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EXPEDITION REPORT

Expedition dates: 2 – 8 September 2013

Report published: August 2014

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

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First Choice Responsible Tourism Awards – **BEST VOLUNTEERING ORGANISATION** UK

The Independent on Sunday – **BEST FOR GREEN-MINDED TRAVELLERS** UK

responsibletravel.com – **TOP RESPONSIBLE HOLIDAY** UK

National Geographic Adventure – **BEST NEW TRIP** USA

Islands – **BEST IN SUSTAINABLE TRAVEL** USA

Umwelt-Online-Award – **ENVIRONMENT AWARD** Germany

P.M. – **TOP HOLIDAY FOR NATURE** Germany

EXPEDITION REPORT

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

Expedition dates:
30 June – 6 July 2013

Report published:
August 2014

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Reef Check Co-ordinator Maldives

Estelle Chassin
Marine Conservation Society

Matthias Hammer (editor)
Biosphere Expeditions

Abstract

One week of Reef Check surveys was carried out in September 2013 with Biosphere Expeditions volunteers in central Maldives atolls. Reef Check sites visited were predominantly inshore house reefs and sheltered locations, both in North Male' and Ari atolls. We re-surveyed reefs first visited in 2011 including Rasdhoo Madivaru, Bathaalaa Magaa and Diggha Thilla. Reef Check training aboard the Carpe Vita was carried out by two Maldivians (Mohammed Ushan and Shidha Afzal) employed by the Maldives government Marine Research Centre, who in 2012 were trained to Reef Check trainer level. Further training of local Maldivians took place on board the vessel with eight international citizen scientist divers, representatives of the local tourist industry and two Maldivians involved with the development of a Maldives-based NGO.

Reef surveys revealed a slight increase in hard coral cover at Rasdhoo Madivaru since 2005, when the site was first surveyed using Reef Check. Diggha Thilla to the southwest of Ari atoll appears to have suffered some storm damage since first being surveyed in 2011 by Biosphere Expeditions. Fish sizes – particularly of commercial species such as grouper – remain low. This is of concern for local fisheries and the grouper export market. We therefore recommend that the recommendations of the Darwin Reef Fish Project are fully incorporated into management. We also recommend that managers and politicians must be pro-active in preventing a shift to algal-dominated reefs from happening by establishing sustainable fisheries, setting aside protected areas and tackling pollution.

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2013 ވަނަ އަހަރުގެ ސެޕްޓެމްބަރ މަހުގައި ވަނީ 1 ހަފްތާގެ މުއްދަތުގެ ރީފް ޗެކް ސާރވޭތަކެއް ކުރިއަށް ގެންދެވިފައެވެ. މިސާރވޭތައް ކުރިއަށް ގެންދެވިފައިވަނީ ބަޔޯސްފިއަރ އެކްސްޕެޑިޝަންސްގެ ވޮލަންޓިއަރުންގެ އެހީގައި މެދުރާއްޖޭގެ އަތޮޅުތަކުގައެވެ. މިސާރވޭތައް މައިގަނޑު ގޮތެއްގައި ކުރިއަށް ގެންދެވިފައިވަނީ މާލެ އުތުރުބުރި އަދި އަރި އަތޮޅުގެ ރަށްރަށުގެ އެތެރެފަރާއި ފަރުތަކާއި ނިވާތަން ސަރަހައްދުތަކުގައެވެ. މިގޮތުން 2011 ވަނަ އަހަރު ފުރަތަމަ ސާރވޭކުރެވިފައިވާ ސަރަހައްދުތަކަށް ކަމަށްވާ ރަސްދޫ މަޑިވަރު، ބަތާލާ މާގާ އަދި ދިއްގާ ތިލަ އަލުން ސާރވޭކުރެވުނެވެ. ކާރޕީ ވިޓާ ނަމުގައިވާ ސަފާރީގައި ކުރިއަށް ގެންދެވުނު ރީފް ޗެކް ތަމްރީނު ކުރިއަށް ގެންދެވިފައިވަނީ ދިވެހި ސަރުކާރުގެ މެރިން ރިސާޗް ސެންޓަރުގެ މުވައްޒަފުން (މުހައްމަދު އުޝާން އަދި ޝިދާ އަފްޒަލް) އެވެ. މިދެމީހުންވަނީ 2012 ގައި ރީފް ޗެކް ޓްރެއިނަރ ފެންވަރަށް ތަމްރީނު ލިބިފައެވެ. ކާރޕީ ވިޓާގައި ހިންގުނު ޓްރެއިނިންގގައި އެކު ގައުމުތަކުގެ 8 ސިޓިޒަން ސައިންޓިސްޓުންނާއި، ޓޫރިޒަމް އިންޑަސްޓްރީގެ ފަރާތްތަކާއި، ދިވެހިރާއްޖޭގެ އެން.ޖީ.އޯއެއްގެ 2 ފަރާތަކާއިން ބައިވެރިވި އިތުރު ދިވެހިންނަށް ރީފް ޗެކް ތަމްރީނު ދެވުނެވެ.

ރަސްދޫ މަޑިވަރުގެ ސާރވޭ ކުރެވުނު ސަރަހައްދުގައި ހުރި ދިރޭ ގަލުގެ ނިސްބަތްވަނީ 2005ގައި ފުރަތަމަ ކުރެވުނު ސާރވޭއާއި އަޅާބަލާއިރު ކުޑަކޮށް އިތުރުވެފައެވެ. އަރިއަތޮޅު ހުޅަނގުދެކުނުގައި އޮންނަ ދިއްގާތިލަ 2011ގައި ސާރވޭ ކުރުމުންފެށިގެން އައީ ބަލާއިރު މޫދުގެ ސާރވޭކުރުމުން އިރު މޫސުމު ސަކަރާތުގެ ސަބަބުން އެސަރަހައްދަށް ގެއްލުން ލިބިފައިވާ ގޮތްތަކެއް ފެނެއެވެ. މަސްމަހުގެ ސައިޒުތައް، ހާއްސަކޮށް ކައުމަށް ބޭނުންކުރާ ބާވަތްތައް ކުޑަކަމުގައި ދެމިހުރުމަކީ ކަންބޮޑުވާ ކަމެކެވެ. މިއީ ކަނޑުގެ މަސްވެރިކަމަށް އަދި ގްރޫޕަރ މަސް ބޭރުކުރުމަށް (ކާއްސަކޮށް ގޮނަ މަސްވެރިކަމަށް) ފައިދާހުރި ކަމެކެވެ. މިސަބަބާހުރެ ޑާވިން ރީފް ފިޝް ޕްރޮޖެކްޓްގެ ހުށަހެޅުންތައް ހިފެހެއްޓުމުގެ ކަންތައްތަކުގައި ފުރިހަމަޔަށް ހިމެނުމަށް ރިކޮމެންޑް ކުރަމެވެ. އަދި ސިޔާސީ ފަރާތްތަކާއި މެނޭޖަރުން ފަރުތައް ގަސްގަހާގެހީން ފުރިގެން ދިއުން ހުއްޓުވުމަށް ދެމެހެއްޓެނިވި މަސްވެރިކަމާއި، ހިމާޔަތްކުރެވޭ ސަރަހައްދުތައް ކަނޑައެޅުމާއި ވެށި ނަޖިސްކުރުމުގެ ކަންތައްތަކުގައި އަމިއްލައަށް ކުރިއަށް އެޅުމަށް ރިކޮމެންޑް ކުރަމެވެ.

Contents

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

1. Expedition review

1.1. Background

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

This expedition report deals with an expedition to the Maldives that ran from 30 June to 6 July 2013 with the aim of surveying and studying the expansive reefs that make up the 1,192 Maldivian coral islands, including photographing whale sharks for a photo identification project when encountered. 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. With this project, Biosphere Expeditions is addressing this need and is working with the Marine Conservation Society and the Maldives Whale Shark Research Programme in order to provide vital data on reef health and whale shark numbers. Reef data collection follows an internationally recognised coral reef monitoring programme, called Reef Check, and will be used to make informed management and conservation decisions. Whale shark photos will be used by the Maldives Whale Shark Research Programme for their conservation efforts. The expedition included training for participants as Reef Check EcoDivers.

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 mining, dredging, reclamation, the construction of maritime structures and pollution represent most impacts on coral reefs.

With the introduction of tourism in the Maldives in the 1970s, the country started to gain a major source of income and employment. Tourism in the Maldives is concentrated around the atolls near to Male' and its infrastructure and resources entirely rely on rich and healthy reefs. However, 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 and many reef areas remain unexplored. Data from the coral reef surveys we carry out 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.

Surveys are being carried out both inside and outside current Maldivian Marine Protected Areas (MPAs) to continue the work of the Marine Conservation Society, which is investigating the impact of MPAs on fish and coral populations.

Photographs of the gill areas of whale sharks are being used by the Maldives Whale Shark Research Programme 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. The Maldives Whale Shark Research Programme can then match one individual's unique markings with the photographic record and add that image and the whale shark's location to their database and see if it has been recorded before and from where. This will then allow conservationists at the Maldives Whale Shark Research Programme to map where individual sharks go, how often they are recorded at individual locations and whether further protection mechanisms are needed for individual hotspot locations.

Coral reef structures of the Maldives archipelago are extraordinarily diverse and rich. There are submerged coral mounds, often rising 50 m from the seabed to 10 m from the surface (thillas), 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 20 km long. The islands of the Maldives are entirely made from the coral sand washed up onto the very shallowest coral platforms. More than 200 species of hard corals form the framework of the 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 massive bleaching event of 1998. There is a strong recovery in many reefs, with extensive recruitment and growth of branching corals.

