EXPEDITION REPORT

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Abstract

In July 2016 Biosphere Expeditions volunteers carried out a week of Reef Check surveys in Ari atoll, Maldives. The surveys were undertaken by four Maldivian placement recipients, fee-paying volunteer citizen scientists from around the world, and staff from Biosphere Expeditions and the Marine Conservation Society. A half-day effort-based whale shark survey was also carried out at the outer reef of South Ari Marine Protected Area, yielding zero encounters.

Coral reef surveys using the Reef Check methodology concentrated on revisiting permanent monitoring sites in Ari atoll, central Maldives, that have been surveyed either since 2005, or every other year since 2011. Surveys were carried out two months after the El Niño coral bleaching event where temperatures reached 33 degrees Celsius, and lasted for two weeks. Most reefs appeared to have been severely impacted by bleaching, with inner reefs more so (7% live coral cover) than outer reefs (25% live coral cover). Some inner reefs (e.g. Angaga and Kudafalhu), which had previously been affected by coral-damaging storms in 2015, had extremely low coral cover (under 5%). Much of the remaining live coral within inner reef sites was being consumed by significant outbreaks of Crown-of-Thorns starfish *Acanthaster planci* (some 1.4x the intensity of the worst Great Barrier Reef outbreaks), and there continues to be strong evidence of consistent overfishing, with an almost complete absence of large grouper at all sites. There is no denying that these results are shocking and extremely worrying. The 2017 expedition will re-survey these reefs to assess coral survival rates and the long-term health and resilience of corals, particularly of the outer reefs where many *Porites* colonies remained bleached two months after the May warming event. We believe the only hope for inner reefs is considerable grazing pressure to remove the colonising algae, so that recruitment of young corals can occur. If this is not enabled, through protection of natural reef fish populations, we may see a more permanent 'phase shift' to an algal or corallimorph-dominated reefs, with concomitant disastrous effects on fish and overall reef biodiversity. This has already been witnessed on two reefs surveyed by this project in the Maldives since 2005.

Overall, the equitable provision of high quality reefs and their resources will further diminish unless drastic actions are taken by government to address the lack of management measures that are pushing reefs in the Maldives to the brink of collapse. These reefs are less likely to recover from mass-bleaching if overfishing and associated trophic cascades and inappropriate infrastructure development continue on a nationwide basis.

އެބްސްޓްރެކްޓް

ރާއްޖޭގެ ފަރުތަކުގެ ދިރުއުޅުންތަކާއި ދިރުން ހުރިވަރު ބެލުމަށްޓަކައި ޖުލައި 2016 ގައި، ބަޔޮސްފިއަރ އެކްސްޕެޑިޝަނުގެ ވޮލަންޓިއަރުން ބައިވެރިވެގެން އަރި އަތޮޅުގައި، 7 ދުވަހުގެ ފަރުބަލަން ބޭއްވުނު (ރީފް ޗެކް) ސާވޭއެއް ކުރިއަށް ގެންދެވުނެވެ. މި ސާވޭ ކުރިއަށް ގެންދިޔައީ ރީފް ޗެކް ސާވޭ ކުރުމަށް ތަމްރީނު ދެވިފައިވާ 4 ދިވެހިންނާއި، ދުނިޔޭގެ އެކިޤައުމުތަކުން ނިސްބަތްވާ ސައިންޓިސްޓުންނާއި، ބަޔޮސްފިއަރ އެކްސްޕެޑިޝަނާއި ދެކުރިން ކޮންސަވޭޝަން ސޮސައިޓީގެ ސްޓާފުންނެވެ. ފަރުތަކުގެ ސާވޭގެ އިތުރުން، އަރިއަތޮޅުގެ ދެކުނު ފަރާތުގައި ހިމާޔަތްކުރެވިފައިވާ ސަރަހައްދުގައި ބައި ދުވަހުގެ ފެހުރިހީގެ (ވޭލް ޝާކް) ސާވޭއެއްވެސް ކުރެވުނެވެ. ނަމަވެސް ފެހުރިހިއެއް ފެންނަކަށްނުވެއެވެ.

އަރިއަތޮޅުގަޔާއި މުޅި ރާއްޖެތެރޭގައި ފަރުތަކުގެ (ގަލާއި މުރަކައިގެ) ސާވޭ ކުރިއަށް ގެންދިޔައީ ’ރީފް ޗެކް މެތަޑޮލޮޖީ‘ ބޭނުންކޮށްގެންނެވެ. މި ސާވޭއަށް ކުރި ކުރިންވެސް ސާވޭ ކޮށްފައިވާ، ދާއިމީ ގޮތަކަށް ބެލުމަށް (މޮނިޓަރ ކުރުމަށް) އަންނަ ފަރުތަކުގައެވެ. މިގޮތުން ބަލާއިރު ބައެއް ތަންތަނީ 2005 އަހަރުން ފެށިގެން ސާވޭ ކުރަމުން ބަލަމުން އަންނަ ތަންތަނެވެ. އަނެއް ތަންތަނީ 2011 އިން ފެށިގެން ކޮންމެ ދެ އަހަރަކުން އެއް އަހަރު ސާވޭ ކުރަމުން އަންނަ ތަންތަނެވެ.

މިފަހަރު މިކުރެވުނު ސާވޭތަކުން ކުރިއަށް ގެންދެވުނުއިރުވެސް މިއަހަރު ’އެލް ނީނޯ‘ ހާދިސާ ދުނިޔޭގެ ފުރި ހުރިހާ ކަންކަމަށް އަސަރު ބަދަލުގެ ސަބަބުން ފަރުތަކަށް (މުރަކަތަކާއި ގައުތަކަށް) ކުރިމަތިވި ’ކޯރަލް ބްލީޗިންގ‘ އިވެންޓް ނުވަތަ ގަލަށް ހުދުވުމުގެ އިވެންޓް ހިނގިތާ 2 މަސްދުވަސް ފުރުނުނެވެ. ގިނަ ފަރުތަކަކަށް ވަނީ މިކަމުގެ ސަބަބުން ވަރަށް ބޮޑު އަސަރުކޮށްފައެވެ. ސާވޭ ކުރެވުނު ފަރުތަކުގެ އެވްރެޖްކޮށް ފަރުތަކަށް ބޮޑު އަސަރުކޮށްފައިވާކަމަށް (ދިރޭ މުރަކަ ހަމައެކަނި 7% ހުރިއިރު)، ބާކީ ފަރާތު ފަރުތަކުގައި ދިރޭ މުރަކަ 25% ހުރިކަމަށް ސާވޭތަކުން ފެނުނެވެ.

ސާވޭ ކުރެވުނު ފަރުތަކުގެ ތެރެއިން، އެތެރެ ފަރާތު ފަރުތަކަށް ކުރުގައިވާ އަސަރާ އާއި ކުރިއަށް ދިޔަ 2015 ގައި ފަރުތަކަށް ދިމާވި ބްލީޗިންގްތަކުގައި ވަރަށް ބޮޑަށް އަސަރުކޮށްފައިވާ ބައިބައިނެވެ. މިބައިންބައިގައި ދިރޭމުރަކަތަކުގެ އިންސައްތަ ވަރަށް ބޮޑަށް (5% އަށްވުރެ ދަށަށް) ދަށްވެފައެވެ. އެހެން ފަރުތަކުގައި ބޮޑު ހުރި ދިރޭ މުރަކަތަކުގެ އިންސައްތަ ވަނީ ރާއްޖޭގެ ފަރުތަކުގައި ކަނޑު އޮށް ބިނަވެގެން ދިޔަ ދުވަސްވަރު ހުސްކޮށްފައި މަރުވެގެން ގޮސްފައެވެ. ކަނޑިއޮށް ކަސްތޫރިޔާ ދިރުމުގެ ހަވާލާ ރާއްޖޭގެ ފަރުތަކަށް އަސަރުކުރާ ސަބަބަކަށް ވެދާނެ ކަސްތޫރިޔާ ދުނިޔޭގެ އެންމެ ބޮޑު އެއް ފަރުގެ މަޝްހޫރު ނިޒާމު ކަމަށްވާ ’ގްރޭޓް ބެރިއަރ ރީފް‘ އަށް ކުރި ފަރަކަށް 1.4 ގުނަ ބޮޑުމިންވަރަކަށް ކަމަށެވެ. މިއީ ރާއްޖެ ފަދަ ކުޑަ ގައުމުތަކަށް ވަރަށް ކަސްތޫރިޔާ ކަމަށްވާތީ ބޮޑު ވާހަކައެކެވެ. މީގެ އިތުރުން މާ ގިނައިން މަސްބޭނުންކުރާ ސަބަބުންވެސް ފަރުތަކަށް ނުރައްކާ އަސަރު ކުރަމުންދާކަމެވެ. މި ސާވޭތަކުން ފެނުނު އަނެއް ކަމަކީ ފަރުތަކުގައި ވަރަށް ކުޑަކޮށް ދަރަ، ހަލިބޭސް ކަށިވަޅި ކަންކަމެވެ.

2017 ވަނަ އަހަރު މި ފަރުތަކުގެ ހާލަތު ދެނެގަތުމަށްޓަކައި އަލުން ސާވޭ ކުރެވޭނެއެވެ. މި ސާވޭ ތަކުގައި ގެނު ދުރާލާ ދިރި އާދޭވާ ވަރު ބެލުމާއި، ދުރާތަކުގެ ދިރުއުޅުންތަކާއި އެތަކެތީގެ ވީމުން ހުރި މިންވަރު ބެލުމަށެވެ. ހާސްވެއްޖެ ބޮޑު ފަރުތަކުގައި ’އެލް ނީނޯ‘ ދެމެހެއްޓުމަށް ހަރުދަނާވަނީ ’ރެޒިލިއަންސް‘ އާ ގުޅޭ ދުރާލާތަކުގެ ހާލަތު ބަލާ ދިރާސާ ކުރެވޭނެއެވެ.

މިފަދަ މި ކުރެވުނު ދިރާސާތަކުން ދައްކާދޭގޮތުގައި، އެހެން ފަރާތުގެ ފަރުތަކުގެ ދިރުމުގެ އެތި ހަމައެކަނި އިންސާނީ ފުރިގެން ހުރި ބޮޑުކަމެވެ. އާބާދީ ކުޑަ އެއްބަސްވެފައިވާ ރާއްޖޭގައި އާދޭސް ފުރާނަ ފަރާތަށް ކަސްތޫރިޔާ ދިރިއުޅުމަށް މަސައްކަތްކުރަމުންދާ ތަން ނުހަނު ނަގާލައިދެވޭ މަސްތަކުން ފަރުތަކުގެ ދިރުމަށް ހުރި ނޭދެވޭ އަސަރުތަކެވެ. އެއީ މި ފަރުތަކާއި، ފަރުތަކުގައި ދިރިއުޅޭ މަސްތަކާއި ފަރުތަކުގެ ’ބަރު ގައިމަސްޗީ‘ އަށް ވެސް އާއި ނުރައްކާ އަސަރު ކުރަމުން ބޮޑު ކުރިމަތިވަމުންދާކަމެވެ. މިފަދަ އަސަރުތަކެއް 2015 ގައި ރާއްޖޭގެ ދަ ހިސާބުތަކުން ފެނިފައިވާކަމީ މިދެ ހަރުކަތެވެ.

