Schmidt Ocean Institute Post Expedition Report

Visioning the Coral Sea Marine Park

Chief Scientist Dr. Robin Beaman

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1 Overview

SOI Expedition ID	FK200429
Vessel	R/V *Falkor*
Expedition Name	Visioning the Coral Sea Marine Park
Expedition Dates	2020/04/29 - 2020/06/15
Departure Port	Cairns, Australia
Termination Port	Cairns, Australia
Ocean	South Pacific Ocean

1.0.1 Map of Expedition Location

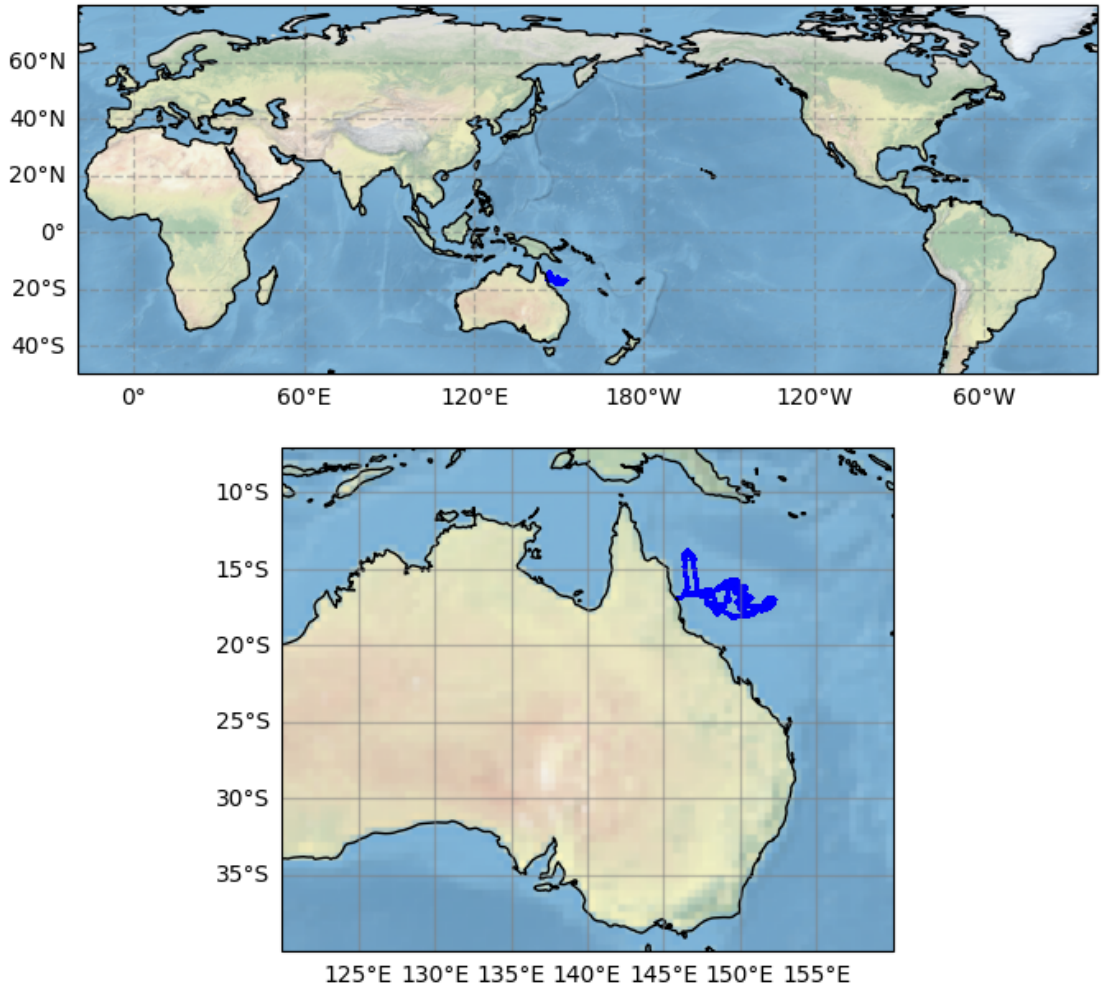

Figure 1: Map of the expedition location.

1.1 Expedition Overview

Within Australia's largest marine reserve, the Coral Sea Marine Park, lies the Queensland Plateau, one of the world's largest continental margin plateaus at ~280,000 square kilometers in area. The plateau supports ~30 emergent reefs including Osprey Reef, Lihou Reef, and Diamond Islets. There is a wide variety of reef systems present, ranging from large atolls and long banks to shallow coral pinnacles. While shallower areas of the reefs had been studied by SCUBA divers and small ROVs, little was known about the surrounding plateau in the deeper waters around these reef systems.

The Queensland Plateau is a submerged carbonate platform comparable in size to the Bahama Banks in the Northern Hemisphere. The plateau is bounded to the west by the 1200-2800 m deep Queensland Trough and to the south by the 1200-2400 m deep Townsville Trough, which separates the plateau from the adjacent Great Barrier Reef. The plateau is bounded to the north by the 4000-4800 m Coral Sea Basin (Figure 2).

The platform formed when the Coral Sea Basin opened in the Paleocene epoch about 60 Mya, splitting off fragments of continental lithosphere from Gondwana. Subsidence and drowning in the Middle to Late Eocene led to its present median depth of about ~1100 m. Reef growth commenced when the Australian plate moved into the tropics in the Early Miocene ~22 Mya, with ~15 percent of the surface of the plateau now occupied by shallow reefs. An unknown number of submerged (drowned) reefs exist on the plateau.

The expedition focused on conducting a multibeam survey around the steeper flanks of the ~30 emergent reefs, across areas of potentially submerged reefs and pinnacles on the deeper plateau surface and along several incised channels tens of km in length lying between the reefs. Another objective was to conduct ROV *SuBastian* dives at selected sites to groundtruth the multibeam data, aiming for full depth imagery profiles of the seafloor from the deeper bases of these reefs up into the shallower waters.

This expedition provided a novel look into the deeper waters of the Queensland Plateau, giving insight into the species that live there and creating new maps to better understand the geomorphology of the seafloor. Comprehensive mapping is critical to reveal the complete reef morphology from their base up to their shallower depths, and to understand the evolution of the reef system. The acquisition of new baseline mapping data and underwater imagery provided a unique window into the geological past and the present-day conditions of these mesophotic (twilight zone) and deeper cold-water coral ecosystems.

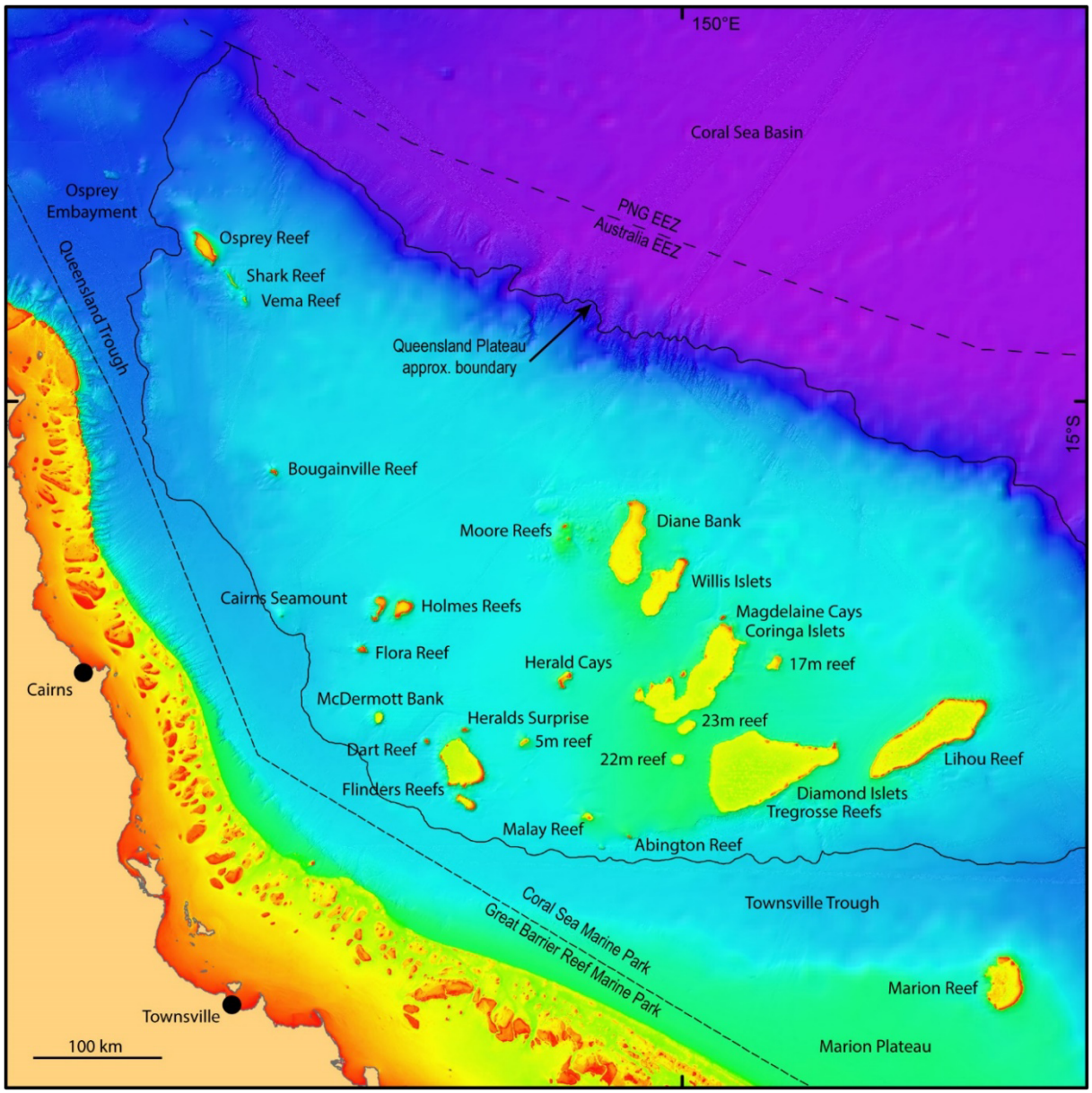

Figure 2: Map of the Queensland Plateau and reefs within the Coral Sea Marine Park.

1.2 Authorizations and Permitting

Permit Number	Permit Authority	Permit Focus
PA2019-00131-10-12	Australian Marine Park Activity Permit	Scientific Research using MBES, SBES, ADCP, SVP, XBT, CTD, ROV

1.3 Expedition Timeline

The expedition commenced on April 29, 2020, departing from Cairns, Australia and returned to Cairns, Australia, on June 12, 2020. The expedition was 45 days long.

1.4 Expedition Objectives

The primary objective of the expedition was to expand the characterization and understanding of deep-sea areas in the Coral Sea Marine Park by mapping in detail the steep reef flanks and seabed features of the surrounding Queensland Plateau surface. High-resolution mapping data were required to capture finer-scale features, such as wave-cut caves on the sides of these reefs, which can provide important insight into past sea levels. The mapping aimed for 100% coverage around these ~30 emergent reefs to reveal full reef flank profiles and whether gullies and landslides are common features on these reefs.

In addition to obtaining a detailed map of deep reef structures, ROV *SuBastian* was used to capture high-resolution imagery upwards along the steep reef flanks to examine how corals and other species group across large depth gradients. The new imagery data could be compared to previous work in the region to identify spatial patterns of deep-sea life. Further, the use of ROV *SuBastian* was a unique opportunity to groundtruth seafloor features revealed by multibeam data to understand their geological origin.

A secondary objective, due to the COVID restrictions in place at the time, was to test and conduct remote operations while all science participants remained onshore during the expedition. Extensive use was made of satellite communications and technologies such as text chat rooms, video conferencing platforms and remote monitoring platforms, to allow participants onshore to maintain situational awareness and help manage the expedition. Live YouTube/Facebook broadcasts of ROV *SuBastian* dives would continue with participants onshore narrating underwater imagery observations.

Therefore, the overall goal of the expedition was a step-change in understanding the geological evolution of the reefs of the Queensland Plateau, and for developing insight into the distribution of deeper reef habitats and biodiversity patterns in this frontier region.

2 Expedition Accomplishments

2.1 At-sea Accomplishments

2.1.1 Science

The *Falkor's* Kongsberg EM 302 and EM710 multibeam systems were run nearly continuously and concurrently wherever depths were suitable over the entire expedition, from Cairns to Cairns during April 29 to June 12, 2020 (Figure 3). Additionally, 14 ROV *SuBastian* dives were conducted (354 to 369). Table 1 shows the summary statistics of the expedition.

