EXPEDITION REPORT

Expedition dates: 6 - 12 September 2014
Report published: July 2015

Little and large: surveying and safeguarding coral reefs & whale sharks in the Maldives.

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Abstract

One week of Reef Check surveys was carried out in September 2014 with Biosphere Expeditions volunteers in North Male' atoll, Maldives. Surveys concentrated on re-visiting sites that were initially surveyed prior to or just after the 1998 bleaching event. CoralWatch, and photo quadrat surveys (analysed using [Coral Point Count software]) were also performed out at most locations. An effort-based whale shark survey was carried out at Hulhumale reef to the south of North Male' atoll, but yielded no sightings. Reef Check sites visited were a mix of house reef and sheltered submerged thila, outer and channel reef locations in North Male', whilst an opportunistic survey was carried out at an unenforced Marine Protected Area (MPA) at Banana Reef (that was initially surveyed by Reef Check in 2010). Surveys showed that the outer reefs in areas of greater oceanic circulation, current and swell were healthier, and less affected by environmental threats than inner reefs (thilas and giris) of North Male' atoll. Coral reef fish populations were low at all sites (compared to well-managed Indian Ocean MPAs, and reefs with little human impact). For example, the outer reef of the large Summer Island where reefs lie obliquely to the current direction showed good coral health of a variety of low-lying branched and massive coral growth forms. An inner reef was affected by wide-scale blanket coverage of *Discosoma* corallimorphs (De Giri). Reethi Faru – a house reef nearer to the centre of the atoll exhibited both bleaching and Crown of Thorn predation pressure. At most sites, the coral cover was higher (in terms of recovery from the 1998 bleaching event) in shallower waters (<5 m) than slightly deeper (>10 m) waters. This may be indicative of greater recruitment in shallow waters by more *r*-strategist coral life-forms (Acroporids) and the slow accumulation of rubble and loose material in deeper areas that is less conducive to coral recruitment, accretion and growth This pattern has been observed in other sites over 10 years of Reef Check surveys across central atoll reefs by the lead author. Relative reef health from our observations correlates at a coarse scale with the thermal stress model according to the [Maldives Bleaching Risk Assessment Tool] (BRAT). As 2015 appears to have strong signals for another strong El Niño event, future surveys are imperative to understand the long-term resilience of areas we monitor. We need more surveys to better understand the status and current resilience of Maldives MPAs. The developing nature of in-country Maldives Reef Check teams (as illustrated in this report) will help us better understand and respond to future bleaching events.

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Contents

Please note: Each expedition report is written as a stand-alone document that can be read without having to refer back to previous reports. As such, much of this section, which remains valid and relevant, is a repetition from previous reports, copied here to provide the reader with an uninterrupted flow of argument and rationale.

1. Expedition review

1.1. Background

Biosphere Expeditions runs wildlife conservation research expeditions to all corners of the Earth. Our projects are not tours, photographic safaris or excursions, but genuine research expeditions placing ordinary people with no research experience alongside scientists who are at the forefront of conservation work. Our expeditions are open to all and there are no special skills (scientific or otherwise) required to join. Our expedition team members are people from all walks of life, of all ages, looking for an adventure with a conscience and a sense of purpose. More information about Biosphere Expeditions and its research expeditions can be found at www.biosphere-expeditions.org.

This expedition report deals with an expedition to the Maldives that ran from 6 to 12 September 2014 with the aim of surveying and studying recovery of reefs since the catastrophic 1998 bleaching event. Our projects tie in sightings of whale sharks with the work of the local charity – the Maldives Whaleshark Research Programme, based in southern Ari atoll. Although the Maldivian reef atolls comprise of a rich mixture of spectacular corals and a multitude of fish and other animals, the Maldives government identified a need for further research and monitoring work as far back as 1997. Biosphere Expeditions with this project is addressing this need and is working with the Marine Conservation Society and the Maldives Whaleshark Research Programme in order to provide vital data on reef health and whale shark sightings. Reef data collection follows an internationally recognised coral reef monitoring programme, called Reef Check, and will be used to make informed management and conservation decisions. Whale shark photos will be used by the Maldives Whaleshark Research Programme for their conservation efforts. The expedition included training for participants as a Reef Check EcoDivers, and for two individuals to become in-country Reef Check EcoDiver trainers.

Many reefs in the Maldives are in a relatively healthy state and of high aesthetic quality. Apart from supporting an expanding tourism and recreation industry, coral reefs also play an unrivalled role in fisheries and in the culture and lifestyle of the people of the Maldives relative to most other Indian Ocean states. Tourism, reef fishing, coral sand mining, dredging, reclamation and the construction of maritime structures and pollution represent most impacts on coral reefs that can be directly managed in the Maldives. Resilience to the impacts of climate change can be monitored (e.g. to record recovery trajectories of different reefs to mass-bleaching events). Reef Check can be an extremely useful tool to inform local managers where conservation action such community-based management and MPAs should be targeted.

With the introduction of tourism in the Maldives in the 1970s, the country started to gain a major source of income & employment. Mass tourism in the Maldives is still concentrated around the atolls near to Male' and its infrastructure and resources entirely rely on rich and healthy reefs. However, there is a significant increase in the amount of licenses being offered to resort developers around the more southern atolls. A new airport in Mamigili (south Ari) has 'opened up' new areas for direct flights, increasing access to the area.

The remoteness of many reefs and their wide distribution make research and monitoring work costly and difficult. The reefs that have been best studied are in the central areas of North Male', Ari and Addu atolls. Pristine reef areas are still found in many parts of the country (particularly to the far south) and many reef areas remain unexplored. Pressure from tourist industry development in more southern areas will increase the footprint of damage that has been widely recorded in more central atolls. With increased development, there is a critical need for management. There is enough ocean to accommodate people and wildlife in the Maldives, but the country is currently failing to accommodate sustainable development.

Data from these and previous Reef Check coral reef surveys will be used at international, regional and national levels to provide a 'status report' on the health of Maldivian reefs. At the national level, it will be used to help make informed management and conservation recommendations.

The expedition undertakes detailed observations of encounters with whale sharks when they are encountered between reef survey locations. Photographs of the gill areas of whale sharks are being used by the Maldives Whaleshark Research Programme to identify individuals in order to record presence / absence of whale sharks in the archipelago. Photos of the markings in and around the gill / pectoral fin areas are unique (like a human fingerprint) for each individual, and over 200 individuals have been recorded so far. The Maldives Whaleshark Research Programme can then match one individual's unique markings with the photographic record and add that image and the whale shark's location to their database and see if it has been recorded before and from where. This will then allow conservationists at the Maldives Whaleshark Research Programme to map where individual sharks go, how often they are recorded at individual locations and whether further protection mechanisms are needed for individual hotspot locations.

Coral reef structures of the Maldives archipelago are extraordinarily diverse and rich. There are submerged coral mounds, often rising 50 m from the seabed to 10 m from the surface (thilas), other mounds that reach the surface (giris) and large barrier reefs, which surround these structures on the perimeter of the atolls, some of which are up to 40 km long. The islands of the Maldives are entirely made from the coral sand washed up onto the very shallowest coral platforms. More than 240 species of hard corals form the framework of a complex coral community, from the shallow branching coral dominated areas, to deeper systems of undercut caves and gullies dominated by soft corals and invertebrates. Most coral communities in the central reefs of the Maldives are still recovering from the mass-bleaching event of 1998, but there appears to have been a reasonably strong recovery in many reefs, with extensive recruitment and growth of branching corals. It is for this reason that our expedition has regularly focused on assessing reef health in areas initially surveyed prior to the 1998 mass-bleaching event. In order to gain a broad range of reef types, we surveyed inner (giri), fringing (house) reefs (faru), outer atoll channel sites and the outer slopes of fringing reefs. This range of habitats gave us a useful understanding of the relative resilience of different reef types to recover from bleaching in the area of northwest North Male' atoll.

The fish populations of the Maldives are exceptionally rich in terms of diversity and biomass. The Maldivian government in 2008 banned shark fishing within the atolls and their numbers appear to be increasing and small reef sharks are still commonly observed in Maldivian waters. Many thilas lie in areas of strong current and can be visited at times when jacks, snapper and shark forage for their prey.

These reefs are 'fed' by the channels between the outer barrier reefs that punctuate this vast archipelago, where the diving can be exciting. The unique location and geology of the Maldives also makes it a rich area for filter feeding whale shark and manta rays, with observations of these species an exciting event for those on board liveaboard dive trips.

Dives range from thilas, farus in inner reefs, channel walls and slopes, fore- and back reefs, where gently sloping reefs are covered by hard corals and the regionally abundant black tube coral, *Tubastrea*. All of our survey dives are to a maximum 18 metre depth, which generally are the shallow water areas that provide the richest coral growth.

1.2. Research area

The Maldives or Maldive Islands, officially Republic of Maldives, is an island country in the Indian Ocean formed by a double chain of twenty-six atolls stretching in a north-south direction off India's Lakshadweep islands. The atolls of the Maldives encompass a territory spread over roughly 90,000 square km. It features 1,192 coral islands, of which only about two hundred are inhabited.

Figure 1.2a. Flag of the Maldives.

The Republic of Maldives's capital and largest city is Male', with a population of around 100,000. Traditionally it was the King's Island, from where the ancient Maldive royal dynasties ruled and where the palace was located. The Maldives is the smallest Asian country in both population and area.

Over 2000 species of fish have so far been catalogued, including reef sharks, moray eels and a wide variety of rays such as manta rays, stingrays and eagle rays. The Maldivian waters are also home to the whale shark.

Sharks, turtles, anemones, schools of sweetlips and jacks, eels, octopus and rays are also found in Maldivian waters.

To date at least 240 hard coral species have been described from 57 genera. 51 species of echinoderms, 5 species of sea grasses and 285 species of alga have also been identified.

The Maldives is considered one of the best places in the world for underwater photography. Sights such as vast schools of thousands of fish or groups of up to 30 manta rays or eagle rays are frequently seen in and around the Maldives.

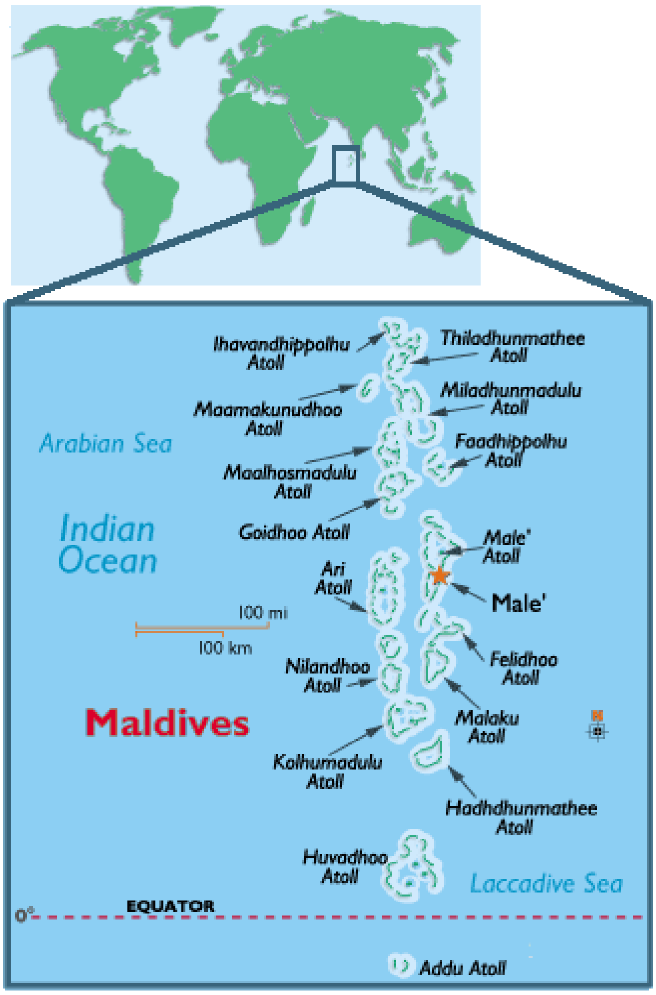

Figure 1.2b. The Maldives. An overview of Biosphere Expeditions' research sites, assembly points, base camp and office locations is at Google Maps.

1.3. Dates

2014: 6 - 12 September

The expedition ran over a seven-day period with one group of participants. The group was composed of a team of international research assistants, guides, support personnel and an expedition leader (see below for team details).

1.4. Local conditions & support

Expedition base

The expedition was based on a modern four-deck, 115 feet live-aboard boat, the MV Carpe Diem with ten air-conditioned cabins, an air-conditioned lounge and an open air dining area. The boat was accompanied by a 55 feet diving dhoni (boat) with multiple compressors, Nitrox and all facilities one would expect on a modern live-aboard. The crew provided tank refills and dive services. A professional cook and crew also provided all meals.

Weather

The Maldives have a tropical and maritime climate with two monsoon seasons. The average day temperature during the expedition months was 28°C with mostly sunshine and an occasional rain shower on a few rare days. Water temperature during the expedition was 28-30°C.

Field communications

The live-aboard was equipped with radio and telephone communication systems. Mobile phones worked in most parts of the study site as long as the boat was within the atolls.

The expedition leader also posted a multimedia expedition on the Biosphere Expeditions' social media sites such as Facebook, Google+ and the Wordpress blog.

Transport & vehicles

Team members made their own way to the Male' assembly point. From there onwards and back to the assembly point all transport was provided for the expedition team, for expedition support and emergency evacuations.

Medical support and insurance

The expedition leader was a trained first aider and the expedition carried a comprehensive medical kit. The main hospital is in Male' city and there are medical posts on many of the resorts. There is a recompression chamber on Bandos Island Resort near Male' and one on Ari Atoll. Safety and emergency procedures were in place, but did not have to be invoked since there were no medical or other incidents during the expedition.

1.5. Scientist

Dr. Jean-Luc Solandt is a Londoner with a degree in Marine Biology from the University of Liverpool. After graduating, he spent a year diving on the Great Barrier Reef assisting field scientists in studies on fisheries and the ecology of soft corals and damselfish. He returned to the UK and enrolled in a Ph.D. in sea urchin ecology in Jamaica, based both in London and Jamaica. He went on to be an expedition science co-ordinator for projects in Tanzania, the Philippines and Fiji, and is now undertaking campaign and policy work in planning and developing Marine Protected Areas in the UK. He has been the Reef Check co-ordinator for the Maldives since 2005 and has thus far led three expeditions to undertake surveys inside and outside Marine Protected Areas on the islands. Jean-Luc has about 1,000 dives clocked up since he trained to be a marine biologist 25 years ago.

1.6. Expedition leader

Catherine Edsell was born in the UK into a family of mountaineers, skiers and adventurers. With wanderlust in her blood and a BA Hons in Creative Arts under her belt, she left her career as a choreographer, and set off to the jungles of Central America and Indonesia, lived in the Himalaya with locals, trekked through the Namib Desert in search of elusive elephants and dived the oceans. Her passion for conservation grew as she sought out and trained with expedition organisations who echoed her ecological beliefs, and for seven years straight, her feet barely touched British soil as she lived the expedition life in all sorts of terrains. Catherine joined Biosphere Expeditions in 2012 to realise her ambition to participate in true conservation work.

1.7. Expedition team

The expedition team was recruited by Biosphere Expeditions and consisted of a mixture of all ages, nationalities and backgrounds. They were (in alphabetical order and with countries of residence):

6 - 12 September 2014: Sissie Chang (USA), Peter Goodman (UK), Rex Gunderson (USA), Matthias Hammer (Germany), Amintha Shaha Hashim* (Maldives), Sharon Heywood (Russia), Ayesha Kyari (UK), Francoise Mathieu Morainville (France), Rafil Mohamed* (Maldives), Ibrahim Shameel* (Maldives), Gordon Thomson (UK), Claudia Vousden (USA).

*Participants marked with a star took part in the expedition as part of an education and placement programme kindly supported by the Rufford Foundation via LaMer.

1.8. Other partners

On this project Biosphere Expeditions is working with Reef Check, the Marine Conservation Society, the Maldives Marine Research Centre (MRC) of the Ministry of Fisheries and Agriculture, the Maldives Whaleshark Research Programme, the MV Carpe Diem, LaMer and the Rufford Foundation. Data will also be used in collaboration with the Global Coral Reef Monitoring Network and the University of York, which has a department of conservation. Our long-term dataset is not only of interest to conservationists working on monitoring the global status on reefs, such as those from the United Nations Environment Programme, the World Conservation Monitoring Centre and the International Coral Reef Action Network (ICRAN), but more locally too, especially as regards the effectiveness of current Maldivian Marine Protected Areas in their ability to protect and recover significant numbers and biomass of commercially important finfish.

1.9. Expedition Budget

Each team member paid towards expedition costs a contribution of £1,690 per seven-day slot. The contribution covered accommodation and meals, supervision and induction, all maps and special non-personal equipment, all transport from and to the team assembly point. It did not cover excess luggage charges, travel insurance, personal expenses such as telephone bills, souvenirs, etc., as well as visa and other travel expenses to and from the assembly point (e.g. international flights). Details on how these contributions were spent are given below.

Income	£
Expedition contributions	13,876
Grants	4,600
Expenditure	
Staff includes local & international salaries, travel and expenses	6,445
Research includes equipment and other research expenses	1,283
Transport includes taxis and other local transport	33
Base includes board, lodging and other live-aboard services	15,522
Administration includes some admin and misc costs	27
Team recruitment Maldives as estimated % of PR costs for Biosphere Expeditions	6,525
Income – Expenditure	**-11,359**
Total percentage spent directly on project	**161%***

*This means that in 2014, the expedition ran at a loss and was supported over and above the income from the expedition contributions by Biosphere Expeditions.

