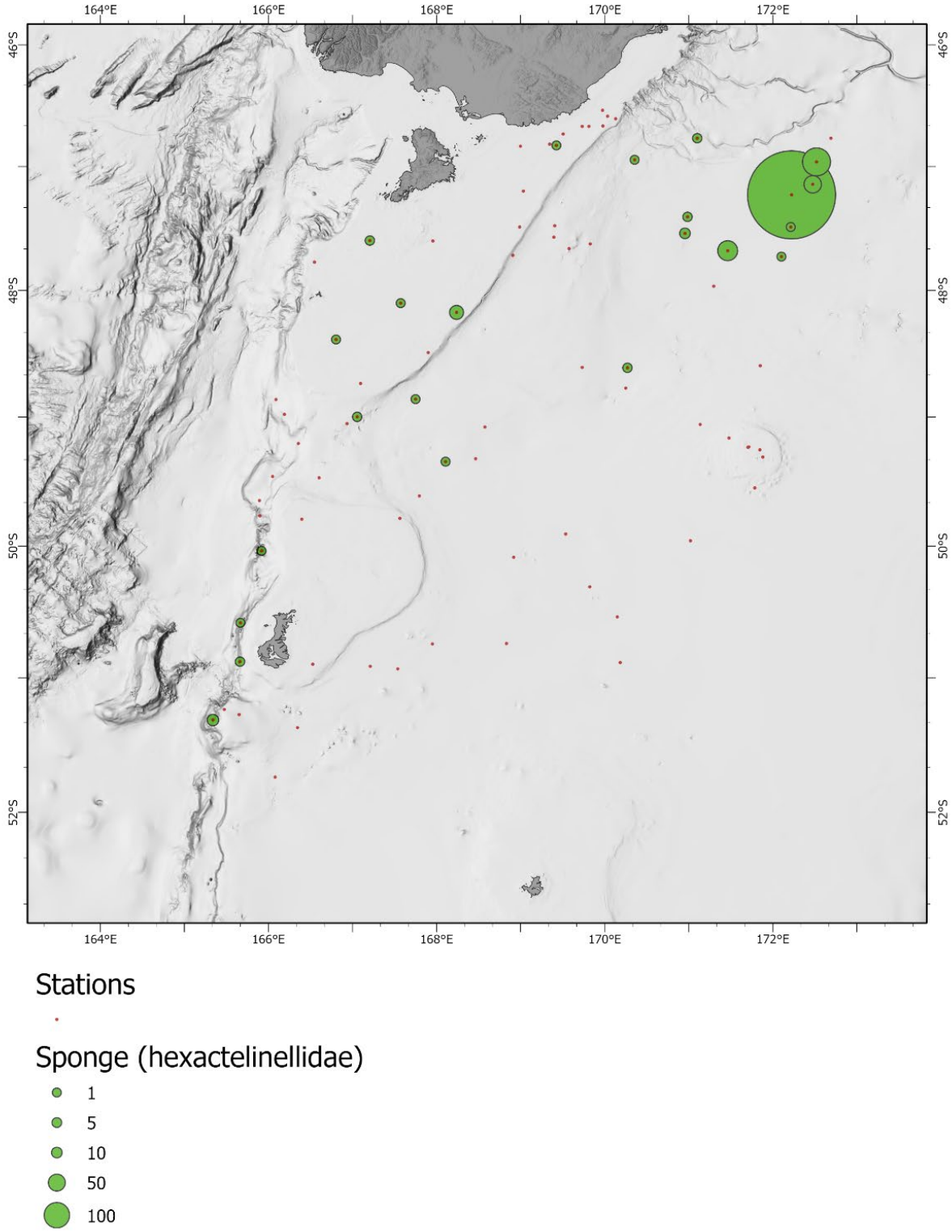

Figure 13: Occurrence and relative densities of glass sponges (Hexactinellidae) across the study area. Details as in Figure 6.

3.3 Multibeam and CTD

Multibeam echosounder data were collected at all sites (except those sites for which data were available from earlier surveys; stations 20, 21, 22, 23, and 86) as well as during all transits between sampling sites. The data collected comprised seabed topography, backscatter, and water column returns and are stored in NIWA's Bathymetric Database (*BathyDataBase – BDB*).

Data from a total of 84 CTD casts were collected during DTIS deployments, each cast including the full dive profile from launch and down-cast, through the seabed transect, and then the up-cast recovery to the surface (see Figure 14 for representative downcast profiles). Data are stored on a dedicated database at NIWA, Greta Point, Wellington (contact Kevin Mackay) and uploaded to the World Ocean Circulation Experiment database, maintained by NOAA in the USA (WOCE, https://www.nodc.noaa.gov/woce/).

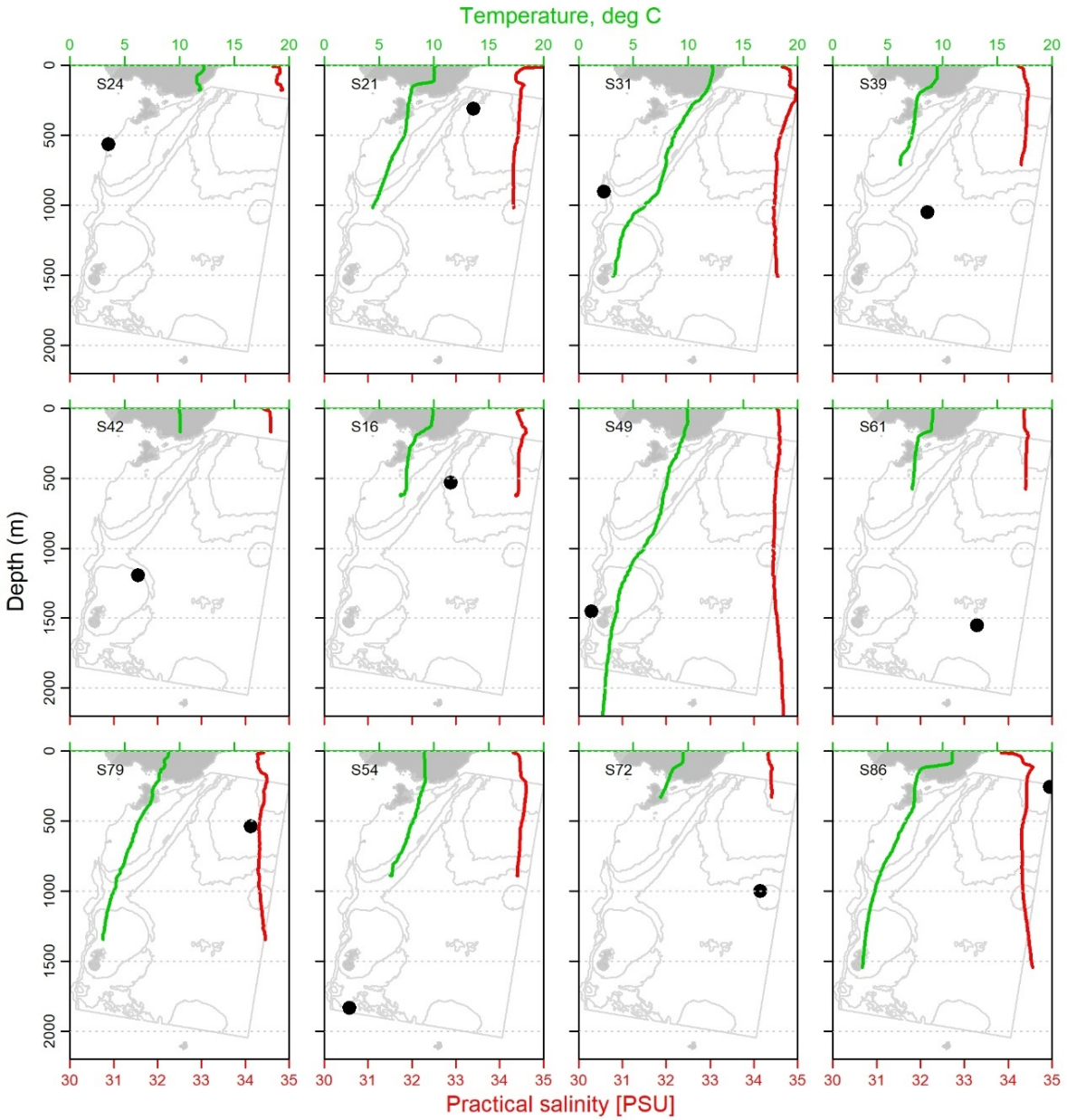

Figure 14: Example CTD profiles from twelve sites across the Campbell Plateau survey area, showing practical salinity (PSU) and temperature (°C). Background shows survey strata and land masses in grey, with locations of CTD samples indicated by black dots; station numbers are indicated in top left of each panel.

