Chagos News

The Periodical Newsletter of the Chagos Conservation Trust and Chagos Conservation Trust US

No 50 July 2017

ISSN 2046 7222

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Editorial

Alistair Gammell, CCT acting chair

In welcoming you to our 50th edition of Chagos News, I thought it timely to reflect on the enormous achievements made by our small organisation in the past 25 years.

Our founder, Commander John Topp RN OBE, had been the British Representative on Diego Garcia in the mid 1980s and whilst there recognised the enormous importance of the Chagos Archipelago for nature. Determined that the islands should be conserved, he established the Friends of the Chagos in 1992, the precursor of the Chagos Conservation Trust (CCT). In the 25 years since CCT's founding, we can proudly look back on many achievements:

Most importantly, the number of people who know about and appreciate the importance of the archipelago for its biodiversity has increased year on year. Back when CCT was founded, the islands were known only to a very few British diplomats and military personnel beyond the Indian Ocean, but thanks in part to our awareness raising efforts, the Chagos Archipelago is now much better known globally.

Since 1992, we have since coordinated more than 26 scientific expeditions to the archipelago. These have revealed just how extraordinarily rich its marine ecosystems are, and have contributed towards a greater understanding of marine ecosystems in the relative absence of humans. CCT promoted the protection of these ecosystems from the outset, initially by giving Ramsar protected area status to a number of sensitive zones around Diego Garcia, followed by getting the British Indian Ocean Territory's government to agree to manage the area as though it was a World Heritage site, and in 1997 by leading a consortium which proposed that the area should be made into a fully protected marine reserve (excepting a small area surrounding Diego Garcia). The latter was achieved in 2010, establishing what was at that time the largest marine reserve in the world, and even today remains one of the largest.

Since that landmark decision in 2010 to fully protect most of the British Indian Ocean Territory, scientific interest in the archipelago has soared, as has interest in its conservation.

Our conservation actions have highlighted and reduced threats from illegal poaching, and have successfully initiated the restoration of several islands by removing introduced rats and coconut plantations so as to restore native vegetation and allow native wildlife such as seabirds and turtles to thrive.

The numbers of seabirds and turtles nesting on these islands are increasing; the number of fish is at one of the highest levels found anywhere in the world; coconut crabs, the world's largest terrestrial arthropod, lives in densities found almost nowhere else; and all of this is due to the protection given to this area. Unfortunately the corals are being damaged by sea temperature rise, as are corals in many places, but we are hopeful that at least in deeper water corals will survive and help repopulate the shallow reefs.

And CCT has not forgotten history, having helped to publish Nigel Wenban-Smith and Marina Carter's definitive book Chagos: A History: Exploration, Exploitation, Expulsion. It is an excellent read and available from CCT for £40.00.

So in 25 years CCT has, with your help, taken the Chagos Archipelago from an unknown, both in an environmental and historical sense, to an area that today is widely regarded as one of the most important and well protected marine environments in the world.

However, there is still much to do. Going forward, we will continue to restore the many islands that are still plagued by rats and over-run by coconuts so that native flora and fauna can re-establish itself, and fight against poaching which remains a threat as other areas of the Indian Ocean become increasingly impoverished though overfishing.

Thank you for continuing to support us.

Director's Report

Helen Pitman, CCT Director

As we slowly glide into summer I've been looking back over the last six months and am happy to report that CCT has been extremely productive.

Our annual event, held at London Zoo, started the year off on a very positive note and was a great success. We hope those of you that made it along found it enjoyable and informative.

CCT announces first successful Chagos island rat eradication

Last month CCT was proud to announce its Ile Vache Marine rat eradication project had been successful!

The island is the first to have rats successfully eradicated as part of our long-term strategy to rid all of the islands of these invasive mammals.

This is some of the most exciting and positive conservation news to come out of the Chagos Archipelago recently.

CCT trustee Pete Carr and Dr Grant Harper evaluated the outcome of the 2014 eradication attempt after the two year waiting time had passed.

This news means we can now develop our archipelago-wide restoration programme, and continue to restore the balance to the terrestrial habitat found there, which will also support the reefs during their recovery. Pete Carr explains more on page 10.

Emergency expedition to the Chagos Archipelago

In April CCT trustees Rachel Jones and Professor John Turner coordinated and led a team of researchers on a two-week emergency expedition to assess the coral reefs after recent bleaching events.

John and his team gathered vital research to document the reefs' ability to respond to environmental changes caused by sea-level rise and sea-surface temperature increases.

Dr Grant Harper (L) and Pete Carr (R) on Ile Vache Marine

We've all heard of the devastating effects climate change has had on Australia's Great Barrier Reef but unfortunately this is a global problem and the Chagos Archipelago reefs have not been spared. John describes what they encountered on page 6.

The Chagos Information Portal

In exciting digital news, CCT launched the new Chagos Information Portal on World Oceans Day last month.

This free reference library of science, research and conservation work conducted in the Chagos Archipelago also includes over 600 images and videos, and an interactive map. Check out page 46 for an in-depth look at the Chagos Information Portal.

New CCT website

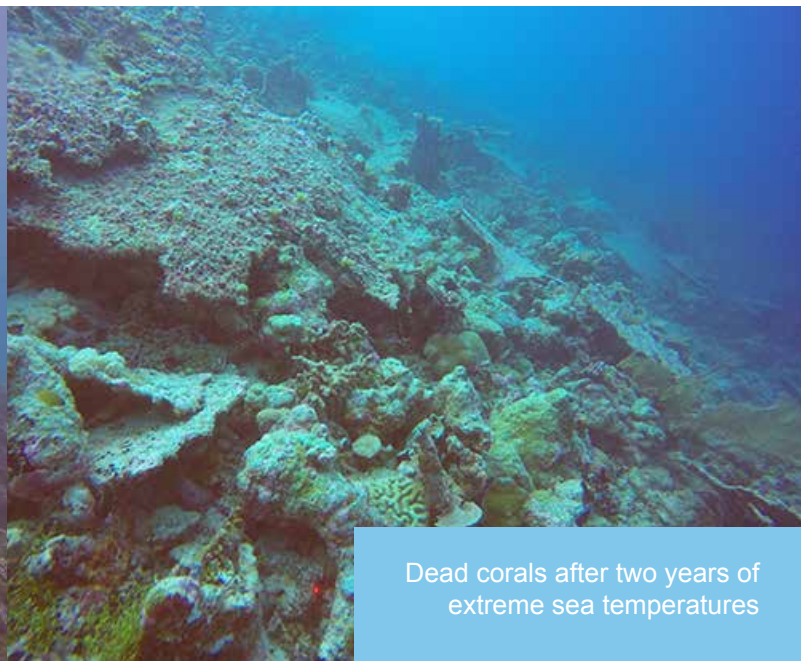
We have also launched the new look CCT website that features information about CCT and the work we do and is beautifully illustrated with images from across the archipelago. Make sure you have a visit soon!

Community event

CCT trustee Claudia Naraina held a community event in Manchester to profile the new *Chagos: A History* book. Participants had the chance to look through the book and hear about some of the highlights including learning about traditional recipies using coconuts harvested on many of the islands.

The book can now be found in the Central and Forum Libraries in Manchester and we hope to have copies in the Crawley Library soon.

As always the CCT is grateful for your support and we hope that together we can continue to have a positive impact on the Chagos Archipelago.



Dead corals after two years of extreme sea temperatures

2017 Chagos Expedition

Professor John Turner, Bangor University and CCT Trustee

Science and Conservation Expedition to the Northern Atolls of the Chagos Archipelago, British Indian Ocean Territory 5th – 22nd April 2017

The April 2017 scientific and conservation expedition to the northern atolls aimed to undertake three separate, but logistically complementary projects: An assessment of reef condition post the 2016 bleaching event; Check of the rat status of Ile Vache Marine post eradication; and field test of hydrophone equipment for IUU enforcement application. The objectives of the three projects were:

Project 1: Coral Reef Assessment

Sustained high sea temperatures between March and June of 2015 and 2016 led to reports of wide-scale bleaching on many reefs, including those of the Chagos Archipelago (Figure 1).

Results from the April 2016 expedition (prior to that year's bleaching episode) had already indicated significant and widespread mortality following the 2015 warming event, resulting in a reduction of live coral cover to less than 20%. However, what was needed was a more detailed study of the impact of the more sustained warming event in 2016, to assess bleaching induced mortality after two consecutive years of warming events (Figure 2), and with the knowledge of White Syndrome coral disease from observations in 2014 and 2015.

Five complementary methodological approaches were used:

(i) Extending existing long-term coral reef datasets (see P24): Coral cover was measured at the same sites and depths around the three northern atolls as measured

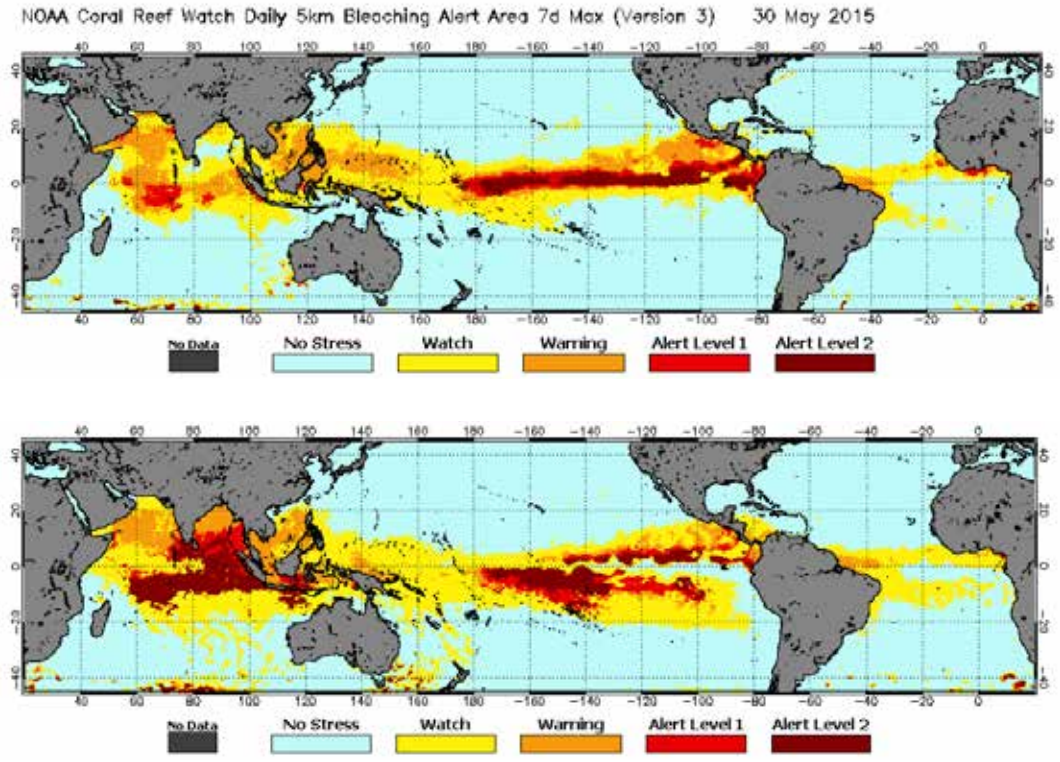


Figure 1: Global coral bleaching alerts derived from 5 km resolution satellite imagery for May 2015 and 2016. https://coralreefwatch.noaa.gov/satellite/bleaching5km/images_archive/

since 1996 to extend the longest time data series that has been recorded for Indian Ocean reefs. Visual assessments of benthic cover at 5 m depth intervals around the three northern atolls help to (1) provide a broad overview of the net effect of stressors (disease, predation, and bleaching mortality) on the coral community, and (2) capture and explain the effects of individual events such as warming events and storms.

(ii) Integrating sea surface temperature (SST) trends into coral reef resilience (see P24): Water temperature measurements were continued, having been recorded at two-hour intervals at 5, 15 and 25 m depth intervals from sites in both lagoons and ocean slopes around all the atolls since 2006. Temperature data loggers were collected from the northern atolls, downloaded and replaced to relate temperature peaks to coral mortality.

(iii) Measuring future resilience via juvenile coral abundance (see P24): Juvenile corals were counted on a variety of substrates (dead standing coral, reef pavement, on calcareous algae) at long-term monitoring sites to assess recruitment to the reefs. Those counted were newly settled adults of less than 5 mm diameter, reflecting 'potential' recovery. The stability of the substrate is important since juvenile corals can be lost from reefs on unstable substrates.

(iv) A Video Archive for Long-term Monitoring of Coral Reef Benthic Communities (see P18): The continuation of the video archiving of coral reef benthic community structure to assess change in coral reef community structure over time. Video archiving commenced in 2006 and has taken place annually since 2013. The data enable analysis of all components of

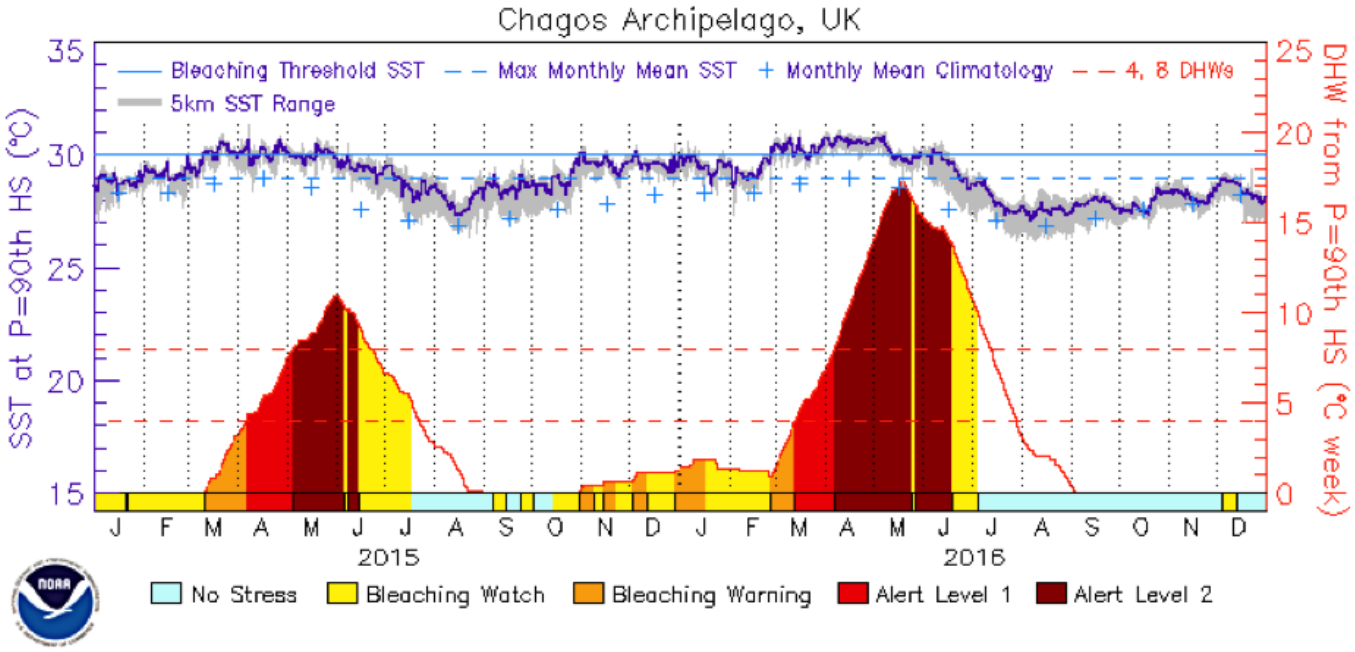


Figure 2: Sea surface temperature (purple line) and stress level due to warming for the Chagos Archipelago from January 2015 to December 2016, illustrating two consecutive annual periods of warming causing bleaching. https://coralreefwatch.noaa.gov/vs/gauges/chagos_archipelago.php

the coral reef benthos, including sponge and soft coral cover, macroalgal cover, crustose coralline algal cover, and turf algae over a relatively large tract of reef and depth without the constraints imposed on an observer underwater.

(v) Three-dimensional determination of reef structural complexity: Rapid capture of the 3D coral reef environment was undertaken using in-water photogrammetry for direct comparison with a survey of the same technique conducted in April 2016, in order to quantify the effects of bleaching induced coral mortality on the reef physical structure and composition. In addition, branching corals were tagged and photographed to assess their fate or growth.