The fish populations of the Maldives are exceptionally rich in terms of diversity and biomass. In 2008 the Maldivian government banned shark fishing within the atolls and shark numbers appear to be increasing, with small reef sharks still commonly observed in Maldivian waters. Many thillas 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, largely because of the congregations of large predators. 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 thillas and walls to 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-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 2,000 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 209 hard coral species have been described from over 60 genera. Fifty-one species of echinoderms, five species of sea grasses and 285 species of algae 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.

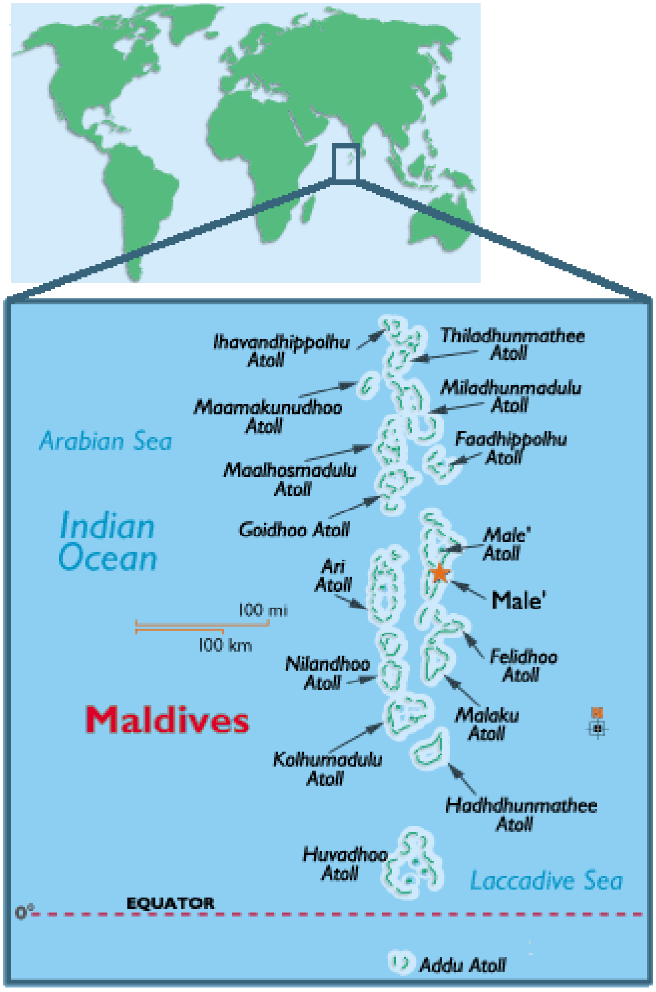

Figure 1.2b. The Maldives. An overview of Biosphere Expeditions' research sites, assembly points, base camp and office locations is at Google Maps.

1.3. Dates

2013: 30 June – 6 July

The expedition ran over a seven-day period with one group of team members. 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, live-aboard boat, the MV Carpe Vita, with 10 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 mostly sunshine and an occasional rain shower on a few rare days. Water temperature during the expedition was 28–30°C.

Field communications

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

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

Transport & vehicles

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

Medical support and insurance

The expedition leader was a trained first aider and the expedition carried a comprehensive medical kit. The main hospital is in Male' city and there are medical posts in 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 there were no medical incidents during the expedition.

1.5. Scientists

Dr Jean-Luc Solandt is a Londoner with a degree in Marine Biology from the University of Liverpool. After graduating, he spent a year diving on the Great Barrier Reef assisting field scientists in studies on fisheries and the ecology of soft corals and damselfish. He returned to the UK and enrolled in a Ph.D. in sea urchin ecology in Jamaica, based both in London and Jamaica. He went on to be an expedition science co-ordinator for projects in Tanzania, the Philippines and Fiji, and is now undertaking campaign and policy work in planning and developing Marine Protected Areas in the UK. He has been the Reef Check co-ordinator for the Maldives since 2005 and has thus far led three expeditions to undertake surveys inside and outside Marine Protected Areas on the islands. Jean-Luc has 900 dives clocked up since he trained to be a marine biologist 20 years ago.

Dr Solandt was not available for this expedition, but he had already trained two experienced staff members from the Maldives Marine Research Centre to function as on-board scientists. They were Ms Mariyam Shidha Afzal and Mr Mohammed Ushan. Both were initially qualified in Reef Check in 2011, first as EcoDiver surveyors and then as EcoDiver trainers. Planning was done remotely in the UK by Dr Solandt in collaboration with Ms Afzal and Mr Ushan and Dr Matthias Hammer who led the expedition.

1.6. Expedition leader

Biosphere Expeditions was founded in 1999 by Dr Matthias Hammer. Born in Germany, he went to school there, before joining the Army at 18 and serving for several years amongst other units with the German Parachute Regiment. After active service he came to the UK and was educated at St Andrews, Oxford and Cambridge. During his time at university he either organised or was involved in the running of several expeditions, some of which were conservation expeditions (for example to the Brazil Amazon and Madagascar), whilst others were mountaineering/climbing expeditions (for example to the Russian Caucasus, the Alps or the Rocky Mountains). With Biosphere Expeditions he has led teams all over the globe. He is a qualified wilderness medical officer, ski instructor, mountain leader, divemaster and survival skills instructor. Once a rower on the international circuit, he is now an amateur marathon runner and Ironman triathlete.

1.7. Expedition team

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

30 June – 6 July 2013

Ann Blackmore (UK), Tim Copsey (UK), Umair Badeeu* (Maldives), Mascha Blome* (Germany), Alexander Brown* (UK), Susannah Cogman (UK), Madeline Coombe (Australia), Shaha Hashim* (Maldives), Michelle Kraemer (USA), Jennifer Lee (USA), Anais Martane (China), Di Song (China).

* Participants marked with a star took part in the expedition as part of an education and placement programme.

1.8. Other partners

On this project Biosphere Expeditions is working with Reef Check, the Marine Conservation Society, the Maldives Marine Research Centre (MRC) of the Ministry of Fisheries and Agriculture, the Maldives Whale Shark Research Programme and the MV Carpe Vita. Data will also be used in collaboration with the Global Coral Reef Monitoring Network, the MRC, and the University of York Department of conservation.

Our long-term dataset is not only of interest to conservationists working on monitoring the global status on reefs, such as those from the United Nations Environment Programme, the World Conservation Monitoring Centre and the International Coral Reef Action Network (ICRAN), but more locally too, especially as regards the effectiveness of current Maldivian Marine Protected Areas in their ability to protect and recover significant numbers and biomass of commercially important finfish. Our data is also important, as it provides an indication of the health status of the reefs themselves, and the extent of the fishing in the archipelagos more heavily populated central reefs. Surveys since 2005 have shown a worrying decline in the abundance and size of top-level predators such as serranids and large lethrinids and lutjanids.

1.9. Expedition budget

Each team member paid towards expedition costs a contribution of £1,690 per seven-day slot. The contribution covered accommodation and meals, supervision and induction, all maps and special non-personal equipment, 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	14,920
Grants	6,418
Expenditure	
Staff includes local & international salaries, travel and expenses	5,072
Research includes equipment and other research expenses	289
Transport includes taxis and other local transport	23
Base includes board, lodging and other live-aboard services	12,727
Administration includes some admin and misc costs	35
Team recruitment Maldives as estimated % of PR costs for Biosphere Expeditions	4,472
Income – Expenditure	**-1,280**
Total percentage spent directly on project	**106%***

*This means that in 2013, the expedition ran at a loss and was supported by Biosphere Expeditions over and above the income from the expedition contributions and grants.

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 consultancy, for his unerring help and advice in setting up the project, and to Agnes van Linden of the MV Carpe Vita 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 Vita for being such excellent hosts. Thank you also to Richard Rees of the Maldives Whale Shark Research Programme. Many thanks to M Shiham Adam (Director General) and Yoosuf Rilwan (Assistant Research Officer) and other members of the Marine Research Centre (MRC). We would particularly like to thank Mariyam Shidha Afzal (Research Officer, MRC) and Mohammed Ushan (MRC & Darwin Reef Fish Project) for undertaking the training of the volunteers – both Maldivian and from overseas.

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 at www.biosphere-expeditions.org/reports. Enquires should be addressed to Biosphere Expeditions via www.biosphere-expeditions.org/offices.

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

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 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 population of 316,000, some 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.

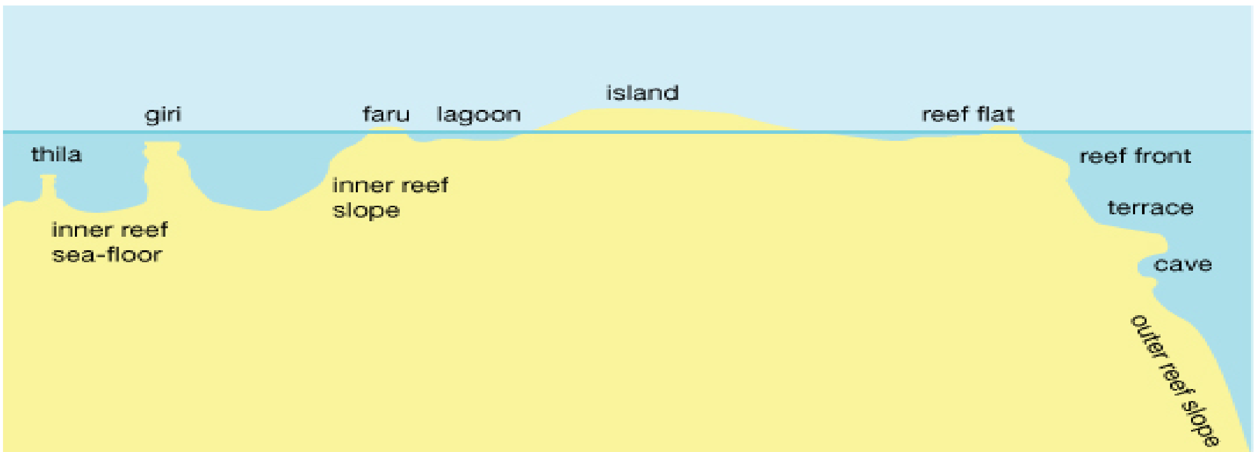

Figure 2.1a. Common reef structures of the Maldives (from Tim Godfrey).