4. SUMMARY

The survey was very successful, achieving the voyage objectives without significant loss of time due to weather or gear failure, despite the time of year and the reduced duration of the voyage. High-quality photographic transect data were collected from 82 sites, this being 22 more than anticipated prior to the survey and more even than was initially planned for under a four-week survey design. This survey has greatly expanded the region of Campbell Plateau for which fully quantitative photographic benthic community data are available and, thus, considerably extends knowledge of seabed habitats and fauna in the area. In addition, the CTD and MBES data collected during the voyage will contribute to refining environmental information layers that are fundamental to developing understanding of oceanographic and biological processes across the region, and thus to the accuracy and reliability of the predictive species-environment models that are the focus of this project.

The photographic transects will be analysed in detail, a process that will take several months and produce fine-level taxonomic identifications and precise population density estimates not possible at sea. Auditing and cross-checking procedures will then be conducted on these data to ensure that they are directly comparable with the photographic survey dataset developed for Chatham Rise under Phase I of the *Quantifying Benthic Biodiversity* project (MPI project ZBD2016-11, see Bowden et al. 2019b).

The new data generated from voyage TAN2004 will be used, first, as an independent dataset with which to assess predictions of taxon and community occurrence arising from the models that were developed for Chatham Rise under Phase I of this project (Bowden et al. 2019a) and have been extended to Campbell Plateau under Specific Objective 1 of Phase II of the project (ZBD2019-01). This assessment will yield information about how useful models developed using data from one part of the EEZ are for predicting to neighbouring areas (Specific Objective 3).

Next, under Specific Objective 4, data from the TAN2004 voyage will be combined with the Chatham Rise dataset and new single-taxon and community models will be developed that encompass Chatham Rise, Campbell Plateau, and the area between them (the eastern continental shelf and slope of the South Island, and the Great South Basin to depths of 2000 m). The combined dataset and models derived from this research will thus provide a spatially extensive, taxonomically detailed, and internally consistent resource for further study of benthic faunal distributions across a broad area of commercially and ecologically important deep sea within New Zealand's EEZ, with practical applications as inputs to risk assessment methods for interactions between fisheries and seabed habitats and fauna.

The success of the voyage in achieving its research aims lends support to the recommendation of Bowden & Hewitt (2012) that a strategy of increasing sampling density by deploying fewer gear types is likely to generate more useful datasets than multi-method approaches in broad-scale surveys of benthic biodiversity across New Zealand's EEZ. This success was strongly underpinned, however, by the professionalism and experience of the entire survey team, both science staff and vessel crew, and by the capability and reliability of the technical systems developed and maintained by NIWA.

5. ACKNOWLEDGMENTS

We thank the officers and crew of RV *Tangaroa* for their professionalism, skill, and enthusiasm throughout the voyage. Constructive discussions with Mary Livingston and members of the Fisheries New Zealand Biodiversity Research Advisory Group were useful in the planning stages of the voyage, especially because the voyage duration was reduced as a consequence of delays resulting from the COVID-19 pandemic, and we are grateful to Mary Livingston for continuing governance and oversight of the project. Finally, thanks to Ashley Rowden at NIWA for thorough and constructive review of this report prior to submission.

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APPENDIX 1: Station records

Table 1.1: TAN2004 station summary, showing: sequential station number (Stn); Site code (Site); GF classification stratum (Stratum); start time (New Zealand Standard Time); latitude (Lat., in decimal degrees, negative values are South) and longitude (Long., in degrees – all are East) of start and end positions; depth (m) of start and end positions; with length (Distance (m)) and direction (Direction, in degrees true) of DTIS camera transects, and summary descriptions of transects. (Continued over next three pages)

Stn	Site	Date	Stratum	NZST	Lat.start	Long.start	Lat.end	Long.end	Depth start (m)	Depth end (m)	Distance (m)	Direction	Description
1	A34	19-May	35	0500	-46.536	169.978	-46.543	169.968	112	112	1138	223	Ripples, shell hash in troughs, sponges, anemones.
2	A31	19-May	35	0814	-46.589	170.037	-46.597	170.027	121	122	1136	220	Similar to A34 but no ripples, slightly coarser.
3	A32	19-May	35	1124	-46.607	170.136	-46.614	170.126	122	123	1164	223	Flat, sandy bottom comprising mainly shell hash, pebbles and gravel.
4	A33	19-May	35	1422	-46.665	169.985	-46.673	169.976	119	119	1096	220	Sand, gravel, pebbles. Queen scallops, asteroids.
5	B33	19-May	35	1719	-46.668	169.818	-46.676	169.809	112	115	1115	219	Shelly gravel substrate with ascidians, bryozoan patches, squat lobsters, anemones, and demosponges.
6	A37	19-May	28	2006	-46.669	169.737	-46.678	169.730	115	115	1093	210	Rippled sand and gravel, shell hash. Ascidians and anemones common.
7	B38	19-May	28	2323	-46.728	169.511	-46.737	169.504	100	101	1127	207	Sand, ripples, some shell hash, asteroids. Occasional pebbles, gravel and fish.
8	A36	20-May	28	0453	-46.829	169.432	-46.827	169.418	115	112	1109	277	Shell hash, asteroids, ophiuroids, anemones, demosponge.
9	B36	20-May	28	0704	-46.819	169.345	-46.818	169.330	92	91	1149	276	Rippled sand with shell hash. Asteroids common.
10	A38	20-May	28	1028	-46.835	169.004	-46.834	168.990	83	84	1133	280	Large sediment ripples composed of gravel and pebbles and shell hash. Ray = rough skate. Asteroids most abundant fauna followed by ophiuroids and crabs.
11	A106	20-May	44	1512	-47.201	169.038	-47.201	169.023	119	119	1137	270	Flat sandy, gravelly bottom with wave-like rippling. Not much fauna - mostly asteroids and anemones; a few holothurians and ascidians.
12	A105	20-May	44	1932	-47.490	168.995	-47.490	168.981	123	123	1114	271	Rippled sand and shell hash. Little life, asteroids, salps, blue cod, flatfish, a few echinoids.
13	A127	20-May	42	2309	-47.718	168.916	-47.717	168.902	458	416	1028	271	Xenophyophores. Along slight incline. Sandy sediment with muddy overlay, sometimes rippled with shell hash. Very few fauna, some gastropods and tracks, a couple of sponges, shark. small fishes.
14	A56	21-May	46	0407	-47.481	169.415	-47.481	169.400	510	513	1106	269	Xenophyophores, fish (roughy, hoki, rattail), shrimp, crab, hermit crab, Lebensspuren, ophiuroids, asteroids, holothurians.
15	A55	21-May	46	0736	-47.575	169.400	-47.571	169.386	567	563	1113	297	Muddy sediment, many giant forams, fish, patches of cobbles. A few asteroids, gastropods and pagurids.
16	B229	21-May	43	1059	-47.666	169.582	-47.661	169.569	619	621	1109	297	Flat muddy seafloor with burrows and tracks, with four to five large patches of bedrock, boulders, cobbles, pebbles and gravel with usual community assemblage. Xenophyophore giant forams, pagurids, gastropods, *Pyrosoma* salps, hydroids, fish.
17	A226	21-May	43	1424	-47.630	169.834	-47.625	169.821	828	815	1101	299	Muddy sediment, lots of fish, Xenophyophores, burrows, salps.
18	A196	21-May	40	2146	-47.544	170.958	-47.539	170.945	1295	1282	1143	298	Xenophyophores. Flat muddy substrate with burrows and ring of burrows. Anemones, forams, cerianthids, demosponges, hexactinellids, eels, fish, *Flabellum* observed in transect.
19	A197	22-May	40	0122	-47.413	170.986	-47.404	170.979	1302	1293	1073	329	Xenophyophores. Mud, burrows, tracks, sponge, eel, holothurian, fish, seapen.

