The Bertarelli Programme in Marine Science Reef 1 Expedition (March 2020)

Chagos in March 2020 – one of the many becalmed days during Reef 1

Overview: The Bertarelli Programme for Marine Science (BPMS) Reef Expedition 1 in 2020 ran from March 12th to March 25th, but was severely impacted by the changing global travel constraints caused by the Covid-19 virus pandemic. The decision to go ahead with the expedition in the first place was not without its challenges, but at the time of the "go, no-go" decision, no travel restrictions to the region were being imposed by the relevant Institutions (except Stanford), and in the UK the FCO were not advising against travel to the Indian Ocean region. On top of this there was a very strong desire by all team members and the project PIs to try to make the Expedition happen (not least because of the importance of the Year 3 data to many projects and aligned PhD research). Our working worst case scenario was that we might achieve about 11 days of fieldwork before having to return on the next DG-Bahrain flight (on 26th March). This would have allowed most of our core activities to be achieved. The expedition participants came from Exeter University (UK), Lancaster University (UK), University of Oxford (UK), Australian Institute of Marine Science, and Stanford University (USA). The Dunbar team from Stanford sadly had travel permission withdrawn just ahead of departure.

The team flew into DG via Bahrain to join the Grampian Frontier on Thurs 12th March. After a day of equipment loading from Moody Brook the team transited overnight to Egmont to start our surveys there early on the 14th of March. Following 2 days at Egmont we moved to Eagle (for half a day of work for part of the team) and then immediately moved to The Brothers on the Great Chagos Bank. At this stage the team were working extremely efficiently and all core survey work was being completed. With a close eye on the rapidly evolving Covid-19 situation the team decided to press ahead with a view to completing as much work as possible before returning to DG to take the first available flight from DG to Bahrain (this flight would have been on Thursday 26th March – our earliest possible departure date). This would have facilitated about 11-12 days of fieldwork and whilst inevitably restricting field activity would have allowed time for most core work to be undertaken.

Working to this revised plan we completed one and half days of fieldwork at The Brothers before a further major change in our travel options developed as Bahrain announced a suspension of all immigration visas and the necessity to complete 14 days of quarantine when entering the country. As a result of this, and following

discussions with ZSL, the team met for a strategy meeting and collectively made the regrettable, but necessary, decision to suspend further field operations and to plan for an exit from BIOT as quickly and safely as possible. Our sister ship the Antsiva chose to follow this same course of action (as did the Tethys). At this point our fall back plan was put into place, this being to return to DG to unload on the 19th March and to then transit as fast as possible back up to Gan with a view to trying to fly up to, and then out of, Male on Sunday 22nd March.

The team arrived early into DG on Thursday 19th March. We were not, however, given permission to go ashore on DG to de-mobilise, and so the Marines kindly took responsibility for moving all our kit from the dock to Moody Brook, with equipment stowage guided with the help of a plan of Moody Brook. However, by the time we were leaving DG later that same day the Maldives Govt. announced a ban on all foreign transit on internal flights (thus necessitating a plan to now go direct to Male). This announcement was followed almost immediately by an additional restriction that required us to have completed at least 14 days quarantine before being allowed to enter the Maldives. This took us to an earliest possible arrival date into the Maldives of Wed 25th March.

In light of this we decided to use our transit time as usefully as possible, spending 2 full days at Salomon Atoll – albeit without all the boats and dive equipment. Here three of the sub-teams (Exeter, Lancaster, AIMS) completed snorkel based work to contribute to their datasets, and then a small group of four undertook a rapid assessment of reef status around the entire perimeter of Salomon (completing photo survey assessments at 24 sites at ~1 km intervals). We completed this work and left Salomon midday on Sunday 22nd March. In the time we were at Salomon the Maldives Govt. then also announced a complete ban on all maritime vessels entering the Maldives. At this point our options began to narrow rapidly and two courses of action were being pursued. First, through ZSL and FCO interventions, very high level diplomatic efforts were put into action to try to secure exemptions for both ourselves and the sister vessel the Antsiva. Alongside this Exped Lead Chris Perry and BPV captain Killian Hickey had started to explore wider regional options within realistic sailing distances. Thankfully, by late on Sunday 22nd March we received notification that the Maldivian Govt. had provided exemptions both to ourselves and the Antsiva to enter the Maldives. Flights were then booked via ZSL and after some further flight shifts all members of the team were able to depart Male to the UK on Thurs 26th March, and then onwards to their home countries.

