SYNOPSIS: UNIVERSITY OF PLYMOUTH RESEARCH CRUISE TO BRITISH INDIAN OCEAN TERRITORY, MARCH 2020

SUMMARY

The University of Plymouth team, comprising 7 scientists with expertise in physical oceanography, mesophotic reefs, fisheries acoustics and manta ecology, undertook their second expedition to BIOT between March 5th – March 23rd, 2020 as part of their project co-funded by the Garfield Weston and Bertarelli Foundations. The team were further accompanied by Annie Murray from the Manta Trust and Alain Diaz from Perpignan Hospital and conducted operations aboard the *MV* Tethys Supporter based in Victoria, Seychelles.

The cruise was severely impacted by the Coronavirus pandemic that necessitated a curtailment to the expedition and a return to the Seychelles after the prospect of being permitted entry back into the Maldives became remote. The most severe impact of the loss of time was the minimal work we were able to do over Sandes Seamount but operations at Egmont were largely achieved, albeit limited by adverse weather that prohibited work at Île de Rats. Despite the challenges, and due to a willingness to exploit every possible working hour aboard, the team acquired a significant portion of the data targeted for the cruise during the 11 days during which we were able to conduct scientific activities. Of particular note were the recovery of long-term moorings deployed in November 2019 and a full servicing of the manta acoustic array to recover similarly long-term data and deploy ten additional receivers. Key achievements include:

- A complete survey, to a depth of 160 m of the mesophotic reef community of 'Manta Alley' on the north-eastern shore of Egmont Atoll
- Deployment of an underwater quantum sensor to measure Photosynthetically Active Radiation along the depth gradient
- Deployment of recruitment tiles at 4 different depths at Egmont Atoll
- Collection of 43 hard coral samples from the mesophotic reef for genetic analysis
- Deployment of 12 acoustic tags and 10 additional receivers at Egmont alongside photo identifications of 67 reef manta rays, increasing the database for Egmont to 190 individuals
- Recovery and redeployment of the 5 acoustic receivers deployed during November 2019
- Collection of 8 manta tissue samples for DNA and stable isotope analysis, and 8 plankton samples
- Deployment and recovery of comprehensive mooring arrays over the steep flanks of Sandes and Egmont to identify the role of internal waves in aggregating biomass and causing zonation in the mesophotic reef community
- Recovery of long-term moorings deployed at Sandes and Egmont during November 2019, and the deployment of a further mooring at both sites with anticipated recovery in November 2020
- 60 hours of joint acoustic fisheries and oceanographic measurements around Egmont, including a calibration of the ES70, maximising confidence in the validation of biomass measurements during November 2019 and March 2020 cruises.

Figure 1. (left) the Tethys Supporter and (right) the science team and Tethys Supporter crew.

EXPEDITION HIGHLIGHTS BY DISCIPLINE

OCEANOGRAPHIC DRIVERS OF ECOSYSTEM VARIABILITY

Phil Hosegood and Ted Robinson

The physical oceanography team aimed to build upon Phil Hosegood's previous work in BIOT and our preliminary findings from November 2019 by deploying further oceanographic moorings and conducting vessel-based observations to monitor how currents and water properties evolve over and around Sandes Seamount and Egmont. We furthermore recovered the long-term moorings deployed during November, providing crucial insight into how the oceanographic conditions evolve during the north-west monsoon period. The length of time for which the moorings were deployed during the cruise was approximately half of what was planned for, and the urgent need to depart BIOT meant we had insufficient time to redeploy the Nortek Signature 500 ADCPs. Opportunistic vessel mounted surveys at Egmont, at Ile Sudest in the south east and Ile de Rats in the north west, revealed a complex circulation that strongly suggests wake effects are generated by the island; this would have profound implications for our interpretation of the localised impact of Egmont on primary production and predator-prey interaction.

We deployed an array of 3 moorings over Sandes Seamount on our transit south and a further 3 at Ile de Rats on arrival at Egmont with the aim of monitoring oceanographic conditions at both sites for the entire duration of the cruise. Following a deep CTD profile off Île Sud-est in the south east corner of Egmont, it became immediately apparent that conditions were very different to November when the thermocline was anomalously deep. During this cruise, the thermocline began at 40 m depth, which was surprisingly shallow and appeared to be accompanied by a wider variety, and greater abundance, of marine life. On inspection of the data recovered from the long-term moorings deployed at Sandes and Egmont, it was clear that the thermocline became shallower from late December onwards, presumably as the reversal in the prevailing winds advected cooler water into the region.

Key result: *The thermocline and underlying stratification, which is a key parameter governing the evolution of internal waves over the flanks of submerged bathymetry such as the flanks of Egmont and Sandes Seamount, was unusually shallow during the cruise. The shoaling stratification was apparent in the data recovered from the long-term moorings and demonstrates that the internal wave dynamics influencing foraging and predation exhibit significant temporal variability due to changes in basin-scale oceanography. Flushing of near surface coral with cold, deep water, is more pronounced in March compared to November.*

Figure 2. (left) deployment of deep=water mooring over the steep slope offshore of Ile de Rats and (right), the long-term Signature 500 kHz ADCP recovered from Manta Alley after initial deployment in November 2019.