1.10. Acknowledgements

This study was conducted by Biosphere Expeditions, which runs wildlife conservation expeditions all over the globe. Without our expedition team members (listed above) who provided an expedition contribution and gave up their spare time to work as research assistants, none of this research would have been possible. The support team and staff (also mentioned above) were central to making it all work on the ground. Thank you to all of you and the ones we have not managed to mention by name (you know who you are) for making it all come true. Thank you also to Hussein Zahir of LaMer for his guidance and advice, and to Agnes van Linden of the MV Carpe Diem for running like clockwork an excellent live-aboard research base. Biosphere Expeditions would also like to thank the Friends of Biosphere Expeditions for their sponsorship and/or in-kind support. We thank the crew of the MV Carpe Diem for being such excellent hosts. Thank you also to Richard Rees of the Maldives Whaleshark Research Programme. Support from the Rufford Foundation via LaMer for the placement programme is gratefully acknowledged also. The placement programme trained three Maldivians in Reef Check survey techniques: Ibrahim Shameel (from the Maldives Whaleshark Research Program), Shaha Hashim (from a local NGO – Gemana) and Rafil Mohammed (from the Maldives Divers Association).

1.11. Further information & enquiries

More background information on Biosphere Expeditions in general and on this expedition in particular including pictures, diary excerpts and a copy of this report can be found on the Biosphere Expeditions website www.biosphere-expeditions.org.

Copies of this and other expedition reports can be accessed via at www.biosphere-expeditions.org/reports. Enquires should be addressed to Biosphere Expeditions via www.biosphere-expeditions.org/offices.

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2. Reef Check survey

2.1. Introduction and background

The Maldives comprises 1,190 islands lying within 26 atolls located in the middle of the Indian Ocean approximately 700 km southwest of Sri Lanka and at the tip of a submerged ridge (the Chagos – Maldives – Laccadive ridge), rising 3,000+ metres from the abyssal plain to the surface, where they emerge to form the atolls (see Figure 1.2b). The Maldives covers approximately 90,000 km^2, yet the land area covers less than 1% of this total (Spalding et al. 2001). Together, the Lakshadweeps and the Maldives constitute the largest series of atolls and faroes in the world (Riska and Sluka 2000).

The highest point of the islands is approximately 2.4 m as all the islands are naturally made from fine coral sand. About 10% (200) of the islands are inhabited, with by far the largest population living in Male' - the capital. Of the (approx.) 350,000 population of the nation, a little over 100,000 people live in the 1.8 km^2 of Male', making it one of the most densely populated urban areas on Earth (World Bank, 2010 figures).

The atoll lagoons range from 18 to 55 m deep and within these are a number of patch reefs. Reef structures common to the Maldives include 'thilas' (submerged reefs with tops from a few metres below the surface), smaller 'giris' and 'faros' (the latter similar to giris, but ring-shaped reefs with a central lagoon) (Figure 2.1a). The outer reefs that fringe the atolls have the greatest expanse of coral growth, growing upwards and outwards towards the incoming current, thereby acting as breakwaters of swell and tide. Dead coral material from these atolls and inner patch reef drifts to the leeward sides of the outer reefs. This process of constant erosion of the reef material and deposition of sediments is responsible for constructing the 1,190 islands of the archipelago. This natural dynamic process has been altered by the numerous human habitations and stabilised to a degree by the colonisation of many of the islands by natural vegetation.

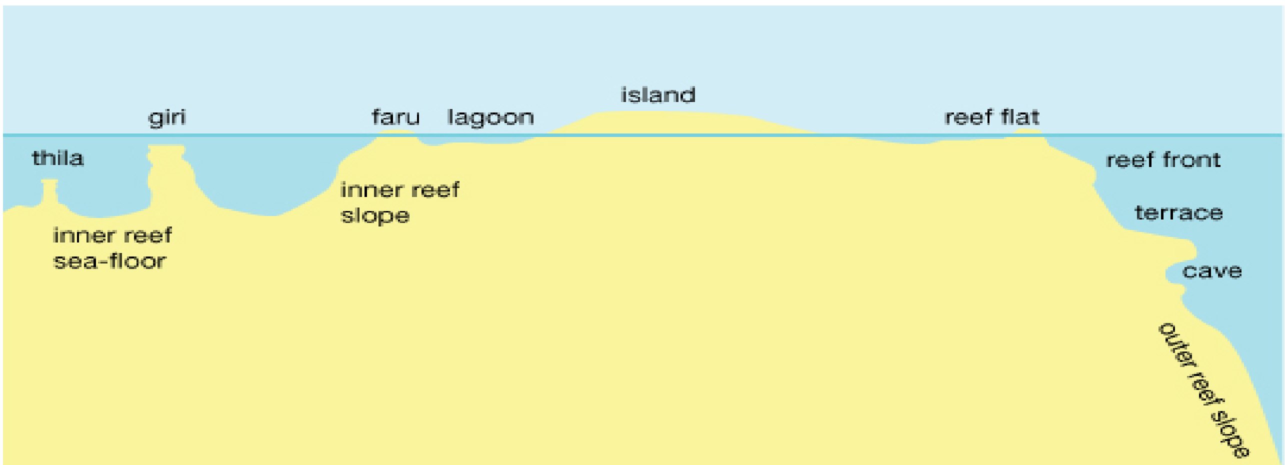

Figure 2.1a. Common reef structures of the Maldives (from Tim Godfrey).

The Maldives has two monsoon (wind and current) seasons. The Northeast monsoon brings in dry winds from the Asian continent that last between January and March. The relatively wet southwesterly monsoon runs from May to November. Air temperature ranges between about 31°C and 21°C and varies little between seasons. The monsoon currents have a key bearing on the distribution of pelagic planktivorous animals across the archipelago. For example, Manta rays (*Manta birostris*) are often found in the sheltered sides of reefs relative to the incoming current, feeding on the plankton that drifts to the leeward side of the reef system (Anderson et al. 2011).

In terms of biodiversity, the Maldives atolls form part of the 'Chagos Stricture' and are an important stepping-stone between the reefs of the eastern Indian Ocean and those of East Africa (Spalding et al. 2001). The fauna therefore comprises elements of both eastern and western assemblages. Diversity is high with over 240 scleractinian corals, with maximum diversity reported towards the south (towards Huvadhoo Atoll) (Picheon and Bnezoni 2007, Risk and Sluka 2000). Over 1,000 fish are recorded from the Maldives, a large proportion of which are reef associated (Anderson et al. 1998).

2.1.1. Fisheries

Tourism and fisheries are the two main generators of income for the Maldives. Most of the finfish taken from the Maldives are tuna (by weight) with both yellowfin and skipjack species dominating the catch with small amounts of bigeye also taken (Marine Stewardship Council). Up until 2010, Maldives fishermen solely used pole, line and hand line fishing techniques to take skipjack and yellowfin tuna. As such, the Maldivian tuna fishery has been marketed by many supermarkets in the UK as sustainable, because the volume of catch taken by pole and line is relatively small compared to many longline fisheries around the Indian Ocean and there is minimal by-catch of other fish, cetaceans and turtles. The Maldives has also recently banned shark fishing (2010), which can be regarded as a major conservation measure because of the catastrophic declines in the global populations of reef and pelagic predatory shark species (Graham et al. 2010). Although this is a commendable measure undertaken by the Maldives government, it is very difficult to enforce without significant investment in water-borne vessels (although the Maldives has a relevant enforcement department called the 'Environmental Protection Agency', it is woefully underfunded). Nor is there the sophisticated satellite-based ship tracking equipment that is used in the Indian Ocean. The ban on the export of shark products introduced in 2011 has undoubtedly made it more difficult for Maldives-based fishers to trade in shark parts and anecdotal evidence from Maldives dive operators suggests that in some areas sharks appear to be increasing in number.

A decision made by the Maldives government in March 2010 to open the Maldives waters to domestic long-line fishing, whilst excluding vessels from other nations (principally from Sri Lanka) is highly controversial. This was as a reaction to the reduction in yellowfin catch by Maldivian fishermen recorded between 2005 (186,000 tonnes) and 2008 (117,000) (Minivan News, 2010)[1], making traditional pole and line fishing techniques from larger vessels unprofitable.

[1] http://minivannews.com/environment/cabinet-approves-long-line-fishing-for-maldivian-vessels-5385

There has been a growing demand for reef fish species in recent decades, partly because of the expansion of the numbers of tourist resorts across the nation (Wood et al. 2011) and mostly because of the growth in the export market to the Far East, which is serviced by grouper cages that have been set up within a number of atolls. Wholesalers periodically visit the grouper cages that are stocked by local fishers to buy the fish to export live and fresh-chilled to foreign markets. A report by the Maldives Marine Research Centre (MRC) in 2005 highlighted a declining catch since 1997, three years after the commercial fishery started in 1994 (Sattar and Adams 2005). A further report by MRC in 2008 showed that demand for reef fish had tripled in the last 15 years and that a management strategy for grouper was needed to ensure sustainable catches into the future. MRC has recently worked with the Marine Conservation Society to develop a management plan for grouper. Some of the recommendations from past reports, including provision to increase the minimum landing sizes for some species into the grouper cages, and for market have met with resistance in some atolls. Given the small sizes of many species seen in the wild as outlined in last years report (Solandt and Hammer 2014), it is regrettable that the trajectory for the Maldives fishing out their grouper population as a viable commercial species is a distinct possibility over the next 10 years.

2.1.2. Coral bleaching

Probably the most serious current threat to global coral reefs is the effect that global warming has by bleaching hard corals. Coral bleaching is the process by which corals expel symbiotic algae (zooxanthellae) from their tissues as temperature rises for a prolonged period above an ultimately lethal threshold. Although the temperature threshold at which corals bleach varies by region and coral type, the temperature threshold at which corals become stressed in the Maldives is regularly cited as 30^{0}C (Edwards et al. 2001). The longer the corals are in contact with elevated sea surface temperatures, the greater the likelihood that the corals will bleach. And the longer the coral host is unable to re-acquire zooxanthellae, the greater the likelihood that the coral will die, as it gains most of its energy from the sugars produced by the algal cells within its tissues.

1997 and 1998 Reef Check surveys

During April and May 1998 a temperature of over 32^{0}C was recorded in the Maldives for a period of more than four weeks. This led to mass bleaching down to at least 30 m (Edwards et al. 2001). Shallow reef communities suffered almost complete mortality with live coral cover of central reefs decreasing from about 42% to 2%, a 20-fold reduction from pre-bleaching cover. Since 2005, Reef Check surveys have observed few large reef building corals, and a much higher proportion of faster growing Acroporids and Pocilloporids. This suggests there has been patchy recovery due to recruitment of new more ephemeral corals, rather than recovery from survival and regrowth of older colonies that recovered zooxanthellae immediately after the warming event.

The 1997 and 1998 Reef Check surveys were carried out by both Maldives Research Centre staff (Zahir et al. 1998) and by local resort marine biologists. This study showed that the principle families to bleach were the shallow-water Acroporidae and Pocilliporidae. More resilient corals included the Agariciidae and Poritidae families that form more massive coral species. Other workers (e.g. Clark et al. 1999) found that the coral cover in the range of 22.5-70% pre-bleaching fell to 0-10% post bleaching in many sites.

Longer term effects of such catastrophic bleaching were said to include erosion of dead coral skeletons to sand and rubble that led to less buffering of wave action around the atolls, leading to beach erosion – a huge potential cost to the Maldives.

A University of British Columbia[2] survey (Hauert et al. 1998) undertook extensive Reef Check surveys in Angaga Island in June 1998, three months after the catastrophic bleaching event. 80% of corals were dead and covered by fine filamentous algae.

MCS and Biosphere Expeditions undertook the first 'bleaching recovery' surveys in 2012, and found that the reefs of Ari atoll were generally recovering well, from the outer channel reefs of the north east, to the inner south central house reefs (including those at Angaga Island in the centre of the atoll) (Solandt et al. 2013). However, it is important to widen the search area, in order to contextualise these findings at a wider scale. Here we report on 'bleaching recovery' surveys that were carried out on six reefs initially surveyed in 1997 prior to the bleaching event in the most densely populated atoll of the Maldives – North Male' atoll. This atoll has seen the biggest change in development of all atolls over the last 40 years, with the influx of more tourists, hosted by more tourist resort islands, within easy reach of the international airport at Male'.

2.1.3. Marine Protected Areas (MPAs)

Between 1995 and 1999 the Maldives set up 25 MPAs around well-known dive sites, whilst three larger reserves were set up in 2010 (www.epa.gov.mv). The 25 MPAs were established to protect dive sites and should be managed as no-take zones that prevent the capture of live bait for the tuna fishery and also for fisheries for all reef-associated species (such as grouper). One of the authors (Jean-Luc Solandt) surveyed nine of the 25 small Maldives MPA dive sites in 2008 with little statistical evidence that the biomass and number of fished species were greater inside the protected areas (Solandt et al. 2009). On one occasion during surveys in 2007 a fishing vessel line fishing at the 'HP reef' MPA to the East of North Male' Atoll was recorded – a stark reminder that MPAs are not adequately enforced. The collective size of the 25 Maldives MPAs (prior to the UNESCO Biosphere Reserve designation in 2010) is only 0.01% of Maldivian waters. During this year's surveys, a fishing boat was seen entering, and fishing the Lankanfinolhu site (see Fig. 2.1.3a) – the site famous for its manta cleaning station, that is also meant to be an MPA (as it lies within 700 m of a tourist island).

Three more recent – an much larger - protected areas designated in 2010 include: Maamigili in South Ari Atoll, where juvenile whale sharks can be seen all year round; Hanifaru Bay in Baa Atoll where manta rays and whale sharks can be seen seasonally; and Angafaru in Baa Atoll, which was previously a breeding ground for both grey (*Carcharhinus amblyrhynchos*) and white tip (*Triaenodon obesus*) reef sharks and where manta rays and whale sharks can sometimes be sighted at certain times of the year. The entire Baa Atoll was designated a UNESCO Biosphere Reserve in 2011, with additional areas proposed as no-take zones to give a total of nine protected areas within Baa Atoll. The Hanifaru MPA has a management plan enforced by rangers, which limits number and duration of people visiting the bay, as well as vessel speed and the number of entry points into the bay.

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[2] http://www.math.ubc.ca/~hauert/publications/ReefCheck98/index.html

Unregulated private vessels, liveaboards and SCUBA diving are now banned in the bay as of 2012. A permit system was introduced in 2012 to control access (www.epa.gov.mv). There is no such management plan developed at the moment for the 42 km^2 Mamigili reef area at south Ari atoll. This is unfortunate, as there are more and more operators offering shark encounters to the tourist public. However, this trade is totally unregulated, leading to many physical interactions between sharks and people.

Figure 2.1.3a. Fishing inside the Lankanfinolhu MPA (southern end of the site). Observed between 09:00 and 10:00, 13 September 2014.

There are many 'unofficial' MPAs around the so-called house reefs of many resorts from the line of lowest shoreward vegetation up to 700 m out to sea. It has been proposed that a number of these resort house reefs will be under new, more robust legislation in the near future. There is currently an IUCN project that is training five Maldives resorts in numerous environmental protocols designed to take data on a wide range of physical and biological attributes of the islands, including indicators of waste management. IUCN hope to see these survey methodologies expanded widely in the future.

2.1.4. Direct environmental threats to Maldives reefs

Maldives reefs are under threat from both local anthropogenic and global climate induced pressures. Key threats are:

- Climate change, & associated sea surface temperature increases leading to coral bleaching (from human caused increases in CO_2 concentration).

- Increased atmospheric CO_2 concentration that results in seawater acidification. This leads to decreased skeletal strength of calcium carbonate-dependent corals, decreased growth rate, and decreased reproductive output of corals.

- Overfishing of keystone species (e.g. predators of Crown of Thorns Starfish and herbivorous fish).

- Sedimentation and inappropriate atoll development.

- Poor water treatment.

2.1.5. Governance and management issues

There are a number of governance, socio-economic and political issues within the Maldives that reduce the ability of local, atoll and national management of these pressing issues. Perhaps paradoxically, the recent past has seen the Maldives embark on a process to establish more Marine Protected Areas, and to lobby for decreases in global CO_2 emissions. At the same time, there is a push to develop more islands for tourism. There is a chasm between the understanding of political leaders in what constitutes good resource management (e.g. the establishment of MPAs on paper) and the requirements to make them work – for both biodiversity and local communities. This is a problem in the UK as much as it is in the Maldives, and requires extensive interaction between community-based scientists and practitioners with government officials – at the highest levels. Only with this investment – from local individuals being empowered to report on declines, and necessary management implementation (and enforcement), will nations start to recover biodiversity where it has been damaged, and preserve it where it has remained in a good condition during the last 50 years of rapid population expansion. Reasons for poor investment in a working programme to recover Maldives reefs include:

1. Political stability - The Maldives has been through a number of considerable political changes in the past five years, reducing a priority for a coherent marine conservation strategy;

2. Economy - The economy has suffered in recent years leading to a decreased investment in marine science, management and conservation;

3. Heavy dependence on a carbon-based economy - Despite the Maldives lobbying at international Climate Change Congress meetings for reduced CO_2 output on a global scale, there is a heavy reliance from Maldives business on international flights, expensive marine transport of goods and humans, and a tourist industry that consumes large amounts of $CO_{2.}$

4. Rapid environmental degradation that is not being adequately reported - The health of Maldives reefs has declined steeply over the past 30 years since the 1998 bleaching event through introduction of mass-tourism, increased global (and local tourist) markets in reef fisheries resources and increased infrastructure development. This has degraded the natural capital of the islands and the reefs that support local and tourist islands. There has been expansion in resource exploitation to meet the demands of an increased human / tourist population without concurrent precautionary management. This costs money, and the cost should be met (but are not) by the developers that are benefitting from the use of the Maldives – this is effectively the tourist industry.