Project 2: Rats and Islands (see P10)

(i) Rat eradication: The outcome of the Darwin Initiative funded rat eradication operation conducted on Ile Vache Marine in August 2014 was tested, as the internationally recognised minimum period of two years before a failed eradication can be detected with certainty has passed. This check involved setting rat tunnels, gnaw sticks, snap-traps and crucially, night-time spot-light searches on the island.

(ii) Rat reinvasion: In August 2014 a rat eradication operation was conducted on Iles Jacobin and Sel on Salomon atoll to test the reinvasion time for islands that have rat-infested islands extremely close by.

(iii) Status of rats on other islands: The presence of rats on Ile de la Passe and Diablo (Salomon) and Iles Finon, Verte, and Manon (Peros Banhos) was investigated since these islands' status was unclear and is required for future management.

(iv) Experiment to determine whether 15 kg/ha of rat poison is sufficient loading to successfully deliver bait to all rats on an island in BIOT: Bait acceptance trials were conducted on Yeye and Manoel in Peros Banhos to assess the density and abundance of rats present, especially on islands where land crabs prevail, to support future rat eradication initiatives in BIOT.

(v) Breeding *Sulidae* populations in BIOT: Over 40 years of breeding seabird data for Chagos have been accumulated. At least two species of breeding seabird (Red-footed and Brown Booby) are increasing in numbers and widening their distribution in BIOT, and this is likely to be the only site in the world where this is occurring. A standard breeding seabird census involving counting Apparently Occupied Nests (AON) was employed on the IUCN designated or proposed Important Bird Areas (Parasol, Longue, both Bois Mangues, and both Coquillages) of Peros Banhos.

Project 3: Hydrophone testing

The British Indian Ocean Territory Administration (BIOTA) and the Zoological Society of London (ZSL) have collaborated to add underwater acoustic sensors to ZSL's instant detect multi-sensor alarm system, designed to provide real-time intelligence on illegal activity to monitor and protect the UK Overseas Territories' Marine Protected Areas (MPAs) in Peros Banhos and Salomon. ZSL has recommended an underwater acoustic vessel detection system (VDS) developed by JASCO Applied Sciences (hereinafter referred to as JASCO), which uses underwater hydrophones to detect vessels and send real time alerts to ZSL.

(i) Field testing in situ in Peros Banhos and Salomon to rigorously test the

performance of the VDS: The VDS was tested in situ within the Peros Banhos and Salomon atolls, confirming the range, sensitivity and other key performance indicators. Long-term baseline acoustic data were established within Peros Banhos to optimize vessel detection algorithms. The proof of concept was validated to identify a recommended solution and design for full implementation in each atoll.

(ii) Land and shore based site reconnaissance within Peros Banhos and Salomon lagoons to identify permanent locations for fixed hydrophones and to recommend cable deployment of the final system: 1 km data cable routes to shore were reviewed and the feasibility of recommended cable deployment methods were considered. Specific locations for full deployment were identified, and development costs assessed.

The expedition was led by Professor John Turner (Bangor University and CCT Trustee), with Dr Ronan Roche (Bangor University), Professor Charles Sheppard and Anne Sheppard; Dr Andrew Mogg (Scottish Association of Marine Science) and Daniel Bayley (University College London and Zoological Society of London (ZSL)); Dr Dominic Andradi Brown (University of Oxford); Dr Grant Harper (Biodiversity Restoration Specialist), Peter Carr (CCT); Emily Smith and Dr Tom Letessier of ZSL; Robin Burns and Stephen Hipsey (JASCO Applied Science), and Simon Watton (Coxswain and field medical specialist).

The team boarded the new BIOT Patrol Vessel, the Grampian Frontier (Figure 3) in Male in the Maldives, and worked in the northern atolls of Peros Banhos, Salomon and Blenheim reef for 10 days, before departing from Diego Garcia. The expedition was mostly funded by the Bertarelli Foundation's Programme in Marine Science with CCT funding the Rats and Islands Project. Reports from some of the projects follow.

Figure 3: The BIOT Patrol Vessel Grampian Frontier in Peros Banhos atoll

Restoring the Balance

Pete Carr, CCT trustee

Expedition Report

In August 2014, after a five-year gestation and planning period, the CCT-led attempt at eradicating rats from a Chagos island was undertaken.

In April 2017 it was confirmed that the operation had been successful and rats had been eradicated from Ile Vache Marine in Peros Banhos and Iles Sel and Jacobin in the Solomons.

This article recounts the human story behind the operation; for the scientific and technical account see Harper, Carr and Pitman (in press).

Background

In 2011, in Birds of BIOT I wrote:

> "What is immediately evident when approaching any island in BIOT from the sea is whether or not it was ever inhabited? Those islands cleared of all native trees and set up as coconut plantations appear dark, lifeless and uniform. Eagle Island is the classic example of these circumstances. On such islands, a walk through the stands of coconut reveals what appears a sterile and empty habitat, with the only life evident being the ubiquitous rats. The dense, closed canopy does not allow other plants to survive underneath. Native seeds that are trying to sprout in the gloom against all odds are likely to be eaten or destroyed by rats…..
>
> ….The smaller islands near Eagle Island on the western side of the Great Chagos Bank are a stark contrast. For example Sea Cow, which was never permanently settled and is rat-free, is a magnificent, healthy and flourishing island. This is evident in the number of boobies, frigatebirds and noddies, and the near lack of invasive plants that the island supports…." (Carr, 2011, pp. 5-6).

I have taken every opportunity over the years to point this out to people visiting the Chagos ranging from former inhabitants of the archipelago through BIOT Commissioners, the Bertarelli family to the newest Royal Marine Commando on his first posting abroad.

The point of revisiting those words is that they were arrived at through the eyes of a soldier, not a university trained ecologist, biologist, botanist or a specialised mammal eradication practitioner. The contrast in the Chagos between "dead" (read rat-infested) and "alive" (rat-free) islands is so apparent anyone viewing the two will notice the difference.

I was truly staggered when I realised that man had introduced an invasive alien predator on to these islands and that their presence was the main reason that the seabirds, found breeding in abundance on nearby islands, did not ever land on these "dead" islands.

Without wishing to sound dramatic, I remember it being an epiphanous moment when I realised I could do something about

Ile Vache Marine, Chagos Archipelago
© Jon Slayer

this situation. Leading a rat eradication operation in the remote Chagos to restore breeding seabirds seemed the logical project for a retired Commando with a passion for birds and adventure.

While reflecting back on the eight years it took to cover inception, conception, execution and conclusion, it is a sobering thought that, whilst the idea was truly mine, the success of the project was actually due to the dedication, expertise and goodwill of a host of other people. It is these I wish to talk about.

Inception

Whilst I'd come up with the initial idea, the fact was that I knew little about how to eradicate rats from tropical islands, even though I did not even realise that at the time. As I was to learn in the ensuing years, rat eradications on wet tropical islands is not a perfected craft and successful operations (still) only occur around 70% of the time (see Harper & Bunbury, 2015 for the latest thoughts on reasons).

Despite these shortcomings, I was encouraged to develop a plan, with the backing of the then BIOT Scientific Advisor Professor Charles Sheppard and the Executive Committee of the CCT, and to submit a bid for funding to the Darwin Initiative. And it was through this process that the first piece of sound advice came my way, "hire a mammal eradication expert."

This advice, from Clare Stringer and James Millett of the UK Overseas Territories Unit of the RSPB, was without doubt the single most important piece of advice I received throughout the project.

Conception

Several people made outstanding contributions to the funding bid to the Darwin Initiative that greatly improved its shape and form, including (again) Prof. Charles Sheppard and James and Clare (RSPB), and in addition by Dr. Colin Clubbe (Royal Botanical Gardens, Kew), Dr. Heather Koldewey (Zoological Society of London), Charley Cranmer (CCT) and of course the project's main partner, the BIOT Administration.

The bid was ultimately successful and money was forthcoming. My top priority was to find someone who actually knew what they were doing and again the RSPB came up trumps by introducing me to Dr. Grant Harper (Biodiversity Restoration Specialists Ltd, Nelson, New Zealand).

Grant was fundamental to the success of the operation and his expertise in the specialist niche of eradicating mammalian predators from tropical islands is hard to match. Together we refined (actually rewrote) the operational plan. Grant brought his years of expertise to the table and I contributed specialist knowledge of the Chagos itself and, in particular, how operations such as the one we were proposing could happen in reality.

The final plan was simple, in a typically Chagos-complicated way. It was simple, in that when we actually arrived on Vache Marine the operation, although precise, was not technically challenging. The complicated bit was delivering stores and equipment to Diego Garcia from the USA, New Zealand and the UK via an agent in Singapore, loading them aboard the BIOT Patrol Vessel and then transferring them to a smaller boat before riding the surf and delivering them onto the island.

Special thanks go to the indomitable Singapore agent Helen Lee who has helped out so many visitors and expeditions to the Chagos over the years.

There was also the organisation of the cutting of the grid-lines to facilitate the hand-spread bait dispersal. This was an enormous task that, for the operation to be successful, had to be cut-in precisely.

With a sterling contribution by British Forces BIOT stationed on Diego Garcia, over 10 members of BF BIOT gave up their own time to hack their way through dense vegetation to assist the project over two weekends in June and July 2013. Without their help, the time and effort Grant and I would have had to put in prior to the eradication phase would have been an order of magnitude higher.

In any operation such as Vache Marine there is a lot of background preparatory work that has to be conducted that largely goes unnoticed. In this case, we needed to compile existing data and conduct surveys of the island to produce a baseline of ecological data against which we can monitor future change.

Many contributed either directly or indirectly to this database. Indirectly, there were contributions from the turtle fraternity, especially Jeanne Mortimer and laterally Nicole Estaban. The two ornithologists who surveyed Vache Marine in 1996 and 2006, Peter Symens and Andy McGowan respectively, also indirectly helped. Directly and worthy of a special mention is the irrepressible Connect Chagos graduate Yannick Mandarin who spent two days on the island in 2012 helping me calculate the numbers of land crab present, essential for calculating bait rates.

James Millett


Charles Sheppard

And finally, the second most important thing that happened prior to the eradication phase was Grant Harper insisting that he conduct a reconnaissance of the island prior to the eradication operation itself. That I had never included this in the original budget beggars belief, especially considering my military background and having read the 2006 post-operation Eagle Island report that identified a lack of reconnaissance by the leader of the eradication phase as a weakness in their plan.

However, Charley Cranmer (the then CCT fundraiser) worked some magic with Eilidh Young of the Darwin Initiative team so that, with no additional funding, Grant was able to conduct a thorough and very worthwhile visit to the island in January 2014 accompanied by Jon Schlayer, a seasoned Chagos hand. And the plan changed slightly again!

Execution

And so on to August 2015 and the actual execution of the eradication phase. Lots of the really challenging work had already been delivered, such as persuading BIOT Administration to allow another rat eradication to go ahead, raising the capital, delivering stores and equipment from around the world to Diego Garcia, negotiating for BIOT Patrol Vessel time, working with British Forces on Diego Garcia to cut the vegetation, collecting the baseline data – it had been a long haul. All Grant and I had to do was spread the bait around the island, surely? As all military folk will know well, no plan survives first contact with the enemy and ours did not differ.

We met our military compatriots who were to assist us as coxswains and muscle-power, training them on board the delivery vessel in


Heather Koldewey


Colin Clubbe


Charley Cranmer

how to handle poisonous bait safely, followed by an “adventurous” delivery of the bait and associated equipment to the shore through some troublesome surf. Grant and I then took our first look at the handiwork of those who had cut the lines in for us. Precision was the order of the day; bait had to be delivered to every 10 m^2 of the island so if the gridlines were not parallel it would reduce the chances of achieving the required delivery pattern. And in one small area near the centre of the island there were bows in the lines. So before the bait dispersal could start, we had to recut four gridlines in.

This incident supplied the prime lesson learnt from the project. Always have an appropriately trained and experienced operator present to supervise any aspect of the project that is crucial to the operational success. With the gridlines cut in, and with unwavering support from the Captain and crew of the BIOT Patrol Vessel and the support team from British Forces BIOT, we delivered the bait effectively across the island. We then repeated the operation 10 days later (to read the Vache Marine full operational plan visit the excellent Darwin Initiative website).

Grant and I were accompanied by Tom Franklin, the Senior Fisheries Protection Officer (SFPO) from MRAG, on both periods on the island when dispensing the poison. Tom not only helped out when his own important duties allowed, he was also a consummate diplomat, balancing the MRAG needs with the requirements for CCT to deliver on its pledge to the Darwin Initiative. It is a very fine balancing act conducted between CCT, MRAG, British Forces BIOT and the British Indian Ocean Territory Administration in London. Thanks to the common-sense, common decency, honesty and enthusiasm for the project by the key personnel in all of the associated organisations, this operation went as smoothly as one could hope for when operating in a remote part of the central Indian Ocean.

Conclusion

The result was not easy to come by. The internationally recognised waiting time after a rat eradication operation on a tropical island is a minimum of 18 months, preferably longer. This allows enough time for, for example, a single surviving pregnant female rat to give birth and eventually give rise to a sufficiently large population that would be detected by a follow-up search. I had visited the island twice during this hiatus to check the signs, once with another Chagos Connect graduate Claudia Naraina, whom I will come back to. On both visits I was not disappointed. All of the tell-tale signs indicated we had been successful. But the required waiting period had not yet elapsed and I was not an internationally recognised expert on mammalian detection.

For a variety of (good) reasons I had not budgeted to have an internationally recognised mammal detection expert costed in to the original plan. For a variety of (bad) reasons my plans to get one to the island on a different budget were thwarted. To finalise the project we needed one to visit Vache Marine to determine the final verdict, but we had no money to finance this hugely important component of the project. It was at this time that the last shining star of the project stepped-in, the Director of CCT, Helen Pitman. Helen somehow managed, in record time, to liase with the CCT Trustees and secure the funding for Grant to accompany me back to the island to make that final,

definitive call. And the successful verdict is now history.

And herein lies the final lesson learnt of the project: Never assume anything. And again coming from a military background I find it hard to believe I never included this in my plans. I was oft told in my service time that, “assumption is the mother of all muck-ups.”

And to conclude? My time with Claudia on Vache Marine summed up the whole experience for me. At the beginning of the expedition with Claudia I had explained the difference between “dead and alive” islands. She quickly grasped the concept, along with the ecological significance of rat presence on oceanic islands. As we approached Vache Marine I asked her which type of island she thought it was, and her answer was “it looks half and half.” At this stage of the island’s ecological rehabilitation, this was an accurate observation. Once on the island Claudia planted some *Intsia bijuga* (a grand oceanic island rainforest climax tree) seedlings in a clearing I had made in the old plantation area.

In order for us to arrive at that special moment, so many other people and plans had to come together. Back in London in 2010 several organisations had to agree to the project, most notably BIOTA, RSPB, RBG Kew, ZSL and of course the proposing organisation CCT.

A successful bid had to be put through the Darwin Initiative process. In the planning and execution of the operation, personnel from the British military and government had to work with and rely on people from NGOs and businesses – not always natural bed-fellows. Citizens of the UK, USA, New Zealand, Singapore, the Philippines, Sri Lanka, South Africa, Mauritius and the Seychelles were actively taking part or contributing to the project. The seedlings Claudia planted were grown on the BIOT Patrol Vessel. The description of how people and organisations interacted successfully could go on much further.

In addition to the “tactical” lessons learnt that I have highlighted above, the “operational” take-home points for me were as follows:

- Honesty and transparency with all, by all, in all of their dealings
- Trust in your fellow workers and organisations that what they say will deliver, they will deliver, and
- Communication. Constant, honest and regular.

I was extremely fortunate that all of the people I dealt with when overseeing this work were honest with me. All delivered what they said they would, on-time and often more than was expected. When things went awry, as they do on these types of operations, all were honest and open about what had happened. This made remedying the situation far, far easier. And being honest, this was a good thing because I was the one who made the most mistakes.