In addition to the deeper moorings deployed over the flanks of Sandes and Egmont, two shallow ADCP moorings were placed adjacent to acoustic receivers to identify the difference in both oceanographic (i.e. currents) and biological (i.e. zooplankton density) conditions between the two sites. The goal of these measurements was to provide an assessment of how the manta exploit changes in conditions around Egmont; as stated below the Manta were observed on the eastern side of Egmont during the current cruise rather than the western flank on the previous cruise. One of the ADCPs, which enable an estimate of zooplankton concentration through the high vertical resolution of the echo intensity on the vertical acoustic beam, was accompanied by a holographic camera to visualise the particles detected by the ADCP. We plan to develop a method for calibrating the ADCP data given definitive knowledge of the particle properties simultaneously visualised by the camera.

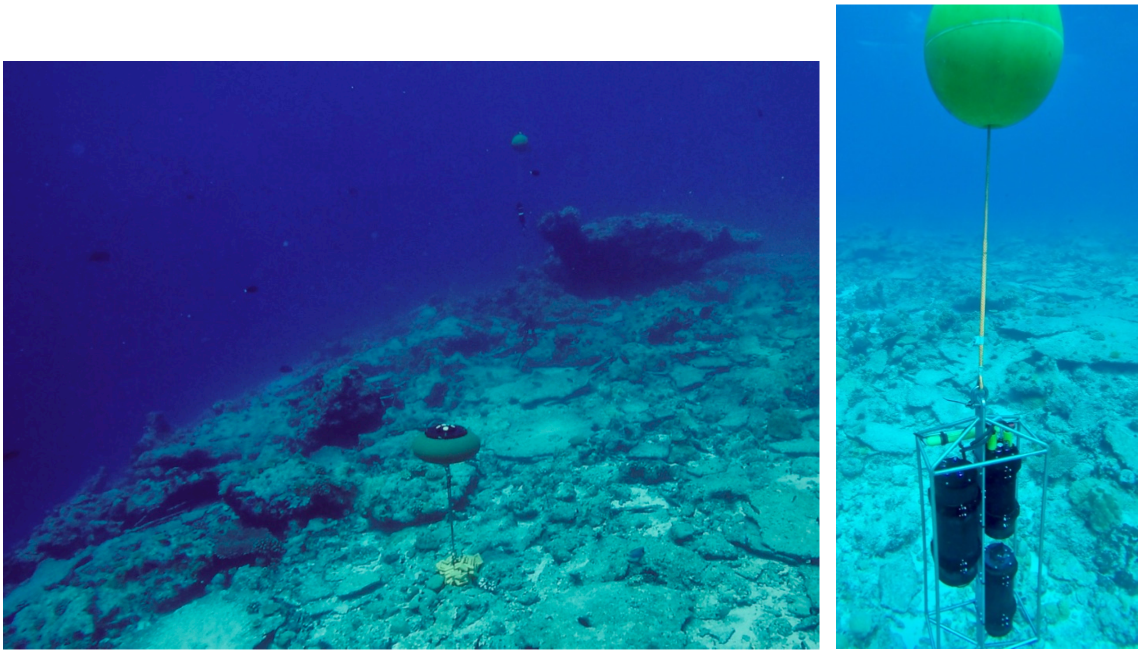


Figure 3. (left) Acoustic Doppler current meter (ADCP) deployed at Egmont to measure the currents and zooplankton at the Manta cleaning station; note the proximity of the mooring to the acoustic receiver in the background that will enable us to match up the abundance of zooplankton with manta presence; (right) a holographic camera deployed adjacent to the ADCP to enable the identification of the particles, including zooplankton whose abundance is measured throughout the water column by the echosounder mode of the ADCP.

Key result: *Initial observations demonstrate the difference in oceanographic conditions between two sites at Egmont where manta preferentially forage at different times of the year. Long-term observations further confirm that manta aggregation is strongly linked to oceanographic internal wave 'events' during which cold water is forced up the slopes, especially in Manta Alley where the majority of detections were made.*

THE DIVERSITY AND CONNECTIVITY OF MESOPHOTIC REEFS IN THE BRITISH INDIAN OCEAN TERRITORY

Kerry Howell, Nicola Foster and Clara Diaz

Mesophotic coral reefs are composed of light-dependent corals and their associated communities and they are found deeper than brightly lit shallow-water reefs, in depths of 30-200 m. It has been suggested that these mesophotic reefs may provide a refuge for shallow-water coral reefs and they may serve as a source of larvae to support the recovery of degraded shallow-water reefs (Deep Reef Refugia Hypothesis). The potential connectivity of mesophotic and shallow reefs depends on a number of factors, including species overlap and water movement. However, little is known about the distribution, abundance, productivity and health of mesophotic reefs in BIOT, and worldwide, due to the difficulties of working at depths beyond conventional SCUBA diving (>30m). Here, we used a remotely operated vehicle (ROV) and deployed recruitment tiles to study the mesophotic reefs of BIOT.

