EXPEDITION REPORT

Expedition dates: 12 – 18 September 2015
Report published: May 2016

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 2015 with Biosphere Expeditions volunteers in Ari Atoll, Maldives. Surveys concentrated on revisiting permanent monitoring sites that have been surveyed in Ari Atoll, central Maldives. The surveys were carried out whilst an El Niño event was taking place elsewhere in the world, but there was no bleaching reported over and above the low levels commonly encountered on these surveys (most reefs had less than 1% of living colonies bleached). The greatest impact to the reefs appeared to be from storm damage that affected shallow transect reefs. Coral reef fish populations were low at all sites (compared to well-managed Indian Ocean marine protected areas, and reefs with little human impact). As the El Niño event has continued at unprecedented levels into 2016, it is important that we continue to survey to understand the long-term resilience of areas we monitor. We need more surveys to better understand the status and current resilience of Maldives marine protected areas (MPAs). The developing nature of in-country Maldives Reef Check teams will help us better understand and respond to future bleaching events.

An effort-based whale shark survey was also carried out for a few hours on 17 September 2015 at the outer reef of South Ari Marine Protected Area. This yielded five encounters, all accompanied by numerous people (up to 70) and boats (up to nine), with many harassing the sharks and not adhering to safe whale shark encounter procedures. The whale shark watching industry at South Ari Marine Protected Area is out of control and needs to be reigned in, with properly enforced regulations, in order to make it safe for whale sharks and sustainable for visitors and local people.

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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 12 to 18 September 2015 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 a local charity – the Maldives Whale Shark Research Programme (MWSRP), based in southern Ari Atoll. Although the Maldivian reef atolls comprise 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 (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 included training for participants as 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 as community-based management and marine protected areas (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 entirely rely on rich and healthy reefs. However, there is a significant increase in the number of licences being offered to resort developers around the more southern atolls. A new airport in Maamigili (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 MWSRP 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 MWSRP can match an 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 MWSRP 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 (farus), 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, snappers and sharks 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 sharks and manta rays, with observations of these species an exciting event for those on board live-aboard dive trips.

Dives range from thilas, to farus in inner reefs, channel walls and slopes, and 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 the Maldives, is an island country in the Indian Ocean formed by a double chain of 26 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 200 are inhabited.

Figure 1.2a. Flag of the Maldives.

The Republic of the 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 1,000 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. Fifty-one 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

2015: 12 – 18 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-foot 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-foot 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 overcast days, some heavy rain and storms and occasional sunshine. 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 multimedia expedition updates on 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, and due to extreme currents at Digha Thila survey site on 16 September 2015, the expedition leader implemented one of these procedures and aborted the scheduled survey dive. No medical emergency resulted, and there were no further incidents during the expedition.

1.5. Scientist

The expedition's usual scientist Dr Jean-Luc Solandt could not attend in 2015. He was replaced by Mariyam Shidha Afzal. Shidha was born in the Maldives and in 2015 was in her final year of a BSc in Marine Science at the University of Malaysia Sabah (Borneo). Prior to her degree, Shidha had worked for the Maldives government's Marine Research Centre as a research assistant for three years, carrying out numerous (Reef Check and other) survey dives for the National Coral Reef Monitoring Programme of the Maldives and the Maldives Environment Management Programme. Shidha had benefitted from our placement programme over two years in the past and was trained by Dr Solandt as a Reef Check Trainer.

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):

Nessrine Alzahlawi (UAE), Lori & Robert Byron (USA), Edgar Evangelista (USA), Heather Galloway (USA), Irthisham Hassan Zareer* (Maldives), Alison Randall (UK), Mohamed Ryan Thoyyib* (Maldives), Yannick Seeland (Germany), Desiree Zhou (UK).

*Participants marked with a star took part in the expedition as part of a Biosphere Expeditions 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 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 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 (MPAs) 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 £1,590 per seven-day slot. The contribution covered accommodation and meals, supervision and induction, all maps and special non-personal equipment, and 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	18,762
Expenditure	
Staff includes local & international salaries, travel and expenses	1,866
Research includes equipment and other research expenses	697
Transport includes taxis and other local transport	0
Base includes board, lodging and other live-aboard services	13,013
Administration includes some admin and misc costs	11
Team recruitment Maldives as estimated % of PR costs for Biosphere Expeditions	4,186
Income – Expenditure	**-1,011**
Total percentage spent directly on project	**105%***

*This means that in 2015, 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 and Shiham Adam from MRC for 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 MWSRP. Support from the Rufford Foundation via LaMer for the placement programme is gratefully acknowledged also.

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 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

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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 it emerges 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 farus in the world (Risk 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 nation's (approx.) population of 350,000, 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 'farus' (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 reefs 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.

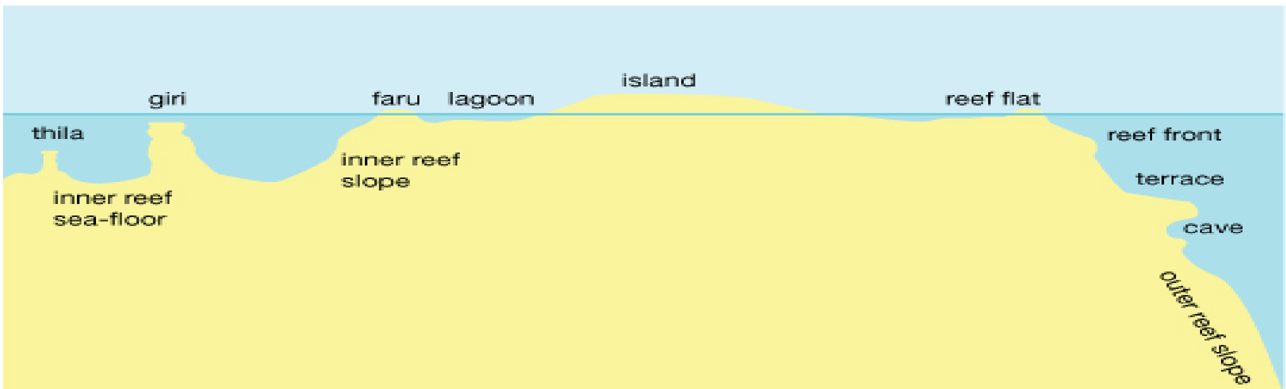

Figure 2.1a. Common reef structures of the Maldives (from Tim Godfrey).

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. Air temperature ranges between about 21°C and 31°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) (Pichon and Benzoni 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 and small amounts of bigeye also taken (Marine Stewardship Council). Up until 2010, Maldives fishermen solely used pole, line and handline fishing techniques to take skipjack and yellowfin tuna. The Maldivian tuna fishery has therefore 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 waterborne vessels (although the Maldives has a relevant enforcement department called the 'Environmental Protection Agency' (EPA), 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 longline 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 tonnes)[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), but 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 Adam 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 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 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°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°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 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 survey (Hauert et al. 1998) undertook extensive Reef Check surveys in Angaga Island in June 1998, three months after the catastrophic bleaching event. It found that 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 northeast 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. Surveys carried out in September 2015 were at various sites that have previously been surveyed along the Ari Atoll, one of the largest north–south atolls in the Maldives. Ari was considered to have been less affected by the 1998 bleaching event than reefs nearer the capital, at Male' Atoll (Zahir, personal communication*).* We visited five sites: the training site at Baros Maldives, Rasdhoo Madivaru, Bathalaa Maagaa, Kudafalhu, and Holiday Thila to the south of the atoll. Unfortunately one other site could not be surveyed because of storms making diving unsafe at this exposed pinnacle.

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 exclude 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. 2.1.3) – the site famous for its manta cleaning station, which is also meant to be an MPA (as it lies within 700 m of a tourist island).

Three more recent – and 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 whitetip (*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 the number and duration of people visiting the bay, as well as vessel speed and the number of entry points into the bay.

Unregulated private vessels, live-aboards 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 Maamigili 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, and 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 costs 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 allows 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 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).

Many Maldives citizens also 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 to 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 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 face 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 / MCS).

- 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, from NGOs and from the tourist and diving industry whilst on live-aboard 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 2015 surveys and training using Reef Check

The 2015 surveys were carried out specifically at Ari Atoll sites that have been repetitively surveyed, last so in 2013 to:

- Record and collect repetitive datasets to provide comparative data on known sites.

- Record any incidents of bleaching in this El Niño year.

- Record other variables such as storm damage, fish and invertebrate populations.

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

- Undertake Reef Check Trainer training for two local people – Irthisham Hassan Zareer and Mohamed Ryan Thoyyib – 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 in 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 before and after the bleaching event of 1998 (Zahir et al. 2005), but the opportunity to undertake research on board the extensive live-aboards and tourist islands of the country has not been fully realised. MCS has been carrying out Reef Check with live-aboards 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 live-aboard 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.

2.1.7. 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 were led by Mariyam Shidha Afzal and Catherine Edsell, both Reef Check trainers.

All training was carried out on board the MV Carpe Diem. 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 indicator algae – predominantly fleshy macroalgae that are nutrient limited such as *Lobophora*), SP (sponge), RC (rock), RB (rubble), SD (sand), SI (silt), and OT (other, such as cnidarians, zoanthids).

2.2. Results

2.2.1. Repetitive data collection

The first international Reef Check[2] 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[3]. Many of the surveys were carried out by Hussein Zahir (then of MRC, now of the LaMer private consultancy). Most of the bleaching was widespread, but it appears that western atolls have fared better in terms of recovery (Tamelander and Rajasuriya 2008).

This expedition visited five sites in Ari Atoll (Fig 2.2.1a) that had been repetitively surveyed in 2013 and 2011 to compare datasets and build up a clearer picture of coral reef health in this region. Any significant changes were noted whilst looking specifically for signs of coral bleaching as surveys were carried out during an El Niño year with global sea surface temperature higher than average, but sea surface temperatures (SSTs) on this trip remained normal (at or below 30ºC).

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 invertebrate 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.

Finally, an effort-based whale shark transect along the outer reef of the South Ari Marine Protected Area with assistance from Irthisham Hassan Zareer from the Maldives Whale Shark Research Programme was carried out for six hours between 10:00 and 16:00 on 17 September 2015. Five whale sharks were observed during the survey.

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[2] http://www.ReefCheck.org/
[3] http://www.math.ubc.ca/~hauert/publications/ReefCheck98/sites.html

Figure 2.2.1a. Location of sites surveyed in 2015 in Ari atoll.
Due to stormy conditions, the survey at Digga Thila had to be aborted.

2.2.2. Seabed cover (substrate composition) and bleaching impact

Surveys were carried out at a minimum of two depths (ranging from 5 to 12 metres) at each dive site visited.

Site 1 – Rasdhoo Madivaru reef

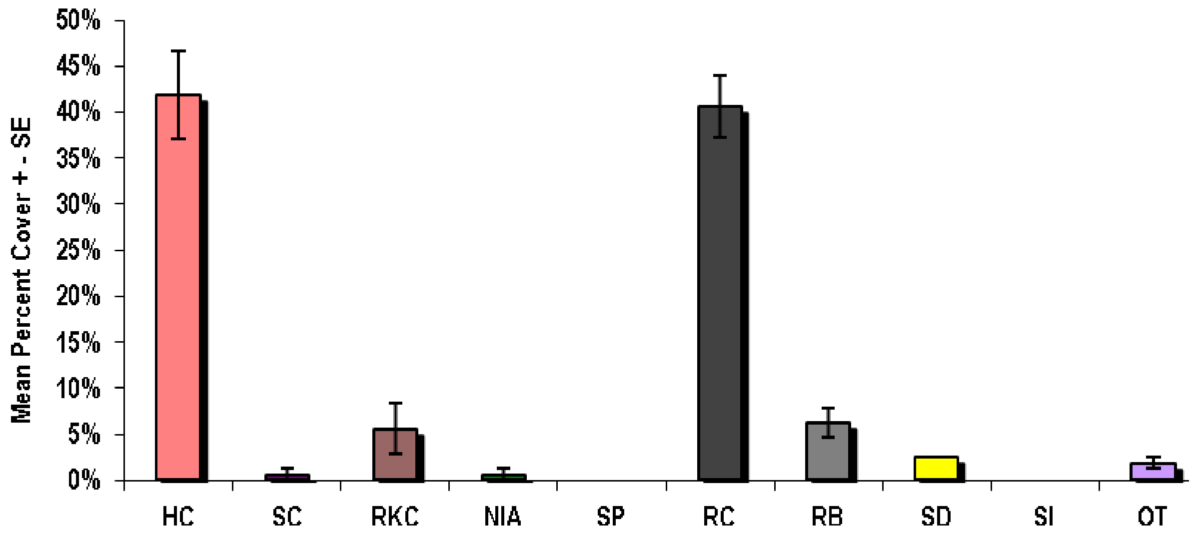

Figure 2.2.2a. Rasdhoo Madivaru substrate composition at 5 m. (HC – Hard Coral, SC – Soft Coral, RKC – Recently Killed Coral, NIA – Nutrient Indicator Algae, SP – Sponge, RC – Rock, RB – Rubble, SD – Sand, SI – Silt, OT – Other).