Acknowledgements

First and foremost I would like to thank the Darwin Initiative for the generous funding that made this project possible, in particular Eilidh Young for her fair, honest, timely and expert advice and support. The BIOT Administration and BF BIOT were a pleasure to work with during this project, especially Rupert Compston who was outstanding in his support, knowledge and grasp of the requirement. Grant Harper has been a consummate professional throughout and I hope we have the opportunity for more eradication work in the Chagos in the future. Our gratitude to ACP (NZ) and Bell Labs (USA) for generously donating the rodenticide and Orillion for non-toxic bait. Also to Helen Lee in

Singapore for foregoing her handling charges and providing a professional service throughout. To the Captain and crews of the two BPVs, both provided support beyond what was expected or required. To all those who joined me in the field, especially Tom Franklin from MRAG and Yannick and Claudia, you were all fun and part of the adventure.

And finally to the Chair and Trustees, past and present, for your support and encouragement. Let us hope this is the first and not the last of many success stories.

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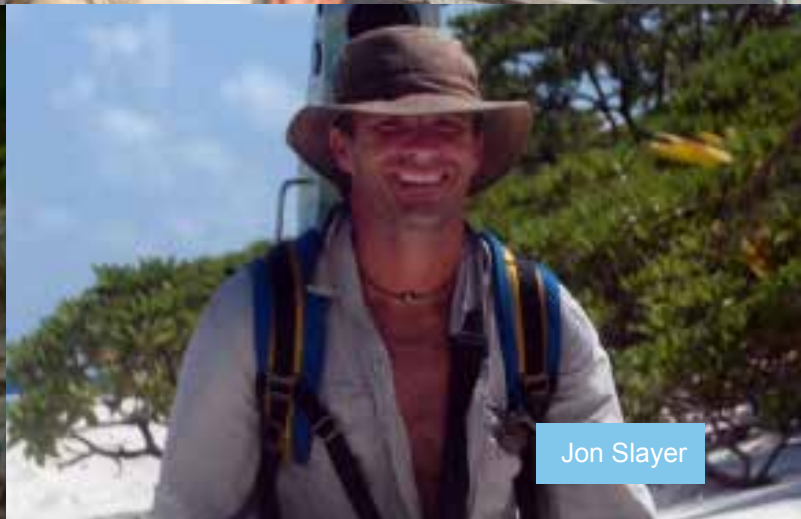
Harper, Carr and Pitman (in press)

Map of the Chagos Archipelago showing islands with and without rats as of June 2017.

Pete Carr (L) and Yannick Mandarin (R)

Claudia Naraina



Jon Slayer

Video Archiving Reefs

John Turner and Ronan Roche, School of Ocean Sciences, Bangor University

Expedition Report 1. Objective iv: Video Archive for Long- Tterm Monitoring of Coral Reef Benthic Communities

Introduction

During the 2017 Expedition, John Turner and Ronan Roche built upon previous work by continuing to develop a video archive of coral reef benthic community structure across depths at permanent monitoring sites (Figure 1) throughout the northern atolls.

The aim of the study is to produce a record that can be analysed to assess change when compared with video records made at sites first recorded in 2006, and again in 2013, 2014, 2015 and 2016. A video archive provides the opportunity to revisit sites over time to assess factors that perhaps have only recently become of note (e.g. disease), and provides a visual baseline allowing newly engaged scientists to compare coral reef community structure in time.

The reefs provide a 'benchmark' for observing the effect of changing conditions in the absence of direct human impact, and indicate how functional reef communities respond to these conditions. Previous studies have shown that benthic cover, especially of hard corals, reduced following bleaching-related mortality after warming events in 1997, 2003 and 2005, but that *Acropora* corals re-established particularly well across the shallow reef slopes and terraces.

Although benthic cover measurements were made on the earliest scientific expeditions to the archipelago, photography and film techniques at this time were comparatively limited. Due to the scant amount of imagery from that period, it is difficult to compare the state of the reefs in the 70s and 80s with today's reef communities.

Recent investigations have shown, however, that visual surveys and video surveys provide comparable measures of cover, and therefore a video archive can provide important data for assessing change. Video recording has a number of advantages over traditional survey techniques, the main advantage being that a

Figure 1

Figure 2

relatively large tract of reef (up to 500 m^2) can be recorded during one dive.

Around 200 randomly 'grabbed' frames (equivalent to sampling from quadrats) can be assessed from the video record of homogeneous reef tracts, which promotes representative sampling. Imagery can be then be analysed in the laboratory where there is access to video play back, identification books and guides, and without the constraints imposed on an observer whilst underwater.

Methodology

Sixteen sites on three atolls (Peros Banhos, Salomon, Blenheim) were surveyed during this expedition as described above, covering approximately 8,000 m^2 in total.

Ten-minute sequences of video were recorded across 5 m depth intervals from 25 m depth to 5 m depth using a Sony HDR 550 video camera and/or a Canon GS30 camera in a Light and Motion Blue Fin housing equipped with a Fathom 90 wide angle port lens and Sola LED video lights for deeper depths and red filter for mid depths. Scale was provided by two 638 nm (red) wavelength lasers mounted below the camera to project dots 10 cm apart on the video image.

Approximately 80 wide angle habitat images were recorded randomly on each dive by a Go Pro Hero camera with red filter and set to record high definition images at 30 second intervals (Figure 2). This year, two cameras were used over slightly different tracts, allowing us to compare reproducibility and test sampling rates.

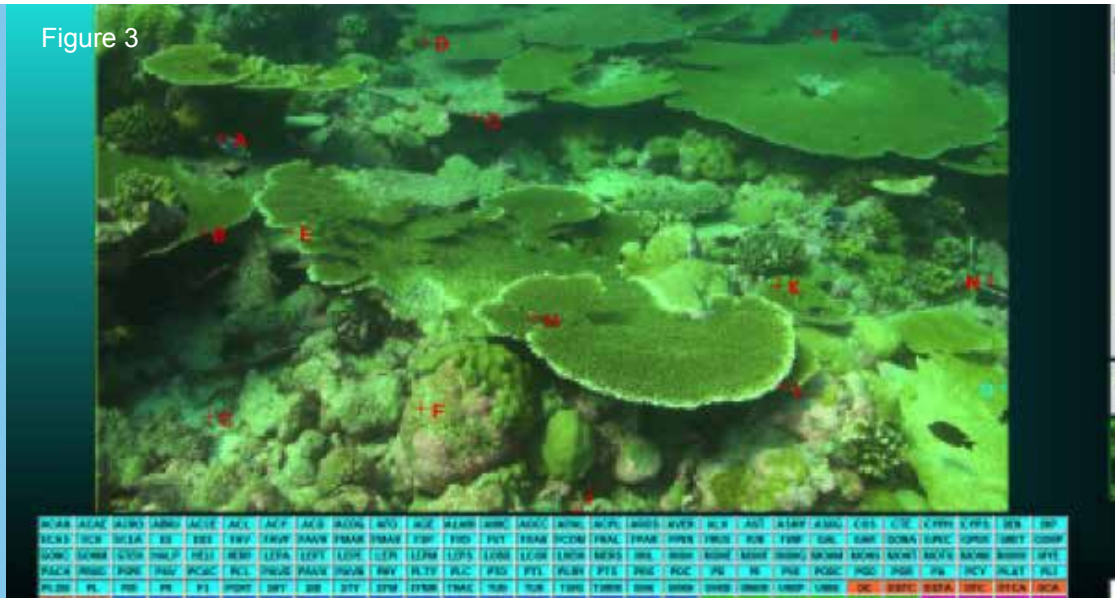
Analysis

Video sequences from the four 5 m depth intervals (5–10 m, 10–15 m, 15–20 m and 20–25 m) are being compared between years over the next few months. Fifty frame grabs are extracted randomly from each depth interval at each site (using Pinnacle Studio 10 software), and these are imported into Coral Point Count with Excel Extensions (CPCe, NCRI Florida) and overlaid by 16 randomly generated points (Figure 3).

Figure 1: Video survey of coral reef community structure

Figure 2; High Definition camera in housing with wide angle port, LED lights, laser scale and Go-Pro camera recording digital images every 30 seconds

Figure 3: Image analysis using CPCe software. The substrate or life form under each point are recorded by entering the relevant category via the tabs at the bottom of the screen to construct an Excel spreadsheet displaying frequency (%)



The substrate, benthic life form and, where appropriate, the genus and species underlying each point are automatically collated in an Excel spreadsheet using tab keys in CPCe and the spreadsheet data are then imported into statistical software for analysis. Frame grabs can be moved frame by frame to assist in identification, and the 'truthing' images are used to identify species where video image resolution is insufficient.

The Go-Pro images provide context and allow reef descriptions. Tissue loss, discolouration, disease and mortality are recorded by playing each video through and recording frequency.

The results can be used to show comparisons of coral cover between atolls (Figure 4), and we can drill down into the data, for example to show coral genera cover by atoll (Figure 5) or soft coral by reef type (Figure 6) or macroalgae cover with depth (Figure 7). Figures 4–7 show results from surveys undertaken in 2015, prior to the warming event of that year.

Results from surveys conducted in 2016 following the 2015 warming event (but before the 2016 bleaching event) identified the severe loss of coral cover (Figure 8), and a comparison with long term data of coral cover shows that the coral reefs were already 'set back' to levels of coral cover seen in 2001 after the 1997/98 warming event (Figure 9).

A clear pattern emerged in 2017 after assessing 16 sites across three atolls, including a mixture of exposed and more protected seaward reefs, lagoon reefs and lagoon patch reefs to a depth of 25 m. Branching and tabular corals, such as *Pocillopora* and *Acropora* were mostly dead in shallow water above c.15 m (Figure 10).

Diseased corals were rarely seen. The smaller branching colonies were still standing, but many of the table corals had collapsed, potentially forming new calcareous substrate which, will eventually become cemented together, and form a suitable surface for coral recruits. The calcified green macroalga *Halimeda* had colonised spaces between corals (Figure 11).

In more exposed locations, the tables had fallen down the reef sleep (Figure 12), often being overturned, and in very exposed sites, they had been swept off the reef entirely, taking the newly settled recruits with them (Figure 13).

Corals surviving in the shallows were most frequently colonies of *Porites* (Figure 14) including the extremely large (>5 m diameter) colonies that could be many hundreds of years old, but many of these showed paling due to bleaching and, in some, partial mortality of parts of the colony (Figure 15).

A different picture emerges at deeper depths, where coral communities were generally in good health (Figure 16). Below 15 m on seaward reef slopes and lagoon (leeward) reefs, most corals are surviving, although some instances of partial bleaching and mortality were evident. On exposed seaward reefs we observed upsurges of colder water at depth that may be helping to cool the corals.

These reefs are mostly composed of the same species as those found at shallow depths, and may be an important continued source of larvae for future recruitment. Detailed analysis of the video material will elaborate on these observations.

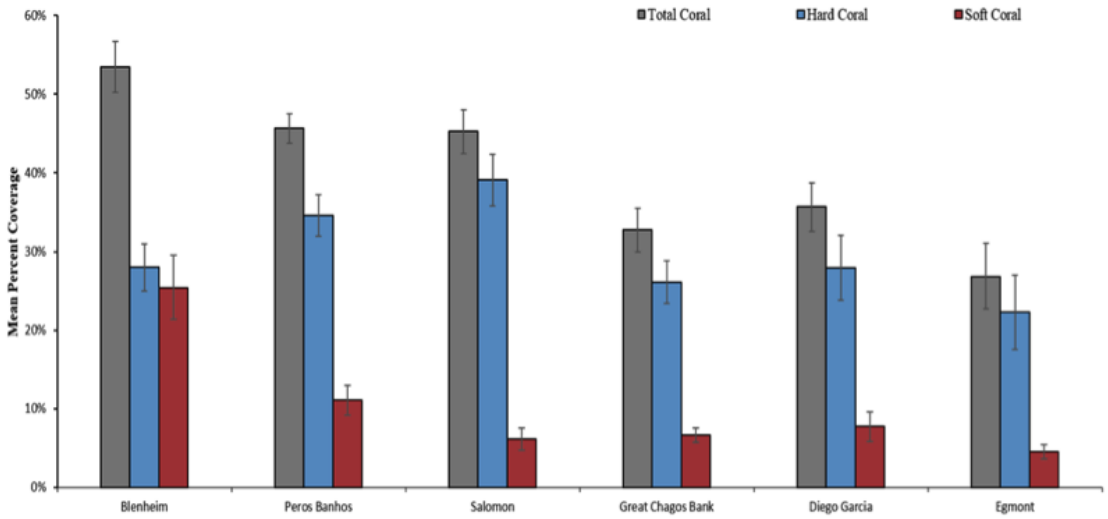


Figure 4: Total cover, hard coral cover and soft coral on atolls in 2015 before the warming event.

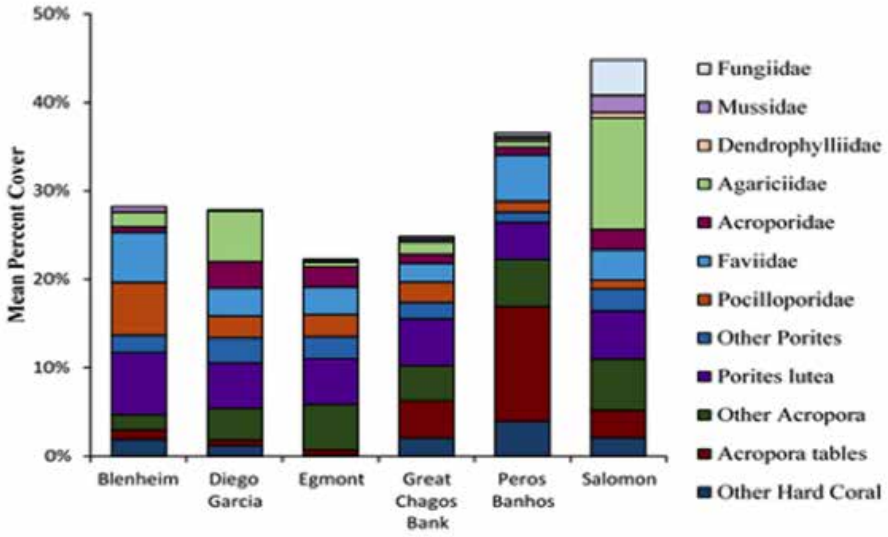


Figure 5: Coral genera cover by atoll in 2015, prior to the warming event.

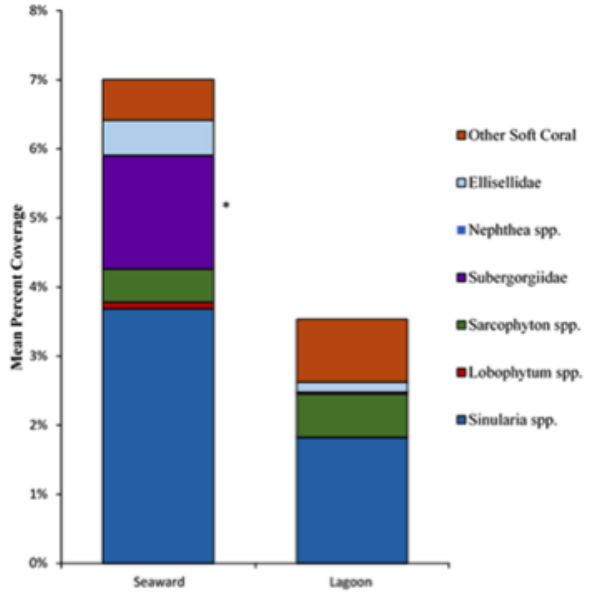


Figure 6: Soft coral by reef type in 2015.

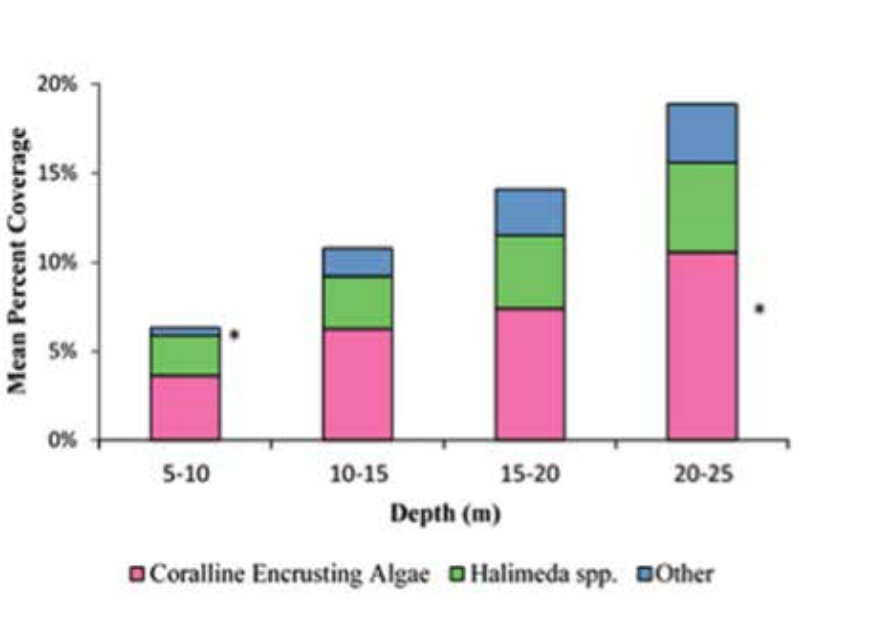


Figure 7: Macroalgae by depth in 2015.