As expedition lead I would like to offer my profound thanks to BPV captain Killian Hickey and the fantastic crew of the Grampian Frontier, and senior fishery protection officer John Caddle, for their support and assistance, not only during the field phase of the project but also through the period of very rapidly changing travel options. The expedition doctor, Tom Hewitt, thankfully had very little medical work to do, but was a big help during our limited field time. Our options for returning to the UK would have been challenging at best were it not for the fantastic support of Rachel and Emma at ZSL, and the FCO – again a huge thank you from the Reef 1 team.

Some key observations from the expedition include:

- The reefs offshore from Ile des Rats (Egmont) remain in excellent condition with very high cover of branching *Acropora*, large *Porites* colonies and a host of secondary coral taxa. These reefs appear to be in near identical condition to those we found them in in 2018, having clearly been unaffected by the 2016/17 bleaching events (Figures 1 and 2).

Figure 1. Offshore Ile des Rats (Egmont) in 2018. Extensive coral fields that survived the 2016 coral bleaching event along the north west flank of Egmont Atoll. (Photo: Ines Lange).

Figure 2. Offshore Ile des Rats (Egmont) in March 2020. Site shows little or no changes since 2018 surveys. (Photo: Chris Perry).

- The reefs on the outside of South and Middle Brother have not fared so well. Coral cover here has not increased significantly. *Acropora* recruitment does not appear to have accelerated since 2018, and many *Porites* corals are now dead. More generally the wider reef substrate appears to be undergoing a phase of severe erosion, driven by populations of very large (12-14 cm test diam.) *Diadema* urchins, parrotfish and endolithic sponges (which are widespread through the dead substrate). The overall impression is of much of the substrate transitioning to a hardground stage with limited colonisation of

what should be ideal coral settlement ground (Figure 3). One must hope that this is only a delay in recovery rather than a more persistent trajectory.

