The Bertarelli Programme in Marine Science
Expedition Report

Coral Reef #1
March 2019

The *Bertarelli Programme in Marine Science* is a collaborative programme bringing together scientists from all around the world to work in the British Indian Ocean Territory (BIOT). Each brings their own expertise to the research programmes and, with the support of the Bertarelli Foundation, tackles some of the most important and challenging questions in ocean science.

This large, remote, near pristine, no-take MPA presents an incredible opportunity to take an integrated and interdisciplinary approach to understanding the role of these complex ecosystems for mobile species such as tunas, sharks, turtles, and seabirds. As BIOT was negatively impacted by the 2015-2016 global coral bleaching event, it also provides an important study area to explore the resilience that large marine reserves offer in the absence of fishing and other anthropogenic pressures.

Between 2017 and 2021 the *Bertarelli Programme in Marine Science* will transform our understanding of the benefits of the BIOT MPA for terrestrial, reef-dwelling and pelagic species.

AUSTRALIAN INSTITUTE OF MARINE SCIENCE 2019

The Bertarelli Programme in Marine Science Reef 1 Expedition

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Cover photo: Aerial view of Salomno Atoll, British Indian Ocean Territory (Photo: Rob Dunbar | Stanford University).

1 SUMMARY

The Bertarelli Programme in Marine Science (BPMS) Reef Expedition 1 in 2019 ran from 2-18 March. We joined the Grampian Frontier in Diego Garcia and transited to Egmont Atoll, starting our surveys there on the 3rd of March. Poor weather at the outset (squalls with accompanying winds reaching 45 knots) caused us to alter our schedule and we transited overnight to the northern atolls of Peros Banhos and Salomon to take advantage of the sheltered lagoons to conduct work as the weather subsided. The next six days were spent surveying reefs across Peros Banhos Atoll, followed by three days at Salomon Atoll. On the 13th March we spent the day at Nelson's Island, followed by two days at the Three Brothers islands and one day at Eagle Island. Finally, we spent the final two survey days back at Egmont Atoll. In the afternoon of the 18th March, we learned that the flight from Diego Garcia to Bahrain scheduled on 20 March was cancelled, and that our other option was to leave the following morning. Hence, we expedited our demobilisation and steamed back to Diego Garcia to offload personnel and equipment that evening. All but four science personnel departed the following morning to Bahrain, with the remaining four preparing for additional fieldwork at sea.

The expedition was focused on various components of the reef ecosystem, including fish, invertebrate and coral communities, as well as quantifying hydrodynamic processes at many scales. Altogether, 6 collaborating teams from BPMS projects were represented. The expedition participants came from the Australian Institute of Marine Science, Exeter University, Lancaster University, Stanford University, the Zoological Society of London, Imperial College London, Oxford University, and University of Victoria. Details of each participating group's research objectives are given below.

The crew of the Grampian Frontier were immensely helpful on a variety of levels. Their support and endlessly positive attitudes, through adjustment of schedules, patching of inflatable boats, deployment and use of the Daughter Craft and Fast Rescue Boat, and repair of equipment, was greatly appreciated. We faced inclement weather in the early part of the expedition when southeast trade winds greatly limited work on the outer reefs. Towards the end of our time at Peros Banhos the weather had subsided to safe working levels, with squalls and high winds appearing only sporadically.

1.1 Key observations from the expedition

Following the mass coral bleaching of 2015/2016, most reefs across the region displayed lower coral cover than several years prior (Figure 1). However, there were strong signs of coral recovery on some reefs. Recent growth and proliferation of acroporid corals was observed at several sites amidst dead coral skeletons presumably from the prior bleaching event (Figure 2). Benthic surveys of coral cover and measurements of reef growth were performed during this expedition and will inform on rates of coral recovery across the region.

Figure 1 A degraded reef with low coral cover between Ile du Sel and Ile Jacobin, Salomon Atoll (Photo: Brett Taylor | AIMS).

Figure 2 High coral cover at Ile du Coin, Peros Banhos (Photo: Rob Dunbar | Stanford University).

Despite the absence of standardized surveys, it appears shark abundance continues to increase across the region. Evidence from diver observations has suggested the numbers of sharks had previously declined since the 1970s. The 2018 expeditions saw the greatest number of sharks per dive in recent years, and this expedition recorded numbers even higher. Grey reef and tawny nurse sharks were the most abundant, with black tip and white tip reef sharks also commonly observed. Silvertip sharks were common at Egmont Atoll (Figure 3). Overall, we noticed a gradient in shark abundance between northern and southern sites. Egmont Atoll appeared to have the highest density and diversity of shark species. It is uncertain if this gradient reflects natural patterns or the history of poaching, which is presumed to be more intense at the northern sites.