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 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 209 scleractinian corals, with maximum diversity reported towards the south (towards Huvadhoo Atoll) (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. As a result, the Maldivian tuna fishery has been marketed by many supermarkets in the UK as sustainable, because the volume of catch taken by pole and line is relatively small compared to many longline fisheries around the Indian Ocean and there is minimal by-catch of other fish, cetaceans and turtles. The Maldives has also recently banned shark fishing (2010), which can be regarded as a major conservation measure because of the catastrophic declines in the global populations of reef and pelagic predatory shark species (Graham et al. 2010). Although this is a commendable measure undertaken by the Maldives government, it is very difficult to enforce. 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) and mostly because of the growth in the export market to the Far East, which is serviced by grouper cages that have been set up within a number of atolls. Wholesalers periodically visit the grouper cages that are stocked by local fishers to buy the fish to export live and freshly chilled to foreign markets – principally at Faafu Atoll in the southwest central area of the Maldives. 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 working with the Marine Conservation Society has developed a management plan for grouper that includes recommendations on minimum size landings for individual species, and agreed closures at five well-known grouper spawning locations (Fig. 2.1.1a). However, the rate of overfishing of the stocks of grouper has increased over the past 10 years (Wood et al. 2011). In a 2005 report, Sattar and Adam (2005) state that 43% of grouper caught were immature (not able to reach a size that allowed spawning, nor sequential maturity into male life-history stage). Since then that figure has increased to 70% (Wood et al. 2011). All authors agree that if management measures are not implemented, the situation will worsen. Full recommendations for grouper landing size limits and closures were considered for gazetting into law in 2013, but there is still resistance to management from Faafu Atoll, from fishers and the local political hierarchy (Y Rilwan, MRC, personal communication, April 2014). As a result it appears that the lack of central government management infrastructure limits the impact such recommendations could have to support a sustainable commercial fishery in the country in future.

Figure 2.1.1a. Location of the five grouper spawning channels that are now protected from all activities that may compromise spawning (courtesy of the Darwin Reef Fish Project – a collaborative project between the Marine Conservation Society and the Marine Research Centre of the Maldives).

2.1.2. Increased CO_2 threats to reefs

Probably the most serious current threat to global coral reef health is the effect of increased CO_2 concentrations, affecting sea temperature rise and ocean acidification. 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, zooxanthellae ‘clade’ and coral type, the temperature threshold at which corals become stressed in the Maldives is regularly cited as 31°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. Acidification is the process whereby the increased concentration of CO_2 is converted in surface waters into H_2CO_3 (carbonic acid). This acid has already increased the acidity of the oceans. Controlled scientific experiments have seen serious stress results for corals from increased acidity, such as reduced calcification rate, reduced reproductive output and slower somatic growth.

1997 and 1998 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 surveys have recorded very 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 surveys were carried out by both Maldives Research Centre staff (Zahir et al. 1998) and local resort marine biologists (1997 was the first year of Reef Check). 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 researchers (e.g. Clark et al. 1999) visiting a variety of sites found that coral cover in the range of 22.5–70% pre-bleaching fell to 0–10% post-bleaching. Longer-term effects of such catastrophic bleaching were said to include erosion of dead coral skeletons to sand and rubble that led to less buffering of wave action around the atolls, leading to beach erosion – a huge potential cost to the Maldives.

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

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[2] http://www.math.ubc.ca/~hauert/publications/reefcheck98/

The Biosphere Expeditions survey in 2012 targeted three central atoll sites where bleaching had been recorded, or where reefs were surveyed using the Reef Check methodology in 1997. Coral cover had recovered very well (in terms of live hard coral) since that time (Solandt and Hammer, 2013). It is debatable whether the natural climax coral communities have been achieved, because it is only a relatively short time since the initial bleaching event, and it is therefore impossible to assume the coral species assemblages on 'recovered' reefs are the same as they were before the bleaching mortality. Given the size of the Maldives, it is also impossible to assume that these isolated sites represent 'recovery' for the entire nation – many more survey locations are required for that kind of deduction. In addition, much greater re-surveying of sites is required to understand the true nature of responses of different reefs in very different areas. This has partly been undertaken with the Maldives government National Coral Reef Monitoring (NCRM) programme, but this suffers from a lack of funds. Historically, however, surveys from these reefs, which are widely scattered around the islands, suggest that northern atoll reefs have generally fared worse – over the medium term (10–15 years post-bleaching) – than central or southern reefs (Zahir and Quinn 2009).

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 as official no-take zones that prevent the capture of live bait for the tuna fishery and also for fisheries for all reef-associated species (such as grouper). One of the authors (Jean-Luc Solandt) surveyed nine of the 25 small Maldives MPA dive sites in 2008 with little statistical evidence that the biomass and number of exploited species were greater inside the protected areas than outside (Solandt et al. 2009). On one occasion during surveys in 2007 a fishing vessel line fishing at the 'HP' MPA to the East of North Male' Atoll was recorded. The collective size of the 25 Maldives MPAs (prior to the UNESCO Biosphere Reserve designation in 2010) is only 0.01% of Maldivian waters. However, with no finances available for enforcement of these small sites (and for increased efforts to monitor and enforce conservation measures on the wider Baa Atoll Biosphere Reserve), it can be argued that increasing the size and number of any protected areas is futile.

Three more recent protected areas designations (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 is a known breeding ground for both grey (*Carcharhinus amblyrhynchos*) and white tip (*Triaenodon obesus*) reef sharks and where manta rays and whale sharks can sometimes be sighted at certain times of the year. The entire Baa Atoll was designated a UNESCO Biosphere Reserve in 2011, with additional areas proposed as no-take zones to give a total of nine protected areas within Baa Atoll. The Hanifaru MPA has a management plan enforced by rangers, which limits 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-aboard and SCUBA diving were banned in the bay in 2012. A permit system was introduced in 2012 to control access (www.epa.gov.mv).

In addition to the statutory ‘stand-alone’ MPAs, 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 legislation in the near future. Similarly, the World Bank recently funded a project that will enable tourist resorts to partner with coral reef scientists to monitor their condition. This is part of the ‘*Wetlands Conservation and Coral Reef Monitoring Adaption to Climate Change*’ (WCCM)[3] project and is currently piloting 16 ‘protocols’ with trained resort staff to record key environmental parameters of island and reef health. This is currently being carried out at five resorts, with the intention to expand this.

2.1.4. 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 problems. Perhaps paradoxically, the past decade has seen the Maldives embark on a process to establish further Marine Protected Areas, and to lobby for decreases in global CO_2 emissions. Some of the current issues are:

i. Political stability – The Maldives has been through a number of considerable political changes in the past three years, reducing the priority for a coherent marine conservation strategy.

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

iii. 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 on international flights, expensive marine transport of goods and humans, and a tourist industry that consumes large amounts of fuel. For example, one resort has an annual fuel budget of $1m (Four Seasons, North Male atoll) in order to power swimming pool filtration pumps, run generators and supply air conditioning to rooms.

iv. Rapid environmental degradation that is not being adequately reported – The status of Maldives reefs has been heavily compromised over the past 30 years through the introduction of mass tourism, increased global markets in 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.

[3] http://www.mrc.gov.mv/program/7

v. 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.

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

In summary, the Maldives are under threat from both local anthropogenic and global climate-induced pressures. Key threats are:

- Climate change – sea surface temperature increases leading to coral bleaching.
- Increased seawater acidification. This leads to decreased skeletal strength of calcium carbonate-dependent corals, decreased growth rate, and decreased reproductive output.
- Overfishing of keystone species (e.g. predators of Crown of Thorns Starfish and herbivorous fish).
- Sedimentation and inappropriate atoll development.
- Poor water quality.
- Poor levels of education and public awareness.
- Poor investment in governance, the law, enforcement and management measures relative to the size of the problems.

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, 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 and significantly more investment in science, monitoring and training.

2.1.5. Maldives reef surveys

To help the Maldives government and population better understand some of these issues, Biosphere Expeditions and The Marine Conservation Society have been developing a survey and training programme. The aims are to:

- Increase the information base on the status of Maldives reefs in collaboration with local partners (e.g. the MRC).
- 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 25 sites in three years, compiled and quality assessed the data, and sent it to Maldivian and international coral reef monitoring programmes.
- Trained 10 individuals employed in government marine resource assessment surveys 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 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 collaborated with resorts to train staff and provide them with reef resources.
- Undertaken repeat monitoring at central atoll sites (North Male' Atoll and Ari Atoll) where bleaching was recorded with the first ever Reef Check surveys in 1997 (Solandt and Hammer 2012).

The aims of the 2013 surveys and training using Reef Check (the 2013 surveys were carried out at sites visited between 2011 and 2012) were to:

- Record and compare the condition of the reefs now to previous years.
- Record other variables such as fish and damage.
- Carry out effort-based transects of the whale shark MPA Maamigili Reef.
- Empower MRC staff (trained on the 2012 expedition) to undertake the training and lead on the surveys.

