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Chagos News

The Periodical Newsletter of the
Chagos Conservation Trust

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EDITORIAL

We have all contributed to something terrific. With the last government's declaration of the BIOT Marine Protected Area (MPA), we have helped to ensure that a significant part of the Indian Ocean will be protected for the future, one small part of the planet that we can possibly leave to future generations without being embarrassed by its condition. There are so few places in the world where this can happen.

There is still much to be done, some details still have to be worked out, for example, how the MPA is to be financed and how it is to be policed to protect the ocean, reef and island life from poachers. CCT will contribute to these discussions with the good of Chagos in mind, as it has all along.

Scientific research has provided the backbone of evidence for the need to protect Chagos and the declaration of the MPA. Research continues all the time and earlier this year another international team of scientists, led again by Prof Charles Sheppard, visited Chagos to carry out further research. The members of the Chagos 2010 Expedition each report, in this issue of *Chagos News*, on the work they did there. As many photographs as there is space for have been included, to give you a bit of a flavour of the expedition.

Other research results continue to come in about Chagos. The last expedition, Chagos 2010, and also previous ones, have all collected samples for analysis by other scientists worldwide. Places on expeditions are very few and so expedition members try to maximise the work done by collecting samples for colleagues. Recent results just becoming available continue to show just how important Chagos is.

From whatever point of view you look at it, the MPA is good news for everyone on the planet and most especially for all those who live on the Indian Ocean rim. A very definite and positive legacy for the future, and one of which we can surely be proud.

Anne Sheppard

From the Chairman

William Marsden CMG
Chairman, Chagos Conservation Trust

What a wonderful year 2010 stands to be for all who care about conserving the Chagos, against the depressing background of constant destruction of the planet's natural environment.

In the Government's 3 month public consultation on whether to establish a marine protected area in the British Indian Ocean Territory, 90% of over a quarter of a million people responding supported greater protection of the entire area, and most of them voted for a strict no-take marine reserve. The Labour Government then formally announced the creation of a huge BIOT Marine Protected Area covering about a quarter of a million square miles and doubling the global coverage of marine protected areas.

The incoming coalition Government has now confirmed its support for implementing the new BIOT MPA and for raising awareness of the environmental and scientific importance of the Chagos. The Minister stated in the House of Lords on 29 June: “The intention to go ahead with the MPA is in place”.

Our small, voluntary Chagos Conservation Trust built up the momentum for this highly successful process with the support of our members and supporters since we were founded by John Topp (as Friends of the Chagos) in 1993. The role of Professor Sheppard, wearing different hats, has been vital throughout. Our creation of the Chagos Environment Network in 2008 and the crucial roles played by the Pew Environment Group, ‘Blue’, ZSL and other members of the Network provided credibility and resources for achieving the final outcome. And very special credit is of course due to the Government Ministers and officials with whom the buck stopped and who took the real decisions.

We have made clear to the Government our strong interest in continuing to work with FCO, DEFRA and others in support of the of the BIOT MPA and of Chagos conservation, science and education generally. We are also very pleased to be cooperating closely with members of the Chagossian community in favour of their involvement with Chagos conservation.

The BIOT Marine Protected Area – a Scientist’s View.

Prof Charles Sheppard
University of Warwick, UK

The new UK Government has confirmed that it intends to go ahead with the implementation of the BIOT MPA. Details remain to be sorted out, but clearly several important things have been achieved.

At over half a million km², this is the largest marine protected area in the world. Its five islanded atolls and many submerged atolls and banks provide over 50,000km² of reef. Most of the rest is open, deep blue water. The only inhabited atoll, Diego Garcia in the southeast occupies about 1% of the whole area.

The history behind this achievement is fundamentally a scientific one. I have been fortunate enough to organise access to Chagos for about 50 - 70 scientists from around the world over the last 20 - 30 years. Each time I have chosen leading scientists from several research centres to create a connected scientific program. This has increased our understanding of how this remarkable place works, and has allowed the government to fulfil some of its conservation obligations.

Why Chagos?

The reason why this is so important now is because of the rapidly declining state of most of the rest of the Indian Ocean due to widespread, poor environmental practices. Millions of people suffer from this, their food for the most part being ultimately derived from their environment, which is now commonly exhausted.

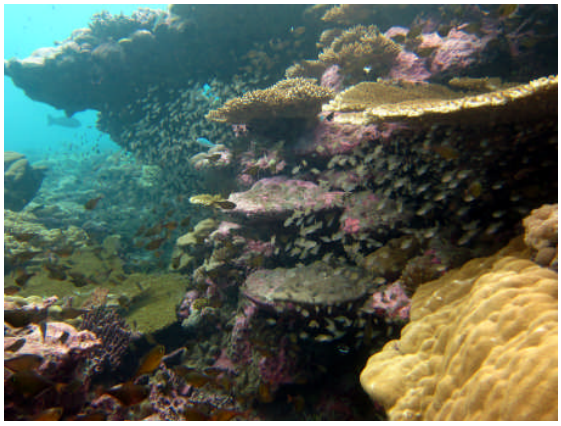


Fig 1 Chagos reefs have the large congregations of reef fish that few places in the world have left today.

Chagos, for reasons that are well known, is in remarkably good condition, and the present need for effective protection is as much because of the dire state of much of the rest of the Indian Ocean as is it because of a wish to save something for its own sake. The latter can be viewed as simply indulgent, if viewed in isolation. Of all the reefs of the Indian Ocean still in good condition - and these are now a minority - Chagos contains half. They are all in one large discrete area, with a government which makes protection possible, which opens many opportunities that should be taken.

Thus the need was there but the means was not. Then, the Pew Foundation started to look for areas which were amenable to effective, large scale conservation. Their Ocean Legacy program came out of the widely accepted view that the condition of our oceans is now in a state of freefall. The people who are being hit most are the local people, in this case those of the ocean's islands and rim. Pew's first two protected areas in this series were in the Pacific, and Chagos is the third and the only one in the Indian Ocean. Nowhere in the Caribbean is flagged for this kind of supreme, flagship measure - but they have another two lined up in the Pacific. Their supportive administrative infrastructure tapped into us and we tapped into them, and we managed to persuade the UK government that this would be a tremendous service for the Indian Ocean as a whole. In fact the evidence is so clear that the UK government took little persuading.

People and Chagos

The only people on Chagos - on the military base - have tough environmental controls. They don't make a living from their environment. Everything they need is shipped in. They are in effect supported not by the local environment but by farmlands and industry elsewhere, which is why Chagos is in such good condition. This is an uncomfortable truth, but one that is necessary to understand.

Are people now putting fish before people as several rather silly headlines have claimed? We are not. It looks like huge numbers of people depend on the ecological and scientific services of Chagos, directly and indirectly. As most reefs of the Indian Ocean continue to collapse and increasingly fail to support people, so it needs the reefs of Chagos (and more) to be kept in good condition to serve them. Unfortunately, Chagos is one of the last great hopes of the Indian Ocean and its people. Fortunately, enough people realise this.

Do Chagos reefs act as a nursery supply? It looks like they do. Only in June two more sets of results show the close linkages of Chagos with downstream marine areas of the Western Indian Ocean. Our earlier suppositions that Chagos might be a crucial, upcurrent link in the Indian Ocean flow of species are looking more likely to be correct and, if this is borne out, Chagos would seem to be an important reservoir as well as a reference site for a lot of species.

There is another people-orientated reason for strict conservation here. While it is too late in many cases, some coastal managers are now aiming for restoration of their reefs. What they are aiming for exactly is too often a lost memory, but Chagos shows us what such areas should look like, and perhaps could look like again. To help management we need to have a reference site, in other words something like Chagos.

Chagos resilience

Science started this and it remains one of the most important future aspects. In the last 20 years when many reefs in the Indian Ocean have become badly damaged, most have remained in a destroyed or badly deteriorated state, unable to recover because of sewage, over-fishing, industrial pollution and the whole range of things that accompany people. Chagos didn't have any of that, and showed itself to be enormously resilient, recovering swiftly from warming pulses to a state similar to that which existed many decades ago. Like it or not, it is a lack of other human impacts which gave Chagos the robustness which enabled it to rebound so quickly to its ecologically first-class condition.

The islands and the MPA

The seabirds of Chagos are also remarkable. The new MPA may not add much more protection to these because they were already protected under local laws. Mostly, only small islands too small for the coconut plantations support huge bird populations now, but historical records talk of many more which vanished when the islands were clear-felled for coconut plantations. The impetus of the new MPA raises hopes that some of the damaged, rat infested islands can be restored to their native condition, in which case we can only guess what bird life might result.

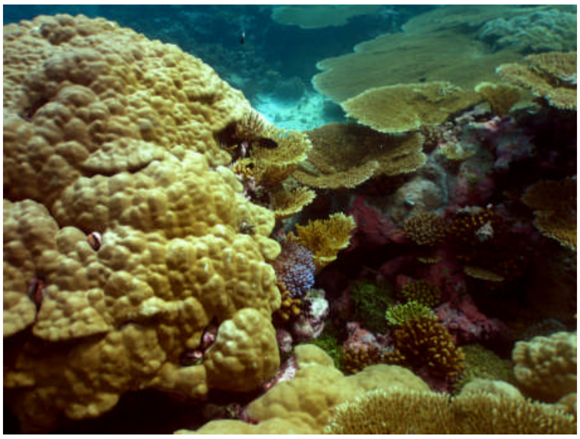


Fig 2 Rich, robust coral reefs with no anthropogenic stressors. *Photo Anne Sheppard*

Fishing

One of the main changes that the new MPA will bring will be a prohibition of pelagic fishing. Non-extractive marine reserves are very much a minority. Conflicting demands such as that from fishing usually results in severe compromises, to the detriment of the area being protected. Most marine reserves permit fishing for example: even the Great Barrier Reef has fishing across half of it, and large, fully protected areas of a size which is significant in ocean or global terms have been virtually missing from the world's inventory of ways to try and counter relentless degradation. One reason for this degradation is the problem caused by lack of direct ownership of the seas.

