Marine Biodiversity Hub

National **Environmental Science** Programme

Post survey report for the Coral Sea Australian Marine Park

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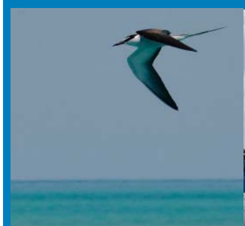
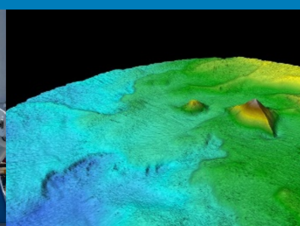
PROJECT D4 – EXPANDING OUR SPATIAL KNOWLEDGE OF MARINE BIODIVERSITY TO SUPPORT FUTURE BEST-PRACTICE REVIEWS

April 2020

Milestone 12 –Post-survey report for the Coral Sea AMP (IN2019_V04) 2019



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Project Leader's Distribution List

Parks Australia	
Department of Agriculture, Water and the Environment – Biodiversity Conservation Division – Biodiversity Policy Section	
Department of Agriculture, Water and the Environment – Heritage, Marine and Reef Division	

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Important Disclaimer

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EXECUTIVE SUMMARY

This post survey report details the data collected within the Coral Sea Australian Marine Park onboard the RV Investigator (IN2019_V04) between the 7th of August and the 3rd of September 2019 associated with the primary voyage *Hotspot dynamics in the Coral Sea-connections between the Australian plate and deep Earth'* (Whittaker 2020). The data and preliminary results in this report pertain to ongoing research to examine spatial patterns in deep-water seafloor biodiversity, in particular, how organisms are related to geomorphic features within the Coral Sea Australian Marine Park (AMP). The seafloor biodiversity and associated geomorphic habitats in this AMP are poorly understood, and given the recent release of the AMP rezoning, it is particularly important to understand the spatial variability of seafloor biodiversity and associated habitats to better quantify the biological assets within the AMP.

Voyage IN2019_V04 has contributed an additional 29,000 kms^2 of seafloor survey data to this knowledge base. This new bathymetric data has been assimilated into the 2010 bathymetric grid (Beaman 2010) to create a new 100 m grid resolution bathymetric data product. Ongoing research with this survey data will provide new insights into the detailed geomorphic shape and spatial relationships between adjacent seabed features. This information will be released in future publications to show the potential of how the scale of such seafloor data can be used for predictive habitat modelling when analysed with the biological data overlays.

The new biological data overlays will be created from the 94 specimens recorded from 30 rock dredges sampled within the Coral Sea Australian Marine Park. Biota that was collected in the sediment bins on the rock dredge, or biota that was maintained in the rock dredge was collected, recorded and preserved. This report provides an overview of these samples and classifies each into specimen groups based on the Ocean Biogeographic Information System (OBIS 2019). Specimens have been deposited in the Queensland Museum and over the next few years will be examined by experts across the various taxonomic fields.

Future research outcomes and interpretations of the survey data reported here will greatly improve our knowledge of the environmental assets within the Coral Sea Australian Marine Park, an area that is identified by Parks Australia as a priority for environmental asset inventories, baseline environmental data and monitoring.

1. INTRODUCTION

This report details the supplementary voyage application *'Understanding the spatial links between geomorphology and biodiversity in the Coral Sea Australian Marine Park'* which was approved to align with the primary RV Investigator Voyage- *'Hotspot dynamics in the Coral Sea- connections between the Australian plate and deep Earth'* IN2019_V04 (Whittaker 2020). The twenty-seven-day voyage left Cairns on the 7th of August 2019 and returned to Brisbane on the 3rd of September 2019 and collected an estimated 29,000 km^2 of new seafloor data within the Coral Sea Australian Marine Park. Figure 1 shows the route of the RV Investigator through the Coral Sea Marine Park.

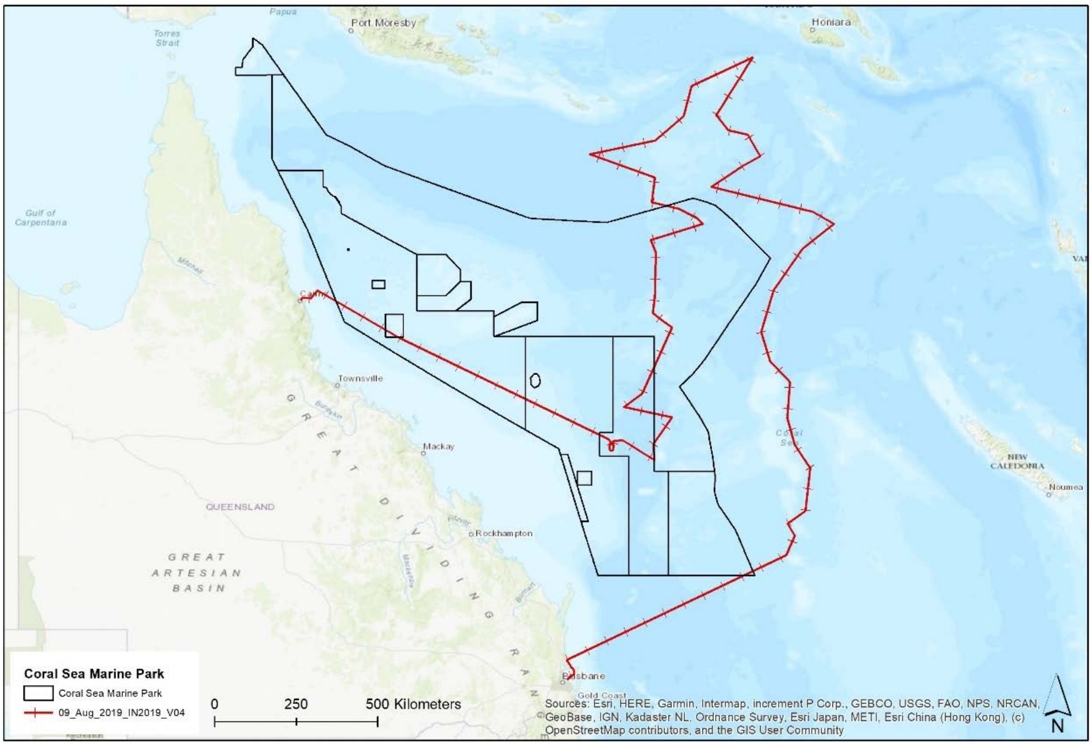


Figure 1 IN2019_V04 survey track through the Coral Sea Australian Marine Park.

This report provides an overview of the data that was collected for the supplementary project only within the Coral Sea Australian Marine Park. The supplementary project had three research aims, all of which are relevant to national research that is being conducted by the University of Tasmania and Geoscience Australia through the National Environmental Science Program (NESP) Marine Biodiversity Hub (MBH). The newly acquired data from this voyage is critical for improving our understanding of ecological processes ranging from habitat/assemblage vulnerability to climate change; assessing rarity; and to provide a baseline of information for future Coral Sea Australian Marine Park (CSAMP) monitoring and management reviews. The research outcomes of this supplementary proposal will seek to make major improvements in our understanding of the links between geomorphic features (over a range of depths) and associated marine biodiversity. Data was collected across five of the six zones within the marine park (with the exception of the General Use Zone), which provides a diversity of outcomes for the different management regimes of the park's management.

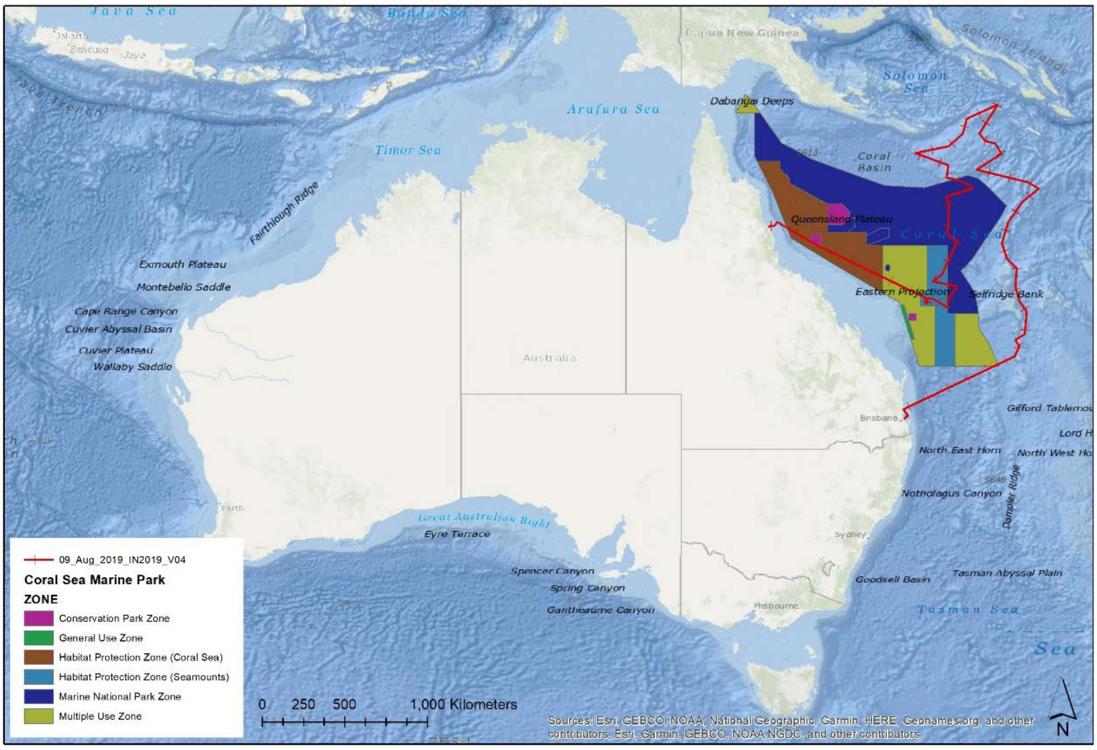


Figure 2 Management zones of the Coral Sea Australian Marine Park in relation to IN2019_V04 survey track.

The key objectives of the supplementary voyage application were to:

1. Increase the knowledge of seafloor habitat features and associated biodiversity within the Coral Sea AMP from seeking advantage in a primary voyage traversing the marine park.

2. Understand the drivers of the spatial distribution of seafloor biodiversity in relation to fine-scale geomorphological variation. For example, are large branching corals associated with a geomorphic feature, or some combination of these features?

3. Develop novel automated processing methods capable of generating geomorphological classifications to standardize procedures applicable to the multibeam data collected using the Marine National Facility.

Objective 1: Knowledge about the biodiversity in the Coral Sea Marine Park is limited, despite it being one of the largest and environmentally important marine parks in the world. This voyage (IN2019_V04) is just the second major survey of biodiversity in the area. The first major expedition was the CIDARIS project, conducted by the Queensland Museum from 1986 to 1992. Specimens collected from CIDARIS led to a greater understanding of biodiversity in the region, including descriptions of new species, an estimation of the number of species that live in the area, and updates regarding species' geographic and bathymetric ranges (Baba 1994, Crowther 2011, Ahyong 2012). The CSAMP contains seamounts that provide a range of depths for diverse seafloor biodiversity such as endemic species, including large erect corals and sponges. Some organisms are hundreds and possibly thousands of years old, hence some of the longest-lived life forms on Earth. The CSAMP is situated in a key location with respect to unique seamounts within an Australian tropical context. This will allow us to compare this work with research by IN2017_V03 and other studies on temperate seamount locations such as the Huon AMP which was mapped by IN2018_V06: *Status and recovery of deep-sea coral communities on seamounts in iconic Australian marine reserves.* Section 2 of this report identifies the preliminary information on the biodiversity collected during IN2019_V04. Remarks for each specimen group are based on the Ocean Biogeographic Information System (OBIS 2019) and per communication with experts. All specimens from IN2019_V04 have been deposited in the Queensland Museum and over the next few years will be examined by experts across the various taxonomic fields.

Objective 2: Prior to this voyage there was a paucity of fine-scale data within the CSAMP, with only 2% of the AMP in areas shallower than 200 m mapped (Lucieer 2016). Beaman (2010) collated all national bathymetric data within the region of the Coral Sea to create a full spatial coverage grid at a resolution of 100 m. This grid was employed to produce the first geomorphic features map of the GBR shelf and Coral Sea region. The 2010 grid utilised all known bathymetric data, and this highlighted that in some regions there was little to no *direct* survey data. Voyage IN2019_V04 has added an additional 29,000 kms^2 (calculation based on average of an 8 km swath width) of seafloor survey data to this knowledge base. 30% of the voyage time was spent within the CMPA, and this data was assimilated into the 2010 bathymetric grid by Rob Beaman during the IN2019_V04 voyage to create a new 100 m grid resolution bathymetric data product. Section 3 of this report will illustrate how this survey will provide new insights into the detailed geomorphic shape and spatial relationships between adjacent seabed features. This data will be used in future publications to show the potential of how the scale of such data can be used for predictive habitat modelling, when analysed with the biological data overlays.

Objective 3: Multibeam bathymetry from the survey has been classified employing Geoscience Australia's geomorphic classification scheme. New methods for extracting geomorphological classes have been developed from this survey data and Lucieer and Beaman are currently preparing these results for scientific publication. Future research will analyse the backscatter data to characterise the sediment surfaces and fine scale rugosities coincident with these geomorphic classes. Geomorphological surrogates of the seabed such as rugosity, slope, aspect and backscatter (hardness and roughness) outputs for the key sites will be made available on the Seamap Australia website (https://seamapaustralia.org/) .

These three key objectives will deliver important information to the Government, Academia and the General Public and Education sector.

Government

The new marine environmental knowledge generated by this survey will be important to marine park managers to enabling them to better address their sustainable management objectives. In developing the supplementary research proposal, we worked closely with the Commonwealth Government's Department of Environment and Energy (since changed to the

Department of Agriculture, Water and the Environment), Parks Australia Division which will be the primary end-users of the research outputs. A meeting was held on the 18th of April 2018 and this research proposal was discussed and received unanimous support from the Departments Regional Marine Park managers. Our additional aim to assess the Standard Operating Procedures of the Marine Biodiversity Hub, with respect to reanalysing the survey data of the IN2019_V04 voyage to effectively answer relevant questions from commonly collected data sources, and address end-user data and information needs, was also supported at this meeting.

At the more general level, new information on the major environmental features in the Coral Sea AMP and its key ecological features (coral reefs and seamounts) and biologically important areas (reef habitats; seamount flanks) will assist in better understanding these reef and seamount ecosystems. The park managers have also highlighted the need for general-public communication products that showcase the environmental assets in the park. We will continue our dialogue with the park managers and endeavour to address the priorities for these communication outputs.

This post survey report presents the preliminary results of the geomorphology maps of the seabed of the CSAMP with a focus on seven key seamounts: 1) Calder- Fredrick seamount, 2) Kenn Seamount, 3) Sula Seamount, 4) Cassowary Seamount, 5) Mellish Seamount, 6) Fregetta Seamount and 7) Lexington Seamount. The data underpinning these maps has been registered through the Marine National Facility and made available to the AusSeabed database. The final geomorphological maps will be made available to the Seamap Australia database for open public dissemination.

It was initially intended to deploy a 'deep towed camera system' during the voyage at key sites to inspect the seafloor for characterising habitats types and key species. Due to the logistical constraints for seafloor dredging, the two methodologies were not assessed as mutually viable on the one voyage due to space on deck and also sampling time available (deep water video deployments in depths of 3-4000 m require up to 8 hours), and preference was given to the rock dredge activities as these were the methods required for the primary voyage project. Biota that was collected in the sediment bins on the rock dredge, or biota that was maintained in the rock dredge was collected, recorded and preserved. Section 2 of this report provides details on the samples that were collected.

On this voyage we employed the national Standard Operation Procedures (SOPs) for marine surveys (NESP Marine Biodiversity Hub- Project D2, https://www.nespmarine.edu.au). Following these SOPs, we have created a dataset from which pilot seafloor habitat baseline sites can be selected, that the government could use as baselines sites to be monitored to evaluate change.

This project has produced new evidence of geomorphological features at finer resolutions (30 m) than currently available (100 m) for the CSAMP, with associated seafloor habitats and biodiversity attributes. This outcome will help us understand if high resolution data is indeed important for constraining the models of seafloor biodiversity across management zones within the CSAMP.

Academia

The processing methodologies for developing a multiscale geomorphic features analysis will be of interest to the international academic seafloor mapping community. One of the key endeavours of the community is to understand nested scales of seafloor features and how these represent habitats at multiple scales. The results from this voyage will contribute to the ongoing research of Lucieer (UTAS) and Nichol (Geoscience Australia) to develop a nationally consistent seafloor geomorphic classification scheme.

The sediment catcher on the side of the dredge was used to collect sediment samples. These data will be processed and provide an opportunity for examination for micro plastics in the deep sea. These data will also provide us with sediment grain size distribution data and can be used to constrain the habitat classification models. Biota present in the dredge samples have been processed by James Cook University PhD candidate, Jeremey Horowitz. These samples were identified and preserved according to the Marine Sampling Field Manual for Sleds and Trawls. Specimens have been lodged at the Queensland Museum (See section 2).

The data will also be used to create optimized workflows to integrate high resolution acoustics from a variety of platforms and sensors; automate techniques to extract relevant data at appropriate scales for mapping, planning, conservation, and scientific analysis; and compare accuracy and error to determine resolution/scale at which different geomorphic classes can be processed. These outcomes will allow us to assess how we might develop automated processing protocols for MNF data to extract geomorphic classifications for deep water AMPs. Newly developed mapping products of physical seafloor morphologies (e.g. seamount morphology; reef structures) and associated biodiversity information (e.g. images of the species samples) can be readily employed in park management and promotion of the CSAMP. All these products will be open-access via Seamap Australia http://seamapaustralia.org/ and the AODN websites.

General public and education sector

During the voyage we engaged with the onboard Australian Science Teachers Association (ASTA) representatives and prepared several outreach activities that highlighted the research on seafloor habitats and associated seafloor flora and fauna pertinent to the Hub. These included profiling research science careers, participating in 'live cross-overs' to children in classrooms in Australia, the USA and the UK. We engaged in the 'Science in Schools' program through asking over 1000 children to colour in polystyrene cups in an 'Art Under Pressure' experiment to teach children about the ocean depth and pressure-demonstrating how the cups shrink when sent to 1000 m water depth (Figure 3).

Table 1 Media and community engagement on Coral Sea Voyage

Public research outcomes	Weblink
Promotion of 'Women in Science Careers'	https://research.csiro.au/educator-on-board/researcher-profile-dr-vanessa-lucieer/
MNF Educator on Board Program	https://mnf.csiro.au/en/Voyages/IN2019_V04
MNF Coral Sea Blog	https://blog.csiro.au/rv-investigators-coral-sea-voyage/
IMAS media release of Coral Sea Voyage	https://www.imas.utas.edu.au/news/news-items/coral-sea-voyage-uncovers-volcanic-secrets-of-the-seafloor

Figure 3 Example of various outreach activities for the general public and education sector

2. BENTHIC BIODIVERSITY

2.1 Introduction

The first major expedition was the CIDARIS project, conducted by the Queensland Museum from 1986 to 1992. The coverage of CIDARIS was constrained to the western Coral Sea on soft, sand, and mud habitats at an average of ~1,000 m depth (shown by green circles in Figure 4). IN2019_V04 provided new information about biodiversity by sampling biology around the Eastern Coral Sea on hard seamount habitats at an average of ~2,000 m depth (shown by red circles in Figure 4 and labelled by dredge number in Figure 5). From the 30 rock dredges collected in the Coral Sea Marine Park, 94 specimens were recorded. Section 2.3 illustrates the location of these dredge sites (Figure 6) and the specimens that were recorded at each dredge site. The remarks for each specimen group are based on the Ocean Biogeographic Information System (OBIS 2019) and per communication with experts. Specimens have been deposited in the Queensland Museum and over the next few years, will be examined by experts across the various taxonomic fields.

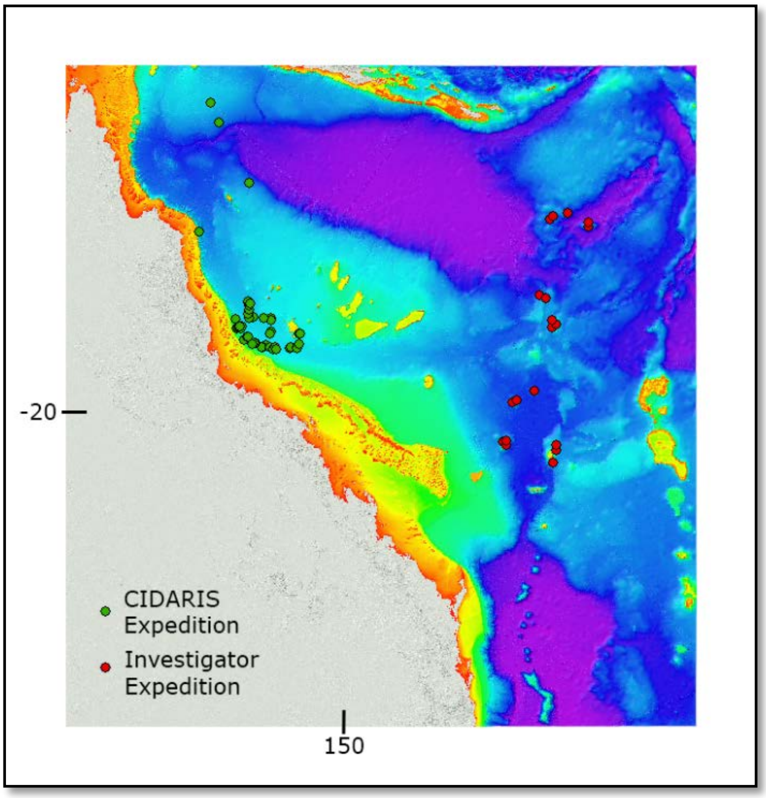


Figure 4 Map of Coral Sea showing dredge sites of the CIDARIS Expedition (green circles) and Investigator Expedition IN2019_V04 (red circles).