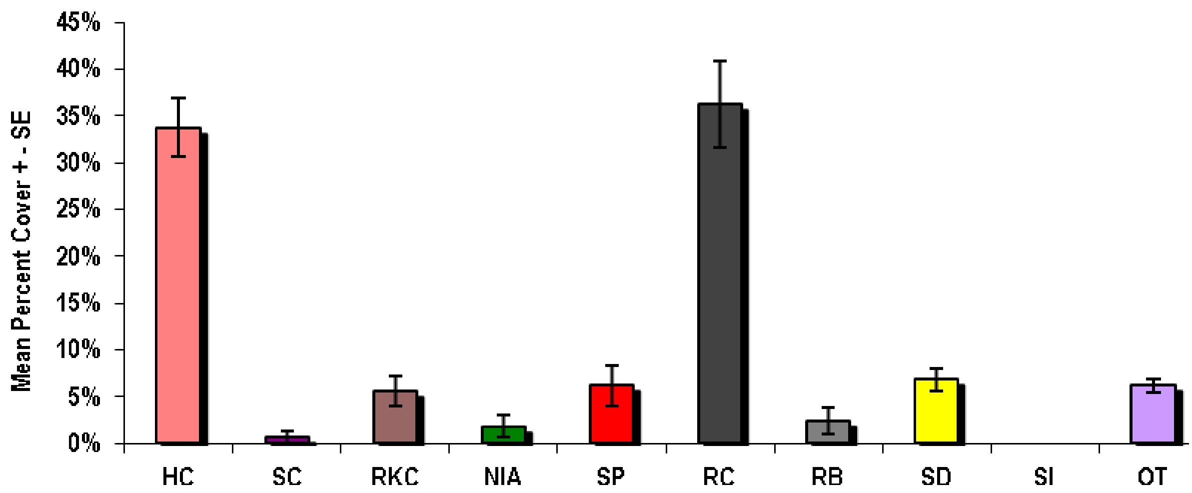

Figure 2.2.2b. Rasdhoo Madivaru substrate composition at 12 m. (HC – Hard Coral, SC – Soft Coral, RKC – Recently Killed Coral, NIA – Nutrient Indicator Algae, SP – Sponge, RC – Rock, RB – Rubble, SD – Sand, SI – Silt, OT – Other).

Compared to the Reef Check surveys carried out in Rasdhoo Madivaru in 2013 (Solandt et al. 2014), hard coral cover at both depths surveyed was slightly lower (5 m: 42% in 2015 vs. 45% in 2013; 12 m: 34% in 2015 vs. 41% in 2013). At the Rasdhoo Madivaru site, the

2015 expedition surveyed only the outer reef, which is more exposed to currents and recreational diving. The reef here is formed by a shallow 3 m reef crest, which slopes down at approximately 60 degrees to a depth of 30 m and more. Hence this is not a typical ‘Reef Check’ reef due to its steep slope down to the seabed. This survey site is very important for reef monitoring due to its habitat complexity and frequent use for recreational diving in the area. This survey site is also known as one of the best dive sites around the area and an average of three to five dive boats visit it each day. The hard coral cover is good, with bare rock and coralline algae as the other dominant substrate types. Slight bleaching and sedimentation at both depths was responsible for the Recently Killed Coral recorded. Sedimentation could be mainly due to current and tidal activity in the area and is presumed to be a relatively natural phenomenon.

Impacts affecting Rasdhoo Madivaru

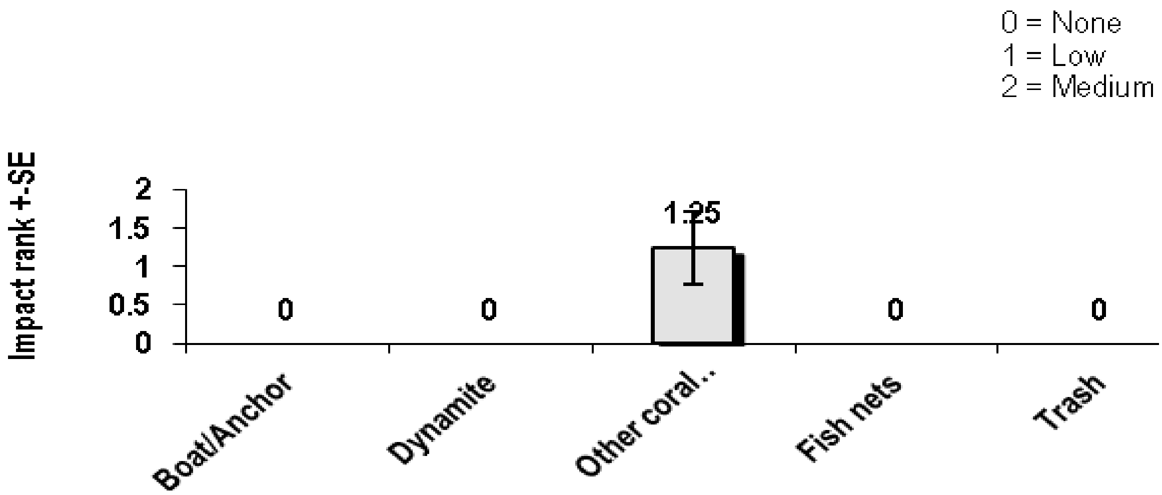

Figure 2.2.2c. Rasdhoo Madivaru coral damage at 5 m.

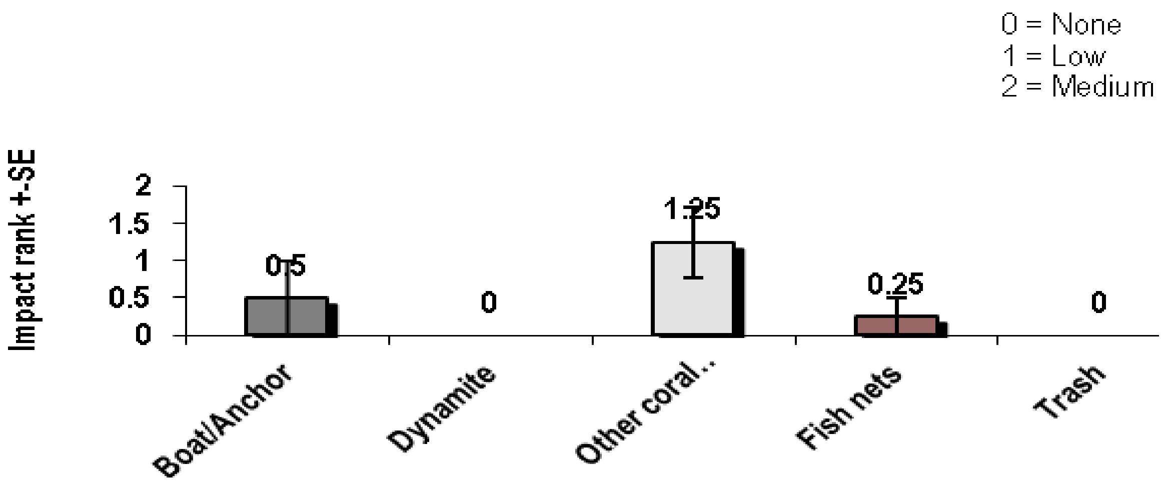

Figure 2.2.2d. Rasdhoo Madivaru coral damage at 12 m.

The only impact observed at the shallow transect was coral damage due to predation from *Drupella* spp. (coral-eating gastropods). At the 12 m transect, impacts such as boat anchor damage, predation and fishing lines were observed. Overall impacts recorded at both transects were relatively low.

Site 2 – Bathalaa Maagaa

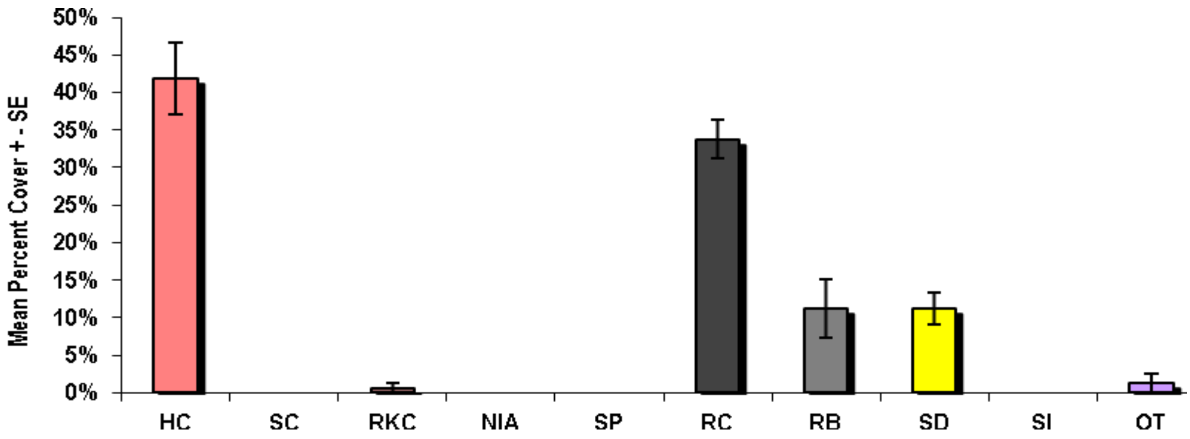

Figure 2.2.2e. Bathalaa Maagaa substrate composition at 5 m. See Figure 2.2.2a for codes.

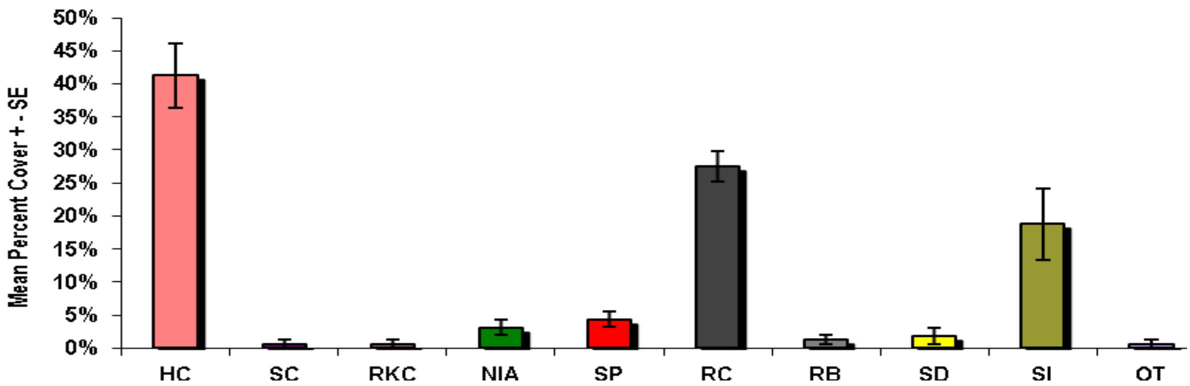

Figure 2.2.2f. Bathalaa Maagaa substrate composition at 12 m. See Figure 2.2.2a for codes.

In comparison to the Reef Check data from previous years at Bathalaa Maagaa, average hard coral cover has slightly increased (from 28% to 42% between 2013 and 2015 at 5 m, and from 35% to 41% between 2013 and 2015 at 10 m depth) (Solandt et al. 2014). Hard coral cover does not differ significantly and remains almost the same at around 40% between shallow 5 m and deep 12 m transects (Figs 2.2.2e and f). Bare rock (47% to 31%) and coralline algae has slightly decreased in this site compared to 2013 survey data, which could indicate new coral recruitment in the area. In the deep transect, mean percentage cover of silt has increased (from 0% in 2013 to 19% in 2015) with some coral colonies covered in sediment and a slight amount of coral bleaching due to the sediment smothering corals. As this site is located on the northeast edge of Ari Atoll, it is often exposed to north-easterly monsoon winds and storms. In the shallow transect some indication of storm damage was observed, i.e. overturned coral colonies.

Impacts affecting Bathalaa Maagaa

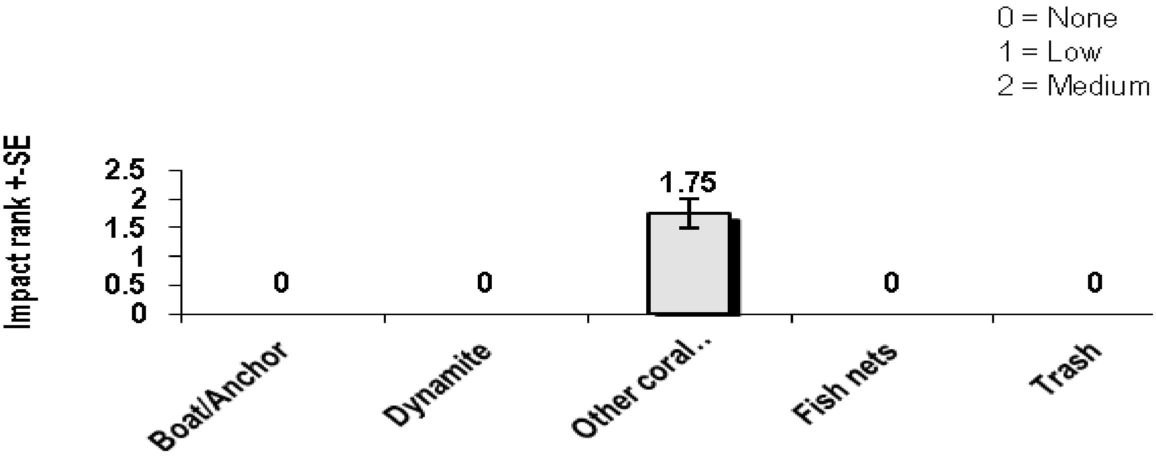

Figure 2.2.2g. Bathalaa Maagaa coral damage at 5 m.

No impacts were observed in the deeper transect of Bathalaa Maagaa. However, in the shallow transect the cause of coral damage was due to sedimentation and the effects of storms (wave action), as evidenced by several overturned coral colonies observed. In general the reef was in a fair condition and a lot of new recruitment and increase in hard coral cover was observed compared to past surveys.