During the latest cruise in March 2020, we built on data collected during the November 2019 cruise. During the course of 13 ROV dives, we collected over 39 hours of underwater high-definition video footage, and sampled over 400 images of the mesophotic communities from 30-160 m depth. We now have complete datasets of two contrasting sites at Egmont Atoll (North-East and North-West of the atoll), which will enable us to assess changes in the diversity of the reefs with depth. The biodiversity and colours of these deeper ecosystems are stunning! We also collected 43 physical samples of hard coral species from between 20 and 100 m depth, which will be used for taxonomic identification and to investigate population connectivity between the shallow and mesophotic reefs.

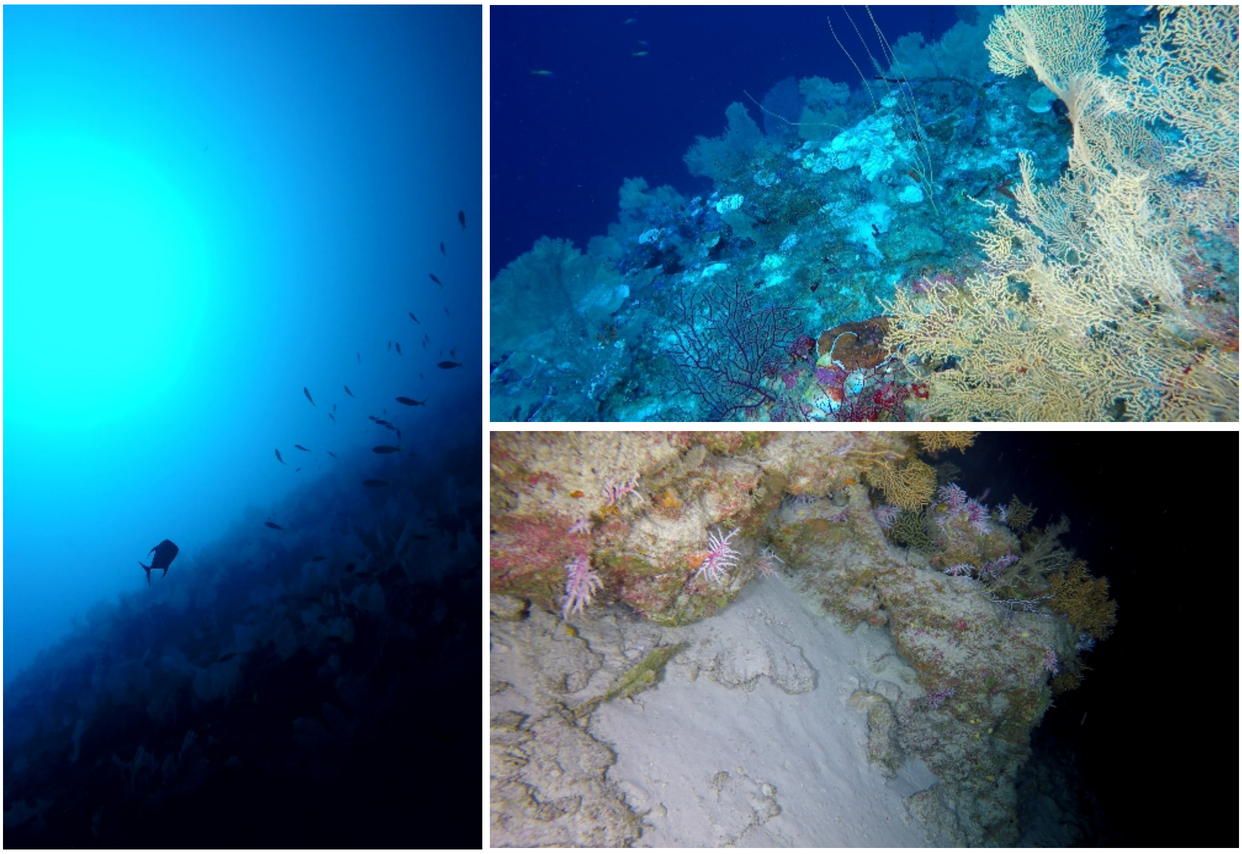


Figure 4. Left: Mesophotic reef at 90 m; Top: Mesophotic reef at 70 m; Bottom: Mesophotic reef at 120 m.

In addition to physical sample collection and video transects, we deployed recruitment tiles at 4 depths (20 m, 35 m, 65 m, and 85 m) in order to study the community structure and diversity of juvenile coral species recruiting to mesophotic reefs. These recruitment tiles will enable us to identify if recruits are settling on or near to their natal reef, or if they are dispersed vertically or horizontally in the currents to neighbouring reefs.

We also completed vertical profiles of Photosynthetically Active Radiation (PAR), temperature and depth at multiple locations around Egmont Atoll between the hours of approximately 12:00 and 13:00. These data will enable us to determine light attenuation with depth and relate this to the distribution of light-dependent benthic communities around BIOT.