Stn	Site	Date	Stratum	NZST	Lat.start	Long.start	Lat.end	Long.end	Depth start (m)	Depth end (m)	Distance (m)	Direction	Description
20	A198	22-May	40	0730	-46.773	171.101	-46.765	171.095	1172	1170	985	330	Xenophyophores, "rings". Burrows, mud, fish, ophiuroids, tracks, holothurian, basketwork eel, sponge, foram.
21	A227	22-May	43	1313	-46.946	170.358	-46.949	170.345	1020	1015	1072	249	Xenophyophores. Muddy/sandy substrate, high densities of xenophyophores. Anemones, sponges, tam-o-shanters, rattails, holothurioids.
22	A103	23-May	32	1118	-47.603	167.960	-47.605	167.945	155	163	1144	261	Fauna dominated by scallops and asteroids. Other observations include salps, anemones, sponges.
23	A102	23-May	32	1618	-47.597	167.211	-47.598	167.196	144	142	1110	265	Lost video feed at 1106 minutes on bottom. Reset after hitting bottom. Lost video again at 48.25. Reset. A few asteroids and fish, sponges in some of the cobbly areas.
24	A100	23-May	32	1001	-47.774	166.552	-47.766	166.543	172	174	1080	325	Sandy, gravelly substrate dominated by asteroids and crabs. Some patches of pebbles which may include sponges or brachiopods.
25	A101	24-May	32	0445	-48.104	167.578	-48.096	167.568	136	138	1142	320	Sandy, gravelly substrate, Bryozoa, sponges, shells, fish.
26	B109	24-May	44	0958	-48.177	168.244	-48.175	168.229	137	136	1110	280	Sandy substrate, pebbles, gravel, shells. Asteroid, ?tubeworms, gastropods, Bryozoa, sponge, ripples. Looks 'barren' for the first 20'.
27	A109	24-May	44	1433	-48.497	167.895	-48.495	167.897	136	137	223	034	Stopped after 13 minutes on the bottom, due to issues with currents and DP. Reran A109 as a new station.
28	A109	24-May	44	1517	-48.495	167.906	-48.490	167.893	138	134	1100	303	Sandy, gravelly substrate. High densities of bushy bryozoans, with some sponges and anemones.
29	A108	24-May	44	2116	-48.732	167.098	-48.741	167.090	131	133	1187	211	Video went offline at 41:19. Elapsed time record didn't continue when back online. Fauna dominated by bryozoans, anemones and sponges with some fish, asteroids and crabs.
30	B102	25-May	32	0232	-48.384	166.811	-48.391	166.801	148	147	1106	224	Sand, gravel, shell hash, ripples. Bryozoa, asteroids, sponge, fish.
31	A115	25-May	37	0935	-48.859	166.092	-48.866	166.087	1503	1420	873	203	Xenophyophores. Barnacle plates, ?coral ? Bryozoa branches, few sponges. Some silt/sand when DTIS landed accidentally. Very homogenous.
32	B116	25-May	37	1311	-48.978	166.189	-48.986	166.177	1556	1593	1148	226	Sand going to bedrock. Ophiuroids, brisingids, crinoids, gorgonians, echinoids, sponges, anemones.
33	A117	25-May	37	1724	-49.203	166.358	-49.211	166.350	1276	1327	1116	213	Sandy, gravelly substrate with fauna dominated by echinoids and *Flabellum*.
34	A125	25-May	42	2159	-49.048	166.939	-49.058	166.934	440	448	1166	200	Variable sandy, gravel, bedrock and all in between. Rich fauna incl. numerous *Gorgonocephalus*, brisingids, echinoids. But video failed after a few minutes and only still images recorded.
35	A126	26-May	42	0110	-48.997	167.060	-49.005	167.052	470	474	1060	213	Sandy substrate with pebbles, gravel, shells, cobbles. *Gorgonocephalus*, anemones, Bryozoa, gastropods, asteroids, echinoids, sponges, hydroids, ophiuroids, fish, squad lobster. Strong current at bottom with a few bumps and two camera stops.
36	A125	26-May	42	0435	-49.049	166.946	-49.052	166.933	439	441	1023	252	Thin layer of sediment (sand?) on bedrock. Some gravel, pebbles, cobbles. Ripples in places (where sediment layer thicker?). Gorgonian, sponge, crinoids, anemones, asteroids, *Gorgonocephalus*, fish.
37	B128	26-May	42	1010	-48.857	167.751	-48.866	167.744	739	736	1106	208	Muddy substrate. Forams, gastropods, hydroids, burrows, asteroids, fish.
38	A223	26-May	46	1548	-49.077	168.580	-49.082	168.567	687	684	1120	240	Muddy substrate throughout. Little macroinvertebrate life, a few asteroids and burrows. Some fish.
39	A144	26-May	46	2012	-49.323	168.473	-49.329	168.460	718	708	1171	232	Muddy substrate throughout. A few asteroids, burrows, quill worms, and shrimps and some fish. Lots of trawl marks.
40	A146	27-May	46	0009	-49.345	168.112	-49.351	168.100	660	664	1076	237	Mud, burrows, tracks, fish. Very barren.

Stn	Site	Date	Stratum	NZST	Lat.start	Long.start	Lat.end	Long.end	Depth start (m)	Depth end (m)	Distance (m)	Direction	Description
41	B126	27-May	42	0459	-49.612	167.800	-49.617	167.787	571	550	1085	238	Wide range of substrate from mud, patches of gravel, cobble, boulders to bedrock patches. Sponge dominated with anemones, Bryozoa, ophiuroids, asteroids, cup-coral, Flabellum, *Hyalascus*?, gastropod, octopus, tracks, *Gorgonocephalus.*
42	A152	27-May	44	0907	-49.782	167.571	-49.789	167.559	172	163	1145	230	Sandy, gravely substrate. Some bedrock at start of line. Boulders, shells, large crab, Bryozoa, sponge, crinoid, asteroid, skate.
43	A129	27-May	42	1510	-49.472	166.610	-49.479	166.595	542	548	1341	236	Mostly asteroid, tam-o-shanterss, holothuroids, rat-tails, sponges on rocky substrate with sand overlay, cobbles, pebbles and gravel.
44	B117	27-May	37	1923	-49.462	166.055	-49.468	166.042	1538	1590	1181	235	Sandy ripples with gravel and pebbles. Lots of tam-o-shanters, brisingids, fish.
45	A116	27-May	37	2349	-49.648	165.898	-49.653	165.887	1452	1487	981	235	Muddy sand, ripples, no burrows observed, some gravel. Tracks, asteroid, anemones, soft coral, fish, shark, eel. 'Meshwire' disk.
46	A120	28-May	38	0408	-49.764	165.901	-49.769	165.891	1584	1633	954	229	Bedrock overlain in places by muddy sand, pebbles to cobbles. Ripples in places. Anemones, sponges, hydroid, forams, echinoids, fish, shark, rattail.
47	A154	28-May	44	0909	-49.792	166.403	-49.798	166.391	169	169	1148	229	Patches of sand with gravel alternating with 'dunes' of rippled sand. Crabs (many), forams, bryozoans, sponge, salps.
48	A121	28-May	38	1321	-50.033	165.922	-50.045	165.915	1327	1615	1422	201	Started with bedrock, boulder substrate with lots of gorgonian corals, bamboo corals, barnacle plates, echinoids; transitioned to sandy, gravelly substrate with barely any fauna apart from echinoids and then back again to bedrock outcrop with high diversity of fauna: bubble-gum corals, gorgonians, sponges, echinoids (mostly *Dermechinus*), crinoids.
49	A160	28-May	38	1930	-50.582	165.668	-50.588	165.655	1954	2062	1151	234	Muddy sediment mainly but steep gnarly bedrock later with DTIS crashing around a bit. gorgonians, echinoids, brisingids, ophiuroids seen, mainly on hard substrate.
50	A162	29-May	38	0048	-50.883	165.664	-50.873	165.664	974	906	1095	000	Diverse facies: Flat muddy to silty areas with burrows. Drop offs with bedrock; base of drop offs with coarser sediment, pebbles, gravel. Fish, rattails, sharks, eels common. Echinoids, Bryozoa, sponges, maybe ?black coral. Abundant forams on little terraces on steep cliff area with finer sediment.
51	A155	29-May	44	0602	-51.278	165.660	-51.273	165.646	141	135	1122	300	Outcrops of bedrock (granite?) changing with flat areas of sand with boulders. Giant crab; gorgonian; sponges.
52	A156	29-May	44	0904	-51.241	165.481	-51.235	165.467	197	200	1137	301	Barren, long wave-length ripples of silty sand to pebbly sand.
53	A161	29-May	38	1134	-51.317	165.343	-51.308	165.330	918	1483	1359	317	Lumpy, bouldery downslope bedrock. Echinoids, crinoids, holothuroids, gorgonians, anemones, dogfish, an orange roughy.
54	B227	29-May	43	1834	-51.739	166.086	-51.741	166.070	890	891	1147	258	Very flat, mostly muddy sediment. Fauna included forams, gastropods, rattails and a skate - fairly depauperate overall.
55	A167	29-May	42	2315	-51.369	166.352	-51.374	166.338	662	661	1134	244	Mud and burrows and echinoids. Lots of fish.
56	A153	30-May	44	0456	-50.897	166.536	-50.900	166.522	141	140	1073	251	Ledges of bedrock (early); sandy-pebbly with larger ripples, in places fines and smaller ripples. Crab, fish, asteroids, squat lobster, sponge, foram, cup coral.
57	A169	30-May	42	0936	-50.915	167.219	-50.914	167.204	473	470	1110	278	Mud, burrows, pits, and mounds. Tracks, asteroids, and fish.
58	A168	30-May	42	1259	-50.932	167.545	-50.935	167.530	492	491	1126	250	Muddy substrate with burrows, scampi burrows and mounds. Fauna present were schools of small fish, rat-tails, eels, scampi, shrimps, anemones, holothurians, asteroids.
59	A165	30-May	42	1703	-50.744	167.957	-50.749	167.943	511	511	1127	241	Soft, muddy sediment. Burrows with lots of small holothuroids, asteroids, gastropods; a few scampi.
60	A224	30-May	46	2157	-50.742	168.839	-50.744	168.824	577	576	1139	259	Fairly flat, soft, muddy substrate with burrows, salps, rat-tails, holothurians, asteroids, anemones, fish.