Site 3 – Kudafalhu

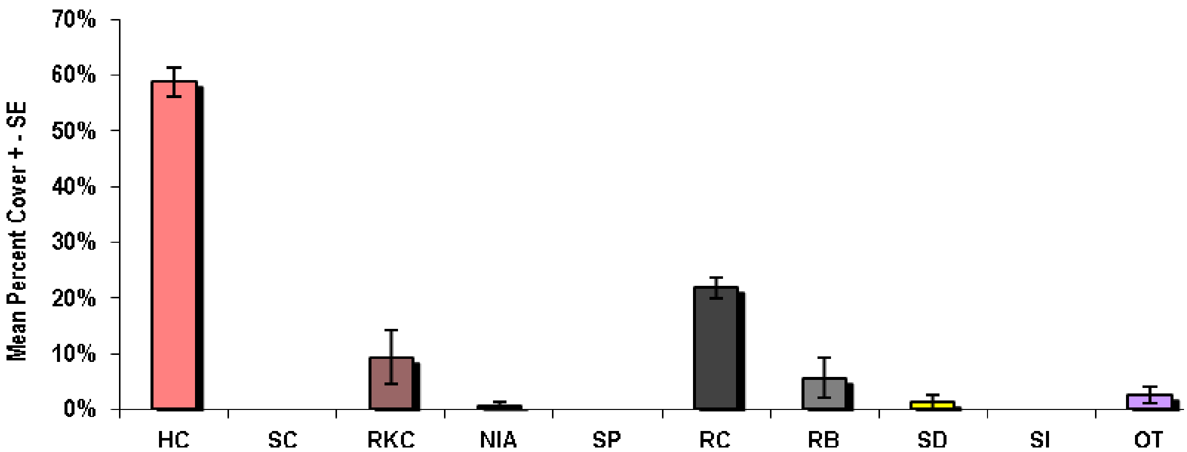

Figure 2.2.2h. Kudafalhu substrate composition at 5 m. See Figure 2.2.2a for codes.

The shallower transect of Kudafalhu had the greatest coral cover (58%) among all the sites surveyed during the 2015 expedition (see Figure 2.2.2h). The deep transect of Kudafalhu was dominated by bare rock (36%), rubble fields (20%) and patches of sand (23%) between the rubble fields. The coral cover is quite low in the deeper transect. Coral cover has decreased from 69% to 59% between 2013 and 2015 at 5 m (originally 74% in 2011). At 9 m the cover has decreased from 23% to 17% between 2013 and 2015.

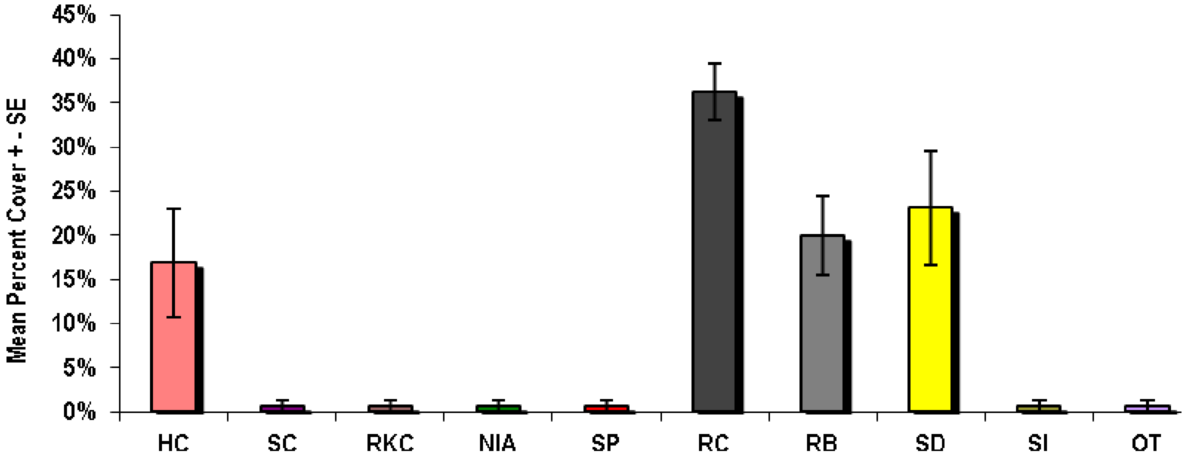

Figure 2.2.2i. Kudafalhu substrate composition at 12 m. See Figure 2.2.2a for codes.

The main reason for the high percentage of rock and rubble fields is likely to be due to the shallower transect being dominated by *Acropora* branching corals and table corals, which are vulnerable to storm damage and will quickly fragment in a catastrophic event such as post-bleaching or a storm. With time these fragments naturally make their way down the slope where they are recorded as rubble or rock. Some overturned and dead *Acropora* table corals were observed in the shallow transect alongside newly settled coral recruitments. This is a good indication that coral reefs are highly resilient to change in environmental conditions and can adapt and regrow after catastrophic events such as storms, provided conditions return to normal.

Impacts affecting Kudafalhu

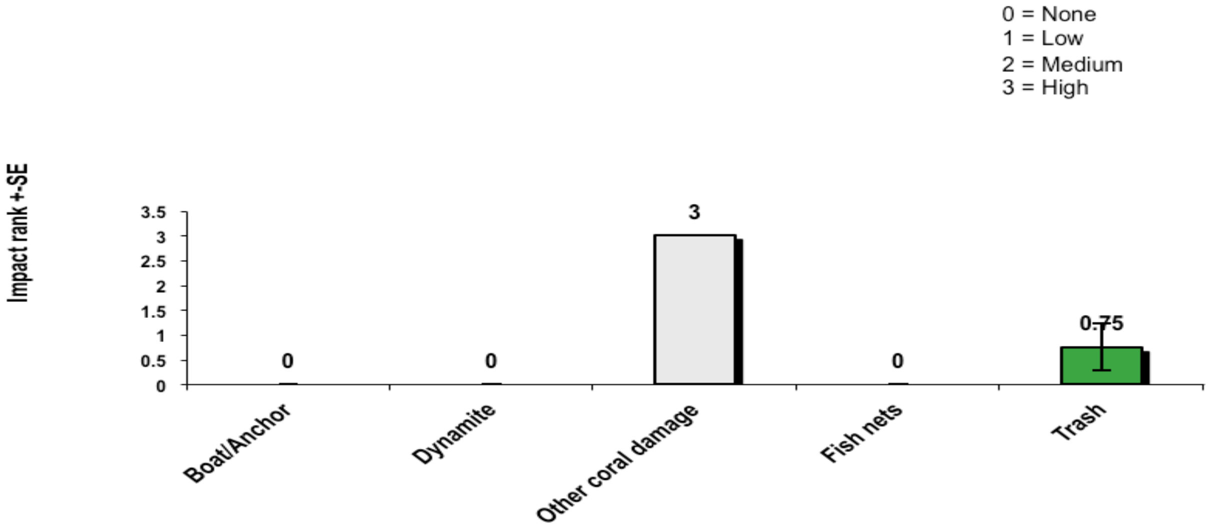

Figure 2.2.2j. Kudafalhu coral damage at 5 m.

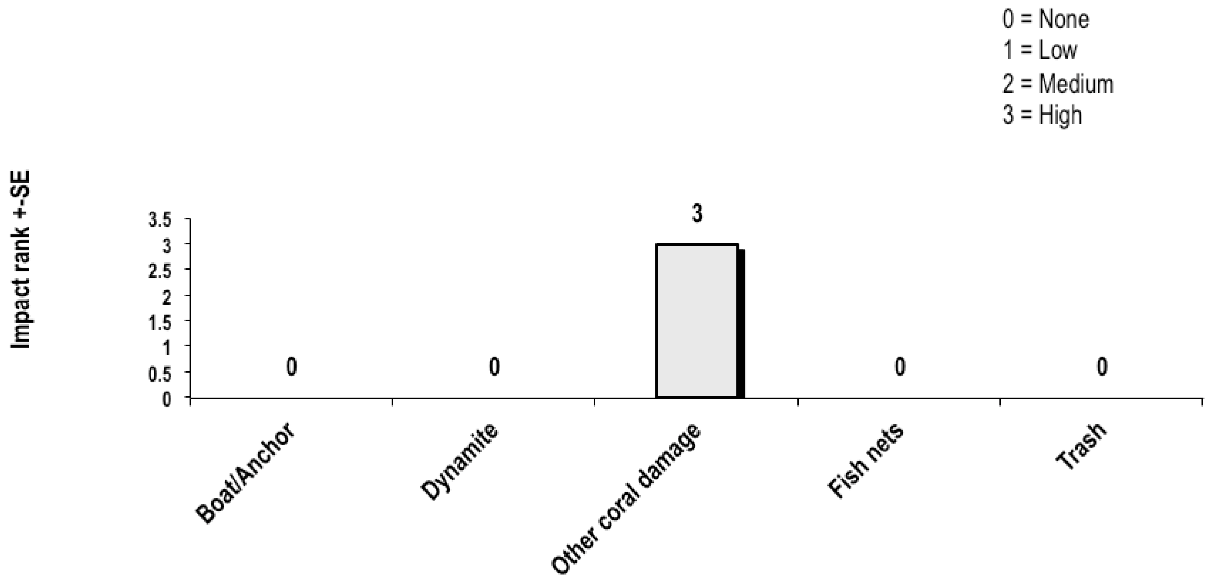

Figure 2.2.2k. Kudafalhu coral damage at 12 m.

Impact to the reef from various factors was observed at this site. ‘Other’ coral damage was predominantly from *Drupella* predation and there was also some storm damage at both transect depths. A small amount of trash was also found at the shallow transect.

Site 4 – Holiday Thila

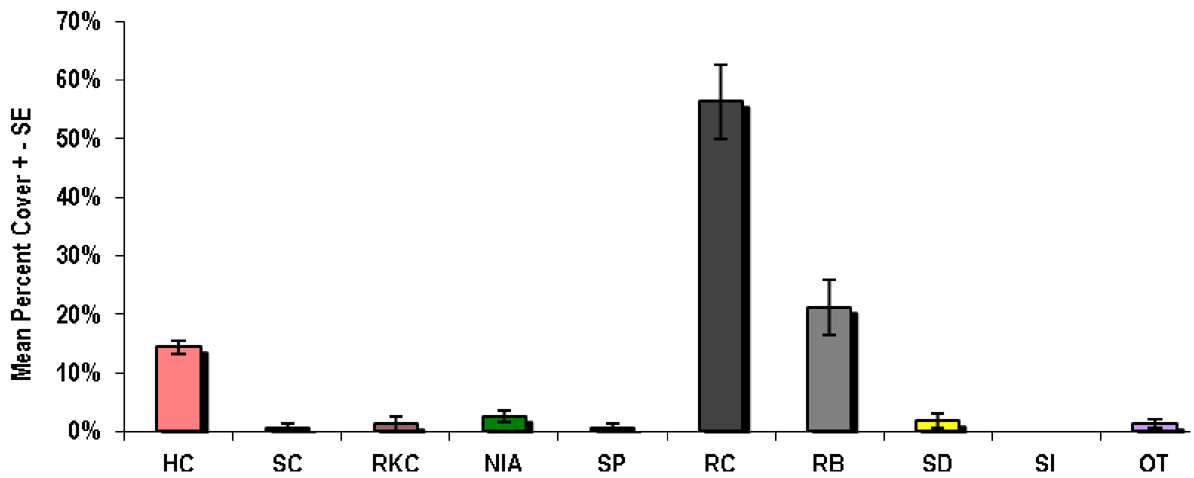

Figure 2.2.2l. Holiday Thila substrate composition at 5 m. See Figure 2.2.2a for codes.

Holiday Thila is located inside South Ari Atoll near to the south of the atoll. Hard coral cover of both the shallow and deep transect was poor at the site. The shallower transect was dominated by bare rock (56%) and rubble fields (21%). The deep transect was dominated by bare rock (24%), silt (26%) and nutrient indicator algae (16%).

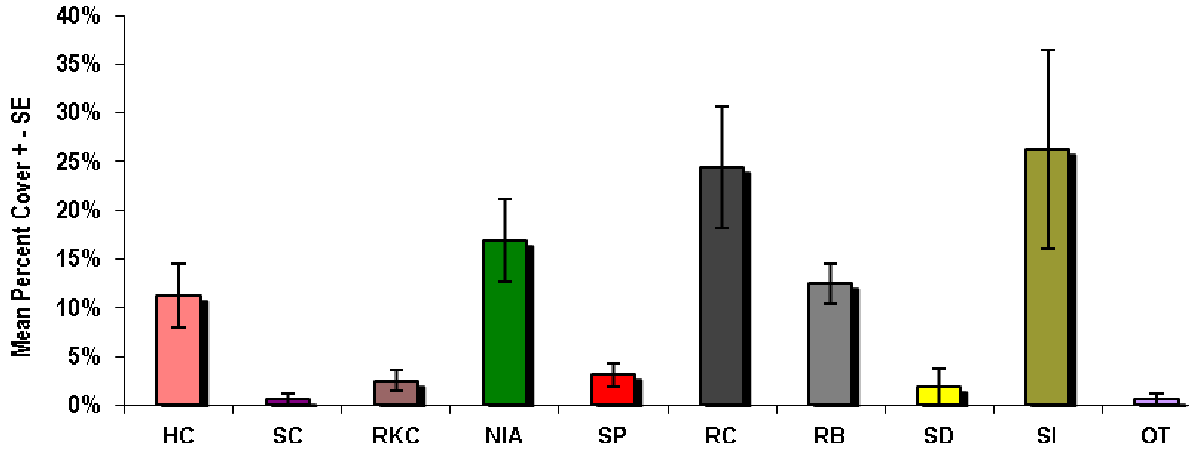

Figure 2.2.2m. Holiday Thila substrate composition at 12 m. See Figure 2.2.2a for codes.