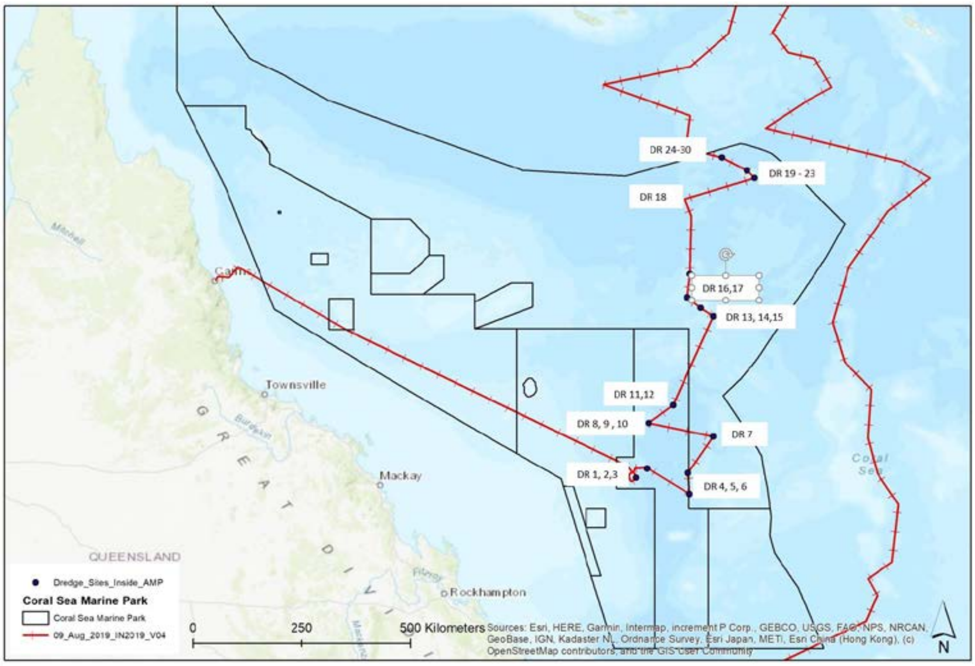


Figure 6 Map showing location of numbered dredge sites within the Coral Sea AMP from IN2019_V04

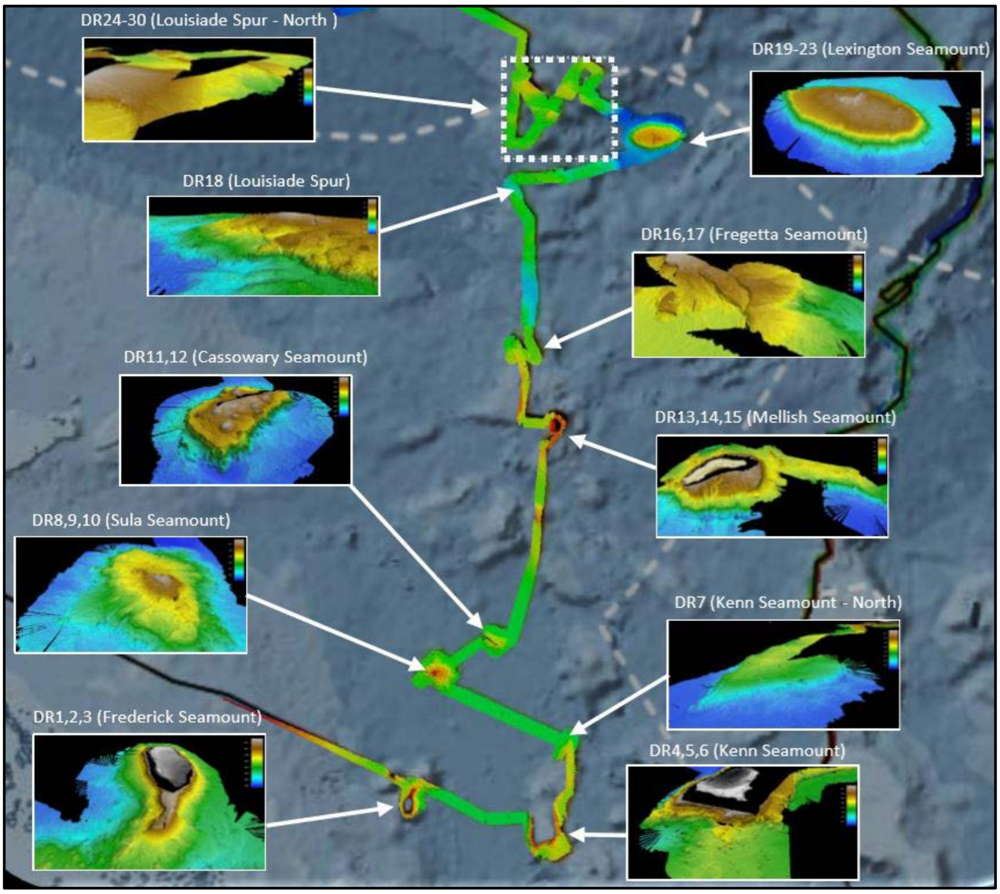


Figure 5 Dredge locations shown with inset of 3D seafloor imagery in relation to transit path through the Coral Sea AMP

2.2 Methods

Biological samples were collected as a bi-product of the geological rock dredge sampling regime. Samples were either collected from the sediment traps on the side of the dredge or were intermixed with the rock samples in the net of the dredge. Figure 7 illustrates the size of the rock dredge. After the rock samples were deposited on the back deck following recovery of the dredge, the biological samples were carefully identified, collected and taken to the wet lab for photographing and preserving.

Figure 7 Example photo of rock dredge being unloaded following a deployment

For each individual dredge target the bridge crew were provided with three points defined in longitude and latitude. The first point is the ‘dredge deployment’ site, which was placed at the position where the dredge should be released. The second point defines the ‘dredge on bottom’ target point at the base of the slope to be dredged up. The third point was the ‘dredge recovery’ point, positioned at, or slightly beyond, the top of the slope to be dredged (Figure 8).

The distance between these points depended on the dredge site - the ‘dredge deployment’ point was designed to lie a distance from the ‘dredge on bottom’ point corresponding to roughly 80% of the water depth at the target point, such that the amount of cable out when the ship was directly over the ‘dredge on bottom’ point would be roughly equal to the water depth (assuming a pay-out rate of 60 m/minute and ship speed of 1-2 knots). The ship would continue to the ‘dredge recovery’ point with cable still being paid out, before slowing to a stop as the recovery point was reached and the maximum cable out was achieved roughly simultaneously. Then, the dredging itself would begin with the ship stationary or creeping forwards, and the winch hauling at 15 m/minute.

The amount of cable deployed relative to the water depth of the target was the subject of some experimentation between different dredges. Experience has shown that values between 110% and 150% of water depth have been successful. On this voyage, the value chosen varied between 110% and 130%. A smaller value allows for more precise targeting of specific parts of a slope and may reduce the degree to which cable is dragged across (and thus potentially damaged by) rough seafloor. On the other hand, smaller values increase the likelihood of missing the seafloor entirely, which occurred on two occasions.

At least one geoscientist remained on the bridge during dredging, working closely with the bridge crew member on watch to determine the stages of dredge deployment and recovery.

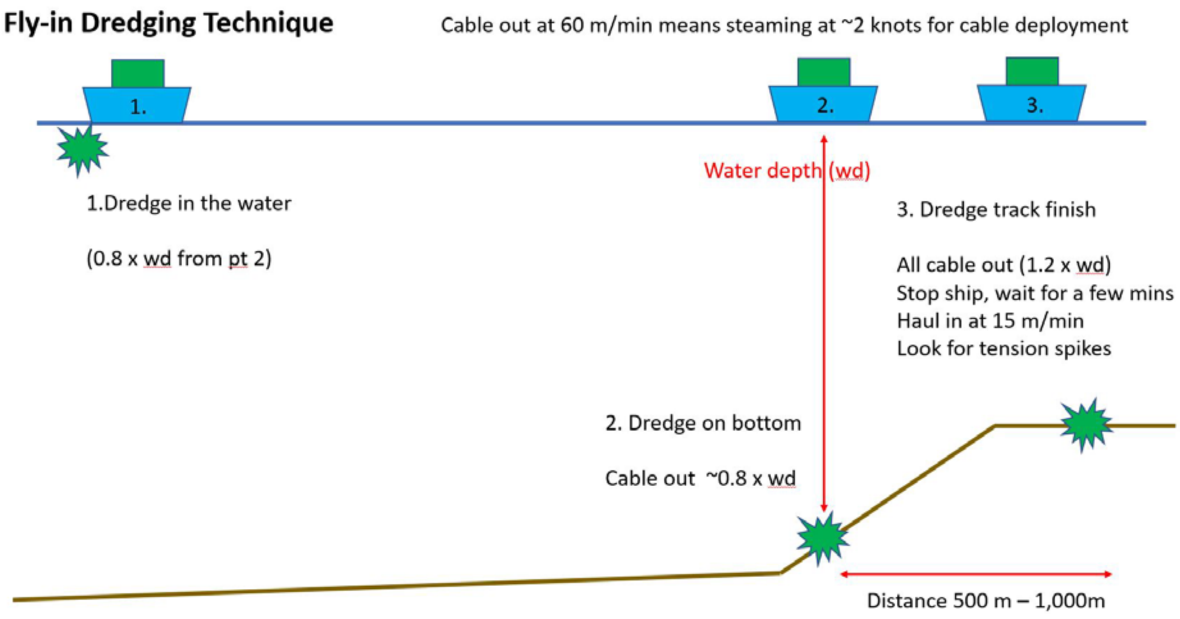


Figure 8 Explanatory figure of rock dredge deployment

The outcome of the dredges was highly variable, with one extreme being deployments where the dredge became stuck on the bottom on multiple occasions before being recovered, while on several other occasions few or no spikes were observed. In some cases where few or no tension spikes were observed in the initial drag, the dredge was redeployed by paying out additional cable and moving the ship up-slope (so-called 'teabagging'). For cases where the dredge became anchored to the seafloor, two approaches were used: either the ship was allowed to drift backwards towards the stuck dredge while still hauling in cable, with the hope that the angle of the cable at the seafloor would become steeper and more likely to become unstuck; and an approach where a relatively small amount (15-60 m) of cable was paid out, in the hope that the dredge would become unstuck as the tension on the cable was released.

Dredging was, with only a few exceptions, undertaken using the 'fly-in' technique, where the ship slowly moves towards the dredge site while the dredge is being deployed. In a few cases the 'stop-and-drop' technique was attempted, though this method gives less flexibility for the bridge crew to compensate for strong currents and lead to one dredge being quickly aborted.

2.3 Results

Thirty dredges were successfully conducted in the Coral Sea Australian Marine Park. Figures 9 to 20 illustrate the locations of these dredges in relation to the seafloor morphology. Table 2 details the depth, date of the sample and the latitude and longitude of the location that the dredge first hit the seafloor.

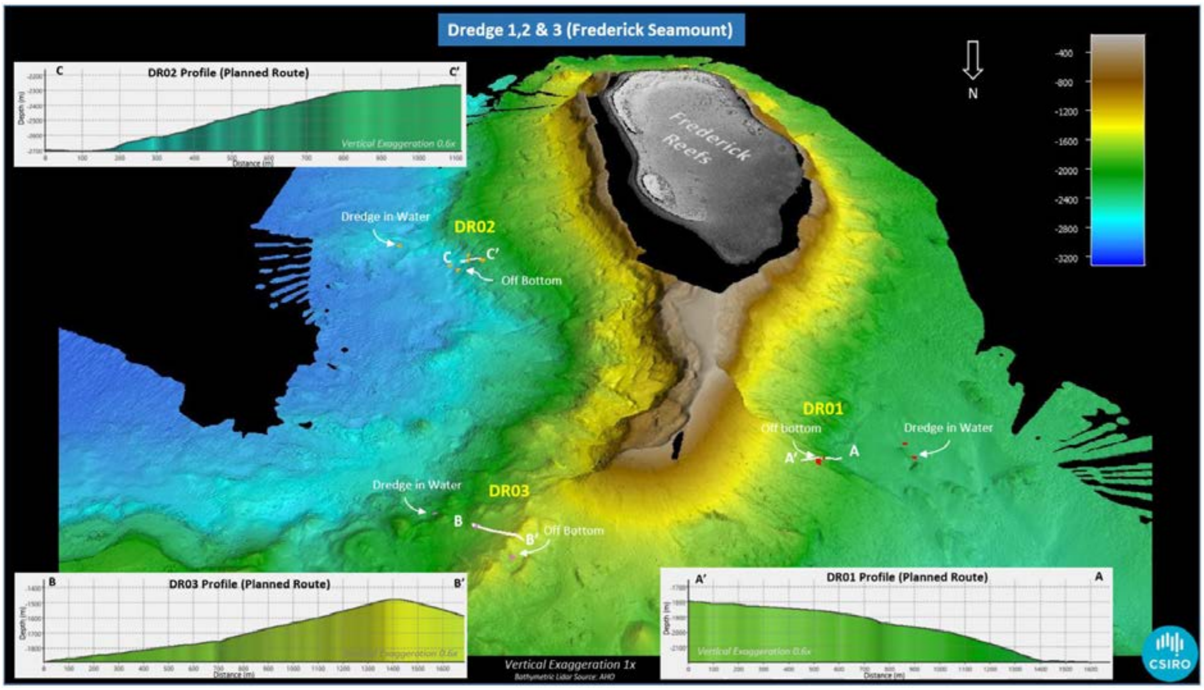


Figure 9 3D seafloor image showing locations of dredges 1, 2 and 3 on Frederick-Calder Seamount

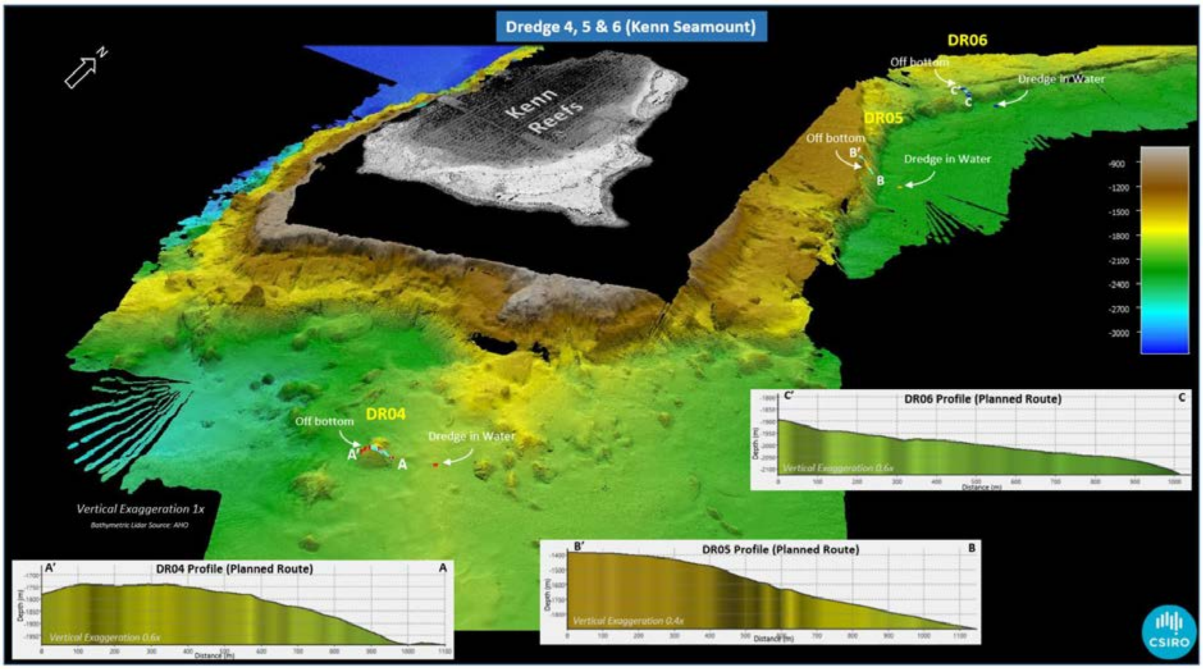


Figure 10 3D seafloor image showing locations of dredges 4, 5 and 6 on Kenn Seamount

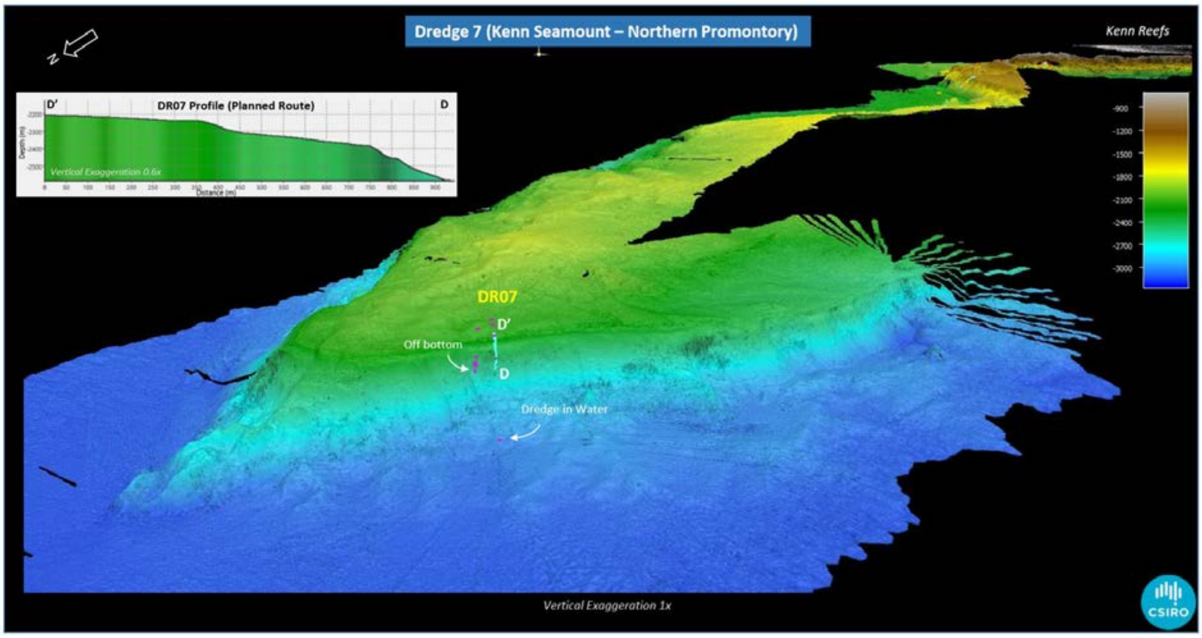


Figure 11 3D seafloor image showing locations of dredge 7 on Kenn Seamount

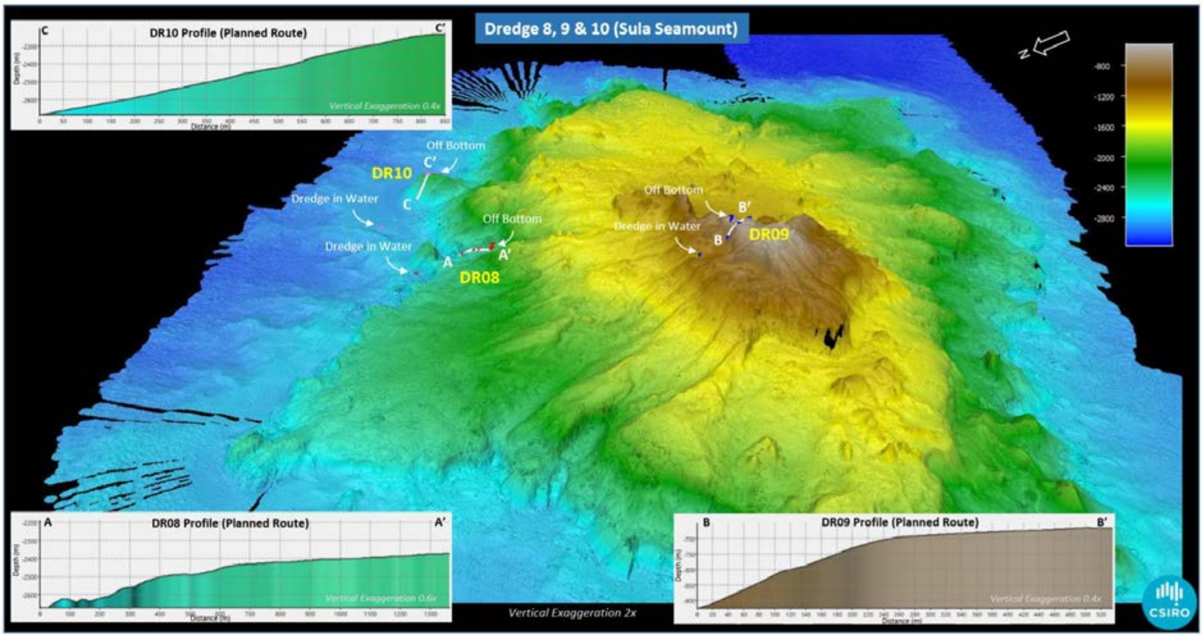


Figure 12 3D seafloor image showing locations of dredges 8, 9 and 10 on Sula Seamount