5. Education regarding the balance of extraction and protection - Many successful measures adopted by natural resource users offer a fallow/closed system where resources are protected for some time before being exploited. This offers natural systems to increase the biomass and abundance of previously exploited species. These species can either be exploited in previously selected ‘fallow’ areas, or permanently protected to ensure spill-over of fish from protected areas to fished grounds, and increased larval export. However, these measures are often difficult to put into place on the ground, particularly if education and awareness of such measures is not part of the national curriculum.

6. Inadequate investment in enforcement - There is a government agency directly responsible for the enforcement of current marine conservation efforts – the Environmental Protection Agency. However, this department is funded directly from the government’s own resources and as priority spending is on other social concerns (such as waste management, island creation and housing), there is little resource available for enforcement of the 25+ Maldivian MPAs. Enforcement is undervalued as a net contributor to the nation’s wealth, because economic returns from such an investment are not easily apparent or quickly attainable. This is not just a problem for the Maldives, but also for the UK, and other developed nations.

In the past, the Maldives has lacked a champion for the protection and recovery of marine resources. However, the Maldives government has recently been making very well intended statements to reverse this trend. In June 2012, Dr Mariyam Shakeela, (then) Minister for Environment and Energy announced a programme of work between 2013 and 2017 in order to achieve UNESCO Biosphere Reserve status for the entire nation. At least half the atolls of the nation will need to implement marine conservation efforts similar to that of Baa atoll. This will require many of the governance problems above to be addressed. There is not a strategy that is being met by the Maldives agencies tasked with dealing with this – such as the EPA or MRC, because government does not understand the requirements to effectively implement this on a national basis. Indeed, recent cuts to the MRC have seen drastic reductions in its staff, and the monitoring team that existed since 2009 has been effectively disbanded. This means that regular monitoring of sites that informed the international community of the health status of Maldives reefs is now only undertaken by outside agencies (such as IUCN and Biosphere Expeditions). And many Maldives citizens have strong scepticism towards western conservation work in their islands. This is likely as a result of ‘foreign’ conservation efforts being considered alongside unsustainable foreign investment in the tourist industry that is at odds with the cultural norms of the nation. This is not ideal, because conservation projects for the Maldives then have to seek investment from foreign trust and grant foundations for long-term (decadal scale) monitoring programmes. It is not easy to ‘sell’ long term monitoring projects funders who like to see ‘new’ projects, and want to see short-term results. For example, the current (‘new’) IUCN funding only covers training of five resorts to be trained over two years of initial funding that will not be able to cover surveillance of sites a long way away from local house reefs. Biosphere Expeditions surveys are carried out on an annual basis, to record conditions at permanent monitoring sites in North Male’ and Ari atolls, and to undertake bleaching recovery surveys. They are relatively cost-effective, but in order to really expand the reach of knowledge of reefs, and their status, we need many more Maldivians to progress Reef Check-style projects, which is why Biosphere Expeditions has a placement programme with the aim of seeding community-based monitoring programmes.

2.1.6. Maldives reef surveys

In order to help the Maldives in facing up to some of these issues, Biosphere Expeditions and the Marine Conservation Society have been developing a survey and training programme. Our aims are to:

- Increase the information base on the status of Maldives reefs in collaboration with local partners (e.g. the MRC / MWSRP / MDA).

- To build capacity in local marine management and resource assessment.

- Provide educational resources at key sites around the Maldives.

- Collaborate with environmentally-sensitive tourism operators and resorts in undertaking reef protection measures, and reef survey assessments.

In order to undertake this we have:

- Undertaken Reef Check surveys at over 26 sites in four years, compiled and quality-assessed the data, and sent it to Maldivian and international coral reef monitoring programmes.

- Trained eight individuals employed in government marine resource assessment surveys, NGOs and from the tourist and diving industry whilst on liveaboard expeditions. We have also undertaken training of 10 individuals (private consultants, resort marine biologists and MRC staff) at the Marine Research Centre in Male' in September 2012.

- Designed, printed and distributed (with the 'Live and Learn' Foundation) over 500 guides on the effectiveness of coral reef conservation to school children.

- Undertaken training in resorts and with local dive operations and have collaborated with resorts to train staff, and provide them with reef resources.

Aims of the 2014 surveys and training using Reef Check

The 2014 surveys were carried out specifically at North Male' atoll sites that have been monitored a year before or just after the catastrophic 1998 bleaching event to:

- Record and compare the condition of the reefs now to 17 years before.

- Record other variables such as fish and invertebrate populations.

- Carry out effort-based transects of the Hulhumale' reef for whale sharks.

- Undertake Reef Check Trainer training for two local people – Shaha Hashim and Rafil Mohammed individuals to allow them to train others in the Reef Check methodology.

Reef Check has been carrying out volunteer dive surveys since 1997 - the International Year of the Reef (Hodgson 1999). It was designed to vastly increase the amount of information of the health status of the world's coral reefs in the absence of funding and manpower to mobilise enough reef scientists to carry out surveys themselves. It has successfully increased the capacity to record the health (and changing health) of reefs and their natural resources (Hodgson and Liebeler 2002). It has been used by tourists to developing countries, but more importantly, has led to increased capacity amongst local populations to record the condition of their own reefs.

Reef surveys have been carried out in the Maldives by Marine Research Centre staff for over 10 years (before and after the bleaching event of 1998) (Zahir et al. 2005), but the opportunity to undertake research on board the extensive liveaboard and tourist islands of the country has not been fully realised. MCS has been carrying out Reef Check with liveaboards since 2005 and trained the Baros Maldives resort in Reef Check survey techniques in 2010. However, training and surveying has been fairly piecemeal up until 2010, only providing data from a few survey locations (Solandt et al. 2009). Reef Check requires surveys to be carried out over relatively flat (<45 degree slope) reef profiles in areas of limited current at between 3 m and 12 m. This limitation often excludes surveys at the most well-known dive sites of the Maldives that tend to be in waters too deep or charged by currents too dangerous to carry out safe line-transect Reef Check surveys. Therefore dedicated survey trips aboard Maldivian liveaboard vessels, such as the ones carried out by Biosphere Expeditions for the purpose of this study, are necessary to realise fully the potential to gather data from a greater range of sites.

2.1.6. Planning & methods

Biosphere Expeditions carries out logistics, health and safety on board the research vessel and recruitment of volunteers. The scientific programme, training and data collection and analysis is led by Dr Jean-Luc Solandt, Reef Check Co-ordinator of the Maldives.

All training was carried out on board the MV Carpe Diem. In-water training was undertaken at Baros and Banyan Tree house reefs in southern North Male' atoll.

The methodology used was the internationally accredited Reef Check method. Reef Check involves three recording teams at each site visited. The first team undertakes a slow swim to record fish populations. The second team undertakes invertebrate and impact surveys. The final buddy pair records the substrate categories. Surveys were carried out at three depths on this expedition: shallow (2-5 m), intermediate (6-8 m) and deep (10-12 m). At all locations a site form was filled in before the divers entered the water, with information on the site, conditions, location and use of the site.

Species, families and categories recorded (so-called indicator species) are determined by Reef Check scientists and advisors because (1) the species or group are of commercial importance (e.g. grouper), (2) the species or group is an ecological 'keystone species' serving a vital function to maintaining a healthy reef (e.g. parrotfish), or (3) the species or group of species are indicators of a declining status of the health of the reef. For example nutrient indicator algae (NIA) abundance on the substrate survey can indicate two things – either nutrient loading in the system or that grazing parrotfish / urchins are low in number. In addition divers on all surveys record the presence / absence of sharks, manta rays, cetaceans, turtles and other unusual megafauna.

Major habitat types and abbreviations used are HC (hard coral), SC (soft coral), RKC (recently killed coral - corals killed within approximately the past year), NIA (nutrient indicating algae - predominantly fleshy macroalgae that are nutrient limited such as *Lobophora*), SP (sponge), RC (rock), RB (rubble), SD (sand), SI (silt), OT(other, such as cnidarians, zooanthids).

2.2. Results

2.2.1. Pre- and post-1998 bleaching results

The first international Reef Check [3] surveys were carried out across the world in 1997, the first IUCN International Year of the Reef. In that year, 60 surveys were carried out at 24 Maldives coral reefs from Faadhippolhu in the north to Mulaku in the south. Baseline data on the live coral cover, sea temperature, surface conditions and principle impacts are available online[4]. Many of the surveys were carried out by Hussein Zahir (then of MRC, now of the LaMer private consultancy).

This expedition visited six sites in North Male' atoll that were first surveyed in 1997 (before the bleaching event) to compare the live coral cover, and to record of the recovery of these sites (Fig 2.2.1a-d). Further sites (initially surveyed in 1997) will be visited on the expedition in 2016 to record the changes to coral cover and any recovery.

Reef Check surveys involve a team of up to eight individuals to record conditions of the site (physical, biological and environmental conditions). A 'site form' is filled in to record key physical and anthropogenic / management attributes of the site. A 'line transect form' is used to record the benthic habitats, and a 'belt transect' is carried out to record fish assemblages, key invertebrates and perceived underwater impacts to the reef. Species and families recorded in the fish and invertebrates categories are keystone species, indicators of overfishing or over-exploitation of reef resources. The Reef Check method has been updated twice in order to capture more distinct categories from around the world. The last update was in 2004. Data is quality assured by the team scientist on site and in California at Reef Check HQ.

Coral Point Count[5] (CPC) software was used subsequently to analyse photoquadrats for dominance of different hard coral life forms. These were either classed as being in *Acropora* or from non-*Acropora* genera. The different life forms include digitate; encrusting; branching, table, foliose, encrusting and mushroom corals. Photos were taken at a height of approximately 2 m off the substrate, covering an area of between 1 and 4 m^2. Photos were taken at approximately 5 m intervals along each transect. 15 random points are then generated on each photo (using the CPC software), and all coral life forms were distinguished, Excel files created that generated a mean cover for each life form category. We also carried out 'CoralWatch'[6] at a number of sites to provide data for this Australia-based project. This project allows volunteers to record the colour of individual coral colonies. The colour of corals provides a very coarse health index of corals and the intensity of zooxanthellae within the coral tissue. Data from these two methodologies are not presented here.

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[3] http://www.ReefCheck.org/
[4] http://www.math.ubc.ca/~hauert/publications/ReefCheck98/sites.html
[5] http://www.nova.edu/ocean/cpce/
[6] http://www.coralwatch.org/web/guest/home1

Figure 2.2.1a. Location of the six 'bleaching recovery' sites resurveyed using the Reef Check methodology in 2014 to the northwest of North Male' atoll. The other sites are the training location at Baros Maldives, and at Banana Reef. The latter is a Marine Protected Area. The yellow line to the bottom right of the atoll represents the transect done twice on 12 September 2014 to attempt to find whale sharks.

Figure 2.2.1b. Location of the 2014 'bleaching recovery' surveys at North Male' atoll.

Finally we carried out an effort-based whale shark transect along the outer Hulhumale' reef to count whale sharks. The survey was carried out for 5 hours between 11:00 and 16:00 on 12 September 2014. No whale sharks were observed during the entire transect.

2.2.2. Bleaching impacts / coral cover

Inner reefs (giris and house reefs)

De Giri – is a patch reef thila that was heavily infested with *Discosoma* (carpet) corallimorphs. In July 1997 (prior to the 1998 bleaching event) at 3 m, the coral cover was at 36.88%. The decline in coral cover is catastrophic from this relatively high coral state to 9% recorded in 2014 and represents a 'phase shift' from a coral-dominated state to corallimorph-dominated. Initial phase shifts after catastrophic natural loss of corals from hurricanes in the Caribbean were first described by Hughes (1994), and are often very difficult to reverse. Post-coral colonisers in the Caribbean tend to be algae, and this community still dominates the reefs of northern Jamaica, over 20 years after the initial catastrophic loss of coral. We assume that *Discosoma* colonised the reef at some point after the initial 1998 bleaching event, and have since become firmly established. A similar benthic community also exists at Adhureys rock to the southeast of Ari atoll, and on the outer deeper margins of the reef at Dega thila to the central west inner part of Ari atoll (Solandt and Wood 2005). The common feature of all 3 of these reefs visited by Reef Check since 2005 is their sheltered natur, and the almost blanket coverage of these very successful corallimorphs – hence their common name, carpet corallimorphs. *Discosoma* was also recorded at very high densities at four locations in Baa atoll (Le Berre et al. 2008). In all reefs where *Discosoma* is present at large densities, it is – in effect – habitat-altering and dominates the substrate (Langmead & Chadwick-Furman 1999, Kurugu et al. 2004). Turbid waters with high plankton and detritus seem to favour corallimorphs growth (Kurugu et al. 2004), which is perhaps why it is only dominant on shallow inshore thilas. It has even been observed to blanket the outer shells of giant clams (both at De Giri and at Dega thila – the latter in the western centre of Ari atoll). In the Caribbean, it has been observed that the dominant predator of corallimorphs are hawksbill turtles. The author has observed hawksbill turtles eating the species at a number of inner atoll thila sites such as Dega thila. Similar observations of hawksbill turtle predation have been observed from the Caribbean (Leon & Bjorndal 2002). It would appear that this is one of the only species that consumes the *Discosoma* which is of concern, because where the corallimorphs are dominant, it needs much greater densities of predators to reduce the carpeting nature of its dominance in order to allow coral recruitment.

1 small grouper, 3 parrotfish, 2 sweetlips were the only commercially or ecologically important fish recorded at the site. There were lots of butterflyfish (30 per 100 m^2) – particularly planktivorous species (rather than benthic feeders), indicating that the reef lies in a rich area for plankton.

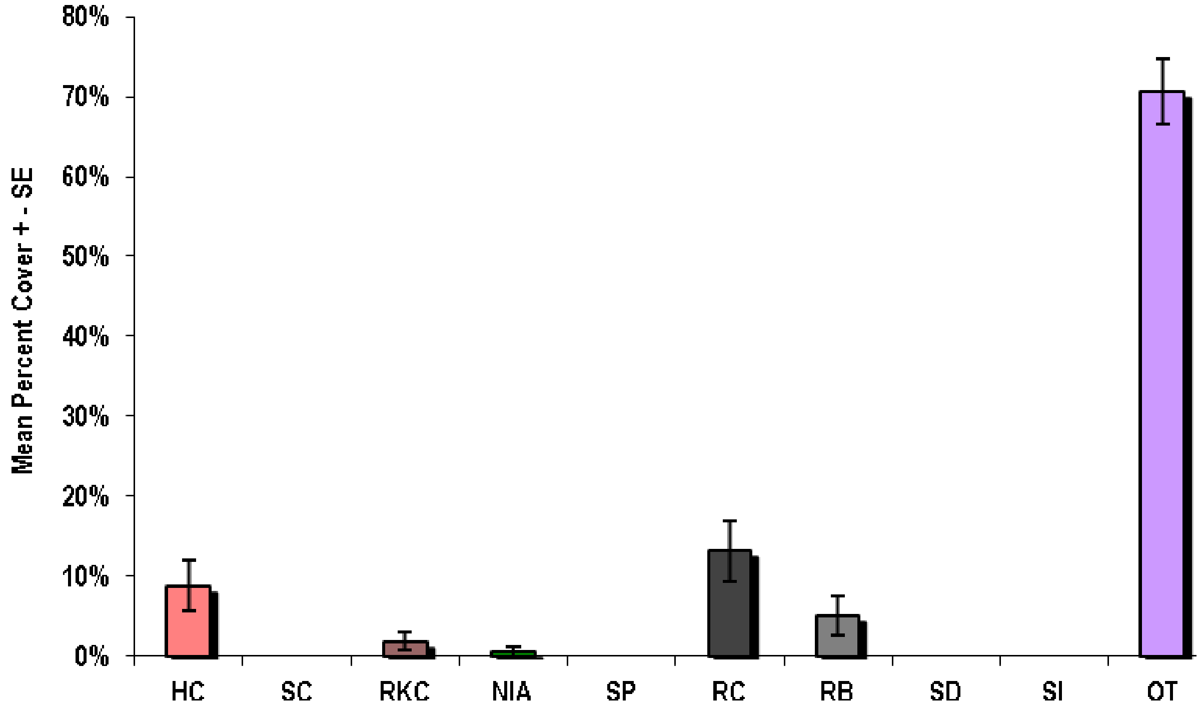

Figure 2.2.2a. De Giri (4 m). (HC – Hard Coral; SC – Soft Coral, RKC – Recently Killed Coral, NIA – Nutrient Indicator Algae, SP – Sponge, RC – Rock, RB – Rubble, SD – Sand, SI – Silt, OT – Other). OT is dominated by Corallimorphs.