This relatively high growth of nutrient indicator algae could be due to a nutrient source coming from nearby resorts. The high number of rock and rubble fields recorded is mainly due to overturned *Acropora* colonies, which have eroded away with time and changed into rubble and rock. This could be an indication of severe wave action caused by storms near the survey site within the last two years (the site was healthy in 2012 when last surveyed). Coral cover has significantly decreased from 50% to 14% at 5 m between 2011 and 2015. At 11 m coral cover has decreased from 31% to 11% in the same period. As this thila is located to the south of South Ari Atoll it has little shelter from the channels that bring in current and waves – particularly if the monsoon winds and wave action are due south.

Impacts affecting Holiday Thila

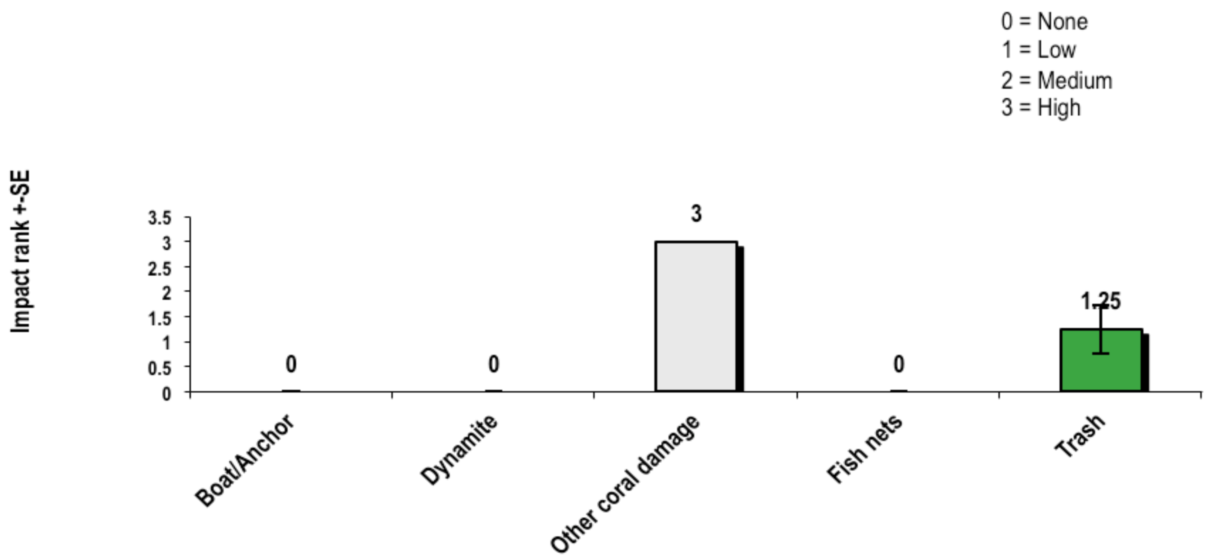

Figure 2.2.2n. Holiday Thila coral damage at 5 m.

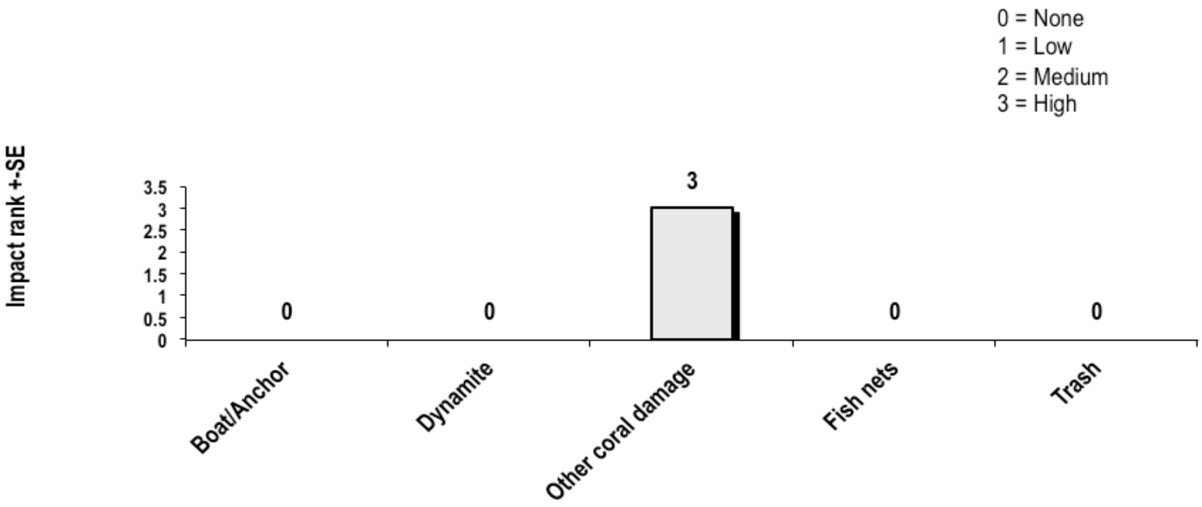

Figure 2.2.2o. Holiday Thila coral damage at 12 m.

We considered impacts to the reef from the shallow transect to be primarily from storms, with some trash also found in the reef. In the deeper transect the only impact recorded is coral damage due to storms. This was concluded to be storm damage by observation of many colonies of corals overturned and some reduced to rubble. Impact from storm damage was high at both transect depths, with divers finding more than five pieces of large broken coral colonies at each depth. In addition to storm damage, siltation seems to be another major problem faced by the coral colonies here, making it more susceptible to bleaching as a result of being covered by sediment.

2.2.3. Fish (grouper) populations

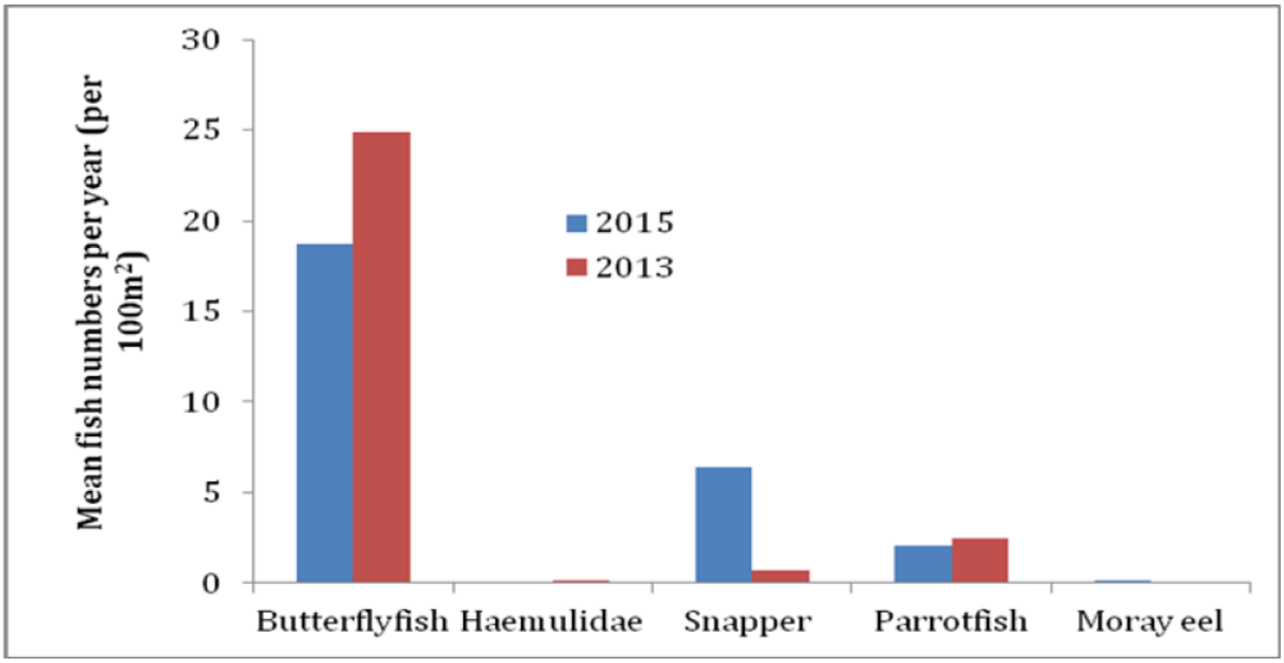

Figure 2.2.3a. Fish populations from sites dived in 2013 and 2015 (pooled data from Rasdhoo Madivaru, Bathalaa Maagaa and Kudafalhu).

There was no statistically significant variation in butterflyfish, parrotfish and sweetlips (Maemulidae) fish populations between sites and depth surveyed. In general, there are similar trends at all sites and depths. The most dominant fish families recorded were butterflyfish and parrotfish. Snapper and Haemulidae were recorded at low densities. Moray eels were recorded in 2015 only and then only at Rasdhoo Madivaru. No sightings of humphead wrasse were recorded. The most significant change between the 2013 and 2015 data appears to be that the numbers of snapper have significantly increased at three dive sites visited, which is from the large numbers of snapper occurring at both shallow and deep depths – with an average of 12 animals per 100 m^2 at shallow depths, and 15 at 12 m.

Butterflyfish are highly abundant on Maldivian reefs and are an important indicator for fishing pressure for the aquarium trade that does occur in the Maldives[4]. In addition they are crucial for reef health as they feed primarily on coral polyps (Cole et al. 2008).

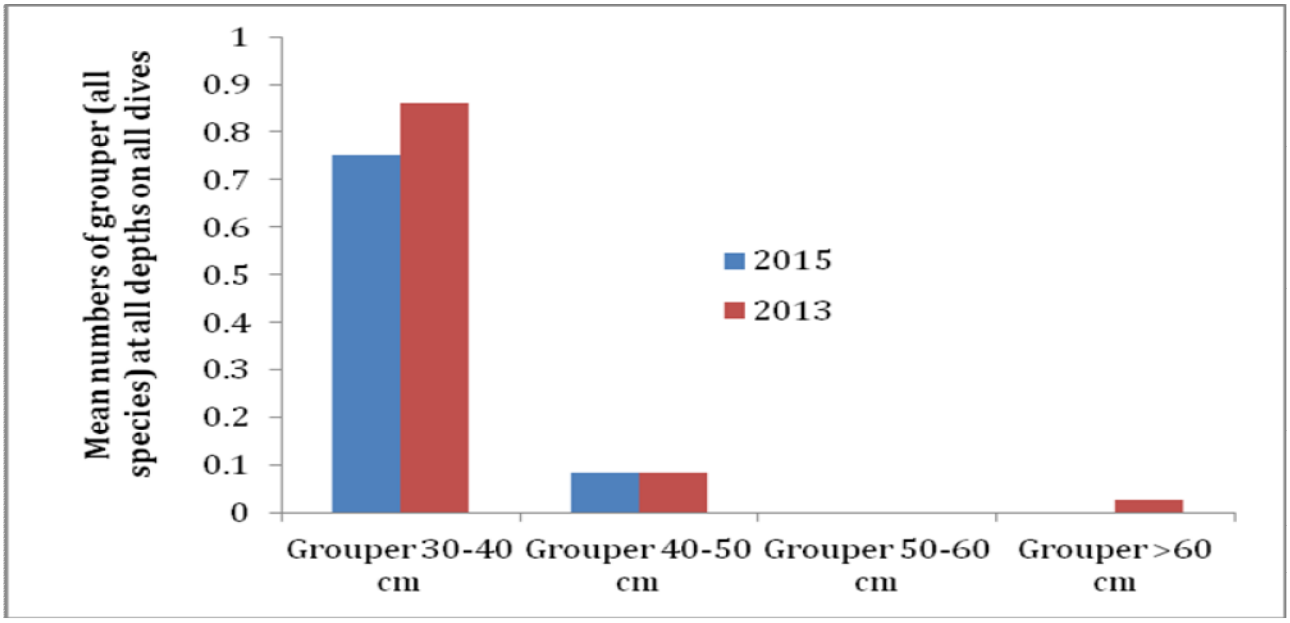

Figure 2.2.3b. Grouper fish populations from sites dived in 2013 and 2015 (pooled data from Rasdhoo Madivaru, Bathalaa Maagaa and Kudafalhu).

There were reasonable numbers of groupers found at some of the survey sites. However, their mean size ranges are small (because the larger species have been fished out, or only exist at smaller sizes). Small groupers such as coral hind (*Cephalopholis miniata*), peacock grouper (*Cephalopholis argus*) and redmouth grouper (*Aethaloperca rogaa*) are generally found near the reef and in shallower depths; and these dominate. Only animals between 30 and 40 cm and 40 and 50 cm were recorded. It is well known that fish populations of the central Maldives suffer from overfishing, particularly of apex level carnivores. Groupers are highly targeted in the Maldives, and exploited for food, export and the tourism industry (Sattar et al. 2012). Grouper species that tend to grow bigger, such as black saddle grouper (*Plectropomus laevis*) and giant grouper (*Epinephelus lanceolatus*), are often found in deeper waters off the shallow reef sites (Fig. 2.2.3c) and so are not captured by Reef Check dives. They can also be more dominant in channels where currents are stronger.