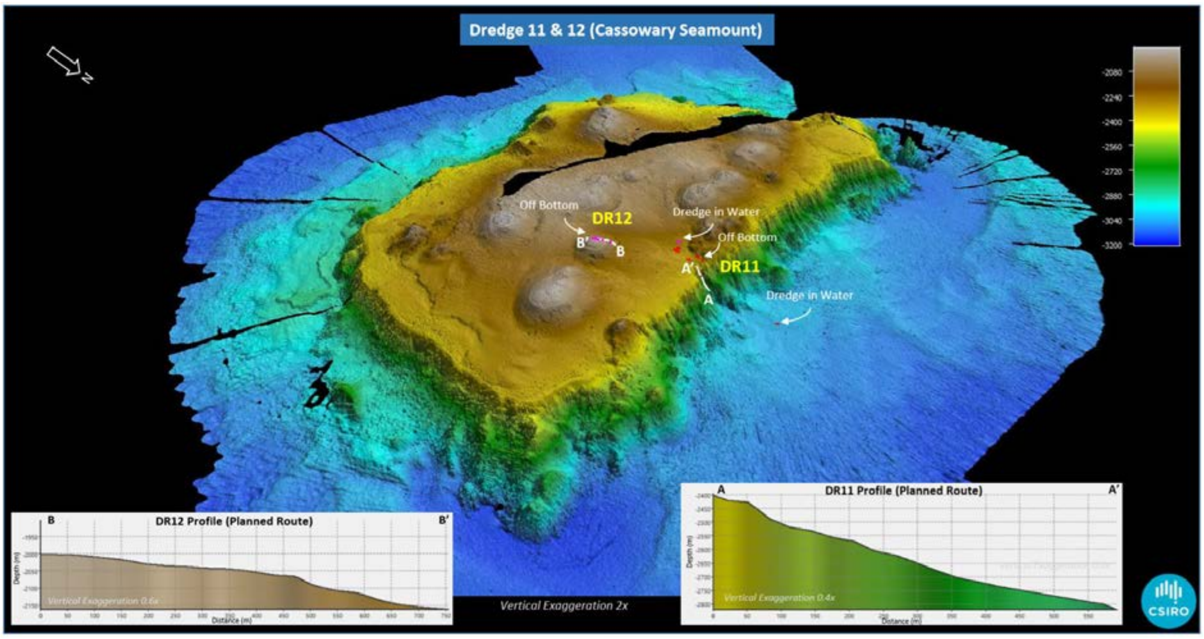


Figure 13 3D seafloor image showing locations of dredges 11 and 12 on Cassowary Seamount

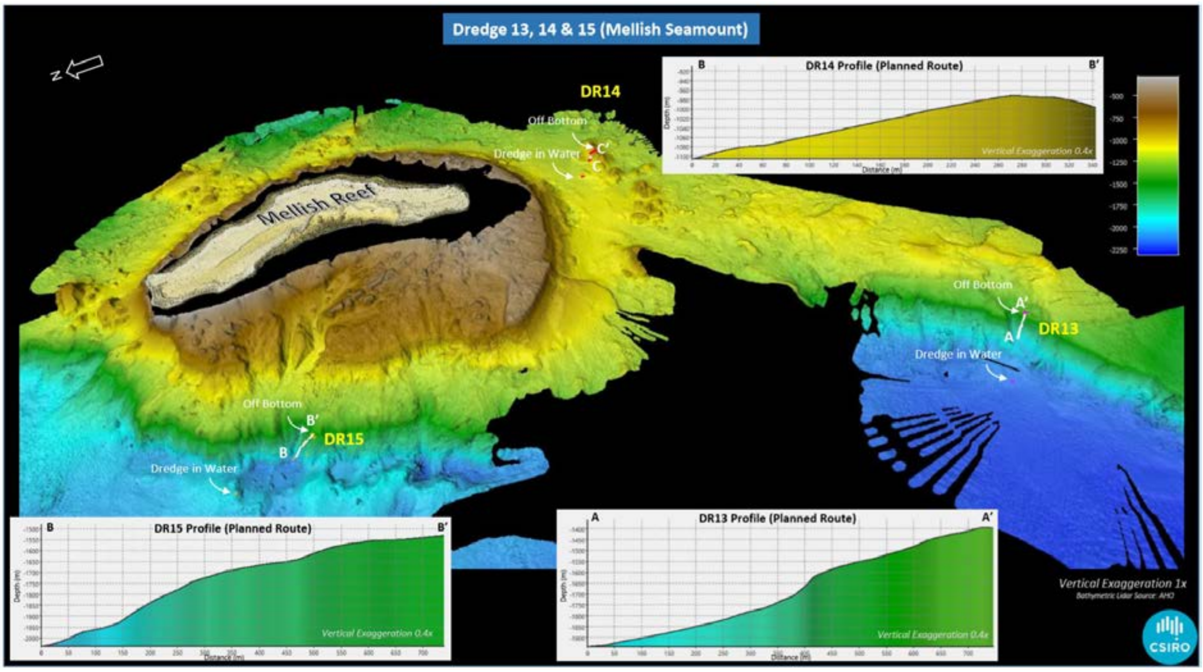


Figure 14 3D seafloor image showing locations of dredges 13, 14 and 15 on Mellish Seamount

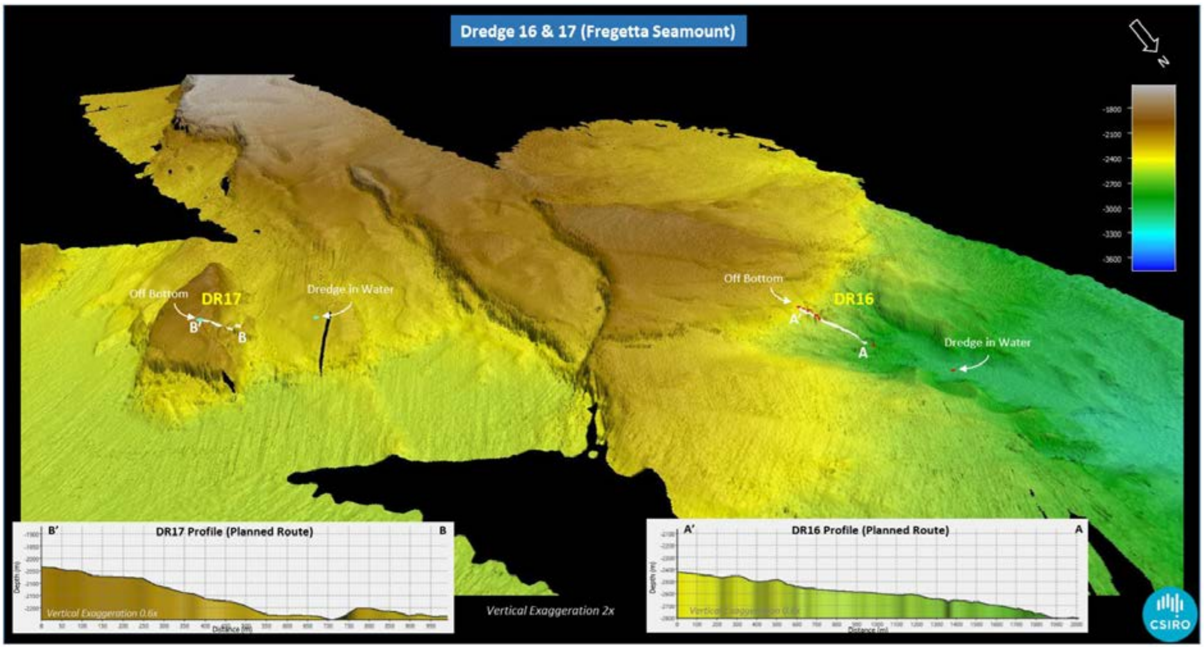


Figure 15 3D seafloor image showing locations of dredges 16 an d17 on Fregetta Seamount

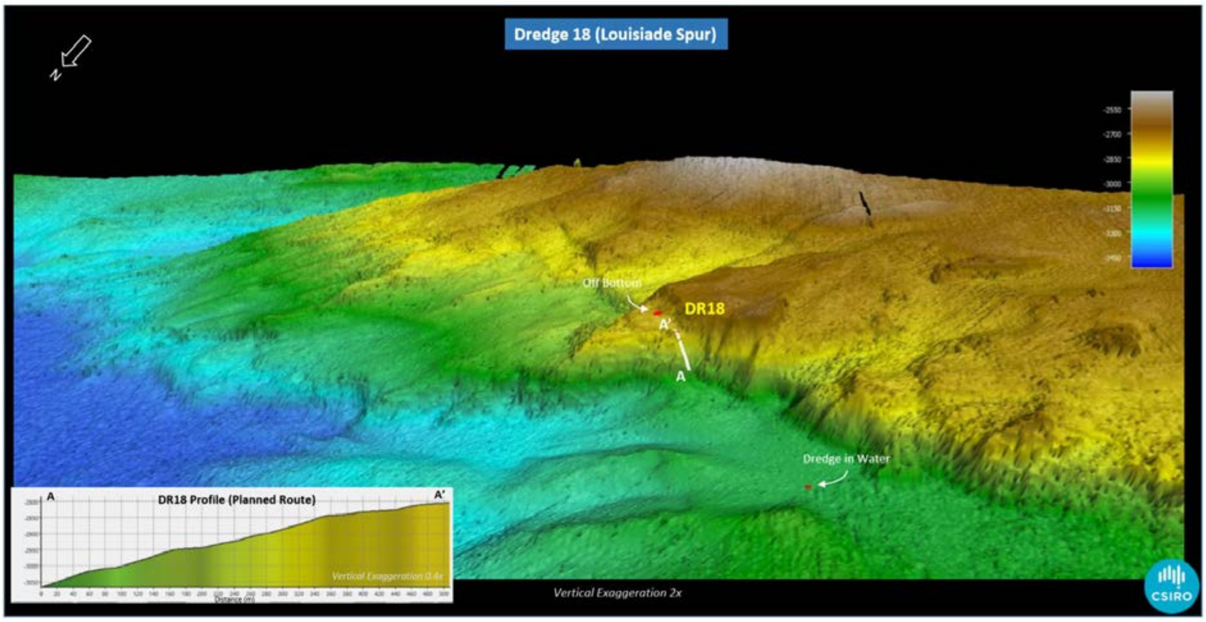


Figure 16 3D seafloor image showing locations of dredge 18 on the Louisiade Spur

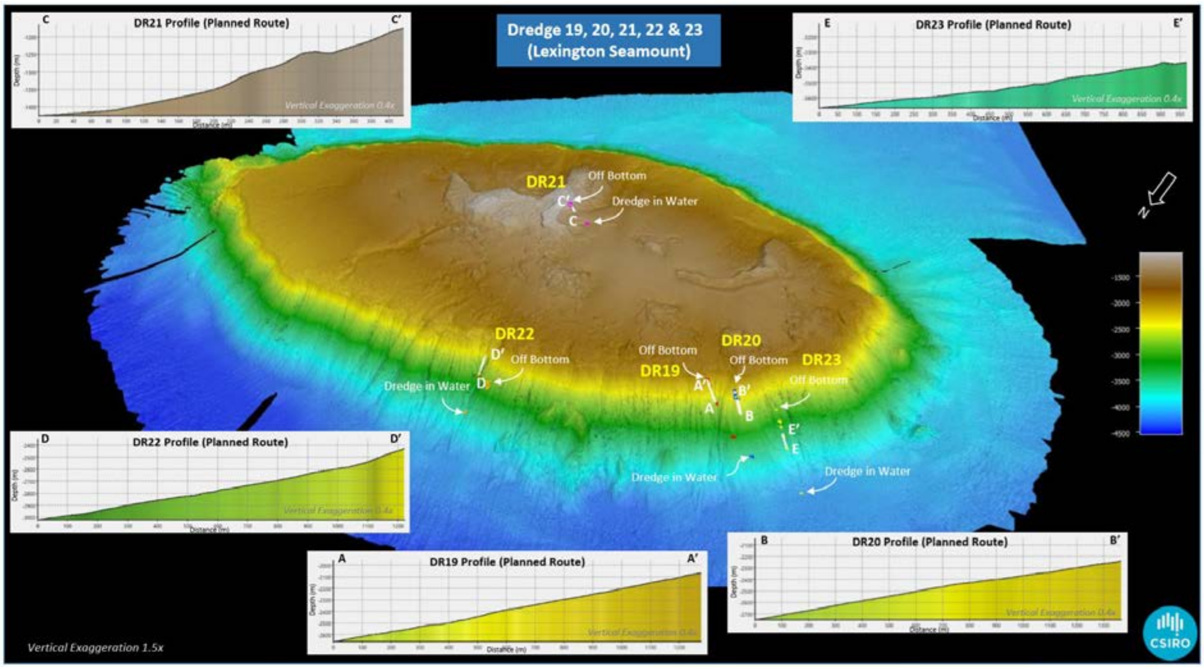


Figure 17 3D seafloor image showing locations of dredges 19 - 23 on Lexington Seamount

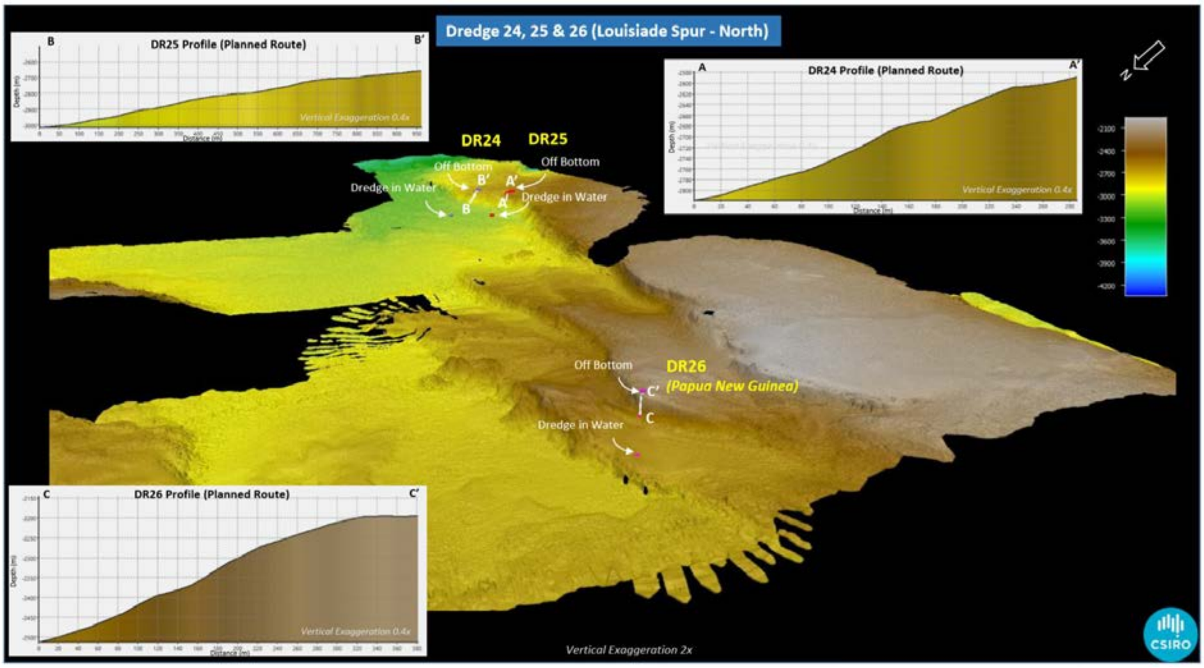


Figure 18 3D seafloor image showing locations of dredges 24, 25 and 26 on the Louisiade Spur North

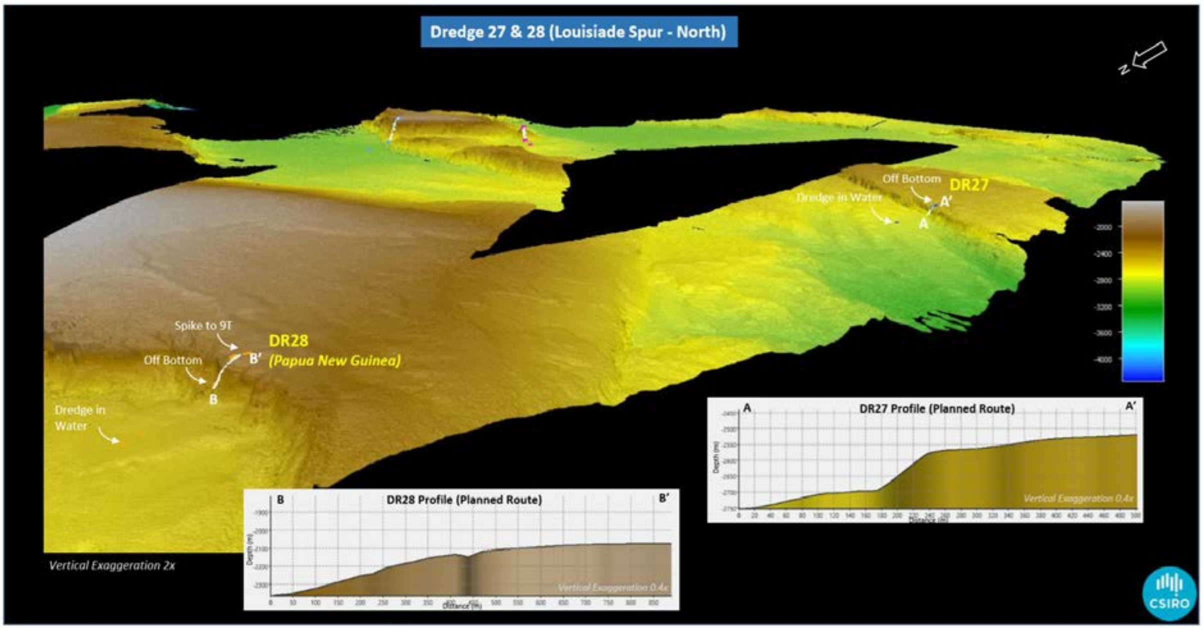


Figure 19 3D seafloor image showing locations of dredges 27 and 28 on the Louisiade Spur North

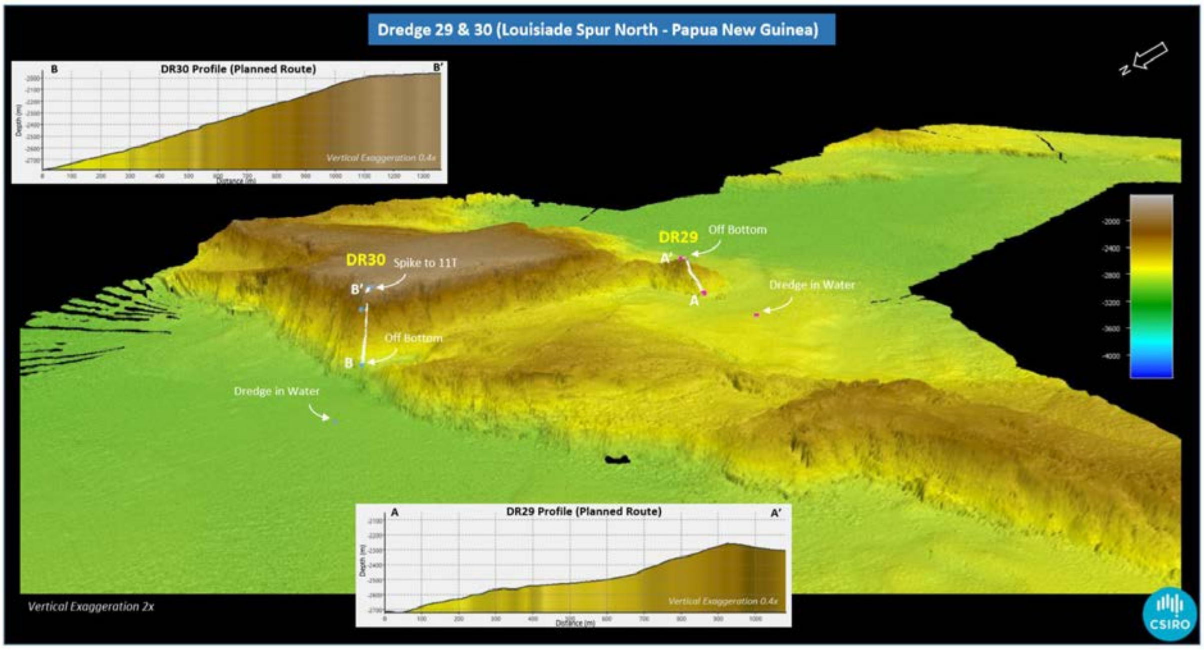


Figure 20 3D seafloor image showing locations of dredges 29 and 30 on the Louisiade Spur North- on the boundary of the Coral Sea AMP

Table 2 Dredge number, depth, Latitude and Longitude and data of sample.

Dredge #	Depth (m)	Latitude	Longitude	Date of Dredge Sample
1	1875	20 49.591 S	154 20.947 E	August 9 2019
2	2730	20 55.232 S	154 28.521 E	August 9 2019
3	1647	20 47.391 S	154 28.216 E	August 10 2019
4	1765	-21.406 S	155.799713	August 10 2019
5	1559	21 04.438 S	155 52.236 E	August 11 2019
6	1988	20 55.522 S	155 52.924 E	August 11 2019
7	2532	20 23.883 S	155 57.092 E	August 11 2019
8	2283	19 39.175 S	154 43.068 E	August 12 2019
9	728	19 42.727 S	154 39.826 E	August 13 2019
10	2292	19 38.921 S	154 46.544 E	August 13 2019
11	2310	19 23.791 S	155 16.356 E	August 13 2019
12	2017	19 25.548 S	155 16.881 E	August 13 2019
13	1384	17 35.655 S	155 46.152 E	August 14 2019
14	983	17 29.37 S	155 52.94 E	August 14 2019
15	1524	17 23.11 S	155 47.36 E	August 14 2019
16	2397	16 41.11 S	155 26.68 E	August 15 2019
17	2033	16 44.92 S	155 35.03 E	August 15 2019
18	2773	15 03.77 S	155 52.46 E	August 15 2019
19	2094	15 03.77 S	155 52.46 E	August 16 2019
20	2391	14 37.29 S	156 40.16 E	August 16 2019
21	1138	14 43.4 S	156 48.51 E	August 16 2019
22	2801	14 35.29 S	156 48.59 E	August 17 2019

23	3145	14 37.58 S	156 38.8 E	August 17 2019
24	2555	14 21.25 S	156 11.8 E	August 17 2019
25	2643	14 20.85 S	156 13.33 E	August 18 2019
27	2513	14 29.11 S	155 25.5 E	August 18 2019
29	2299	14 30.85 S	155 43.96 E	August 19 2019
30	2171	14 27.06 S	155 48.5 E	August 20 2019

The 94 specimens collected on this expedition represent two Kingdoms, nine Phylums, and 12 Classes, with most specimens not yet identified to the Family level. Future work on these specimens will lead to greater resolution regarding species identifications and how many species occur in the region. The occurrences of these specimens represent many new records for the region and highlight the benefit of, and need for additional surveys of biota to better understand and protect the biodiversity in the Coral Sea.

A summary of the specimens is presented below:

Kingdom Animalia
Phylum Annelida
Class Polychaeta
Figure 21
Material examined: Queensland Museum material (preserved in ethyl alcohol): iv25, iv28, and iv33 (Station data inTable 2).

Remarks: Class Polychaeta is present worldwide and has over 1,000 occurrences in the Coral Sea. These specimens were collected from dredges 4, 5, and 6.

