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Tini a Tangaroa

# Quantifying benthic biodiversity: developing a dataset of benthic invertebrate faunal distributions from seabed photographic surveys of Chatham Rise

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A key gap in the knowledge required to understand and manage ecosystem effects of bottom-contact fishing, and other seabed disturbances is the lack of quantitative baseline information about the distributions of benthic habitats and fauna. Consequently, management decision-making relies increasingly on outputs from habitat suitability models that are used to estimate likely distributions of key fauna based on correlations between available point-sampled faunal data and environmental characteristics. However, the lack of quantitative baseline knowledge of benthic distributions, combined with a lack of fine-scale detail in environmental layers and understanding of biotic interactions, can result in high levels of uncertainty associated with model outputs.

To address the issue of uncertainty in outputs from habitat suitability models for a key fisheries region in the New Zealand Exclusive Economic Zone, Chatham Rise, The Ministry for Primary Industries instigated a project (ZBD2016-11) with four specific objectives: (1) to increase the density of empirical data on benthic distributions by means of a dedicated seabed photographic survey; (2) to compile and merge all available photographic data in a single, internally consistent dataset; (3) to use this dataset as an independent test set to assess the utility of outputs from existing habitat suitability models, and (4) to develop new habitat suitability models based on the new dataset.

This report is a summary of work conducted under the second objective, above; to develop a single coherent dataset of benthic invertebrate distributions on Chatham Rise from seabed photographic surveys. We assessed all available image-based seabed surveys of Chatham Rise, including film and digital camera technologies, and selected five digital-era surveys for development of a combined dataset: three broad-scale Ocean Survey 20/20 biodiversity surveys; one survey of seamounts in the *Graveyard* and *Andes* groups, and one commercial survey of phosphorite nodule habitats on the central crest of the rise. In combination, this set of surveys provides broad spatial coverage with consistent methods and relatively even distribution of sample sites across the region, and incorporates existing data about all areas known to have high biological diversity or be of specific interest for environmental management.

The final, audited dataset spans the full extent of Chatham Rise in depths from 40 m to 1850 m, representing analyses of 358 seabed transects, with 125 658 records of individual organisms in 354 taxa across 13 phyla: Echinodermata (95 taxa), Cnidaria (87), Porifera (58), Arthopoda (43), Mollusca (37), Annelida (10), Bryozoa (9), Chordata (Ascidiacea, 6), Brachiopoda (1), Echiura (1), Foraminifera (1), Hemichordata (1), Nemertea (1). All observations of individual organisms are spatially referenced within transects, enabling retrospective audit by reference to the original imagery if required, and all data are maintained in a purpose-designed *postgres-postgis* database. The approach used here, incorporating data from surveys conducted across a number of years, depends on the assumption that distributions of the taxa vary little over time; an assumption that is implicit in most broad-scale benthic habitat and species modelling initiatives.

In comparison with published studies that have used photographic data to inform habitat suitability modelling at comparable depths in other parts of the world, the Chatham Rise dataset developed here ranks among those with the largest spatial extents and the highest density of sample sites. It provides a coherent body of information about the distributions of benthic fauna across the study region that will have applications including: assessing the usefulness of existing habitat suitability models and their underlying methods; developing new habitat suitability models based on more complete and coherent data, and developing methods to assess the impacts of bottom-contact fishing and other forms of seabed resource exploitation on benthic habitats.

# 1. INTRODUCTION

A key gap in the knowledge required to understand and manage ecosystem effects of bottom-contact fishing, and other seabed disturbances is the lack of quantitative baseline information about the distributions of benthic habitats and fauna. Consequently, in waters beyond coastal areas, management decision-making relies increasingly on outputs from habitat suitability or 'species distribution' models (e.g., EPA 2015). Such models use complex non-linear correlations between point-sampled faunal occurrence records and spatially continuous environmental variables to predict probabilities of occurrence across unsampled environmental space (Reiss et al. 2015, Vierod et al. 2014). Various methods are in use (e.g., Boosted Regression Trees – BRT, Generalised Dissimilarity Modelling – GDM, Maximum Entropy – MaxEnt, Random Forests – RF, and Generalized Additive Models – GAM) and this modelling field is in constant development. The fundamental requirements of all methods are the same, however; (1) accurate and sufficient point-sample data about where a given taxon has been recorded (and, ideally, where it is absent), and (2) accurate and ecologically relevant environmental data as continuous layers spanning the area of interest. The relative paucity, patchiness, and taxonomic selectivity of available faunal sample data, particularly in the deep sea, combined with a lack of fine-scale detail in environmental layers and understanding of biotic interactions (competition, facilitation, inhibition, etc.), can result in high levels of uncertainty associated with the outputs from habitat suitability models (Araujo & Guisan 2006, Reiss et al. 2015, Vierod et al. 2014).

Knowledge about New Zealand's benthic fauna beyond coastal areas has been accumulating since the Challenger Expedition (Gordon et al. 2010, Rowden et al. 2012). Benthic fauna have typically been sampled using grabs, epibenthic sleds, trawls, and corers, providing a growing resource of occurrence records at fine taxonomic resolution. However, a relatively large proportion of these data have come from fisheries by-catch; records of benthic organisms caught by bottom-contact trawls and long-lines. These fishing gears are designed to catch demersal fish, rather than benthic invertebrates, and a single deployment can span several kilometres of seabed, potentially sampling multiple habitats. Thus, the catchability of benthic taxa by fishing gear is generally low, highly variable among taxa, and unquantified, and fine-scale patchiness of distributions is masked. Furthermore, the accuracy and consistency with which by-catch data are recorded has been variable, both over time and between fisheries and boats, resulting in the need to aggregate data to coarse taxonomic levels for combined use (Bowden et al. 2015). Low, unquantified, catchability and inconsistent recording associated with by-catch records also result in such data being useful only for recording the presence of a taxon; its absence cannot be inferred with any confidence. Thus, these data, which have been used among other data to inform most existing habitat suitability models of benthic faunal distributions have shortcomings associated primarily with low and variable catchability and coarse taxonomic resolution.

Photographic surveying differs from other methods of sampling benthic habitats and fauna in that it: (1) records the full detail of habitat structure at scales from centimetres to kilometres; (2) records a broad range of epifaunal taxa (i.e., catchability is high across most epifaunal taxa); (3) samples quantitatively; (4) enables retrospective audit of identifications and counts, and (5) is non-destructive. Seabed photographic methods have been used in surveys of Chatham Rise for some decades, initially for geological research and minerals prospecting (von Rad & Kudrass 1987), then to inform management of the scampi fishery (Tuck et al. 2015), and since approximately 2000 to describe and quantify benthic habitats and fauna (Clark, M. R. et al. 2010). The first dedicated surveys of benthic habitats and fauna were of seamounts on the northern Chatham Rise (Clark, M. R. et al. 2010) but broad-scale surveys began with New Zealand's *Ocean Survey 2020* initiative (https://www.beehive.govt.nz/speech/ocean-survey-2020-launch-speech) and the development of NIWA's Deep Towed Imaging System (DTIS, Hill 2009) in 2006.

In 2016, the Ministry for Primary Industries (MPI), working with NIWA, identified a need to reduce uncertainty in predictive models of the distributions of seabed habitats and fauna, particularly in areas where impacts from anthropogenic activities are either happening or likely to happen in the future. To address this issue, MPI initiated a project that would improve understanding of benthic distributions across the Chatham Rise; the most important deep-sea fisheries area for New Zealand

## 1.1 Objectives

The overall objective of the project is to improve predictive models of seabed habitat, communities, and species across Chatham Rise, and it is structured around four specific research objectives:

1. to collect quantitative data about seabed habitats and fauna by undertaking a survey of unsampled areas on Chatham Rise;
2. to process and compile seabed habitat and fauna data from the survey and merge these with comparable data from previous quantitative surveys on Chatham Rise;
3. To use the new dataset to assess the utility of existing community and species distribution models for Chatham Rise, and
4. to use the new dataset to build new community and species distribution models for Chatham Rise.

The results of objective (1), the voyage to collect new data, are described by Bowden et al. (2017). Here, we describe work under objective (2): to process and compile seabed habitat and fauna data from the survey and merge these with comparable data from previous quantitative surveys on Chatham Rise.

# 2. METHODS

## 2.1 Study area

The Chatham Rise is a continental rise extending eastwards from the South Island of New Zealand across approximately 10 degrees of longitude, with Mernoo Bank at its western end and the Chatham Islands at the eastern end (Figure 1). Because the Sub-Tropical Front coincides with, and is partially constrained by the rise, it is the most biologically productive fisheries region in New Zealand’s exclusive economic zone (EEZ) (Clark, M. R. et al. 2000, Marchal et al. 2009, McClatchie et al. 1997), with intense phytoplankton blooms propagating from west to east along its length (Chiswell 2001, Nodder et al. 2012, Nodder et al. 2007). Commercially important bottom trawl fisheries target populations of scampi (*Metanephrops challengeri*), hoki (*Macruronus novaezelandiae*), orange roughy (*Hoplostethus atlanticus*), and oreos (*Pseudocyttus maculates*, *Neocyttus rhomboidalis* and others). Recent summaries of bottom-contact trawl history across Chatham Rise (Baird & Wood 2018) show highest trawling intensity, primarily from the hoki fishery, at 450–700 m depth west of Mernoo Bank and on the southern and northern central flanks of Chatham Rise. At present, initiatives to protect benthic habitats and fauna on the Rise consist of spatial closures of fisheries on some seamounts in the ‘Graveyard’ and ‘Andes’ regions on the northwest flank and southeast flanks of the rise, respectively (Clark, M. R. & Dunn 2012), and the establishment in 2007 of two Benthic Protection Areas (BPAs); the Mid Chatham Rise BPA and the East Chatham Rise BPA.

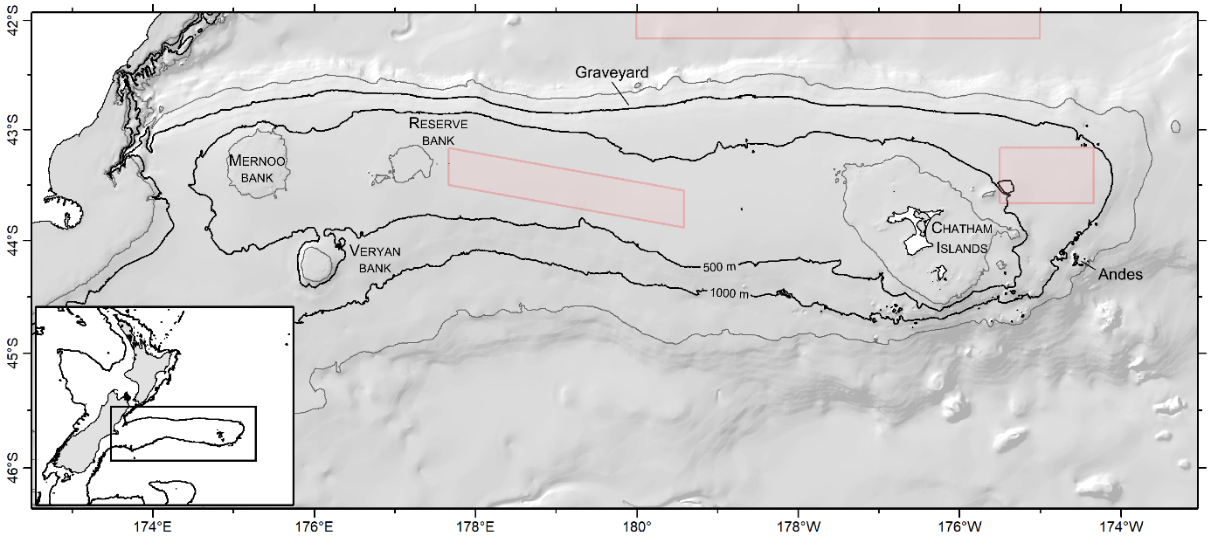


**Figure 1: Chatham Rise. Isobaths show 250, 500, 1000, and 1500 metres depths, red polygons show Benthic Protection Areas (BPAs), locations of the Graveyard and Andes seamount groups are indicated, and inset map shows location of the study area in relation to New Zealand and the 1000 m isobath.**

## 2.2 Surveys

We considered all photographic surveys that have been conducted on Chatham Rise, assessing each in terms of: (1) spatial extent; (2) camera type (still or video, film or digital, monochrome or colour) and image quality; and (3) survey purpose (have benthic invertebrate data been derived from the survey already?). Surveys were identified by interrogation of NIWA's *marinedb* database, using search terms including all codes known to have been used for camera gear, primarily *UWC* (underwater camera system) and *DTIS* (Deep Towed Imaging System) but including *UWH*, *UWCS*, *UWCR*, *UWCD*, and *CAM*.