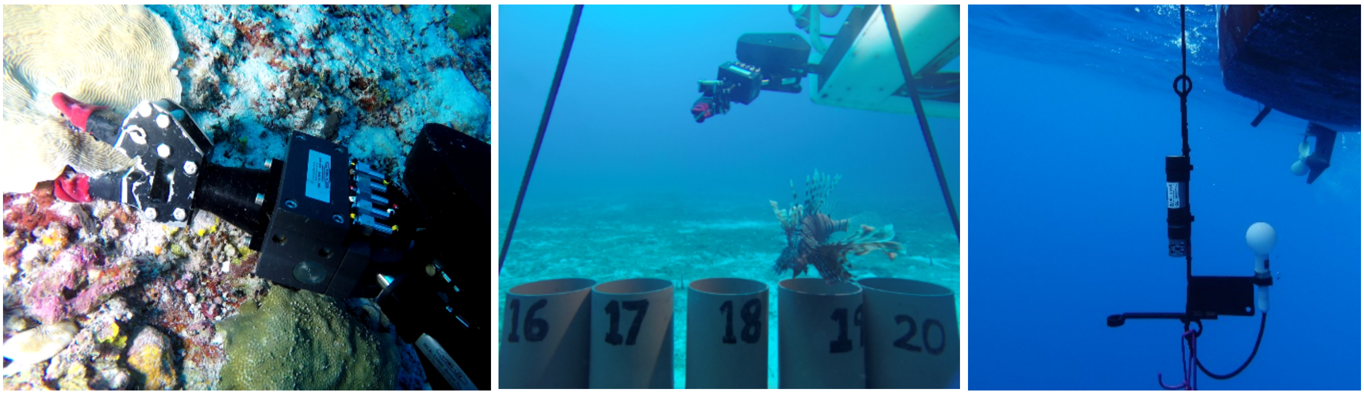


Figure 5. Left to right: Hard coral sampling with the ROV robotic arm; Storage of samples in the ROV 'garage', with the ROV robotic arm dropping off a coral sample in one of the tubes; Deployment of an underwater quantum sensor.

These data are extremely important in helping us to understand the diversity and community structure of mesophotic reefs in BIOT and how this varies with depth, in order to understand how these deeper reefs may support the more degraded shallow-water reefs. An initial look at the video data suggests that although the mesophotic reef communities are relatively healthy and diverse, they are composed of different species to the shallow-water reefs, although this will be confirmed following further analysis. The population genetic analysis will take a number of months to conduct. We are currently extracting DNA from the samples of hard coral species and will use this to develop markers (microsatellites or SNPs) to investigate the vertical and horizontal connectivity of shallow and mesophotic coral species. These data will enable us to determine the role of mesophotic reefs in supporting the shallow-water reefs of BIOT.

MANTA RAY RESEARCH

Joanna Harris and Annie Murray

Reef manta rays (*Mobula alfredi*) are listed as Vulnerable to Extinction on the IUCN Red List of Threatened Species due to catastrophic declines caused mainly by targeted and bycatch fisheries. Effective conservation relies heavily on understanding their movements and behaviours and what environmental factors influence these. However, human activities such as pollution, overfishing and habitat degradation can disrupt natural patterns; therefore, we need to be able to study the species in an environment where human influence is minimal.

With the near absence of human influence, the subpopulation of reef manta ray that inhabits the Chagos Archipelago, British Indian Ocean Territory (BIOT), offer the Manta Trust and the University of Plymouth a unique opportunity to study the species in a near-natural environment where the association between environmental variables, movements and behaviour can be developed to help understand the effects of human pressures.

In November 2019, the Manta Trust and the University of Plymouth embarked on their first research cruise to the region where work focused on Egmont Atoll, a known reef manta ray aggregation hotspot. The research conducted assists in addressing four main areas: i) Population size, demographics and health, ii) Reef manta ray visitation patterns at Egmont Atoll in relation to oceanographic processes, iii) Dietary preferences and subpopulation connectivity, iv) Reef manta ray feeding behaviour, zooplankton community dynamics and oceanographic processes. During the second cruise in March 2020, activities continued to focus on these areas.

Research progress from March 2020 cruise

i) Population size, demographics and health

The BIOT reef manta ray subpopulation is one of the least studied in the world thus largely undocumented. By photographically documenting all of the reef manta rays encountered during each research cruise, we will be able establishing population size, demographics and the physical condition of the individuals. During the second cruise, the manta team documented a total of 67 encounters of 52 reef manta rays, 28 of these were previously undocumented, which has increased the Manta Trust's database to 190 individuals. Images were captured on camera while freediving (Figure 6 and 7) by video cameras placed in strategic locations (Figure 8) and also during ROV surveys (Figure 9).

Figure 6. Joanna Harris (PhD Student) freediving at North IdR Cleaning Station to obtain a photograph of the reef manta ray for identification.

Figure 7. Image captured at reef manta ray aggregation hotspots (Images: ©Annie Murray, Manta Trust).

ii) Reef manta ray visitation patterns at Egmont Atoll

Five acoustic receivers that were deployed in November 2019 were retrieved (Figure 10), so they could be serviced and the detection data downloaded. Preliminary analysis has begun to reveal how the tagged manta rays utilise Egmont Atoll (Figure 11).