Stn	Site	Date	Stratum	NZST	Lat.start	Long.start	Lat.end	Long.end	Depth start (m)	Depth end (m)	Distance (m)	Direction	Description
61	B222	31-May	46	0518	-50.885	170.192	-50.883	170.177	574	576	1068	280	Mud, burrows, tracks, fish, echinoids, salps.
62	B147	31-May	43	0945	-50.540	170.157	-50.537	170.142	598	598	1089	288	Mud, burrows, tracks, fish, asteroid.
63	A141	31-May	43	1348	-50.313	169.832	-50.311	169.816	607	606	1124	279	Mud, burrows, tracks, fish, asteroid.
64	A220	31-May	46	2005	-50.090	168.920	-50.082	168.910	611	613	1117	320	Muddy substrate with burrows, fish, eels, ghost shark, echinoids, asteroids, algae debris, salps.
65	A140	1-Jun	46	0053	-49.910	169.543	-49.906	169.528	631	627	1132	294	Mud, burrows, tracks, fish, asteroid, echinoid.
66	B221	1-Jun	46	2036	-49.961	171.025	-49.956	171.011	512	512	1101	298	Mud, burrows. Fish, eel.
67	B112	1-Jun	47	1423	-49.553	171.792	-49.550	171.779	369	367	1007	292	Muddy bottom with burrows. Occasional asteroid, holothuroid and bony fish. Last 10 minutes had numerous ophiuroids.
68	A113	1-Jun	47	1803	-49.318	171.885	-49.308	171.880	132	131	1112	341	Gravelly substrate with little fauna apart from crabs, fish, anemones and possibly bryozoans.
69	B113	1-Jun	47	2120	-49.260	171.850	-49.251	171.842	123	123	1131	329	Sand, gravel, bryozoan rubble, bedrock. A few small fish and a few sponges.
70	B110	2-Jun	47	0111	-49.239	171.714	-49.237	171.699	139	150	1115	285	Sand, ripples. Near cliffs coarser up to cobble size. In places shell hash. Tracks (fish?), sponges, Bryozoa, fish, soft coral, kelp fragments?, foram.
71	B110	2-Jun	7	0330	-49.236	171.721	-49.231	171.707	132	137	1120	296	Sand and ripples at the start, then increasing gravel, cobble, boulders, bedrock. Sponges, Bryozoa, a few fish. Large expances of bedrock with sand/ripples in between. At the end a steep drop-off (short loss of video feed), back to sand/ripples at base.
72	A111	2-Jun	47	0705	-49.168	171.483	-49.161	171.474	314	331	1090	321	Sand/mud with numerous (100's) of ophiuroids.
73	A222	2-Jun	46	1047	-49.063	171.143	-49.056	171.132	577	582	1088	317	Mud. Very barren. Some tracks.
74	A999	2-Jun	43	1741	-48.774	170.257	-48.770	170.243	922	1071	1066	293	Into channel from lip. High density of fish, rattails, also holothuroids, echinoids, forams, salps. Muddy sediment.
75	B228	2-Jun	43	2218	-48.611	169.737	-48.609	169.722	782	784	1153	285	Mud and burrows, forams, black oreos, blobfish.
76	A666	3-Jun	43	0312	-48.615	170.276	-48.609	170.265	1104	1097	1045	310	Mud and burrows, mounds. Sponges, holothurians, ring of burrows, burrows, scampi burrows, fish, rattail, tracks.
77	B225	3-Jun	43	1152	-48.600	171.853	-48.590	171.848	788	818	1123	341	Mud and burrows, giant forams abundant, sponges, asteroids, holothurians, echinoids, rattails.
78	A195	3-Jun	40	1816	-47.966	172.301	-47.961	172.288	1318	1319	1128	302	Mud and burrows, numerous anemones, some xenophyophores, salps, and sponges.
79	A998	3-Jun	40	2309	-47.682	171.457	-47.676	171.468	1347	1347	1067	052	Rippled/wavy sand and gravel substrate for the majority of the transect, with many fish and not much else except the occasional sponge, *Pyrosoma* slap, algal debris and forams. Bedrock at the last minute of the transect with sponges and bryozoans.
80	A997	4-Jun	40	0418	-47.729	172.101	-47.738	172.101	1377	1375	964	179	Mud, flat. Burrows and mounds. Holothurians. Tracks.
81	A199	4-Jun	40	1356	-47.486	172.213	-47.496	172.213	1395	1395	1129	180	Muddy sediment, burrows, tracks, mound, glass sponges, anemones, asteroids, echinoids.
82	B65	4-Jun	36	1953	-47.226	172.220	-47.227	172.220	1396	1396	83	191	Transect too rough with high swells; terminated transect at 4 minutes in. Muddy substrate with burrows, tracks, sponges, anemones.
83	B65	5-Jun	36	0140	-47.225	172.221	-47.234	172.221	1391	1391	957	179	Mud, burrows, some tracks. Sponges, anemones, fish, Bryozoa.
84	A65	5-Jun	36	0538	-47.140	172.473	-47.148	172.473	1419	1422	818	181	Mud, burrows, tracks.
85	A67	5-Jun	36	1042	-46.950	172.522	-46.967	172.515	1447	1444	1960	194	Mud, tracks, anemones, holothurians.
86	A69	5-Jun	36	1422	-46.766	172.694	-46.775	172.687	1548	1543	1111	211	Muddy sediment, burrows, tracks, mounds, holothurians, sponges, anemones, asteroids.

APPENDIX 2: DTIS video taxa

Table 2.1: Benthic invertebrate taxa recorded during real-time observation of DTIS video transects, with summary data showing the total number of individuals across all sites (Total inds.) and the number of sites at which each taxon was recorded (Total sites). (Continued on next page)