On examining all the photographic surveys resulting from this search, the first decision in the selection process was to work only with digital-era surveys because the extra time and resources required to find and digitize original gelatine-silver film negatives would have been beyond the funding scope of the project. There were 14 digital camera surveys: 2 broad-scale surveys of biodiversity; 4 surveys of seamounts on the northern and eastern flanks of the rise; 1 survey covering fishing effects on the southern and western flanks and biodiversity of the central crest; 1 survey of biodiversity within a minerals licence area on the central crest, and 6 surveys for stock assessment of scampi (*Metanephrops challengeri*) (Table 1, Figure 2).

**Table 1: Digital era photographic surveys of seabed habitats and fauna of Chatham Rise. 'TAN' prefix survey codes refer to voyages with *RV Tangaroa*, 'CRP' code refers to *RV Dorado Discovery* chartered by Chatham Rock Phosphate Ltd. DTIS; Deep Towed Imaging System, ROV; Remotely Operated Vehicle, HD; high definition, MP; megapixels.**

| Survey | Year | Extent | Platform | Digital | video | stills | Purpose |
|---|---|---|---|---|---|---|---|
| TAN1701 | 2017 | Chatham Rise | DTIS | Yes | HD1080p | 24MP | Biodiversity |
| TAN1503 | 2015 | Seamounts | DTIS | Yes | HD1080i | 12MP | Fishing effects and biodiversity |
| TAN1306 | 2013 | Hoki depths and Central BPA | DTIS | Yes | HD1080i | 12MP | Fishing effects and biodiversity |
| CRP2012 | 2012 | Central BPA | ROV | Yes | SD | 5MP | Minerals EIA |
| TAN0905 | 2009 | Seamounts | DTIS | Yes | HD1080i | 10MP | Fishing effects and biodiversity |
| TAN0705 | 2007 | Chatham Rise | DTIS | Yes | HD1080i | 10MP | Biodiversity |
| TAN0604 | 2006 | Seamounts | DTIS | Yes | SD | 5MP | Fishing effects |
| TAN0104 | 2001 | Seamounts | Prototype | Yes | None | 1.5MP | Fishing effects |
| *RV Kaharoa* (6 surveys) | 2001-2013 | Western crest | 'Scampi-cam' | Yes | None | 1.3-15.8 MP | Scampi stock assessment |

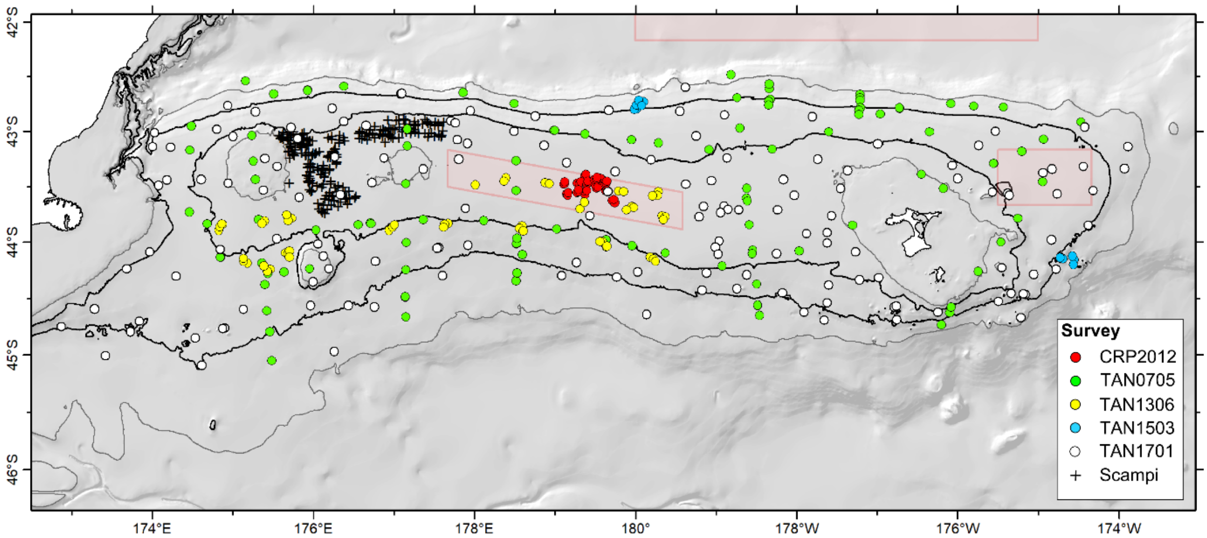


**Figure 2: Digital era photographic surveys of seabed habitats and fauna on Chatham Rise. Surveys are colour coded (see legend) and each point represents the start or mid-point of a seabed transect. See text for details. Only the most recent survey of the Graveyard and Andes seamounts is shown (blue points, TAN1503) because earlier surveys are co-located and thus obscured at the scale of this map. Scampi points represent 6 surveys over the period 2001–2013.**

The higher level aims of the project were also important in setting criteria for the further selection of surveys. Specific Objective 3 of the overall project required that the image-derived data should be suitable for use in formal statistical assessment of existing habitat suitability model outputs. This testing required that *prevalence* – a measure of the likelihood of a taxon being detected at a given station – could be calculated for every station in the dataset using a consistent method. Achieving this consistency becomes problematic when the dataset includes surveys based on widely varying swept-areas, image resolutions, or frequencies of image capture. The final objective of the overall project, to generate new predictive models using the new dataset, does not have the same limitation, however, because all image-derived data can be used to generate presence data, if not density data.

For these reasons, we next selected a core set of surveys that used similar methods and camera types and provided wide spatial coverage of the study area. This set consisted of three broad-scale biodiversity surveys: TAN1701; TAN1306, and TAN0705. These surveys are most useful for mapping benthic distributions because of their combined spatial scope, use of the same high-quality imaging system (DTIS), and consistent methods for logging navigational and observational data. We then added data from surveys of two habitats that were known to be under-represented in the core dataset: seamounts and phosphorite-rich sediments. Both of these habitats are associated with protected, habitat-forming, scleractinian coral species and have been the subject of multiple dedicated research voyages with more tightly-focussed spatial extent than the core set of surveys.

Existing datasets from seamounts were from surveys of the *Graveyard* on the northern central flank of Chatham Rise (TAN0104, TAN0604, TAN0905, TAN1503), and the *Andes* on the south-eastern flank (TAN1503). In the Graveyard seamount complex, all of these surveys were designed to repeat the same transects to monitor change in benthic communities after cessation of trawling. Therefore, we selected only the most recent of the surveys (TAN1503) because it had the best overall image quality and was the only survey to include the *Andes* seamounts. Available data consisted of counts of organisms in individual still images from multiple transects on each of six features in the *Graveyard*. Seamount transects were run from summit to base of each feature and thus lengths varied. No analyses had been run on transects from the *Andes* prior to the present project.

Phosphorite-rich sediments occur on the central crest of Chatham Rise. In 2012 a dedicated survey designed by NIWA was run by Chatham Rock Phosphate Ltd, using RV *Dorado Discovery* (voyage referenced here as CRP2012). The photographic survey used a work-class Remotely Operated Vehicle (ROV) along transects designed to match standard DTIS transects but with cameras of lower image resolution. Data available from this survey consisted of counts of organisms in individual still images from 39 transects (Rowden et al. 2014).

In combination, this set of surveys provides broad spatial coverage with relatively even distribution of sample sites across the region, and incorporates existing data about all areas known to have high biological diversity or be of specific interest for environmental management. While it is probable that other sites of interest will be discovered in future surveys, the current set is likely to provide the most complete representation of benthic invertebrate distributions on Chatham Rise available to date.

## 2.3 Data extraction from imagery

Developing quantitative data about benthic fauna from seabed imagery entails recording the identity and numbers of individual organisms observed during review of either video or still imagery. Imagery from the surveys selected for the generation of a new merged dataset fell into one of four categories: video imagery analysed (in full or in part); still imagery analysed (in full or in part); video and still imagery analysed (in full or in part), or no imagery analysed. Although video and still imagery were recorded simultaneously in surveys where both were collected, there are important differences between the two mediain terms of analysis methods and the resulting data. Video imagery is continuous and thus covers greater seabed area than discontinuous still images, but generally has lower optical resolution than still images. Thus, video enables more reliable density estimates for larger, more conspicuous, or more patchily distributed taxa, while still images enable detection and quantification of smaller taxa. For a given seabed area, analysis of still imagery is generally more time-consuming than of video (Bowden & Jones 2016).

Prior to the dedicated sampling voyage for objective (1) of this project (TAN1701), the most extensive photographic surveys on the rise were the OS2020 voyages TAN0705 and TAN1306. All video imagery from these two surveys has been analysed in full (Bowden 2011, Bowden & Leduc 2017), generating datasets of taxon identities and densities based on a consistent transect length of approximately 1.4 km and using consistent analysis methods. The methods used in analysis of imagery from these surveys are detailed in Bowden (2011) and Bowden and Leduc (2017). In brief, in consultation with the relevant taxonomic experts, taxon image identification libraries were compiled for all taxa seen during the survey. Video files were then synchronised with navigation and metadata files recorded during transects at sea, in appropriate software (Ocean Floor Observation Protocol, OFOP – www.ofop-by-sams.eu - was used for all survey analyses reported here) to enable video transects to be re-played under controlled conditions in the laboratory. By reference to the image libraries and using taxon lists in OFOP, analysts then worked through the full length of each transect, recording individual organisms by clicking on the relevant taxon label. In this method, each organism is recorded as a separate observation complete with its seabed coordinates (from RV *Tangaroa*'s ultra-short baseline acoustic tracking system), depth, camera metadata, and other information available from the navigation file, typically including surface position of the ship, speed over ground, course over ground, and camera altitude.

All 147 video files from voyage TAN1701 (Bowden et al. 2017) were analysed in full under the present project and all video from TAN0705 (108 transects) had already been analysed using the same protocols (Bowden 2011). Of 59 DTIS video transects collected during TAN1306, 32 had already been analysed (Bowden & Leduc 2017) and a further 14 were analysed under the present project to improve representation of the central crest of the rise and hard substratum habitats around Veryan and Mernoo Banks.

Data from analyses of 1738 still images from 49 transects on the six main features in the *Graveyard* (voyage TAN1503) (Clark, M. R. et al. 2015) were used in full. Because individual seamounts in the *Graveyard* are small (less than 1 km radius), and as summed seabed swept areas for all images on a given seamount approximated to the swept area of standard DTIS transects (about 800 $m^2$), data were pooled by seamount, rather than per transect. No imagery had been analysed from the *Andes*, so five video transects from TAN1503, representing the five main features in the group, were analysed for this project using standard protocols.

## 2.4 Merging data across surveys

Two key stages were required before data from the selected surveys could be merged to form the final dataset: mapping of taxon synonyms to consistent nomenclature and taxonomic hierarchy, and standardisation of density values to standard unit area of seabed.

*Taxon names*

Surveys have been undertaken to address a range of different research aims and the methods used for analyses of imagery have been tailored to address specific questions. For instance, whereas biodiversity surveys aim to record all taxa, surveys to identify effects of fishing might emphasise erect sessile fauna within a certain size range. The taxonomic accuracy and precision with which taxa are identified has also changed with time as taxonomists have become more familiar with assigning identifications from imagery alone, and analysts have gained experience. Consequently, ensuring consistency of taxon identification and naming, both within and between surveys, was a major stage in developing the dataset, requiring generation of a master taxon table in which synonymous labels from different analyses were matched to unique taxon codes and placed in a full taxonomic hierarchy.

*Density standardisation*

Base data from each survey were in the form of counts of organisms, either per video transect or per image. Because transects were variable in length and image frame width, standardisation to consistent unit area was necessary. For video transects, seabed swept area was estimated by multiplying the distance travelled, minus any sections in which the seabed was not visible, by the frame width. Frame width was calculated for each survey separately as the mean of 50–100 measurements of frame-grabs selected at random from multiple transects, using parallel laser points in the image for scale (Table 2). For still images, the full seabed area was calculated for each image individually and image areas were summed either by transect (CRP2012 data) or by seamount (TAN1503 data), again, using laser points for scale. All image measurements were made in *ImageJ* (https://imagej.nih.gov/ij/).

DTIS transects for biodiversity surveys are of standard 1 h duration with a target speed range of 0.3 to 0.5 $ms^{-1}$. While the basic geometry and layout of DTIS has remained the same through its lifespan, a major upgrade in 2016 resulted in wider field of view for video (through use of dome ports, rather than flat ports). Consequently, seabed swept-areas for DTIS video increased from 1500 – 2800 $m^2$, to 2800 – 3000 $m^2$ from

2016. Use of RV *Tangaroa*'s Dynamic Positioning for DTIS deployments from late 2015 also greatly improved consistency of transect speed, resulting in generally improved video image quality. Where still images were analysed, rather than video (i.e., for *Graveyard* seamounts and CRP2012 phosphorite habitats), analysed swept-areas per transect were smaller; in the range 700 – 1200 $m^2$. Given these ranges, and following existing practice in New Zealand and globally, we standardised counts from all surveys to the number of individuals per 1000 $m^2$ of seabed.