[4] http://www.fao.org/docrep/x5623e/x5623e0l.htm

There is little difference in the grouper populations between 2013 and 2015, indicating no change in populations of the family, which is heavily targeted and overfished by commercial fishing for export and the tourist industry.

Figure 2.2.3c. Two individuals of *Plectropomus laevis* (black saddle grouper) over 60 cm spotted off the transect in deeper waters at Rasdhoo Madivaru – a rare sight in at popular Maldives dive sites.

2.2.4. Megafauna

Sharks and eagle rays were recorded only at Rasdhoo Madivaru (one spotted eagle ray *Aetobatus narinari*, three whitetip reef sharks *Triaenodon obesus*, two grey reef sharks *Carcharhinus amblyrhynchos*). Elsewhere no rare species or megafauna were recorded.

2.2.5. Bleaching

With a global El Niño event of unprecedented scale happening as this report is being written and rising sea surface temperatures (SSTs), corals are vulnerable to bleaching when SST exceeds temperatures normally experienced during the hottest months. In early 2015, there was a temperature hotspot circulating the Maldives and Great Barrier Reef with extremely high thermal stress. Risk from bleaching currently appears to be in southern hemisphere waters. The real-time NOAA bleaching website[5] offers a useful real-time view of where problems are currently occurring for reefs (Fig. 2.2.5a). However, SSTs for now indicate that the Maldives are currently at low risk from a bleaching event.

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[5] http://coralreefwatch.noaa.gov/satellite/bleaching5km/index_5km_baa_max_r07d.php

At the time of writing the 2015/2016 El Niño is the strongest ever recorded, and the current bleaching event is considered to be third ever worldwide event[6]. The Caribbean has so far been the worst affected. The outcome of such an El Niño could be dramatic, especially for countries such as the Maldives, which is composed of coral islands and heavily dependent on their reefs for local livelihoods.

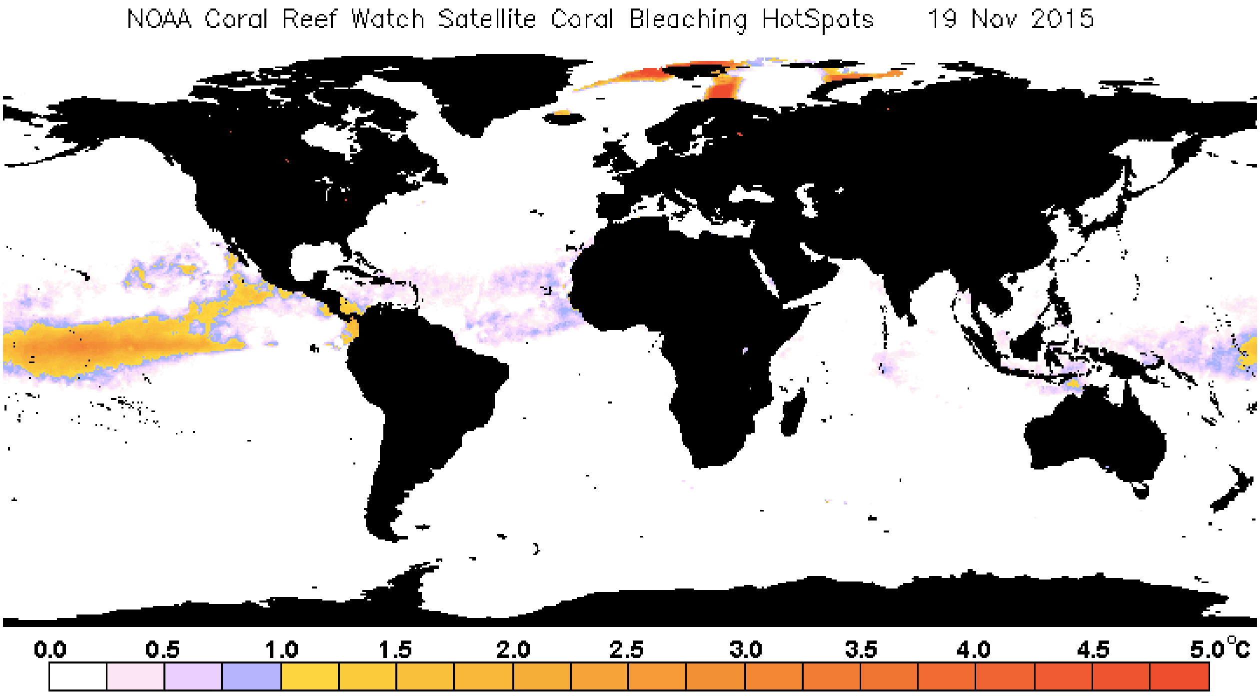

Figure 2.2.5a. Bleaching 'hotspots' on 19 November 2015 from the NOAA bleach watch website.

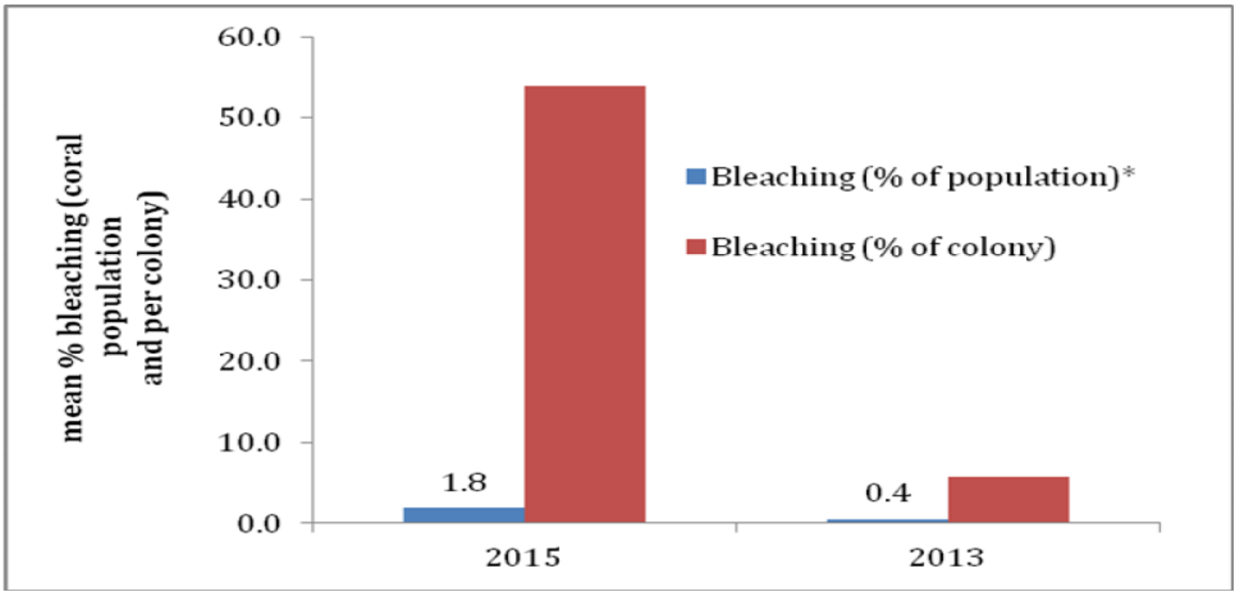

Figure 2.2.5b. Bleaching as % of the entire living reef population and per colony (for those colonies bleached, the % of the individual colonies that are bleached) for 2015 and 2013 (pooled data from Rasdhoo Madivaru, Bathalaa Maagaa and Kudafalhu).

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[6] http://www.noaanews.noaa.gov/stories2015/100815-noaa-declares-third-ever-global-coral-bleaching-event.html

Having said all this, when the expedition conducted its survey in September 2015, the El Niño was only just beginning and so no major bleaching was recorded (Fig. 2.2.5b). There was little bleaching overall, and when there was, it was mainly due to corals being smothered by sediment. This is indicative of severe weather patterns transferring sediments from reef crests down the reef slope, where they deposit on coral colonies in deeper waters. The percentage of coral populations affected by such bleaching was estimated at between 1 and 4%, so the impact on any climate phenomena was not apparent during surveys. Some ‘bleaching’ could also have been due to *Drupella* predation, as these damage types are difficult to distinguish, especially for citizen science volunteers.

Maldivian bleaching is estimated to be quite localised in any given year at any given site due to local environmental variables differing in time and space (Sapp 1998, Wilkinson and Buddemeier 1994). For example, if the reefs of the southern part of the Maldives face a bleaching event, conditions could be totally different in the northern waters (the Maldives is one of the world's most geographically dispersed countries, covering 90,000 square kilometres and being 820 km in length and 130 km in width). It is therefore hard to predict which reefs are going to be impacted by a bleaching event. Isolated locations of bleaching are also likely to recover at different speeds, as some reefs appear to be totally dominated by corallimorphs – see Solandt et al. (2014), who report an inner giri totally dominated by these life forms.

2.2.6. Disease

A very small proportion of the living coral community (in fact only a single colony) was considered to be affected by coral disease (white band or white syndrome). No black band disease was recorded.

2.3. Discussion and conclusions

The 2015 Reef Check surveys carried out by the annual Biosphere Expeditions survey expedition to permanent monitoring sites in the Maldives show no significant trends in comparison to surveys carried out at the same the sites in 2013 and 2011. Coral cover at all sites shows an increase or decrease of 10% compared to past surveys that may be simply due to the transect being laid in a slightly different location in different years. In general, according to Coral Reef Health Criteria developed by Chou et al. (1994), Maldivian reefs are considered to be in ‘fair’ condition with an average live hard coral cover of 32.52% in 2015.

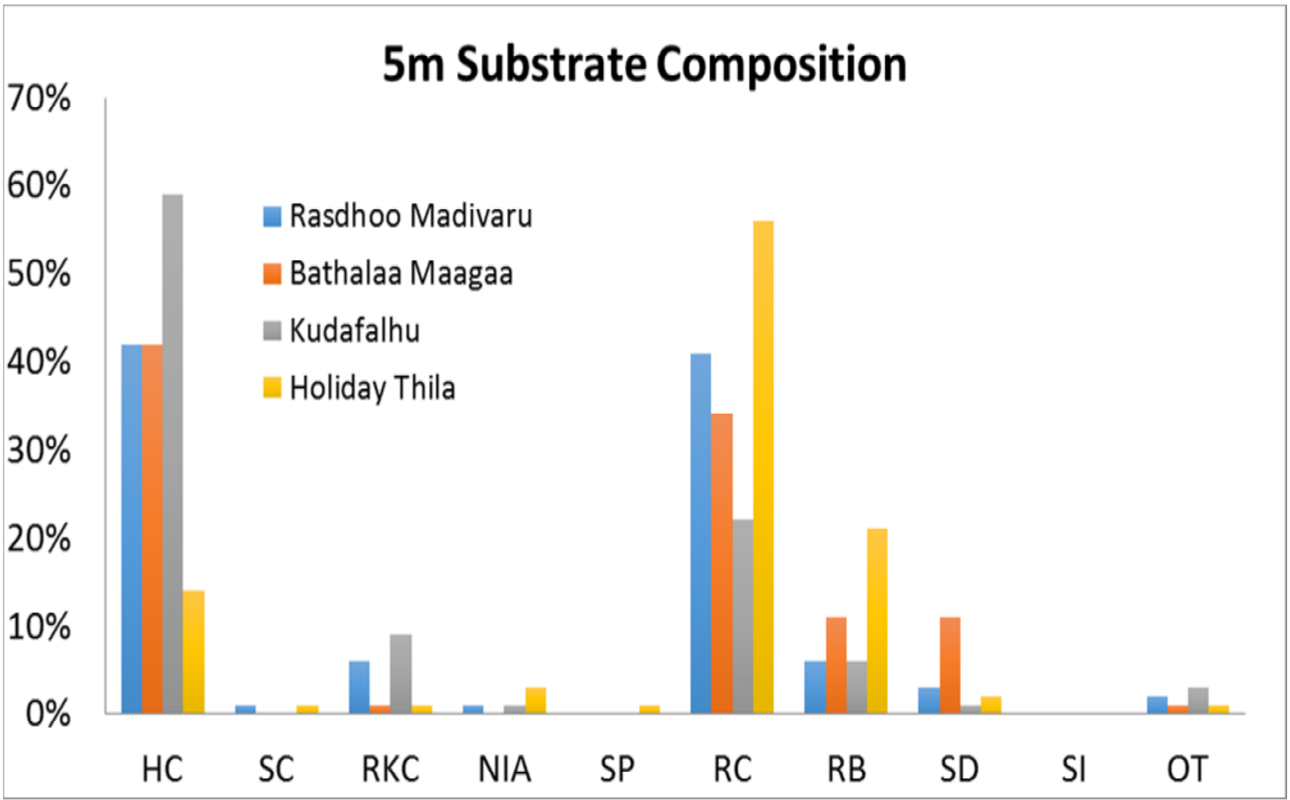
Percentage of live coral cover	Rating
0-25	Poor
26-50	Fair
51-75	Good
76-100	Excellent

Figure 2.3a. Coral reef health criteria (according to Chou et al.1994).