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Contents

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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 9 to 15 July 2016 with the aim of surveying and studying the response and recovery of reefs since the catastrophic 1998 and 2016 bleaching events. The project also ties in sightings of whale sharks with the work of a local charity – the Maldives Whaleshark Research Programme (MWSRP), 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 government of the Maldives identified a need for further research and monitoring work as far back as 1997. With this project Biosphere Expeditions is addressing this need and is working with the Marine Conservation Society (MCS) and the MWSRP 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 MWSRP for their conservation efforts. The expedition also included training for participants as Reef Check EcoDivers, and for an individual (of the Maldives Whaleshark Research Project) to become an in-country Reef Check EcoDiver Trainer.

Many reefs in the central Maldives are showing significant signs of stress. Some remain resilient and are in good condition, but others are faring much worse with disease (principally white syndrome), predators (Crown-of-Thorns, *Drupella* snails), and persistent low-level bleaching. Many reefs are also outcompeted by algal turfs, macroalgae and some sponges. Indeed, some reefs we have encountered have already shifted to a non-coral state such as those dominated by turfs and corallimorphs (principally *Discosoma*).

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, as well as pollution represent most of the impacts on coral reefs that can be directly managed in the Maldives. Resilience to the impacts of climate change can be monitored (e.g. by recording recovery trajectories of different reefs to mass-bleaching events). Reef Check is an extremely useful tool to inform local managers where conservation action such as 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 and employment. Mass tourism in the Maldives is still concentrated around the atolls near to Male' and its infrastructure and resources rely entirely 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. The Mamigili (south Ari) airport, opened in 2011, has allowed for direct flights to access more of the country for development.

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. Healthy reef areas – and 'balanced' fish populations 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, and for ensuring that there are enough islands and reefs that remain 'off limits' to major commercial activities. 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 aimed to take detailed observations of encounters with whale sharks when they were encountered between reef survey locations. Photographs of the gill areas of whale sharks are being used by the MWSRP to identify individuals in order to record presence / absence of individual 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 animal, and over 200 individuals have been recorded so far. The MWSRP 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 in order to see if it has been recorded before and if so from where. This allows conservationists at the MWSRP to map the movements of individual sharks, how often they are recorded at individual locations and whether further protection mechanisms are needed for individual hotspot locations.

Coral reef structures of the Maldivian archipelago are extraordinarily diverse and rich. There are submerged coral mounds, often rising within lagoons 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 and plunge to thousands of metres depth a few hundred metres from shore. 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 were still recovering from the mass-bleaching event of 1998, prior to the 2016 bleaching event (with some intermittent bleaching). Recovery identified by our surveys prior to 2016 has been reasonable in many inner atoll reefs, with extensive recruitment and growth of branching and table *Acropora* corals even by 2005 – many tables exceeded 3 m in diameter at reef tops (e.g. Dega thilla; Diga thilla; Kudafalhu). 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 assess a broad range of reef types, inner (giri; thilla and house) reefs, and the outer slopes of atoll reefs around Ari atoll were surveyed. This range of habitats provided a useful understanding of the relative resilience of different reef types to the warming event of 2016.

The fish populations of the Maldives are exceptionally rich in terms of diversity, but the number, size and biomass of commercial species has been seriously impacted – particularly since the advent of mass-tourism and exporting of grouper in the mid-1990s. The Maldivian government in 2008 banned shark fishing within the atolls and their numbers appear to be increasing as a result. Small reef sharks are still commonly observed in Maldivian waters. Inner-atoll 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, major attractions 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 are generally the shallow waters 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' capital and largest city is Male’, with a population of around 135,000. (Total population of the country is 350,000). Traditionally Male’ was the King's Island, from where the ancient Maldivian royal dynasties ruled and where the royal palace was located. The Maldives is the smallest Asian country in terms of both population and area.

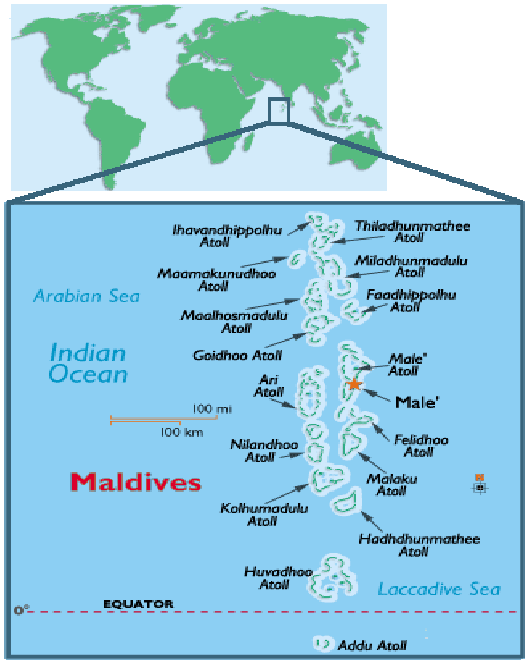

Figure 1.2b. The Maldives. An overview of Biosphere Expeditions’ research sites, assembly points, base camp and office locations can be found at Google Maps.

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.

1.3. Dates

2016: 9 – 15 July.

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-foot liveaboard boat, the MV Carpe Vita, with ten air-conditioned cabins, an air-conditioned lounge and an open-air dining area. The boat was accompanied by a 55foot diving dhoni (boat) with multiple compressors, Nitrox and all facilities one would expect on a modern liveaboard. The crew provided tank refills and dive services. A professional cook and crew provided all meals.

Weather

The Maldives has a tropical and maritime climate with two monsoon seasons. The average daytime temperature during the expedition months was 28°C, with overcast days, and occasional sunshine. Water temperature during the expedition was 28-30°C.

Field communications

The liveaboard was equipped with radio and telephone communication systems. Mobile phones worked in most parts of the study site whilst 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, including expedition support and any necessary 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 in addition there are medical posts in many of the resorts. There is a recompression chamber on Bandos Island Resort near Male' and one on Ari Atoll. Emergency and evacuation procedures were in place, but did not have to be invoked as there were no incidents, medical or otherwise.

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 on 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 four expeditions to undertake surveys on the islands. Jean-Luc has 1000+ dives clocked up since he trained to be a marine biologist 25 years ago.

1.6. Expedition leader

Kathy Gill is a founding member of Biosphere Expeditions and has been there since the start in 1999. Kathy was born and educated in England. Since gaining her BA in Business at Bristol, she has worked in sustainable development and regeneration for a variety of public sector organisations, most recently the Regional Development Agency for the East of England where she was responsible for developing and supporting partnership working to establish sustainable development activities. At the main office Kathy is the organisation's Strategy Adviser. She has travelled extensively, led expeditions and recced projects all over the world. She is a qualified off-road driver, divemaster, marathon runner, keen walker, sailor, diver and all round nature enthusiast.

1.7. Expedition team

The expedition team was recruited by Biosphere Expeditions and consisted of a mixture of ages, nationalities and backgrounds. They were (in alphabetical order and with countries of residence): Jenan Alasfoor (Oman), Jonathan Chia (Singapore), Astrid Därr (press, Germany), Cassondra DeMolick (USA), Madhavi Denis (UAE), Fathimath Farah Amjad (Maldives)*, Amintha Shaha Hashim (Maldives)*, Irthisham Hassan Zareer (Maldives)*, Ian Hussain (Malaysia), Rajiv KP (India), Thomas Wai Hong Leun (China), Petra Lohse (Malaysia), Arushad Mohamed (Maldives)*, Nicolas Thobois (France), Jeff Wilson (USA), Kate Wilson (USA), Stacie Wilson (USA), Taylor Wilson (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 worked with Reef Check, the Marine Conservation Society, the Maldives Marine Research Centre (MRC) of the Ministry of Fisheries and Agriculture, the MWSRP, 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 international Union for the Conservation of Nature (IUCN), the World Conservation Monitoring Centre and the International Coral Reef Action Network (ICRAN), but more locally too, especially with regard to 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 a contribution of £1,630 per seven-day slot towards expedition costs. 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., or 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	20,890
Grants	4,600
Expenditure	
Staff includes local & international salaries, travel and expenses	2,690
Research includes equipment and other research expenses	587
Transport includes taxis and other local transport	12
Base includes board, lodging and other live-aboard services	15,277
Administration includes some admin and misc costs	173
Team recruitment Maldives as estimated % of PR costs for Biosphere Expeditions	6,430
Income – Expenditure	**321**
Total percentage spent directly on project	**99%**

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, and to Shiham Adam from MRC for guidance and advice, and to Agnes van Linden of the MV Carpe Vita for keeping an excellent live-aboard research base running like clockwork. Biosphere Expeditions would also like to thank the Friends of Biosphere Expeditions for their sponsorship and in-kind support. We thank the crew of the MV Carpe Vita for being such excellent hosts. Thank you also to Richard Rees of the MWSRP. Support from the Rufford Foundation via LaMer for the placement programme is also gratefully acknowledged.

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, over 130,000 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.

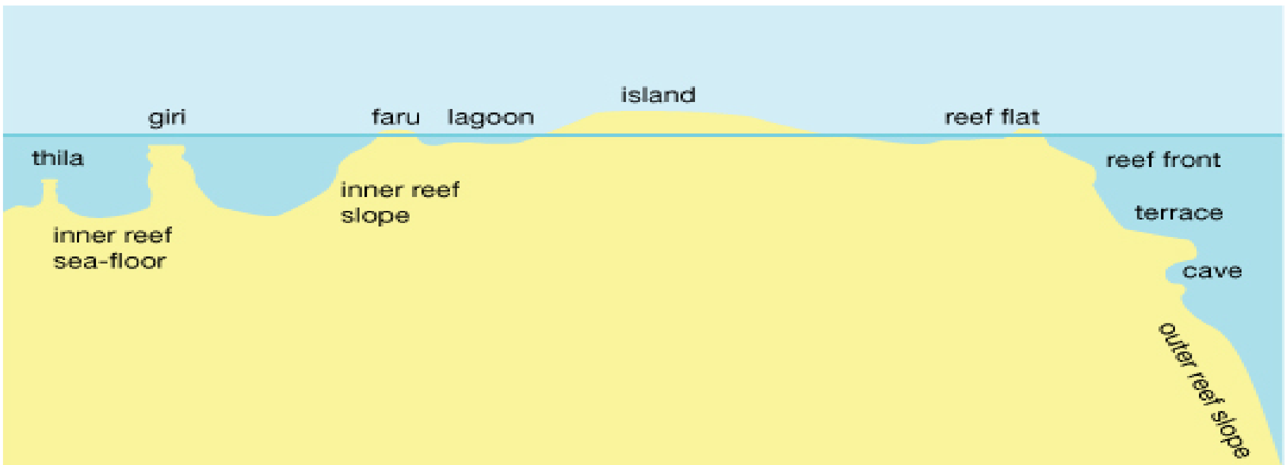

Figure 2.1a. Common reef structures of the Maldives (from Tim Godfrey).