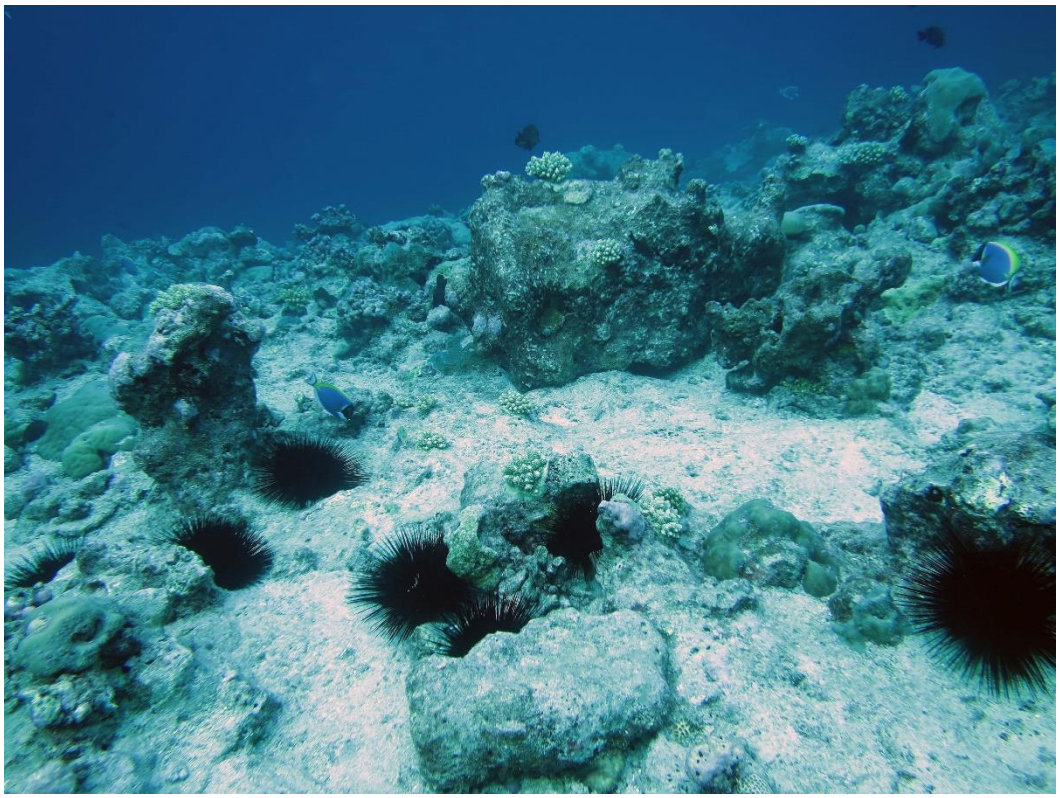

Figure 3 – Site on the western end of South Brother, GCB showing large *Diadema* urchins and heavily eroded reef substrate (photo Chris Perry)

- More positively we observed no evidence of recent or on-going bleaching at any of the sites we visited.
- The lagoon reefs inside Salomon Atoll appear to be in excellent condition, with high coral cover and high coral species diversity, and impressive fish populations.
- The outer reefs around Salomon Atoll are in variable stages of recovery. There is emerging cover of *Acropora* spp. at many sites, but this was especially evident at sites but most of this is on the exposed S-SE sides of the atoll, with corals settling on exposed planar hardground substrate. There is and never has been any evidence of major reef framework accumulation here.
- Sharks sightings were again common (as reported in 2018), with 2-3 sharks seen by all divers on most dives, and as many as 5-6 sharks seen on some dives. As noted in the 2018 report this is substantially better than in 2015, when very few sharks were seen during the entire expedition. Of note, most of the sharks seen on the current expedition were gray reef and silvertip sharks. Preventing poaching of these sharks should be a high management priority.

Details of the work achieved are provided below, but clearly there will now be a need to start consideration of whether another expedition can be funded (for late 2020 or Spring 2021). This will be essential if the key objectives of each of these sub-projects are to be achieved (including PhD work satisfactorily completed).

Details of kit and equipment issues are available as a separate document on request.

The expedition had 5 distinct teams, with the following projects:

1. Carbonate budgets and the future growth potential of coral reefs across the Chagos Archipelago
(University of Exeter – Prof Chris Perry & Dr Ines Lange)

Reef carbonate budgets are indicators of reef health, in terms of whether the reef structure is growing or eroding. The overall aim of this sub-project has been to assess the impacts of the bleaching event in 2015-2016 on carbonate budgets and future reef growth potential across the Chagos Archipelago.

Reef sites first surveyed pre-bleaching in 2015 showed very high carbonate budgets compared to other reefs in the Indian Ocean and globally (Perry et al. 2015). In 2018, 13 long-term monitoring sites (four in each of Salomon, Peros Banhos and Great Chagos Bank, one in Egmont) were established and we documented a 70% decrease in carbonate production following the bleaching event (Lange & Perry 2019). In 2020, we re-surveyed four sites in Egmont and Great Chagos Bank before the trip had to be aborted. The site in Egmont still displayed higher than average coral cover (30%) and carbonate production rates were similar to 2018 values. At the Brothers, coral cover was slightly higher than in 2018 (13% compared to 8%), but the recovery of carbonate budgets is negligible, and structural complexity decreased slightly. Contrary to most visited sites across the Archipelago, reefs at the Brothers are inhabited by large *Diadema sp.* sea urchins, which are likely responsible for decreasing complexity and high sediment cover on the reef terraces.

The second focus of this year's trip was to collect empirical data on rates of coral and crustose coralline alga (CCA) calcification, parrotfish bioerosion, endolithic bioerosion and sediment generation rates in order to improve the accuracy of local reef budget assessments. Due to the short time of the trip we only managed to recover one set of CCA carbonate tiles at Egmont, but we successfully collected data on parrotfish bite sizes for four more species which completes a dataset collected in the Chagos Achipelago and the Maldives in 2019. The re-photographing of 90 coral colonies which were tagged in 2018 for the purposes of photogrammetry-based assessments of coral growth rates could not be repeated this year but growth rates determined in 2019 were published recently (Lange & Perry 2020) and incorporated into the ReefBudget model to improve local estimates of carbonate production. The sampling of different *Halimeda* species to estimate their contribution to sediment production could not be achieved during this trip and is planned for the future.