The Recently Killed Coral (RKC) count indicates the amount of coral killed within the past 12 months due to various impacts such as bleaching, predation (e.g. crown of thorns, *Drupella*, etc.) and other local environmental stresses (e.g. temperature-induced bleaching, sedimentation and storm damage). Low levels (lower than 10%) of RKC were recorded. This indicates that Maldivian reefs are currently suffering low levels of impact. However, there is a significant increase in the percentage of rock (RC) in some survey sites, specifically at Holiday Thila (Fig. 2.3b) where 56.3% of substrate cover was composed of rock at the shallow transect. It appears the site was impacted by storm damage as mature *Acropora* table colonies were overturned. In addition to a high percentage of rock, there was a significant amount of rubble (RB) (21.3%) at this site's shallow transect as well. The amount of rubble and rock is a cause for concern at Holiday Thila. The stabilising nature of coralline algae is the main factor that cements rubble and provides a surface for new coral recruitment. Rubble that does not get colonised by coralline algae is a threat to reef health (Solandt et al. 2013) and the only rubble that we have observed effectively colonised by corraline algae since 2005 is in very shallow reef areas. Over time some of the dead reef material, such as rubble, falls down the reef slope, thus increasing the rubble and sand cover in the deeper reefs. More ephemeral coral species such as *Acropora* table and branching life forms may have reached their maximum size in terms of their ability to withstand moderate storm wave surges at Holiday Thila (Solandt and Hammer 2013). This appeared to be the case for shallow Digga Thila in 2013 and the 2015 survey at Holiday Thila and Kudafalhu (Fig. 2.3c), where overturned and broken *Acropora* tabular and branching species were found, next to large areas of 'new' bare rock supporting new coral recruitment.

Another observation that suggests recent storm damage was the relatively common observation of sediment covering some colonies, particularly on deeper corals. Rough weather conditions will cause sediment from the reef crest to cascade down the slope, covering some deeper coral colonies. Such colonies covered in sediment were observed at almost every site – even exposed Rasdhoo Madivaru (Fig. 2.3e). More than five such colonies were observed at Rasdhoo Madivaru and at the Bathalaa Maagaa deep transect. Sedimentation particles often smother reef organisms such as corals and reduce the availability of light for photosynthesis and increase the amount of mucus produced by the coral in order to slough off the additional sediment. By altering both physical and biological processes, excessive sedimentation can unfavourably affect the structure and function of coral reef ecosystems (Rogers 1990).

Throughout the expedition monsoon storms battered the more exposed atolls and sites (Fig. 2.3g). Due to climate change and other factors, the Maldives weather patterns have become more unpredictable and severe weather patterns are observed throughout the year in the country. One of our planned surveys in Dhigga Thila had to be aborted due to bad weather. Dhigga Thila is an isolated outcrop located in central Ari Atoll 6 km due east from the outer (west-facing) channel of southern Ari Atoll. It is exposed to the currents and waves that come through the west-facing outer channel reefs. Past surveys carried out at the site in 2011 and 2013 identified storm damage (broken table *Acropora* colonies). According to the Maldivian climate reports of July, August and September 2015, strong wind speeds of >20 mph were recorded in the west of the Maldives from Hulhule' weather station (nearest to the survey sites) (Fig. 2.3f). As Ari Atoll is located on the west side of the Maldives, some of these sites could also have been exposed to high winds and storm conditions throughout these three months, making some of our survey sites highly vulnerable to storm damage. This must be borne in mind when revisiting these sites during future surveys.



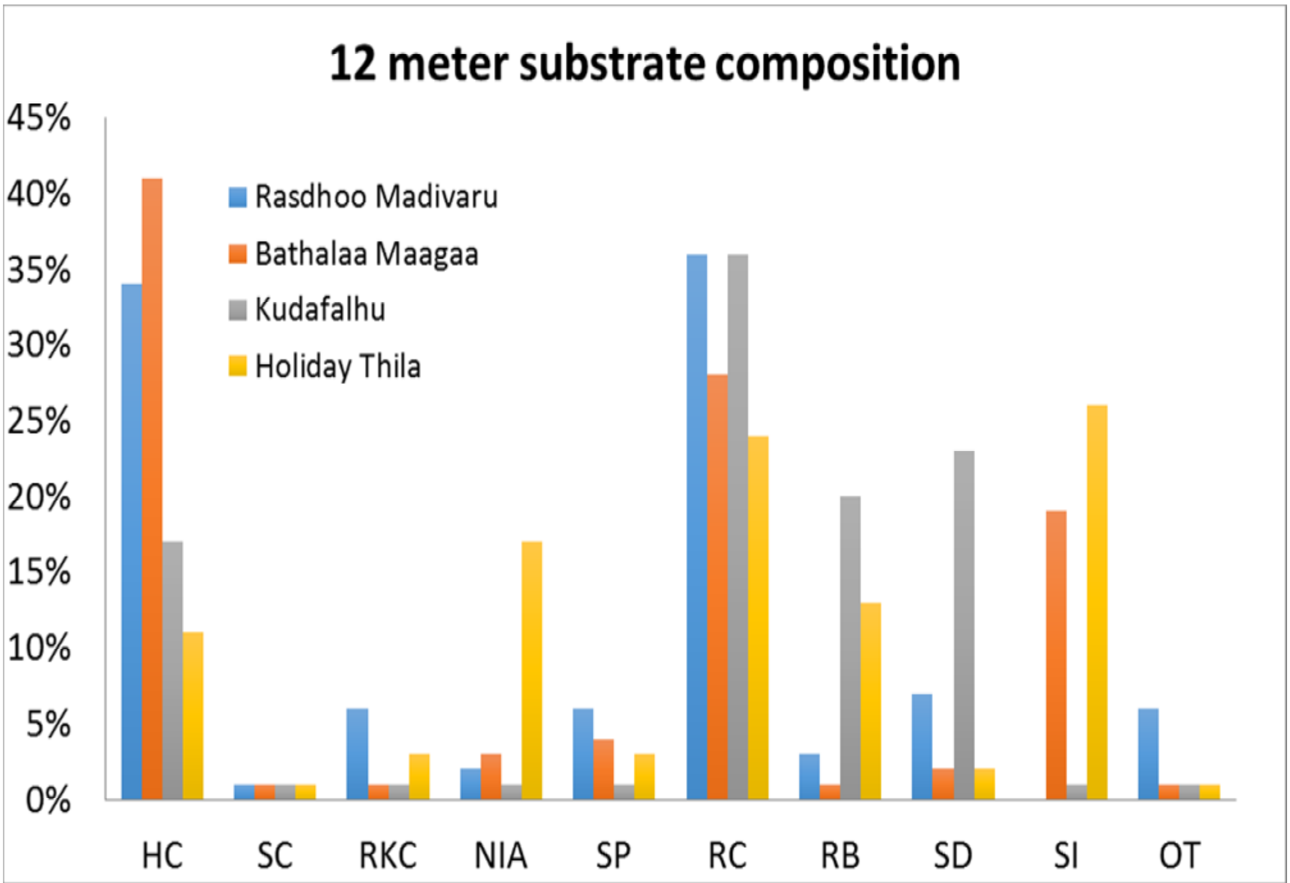


Figure 2.3b. Percentage substrate cover of all the sites surveyed in 2015 at the two depth bands.

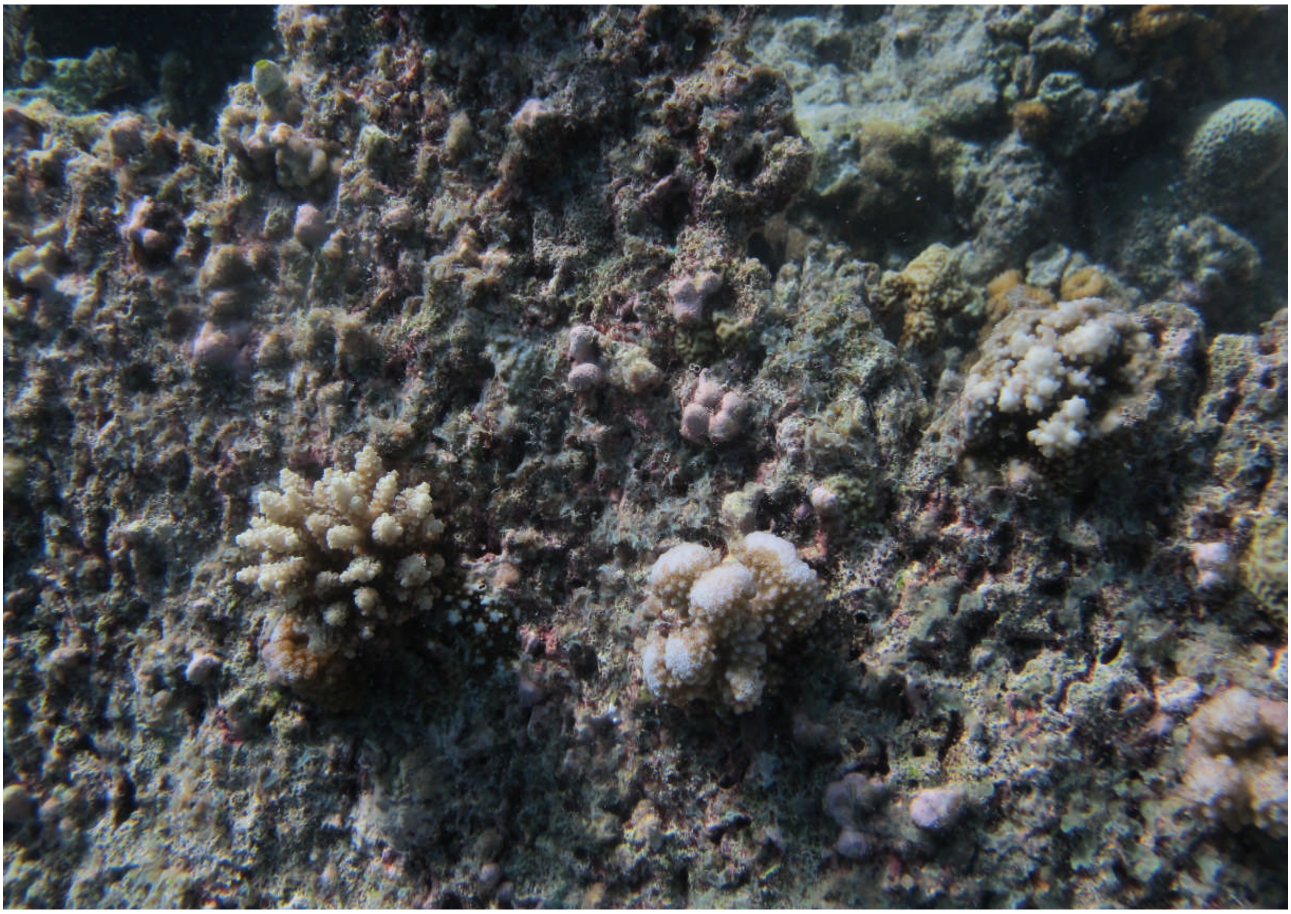


Figure 2.3c. Overturned dead *Acropora* coral (whole background) supporting new coral recruitments at the Kudafalhu shallow transect.

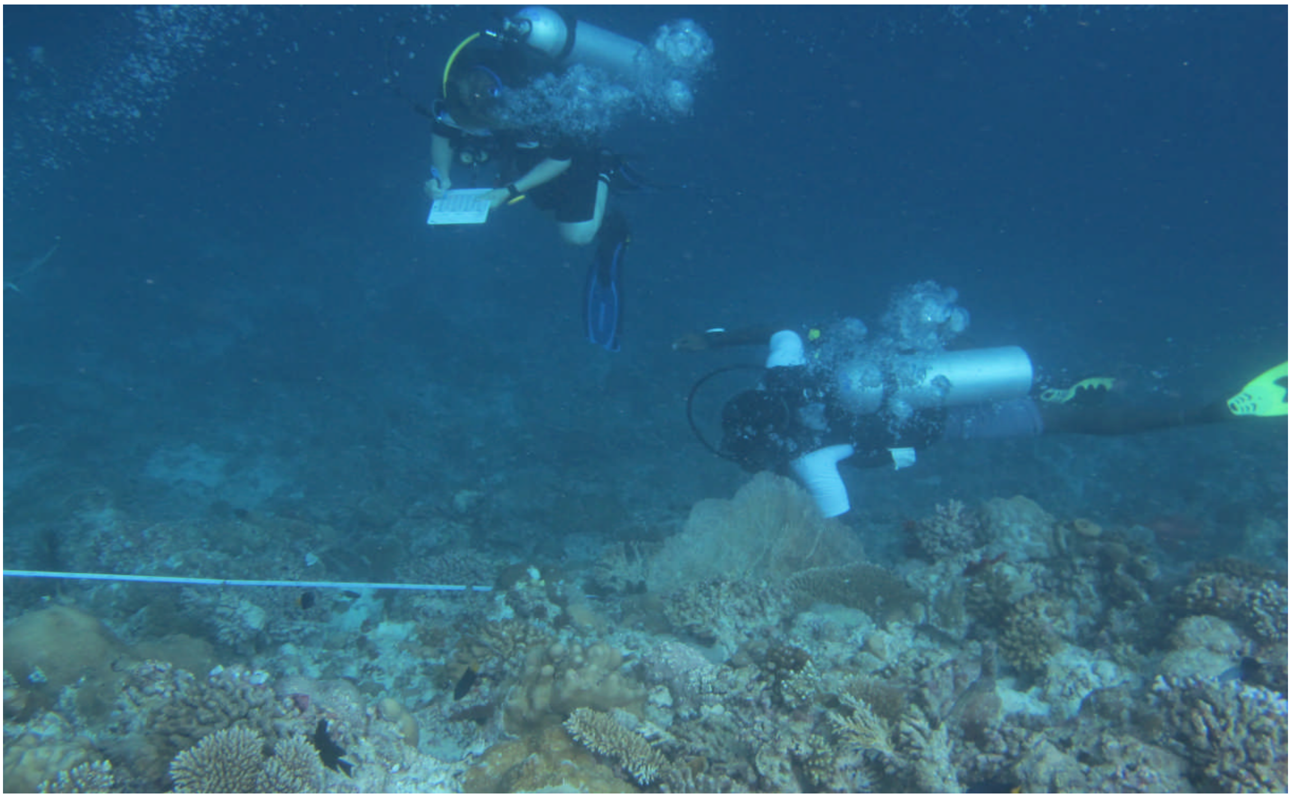


Figure 2.3d. Citizen scientist volunteers conducting a Reef Check survey at Rasdhoo Madivaru.