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 south-westerly monsoon runs from May to November. Global warming may have affected these seasonal trends in recent years, with less clear discrepancy between wet and dry seasons. The current direction, however, has remained relatively constant. 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 yellowfin and skipjack dominating the catch, with lesser quantities of bigeye also taken (Marine Stewardship Council) (Ahusan et al. 2016). In 2010, the Maldives government opened up Maldivian waters to domestic long-line fishing, whilst excluding vessels from other nations (principally from Sri Lanka)[1]. This was in reaction to the reduction in yellowfin catch by Maldivian fishermen recorded between 2005 (186,000 tonnes) and 2008 (117,000 tonnes)[2], making traditional pole and line fishing techniques from larger vessels unprofitable. Because of the historical pole and line fishery, 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. But major fishing concessions offered by the EU to surrounding states in Arabia and Africa are denuding major stocks of bigeye, skipjack and yellowfin – stocks that appeared healthy up to 2010[3].

The Maldives banned shark fishing in 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). The ban on the export of shark products introduced in 2011 has undoubtedly made it more difficult for Maldives-based fishermen to trade in shark parts and anecdotal evidence from Maldives dive operators suggests that in some areas sharks appear to be increasing in number.

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[1] http://www.bluepeacemaldives.org/blog/biodiversity/long-line-fishery-controversy-maldives
[2] http://minivannews.com/environment/cabinet-approves-long-line-fishing-for-maldivian-vessels-5385
[3] http://www.wwf.or.jp/eng/activities/2016/05/1320319.html

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) but primarily 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 fishermen in order 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. Between 2009 and 2013, MRC 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/for market, have met with resistance in some atolls. Given the small sizes of many species seen in the wild as outlined in last year's report (Solandt and Hammer 2015), 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 the 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 30^0C (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 and bleaching event

During April and May 1998 a temperature of over 32^0C 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%.

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. A University of British Columbia[4] survey (Hauert et al. 1998) undertook extensive Reef Check surveys in Angaga Island in June 1998, three months after the catastrophic bleaching event, and found that 80% of corals were dead and covered by fine filamentous algae.

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

Since 2005, Reef Check surveys have observed few large reef building corals and a much higher proportion of faster growing *Acroporidae* and *Pocilloporidae*. This suggests there has been patchy recovery due to recruitment of new, more ephemeral corals, rather than recovery from survival and re-growth of older colonies, which recovered zooxanthellae immediately after the warming event.

Longer term effects of such catastrophic bleaching were said to include erosion of dead coral skeletons to sand and rubble, which in turn led to less buffering of wave action around the atolls, leading to beach erosion – a huge potential cost to the Maldives. Many recent years of surveys by our expeditions have identified rubble slopes around 10-15 m in some of the more sheltered reefs. We believe these are predominantly made up of corals that died during the 1998 bleaching event and have been broken down by subsequent wave action and the boring action of worms and bivalves (Solandt and Hammer 2013). Under gravity, they fall to the lower reaches of the reef.

Biosphere Expeditions and MCS 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). Surveys carried out in September 2015 found many sites to be affected by storms, leading to breakage of corals and damage to shallow and deeper reefs. Ari was considered to have been less affected by the 1998 bleaching event than reefs nearer the capital, at Male' atoll (Zahir, personal communication) During this expedition seven sites were surveyed (see Fig. 2.2a): the training site at Baros Maldives, Rasdhoo Madivaru, Bathaalaa maagaa, Kudafalhu, Dega thilla, Angaga Island, Holiday thilla and Dhigurah Wall to the south of the atoll.

The 2015/2016 El Niño / bleaching event

The El Niño of 2015/2016 was the second-largest bleaching event on record for the Maldives since the 1998 bleaching event. Large tracts of Indian Ocean reefs bleached over the period of March – May 2016 (see Fig. 2.1.2a). Prior to this the bleaching event was more profound over the reefs of Asia (Thailand, Malaysia, Indonesia and the Philippine archipelago). 22% of the reefs of the Great Barrier Reef were very seriously bleached and the wider Pacific Ocean saw bleaching throughout most of 2015.

Seawater temperatures were recorded by colleagues at Baros Maldives throughout the 2016 bleaching event. They recorded the temperatures at their house reef on the island from April to May 2016.

Table 2.1.2a. Surface seawater temperatures (SST) recorded at Baros Maldives from 1 April through to 26 May 2016.

	Temperature degrees C			
	5 m	10 m	15 m	20 m
1-Apr	30	30	29	29
7-Apr	30	30	29	29
14-Apr	31	30	30	30
21-Apr	32	31	30	30
28-Apr	32	32	31	31
5-May	32	32	31	31
12-May	31	30	30	30
19-May	30	30	30	30
26-May	30	30	30	30

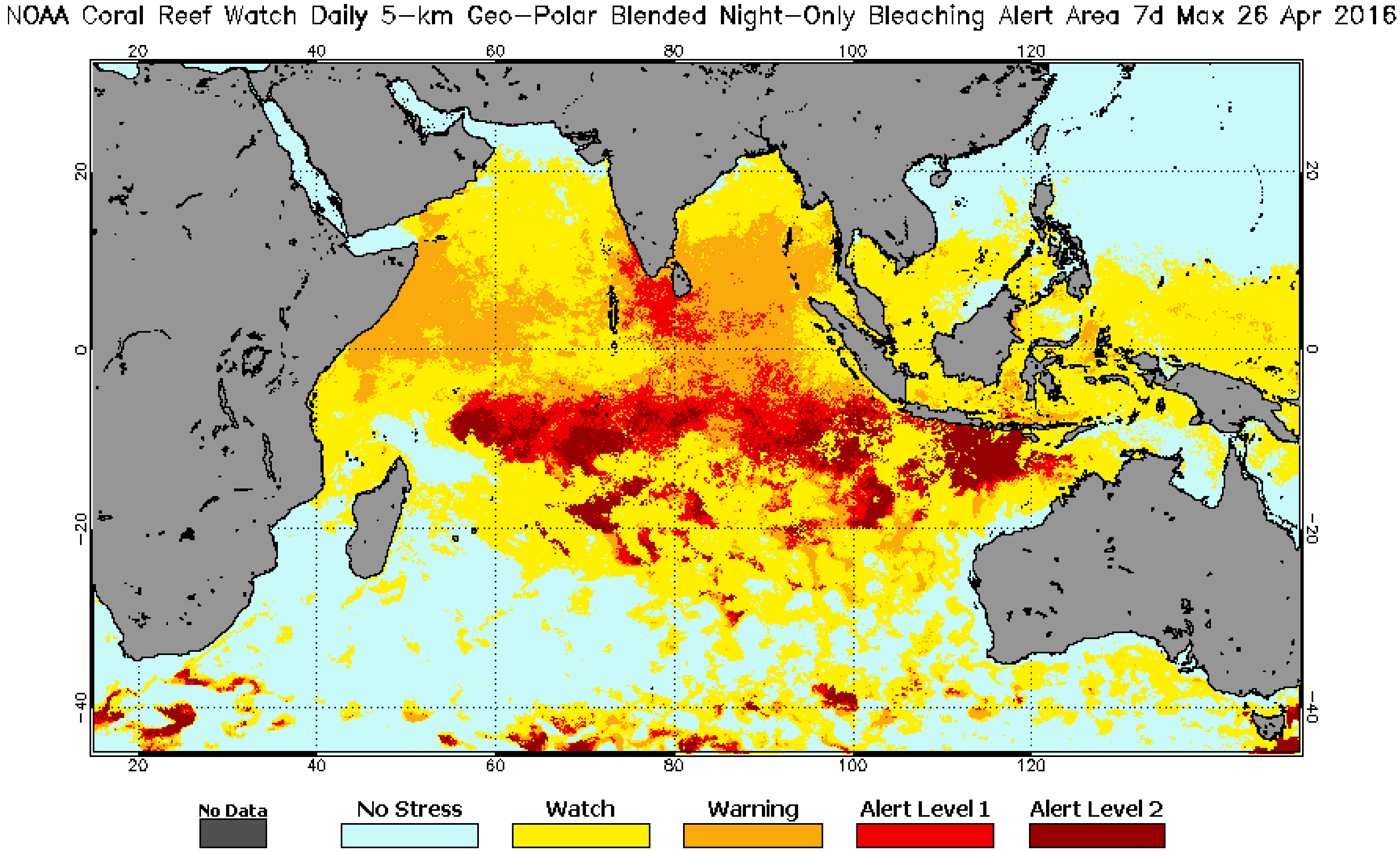


Figure 2.1.2a. Coral bleaching coincided with a warm water 'pulse' that moved from south to north over the islands between April and May 2016 (Data from NOAA).

2.1.4. Other 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 had seen the Maldives embark on a process to establish more Marine Protected Areas (MPAs), and to lobby for decreases in global CO_2 emissions. Currently 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) – that ‘service’ to the economy and the requirements and measures 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/practitioners and 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 instability - The Maldives has been through a number of considerable political changes in the past five years, reducing the chance that a coherent marine conservation strategy will be treated as a priority;

2. Economic decline - 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 businesses on international flights, expensive marine transport of goods and people, and a tourist industry that generates large amounts of carbon.

4. Rapid environmental degradation that is not being adequately reported - The health of Maldivian reefs has declined steeply over the past 30 years since the 1998 bleaching event through the 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 costs should be met (but are not) by the developers who 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 years 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 are few resources 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. This is a global problem for countries such as the Maldives and also for the UK.

In recent years the Maldives has lacked a political champion for the protection and recovery of marine resources. Up until five years ago the Maldives government was 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. According to this plan, at least half the atolls of the nation will 'need to implement marine conservation efforts similar to that of Baa atoll'. 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 the government does not invest sufficiently to effectively implement this on a national basis. Indeed, since Biosphere Expeditions started working in the Maldives in 2011, cuts to the MRC have seen drastic reductions in its staff, and the monitoring team that existed since 2009 has been effectively disbanded. 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). But many Maldivian citizens have strong scepticism towards western conservation work in their islands, which is likely to be 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 – and indeed, the environmental limits of the nation. This is not ideal, because conservation projects for the Maldives will 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 to funders who like to see 'new' projects, and want to see short-term results.

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 as fee-paying volunteers and external funding (from the Rufford Foundation) helps to support the work. 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 Maldivian reefs in collaboration with local partners (e.g. the MRC / MWSRP / MDA).
- 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 2016 surveys and training using Reef Check

The 2016 surveys were carried out specifically at Ari Atoll sites that have been repetitively surveyed, last so in 2015, in order to

- Record the impact of bleaching in this El Niño year.

- Carry out effort-based transects of the South Ari Marine Protected area reef for whale sharks.

- Undertake Reef Check Trainer training for three local people – Irthisham Hassan Zareer, Arushad Mohamed and Farer Fathimath. Irthisham was being trained as a Reef Check EcoDiver Trainer to allow her to train other Maldivians in Reef Check.

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 in developing countries by tourists, 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 surveys with liveaboards since 2005 and trained staff at the Baros Maldives resort in Reef Check survey techniques in 2010. However, training and surveying was 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. 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 was led by Dr Jean-Luc Solandt and Shaha Hashim, Reef Check Course Director and Reef Check Trainer respectively.