Phylum	Class	Subclass	Order	Family	Taxon	Total inds.	Total sites
Annelida	Polychaeta	Palpata	Aciculata	Onuphidae	Quill worm	45	6
		Sedentaria	Sabellida	Sabellidae	Sabellidae (fan worm)	4	2
					Tube worms	11	7
Arthropoda	Malacostraca	Eumalacostraca	Decapoda (Anomura)	Galatheidae	Crustacean (galatheid/Chirostylidae)	186	13
				Paguridae	Crustacean (pagurid)	47	15
			Decapoda (Astacidea)	Nephropidae	Crustacean (scampi)	44	4
			Decapoda (Brachyura)		Crustacean (crab)	225	25
			Decapoda (Caridea)		Crustacean (shrimp)	79	21
	Pycnogonida		Pantopoda		Pycnogonid	4	4
Brachiopoda					Brachiopods	4	2
Bryozoa					Bryozoans	3 692	42
Chordata	Ascidiacea				Ascidians (clonal)	6	3
					Ascidians (solitary)	720	8
	Thaliacea				Salp	336	33
Cnidaria					Medusa	4	3
	Anthozoa	Hexacorallia	Actiniaria		Anemones	4 320	78
			Antipatharia		Antipatharia	4	3
			Ceriantharia		*Ceriantharia* spp.	1 445	20
			Corallimorpharia		Corallimorpharia	4	2
			Scleractinia		Scleractinia	1	1
				Caryophylliidae	Cup corals (*Stephanocyathus* spp.)	8	2
					Desmophyllum/ Caryophyllia	22	7
				Flabellidae	*Flabellum*	55	9
			Zoantharia		Zoanthidea	18	1
		Octocorallia	Alcyonacea		Alcyonacea	11	5
				Alcyoniidae	*Anthomastus* sp.	148	11
				Taiaroidae	*Taiaroa tauhou*	8	1
			Gorgonacea		Gorgonacea	241	13
				Chrysogorgiidae	*Radicipes* spp.	4	3
				Isididae	Isididae	36	4
				Primnoidae	Primnoidae	47	5
				Paragorgiidae	Paragorgiidae	1	1
			Pennatulacea		Pennatulacea	25	12
	Hydrozoa				Hydroids	61	14

Phylum	Class	Subclass	Order	Family	Taxon	Total inds.	Total sites
		Hydroidolina	Anthoathecata	Stylasteridae	Stylasteridae	356	6
Echinodermata	Asteroidea				Asteroid	2 481	78
			Brisingida		Brisingid	87	12
			Valvatida	Solasteridae	Solasteridae	2	1
	Crinoidea				Crinoidea (motile)	245	17
					Crinoidea (stalked)	8	3
	Echinoidea				Echinoid	2 084	58
		Euechinoidea	Echinothurioida		Echinothuriidae/Phormosomatidae	96	10
	Holothuroidea				Holothurian	594	58
	Ophiuroidea				Ophiuroid	6 741	23
		Myophiuroidea	Euryalida	Gorgonocephalidae	Gorgonocephalidae	396	5
Foraminifera	Monothalamea			Xenophyophoroidea	Foram (giant)	1 993	32
Mollusca	Bivalvia				Molluscs (bivalves)	738	6
		Autobranchia	Pectinida	Pectinidae	Scallop	569	11
	Cephalopoda	Coleoidea	Octopoda		Mollusc (octopod)	26	16
	Gastropoda				Mollusc (gastropod)	352	55
		Heterobranchia	Nudibranchia		Mollusc (nudibranch)	2	2
	Scaphopoda				Scaphopoda	1	1
Porifera	Demospongiae				Sponge (Demospongiae)	6 260	69
	Hexactinellida				Sponge (Hexactinellidae)	794	24
		Hexasterophora	Lyssacinosida	Rossellidae	*Hyalascus maui* sp. nov.	3	2

APPENDIX 3: Site summaries

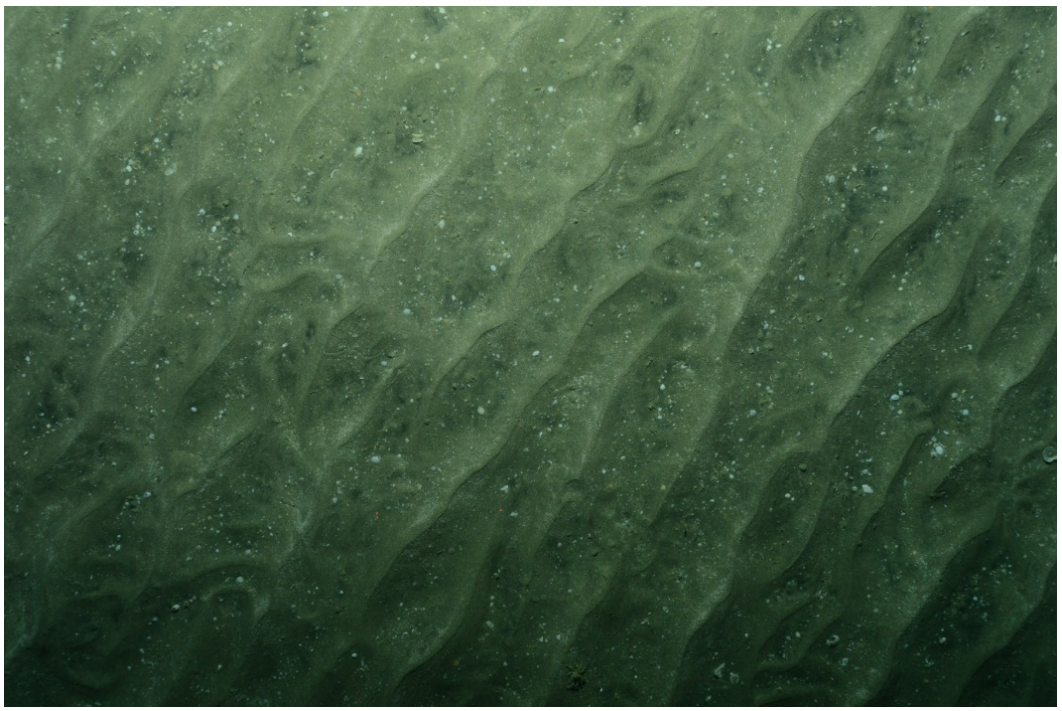
Individual site summaries are provided below for every tenth site.

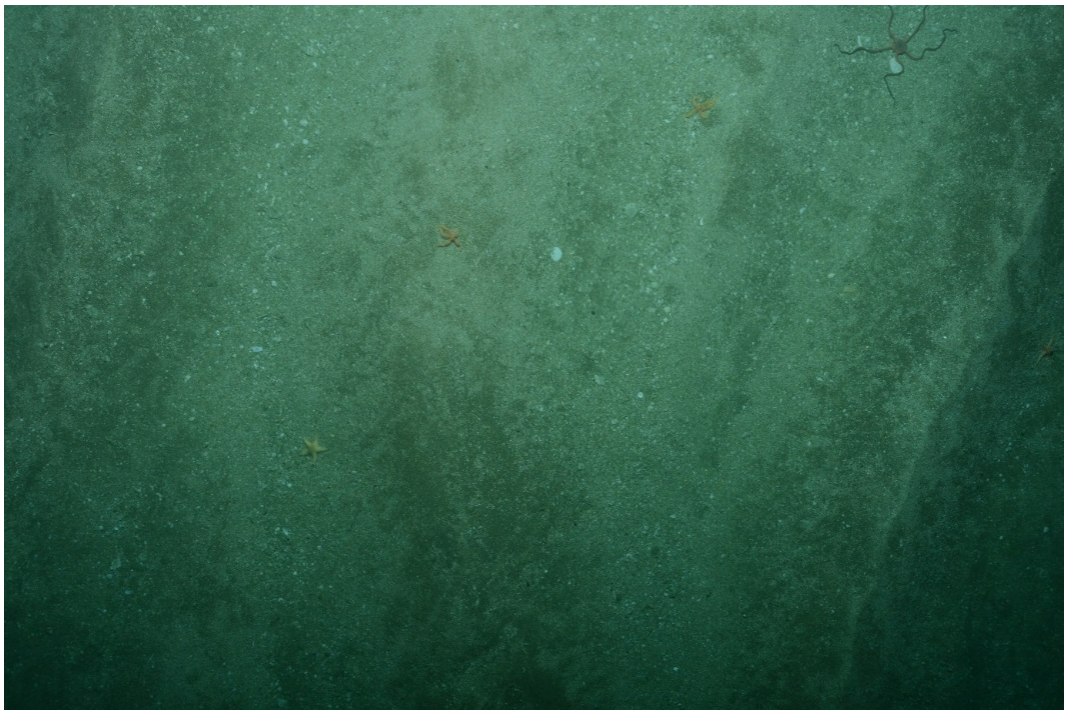
Station 001, Site A34 (19/5/2020, Start: 0502 h, End: 0605 h NZST). Moving from E to W
108–110 m
Flat, sandy bottom with shell hash, pebbles, and gravel. Sand ripples visible throughout the transect. Fauna mainly comprising numerous demosponges, asteroids, and anemones.


TAN2004_001_006. Typical substrate.


TAN2004_001_017. Typical substrate, with anemones and galatheids.