Taking advantage of a half day stay and favourable weather conditions at Salomon Atoll we conducted a rapid assessment of the status of the fore reefs around the atoll by visiting 24 sites on the reef terrace at ~1 km distance to each other. At each site (5-8 m depth), 20 photographs were taken (10 from the surface, 10 from 2-3 m above the reef substrate) to assess benthic community composition and a short DOV (Diving Operated Video) survey was conducted to assess fish populations and reef rugosity. The dominating reef type along the eastern, wave exposed side of the atoll consists of flat (probably pre-Holocene) reefal substrate colonised with tabular and corymbose colonies of different *Acropora* species (Fig. 4A). At some high energy sites between islands, deep spur and groove structures have formed which to our knowledge have not been documented at Salomon before (Fig. 4B). The southern and western side of the atoll is more protected and harbours rugose reef structures with a higher diversity of species, yet planar coral cover seems to be similar or lower than at eastern sites (Fig. 4C). Community composition, diversity and rugosity at each site will be analysed from photographs and videos and prepared for publication by the whole Reef 1 team.

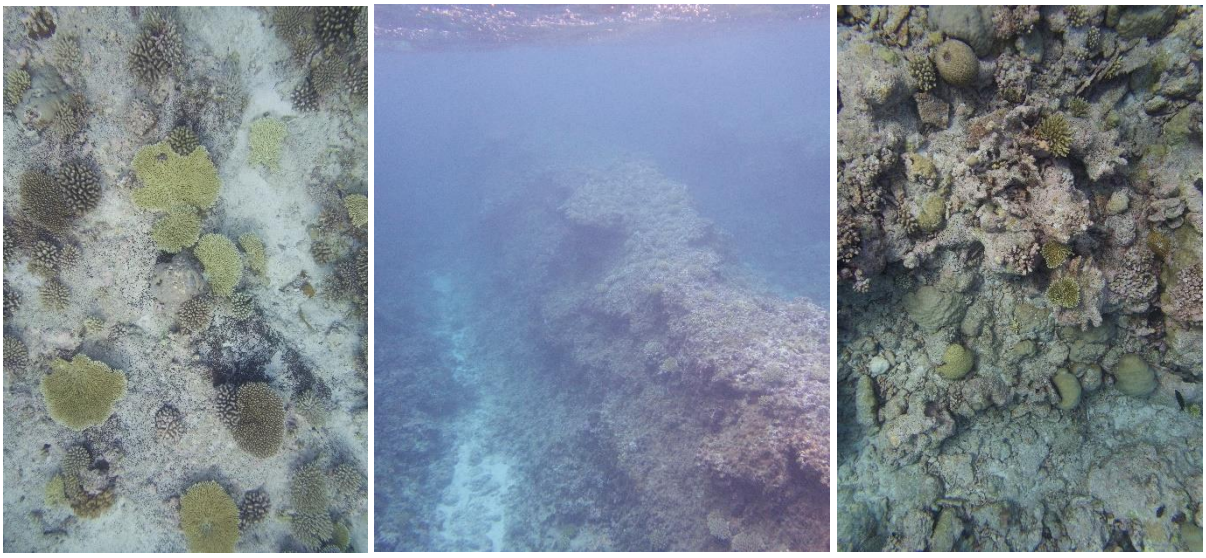

Figure 4: Status of fore reefs at the eastern (A, B) and western side (C) of Salomon atoll

2. Do seabird nutrient inputs influence the resilience of coral reefs to climate change? (Lancaster University - Prof Nick Graham & Dr. Casey Benkwitt; Dr. Casey Benkwitt and PhD student Rachel Gunn were on expedition)

Lancaster's overarching goal for the 2020 Reef 1 trip was to continue determining how nutrients from seabirds nesting on islands influence adjacent coral reefs, especially whether seabird nutrients boost recovery of coral reefs following bleaching events. Our main planned activities were to (1) re-survey fish and benthic communities, including coral recruits, on the lagoonal sides of islands to track the recovery of reefs around birdy versus ratty islands following the 2015/2016 bleaching event, (2) re-measure growth rates and health of tagged coral colonies around islands with seabirds and islands with invasive rats, and (3) determine how seabird nutrients influence key demographic rates of fishes at multiple trophic levels (sampling in collaboration with the AIMS team).