'Freedom of the oceans' has long been a cherished human goal but its downside has been that various industries have been free to exploit it with little restraint, leading to a maritime equivalent of Hardin's 'Tragedy of the Commons'.

Fishing interests have been vocal in opposition to this fishing prohibition: some have stated that the area under protection is too small for oceanic fish such as tuna so we should not bother. Others have said it is too large and thus is not fair to the blue water fishing fleets, so we should not bother. (Perhaps, therefore, the size is about right!)

Fig 3 The crew of the BIOT patrol ship *Pacific Marlin* remove fishing gear which had drifted in from outside BIOT waters. *Photo Anne Sheppard*

At present the Chagos MPA is the world's largest. Personally I hope it will not remain so for long and that other areas receive similar protection. The world needs them. This kind of MPA is not a total remedy but, given the world's rising human population, they are crucial in supporting people who depend on marine resources. The Government is to be congratulated on this declaration.

Photo Anne Sheppard

CCT/CCC Conservation Scholarships for Chagossians

The Chagos Conservation Trust, Coral Cay Conservation and the Diego Garcian Society are delighted to announce the worthy winners of the 2010 International Year of Biodiversity Coral Reef Scholarship Programme.

Left to right: Dr Allen Vincatassin (Founder, Diego Garcian Society), Louis Augustin and Pascaline Cotte (Coral Cay Conservation Scholars), Lee Burke (Mayor of Crawley) and Peter Raines (Founder, Coral Cay Conservation)

In July 2010, Pascaline Cotte and Louis Augustin, both 18 years of age and descendents of the Diego Garcian and Chagossian communities in Crawley, will visit the coral reefs of Southern Leyte in the Philippines as part of a Coral Cay Conservation training programme funded by the Chagos Conservation Trust.

Joining a team of volunteers from all over the world, Pascaline and Louis will help survey some of the least researched habitats in the Philippines, learning to dive and protect coral reefs through the implementation of crucial marine conservation measures.

"This is a great opportunity for members of the Diego Garcian and the Chagos community at large, that marks the initial steps to our people becoming stewards of the protected area," says Allen Vincatassin, Community Leader and Founder of the Diego Garcian Society. "We look forward to our scholar's return so that we might share their experiences and learn the importance of coral reef protection and community work."

Chagos Film

A short film, made at the request of BIOT by ex Royal Marine and BIOT training officer Jon Schleyer, is available to view on both the Protect Chagos website and Jon's own website.
www.protectchagos.org and
http://vimeo.com/channels/jonslayer#12765395

Chagossian Visit to Diego Garcia

In January this year the leader of the Chagossian community in Crawley, Allen Vincatassin, visited Diego Garcia with six other members of the UK Chagossian community.

While they were there, they participated in the habitat restoration project at Barton Point Strict Nature Reserve with Major Pete Carr.

The Chagossian party at the Barton Point restoration project.

The Chagos 2010 Scientific Research Expedition

Prof Charles Sheppard
University of Warwick, UK

In early 2010 another scientific expedition visited the Chagos archipelago, which visited all atolls and, like earlier expeditions, was for the most part based on the BIOT patrol ship *Pacific Marlin*. About a dozen scientists of international repute participated for between two to three weeks, and a mixture of terrestrial and marine aspects were looked at.

As always, the nature of the work was determined by two main criteria. Firstly the perceived needs of the archipelago were considered: aspects such as monitoring the continuing recovery of the atolls from the massive mortalities of 12 years ago, effects (if any) of sea level rise and shoreline erosion, issues connected with monitoring populations of organisms which are fished illegally, and further work on fish and their biomass were all considered to be important and relevant. Strongly influencing this was the possibility (only a possibility at the time - subsequently confirmed) that the archipelago might be declared a marine protected area by the government before too long. Certainly the science carried out on previous occasions more than justified such a designation, and central to that was not only the intrinsic nature and value of this archipelago but also its position in scientific terms within the larger Indian Ocean. On land, great progress was also made on the science of the huge bird populations and of the vegetation.

The second criterion that determined which expertise was needed in 2010 was the needs of the BIOT government in terms of both environmental management and its compliance with international obligations.

The following is a brief account of the work that was done, written by the scientists. Once again the officers and crew of the *Pacific Marlin* were enormously supportive. There is always a potential drawback with a small, short expedition in which a dozen scientists start chasing at least a dozen different but related themes, of arranging things in such a way that they can all do all the work that they wish. I have heard that organising scientists is like herding cats (though scientists of course will deny any such thing). This year, as with earlier occasions, the scientists involved were experienced, and have worked in such situations repeatedly in the past, so when on board all this organiser had to do was to arrange for the ship and the equipment to get to the prearranged locations and leave the scientists (ably supported by the *Marlin* crew) to get on with it. Scheduling in terms of moving the ship from one location to another was deliberately flexible, but in the event very few changes were needed in the original work plan.

As is frequently the case in science, it would have been good to get more data, but sufficient was achieved to fulfil the tasks required. What was always gratifying was to hear comments from scientists who have not visited this archipelago before expressing amazement and delight at the condition of the site.

Organising was principally done by Pete Raines, who magically did the filling of almost all diving cylinders and very much more besides, along with the ship's engineer Les Swart, who kept our engines and boats in good running order and filled with fuel. Our medic was Simon Williams, whose boat support for the divers was superb but whose medical support fortunately remained untested. From Diego Garcia, pre-departure support by Martyn Dorey was indispensable, as was the help received from the British party there. The skipper of the ship, Paul Cragg, was of course central to ensuring that we arrived anywhere we needed safely and on time, and had all the help we needed from the excellent *Marlin* crew. Sincere thanks from all the scientists to all of them.

Loading the dive boats requires concentration and muscles!

The hot and boring task of surface support for the divers.

Exhilaration after the challenging landing on Gunners Coin.

Rinsing equipment after a dive on the deck of the *Marlin*

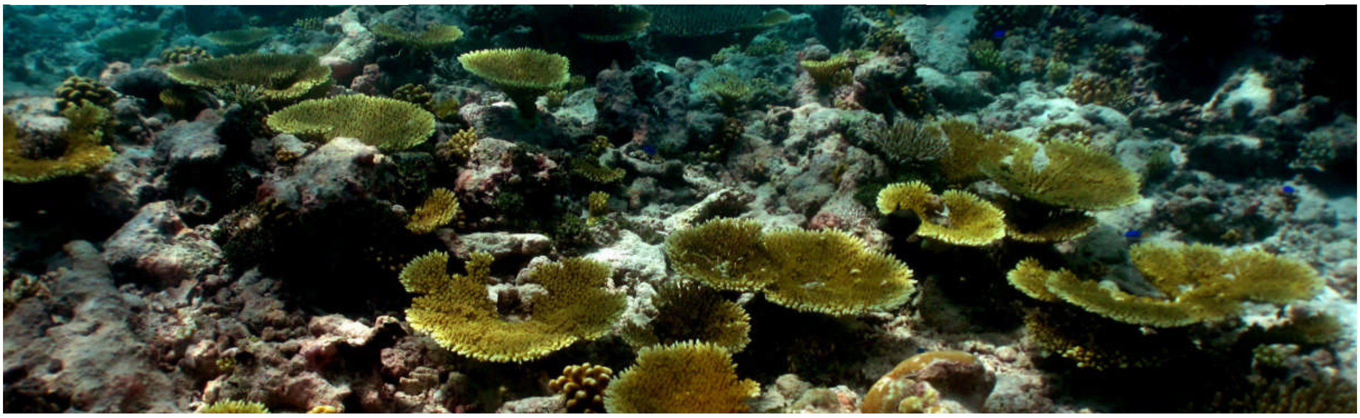
The BIOT patrol ship *Pacific Marlin*. The entire crew provided magnificent support.

The *Marlin* crew loading our dive boats back onto the ship.

The unloved task of filling aqualungs. A job taken on by logistics manager Pete

A dive party returning to the *Marlin* after a dive.

It may be paradise but it's still a hot hard day's work. A cold beer at the end of the day goes down very well.



The underwater paradise that we were working on: Healthy, resilient, coral reefs.

Photos Anne Sheppard

Botanical Explorations of the Chagos Archipelago

Dr Colin Clubbe
Royal Botanic Gardens, Kew, UK

Much of our knowledge of plant distribution across the Chagos Archipelago is based on the excellent work done by John Topp in the mid 1980s when he undertook botanical surveys on most of the islands and compiled an invaluable island by species checklist containing 276 taxa. Several years ago John offered Kew his personal herbarium compiled over his intensive two year collecting programme. We also talked about updating the nomenclature to take into account recent changes in plant taxonomy. Working with my colleague Martin Hamilton at Kew, we accessioned John's specimens and produced an updated checklist which has been published on the CCT website. Over this period John, Martin and I talked about Chagos, its plants and the need for more botanical work. So when Charles Sheppard offered us a place on the 2010 Scientific Expedition we jumped at the chance, despite the need for much re-arrangement of schedules that it required! I got lucky as it was easier to re-organise my commitments than Martin's and that's how I spent a most remarkable 3 weeks as a member of a wonderful small team, living on the *Pacific Marlin*, investigating 39 islands, walking many miles and gaining some familiarity with an extraordinary part of the World and it's unique biodiversity.

The Islands of the Chagos Archipelago have been colonised by plants since there was sufficient soil to support them – probably less than 4,000 years. Seeds and spores arrived by wind, sea or attached to passing sea birds to colonise the emerging islands. This original native flora is considered to comprise some 40 species of flowering plants, 4 ferns, plus a variety of mosses, liverworts, fungi and cyanobacteria. John's checklist contains 232 non-native taxa, 128 of which had only been recorded from Diego Garcia. These represent plant species introduced to Chagos either accidentally or deliberately by man's activities, many of them through Diego Garcia in relatively recent times. Some of these non-natives have become invasive and pose a real threat to native communities. However, even this situation is not clear cut. Determining what is native and what is non-native is challenging, more so when we do not have a long data record – apart from a few from the Transit of Venus Expedition in 1882, most Chagos specimens in the Kew Herbarium are from the 1960s-1980s.