Reef Check has been carrying out volunteer dive surveys since 1997 – the International Year of the Reef (Hodgson 1999). It was designed to 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).

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 live-aboard dive boats and tourist islands of the country has not been fully realised. A new World Bank funded IUCN project is conducting new surveillance methodologies with five resorts across the Maldives (WCCM project described above). MCS has been carrying out Reef Check with live-aboards since 2005 and trained a Maldives resort (Baros) 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° slope) reef profiles in areas of limited current at between 3–6 m and 7–12 m. This limitation often excludes surveys at the best-known dive sites of the Maldives that tend to be in waters too deep or charged by currents 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. The business model we have developed offers a sustainable finance model, where the largest contribution to expedition costs is met by foreign volunteers. This lessens the dependency on large-scale third-party funding that can come and go depending on the aims of different funding agencies.

2.1.6. Planning & methods

Biosphere Expeditions carried out logistics, health and safety on board the research vessel and recruitment of volunteers. The scientific programme and analysis was led by Dr Jean-Luc Solandt, Reef Check co-ordinator of the Maldives, whilst MRC colleagues carried out the training on board the vessel.

All training was carried out on board the MV Carpe Vita. In-water training was undertaken at Banyan Tree house reef in 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 of 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), OT (other, such as cnidarians, zoanthids).

Reef Check surveys involve a team of up to eight individuals recording conditions of the site (physical, biological and environmental conditions). A 'site' form is completed to record key physical and anthropogenic / management attributes of the site. A 'line' transect form is used to record the benthic habitats and a 'belt' transect is carried out to record fish assemblages, key invertebrates and perceived underwater impacts to the reef. Species and families recorded in the fish and invertebrates categories are keystone species, indicators of overfishing or indicators of 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 are quality assured by the team scientist on site, in the UK (by the Reef Check co-ordinator for the Maldives, Dr Solandt), and in California at Reef Check HQ.

2.1.7 Coral Point Count

Coral Point Count[4] (CPC) software was used subsequently to analyse photoquadrats for dominance of different hard coral growth forms, and other living and non-living benthic categories. Coral growth forms were either classed as being from *Acropora* or from non-*Acropora* genera. The different growth forms include digitate, encrusting, branching, table, foliose, encrusting and mushroom corals. Photos were taken at a height of approximately 2 m off the substrate, covering an area of between 2 and 4 m^2. Photos were taken at approximately 5 m intervals along each transect, giving 20 photos per transect. Fifteen random points were generated on each photo, all coral growth forms were distinguished, and Excel files created that generated a mean cover for each life form category.

2.1.8 Whale Shark survey

Finally an effort-based transect along the Maamigili MPA along the southern shore of Ari Atoll to count whale sharks was carried out for five hours between 11:00 and 16:00 on 8 September 2013. No whale sharks were observed during the entire transect.

[4] http://www.nova.edu/ocean/cpce/

2.2. Results

2.2.1. Survey sites visited during the 2013 expedition

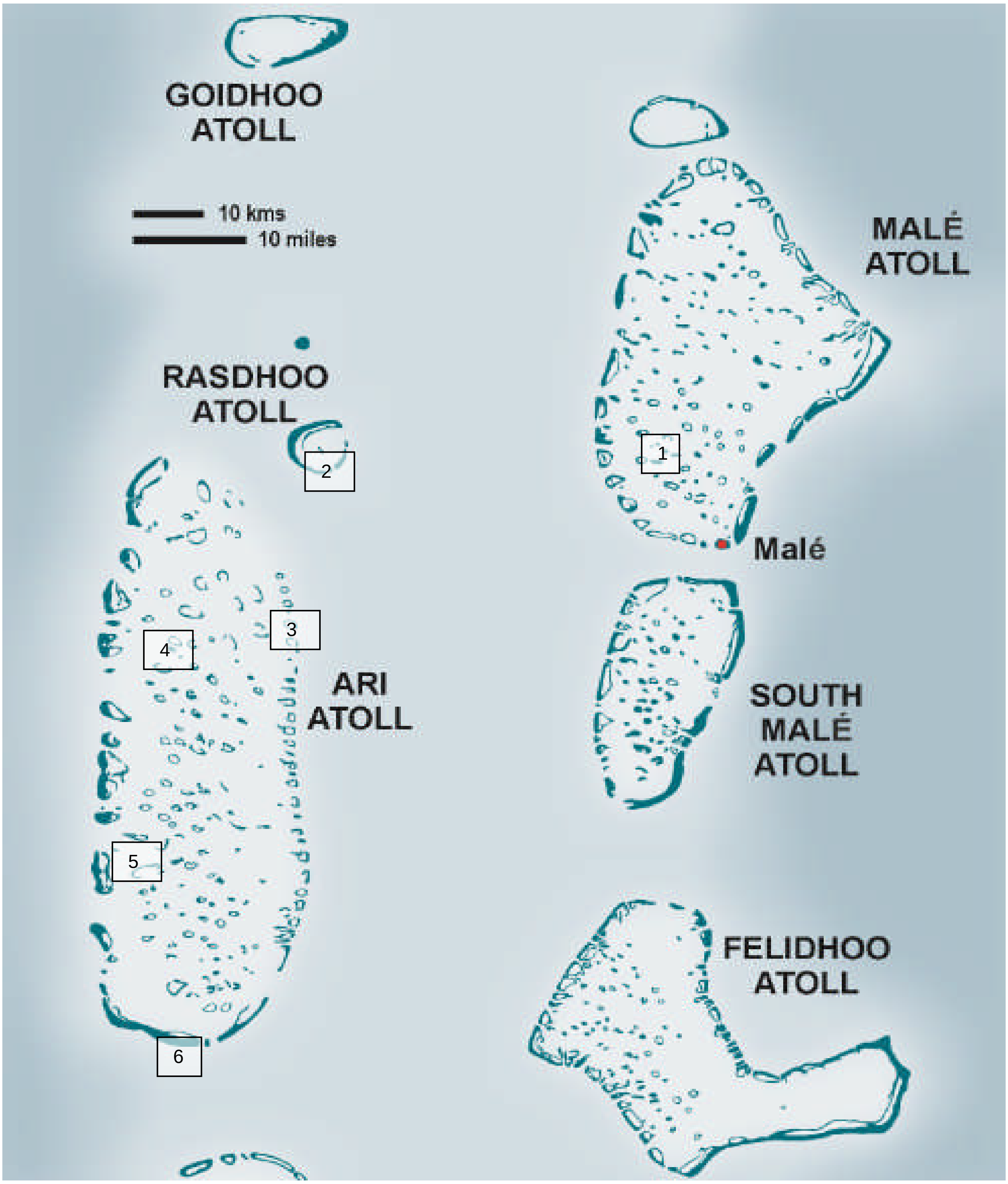


Figure 2.2.1a. Location of the five sites surveyed using Reef Check methodology in 2013. 1 – Banyan Tree house reef; 2 – Rasdhoo Madivaru; 3 – Bathalaa Maagaa; 4 – Kudafalhu; 5 – Diggha thilla. Site 6 – whale shark survey at Maamigili, South Ari Atoll.

2.2.2. Seabed cover

Surveys were carried out at (at least) two depths at each dive site visited.

Site 1 – Banyan Tree house reef

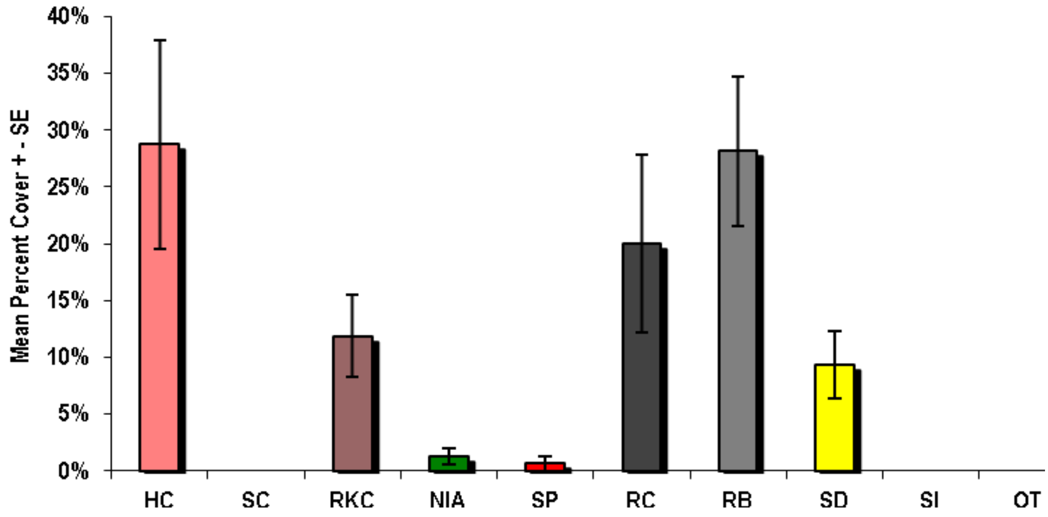


Figure 2.2.2a. Banyan Tree house reef (5 m). (HC – Hard Coral; SC – Soft Coral, RKC – Recently Killed Coral, NIA – Nutrient Indicator Algae, SP – Sponge, RC – Rock, RB – Rubble, SD – Sand, SI – Silt, OT – Other).