During the 2020 Reef 1 Trip, Lancaster's team conducted benthic, fish, and coral recruit surveys around 3 islands on the Great Chagos Bank (Eagle Island, Middle Brother, and South Brother) (Objective 1). We also re-measured the growth rates of 24 tagged coral colonies, spread across 6 islands (Eagle, Middle Brother, and South Brother on the Great Chagos Bank, and Ile de la Passe, Ile Anglaise, and Ile Fouquet in Salomon Atoll) (Objective 2). However, due to the shortened schedule, we were unable to conduct many key aspects of our planned activities. Specifically, we missed surveying 9 islands (Objective 1), missed re-measuring coral growth rates at 6 islands, and we were unable to obtain many coral samples (Objective 2) or fish samples (Objective 3).

Figure 5: The same coral colony in 2018 (left), 2019 (middle), and 2020 (right) that we transplanted from an island with invasive rats to a nearby island with seabirds. (Photos: Casey Benkwitt).

Figure 6: A seabird visiting our boat while conducting surveys at Middle Brother. (Photo: Casey Benkwitt)

3. Fish predatory control and reef resilience (Stanford University - Jamie McDevitt-Irwin, Fiorenza Micheli (PI, not on expedition), Kristina Tietjen, Melissa Palmisciano)

For Reef 1, Stanford's research aims were to: 1) collect and process 225 experimental terracotta tiles (caged, uncaged, and partial) from eight sites across the archipelago; and 2) deploy GoPro frames for herbivore grazing observations at these same eight sites across the archipelago; and 3) collect a total of 60 more fish tissue samples for stable isotope analysis at three sites across the Archipelago. These eight sites have been previously characterized as having significantly different shark abundance (in collaboration with the AIMS team through BRUVs in March 2019). However, with the coronavirus pandemic and curtailment of the trip, we were unable to collect all of this data. Yet, we were able to collect data from three sites at the beginning of the trip:

Egmont x 2 (high shark abundance) and Brothers x 1 (low shark abundance). We took photographs of all of our experimental tiles (n=30 per site, see Figure 7 below) at these three sites (in situ) to get percent cover of organisms growing on the surface, took macro-video for high resolution identification of these organisms, and used an underwater UV light to count the number of coral recruits at both a high shark (Egmont x 2) and low shark (Brothers x 1) sites. Thus, when we do pick up the tiles, we will have additional data of a time series at these three sites, to help us understand our aim of how shark abundance may mediate coral reef recovery through a trophic cascade. In addition, we were able to deploy 8 x 2-hour GoPro herbivore grazing videos at both Egmont and Brothers (total = 16) to understand how shark abundance influences herbivore grazing rates (see Figure 8 below). Finally, in collaboration with AIMS we collected 12 fishes for stable isotope analysis at Egmont (*Scarus rubroviolaceus* and *Lutjanus bohar*) to enhance our understanding of how shark abundance affects reef fish diet.