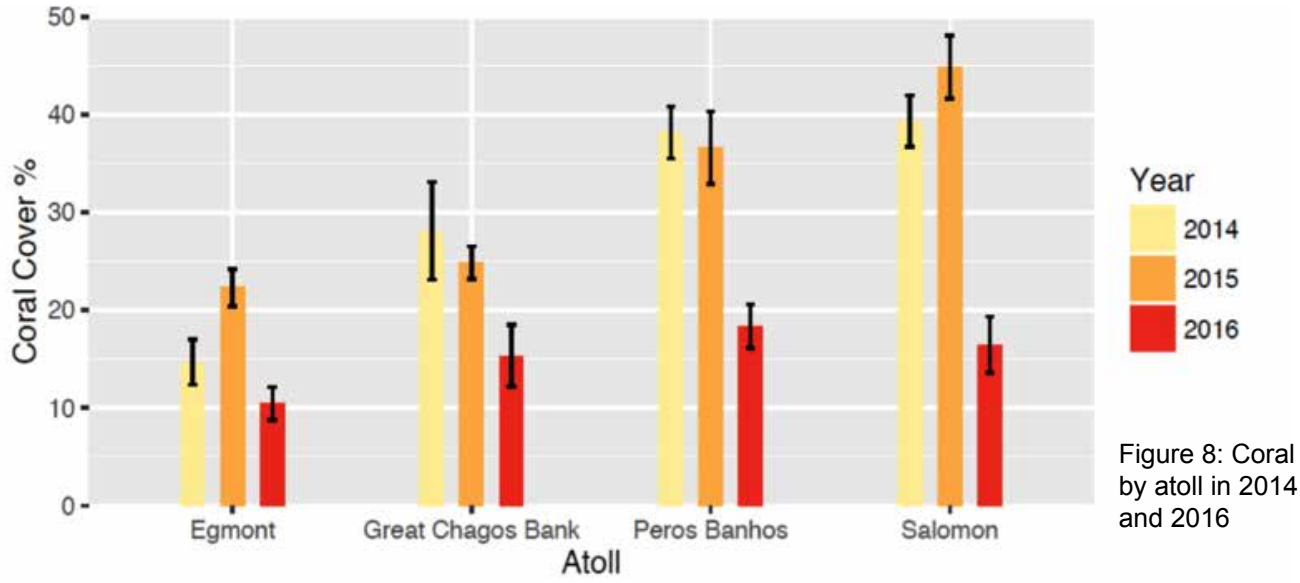


Figure 8: Coral cover by atoll in 2014, 2015 and 2016

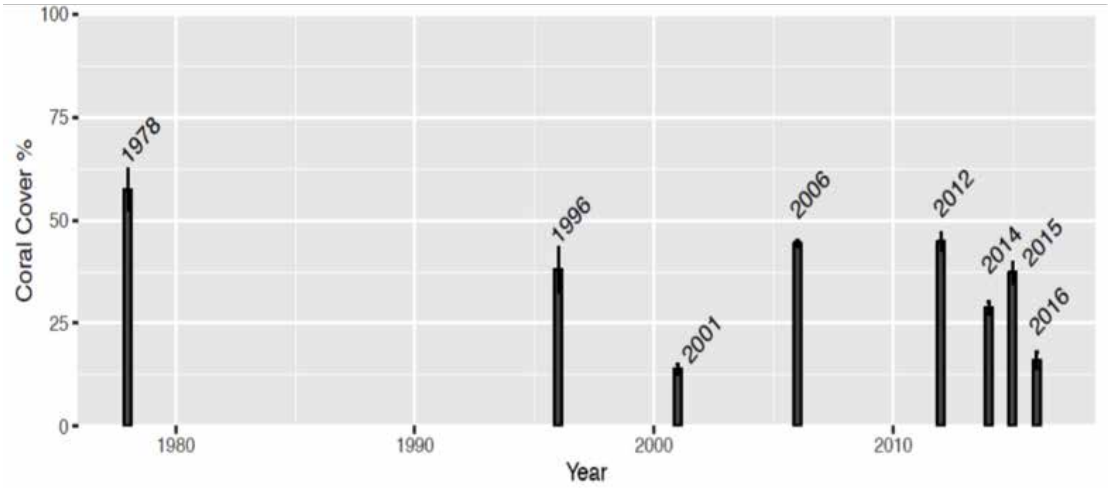


Figure 9: Coral cover by year from visual assessment (1978, 1996, 2001, 2012) and from video archive (2006, 2014, 2015, 2016)

Figure 10: Dead branching and tabular corals in shallow water, Ile Diamont, Peros BanhosFigure 2; High Definition camera in housing with wide angle port, LED lights, laser scale and Go-Pro camera recording digital images every 30 seconds.

Figure 11: Green calcareous Halimeda growing amongst dead standing coral, Ile Diamont, Peros Banhos.

Figure 12: Exposed reef with low living coral cover at Blenheim Reef East.This reef previously had high cover of soft corals.

Figure 13: Acropora table fallen down reef slope harbouring new recruits, Ile de la Passe, Salomon.

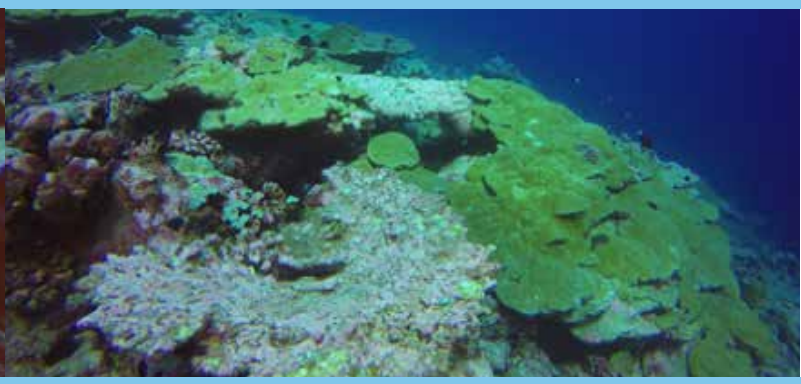


Figure 14: Porites colonies survive in shallow waters, Ile de la Passe, Salomon.

Figure 15. Large Porites with paling and partial mortality, Ile Diamont, Peros Banhos.

Figure 15. Large Porites with paling and partial mortality, Ile Diamont, Peros Banhos.

Extending Long-term Datasets

Charles Sheppard and Anne Sheppard

Expedition Report Project 1. Objectives i-iii: Extending existing long-term coral reef datasets; Integrating sea surface temperature trends into coral reef resilience; Measuring future resilience via juvenile coral abundance.

Summary

Across the three northern atolls of Chagos (Peros Banhos, Salomon, Blenheim) reef condition was assessed for mortality following the warming event that occurred in 2015–2016. Methods used were similar to those used in the preceding 20 years and, for comparison, were at the same locations. Cover of the major substrate forms was measured in over 600 quadrats with side of 0.5 metre, a size previously chosen for its optimal sampling efficiency in such a broad and rapid survey.

At the same time, juvenile corals were counted in the same quadrats. Also, eight temperature recorders across the two islanded atolls were recovered and replaced with new ones. It is clear that the coral reef ecosystem has essentially collapsed to about 15 m depth, and the reefs are currently probably in an erosional state.

Cover of corals and other key species groups

Several incremental plots of coral cover data over the years have shown, firstly, the initial good state of coral cover in the 1970s and 1996, followed by the near-collapse after the warming episode of 1998, then a pause of at least three years followed by a rapid recovery of several benthic forms including corals over the following decade.[1,2] In rough terms, the 1998 warming event reduced the cover of corals to below that needed to maintain the reefs (and islands), and the values gathered in 2017 look similar to, or even worse than, the pattern that was seen in 1998.

Broad eye estimates were also made of benthic cover, at each site and depth over areas each greater than 200–300 m^2. Some broad conclusions follow:

1. Corals have declined markedly to at least 15 m depth, and throughout this depth span the coral ecosystem has essentially collapsed. The reefs are variously covered mainly by dead table corals, or by jumbles of mixed, dead coral skeletons. (Figures 1–2)

Of particular note were two areas that previously were dominated by soft corals on the southeast aspects of the two islanded atolls that were visited. Here, the soft corals have likewise vanished, but as these leave no skeletal traces, these huge, gently sloping reef surfaces were strangely featureless and devoid of relief or much living benthic forms (Figure 3).

In all such areas, coral cover is extremely low, being less than one or two per cent over large expanses.

1 Sheppard CRC and 20 others. 2013. British Indian Ocean Territory (the Chagos Archipelago): Setting, Connections and the Marine Protected Area. In: Sheppard (ed) Coral Reefs of the British Indian Ocean Territories. Springer. Chapter 17 pp 223- 240.

2 Sheppard CRC and 17 others. 2013, Coral Reefs of the Chagos Archipelago, Indian Ocean. In: Sheppard (ed) Coral Reefs of the British Indian Ocean Territories. Springer. Chapter 18 pp 241-252.

Figures 1 and 2: Dead table corals over 1 m across in a lagoon (left), and a mixed jumble of dead corals on an ocean-facing reef.

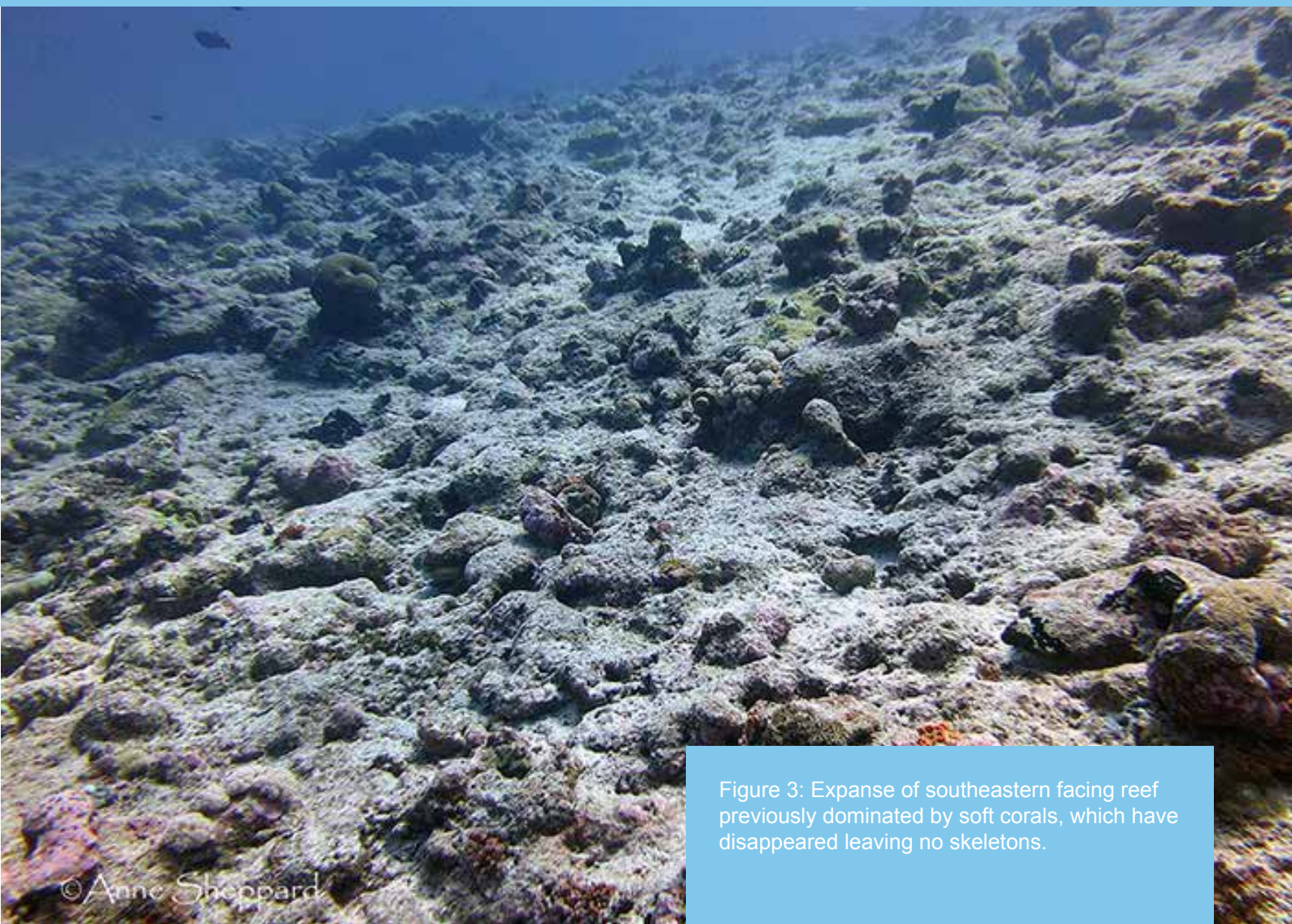


Figure 3: Expanse of southeastern facing reef previously dominated by soft corals, which have disappeared leaving no skeletons.

2. In 2017 a much increased area was covered by the calcareous algae *Halimeda*, and sometimes by a small but significant percentage of the fleshy green *Caulerpa* (Figures 4–5). Fleshy red seaweeds were common too.

3. While data collected is inadequate to perform proper calculations, it is clear that these reefs have most likely flipped from being in a growing phase into an erosion phase. Sheets of boring sponge that substantially erode the reef rock (mostly *Cliona* spp.) occupy shallow bare areas. These sponges have always been present here, often abundant in some areas, but when corals are absent and the proportion of bare substrate is hugely increased, they have a far greater area on which to settle and burrow (Figure 6).

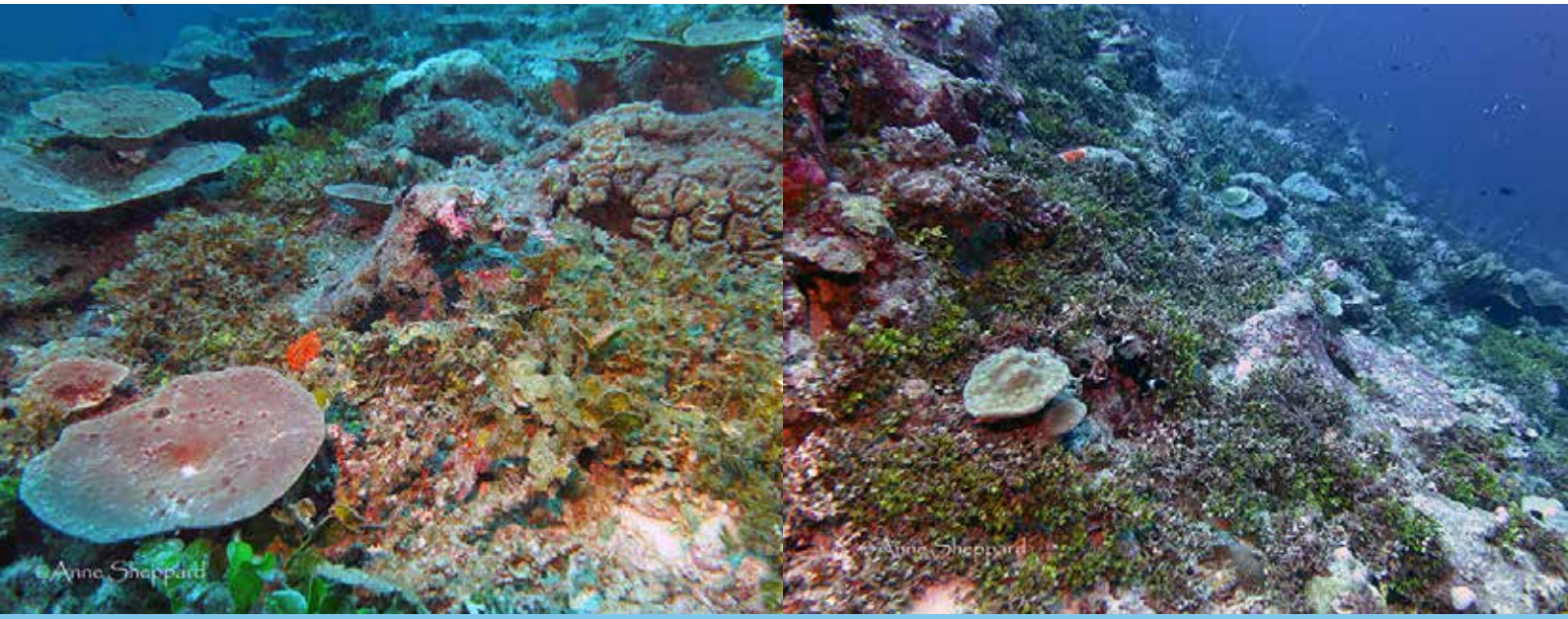
The Great Chagos Bank and southern atolls were not examined on this expedition, and in the last mass mortality event at least, they were affected more severely than these northern atolls. At that time, in the north the dead zone extended to about 15 m deep, with cover improving at a depth of around 20 m, whereas the more southerly atolls showed equally severe mortality to much greater depth, 40 m or more in the case of Diego Garcia.