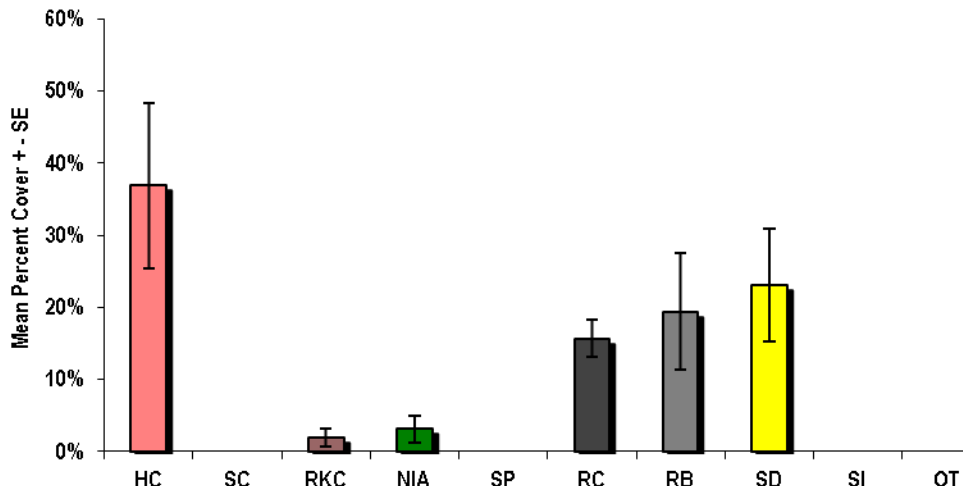


Figure 2.2.2b. Banyan Tree house reef (8 m). (HC – Hard Coral; SC – Soft Coral, RKC – Recently Killed Coral, NIA – Nutrient Indicator Algae, SP – Sponge, RC – Rock, RB – Rubble, SD – Sand, SI – Silt, OT – Other).

The amount of rubble and recently killed coral at Banyan Tree house reef is a cause for concern. It is a sheltered inshore house reef, so rubble will not be quickly washed down the reef to deeper waters, as there is limited wave action at the site. Persistent rubble that does not get colonised by coralline algae is a threat to the health of the reef, as it cannot then support new coral recruits. The stabilising nature of coralline algae cements the rubble, and allows a surface on which corals can recruit. Without the cementing nature of coralline algae, it is unlikely the reef will recover to a significant coral-dominated community in the area of the survey.

Site 2 – Rasdhoo Madivaru

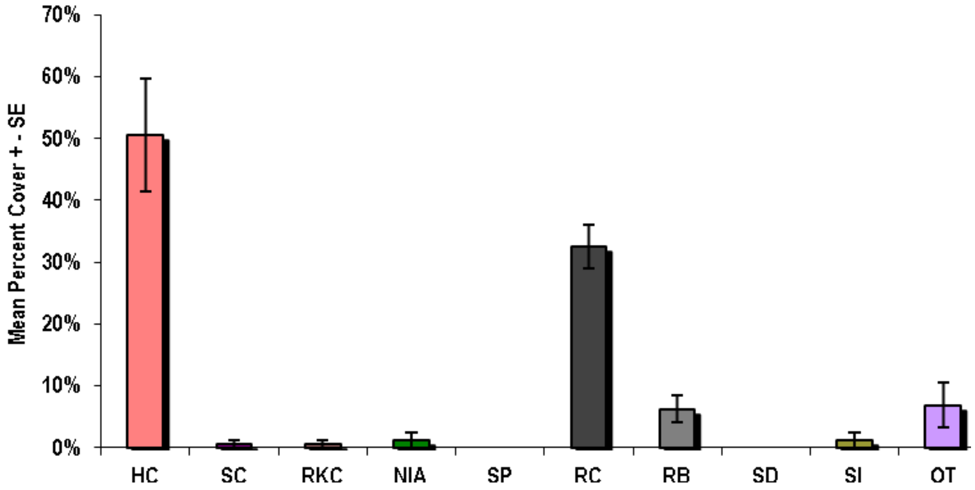


Figure 2.2.2c. Rasdhoo Madivaru reef (6 m) substrate cover for 2013. See Figure 2.2.2a for codes.

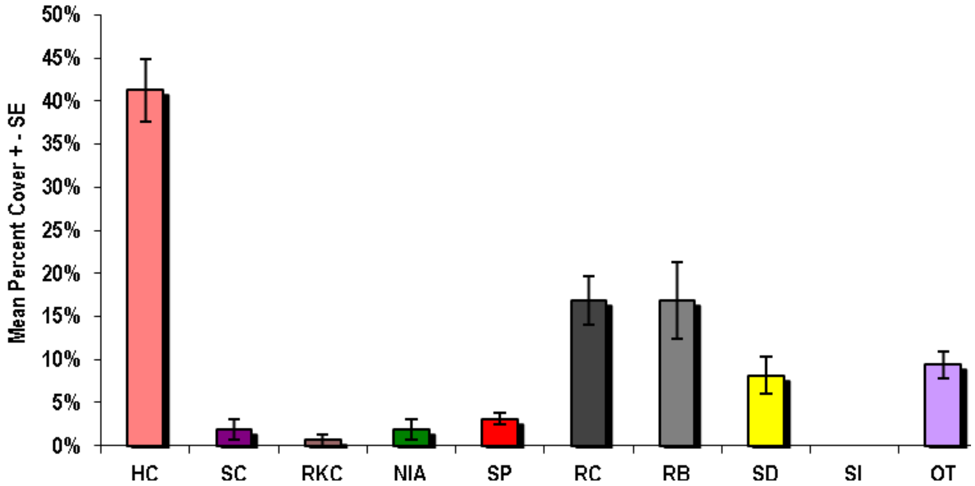


Figure 2.2.2d. Rasdhoo Madivaru reef (12 m) substrate cover 2013. See Figure 2.2.2a for codes.

Rasdhoo Madivaru has had coral cover that is stable / slightly increasing over time since it was first surveyed in 2005 (Fig. 2.2.2e). It is the only 'outer' reef we permanently survey, as these sites are generally affected more seriously by currents than other inshore reefs, making them more difficult to survey. Here the reef drops at 60° from a shallow (3 m) reef crest to approximately 30 m. This is therefore not a conventional 'ReefCheck' reef because of its steep incline, but we feel it is a necessary survey site because of its habitat complexity, and significance to the live-aboard dive community.

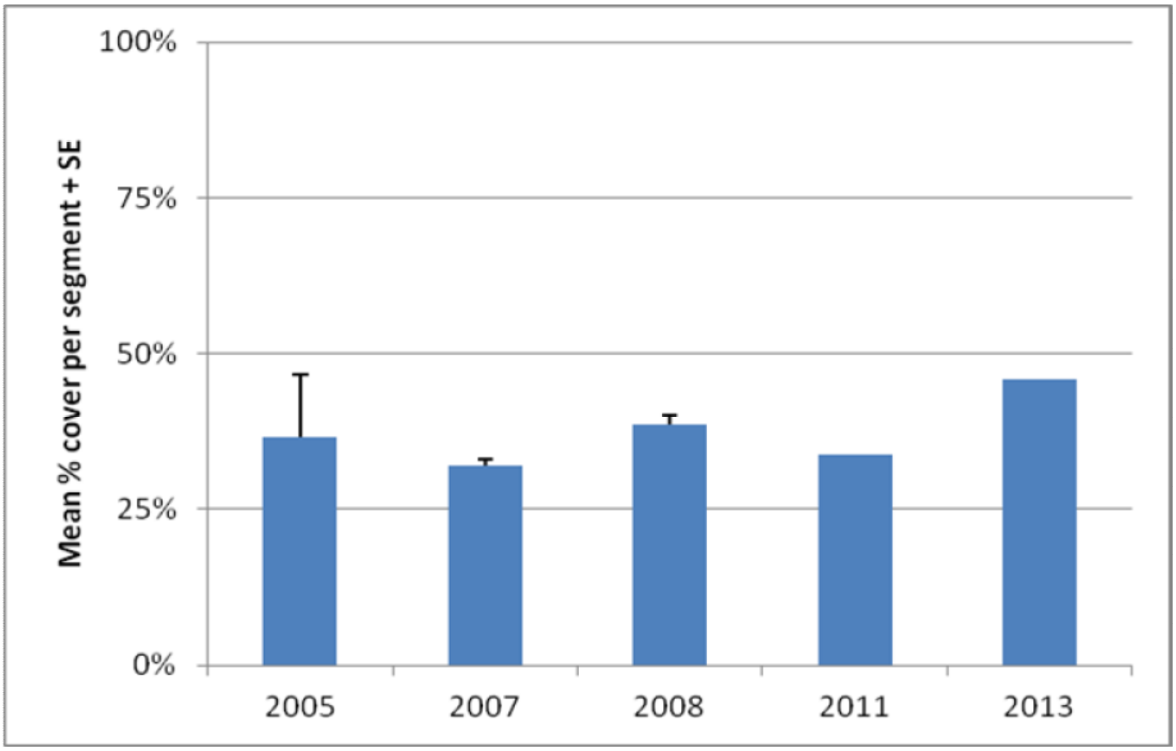


Figure 2.2.2e. Rasdhoo Madivaru coral cover over time (all surveys / all depths combined).