Fig 1 The invasive *Pipturus argenteus*
Photo Colin Clubbe

One species of current interest is *Pipturus argenteus*, a shrubby member of the Urticaceae (Fig 1). Listed by John as part of the non-native flora, it is rapidly colonizing many islands where it is acting like a typical invasive species. In particular it seems to colonize open areas, and we've seen it crowding out regenerating *Pisonia grandis* – all the hall marks of an invasive species. We initially flagged it up as one of the most troublesome plant invasives currently in Chagos. Research on this species since returning has shown it to have an Australasian/Indonesian centre of distribution with no records as an invasive. Although we haven't solved this one yet, it may be that it is a native species that is an aggressive primary colonist. I've seen this syndrome in the Caribbean eg with *Lantana camara*, native to the shrubland community on most islands. In intact communities it is a benign component of the vegetation, but when community dynamics are disrupted eg after land clearance it can become a problem invasive, strangling any native regeneration. It has also become one of the world's worst invasive species especially across Africa. It is one of the plants that helped change my mind on invasives and decide that we can consider native plants as invasive and not reserve this for non-native aliens. Certainly *Pipturus argenteus* seems to be the first plant to colonise abandoned habitation, areas previously cleared for agriculture and areas of storm damage. There are several other Chagos species offering similar challenges.

With these data on plants to hand, I set out for Chagos and a meeting with Pete Carr to develop our terrestrial sampling strategy. My overall goal was to undertake a rapid assessment of the status of flora of as many islands as I could visit in the time available (Fig 2). I was keen to investigate native species richness and habitat uniqueness with a view to updating John's checklist and use these data to try and identify Important Plants Areas (IPAs). The Global Strategy for Plant Conservation (GSPC) is an internationally agreed strategy approved by the Convention on Biological Diversity whose goal is to halt the current and continuing loss of plant diversity (www.cbd.int/gspc/). Target 5 of the GSPC is about identifying the most important plant areas of the world at local, regional and international scales and I am applying the methodology to Chagos (www.plantlife.org.uk/international/campaigns/important_plant_areas-1/). We hope that IPAs will do for plants what IBAs have done for birds.

Fig 2 Recording plant data during an assessment of Moresby Is. *Photo Anne Sheppard*

I was also keen to assess the invasive species threat on the islands I visited, by documenting non-native species and assessing their potential or actual threats to native communities. Many islands are gradually being turned into coconut chaos. A mature coconut palm can produce about 70 mature nuts a year which drop to the ground, germinate, and establish an impenetrable understory of coconut fronds to 2-3m which prevent any native regeneration. Happily though, initial analysis indicates that few of the non-natives recorded from Diego Garcia are moving onto other islands, there seems not to have been an explosion of new invasives on the outer islands since the 1980s.

I was particularly pleased to visit islands such as Sea Cow, Moresby, and the Three Brothers, where invasive activity seemed minimal and because of their relative remoteness and difficult access little or no coconut plantations were established. These islands give us a glimpse of the pristine state of the islands before man and can provide us with clues to the original species composition and structure as we try and restore some of the coconut plantations back to native communities, which will improve the future for the biodiversity of Chagos. To this end one of the most exciting aspects of the work as I write is working on the island priority matrix started by Pete Carr to help identify priority islands for restoration potential.

Fig 3 The pristine mangrove ecosystem on Moresby Is. *Photo Colin Clubbe*

A botanical highlight was the discovery of a major mangrove ecosystem on Moresby Island which had not been previously documented (Fig 3). Until this point the only mangrove ecosystem known in the Chagos Archipelago was the one on Eagle Island which was reported to be in decline. Our visit to Eagle confirmed this and unless we undertake some serious restoration activity we will lose this valuable habitat because it is drying out and being swamped by a combination of over-topping vines, most seriously *Cassytha filiformis* (dodder) and *Ipomoea macrantha*, as well as being squeezed out by encroaching *Cocos nucifera* and by *Hibiscus tiliaceus* (Fig. 4). In contrast the Morseby mangrove ecosystem is pristine. It comprises two species of mangrove – *Lumnitzera racemosa* and *Pemphis acidula*. The open water was alive with dragonflies providing Pete with several new records. It really was a special moment and definitely qualifies as an Important Plant Area.

Fig 4 The degraded mangrove ecosystem on Eagle Is *Photo Colin Clubbe*

There is a lot more to do with our botanical data. The herbarium specimens collected have arrived at Kew. These data and specimens will increase our knowledge of the plant communities of Chagos and I hope help provide the information we need to make informed decisions about the future of the biodiversity of this remarkable area. All the botanical information will be available on the CCT website and on Kew's new UK Overseas Territories Virtual Herbarium – an exciting project in its early stages http://dps.plants.ox.ac.uk/bol/ukot).

Chagos Bird Survey

Major Peter Carr RM

My involvement with the expedition started 16 months prior to its arrival in Chagos, during which time I managed to lead a military patrol around the atolls about once every three months. On these, I usually was able to visit most islands and to count the breeding seabirds. The Chagos 2010 Expedition gave the opportunity to take another set of seabird counts in the first quarter of 2010.

Meanwhile, I had been trialling methods of island restoration on several islands, and had reconnoitred several more with this in mind at some point in the future. This proved extremely useful when working with Dr Colin Clubbe on the expedition, because it led to some preliminary identification of ecological restoration requirements and prioritisation of the islands of the Chagos for this restoration work.

Ornithological Background to the 2010 Research

In the 1970s the Joint Services Expeditions to Chagos collected useful data on breeding seabirds, especially on the Great Chagos Bank (Baldwin, 1975). Then, in 1996, an archipelago-wide count of breeding seabirds was conducted by Symens (1999), and the counts from these two sources and additional material from Diego Garcia collected in 1997 and 2005 (Carr, 1998, 2005, 2007) facilitated the recognising of ten IUCN categorised Important Bird Areas (IBAs) in the Chagos (Carr, 2006). In 2006, another archipelago-wide ornithological survey was conducted using essentially the same counting methodology as that in 1996 and over approximately the same dates (McGowan et al, 2008). The 2006 report nominated a further two islands for IBA status and highlighted a possible catastrophic decline in two breeding seabirds, Lesser Noddy *Anous tenuirostris* and Brown Noddy *Anous stolidus*.

The Research

Past research has revealed that seabirds breeding on or around the Equator do not necessarily nest at a specific period and historical bird reports from the Chagos indicate that seabirds breed in all months (e.g. Loustau-Lalanne, 1962; Carr, 1998). To gain an accurate figure of the number breeding in the Chagos, counts over an entire year are required. Therefore, over a period of 18 months, including the February 2010 expedition, birds were recounted at approximately three month intervals, on as many islands as possible. The data set has afforded an insight in to the breeding phenology of these internationally important breeding seabirds and has also supplied a more accurate picture of the total numbers involved.

Results

For brevity, only one species' results are detailed here. Similar data exist for Wedge-tailed Shearwater *Puffinus pacificus*; Tropical Shearwater *P. bailloni*; Masked Booby *Sula dactylatra*; Red-footed Booby *S. sula*; Brown Booby *S. leucogaster*; Great Frigatebird *Fregata minor*; Lesser Frigatebird *F. ariel*; Crested Tern *Sterna bergii*; Black-naped Tern *S. sumatrana*; Bridled Tern *S. anaethetus*; Sooty Tern *S. fuscata*; Brown Noddy *Anous stolidus* and Common White-tern *Gygis alba*.

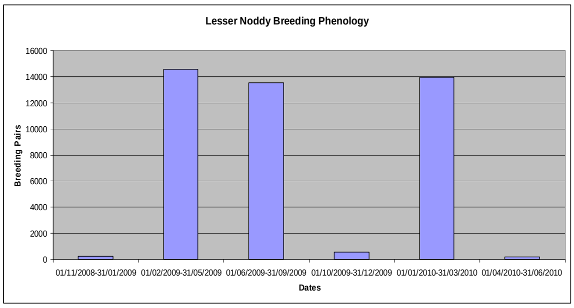


Fig 1 Lesser Noddy *Anous tenuirostris* breeding population during November 2008 - June 2010 in the Chagos Archipelago

Fig 2 Lesser Noddy *Photo Pete Carr*

Table 1 Lesser Noddy *Anous tenuirostris* peak breeding periods from different locations in the Chagos Archipelago during Nov 2008 - June 2010.
X - peak breeding activity for the 12 month period
x - breeding activity in low (>100 pairs) numbers
0 - no breeding activity

ISLAND	PEAK BREEDING ACTIVITY			
	Jan - Mar	Apr - Jun	Jul - Sep	Oct - Dec
South Brother	0	0	X	x
North Brother	0	0	X	x
Grand Ile Bois Mangue	X	0	x	x
Petite Ile Bois Mangue	X	0	x	x
Nelsons Island	0	0	X	x

Discussion

The results for Lesser Noddy (Figs 1 & 2 & Table 1) demonstrate the importance of counts made throughout the year rather than a snap-shot from a single month. Symens (1999), during February and March 1996, recorded a total of 43,275 breeding pairs of Lesser Noddy, with the bulk of the population being found on four islands, North Brother, South Brother, Nelsons Island and Petite Ile Bois Mangue. McGowan et al (2008), who repeated the counts in March 2006 recorded only 2,682 breeding pairs, with no birds breeding on North and South Brother (Nelsons Island was not surveyed in 2006). Based upon the comparison of breeding numbers between 1996 and a decade later, it could be assumed that there had been a catastrophic decline in the breeding numbers of this species.

However, when breeding numbers are viewed over a twelve month period, it becomes evident that February/March is not the only breeding period. In 2009, there were two peak breeding periods, one in February/March and, crucially, a second peak in July involving similar numbers.