Figure 3 Silvertip shark observed at Egmont Atoll (Photo: Ines Lange | Exeter University).

Forty-three SBE-56 high precision sea temperature loggers were recovered during the expedition. About half were deployed in April, 2018 and were still logging upon recovery in March, 2019. The remaining T loggers were deployed for short duration experiments examining stratification within the coral reef water column. Many forereef records showed short-lived (minutes to hours) and sudden declines in temperature at 10 meters (Figure 4). These short-lived cooling events can be large, as much as 7°C. They are not apparent in lagoons so we suspect they result from interactions of internal waves with the island pedestals. Corals that live along many Chagossian forereefs are exposed to very different thermal regimes than corals in the lagoons.

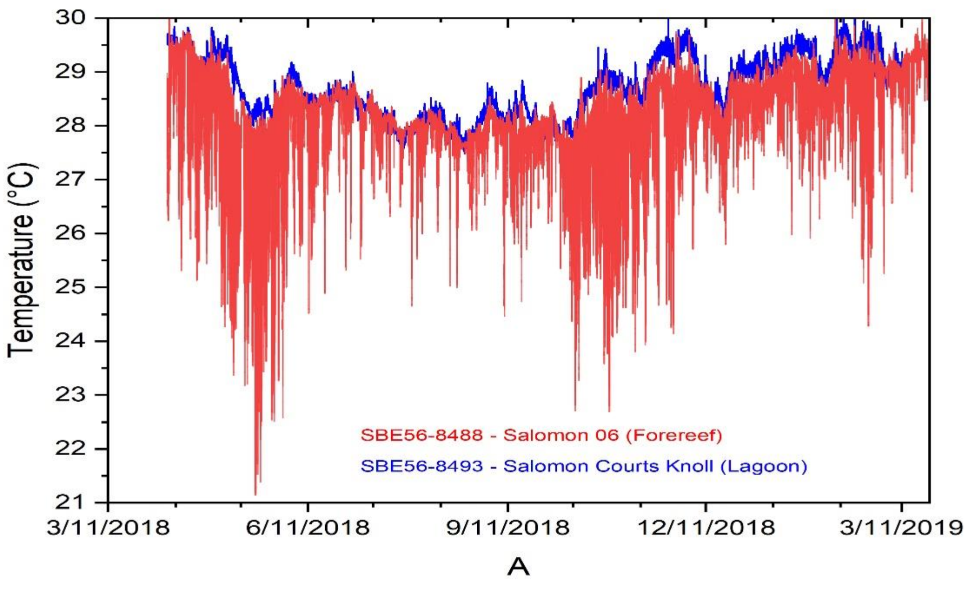

Figure 4 Time series' of sea temperature at 10 meters from two sites at Salomon Atoll, one in the lagoon and one on the forereef outside the lagoon (red: Salomon Forereef site 6; blue: Salomon Lagoon, Courts Knoll). Temperatures were slightly warmer in the lagoon and varied from 28-30°C. Forereef temperatures ranged from 21-30°C, a very large range for a coral reef. (Credit: Rob Dunbar | Stanford University).

1.2 Projects of the expedition

(1) Fish surveys to monitor change in abundance, biomass and composition of the fish community through time (Dr. Mark Meekan, Dr. Brett Taylor & Mark Chinkin, Australian Institute of Marine Science; Prof Nick Graham & Dr. Casey Benkwitt, Lancaster University)

Prior underwater visual census (UVC) surveys of coral reef fishes have found that the BIOT MPA has some of the highest biomass estimates for reef fish globally. This project has extended prior surveys into a longer-term monitoring program with annual surveys of coral reef fish communities at fixed sites across the Chagos Archipelago. Surveys methods are alternated each year between UVC and Diver-operated Stereo-Video surveys (DOVs), and this year researchers from Lancaster University performed UVC surveys at ten fixed outer reef sites as part of the long-term monitoring project (Figure 5).

Complementary to these annual surveys, the team from AIMS conducted baited remote underwater video system (BRUVS) surveys to estimate the relative abundance of reef sharks and other predatory reef fishes across various sites spanning the archipelago (Figure 6). In total, 95 hour-long video surveys were deployed across Peros Banhos Atoll, Salomon Atoll, Nelson's Island, North Brother Island, Eagle Island, and Egmont Atoll. This data set represents the most comprehensive survey of reef sharks across the archipelago and will be compared with global standardized BRUVS data (Global FinPrint) to assess shark abundance within the BIOT MPA.

Figure 5 Prof Nick Graham surveying the fish community at a long-term monitoring site (Photo: Casey Benkwitt | Lancaster University).