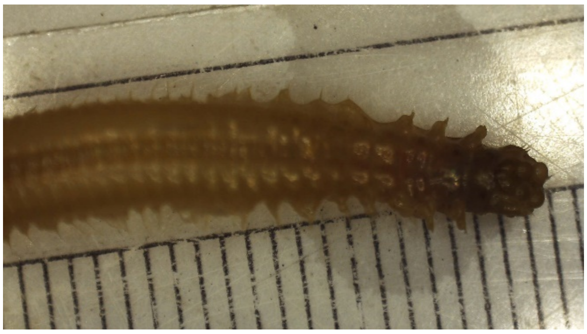



Figure 21 Left, iv25 (scale in cm); right, iv33 (scale in mm)

Phylum Arthropoda
Class Crustacea
Order Amphipoda
Figure 22
Material examined: Queensland Museum material (preserved in ethyl alcohol): iv34, iv40, and iv78 (Station data in Table 2)
Remarks: Order Amphipoda is present worldwide and has over 5,000 occurrences in the Coral Sea. These specimens were collected from dredges 6, 9, and 25.

Figure 22 Left, Photograph of IV34 (scale in mm); right, iv78 (scale in mm)

Class Decapoda
(Figure 21, Figure 23)
Material examined: Queensland Museum material (preserved in ethyl alcohol): iv53 (Station data in Table 2)
Remarks: Class Decapoda is present worldwide and has over 50,000 occurrences in the Coral Sea. This specimen was collected from dredge 15.

Figure 23 Photograph of IV53 (scale in cm)

Class Hexanauplia
Order Pedunculata
Genus Anguloscalpellum
Species pedunculatum
Figure 24
Material examined: Queensland Museum material (preserved in ethyl alcohol): iv16, and iv73 (Station data in Table 2).
Remarks: This species has 77 records, 33 of which are in the Coral Sea. This species is known to occur from 300 m to 540 m depth; however, these specimens were collected at a maximum depth of 1,600 representing a bathymetric range expansion for the species. These specimens were collected from dredges 3 and 21.

Figure 24 Photograph of IV16 (scale in cm)

Genus Trianguloscapellum
Species Hamulus
Figure 25

Material examined: Queensland Museum material (preserved in ethyl alcohol): iv45, and iv85 (Station data in Table 2)

Remarks: This species has 3 records for the Coral Sea. This species is known to occur from 128 m to 1,119 m depth; however, these specimens were collected at a maximum depth of 2,300 m representing a bathymetric range expansion for the species. These specimens were collected from dredges 11 and 29

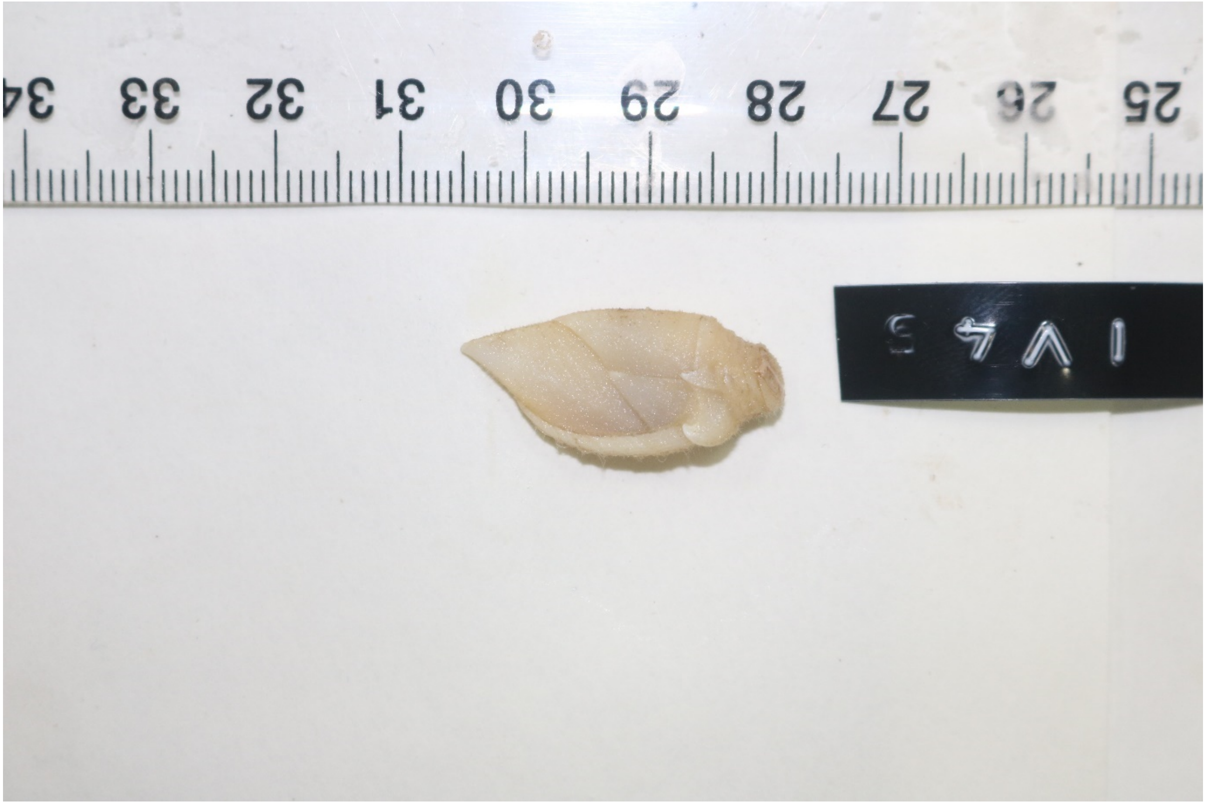


Figure 25 Photograph of IV45 (scale in cm)

Phylum Brachipoda

Figure 26

Material examined: Queensland Museum material (preserved in ethyl alcohol): iv74 (Station data in Table 2)

Remarks: This phylum is present worldwide and has less than 300 records for the Coral Sea. This specimen was collected from dredge 21.

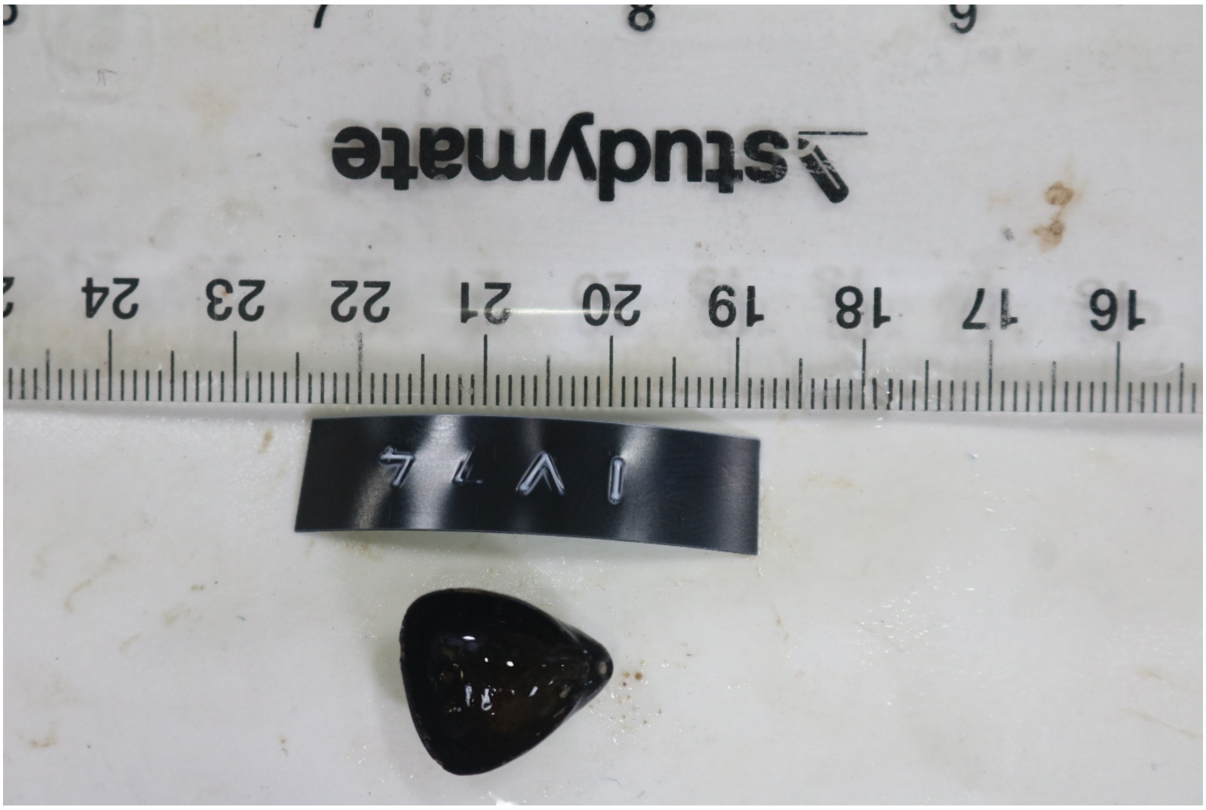


Figure 26 Photograph of IV74 (scale in cm)

Phylum Bryozoa
Figure 27
Material examined: Queensland Museum material (preserved in ethyl alcohol): iv57 (Station data in Table 2)
Remarks: This phylum is present worldwide and has over 4,000 records for the Coral Sea. This specimen was collected from dredge 15.

Figure 27 Photograph of IV57 (scale in mm)

Phylum Cnidaria
Class Anthozoa
Order Alcyonacea
Family Chrysogorgiidae

Figure 28

Material examined: Queensland Museum material (preserved in ethyl alcohol): iv23, iv54, iv55, and iv56 (Station data in Table 2)

Remarks: This family is present worldwide and has less than 200 records for the Coral Sea. These specimens were collected from dredges 4 and 15.

Figure 28 Photograph of IV23

Family Corallidae

Figure 29

Material examined: Queensland Museum material (preserved in ethyl alcohol): iv13, iv15, iv17, iv18, iv61, iv62, iv66, iv68, and iv70 (Station data in Table 2)

Remarks: This family has over 9,000 records worldwide and 38 records for the Coral Sea. These specimens were collected from dredges 3 and 21.

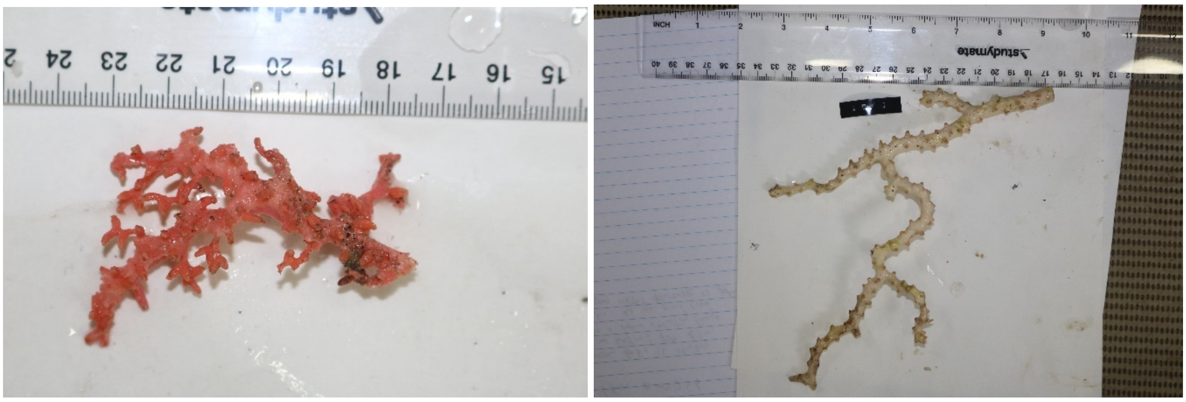


Figure 29 Left, Photograph of IV15 (scale in cm); right, IV61 (scale in cm)

Family isididae

Figure 30

Material examined: Queensland Museum material (preserved in ethyl alcohol): iv20, iv27, iv36, iv37, iv49, iv50, iv51, iv64, iv69, iv71, iv86, iv87, and iv92 (Station data in Table 2)

Remarks: This family has over 30,000 records worldwide and about 1,000 records for the Coral Sea. These specimens were collected from dredges 3, 4, 9, 14, 21, 30, 21.

Figure 30 Left, whole colony IV36; right, close-up IV36 (scale in cm)

Family Plexauridae
Figure 31
Material examined: Queensland Museum material (preserved in ethyl alcohol): iv21 (Station data in Table 2)
Remarks: This family has over 20,000 records worldwide and about 2,000 records for the Coral Sea. This specimen was collected from dredge 3.

Figure 31 Photograph of IV21 (scale in cm)

Family Victorgorgiidae
Figure 32
Material examined: Queensland Museum material (preserved in ethyl alcohol): iv63 (Station data in Table 2)
Remarks: This family has 142 records worldwide and this is the first record of this family in the Coral Sea. This specimen was collected from dredge 21.


Figure 32 Left, whole colony IV63; right, close-up IV63 (scale in cm)

Order Scleractinia
Figure 33
Material examined: Queensland Museum material (preserved in ethyl alcohol): iv39a, iv8, iv5, iv48c, and iv58 (Station data in Table 2)
Remarks: This order has over 500,000 records worldwide and over 100,000 records in the Coral Sea; however, the majority of the material collected are over 1,000 m depth, of which there are only 640 records in the Coral Sea. These specimens were collected from dredges 1, 2, 9, 13, and 15.

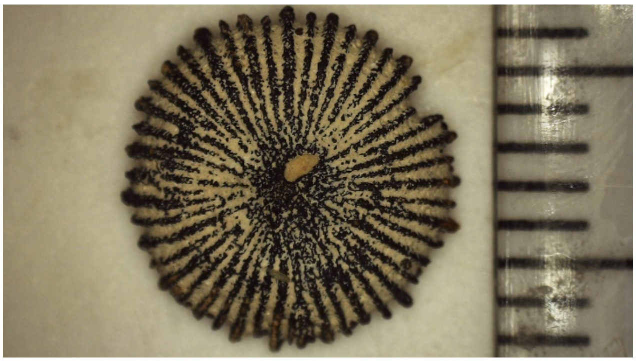



Figure 33 Left, Photograph of IV8; right, IV39a

Class Hydrozoa
Figure 34
Material examined: Queensland Museum material (preserved in ethyl alcohol): iv1, iv2 (Station data in Table 2)
Remarks: This class has about 400,000 records worldwide and over 4,000 records in the Coral Sea; however, only 35 of the 4,000 records are deeper than 1,000 m. These specimens were collected from dredge 1.

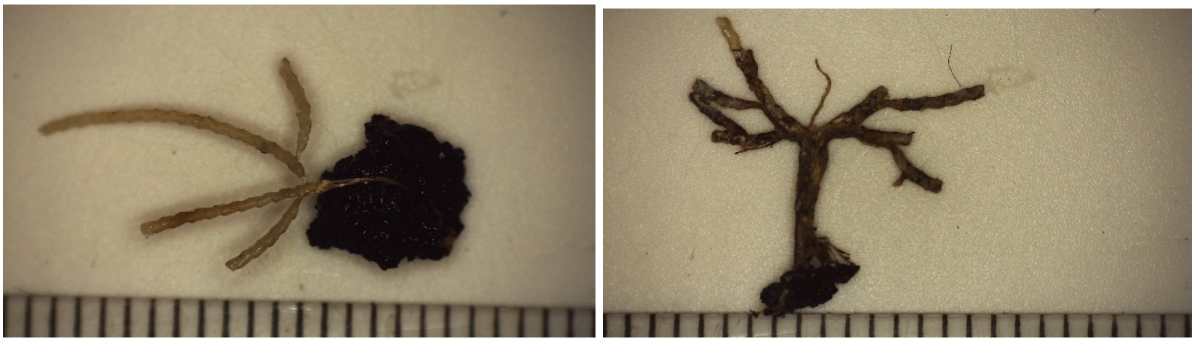


Figure 34 Left, Photograph of IV1 (scale in mm); right, IV2 (scale in mm)

Phylum Echinodermata
Class Echinoidea
Figure 35
Material examined: Queensland Museum material (preserved in ethyl alcohol): iv6 (Station data in Table 2)
Remarks: This Class has almost 200,000 records worldwide, over 5,000 records in the Coral Sea, and 60 records in the Coral Sea deeper than 1,000 m. this specimen was collected from dredge 1.

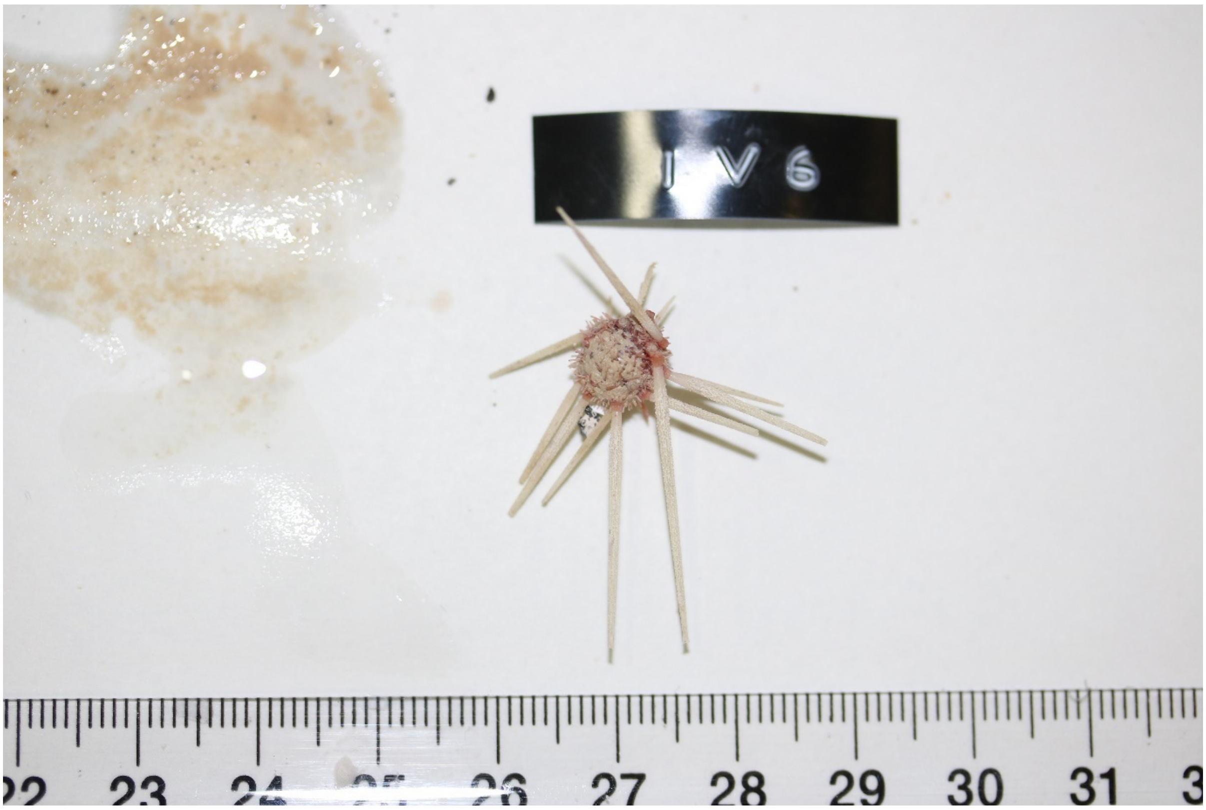


Figure 35 Photograph of IV6 (scale in cm)

Class Ophiuroidea

Figure 36

Material examined: Queensland Museum material (preserved in ethyl alcohol): iv22, iv24, iv26, and iv44 (Station data in Table 2)

Remarks: This Class has over 275,000 records worldwide and over 10,000 records in the Coral Sea. These specimens were collected from dredges 3, 4, and 11.

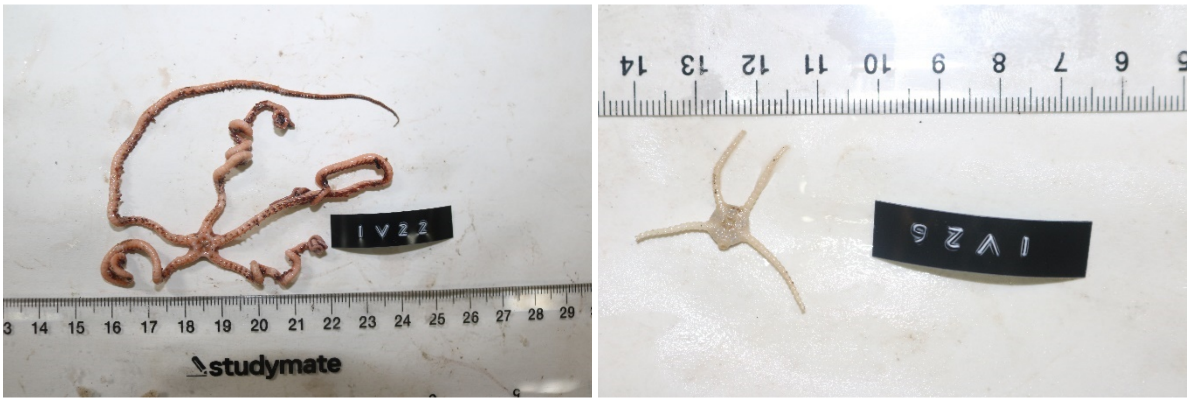


Figure 36 Left, Photograph of IV22 (scale in cm); right, IV26 (scale in cm)

Phylum Mollusca

Class Gastropoda

Figure 37

Material examined: Queensland Museum material (preserved in ethyl alcohol): iv47, iv77 (Station data in Table 2)

Remarks: This Class has over 1,000,000 records worldwide and over 100,000 records in the Coral Sea. However, only 506 of the 100,000 records are from greater than 1,000 m depth. These specimens were collected from dredges 13 and 22.

Figure 37 Left, Photograph of IV47 (scale in mm); right, IV77 (scale in mm).

Class Scaphopoda

Figure 38

Material examined: Queensland Museum material (preserved in ethyl alcohol): iv7, and iv9 (Station data in Table 2)

Remarks: This Class has about 20,000 records worldwide and over 2,000 records for the Coral Sea. These specimens were collected from dredges 1 and 2.