All training was carried out on board the MV Carpe Vita during the first three days of the expedition. In-water training was undertaken at Baros Maldives 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

Sites surveyed

Sites surveyed in the 2016 expedition were a mixture of inner atoll sites (thillas and giris) and outer reef walls and slopes. Sites were selected on the basis that Biosphere Expeditions and MCS had surveyed these areas since 2005 (Rasdhoo) and 2008 (Dega thilla), thus giving a longer-term perspective to the data of reefs that had recovered since the 1998 bleaching event. The expedition also set out to understand any differences in patterns between the more sheltered inner atoll reefs with lesser water circulation and depth, and the outer reefs, which are adjacent to much greater water depths.

Table 2.2a. Site names and locations. For numbers see Figure 2.2a below.

Site name	Latitude	Longitude	Inner or outer reef
Baros Maldives*	4 16 59.4 N	73 25 40.2 E	Inner
1. Rasdhoo Madivaru	4 15.947 N	73 0.17 E	Outer
2. Bathaalaa	4 3.34 N	75 57.41 E	Outer
3. Kudafalhu	4 1.052 N	72 48.311 E	Inner
4. Dega thilla	3 50.665 N	72 45.083 E	Inner
5. Holiday thilla	3 29 40.56 N	72 49 21.85 E	Inner
6. Dhigurah Wall	3 30 57.54 N	72 55 6.11 E	Outer

*Training site.

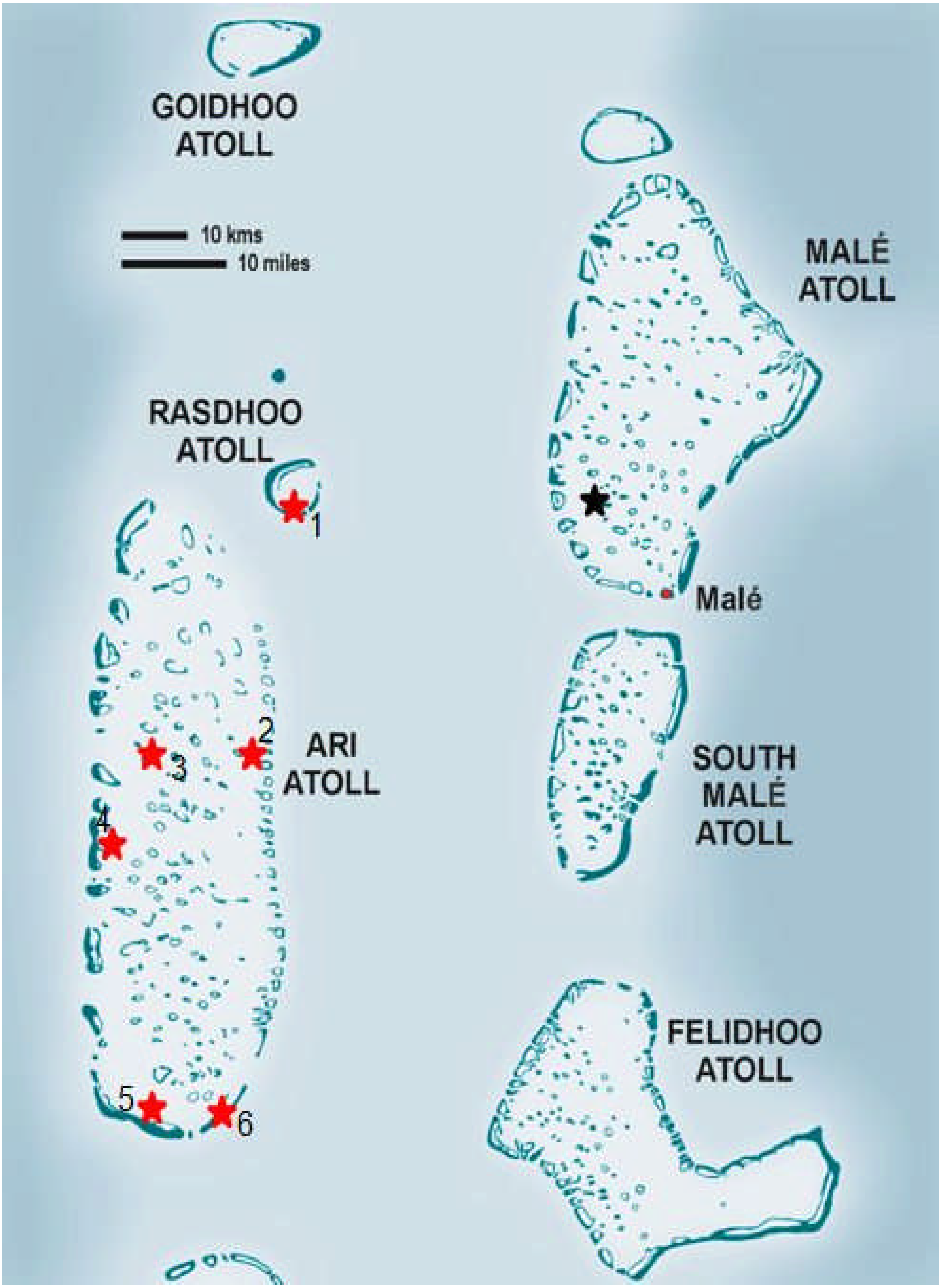


Figure 2.2a. Central Maldives atolls with the location of training (Baros Maldives – black star) and surveys (red stars): 1 – Rasdhoo Madivaru; 2 – Bathaalaa maagaa; 3 – Kudafalhu; 4 – Dega thila; 5 – Holiday thilla; 6 – Dhigurah Wall.

Baros Maldives recorded the bleaching at their house reef (Table 2.2b). As with other bleaching events, the *Acropora* genera was more susceptible to bleaching in initial phases.

Table 2.2b. Immediate bleaching impacts on coral populations (as recorded by staff at Baros Maldives).

Date	SST in ºC @ (5/15 m)	Notes on coral bleaching			
		5 m	10 m	15 m	20 m
1 April 2016	30 / 29	First sign porites and acropora (staghorn, table) are "stressed"	First sign porites and acropora (staghorn, table) are "stressed"	ok	ok
14 April 2016	31 / 30	First signs porites (and acropora staghorn, table) are bleaching	First signs porites and acropora (staghorn, table) are bleaching	First sign porites and acropora (staghorn, table) are "stressed"	First sign porites and acropora (staghorn, table) are "stressed"
28 April 2016	32 / 31	60-80% porites and acropora (staghorn, table) are bleached 30-40% are white	30-40% porites and acropora (staghorn, table) are bleached 10-20% are white	20-30% porites and acropora (staghorn, table) are bleached	10-20% porites and acropora (staghorn, table) are bleached
12 May 2016	31 / 30	80% porites and acropora (staghorn, table) are white	40-50% porites and acropora (staghorn, table) are bleached 20-30% are white	30-40% porites and acropora (staghorn, table) are bleached 10-20% white	30-40% porites and acropora (staghorn, table) are bleached 10-20% white
26 May 2016	30 / 30	40% porites and acropora (staghorn, table) are white 50% are with algae overgrown	20% porites and acropora (staghorn, table) are bleached 10-20% are white 10-20% are with algae overgrown	10% porites and acropora (staghorn, table) are bleached 20% are white 5-10% are with algae overgrown	20 % porites and acropora (staghorn, table) are bleached 10% are white

Coral populations showed a stress response as early as 1 April 2016. Underlying and long-term temperatures recorded at Baros Maldives are often at 28/29 degrees when monitoring occurs (typically March) (2010 - 28 degrees, 2011 - 28 degrees, 2012 - 29 degrees, 2014 - 29 degrees). It is notable that a 1-2 degree rise in temperature above this high mean value elicits bleaching. This could mean that corals are always on the brink of bleaching. Corroborating evidence for this is that Biosphere Expeditions Reef Check training at this site has always recorded one or two bleached colonies at most sites during most years. There is further evidence that depth is a major factor in the effect of bleaching, with the majority of the living coral population below 10-15 m showing no impacts of bleaching at all. The bleaching 'event' lasted at least six weeks in total, with the most serious stress occurring over a four week period (14 April to 12 May 2016) – enough to stress and kill many colonies.

Individual sites and overall picture of bleaching compared to historic (10 year) baseline.

The bleaching event, and apparent reduction in coral cover as a result of bleaching, were compared to the historic baseline ‘health’ of the live hard coral community between 2005 and 2015 (the duration of recording at various permanent monitoring sites) (Fig. 2.2b).

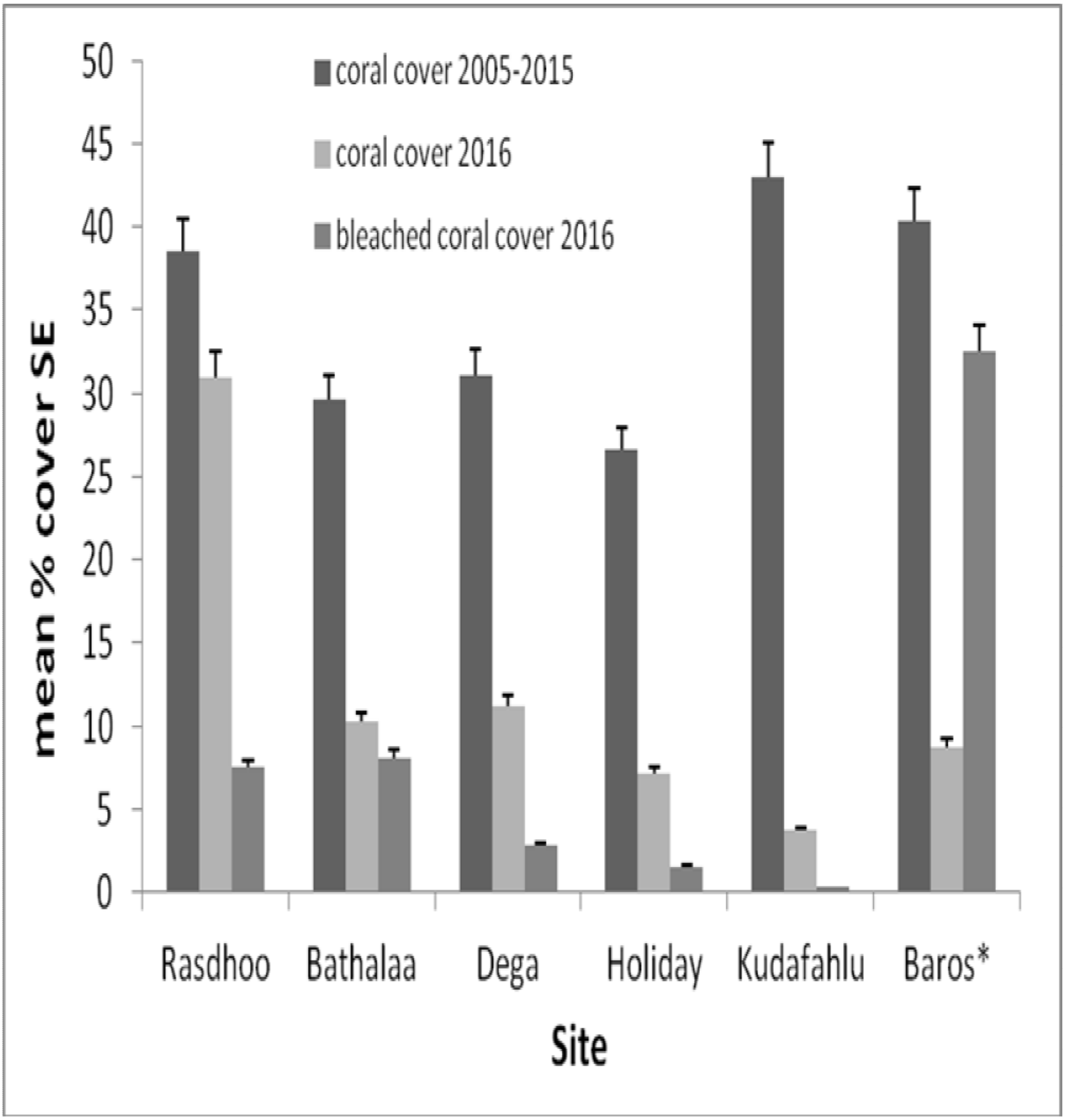


Figure 2.2.b. Coral bleaching impacts on the coral population at five sites in July 2016, two months after the warming event in May. *Baros Maldives data were recorded during the bleaching event in May 2016.