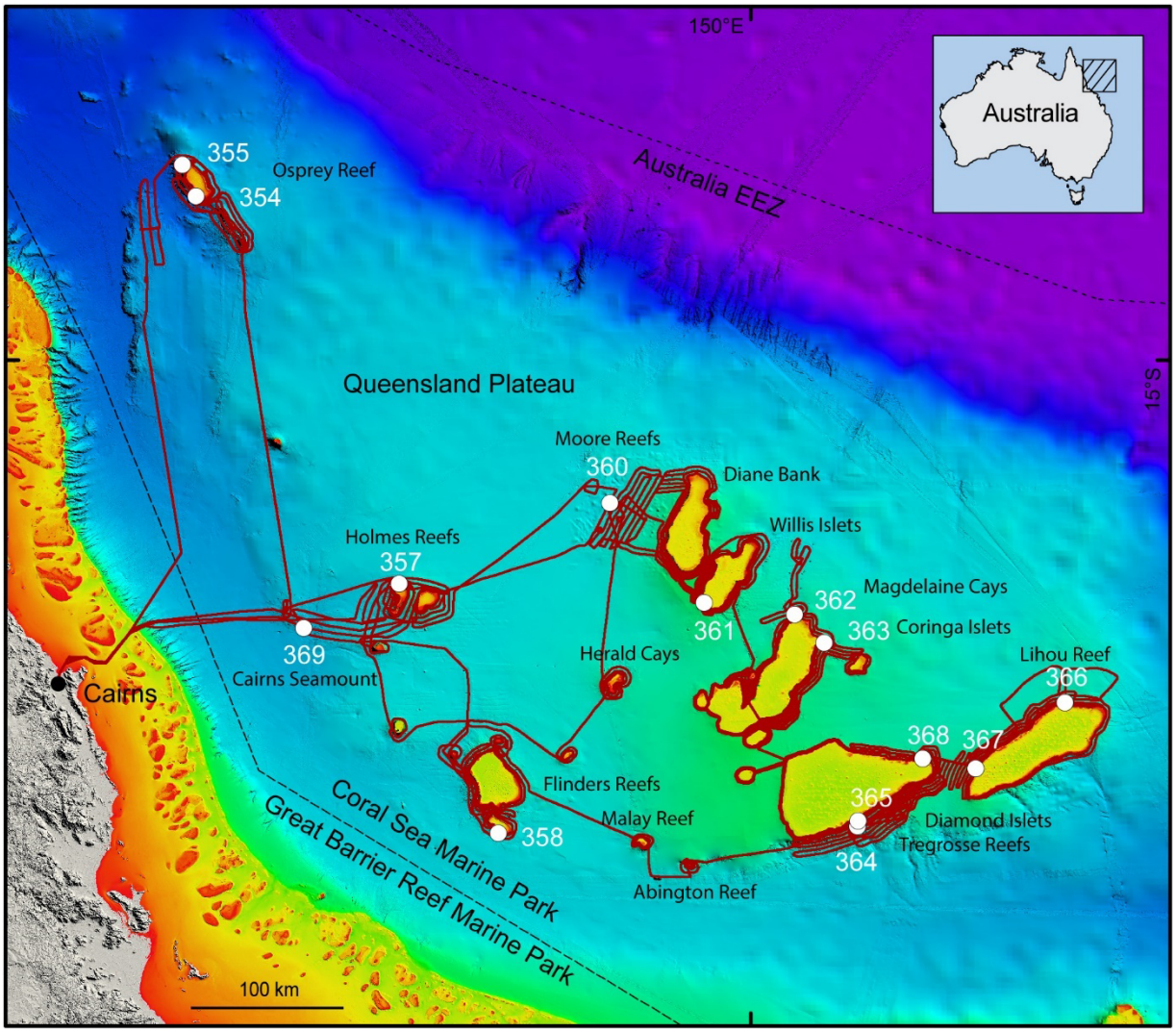

Figure 3. Regional map of the FK200429 expedition from Cairns to Cairns, April 29 to June 12, 2020. Brown line is the ship track. White dots are the ROV *SuBastian* dives.

Summary statistics	**Value**
Duration (days)	45
Ship track line (km)	13031
Multibeam coverage (sq km)	29007
Minimum depth (m)	10
Maximum depth (m)	2748
ROV dives	14
XBT casts	13
Data size (TB)	12

Table 1. Summary statistics of the expedition.

The following mapping descriptions around reefs are listed in sequence from the northern Queensland Plateau (Osprey Reef) then towards the southern-eastern plateau (Tregrosse Reefs/Diamond Islets and Lihou Reef), as the expedition progressed over the 45 days (Figure 4).

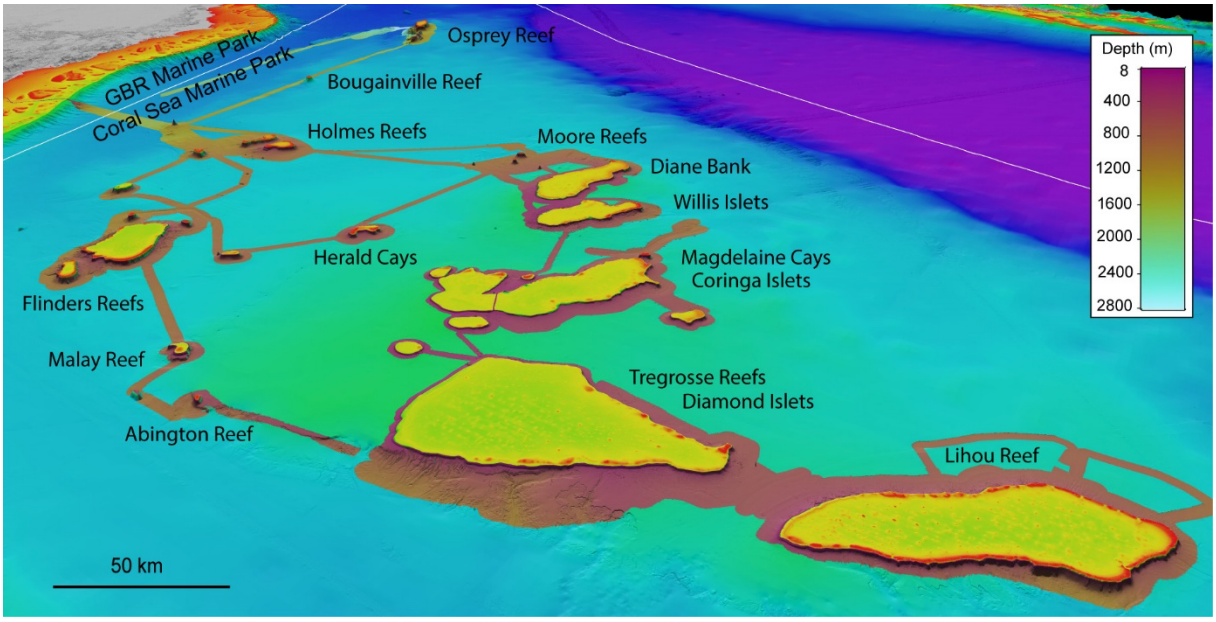

Figure 4. 3D view of the expedition study area, showing multibeam bathymetry coverage. Vertical exaggeration x3. Background 3D depth model (gbr100) from https://www.deepreef.org/2010/07/06/gbr-bathy/

Osprey Reef:

Osprey Reef is about 27 km long by 10 km wide rimmed with a shallow reef flat surrounding a lagoon to about 40 m depth. Long considered the 'jewel' in the Coral Sea Marine Park, the multibeam mapping aimed to map 100% around this iconic reef to discover its full steeper flank detail onto the surrounding plateau surface (Figure 5).

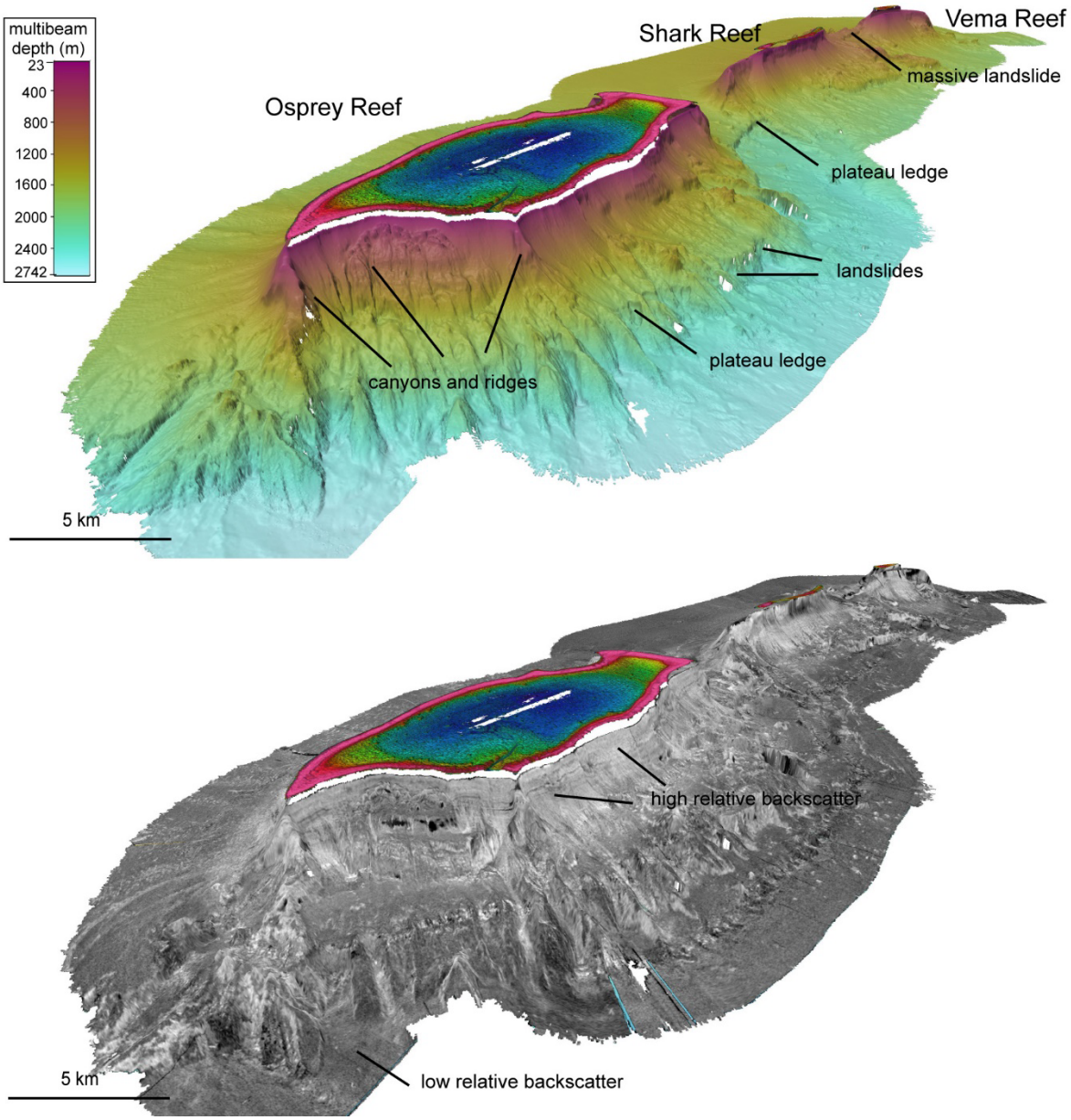

Figure 5. 3D view of Osprey Reef area: (top) multibeam bathymetry (bottom) multibeam backscatter. Shallow reef lidar bathymetry courtesy of the Australian Hydrographic Office. Vertical exaggeration x2.

The western side of Osprey Reef has incredibly dramatic relief with a near-vertical, relatively smooth cliff in the upper 300-500 m just below the shallow reef rim, followed by deeply incised canyons interspersed with eroded ridges over the full vertical height of the flanks down to ~2500 m. There appears to be general plateau ledge stretching around Osprey Reef at 1700-1900 m depth, before dropping to ~2500 m depth with steeper gradient cliffs that are the remains of numerous underwater landslide scarps.

On the eastern side of Osprey Reef, the vertical cliff continues around Osprey Reef to ~300 m just below the shallow reef rim, then angles out slightly as a relatively smooth, narrow shoulder to 500-600 m depth before the gradient becomes gentler as a wide smooth apron stretching onto the surrounding plateau surface at 1500-1600 m. On the south-eastern corner of Osprey Reef are the remains of a huge underwater landslide about 9 km long that has resulted in debris blocks stranded over 6 km from the reef on the deeper plateau, and with vertical scarps up to 600 m in height on the higher flanks.

About 15 km southeast of Osprey Reef is the narrow ~400 m wide Shark Reef and the smaller Vema Reef. Like the western side of Osprey Reef, these two reefs have an incredibly rugged seafloor topography with a general plateau ledge at 1400 m before steeper cliffs as the remains of landslides to the plateau surface at ~2000 m. The eastern side shows a massive underwater landslide 9 km long forming a saddle at ~900 m depth between these two reefs, with the remains of debris blocks up to 2 km in size.

Cairns Seamount:

The closest Queensland Plateau reef to mainland Australia is the Cairns Seamount, lying 150 km northeast from Cairns (Figure 6). The mapping revealed a nearly perfectly conical drowned reef with a small 'cap' about 500 m long by 300 m wide and a shoal depth of 37 m. This cap has steep sides to 200 m depth then a gentler gradient down to general plateau depths of 1100-1200 m, incised with small vertical gullies. On the southern flank is the subtle remains of a landslide scarp at 800 m depth.