When comparing the 1996 total of 43,275 breeding pairs against the numbers recorded throughout a twelve month period from January 2009 to January 2010, when an overall population of 28,940 breeding pairs were counted, it can still be assumed that this species has declined. It is possible, though, that the methodology is to blame: Symens (1999) used a slightly broader definition of the standard counting unit for tree nesting terns (Apparently Occupied Nest) than used in this study, and assessing dense colonies of tree nesting terns, where hundreds of pairs can be nesting in a single tree, is notoriously difficult. Ideally, repeat counts should be made by the same individual.

These counts between November 2008 and June 2010 have exposed some interesting breeding information (Table 1). This shows that there are two (possibly three) separate breeding populations. There is a population grouped around the islands of the western side of the Great Chagos Bank (principally North and South Brother with smaller populations on Middle Brother, Sea Cow and Danger) and likely includes the Nelsons Island population and a second population centred upon the north-eastern islands of Peros Banhos (mainly on Grand and Petite Ile Bois Mangue).

The data suggest that the two populations nest temporally independent of each other but as an integral unit in their area. In both February 2009 and February 2010, peak breeding was recorded for this species in north-eastern Peros Banhos. In July 2009, the second breeding spike was centred upon the western islands of the Chagos Bank and Nelsons Island. Unfortunately, Nelsons Island was not surveyed in the first quarter of 2009. This island appears to be an anomaly in that it had a breeding spike (1,000 pairs) in July 2009 and then again in February 2010 when 1,400 breeding pairs were present.

Conclusion

This brief look at a small portion of the results of the seabird surveys conducted on the 2010 Scientific Research Expedition and on other dates, helps to demonstrate how little is known of the seabirds of the Chagos. Equally important is how these results demonstrate that, as recommended by the ornithologists on the 1996 and 2006 Scientific Expeditions (Symens, 1999; McGowan et al, 2008), long term monitoring of these internationally important breeding seabird colonies is desperately needed to understand the dynamics of the populations.

ACKNOWLEDGEMENTS: I would like to thank Charles Sheppard for the opportunity to join the Chagos 2010 Scientific Research Expedition and the members of the expedition for their convivial company. Particular thanks and respect to Colin Clubbe who was inspirational in the field and Pete Raines for support. Possibly the most important assistance provided was from the out-going Senior Customs and Immigration Officer, Martyn Dorey, who remained on the island for three months in order to assist Pete Raines in the expedition logistics; he provided outstanding logistics support. Finally thanks to Zoë Townsley and Zoe Brown for proof reading this article.

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Chagos Paleoclimatic Research

Dr Miriam Pfieffer
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Coral paleoclimatic research in Chagos started in 1996, when coral cores over 2m long were extracted from the largest live *Porites* corals found (*Chagos News* No. 33). These cores provided records of sea surface temperature (SST) and rainfall variability over the past 120 years. The results revealed that Chagos is a unique site for monitoring past (and future) climate change for a number of reasons: (1) SST at Chagos is tightly coupled to global mean temperatures, (2) Chagos lies in the centre of positive SST and rainfall anomalies caused by El Niño and the Indian Ocean Dipole, and (3) the recent warming of the central Indian Ocean may impact rainfall variability at Chagos and in East Africa.

Massive hermatypic corals of the genus *Porites* are particularly well suited for climate reconstructions, as their uniform growth and longevity allows the development of long, continuous chronologies that extend over centuries. Coral growth includes linear extension and thickening of their aragonite skeleton. This results in a characteristic pattern of alternating high and low density bands. Each high and low density band pair represents one year of coral growth. Patterns of annual density bands may reflect changes in a number of environmental parameters (for example, temperature, nutrient availability and light conditions).

Massive *Porites* corals carry a suite of so-called geochemical proxies in their aragonite skeletons that provide excellent records of the environmental conditions in which the coral grew. Currently, the two most widely used coral proxies are the Sr/Ca ratios and the stable oxygen isotopes ratios ($\delta^{18}O$) of coral aragonite. The Sr/Ca ratios are an excellent tool for deriving high-resolution proxy records of past SST. Application of the Sr/Ca thermometer relies on the assumption that coral Sr/Ca varies predictably with temperature and that seawater Sr/Ca is invariant on millennial timescales due to the long residence time of Sr and Ca in the ocean. In contrast, the oxygen isotope ratios of coral aragonite vary in response to temperature and changes in the $\delta^{18}O$ of seawater. The latter depends on the freshwater balance (evaporation and precipitation) and co-varies with salinity. Thus, at sites like Chagos, where rainfall is high and $\delta^{18}O$ seawater variations are large, the combination of coral Sr/Ca and $\delta^{18}O$ measurements allows the reconstruction of SST, changes in the freshwater balance and salinity.

The rapid growth of massive *Porites* corals (typically 1-1.5 cm/year) allows the development of weekly to monthly resolved geochemical records, with a quality comparable to instrumental records of climate. This is of great importance as the dominant modes of tropical climate variability (for example, El Nino and the Indian Ocean Dipole) operate on a seasonal time scale.

Instrumental records of SST exhibit large uncertainties prior to 1960 due to changes in the measurement procedures and the lack of temporal and spatial homogeneity, which has been provided from satellite measurements since about 1980. Recently, it has been shown that an abrupt drop of 0.3°C in global mean SST after 1945 merely results from uncorrected instrumental biases. This cold bias has a profound impact on the historical record of 20th century surface temperatures. Thus, independent SST records, free of systematic biases, are needed in order to validate historical SST. The tropical Indian Ocean is tightly coupled to global mean temperatures. An SST reconstruction developed from a set of *Porites* coral geochemical records, including the three longest Chagos cores drilled in 1996 and two additional cores from the Seychelles, confirms the pronounced warming of the Indian Ocean during the 20th century that has been attributed to anthropogenic forcing.

Moreover, the coral index closely follows globally averaged surface air temperature (SAT). The distinct temperature drop after 1945 that is evident in Indian Ocean and global SST series neither appears in the coral record nor in global SAT. The results thus suggest that the multi-core coral temperature reconstruction provides an unbiased record of 20th century SST in the tropical Indian Ocean.

During the 2010 expedition, new cores were taken from live corals in order to extend the Chagos chronology until 2010 (Figs 1&2). The new cores were taken at sites were SST loggers have been deployed over the past few years by Charles Sheppard, and will provide a basis for a much more accurate calibration of the coral proxies.

Fig. 1 Cores from live corals were drilled using an air drill powered by SCUBA tanks.
Photo Anne Sheppard

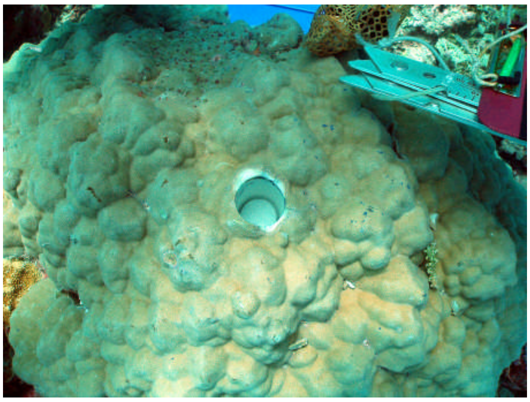

Fig 2 A small coral core is removed.
Photo Anne Sheppard

In addition, 25 fossil coral samples were collected (Fig. 3). These samples vary in length between 25 and 70 cm, and will provide time windows of past climate variability at Chagos spanning between 20 and 70 years (in total, more than 10 m of coral have been collected, providing 800-1000 years of climate history at Chagos). Some of the fossil coral samples were taken from blocks found on Eagle Island, while other fossil corals were collected on boulder beaches at Ile Boddam, Moresby Island, South Brother and Eagle Island.

Fig. 3 Miriam Pfeiffer collecting fossil corals for radiometric dating. *Photo Anne Sheppard*

The ages of the coral samples still need to be determined using radiometric dating techniques. However, it appears that some of the coral samples were collected alive at the time of construction of the settlements over a century ago. Others were probably, according to historic sources, dug from shallow pits on the islands a century or more ago, perhaps to make pits for coconut trees, and these are probably of Holocene age. Thus, the fossil corals are expected to (1) extend the Chagos Chronology back in time into the early 19th to 18th century, and (2) provide time windows of past climate variability at Chagos over the course of the Holocene.

Sea Level Changes and Island Evolution in Chagos over the Last 6000 Years

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Dr Sarah Woodroffe
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Our aim on the expedition was to collect data on past sea-level changes and the evolution of the islands in the Chagos Archipelago. Since the last ice age (c. 20,000 years ago), large ice sheets in the polar regions and the northern hemisphere have melted, causing sea level to rise by c.120m. The best place to record this rising sea level over time is locations such as Chagos, which are situated in the Indian or Pacific oceans, a long way from the former northern hemisphere ice sheets or the poles. Coral or bedrock islands away from plate margins or volcanic hotspots in these oceans act as 'dipsticks', recording predominantly changing ocean volume over time. Collecting sea-level data from locations such as these, known as 'far-field' locations, allows modellers to calculate how much ice has melted from the ice sheets and ice caps since the last ice age.

It is difficult to reconstruct sea-level changes during the early post-glacial period because the evidence is now submerged, only retrievable using ocean coring. We therefore focus on a period known as the mid-late Holocene, (last 6000 years or so) when sea level has been within a few metres of present. Most ice had melted by 6000 years ago and sea level in the Indo-Pacific has been relatively stable since that time. Any sea-level fluctuations during this period reflect a number of processes, but in Chagos they are mainly due to additional small-scale changes in the polar ice sheet mass. The climate in the last 6000 years has been as warm as, if not slightly warmer than, today. Therefore, furthering our understanding of sea-level changes during this period will help us to understand how much the polar ice sheets melted during this period of warm climate, with knock on effects for predictions of ice sheet melt and sea-level rise under future climate change scenarios. In addition, we are interested in how the islands have evolved during this period. Interesting questions include – how old are the islands, how did they form, what is the relationship between sea-level change and island size and stability and how resilient are they to future sea-level rise?