Figure 38 Left, iv7 (scale in mm); right, iv 9 (scale in mm).

Phylum Porifera

Class demospongiae

Figure 39

Material examined: Queensland Museum material (preserved in ethyl alcohol): iv3, iv4, iv10, iv14, iv19, iv31, iv38, iv42, iv43, iv46, iv48, iv48b, iv75, iv91, and iv93 (Station data in Table 2)

Remarks: This Class has over 200,000 records worldwide and 20,000 records for the Coral Sea. Within the Coral Sea, only 62 records are greater than 1,000 m depth. These specimens were collected from dredges 1, 2, 3, 6, 9, 10, 11, 13, 21, 22, and 33.

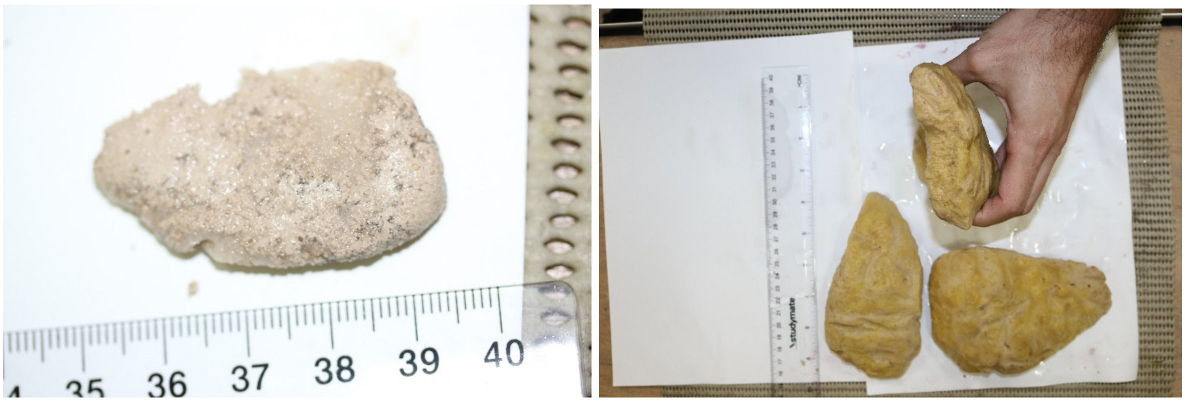


Figure 39 Left, IV4 (scale in cm); right, IV38.

Class Hexactinellida
Figure 40
Material examined: Queensland Museum material (preserved in ethyl alcohol): iv11, iv12, iv48a, iv60, iv67, iv72, iv83, iv84, iv88, and iv89 (Station data in Table 1)
Remarks: This Class has over 20,000 records worldwide and over 400 records for the Coral Sea. These specimens were collected from dredges 3, 13, 17, 21, 29, and 30.

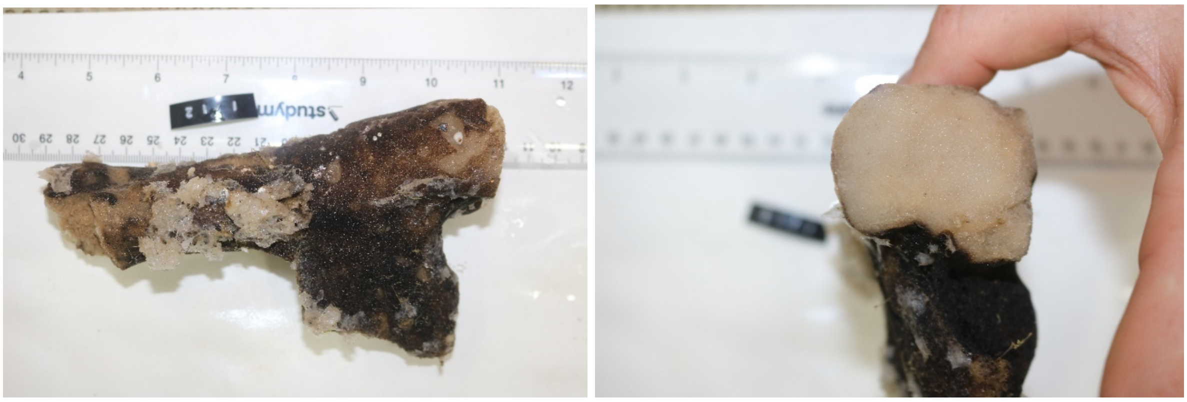


Figure 40 Left, Photograph of IV12; Right, close-upIV12.

Kingdom Rhizaria
Phylum Foraminifera
Figure 41
Material examined: Queensland Museum material (preserved in ethyl alcohol): iv29, iv30, and iv32 (Station data in Table 2)
Remarks: This Phylum has over 1,000,000 records worldwide and over 9,000 records in the Coral Sea; however, no records in the Coral Sea have been documented beyond 1,000 m. These specimens were collected from dredges 5 and 6.

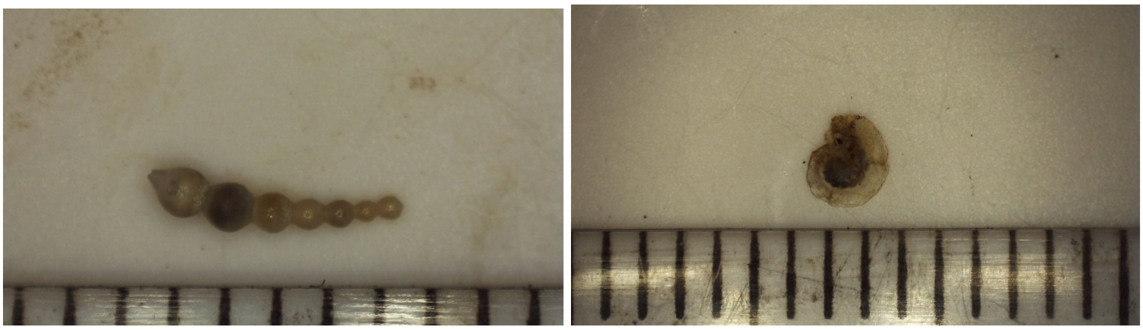


Figure 41 Left, Photograph of IV29; right, IV32

2.4 Discussion

Little is known about global marine biodiversity, especially in areas with low survey effort such as habitats in developing countries that are hard to access. This expedition provided new information about what lives in the deep Coral Sea Australian Marine Park. However, the Coral Sea is a large area with great ecological and economic importance. Additional surveys are required to bridge the gap between how many species we think occur in the region, and its actual species richness.

Lastly, when comparing the number of Orders that occur at different depths, a right-skewed relationship is evident (Figure 42). Species richness decreases as depth increases; however, we are missing data from 0 m to about 1,000 m deep. Future expeditions that sample at these depths in the Coral Sea will allow for explanations as to what depths have the greatest species richness, and what drives and maintains marine biodiversity, which are required pieces of information to effectively conserve marine resources.

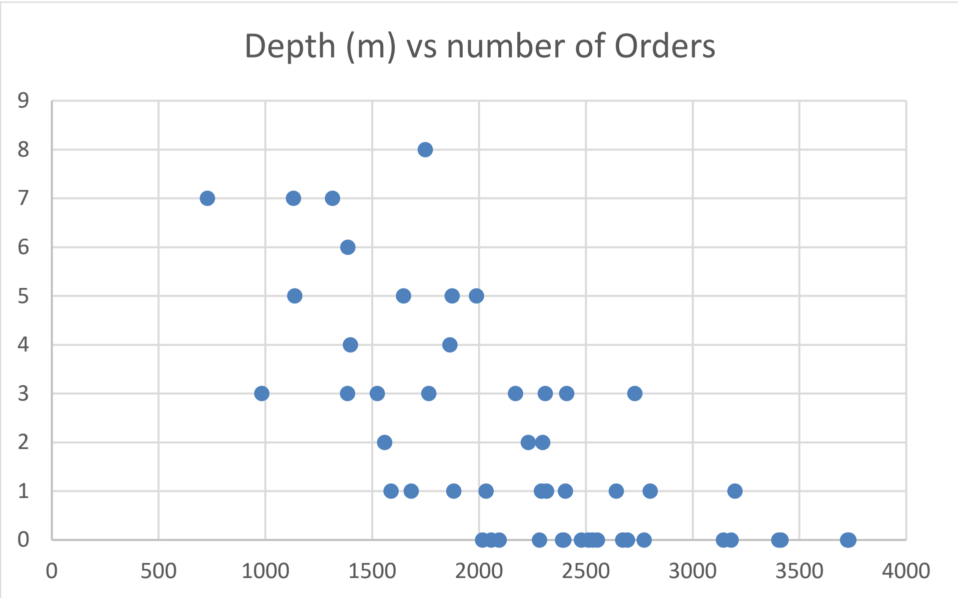


Figure 42 X-axis represents depth of each dredge, and y-axis represents the number of Orders collected in each dredge.

3. MARINE BIODIVERSITY- SEABIRDS AND MARINE MAMMALS

3.1 Introduction

RV Investigator Voyage IN2019_v04 provided an opportunity to undertake quantitative and spatially-explicit surveys of seabirds and marine mammals in remote areas of the Coral Sea for which there have been no previous surveys. The 27-day voyage departed Cairns on the 7th of August, headed southeast then north towards the Solomon Islands before returning southward to the west of New Caledonia before returning to Brisbane on the 3rd of September (Figure 43).

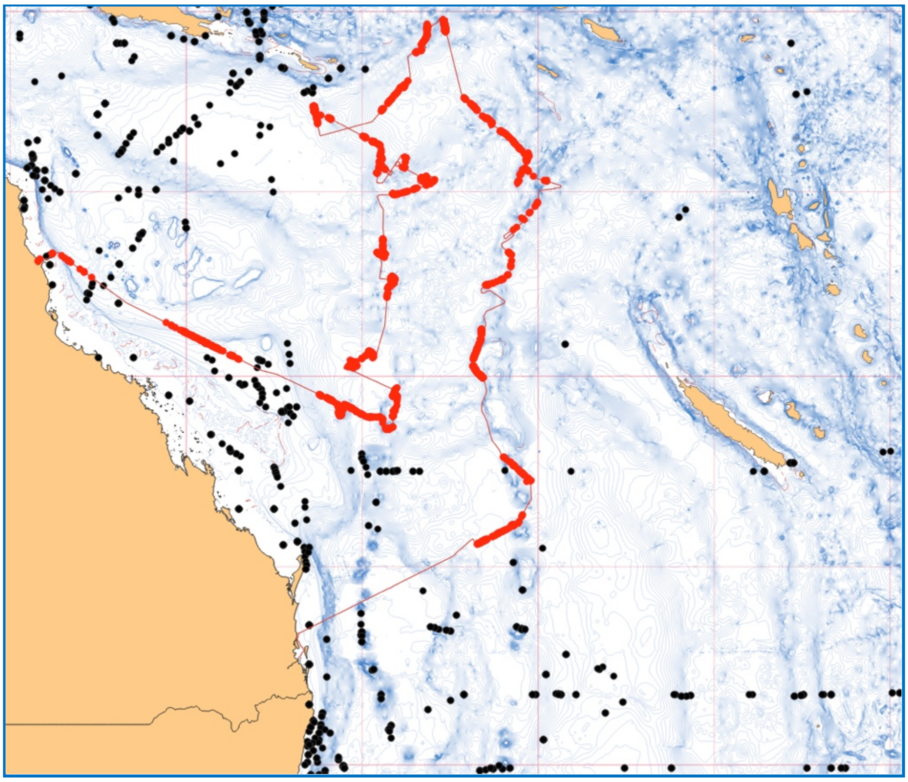


Figure 43 Map showing the northeast Australia, New Caledonia and the Coral Sea. Black symbols are locations of previous seabird observations (Australasian Seabird Group unpubl. data). Red circles show the locations of seabird and marine mammal observations collected during IN2019_V04.

3.2 Methods

Observations were undertaken continuously from before sunrise to sunset daily. A team of 3 observers were present on board for the voyage. Observations were conducted from Deck 7, approximately 25 m ASL. All seabirds within a 300 m arc from the bow to the side of the ship with least glare were recorded, with details of species, behaviours and numbers recorded in real time on a dedicated data collection portal connected to the vessel's underway data system. All marine mammals with a 1 km radius were recorded in a similar manner. All seabirds and marine mammals seen beyond these bounds were recorded in the system as 'out of zone' records. The vessel's underway data system recorded extensive additional details on location, water temperature and salinity, fluorometry and depth etc.

3.3 Results

More than 13,800 seabirds and 128 marine mammals were recorded during the voyage, Tables 1 and 2. A total of 26 seabird taxa were identified to species, with several unidentified taxa observed that could not be identified with certainty (Table 3). Three marine mammal taxa were identified to species, with an unidentified dolphin and unidentified whale also observed. A Minke Whale was seen briefly, and we are awaiting confirmation as to whether it is a Dwarf Minke Whale.

Brief comments follow on selected seabirds and marine mammals recorded on the voyage; the seabird taxonomy follows BirdLife Australia Working List v2 (2018). All scientific names are given in Table 3 and Table 4.

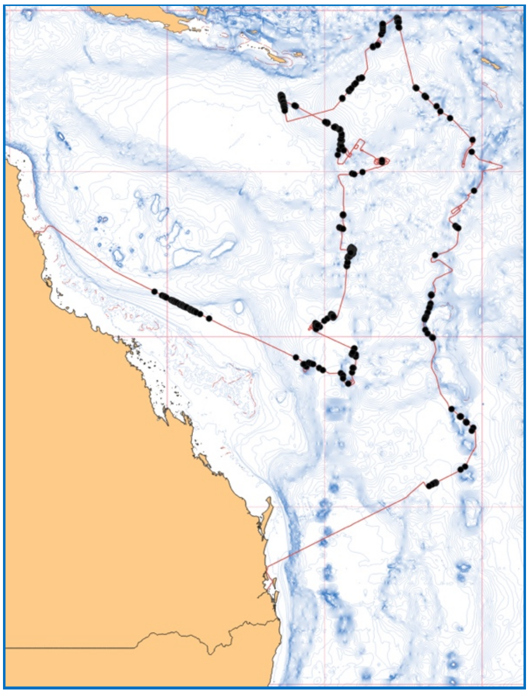


Figure 44 Map showing records of Sooty Terns, in2019_v04 (black symbols). The cruise track is also shown. Isobaths at 100m increments, and Latitude and Longitude are shown at 5° increments.

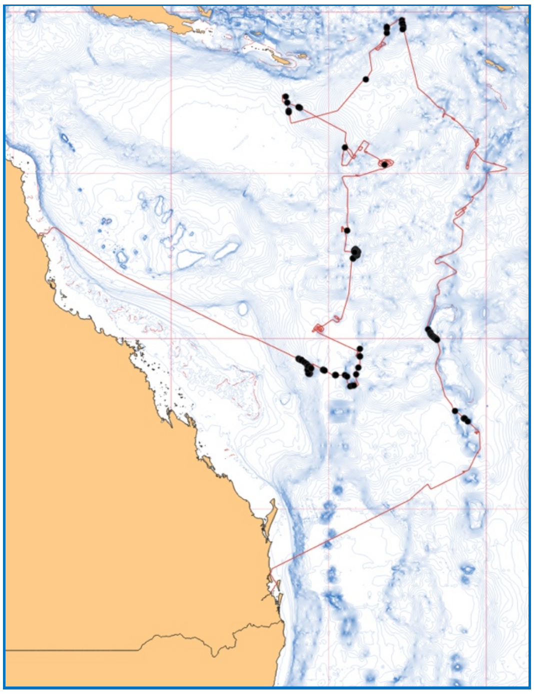


Figure 45 Map showing records of Brown Noddy, in2019_v04 (black symbols). The cruise track is also shown. Isobaths at 100m increments, and Latitude and Longitude are shown at 5° increments.

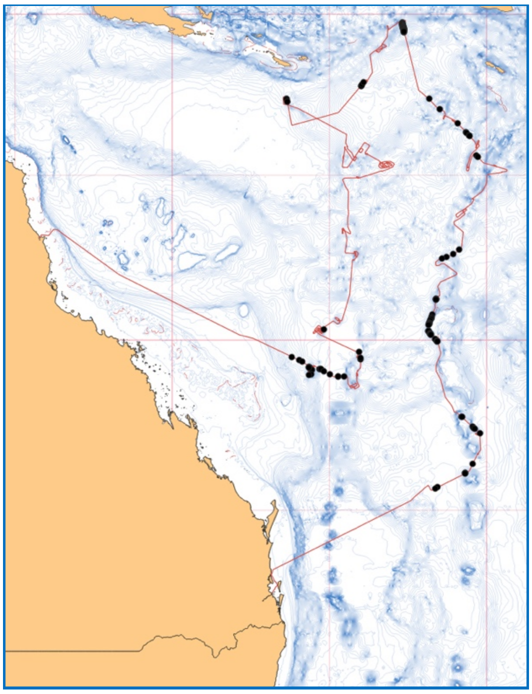


Figure 46 Map showing records of Bridled Tern, in2019_v04 (black symbols). The cruise track is also shown. Isobaths at 100m increments, and Latitude and Longitude are shown at 5° increments.

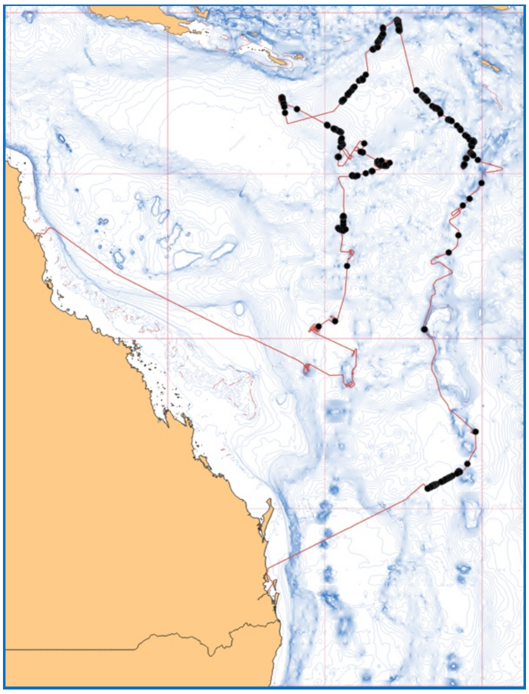


Figure 47 Map showing records of Wedge-tailed Shearwater, in2019_v04 (black symbols). The cruise track is also shown. Isobaths at 100m increments, and Latitude and Longitude are shown at 5° increments.

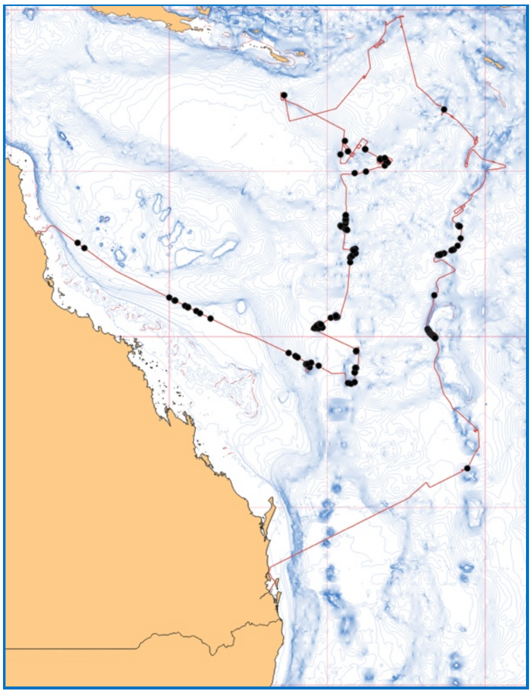


Figure 48 Map showing records of Red-footed Booby, in2019_v04 (black symbols). The cruise track is also shown. Isobaths at 100m increments, and Latitude and Longitude are shown at 5° increments.

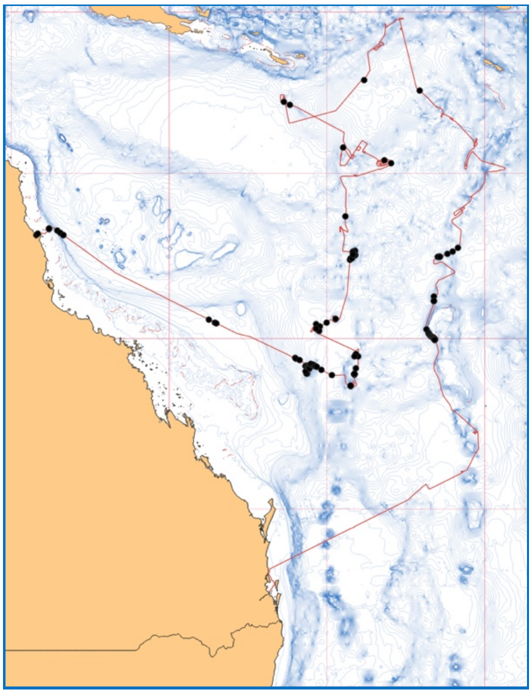


Figure 49 Map showing records of Brown Booby, in2019_v04 (black symbols). The cruise track is also shown. Isobaths at 100m increments, and Latitude and Longitude are shown at 5° increments.

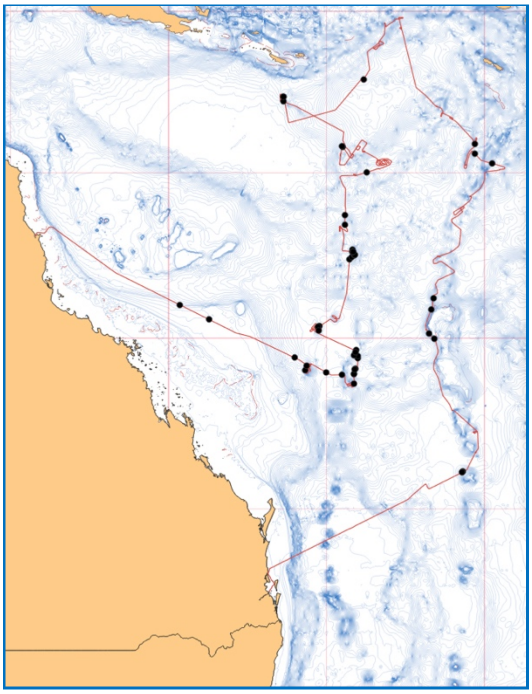


Figure 50 Map showing records of Masked Booby, in2019_v04 (black symbols). The cruise track is also shown. Isobaths at 100m increments, and Latitude and Longitude are shown at 5° increments.