Reef Health

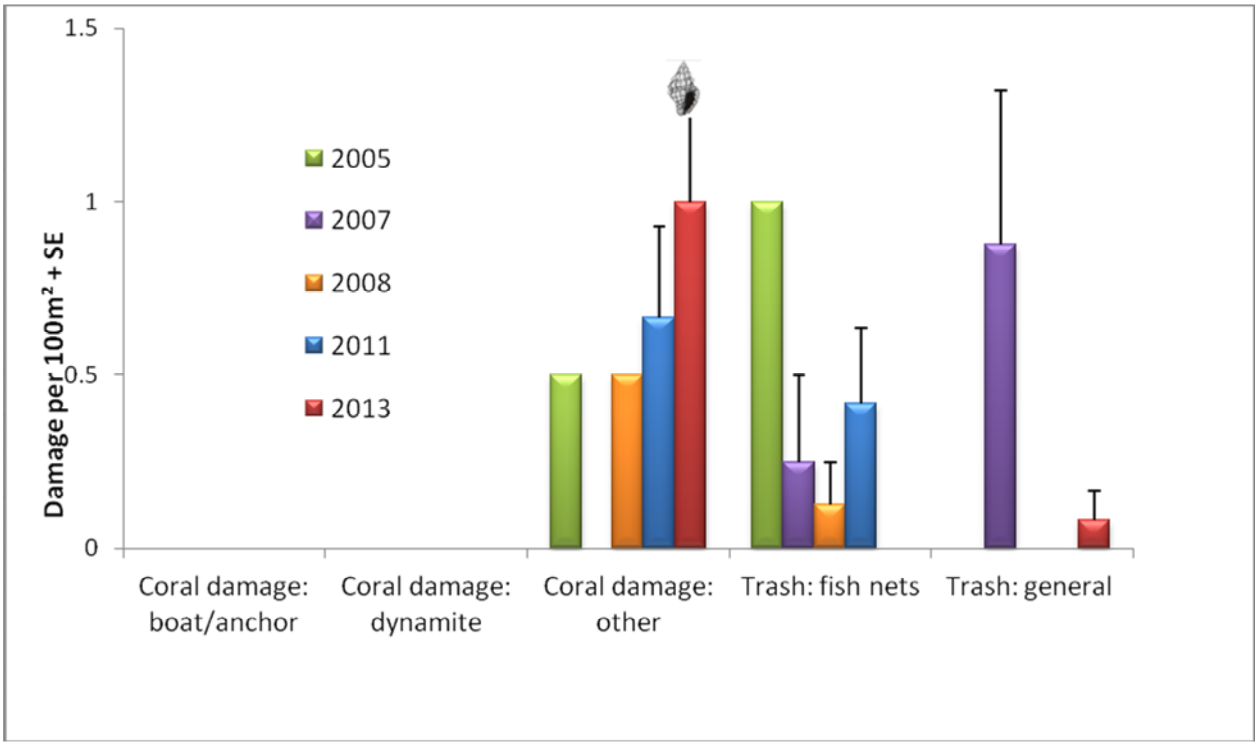


Figure 2.2.2f. Damage to Rasdhoo Madivaru reef since 2005. The gastropod symbol over 2011 denotes *Drupella* predation on *Acropora* coral in 2013 in the deeper transect. All damage 'other' and fish nets is fishing line rather than fishing nets. Fishing line is usually found wrapped around both live and dead coral life forms. This suggests that there is extensive handline fishing for predatory reef fish (grouper, sweetlips, snapper). The Y axis denotes a semi-quantitative scale (1 = 1–2 pieces/incidents of damage; 2 = 3–4 pieces of damage; 3 = 5 or more pieces of damage).

Site 3 – Bathalaa Maagaa

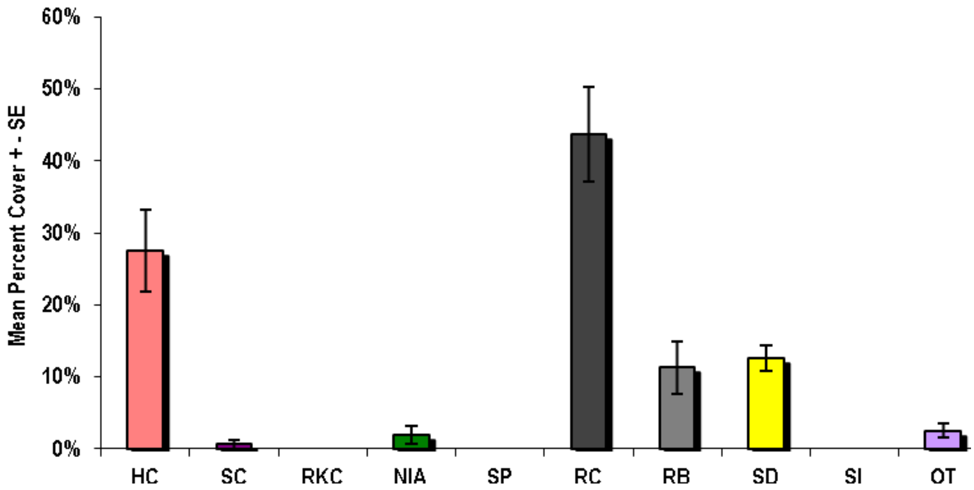


Figure 2.2.2g. Bathalaa Maagaa (3 m) substrate cover. See Figure 2.2.2a for codes.

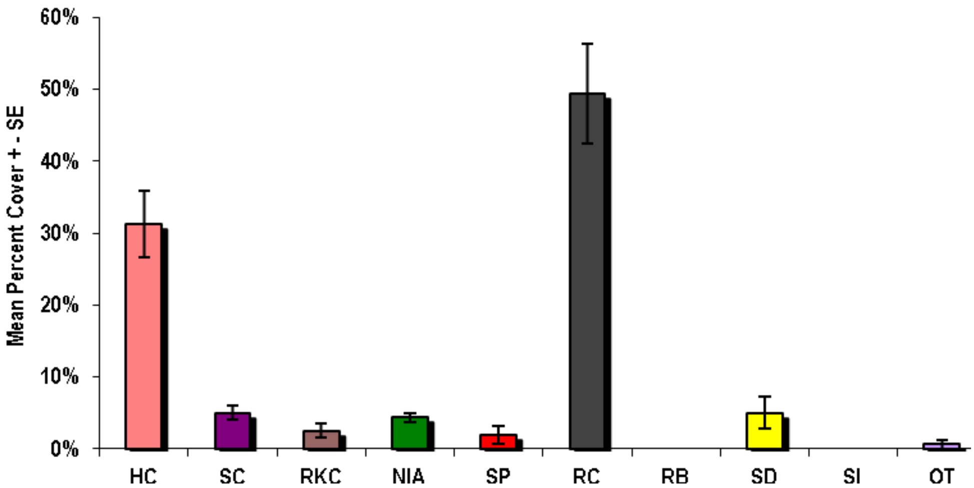


Figure 2.2.2h. Bathalaa Maagaa (12 m), substrate. See Figure 2.2.2a for codes.

Bathalaa Maagaa shows average coral cover that does not differ significantly between shallow and deep transects (Fig. 2.2.2g and h). The greatest cover of seabed habitat is bare rock and coralline algae. The site is located to the northeast edge of Ari Atoll and forms a barrier reef to the deeper waters between Ari, South Male' and North Male' atolls. As such, it is often exposed to north-easterly monsoon winds and storms. There are relatively low impacts from fishing and *Drupella* and no disease was observed at the site in 2013 (Fig. 2.2.2i).

Reef Health at Bathalaa maagaa

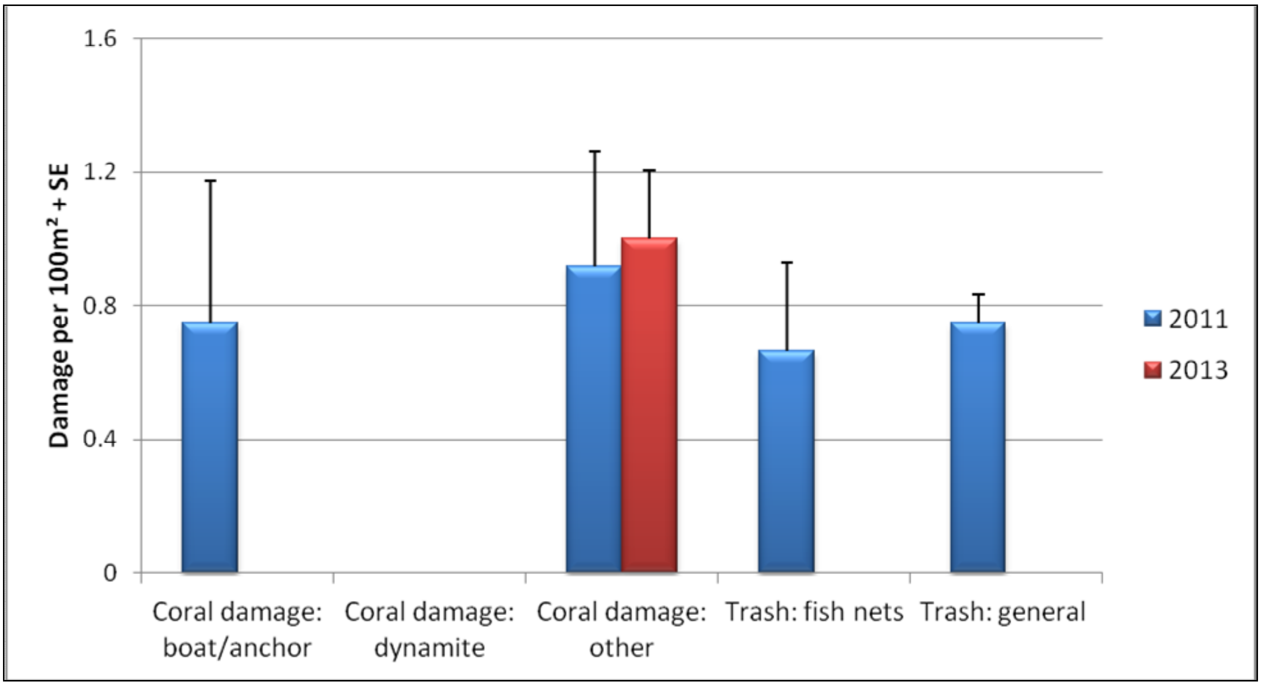


Figure 2.2.2i. Bathalaa Maagaa coral damage. Coral damage ‘other’ is predominantly from discarded fishing line.