The basis of our work is therefore to understand how sea level has been changing in Chagos over the past 6,000 years, and how the islands of the archipelago have developed under this sea-level regime. A second area of interest is what has happened to sea level in the 20th century. If we are able to precisely reconstruct changing water level over the recent past in Chagos and compare this to other locations in the Indian Ocean, we can begin to understand spatial patterns in recent sea-level changes and the impact of current melt from Greenland and Antarctica on small oceanic islands in the future.

The methods that we use are based predominantly on coral. Corals live underwater, but only in the photic zone, where daylight penetrates. Certain species such as *Porites* grow up to the sea surface, but if they are exposed at low tide their upper surface dies. Many specimens of *Porites* live on the reef flats on the lagoonal side of Chagos atolls. They have grown up to sea level through time and have dead upper surfaces, but their sides are still alive and continue to grow outwards. These coral 'microatolls' are usually circular in shape, up to 2m in diameter with a relatively flat top and annual growth rings which radiate from the centre to the edges. The living, outer part of microatolls continually responds to changes in the height of their constraining water level. This makes them excellent sea-level indicators. If we take a slice through a modern microatoll we can count the annual growth rings and examine changes in the upper surface height to infer sea-level changes over the life of the coral. Some long-lived corals in the Chagos archipelago contain a filtered sea-level record extending back for up to 100 years. A second advantage of microatolls is that they are very robust and are easily preserved in their growth position when they die. If sea level was higher than present during the mid-late Holocene, microatolls growing at that time will today be stranded on the shoreline. If we can radiocarbon date these microatolls we can reconstruct sea level when they formed, and extend reconstructions of past sea-level changes back into the Holocene.

Our interest in island evolution requires study of the shape and profile of the islands, the type and age of vegetation present and age of the island's foundation material. To investigate the age of each island we radiocarbon date coral rubble that forms the substrate of the island. This gives an approximate age for its formation. We surveyed across each island from lagoon side to ocean side to produce a profile which identifies the highest (and oldest) parts. Island profiles also tell us a lot about the processes which cause material to build up in the first place - e.g. whether the island is made up of successive ridges (former beaches) stacked up against one another, which also gives an indication of island age.

We visited, in all, 13 different islands in the four atoll groups in Chagos, and sampled living *Porites* microatolls on the reef flats of Middle Island (Diego Garcia), Ile Boddam (Salomon Atoll) and Middle Brother (Great Chagos Bank). We took a slice from a large microatoll at each location and returned them to the UK for further analysis under UV light (to count annual growth rings and accurately measure changes in surface morphology) (Fig 1). This will allow us to reconstruct

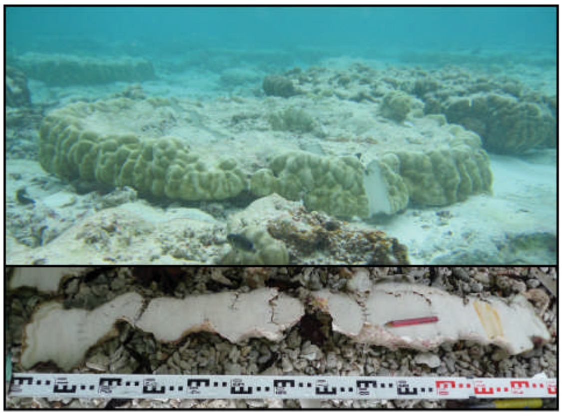


Fig. 1 A modern microatoll sampled close to Ile Boddam showing a flat upper surface and growing outer rim. The coral slice will be analysed to reconstruct sea-level changes over the life of the coral (c. 40 years). *Photo Sarah Woodroffe*

recent sea-level changes across the archipelago and to compare records from different locations. We found older dead microatolls on the shoreline at Ile Boddam (Salomon Atoll), Ile Lubine (Egmont) and Middle Island (Diego Garcia). These are likely to be up to 4000 years old and record a time when sea level was up to c. 0.8m above present. In the next few months we will date samples from these stranded microatolls to reconstruct sea-level changes over the past 4000 years (Fig2)

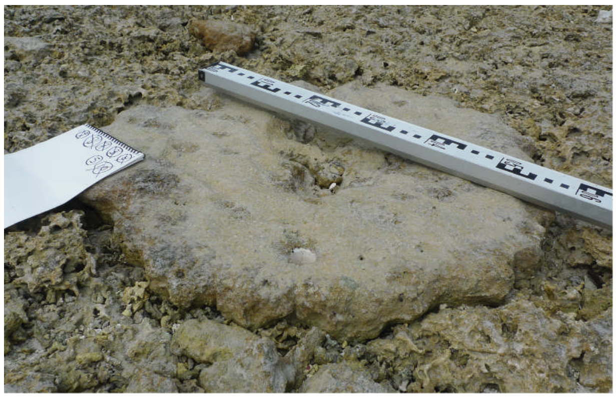


Fig. 2 A fossil microatoll stranded above its living position on the shore of Ile Boddam.
Photo Sarah Woodroffe

We completed transects and profiles across seven islands in the archipelago, and walked the toe of the beach around each of these islands to confirm island area and shape (Fig 3). We also dug pits on Ile Boddam (Salomon Atoll) and

Ile de Coin (Peros Banhos) to collect coral material for radiocarbon dating to establish the age of these islands. We selected these islands because they are amongst the largest in the archipelago and may be the oldest.

Fig. 3 Scott operating our RTK receiver on Diego Garcia with the *Pacific Marlin* in the background. This device gives precise elevation and spatial data using satellites. *Photo Sarah Woodroffe*

In the course of our work we discovered many interesting things. To our surprise there is evidence across the archipelago for a high stand in sea level during the last few thousand years (to be confirmed by radiocarbon dating), suggesting that the islands are either uplifting independent of sea level or that there has been a drawdown in the ocean caused by polar ice accumulation during this period. Secondly we did not see extensive evidence in the microatolls we sampled for fast rising sea level during the 20th century, recorded elsewhere in the Indian Ocean by short tide gauge records. Our third surprising field observation was on an excursion to Coin de Mire, which is a small carbonate island in the Peros Banhos group, isolated and battered by the swell of the Indian Ocean. This island is known locally as 'uplifted reef' but we think it may be part of reef which has survived since the Eemian Interglacial, c. 120,000 years ago. This was the last warm period before our current interglacial and the most recent time that sea level was close to its current level before last the ice age. If this proves to be the case (pending dating) it suggests that sea level in this region was within 3-4m of its present level during this previous warm period, when models suggest that the polar ice sheets were smaller than today. This is an interesting result and may suggest models of polar ice melt during the Eemian need to be revised.

Our fieldwork in Chagos was only the beginning of our research into these islands. In the coming months we will prepare material for radiocarbon dating, analyse the slices of modern microatolls we brought home and calibrate survey data to produce a full picture of past sea level changes across the archipelago. This will be reported in a future edition of *Chagos News*.

Fig 4 Scott and Sarah surveying the fossil corals on Middle Brother. *Photo Anne Sheppard*

Acknowledgements
We would like to take this opportunity to thank Prof Charles Sheppard, Anne Sheppard, Pete Raines, Pete Carr, Simon Williams, the rest of the expedition team and the crew of the *Pacific Marlin* for making this work possible and a highly enjoyable experience.

Feeding Habits of Butterflyfishes in the Chagos Archipelago

Dr Morgan Pratchett,
Arc Centre of Excellence for Coral Reef Studies, James Cook University, Townsville QLD 4811, Australia

I travelled to Chagos in February, as part of the Chagos 2010 research expedition. My primary responsibility during this expedition was to assess coral cover and benthic composition along transects on which Dr Nick Graham (also from the ARC Centre of Excellence for Coral Reef Studies) was recording the abundance and biomass of a comprehensive suite of different reef fishes. However, this expedition also provided a unique opportunity to explore the dietary composition and feeding preferences of butterflyfishes, building upon work I have done previously in many parts of the Pacific. Importantly, there are several butterflyfishes that are restricted to the central and western Indian Ocean, for which the feeding ecology is almost completely unknown, including *Chaetodon zanzibarensis*, *Chaetodon interruptus*, and *Chaetodon xanthocephalus.*

Fig 1 Dr Nick Graham counting butterflyfishes and other reef fishes along transects in coral-rich habitats of the Chagos Archipelago. *Photo Morgan Pratchett*

There is considerable interest in the feeding habits of coral reef butterflyfishes, especially *Chaetodon* butterflyfishes, largely due to their propensity to feed on corals (more specifically, reef-building scleractinian corals). Coral feeding infers a very high dependence upon living corals, which has led to suggestions that changes in the abundance (or behaviour) of butterflyfishes may provide an effective indicator for declines in coral cover, or even declining condition of entire coral reef ecosystems. Butterflyfishes are typically among the first and worst affected family of fishes following disturbances, such as climate-induced coral bleaching, which cause extensive coral loss. There is some concern that the increasing incidence of climate-induced coral bleaching may actually lead to the extinctions of some butterflyfishes, but this mostly depends on how particular these fishes are in terms of the corals they eat.

Fig 2 The Seychelles butterflyfish, *Chaetodon madagaskariensis*, which is one of the butterflyfishes in Chagos for which the ecology (e.g., food preferences) was poorly known. This species spends it's time searching for small (often inconspicuous) prey items that live on reef substrates, and so may be seen picking at seemingly bare substrate. *Photo Morgan Pratchett*

Previous studies have shown that some butterflyfishes, especially very specialized, are very sensitive to coral loss. On the Great Barrier Reef in Australia, for example, nearly all coral feeding butterflyfishes disappeared from reefs affected by coral bleaching in 2001-02. Declines in the abundance of butterflyfishes were most pronounced for the chevron butterflyfish, *Chaetodon trifascialis*, which is extremely specialized and will only feed on 1 or 2 different types of coral. It is important therefore, to know which butterflyfishes feed on coral, but also how specialized they are in terms of the corals they will eat, to assess which butterflyfishes may be vulnerable to further instances of coral loss.