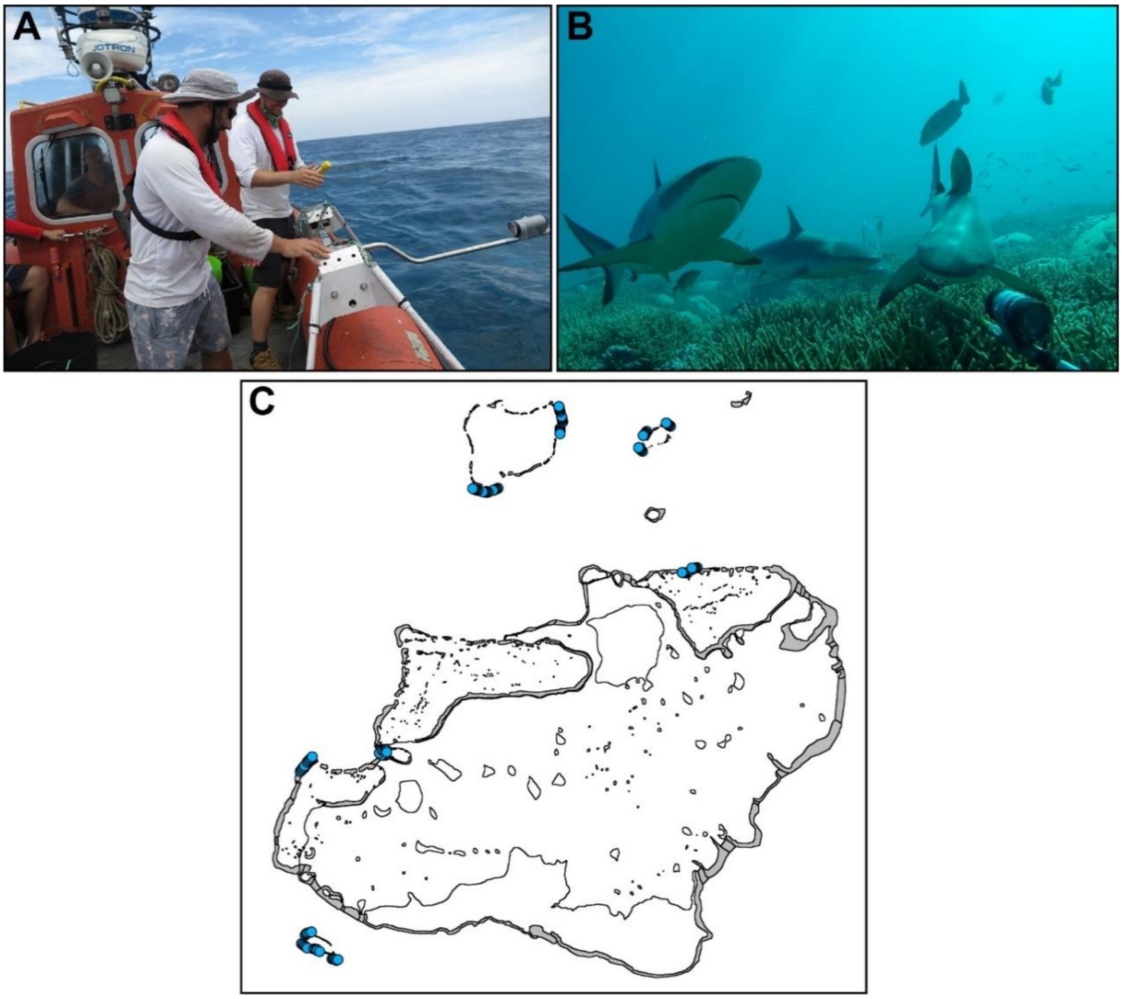

Figure 6 (a) Deployment of baited remote underwater video survey (BRUVS) frames by Mark Chinkin and Dr. Brett Taylor from the Grampian Frontier Daughter Craft (Photo: Mark Meekan | AIMS). (b) Video frame of BRUVS footage showing grey reef sharks (Carcharhinus amblyrhynchos) attracted to the bait at Egmont Atoll. (c) Map of BRUVS deployments across the Chagos Archipelago.

(2) Development of biochronologies of fish and tree growth across BIOT for selected species (Dr. Mark Meekan, Dr. Brett Taylor & Mark Chinkin, Australian Institute of Marine Science)

Techniques derived from dendrochronology (tree ring) studies offer a new means to reconstruct historical patterns of fish growth from otoliths (fish ear bones), which also deposit annual growth rings. The long life spans of many species of fish allow construction of multi-decadal bio-chronologies that can detect and predict fish growth responses to climate change. However, these techniques can also inform on responses of shorter-lived species to anomalous disturbance events. Growth rate is one of the key traits that determine productivity of fish stocks and so identifying the impact of climate change on growth rates is a key research challenge.