Figure 2.2b shows that the outer reef sites – Rasdhoo and Bathalaa maagaa - had higher *combined* coral cover and bleached coral cover remaining after the bleaching event than the inner reef sites of Dega, Holiday and Kuda fahlu. Added to Dhigurah Wall, a side facing the ocean on the southern part of Ari atoll, there is a clear trend of inner atoll reefs being more seriously affected by the warm waters than outer reefs (Table 2.2c, Fig. 2.2c).

Table 2.2c. Summary data of % coral cover and bleached coral cover inside and outside atoll rim reefs during the July 2016 surveys.

Site (% cover)	Bathalaa maagaa	Rasdhoo	Dhigurah Wall	Dega thilla	Holiday thilla	Kudafalhu
Inner/outer		**Outer**			**Inner reefs**	
Bleached	8.13	7.5	5	2.81	1.56	0.31
Hard coral	10.31	30.9	34	11.25	7.19	3.75
Mean hard coral cover		**25.07**			**7.40**	

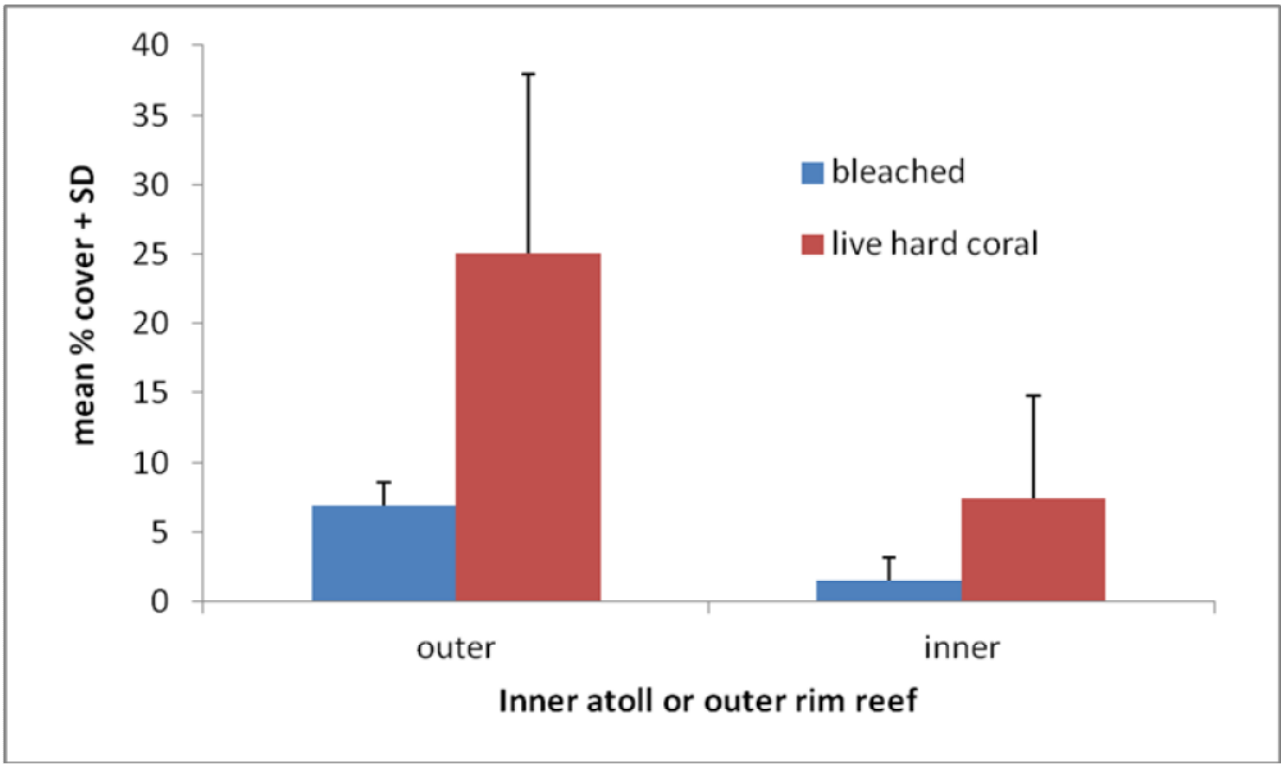
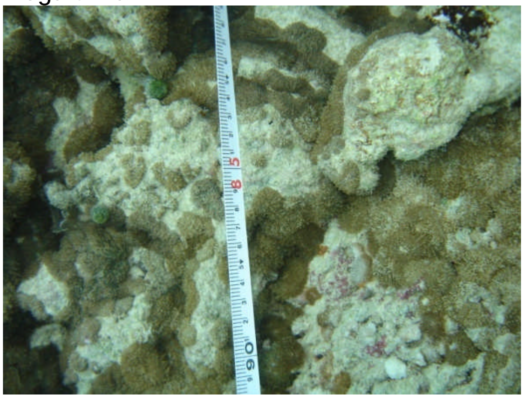
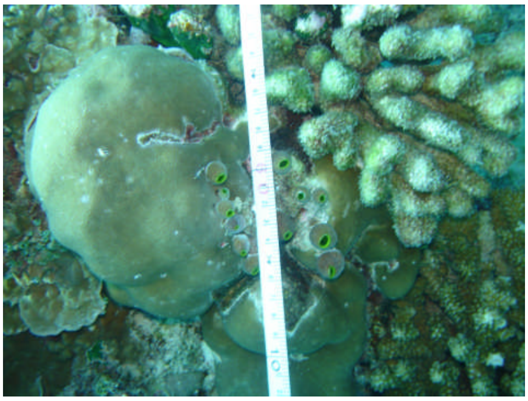
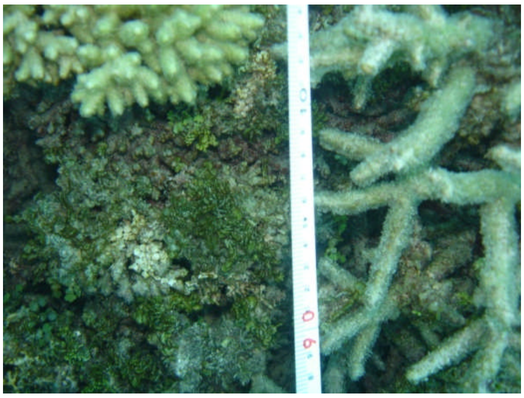
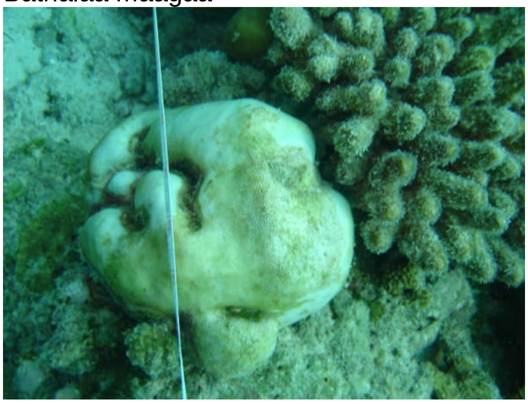
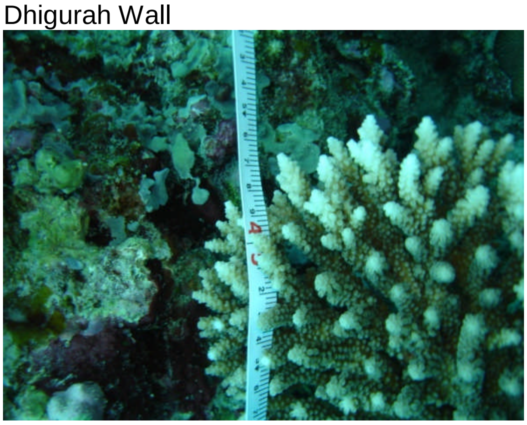


Figure 2.2c. Mean % hard coral and bleached hard coral cover from inner and outer reefs visited during 2016 surveys.

Table 2.2d. Observations on reef colonisation at inner and outer reefs, July 2016.

Inner reef	**Outer reef**
Dega thilla 	Rasdhoo Madivaru 
Kudafalhu 	Bathalaa maagaa 
Angaga thilla 	Dhigurah Wall 
Summary observations: Large amounts of thicker algal turf, macroalgae (particularly at Angaga and Holiday thilla). ‘Other’ lifeforms such as *Discosoma* carpet anemone (corallimorphs) were dominant at Dega thilla. Opportunities for colonisation by coral recruits are currently low, because of the lack of free space on clean rock. Herbivory is essential to allow coral recruitment.	Summary observations: Partial to low bleaching of massive hard corals, particularly of *Poritidae*. Partial bleaching over *Acropora* colonies in addition. There is low turf colonisation of bleached/dead corals, with macroalgae absent. There is considerable ‘free space’ for coral recruitment.

Benthic species and lifeform colonisation

There is considerable evidence that reefs do better post-bleaching with lower amounts of nutrient indicator algae / macroalgae and thick algal turfs. Inner reefs have approximately 29% 'rock' and about 10% hard coral. This means that only about 40% of the substrate is immediately able to be colonised by recruiting corals and that present conditions mean that the reefs can only partially recover. Scenarios that could enable change are: conditions less conducive to algal growth, and: an increased availability of 'free space' – i.e. clean rock. Herbivory (grazing of algal lifeforms) and low nutrient availability is essential for pre-bleaching conditions and coral recruitment to be able to occur. In some reefs (such as Holiday Thilla and Angaga housereef) conditions are extremely poor for coral regeneration with an average of 31% and 33% macroalgal / NIA cover. Also the reef at Dega thilla has 45% *Discosoma* cover of corallimorphs. Other reefs that have exhibited such a change in state to corallimorphs from corals have been described in reefs almost totally unaffected by pollution (Work et al. 2008).

The evidence from these dives suggests that those reefs with a relatively high cover of algae and corallimorphs are in the balance – they could become coral dominated again, with good recruitment and herbivory, or they could move further towards a non-coral life-state. This phenomenon is called a 'phase shift' (Hughes 1994). This is where the ecosystem moves from one state to another. Concerning to ecologists, reef managers, dive operators and the Maldives as a whole, is where this 'shift' becomes ecologically stable. This happens when a number of chronic and short-term factors come into play that reduce coral cover and boost other lifeforms.