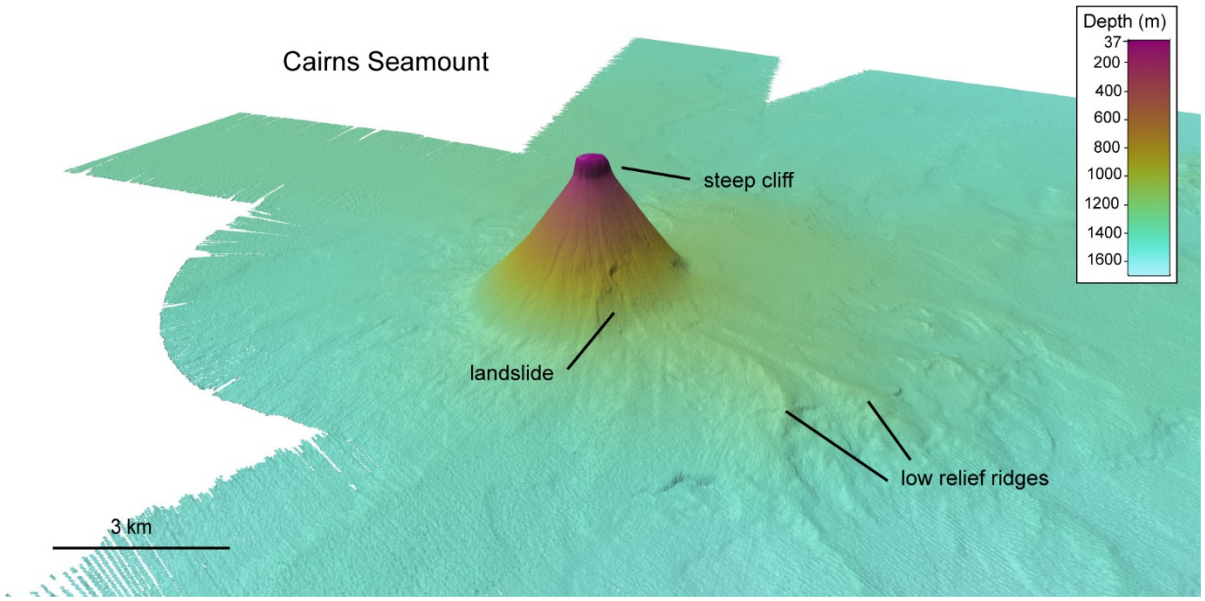

Figure 6. 3D view of the Cairns Seamount. Vertical exaggeration x2.

Holmes Reefs:

With prevailing winds and currents westerly-going, the leeward flanks of the Holmes and Flora reefs have many small gullies between ~400-700 m draining into fewer larger channels, some with levee banks, down to 1200 m depth and up to 15 km away (Figure 7). Many channels have dunes running down their axes at wavelengths of 50-100 m with heights of ~2 m, indicating currents are directing sediments down the channels forming into dune bedforms. About 10 km south of East Holmes Reef lie a cluster of conical drowned reefs ranging 140-335 m tall in depths 885-1020 m on the plateau.

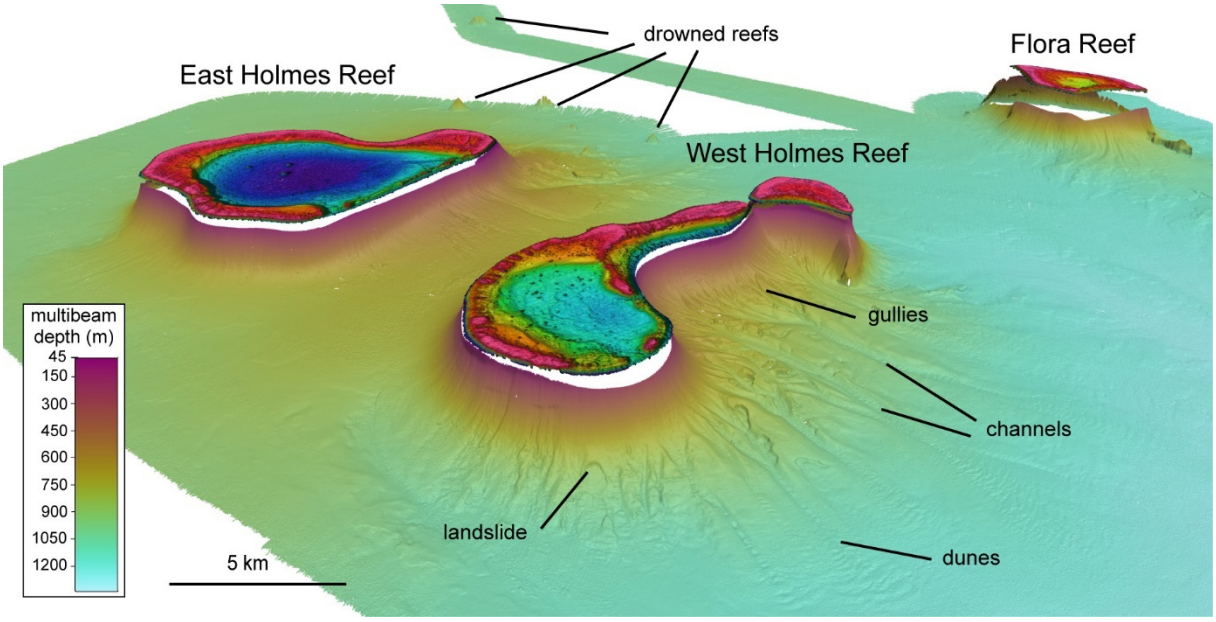

Figure 7. 3D view of West and East Holmes Reefs and Flora Reef. Shallow reef lidar bathymetry courtesy of the Australian Hydrographic Office. Vertical exaggeration x3.

Herald Cays:

Both the western and eastern longer side flanks of Herald Cays have numerous small gullies starting around 200 m as tributaries draining into larger channels which may extend over 6 km distance from the reef (Figure 8). These deeper channels show low relief ~2 m dunes within the channel axes. On the southern and northern flanks are the remains of landslides shown as steep scarps across the full ~600 m depth range. Downslope are extensive debris block fields showing reef blocks stranded up to 5 km from the reef.

The surrounding deeper plateau has erosional cut terraces in places, about 60 m high with 10 m deep moats scoured at the bases of the terraces. About 45 km southwest of Herald Cays is an unnamed shallow reef, where the new mapping data revealed another tall conical-shaped drowned reef, 569 m in height with a shoal depth of 276 m.

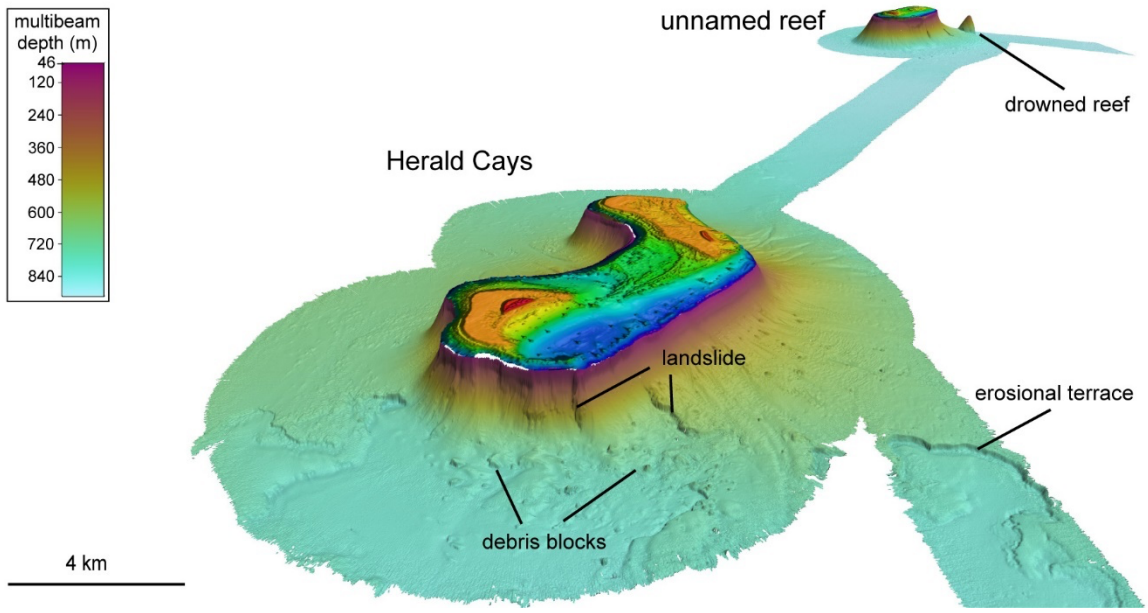

Figure 8. 3D view of Herald Cays and unnamed reef. Shallow reef lidar bathymetry courtesy of the Australian Hydrographic Office. Vertical exaggeration x3.

Flinders Reefs:

The Flinders Reefs are spectacular coral atolls, with the north reef about 38 km long by 30 km, and the south reef 16 km long by 7 km wide (Figure 9). Both are rimmed by a shallow reef flat around 55-65 m deep lagoons, together with numerous 20-40 m high pinnacles. North of the Flinders Reefs are the smaller Dart Reef and Heralds Surprise. Map data around this reef complex revealed an unusual ~1 km wide 40 m deep channel. The head lies 9 km north of Heralds Surprise in 910 m depth, draining westerly for 20 km then bends southwesterly and continues for another 30 km past Dart Reef.

The extensive flank areas of these four reefs show a wide variety of flank erosion features from landscape scarps up to 4 km across and extensive debris block fields downslope of these landslides, to deeply incising channels cut into the flanks leaving prominent ridges between the channels. Dunes appear both within channel axes and in places on the seafloor around and between these reefs. Erosional terraces 40-50 m high are also cut into the plateau surface lying between north and south Flinders Reefs.

The backscatter data clearly shows high reflectance data for the relatively steep upper flanks to 400 m depth, transitioning to low reflectance data for general lower flanks, interspersed with high reflectance landslide scarps and the channels cutting across the lower flanks. The scattered debris blocks and individual boulders also show up as high reflectance data against the background low reflectance data of the plateau surface.

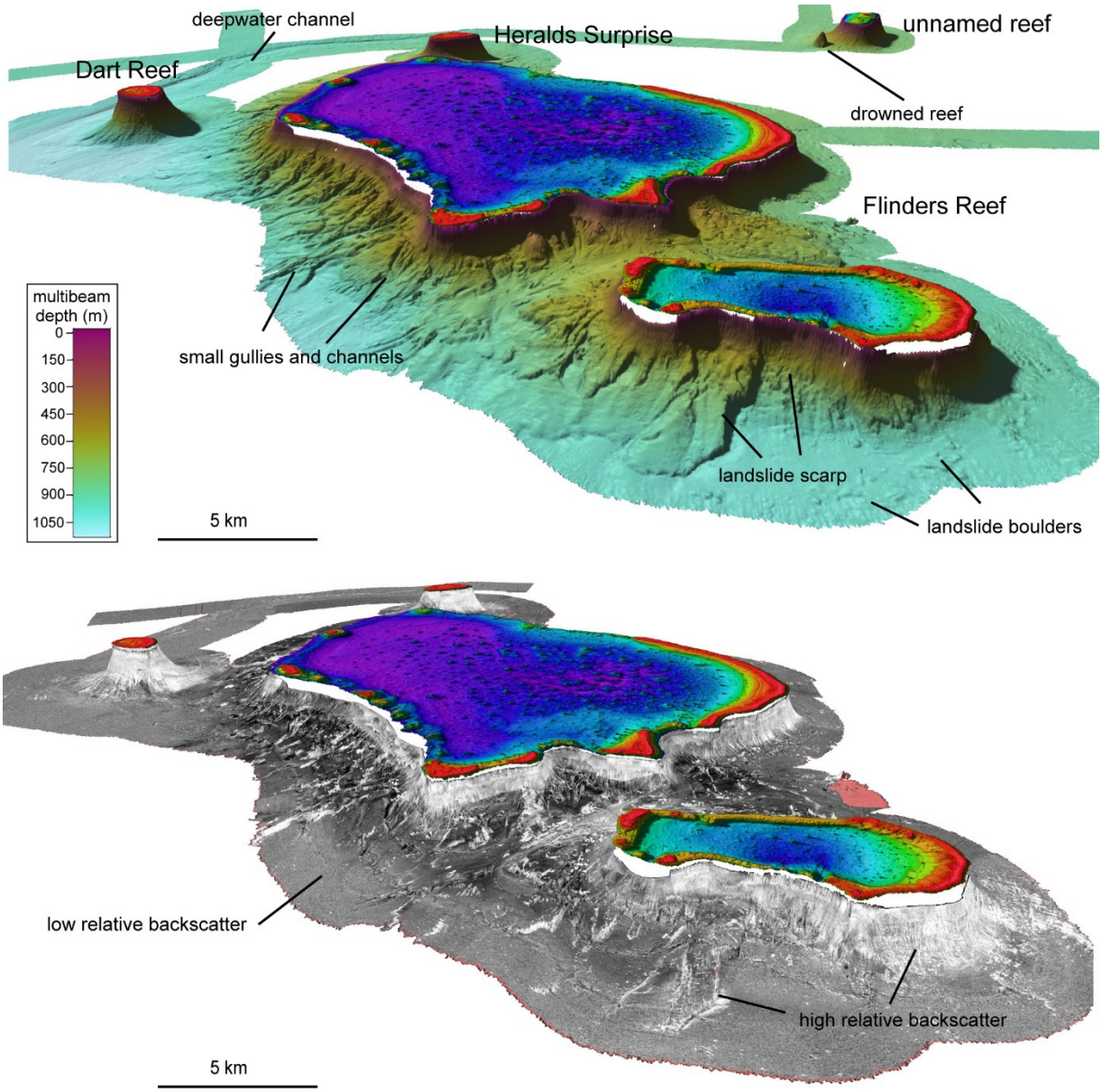

Figure 9. 3D view of Flinders Reefs area: (top) multibeam bathymetry; (bottom) multibeam backscatter. Shallow reef lidar bathymetry courtesy of the Australian Hydrographic Office. Vertical exaggeration X3.

Willis Islets:

The two large banks of Willis Islets and Diane Bank are 54 km long by 24 km wide, and 66 km by 24 km wide, respectively (Figure 10). These banks are not fully rimmed by shallow reef flats but are generally more open to the surrounding waters on their western sides. Lagoon depths are about 50 m and dotted with ~20 m tall pinnacles. Willis Islets is the site of the only human habitation with a meteorological station.