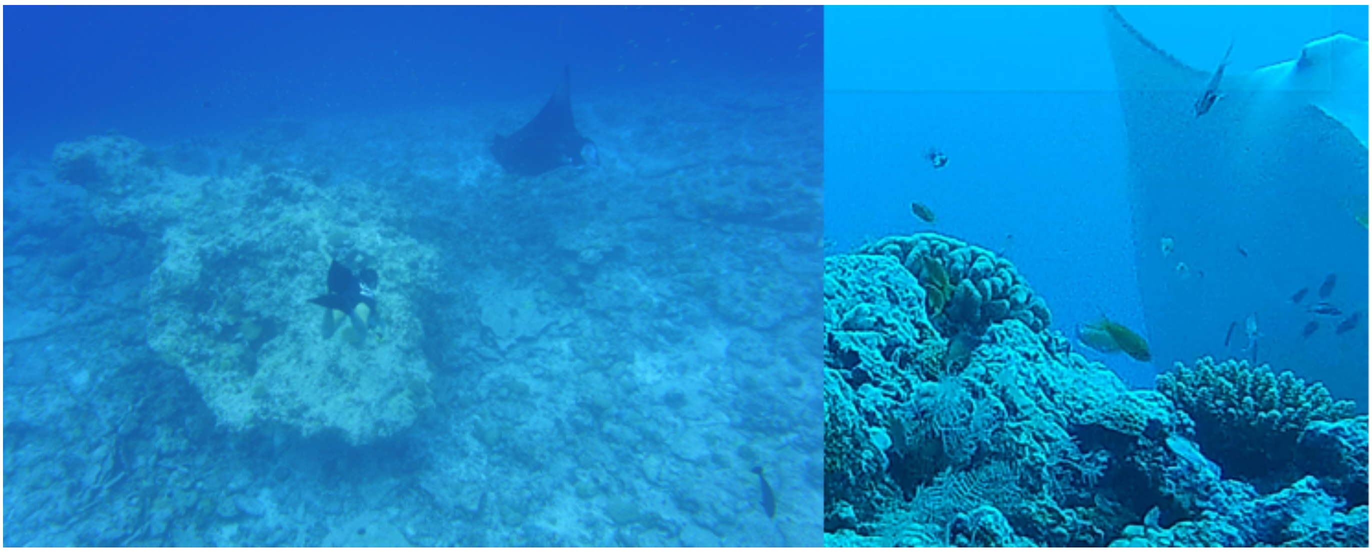


Figure 8. A researcher (Joanna Harris, PhD Student) deploying a video camera at North IdR Cleaning Station (left), and an example of a reef manta ray captured on video at the location (right).

Figure 9. (left) Reef manta rays cruising at 75m , recorded by ROV camera and (right) Reef manta rays recorded by the ROV camera feeding at 112m deep in Manta Alley. This is the first known photographic record of a reef manta ray feeding at this depth.

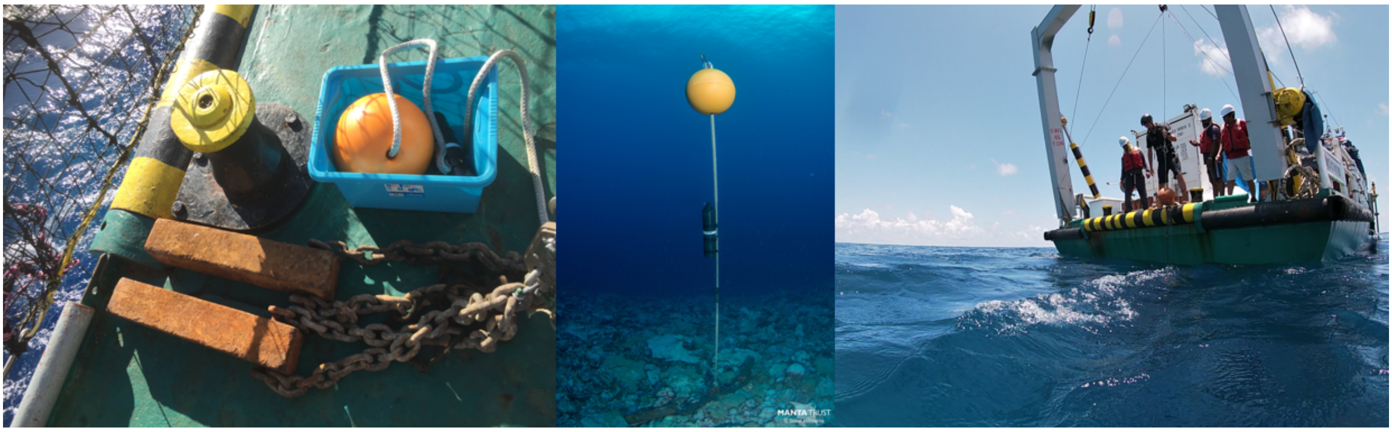


Figure 10.Acoustic receiver mooring before deployment from the Tethys Supporter (left), after deployment at Ile Sipaille (centre, ©Simon Hilbourne, Manta Trust) and an acoustic receiver being recovered by the Tethys Supporter for servicing and to download detection data.

Figure 11 shows the highest percentage of tag detections occurred at the acoustic receiver deployed on the oceanographic mooring in Manta Alley (51.4%). North IdR Cleaning Station has the second-highest percentage of detections and the acoustic receivers at these two locations were the most frequently connected by subsequent detections (i.e. tagged reef manta rays which were detected by the acoustic receiver at North IdR Cleaning Station were next detected most frequently by the acoustic receiver in Manta Alley and vice versa).