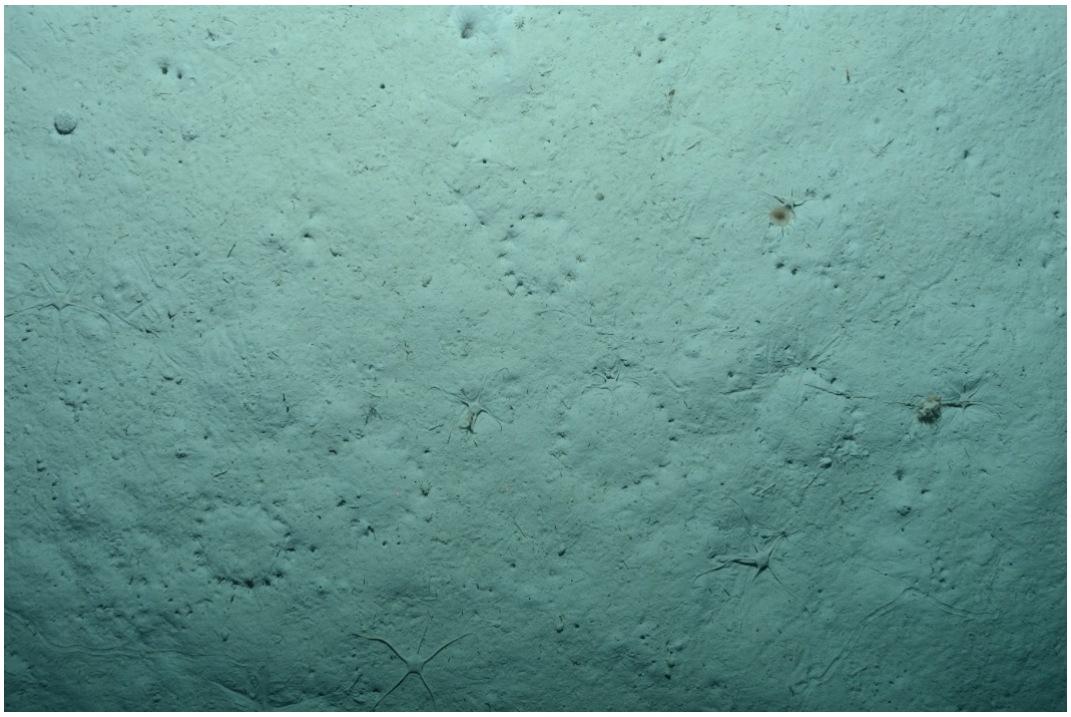
Station 010, Site A38 (20/5/2020, Start: 1033 h, End: 1134 h NZST). Moving E to W
87–88 m
Flat bottom with ripples and shell hash along the entire transect. Few faunal observations mostly of asteroids, ophiuroids, crabs and fish.


TAN2004_010_028. Typical shelly substrate with ripples.


TAN2004_010_170. Patches of shell hash substrate with asteroids and ophiuroid.

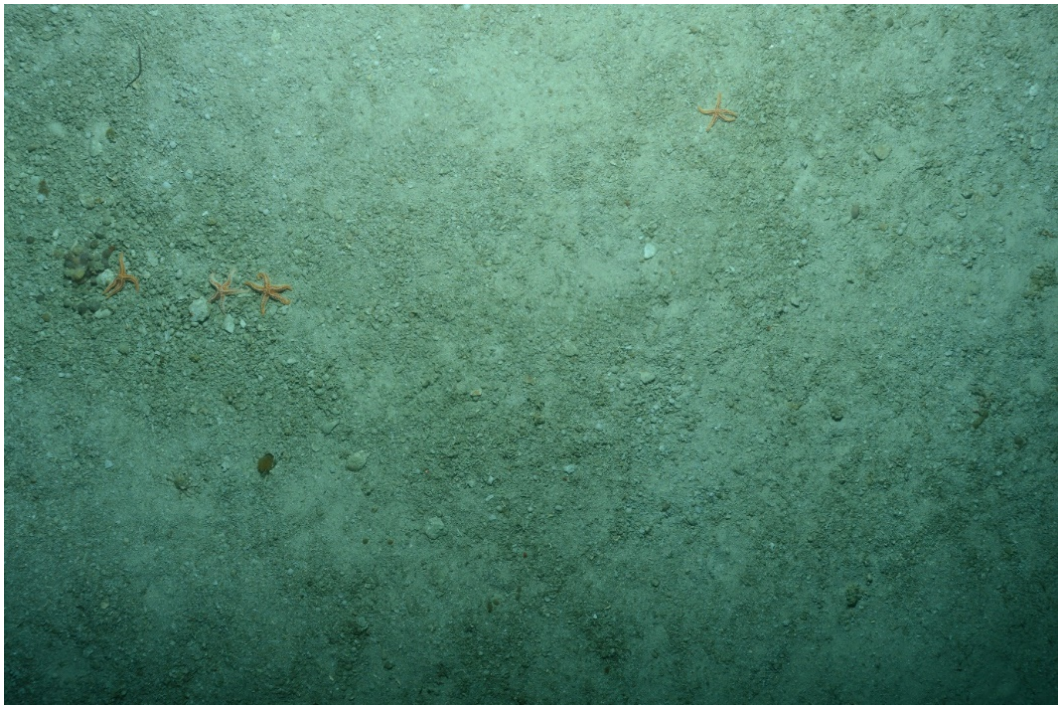
Station 020, Site A198 (22/5/2020, Start: 0730h, End: 0830 h NZST). Moving SSW to NNW
1172–1170 m
Sensitive habitat.
Flat muddy substrate with many rings of burrows, tracks and burrows occupied by ophiuroids. Fauna dominated by ophiuroids and cerianthids. Xenophyophores, fish, eels, asteroids, holothurians, anemones, zoantharians, pennatulaceans, demosponges, alyconaceans, dead pyrosoma salps, bryozoans were also observed. Cup corals may have been present.

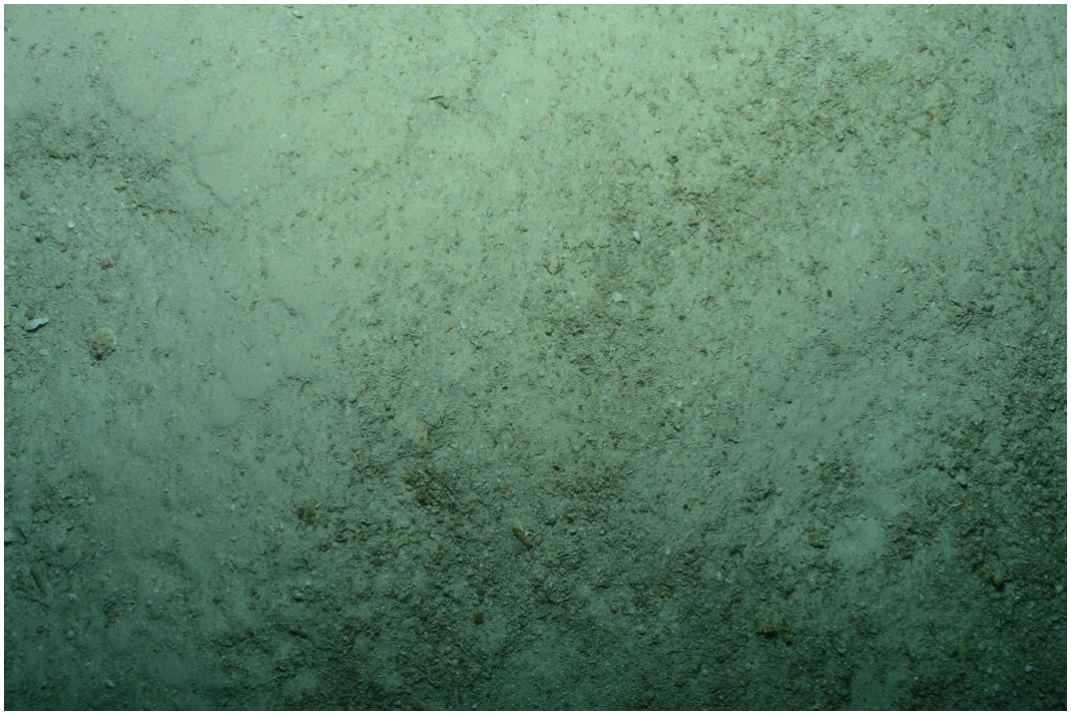
TAN2004_020_023. Typical muddy substrate covered in several ring of burrows and with a soft coral and a cerianthid.