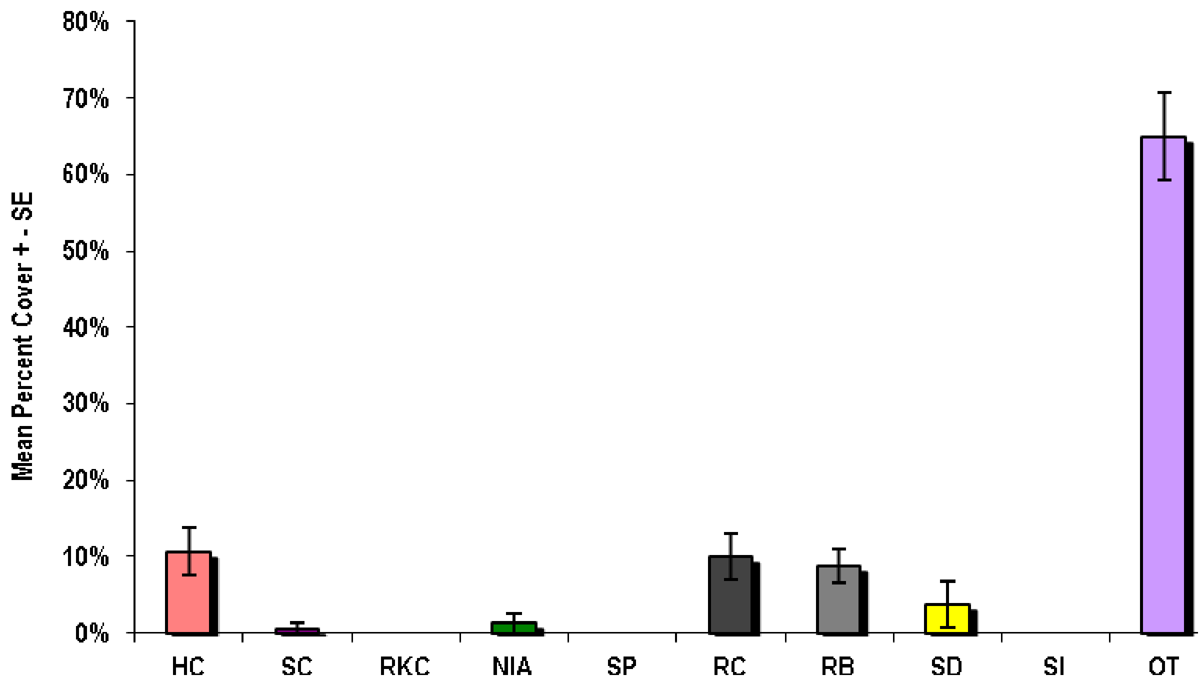

Figure 2.2.2b. De Giri (10m). OT is dominated by Corallimorphs. Principally *Discosoma*.

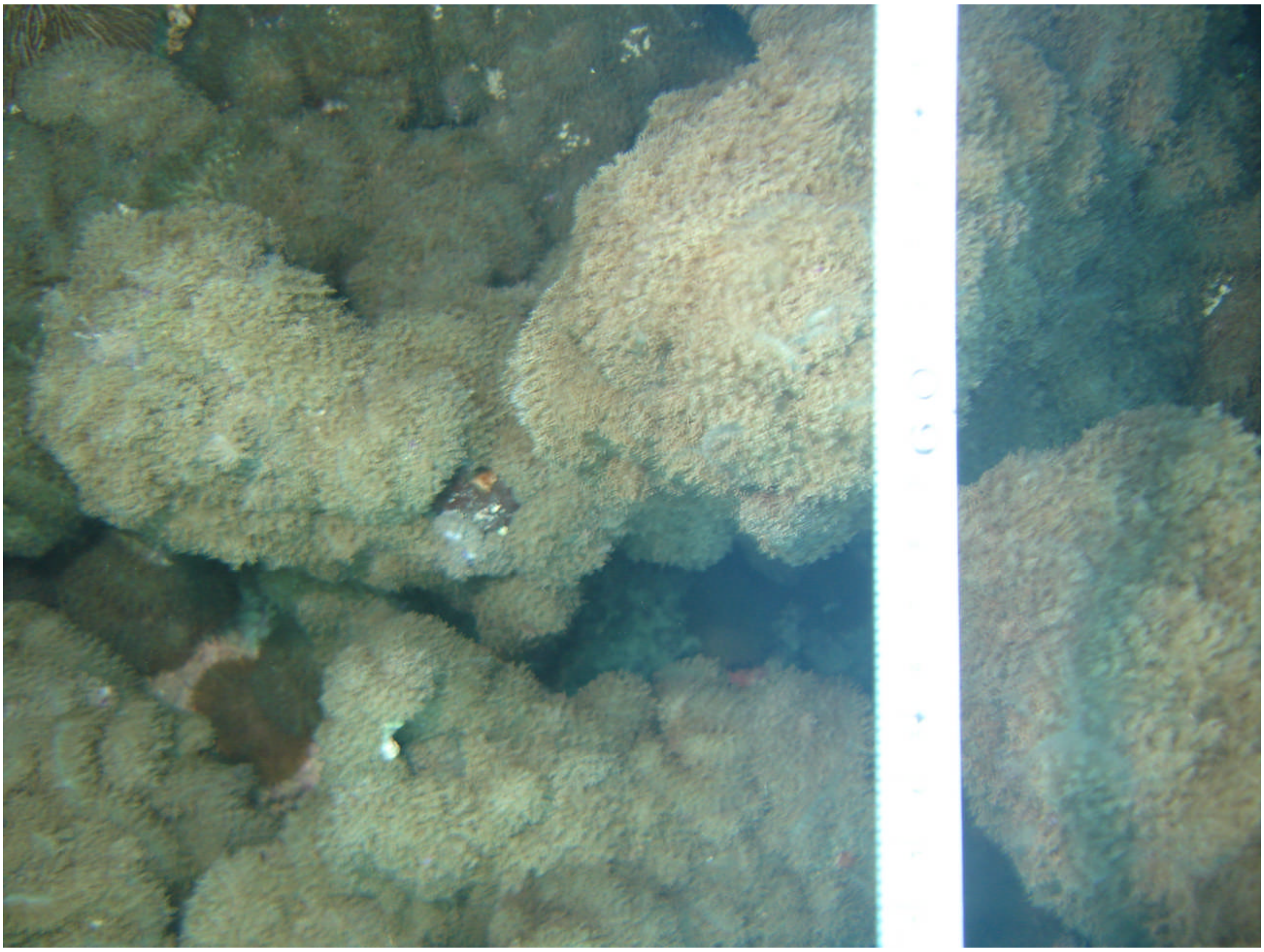

Figure 2.2.2c. De Giri (6m). OT is dominated by corallimorphs, principally Discosoma.
The white strip to the right of the image is the transect tape.

Reethi Faru house reef - was dominated by Crown of Thorns starfish at both shallow and deep transects. The benthic community was much more diverse and dominated by corals than at De Giri (Fig. 2.2.2d). Surveyors counted over 100 colonies on (and adjacent to) this transect that were likely recently killed by COT predation. But the coral community was significantly damaged and under further threat from COT predation and perhaps by bleaching. It is very difficult to distinguish between bleaching damage and COT predation at sites such as these, as both effect similar branching coral colonies and look to the eye to be very similar (white young colonies). Younger Acropora colonies are more susceptible to damage from both causes (bleaching and COT predation). The coral cover recorded during Reef Check dives in August 1997 was 37.5% at 3 m and 26.9% at 10 m. Therefore, at 3 m, the coral cover had decreased by approximately 10%. It will be important to come back to this site in the near future to record the long-term impact of the COT outbreak.

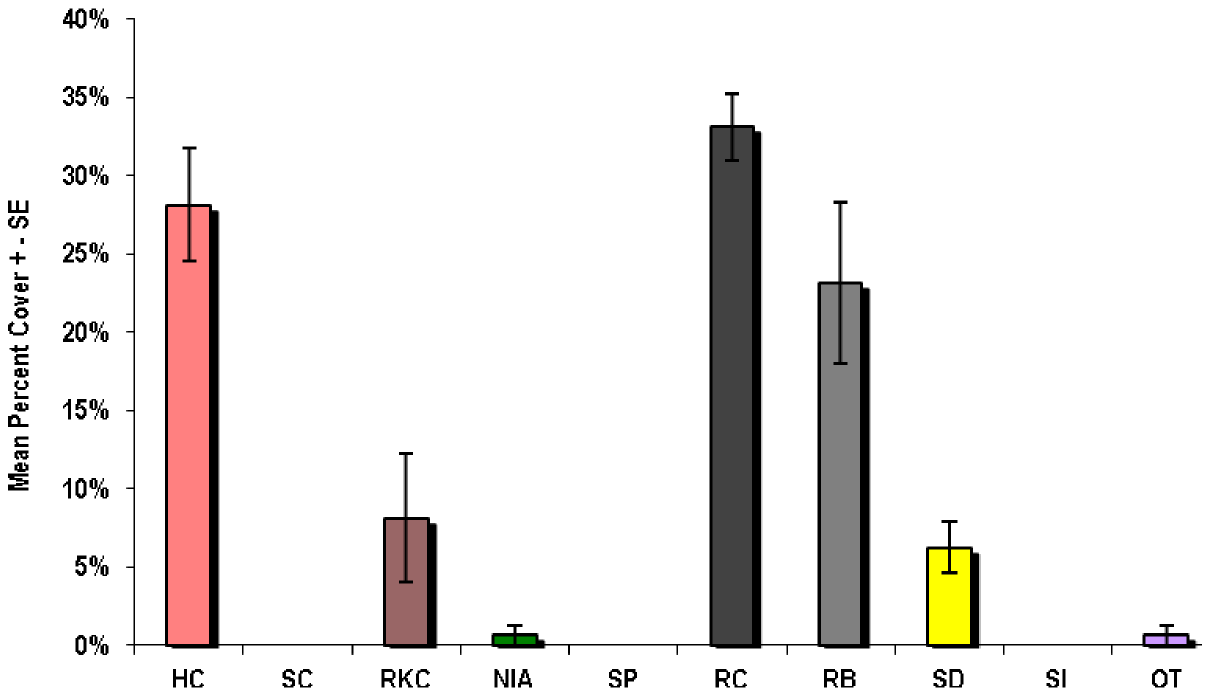

Figure 2.2.2d. Reethi Faru shallow (3 m). The large 'bare rock' percentage is caused by bleaching or COT predation. Similarly, the rather large RKC percentage is likely to have been caused by COT predation in particular. Densities of COTs at this depth were 6.5 animals per 100 m^2.

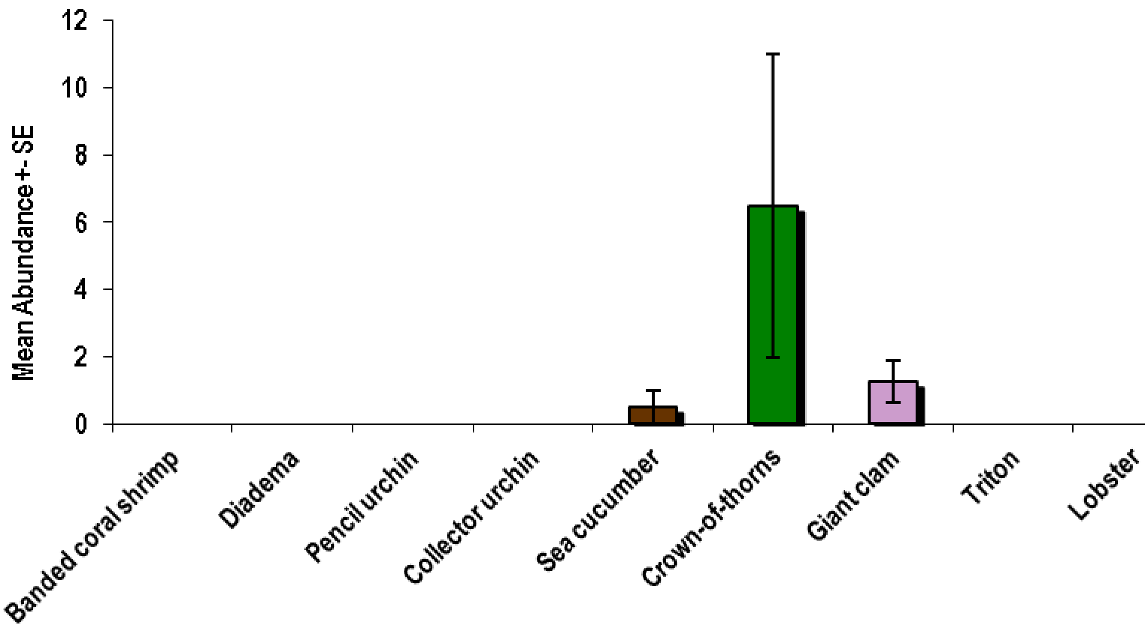

Figure 2.2.2e. Reethi Faru shallow (3 m) invertebrate community (abundance per 100 m^2 replicate). Densities of COTs at this depth were 6.5 animals per 100m^2.

In deeper waters (10 m), the coral cover of 33% was higher than the cover reported in August 1997 (26.9%) (Fig. 2.2.2f). This is an increase of 6% despite the observed bleaching and COT predation. Surveyors estimated that bleaching had affected 10% of the live colonies observed on the transect – at most Maldives sites since 2011, we estimate that this figure is less than 1%. In the vast majority of cases, the bleaching had affected 100% of each colony, i.e. they were completely bleached. Again, the deeper transect was noted for the relatively significant numbers of COTs present, but the percentage of Recently Killed Coral (RKC) was much lower for this depth than for the shallower transect (Fig. 2.2.2c). *Drupella* were also recorded on the transect. Very few commercial (zero groupers, sweetlips or snapper) or ecologically important (e.g. grazing parrotfish) fish species were recorded on the transect.

This is concerning both for the health of the reef, and – in commercial/subsistence terms – for the provision of food for the local population. It is clearly a site that has had its grouper population fished out.

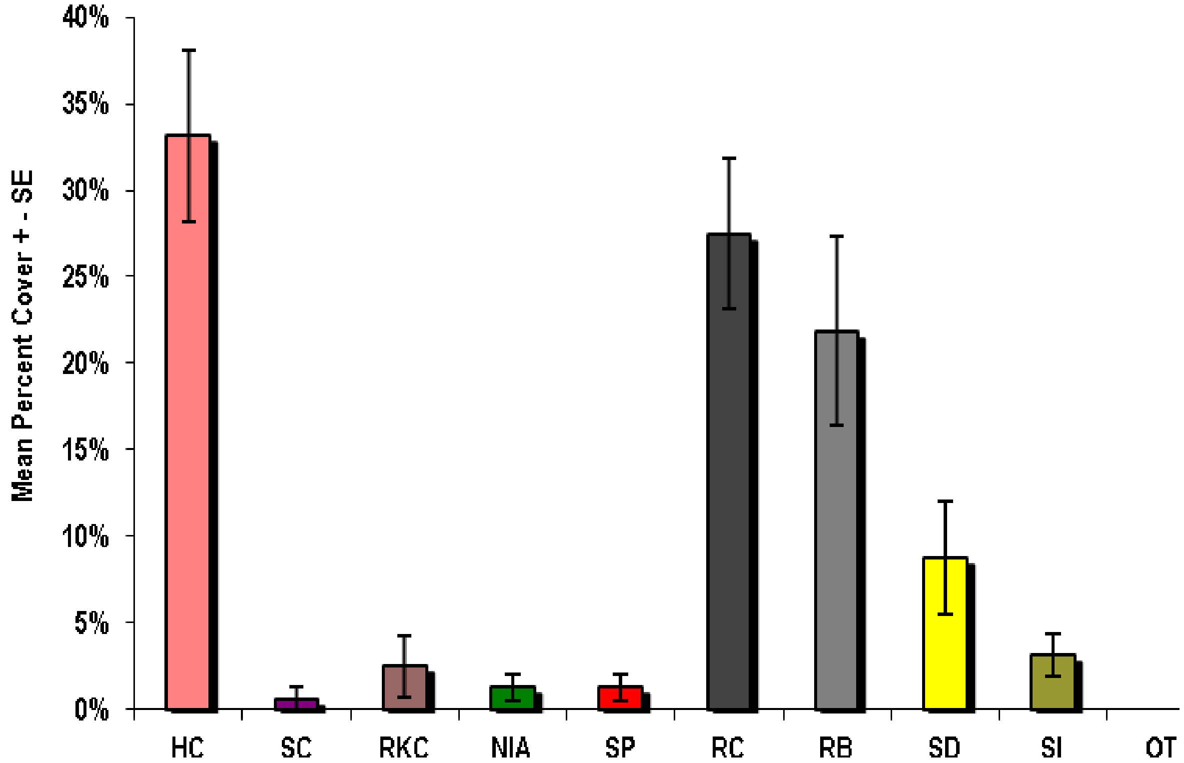

Figure 2.2.2f. Reethi Faru deep (10m). Note the smaller proportion of RKC compared to the shallower transect.

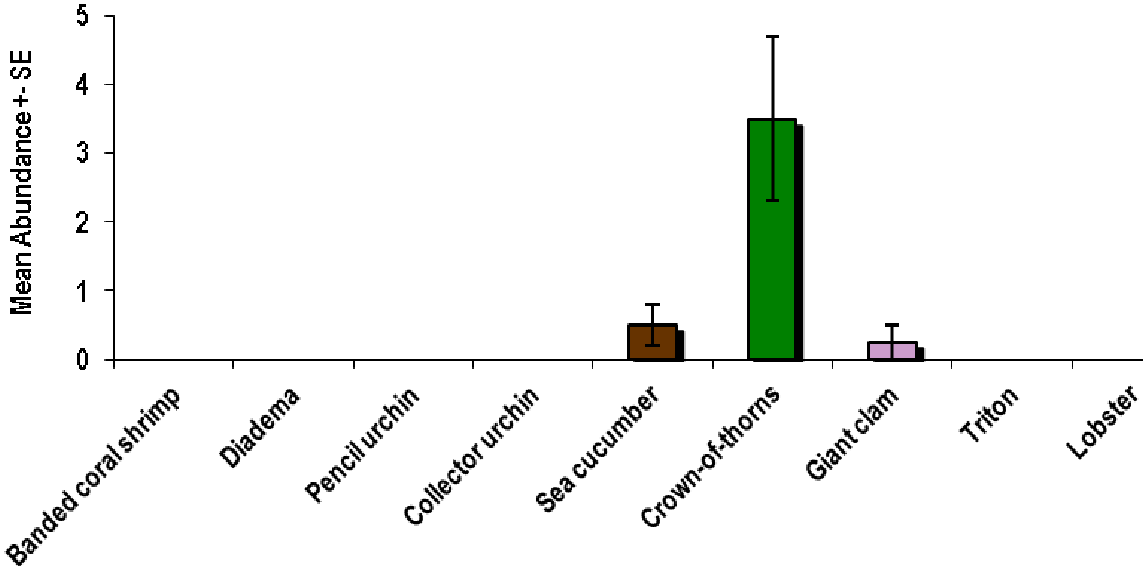

Figure 2.2.2g. Reethi Faru deep invertebrate community (10 m). There is a smaller density of Crown of Thorns per square metre, but the abundance is still considerable compared to past surveys in the Maldives.