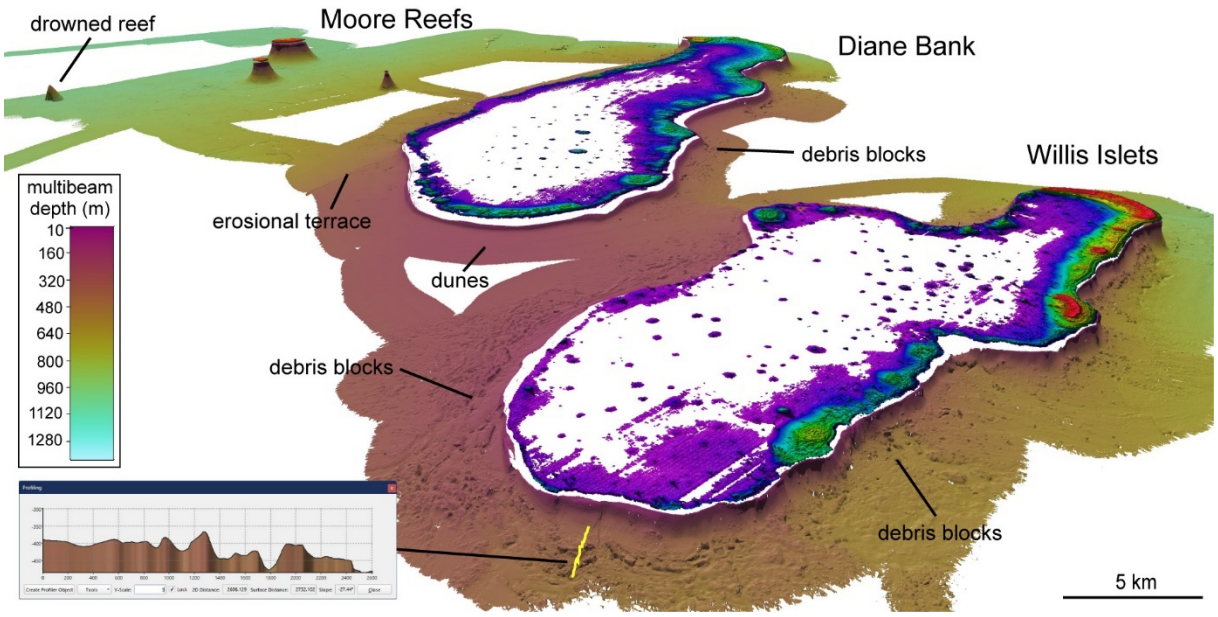

Figure 10. 3D view of Willis Islets, Diane Banks and Moore Reefs. Shallow reef lidar bathymetry courtesy of the Australian Hydrographic Office. Vertical exaggeration X3.

The entire perimeter of Willis Islets shows catastrophic dismantling of the steep flanks through landslides resulting in extensive debris block fields that stretch to over 9 km from the reef. Debris block fields appear chaotic, however, in places showing multiple parallel lines of blocks as successive flank dismantling has pushed the previous blocks farther downslope. Some blocks are quite intact and linear, over 1.5 km long and up to 60 m tall, and can be traced back to the shape of the landscape scarp above them.

Diane Bank does not have the same extensive dismantling as Willis Islets but still very prominent around the perimeter particularly on the western side, interspersed with gullies and channels draining down the flanks to depths of ~550 m. The southern side of Diane Bank is remarkably smooth, almost devoid of any debris blocks, instead covered in a vast dune field as westerly-flowing oceanic currents are forced between these banks. Dune crests have wavelengths of 120-140 m and up to 5 m in height.

Magdelaine Cays:

Magdelaine Cays and Coringa Islets are part of the same large bank system, together with four unnamed shallow reefs in close (less than 5 km distance) proximity (Figure 11). This large complex bank is about 90 km long by up to 50 km wide. Shallow reef flats generally rim only the northern half of this bank, with the southern half of the bank open to deeper waters. Lagoon depths are ~50 m and interspersed with 20-30 m tall pinnacles. The close unnamed reefs are themselves quite large at up to 15 km across.

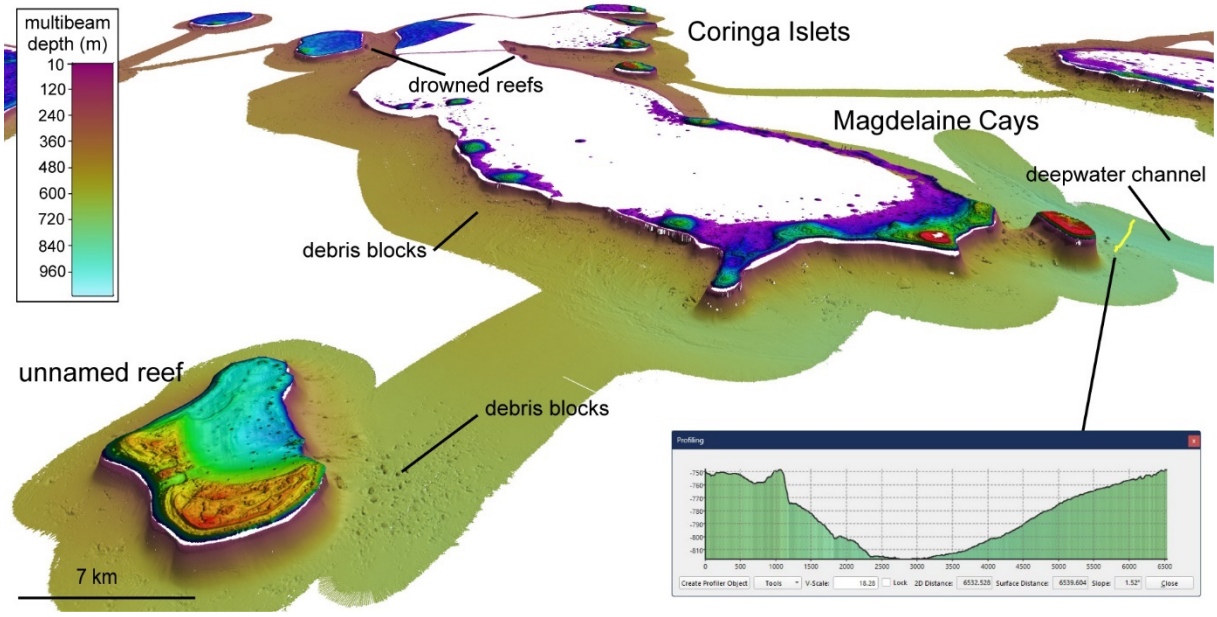

Figure 11. 3D view of Magdelaine Cays and Coringa Islets. Shallow reef lidar bathymetry courtesy of the Australian Hydrographic Office. Vertical exaggeration X3.

Extensive debris block fields again feature on the downslope flanks of Magdelaine Cays and Coringa Islets, appearing like a 'halo' of disintegrated chaotic boulders surrounding the bank. Debris blocks can extend up to 10 km distance from the reef edge demonstrating significant momentum at the time of reef flank collapse. Landslide scarps are clearly seen on the flank over the full depth range of ~300-400 m and in places can be over 7 km long, leaving wide fields of boulders 100s m long and up to 20-30 m high.

An unusual low-gradient deepwater channel lies on the northwestern side of Magdelaine Cays bank, formed by sediments draining and eroding into the broad passage between this bank and Willis Islets. This deepwater channel can be traced for over 60 km distance to the limit of the map data in a northerly direction across the Queensland Plateau. The channel is about 1 km wide at the head and up to 30-40 m deep, gradually becoming wider to ~5 km across at the limit of the map data.

This complex Magdelaine Cays and Coringa Islets bank also has five conical-shaped drowned reefs growing on the steep flanks themselves, or lying just at the base of the flanks and offset slightly by several 100 m distance from the shallow reef edge. These drowned reefs range in vertical height from 182 to 209 m tall, with base dimensions of between 360 to 1000 m wide. All five drowned reefs come within about 30 m of the sea surface thus posing a danger to the surface navigation of vessels transiting close by.

Diamond Islets/Tregrosse Reefs:

Diamond Islets and Tregrosse Reefs are part of the same large bank (Figure 11). Together with Lihou Reef, these are the largest banks/atolls on the Queensland Plateau

at about 100 km long and up to 50 km wide, and also in the group of the top 20 largest atolls in the world. Lihou Reef is nearly fully rimmed by a shallow reef flat. The Diamond Islets/Tregrosse Reefs bank is only partially rimmed by shallow reefs on the eastern half. Lagoon depths of both these large banks/atolls are about 50-65 m and peppered with numerous 20-40 m high pinnacles.

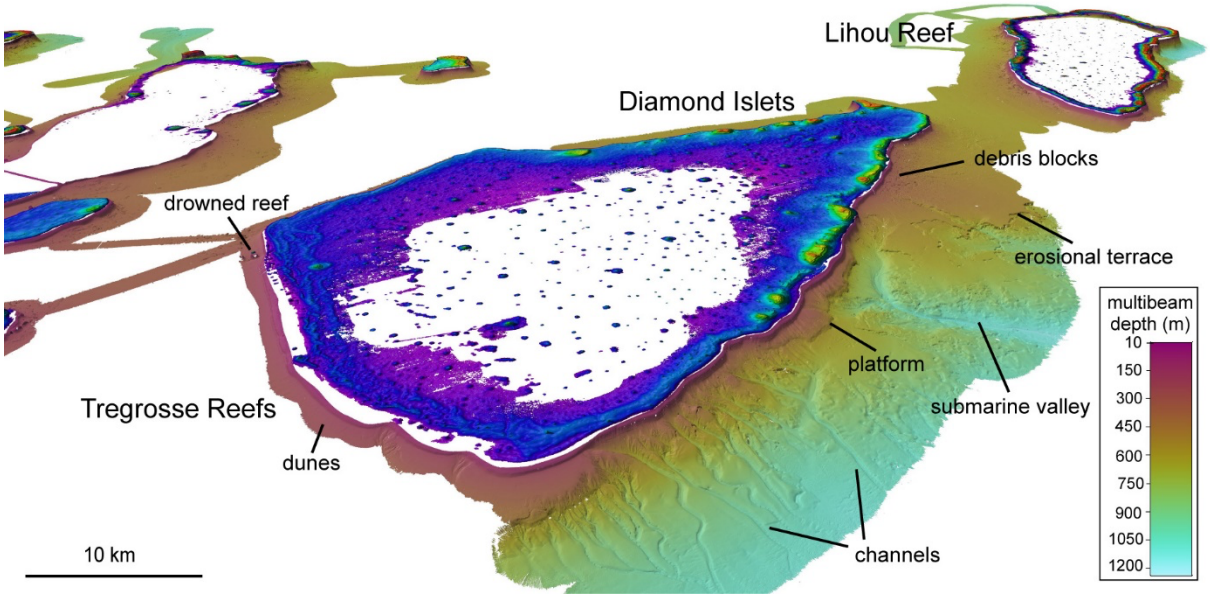

Figure 12. 3D view of Tregrosse Reefs/Diamond Islets and Lihou Reef. Shallow reef lidar bathymetry courtesy of Australian Hydrographic Office. Vertical exaggeration X3.

The southern flank of Diamond Islets/Tregrosse Reefs is heavily incised by channels and includes several large submarine valleys draining sediments from the reef edge. The large 'Y-shaped' valley in the middle, incising up to ~100 m deep into the broader flank, can be traced over 30 km distance to the limit of the map data. Upslope from the valley is a prominent platform in 250-450 m and nearly 3 km wide, before dropping steeply to the broader plateau surface and the head of the valley in 600-700 m depth.

Both Diamond Islets/Tregrosse Reefs and Lihou Reef are heavily affected by underwater landslides including obvious sections up to 5 km long that have collapsed and left parallel ridges of rock close to the scarp and then vast debris block fields downslope of these landslides. A conical drowned reef is located on the western flank of Tregrosse Reefs, about 210 m tall and coming to within ~30 m of the sea surface. On the deeper western plateau in depths greater than ~200 m are dunes that wrap around the reefs.

2.1.2 ROV

Fourteen (14) ROV *SuBastian* dives were conducted during the expedition. All dives were live streamed on YouTube and Facebook to a world-wide audience. With the

entire science team ashore due to COVID restrictions, this meant that satellite communications and production software were vital to allow scientists ashore to observe dives and allow commentary in real-time. The Cruise Records below summarizes each dive and includes links to the YouTube videos. Figure 13 shows some examples of marine life found during the dives.

Dive	Location	Start dive (UTC)	Latitude	Longitude	Depth (m)	Time (h:m)
354	SW Osprey Reef	2020-05-01T03:20:50	-14.004836	146.618255	1564	06:27
355	NW Osprey Reef	2020-05-01T23:33:34	-13.810926	146.534307	1011	06:44
357	NW Holmes Reef	2020-05-07T00:05:04	-16.365981	147.855037	884	06:07
358	S Flinders Reefs	2020-05-09T22:07:46	-17.886282	148.460425	1006	06:40
360	NW Moore Reefs	2020-05-21T23:54:41	-15.873805	149.139348	944	07:17
361	SW Willis Islets	2020-05-22T23:03:18	-16.479168	149.711966	260	02:14
362	N Magdelaine Cays	2020-05-25T22:07:39	-16.553094	150.264997	650	05:04
363	NE Magdelaine Cays	2020-05-28T23:38:19	-16.725032	150.443348	571	08:08
364	S Diamond Islets	2020-05-31T22:57:59	-17.841545	150.649087	935	08:18
365	S Diamond Islets	2020-06-01T23:59:53	-17.811004	150.649451	685	08:14
366	NE Lihou Reef	2020-06-06T22:17:21	-17.088204	151.911874	562	07:42
367	NW Lihou Reef	2020-06-07T22:01:14	-17.488722	151.369093	391	04:58
368	NE Diamond Islets	2020-06-08T22:42:11	-17.428597	151.043666	549	06:00
369	SE Cairns Seamount	2020-06-10T22:07:47	-16.636270	147.271872	1548	07:21

Table 2. Summary of the ROV *SuBastian* dives during the FK200429 expedition.