**Table 2: Standard values for video image frame width and still image seabed area used in calculations of swept area for standardisation of taxon densities. Video values were derived as the average of 50–100 frame-grabs taken at random from each voyage. Seabed area of each still image was measured and these values were summed over all analysed images in a given transect to yield total swept area for density calculation. Still image area values shown here are indicative means for the two surveys from which still image data were used.**

| Survey | Video frame width (m) | Still image area ($m^2$) |
|---|---|---|
| TAN1701 | 3.2 | |
| TAN1503 | 3.2 | 2.3 |
| TAN1306 | 1.5 | |
| CRP2012 | | 12 |
| TAN0705 | 1.5 | |

*Merging*

For point-observation datasets for each voyage individually, recorded taxon labels were initially mapped to audit taxon names and codes using the VLOOKUP function in MS Excel. The Point-observation datasets were then merged in R (www.r-project.org). Density datasets developed from the point-observation data for each survey individually were then imported into R (R Core Team 2017), taxon labels aggregated to their audit codes (using *aggregate* function in *readr*) and data were merged (function *merge*) into a single dataset and exported as text files.

After each survey was incorporated into the dataset via the merging process, density data were plotted in a geographic information system (GIS, ArcGIS 10.4.1) using proportional scaling symbols. This step enabled distributions to be compared with known occurrences (i.e., by comparison with the data from other surveys, published studies, trawl survey data, and evaluation by researchers with direct experience from the surveys). Where data points appeared anomalous, for example, through high or low-density values or absence of taxa at sites where they were known to occur, images and the original at-sea and rerun analysis logs were reviewed.

## 2.5 Database

A key requirement of this project was to develop data management structures that would enable access to the merged image-derived dataset and facilitate addition of new data as they become available. To achieve this, a dedicated database was designed, using *postgres/postgis* architecture, to be hosted and maintained on NIWA's secure server system. The specifications of the database were planned to allow direct interrogation via existing tools (e.g., PGAdminIII, QGIS) and access via on-line portals (e.g., NIWA's Coastal and Marine Data Portal, https://marinedata.niwa.co.nz/, and the New Zealand Ocean Data Network https://nzodn.nz/).

# 3. RESULTS

## 3.1 Data

The final data set consisted of 125 658 records of individual organisms from analyses of 358 seabed transects across 5 surveys, with 109 161 records from analyses of video, and 15 795 from still images (Table 3). Data spanned the full extent of Chatham Rise from 172° 50' E to 173° 53' W and from 42° 29' S to 45° 5' S in depths from 40 m to 1850 m (Figure 3).

**Table 3: Chatham Rise image-derived data, showing digital-era surveys used, number of seabed transects analysed (total and numbers from video or still imagery), and numbers of benthic invertebrate fauna observations recorded. Note, still-image data from seamounts in the Graveyard complex (TAN1503) were combined by seamount, thus each of the 6 still-image sites noted here represents multiple individual transects.**

| Survey | Analysed | video | stills | Fauna observations |
|---|---|---|---|---|
| TAN1701 | 147 | 147 | 0 | 51 597 |
| TAN1503 | 11 | 5 | 6 | 3 861 |
| TAN1306 | 53 | 53 | 0 | 18 603 |
| CRP2012 | 39 | 0 | 39 | 13 689 |
| TAN0705 | 108 | 108 | 0 | 37 908 |

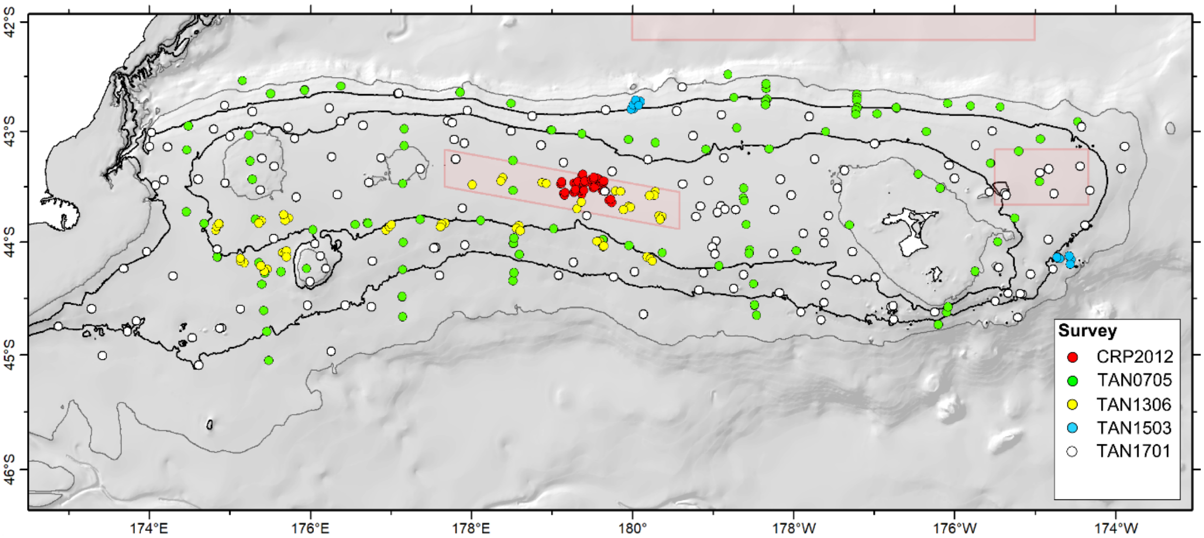


**Figure 3: Chatham Rise showing locations of all seabed photographic transects from which data on benthic invertebrate taxon identities and densities were compiled for the current project. Locations are colour coded by survey; see legend and text for details.**

The full dataset is stored in the dedicated postgres-postgis database developed under this project and can be interrogated via NIWA's Coastal and Marine Data Portal (https://marinedata.niwa.co.nz/) and the New Zealand Ocean Data Network (https://nzodn.nz/) or, from within NIWA and MPI, directly using standard database and GIS tools.

## 3.2 Taxa

The merged taxon list consisted of 354 taxa across 13 phyla (Table A 1), with most taxa in the phyla Echinodermata (95 taxa), then Cnidaria (87), Porifera (58), Arthopoda (43), Mollusca (37), Annelida (10), Bryozoa (9), Chordata (Ascidiacea, 6), Brachiopoda (1), Echiura (1), Foraminifera (1), Hemichordata (1), Nemertea (1).

Taxonomic resolution of records among analysts and between surveys was consistent for most taxa but variations were apparent for some groups for which detailed, species-level guides had been developed. Such variations were particularly noticeable for Porifera, where taxonomists had provided many species- and genus-level identifications from images but in which intra-specific growth form can be variable and inter-specific similarity of form can be high. For other taxa, the main source of inconsistencies in identification was the variability in image resolution within and between transects (e.g., through variations in camera height above seabed), which can result in neighbouring individuals of the same taxon being recorded at different taxonomic levels. To address this issue, a set of aggregated taxon labels was developed in which each recorded taxon was mapped to a taxonomic level at which its identity could be expected to be recorded with confidence (Table A 1). This process yielded a list of 79 'aggregated' taxa, ranging in taxonomic resolution from species-level for distinctive taxa (e.g., *Metanephrops challengeri* and *Dermechinus horridus*), to family (e.g., primnoidae and brisingidae), order (e.g., Cerantharia), class (e.g., Asteroidea and Holothuroidea), or phylum (e.g., Brachiopoda). Some finer taxonomic detail is certainly masked in this aggregation approach but distinctions likely to be relevant to management of benthic impacts, such as differentiation of brisingid seastars in the class Asteroidea and *Dermechinus horridus* in the class Echinoidea, are retained. Furthermore, because the underlying seabed photographic material from all voyages remains available for re-analysis or targeted audit, individual species or higher taxonomic groupings can be revisited at any point should their occurrence become important to future analyses for management or fundamental science objectives.

## 3.3 Distributions

Representative distribution maps for selected taxa are shown in Figure 4 to Figure 10. These maps use expanding symbols to show standardised densities of taxa (individuals 1000 $m^{-2}$) on a uniform scale (i.e., symbol size range is the same for all taxa). Symbols occur only at sites where a given taxon was observed (present), all other sites (see Figure 3) are taken to be absences.

Colonial scleractinian corals (Figure 4) are protected in the New Zealand EEZ and are highly vulnerable to bottom-contact trawling and other seabed disturbances. Distinguishing between species can be problematic without detailed taxonomic examination however, and in analyses of video or still imagery, identifications are made primarily on the basis of gross colony form and colouration. The two species most frequently recorded in the combined dataset were *Goniocorella dumosa* and *Solenosmilia variabilis*, the latter being recorded only on the *Graveyard* hills. *Enallopsammia* sp. colonies were recorded only on the *Andes* seamount, and the generic observation *Scleractinia* (used when there was doubt about finer-level identification) was recorded in low numbers across the rise. The combined distribution of all colonial scleractinian corals shows highest densities on the Graveyard and Andes seamounts and on phosphorite nodules in the mid-Chatham Rise BPA. Outside of these areas, abundances were low and strongly dependent on the presence of hard substrata.

Sea-pens (Pennatulacea) were widely distributed on soft sediments in depths from 400–1000 m. Very high densities recorded at about 500 m on the central southern flank of the rise were of a small, truncated, taxon identified in the dataset as *Kophobelemnon* sp. Gorgonian corals (Gorgonacea) are a diverse grouping in which individual taxa are poorly distinguished in video analyses. They are widely distributed across the rise, generally associated with hard substrata, with highest densities recorded on the *Graveyard* hills. Soft corals (Alcyonacea) are generally associated with hard substrata but the dataset was dominated by the endemic solitary soft coral *Taiaroa tauhou*, which occurred in very high densities on soft sediments along the southern flank of the rise in about 500 m depth (Figure 5).

Echinoids were recorded at most sites in the dataset (Figure 6). Highest densities were recorded for the regular urchin *Gracilechinus multidentatus*, which occurred along the southern and north-western flanks of the rise in 600 – 1000 m depth, and spatangoid burrowing urchins (Spatangoida), which occurred in soft sediments primarily on the central and central-western crest of the rise in 300–500 m depth. Cidaroid ('pencil') urchins occurred widely but in lower densities, with highest densities occurring in phosphorite nodule habitats on the central crest of the rise and at the western end of the rise around Veryan Bank.

Sponges (Figure 7) were widely distributed across the rise, again, dependent on the presence of hard substrata. The dataset included many identifications to species or genus level but high diversity in this taxon coupled with difficulties in confirming identifications from video imagery generated some inconsistencies among surveys in the level of identification achieved. Considerably more detail could be achieved for this group by reanalysis of the data and review of the underlying imagery. Highest densities of sponges were on the Graveyard hills, Veryan Bank, and the Andes seamounts, with Demospongiae occurring commonly on hard substrata across the rise and Hexactinellida primarily on the two seamount groups and Veryan Bank. The distinctive, large, conical sponge *Hyalascus* n. sp. was one of the few sponge taxa reliably and consistently identified to species level in the dataset. It occurred in low densities (less than 1 individual 1000 $m^{-2}$), however, and primarily on the central crest of the rise but also on the southern flank.

The echinoderm classes Holothuroidea and Asteroidea occurred widely across the rise (Figure 8), generally at lower densities than the echinoids (Figure 6). Highest densities of holothuroids occurred around Veryan Bank, on the northern flank of the rise in about 500 – 1000 m depth, and around the Graveyard hills. Asteroids showed distribution, with highest densities around Veryan Bank, on the Graveyard hills, and at sites around the Chatham Islands. The distinctive and conspicuous suspension-feeding asteroid family, Brisingidae, was widely but sparsely distributed, occurring at very low densities other than in phosphorite nodule habitats on the central crest of the rise and on the Graveyard hills.

Three distinctive taxa associated with sensitive or vulnerable marine habitats are shown in Figure 9: stylasterid corals; brachiopods, and Xenophyophores ('giant' forams). Stylasterids, while distributed widely on hard substrata, occurred at highest densities on the Andes seamounts, with lesser concentrations on Veryan Bank, the Graveyard hills, and phosphorite substrata on the central crest of the rise. Brachiopods were recorded in the central crest phosphorite habitats, Veryan Bank, and at sites around the Chatham Islands. Xenophyophores occurred on soft sediments deeper than 500 m and primarily on the extreme southwestern and eastern flanks of the rise and around the Graveyard seamounts.

Three mobile taxa that might be resistant to, or benefit from, seabed disturbance by trawling (Jennings & Kaiser 1998, Kaiser et al. 2006) are shown in Figure 10: hermit crabs (family Paguridae); carnivorous and scavenging snails (families Buccinidae and Volutidae), and the quill worm *Hyalinoecia* sp. (probably *H. longibrachiata*). Hermit crabs were widely distributed across the rise but with highest densities along the southern flanks in about 500 m depth and around the Graveyard seamounts. Carnivorous and scavenging snails were also widespread but, again, with highest densities recorded along the southern flank at about 500 m depth, and on the north-eastern flank at about 1000 m depth. *Hyalinoecia* sp. quill worms were widespread but occurred in high densities primarily along the southwestern and southern flanks of the rise and on the continental slope of the South Island, in depths of about 500 – 800 m, with high densities also recorded in these depths at sites northeast of the Chatham Islands.