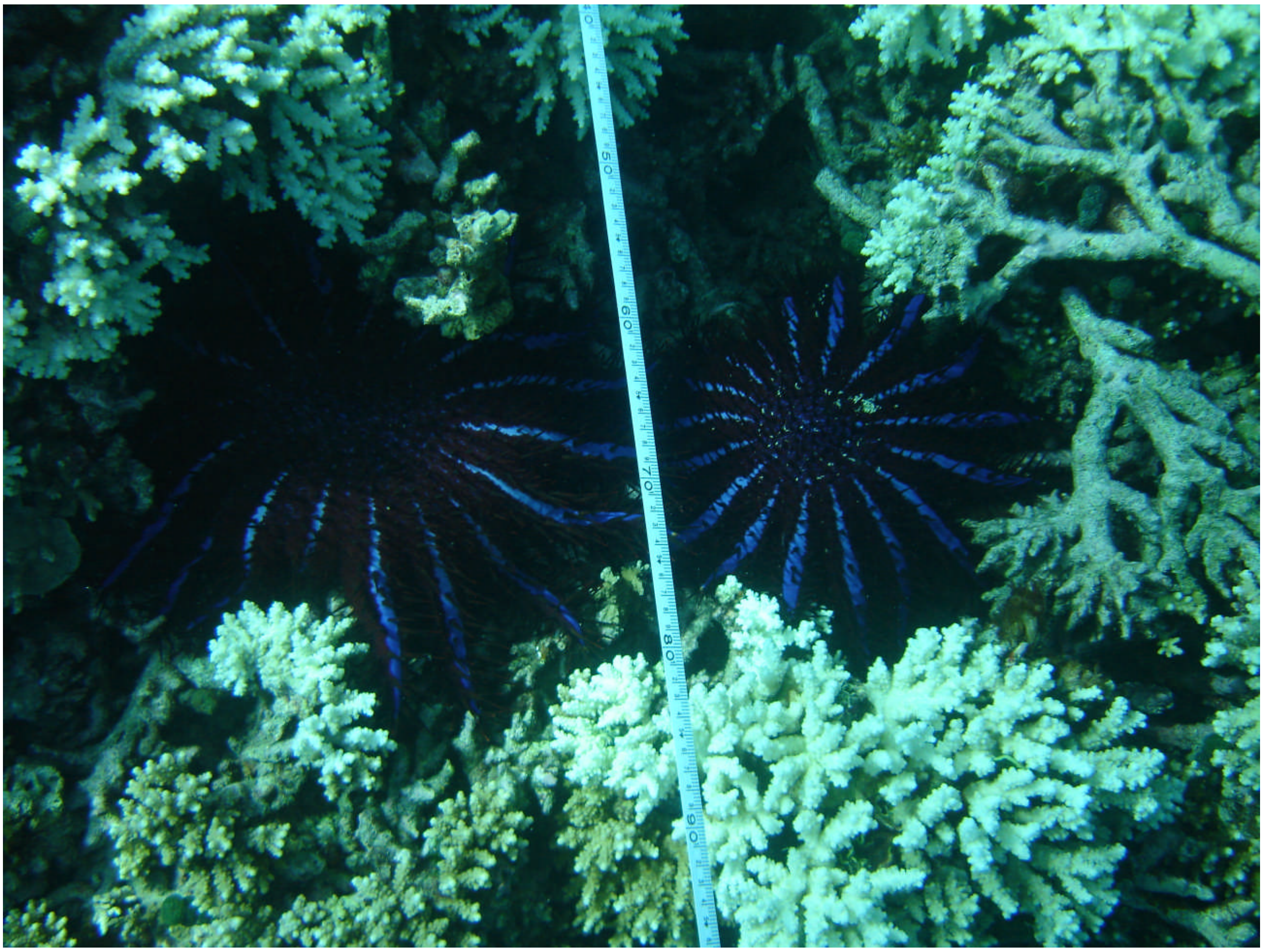

Figure 2.2.2h. Crown of Thorns at Reethi Faru.

Outer reefs

<u>Madi Gaa</u> – Madi Gaa (and Hufi Faru) reefs are on the outer side of the large outer atoll island and receive the full force of the southwesterly monsoons. Madi Gaa in particular is a classic fringing reef facing a longshore current. The shallower reef (from about 4 to 7 m) forms low-lying spurs that lie perpendicular to the north-south orientation of the island (Fig 2.2.2i). The coral lifeforms are dominated by ramose and digitate and small branching forms, largely because of the force of the currents. There appears to be no evidence of disease, bleaching or COT mortality in this area. There is no incidence at all of corallimorphs presence and COTs and *Drupella* are absent. Coral cover at 3 m depth was 39% in August 1997. During this year's surveys, this percentage (at 6 m) was 49% - 10% higher than in 1997. The deeper transect (12 m) has a coral cover of 38% (2014 surveys) that was at 41% in 1997 – an almost identical cover. Rubble at both depths is very low compared to inner reef surveys.

Figure 2.2.2i. Typical habitat at 6 m depth on the forereef of Madi gaa. Note the dominance of smaller growth forms of species such as Porites that can typically grow much larger. Colonies of Pocilipora – both live and dead, and digitate Acropora can be seen in the foreground of the image. The 'spur' of this image runs from the bottom left corner to centre right. A 'groove' dominated by sand can be seen to the centre-right of the image, where coral rubble and sand settles out in these wave-affected environments. There was almost a total lack of bleaching, predation or disease observed on both shallow and deep transects.

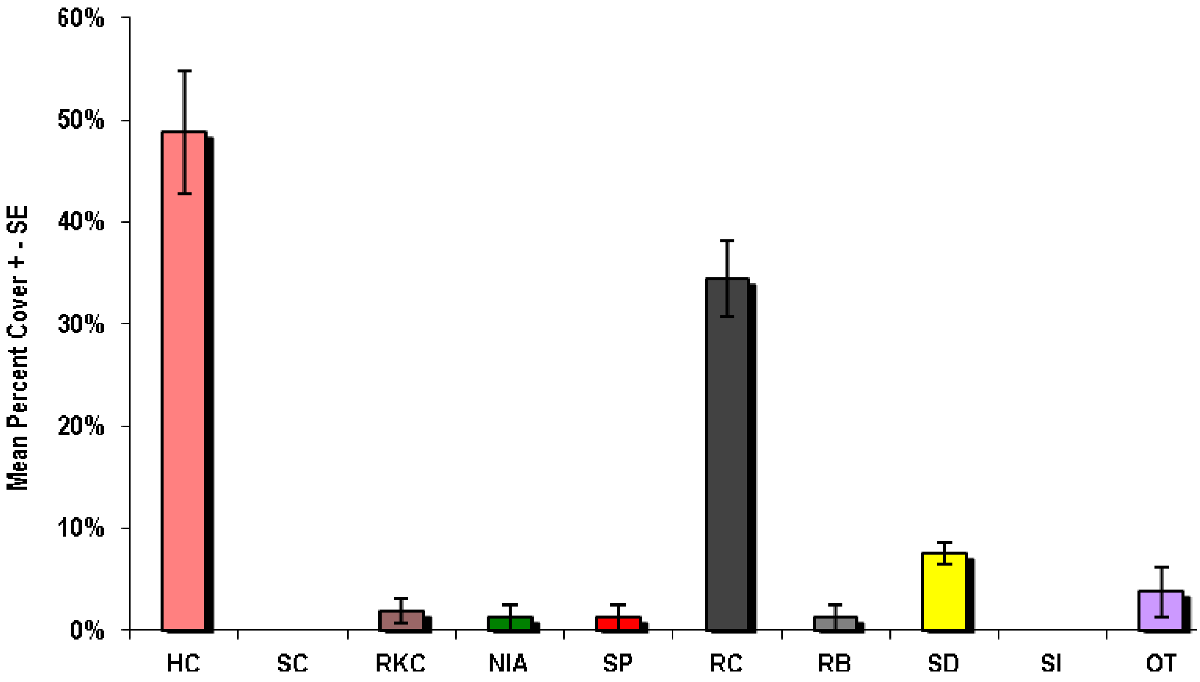

Figure 2.2.2j. Madi gaa shallow (6 m) substrate.

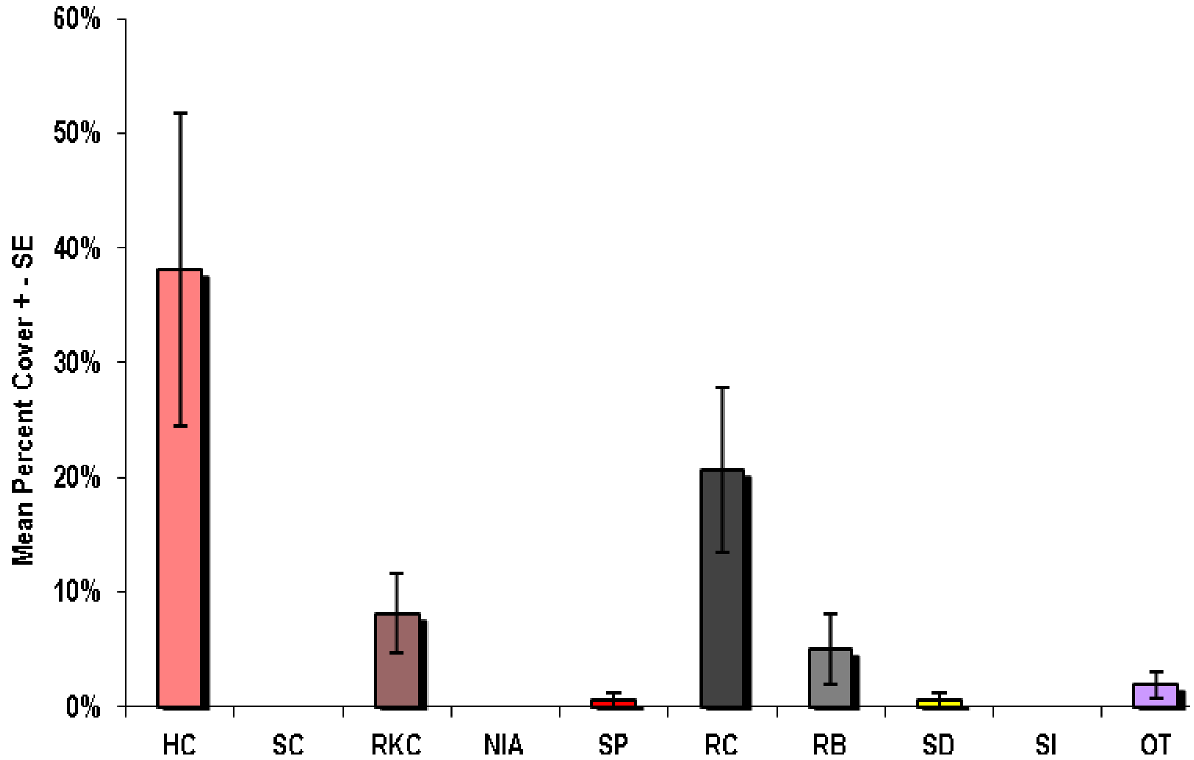

Figure 2.2.2k. Madi gaa deep (12 m) substrate.

Snapper, parrotfish, and grouper were recorded at all sites. Four dogtooth tuna and two whitetip reef sharks were also recorded at the deeper transect.

Hufi Faru – had less 'spur and groove' than Madi Gaa. However, the coral lifeforms were similar, with more robust coral lifeforms dominating the substrate than at inner reef sites (Fig. 2.2.2l). The shallow transect (2014 data) had a coral cover of 40%, whilst in 1997, coral cover was 29.38%. This is an 11% increase in coral cover. At the deeper transect, the coral cover (2014) was 41%, whilst in 1997, the cover was at 51.25%. This represents a decrease in live coral cover of 10%.

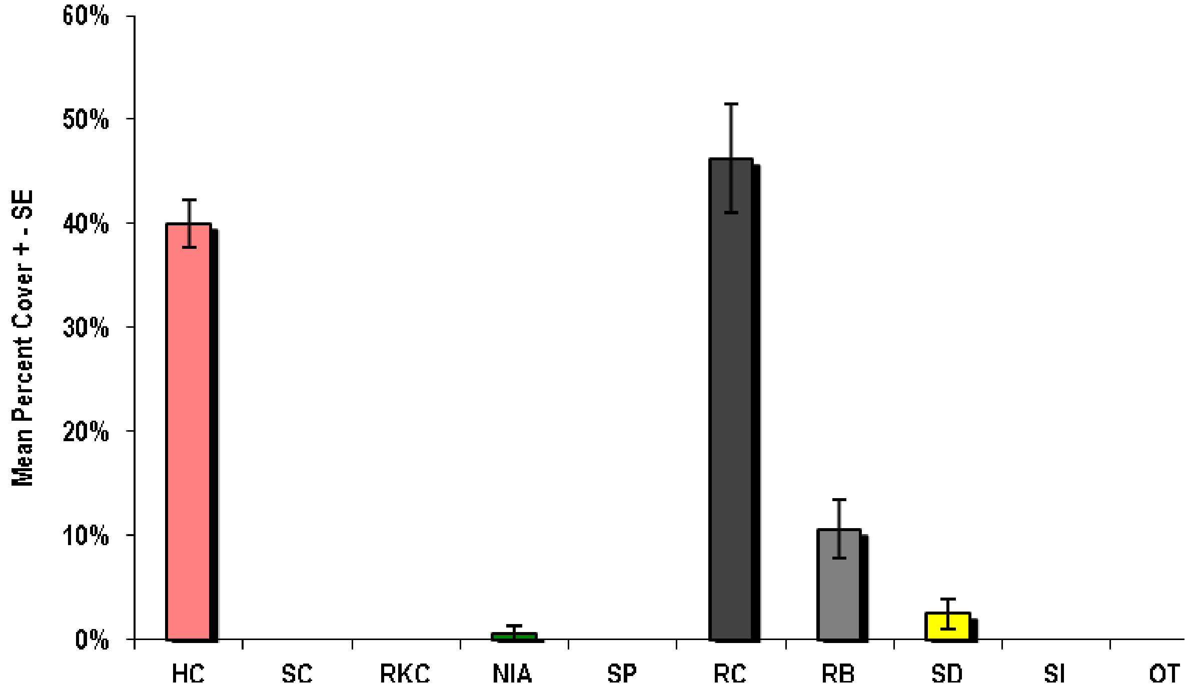

Figure 2.2.2l. Hufi Faru shallow (5 m) substrate.
Note the high coral and rock cover. Rubble is relatively low compared to inner reef sites.

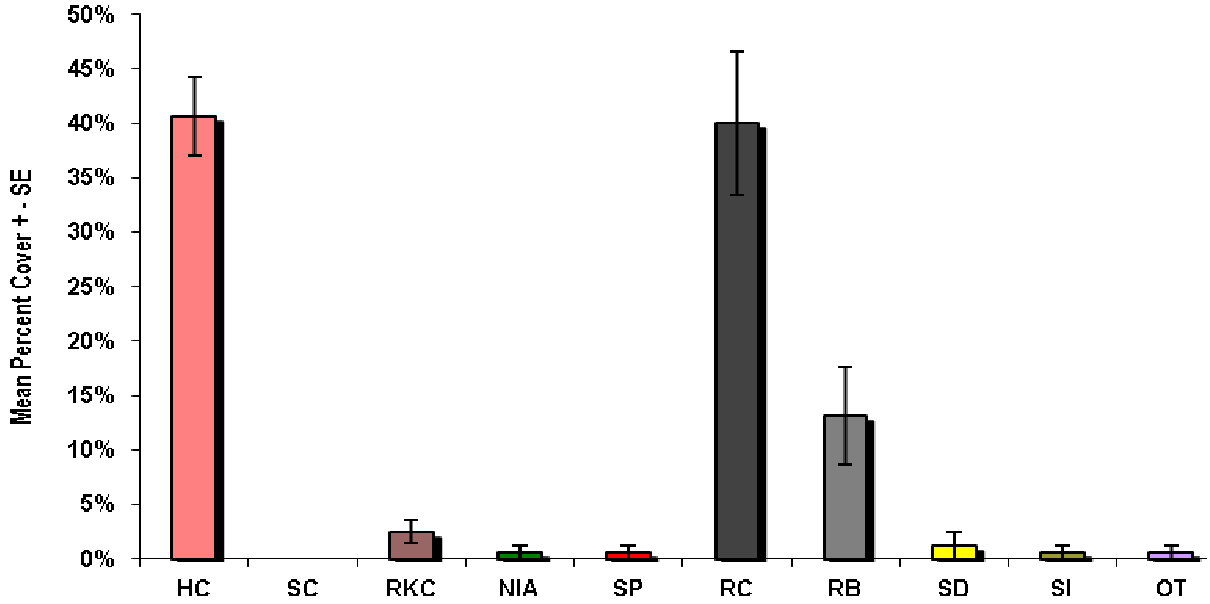

Figure 2.2.2m. Hufi Faru deep (9 m) substrate. Note the high coral and rock cover.