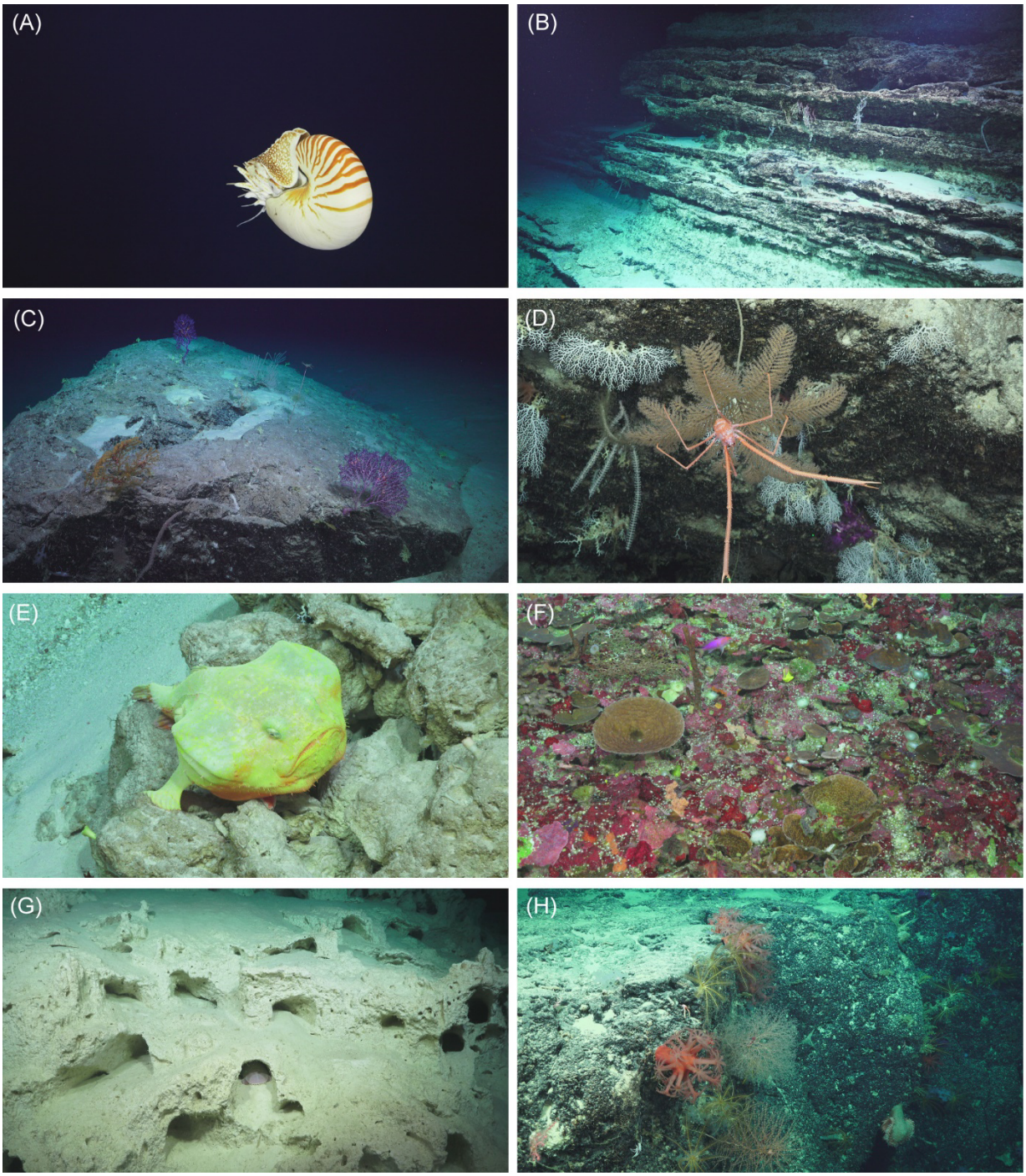

Figure 13. Selection of ROV images. (A) Nautilus cephalopod, dive 362, Magdelaine Cays, 600 m. (B) Exposed coral strata, dive 357, West Holmes Reef, 696 m. (C) Landslide boulder, dive 357, West Holmes Reef, 835 m. (D) Squat lobster on stalked crinoid, dive 360, Moore Reefs, 873 m. (E) Coffin fish, dive 360, Moore Reefs, 340 m. (F) Mesophotic corals, dive 365, Diamond Islets, 86 m. (G) Giant isopod burrows in chalk, dive 364, 816 m. (H) Coldwater corals and stalked crinoids, dive 369, Cairns Seamount, 1456 m.

2.1.3 Software Utilized

- The QPS Fledermaus and Qimera software: https://qps.nl/
- Teledyne CARIS HIPS&SIPS software: https://www.teledynecaris.com/en/HOME/
- ESRI ArcGIS software: https://www.esri.com/en-us/arcgis/products/index

2.2 Post-Expedition Activities and Accomplishments

Mapping Seafloor

More than 29,007 sq km was mapped with high-resolution multibeam sonar, an area only slightly less than the size of Tasmania. The depths mapped ranged from 2748 m to 10 m.

Geological Evolution Insight

The expedition revealed a step-change in our knowledge of the deeper seafloor features existing on the Queensland Plateau: from drowned reefs formed during the long subsidence events of this plateau, to catastrophic erosional processes such as underwater landslides dismantling reef flanks leaving obvious scarps and extensive debris block fields downslope, or flank gullies draining into larger channels then into deeper submarine valleys and unusual low-gradient channels, and to modern processes such as near-seabed currents sweeping between the reefs that result in vast dune fields.

Biological Knowledge

The expedition was the first deepwater ROV expedition of the Coral Sea Marine Park. While no physical samples were collected due to Scientific Permit restrictions, the new high-resolution video and still frame imagery provided a plethora of samples to study, including new marine species observed (see Publications section), as well as new records of significant range extensions. For example, progress is being made on a major science publication for new records of fishes from the Coral Sea Marine Park, involving 23 fish Families with new species described together with range extensions.

Telepresence Operations

The expedition was the Schmidt Ocean Institute's first 'telepresence' expedition where all the scientists were participating remotely due to COVID restrictions. These restrictions continued for the remainder of 2020 and into 2021, affecting all subsequent expeditions during the Australia campaign. The rapid uptake of texting through social media platforms, remote video conferencing and the monitoring of onboard acquisition systems, provided invaluable experience to share with the science teams that followed.

3 Impact to date

The expedition focused on the Queensland Plateau through geophysical mapping and ROV imaging around the steeper flanks of the ~30 large coral reefs that lie across the plateau, including areas of clusters of drowned reefs, and several low-gradient deepwater channels incised into the plateau surface. Prior to this expedition, only limited multibeam data existed on the Queensland Plateau, either across the broader platform surface or around the steeper flanks of these ~30 emergent reefs.

The mapping effort resulted in 29,007 sq km of seafloor mapped with high-resolution multibeam bathymetry data, with new map data around all 30 of the large coral reefs found on the Queensland Plateau. Depths mapped ranged from 2748 m to 10 m. A complex seafloor was revealed, including conduits of soft sediment ranging from smaller gullies to channels and larger valleys, and catastrophic flank collapse due to underwater landslides, with vast debris block fields around the periphery of the reefs.

ROV *SuBastian* collected video and imagery across the landslide scarps, which show internal strata layers of ancient coral from these reefs. Imagery across the debris fields confirmed these were limestone boulders sourced from shallower reef flank collapse events. A wide variety of mesophotic reef habitats were observed, with different ecological communities between the steeper gradient upper flanks compared to the gentler gradient slopes. There was no evidence of mass bleaching in the corals observed within the shallower mesophotic zones.

This expedition was the first time the weather-exposed, upper reef flanks were explored in the mesophotic zone and found prolific *Leptoseris* (zooxanthelate hard coral) fields, including the deepest records of *Leptoseris* found for Australia, at 149 m. We now have a better understanding of the depth trends and habitat preferences of deeper coldwater coral communities and mesophotic coral ecosystems within the Coral Sea Marine Park.

Further, this FK200429 expedition has helped address a range of priorities of the Australian Government in terms of mapping and characterizing a poorly known frontier area of the Australia's marine estate.

The mapping of reefs and seamounts in the Coral Sea Marine Park is a high priority for Parks Australia, the managers of Australia’s Commonwealth Marine Parks. The new multibeam data are now included within the national multibeam database hosted by Geoscience Australia and released through the AusSeabed Marine Data Portal.

Information from the ROV imagery, such as potential new species or range extensions, will be added to the living resources databases managed by the Australian Government and made publicly available. Parks Australia utilize the derived information products to communicate the important environmental values of the park to the community.

The information from this research is of great interest to the public, who were widely consulted on the zoning and activities prior to the nearly 1 million sq km Coral Sea Marine Park being declared in 2017, which is the largest Marine Park in Australia.

Having 4K-resolution underwater video imagery of the deeper reef environments of the Coral Sea, allows us to tell the full story of the interconnected environments of the Coral Sea. This vision is invaluable for educational, social and mainstream media platforms.

4 Data

The datasets acquired during this expedition and those derived from the analysis of collected data and samples, as of the date of this report's publication, are in Table 3.

Data Type	Curator	Completed
Environmental sensor data (raw)	Rolling Deck to Repository	Yes
Multibeam data (processed)	AusSeabed	Yes
Acoustic data (raw backscatter, bathymetry, ROV CTD/Oxygen, Eventlogger and navigation)	Marine Geoscience Data System	Yes
Acoustic Doppler Current Profiler data	University of Hawaii Data Acquisition System	Yes
Video data	Australian Marine Parks Science Atlas	Yes
Annotated imagery (Platform = SOI ROV Subastian, deployment = FK200429.	Squidle+	Yes
ROV site locations	JCU – Excel spreadsheet	Yes
ROV dive reports (S0354-S0369)	JCU – Dive reports	Yes
Google Earth layers (ship track, ROV dives, multibeam coverage)	JCU – Google Earth	Yes
SCS ROV dive sensor data (1-sec)	JCU – SCS data	Yes
Shapefiles (shiptrack, ROV dives)	JCU - Shapefiles	Yes
Ship track (1-min)	JCU – Excel spreadsheet	Yes
Multibeam ROV site images (colored hillshade geotifs)	JCU – Multibeam images	Yes

Table 3. List of all publicly available data.

5 Publications

Betzler, Christian, Christian Hübscher, Sebastian Lindhorst, Thomas Lüdmann, Carola Hincke, Robin J. Beaman, and Jody M. Webster. 2024. "Seismic Stratigraphic and Sedimentary Record of a Partial Carbonate Platform Drowning, Queensland Plateau, North-East Australia." *Marine Geology* 470 (April): 107255. https://doi.org/10.1016/j.margeo.2024.107255.

Betzler, Christian, Sebastian Lindhorst, Carola Hincke, Jan Oliver Eisermann, Or M. Bialik, Alex Petrovic, Jesus Reolid, et al. 2024. "Dismantling of an Isolated Tropical Carbonate Platform Through Flank Collapse and Canyon Erosion, Coral Sea, Northeast

Australia." *Marine Geology* 475 (September): 107361. https://doi.org/10.1016/j.margeo.2024.107361.

Mah, Christopher L. 2023. "A New Species of Astrosarkus from Western Australia Including New Mesophotic Occurrences of Indian Ocean Oreasteridae (Valvatida, Asteroidea)." *Memoirs of Museum Victoria* 82: 143–65. https://doi.org/10.24199/j.mmv.2023.82.08.

Reolid, Jesus, Or M. Bialik, Sebastian Lindhorst, Jan Oliver Eisermann, Alexander Petrovic, Carola Hincke, Robin J. Beaman, Jody M. Webster, and Christian Betzler. 2024. "A New Type of Halimeda Bioherm on the Queensland Plateau, NE Australia." *Coral Reefs* 43 (4): 801–21. https://doi.org/10.1007/s00338-024-02500-0.

6 Appendix

6.1 Science Party Information

Scientist	Institution
Robin Beaman	James Cook University
Tom Bridge	Museum of Tropical Queensland
Brendan Brooke	Geoscience Australia
Jody Webster	University of Sydney
Daniella Ceccarelli	James Cook University
Merick Ekins	Queensland Museum
Richard Fitzpatrick	Biopixel
Yi-Kai Tea	University of Sydney

Table 4. List of scientists during the expedition.

6.2 Conferences/Presentations/Posters

- Beaman, R.J., 2021. Schmidt Ocean Institute R/V *Falkor* Australia campaign 2020-2021, Queensland–Smithsonian Fellowship Speaker Series. Oceans: life on the edge, 16 November 2021. Queensland Department of Environment and Science - Smithsonian Institution, Remote conference, pp. 13. Available at: https://www.deepreef.org/2021/11/17/soi-rvfalkor-australia/
- Beaman, R.J., 2021. Schmidt Ocean Institute R/V *Falkor* Australia campaign 2020-2021, Sub-Committee on Regional Undersea Mapping (SCRUM), GEBCO Week, 11-15 January 2021. General Bathymetric Chart of the Oceans (GEBCO) www.gebco.net, Virtually from Paris, France. Available at: https://www.deepreef.org/2021/01/13/soi-falkor-campaign/
- Beaman, R.J., Picard, K., Miller, A., 2022. R/V *Falkor* surveys in Australia 2020-2021. In: Maschke, J. (Editor), Hydrospatial 2021 Conference, 16-18 Feb 2022. Australasian Hydrographic Society, Cairns, Australia. Available at: https://www.deepreef.org/2022/02/17/rv-falkor-hydrospatial/

- Beaman, R.J., 2022. R/V *Falkor* surveys in Australia 2020-2021, SSSI NSW & ACT Asia- Pacific Spatial Excellence Awards, 10 November 2022. Surveying & Spatial Sciences Institute (SSSI), Sydney, Australia. Available at: https://www.deepreef.org/2022/11/10/rv-falkor-sssi/
- Beaman, R.J., 2023. Recently discovered drowned reefs on the Queensland Plateau, Coral Sea Marine Park, Australia, AMSA 2023 Conference, 04 July 2023. Australian Marine Sciences Association, Gold Coast Australia. Available at: https://www.deepreef.org/2023/07/08/drowned-reefs-queensland-plateau/

6.3 Student Projects, Thesis, and Dissertations

- Sun, J., 2020. Composition and zonation of mesophotic communities on windward, gently sloping versus leeward, gently sloping reef slopes on the Queensland Plateau. Masters Thesis, The University of Sydney, Sydney, Australia, pp. 27.