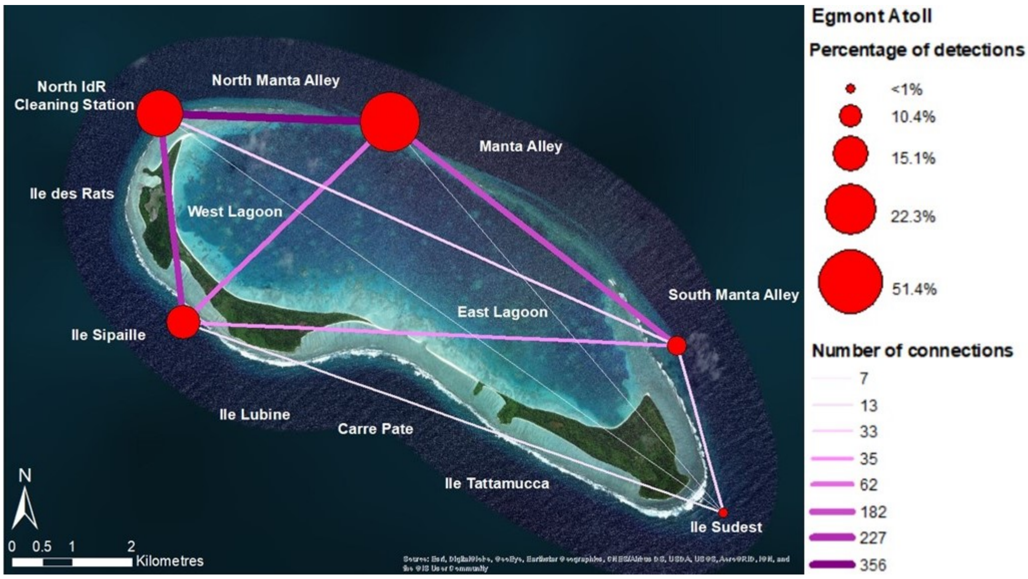


Figure 11. Network map of the Egmont acoustic receiver (AR) array, showing the percentage of reef manta ray detections recorded by each receiver between November 2019 and March 2020 (graduated red circles). Lines between the ARs show how often each AR was connected by subsequent detections.

A further ten acoustic receivers were deployed at Egmont in March 2020 to compliment the current array. An additional 12 acoustic transmitter tags (Figure 12) were also deployed, bringing the total to 32. The extension of the array and the additional tags have enhanced data collection efficiency and will help to provide an unprecedented insight into reef manta ray visitation patterns and habitat use at Egmont Atoll.

Figure 12. A tagged reef manta ray returns to the researcher (Joanna Harris, PhD Student) that deployed the acoustic transmitter onto its dorsal musculature (Image: ©Annie Murray, Manta Trust).

iii) Dietary preferences and subpopulation connectivity

To investigate dietary preferences and long-term changes in the species movements, tissue samples were taken for genetic and stable isotope analysis (Figure 13).

iii) Reef manta ray feeding behaviour, zooplankton community dynamics and oceanographic processes.

Reef manta ray behavioural surveys (feeding and not feeding), plankton tows and measurements of oceanographic variables (Figure 14) were performed concurrently at feeding activity hotspots on eight occasions. This data complements the data collected in November 2019 and will help to identify how fine-scale changes in the environment influence reef manta ray feeding behaviour.

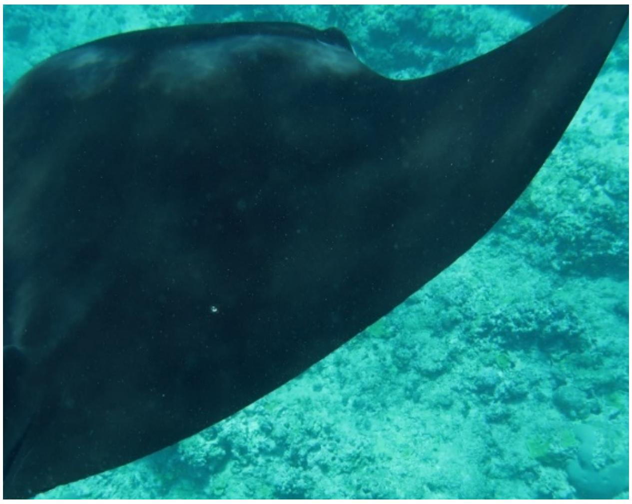


Figure 13. Dorsal surface of a reef manta ray after a small tissue biopsy, which can be seen as a white dot.

Figure 14. Bottom mounted Nortek Signature 500 (top left). Maestro Conductivity Temperature Depth (CTD) profiler fitted with a Rinko dissolved oxygen sensor and Seapoint chlorophyll-a fluorometer sampling the water (top right). Plankton net being towed (bottom left) and a reef manta ray (bottom right) recorded as 'not feeding'.