Site 4 – Kudafalhu

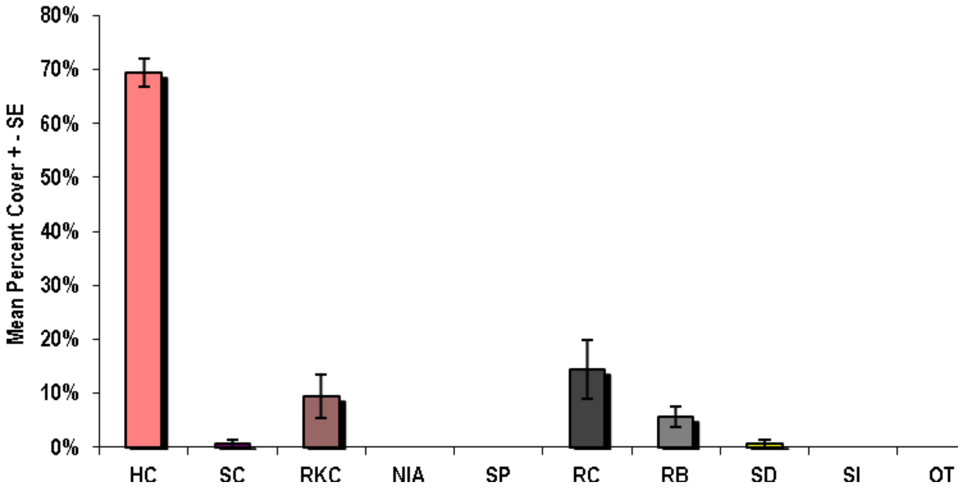


Figure 2.2.2j. Substrate at 5m depth at Kudafalhu (central Ari Atoll). See Figure 2.2.2a for codes.

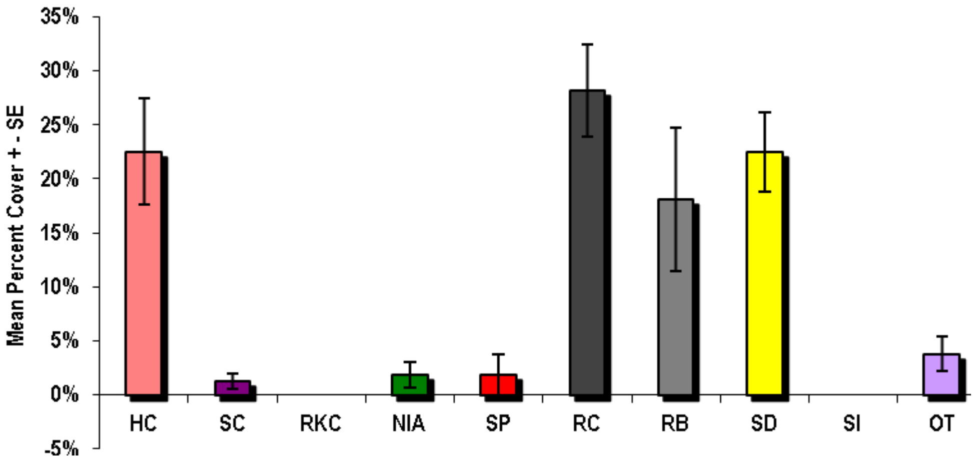


Figure 2.2.2k. Substrate at 12 m depth at Kudafalhu.

The deeper transect at Kudafalhu has considerable areas of rubble fields and sandy beds. These tend to be in patches, strewn down the reef from 7 m or so into deeper waters. Shallow reef areas of this site can have areas of extensive table *Acropora* that are susceptible to storm damage and would quickly fragment post-bleaching or after any other catastrophic event. Over time, this dead reef material cascades down the slope – particularly during stormier conditions. This is probably why the rubble and sand cover is so high (over 40%) in the deeper reef.

CPC analysis from Kudafalhu

Sixteen photoquadrats were analysed from Kudafalhu that showed a dominance of branching *Acropora* species at 12 m depth for this site (Fig. 2.2.2l and m).

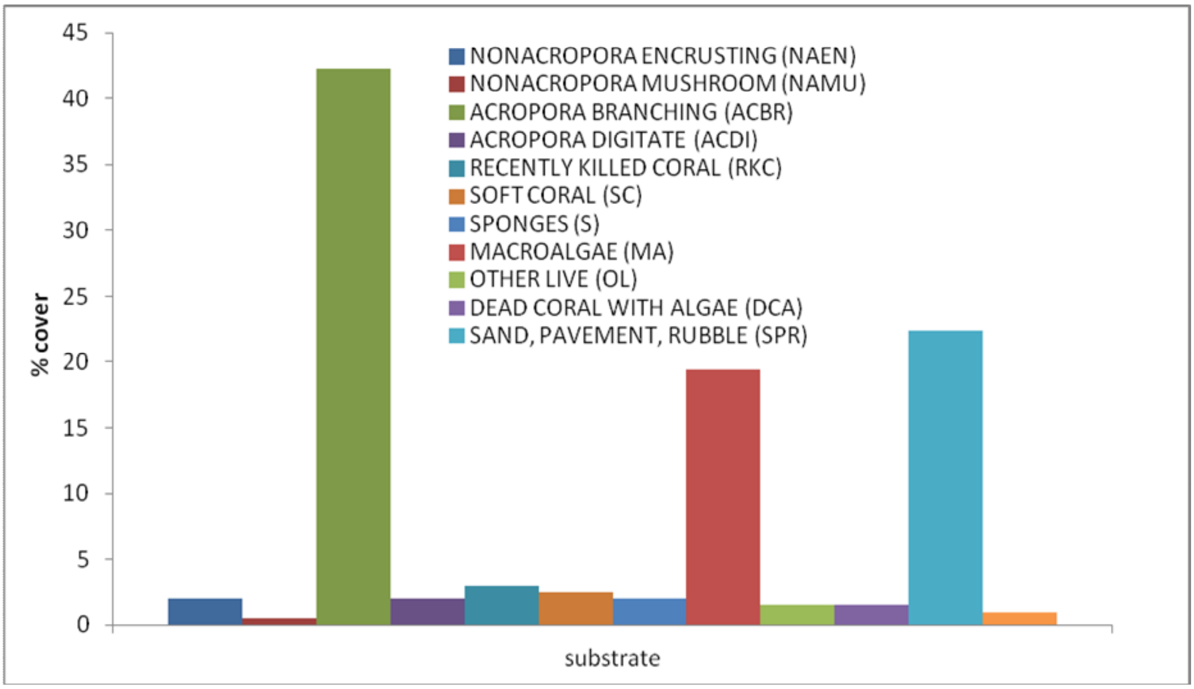


Figure 2.2.2l. Life forms at Kudafalhu reef at 12 m depth (data from CPC[5] analysed photoquadrats, n=15). The most dominant coral growth forms were branching *Acropora* (ACBR) and non-coral lifeform, macroalgae.

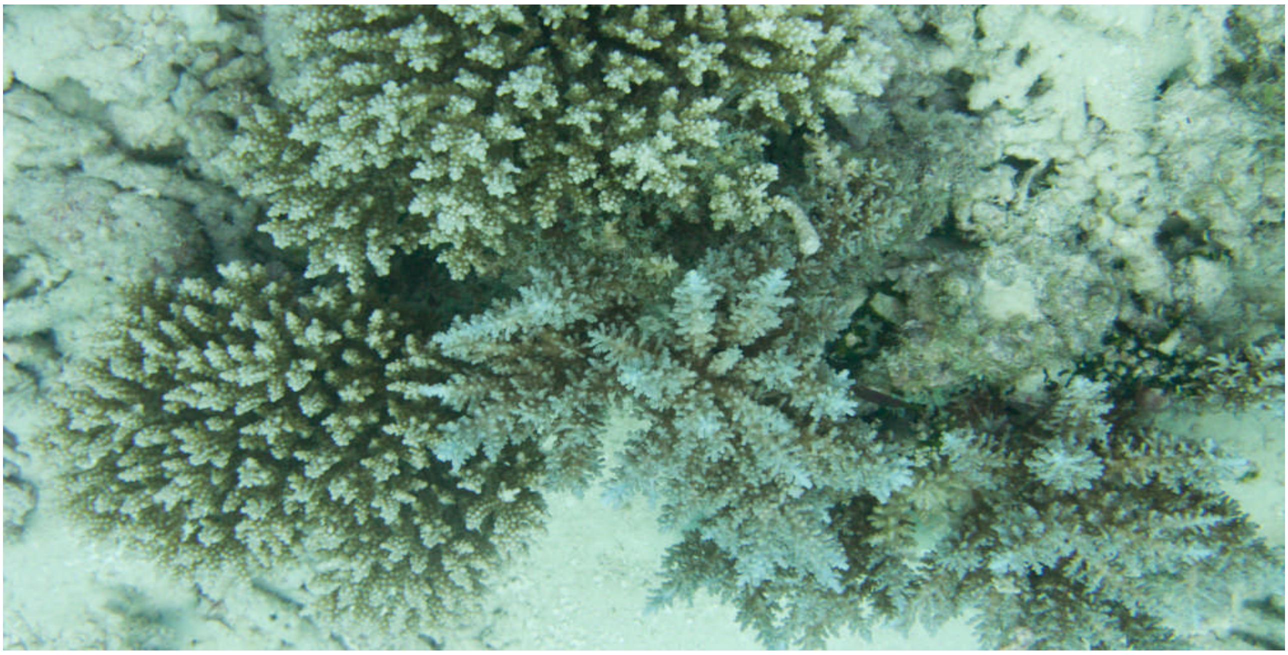


Figure 2.2.2m. Typical coral growth forms at Kudafalhu. Two different species of *Acropora* are seen in this image. Table coral growth dominates in the very shallowest reef areas (<5m), whilst branching growth forms occur slightly deeper on the moderately exposed reef slope.