In order to quantify the feeding habitats of butterflyfishes in Chagos, I spent many hours underwater (on SCUBA or snorkel) and completed feeding observations for 285 butterflyfishes across 13 different species. I observed each individual butterflyfish for a period of three minutes; recording all bites it takes from different reef substrates. Butterflyfishes are generally very amenable to these sorts of observations as they will continue to feed in close proximity to divers . For example, while watching a butterflyfish it may take three bites from one coral colony located immediately beneath my feet, then swim over to a nearby colony, where it takes a further ten bites. Over the course of 3-minutes, most butterflyfishes will take between two and thirty bites. There is also a very conspicuous pattern, whereby the butterflyfishes that feed on coral feed at a faster rate, compared to species that do not eat coral, but pick at small (often inconspicuous) animals that live on the reef substrates (e.g. small crustaceans and annelid worms).

As expected, this work revealed that there are marked differences in the feeding habitats of butterflyfishes in Chagos. Of the 13 species studied, there were 6 butterflyfishes that feed almost exclusively on reef-building ("hard") corals, including *Chaetodon trifascialis* and *Chaetodon zanzibarensis.* A further 5 species fed partly on corals, but also supplemented their diets with other non-coral prey. The Indian Ocean teardrop butterflyfish, *Chaetodon interruptus*, was one such species, which, like its sister species (*Chaetodon unimacultaus*) located in the Pacific, fed on both soft corals and hard corals. The remaining butterflyfishes (such as *Chaetodon xanthocephalus*) only rarely fed on hard corals. Interestingly, *C. xanthocephalus* appeared to be feeding mainly on sponges, which is the first time this behaviour has been observed.

Morgan Pratchett with the tapes for the transects for butterflyfish counts. *Photo Anne Sheppard*

As for many other locations where I have worked, the most specialised butterflyfish in Chagos was *Chatodon trifascialis*, which fed almost exclusively on the table coral *Acropora cytherea*. This was also the most abundant of the butterflyfishes recorded in Chagos, which suggests that butterflyfish populations are very resilient in this location. Given the recent bleaching (1998), and associated loss of corals throughout much of the shallow water habitat in the Chagos Archipelago, I had expected to find very limited number of coral-feeding butterflyfishes. However, coral-feeding species dominated the butterflyfish assemblages, indicating that there has been rapid recovery in both coral and fish assemblages since 1998. Results of this research are currently being prepared for publication in the *Journal of Fish Biology.*

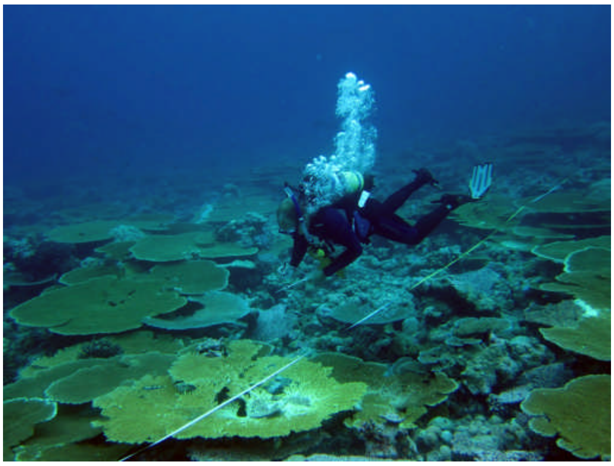
Quantifying reef fish biomass and reef shark numbers in Chagos

Dr Nicholas A J Graham
ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, QLD 4811, Australia

My first visit to Chagos was on the 2006 scientific expedition. My aims in that expedition were to repeat work conducted on reef fish assemblages by Mark Spalding in 1996. The Indian Ocean experienced a major coral mortality event in 1998 when seawater temperatures became too hot, and ~45% of corals in the entire Indian Ocean bleached and died. Worst hit sites lost over 90% of their coral cover, and reefs in relatively shallow water (15-25m depth) in Chagos were among them. I aimed to assess how this had impacted reef fish assemblages, as part of a study in 6 other Indian Ocean countries. Chagos had showed the most rapid recovery in coral cover. This work really confirmed what a unique location Chagos is.

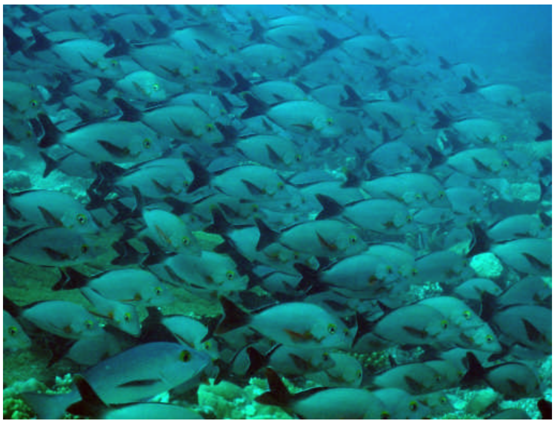
In the 2006 expedition I had been overwhelmed by the sheer number and size of the reef fish communities. Most coral reefs around the world are fished, many heavily. The majority of marine protected areas in most countries are small and experience some poaching. Here was a location, that is geographically substantial, and where almost no fishing of reef fish has occurred since the early 1970s. Unfortunately, I was unable to estimate reef fish biomass on the 2006 expedition, because the methods I was using were more appropriate for estimating diversity and density of fish assemblages. To obtain biomass estimates, you also need to estimate fish length underwater and use established conversions of length to weight for each species you count. It is a tedious process, but provides very useful estimates of biomass, and is the standard technique used in coral reef science worldwide. However, this had never before been conducted in Chagos.

When I was given the opportunity to return to Chagos on the 2010 expedition, it seemed the perfect opportunity to obtain reef fish biomass data. My other objectives were to assess the diversity of fish communities in different habitats and depth strata to estimate the role of fish in promoting the rapid coral recovery observed in Chagos since 1998. I worked with a colleague, Dr Morgan Pratchett (see article in this issue of Chagos News), who was quantifying the composition and structure of the reef habitat at the same sites at which I was working. Together we surveyed 18 locations around Salomon and Peros Banhos atolls and the western area of the Great Chagos bank. We swam over 14km of transects underwater during these surveys. At each site I was counting the number, species and size of the fish present within a 5m wide belt along eight 50m transects.



Morgan Pratchett surveying coral community structure in Salomon atoll. *Photo Nick Graham*

I converted these data to biomass (in the units kilograms per hectare) using the length weight conversion techniques outlined above. This is the common currency used in many locations around the world, so I was interested to see how Chagos compares. As expected, the fish biomass at Chagos dwarfs that of most other coral reef locations in the world, and is only paralleled by some very remote unfished locations in the Pacific Ocean. This exceptional biomass is very likely a significant reason why the reefs of Chagos appear to be so resilient to impacts such as global warming, compared to many other locations around the world. A reef operating with natural ecosystem dynamics, without the effects of human extraction and input (e.g. nutrients), is extremely rare and provides a unique baseline against which the state of other reefs can be compared. With the majority of coral reefs around the world in serious decline (coral being replaced by algae and by fish that rely on the corals disappearing), it is heartening to work in a location where the ecosystem is thriving.



A large school of Lutjanus gibbus (paddletail snapper) at Peros Banhos atoll. Schools of up to 500 individuals were observed of this species.

Photo Anne Sheppard

My other objective on the 2010 expedition was to continue a reef shark abundance data set that Charles Sheppard started in 1975. We repeated these shark observations (during scientific dives) during the 2006 expedition and found that shark numbers had dropped substantially since the 1970s, likely due to the poaching activities for shark fins in Chagos waters. During the 2010 expedition, along with the underwater counts of shark numbers, Morgan and I swam 400m long snorkels hovering off the reef drop-off into very deep water, and counted any sharks we encountered within a 20m belt. We conducted these swims at 27 reef locations in the 3 northern atolls mentioned above and around the north eastern tip of Diego Garcia. As such, we swam a total of over 1 km searching for sharks. Interestingly, we encountered more sharks whilst conducting the SCUBA diving surveys, than during the snorkels. These data will be used to compare among methods of surveying reef sharks in the water, and to compare numbers to other remote locations around the world.

The following 2 publications relate to the work from the 2006 expedition I mention above. If interested in reading more about that work, please email me (nick.graham@jcu.edu.au) and I will send you a PDF.

Graham NAJ, McClanahan TR, MacNeil MA, Wilson SK, Polunin NVC, Jennings S, Chabanet P, Clark S, Spalding MD, Letourneur Y, Bigot L, Galzin R, Öhman MC, Garpe KC, Edwards AJ, Sheppard CRC (2008) Climate warming, marine protected areas and the ocean-scale integrity of coral reef ecosystems. PLoS ONE 3(8): e3039: doi:10.1371/journal.pone.0003039

Graham NAJ, Spalding MD, Sheppard CRC (2010) Reef shark declines in remote atolls highlight the need for multi-faceted conservation action. Aquatic Conservation: Marine and Freshwater Ecosystems doi: 10.1002/aqc.1116

Coral Reef Condition

Prof Charles Sheppard
University of Warwick, UK

Because the fundamental structure of a reef is provided by the corals, a lot of work was done on measuring their condition, from several perspectives. The proportion of the reef surface covered by corals is a fundamental estimator of reef condition, but there is not a straightforward link between coral cover and condition. A very healthy reef may, for example, have between 40% to 100% cover depending on, depth, on whether it faces sheltered conditions or is exposed to strong waves, or whether it is in a lagoon or faces the open ocean. Soft corals take up space also and these compete with corals. A second reason why corals are important is because of the 3-dimensional structure that they develop, which provides habitat for so many other organisms.