During this expedition, individual fish from eight species were collected, including piscivorous and plantivorous snappers, herbivorous surgeonfish, and parrotfishes that feed on microbes from the reef matrix. A very limited number of individuals were collected, as the collections built upon efforts from the previous year's expedition, and collections were spread across regions of the archipelago. The otoliths of long-lived species (snappers and surgeonfish) will be used to generate multi-decadal growth chronologies from which historical relationships with regional and basin-wide climate factors will be explored. For the shorter-lived parrotfishes (Figure 7), species-specific and general responses to the 2015-2016 coral bleaching will be explored, as the nutritional ecology of these species is intricately tied to reef substrates. Both approaches will inform on productivity of fish populations under future climate change.

Figure 7 Initial phase parrotfishes *Scarus rubroviolaceus* (left) and *Chlorurus sordidus* (right). Chronological reconstructions of parrotfish growth will help determine the short-term response to bleaching across species. (Photos: Brett Taylor | AIMS).

(3) The influence of seabird versus rat islands in promoting the resilience of coral reefs and associated fish communities (Prof Nick Graham & Dr Casey Benkwitt, Lancaster University)

We continued our work examining how seabirds nesting on islands influence adjacent coral reefs. By comparing islands with abundant seabird populations to nearby islands that lack seabirds due to the presence of invasive rats, we tested how nutrient inputs from seabirds influence the recovery of coral reefs following major disturbance events such as the 2015/2016 coral bleaching event. On this expedition, we focused on the effects of seabirds on the growth and physiology of corals and herbivorous fishes, both of which are essential to reef resilience.

To test whether seabird nutrient inputs enhance coral growth rates, and thus quicken recovery rates of coral reefs following disturbance events, we re-measured 20 coral colonies that we tagged last year (Figure 8). We tagged an additional 40 coral colonies so that we are now monitoring coral growth around 5 islands with seabirds and 6 islands with invasive rats. We also re-sampled 20 coral colonies that we experimentally transplanted between islands with seabirds and islands with rats to unequivocally determine the effect of seabird nutrient subsidies on the physiology and performance of corals. In addition, we sampled the microbiome of corals, water, sediments, and guano to test how seabirds influence the microbial communities of nearby coral reefs. Finally, we collected parrotfish from lagoons to test how seabird nutrients influence the growth and reproduction of herbivorous fishes, which is key to the productivity and persistence of these populations and to maintaining healthy reefs.

Figure 8 The same coral colony in 2018 (left) and 2019 (right) that we transplanted from an island with invasive rats to a nearby island with seabirds (Photo: Casey Benkwitt | Lancaster University).

Figure 9 Red-footed boobies nesting on Middle Brother, adjacent to one of our study sites (Photo: Casey Benkwitt | Lancaster University).

(4) Carbonate budgets and the future growth potential of coral reefs across the Chagos Archipelago (Dr. Ines Lange & Jen McWhorter, Exeter University; Project PI Prof Chris Perry [not on 2019 expedition])

The aim of this research project is to assess the impacts of the recent bleaching event in 2015-2016 on the carbonate budgets of the reefs around the Chagos Archipelago. This year the focus of the trip was to collect empirical data on local calcification and erosion rates in order to improve the local accuracy of reef budget assessments.

We successfully recovered 50 experimental crustose coralline alga settlement tiles and 14 coral blocks with endolithic borers that were deployed in 2018. New sets of tiles and blocks were deployed for recovery in 2020. We also re-photographed 70 coral colonies which were tagged in 2018 for the purposes of photogrammetry-based assessments of coral growth rates (Figure 10). To be able to quantify coral calcification rates, we recovered small sub-samples of 140 coral skeletons of the dominant 20 species to measure their skeletal density. This will provide the first comprehensive dataset for coral growth and calcification rates in the Chagos Archipelago. To estimate rates of parrotfish bioerosion we counted bite rates of a range of parrotfish species and sizes, and measured their feeding scars. Together with a dataset on fish erosion obtained by our group in the Maldives, this data will significantly increase the knowledge of the impacts of parrotfish bioerosion on reefs in the central Indian Ocean.

In addition to obtaining these important metrics we conducted ReefBudget surveys at three sites across Salomon, which were characterized by different coral cover and structural complexity. The exact same sites have been, and will be, visited by Dan Bailey (Reef 2) who constructs 3D-photomosaics of reef areas and calculates changes in reef volume over time. By comparing our estimates at the same reef sites we will be able to discuss and improve limitations of each method. We are happy to report that, in contrast to last year, net carbonate budgets at the investigated sites where slightly positive due to growing coral recruits.