Channel reefs

Kuda Faru – was in the northern section of the large channel to the northwest of North Male' atoll. This was a rich reef complex and the survey took place slightly in the lee of the current entering the atoll. [NB. coral cover results are not a true reflection of the change in coral community cover over time, as the transect was undertaken in a different location to the GPS position in 1997 in order to ensure diver safety.]

Coral cover during the current (2014) survey at 5 m was 34%. At 3 m in July 1997, the cover was 25% (Fig. 2.2.2n). At 10 m during the current survey, coral cover was low at 11%, whilst in July 1997, it was much higher at 29.4% (a 18% decline in live coral cover). The greatest substrate category at the deeper depth in 2014 was of rubble (40% of the substrate cover). Rubble is often an indicator of past disturbance, particularly as the site is on a relatively steep slope and is exposed to southwesterly waves and winds. There was strong evidence of considerable damage from triggerfish predation (triton and yellowmargin) from fresh feeding scars within live or dead coral that have distinct small hollows made by boring molluscs – the boring molluscs is the food that the triggerfish are hunting. There were occasional colonies impacted by *Drupella* predation, with six recorded on the shallow transect.

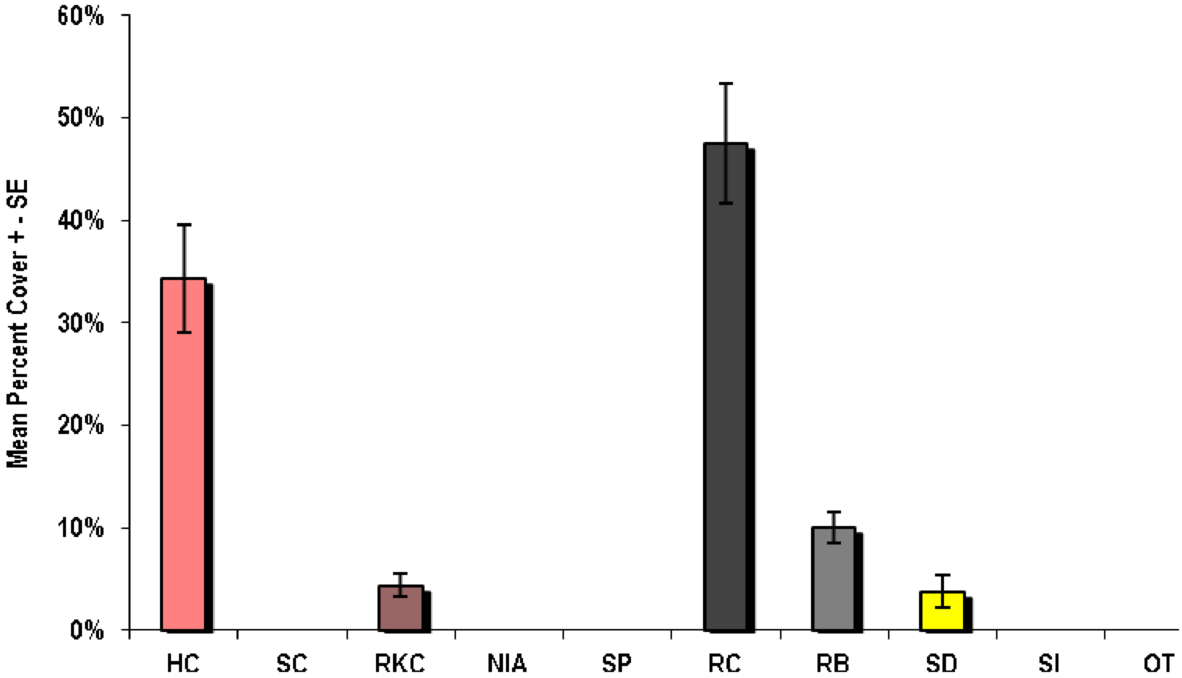

Figure 2.2.2n. Substrate categories at 5 m, Kufa Faru.
Note that rock and hard coral combined results in 80% of the substrate.

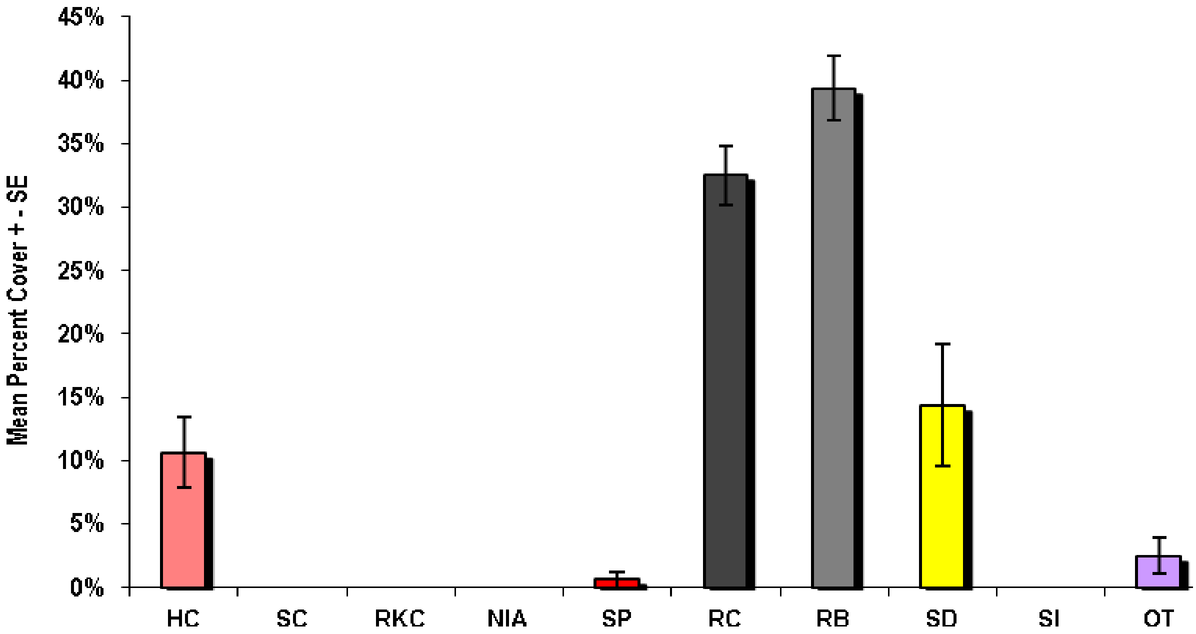

Figure 2.2.2o. Substrate categories at 12 m, Kuda Faru.

Fish populations at the site were richer than at other sites, indicative of the site being located in a channel. There were many medium level omnivores (snapper), with a mean of 5.25 per 100 m^2 of the reef. An average of six parrotfish and 0.75 grouper were recorded in the same area. Two humphead wrasse, one whitetip reef shark and six eagle rays were also observed off transect on the shallow dive. The deeper transect had one sweetlips and grouper per 100 m^2. An average of 3.75 parrotfish were also recorded on the transect.

Weng gaa - is a slightly more sheltered reef than Kuda Faru. The survey took place on a straight reef edge that lay in an east-west orientation. Coral cover at 5 m (2014 surveys) was 31% (23.1% in July 1997 at 3 m) (Fig. 2.2.2p). Twelve colonies were recorded with *Drupella* colonies on them. At 5 m bleaching was minimal (affecting less than 1% of the live coral population – a similar low figure was recorded for Kuda Faru). At 10 m (2014 surveys) coral cover was 29% (Fig. 2.2.2q). In 1997, this figure was 45%. This represents a reduction of coral of 16%. Rubble at 10 m is 18% in 2014 surveys, indicating that there has in the past been some incidence of damage to corals.

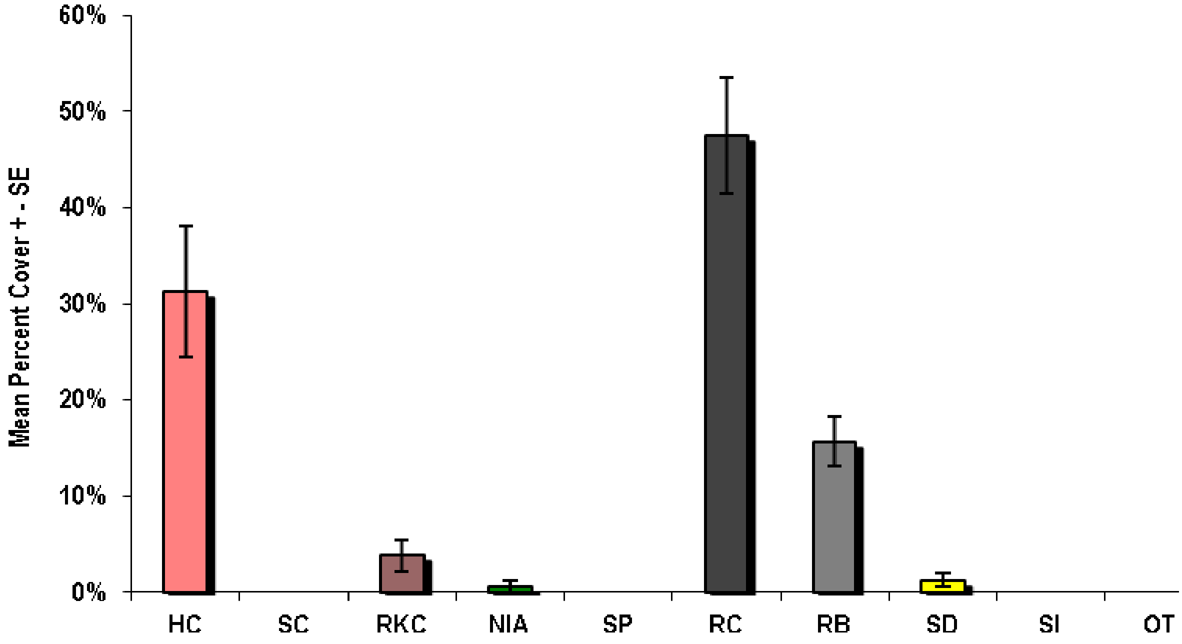

Figure 2.2.2p. Weng Gaa reef (3 m). Benthic cover.

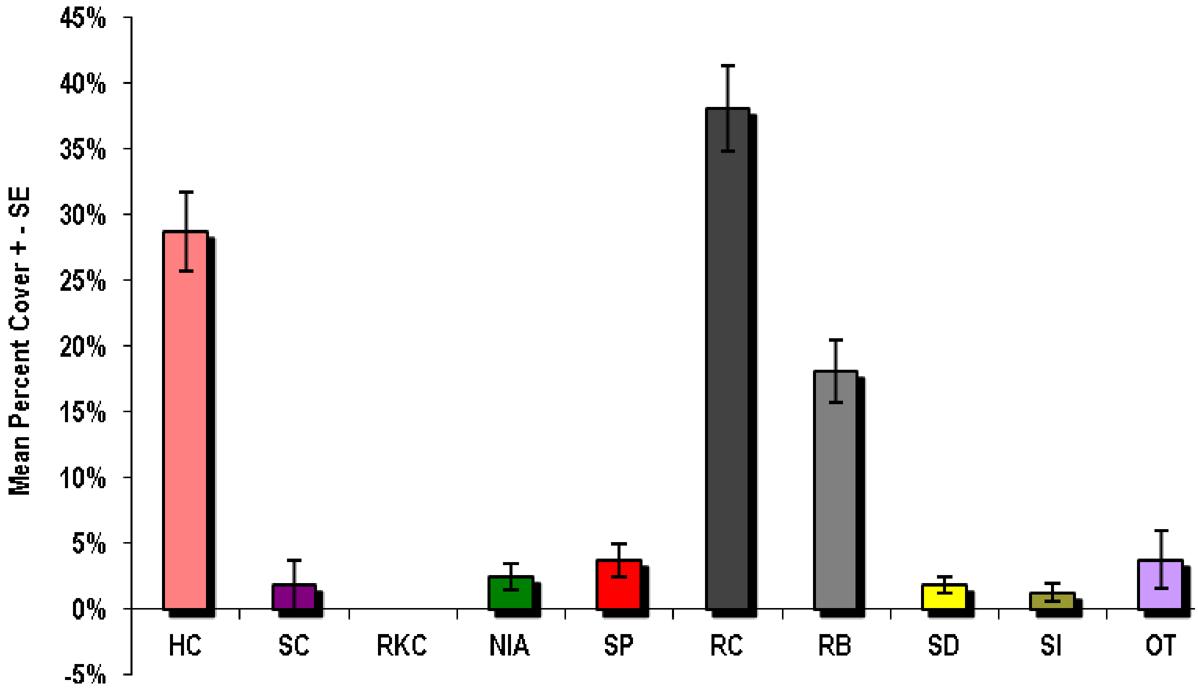

Figure 2.2.2q. Weng Gaa reef (10 m). Benthic cover.

Bleaching recovery meta-data

Table 2.2.2a. Summary of observed coral cover (1997 and 2012 for sites in Ari atoll)

Site	Depth (m)	1997 ('98 for *Vilamendhoo)	2012	Change (%)
Ellaidhoo house reef	3	50.6	33	⇩ (17.6)
	8	34.4	21	⇩ (13.4)
Angaga Northeast	3	49.4	61	⇧ (11.6)
	12	26.9	46	⇧ (19.1)
Angaga Southwest	3	44.7	43	⇩ (1.3)
	12	40.5	60	⇧ (19.5)
Vilamendhoo*	3	5.6	44.5	⇧ (38.9)
	10	6.9	26	⇧ (19.1)

*Vilamendhoo was first surveyed within three months of the 1998 Jan-March bleaching event. All other sites were surveyed pre bleaching (1997) and in 2012, 14 years after the bleaching event.

Table 2.2.2s. Summary of observed coral cover (1997 and 2014 for sites in North Male' atoll).
Habitat T – Thila; O – Outer reef; C – Channel reef.

Site	Habitat*	Depth (m)	1997	2014	Change (%)
De Giri	T	3	36.9	9	⇩ (27.9)
Reethi Faru	T	3	37.5	28	⇩ (9.5)
		10	26.9	33	⇧ (6.1)
Madi Gaa	O	6	39	61	⇧ (22)
		12	41	38	⇩ (3)
Hufi faru	O	3	29.4	40	⇧ (10.6)
		12	51.3	41	⇩ (10.3)
Kuda faru	C	5	25	34	⇧ (11)
		12	29.4	11	⇩ (18.4)
Weng gaa	C	3	23.1	31	⇧ (7.9)
		10	45	29	⇩ (16)

The overall pattern from the two years of post-bleaching monitoring is of little discernable difference in overall cover when averaged across all sites. Of the sites and transects where coral cover has decreased, it has gone down by 13.04% on average with a range of 27.9 (De Giri) to 1.3 (Angaga, in central Ari atoll). Of the sites where coral cover has increased, the greatest increase is at Vilamendhoo where the coral cover post bleaching was under 10% at both depths. This increased in 15 years considerably, with the shallower depth seeing an *Acroporid*-dominated habitat reach 39% cover.

Variance between reef types

The variance in patterns of recovery appears to be somewhat different between reef types and atolls. It would appear that inner atoll (thila) reefs of North Male' are worst affected, with better recovery seen at outer and channel *shallow* reefs. It also would appear that the deeper reefs of more exposed channel and outer reef sites suffer more than shallow reefs. We have postulated in previous survey reports (Bento and Hammer 2012, Solandt and Hammer 2014, Solandt et al. 2013) that the bleaching may have resulted in dead coral colonies eventually eroding and falling with gravity and the occasional storm into slightly deeper waters where they settle out. These coral fragments are then slowly continually eroded by tide, swell, wave action, and boring organisms. However their unstable nature at the slightly deeper depths of sheltered reefs makes recruitment of deeper areas more problematic in the medium to long term, as there is less rock available for recruitment.

The incidence of significant populations of *Discosoma* on some shallow reefs is also a cause for concern. It would appear (from the literature) that this species is more inclined to colonise areas of higher concentration of nutrients or plankton. We have observed carpets of the species only in inner atoll reefs whilst outer and channel reefs do not appear to be as seriously affected by the species.

Will 2015 be a big or small El Niño?

There are concerns at the time of this report being written that another El Nino is being tracked around the globe[7] (Fig 2.2.2r). Signals were for an El Nino in 2014, but this did not transpire to shift conditions enough to stimulate a strong event. This year, there has been a hotspot circulating around the Maldives and the Great Barrier reef has had extremely high thermal stress in early 2015. The eastern Australia 'wet' rainforest area has suffered with very low rainfall over the past year. Seawater temperature, current and wind data loggers in the Pacific are showing a slowing down, heating and easterly shift of warm surface waters, so El Niño is officially happening – it is now simply the intensity that needs to be anticipated and recorded.

Mumby et al. (2011) developed a model that used mapping tools such as Google Earth to plot the 'bleaching risk' indicators over the map of the Maldives (Fig. 2.2.2s). Although this is a particularly coarse tool (called Bleaching Risk Assessment Tool – BRAT), it is useful in that it allows reef managers to look at areas that have been particularly susceptible to increased SST (sea surface temperature) and, just as importantly, areas where the 'degree heating weeks' (periods when SST is above the normal mean seasonal maxima) was high, based on the 1998 bleaching event. This gives reef managers an important coarse view to observe areas that are more or less likely to be bleached over the long term, or alternatively are resilient (still healthy) in the face of the stress associated with ocean warming. This is important because of the inability for surveys such as Reef Check to visit all areas of the Maldives to report on national bleaching events. The BRAT tool indicates that the western central part of North Male' atoll has 'red' risk reefs, where there has been both a build-up of longer term (chronic) areas of higher sea surface temperature, and was this synergistically combined with increased 'degree heating weeks' (Fig. 2.2.2s).