Because of this importance, and because about 12 years ago there was a massive mortality of corals from warming throughout the Indian Ocean, we repeated measurements of corals taken on earlier expeditions, in order to determine their health and especially their recovery. This in turn lets us estimate the resilience of these reefs, or their capacity to bounce back from such global disturbances.

The work was done at the same sites and depths around the same atolls that have been monitored in this or in similar ways since the 1970s. There are in fact very few locations in the world which have such a long time series as this, and having a long time series is an advantage because we can obtain not only a ‘snapshot’ of condition as it is, but also the trajectory. From the work in 2010 we can see that the trajectory of the reefs in Chagos is either good and steady, or in several cases, is good and still improving. This work demonstrates the extraordinary condition of the reefs in Chagos but it has the added value of showing the dips and turns in the condition over a period of nearly 40 years.

Fig 1 Pete Raines who, with Simon Williams, surveyed hundreds of metres of tape transect.
Photo Anne Sheppard

The way this work was done was twofold and mostly required two pairs of divers. Firstly one diver laid out tape transects, each 20 metres long, running along a constant depth contour at a range of depths down to 25 metres deep and the second diver recorded the identity of the nature of the reef at half meter intervals along the tape. This method is a fairly standard one. In total, several hundred metres were laid out and measured in this way by Simon Williams and Pete Raines.

In a second method, quadrats were used, each half a meter square, repeatedly laid out in random fashion at the same depths at exactly the same sites. Within these quadrats, counts were made of both adults and, most importantly, juvenile corals. Juveniles are rarely captured in the tape transects because of their very small size and often because of their rather cryptic nature in which many corals start life in tiny crevices before growing to a size which is conspicuous. Of course, it is obvious that the juveniles will become the next generation of reef-constructing corals, so they form one of the keys to the healthy continuance of a reef. This is why their counting and measuring is so important, but even so it is often a neglected element in reef research. Anne Sheppard assisted with this work.

All four member of this group also were engaged in the retrieval and redeployment of a series of temperature recorders. Several of these had been deployed in previous years. They had been emplaced at different depths (the same depths as the above transects in fact) and had been programmed to record the water temperature at two hourly intervals continuously (their batteries last for about 3 years). After finding and recovering them, their data were downloaded on the ship into a laptop using an optical link (the units are totally encapsulated in plastic), after which they were replaced. In some cases new replacements were deployed. Data has been obtained from these since 2006 and these are proving to be exceptionally useful, and surprising too, recording as they do severe and regular temperature drops in seaward facing reefs of up to 5^{o}C, occurring in rhythmic patterns that cycle over a few days each.

Fig 2 Changing the temperature data logger on Egmont Atoll. *Photo Anne Sheppard*

Early analyses show that the reefs are even more profuse in terms of coral and soft coral cover than was the case when measured before in 2006. Their resilience is substantial, and while it remains in this good condition, the reefs continue to support both the extraordinary

Fig 3 Charles Sheppard recording coral cover data. *Photo Anne Sheppard*

abundance of life that can be seen there, as well as providing enough coral growth to support the islands themselves. In the shallowest regions where waves break the shallowest corals need to be physically tough to withstand breaking waves. In much of the world these are suffering along with the rest, which is especially important because these act as a breakwater, and here too there is a very gratifying density of corals. These reefs are in very good condition; amongst the best in the world, and certainly amongst the best in the Indian Ocean.

Rapid Coastal Environmental Assessment

Dr Andrew Price
University of Warwick

During the 2010 Chagos expedition, I carried out rapid environmental assessments at the same 21 sites/islands examined in 1996 and 2006. The methodology, which is simple yet surprisingly robust, provided a ‘health check’ on the coastal environment of Chagos. It entails semi-quantitative assessment of the abundance of major ecosystems and species groups and of the magnitude of disturbances such as fishing/collecting, pollution, construction and solid waste.

Fig 1 Andrew Price wades ashore to begin another beach assessment.

Analysis of the 2006 data had revealed major changes in ecosystem structure and environmental disturbance. Evidence of collecting/fishing was significantly greater in 2006 than 1996. This is attributed mainly to an illegal fishery for holothurians (sea cucumbers), which has expanded over recent years and now exerts substantial pressure on the resource. The significant decline observed in beach wood, a readily accessible fuel for fishing camps, is consistent with this. Solid waste on islands was high (median 2 to 20 items per metre of beach) in both 1996 and 2006. Potentially harmful biological impacts, determined from other studies, include entanglement, toxic effects and provision of transport for invasive or other ‘hitchhiker’ species. Significantly higher bird abundances were recorded in protected areas than ‘unprotected’ areas, attributed mainly to absence of predation by rats. Rapid assessment augments more comprehensive ecosystem investigations. It provides a valuable snapshot of environmental conditions based upon a broad suite of features (ecosystems and disturbances) determined, concurrently, within the same site inspection quadrats and using the same scale of assessment.

Data from the 2010 survey are currently being analyzed to determine whether, at a broad (ecosystem) level, Chagos remains a pristine environment and valuable benchmark for monitoring global and regional change.

Repeat Sea Cucumber Census

With colleagues on *Pacific Marlin*, I also examined holothurian (sea cucumber) populations. The surveys were undertaken at the same sites examined in 2006, for an update on population status and possible ongoing effects of illegal harvesting.

Sea cucumbers are a highly prized resource across the Indian Ocean. Species are often large and conspicuous elements of reef fauna. Being largely detritus feeders, they play an important role in recycling sedimentary habitats, including sandy banks and reef lagoons, thereby ‘conditioning’ the substratum. More specifically, researchers have noted that holothurians have important functions in nutrient recycling, which increases the benthic productivity of coral reef ecosystems. Thus, removal of these animals through fishing may reduce the overall productivity of affected coral reefs. Holothurians likely play a pivotal role in maintaining ecosystem integrity and resilience of coral reef systems.

Despite extensive protected area coverage in Chagos, scientists have expressed concern that certain species groups (sea cucumbers & sharks) within coastal waters of Chagos are being harvested illegally and are diminishing. This mirrors the decline in sea cucumber populations across much of the Indian Ocean.

Findings from the 2006 surveys had supported these contentions. In the case of sea cucumbers, the following results were obtained from visual censuses of shallow-water sea cucumbers in 72 shallow water transects of 100m x 2m within four atolls of Chagos. Mean holothurian abundance in Diego Garcia, where harvesting is absent, was 18.5 individuals/transect (all transects) and 55.4 individuals/transect (only those containing holothurians). In the three exploited atolls, mean abundance did not exceed 3.5 and 5.2 individuals/transect respectively.

Fig 2 *Holothuria nobilis* at Ile Diamant , Peros Banhos atoll. *Photo Anne Sheppard*

Comparison of 2010 results with data collected in 2006 and an earlier investigation reveals a marked decline over 4 years in both mean and maximum density of commercially valuable *Stichopus chloronotus* and *Holothuria atra* in Salomon and Peros Banhos, both exploited atolls, and also for *Holothuria nobilis* in the latter.

Holothurian counts were also made along an extensive transect (21km x 4m) encircling Salomon atoll. Abundance showed highly significant negative correlation with fishing pressure; the latter estimated using an ordinal (0-3) scale). Harvesting effects were not discernible using data from 200m^2 transects.

While recent studies have shown Chagos is virtually pristine regarding contaminant levels, its holothurian resources are under increasing pressure. Results from this study, and examination of Sri Lanka's fishing activity in distant waters, point to heavy and illegal harvesting.

Stronger measures are needed to control the illegal fishery, to prevent holothurian abundances falling to the non-sustainable levels now prevalent across much of the Indo-Pacific, and to ensure that Chagos remains a biodiversity hotspot and environment of international renown
It is against this background that sea cucumbers were re-surveyed in 2010, along the same transects censused in 2006. Abundance data is currently being analyzed to test the assertion that illegal poaching was largely brought under control in 2006/7.

Contaminant Analysis
Anne Sheppard organised the collection and preparation of sediment samples for analysis for the organic pollutant PFOS, petroleum hydrocarbon residues and microplastic particles – tiny pieces of the global plastic waste that, in the marine environment, can be ingested by small organisms and harm them). The study is in collaboration with Jim Readman at Plymouth Marine Laboratory. Chagos waters are so pristine that they are used as a global baseline reference.

Recent studies have largely supported the view that Chagos is one of the world's few remaining pristine marine environments. Concentrations of PCBs, lindane, petroleum hydrocarbons in 1996, and antifouling paint residues in 2006, were mostly undetectable. Chagos is, however, potentially vulnerable to certain Persistent Organic Pollutants (POPs), many of which are ubiquitous on a global scale, bioaccumulate in animals and are toxic. On the 9th May 2009 one such compound [perfluorooctane sulfonate (PFOS)] was added to the list of POPs controlled by the Stockholm Convention. This compound is a man-made fluorosurfactant used in abundance for many years (for example, it is the active ingredient in Scotchgard. Whilst 3M recently withdrew this product, PFOS is still manufactured in several countries and it has been detected on a global scale including in remote and perceived pristine environments.

Fig 3 Anne Sheppard collecting sediment samples from the beach on Eagle Island, Great Chagos Bank. *Photo Charles Sheppard*

In Chagos, there might be several possible sources of environmental entry. One would be local, if PFOS may be used as a fire fighting foam on the military base in Diego Garcia. Another is by airborne transport from parts of the world where PFOS use is more widespread. From samples collected during the 2010 research efforts, we are seeking to investigate the distribution and levels of PFOS (and related compounds) in different parts of Chagos Funding has been provided by Save Our Seas Foundation to analyze the samples.

A proposal has also been submitted to the European Environment Agency for funding to analyze the collected samples for petroleum hydrocarbons and microplastic particles.

Lots of flotsam and jetsam ends up in Chagos and we are conscious that it could build up to where it could, for example, impede turtle nesting. We have just embarked on a program of micro plastics analyses - the answers are unknown as yet. These plankton sized particles are ultimate disintegration products. Plankton feeding organisms therefore feed on them but it doesn't benefit the feeders.