Figure 10 Ines Lange photographing a tagged coral colony which will be analysed for annual growth rates by comparing 3-dimensional models of the coral over several years. (Photo: Kristina Tietjan).

(5) Trophic cascades, mesopredator release and reef resilience (Jamie McDevitt-Irwin & Kristina Tietjan, Stanford University; Project PI Prof Fio Micheli [not on 2019 expedition])

Our project conducts field studies and sampling at sites spanning a gradient in the abundance of large predators aimed at complementing analyses of community change associated with varying abundances of top predators. We hypothesize that differences in shark abundances and/or mesopredator release will result in shifts in trophic organization and physiological condition of species at the lower levels of food webs, and these effects cascade all the way to the benthos, to influence recruitment and survival of corals and other sessile organisms.

During this trip, we installed 225 terracotta tiles at eight sites across the archipelago to quantify coral recruitment and benthic community development over the next year (Figure 11). At each of our eight sites (including Salomon, Peros Banos, and the Great Chagos Bank), we deployed 24-30 triplicate tiles with one uncaged, thus accessible to all fishes, and one caged to exclude large fishes, and one partially caged. All tiles will be recovered in one year for detailed characterization of benthic assemblages using DNA barcoding. At each of these sites where we installed tiles, we conducted DOV (diver operated videos) to document the fish community, photoquadrats to document the existing benthic community, and we collaborated with the AIMS team and they conducted BRUVS (baited remote underwater video systems) to document shark/predator communities near our tile sites. In addition, we collaborated with the AIMS team and took fish muscle samples from the fishes used for biochronology work, to evaluate changes in isotopic niche, morphology and size of both herbivores and mesopredatory fishes at sites with varying predator abundance. Finally, we conducted herbivore feeding assays at sites to evaluate changes in herbivore fish behaviour across the atolls. This data will be used in analyses to evaluate the impact of top predators on lower trophic levels (i.e. DOVS, herbivore feeding assays) and how this cascades down to the benthic community (i.e. recruitment tiles).

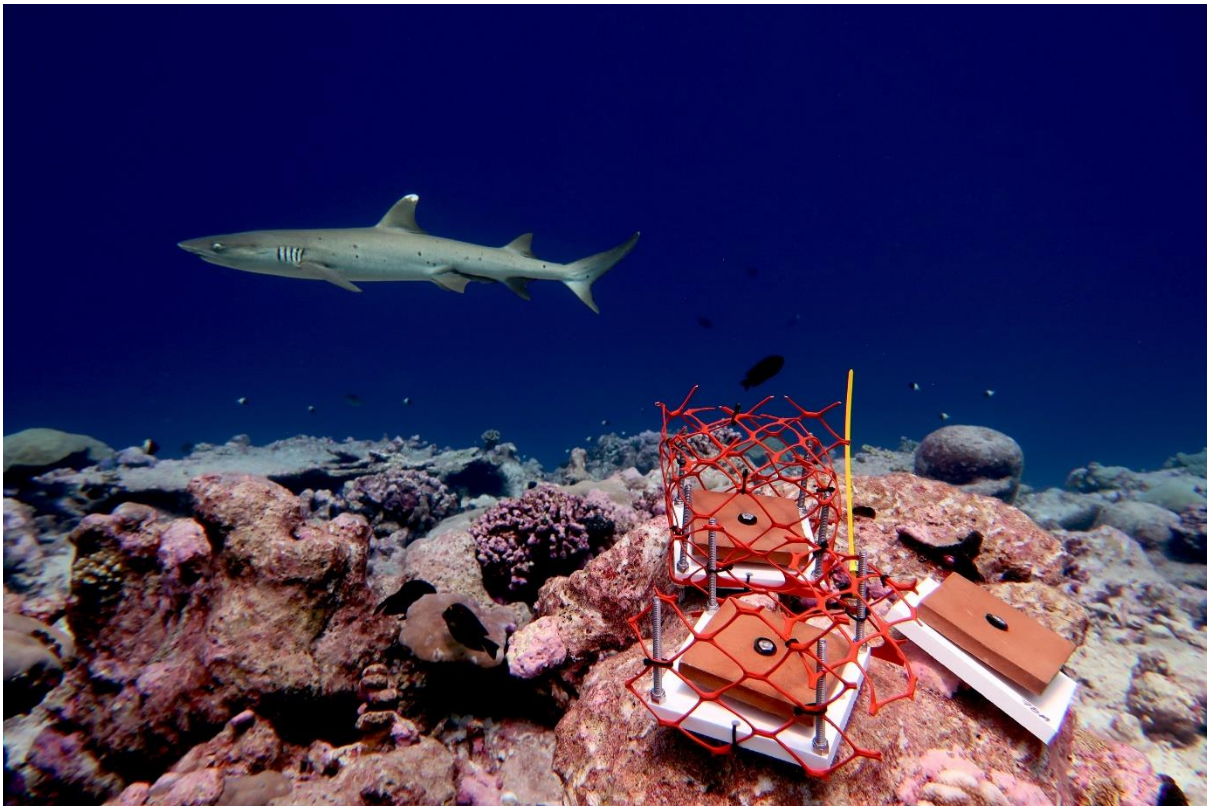

Figure 11 Experimental recruitment tiles (Caged, Uncaged and Partially Caged) to monitor the cascading influence of fish and shark communities on coral reef development and recovery. (Photo: Kristina Tietjan).