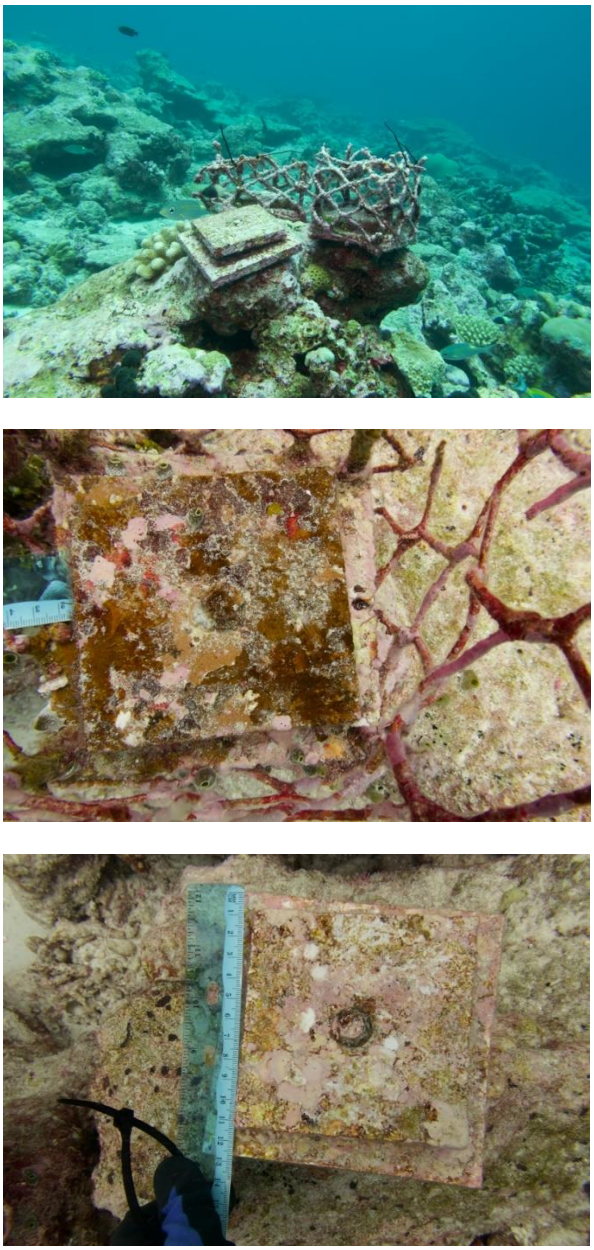

Figure 7. Examples of photographs taken in situ of both caged and uncaged experimental tiles.

Figure 8. Screenshot of herbivore grazing videos deployed for two hours at each of the three site we visited.

4. Long-term monitoring of reef fish assemblages in the BIOT Marine Protected Area: Reef fish communities of the BIOT MPA in space and time (AIMS – Dr Brett Taylor and Mark Chinkin, Meekan (PI not on expedition)).

For the 2020 Reef 1 Expedition, the AIMS team set out to complete approximately 20 diver operated visual surveys of fish communities across the northern atolls, Great Chagos Bank, and Egmont Atoll. These surveys were designed to extend annual standardized surveys into 2020, as well as to test drivers of life history variation in species across sites as a standalone analysis. In total, we completed 7 surveys before the termination of the research cruise: three at Egmont Atoll, one at Eagle Island, two at the Brothers Islands, and one at Ile de la Passe (Salomon Atoll). These comprised 40-minute timed swims along the reef slope at a constant depth (7-9 m) with position georeferenced using a handheld GPS towed in a surface buoy. Additionally, the AIMS team collected fish species for collaborative work with Lancaster University (*Cephalopholis argus*, *Abudefduf vaigiensis*) and Stanford University (*Lutjanus bohar* and *Scarus rubroviolaceus*).

Figure 9: Dr. Brett Taylor from the Australian Institute of Marine Science (AIMS) surveys fish communities at Egmont Atoll using a diver-operated stereo video system. Photo by Mark Chinkin, AIMS.

Figure 10: Researchers from the Australian Institute of Marine Science and Lancaster University dissect fish samples on the deck of the British Patrol Vessel Grampian Frontier.