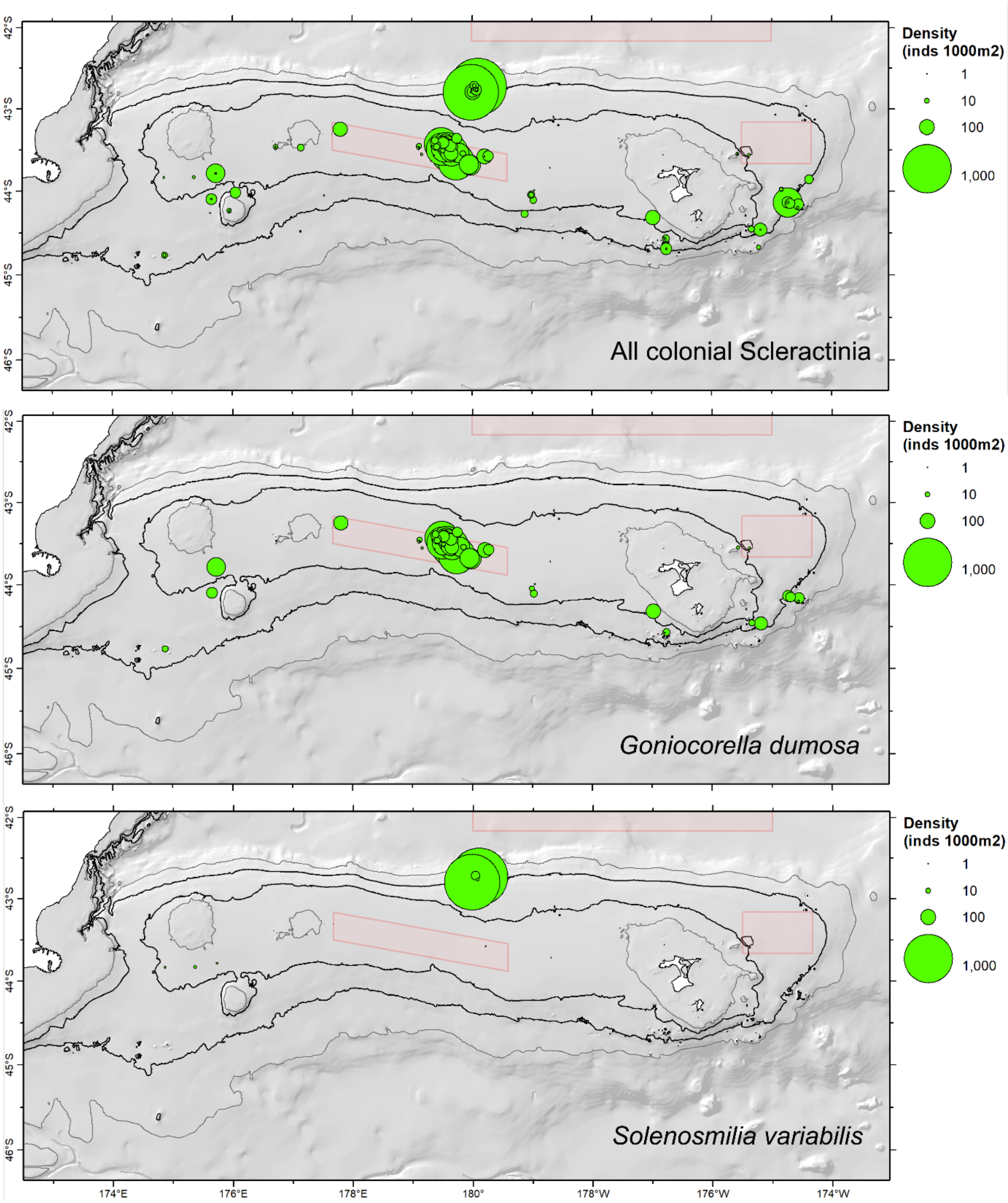


**Figure 4: Colony-forming scleractinian corals. Top; all colonial scleractinian observations. Middle; *Goniocorella dumosa*. Bottom; *Solenosmilia variabilis*. Colonial scleractinia were represented by five observation labels: *Solenosmilia variabilis*; *Goniocorella dumosa*; *Enallopsammia* sp.; *Madrepora* sp., and 'Scleractinia'. 'Scleractinia' was used by analysts when the identity of colonies was uncertain.**

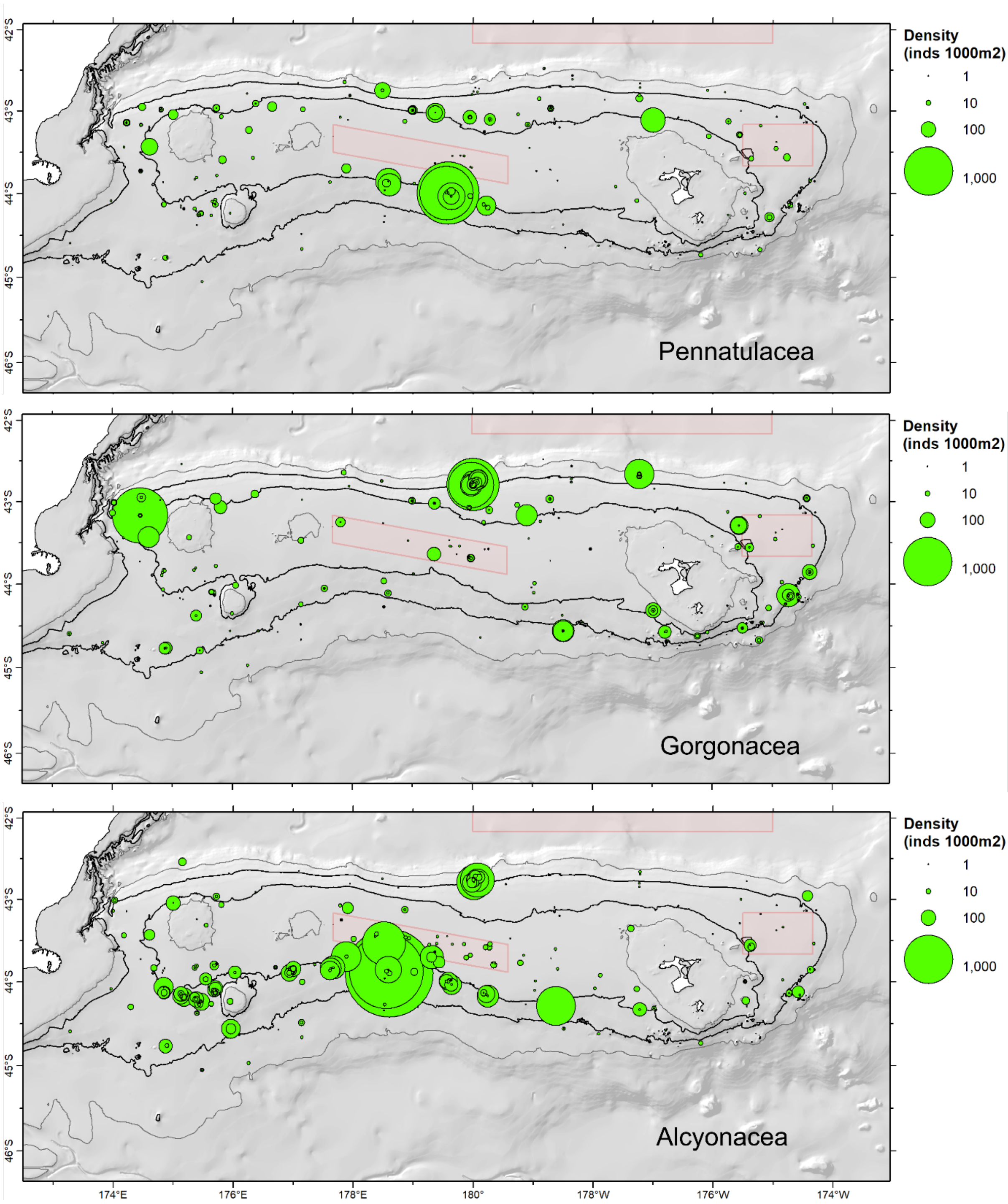


**Figure 5: Pennatulacea, Gorgonacea, and Alcyonacea observations.**

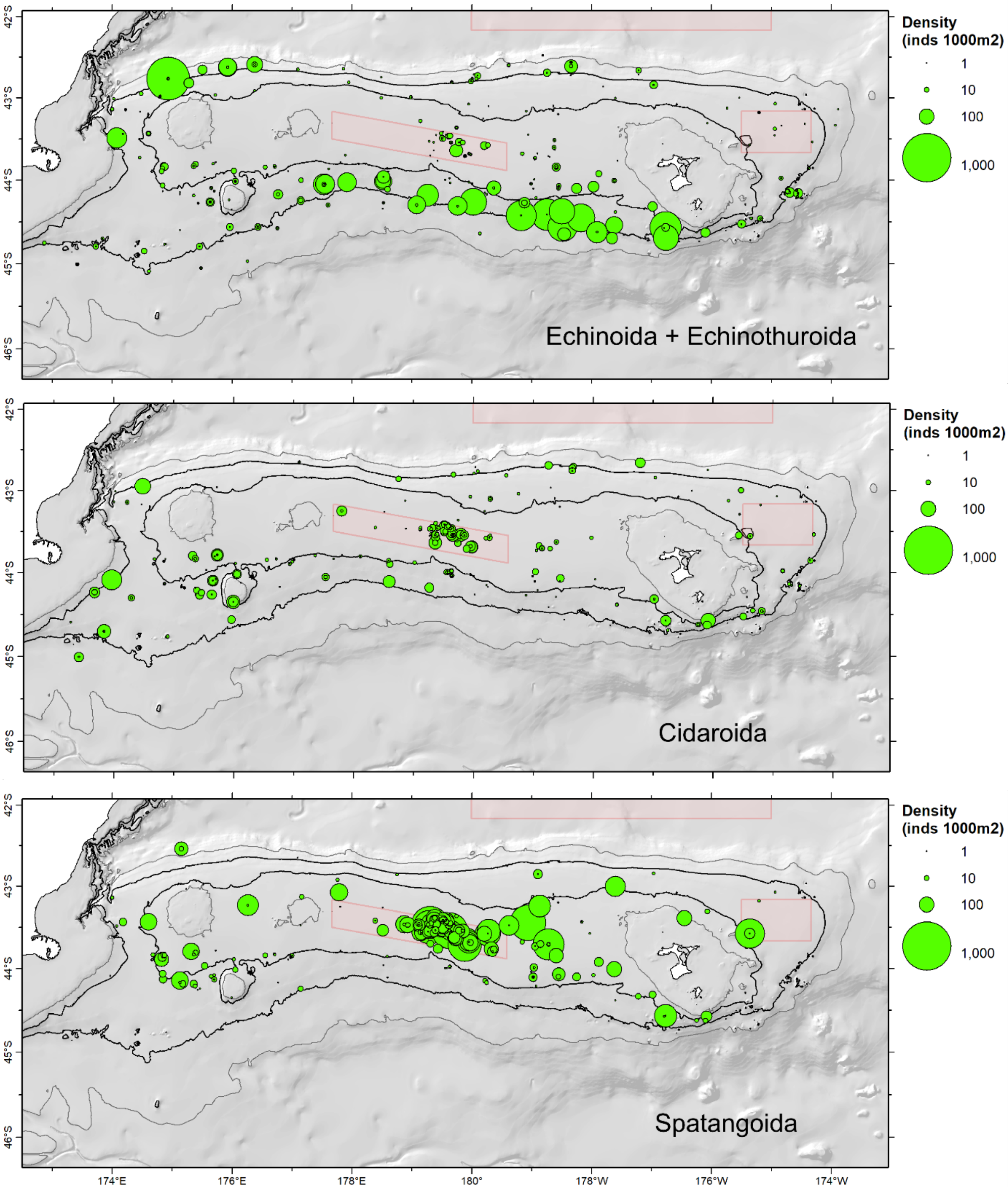


**Figure 6: Echinoid observations in the orders Echinoida and Echinothuroidea (top), Cidaroida (middle), and Spantangoida (bottom).**