(6) Reef biodiversity, connectivity, productivity and the environmental drivers (Dr. Catherine Head, Margaux Steyaert, & Nick Dunn, Zoological Society of London, Oxford University, and Imperial College London) – project in conjunction with (7) below

1.3 Objectives:

1. Collection of coral fragments of three species to investigate genetic connectivity
2. Water sampling and filtration to assess reef plankton biogeography patterns using environmental DNA (eDNA), including a method validation component.
3. Collection and processing of six Autonomous Reef Monitoring Structures (ARMS) to identify reef cryptofauna community structure and the environmental drivers.

Objective 1: Specimens of three species of scleractinian coral (Acropora cytherea, Acropora tenuis and Porites lutea) were collected from 17 sites across BIOT. In total small fragments (2cm x 2cm approx.) of 276 individuals were collected (91 A. tenuis, 101 A. cytherea, 84 P. lutea; Figure 12). The specimens will be used to investigate the population structure of the species across the Archipelago using genomic techniques. This will enable us to identify how the reefs within the Archipelago are connected by their larvae flow. This is important because well-connected reefs will likely have enhanced potential for recovery following disturbance, such as the 2015-2016 coral bleaching event. These coral collections add to collections made in 2018 to increase replicate size and coverage across the Archipelago for a more informative study.

Figure 3 A small colony of *Acropora cytherea* sampled to assess population structure of the species across the Archipelago (photos: Margaux Steyaert).

Objective 2: Triplicate water samples (2L each) were collected directly above the reef matrix at 28 locations to investigate plankton biogeography patterns across BIOT using environmental DNA (eDNA). The water samples were processed using a vacuum pump system to capture the DNA found in the water samples on filter papers (47 mm 0.22 µm PVDF filters). The filters were then frozen for preservation and transported back to ZSL. These will now be analysed using metabarcoding techniques over the next few months. In addition, a separate methods comparison study was undertaken to compare the effect of different types of filters and storage methods on the concentration of DNA extracted using popular eDNA protocols. A total of 84 litres of surface water were collected and filtered from a single location for eDNA. This will provide important insights into which protocols are most affective for future eDNA work in BIOT.

Objective 3: Thirty Autonomous Reef Monitoring Structures (ARMS, Figure 13) were deployed in March 2018 at four sites across BIOT (Ile du Coin (Peros Banos), Moresby (Peros Banos), Ile Anglaise (Salomon) and Courts Knoll (Salomon)). These devices have been left out on the reefs for colonisation by sessile and motile reef invertebrates, often termed cryptofauna. The aim of the study is to: 1) understand successional processes of the cryptofauna community over a period of three years, 2) identify the important environmental drivers of cryptofauna diversity in collaboration with Rob Dunbar's team (Stanford University) who measure the physical and chemical drivers, e.g. pH and temperature. This year we achieved our aim to retrieve and process the first set of nine ARMS, six of which we undertook on this expedition. Inhabiting the six ARMS we recorded; 146 sub-samples of sessile organisms, 221 motile invertebrate morpho-species, 36 samples of bulk sessile fauna, and 54 samples of microscopic motile organisms (< 2mm). High variation in communities of motile fauna was observed between sites. Benthic transects (using video methods) were also carried out at each of the three sites. Furthermore, sediment samples were collected in the vicinity of ARMS locations to assess the microbial diversity. All samples were fixed in ethanol or DMSO and transported back to ZSL where they will be analysed over the next nine months using barcoding and metabarcoding methods. Macro-photos of sessile and motile organisms were also taken to taxonomically identify species where possible to support barcoding and metabarcoding results.