[7] http://www.newscientist.com/article/dn27509-extreme-el-nino-expected-to-wreak-havoc-on-weather-this-year.html#.VVNQxZMYHGc

The latter is associated with mass bleaching such as the 1998 event. It is clear that from our own surveys that the inner atoll thila reefs of North Male' atoll are generally of lower quality than those of central Ari atoll that have healthier reefs.

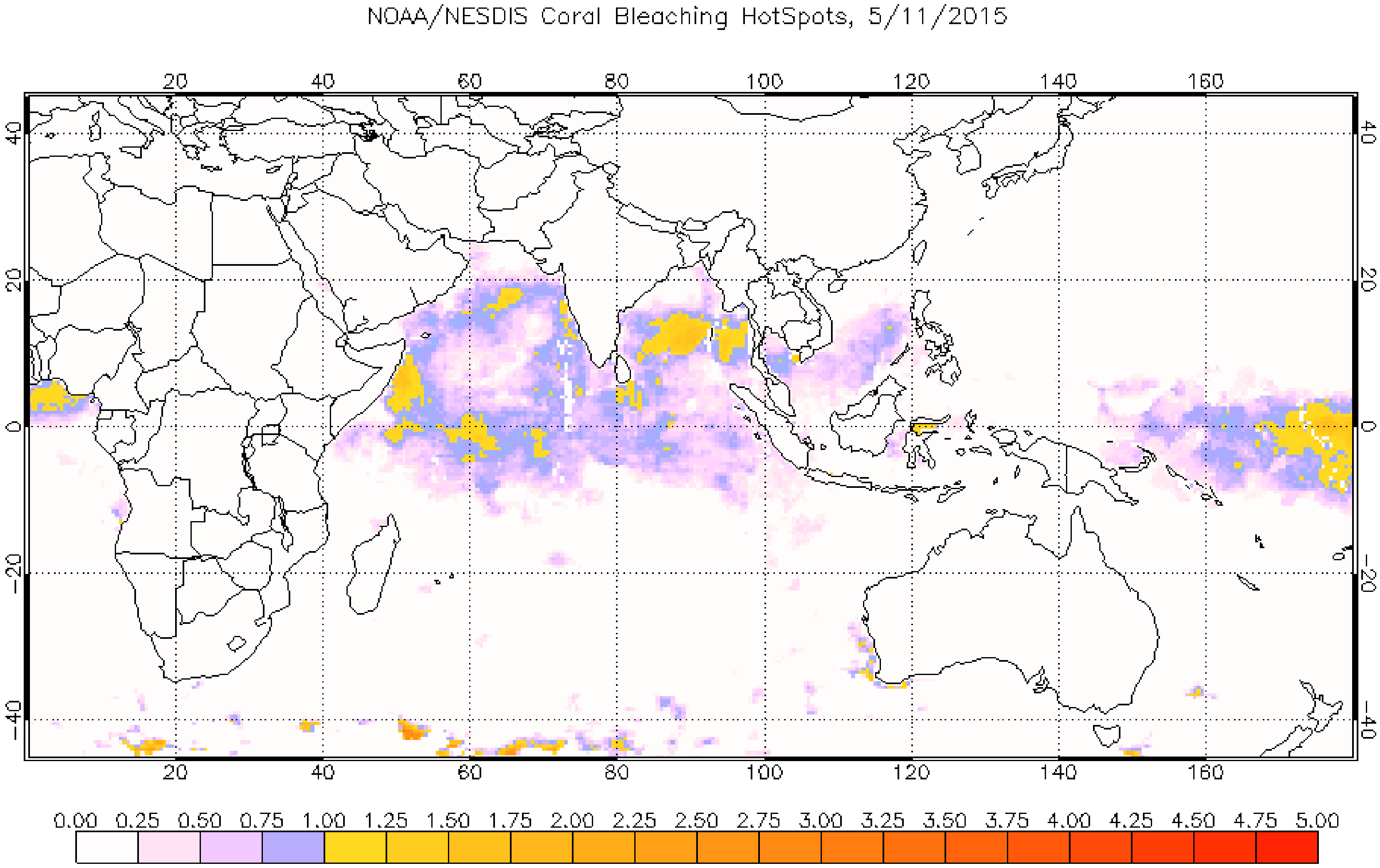

Figure 2.2.2r. Bleaching 'hotspots' from the NOAA bleach watch website.

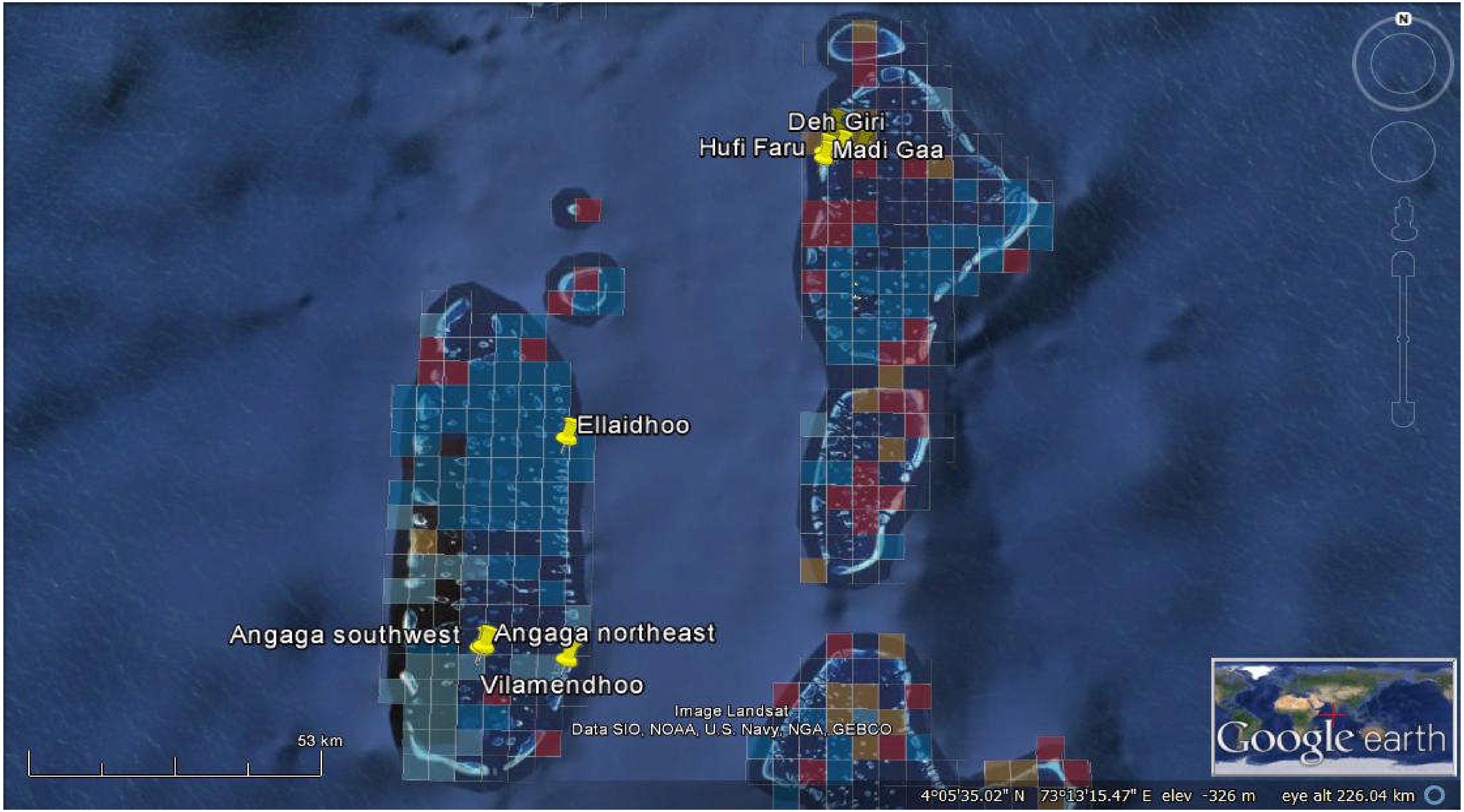

Figure 2.2.2s. Bleaching 'hotspots' from the 'Bleaching Risk Assessment Tool (BRAT) for the Maldives for sites visited in 2012 (Ari atoll to the southwest) and sites visited in 2014 (North Male' atoll (concentrated sites in the northeast)). This Google Earth product has been designed by the Marine Spatial Ecology Lab of the University of Queensland. Red: High acute (degrees heating weeks) and chronic (sea surface temperature) stress. Amber: Low acute and high chronic stress. Dark Blue: High acute and low chronic stress. Light Blue: Low acute and chronic stress.

Figure 2.2.2t. Bleaching 'hotspots' from the 'Bleaching Risk Assessment Tool (BRAT) for the Maldives for sites visited in 2012 (southwest Ari atoll), There is considerably lower 'stress' associated with sea surface temperatures and degrees heating week models for this part of the Maldives compared to North Male' (see below). See Fig. 2.2.2s for colour codes.

Figure 2.2.2u. Bleaching 'hotspots' from the 'Bleaching Risk Assessment Tool (BRAT) for the Maldives for sites visited in 2014 (northwest North Male' atoll). According to distribution of sea surface temperature and degree heating weeks, North Male' atoll is subject to much greater temperature stress than south and central Ari atoll. See Fig. 2.2.2s for colour codes.

2.2.3. Surveys of an MPA - Banana Reef

The expedition undertook a further survey at Banana Reef MPA very near to Hulhumale' in the south of Male' atoll. This was last surveyed in 2010 by Dr Solandt and staff members of Baros Maldives. Surveys were carried out along the western edge of the reef at the end of the expedition just prior to the whale shark surveys.

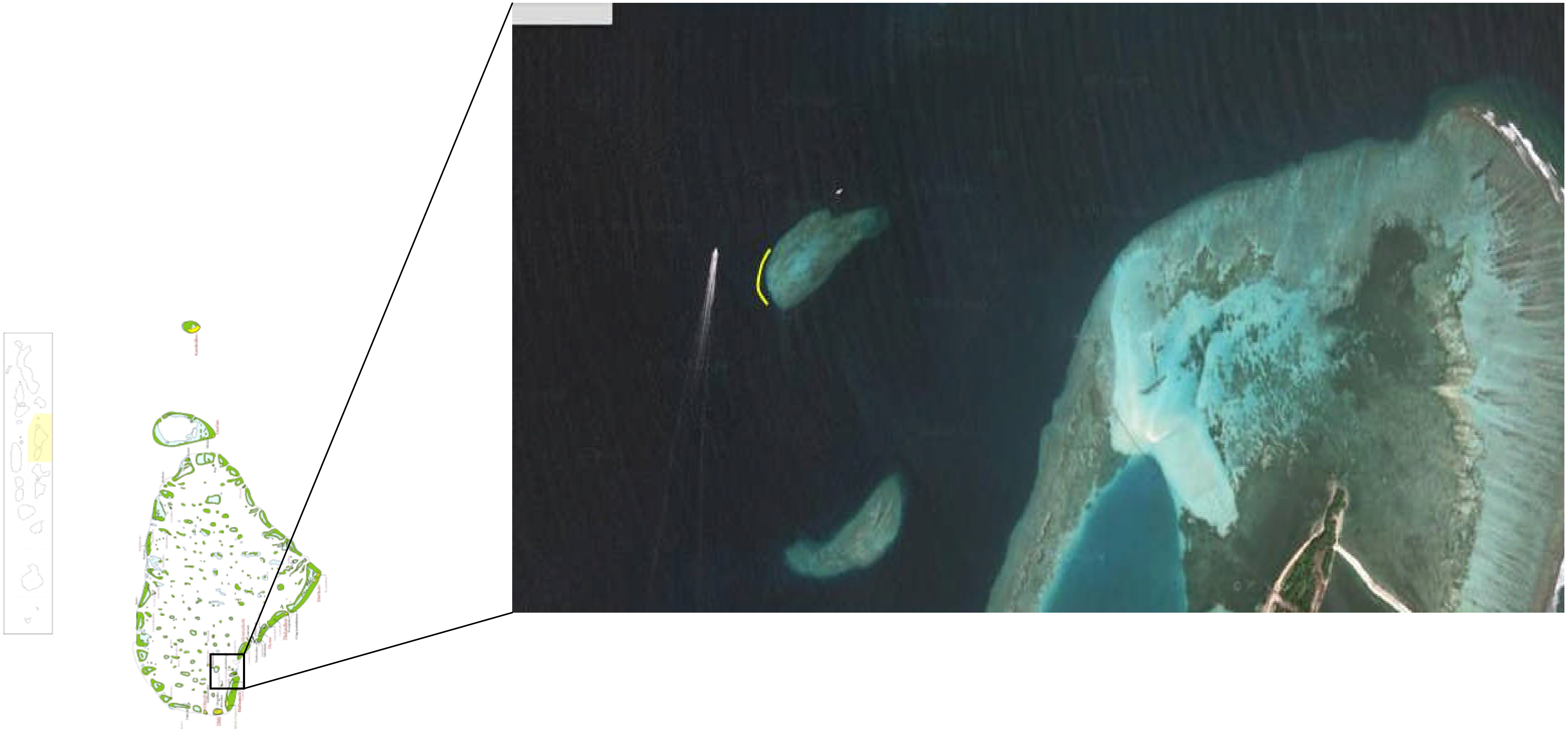

Figure 2.2.3a. Location of Reef Check survey to the west of Banana reef. Banana reef lies to the southeast of Male' atoll.

Surveys there showed coral cover to be low and (for an MPA) the fish populations (on the west side) were also low. As the transect runs along a wall, it is not an ideal habitat for scleractinian coral reef growth. This site was selected to elucidate fish populations of the site, as it is an MPA. However, only two snapper, and six moray eels were recorded along the transect, with no reports of grouper. Many of the larger species of fish swam deep of the transect (including grouper and trevally), and therefore were not recorded. Both fishing nets and line were recorded on the transect clearly indicating that the MPA is regularly fished. Much of the fishing material was clean, indicating that it has been used recently, in disregard of the MPA status. There was no bleaching or disease at the site. Large numbers of large parrotfish were observed off transect at the end of the dive along the top of the reef (Fig 2.2.3c), where the conditions for growth of ephemeral algae are good.

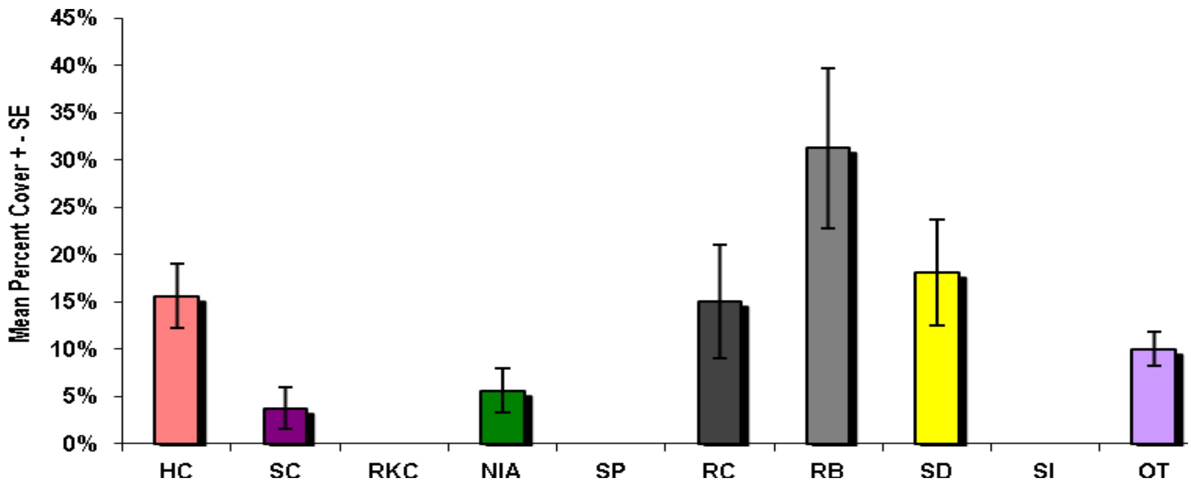

Figure 2.2.3b. Substrate characteristics at Banana reef. Note the large proportion of rubble. Survey was carried out at 5 m along the edge of the drop-off. In 2010, the last time this survey was carried out in almost the same place, coral cover was 38%.

Figure 2.2.3c. Mature phase parrotfish photographed at the end of the survey at 6 m.

2.2.4. All-Maldivian Reef Check survey of South Male' reefs
By Rafil Mohammed, Dive Association of the Maldives

Following their participation in the placement programme, during which Rafil Mohammed and Shaha Hashim were trained to Reef Check EcoDiver Trainer level, they both started to develop their own Reef Check surveys and training. This resulted in a survey of Velassaru reef, 14 November 2014 (Fig. 2.2.4a), which was the first-ever community-based Reef Check survey initiated in the Maldives (Fig. 2.2.4e and press release).

Both shallow and deep surveys were carried out. The survey jointly was organised by Gemana NGO, Divers Association of Maldives and Dive Desk, supported by the Maldivian Whaleshark Research Programme and Save the Beach Maldives.

The survey covering fish, invertebrate and substrate components was carried out at 9 m and 5 m depths.

Hard coral cover at both depths was high (mean 41%). There was also a high incidence of rock (mean 36% at 9 m and 50% at 5 m), which would favour new coral recruitment (Fig. 2.2.4b).