In some parts of the world this is a big problem as their quantity can exceed the real plankton. In Chagos, the overall very good water clarity suggests it is not a problem here, but as part of the role of the archipelago can again provide a global reference site, we aim to see exactly how much is detectable. Plastics don't originate in Chagos but currents bring them from other parts of the ocean.

What are the next steps for scientific research which will benefit Chagos?

Prof Charles Sheppard
University of Warwick, UK

Recently I contacted scientists who have been to Chagos in the last few years, seeking views on the way forward, in terms of science, what they see as being important, and in view also of the 'new' status of Chagos as a huge MPA. A more complete document is being prepared which will be circulated to CCT members via the CCT website. The following is a selection of some of the points.

The foundation of successful conservation and management is knowing what you've got and where it is. In some respects this area is still one of the least explored in the Indian Ocean, with huge swathes never even looked at. This is ironic considering enough is understood about the areas that we have visited several times over many years to tell us that Chagos forms a key location for many global programs. It also has given us substantial understanding of how high quality reef systems function. But still, many parts of Chagos remote from the lagoons and islands remain quite unexplored in a biological sense.

Managing what is now becoming a large volume of information, as well as starting to fill these large spatial gaps, requires a good database system. Very useful in this case will be a spatial database (a geographical information system, or GIS). There are now several new satellites whose data can help feed into this because they have very good penetration of view into sea water, so the key central step will be the construction of a first rate, web-based GIS for all of BIOT, coupled with a high resolution satellite-based mapping audit. This would lead to an elegant GIS stack for the entire MPA, eventually perhaps building to become a web-based resource that would be updated with each scientific visit. This can easily accommodate multiple kinds of data, not only spatial habitats but also data from e.g. temperature loggers, videos, bathymetric information, currents, photos, the lot. This is also a great way to get science to the public and might even be tendered through Google Earth.

We must also continue the long time series of coral reef monitoring, with more emphasis on the nature of coral recovery in Chagos, in particular the structure and composition of recovering communities. Two aspects are required: the density and identity of juvenile corals (because these are of course the next generation of reef-building adults) and population demography of the entire communities. This is related to the need to understand why the Chagos reefs are clearly very resilient and robust. Linked with this is inclusion of more work on key groups that so far have been rather neglected, such as seaweeds and seagrasses. (Referring back to the issue of being unexplored, large beds of seagrasses were found on offshore banks in 2010, a surprising and quite unexpected discovery. This provides a quite different habitat and one not seen at all around the islanded atolls!). On far offshore sites and on more frequently visited sites, we should continue to monitor just how rich and how dense the Chagos populations are.

Because poaching remains an issue, we need to continue direct measurement of fishing effort and catch rates of the two important and representative groups that are poached, namely sharks and sea cucumbers. While populations of both of these remain depressed we cannot say that Chagos is a pristine site.

Turtles also should be included in this part, though with these at least, populations appear to have been steadily recovering.

The biological connections that Chagos forms with the rest of the Indian Ocean are clearly very important issues. Using DNA techniques, this is starting to provide some fascinating information, showing the existence of strong connectivity with the Western Indian Ocean. At the moment this begs several questions regarding the crucial issue of exactly how much benefit Chagos provides the Western Indian Ocean. Today the collection of a wide range of samples for DNA analyses is relatively straightforward and, hopefully, the scores of samples from dozens of different species that have recently been taken is just the start of a promising line of research, but already enough is known to show that this is likely to become a very valuable avenue in the near future. Chemical contamination work is an essential component. While we have analyzed many substances, and generally found levels to be exceptionally low, there are of course many more and new contaminants such as micro-plastics might prove to be crucial. Introduced species are another key element. While there are none in the marine area at present, this status can never be guaranteed to last, and any success here can only ever be a provisional result.

The deep ocean life, and life on many offshore banks and seamounts, remains one of the greatest unknowns in Chagos. The Southampton workshop of 2009 highlighted this very important but very expensive area of much needed work (see the report from that meeting on the CCT website for a lot more detail).

On land, exciting progress might soon be possible. It is clear that the majority of important bird and plant species are found on a minority of the total land area. It is considered well worth attempting rat eradication again, this time coupled with vegetation restoration, starting perhaps with some small islands.

With this and more, the focus must always be on the scientific value that Chagos can provide to the wider picture, as well as on the needs of the BIOT Administration to aid its environmental governance. There is a good chance for Chagos to become an exceptionally valuable location not only in terms of the wealth of scientific information that it can provide us but also in terms of safeguarding a very large part of the world for the benefit of everybody.

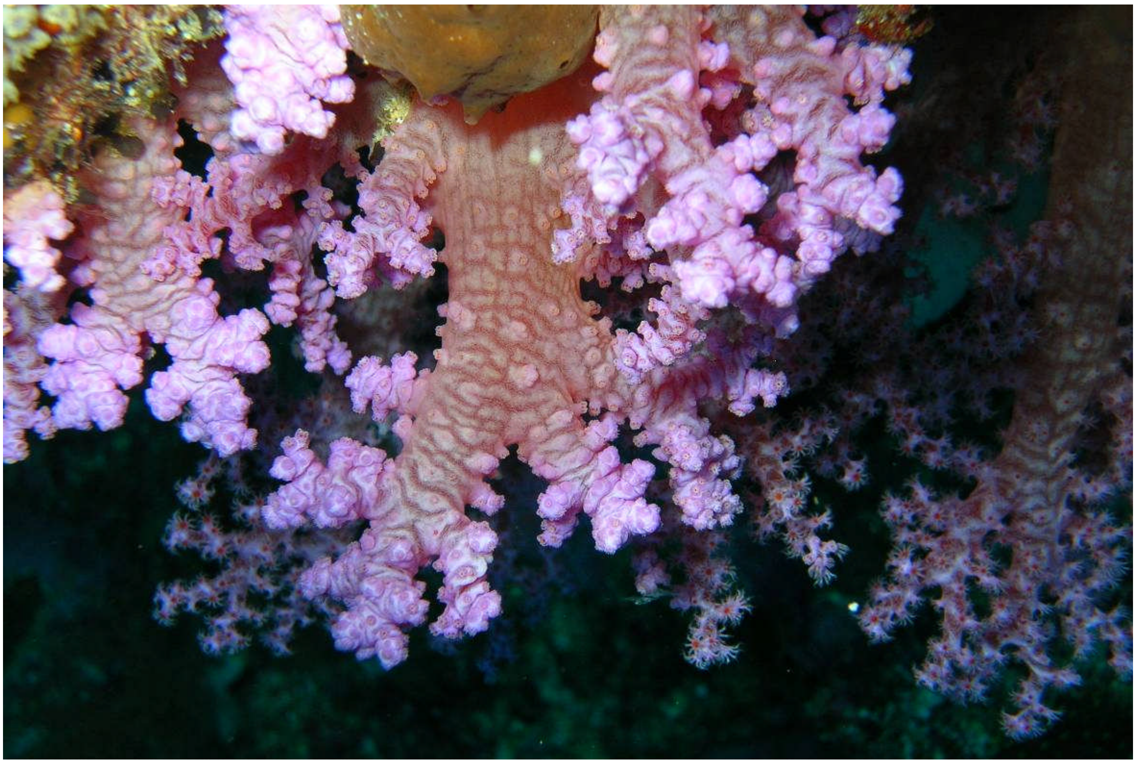
Membership News
Email Alerts
Occasional information bulletins are sent out to members by email. If you would like to receive these bulletins (very occasional, you will not be plagued by them!), please send your email address to the membership secretary at cctmembersec(at)chagos-trust.org

Chagos News
We are always very pleased to receive submissions for *Chagos News* from members. Articles or photographs for consideration should be submitted to chagosnews(at)chagos-trust.org

Chagos Conservation Trust Website
The website is regularly updated with news. It is in the process of a major update at the moment, so log on regularly to keep up with events.

One of the recent additions is a link to an interview with Prof Charles Sheppard about the BIOT MPA: online at http://www2.warwick.ac.uk/newsandevents/expertcomment/coral_reef

A list of weblinks, collected by Taffeta Grey of the Pew Environment Group, for all recent media regarding Chagos is also on the website.



Soft corals on Chagos reefs are diverse, comprising vividly coloured species in deeper water, sea fans, fast-growing fugitives, leather corals and soft mushroom corals.

Soft corals on Chagos reefs

Soft corals are so called because they lack the continuous skeleton of the hard or stony corals. Nevertheless, many do have calcareous needle-like inclusions within their tissues. They comprise colonies formed by anemone-like polyps, as do the stony corals. The soft corals have eight tentacles, giving the group their collective designation, the octocorals. Some do not have symbiotic algae (zooxanthellae) and these are brightly coloured, unlike their more dull cousins that possess these symbionts. By and large, soft corals fall into two categories; slow-growing and persistent species and fast-growing “fugitives” that might only survive for a season.

Soft corals are well-represented but never abundant on the Chagos reefs, which are dominated by a rich diversity of hard corals. However, they are locally abundant in darker areas of the reef (deep walls and overhangs) where the light is insufficient for more light-dependent stony corals. Here one encounters what are known as the leather corals, usually tough encrustations, and soft mushroom corals. With a further reduction in light, brightly coloured species without zooxanthellae come into their own, as well as sea fans.

Being soft, this group of corals is vulnerable to predation. As a result, soft corals produce defensive toxic substances, a biological form of chemical warfare. While these toxins undoubtedly assist soft corals in securing and maintaining territory on the reef, they are also of interest in human medicine e.g. in cancer chemotherapy.

It is difficult to assess the role that soft corals play on a reef. They are not reef-builders like the stony corals. However, they may opportunistically cover a damaged reef and bind its surface. They also add to the diversity on coral reefs, making them fair competition with the Amazon forests as the habitats richest in biodiversity on the globe.