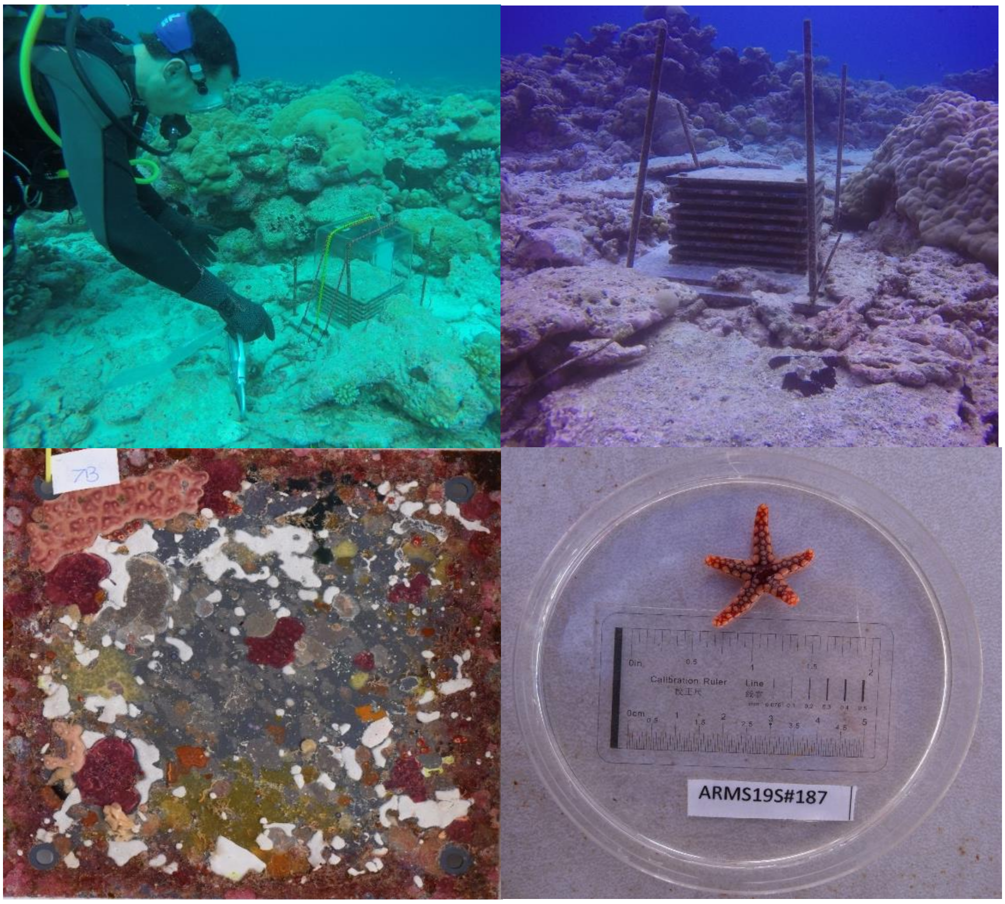

Figure 4 An ARMS device anchored to the reef at Ile Anglaise, Salomon atoll (*top right*) and during the removal process (*top left*). Close up of the bottom of plate 7 of one ARMS device colonised by sessile species (*bottom left*) and an example of a common asteroid species (*bottom right*) found inhabiting the ARMS.

(7) Physical and biogeochemical drivers on coral reefs of the Chagos Archipelago (Prof. Rob Dunbar, David Mucciarone, & Mathilde Lindhart, Stanford University) – project in conjunction with (6) above

We seek to understand how physical and biogeochemical drivers influence reef biodiversity, biomass, and productivity over time and how these drivers impact the provisioning of resources to the pelagic ecosystem. In 2018, we installed current meters as well as temperature, salinity, pH, PAR (photosynthetically available radiation), pressure, and oxygen, with the goal of determining drivers of variance in reef biodiversity and health at different sites and through time. Instruments were installed at the same locations as the ARMS (Project 6 above) sites, and water samples were collected for calibration. Figure 14 shows the study sites where instruments were installed during 2019. Nearly all instruments from 2018 were recovered, serviced, and replaced. Ten additional T loggers were installed in 2019 to track stratification and upwelling impacts on forereefs versus lagoons (Figure 14).