Coral Reef Recovery and Resilience. Bryan Wilson, Margaux Steyaert, Catherine Head (not on expedition), Stephen Preston (not on expedition) and Adrian Smith (PI, not on expedition)

Having initially comprised part of the 2019 Reef2 Expedition (whose focus was primarily the ongoing annual monitoring of many and diverse sites in the archipelago), the Oxford team joined this year's Reef1 Expedition, which has historically spent longer periods of time at fewer but better characterised sites, potentially allowing for a more in-depth and hypothesis-driven set of research questions to be posed. Following immediately on from the University of Oxford and ZSL's Reef0 Expedition (based entirely on and around Diego Garcia), there were a number of continuing research themes, based around our ongoing genomic characterisation of coral health. Our primary investigation was the search for colonies of scleractinian corals of the same species (and restricted to the genera *Acropora, Porites, Pocillopora, Pavon*a and *Leptoria*) and within close proximity, exhibiting differential bleaching responses. However, unfortunately for the team (but on a decidedly positive note for the reefs), we found no evidence whatsoever of thermal bleaching, differential or otherwise, of these coral taxa at any of the sites surveyed - the overwhelming observation from this expedition were of reefs on an upward recovery, with the number, size and apparent health of young corals seemingly much greater than those witnessed on the 2019 Reef2 Expedition. Had the expedition continued, it was planned to sample and tag as many putatively healthy corals as time permitted, for collection and genomic analysis over subsequent years' return to the region, but this was unfortunately not possible. However, several samples of *Pocillopora* spp. and *Leptoria* spp. were collected during the Reef1 Expedition and analysis of these species will be the first genomic characterisations of their kind in the Chagos Archipelago; *Leptoria* spp. were selected on the basis that previous observations suggest these taxa to be thriving on BIOT reefs; *Pocillopora* spp. on the other hand, are a

cosmopolitan species found on reefs worldwide and are frequently cited as a model study coral, and investigations of samples collected here will be used in global biogeographical comparisons.

A second (and new collaborative) line of investigation was the sampling of corals (from the genera *Acropora, Porites, Pocillopora*) on the reefs adjacent to islands with and without nesting seabirds, in genomic research that we hope will support the ongoing work of the Lancaster University team - and indeed, this was much more successful. Accompanying the Lancaster team, we collected samples from several islands on the Great Chagos Bank, including Eagle Island (rat-infested, with no seabirds) and Middle Brother and South Brother (both with seabirds). Coral fragments were harvested into ziplock bags underwater, transferred to an enclosed coolbox for the inflatable boat return to the ship's laboratory container and immersed in RNALater reagent (essentially arresting ongoing biological processes and maintaining genomic material in stasis), all within one hour of collection. After 24 hours' immersion in RNALater at room temperature (18°C), samples were stored at -20°C - however, due to an unfortunate delay in the conferral of CITES Export and Import Permits, transport of these samples could not be approved prior to our departure date and they are therefore currently being stored at -20°C by the BIOT Environment Officer (Harri Morrall) in Diego Garcia, for which we are incredibly grateful to her. Upon eventual receipt of these at the University of Oxford, we shall extract total DNA and RNA from the coral tissues and perform genomic and transcriptomic analyses. Lancaster University's previously published research has shown that seabird nutrients are beneficial to the growth and maintenance of coral reefs nearby, and it is therefore hoped that our investigations will highlight the differential expression of key coral metabolic genes between these sites, which will offer further robust empirical evidence in support of the ongoing BPMS investigations into the benefits of removing invasive rats from these islands.

Species of *Acropora* and *Porites* (specifically *A. tenuis, A. cytherea* and *P. lutea*) were also collected from Egmont and Brothers to supplement the existing collctions of these species (collected in 2018 and 2019) for a population genomics study lead by Catherine Head (ZSL/Oxford Uni). The aim of this study is to understand how connected areas are within the archipelago in terms of their coral larvae dispersal. This knowledge would help inform management of the MPA by highlighting “source” reefs or reefs that are well connected and hence may be a priority for better protection.

In work continuing on from the Reef0 Expedition (a twofold experiment, investigating whether corals could be kept alive during the ship's transit and whether they might also be observed spawning), the three *Acropora* spp. collected from Barton Point Lagoon in Diego Garcia were maintained onboard the seagoing Grampian Frontier for twelve days, before the experiment was terminated prior to arrival in the Maldives. The fragments were kept in a 70L coolbox on eggcrate mesh, aerated with an air bubbler and seawater changed daily, with water temperature being monitored by a temperature probe. During squalls and at night, the coolbox lid was closed to prevent seawater dilution and maintain diel cycles for coral spawning, respectively. Coolbox water temperature remained between 28-29°C for the duration of the study. Using this regimen, corals remained seemingly healthy until Day 12, but unfortunately, no spawning of the captive colonies occurred. Whilst evidence of spawning was also not observed on reefs during diving, a telltale slick was seen on the water's surface in Salomon Atoll on Sunday 22nd March (several weeks after March 9th's full moon) and samples collected and frozen for analysis. In summary therefore, we successfully demonstrated that it is indeed feasible to maintain live corals onboard whilst transiting, and there is every possibility that should a future expedition occur in the week after the March full moon, spawning may be observed ex situ.