This is an important difference given that corals have an optimum depth span: where mortality extends 'only' to the peak diversity zone of about 20 m there is a good chance that survivors of that species might occur deeper and be able to repopulate the shallow zones. But where the mortality is severe to 40 m then there is a likelihood of much less survival of shallow or mid-depth species and thus a more limited possibility of any swift recovery.

No reef fish estimates were undertaken. Our broad observations suggest that while there were some large schools, the reef fish were considerably depleted at the time of our visit.

Juvenile Corals

Juveniles (defined here as coral colonies less than 15 mm across) are present at most sites, though not usually very



Figures 4 and 5. Substantially increased growths of green algae were present, most commonly *Halimeda* and *Caulerpa*, with several other more fleshy species. Left: lagoon, right: ocean slope. (The table-shaped fauna in these photos are a leafy sponge in the left image, and a *Porites* coral which is possibly the species most resistant to temperature rise in the right photo.)

abundant. They were measured in 2001 three years after the 1998 event when juveniles were common[3] (especially on dead *Acropora* tables (Figures 7–8), a phenomenon that seems to be universal).

Recruit number was next measured in 2006[4] after total coral cover had returned, at which time the numbers of similarly sized recruits seen on bare substrate were the highest recorded anywhere. Mean numbers at that time ranged from 30–60 m^2 depending on depth. In 2017, results indicate lower numbers (still awaiting detailed analysis), but they were at least present on all reefs.

Corals that were clearly very young but over a year old were also common in 2017, but the intention was to focus on the very young cohort, this being the most indicative of reproductive success (or otherwise) of corals that survived the 2016 warming.

3 Sheppard C.R.C., Spalding M, Bradshaw C, Wilson S. 2002. Erosion vs. recovery of coral reefs after 1998 El Niño: Chagos reefs, Indian Ocean. Ambio. 31:40-48.
4 Francis B, Sheppard ALS, Sheppard CRC. 2013. Coral juveniles in Chagos: The Next Generation. Poster given at 2013 conferences of UK Coral Reef Conservation Society.

Numbers in 2017 are clearly lower, unsurprisingly,

but they are certainly present, which does suggest that recovery to some degree will occur.

The identity of the juveniles did seem to be rather limited to a few species – only a later survey can determine these.

Surviving corals

As has been the case previously in many places in the Indo-Pacific Ocean, boulder corals of the genus *Porites* are the best survivors. On several shallow reefs these form the main, or sometimes only coral component in 2017, and are relatively strongly present to about 3 m depth, surrounded by dead colonies of other shallow water dwelling genera such as *Stylophora, Pocillopora* and stubby branching forms of *Acropora*.

Common also were examples where adults had small surviving patches, possibly single polyps that were more deeply embedded in their colony, which survived and have started

Figure 6: Shallow reefs on ocean-facing slopes are devoid of coral, providing greatly increased substrate for the burrowing and eroding sponge *Cliona* and its relatives.

to regrow over their old skeleton (Figure 9). Also present, though less common, were examples where only the top of the colony was killed and most of the shaded part survived (because the tops of colonies receive greater illumination, and light is also involved in the mortality process – Figure 10). From both of these phenomena, as well as from juveniles, recovery can occur.

Temperature recorders

Eight temperature loggers, recording at two-hour intervals, had been placed in the northern atolls in either 2014 or 2015. Some are parts of a series first started in 2006. All were recovered and replaced with new ones (Figure 11).

Because no replacements were carried out in 2016, some considerable luck was present in this recovery as some of the loggers had been in place for three years.

Several were on dangerously low battery level and about to expire, one was returned to the manufacturers to see if data can be recovered from it, while two had detached from their posts in the very recent past and were found under sand or in a crevice near their stakes!

In the end, all eight had recoverable data. The data show that in about June last year (uncharacteristically late), the ocean temperatures started to fall to levels more compatible with coral life.

Analysis will involve changes in mean seawater temperature over 11 years, changes in the number of times temperature exceeded fixed levels (governed by defined lethal values for corals previously determined for Chagos), and will explore changes, if any, in the extent and frequency of cooling pulses resulting from rising thermoclines of cool water, thought to be an important reason for good coral recovery in this archipelago.[5]

The two temperature loggers in Diego Garcia from 15 and 25 m depth were collected in December 2016, which was very helpful, but they were not replaced and

5 Sheppard CRC 2009. Large temperature plunges recorded by data loggers at different depths on an Indian Ocean atoll: comparison with satellite data and relevance to coral refuges. Coral reefs 28:399-403.

Figures 7 and 8: Juvenile corals from 2016 (left) and 2017 (right). The fragile substrate in these cases (a dead table coral) will probably not allow them to grow into adult corals. Most coral juveniles here are older than 1 year – those of less than a year are too small to see here.

there was no opportunity to do so during our transit through on this expedition.

There are also some loggers at these depths on the Great Chagos Bank and Egmont atolls that were not visited, and which will most likely expire or become lost during 2017. The long-time series of data are always of greatest value, and hopefully an opportunity to attend to these loggers might be possible before they or their data are lost.

This is a suitable time, after 11 years of records, to make available this very detailed temperature set for the wider community, and this is currently being done.

Apparent losses of some species

It has been noted before that the large massive coral *Diploastrea heliopora* (Figure 12) which used to be common in lagoons especially in 1996 and before, has not been recorded since the 1998 warming.[6]

All species of the genus *Seriatopora* (Figure 13) likewise vanished after 1998 but then began to recover in recent years; however, it has now disappeared again. (This genus also disappeared from the Maldives and has still not recovered since 1998.)

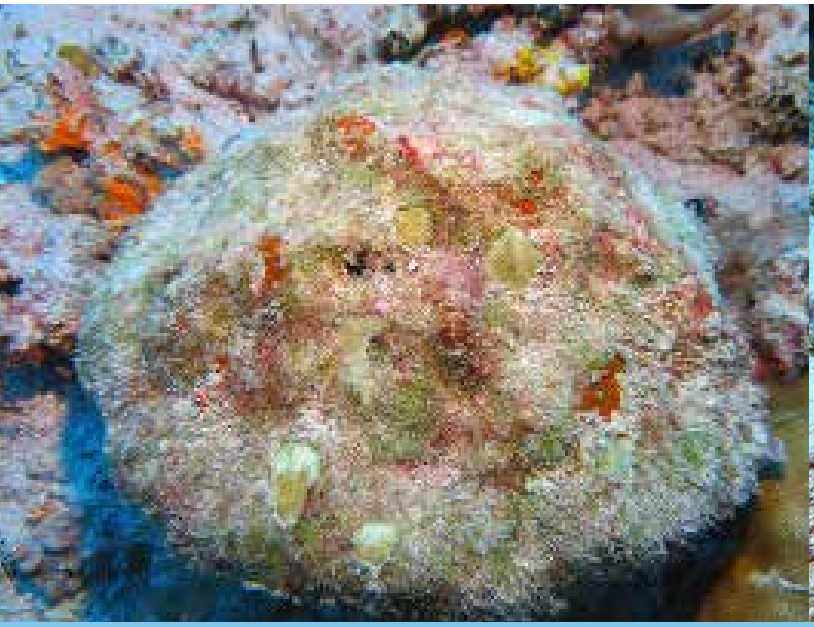
The coral *Ctenella chagius* (Figure 14), which used to be common in 1996 and before, was severely reduced by the 1998 event but was seen in lower numbers subsequently; in 2017 no live colonies were seen at all, by any diver at any depth or site. Commonly known as the Chagos brain coral, it is a near-endemic species (one colony was photographed by Dr David Obura from St Brandon Banks to the west – photo dated 2012). The depth range of this coral is mainly 5–25 m depth on both ocean reefs and lagoons. Thus its present demise is alarming.

Prognosis

Considerable work today is being devoted to the declining condition of coral reefs around the world, and also of the effect this is already having on coral islands.[7]

6 We collected a sample before this which is in the Natural History Museum (Accession number nhm2001.1010).

7 Storlazzi et al 2017. Many Atolls May be Uninhabitable Within Decades Due to Climate Change. Scientific Reports | 5:14546 | DOI: 10.1038/srep14546.



Figures 9 and 10: Examples of surviving patches. Left, example of surviving single polyps or patches on a *Goniastrea* species that have started to grow again. Right, *Astrea* or *Phymastrea* colony whose shaded parts survived more completely.

Numerous studies document the demise of reefs in different areas and a few have predicted dates for the collapse of reefs in various areas. The recent massive mortality on the Great Barrier Reef, for example, has gained considerable publicity[8] where it was shown that recent warming has essentially swamped all other local conservation measures as well as any ability of corals to acclimate to the gradually warming seas, leading to overwhelming loss of corals.

Recovery of reefs, even where this leads to different dominant species, is only possible when that recovery is not interrupted too soon by further warming events.

Predictions have been derived for Chagos reefs on two occasions: firstly in 2003 it was predicted using Hadley Centre data, together with the fact that corals need to be an average of five years old to reproduce, that the mid-2020s would see mass coral mortality in the Chagos reefs about every five years, i.e. repeat killing would recur before they could properly re-establish after the previous event.[9]

Secondly and more recently, in 2016 it was predicted that severe bleaching temperatures in the Chagos would become annual around the year 2041.[10]

Since it is clear that a terminal state for corals will occur at frequencies less than annual (since corals need to be a few years old before they reproduce) these results roughly support the earlier predictions.

It is clear enough that local management can do little about this on a local (Territory) level, since these warming events negate any local management effects,[8] and also swamp any ability of corals to acclimate to warmer conditions.

In a territory like BIOT, where the islands'

8 Hughes and 35 others. 2017. Global warming and recurrent mass bleaching of corals. Nature 543:373-377.

9 Sheppard, C.R.C. 2003. Predicted recurrences of mass coral mortality in the Indian Ocean. Nature 425:294-297.

10 Van Hooidonk and 8 others. Local-scale projections of coral reef futures and implications of the Paris Agreement. Scientific Reports. 6:39666 | DOI: 10.1038/srep39666.

Figure 11: New temperature logger in protective pipe attached to the stake at 15 m depth in Peros Banhos lagoon. The surrounding corals are all dead at this location (the live plate in foreground is a sponge).

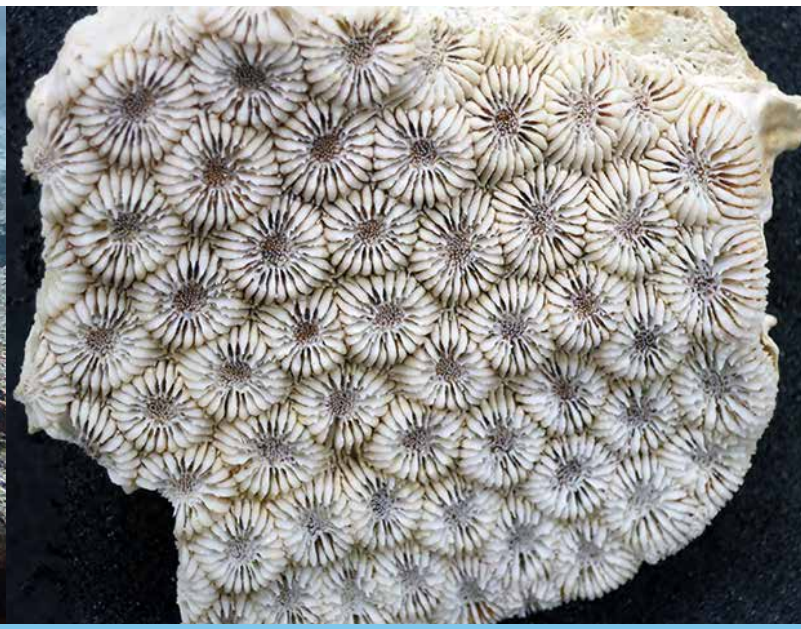


Figure 12: The massive coral *Diploastrea heliopora* museum specimen from before 1998.

maintenance is entirely dependent on reef growth, this is critical.

However, it is also clear that recovery from any one mortality event is determined by different factors from the one that caused the mortality in the first place.

Recovery of a killed reef, when it occurs at all, takes place when the higher temperature has abated.

Impediments to reproduction and recovery do include a range of local stressors which can be managed in Chagos atolls – sedimentation, sewage, fishing, industrial pollution, shoreline disturbance, etc.

Continuing these controls will be essential to prolonging the chances of successful reef recovery after this and future mortalities.

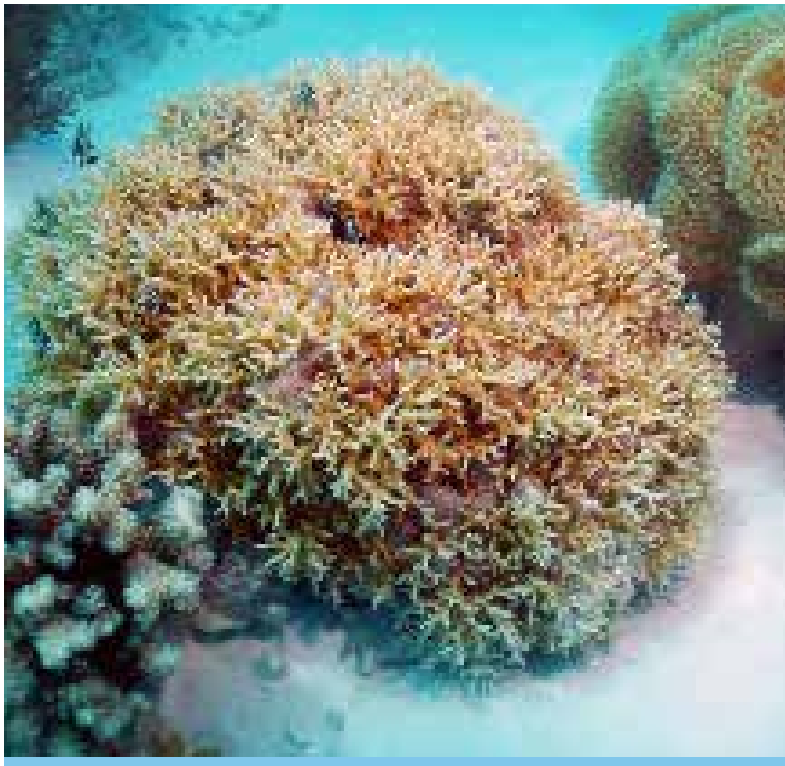


Figure 13: *Seriatopora hystrix*, formerly a common lagoon and sheltered water coral.

Figure 14: Colonies of the Chagos brain coral *Ctenella chagius*. This was not seen alive at any site in 2017.

Nobody get hurt, that's an order!

By Simon Watton, BIOT expedition 2017 medic

Earlier this year, I eagerly and gratefully answered the call for an expedition medic on the Science and Conservation Expedition that, at the time, was still waiting to be given the green light.

The Chagos Archipelago has always been a very special place to me, having been based on Diego Garcia as a Landing Craft coxswain within the Royal Marines Detachment, and I would imagine that to be the case for anyone who has had the good fortune to spend any length of time there.