6.4 Cruise Records

Cruise Logs:

- Science expeditions in the time of COVID19 – April 30, 2020
- Going live in three, two, and one… - May 04, 2020
- Exploration with a remote science team: A Marine Tech's perspective – May 15, 2020
- Searching for carnivorous sponges – May 18, 2020
- From underwater video to 3D modelling – May 19, 2020
- New species and range extension records for the Coral Sea – May 24, 2020
- A tale of life or death and recovery Science@Sea seminar – May 26, 2020
- Visioning the Coral Sea – Video Update 1 – May 27, 2020
- History of mapping the Coral Sea Science@Sea seminar – May 30, 2020
- Uncharted waters – June 02, 2020
- Studying sharks in the Coral Sea Science@Sea seminar – June 10, 2020
- Exploring the Coral Sea 'Twilight Zone' – June 15, 2020
- Video wrap up – Setting a high bar – June 19, 2020
- Rapid data publication: From ship to home – June 24, 2020

ROV *SuBastian* Dive List:

- ROV dive 354: ROV dive 354 was conducted on the southwest corner of Osprey Reef with a maximum depth of 1564 m, aiming for about 4-hour dive to ~1000 m for transect up a steep rock cliff. This was our first 'telepresence' dive with all science team commentary presented from ashore.
- ROV dive 355: ROV dive 355 was conducted at North Horn, on the northwest corner of Osprey Reef, with a maximum depth of 1011 m. The dive targeted the

base of a steep ridge, then followed the ridge towards the surface and into mesophotic depths. Numerous nautilus cephalopods were observed on the dive.

- ROV dive 357: ROV dive 357 was conducted on West Holmes Reef with a maximum depth of 884 m. The dive traversed a prominent exposed rock wall comprised of ancient coral layers. Marine life was prevalent amongst the rock strata with coldwater corals, crinoids and other benthos clinging to the rock.
- ROV dive 358: ROV dive 358 was conducted at South Flinders Reef with a maximum depth of 1006 m. The dive targeted an exposed ~100 m high landslide scarp on the side of the reef. Again, rock strata comprising ancient coral layers were seen. Abundant soft corals were observed in the mesophotic zone.
- ROV dive 360: ROV dive 360 was conducted on the largest of the three Moore Reefs with a maximum depth of 944 m. This seamount-like reef has high biodiversity from earlier SCUBA surveys. The ROV dive also found higher densities of coldwater corals, sponges and fish than seen on previous dives.
- ROV dive 361: ROV dive 361 was conducted on the southwest corner of Willis Islets with a maximum depth of 260 m. The dive aimed to confirm whether the large blocks mapped lying scattered around the perimeter of Willis Islets are hard limestone blocks fallen off the shallower upper flanks of this large bank.
- ROV dive 362: ROV dive 362 was conducted at the northern tip of Magdelaine Cays with a maximum depth of 650 m. The target was a landslide scarp to look for exposed coral rock strata. The layers of rock provide micro-habitats for cold-water corals and fish life. The dive finished in the shallower mesophotic depths.
- ROV dive 363: ROV dive 363 was conducted on the northeast tip of Magdelaine Cays with a maximum depth of 571 m. The dive targeted debris field of large boulders because of flank collapse on the side of the reef. Also, more evidence of underwater landslides, such as exposed scarp faces with internal strata layers.
- ROV dive 364: ROV dive 364 was conducted on the southern side of Diamond Islets/Tregrosse Reefs with a maximum depth of 935 m. The dive targeted a large y-shaped canyon, traversing from the canyon floor and up the steep sides, looking for signs of an actively draining canyon and coldwater marine life.
- ROV dive 365: ROV dive 365 was conducted on the southern side of Diamond Islets/Tregrosse Reefs with a maximum depth of 685 m. The dive is a shallower continuation of dive 364, across a prominent terrace at 400 m and up to the mesophotic zone to observe the benthic community transition across the depths.
- ROV dive 366: ROV dive 366 was conducted at northeast Lihou Reef with a maximum depth of 562 m. located at a prominent landslide where the entire flank appears collapsed. The dive transited across a debris field and several large blocks then across the steep landslide scarp face to look for exposed coral strata.
- ROV dive 367: ROV dive 367 was conducted on the northwest side of Lihou Reef with a maximum depth of 391 m. The dive transited over prominent debris

blocks that have broken off the steeper reef flank, then crossed into the upper flank towards the reef edge in search of mesophotic marine life.

- ROV dive 368 (World Ocean Day, Part B): ROV dive 368 was conducted at northeast Diamond Islets/Tregrosse Reefs with a maximum depth of 549 m. The dive started with guests celebrating World Ocean Day, then continued the dive exploring a rock debris field as the remains of flank disintegration by landslide.
- ROV dive 369: ROV dive 369 was conducted southeast of Cairns Seamount with a maximum depth of 1548 m. The dive investigated some low relief, sculptured seafloor on the Queensland Plateau and to confirm the seafloor substrate, whether hard rock or soft eroded sediments, and any cold-water marine life.

6.5 Media

- First completely remote at-sea science expedition in Australia's Coral Sea Marine Park discovers new corals and possible species never before seen - Schmidt Ocean Institute media release.
- Remote control - Signals magazine, Summer 2021-22, Volume 137, pages 2-9. Australian National Maritime Museum, Sydney, Australia.

6.6 Community Outreach

- Ocean Wonders Exhibition - Australian National Maritime Museum. November 2021, Sydney, Australia.
- One Ocean, Our Future Exhibition - Australian National Maritime Museum. 6 April 2022, Sydney, Australia.

6.7 Daily Diary of FK200429

Wednesday 29 April 2020

Wind 3 kn from 150°. Sea state 1. Nil swell.

0800 in position 16.823199°S 145.851310°E anchored at Cairns Harbour.

At 0800, the *Falkor* left its anchor position and headed into Cairns Harbour for reprovisioning and refuelling at Cairns Wharf. At 1500, I visited the ship briefly to meet with the crew before sailing with appropriate social distancing due to COVID-19 restrictions. At 1600, the vessel departed Cairns to commence the expedition. R/V *Falkor* transited through Grafton Passage across the Great Barrier Reef (GBR) shelf and then turned northward towards the first Queensland Plateau ridge survey area. The EM302 multibeam system was turned on after entering the Coral Sea Marine Park to collect new multibeam data on the transit.

Thursday 30 April 2020

Wind 12 kn from 120°. Sea state 3. Low swell.

0800 in position 14.503716°S 146.326232°E in vicinity of plateau ridge survey area.

The *Falkor* continued transiting northward through the night towards the Queensland Plateau ridge survey area. This survey target already had some multibeam data collected across it from the previous Torres Strait-Cairns transit during the transit for the previous expedition, so additional map data were collected on the eastern side of the ridge. On completion, the *Falkor* headed northeast towards the northern tip of Osprey Reef.

Friday 01 May 2020

Wind 12 kn from 130°. Sea state 3. Low swell.

0800 in position 13.984582°S 146.729155°E at the southeast corner of Osprey Reef.

Overnight the ship continued mapping around the northern and western side of Osprey Reef on the deeper flanks. During daylight hours, the ship mapped higher up the flanks towards the shallower reef around the eastern and southern side of Osprey Reef. At 1400, the ROV *SuBastian* was lowered into the water at the southwestern corner of Osprey Reef for ROV dive #354. Target depth was 1564 m with a ~4-hour dive up to ~1000 m for a vertical transect up a steep cliff. This was the first test of the shore side communications with myself providing commentary through Rendevous-Wirecast software. The broadcast seemed to go well, with some highlights being the stalked crinoids, pygmy dumbo octopus and coldwater corals. The ROV was recovered around 1800 and the *Falkor* commenced multibeam mapping through the night within the Osprey Reef survey area.

Saturday 02 May 2020

Wind 16 kn from 130°. Sea state 4. Low swell.

0800 in position 13.819541°S 146.553568°E at North Horn, Osprey Reef.

The *Falkor* had completed much of the deeper flank mapping around Osprey Reef overnight including one pass around Shark and Vema Reefs. A large underwater landslide and debris boulders revealed a flank collapse of the Shark and Vema Reefs. The ship then transited towards North Horn at the northwestern tip of Osprey Reef. At 0930, the ROV *SuBastian* was launched with a live broadcast from ~1015 as ROV dive #355. The target was 1011 m at the base of a steep ridge and then generally follow the 2009 German Deep Downunder ROV transect up the ridge. The live broadcast went well but some lag was noticed between the timing of the video and the audio from ashore. Highlights were the numerous nautilus bobbing around the ROV, over 15 counted, between ~700-500 m. We also saw the transition from coldwater communities to warmer mesophotic communities around ~500-400 m. The ROV was recovered at 1600 and the vessel commenced surveying the shallower flanks while in daylight.

Sunday 03 May 2020

Wind 16 kn from 115°. Sea state 4. Low swell.

0800 in position 13.926814°S 146.477337°E on west side of Shark and Vema Reefs.

The ship continued mapping through the night as the wind picked up. A second pass around Shark and Vema Reefs helped map the deeper parts of these reefs where the plateau flattens out. Through the morning with daylight, the vessel mapped the shallower flanks on the western side of Osprey Reef then turned southward again to map the deeper flanks of Osprey Reef. Through the afternoon, the shallower sides of Shark and Vema Reefs were mapped. These two elongate reefs were clearly once joined, with a low ridge stretching between them, separating the shallower reef tops. These two reefs are separate structures from Osprey Reef to the northwest, i.e. a deep trough lies between Osprey Reef and closest Shark Reef. At 1900, the *Falkor* completed the Osprey Reef survey area and commenced transit southward towards the Bougainville Reef survey area.

Monday 04 May 2020

Wind 25 kn from 120°. Sea state 4. Moderate swell.

0800 in position 15.64370°S 147.06560°E in vicinity of Bougainville Reef.

The *Falkor* continued its southerly track towards Bougainville Reef approx. 6 hours away. Rough seas slowed progress but multibeam mapping continued along the north-western side of the Queensland Plateau in depths 1700 to 1400 m, rising slowly towards Bougainville Reef. The vessel arrived in the morning and commenced a slow loop around the unmapped portions of Bougainville Reef. By 0800, the Bougainville Reef survey was completed and transit commenced towards the Cairns Seamount about 5 hours away. At 1500, the *Falkor* arrived at the Cairns Seamount survey area and commenced a lap around the flanks of this small reef. Base depths are ~1300 with a relatively smooth eastern side.

Tuesday 05 May 2020

Wind 21 kn from 140°. Sea state 4. Low swell.

0800 in position 16.433116°S 147.80148°E in vicinity of Holmes Reefs.

The *Falkor* completed mapping around the Cairns Seamount revealing an almost conical bank topped with a small (few 100s m wide) shallow coral reef. The ship then commenced transit towards Holmes Reefs, about 230 km east of Cairns. Through the morning, a wide pass was made around both reefs, which established the extent of the deeper drainage channels. From midday, a clockwise pass was conducted between the two reefs, then two shallower passes around West Holmes Reef to survey as high up on the flanks as possible.

Wednesday 06 May 2020

Wind 24 kn from 120°. Sea state 4-5. Low swell.

0800 in position 16.474130°S 147.950151°E in vicinity of Holmes Reefs.

With the wind still high, the *Falkor* had to plan mapping away from the shallower edges of reefs. A transit was made around Flora Reef, about 1 hour away from the Holmes Reefs, then the *Falkor* continued back to map East Holmes Reef. Through the daylight hours, shallow mapping was done around the lee side of East Holmes Reef getting as close as possible to the reef. The multibeam backscatter shows high reflectance on the upper flanks as expected where mesophotic corals and harder substrate would be present. Down the flank, reflectance becomes lower as softer sediment drapes the lower slopes. The squally weather still restricted windward mapping of reefs, so from 1400 the *Falkor* moved behind West Holmes Reef with the multibeam system turned off.

Thursday 07 May 2020

Wind 22 kn from 115°. Sea state 4-5. Low swell.

0800 in position 16.375277°S 147.850535°E in vicinity of Holmes Reefs.

Poor weather overnight required the ship to heave to in the lee of West Holmes Reef. No multibeam data were collected. At 0830, the *SuBastian* ROV was launched for Dive #356 at the northern end of West Holmes Reef but was recovered soon after because of a technical issue. The next ROV Dive #357 then commenced around 0930 starting at a target depth of 883 m. Through the day, the ROV climbed steadily upwards, at times traversing a prominent exposed rock wall comprised of rock strata, likely coral layers built up through time. Marine life was prevalent amongst the rock strata with coldwater corals, crinoids and other benthos clinging to the rock. The ROV traversed through the thermocline around 450 m and entered the lower mesophotic zone. Here we saw soft corals and black corals become more common attached to exposed rock cliffs and boulders. The ROV was recovered at 1600 then commenced a southwest transit towards Flora Reef to collect additional multibeam data around the deeper plateau surface adjacent to the reef.