Table 2.2e. Chronic and short-term impacts to reefs that enable a shift from a coral to non-coral state. Note the bleaching state moving from short-term to chronic.

Factor	Chronic (low or high impact)	Short-term (low or high impact)
Hurricanes / cyclones / storms		X (high)
Temperature induced bleaching		X (high)
Disease	X (low – Maldives)	
Acidification	X (unknown)	
Pollution	X (unknown)	X (moderate)
Crown of Thorns outbreaks		X (high)

Historical perspective

The Maldives is at a critical state in time, with many reefs over the past 18 years changing from a coral-dominated to a non-coral dominated state. Some reefs surveyed by Biosphere Expeditions and MCS since the major 1998 bleaching event are no longer true 'coral' reefs and are dominated by non-corollaceous lifeforms. Adhureys reef (surveyed in 2005), Deh giri (surveyed in 2012) and Dega thilla (first surveyed in 2007) have large (and in the case of Dega thilla, increasing) tracts of the substrate dominated by corallimorphs (*Discosoma*). Given the state of the central atoll reefs surveyed during the 2016 surveys, conditions are pushing more reefs to attain this 'phase shift' state, where recovery to a coral-dominated assemblage is unlikely. Outer reefs fare much better, both historically, and during recent surveys.

Many of the impacts within Table 2.2e are entirely natural and can be recorded through the fossil record (e.g. Crown-of-Thorns outbreaks / storms). But the synergistic and more persistent nature of these threats, and their more regular occurrence makes reefs much more threatened than ever before. For example, the storms and increased wave action during recent Reef Check surveys has been understood to be a cause of shallow-water coral damage at western sites in the archipelago in 2015 (Afzal et al. 2015; Solandt et al. 2016). More recent research has also shown that corals persistently stressed at their upper thermal tolerances are less able to withstand disease, and are more susceptible to a wider range of infection by pathogens (Tkachenko et al. 2007, Ateweberhan et al. 2013). More regular warming events will further threaten the coral communities of the Maldives and where nutrients are available from anthropogenic sources, it may be that corallimorphs, sponges and algae may outcompete seabed space after future disturbance events (Kuguru et al. 2004).

Fish populations

Fish populations have not significantly changed in the Maldives sites we visited in Ari atoll since 2005 (Figs. 2.2d & e). There are plentiful numbers of both benthic and planktonic feeding butterflyfish, with a large abundance of planktiviorous butterflyfish at the outer reef sites (such as Rasdhoo Madivaru) and channel reefs. Sites with lower coral cover (Kudafalhu and Angaga thilla) have lower numbers of butterflyfish, which can be an indication of low-quality habitat and feeding areas for these species. Many butterflyfish species are invertivores with specific requirements of habitat to survive. Another family – the *Pommacentridae* do better (in terms of abundance and biomass rather than diversity) when reefs are dominated by algal turfs. Commercial species such as sweetlips (*Plectorhincus*) are low in numbers, with a single individual seen at most sites. At Rasdhoo, there used to be greater number of both sweetlips and horse-eye jack, both recorded on and off transect in 2005. These animals are now increasingly rare at the site. Snapper (*Lutajnidae*) are reasonably common, but not abundant. Larger species such as the midnight and black and white snapper are missing from almost all sites and numbers at Rasdhoo Madivaru have declined since 2005 when the site was first surveyed.

Grouper have been earmarked within the Reef Check survey as an important commercial species that indicate overfishing. Numbers in this year's survey remain low, although an average of one or two individuals were recorded both at the deeper part of Rasdhoo Madivaru, and at Holiday thilla (Fig. 2.2e). These are of individuals of a minimum of 30 cm – a small size for most dominant, large-growing grouper species (such as the marbled groupers of the *Epinephalidae* and 'coral trout' species of the *Plectropomidae*). All this indicates consistent overfishing and previous expedition reports (all available via www.biosphere-expeditions.org/reports) have recommended minimum landing sizes for grouper in line with The Darwin Reef Fish Project[5]. This was a collaboration between the Marine Research Centre and the Marine Conservation Society between 2009 and 2014 that set specific management recommendations for the fishery of these high-value fish. It is now extremely rare to record grouper greater than 40 cm size. Some of the larger subfamilies such as *Epinephalidae* are now absent from shallow reefs we survey, particularly at larger sizes.

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[5] http://www.mrc.gov.mv/assets/Uploads/February-2014-Current-Status-of-the-Reef-Fisheries-of-Maldives-and-Recommendations-for-Management.pdf

As these species are broadcast spawners, low numbers and sizes will compromise regeneration of populations within central atolls, unless animals occur in large numbers in the deeper areas of reefs beyond the survey depth of Reef Check, which is unlikely.

Importance of herbivores on reefs.

Large abundances of herbivores are extremely important to enable reefs to be in good condition after a bleaching event (Hughes et al., 1997). Herbivorous fish of the parrotfish and surgeonfish family are vital for keeping the reef clear of thick algal turfs and macroalgae that stop the re-colonisation of hard corals. The parrotfish numbers and sizes within the Maldives appear stable, although numbers appear to be greater on the healthier outer reefs than the inner reefs from these surveys (Fig. 2.2d).

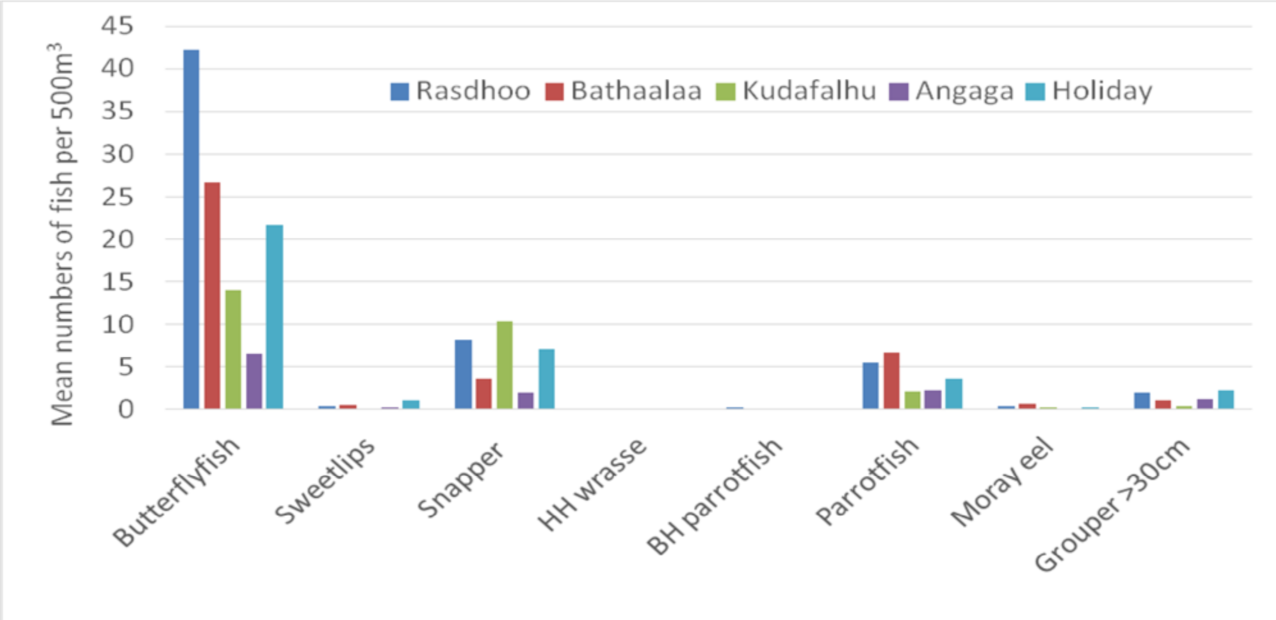

Figure 2.2d. Reef fish populations at Maldives reefs in 2016.

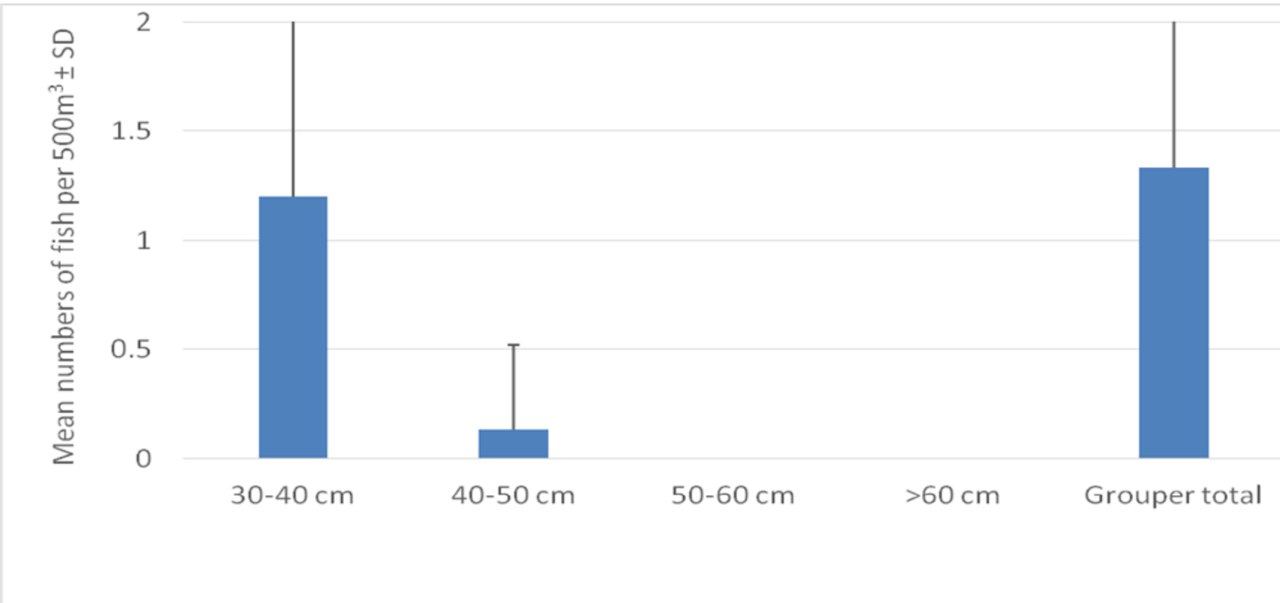

Figure 2.2e. Grouper populations (at sizes <30 cm) at Maldives reefs in 2016.

Invertebrate populations

Invertebrate populations show dominance of giant clams and Crown-of-Thorns (COT) starfish. The COT dominance comes principally from only two sites – Angaga housereef (2.7 animals/100 m^2) and Kudafalhu (14.3 animals/100 m^2) (Fig. 2.2f). Both sites have been severely affected by bleaching (2016) and storms (2015) in recent years, with associated low coral cover. It would appear that the COTs are feeding on the last remaining hard corals available. Numbers of COTs over 30 per hectare constitute an outbreak according to past research (Dixon 1996), so the numbers being observed in the Maldives in recent years is a concern and constitute significant outbreaks at both Angaga and Kudafalhu (as numbers equate to 270 per hectare at Angaga, and 1430 per hectare at Kudafalhu). The numbers at Kudafalhu represent 1.4 x the highest numbers recorded during the devastating outbreaks at the Great Barrier Reef (Dixon 1996).