I'd also had some interactions with the various expedition teams whilst based there, and again during March 2016 as I was working on the ship MY VAVA II. We were being utilized as the research platform for the expedition and I was the on-board medic at the time.

I was impressed by the scale of the operations being conducted and spoke to Tom Letessier and Malcolm Nicoll about the possibility of being involved in future trips, but I certainly would never have imagined myself being lucky enough to return there.

Preparation for all elements had to be done on borrowed time as we were still waiting for the trip to officially be given the go ahead, but to my relief it was decided that it would be best to resupply the medical kit with a new setup and I was happy to help facilitate this.

The new equipment also included an oxygen concentrator unit to use aboard the Grampian Frontier BIOT Patrol Vessel (BPV), should it be required for serious cases needing lots of the lifesaving gas!

After we'd all boarded, it was time for the usual safety briefs from the ship's company and the expedition "look-forward" from CCT trustee and expedition leader John Turner. I gave the first instructional presentation to

Drawing up medication in preparation for treatment
© Emily Smith

familiarise everyone with the new medical equipment on board, discuss likely scenarios and the procedures for dealing with them, as BIOT is an extremely remote area and the activities undertaken come with many risks that need to be managed as best as practicable.

With my access to both the old and new kit, plus the backup of having the doctor on Diego Garcia to provide radio advice, there was not much that we couldn't manage through onto definitive care.

The medical facility on Diego Garcia was also extremely helpful in providing radio advice to back up my intended treatment plans and provide the "thumbs-up" for any prescription medications deemed necessary by me and/or the on-call doctor.

Day to day, I was overseeing the general wellbeing of the team and acting as coxswain and top cover for the diving operations. We had a few minor bumps and scrapes from things like coral and launching the inflatables, seasickness and a potential spider bite.

The latter gave cause for a Hydrocortisone intramuscular (IM) injection (pictured) but thankfully that was as bad as it got!

The Chagos Archipelago is a stunningly beautiful area with an abundance of flora and fauna and it needs our protection. I am extremely proud and thankful to have been a part of the efforts to protect and conserve it, both within the military and as a civilian.

This year I start my studies to become a Registered Nurse but I will be keeping an ear out and my fingers crossed for the next trip and have my stethoscope and toothbrush ready and waiting by the door with my passport!

Treating an expedition team member by injection
© Emily Smith

Exploring the twilight zone

By Dominic A. Andradi-Brown, University of Oxford

During April 2016, a team of researchers taking part in the Berteralli Foundation British Indian Ocean Territory Expedition undertook the first surveys of the Chagos Archipelago's 'twilight zone' reefs since the 1970s.

The twilight zone, known scientifically as mesophotic coral ecosystems, includes coral reefs from 30 m to 150 m depth. These reefs are characterised by light-dependent corals that have adapted to very low levels of light (Fig 1).

Due to the remote nature of the archipelago, in recent times diver surveys have been limited to a maximum depth of 25 m, leaving most mesophotic reefs in the Chagos Archipelago having never been scientifically surveyed.

Why are we interested in the twilight zone?

Most coral reef research is focused on shallow reefs because of the difficulties in accessing deeper reefs. Yet many reef threats disproportionately affect shallow reefs; coral bleaching, for example, is caused by a combination of high temperature and high light intensity.

Research in the Chagos Archipelago has identified that previous bleaching has often been most severe on shallow reefs, with declining coral mortality on deeper reefs (approximately 25 m).

Therefore, mesophotic reefs, by virtue of being even deeper, potentially could be more protected from the impacts of bleaching than shallow coral reefs. Other processes that directly damage reefs, such as storm impacts, also tend to decline with depth. Mesophotic reefs may therefore have an important role in supporting overall reef resilience.

Studies in the Caribbean have indicated many upper-mesophotic reefs (30–60 m) contain threatened shallow reef species, including corals. And in Japan, healthy colonies of a coral species that previously was thought to have gone locally extinct following the 1998 coral bleaching event was rediscovered by deep divers several years later in the mesophotic zone.

If depth acts as a refuge in a similar way in the Chagos Archipelago, it suggests mesophotic reefs may provide local sources of fish and corals to aid recovery following shallow reef damage. This idea, known as the deep reef refugia hypothesis was first proposed in the mid-1990s, but was not formalised or widely tested until the past 5–10 years.

Two crucial components are required for the deep reef refugia hypothesis to work: (i) threatened shallow reef species must also be found on mesophotic reefs, and (ii) mesophtoic reef and shallow reef populations must be connected.

Surveying the mesophotic reefs in Chagos

During the April 2016 expedition, University of Oxford researchers with the assistance of other expedition members used a remote-operated vehicle (ROV) unit to conduct surveys around the archipelago.

The ROV contained a small camera and had battery-powered motors, and was connected via a long cable to the surface where we could control it. The ROV allowed us to survey to 60 m maximum depth, where we spent approximately 5–10 minutes filming at each location before slowly piloting the ROV up the reef slope towards the surface.

This allowed us to capture the changes in mesophotic reef fish and seabed communities from 60 m depth up to approximately 20 m, where we ended the surveys. In total, we conducted multiple transects up the reef slope at each of eleven sites in this way, both on steep outer atoll reefs in Peros Banhos, Egmont and Salomon, but also inner-lagoon bed reefs in Peros Banhos. We also conducted some preliminary surveys over Sandes seamount.

Preliminary coral observations

We observed structural differences between shallow and mesophotic reefs. One of the most common corals found on the shallow reefs of the Chagos Archipelago belongs to the genus *Porites*. On shallow reefs these corals have distinctive rounded boulder shapes. On mesophotic reefs in Peros Banhos lagoon we documented very flattened plate-like *Porites* colonies (Fig 3).

We think this change in shape is an adaptation to the lower light levels on these deeper reefs, as this pattern has been observed on mesophotic reefs elsewhere in the world.

However, researchers are still trying to understand the advantages to corals of changing morphology at depth, particularly how variations in surface texture can affect

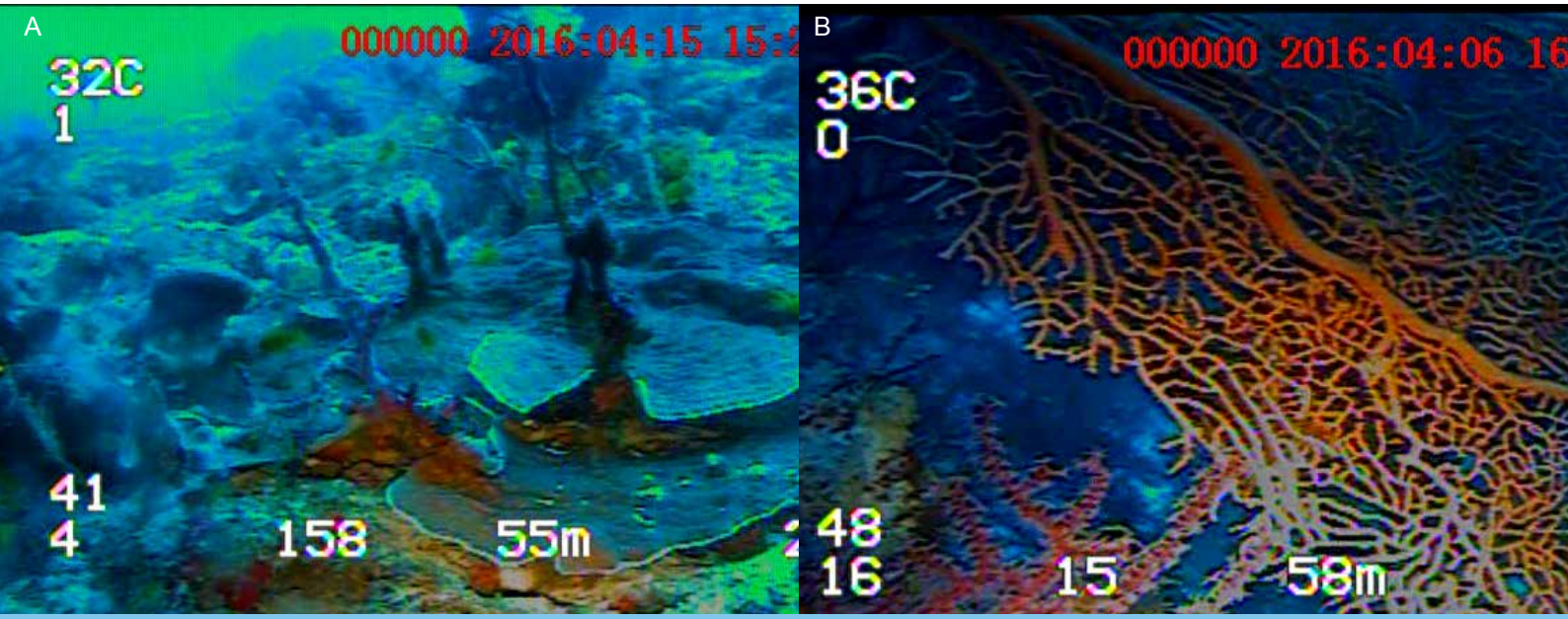


Fig 1: (A) Yellow damselfish associated with mesophotic corals at 55 m at Ile Passe, Salomon. (B) Large sea fans are commonly observed on the mesophotic reefs in Chagos Archipelago, as illustrated here at 58 m off Peros Banhos.

how easily light can reach the symbiotic algae living within coral tissues.

During surveys we identified particularly high coral coverage off Ile Anglais, Salomon, which had close too 100% live coral cover in some areas at 35–45 m depth (Fig 4). This contrasted with the shallow reefs, which contained low levels of live coral cover.

Preliminary reef fish observations

Many fish species were also identified from the mesophotic reefs of the archipelago. These include bluefin trevally (Fig 5A) and large schools of Thompson surgeonfish (Fig 5B).

Fish families such as trevally are known to rove large distances over the reef and are common on shallow reefs as well. This suggests these fish populations have the potential to rove across the shallow to mesophotic reef depth range, though this requires more research.

The known depth limits of several fish were expanded, including the Chagos clownfish, which had previously only been recorded to 25 m depth. We identified individuals living at 37 m depth (Fig 6A), with anemones down to 54 m depth (Fig 6B).

Deep reef sharks

Three species of sharks were also observed regularly on twilight reefs: silver tip, grey reef and black tip reef sharks (Fig 7A). This suggests that sharks are using the full depth range of reefs, highlighting the importance of deeper reefs for pelagic mobile predators. In addition, while surveying Sandes seamount we identified large numbers of silver tip and grey reef sharks that swam up to the ROV unit and circled it (Fig 7B).

These sharks followed the ROV down onto the top of the seamount, and also as it returned to the surface, allowing many close up images to be captured by the mesophotic reef survey team by holding cameras into the water.

Full quantitative video analysis of the ROV footage is underway. The team aim to produce a scientific paper that identifies the coral cover at various depths on twilight reefs around the Chagos Archipelago, and the associated fish communities.

Acknowledgments

We would like to thank the Bertarelli Foundation for funding this work, the captain and crew of the Bertarelli Foundation Expedition vessel, and all members of the April 2016 expedition team.

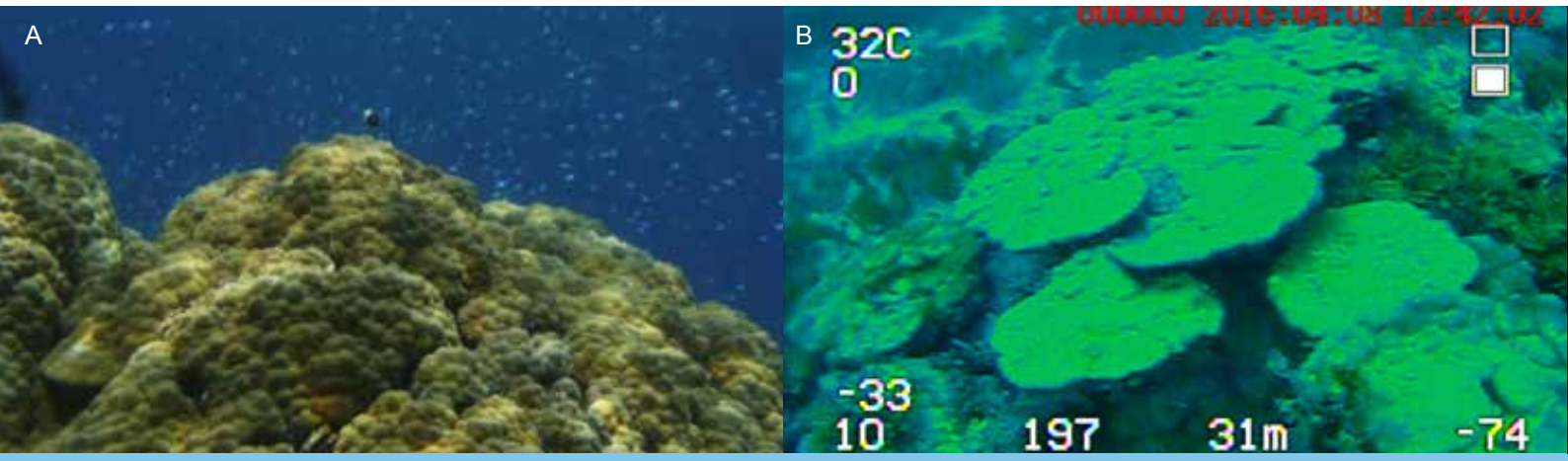


Fig 2: (A) Shallow Chagos reef rounded boulder shaped *Porites* colonies. (B) Flattened *Porites* colonies at 31 m in Peros Banhos lagoon.

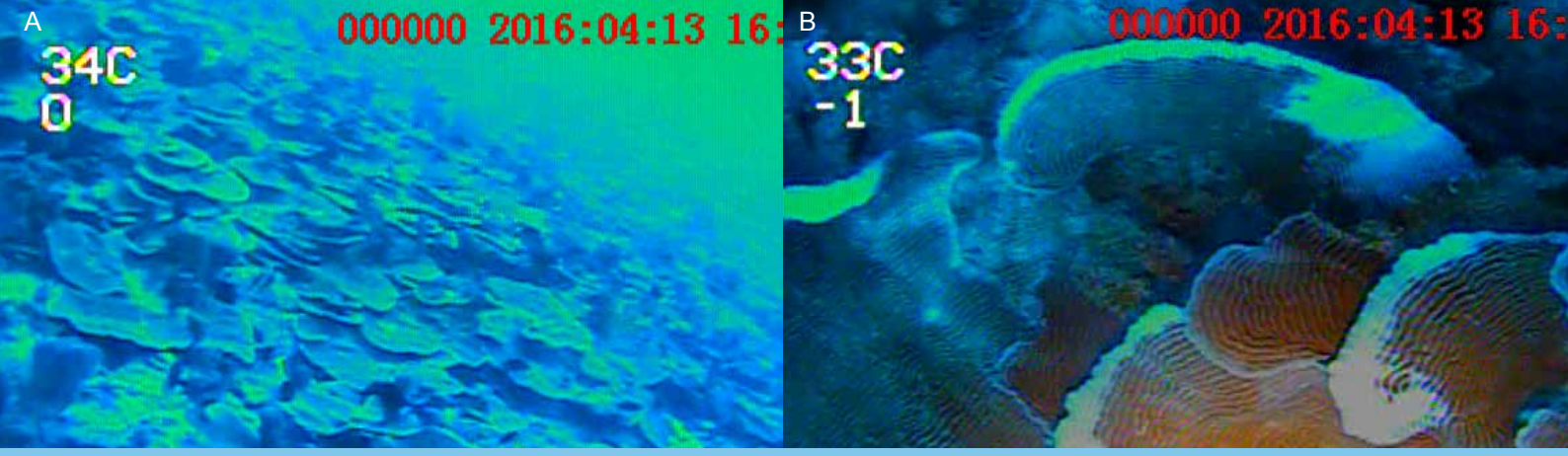


Fig 3. High hard coral cover in the 35–45 m depth range at Ile Anglais, Salomon.