Friday 08 May 2020

Wind 21 kn from 115°. Sea state 4-5. Low swell.

0800 in position 17.365697°S 148.142091°E in vicinity of Dart Reef.

Through the night the *Falkor* mapped around McDermott Reef, a small reef lying between Flora Reef and the Flinders Reefs. Then a transit was made east to try and map an enigmatic seabed feature looking like a long meandering channel incised into the plateau surface over 30 km in length. More mapping was required to find the head of the channel and where it drains to the western side of the plateau. From 0900, the vessel

made a near pass around the small Dart Reef, then the western side of North Flinders Reef, taking advantage of the daylight to map the shallower upper flanks of this large atoll. From midday, the *Falkor* mapped the South Flinders Reef in a clockwise direction. By the end of daylight, the *Falkor* had completed one complete circle around South Flinders Reef and then headed up the eastern side of North Flinders Reef.

Saturday 09 May 2020

Wind 15 kn from 105°. Sea state 4. Low swell.

0800 in position 17.503978°S 148.278083°E in vicinity of North Flinders Reef.

The ship continued mapping through the night with winds easing to around 15 kn. A deeper loop commenced around South Flinders Reef, then northward along the western side of North Flinders Reef and around Dart Reef. The hint of a wave cut platform was detected at ~120 m, possibly indicating maximum sea-level lowstand during previous glacial periods. A similar wave cut terracing had been detected on the adjacent Great Barrier Reef shelf edge. With the improved weather, the *Falkor* continued mapping along the eastern North Flinders Reef flanks. Into the evening, the vessel mapped the area between Dart Reef, Heralds Surprise and North Flinders Reef.

Sunday 10 May 2020

Wind 14 kn from 145°. Sea state 4. Low swell.

0800 in position 17.879219°S 148.469603°E in vicinity of South Flinders Reef.

Overnight the *Falkor* continued mapping around the outside deeper waters surrounding North Flinders Reef, Heralds Surprise and Dart Reef. Towards the morning, the ship mapped down the western sides of the Flinders Reefs to take up position for ROV Dive #358 on a landslide scarp found on the west side of South Flinders Reef. Dive #358 commenced at 0800 and on the seafloor at ~0830 in a depth of 1006 m for a video livestream. Through the day, the ROV followed a long vertical transect up the ~100 m high face of the landslide, then along the upper flanks and into the lower mesophotic zone. Towards the end of the dive, abundant soft corals and other mesophotic biota were observed, including the overhanging caves around 120 m, again possibly indicating lowstand sea-level positions, causing wave cutting of the limestone rock. The ROV was recovered at 1430 and the vessel commenced mapping of shallow areas on North Flinders Reef during remaining daylight hours.

Monday 11 May 2020

Wind 17 kn from 120°. Sea state 4. Low swell.

0800 in position 17.419672°S 148.921411°E in vicinity of Unnamed 5m Reef.

Through the evening, the *Falkor* mapped farther along the incised channel east of Dart Reef on the main plateau surface to find the head of this long channel. The ship then transited towards the Unnamed 5m Reef lying about 30 km east of the Flinders Reefs. Previous LIDAR bathymetry covers this shoal and the vessel mapped through the morning around the shallower flanks. By 1300, the Unnamed 5m Reef was completely mapped around the flanks and the *Falkor* commenced the transit to Herald Cays in around 880 m depth across the plateau surface. From midday until 1800, the ship mapped the shallower upper flanks around Herald Cays reef, then during the night the deeper flanks of this reef.

Tuesday 12 May 2020

Wind 20 kn from 130°. Sea state 4. Low swell.

0800 in position 16.402862°S 149.165538°E in transit Herald Cays and Moore Reefs.

The *Falkor* completed mapping around the Herald Cays and commenced the ~100 km transit northward to the Moore Reefs, lying northeast of Diane Bank. Around midday, the ship arrived and commenced mapping the three small shallow reefs that comprise Moore Reefs. This area is dotted with strange pinnacles in older mapping data so a systematic survey was commenced at 1600 to try and broadly map the surrounding plateau and see if these pinnacles are real. Throughout the day, the seafloor revealed a lack of pinnacles and was relatively flat, thereby disproving the existence of multiple pinnacles.

Wednesday 13 May 2020

Wind 21 kn from 120°. Sea state 4. Low swell.

0800 in position 16.059367°S 149.137946°E in vicinity of Moore Reefs.

After a night of systematic surveying between the three Moore Reefs, no field of drowned reefs or pinnacles was revealed. The seafloor is continues to be relatively flat or with only low scarps of exposed rock on the seafloor. At 0800, with winds easing the *Falkor* left the Moore Reefs and transited towards Diane Bank to map the shallower flanks during daylight hours and while weather was conducive for shallower mapping. The *Falkor* arrived at the Diane Bank at 1100 and started an anti-clockwise survey of the shallower flanks.

Thursday 14 May 2020

Wind 21 kn from 125°. Sea state 4-5. Low swell.

0800 in position 15.789163°S 149.602273°E in vicinity of Diane Bank.

The *Falkor* had continued the anti-clockwise mapping of Diane Bank through the night, with the weather still quite windy. Depths between Diane Bank and the Willis Islets to

the east were around 350 m, quite shallower compared to the previous mapping over the plateau around 1000 m deep. Throughout the morning, the ship continued around the northern then western side of Diane Bank, mapping the shallower flanks during daylight hours. At 1600 the ship at reached the southern side of Diane Bank which revealed possible bedforms on the seafloor. From here, the ship transited towards the Willis Islets, east of Diane Bank.

Friday 15 May 2020

Wind 21 kn from 130°. Sea state 4. Low swell.

0800 in position 16.294416°S 149.984137°E in vicinity of Willis Islets.

The *Falkor* worked in the deeper waters east of Willis Islets overnight, then at daybreak started mapping the shallower flanks near the Willis Islets-Bureau of Meteorology weather station. The shallower flanks were mapped with multibeam showing undercutting terraces around 100 m depth, indicating possible lowstand sea-level erosion. Through the day, the *Falkor* worked out into deeper water continuing the anti-clockwise survey around Willis Islets. The seafloor was ~600 m deep and covered in smaller disaggregated blocks lying stranded on the surrounding plateau surface.

Saturday 16 May 2020

Wind 20 kn from 125°. Sea state 4. Low swell.

0800 in position 15.849369°S 149.736014°E in vicinity of Diane Bank.

Overnight, the *Falkor* continued mapping anti-clockwise around Diane Bank over the deeper flanks and plateau surrounding the bank. At 1100, the ship commenced east-west lines between the northern side of Diane Bank and the Moore Reefs to try and understand the low erosional feature between them in about 500 m depth. The systematic survey continued to until 1900, revealing ~100 m high cliff faces along this erosional scarp, with superimposed dunes on top. Parts of these reef platforms have collapsed with large blocks stranded at depths ~1000 m. The ship then continued mapping the west side of Diane Bank.

Sunday 17 May 2020

Wind 20 kn from 125°. Sea state 4. Low swell.

0800 in position 16.030018°S 149.070580°E in vicinity of Moore Reefs.

In the early morning, a systematic survey commenced to the southwest of Moore Reefs. At 0800, a new seamount, likely a drowned reef, was discovered rising from 981 to ~370 m, and conical in shape. At 0900, the ship completed the systematic surveying and started the transit to Cairns. Around 1500, the *Falkor* had made great progress and commenced mapping the shallower upper flank of East Holmes Reef, revealing a clear

steeper zone before a flank filled with smaller gullies. By 1600, the ship continued on towards Cairns.

Monday 18 May 2020

Wind 15 kn from 140°. Sea state 4. Nil swell.

0800 in position 16.842108°S 145.822822°E at anchor near Cairns harbour.

The ship continued transiting across the Queensland Plateau and Queensland Trough towards Cairns. At 0400, the ship entered Grafton Passage and proceeded to the anchorage off Cairns Harbour entrance. At 0800 the ship came to anchor with all multibeam mapping systems turned off.

Tuesday 19 May 2020

Wind 16 kn from 120°. Sea state 4. Nil swell.

0800 in position 16.929636°S 145.779900°E at Cairns wharf.

The *Falkor* remained at anchor overnight, then at 0730 left the anchorage and proceeded into the Cairns wharf, to be alongside by 0800. Crew changeover and reprovisioning occurred throughout the day.

Wednesday 20 May 2020

Wind 16 kn from 120°. Sea state 4. Nil swell.

0800 in position 16.848992°S 145.821052°E at Cairns port anchorage.

The *Falkor* remained at anchor overnight and planned for a crew changeover by boat. At 1200, the *Falkor* weighed anchor and departed for the Coral Sea Marine Park through Grafton Passage. The ship commenced surveying with the EM710 multibeam system and mapped across the shelf-break at ~100 m at 1540. Heading easterly, the ship transited across the Queensland Trough with the EM300 multibeam system now turned on and then towards the Queensland Plateau. Around 2200, the ship approached the Cairns Seamount mapping along the southern and deeper sides.

Thursday 21 May 2020

Wind 20 kn from 085°. Sea state 4-5. Low swell.

0800 in position 16.570673°S 147.996868°E in vicinity of Holmes Reefs.

The *Falkor* mapped between the Cairns Seamount and Holmes Reefs, completing filling some mapping gaps around East Holmes Reef. At 1100, the ship started the transit to the Moore Reefs and Diane Bank area to continue mapping gaps in preparation for the next ROV dive. During the 1100-1200 live Ship2Shore discussion, the *Falkor* mapped three small, drowned reefs on the south side of East Holmes Reefs. The largest drowned

reef lies at 937 m with its top at 659 m, so 278 m in vertical height. Moats lie around the bases of these drowned reefs.

Friday 22 May 2020

Wind 13 kn from 110°. Sea state 3. Low swell.

0800 in position 15.882600°S 149.151228°E in vicinity of Moore Reefs.

Overnight, the *Falkor* continued mapping around the Moore Reefs trying to determine whether enigmatic seafloor bumps were real seamounts. Only one new seamount was detected, so concluding that these bumps seen in previous 3D depth models were likely noise artefacts. The ship positioned itself on the lee side of the northwest Moore Reef and commenced ROV Dive #360 at 0900 and on the seafloor at 944 m. The dive site was chosen to give a complimentary deep dive against an earlier shallow-water survey by SCUBA divers that had revealed high biodiversity in fish and coral life. This deeper ROV dive also found higher densities of coldwater corals, sponges and fish than we had seen on previous dives. In the mesophotic zone, were also high concentrations of softcorals and fish. At 1730 the ROV was recovered, and the ship commenced mapping towards the southern Diane Bank.

Saturday 23 May 2020

Wind 20 kn from 170°. Sea state 4. Moderate swell.

0800 in position 16.495350°S 149.706782°E in vicinity of Willis Islets.

Through the night, the *Falkor* mapped around the flanks of Diane Bank and Willis Islets, ending up at the southwest side of Willis Islets for ROV dive #361. This dive aimed to confirm whether a large ~1.4 km long block-like feature lying at ~250 m depth was hard limestone and therefore likely to be the remains of an underwater landslide. At 0830, the ROV *SuBastian* was on the seafloor at 260 m and sand ripples came into view. The dive transited up onto the rock and was clearly hard limestone with a veneer of soft sediments. Patches of softcorals sheltered mesophotic fish species not described. Unfortunately, bad weather terminated the dive and the ROV was recovered at 1000. The ship commenced surveying between Diane Bank and Willis Islets as the weather deteriorated. Extensive dunes were observed lying between these two banks. By nightfall, the *Falkor* had rounded the northern side of Willis Islets and heading down the eastern side into the rough seas.

Sunday 24 May 2020

Wind 15 kn from 190°. Sea state 4. Low-Moderate swell.

0800 in position 17.147235°S 149.752565°E in vicinity of Willis Islets.

The *Falkor* transited from Willis Islets towards Coringa Islets lying to the south, and at daybreak, started mapping anti-clockwise around the western and southern side of Coringa Islets reef. Depths were relatively shallow, around 200-300 m with a gentler flank gradient extending onto the plateau surface. At 1100, the *Falkor* cut across the top of the bank over the lagoon in ~60 m depth, exiting on the northern side at 1200. During the remaining afternoon, the ship surveyed the northern upper flanks of Coringa Islets reef. At 1600, the vessel commenced mapping across the deeper plateau surface around 450 m depth.

Monday 25 May 2020

Wind 17 kn from 170°. Sea state 4. Low-Moderate swell.

0800 in position 16.526272°S 150.302846°E in vicinity of Magdelaine Cays.

The *Falkor* continued mapping along the northern flank of Coringa Islets reef towards Magdelaine Cays reef at the northern end of this large ~80 km long bank. From daybreak, the ship commenced mapping around Magdelaine Cays reef, identifying a potential ROV site for the next day. Through the morning the ship transited across to the Unnamed 17m Reef about 25 km east of Magdelaine Cays reef. The ship commenced mapping the shallower upper flanks from 1200 for two laps around this reef. In the evening, the ship transited back to Magdelaine Cays and mapped the southern flank of this large bank.

Tuesday 26 May 2020

Wind 11 kn from 135°. Sea state 3. Low swell.

0800 in position 16.545512°S 150.269814°E in vicinity of Magdelaine Cays.

The *Falkor* mapped the deeper southern flanks of Magdelaine Cays reef through the night then positioned itself at the northernmost Magdelaine Cay reef for ROV Dive #362. The ROV *SuBastian* entered the water at 0800 and conducted a dive up the southern wall with a starting depth of 650 m. The dive concluded at 1330 having seen several live chambered nautilus cephalopods and numerous seapens in deeper waters. At 1400, the ship departed and transited southwest towards a possible deep channel incised into the plteau surface between Willis Islets and the Magdelaine Cays reef.