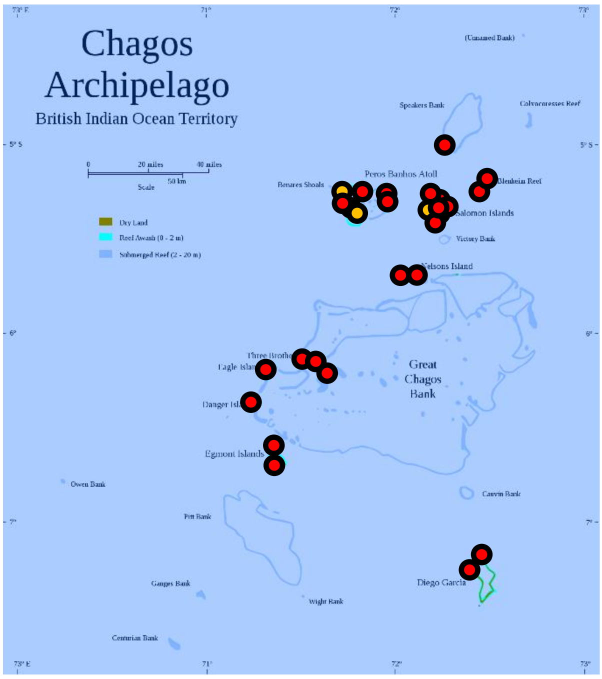

Figure 5 Red dots show locations of instruments installed on forereefs and in lagoons for operation during 2019-2020. Orange dots show locations of BEAMS (Benthic Ecosystem and Acidification Monitoring Systems) experiments wherein up to 20 different instruments were installed to log at high frequency for 2-3 weeks during March, 2019. Altogether 39 instruments (logging T, S, 0_2, currents, light, pressure) were deployed for the year. Another 43 instruments (logging T, S, 0_2, currents, light, pressure, and light) were deployed for the BEAMS experiments.

Benthic ecosystem and acidification monitoring systems (BEAMS, Figure 15) were deployed at three locations to precisely measure reef metabolism using benthic boundary layer physics and chemical flux gradient methods. This will allow us to determine rates of primary production as well as ratios of primary production to calcification on BIOT reef tracts. One BEAMS site is close to a Perry/Lange study site, allowing for direct comparison of different methods of estimating reef growth.

Instruments deployed in 2018 and during the 2019 BEAMS operated with a 95% success rate, a good result for moored instrumentation in energetic reef environments. Initial results indicate net autotrophy at all sites, suggesting that food is available for export offshore and to depth in at least some BIOT reef systems. Examining the time series data from 2018-2019 we observed several additional instances of cold water intrusions on BIOT forereefs. We first reported these events at the 2018 London BPMS symposium and now consider them to be widespread and likely to impact thermal resilience/tolerance of Chagossian corals.

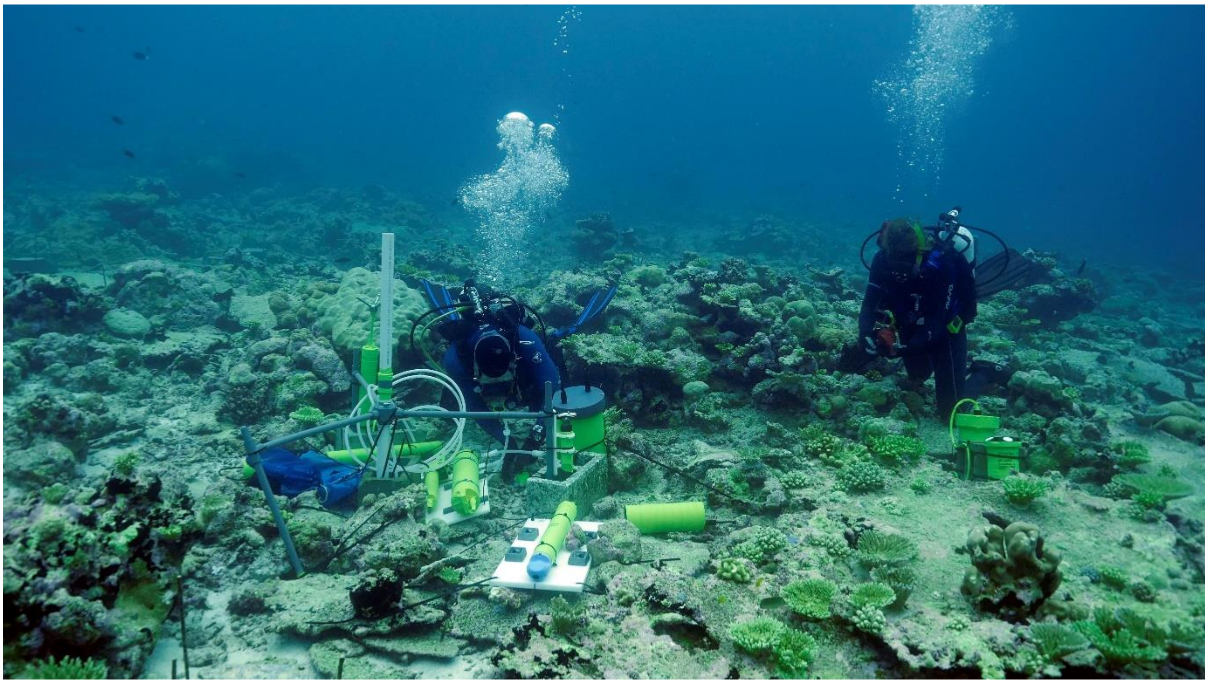

Figure 6 Divers deploy BEAMS at Ile Anglaise. (Photo: Rob Dunbar | Stanford).