TAN2004_020_217. Mud, ring of burrows, ophiuroids, small holothurian sea pigs, xenophyophore (top left), zoantharian (centre right), soft coral (centre) and possible cup coral (top right).

Station 030, Site B102 (25/5/2020, Start: 0232 h, End: 0333 h NZST). Moving NE to SW
148–147 m
Gravelly sandy substrate with abundant shell hash comprised of dead brachiopods, bivalves and bryozoans. Some patches of sand ripples. Not much fauna - mostly asteroids, paddle and decorator crabs, bushy bryozoans, sponges, ascidians, some dead echinoid tests.


TAN2004_030_075. Asteroids on gravelly sand and shell hash.

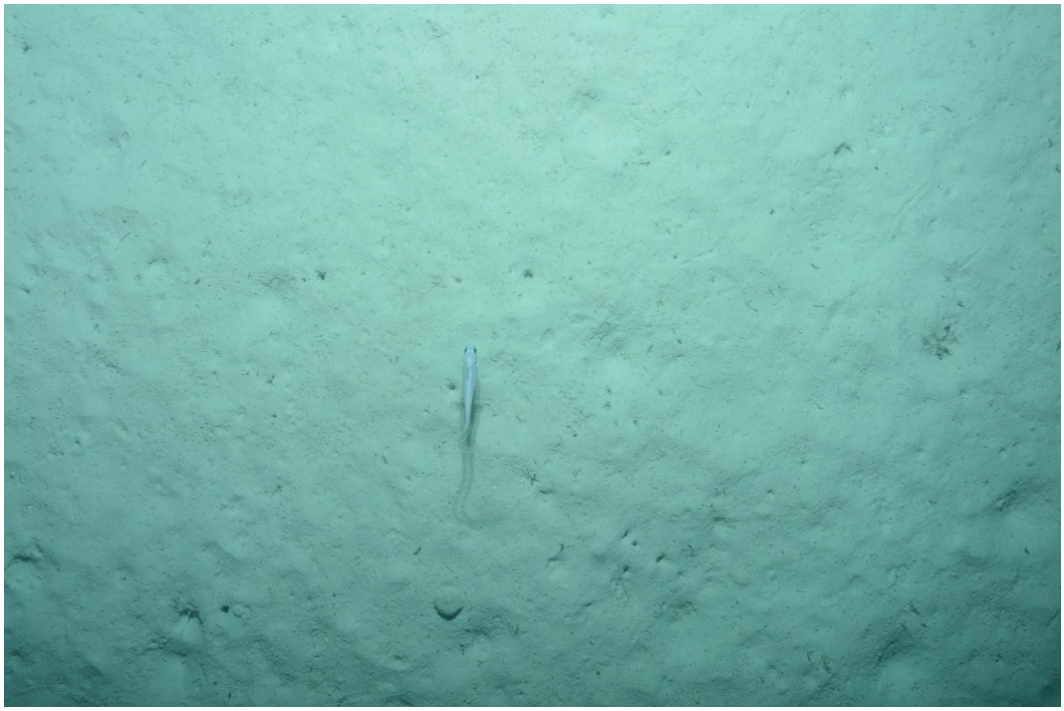

TAN2004_030_159. Contrast of lightly rippled sand and gravelly shell hash.

Station 040, Site A146 (27/5/2020, Start: 0009 h, End: 0110 h NZST). Moving NE to SW

660–669 m

Sensitive environment.

DTIS in the water at 2352 on 26/5/2020, video started recording at 0009 on 27/5/2020. Uniform muddy substrate across the whole of the transect – no hard bottom-material seen. Burrows and tracks were sporadically observed. Fish (rattails and ghost sharks) and asteroids were mainly observed, with some xenophyophores, sponges, quill worms, hydroids, anemones and prawns also seen.



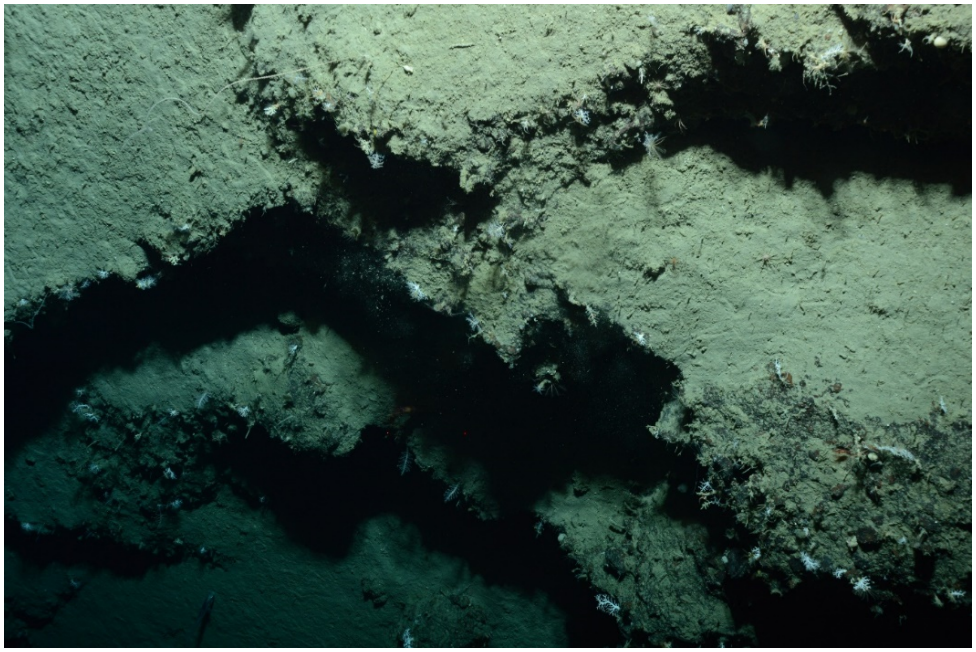
TAN2004_040_016. Muddy sediment with a fish, a xenophyophore (below the fish) and a hydroid (right centre).

Station 050, Site A162 (29/5/2020, Start: 0048 h, End: 0151 h NZST). Moving S to N

974–906 m

Sensitive environment.

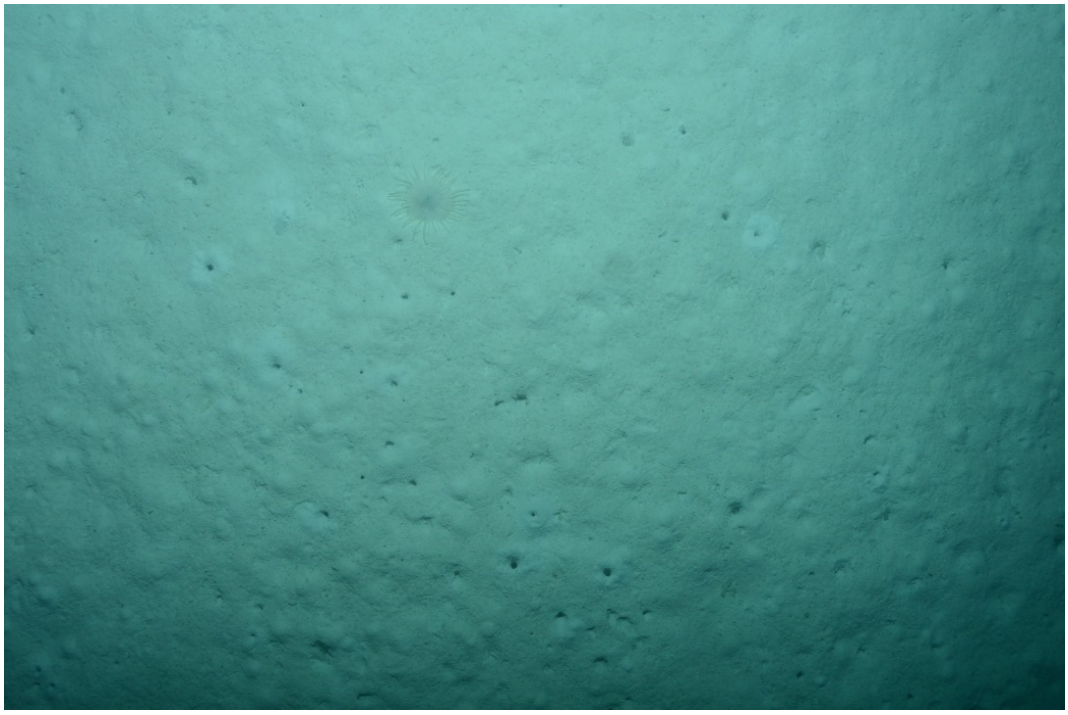
Transect travelled north over mixed terrain, including muddy sediment, bedrock, boulders, cobbles, gravel and drop offs. Muddy patches were scattered with burrows and tracks. Many fish, rat-tails, eels, sharks and a skate. Primnoids, isidids, anemones, echinoids, cerianthids, stylasterids, epizoanthids and xenophyophores common. Bryozoans, sponges, cup corals, tube worms, ascidians, gastropods, crinoids, hydroids, sea pens, *Anthomastus,* holothurians, asteroids, ophiuroids, a couple of umbrella octopuses and Antipatharia back corals also observed.