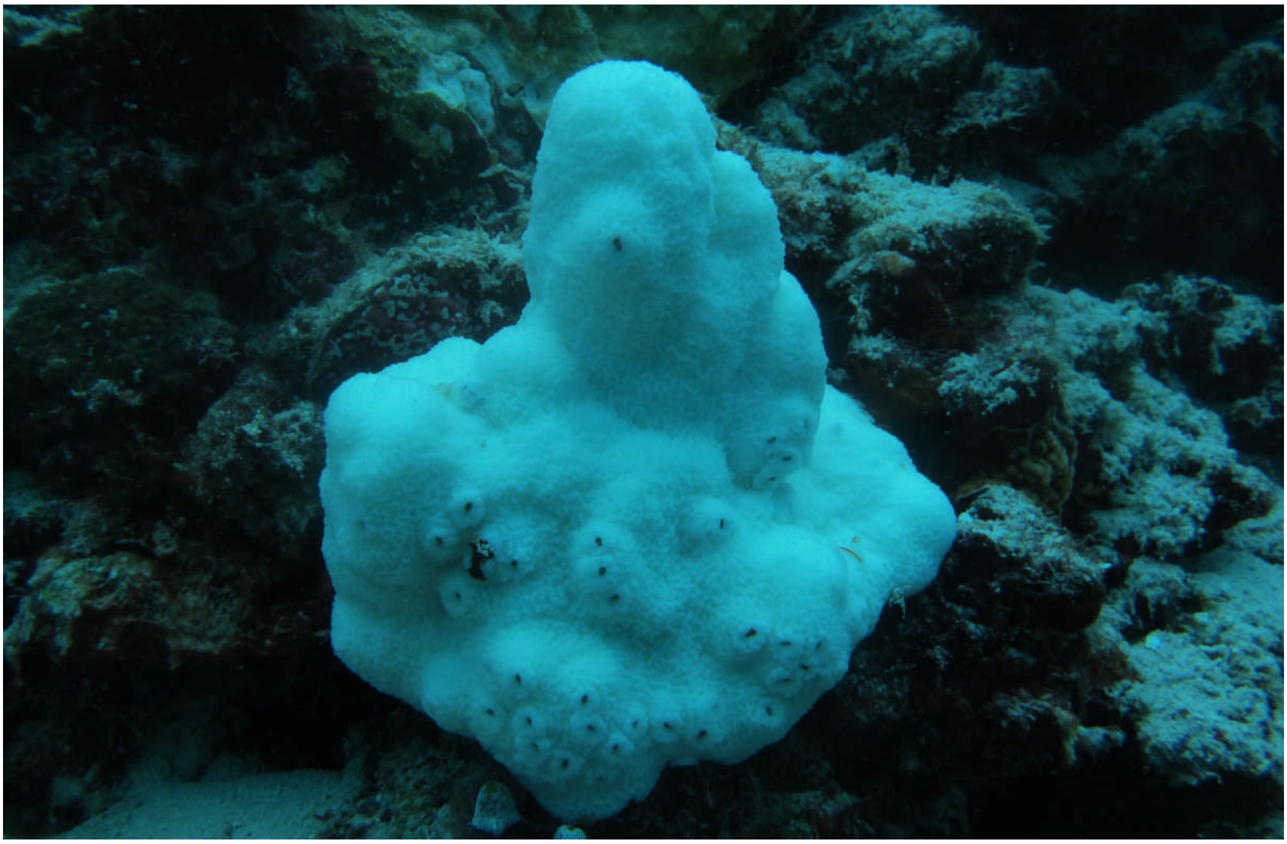


Figure 2.3e. Colony killed by sedimentation at 12 m depth at Rasdhoo Madivaru, showing characteristics of freshly killed white structure. In order to take the picture, the photographer brushed off the sediment.

Other impacts

The number of sites where *Drupella* are found feeding on corals remains high. Disease remains an occasional occurrence on surveys. Our training of volunteers involves identification of coral disease. However, it is almost impossible to teach volunteers the difference between white band and white syndrome and so we have only an approximate record of relative incidences of these two different disease events together. Although both the numbers and abundances of corals that are affected by either disease or *Drupella* are very low, it is of concern, given the isolated location of the islands. The literature has historically linked the increase in nutrients and chemicals associated with human activities with both crown of thorns and disease outbreaks (De'ath et al. 2014). The more constrained, heavily nutrified and heavily fished seas of the Caribbean are subject to serious, large-scale disease incidence. The remaining areas of healthy corals in the Caribbean are significantly at threat from these impacts, particularly in nearshore habitats. We remain concerned that we are still seeing a low level of disease at most Maldivian reefs, even if it is in isolated patches (Solandt et al. 2013).

At present the Maldivian reefs surveyed do not seem to be suffering from significant levels of bleaching and disease. The low incidence of coral damage recorded seems to be due to storm damage and *Drupella* predation. No crown of thorns were recorded from any of the survey sites. There has been a recent outbreak of crown of thorns in North Male' Atoll reefs, whilst some other reefs are hardly hit by the outbreak. It is crucial to keep a lookout on Ari Atoll reefs as well, given the imminent threat of bleaching.

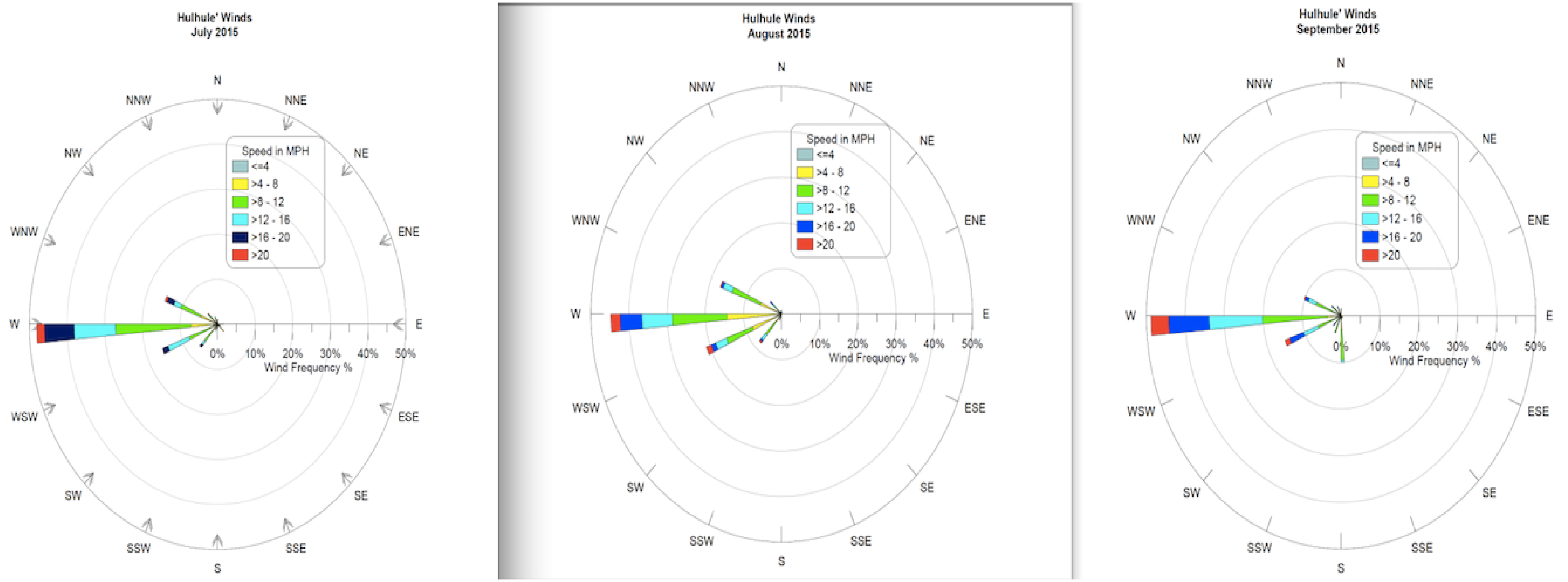


Figure 2.3f. Wind frequency chart (wind rose) of Hulhule' for July, August and September (source: Maldives Meteorological Service).

Figure 2.3g. Severe storm conditions observed near Dhigga Thila.

Figure 2.3h. *Acropora* branching and table corals dominate the shallow reef of Kudafalhu and show signs of *Drupella* predation or some form of disease.

Furthermore, given that the unprecedented 2015/2016 El Niño event was just gathering pace when the expedition surveyed its reefs in September 2015, it will be interesting to compare these survey data with those of the next annual survey, planned for July 2016.

Recommendations

Maldivian local communities are only slowly becoming more aware of human impacts on reefs and therefore the source of their livelihoods and homes. Given the very real threats to coral reefs and the rapid pace of change, communities, politicians and government must be more proactive in managing the coral reefs of the Maldives properly and sustainably.

We therefore we recommend that:

- Fish populations are protected and sustainable fisheries are established and enforced. Minimum and maximum size limits should be set for fisheries or species under threat and no-take zones should be established to encourage spawning and breeding in these areas.

- Proper, proactive policing and enforcement of protected areas such as Marine Protected Areas (MPAs) is put in place, rather than the current ‘paper park’ status quo where parks only exist on paper, but regulations and management directives are flouted and ignored at will with very little danger of punishment for doing so or indeed very few incentives or education as to what protected areas are for people and communities.

- Individuals littering with plastics and other non-biodegradable waste are identified and prosecuted.

- Resources to monitor and manage reefs sustainably are strengthened and proper management of coral reefs is legislated for and endorsed by government.

We believe that these basic measures are necessary if Maldivian reefs are to survive the current suite of pressures they are facing. With a growing population, climate change and countless coastal development projects, the Maldives are in dire need of proper coral reef conservation and management.

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3. Whale shark survey

Irthisham Hassan Zareer
Maldives Whale Shark Research Programme

3.1. Introduction

Whale sharks (*Rhincodon typus*) are known to aggregate in tropical and subtropical waters worldwide seasonally. The South Ari Marine Protected Area (SA MPA, 42 km^2, Fig. 3.2a), established in 2009, is one of the few places one earth where whale sharks can be seen all year round.

The MPA consists of the area encompassing the northwestern tip of the reef crest of Adh, Rangali Island (Conrad Maldives) up to the northeastern tip of Adh, and Dhigurah Island, with the boundary extending 1 km from the epipelagic reef fringe. Here the sharks are commonly seen from the surface, swimming at depths easily accessible to snorkellers, making it an interesting study area for researchers, and more recently for tourists wanting to swim with the whale sharks.

The last day of the expedition is allocated to record sightings of whale sharks at the MPA. The Maldives Whale Shark Research Programme (MWSRP) has successfully worked with government and local tourism operators over a number of years to record and survey whale sharks. Sharks are visually recorded using fin and gill ID methodologies and sharks have been PAT (satellite) tagged in the past to allow researchers to observe their long-term movements.

The survey task for this part of the expedition was to record the number of sharks, size, sex, location, date and time. This survey involved constant watches either side of the vessel MV Carpe Diem as she steamed 300 m from the reef crest of Maamigili, cutting through the inside of the atoll to the outside past the Maamigili-Ariadhoo channel and then steaming along the reef crest (Fig. 3.2a). The survey started at 09:30 on 17 September 2015.

3.2. Results

Five sharks were sighted during the survey. After getting into the water, interaction between people (Biosphere Expeditions volunteers and others) and the sharks was observed and recorded (Table 3.2) and photos of the left (LHS) and right (RHS) gills where taken for later identification purposes by the MWSRP.