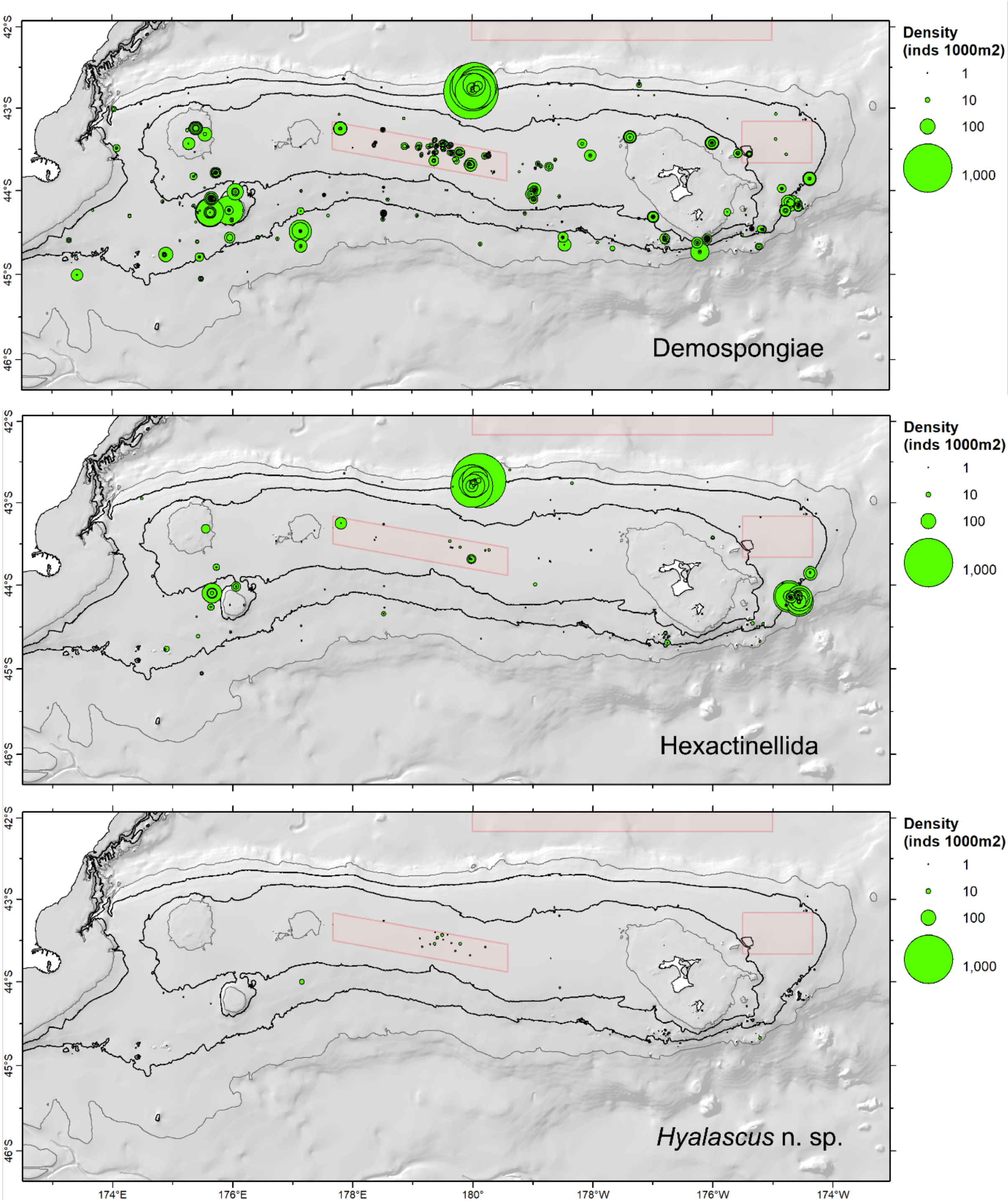


**Figure 7: Porifera observations. Class Demospongiae (top), class Hexactinellida (middle), and the distinctive large cone-shaped hexactinellid sponge *Hyalascus* n. sp. (bottom).**