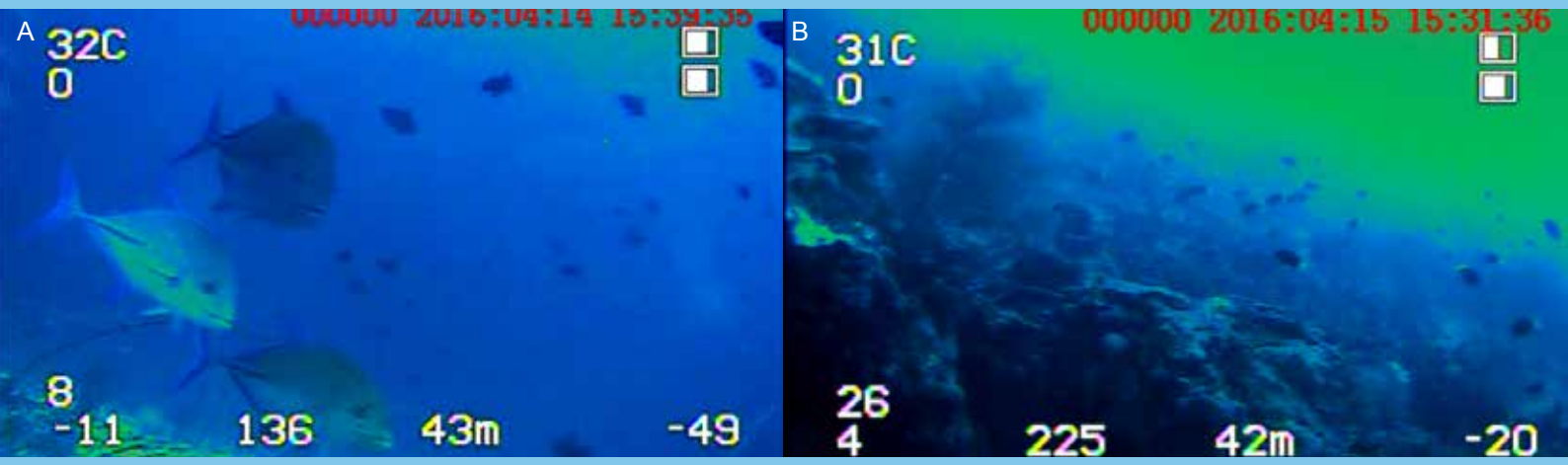


Fig 4 Reef fishes observed on mesophotic reefs in Chagos. (A) Bluefin trevally at 43 m and (B) large schools of Thompson surgeonfish at 42 m off Ile Passe, Salomon.

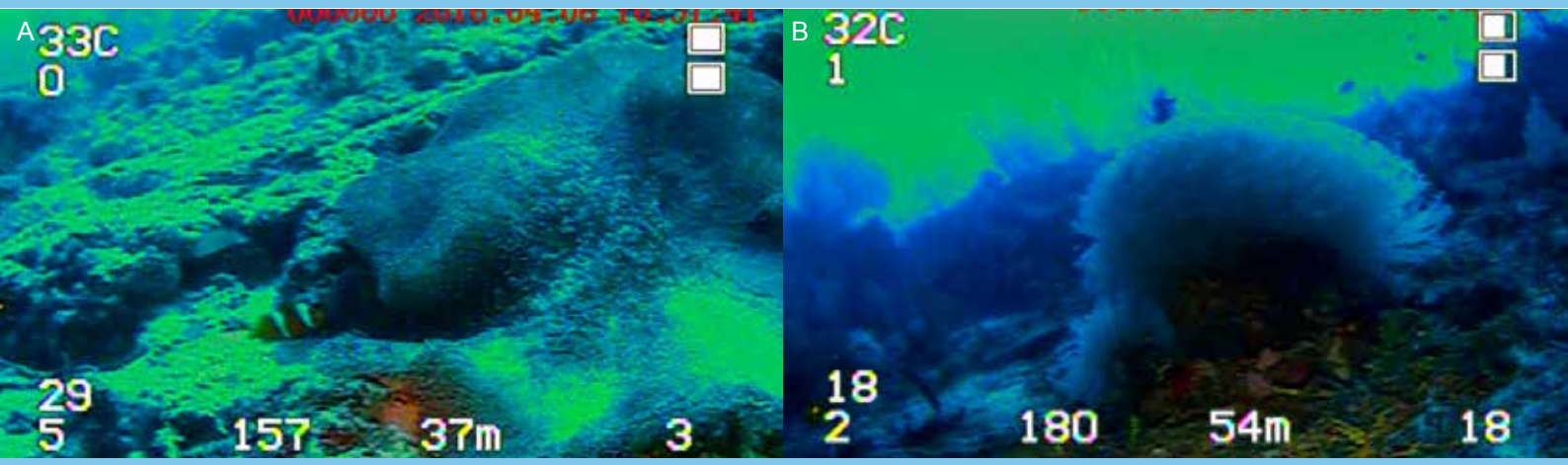


Fig 5: Deep records of anemones on the reefs of Chagos, with (A) the endemic Chagos clownfish at 37 m, and an anemone at 54 m.

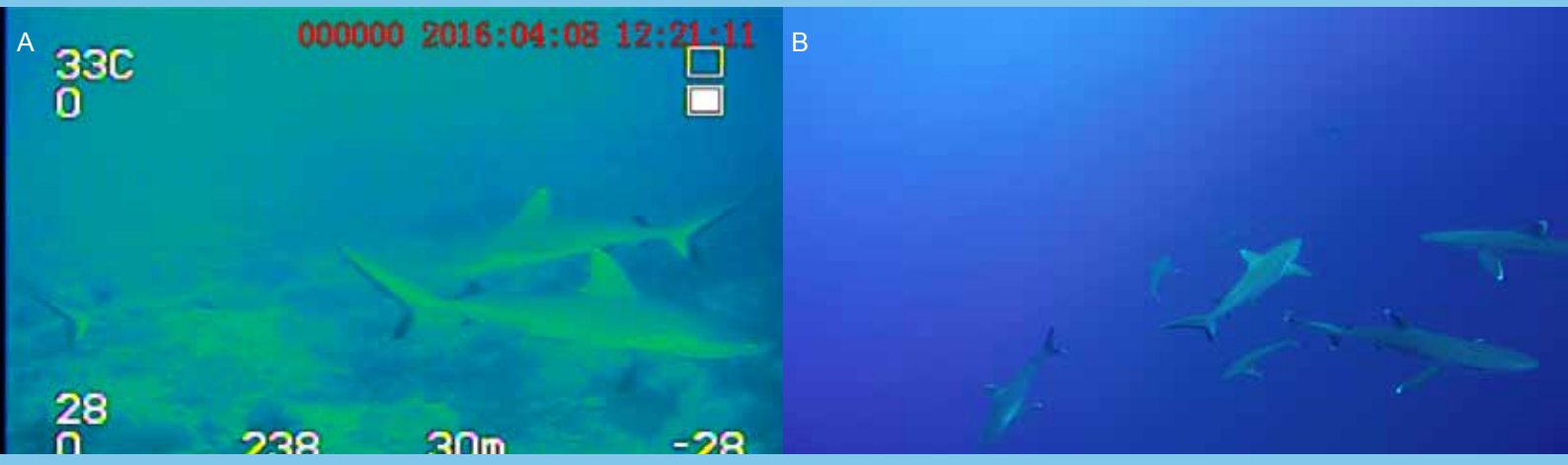


Fig 6: (A) Grey reef sharks at 30 m in Peros Banhos lagoon. (B) A large number of silver tip sharks followed the ROV up to the surface following deployment at Sandes seamount.

Exploring the impacts

By Lily A. Stokes

An Overview of the Report 'Potential Impacts of Human Activities and Behaviour by Yacht Cruisers on the Chagos Marine Reserve'

The Chagos Archipelago is made up of around 50 islands, and lies in the centre of the Indian Ocean just south of the equator, belonging to the British Indian Ocean Territory (BIOT).

As of April 1st 2010 Chagos was designated a no-take Marine Protected Area (MPA) covering around 640,000 km^2. Since the 1970s the islands have been uninhabited with the exception of the largest island, Diego Garcia, upon which there is a US army base.

The lack of anthropogenic influence over the past four decades has preserved the corals and marine life of the MPA in a favourable condition when compared to reefs in other parts of the world. However, they are still negatively impacted by global climate changes, especially those caused by El Niño-Southern Oscillation (ENSO) events.

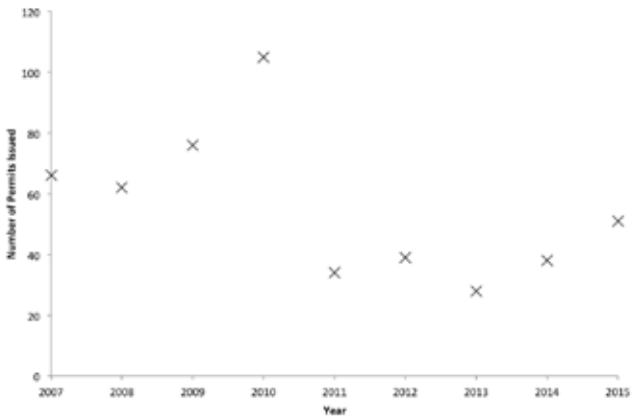


Figure 1: Number of permits for visits to Chagos issued by the British Indian Ocean Territories Administration (BIOTA), between 2007 and 2015.

Due to their isolation, the ecosystems in the MPA are able to recover from such events that might permanently destroy coral reefs in other regions. In the past year, the Chagos Archipelago's corals have undergone mass bleaching, which is thought to have severely impacted the reefs that were recovering after the last major ENSO event of 1997.

Despite the Chagos being an uninhabited MPA, those travelling by private yacht are permitted to visit providing they request a permit months in advance of their trip, and pay a small fee of £50 per week, staying no longer than 28 days. Permits are then checked upon arrival by the BIOT patrol vessel.

When staying in the MPA, visitors are permitted to anchor at specific sites on just two of the archipelago's atolls; Salomon and Peros Banhos. Visiting cruisers must agree not to interfere with any of the wildlife, be it terrestrial or marine, and to store all waste produced during their stay for disposal outside of the MPA.

As the nearest shop is in Mauritius, visiting cruisers are allowed to fish to feed themselves despite the area being a no-take zone. However they are only permitted to take what they can eat within a three-day period, keeping a log of the species caught. Anyone caught exploiting the marine life, be they permitted visitors or illegal fishers, will be forced to leave the MPA immediately, facing fines for their actions.

The visiting cruisers are a possible source of local impact on the environment of the Chagos and are therefore worthy of investigation. Cruisers have been visiting the Chagos since long before it was designated an MPA, and many have kept reports of their visits in the form of online blogs.

By scrutinising these blogs, it was possible to determine the activities undertaken by visitors as well as the diversity of species seen and interacted with. A total of 69 blogs were read dating from 1990–2016 to extract the following information: length of visit, areas visited, activities recorded, and species taken (for food) and interacted with (seen).

Findings were split into 'pre MPA' (prior to 2010), and 'post MPA' (post 2010), to see how activities and species interacted with changed following the creation of the MPA.

It was determined that Salomon was the most visited of the atolls both pre and post MPA. Within this atoll, Ile Boddam was the most visited site with 58 out of the total 69 blogs reporting visits there during their stay.

Snorkelling was the most commonly reported activity (57 blogs reported) undertaken by visitors, closely followed by fishing (56 blogs reported).

Many activities prohibited under the MPA regulations have shown clear decreases since the designation, such as spear fishing, possessing coconut crabs and scuba diving. Yet some activities not currently prohibited, but with the potential to cause detrimental impacts, have been reported to have increased post MPA, such as boat maintenance and anchoring.

Despite requirements to keep a log of fish caught, very few blogs reported keeping one, whilst none published a copy online. Some even admitted to omitting one or two fish from the log. However, most blogs mentioned the species they commonly caught and some even posted photos of their catch to accompany the blog, which were used to identify species taken.

Many forms of fishing were reported by cruisers such as line, trolling, fly, bottom

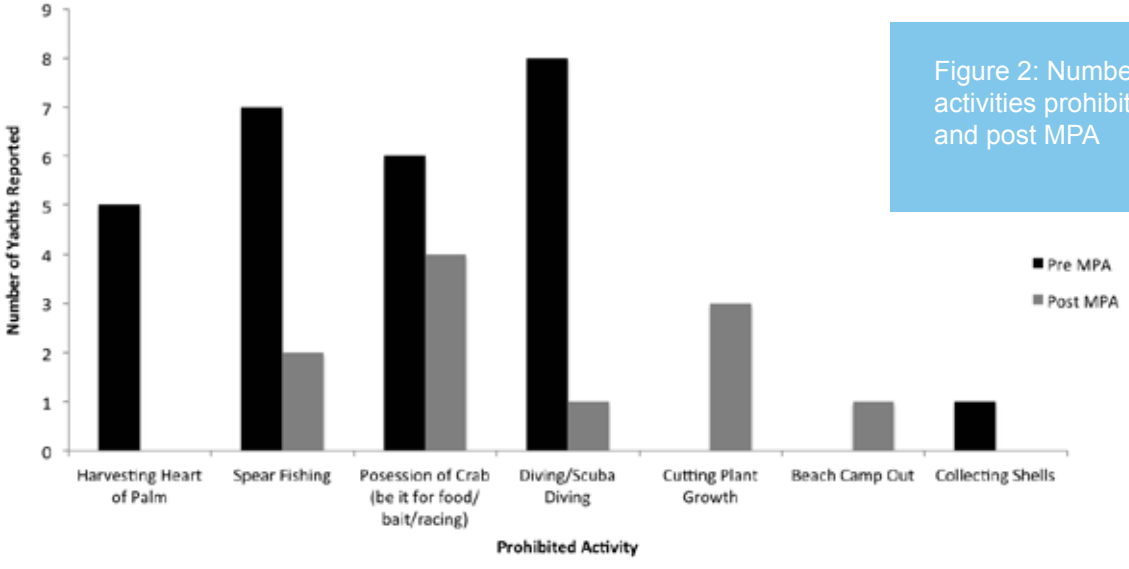


Figure 2: Number of reported activities prohibited at Chagos, pre and post MPA

and spear fishing, the latter having been prohibited within the MPA regulations but is still reported post MPA nonetheless.

Overall, reports of catching pelagic species of fish such as wahoo and tuna were greater pre MPA than post MPA, coinciding with an increase in the reports of reef species being caught.

The most commonly reported reef species caught post MPA was grouper, followed by Coral Trout (*Plectropomus leopardus*), with cruisers stating they selectively fished for these species. Grouper and Coral Trout are often top of the food chain in many reef environments and removal of these fish could result in trophic cascades detrimental to the health of the reef.

Seven species of grouper were identified from photos in the blogs, two of which are on the IUCN Red List as Near Threatened (the Coral Trout and the Brown-marbled Grouper, *Epinephelus fuscoguttatus*), and one classed as Vulnerable (the Black-saddled Coral Grouper, *Plectropomus laevis*), so fishing has been highlighted as a cause for concern within the MPA.

The overall increase in reports of reef species being caught is a cause for concern as many, such as parrotfish, graze on growing algae. If not kept under control, algae could potentially out-compete the corals which are already under stress from sea temperature rise.

Once a reef has shifted dominance from coral to algal, it is very unlikely the shift will be reversed.

Another of the reported behaviours with the potential to negatively impact the MPA is boat maintenance. Most of the visiting cruisers use the MPA as a place to stop off on long journeys across the Indian Ocean, and so make use of their stay by maintaining or repairing their yachts Although this activity does not result in the direct removal of species, it could result in the prevention of species recruitment. Some of the visiting cruisers reported painting their yachts with antifouling paints during their stay.

As there is no means of hoisting the yachts out of the water to do this, all painting must have been carried out on the water. Antifouling paints commonly contain three main chemicals; Tributyltin (TBT), Copper (Cu) and Zinc (Zn), all of which have been known to be detrimental to the marine environment by preventing coral larval development and causing bleaching of fully developed corals.