Greater numbers of *Diadema* urchins would provide considerable grazing impact that would convert much of the inner reef algae into rock, which can subsequently be colonised by coral recruits. However, urchin numbers are very low, particularly compared to other Indo-Pacific locations such as the Persian Gulf (Musandam) reefs, where numbers in excess of 100 individuals/100 m^2 are commonly recorded. At these densities, *Diadema* actually act as a significant bioeroder of reef material, as they graze below the algal turf fringe, which can lead to collapse of the living coral framework in shallow water habitats. The great difference in *Diadema* numbers between these different regions is not well understood, but may relate to predation pressure in areas with more predatory fish (e.g. humphead wrasse, titan triggerfish), availability of shelter, nutrients in the water and the availability of plankton (Young and Bellwood 2012).

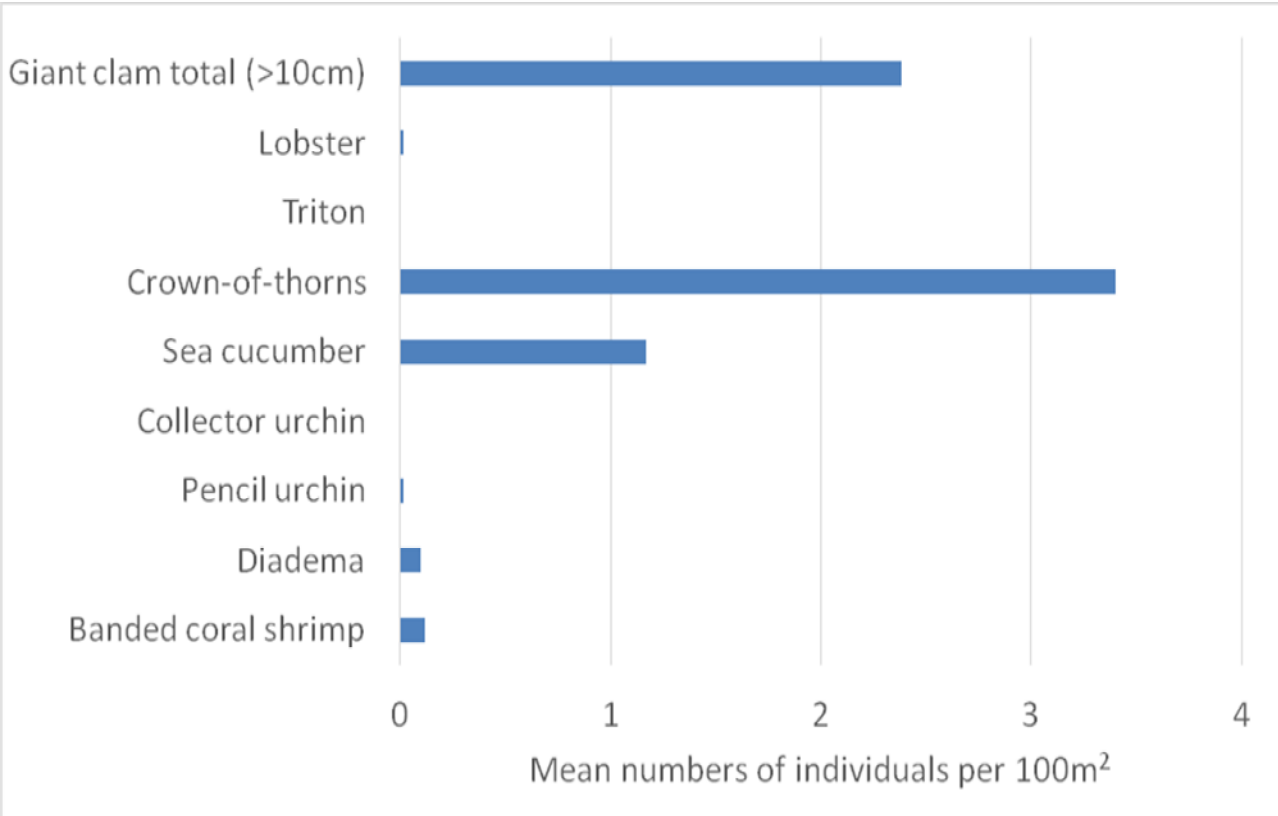

Figure 2.2f. Numbers of different invertebrates recorded on the dives.
Crown-of-thorns numbers were recorded from two inner reef sites where live hard coral cover was low (<5%).

Other impacts

Impacts beyond bleaching were relatively limited on the reefs surveyed. Most incidents of damage are caused by *Drupella* gastropods feeding from deep within the corals of branching *Acropora* colonies. Where coral reefs exhibit high coral cover, with good water quality and limited predation by COT starfish, such grazing pressure by these animals is not a significant factor. However, where reefs have already been denuded by the chronic and short-term impacts listed in Table 2.2e, pressure from *Drupella* grazing is more consequential.

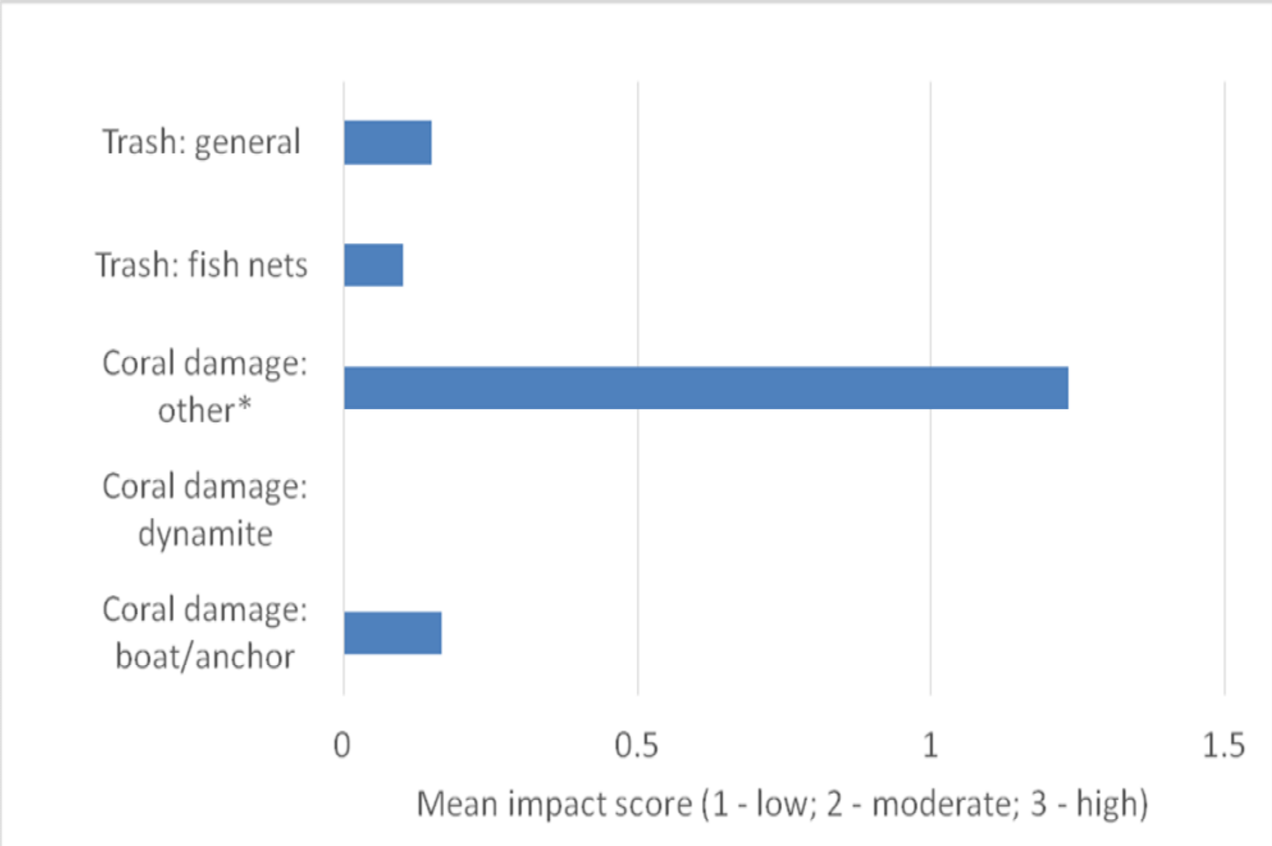

Figure 2.2g. Other impacts observed by the expedition.

Surveys by Gemana NGO and Maldives Whaleshark Research Project at Dhigurah

In a positive development arising out of the Biosphere Expeditions placement programme that trains local Maldivian in Reef Check, a pre-bleaching survey was carried out by an all-Maldivian community-based Reef Check team on 11 March 2016 at Coral Gardens, north of Dhigurah Island, the base of the Maldives Whaleshark Research Project. This survey is an interesting addition to the monitoring dataset, as this reef is a back reef, dominated by staghorn corals. As such it will be susceptible to coral bleaching and should be monitored again to reveal the extent of the bleaching damage to the site.

The team undertaking the surveys were: Aminath Shaha Hashim (Reef Check team leader), Naushad Mohamed, Arushad Mohamed, Ali Sobah, Moamed Adam, Hassan Hameez and Saamee Mohamed and Irthisham Zareer.