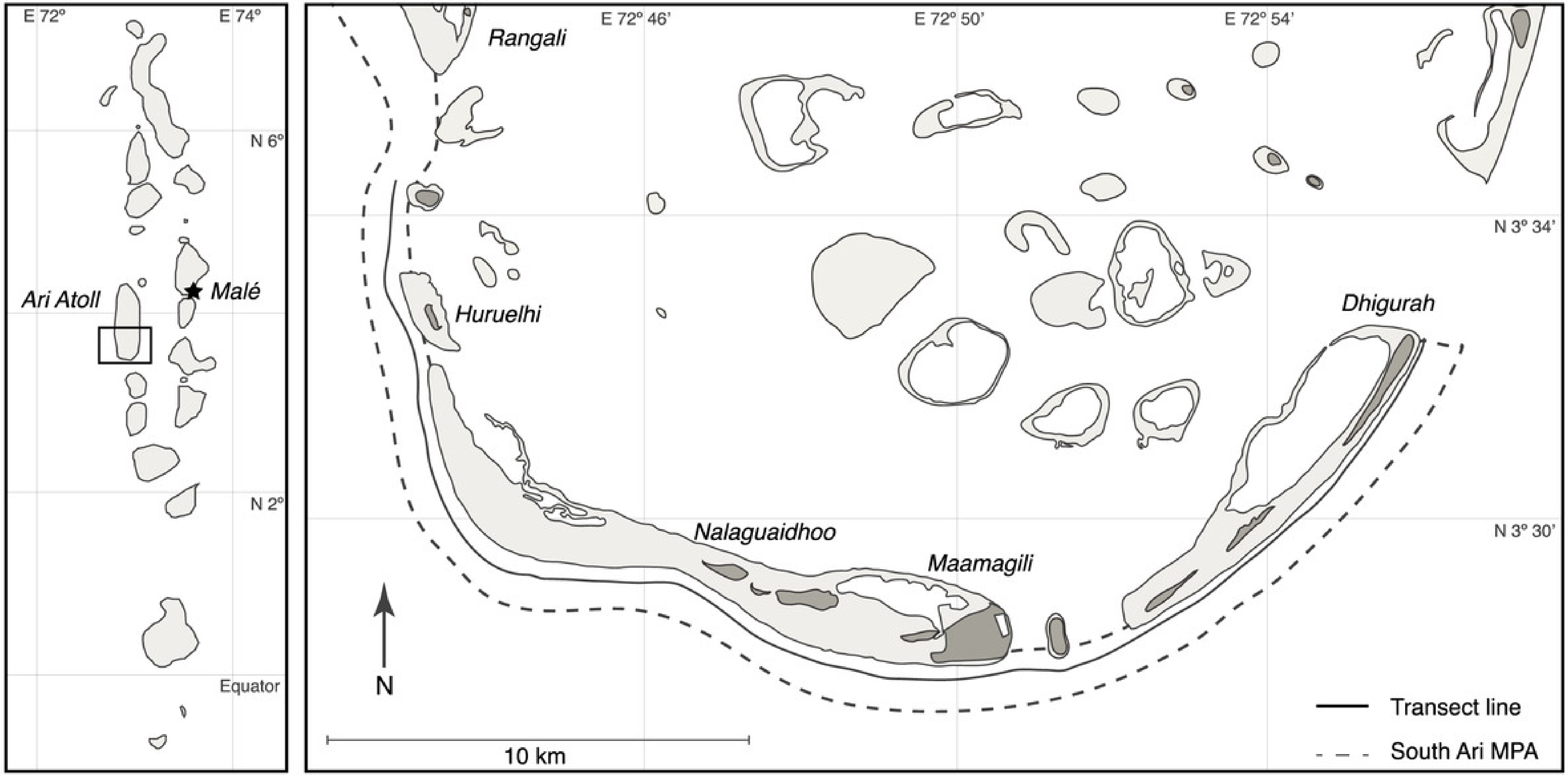
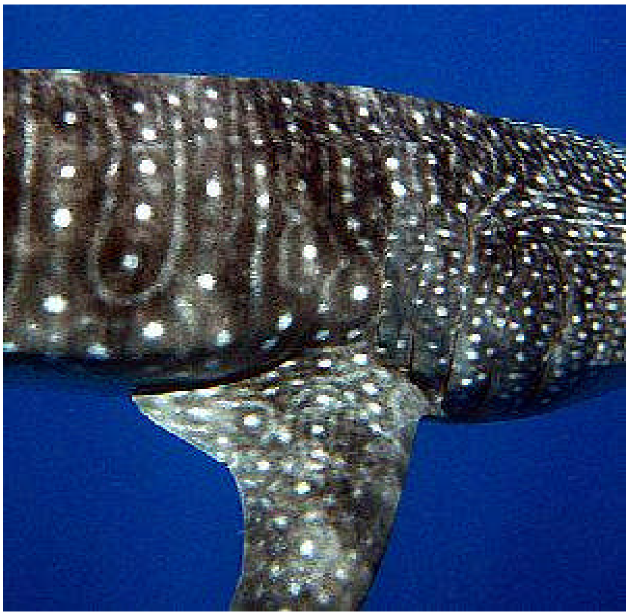


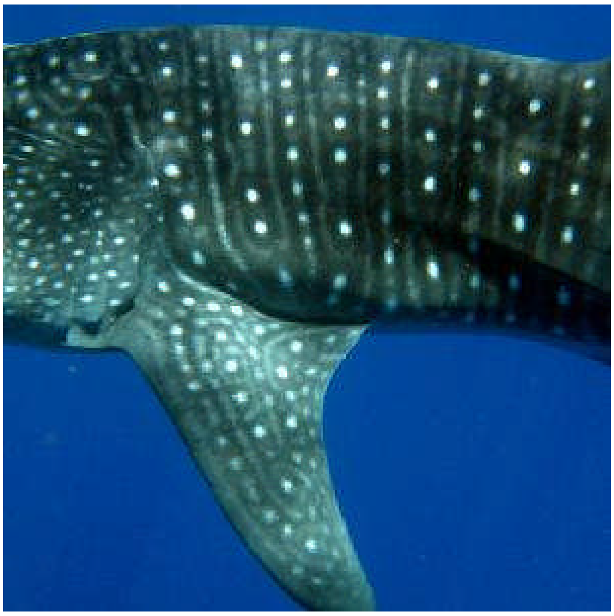
Figure 3.2a. South Ari MPA, from Cagua et al. 2014.

Table 3.2. Details of whale shark encounters on 17 September 2015.

Encounter No	1	2	3	4	5
Location (GPS) Lat/Long					3.482450 72.883983
Time					11:04
Shark ID & name	WS183 (Kokko)	WS018 (Adam)	WS018 (Adam)	WS183 (Kokko)	WS175 (Dhombe)
Sex	Male	Male	Male	Male	Male
Size (m)	6	6	6	6	5
Behaviour	Evasive	Cruising	Evasive	Evasive	Cruising
Duration (min)	3	5	1	6	7
No. of people at start	20	15	20	20	23
Max no. of people	70	30	35	40	40
No. of boats at start	5	3	1	4	4
Max no. of boats	9	6	3	7	6
Reef depth (m)	15	8	5	20+	15
Shark first seen	09.05.2013	21.04.2006	21.04.2006	09.05.2013	15.03.2011
Notes	Encounter had already started when we arrived. Shark was leaving the reef when we arrived, was at a depth of around 12 m.		Shark changed direction and sped off reef when one of the boats dropped divers metres from the shark. Boat was metres away from snorkellers in the water, upsetting a lot of snorkellers.		MWSRP team was present during this encounter as well.



Right gill ID

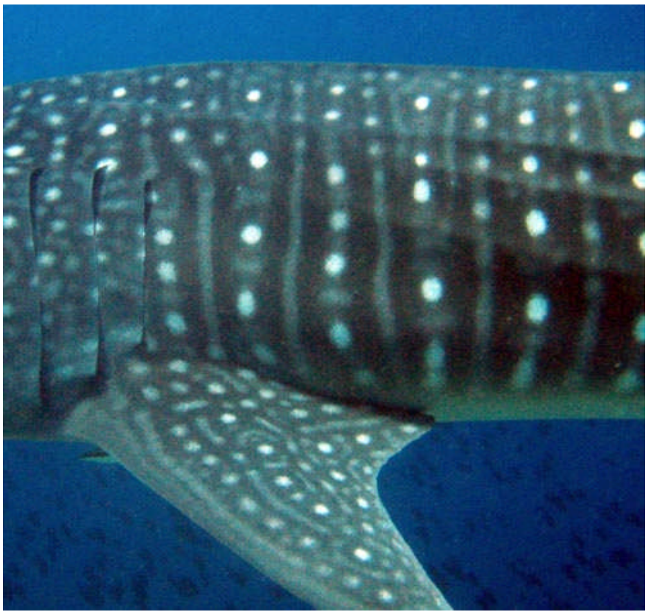


Left gill ID

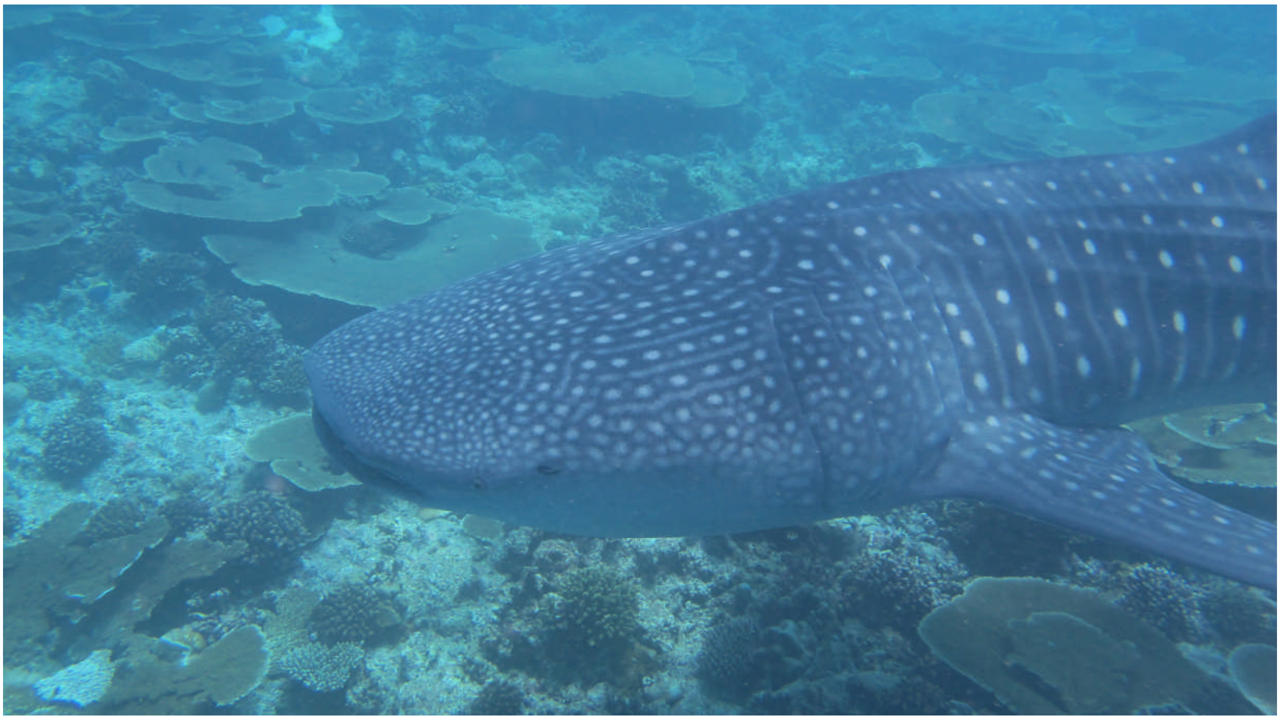
Whole animal

Figure 3.2b. WS183 Kokko.

Right gill ID



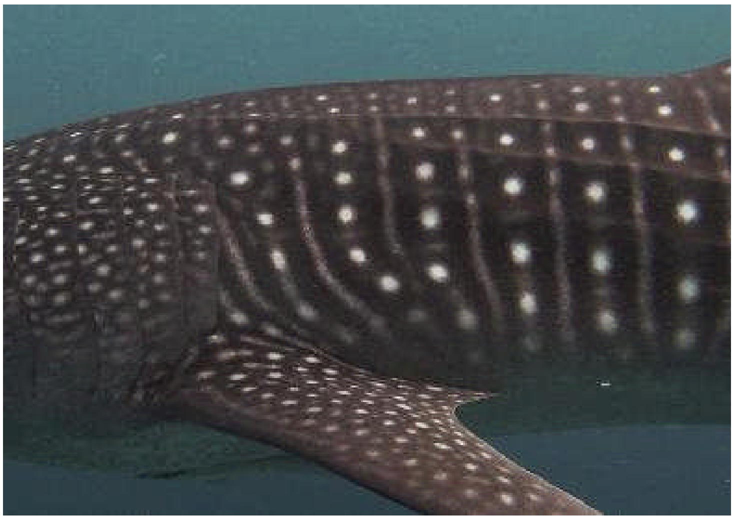
Left gill ID



Front of the animal

Figure 3.2c. WS018 Adam.

Right gill ID



Left gill ID

Figure 3.2d. WS175 Dhombe.

3.3. Discussion & conclusions

Although the area is a Marine Protected Area, as of yet it is merely a paper park. Despite suggestions for regulations being put forward by the MWSRP, there is neither a proper management plan that all the stakeholders agree on, nor a governing body actively involved in enforcing these regulations. As a result, boat collisions that result in major injuries to the sharks and harassment by boats and divers / snorkellers engaged in irresponsible tourism activities are the rule, rather than the exception.

There is no limit to the number of boats or snorkellers / divers able to join encounters. At times up to 20 vessels can be on a single shark with 150 or even more snorkellers and divers. In most cases, it is clear that some of these tourists are either not given a safety or environmental briefing about the code of conduct while swimming with sharks, or they do not care, or both.

There are numerous examples worldwide of well-managed MPAs engaging in sustainable income generation through intact nature and the presence of whale sharks. Ningaloo in Australia is only one example with strictly enforced codes of conduct, limits on boats and people allowed at any one time with the animals and a premium price policy that funds enforcement.

At South Ari, on the other hand, current conditions of whale shark tourism are far from sustainable and the MPA has a long way to go until it is no longer just a paper park. The large size of the MPA also adds to the challenge in bringing forth a proper management plan. The MWSRP is collecting data on the condition of the MPA and the effect tourism has on shark behaviour in order to present these data to the government so they can make informed decisions to improve the MPA and conditions for the whale sharks. A proper management plan, including codes of conduct with enforcement, is crucial to conserve this iconic species and prevent more sharks from getting harassed and injured.

Appendix I: Expedition diary and reports

A multimedia expedition diary is available at https://biosphereexpeditions.wordpress.com/category/maldives-2015

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