Finally and in light of the discovery of remnant specimens of the critically endangered Chagos Brain Coral, *Ctenella chagius*, in the northern atolls during last year's Reef2 Expedition, we continued our survey for this iconic species. Having chanced upon only six colonies over a three-week period in 2019 and a single colony during the Reef0 Expedition in Diego Garcia this year, the team were cautiously optimistic in their expectations. However, we were astonished to discover a cluster of approximately ten to fifteen colonies at 7-10m depth in Middle Brother Lagoon. It is thought that the coral is particularly sensitive to solar irradiation and increased ocean temperatures, these potentially being responsible for the decimation of its numbers during bleaching events in the region over the last decade. Anecdotally, where entire surviving colonies have been found, it has been in relatively shaded and high energy areas of reefs, and where only fragments of colonies persist, these have been observed on the undersides of the otherwise dead hemispherical structures. The clustered *C. chagius* colonies found in Middle Brother Lagoon this year were no exception and were all recorded at the sheltered base of a reefal ridge. An ongoing concern for the continued existence of a viable population of the species has been the remoteness of surviving colonies and whether cross-fertilisation between individuals is even possible. The serendipitous discovery of this grouped collection of colonies, a number of which were of a size suggestive of being five or more years old and therefore having survived the most recent bleaching events, holds the best promise yet of this relatively protected lagoonal site being a potential stronghold and seedbank for the species.

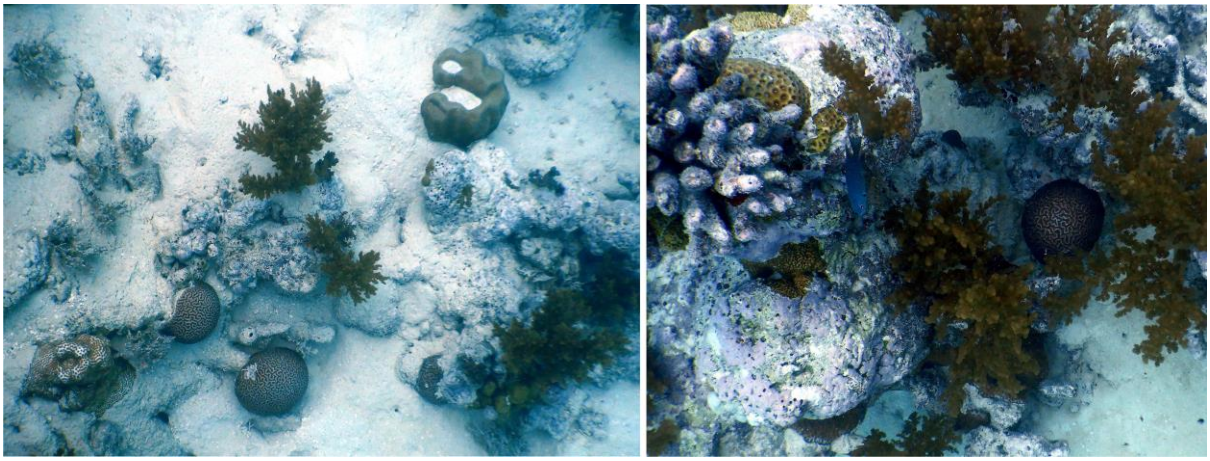

Figure 11. Examples of a rare and extant population of the Chagos Brain Coral, *Ctenella chagius*, in Middle Brother Lagoon

Prof Chris Perry

University of Exeter

BPMS Reef Trip 1 2020 expedition leader

Team meeting – another night explaining changing travel plans!