Fisheries Acoustics

Dannielle Eager, Clare Embling, Benjamin Williamson

Pelagic biomass can be influenced by both large and fine scale oceanographic processes affecting their spatial and temporal distribution through behavioural changes. With such unique topography, as found in BIOT, surveying the biomass acoustically provides an insight into both biological and physical processes over large areas. Using a pole mounted Simrad ES70 at 38 and 200 kHz which was synchronised to a VM Signature 100 ADCP (Figure 15), multiple surveys were carried out around Egmont Atoll. Calibration of the instrument was also successfully completed increasing confidence in the validation of biomass measurements based on recorded target strengths. In total, 60 hours of joint acoustic and oceanographic measurements were collected at three different locations around Egmont Atoll.

Research Progress from Expedition

Calibration of the ES70 was completed following the guidelines set out by ICES (ICES, 2015). Using a tungsten carbide 38.1 mm diameter sphere suspended under the transducer, data were recorded to allow the mean on-axis area backscattering coefficient (Sa) and transducer gain values to be accurately measured. These values have been applied to the March 2020 and November 2019 datasets to maximise confidence in target strength values when they are extracted and analysed.

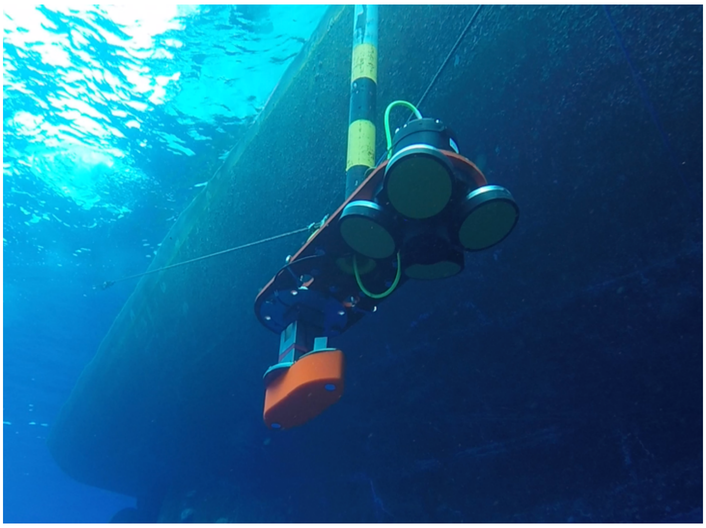
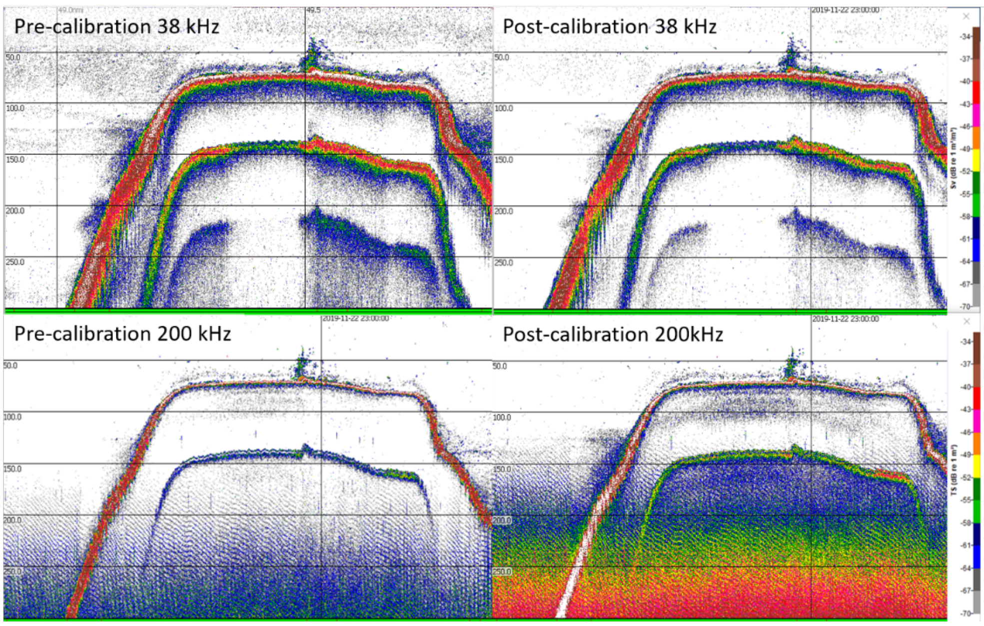


Figure 15. Joint pole mount for the Simrad ES70 and Nortek Signature 100.

A 36-hour survey repeating 1-hour transects on the south east side of Egmont Atoll was designed to compare the abundance of biota of two different depth contours (50 and 100 m). Initial results show the potential flow of plankton from the lagoon to deeper water due to the tidal cycle and that diel vertical migration is present.