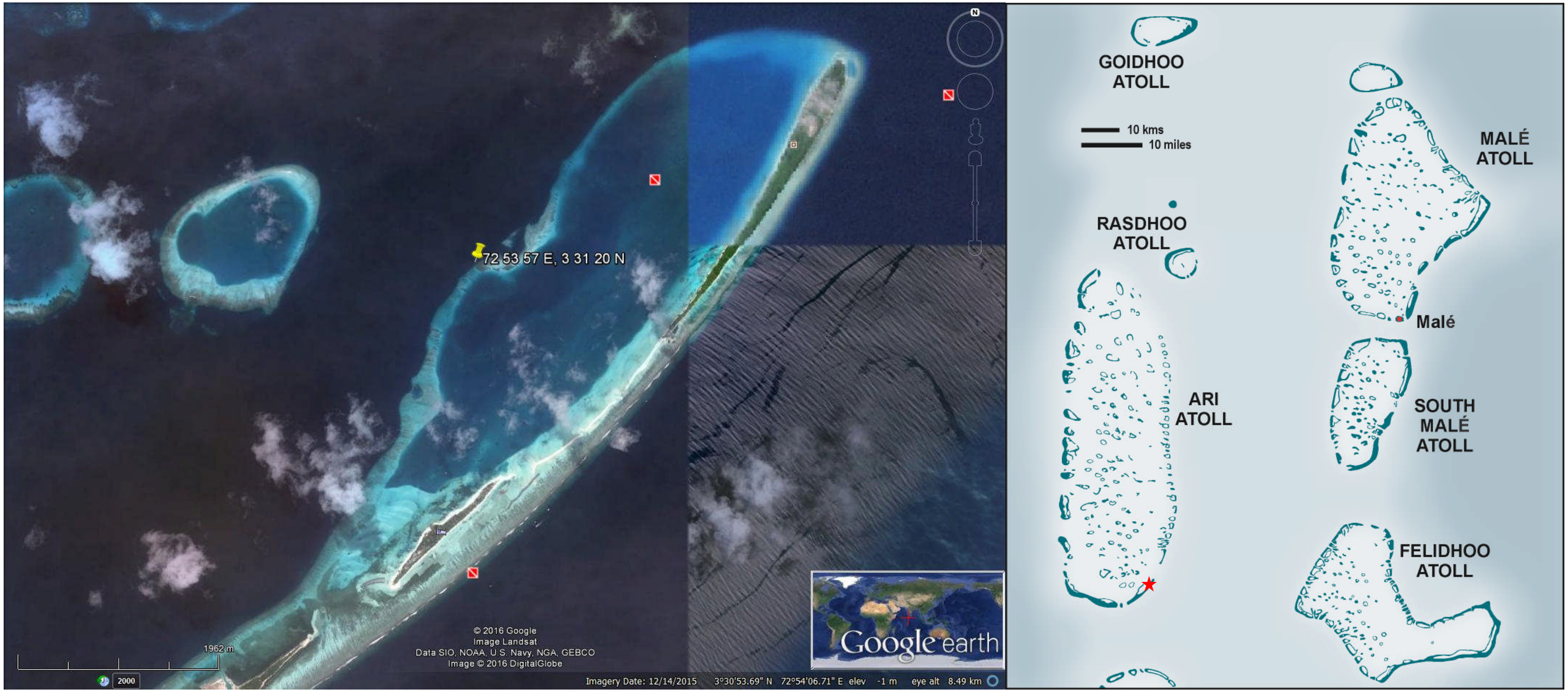

Figure 2.2h. Location of Dhigurah Island (red star on right image) and the 'coral gardens' site (yellow pin on the northern edge of the shallow lagoon).

Typical habitat and species at coral gardens:

The habitat was typical of a back reef environment with branching and table corals. The dive was undertaken at a single depth – 6m. The fish populations included one sweetlips per replicate, an average of seven parrotfish per replicate, but no recordings of commercially important grouper. Moderate numbers of sea cucumber and giant clams were also recorded on the reefs (although fewer than one per replicate).

Figure 2.2i. A matted leatherjacket filefish (*Acreichthys tomentosus*). About 8 cm in length, concealing itself amongst the branching *Acropora*. It can only feed on the coral polyps of the associated corals, so the May bleaching event would have likely had a serious impact on this species. Photo by Gemana NGO from www.facebook.com/gemanango.

Figure 2.2j. Pre-bleaching view of the coral reef at Coral Gardens, March 2016. What does this look like now? Photo by Gemana NGO from www.facebook.com/gemanango.

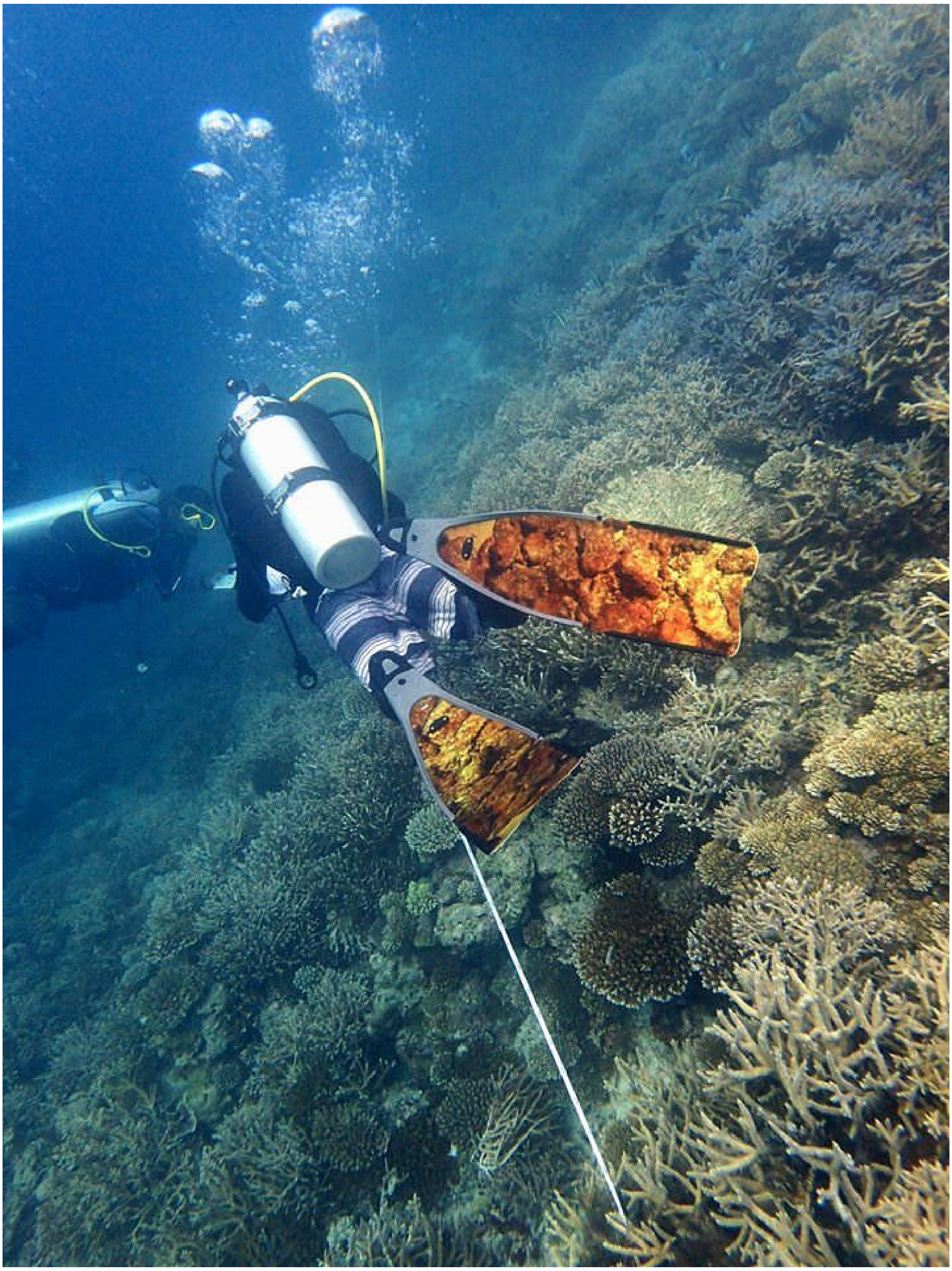

Figure 2.2k. The back reef slope at coral gardens that ranges from 3 m at the shallowest point, down to 20 m. The survey was carried out at 6 m, in the most productive part of the ecosystem (where light is intense, currents moderate and plankton supply good). Photo by Gemana NGO from www.facebook.com/gemanango.

Conference presentation

Hussein Zahir of the LaMer Group (a local consultancy) gave a presentation on the bleaching impacts of the 2016 surveys at a Rufford conference in Sri Lanka in November 2016 (Solandt et al. 2016).

2.3. Discussion and conclusions

Governance

A very worrying trend is emerging in the central Maldives: one of chronic and point impacts making a lasting impression on the coral assemblages (this report), fish populations (Sattar et al. 2012) and the general health of the marine life surrounding the islands. This is leading to increasing incidences of disease (Montano et al. 2012), COT (Saponari et al. 2014) and corallimorph outbreaks (this report). This trend is not new; it has been emerging since the mid to late 1990s. The decline of the Maldivian reefs was set in the 1990s by three principal factors:

1. The first mass-bleaching event triggered by climate change and increased SST.
2. The development of commercial fisheries for the live-fish trade (principally targeting grouper).
3. The large-scale expansion of the tourism infrastructure beyond a sustainable limit, increasing demand for seafood and construction.

All of these three issues have had their associated costs. Many would indeed argue that the second and third points have helped provide jobs for Maldivian citizens – this is true, but at a considerable cost. Indeed the primary area of concern (point 1) has been debated by former President Mohammed Nasheed in terms of concern over climate predictions resulting in sea level rise and increased storminess that may inundate the islands of the country. There are various climate models that predict the Maldives to be underwater within 50 to 100 years (e.g. Viner 2000[6]). A more immediate concern is the 'second wave' of resort expansion that is hitting the nation. The instability of the political situation, along with the national debt, has led to a policy response to massively increase land, and island reclamation for tourism expansion, arguably well beyond any sustainable limit. This may have a short-term positive impact on the GDP of the islands, but the impacts on the wider ecosystem and population are likely to be negative in the long run.

A wholly different approach to managing the Maldives is needed, whereby power is devolved to atoll councils with a requirement to sustain local economies and growth, within environmentally sensible and sustainable limits. This may ineeed require a reduction in some aspects of national GDP, but with this comes a sense of justice, resources and entitlement that local people deserve. This will also result in well-being and security for local islands and populations, with funding available for local infrastructure moved away from private to public areas (e.g. better housing, schools, shoreline protection). For example, the revenue from 2 and 3 above does not necessarily stay within the Maldives, because of (corporate) foreign ownership of many of the businesses. This is inevitable to a certain degree within the tourism sector, but is regrettable within the export business for live fish. The latter will only ever result in the demand of the market being met overseas, with no intrinsic value associated with the quality of the local resource. The market demand can be met from any other fish-rich nation if the Maldives runs out of larger fish. Indeed there is such a high price willing to be paid at the market (large live grouper can fetch $100s in restaurants per kilo) that an expensive supply-side will continue to be provided, even if suppliers have to travel to more and more remote atolls and countries.

[6] https://crudata.uea.ac.uk/cru/posters/2000-11-DV-tourism.pdf

Clearly the environmental assets that allow such income for foreign markets do not 'feed the nation', but do provide large incomes for a small minority within the political and business elite.

A view on the patterns in this report and a decade of observations

So how does this manifest into the current condition we see on the reefs of the Maldives? It is hard to tell what is going on from a few isolated sites, but the general trend is that the inner reefs have been widely and largely impacted, whilst the outer reefs are less affected, and appear to be 'holding on' two months after the initial bleaching event.Bleaching severity also decreases with depth with deeper sites less bleached. However, these patterns are only from a few sites, with little time over the course of the Biosphere Expeditions / MCS surveys to really understand the pattern on a much wider scale. Impacts coincident with depth do, however, also appear to be observed by other surveyors (e.g. IUCN).

The impression gained is that there are three reef types of reef location and condition:

1. Outer reefs associated with greater current and wave action that are generally healthy.
2. Inner reefs that are affected by disease, *Drupella*, high wave action on old-growth *Acropora* colonies.
3. Inner reefs that are exhibiting change from a coral-dominated state to an algal and *Discosoma*-phase state.

Our recommendations on issues related to vulnerability have been highlighted in previous reports available from the Biosphere Expeditions website www.biosphere-expeditions.org/reports. Our observations and training will hopefully increase awareness. It is possible that the Maldives can withstand – in the short term – such a major bleaching event. But in the long term, the equitable provision of high quality reefs and their resources will further diminish unless drastic actions are taken by those in government.

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Appendix I: Expedition diary and reports

A multimedia expedition diary is available on https://biosphereexpeditions.wordpress.com/category/expedition-blogs/maldives-2016-expedition-blogs/

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