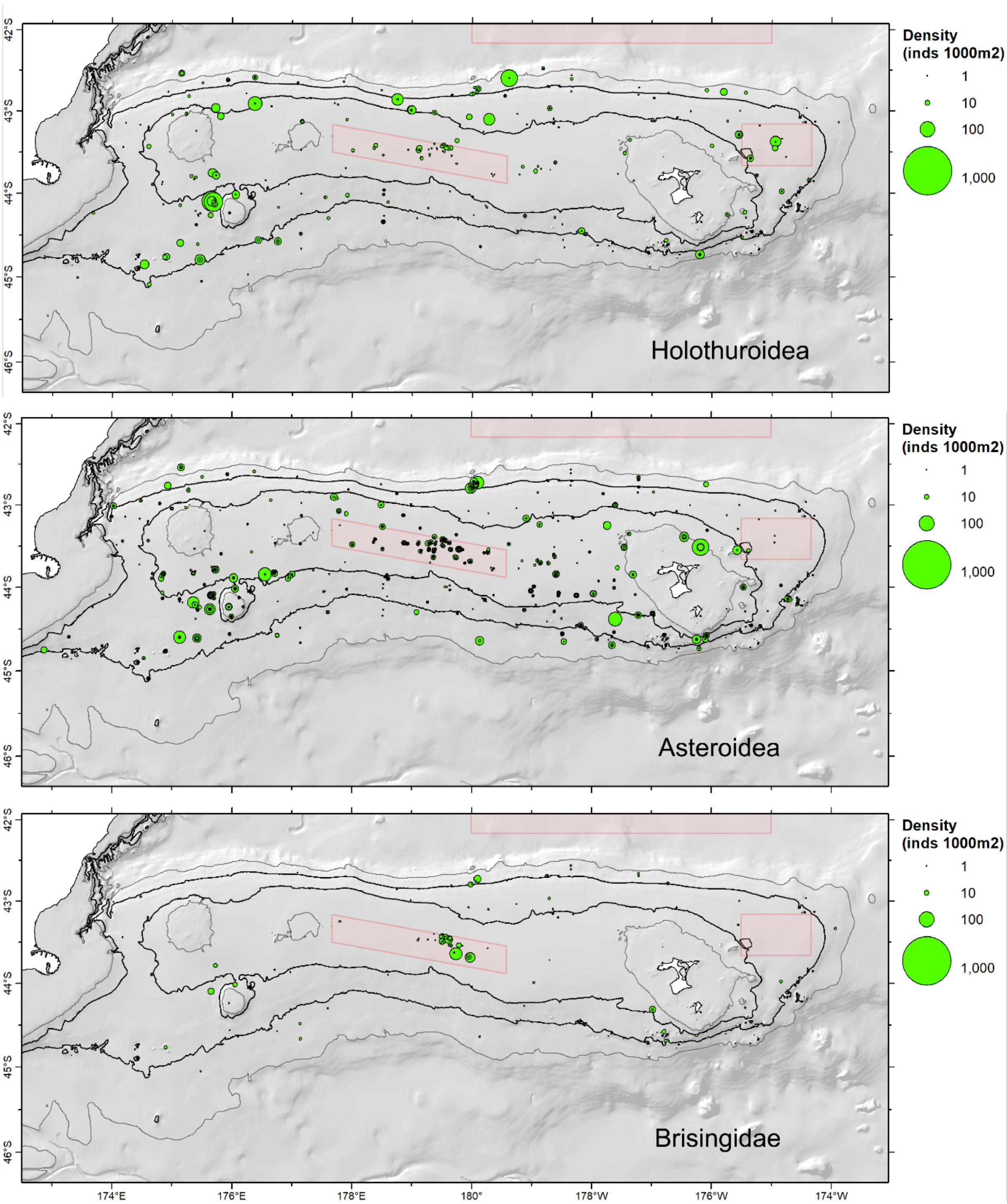


**Figure 8: Holothuroidea (top), Asteroidea (middle), and filter-feeding asteroids in the family Brisingidae (bottom).**

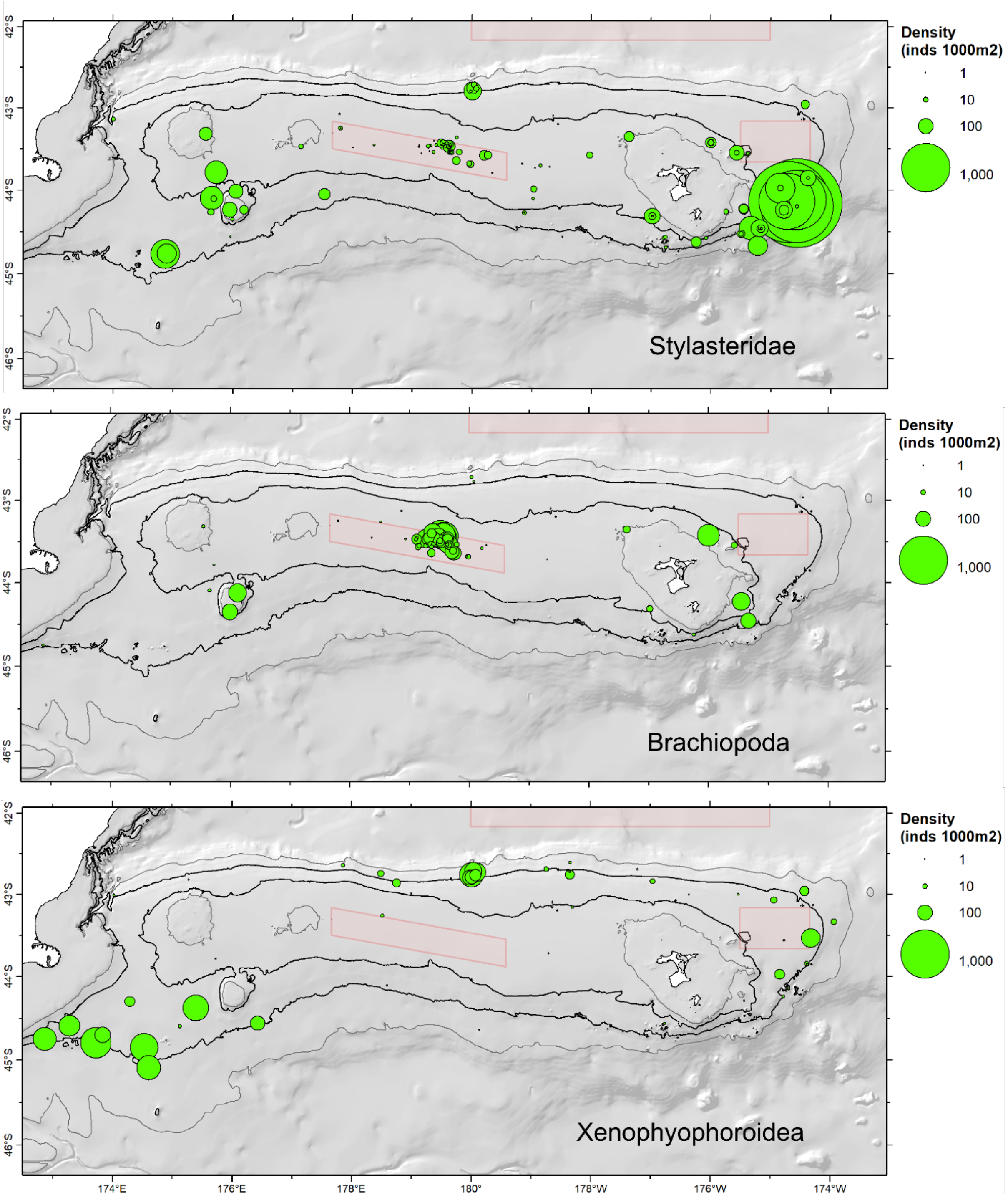


**Figure 9: Stylasterid hydrocoral, brachiopod, and Xenophyophore observations.**

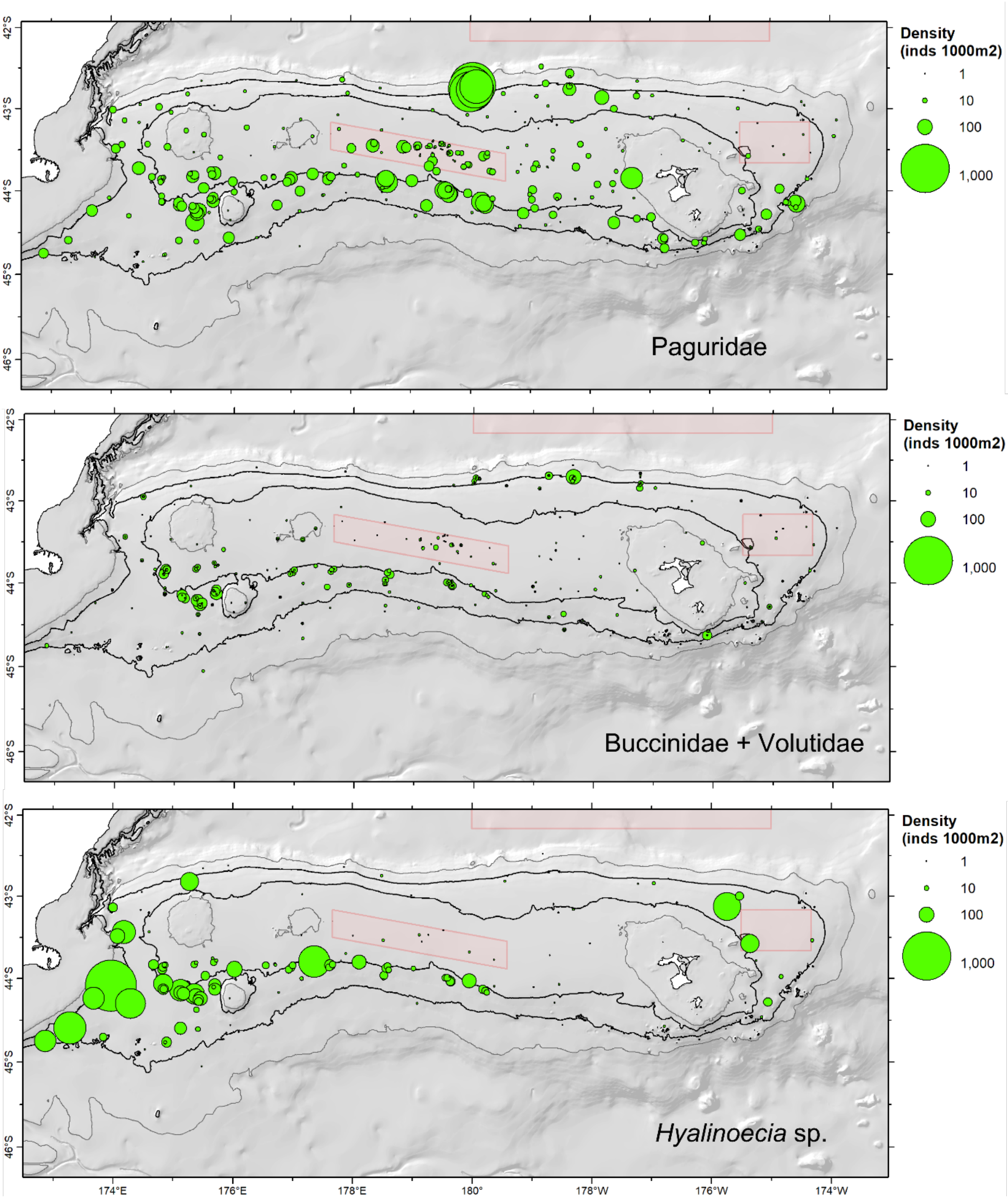


**Figure 10: Hermit crabs (Paguridae), whelks (Buccinidae and Volutidae), and quill worms (*Hyalinoecia* sp.).**

## 4. DISCUSSION

The combined dataset of benthic epifaunal invertebrate distributions developed here is rare for deep-sea environments beyond the continental shelf, in that it combines broad spatial extent and relatively even distribution of sample sites with consistent survey and analysis methods appropriate for sampling of benthic fauna. In comparison with published studies using photographic data to inform habitat suitability modelling at comparable depths in other parts of the world (e.g., Howell et al. 2016, Robert et al. 2016), the Chatham

Rise dataset ranks among those with the largest spatial extents and the highest density of sample sites. By comparison with other areas of the New Zealand EEZ, Chatham Rise has been sampled intensively for benthic research, with a higher density of photographic sampling than any other area, including the other Ocean Survey 20/20 areas, Challenger Plateau (Bowden 2011) and the eastern Northland continental shelf (Morrison et al OS2020 report). When research trawl bycatch records are included, the density of benthic sampling is very high indeed but these data have issues in relation to low catchability of many benthic taxa by fish trawls and inconsistent and un-auditable variations in taxonomic identifications between years (O'Driscoll et al. 2011). Until now, therefore, data on the distributions of benthic fauna used in habitat suitability models have been limited to either results from a single dedicated survey of biodiversity (e.g., Compton et al. 2013) or records accumulated over many years from diverse sources, including benthic research, fisheries research, and commercial fisheries bycatch (e.g., Anderson et al. 2014, Tracey et al. 2011). The dataset developed here enables all digital-era seabed photographic data collected across Chatham Rise to be used as a single, coherent, source of information to support assessments of the utility of existing habitat-suitability models and the development of new models with greater reliability.

The approach used here, merging data across multiple surveys conducted over a decade (2007 to 2017), depends on the assumption that distributions of relatively large epifaunal taxa vary little over time. This assumption underlies almost all attempts to model the distributions of benthic organisms because the datasets of species' presence are generally reliant on the accumulation of knowledge over time. There is some support for the assumption of invariant distributions here, however, in that co-located survey transects from TAN0705 and TAN1701 show similar community make-up and that overall patterns of distribution for most taxa are similar between these two broad-scale surveys. Repeat surveys of seamounts in the Graveyard complex from 2001 to 2015 have also shown no detectable change in community composition (Clark, M. R. et al. 2010, Williams et al. 2010). The assumption will also be tested more formally in the next phase of this project, when existing habitat-suitability models developed using only data from TAN0705 (Compton et al. 2013) will be assessed using combined data from the other surveys incorporated here (CRP2012, TAN1306, TAN1503, and TAN1701).

Despite careful auditing undertaken here, it is inevitable in a dataset of this complexity, compiled from multiple sources by multiple analysts, that some residual errors and inconsistencies in terms of both taxon identifications and relative density estimates will remain. Inconsistencies in taxon identities can arise through differences in the experience level of individual analysts, variations in image quality within and between transects and surveys, and name changes at species or higher levels resulting from taxonomic reviews, whereas density estimates are affected primarily by differences in the size of organism and differences in the optical resolution of the imagery. Density estimates for larger species are generally more reliable than those for smaller ones, because they are more likely to be seen and identified correctly from the imagery, and a key dichotomy in image resolution is between video and still imagery, with still imagery being of higher resolution than video but usually sampling smaller seabed area at the scale of individual transects. This has implications for both the number of taxa identified and the estimates of their relative densities (Andrew & Mapstone 1987); sampling less seabed area means that taxa occurring at low densities are less likely to be recorded and higher resolution means that smaller taxa are more likely to be recorded and their densities to be estimated accurately. Thus, in the full dataset here, the estimated diversity and density of smaller taxa might be expected to be higher in the two areas represented by data from still imagery; the Graveyard hills (TAN1503), and phosphorite nodule habitats on the central crest of the rise (CRP2012). However, total seabed swept areas per site were similar between video and still image transects (because we summed still image areas across multiple individual transects, e.g., combining images from all transects on each seamount in the Graveyard complex) and taxon densities derived from still images fall within the ranges estimated for all sites across the study area (Figures 4 – 10). It is still likely that more species-level identifications will have been made from still images but the taxon aggregation levels at which the data will be used in most applications should largely negate this in the final dataset.

A major advantage of photographic surveys is that the source samples (video and still image files) are retained in full and are not modified or degraded during analysis. Thus, the auditing process undertaken for this initial compilation under the current project, in which apparently anomalous identifications or density values detected are checked against the original imagery and log files, can be revisited at any time. While we are confident that the current dataset presents a largely accurate and realistic description of distributions across Chatham Rise, we anticipate that the audit process will continue as the dataset is taken up for use in research applications and as data from future surveys are incorporated.

In summary, the combined dataset developed here makes available a detailed body of information about the distributions of benthic fauna of Chatham Rise that represents ten years of research effort. Until now, most of these data were not generally accessible and thus had no application beyond the disparate research projects under which they were collected. By merging data from all broad-scale digital-era photographic surveys on Chatham Rise, we now have an independent data resource that can be used in a range of research applications including: assessing the usefulness of existing habitat suitability models and their underlying methods; developing new habitat suitability models based on more complete and coherent data, and developing methods to assess the impacts of bottom-contact fishing and other forms of seabed resource exploitation on benthic habitats.

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## 7. APPENDIX 1 – Taxa

**Table A 1: Benthic invertebrate taxa observed in post-voyage analyses of seabed video and still images collected during surveys on Chatham Rise. 'Taxon observed' is the label used by analysts (audited here to combine synonyms, mis-spellings, etc.). 'ID_code' is a unique identifier for each taxon, as developed for use in OFOP. 'Taxon aggregated' is a higher-level aggregation that groups taxa at taxonomic levels at which we have confidence that identifications are both accurate and consistent across all surveys and analysts.**

| Phylum | Class | Order | Family | Taxon observed | ID_code | Taxon aggregated |
|---|---|---|---|---|---|---|
| Annelida | Polychaeta | | | Polychaete (errant) | T_117 | Polychaeta |
| | | | | Sedentaria | T_2430 | Polychaeta |
| | | | | Tube worms | T_212 | Polychaeta |
| | | Aciculata | Onuphidae | Onuphidae | T_2367 | Polychaeta |
| | | | | Quill worm | T_130 | *Hyalinoecia* sp. |
| | | Sabellida | Sabellidae | Sabellidae (fan worm) | T_710 | Polychaeta |
| | | | Serpulidae | *Protula* | T_2323 | Polychaeta |
| | | | | *Salmacina australis* | T_2408 | Polychaeta |
| | | | | Serpulidae | T_1023 | Polychaeta |
| | | | Chaetopteridae | Chaetopteridae | T_2309 | Polychaeta |
| | | | | | | |
| Arthropoda | Malacostraca | Amphipoda | | Amphipoda | T_125 | Amphipoda |
| | | Decapoda | Atelecyclidae | Atelecyclidae | T_508 | Brachyura |
| | | | | *Trichopeltarion fantasticum* | T_509 | Brachyura |
| | | | Campylonotidae | *Campylonotus rathbunae* | T_524 | Caridea |
| | | | Chirostylidae | Chirostylidae | T_530 | Galatheidae/Chirostylidae |
| | | | | *Gastroptychus novaezelandiae* | T_531 | Galatheidae/Chirostylidae |
| | | | Galatheidae | Crustacean (galatheid/Chirostylidae) | T_111 | Galatheidae/Chirostylidae |
| | | | | Galatheidae | T_528 | Galatheidae/Chirostylidae |
| | | | | *Munida gracilis* | T_529 | Galatheidae/Chirostylidae |
| | | | Goneplacidae | Goneplacidae | T_510 | Brachyura |
| | | | | *Neommatocarcinus huttoni* | T_512 | Brachyura |
| | | | Homolidae | Homolidae | T_2533 | Brachyura |

| Phylum | Class | Order | Family | Taxon observed | ID_code | Taxon aggregated |
|---|---|---|---|---|---|---|
| | | | Inachidae | *Carcinoplax victoriensis* | T_511 | Brachyura |
| | | | | Inachidae | T_513 | Brachyura |
| | | | Lithodidae | Lithodidae | T_516 | Lithodidae |
| | | | | *Paralomis zealandica* | T_517 | Lithodidae |
| | | | Majidae | *Leptomithrax longipes* | T_523 | Brachyura |
| | | | | Majidae | T_521 | Brachyura |
| | | | | *Platymaia maoria* | T_515 | Brachyura |
| | | | | *Teratomaia richardsoni* | T_522 | Brachyura |
| | | | | *Vitjazmaia latidactyla* | T_514 | Brachyura |
| | | | Nematocarcinidae | *Nematocarcinus* sp. | T_526 | Caridea |
| | | | Nephropidae | Crustacean (scampi) | T_112 | *Metanephrops challengeri* |
| | | | Nephropidae | *Metanephrops challengeri* | T_533 | *Metanephrops challengeri* |
| | | | | Nephropidae | T_532 | Crustacean (lobster) |
| | | | Paguridae | Crustacean (pagurid) | T_108 | Paguridae |
| | | | Pandalidae | *Notopandalus magnoculus* | T_2366 | Caridea |
| | | | | Pandalidae prob *Plesionika* sp. | T_525 | Caridea |
| | | | Polychelidae | Crustacean (polychelidae) | T_122 | Polychelidae |
| | | | Scyllaridae | *Ibacus alticrenatus* | T_535 | *Ibacus alticrenatus* |
| | | | Solenoceridae | *Haliporoides sibogae* | T_527 | Caridea |
| | | | | Crustacean (crab) | T_107 | Brachyura |
| | | | | Crustacean (lobster) | T_106 | Crustacean (lobster) |
| | | | | Crustacean (peracarid) | T_110 | Caridea |
| | | | | Crustacean (shrimp) | T_109 | Caridea |
| | | Euphausiacea | | Euphausiacea | T_123 | Euphausiacea |
| | | Isopoda | Serolidae | *Acutiserolis* sp. | T_538 | Serolidae |
| | | | | Serolidae | T_537 | Serolidae |
| | | | | Isopoda | T_126 | Serolidae |
| | | Mysida | | Mysidacea | T_124 | Mysidacea |
| | Maxillopoda | | | Barnacles | T_215 | Barnacles |