Calibration setting	Value	Calibration file	Data file
AbsorptionCoefficient (dB/m)	0.0058660	0.0058660	0.0094821
EK60SaCorrection (dB)	-0.7622	-0.7622	0.0000
Ek60TransducerGain (dB)	23.5140	23.5140	19.5000
Frequency (kHz)	38.00	38.00	38.00
MajorAxis3dbBeamAngle (º)	21.00	21.00	21.00
MajorAxisAngleOffset (º)	0.00		0.00
MinorAxis3dbBeamAngle (º)	13.00	13.00	13.00
MinorAxisAngleOffset (º)	0.00		0.00
SoundSpeed (m/s)	1544.00	1544.00	1544.00
TransmittedPower (W)	1000.00000	1000.00000	1000.00000
TransmittedPulseLength (ms)	0.512	0.512	0.512
TvgRangeCorrection	SimradEx60		SimradEx60
TwoWayBeamAngle (dB re 1sr)	-13.300000	-13.300000	-14.000000

Calibration setting	Value	Calibration file	Data file
AbsorptionCoefficient (dB/m)	0.0893730	0.0893730	0.0513772
EK60SaCorrection (dB)	-0.7947	-0.7947	0.0000
Ek60TransducerGain (dB)	28.6218	28.6218	26.3000
Frequency (kHz)	200.00	200.00	200.00
MajorAxis3dbBeamAngle (º)	7.20	7.20	7.20
MajorAxisAngleOffset (º)	0.00		0.00
MinorAxis3dbBeamAngle (º)	7.20	7.20	7.20
MinorAxisAngleOffset (º)	0.00		0.00
SoundSpeed (m/s)	1544.00	1544.00	1544.00
TransmittedPower (W)	200.00000	200.00000	200.00000
TransmittedPulseLength (ms)	1.024	1.024	1.024
TvgRangeCorrection	SimradEx60		SimradEx60
TwoWayBeamAngle (dB re 1sr)	-20.730000	-20.730000	-20.500000

Figure 16. (top) echograms for 38 kHz pre and post calibration with the calculated new parameters and (bottom) pre and post calibration echograms for 200 kHz with the new parameters.

Two overnight surveys were designed to compare the flow of water around the north west and south east tips of Egmont Atoll to observe how this influenced the behaviour of biomass. A similar grid design was used for both surveys which crossed the different depth contours allowing a large spatial coverage of the area. At the south east tip, Île Sud-est, fish aggregations and plankton were only seen at the pinnacles of the depth contours and with their abundance decreasing with depth. This suggests that oceanographic processes may be enhancing these regions by retaining smaller organisms or that the strong currents are trapping biota in these areas during strong tidal flows (Figure 17). In comparison, at the north west tip of Ile des Rats, there was only one steep change in topography that had biota present. The aggregation of this biota is likely due to the strong currents and current direction which were recorded simultaneously by the VMADCP. Further analysis will look at the behavioural changes in biota brought about by both spatial and temporal changes in oceanography and topography.

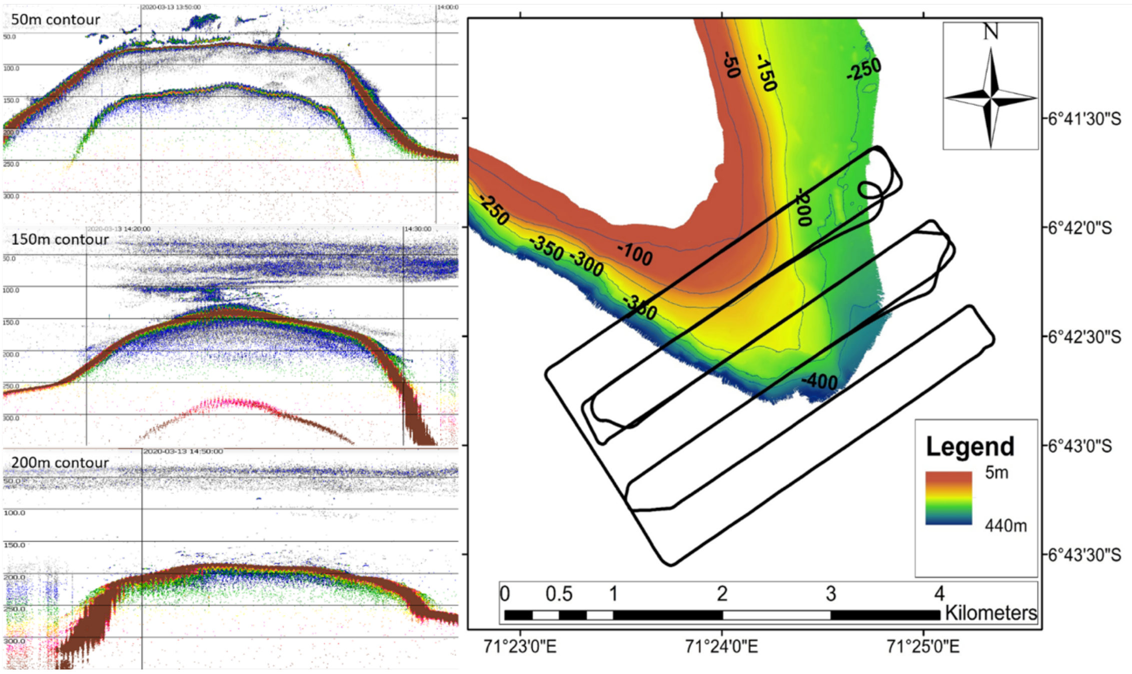


Figure 17. (left) 200 kHz echograms showing an aggregation of fish and plankton at Ile Sudest over 3 different depth contours and (right) the transect grid overlaid on MBES bathymetry with contour lines in metres.