TAN2004_050_139. Bedrock on the edge of a trench with stylasterids, cidarids, gorgonian corals and crinoids.

TAN2004_050_244. Bedrock, cobbles and muddy sediment with a rat-tail, stylasterids, cidarids, crinoids, sponges and squat lobsters.

Station 060, Site A224 (30/5/2020, Start: 2156 h, End: 2325 h NZST). Moving ENE to WSW
577–577 m
Very flat seabed with sediment of mud with scattered burrows. Fauna fairly sparse, although anemones common enough; asteroids, salps (some in bunches in hollows), gastropods, cerianthids, and a single flabellum were also observed. Fish present in some numbers (mostly rattails but other bony fish, a flatfish and a deep-sea skate also seen).

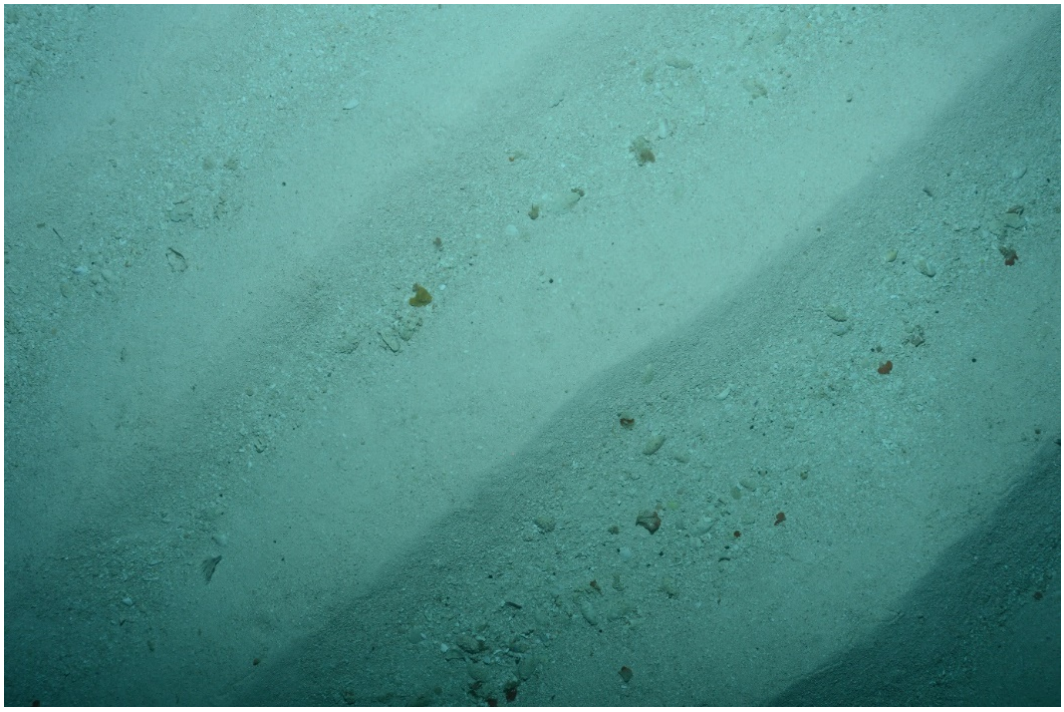


TAN2004_060_092. Typical soft muddy substrate with burrows and an anemone.

Station 070, Site B110 (02/6/2020, Start: 0111 h, End: 0211 h NZST). Moving SE to NW

139–150 m

Near the centre of the Pukaki Rise. Transect ran along the bottom of a valley bisecting the north west and south west raised plateau sections of the rise. These interesting geographical features were unmapped until now. The valley substrate consisted of rippled sandy gravel with pebbles, shell hash and a few cobbles. Minimal fauna throughout the transect comprising mostly of bushy and cornflake bryozoans (including a brilliant red species), fish, cerianthids and sponges.



TAN2004_070_052. Sand ripples with shell hash and bryozoan.

TAN2004_070_126. Typical sand, gravel and shell hash substrate with bryozoans.

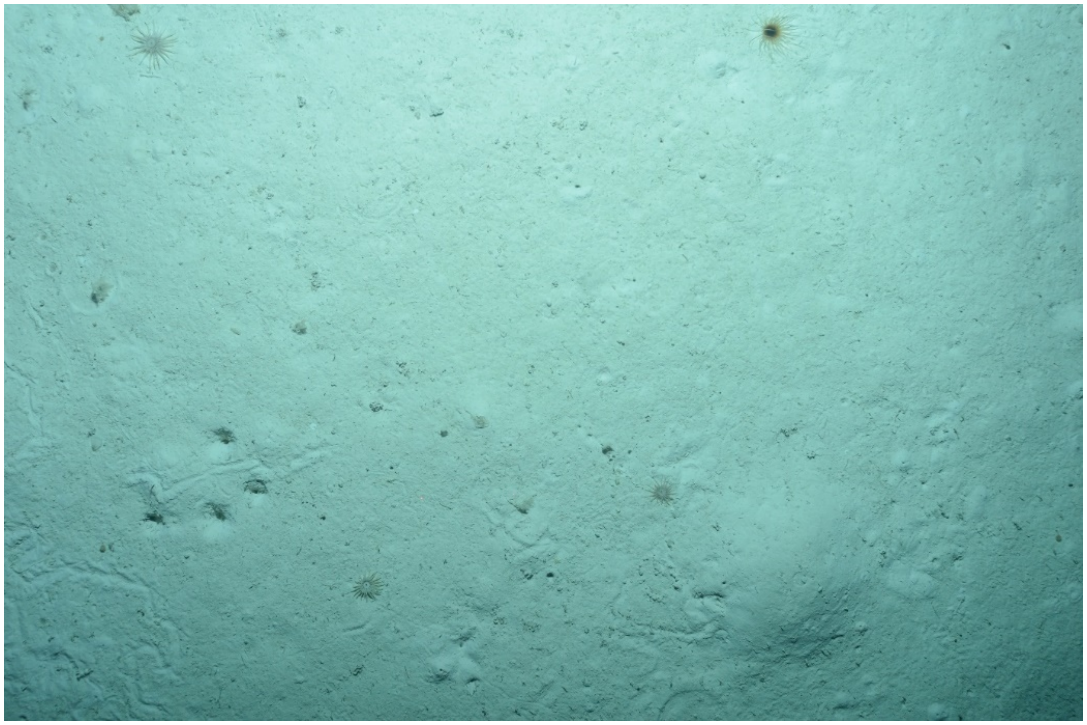
Station 080, Site A997 (04/6/2020, Start: 0419 h, End: 0519 h NZST). Moving N to S

1377–1375 m

Sensitive environment.

Transect heading into swell of 4–5 m, resulting in a few obscured still images due to DTIS being towed higher than normal from the bottom for some of the transect. Flat transect over muddy sediment with numerous burrows and tracks, as well as moderate numbers of mounds and pits. Fauna dominated by anemones (called cerianthids in the OFOP *prot file), particularly the low-profile, mud-coloured variety as seen at station 078. Other taxa seen included dark coloured cerianthids, hexactinellid glass sponges ('tulip' and basket sponges, often with an ophiuroid at its base), corallimorpharians salps, xenophyophores, echinoids, holothurians, gastropods, shrimps and demosponges. Dead hexactinellid sponges were also observed and were encrusted with ascidians. Few fish observed, mostly rattails and eels. Errors found in *.prot OFOP file (unknown problem, stopped recording observations after about 13 mins) but the *.obser and *.posi files not affected.

TAN2004_080_074. Typical muddy sediment with a mound, corallimorpharian and anemones.



TAN2004_080_082. Burrows, tracks, a mound, dark coloured cerianthid and anemones. Fragments of xenophyophores can also be seen.