Wednesday 27 May 2020

Wind 11 kn from 150°. Sea state 3. Low swell.

0800 in position 17.038858°S 149.971757°E in vicinity of Coringa Islets.

The *Falkor* continued mapping the deep channel between Willis Islets and Magdelaine Cays reef through the night, revealing ~30 km long, 700 m wide channel draining towards the northeast. The channel terminated at a series of eroded platforms,

appearing like stepped terraces at 908, 935 and 990 m depth. The ship then continued mapping the northern flanks and surrounding plateau of the Magdelaine Cays and Coringa Islets area through the morning. At 1230, the ship passed through the narrow gaps separating the western-most reef from the larger bank. Through the afternoon and evening, the ship mapped around an isolated reef on the south-western side of Coringa Islets, then continued along the southern deeper flank towards the ROV dive site on the north-eastern tip of Magdelaine Cays reef.

Thursday 28 May 2020

Wind 13 kn from 130°. Sea state 3-4. Low swell.

0800 in position 16.730229°S 150.445021°E in vicinity of Magdelaine Cays reef.

The *Falkor* had mapped the southern flank of Magdelaine Cays reef through the night and positioned itself for a ROV dive on a promontory on the north-eastern point. Unfortunately, technical issues meant the dive was aborted and so the ship continued mapping the northern deeper flanks of this large bank, heading anti-clockwise around the reef. By 1500, the ship was back in the large embayment at the southern side of the bank while mapping the shallower reef edge missing on previous mapping passes. Towards the evening, the ship passed again across the shallow sandy lagoon where the Knudsen sub-bottom profiler was tested. During the night, the ship continued mapping gaps within existing coverage along the southern side of Magdelaine Cays reef.

Friday 29 May 2020

Wind 15 kn from 150°. Sea state 3-4. Low swell.

0800 in position 16.725690°S 150.446294°E in vicinity of Magdelaine Cays reef.

The *Falkor* continued mapping the southern margin of Magdelaine Cays and Coringa Islets reefs through the night and morning, filling in gaps within the existing multibeam data coverage. This included more passes around the Unnamed 23 m reef on the south-western side of Coringa Islets reef, then heading north-easterly towards the Unnamed 17 m reef. At 0800, the ship positioned itself at a site on the prominent 'horn' of reef on the northeast corner of Magdelaine Cays reef for ROV dive #363. The start depth was around 571 m and then climbed steadily upwards through the day towards the mesophotic zone in ~100 m depth. The dive completed around 1500 then continued mapping south-westerly towards the Coringa Islets side of the bank, and several laps around the Unnamed 23 m reef at the south-western corner of Coringa Islets reef.

Saturday 30 May 2020

Wind 16 kn from 135°. Sea state 3-4. Low swell.

0800 in position 17.768338°S 150.723981°E in vicinity of Diamond Islets reef.

Overnight, the *Falkor* had mapped down the western side of Diamond Islets reef for the first time and then rounded the southern flanks. At 0800, the ship was halfway along the southern flank then continued mapping the shallower depths close to the reef edge and then up around the prominent 'horn' of reef jutting out at the northeast side of Diamond Islets reef. Weather conditions were good and so the ship spent the remainder of the day and into the night adding more data coverage to this deeper southern side of the reef. A picture emerged of a very complex seafloor, including numerous gullies, a large canyon and the more familiar landslide debris fields lying along the base of the reef.

Sunday 31 May 2020

Wind 15 kn from 140°. Sea state 3-4. Low swell.

0800 in position 17.901425°S 150.701289°E in vicinity of Diamond Islets reef.

The *Falkor* had continued mapping along the southern margin of Diamond Islets reef, extending farther the extensive mapping coverage over the distinct y-shaped canyon that extended south of the reef. Closer to the reef, a series of prominent steps and ledges appeared. Superimposed on top of the ledges were wide linear 'dunes' extending out across the ledges, each 'dune' seemingly lined up with the 'dune' on the lower ledges. The y-shaped canyon and ledges were decided as targets for the following ROV dives. The ship continued mapping along this deeper >1000 m seafloor through the night.

Monday 01 June 2020

Wind 14 kn from 145°. Sea state 3-4. Low swell.

0800 in position 17.8421179°S 150.649971°E in vicinity of Diamond Islets reef.

The *Falkor* had continued mapping the southern flanks of Diamond Islets reef to around 14 km away from the edge of the shallow reef. At 0800, the ship positioned itself over the left-hand arm of the y-shaped canyon for ROV dive #364 with a start depth of around 935 m in the floor of the canyon. The early part of the dive was over sand with prominent ripples before a gradual climb up the steeper sides of the canyon to an exposed friable chalky outcrop. The chalky outcrop was filled with small burrows and looked much eroded. A clue to the cause of the burrowing was seeing a large isopod inside a burrow, which had likely excavated these holes into the soft chalk. The dive completed at 1700 and the ship continued mapping the outer flanks of the Diamond Islets through the night.

Tuesday 02 June 2020

Wind 12 kn from 145°. Sea state 3. Low swell.

0800 in position 17.792913°S 150.654080°E in vicinity of Diamond Islets reef.

The *Falkor* had mapped some additional deeper seafloor to the south of Diamond Islets reef overnight, then at 0800 positioned over a site for ROV Dive #365. This site was the companion to the previous Dive #365, with a start depth of 685 m and climbing up a series of steep steps to ledges at 550, 416 and 300 m, before the final climb into the mesophotic depths around 100 m. The dive showed an obvious transition from the coldwater environment, through the thermocline at ~450 m, into the lower mesophotic and upper mesophotic zones. Towards the end of the dive, we saw a succession of rhodoliths, then zooxanthelate corals, and Halimeda green algae meadows, before recovery at 1700. The ship continued mapping along the southern flank of Diamond Islets reef overnight, adding to the impressive mapping data over the complex canyons draining the steeper flanks.

Wednesday 03 June 2020

Wind 25 kn from 135°. Sea state 4-5. Low-Moderate swell.

0800 in position 17.496884°S 150.061359°E in vicinity of Unnamed 22 m reef.

The *Falkor* mapped additional lines along the southern side of Diamond Islets, and then headed along the western steeper flanks before a short western transit to the Unnamed 22 m reef situated ~16 km northwest of Diamond Islets. The shallower flanks were mapped on this Unnamed 22 m reef through the evening, then *Falkor* transited back to the Diamond Islets reef and mapped along the northern side of reef. Weather conditions continued to deteriorate but the Diamond Islets reef provided some shelter as the ship headed north-easterly along its flank. The seafloor was generally smooth with occasional clusters of rock debris at base of the flanks.

Thursday 04 June 2020

Wind 25 kn from 135°. Sea state 4-5. Low-Moderate swell.

0800 in position 17.433262°S 151.157990°E in vicinity of Diamond Islets reef.

With the wind still quite high, the *Falkor* continued mapping along the northern side of Diamond Islets reef. At 0800, the ship investigated a prominent reef extension on the north-eastern side of Diamond Islets reef in the event of the upcoming World Oceans Day ROV dive, which required a sheltered position. The ship then transited easterly towards Lihou Reef, this being the largest of all the Queensland Plateau reefs at ~100 km long. Through the day, the ship mapped the shallower flanks on the northern side of Lihou Reef. Depths were around 400 m at the base of the flanks. From 1330 to 1700, the ship hove to on the lee side of Lihou Reef for engine testing, then continued mapping along the deeper flanks through the night.

Friday 05 June 2020

Wind 25 kn from 120°. Sea state 4-5. Low-Moderate swell.

0800 in position 17.326870°S 151.497243°E in vicinity of Lihou Reef.

The windy conditions continued through the night and so the *Falkor* remained mapping along the leeward northern side flanks of Lihou Reef. With daylight, the ship headed in a north-easterly direction towards the very eastern tip of Lihou Reef. By 1400, the ship had reached the eastern side of the mapped area, then turned around heading westerly again, continuing to map farther away from the reef edge and across the deeper surrounding plateau. At 1700 the ship sailed northward away from Lihou Reef then returned back to continue mapping the deeper flanks of Lihou Reef through the night.

Saturday 06 June 2020

Wind 20 kn from 120°. Sea state 4-5. Low-Moderate swell.

0800 in position 17.218074°S 152.141085°E in vicinity of Lihou Reef.

At daybreak, several potential ROV dive sites were visited along the northern Lihou Reef to test current speeds and risk. A potential dive site was chosen over an obvious landslide scarp and with minimal current. At 0900, the ship headed around the eastern point of Lihou Reef into the high winds. The ship then headed in a south-westerly direction along the southern flanks of Lihou Reef mapping a relatively steep wall down to over 800 m. At 1300, a short reverse in direction was made to survey a site identified as highly biodiverse from previous SCUBA surveys at Lihou Reef. A prominent ledge could be seen in the multibeam data around 350 m. The ship then continued mapping in a south-westerly direction, with several reversals to fill in gaps along the deeper flank. At 1800, the *Falkor* reached the western limit of Lihou Reef, and because the weather continued to be windy, the mapping continued in a clockwise direction, adding to map data along the northern leeward side.

Sunday 07 June 2020

Wind 20 kn from 115°. Sea state 4. Low-Moderate swell.

0800 in position 17.087801°S 151.913200°E in vicinity of Lihou Reef.

After a night of mapping around the deeper northern flanks of Lihou Reef, the ship positioned near the north-eastern side for ROV dive #366 at a prominent landslide where the entire flank appears collapsed. The ROV entered the water at 0800 for a target depth of 562 m. The dive transited across a debris field and several large blocks, and then across the exposed landslide scarp face. We observed exposed strata or the internal layers of the ancient reef, and the diverse coldwater community and mesophotic marine life attached to these layers. At 1530, the ROV was recovered. Through the night, the *Falkor* continued mapping clockwise around the southern side of Lihou Reef.

Monday 08 June 2020

Wind 23 kn from 135°. Sea state 4-5. Low-Moderate swell.

0800 in position 17.490356°S 151.367634°E in vicinity of Lihou Reef.

The *Falkor* continued mapping the southern side of Lihou Reef through the night, then positioned at the north-western side of Lihou Reef for ROV dive #367. This dive commenced at 0800 and had a shallower starting depth of 391 m, then worked towards the reef over prominent debris blocks that had broken off the steeper reef flank. The last part of the dive crossed a relatively gentle gradient, upper flank to about 100 m depth, in search of interesting mesophotic marine life. The ROV *SuBastian* was recovered at 1300 as the wind increased, with the ship then commencing a systematic survey of the deeper plateau area between Lihou Reef and Diamond Islets reef.

Tuesday 09 June 2020

Wind 18 kn from 130°. Sea state 4. Low-Moderate swell.

0800 in position 17.403006°S 151.048388°E in vicinity of Diamond Islets reef.

The *Falkor* did some east-west mapping along the northern side of Diamond Islets reef through the night, then positioned at the north-eastern point for ROV dive #368. The ROV was in the water around 0900 for a World Oceans Day live event recorded to the world, with a target depth 549 m. The livestream was from 1000-1100 with speakers from around the calling in around their ocean experiences. On conclusion, the ROV dive continued in and around two large blocks of limestone as the remains of an underwater landslide in the long geological past. The dive was generally in depths around 500 m and again lots of nautilus were seen. The ROV was recovered at 1400 and the ship commenced a transit around the southern side of Diamond Islets, trying to minimise the effects of poor weather on the ship.

Wednesday 10 June 2020

Wind 14 kn from 130°. Sea state 4. Low-Moderate swell.

0800 in position 18.150732°S 149.595579°E in vicinity of Abington Reef.

Following a night mapping along the southern side of Diamond Islets reef, the *Falkor* transited to Abington Reef bordering the southern Queensland Plateau. Several loops around Abington Reef were completed then a short transit to Malay Reef, a deeper bank compared to Abington Reef. Several laps around the reef completed the survey at 1430, revealing very steep cliffs on the Townsville Trough side. The ship then commenced the long transit northwest towards the Flora Reef and Holmes Reefs area with the aim to add additional data to existing multibeam coverage while transiting past the Flinders Reefs area.

Thursday 11 June 2020

Wind 16 kn from 140°. Sea state 4. Low swell.

0800 in position 16.628276°S 147.277562°E on western margin of Queensland Plateau.

The *Falkor* mapped around the eastern side of Flinders Reefs and Heralds Surprise reef through the night, heading across several anomalous bathymetry spikes seen in the 3D depth model. Mapping revealed these to be drowned reefs with heights around 200 m above the surrounding seafloor in depths of ~1000 m. The ship then continued westerly towards the ROV dive #369 site about 15 km southeast of the Cairns Seamount with a target depth of 1548 m. The site was located at the western limit of the Queensland Plateau, close to the adjoining Queensland Trough, and well away from any coral reefs. The dive investigated some low relief, sculptured seafloor on the plateau surface in depths 1500-1300 m. The dive confirmed the seafloor substrate was mostly hard rock with a veneer of softer sediments on the top. At 1530, the ROV was recovered back onboard. The ship commenced a systematic survey between the Cairns Seamount and Holmes Reefs.

Friday 12 June 2020

Wind 16 kn from 140°. Sea state 4. Low swell.

0800 in position 16.638766°S 146.240979°E in Grafton Passage.

At the conclusion of the systematic surveying between the Cairns Seamount and Holmes Reefs, the *Falkor* departed the Queensland Plateau area around 0100 and commenced the return transit westerly towards Cairns. The *Falkor* continued mapping while crossing the Queensland Trough, entering Grafton Passage at 0800. The *Falkor* came to anchor off Cairns harbour at 1200, concluding the expedition "Visioning of the Coral Sea Marine Park".