| Phylum | Class | Order | Family | Taxon observed | ID_code | Taxon aggregated |
|---|---|---|---|---|---|---|
| | Pycnogonida | Pantopoda | | Pycnogonid | T_539 | Pycnogonida |
| | | | Colossendeidae | *Collossendeis* sp. | T_119 | Pycnogonida |
| Brachiopoda | | | | Brachiopods | T_210 | Brachiopoda |
| Bryozoa | Gymnolaemata | Cheilostomata | | *Bitectipora retepora* | T_2348 | Bryozoa |
| | | | | Bryozoan - filamentous form | T_2041 | Bryozoa |
| | | | | Bryozoans | T_211 | Bryozoa |
| | | | | Bryzoan - Branched coral-like form | T_716 | Bryozoa |
| | | | | Bryzoan - bushy form | T_715 | Bryozoa |
| | | | | Bryzoan - Encrusting form | T_719 | Bryozoa |
| | | | | Bryzoan - Erect cheilostome | T_714 | Bryozoa |
| | | | | Bryzoan - Lacy fan form | T_717 | Bryozoa |
| | | | | Bryzoan - Stylasterid look-alikes | T_718 | Bryozoa |
| Chordata | Ascidiacea | | | Ascidians (clonal) | T_213 | Ascidiacea |
| | | | | Ascidians (solitary) | T_214 | Ascidiacea |
| | | Aplousobranchia | Didemnidae | Didemnid | T_2341 | Ascidiacea |
| | | | | *Diplosoma* | T_2342 | Ascidiacea |
| | | | Polyclinidae | *Synoicum otagoensis* | T_2345 | Ascidiacea |
| | | | | Aplousobranchia | T_1951 | Ascidiacea |
| Cnidaria | Anthozoa | Actiniaria | | Anemones | T_203 | Anemones |
| | | | | Anenome uni 1 | T_615 | Anemones |
| | | | | Anenome uni 10 | T_624 | Anemones |
| | | | | Anenome uni 11 | T_625 | Anemones |
| | | | | Anenome uni 12 | T_626 | Anemones |
| | | | | Anenome uni 13 | T_627 | Anemones |
| | | | | Anenome uni 14 | T_628 | Anemones |

| Phylum | Class | Order | Family | Taxon observed | ID_code | Taxon aggregated |
|---|---|---|---|---|---|---|
| | | | | Anenome uni 16 | T_630 | Anemones |
| | | | | Anenome uni 17 | T_631 | Anemones |
| | | | | Anenome uni 18 | T_632 | Anemones |
| | | | | Anenome uni 2 | T_616 | Anemones |
| | | | | Anenome uni 3 | T_617 | Anemones |
| | | | | Anenome uni 4 | T_618 | Anemones |
| | | | | Anenome uni 5 | T_619 | Anemones |
| | | | | Anenome uni 6 | T_620 | Anemones |
| | | | | Anenome uni 7 | T_621 | Anemones |
| | | | | Anenome uni 8 | T_622 | Anemones |
| | | | | Anenome uni 9 | T_623 | Anemones |
| | | | Actinostolidae | Actinostolidae | T_2110 | Anemones |
| | | | Edwardsiidae | Edwardsid | T_2351 | Anemones |
| | | | Hormathiidae | Hormathiidae | T_959 | Anemones |
| | | | Liponematidae | cf. *Liponema*/*Bolocera* | T_957 | Anemones |
| | | Alcyonacea | | Alcyonacea | T_501 | Alcyonacea |
| | | | Alcyoniidae | Alcyoniidae | T_704 | Alcyonacea |
| | | | | *Anthomastus* sp. | T_688 | *Anthomastus* sp. |
| | | | Clavulariidae | *Clavularia* sp. | T_706 | Alcyonacea |
| | | | | *Telesto* sp. | T_720 | *Telesto* sp. |
| | | | Isididae | *Keratoisis* sp. | T_2330 | Isididae |
| | | | Plexauridae | Plexauridae | T_2331 | Alcyonacea |
| | | | Primnoidae | *Thouarella* | T_694 | Primnoidae |
| | | | Taiaroidae | *Taiaroa tauhou* | T_709 | *Taiaroa tauhou* |
| | | Antipatharia | | Antipatharia | T_2131 | Antipatharia |
| | | | Antipathidae | *Antipathes* | T_707 | Antipatharia |
| | | | | *Bathypathes* | T_703 | Antipatharia |
| | | | Leiopathidae | *Leiopathes* | T_2352 | Antipatharia |
| | | Ceriantharia | | *Ceriantharia* sp. | T_708 | Ceriantharia |

| Phylum | Class | Order | Family | Taxon observed | ID_code | Taxon aggregated |
|---|---|---|---|---|---|---|
| | | Corallimorpharia | | Corallimorpharia | T_634 | Corallimorpharia |
| | | | | Corallimorpharia 1 | T_635 | Corallimorpharia |
| | | | | Corallimorpharia 2 | T_636 | Corallimorpharia |
| | | | | Corallimorpharia 3 | T_637 | Corallimorpharia |
| | | Gorgonacea | | Gorgonacea | T_503 | Gorgonacea |
| | | | Chrysogorgiidae | Chrysogorgiidae | T_698 | Gorgonacea |
| | | | | *Radicipes* sp. | T_699 | Radicipes sp. |
| | | | Coralliidae | Coralliidae | T_690 | Gorgonacea |
| | | | | *Corallium* sp. | T_701 | Gorgonacea |
| | | | Isididae | Isididae | T_667 | Isididae |
| | | | Paragorgiidae | *Paragorgia* sp. | T_696 | Paragorgiidae |
| | | | | paragorgiidae | T_695 | Paragorgiidae |
| | | | Primnoidae | *Callogorgia* sp. | T_692 | Primnoidae |
| | | | | *Narella* sp. | T_2536 | Primnoidae |
| | | | | *Primnoella* sp. | T_693 | Primnoidae |
| | | | | Primnoidae | T_691 | Primnoidae |
| | | | | *Tokoprymno* sp. | T_2537 | Primnoidae |
| | | Pennatulacea | | Pennatulacea | T_502 | Pennatulacea |
| | | | | Pennatulacea 1 | T_669 | Pennatulacea |
| | | | | Pennatulacea 2 | T_670 | Pennatulacea |
| | | | | Pennatulacea 3 | T_671 | Pennatulacea |
| | | | | Pennatulacea 4 | T_672 | Pennatulacea |
| | | | | Pennatulacea 5 | T_673 | Pennatulacea |
| | | | Funiculinidae | *Funiculina* sp. | T_2530 | Pennatulacea |
| | | | Kophobelemnidae | *Kophobelemnon* sp. | T_1944 | Pennatulacea |
| | | | Protoptilidae | Protoptilidae | T_2423 | Pennatulacea |
| | | | Umbellulidae | *Umbellula* sp. | T_1107 | Pennatulacea |
| | | | Anthoptilidae | Anthoptilidae | T_2427 | Pennatulacea |
| | | | Pennatulidae | *Pennatula* sp. | T_2117 | Pennatulacea |

| Phylum | Class | Order | Family | Taxon observed | ID_code | Taxon aggregated |
|---|---|---|---|---|---|---|
| | | Scleractinia | | Corals (stoney) | T_206 | Scleractinia |
| | | | | Scleractinia | T_504 | Scleractinia |
| | | | Caryophylliidae | cup corals (stalked) | T_678 | Caryophylliidae |
| | | | | cup corals (Stephanocyathus sp.) | T_679 | *Stephanocyathus* sp. |
| | | | | *Desmophyllum*/ *Caryophyllia* | T_680 | Caryophylliidae |
| | | | | *Goniocorella dumosa* | T_689 | *Goniocorella dumosa* |
| | | | | *Solenosmillia variabilis* | T_675 | *Solenosmillia variabilis* |
| | | | Dendrophylliidae | *Enallopsammia* sp. | T_677 | *Enallopsammia* sp. |
| | | | Flabellidae | *Flabellum* | T_682 | Flabellum |
| | | | | *Flabellum* 1 | T_683 | Flabellum |
| | | | | *Flabellum* 3 | T_685 | Flabellum |
| | | | | *Flabellum knoxi* | T_687 | Flabellum |
| | | | | *Flabellum loure kexeii* | T_686 | Flabellum |
| | | | | *Flabellum rubrum* | T_684 | Flabellum |
| | | | Oculinidae | *Madrepora* sp. | T_676 | *Madrepora* sp. |
| | | Zoantharia | Epizoanthidae | *Epizoanthus* sp. | T_2011 | Epizoanthidae |
| | | Zoanthidea | | Zoanthidea | T_638 | Zoanthidea |
| | Hydrozoa | Anthoathecata | Stylasteridae | Stylasteridae | T_506 | Stylasteridae |
| | | | | *Lepidotheca* sp. | T_2358 | Stylasteridae |
| | | | | *Calyptopora* sp. | T_2099 | Stylasteridae |
| | | | | *Errina* sp. | T_702 | Stylasteridae |
| | | Leptothecata | | Hydroids | T_208 | Hydrozoa |
| | | | Aglaopheniidae | *Lytocarpia* sp. | T_2529 | Hydrozoa |
| Echinodermata | Asteroidea | | | Asteroid | T_101 | Asteroidea |
| | | Brisingida | Brisingidae | Brisingid | T_120 | Brisingidae |
| | | | | Brisingid 1 | T_440 | Brisingidae |
| | | | | Brisingid 2 | T_441 | Brisingidae |
| | | | | Brisingid 3 | T_442 | Brisingidae |

| Phylum | Class | Order | Family | Taxon observed | ID_code | Taxon aggregated |
|---|---|---|---|---|---|---|
| | | | | Brisingid 4 | T_495 | Brisingidae |
| | | Forcipulatida | Asteriidae | Asteriidae | T_413 | Asteroidea |
| | | | | *Coronaster* sp. | T_1956 | Asteroidea |
| | | | | *Pseudechinaster rubens* | T_415 | Asteroidea |
| | | | | *Sclerasterias mollis* | T_2355 | Asteroidea |
| | | | Zoroasteridae | *Zoroaster* sp. | T_412 | Asteroidea |
| | | | | Zoroasteridae | T_411 | Asteroidea |
| | | | Zoroasteridae/Asteriidae | Zoroasteridae/Asteriidae | T_410 | Asteroidea |
| | | Notomyotida | Benthopectinidae | *Benthopecten* sp. | T_417 | Asteroidea |
| | | | | Benthopectinidae | T_416 | Asteroidea |
| | | Paxillosida | Astropectinidae | *Astromesites*/*Psilaster*/*Proserpinaster* | T_424 | Asteroidea |
| | | | | Astropectinidae | T_420 | Asteroidea |
| | | | | *Dipsacaster magnificus* | T_422 | Asteroidea |
| | | | | *Dipsacaster* sp. | T_421 | Asteroidea |
| | | | | *Plutonaster*/*Dytaster* | T_423 | Asteroidea |
| | | | Radiasteridae | *Radiaster* sp. | T_426 | Asteroidea |
| | | | | Radiasteridae | T_425 | Asteroidea |
| | | Spinulosida | Echinasteridae | Echinasteridae | T_418 | Asteroidea |
| | | | | *Henricia* sp. | T_419 | Asteroidea |
| | | | Pterasteridae | *Hymenaster* sp. | T_436 | Asteroidea |
| | | | Pterasteridae | Pterasteridae | T_435 | Asteroidea |
| | | | Solasteridae | *Crossaster multispinus* | T_439 | Asteroidea |
| | | | | *Solaster torulatus* | T_438 | Asteroidea |
| | | | | Solasteridae | T_437 | Asteroidea |
| | | Valvatida | Goniasteridae | *Ceramaster* sp. | T_432 | Asteroidea |
| | | | | Goniasteridae | T_427 | Asteroidea |
| | | | | *Hippasteria* sp. | T_428 | Asteroidea |
| | | | | *Lithosoma novazealandiae* | T_434 | Asteroidea |
| | | | | *Lithosoma*/*Pseudarchaster* | T_433 | Asteroidea |

| Phylum | Class | Order | Family | Taxon observed | ID_code | Taxon aggregated |
|---|---|---|---|---|---|---|
| | | | | *Mediaster* sp. | T_429 | Asteroidea |
| | | | | *Pillsburiaster* sp. | T_431 | Asteroidea |
| | | | | Plinthaster/Ceramaster | T_430 | Asteroidea |
| | Crinoidea | | | Crinoid | T_105 | Crinoidea (motile) |
| | | Bourgueticrinida | | Crinoidea (stalked) | T_711 | Crinoidea (stalked) |
| | | Comatulida | | Crinoidea (motile) | T_507 | Crinoidea (motile) |
| | Echinoidea | Cidaroida | | Cidaroida | T_453 | Cidaroidea |
| | | | Cidaridae | Cidaridae | T_454 | Cidaroidea |
| | | | | *Goniocidaris parasol* | T_2356 | Cidaroidea |
| | | | | *Goniocidaris* sp. | T_455 | Cidaroidea |
| | | | | *Ogmocidaris benhami* | T_456 | Cidaroidea |
| | | | Histocidaridae | Histocidaridae | T_457 | Cidaroidea |
| | | Echinoida | | Echinoid | T_103 | Euechinoidea |
| | | | Echinidae | *Dermechinus horridus* | T_464 | *Dermechinus horridus* |
| | | | | Echinidae | T_462 | Euechinoidea |
| | | | | *Gracilechinus multidentatus* | T_463 | Euechinoidea |
| | | | | Echinoida | T_459 | Euechinoidea |
| | | Echinothurioida | Echinothuriidae | *Phormosoma bursarium* | T_461 | Echinothurioida |
| | | | Echinothuriidae/Phormosomatidae | Echinothuriidae/Phormosomatidae | T_460 | Echinothurioida |
| | | Pedinoida | Pedinidae | Pedinidae | T_465 | Euechinoidea |
| | | | Pedinidae | *Caenopedina* sp. | T_466 | Euechinoidea |
| | | Spatangoida | Spatangidae | *Paramaretia peloria* | T_470 | Spatangoida |
| | | | | Spatangidae | T_469 | Spatangoida |
| | | | | *Spatangus* sp. | T_471 | Spatangoida |
| | | Temnopleuroida | Temnopleuridae | *Pseudechinus flemingi* | T_468 | Euechinoidea |
| | | | | Temnopleuridae | T_467 | Euechinoidea |
| | Holothuroidea | Aspidochirotida | | Holothurian | T_104 | Holothuroidea |
| | | | | holothurian uni 1 | T_491 | Holothuroidea |
| | | | | holothurian uni 2 | T_492 | Holothuroidea |