3.3.1 Gulls, Terns and Noddies

Three species of oceanic terns – Sooty Tern, Brown Noddy and Bridled Tern – accounted for more than 11,400 individuals, or more than 83% of all seabirds observed (n = Table 3).

Flocks of all three species were frequently observed in mixed-species feeding assemblages of seabirds and Tuna *Thunnus* spp. These assemblages were of birds feeding on near-surface schools of fish (bait balls). The observed flocks were between 50 and 500 seabirds. The feeding events were typically brief, often less than a minute in duration. On several occasions, Tuna were observed and photographed above the surface chasing bait fish.

There are substantial populations of Sooty Tern, Brown Noddy and Bridled Tern in the great Barrier Reef, and are amongst the most numerous of oceanic seabirds in the region, with estimated populations of 48,000, 46,000 and 13,900, respectively (GBRMPA 2011). All three species were observed throughout the voyage in deeper waters off the continental shelf (Figures 44-46).

Four other taxa of terns and gulls were observed, albeit in very low numbers (Table 3).

3.3.2 Petrels and Shearwaters

One species of shearwater predominated the observations of petrels and shearwaters. Wedge-tailed Shearwaters are the most abundant seabird breeding in the Great Barrier Reef region, with a population estimated to be more than 560,000 birds (GBRMPA 2011).

Wedge-tailed Shearwaters were observed predominantly in the northern part of the voyage

(Figure 47). Individuals migrate to equatorial waters around Australia before returning to their breeding sites in late August. It is believed that the birds seen late in the voyage northeast of Brisbane were birds on southward flights to their colonies. Similarly, two observations of Short-tailed Shearwaters late in the voyage are believed to be of birds returning from the Northern Hemisphere to their colonies in Southeast Australia. Seven other taxa of petrels and shearwaters were observed, all in very low numbers (Table 3).

3.3.3 Gannets and Boobies

Three species of booby were observed throughout the voyage (Table 3, Figures 48 - 50). Brown Booby has the greatest estimated population of these species in the Great Barrier Reef region, with a population of 18,500 pairs; Masked and Red-footed Boobies' breeding populations for the region are estimated at 1100 and 172 pairs, respectively (GBRMPA 2011). As more than 500 Red-footed Boobies were recorded during the voyage, the observations suggest the survey area supports Red-footed Boobies from farther afield.

3.3.4 Marine Mammals

Very few marine mammals were observed (Table 4). Four observations were made of Short-finned Pilot Whales associated with Bottle-nosed Dolphins (Figure 51). All observations were in the southern survey area early in the voyage. Three of the observations were made at Calder and Mellish Reefs.

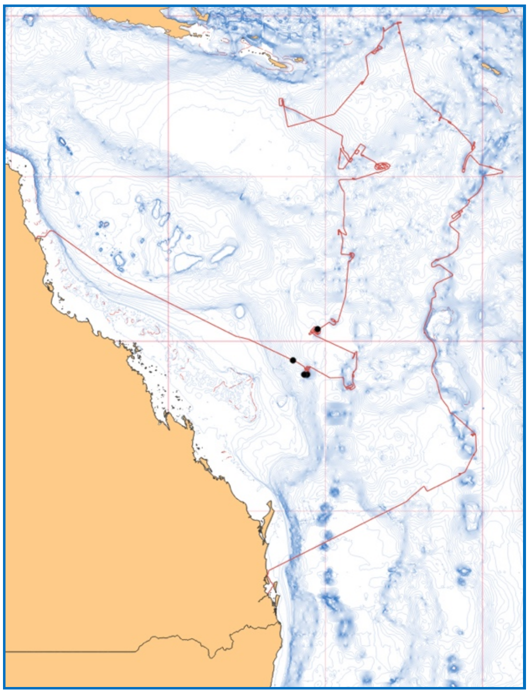


Figure 51 Map showing records of Short-finned Pilot Whale and Bottle-nosed Dolphin, in2019_v04 (black symbols). The cruise track is also shown. Isobaths at 100m increments, and Latitude and Longitude are shown at 5° increments.

3.4 Discussion

More seabirds and a greater diversity of seabird species were observed than expected on the voyage, based on the limited data available. In contrast, fewer than expected marine mammals were observed. The expectations were based on previous surveys by Woehler off the SE Queensland coast and on a transit from Sydney to Broome. The limited data available for the Coral Sea prevents an assessment as to whether the results from in 2019_v04 are representative of the area at the time of the survey or not.

A number of migratory seabirds were observed, including jaegers from the Northern Hemisphere. Several of the petrels and shearwaters observed were believed to have observed returning from their wintering areas to their breeding colonies off the east and southeast coasts of Australia. The substantial number of Red-footed Boobies observed exceeds the reported breeding population for the Great Barrier Reef region, suggesting that the survey area supports Red-footed Boobies from farther afield.

The low number of marine mammal observations may be interpreted as the Coral Sea supporting few species in low abundances at the time of the survey in the survey area – again, the lack of previous data prevents any assessment of the representativeness or otherwise of the data for the area.

The survey has provided a substantial data set for an area of the Coral Sea Australian Marine Park, for which there were little or no previous data. Earlier surveys were typically closer to shore and often associated with the GBR. The survey collected spatially-explicit quantitative data on the distributions and abundances of 26 seabird taxa and three marine mammal taxa.

Further surveys are required to provide greater spatial and temporal coverage of the Coral Sea. The data from future surveys, in conjunction with the data from in2019_v04 and potentially some of the historical data will provide the opportunity for a regional synthesis required for an understanding of the distributions of seabirds and marine mammals in the Coral Sea throughout the year. This applies both to resident breeding species, such as the noddies and boobies etc, and to the migratory species that travel to, or pass through the Coral Sea.

<u>Feeding associations</u>

A number of feeding assemblages were observed and documented during the voyage. These assemblages comprised several species of seabirds feeding on bait fish at or close to the surface, in association with tuna that are believed to have formed the bait ball. Analyses of similar observations on previous *Investigator* trips are presently underway.

Multi-species feeding associations have been documented in tropical seas elsewhere but are poorly known from Australia. Initial analyses suggest these feeding events are brief (typically lasting less than 5 minutes) and may represent a major feeding strategy for many species of warm-water seabirds around Australia.

The additional data from IN2019_v04 will be integrated into the current analyses to provide greater spatial and temporal coverage of these events, and further insights into the species involved. The observations reinforce a developing focus and interest in the project on the role of biological interactions in driving ecosystem processes (i.e. energy and carbon fluxes etc). It is possible that biological interactions (i.e. behavioural) may be greater contributors than physical oceanographic processes.

Bathymetry

Numerous seamounts were traversed during the voyage (Section 4). Elevated seabird and marine mammal abundances were recorded when the seamounts were close to the surface (e.g. Mellish Reef, c.45 m below the surface). Seabirds or marine mammals were not associated with deeper seamounts, and there was no evidence of enhanced biological activity.

Convergence lines believed to be associated with local upwelling were observed extensively on the water surface at Mellish Reef. No seabirds or marine mammals were seen associated with these features. Further analyses are underway to examine the role of bathymetry in the study region, and to assess the relative importance to seabirds and marine mammals in the Coral Sea.

A number of atolls were approached during the survey. Several of them were used by roosting seabirds, and likely to be used for breeding at other times of the year. At some atolls, surface convergences were observed.

The observations of seabirds and marine mammals collected during IN2019_v04 provide contemporary data on the distribution and abundance of species inside the Australian EEZ and over adjacent international waters. In many cases, the data are novel, with no previous survey data available for the area. The survey data provide spatially-explicit quantitative data on resident and migratory species, many of which are listed under the EPBC Act 1999.

In many cases, the observations will also provide initial species lists for marine protected areas inside the Australian EEZ. These species' data are critical for agencies involved in, or responsible for the management of threatened and migratory species for example. Future surveys will provide further data on the spatial and temporal patterns of species in the Coral Sea, and around Australia more broadly.

Analyses underway into feeding associations and species assemblages will complement studies elsewhere, enabling assessments of the representativeness of the processes observed and the species involved. It is likely that the results will parallel those from previous studies, reinforcing the role of behavioural interactions as a key driver of ecosystem processes in tropical waters.

Analyses of the biological oceanographic data will examine the relationships between oceanographic productivity and the presence of high trophic order predators such as tuna, seabirds and marine mammals.

Table 3 Seabirds observed during IN2019_V04 Whittaker, Coral Sea, 7 August – 2 September 2019 (total 13,833). Occurrences is the number of observations per taxon, and individuals is the total numbers recorded per taxon for the voyage. Percentages are given for species that contributed 1% or greater to total seabirds observed. Taxonomy follows BirdLife Australia Working List v2 (2018).

	Taxon	Occurrences	Individuals	%
				Skuas and Jaegers
Long-tailed Jaeger	*Stercorarius longicaudus*	2	10	
Subantarctic Skua	*Catharacta lonnbergi*	1	1	
				Gulls, Terns and Noddies
Sooty Tern	*Sterna fuscata*	328	6291	45
Brown Noddy	*Anous stolidus*	110	3686	27
Bridled Tern	*Sterna anaethetus*	117	1458	11
White Tern	*Gygis alba*	3	4	
Crested Tern	*Sterna bergii*	2	3	
Silver Gull	*Chroicocephalus novaehollandiae*	2	2	
Roseate Tern	*Sterna dougallii*	1	41	
Unidentified tern		12	22	
				Tropicbirds
White-tailed Tropicbird	*Phaethon lepturus*	69	90	1
Red-tailed Tropicbird	*Phaethon rubricauda*	1	1	
				Southern Storm-petrels
Black-bellied Storm-petrel	*Fregetta tropica*	60	86	1
White-faced Storm-petrel	*Pelagodroma marina*	3	6	
Unidentified storm-petrel		5	6	
				Petrels and Shearwaters
Wedge-tailed Shearwater	*Puffinus pacificus*	276	750	5
Grey-faced Petrel	*Pterodroma gouldi*	9	11	
Flesh-footed Shearwater	*Puffinus carneipes*	8	9	
Kermadec Petrel	*Pterodroma neglecta*	5	5	
Fluttering Shearwater	*Puffinus gavia*	3	14	
Tahiti Petrel	*Pterodroma rostrate*	3	3	
Short-tailed Shearwater	*Ardenna tenuirostris*	2	2	
Providence Petrel	*Pterodroma solandri*	1	1	
Unidentified shearwater		4	163	
				Frigatebirds
Lesser Frigatebird	*Fregata ariel*	29	46	
Greater Frigatebird	*Fregata minor*	10	10	
Unknown frigatebird		8	14	
				Gannets and Boobies
Red-footed Booby	*Sula sula*	148	507	4
Brown Booby	*Sula leucogaster*	107	430	3
Masked Booby	*Sula dactylatra*	49	161	1

Table 4 Marine mammals observed during IN2019_V04 Whittaker, Coral Sea, 7 August – 2 September 2019. Occurrences is the number of observations per taxon, and individuals is the total numbers recorded per taxon for the voyage. The specific identity of the Minke Whale is awaiting confirmation.

Common name	Scientific name	Occurrences	Individuals
Short-finned Pilot Whale	*Globicephala macrorhynchus*	4	64
Bottle-nosed Dolphin	*Tursiops truncates*	4	58
Humpback Whale	*Megaptera novaeangliae*	2	3
(Dwarf?) Minke Whale	*Balaenoptera spp*	1	1
Unidentified dolphin		1	1
Unidentified whale		1	1

4. MARINE GEOMORPHOLOGY

4.1 Introduction

Spatial derivatives created from seafloor bathymetry data that describe the shape of the seafloor can be used to attribute seafloor geomorphology classes that can helps to explain the geological or oceanographic processes that created them. The spatial morphology of the seafloor is reported to influence the distribution, biomass, productivity and diversity of biota in seafloor canyons and seamounts. Seafloor morphology (or shape) can be used as a proxy for hard and rough habitat associations on the continental shelf and slope and this information can be used to explore how this influences preferential habitat for reef associated species.

The Marine Biodiversity Hub has supported research to develop quantitative methods to standardise the classification of geomorphic features on targeted surveys around Australia. Through 'Seamap Australia' and in collaboration with Geoscience Australia we are working towards the adoption of a standardised classification scheme to characterise geomorphological classes with Australian waters.

The geomorphological maps presented in this report will be used in additional analyses that will chart the broad scale distribution of the principal epibenthic assemblages across eastern Australia and in particular, to regions that exhibit offshore canyons and seamounts. The application of these spatial datasets will explore how geomorphic features (here used as proxy for the diversity of landscape fragments) support richer fauna and possibly more fish species.

4.2 Methods

The deliverables from this post survey report include spatial products and spatial derivatives for several distinct survey regions all pertaining to seamount features: 1) Calder- Fredrick seamount, 2) Kenn Seamount, 3) Sula Seamount, 4) Cassowary Seamount, 5) Mellish Seamount, 6) Fregetta Seamount and 7) Lexington Seamount. These results will form the basis of scientific manuscripts in 2020/2021. The transits between these sites will not be included in this analysis due to the data quality being reduced due to the increased vessel speed.

Acoustic backscatter data corresponding to these sites has not yet been analysed. Further data cleaning and processing will be required before this data is suitable to be analysed using existing techniques such as Geographic Object Based Image Analysis (GEOBIA). It is intended that the acoustic backscatter data will be analysed in conjunction with the seafloor sediment samples to create benthic habitat maps to complement the geomorphological classifications.

4.2.1 Bathymetric data processing

Each of the bathymetric surfaces was reprocessed in ArcGIS 10.2 to remove small NODATA gaps created as a result of multibeam data cleaning processes. A script called -FILL HOLES

IN RASTER- was executed for each of the layers using a 5 x 5 cell search radius to interpolate missing data. The final bathymetric grids are hosted on the AusSeabed website- http://www.ausseabed.gov.au/ . The final grids were produced with a cell size of 30 m standardised across all sites.

4.2.2 Bathymetric derivatives

For each of the seven sites within the Coral Sea AMP bathymetric derivatives were derived from the reprocessed bathymetric rasters and are listed in Table 5.

Table 5 Spatial layers derived from bathymetric grids.

Derivative	Variable description (3x3 pixel analysis extent unless specified below)	Software
Bathymetry	Depth (negative elevation) of the grid cell. Bathymetric product generated from ascii output file into grid with 30 m resolution	Spatial Analyst- ArcGIS 10.2.1
Slope	Slope denotes the maximum change in depth between each cell and the cells in an analysis neighbourhood. Calculated in degrees from horizontal (Wilson 2007).	Spatial Analyst- ArcGIS 10.2.1
Curvature	Seabed curvature defined as the derivative of the rate of change of the seabed. It is a quantifiable measure of the shape of the seabed surface.	Spatial Analyst- ArcGIS 10.2.1
Profile curvature	Profile curvature is a measure of the seabed in the direction of the slope of the seabed	Spatial Analyst- ArcGIS 10.2.1
Planiform curvature	Planar curvature is a measure of the seabed perpendicular to the slope direction of the seabed	Spatial Analyst- ArcGIS 10.2.1
Eastness (aspect)	Eastness is a value that reflects how much the aspect value deviates from 90 degrees.	Benthic Terrain Modeller Tool for ArcGIS
Northness (aspect)	Northness is a value that reflects how much the aspect value deviates from 0 degrees.	Benthic Terrain Modeller Tool for ArcGIS
Terrain ruggedness	This present the terrain ruggedness as the variation in three dimensional orientation of grid cells within a neighbourhood. This method effectively captures variability in slope and aspect in a single measure. Ruggedness values in the output raster can range from 0 (no terrain variation) to 1 (complex terrain variation).	Benthic Terrain Modeller Tool for ArcGIS

4.2.3 Geomorphological classification

For each of the survey regions a geomorphological classification was derived using the geomorphological classification scheme developed by Geoscience Australia (Nanson 2018). Geoscience Australia delineates three hierarchies in the classification scheme (Figure 52) beginning with Level 1) Provinces, Level 2) Surfaces and Level 3) Features. Provinces define the geographical location of the study region to be on the shelf, slope or rise determined by the depth and distance from shore.

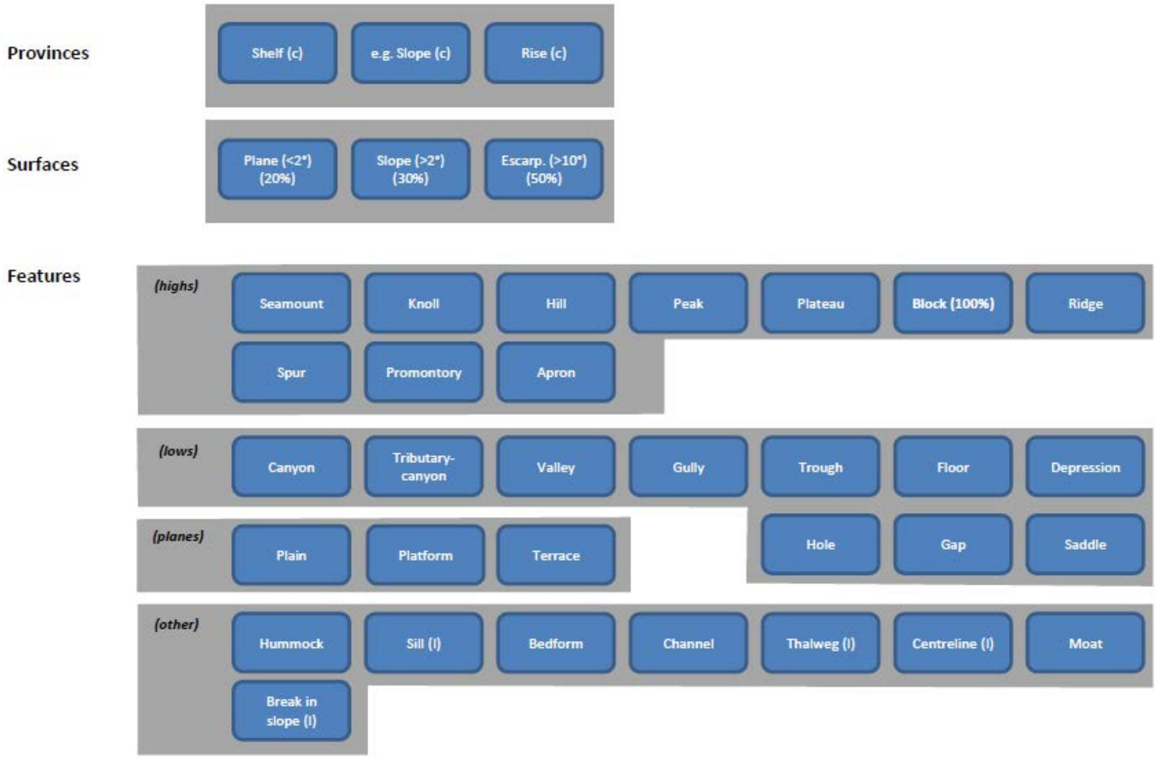
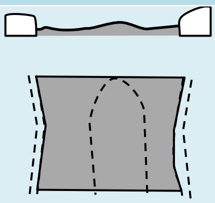


Figure 52 Proposed Geomorphological classification by Geoscience Australia (Nanson et al 2018).

The ‘Surface’ is defined by the slope of the grid cell. This was created in ArcGIS 10.2 by first creating a ‘slope’ layer and then using the ‘Raster Calculator’ to reclassify the grid cells based on the change in slope of each cell. A plane was defined as a cell with a slope between 0 and 2 degrees. A ‘slope’ was defined as a cell with a slope between 2 and 10 degrees and an ‘Escarpment’ is defined as a cell with a slope greater than 10 degrees.

Surfaces		
BGS listed term	**GA adopted definition**	
Plane	Level or gently undulating surface, which terminates at a break in slope, and can be part of the shelf or abyss (modified from AADC SCAR feature catalogue https://data.aad.gov.au/aadc/ftc/display_feature_type.cfm?feature_type_code=404) Contrast with elevated “platform” features and confined “floor” features.	

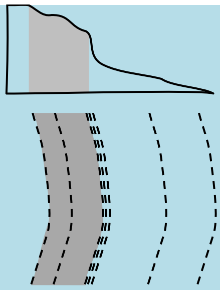
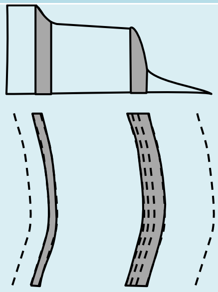
Slope	An inclined smooth to irregular surface typically 2-10 degrees.	
Escarpment	An elongated steep to vertical slope, predominantly > 10 degrees, and separating horizontal or sloping surfaces (modified from IHO).	

Figure 53 Geomorphology- Level 2- Surface classification.

Each of the bathymetric grids was processed to create a 'surface' layer which will be made available on the Seamap Australia website. A legend file has been created for the surface classification and this will be available with the raster file download package.

4.2.4 Method 2- TPI Based Landform Classification [SAGA]

Although a classification scheme exists, methods to extract the geomorphological features is the focus of ongoing work for this dataset by Lucieer and Beaman. Two different methods are being assessed for their accuracy and viability for processing and a manuscript comparing and contrasting these methods is in preparation.

In this report the geomorphological classification is generated using a modified method based on TPI based landform classification. The Topographic Position Index (TPI) calculation as proposed by Guisan et al. (1999) is implemented in the freeware SAGA- System for Automated Geoscientific Analysis [see: http://www.saga-gis.org/en/index.html *last accessed 09/04/2020*].

The parameters required for implementing this tool are listed in Table 6. The bathymetric grid (ArcGIS form) must be exported from ArcGIS as a 'floating point file' for input into SAGA- TAB- Tools:

[ArcGIS10.2- Toolbox- Conversion Tools- From Raster- Raster to Float]

The bathymetric.flt is then loaded into SAGA using the function:

[SAGA- Tool Library- Import/Export- GRIDS- Import ESRI Arc/Info Grid]

The bathymetric grid can be viewed by clicking on the TAB- Data.