Ascidians were common (mean cover 10% at 9 m and 3% at 5 m), which indicates that there has been some colonisation of the dead corals by these opportunistic animals.

No disease or Crown of Thorns feeding scars were observed and there was only one case of Recently Killed Coral. There was also almost no bleaching and no coral-eating *Drupella* snails.

Parrotfish and other herbivorous species keep algal growth in check (Fig. 2.2.4c).

There were very low grouper numbers, which indicates overfishing. This observation was supported by the high number of fishing lines recorded.

No Reef Check indicator invertebrates, expect for a few giant clams (10-20 cm), were seen, which is another indicator of overfishing.

Whilst the benthic cover looks promising on Velassaru Faru, there are some serious concerns. The most concerning is overfishing. It would appear that the proximity of this reef and the Banana reef MPA above Male' increase the incidence of fishing gear (and hence fishing effort) seen at the site.

Figure 2.2.4a. Location of Velassaru reef surveys, South Male'.

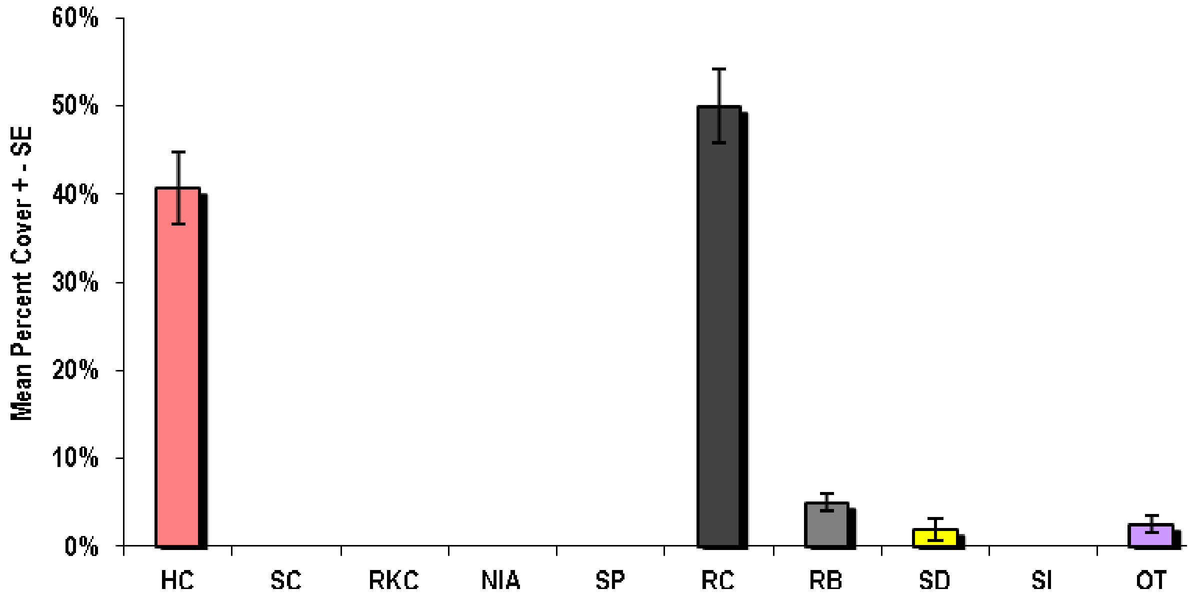

Fig 2.2.4b. Benthic communities at Velassaru reef, November 2014 (5 m).

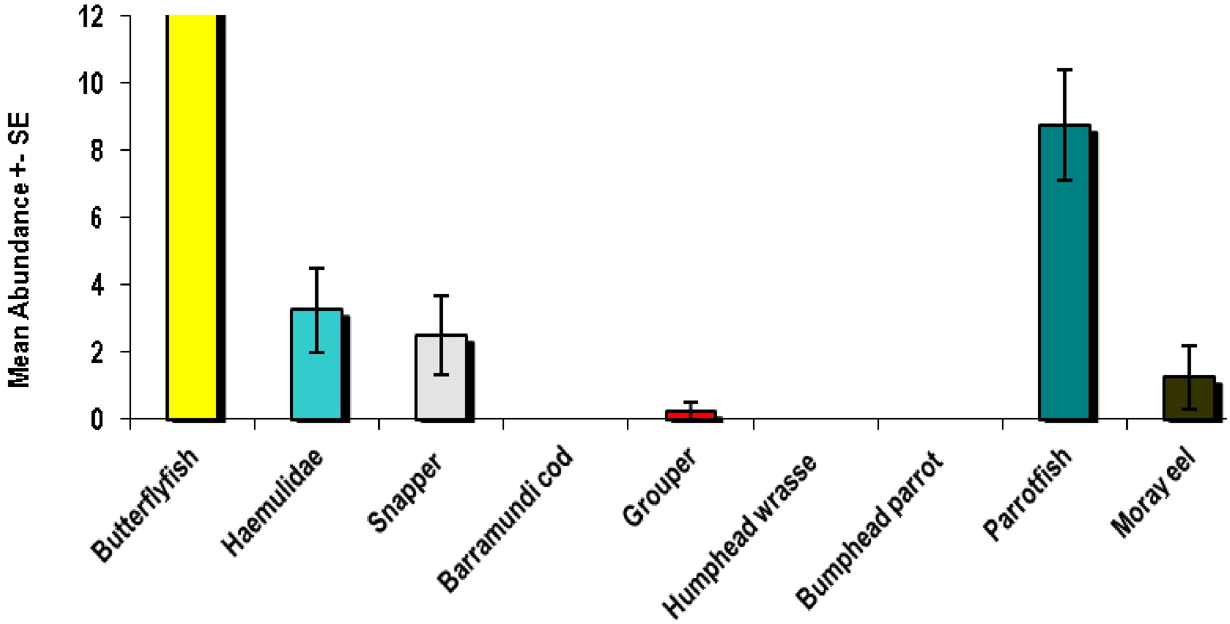

Fig 2.2.4c. Fish observations at 9 m depth at Velassaru reef, November 2014.
Note the high numbers of parrotfish and relatively high diversity of species compared to sites in North Male' atoll.

The condition of Valassaru Reef seemed better than those of North West Male' inner atoll reefs (thilas and faros) in the rest of this report. According to the BRAT model for the central Maldives reefs, Velassaru Faru suffers from chronic high sea surface temperature, but was not one of the reefs to suffer high degree heating week anomalous conditions in 1998 (Fig. 2.2.2s).

Figure 2.2.4d. The survey team with EcoDiver trainers Rafil Mohammed (3rd from left), Shaha Hashim (far right), and Maldives Whaleshark Research Project staff member Ibrahim Shameel (2nd from right) aboard the survey vessel.

Figure 2.2.4e. Publicity for the surveys, generated by placement recipients with the support of Sai Level Change.

2.2.5 Training of 'Save the Beach'
By Shaha Hashim, Gemana NGO

Eight Maldivians were trained at The 'Save the Beach' NGO and resort near to Male' on 28 February 2015 by Shaha Hashim. Training took place at Villingili, with support from the local dive operation. The individuals ranged in experience, with some having undertaken over 2000 dives, and others newly qualified as PADI Open Water divers with only 5 dives. Details of the event can be found on https://www.facebook.com/gemanango. The surveys were marketed throughout the Maldives to ensure that good numbers were able to be trained up[8].

Figure 2.2.5a. The trainees at Save the Beach Villingili with EcoDiver Trainer Shaha Hashim (3rd from left).

Before the expedition departed Male', meetings were held between Jean-Luc Solandt, the head of MRC (Dr Shiham Adam), IUCN (Gabrielle Grimsditch), Hussein Zahir (LaMer Group, and initial co-ordinator of Reef Check Maldives activities), Shaha Hashim (Gemana) and Rafil Mohammed (MDA).

[8] https://savethebeachvillingili.wordpress.com/2015/02/12/reef-check-training-27-28-feb-2015/

Discussions were had with MRC about the pending MRC status report on the status of Maldives reefs. Dr Solandt reiterated that we are happy to provide MRC with all our data going back to 2005 on Reef Check surveys. Similarly, with Dr Grimsditch and the development of the IUCN WCMP database, we are delighted to contribute our data and photoquadrats to the database. IUCN protocols should already (at the time of this report being written) be in place within Dhigurah Island community.

Shaha Hashim is undertaking discussion with two liveaboard operators in the Maldives concerning the potential to do more Reef Check training. This will develop the potential to gather more data from other reef sites and train more Maldivians.

Dr Hussein Zahir mentioned that the Reef Check methodology could be useful for input to the IUCN WCMP database, as it is quantitative data. There are also opportunities to report on megafauna observations both on and off transect (e.g. sharks and manta rays).

Dr Grimsditch described the two-year 'Project Regenerate' work that IUCN are carrying out in North Ari atoll. This involves collaboration with twelve resorts and eight local islands. The aims of the project are: (1) Enhance and expand on spatially explicit national information system for information sharing, decision-support and planning, (2) Extend current status of knowledge of Maldivian coral reef fisheries to apply resilience-based management in one selected atoll (North Ari), (3) Enhance and promote civil society engagement in natural resource management, (4) Strengthen and operationalise public-private partnerships to further extend decentralised marine governance, (5) Enhance generation of knowledge and science associated with marine resources of the Maldives to apply resilience-based management.

Finally, There are now also plans for Shaha Hashim & Rafil Mohamed and other qualified Reef Check EcoDivers to take part in a private cruise around remote parts of the Maldives from January to March 2016 in order to survey seldom-visited reefs.

2.3. Discussion and conclusions

It is clear from the surveys that there is great variance in the health of reefs in the northwest of North Male' atoll, which is typical of the Maldives wherever we survey. Adjacent reefs separated by a few kilometres can have very different reef conditions. The channel and outer reefs generally show greater consistency of health than those of inner reefs. The outer reefs of Madi gaa and Hufi faru in areas flushed by oceanic water showed low disease, bleaching, predation or other damage. The reefs of Madi gaa showed spur and groove formation at 7 m, evidence of quite strong longitudinal currents (Shinn 2011). Coral growth was limited at these outer reef sites, with smaller colonies of massive, submassive, beaching and digitate lifeforms. Commercial reef fish species and families were rare at all North Male' sites, indicating intense overfishing.

The southern channel site (Weng gaa) has a 45 degree slope, reaching the sandy seabed at 17 m, whilst the northern channel site (Kuda Faru) was more exposed to currents and the slope ended at 25 m with a sandy seabed that hosted patch reefs. Fish populations recorded in the channel - particularly to the southern channel entrance - showed the highest number and biomass of commercial species. However, many of these species were recorded off transect - the most notable being three giant sweetlips (*Plectorhinchus obscurus*) hanging some 4 m above the reef surface at about 12m at the western end of the Weng gaa site. Currents at the westward margin of the survey increased the input of plankton into the site. Here, six eagle rays were observed and two humphead wrasse. Planktivorous butterflyfish were common at all sites, often at densities in excess of 35 per 100 m^2 of reef.

Inner atoll reef sites were badly affected by blanket coverage of *Discosoma* corallimorphs covering almost the entire recordable surface of De Giri reef, whilst the reef at Reethi Faru had high numbers of Crown of Thorns (COT) starfish feeding on colonies – the greatest densities recorded since our Reef Check surveys began in 2005. This reef appeared to be in a regressive condition, with many bleached or dead colonies and much of the substrate colonised by sponges, ascidians, bryozoans and other non reef-building lifeforms. Many colonies on this dive were also badly affected by *Drupella* predation. It was difficult for our surveyors to record the difference between bleached or dead (predated by COT) colonies, because both recently bleached or predated colonies appear the same upon external inspection. Many colonies in this state were branching and table *Acropora* colonies measuring less than 30 cm in diameter. It is known from the literature that COTs preferentially feed on *Acropora* because they have larger more accessible polyps, and therefore are more nutritionally beneficial to COTs (De'ath and Moran 1998). Other areas of the Reethi Faru site appeared also to have been affected by previous coral die-off, as coral cover was not that high. This makes the observed COT outbreak a great concern as this will further limit the remaining coral community that is already stressed by acidification, pollution (perhaps from the nearby resort), competition with sponges, an apparent paucity of herbivorous fish and bleaching.

The De Giri reef has undergone a phase shift from coral (presumably pre-1998 given 1997 coral cover figures) to a reef dominated by *Discosoma* corallimorphs. To all intents and purposes, this is no longer a 'coral' reef, and can be considered to be 'lost' (Chin et al 2011). There is little chance for this reef to recover to a coral-dominated state as corallimorphs completely cover the seabed and as such do not yield space for corals to recruit and grow. Corralimorphs also have toxic filaments with which they are able to overgrow and outcompete other living benthic organisms. We observed a giant clam shell being overgrown by corallimorphs. The phenomenon of such changes in science and in ecological communities is described as a 'phase shift'. This was described in 1994 in a seminal paper in 'Science' by Terry Hughes (1994), detailing the change in the Jamaican coral reef to an algal state from a coral-dominated state. It is an unfortunate condition for any coral reef to change into an algal state from a coral-dominated state, as the new state can be ecologically and functionally very stable, i.e. it is difficult for the state to recover or change back to the original ecological state. In the case of Jamaica, the reefs need herbivorous fish to recover, massive coral recruitment, and a lack of hurricanes to grow, and once more come to dominate the seabed space. At present in Jamaica herbivorous species are at such low abundance that they cannot graze the reef of algae to allow corals to recruit and grow. Furthermore, there has been a succession of algae that contain toxic secondary metabolites that makes much of the plantlife of the Caribbean unpalatable to reef grazing species. Parrotfish, and especially surgeonfish, much prefer to feed on species that are naturally ephemeral and adapted to constant cropping. For reefs dominated by *Discosoma* there are few predators of such animals. They are cnidarians, and therefore possess nematocysts (stinging cells) that fire poison into any animals. The only animal observed feeding on this animal has been the hawksbill turtle (by Jean-Luc Solandt).

The question for reef managers, conservationists and perhaps the future of the Maldives, is whether such phase shifts are becoming more widespread throughout the archipelago? How many individual reefs can be ecologically 'lost' (we have counted at least two, but there are more) before the system is no longer self-sustaining? What further events would precipitate widespread change in other reefs from a relatively diverse state to conditions similar to those seen at De Giri, Adhureys Rock (South Ari) and deep Dega thila (central Ari)? Unfortunately it is possible to see reefs colonised by small patches of *Discosoma* in other areas, as well as other benthic invertebrates such as sponges and algal turfs. There is also a growing amount of so-called 'coral eating sponges[9]' seen in the reefs near to Male' on training dives (south Baros island, and Banyan Tree) – these are amongst the growing list of species taking over from the Scleractinian corals.

So corals, through acute and chronic stress, face an increasing threat of further bleaching events, a long-term weakening of skeletal matter and reproductive capacity through acidification. This suggests that the prognosis for full recovery from the 1998 bleaching event is poor, because of the plethora of current in-combination impacts that continue, rather than decline. Furthermore, any repeat of such an event will likely be much worse for many of the reefs that remain in a condition that is far less coral rich (and coral diverse) than those of the reefs prior to the 1998 bleaching event. The influx of poorer water quality, resort development, pollution and further changes in the natural balance of the reef fish community in the past 17 years needs urgent attention – particularly to those practices that can indeed be managed. There is no excuse for political inaction for the people of the Maldives – remedial conservation management is needed now to stave off such deleterious effects.

With this in mind we recommend:

Resorts to have guests pay at least a 5% room rate towards local marine conservation initiatives by national law. These will include:

1. A stipend to manage a local reef as a no take zone.

2. Implement fully the recommendations from the recent grouper management plan in terms of size limits of species and enforce protection at the designated spawning grounds.

3. Full treatment of water from sewage and filtration systems of the resorts such that there is no nitrification or chemicals put into the water system.

4. Prosecution of individuals littering with plastics and other non-biodegradable waste.

5. Investment in a Maldivian coral reef conservation University / college, with jobs available to the commercial and government sector upon graduation.

6. Proper, pro-active policing and enforcement of protected areas such as Marine Protected Areas (MPAs), rather than the current 'paper park' state.

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[9] - http://www.whatsthatfish.com/fish/coraleating-sponge/1156

Without these most basic measures, the Maldives reefs will not survive the current suite of pressures they are facing over the next generation. Furthermore, coral reef conservation makes business sense for long-term investment into the country. The country cannot simply blame other nations for increased CO_2 emissions being causative of damage. It must also face up to its own environmental responsibilities where change can be made at a national level. Continued expansion of tourism has to go hand in hand with management, otherwise all other atolls will simply suffer the same catalogue of decline as that which we are scientifically recording at North Male' atoll.

We congratulate Shaha Hashim and Rafil Mohammed for 'growing' the reef conservation message from Reef Check dives and training. Their experience has shown that there is a real will to engage with coral reef awareness and training. According to Shaha Hashim, and the training of Villingili, she was "very impressed with the trainees' knowledge and enthusiasm."

Perhaps these small local initiatives can start the process of developing progressive policies for conservation of the Maldives. The Maldives remains a special place to the authors, but it needs to be sustained by the government for the people to ensure its resources are there for future generations. Current tiny investment into sustainable resource use and reef recovery is not having any effect, and unsustainable and destructive exploitation of nature by tourism resorts is rampant. Two to three years of investment in effective MPA enforcement and more sustainable tourism policies would change much of this. Successful regeneration of fish populations would be seen to be a success, and people may start to want to see their own conservation measures in place in their own islands.

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Appendix I: Expedition diary and reports

A multimedia expedition diary is available on https://biosphereexpeditions.wordpress.com/category/maldives-2014/

All expedition reports, including this and previous expedition reports, are available on www.biosphere-expeditions.org/reports.