| Phylum | Class | Order | Family | Taxon observed | ID_code | Taxon aggregated |
|---|---|---|---|---|---|---|
| | | | | holothurian uni 3 | T_493 | Holothuroidea |
| | | | | holothurian uni 4 | T_494 | Holothuroidea |
| | | | Stichopodidae | *Australostichopus mollis* | T_486 | Holothuroidea |
| | | | | Stichopodidae | T_485 | Holothuroidea |
| | | | Synallactidae | *Bathyplotes* | T_2337 | Holothuroidea |
| | | | | *Pseudostichopus mollis* | T_476 | Holothuroidea |
| | | | | *Pseudostichopus peripatus* | T_477 | Holothuroidea |
| | | | | *Pseudostichopus* sp. | T_475 | Holothuroidea |
| | | | | Synallactidae | T_472 | Holothuroidea |
| | | | | *Bathyplotes moseleyi* | T_473 | Holothuroidea |
| | | | | *Bathyplotes sulcatus* | T_474 | Holothuroidea |
| | | | | *Benthodytes incerta* | T_484 | Holothuroidea |
| | | Dendrochirotida | Psolidae | Psolidae | T_2338 | Psolidae |
| | | Elasipodida | | Elasipoda | T_489 | Holothuroidea |
| | | | Deimatidae | Deimatidae | T_481 | Holothuroidea |
| | | | Elpidiidae | *Scotoplanes* sp. | T_578 | Holothuroidea |
| | | | Laetmogonidae | *Laetmogone* sp. | T_479 | Holothuroidea |
| | | | | Laetmogonidae | T_478 | Holothuroidea |
| | | | | *Pannychia* sp. | T_480 | Holothuroidea |
| | | | Pelagothuridae | Pelagothuridae | T_487 | Holothuroidea |
| | | | Pelagothuriidae | *Enypniastes eximia* | T_488 | Enypniastes eximia |
| | | | Psychropotidae | *Benthodytes incerta* | T_484 | Holothuroidea |
| | | | | Psychropotidae | T_483 | Holothuroidea |
| | Ophiuroidea | | | Ophiuroid | T_102 | Ophiuroidea |
| | | Euryalida | | Euryalida | T_449 | Ophiuroidea |
| | | | Gorgonocephalidae | *Astrothorax waitei* | T_2531 | Gorgonocephalidae |
| | | | | Gorgonocephalidae | T_450 | Gorgonocephalidae |
| | | Ophiacanthida | Ophiodermatidae | *Bathypectinura heros* | T_2430 | Ophiuroidea |
| | | Ophiurida | Ophiacanthidae | Ophiacanthidae | T_444 | Ophiuroidea |

| Phylum | Class | Order | Family | Taxon observed | ID_code | Taxon aggregated |
|---|---|---|---|---|---|---|
| | | | Ophiomyxidae | *Ophiomyxa brevirima* | T_446 | Ophiuroidea |
| | | | Ophiuridae | *Ophiomusium lymani* | T_443 | Ophiuroidea |
| | | | | Ophiurida unspecified | T_447 | Ophiuroidea |
| | | | | Unknown ophiurida 1 | T_448 | Ophiuroidea |
| Echiura | | | | Echiura | T_217 | Echiura |
| Foraminifera | | | Xenophyophoroidea (superfamily) | Foram (giant) | T_218 | Xenophyophoroidea |
| Hemichordata | Enteropneusta | | | Hemichordate | T_129 | Hemichordata |
| Mollusca | Bivalvia | | | Molluscs (bivalves) | T_209 | Bivalvia |
| | | Ostreoida | Pectinidae | Pectinidae | T_1110 | Bivalvia |
| | | Pteriomorpha | Limidae | *Acesta maui* | T_2325 | Bivalvia |
| | Cephalopoda | Octopoda | | Mollusc (octopod) | T_127 | Octopoda |
| | | | Cirroteuthididae/Luteuthididae | Cirroteuthidae/Luteuthididae | T_570 | Octopoda |
| | | | Enteroctopodidae | *Enteroctopus zealandicus* (yellow) | T_562 | Octopoda |
| | | | Octopodidae | *Benthoctopus* sp. | T_565 | Octopoda |
| | | | | *Graneledone* sp. | T_567 | Octopoda |
| | | | | Octopodidae | T_561 | Octopoda |
| | | | Opisthoteuthidae | *Opisthoteuthis* sp. | T_569 | Octopoda |
| | | Sepiida | | Sepioloidea | T_1284 | Squid |
| | | Teuthida | | Squid | T_408 | Squid |
| | | | | Mollusc (vampire squid) | T_128 | Squid |
| | Gastropoda | | | Mollusc (gastropod) | T_113 | Gastropoda |
| | | Archaeogastropoda | Calliostomatidae | *Calliostoma alertae* | T_557 | Gastropoda |
| | | | | *Calliostoma* sp. | T_2326 | Gastropoda |
| | | | | Callostomatidae | T_556 | Gastropoda |
| | | Littorinimorpha | Ranellidae | *Fusitriton magellanicus* | T_550 | Buccinidae |

| Phylum | Class | Order | Family | Taxon observed | ID_code | Taxon aggregated |
|---|---|---|---|---|---|---|
| | | Neogastropoda | Buccinidae | *Aeneator recens* | T_548 | Buccinidae |
| | | | | *Austrofusus glans* | T_546 | Buccinidae |
| | | | | Buccinidae | T_545 | Buccinidae |
| | | | | *Penion* sp. | T_547 | Buccinidae |
| | | | Muricidae | Muricidae | T_551 | Gastropoda |
| | | | Olividae | Olividae | T_553 | Gastropoda |
| | | | Turbinellidae | *Coluzea* sp. | T_559 | Gastropoda |
| | | | | Turbinellidae | T_558 | Gastropoda |
| | | | Turridae | Turridae | T_543 | Gastropoda |
| | | | Volutidae | Volutidae | T_540 | Volutidae |
| | | | Volutomitridae | *Volutomitira banksi* | T_542 | Volutidae |
| | | | | Volutomitridae | T_541 | Volutidae |
| | | Neotaenioglossa | Cassidae | Cassidae | T_560 | Gastropoda |
| | | | Ranellidae | *Fusitriton magellanicus* | T_550 | Buccinidae |
| | | | | Ranellidae | T_549 | Gastropoda |
| | | Nudibranchia | | Mollusc (nudibranch) | T_2012 | Nudibranchia |
| | | | | Mollusc (opisthobranch) | T_115 | Nudibranchia |
| | | | Dorididae | Dorididae | T_1271 | Nudibranchia |
| | | Trochida | Turbinidae | Turbinidae | T_1260 | Gastropoda |
| | Scaphopoda | | | Scaphopoda | T_121 | Scaphopoda |
| Nemertea | Anopla | | | Nemertean | T_116 | Worm indet. |
| Porifera | Calcarea | | | Calcarea | T_1118 | Calcarea |
| | | Leucosolenida | Leucosoleniidae | Leucosolenia | T_1119 | Calcarea |
| | Demospongiae | | | Encrusting sponges | T_660 | Demospongiae |
| | | | | Sponge (demospongiae) | T_204 | Demospongiae |
| | | Astrophorida | | Astrophorid | T_645 | Demospongiae |
| | | | Ancorinidae | *Tethyopsis* n. sp. | T_648 | Demospongiae |

| Phylum | Class | Order | Family | Taxon observed | ID_code | Taxon aggregated |
|---|---|---|---|---|---|---|
| | | | Geodiidae | *Geodia regina* | T_646 | Demospongiae |
| | | | | *Geodia* sp. | T_2088 | Demospongiae |
| | | | Pachastrellidae | Pachastrellidae | T_650 | Demospongiae |
| | | | | *Thenea novaezelandiae* | T_649 | Demospongiae |
| | | | | *Poecillastra laminaris* | T_2072 | Demospongiae |
| | | Hadromerida | | Hadromerid | T_651 | Demospongiae |
| | | | Suberitidae | *Suberites affinis* | T_652 | Demospongiae |
| | | Halichondrida | | Halichondrid | T_653 | Demospongiae |
| | | | Axinellidae | *Axinella* sp. | T_654 | Demospongiae |
| | | Haplosclerida | | Haplosclerid | T_658 | Demospongiae |
| | | | Callyspongiidae | *Callyspongia* sp. | T_1176 | Demospongiae |
| | | | | Callyspongiidae | T_1175 | Demospongiae |
| | | | Petrosiidae | *Petrosia* | T_659 | Demospongiae |
| | | Lithistida | | Lithistid | T_639 | Demospongiae |
| | | | Corallistidae | *Awhiowhio sepulchrum* | T_642 | Demospongiae |
| | | | Isoraphiniidae | *Costifer wilsoni* | T_641 | Demospongiae |
| | | | Phymatellidae | *Neoaulaxinia persicum* | T_640 | Demospongiae |
| | | Poecilosclerida | | Poecilosclerid | T_643 | Demospongiae |
| | | | Cladorhizidae | Cladorhizidae | T_1188 | Cladorhizidae |
| | | | Coelosphaeridae | *Coelosphaera globosa* | T_2361 | Demospongiae |
| | | | | Coelosphaeridae | T_1229 | Demospongiae |
| | | | | *Lissodendoryx* (*Ectyodoryx*) | T_2104 | Demospongiae |
| | | | Desmacididae | *Desmacidon mammilatum* | T_2362 | Demospongiae |
| | | | Esperiopsidae | *Esperiopsis* cf. *inodes* | T_2070 | Demospongiae |
| | | | Hymedesmiidae | *Hymedesmia* (*Stylopus*) n. sp. 1 | T_2538 | Demospongiae |
| | | | | *Phorbas aerolata* | T_1192 | Demospongiae |
| | | | Latrunculiidae | *Latrunculia* sp. | T_644 | Demospongiae |
| | | Polymastiida | Polymastiidae | *Tentorium papillatum* | T_2535 | Demospongiae |
| | | Spirophorida | Tetillidae | *Tetilla leptoderma* | T_657 | Demospongiae |

| Phylum | Class | Order | Family | Taxon observed | ID_code | Taxon aggregated |
|---|---|---|---|---|---|---|
| | | Suberitida | Suberitidae | *Suberites* sp. | T_1200 | Demospongiae |
| | | Tetractinellida | Ancorinidae | *Ecionemia novaezealandiae* | T_2363 | Demospongiae |
| | | | | *Stelletta* sp. | T_1164 | Demospongiae |
| | | | Geodiidae | *Geodia vestigifera* | T_1161 | Demospongiae |
| | | | Vulcanellidae | *Poecillastra* sp. | T_1067 | Demospongiae |
| | | | | *Xestospongia*/*Poecillastra* | T_2364 | Demospongiae |
| | Hexactinellida | | | Sponge (hexactinellidae) | T_205 | Hexactinellida |
| | | Amphidiscosida | Hyalonematidae | *Hyalonema* (*Cyliconema*) sp | T_1116 | Hexactinellida |
| | | | Pheronematidae | *Sericolphus* sp. | T_2075 | Hexactinellida |
| | | | Pheronematidae | *Pheronema* sp. | T_1117 | Hexactinellida |
| | | Hexactinosida | Farreidae | *Farrea* sp. | T_2324 | Hexactinellida |
| | | | | Hexactinosida | T_131 | Hexactinellida |
| | | Lyssacinosida | Euplectellidae | *Euplectella regalis* | T_662 | Hexactinellida |
| | | | | Euplectellidae | T_2100 | Hexactinellida |
| | | | | *Regadrella* sp. | T_2079 | Hexactinellida |
| | | | Rossellidae | *Crateromorpha* | T_2244 | Hexactinellida |
| | | | | *Hyalascus* n. sp. | T_661 | *Hyalascus* n. sp. |
| | | | | *Hyalascus* sp. | T_2037 | Hexactinellida |
| | | | | *Rossella* sp. | T_2083 | Hexactinellida |
| | | | | *Symplectella* sp. | T_2086 | Hexactinellida |
| | | Sceptrulophora | Aphrocallistidae | *Aphrocallistes beatrix beatrix* | T_2098 | Hexactinellida |
| | | | Euretidae | *Chonelasma* | T_2085 | Hexactinellida |
| | | | | *Chonelasma lamella* | T_2360 | Hexactinellida |
| | | | Rossellidae | *Rossellidae Acanthascus* (*Rhabdocalyptus*) sp. 1 | T_2434 | Hexactinellida |
| Indet | | | | Worm (indeterminate) | T_118 | Worm indet. |