The TPI Based Landform Classification can be found under the TAB- Tools- Terrain Analyses- Morphometry- TPI Based Landform Classification.

[GRID SYSTEM- Select the parameters of the study region- ELEVATION- input is bathymetric.flt file- LANDFORMS- <create>]

[OPTIONS- Radius <leave default- 0-100>]

[Distance Weighting- select- Gaussian and Exponential Weighting Bandwidth 75]

This option is selected in the Distance Weighting to try and overcome the variance (noise) in the bathymetric data layers and create a smoother result.

Table 6 Parameters for the tool: TPI Based Landform Classification in SAGA.

Parameters

Name	Type	Identifier	Description	Constraints
Input				
Elevation	Grid (input)	DEM		
Output				
Landforms	Grid (output)	LANDFORMS		
Options				
Radius	Value range	RADIUS_A	radius in map units	
Radius	Value range	RADIUS_B	radius in map units	
Weighting Function	Choice	DW_WEIGHTING		Available Choices: [0] no distance weighting [1] inverse distance to a power [2] exponential [3] gaussian weighting Default: 0
Inverse Distance Weighting Power	Floating point	DW_IDW_POWER		Minimum: 0.000000 Default: 1.000000
Inverse Distance Offset	Boolean	DW_IDW_OFFSET	Calculates weights for distance plus one, avoiding division by zero for zero distances	Default: 1
Gaussian and Exponential Weighting Bandwidth	Floating point	DW_BANDWIDTH		Minimum: 0.000000 Default: 75.000000

Fourteen maps (Figure 54- Figure 67) have been produced from the seven survey sites. The maps include both the Level 2- surface classification and the Level 3- geomorphology classification. Each site illustrates a seamount feature- and the fine scale geomorphology on the seamount is classified.