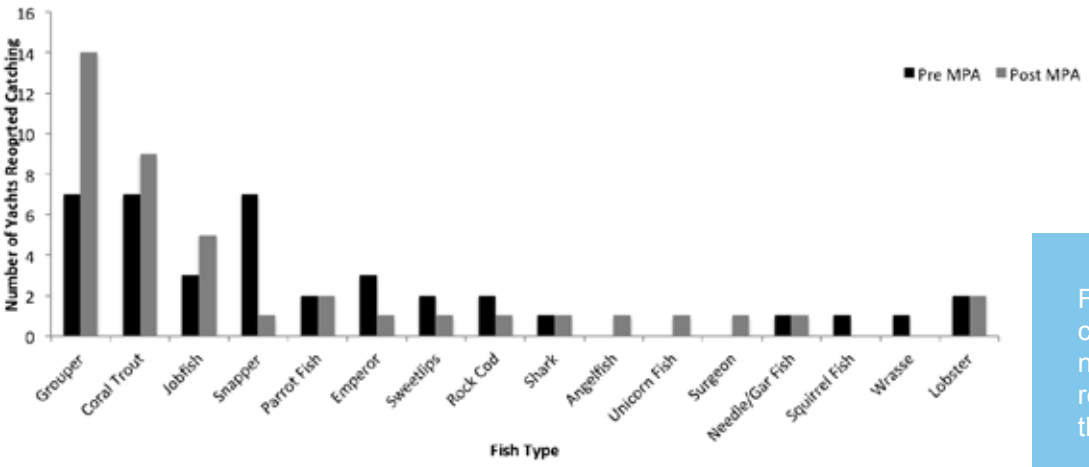


Figure 3: Reef species caught, and the total number of yachts reporting to have caught them pre and post MPA

By painting their boats on the water, visiting cruisers are likely to be spilling or leaking these chemicals into the environment directly surrounding the corals, potentially restricting their recovery and possibly inducing localised bleaching.

Conclusion

The full report focuses in detail on the above stated human uses of and threats to the Chagos MPA, as well as many more, all inferred from the blogs kept by visiting cruisers.

In 2015 alone, 51 yacht permits were issued to visit the MPA (permits being per boat, not per person), yet only 11 of those visitors kept online blogs freely available for public viewing, so the numbers associated with each activity and species gained through the reading of blogs can be presumed to be the minimum.

This would mean that the actual number of cruisers in Chagos catching each species and undertaking each activity is likely to be far greater, and is likely to be having greater impact on the species present. Although not true for all, the majority of visiting cruisers stayed in the MPA between the months of April to June, as weather conditions during other times of the year reduce the likelihood of a safe passage in this region.

This means that most influences on the fauna and flora present are concentrated in these three months, which could further add to the negativity of the impacts. Due to the remoteness of the Chagos Archipelago and the lack of human inhabitants, it is not possible to assess human interactions easily.

So whilst the results of the report should be applied with caution, they are a reasonable representation of the impacts the yachting community may have on the MPA.

Their visits may not result in purely detrimental or neutral impacts, however, as it is indeed possible (though difficult to quantify) that their presence may be deterring poachers.

Lily Stokes is a final year student at Bangor University and was awarded a Piers and Lesley Chapman summer bursary last summer to undertake a project using the blogs and social media of visiting yachts to investigate their activity in Chagos. Here she reports on some of her findings.

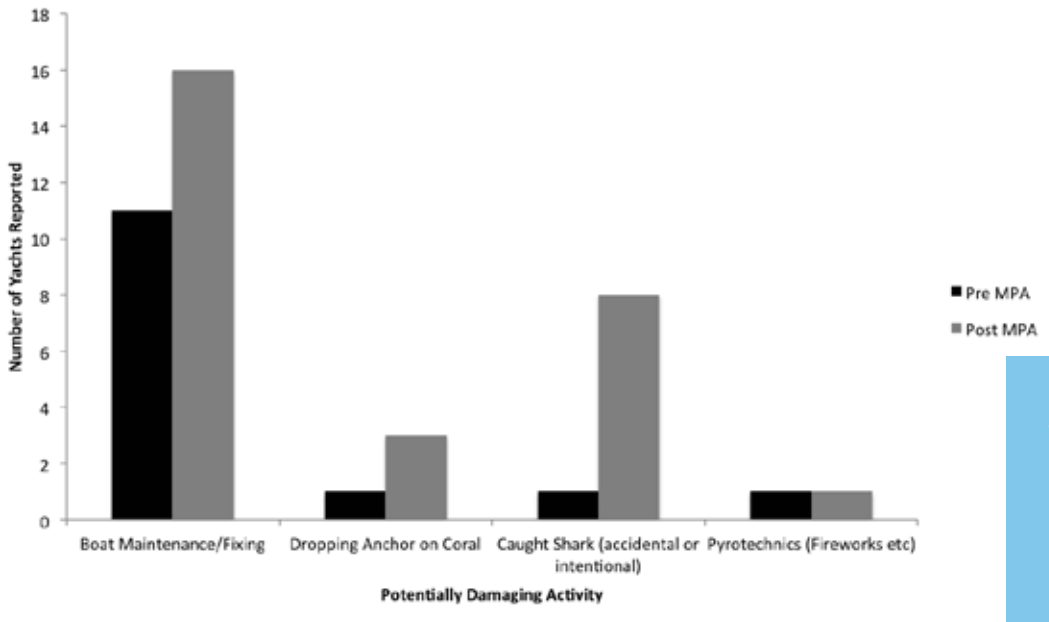


Figure 4. The number of yachts reported taking part in activities that, although not prohibited, could potentially be damaging to the Chagos environment, both pre and post MPA

Charles Sheppard

By Jonathan Hunt, CCT Trustee

Lazy chairs too frequently announce speakers using the old cliché about “needing no introduction”. On first appearance, it could well be applied in Chagos circles to Charles Sheppard. He has been involved in the research and conservation of the Chagos Archipelago for 42 years, both as a top marine scientist and for the last five years as chair of the Chagos Conservation Trust, of which he was one of the founders.

But it would be wholly wrong to believe he could be described so easily. Charles Sheppard is not easy to pigeon-hole and remains capable of surprising us all, as we shall see.

He is largely credited with suggesting to fellow members of the then Friends of Chagos that the conservation of Chagos was well worth doing, which in turn led to the establishment in 2010 of the 200-mile fully protected marine reserve, containing half the reefs in good condition in the Indian Ocean and six times more fish than in any other known area of that ocean.

He first visited the Chagos Archipelago in 1975 as a “novice assistant” to David Bellamy, the well-known and much imitated TV botanist who was undertaking a project there. Sheppard had gone to Durham to study for his PhD and Bellamy was among his professors. “I was very lucky that he asked me to go,” he says. “It changed my career and my life.”

In fact he initially wanted to study a different subject. “But before confirming, I discovered scuba diving, and was totally fascinated by everything I saw in the sea. That decided my final choice of subject.”

In 1975 he also met Anne, who became his wife and “very skilled colleague”. She has been an important and active trustee of the CCT, which included editing this newsletter for many years. Anne is a distinguished scientist in her own right, as we shall find out in a future issue.

Until the age of 13 Charles lived in Singapore, so working in Australia, mainly as a researcher on the Great Barrier Reef, seemed natural. With that, and adding time as an environmental adviser to two Middle East governments, he calculates he has “done more research there and in the Red Sea, Arabian Sea and the Gulf than in Chagos”!

His return to academia at Warwick University in 1993 was “always part time. I spent half my time in an academic post, and the rest researching practical issues– great for combining practical info for students – which is what they really want – as well as the academic.”

He was a Reader for a few years in the School of Life Sciences before becoming a Professor in the mid-noughties. It demonstrated his value to the university that a part-time academic merited a chair’s position. Since his retirement last year he is now an Emeritus Professor.

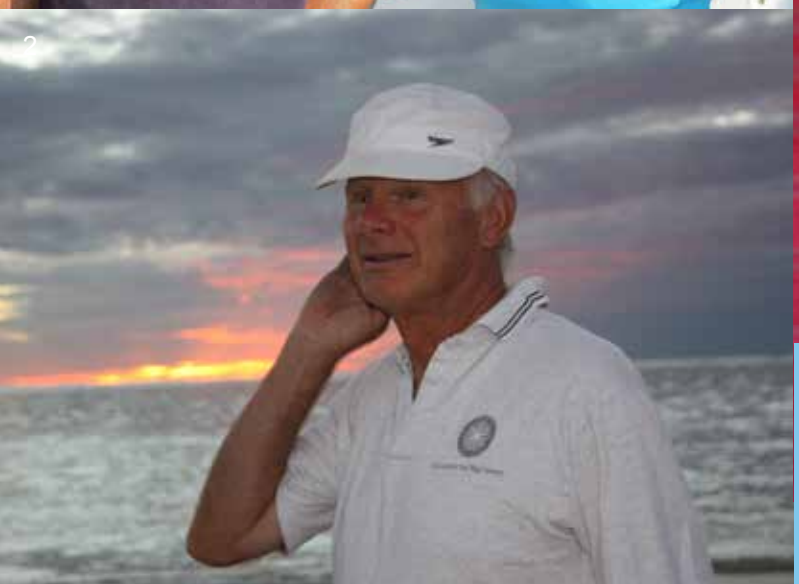
With his charm, vast and almost unparalleled knowledge, sense of humour and ability to make people feel at home, he was a natural to succeed Alan Huckle as chair of CCT. His

fellow trustees speak of his ready willingness to help people, and to respond to requests speedily and professionally, and if unsure, to consult another expert to get it right. “He is always prepared to devote time and effort to assist you,” says one.

But while his period in office was one of advancement in terms of recognition and respect for the Trust, for the chair himself it was blighted by a torrent of professional and personal abuse.

He suffered repeated attacks on his life’s work by some of those seeking to bring about resettlement of Chagossian people on the islands and others wanting to end the MPA and allow commercial fishing to resume. This despite Charles’s own sympathy for the former inhabitants and the CCT having a programme to take Chagossians back to Chagos to share in its work.

In a legal appeal about resettlement being heard by the UK Supreme Court lawyers made an effort “to trash the science I had been



1: Anne and Charles. In the bow of Pacific Marlin, leaving Egmont atoll, 2: Dawn on the Pacific Marlin, getting ready for another day, 3: At Buckingham Palace, receiving the OBE from HRH the Prince of Wales “For services to environmental conservation in the British Indian Ocean Territory”.

doing, and equally to trash me," repeating allegations that proved to be unfounded.

The judges must have also thought Charles was an important player in the overall scene, naming him more than 50 times in their pronouncement of 2016.

"Well, the result was that I and 'my' science were completely exonerated, and while their lordships and ladyship had a minority view on other issues, they all agreed that the cases made against me and my advice were unsupportable," he recalls.

As Lord Neuberger, the court president, commented about him: "Nothing in the evidence suggests anything but a proper, professionally oriented and independent process, with all involved seeking to arrive at objective and sustainable findings and conclusions."

He continued to declare that although "the applicant has for a long time cast wide-ranging aspersions on Dr Sheppard, I do not think that they are made good. That includes the suggestions that Dr Sheppard allowed his interest in preserving coral reefs to influence the advice he gave government.

"On the contrary, Dr Sheppard comes across in the material as a forthright and very independent character, not hesitating to comment bluntly on those working for government or for the applicant…"

Both Lord Kerr and Lady Hale dismissed the point that his advice to the BIOT Administration lacked authority because undue reliance was placed on Sheppard's expertise in a study by six specialists. They also threw out what they described as the "highly contentious and untested claims" that he "might have allowed his interest in preserving coral reefs to influence the advice that he gave to the government", saying they were "at best, speculative. I consider this argument is without merit."

Some people hated the fact that I supported conservation in Chagos, making me out to be anti-people. A 'scientific fascist' even! " And one headline suggested that 'Sheppard prefers the warty sea slug to people'."

Sheppard explains he did not want to publicise this judgment at the time, but has now decided to make the judgments and his obvious relief public through this interview. He also praises his wife Anne who has been hugely supportive during the two to three years of quite strong abuse.

A further endorsement of Charles's work in Chagos came when a government assessment decided that research led by Charles in Chagos was one of the 20 most important UK contributions to development science (assessed out of several thousand people investigated).

He was awarded an OBE three years ago for his conservation work. Charles and Anne Sheppard both remain "addicted" to the Chagos and are starting a new work on the Corals of Chagos

Charles is also pleased by a new record he has established as "the oldest man to have dived there", beating an earlier effort by several years. And far from the warm waters of the Indian Ocean, they are now able to spend more time on their boat moored in the somewhat cooler waters of the west coast of Scotland.

Chagos Information Portal

chagosinformationportal.org

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ChIP CHAGOS INFORMATION PORTAL

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The Chagos Information Portal

By Helen Pitman, CCT Director

Over the past four decades numerous significant discoveries have been made in the Chagos Archipelago and the understanding of the ecology of this unique tropical ecosystem has increased rapidly.

However, until recently there was no central repository for all of this critical work, and much of the data collected by scientists is scattered in academic papers, government reports, unpublished data, and the photo and video libraries of individuals.

That's where CCT came in. We decided to create the Chagos Information Portal, a free reference library of scientific research and conservation work conducted in the Chagos Archipelago that also includes an interactive map and over 600 images and videos.

We're hoping that, in addition to the portal being an efficient way to find information on everything from coconut crabs to corals, it will also be a way to reach out to people who don't know much about this living laboratory.

Explore the archipelago

One of the most exciting elements of the portal is the interactive map. You can zoom around the archipelago and learn about the different species and habitats found there. The map currently features 13 islands, including Important Bird Areas, islands with significant reef systems, and islands with invasive rats.

Clicking on an island triggers an information pop-up in the right-hand panel. Specially designed icons indicate the information categories available for that island – coral, bird, plant, fish, turtle, invertebrate, science – and the tabs indicate the various media formats available, including an island overview, 360o Google Street View, images, videos and other resources.

You can spend hours reading publications, flicking through photos, watching videos, and strolling across the islands with Street View to immerse yourself in this tropical ecosystem.

The species encyclopaedias

Corals of Chagos: Our coral experts, Professor Charles Sheppard, Dr Doug Fenner and Anne Sheppard worked for a year to finalise the fully illustrated taxonomic descriptions of over 300 coral species that exist in the Chagos Archipelago and form the basis of this reference tool.

Corals of Chagos gives the portal user the opportunity to browse through the many corals found in the archipelago's reefs and can be used as an identification tool on expeditions.

Birds of Chagos: Chagos bird expert Pete Carr produced A guide to the birds of the British Indian Ocean Territory in 2011, upon which the Birds of Chagos is based. This section is a comprehensive, illustrated reference of all bird species, native and introduced, recorded in the Chagos Archipelago.

The resource library

The resource library contains publications,

datasets, expedition reports, images and videos. This will continue to grow and develop over the coming year and beyond as more research and conservation occurs in the region.

The next steps

CCT is extremely proud to have been able to produce the Chagos Information Portal with the generous support of the John Ellerman Foundation. The Foundation has committed to continue its support over the next year, which will enable the portal to develop further by including plants and fish encyclopaedias, turtle tracking data and an education section.

We are very thankful to all the people who have contributed to the portal and look forward to continuing to help it grow as a vital resource for everyone.

The Ocean Conference

CCT Trustee Rachel Jones attended the first ever Ocean Conference held at the United Nations in New York from the 5th – 9th June.

"I was in New York with a couple of different hats on, but the most important priority was discussing science and conservation in the Chagos Archipelago at the inaugural Ocean Conference.

It had been convened to support the implementation of Sustainable Development Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development. With over 5,000 delegates and delegations from all over the world the event brought together professionals and officials working on ocean issues to discuss policy, share management experiences, and offer best practice solutions to shared problems.

Over five full days of meetings I met hundreds of people, many of them working on Marine Protected Areas (MPA) in other parts of the world. There are thousands of MPAs globally and they vary hugely in size, purpose and management style, from tiny coastal areas managed by children in Palau to huge oceanic reserves.

Obviously the BIOT MPA is one of the very biggest and best protected, but even the little ones share many of the same issues: How do we protect our area round the clock? How can we track and control fishing vessels from distant countries? Are our protection measures working for the species and habitats we are managing?

What encouraged me was the mainstream acceptance that protecting some areas of our ocean is an entirely rational and beneficial thing to be doing. This idea was supported across the board, from members of indigenous communities using ancient rules on fishery management to protect coastal habitats through to the inter-governmental organisations charged with bringing sustainability to the world's commercial fisheries on the high seas.

On Thursday the 8th the conference celebrated World Oceans Day in the general assembly with an amazing line-up of inspirational speakers, but for me the highlight was the announcement of a grand total of 1,372 voluntary commitments made to the UN to improve ocean sustainability. Of these, 237 conservation actions are to take place in the Indian Ocean, including a four-year programme of science in the Chagos Archipelago funded by the Bertarelli Foundation.

Overall it was a busy and rewarding week and I'm looking forward to seeing how many of those commitments have been met at the next Ocean Conference in 2020.