4.3 Results

4.3.1 Calder-Frederick Seamount

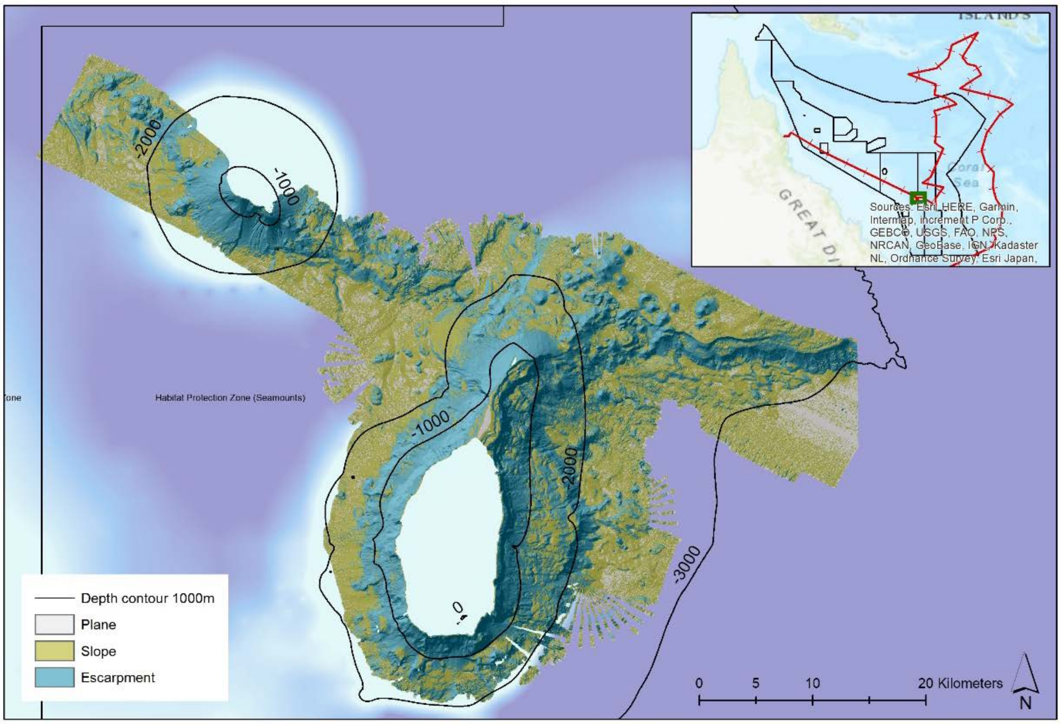


Figure 54 Surface classification of the Calder Frederick Seamount

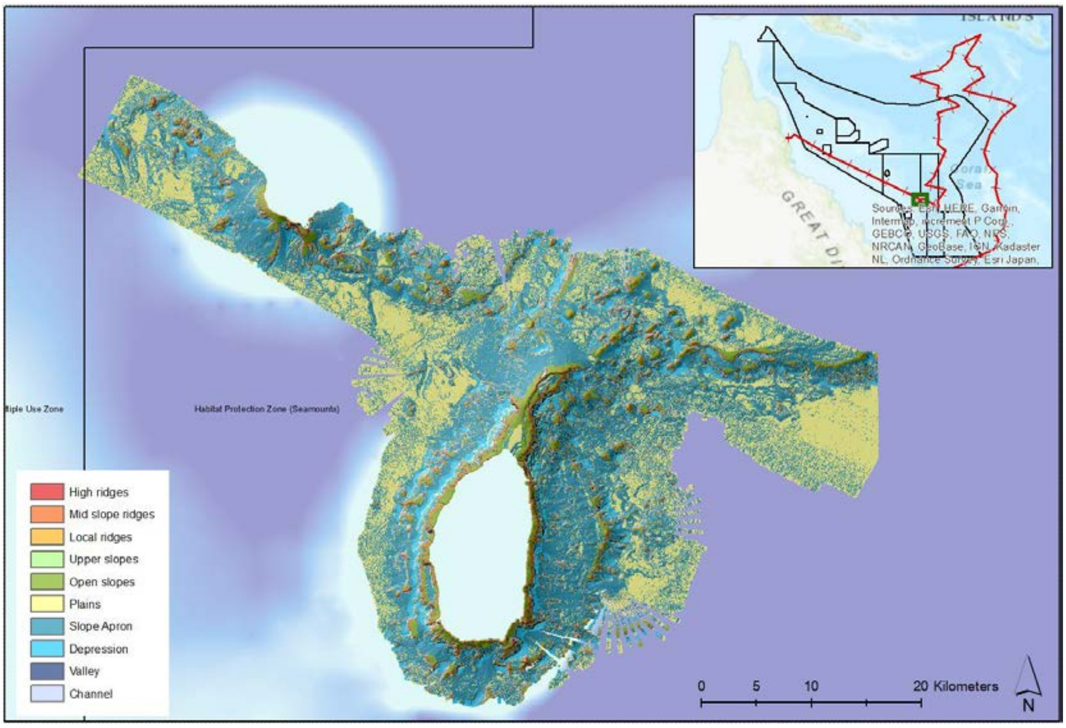


Figure 55 Geomorphology classification of the Calder Frederick Seamount

4.3.2 Kenn Seamount

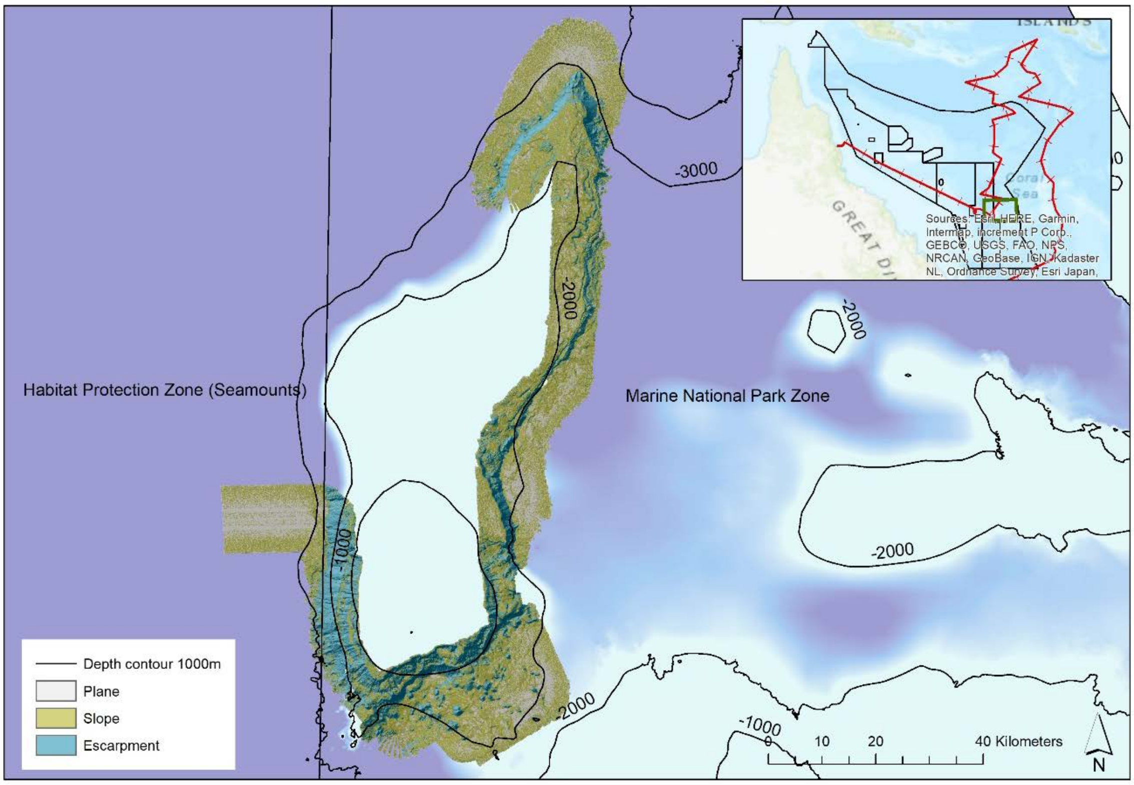


Figure 56 Surface classification of Kenn Seamount

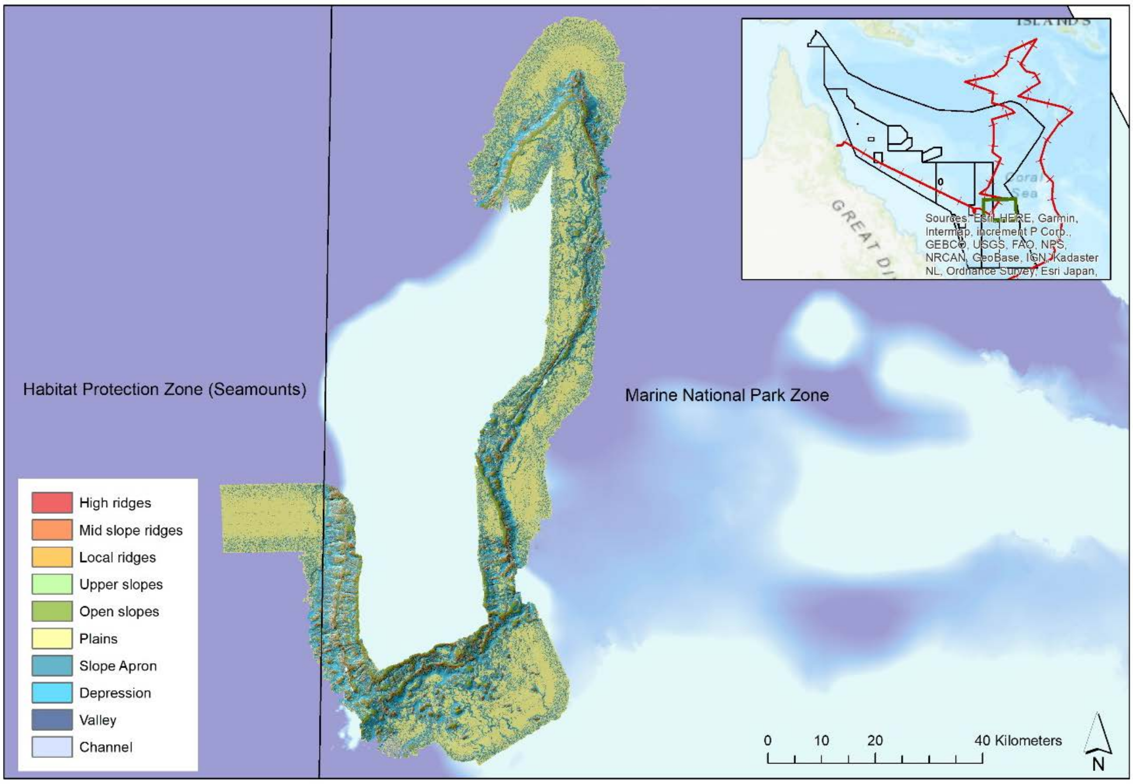


Figure 57 Geomorphology classification of Kenn Seamount

4.3.3 Sula Seamount

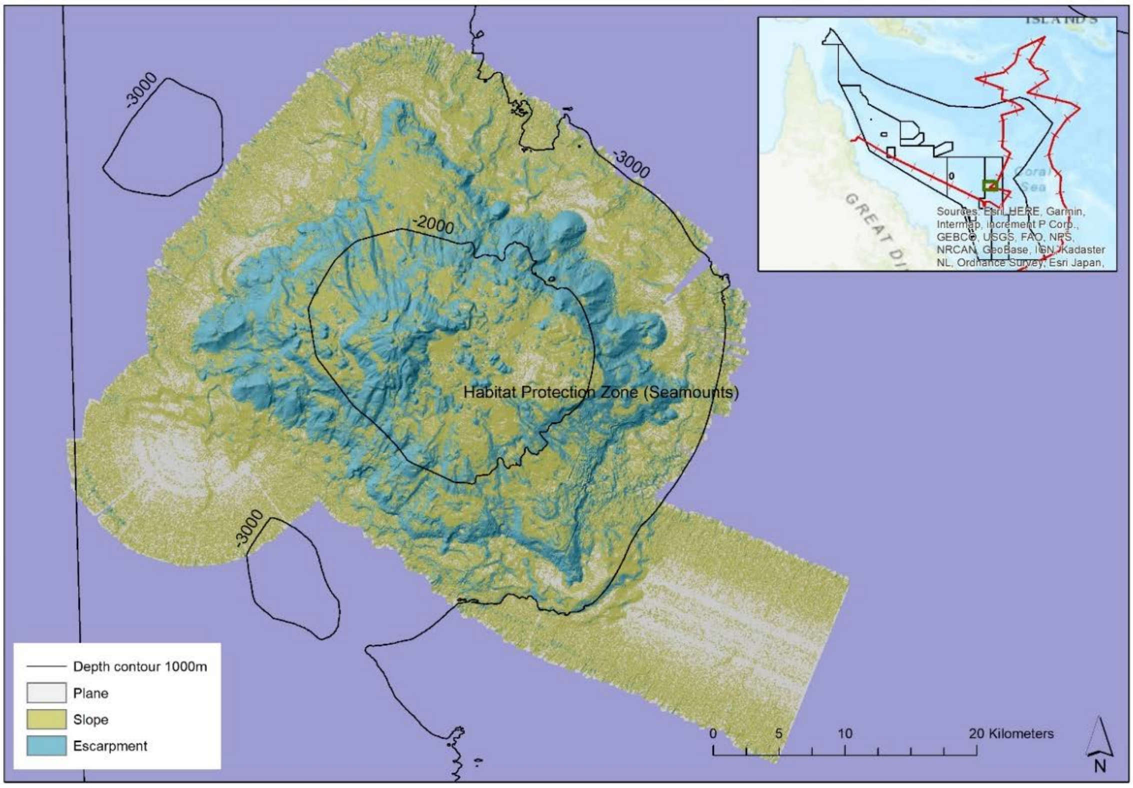


Figure 58 Surface classification of Sula Seamount

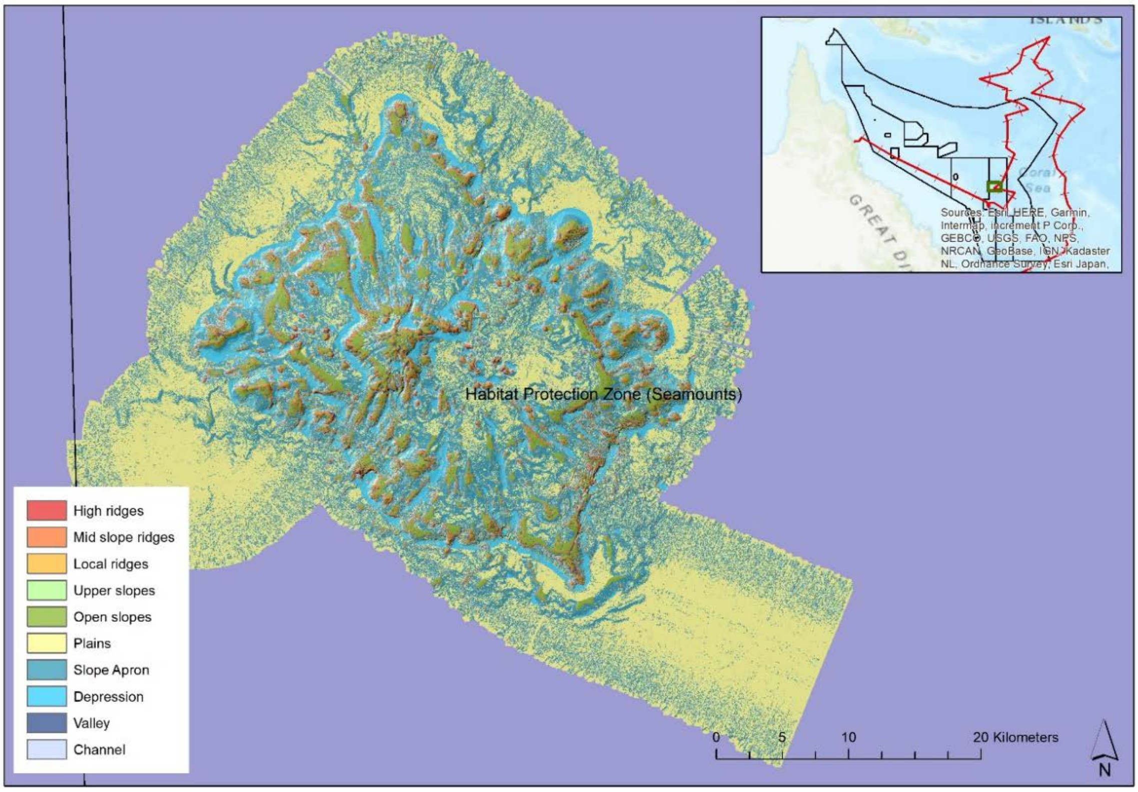


Figure 59 Geomorphology classification of Sula seamount

4.3.4 Cassowary Seamount

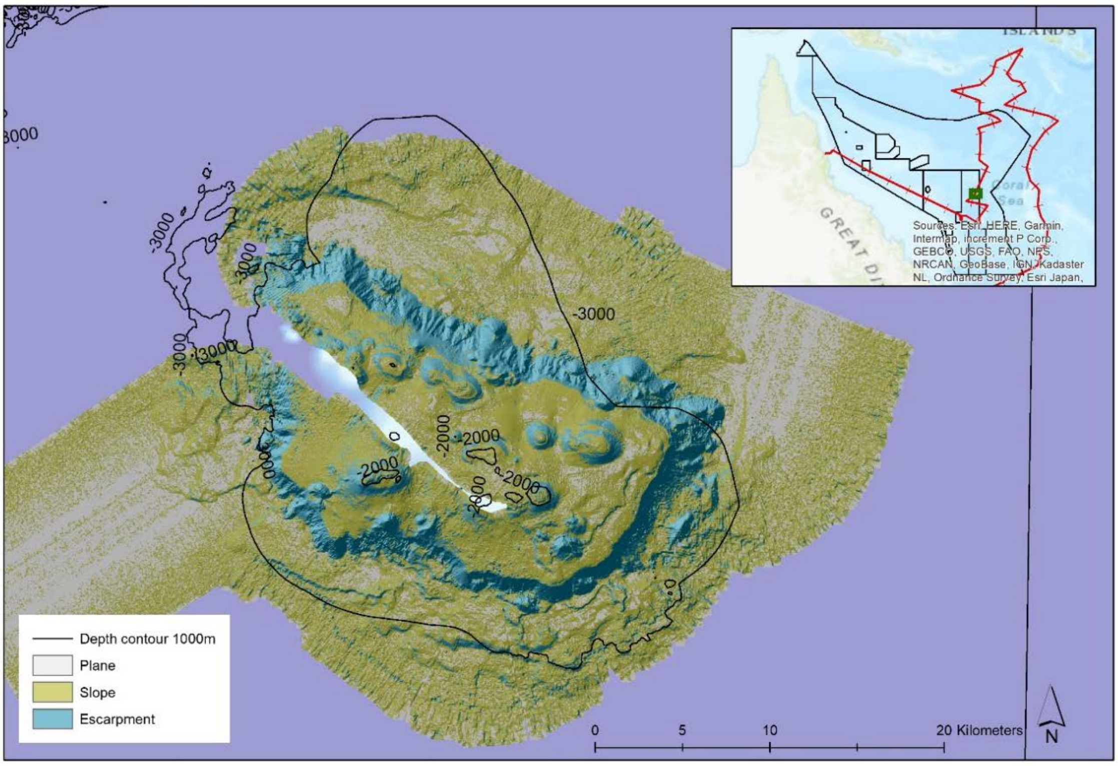


Figure 60 Surface classification of Cassowary Seamount

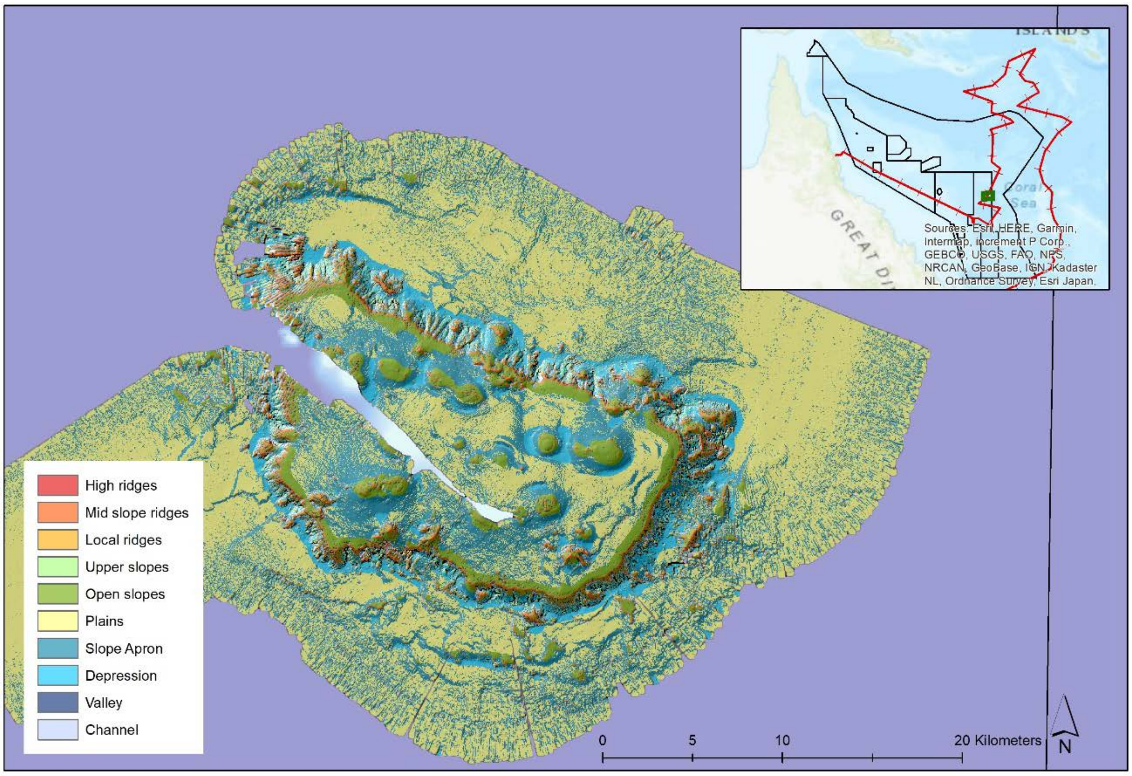


Figure 61 Geomorphology classification of Cassowary Seamount

4.3.5 Melish Seamount

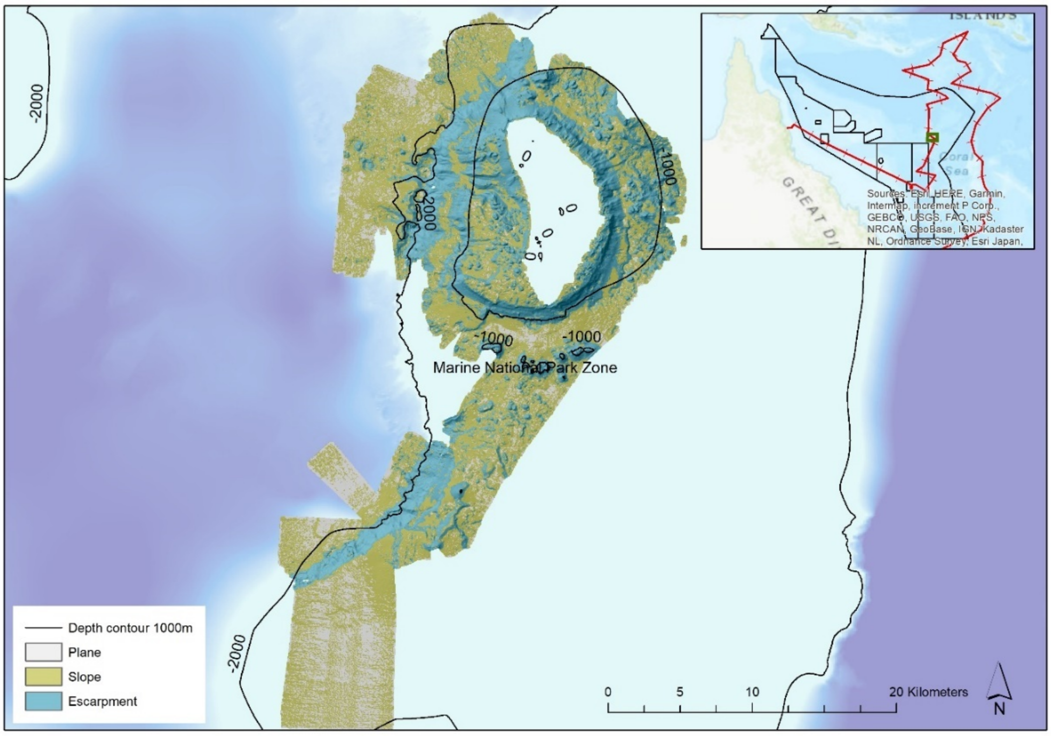


Figure 62 Surface classification of Mellish Seamount

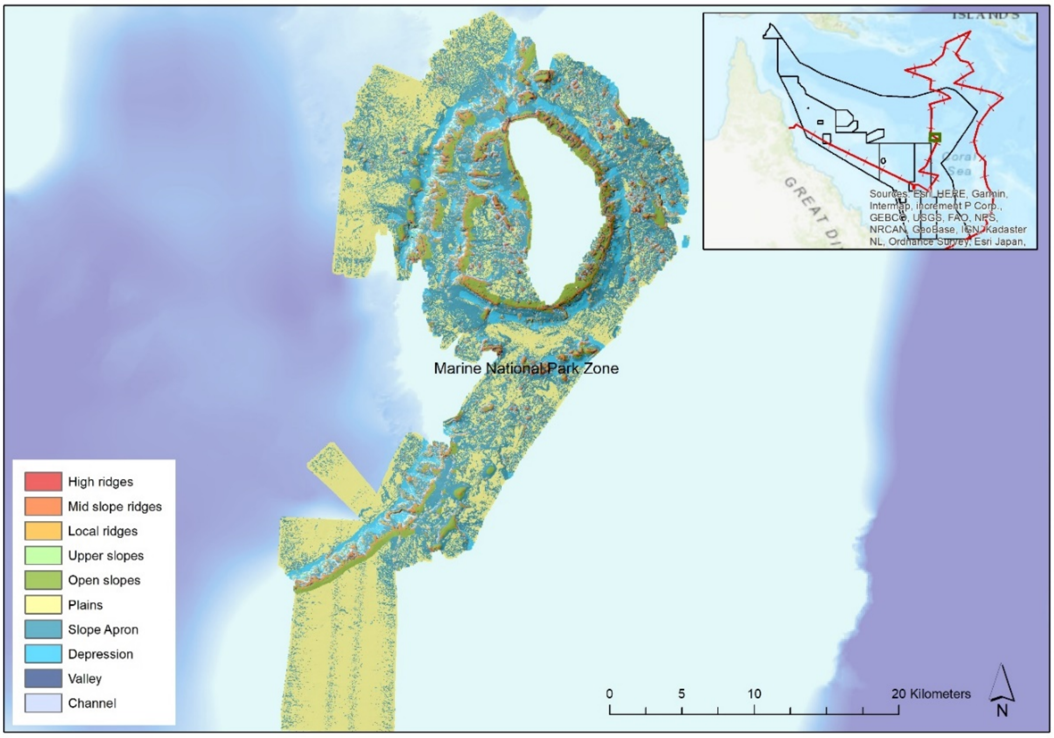


Figure 63 Geomorphology classification of Mellish Seamount

4.3.6 Fregetta Seamount

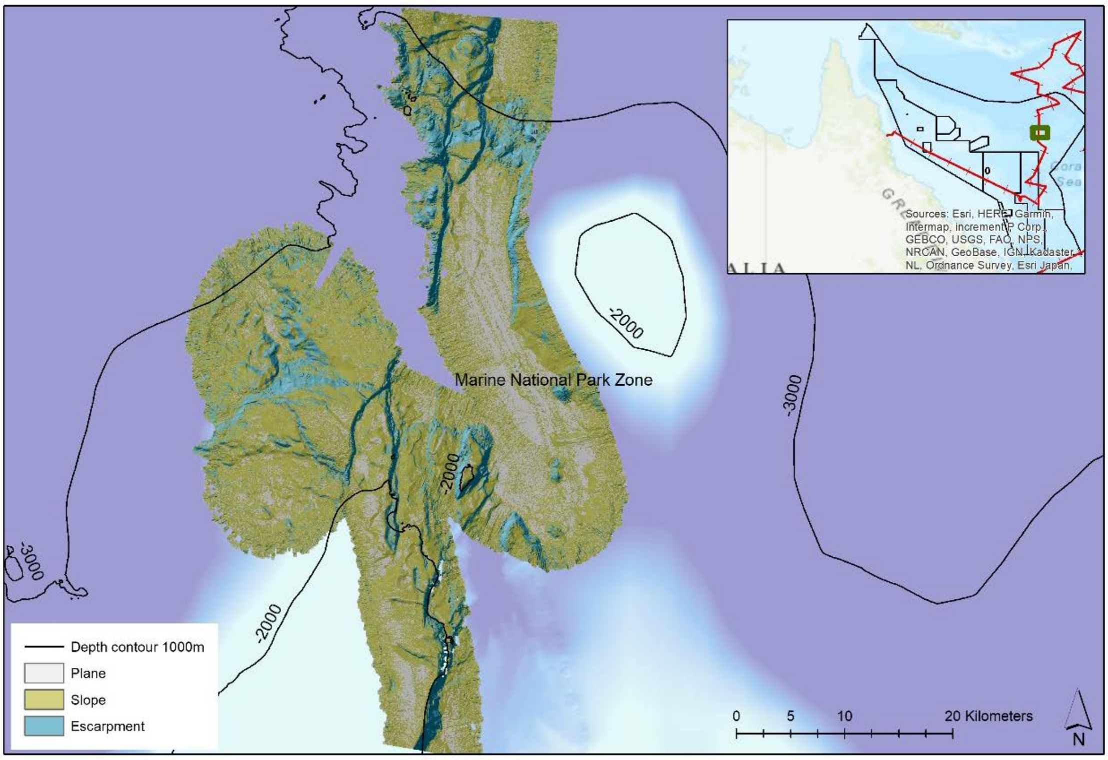


Figure 64 Surface classification of Fregetta Seamount

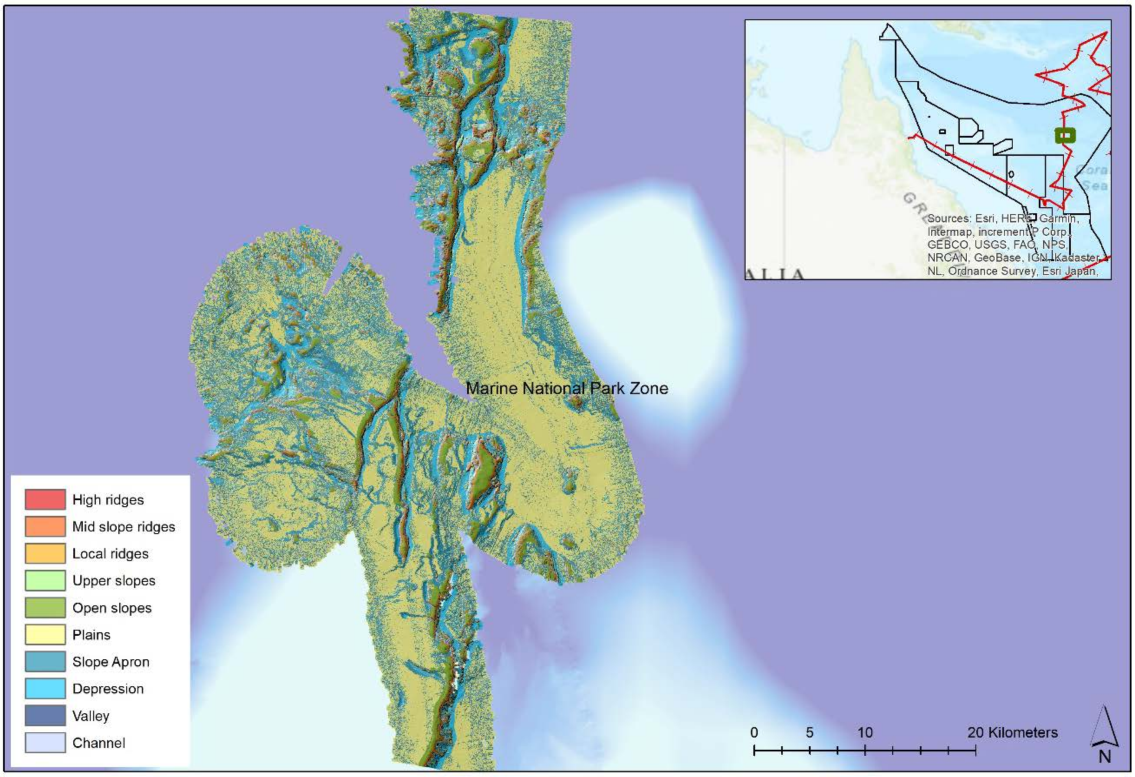


Figure 65 Geomorphological classification of Fregetta Seamount

4.3.7 Lexington Seamount

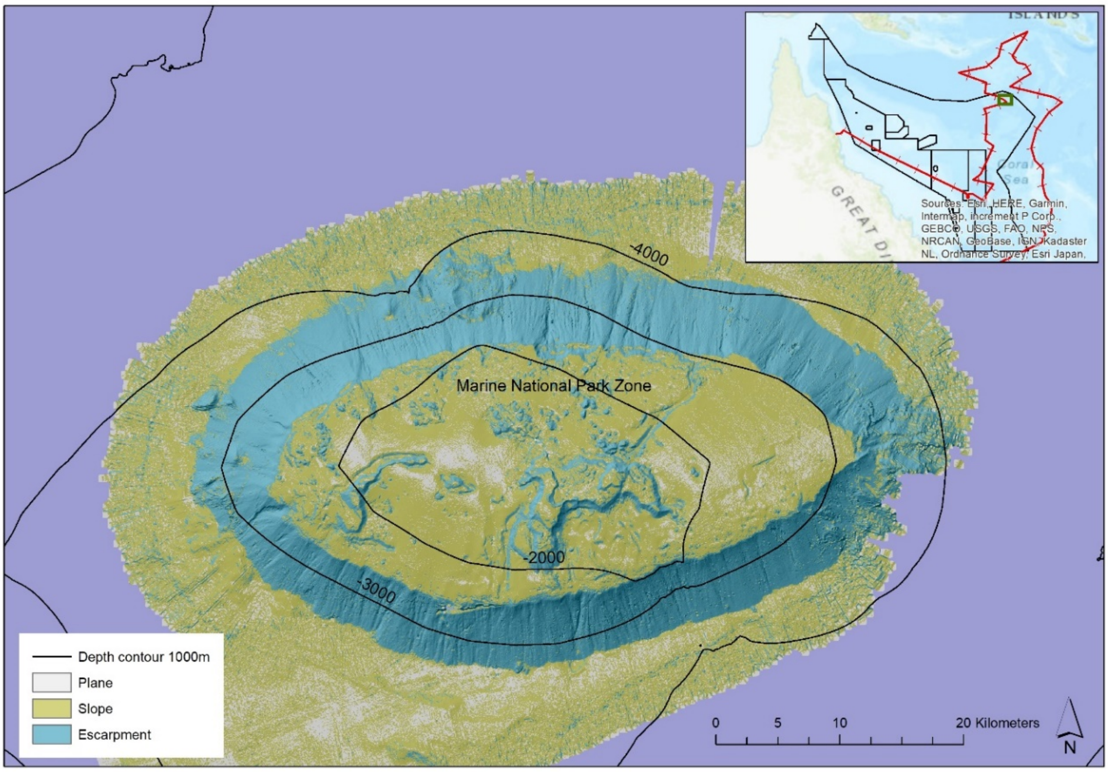


Figure 67 Surface classification of Lexington Seamount

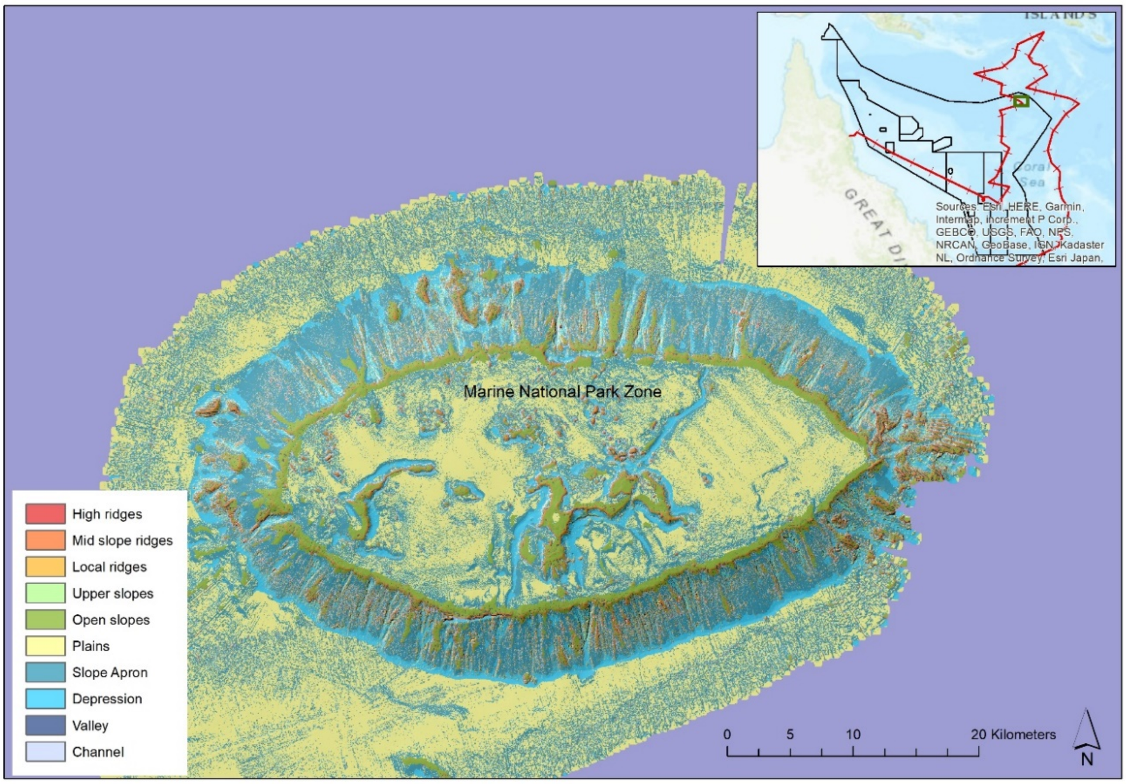


Figure 66 Geomorphological classification of Lexington Seamount

4.4 Discussion

There are several research outputs currently under preparation utilising the seafloor data collected on IN2019_V04 voyage. These include, but are not limited to:

- A research project to generate an understanding of seamount geomorphology and associated coral community structures specifically at Fredrick Reef and Kenn Reef. *This outcome will provide the data and evidence to qualify why these habitat protection zones are special.*
- Methods for extracting geomorphological classes from the seafloor data is the focus of current research conducted by Lucieer and Beaman. *This outcome will help to provide us with a nationally consistent method for which to process past and future MBES data from the Marine National Facility.*
- Single-beam and multi-beam water column acoustic data collected with the EK60 and ME70 systems continuously sampled during IN2019_VO4 is being analysed to reveal water column biota and characteristics at the seafloor interface that are relevant for seafloor habitat mapping (such as biomass load on the surface of the seafloor). These results will be contrasted and compared with data collected on the Investigator Voyage IN2017_V03 (*Sampling the Abyss*).
- Seismic profiles data from IN2019_V04 is being analysed to provide additional context to the nature of the near surface sediment and geological structure. These data will be re-examined to determine the nature of the veneer habitats which may be represented by seafloor expressions determining a geomorphic feature but to which a seafloor habitat needs to be discerned. These files will be used to generate cross-sections of the stratigraphy of the reefs, identifying reflectors that record episodes of reef growth/sediment accumulation, providing a baseline for this region for 2019.

5. CONCLUSIONS

The new baseline environmental and biodiversity data that was collected on IN2019_V04 will, in time, significantly increase our knowledge of the distribution and characteristics of key ecosystem features and seafloor biodiversity in deep regions of the Coral Sea Marine Park where little is known of the ecological significance of the remote seamounts and reefs that were surveyed. .

This collaborative survey explicitly addresses the Call to Action recommendations in the National Marine Science Plan (2015-2025), in particular, the need to establish national marine baselines and monitoring, facilitate coordinated national studies of marine ecosystems and develop marine science research training. Both IMAS and GA participate in the National Marine Science Committee (NMSC) and are contributing to the NMSC's recently formed National Baselines and Monitoring Working Group. We will adopt the Group's recommended nationally consistent approach to the development of baselines and establishment of monitoring sites and provide a project update for dissemination to NMSC member organisations.

Our survey data will greatly improve knowledge of the environmental assets in the Coral Sea Australian Marine Park, an area that is identified by Parks Australia as a priority for environmental asset inventories, baseline environmental data and monitoring. The Coral Sea AMP is of current national interest especially given the rezoning classifications released on the 12th of April 2018. This survey will help to establish potential future survey sites that set the baseline for monitoring and which can be revisited to detect future change in seafloor habitats and ecological communities.

Rock and sediment samples collected during voyage IN2019_V04 and shipped from Brisbane to Hobart with the support from the Marine Biodiversity Hub, form the basis of a number of on-going research projects, including recently funded ARC Discovery Project 200100966 “Eruption and disruption: how Earth’s deep interior and surface communicate”. These data will form the basis of a PhD project commencing in 2019 “Plume-driven uplift and subsidence offshore Eastern Australia and Zealandia”. The Marine Biodiversity Hub will be acknowledged in the research outputs of these projects and any other research and student projects that are undertaken utilising these samples.

Understanding the broad marine realms that surround Australia and providing ecological information that can better inform adaptation to the impacts of climate change are national priorities. The impact of research science conducted from this survey data will address these national goals but will also have broader significance internationally.

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Researcher Lucieer, was supported by the Marine Biodiversity Hub through funding from the Australian Government's National Environmental Science Program. The Marine Biodiversity Hub is funded by the Australian Government's National Environmental Science Program. Our goal is to assist decision-makers to understand, manage and conserve Australia's environment by funding world-class biodiversity science.

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