[5] CPC – Coral Point Count with Excel extensions. A computer package specifically designed for assessing coral cover from photoquadrats. http://www.nova.edu/ocean/cpce/

Reef Health at Kudafalhu

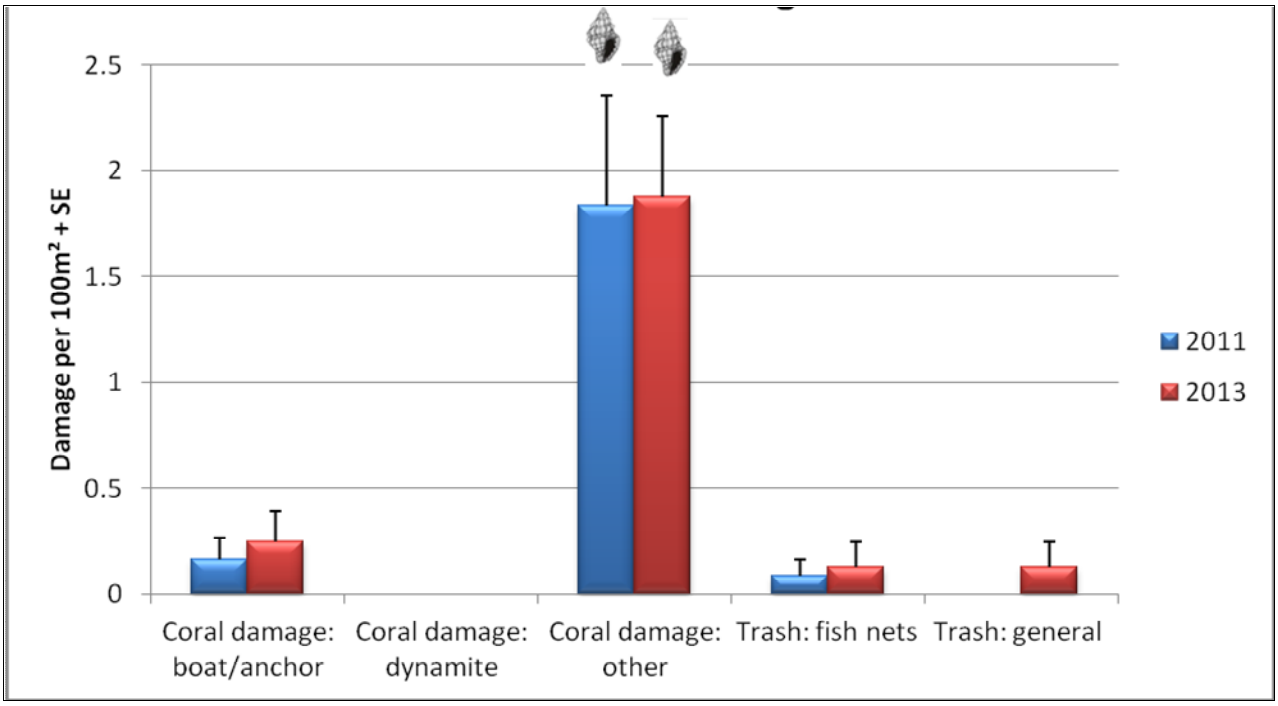


Figure 2.2.2n. Damage to corals from various factors including nets, boat anchors, storms and principally from *Drupella* and fishing line (shells denote years when *Drupella* were recorded feeding on colonies).

Site 5 – Diggha thilla

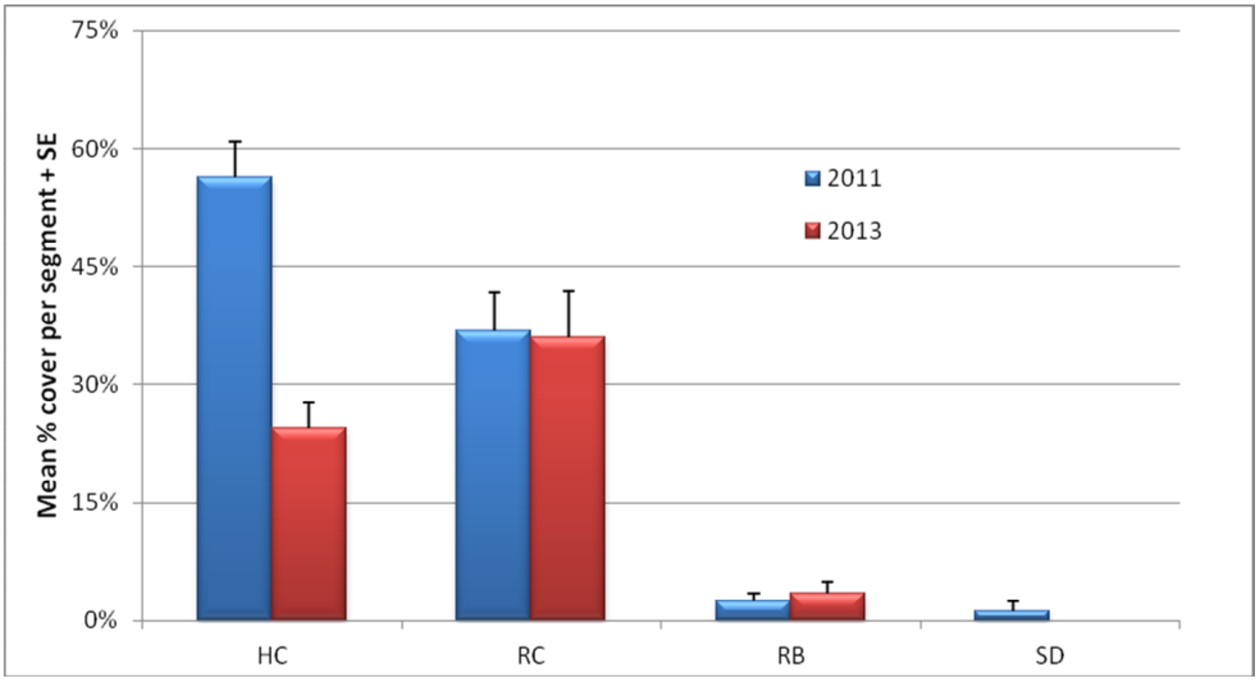


Figure 2.2.2o. Change in coral cover (and other physical categories) between the 2011 and 2013 Biosphere Expeditions surveys for all depths. The change in coral cover is signficant from 56% to 33% (Wilkoxon rank sum test, W=16, p<0.03). See Figure 2.2.2a for codes.

The corals at Diggha thilla appear to have suffered a decline since 2011. Diggha is an interesting site with steep vertical walls leading up to form a 300 m wide pinnacle from 40 m+ depth of water at the base of the atoll. The westward side of the atoll is a sheer wall. It lies approximately 6 km due east from the outer (west-facing) channel of southern Ari Atoll. There is very little shelter for this thilla from the channel and any currents and waves that come through that channel. The reef flat is comprised of mature *Acropora* table colonies. Since the surveys of 2011, there have been storms and it appears that some of the reef in the shallow waters of the site was broken and has since further broken down. This would have increased the rubble content of the shallow surveys between 2011 and 2013.

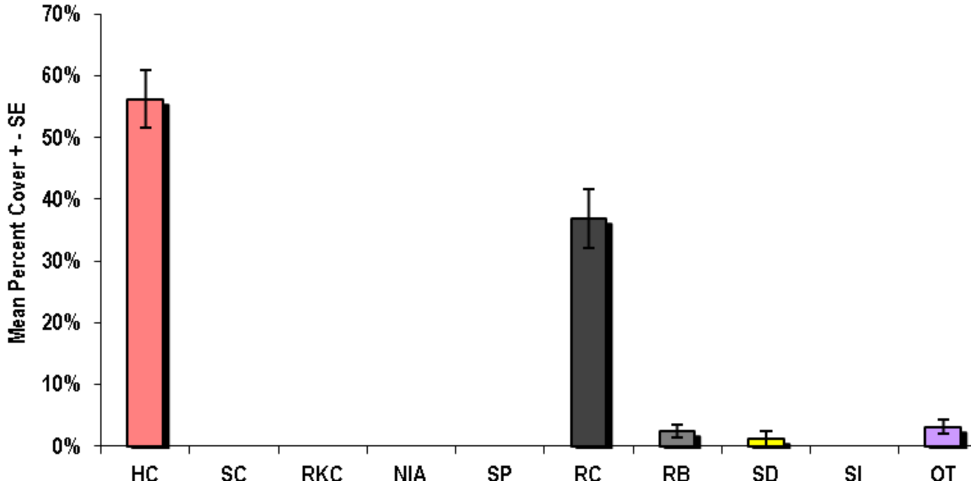


Fig. 2.2.2p. Substrate composition at 4 m in 2011, showing the considerable proportion of hard coral and bare rock surface on which new coral colonies can settle. See Figure 2.2.2a for codes.

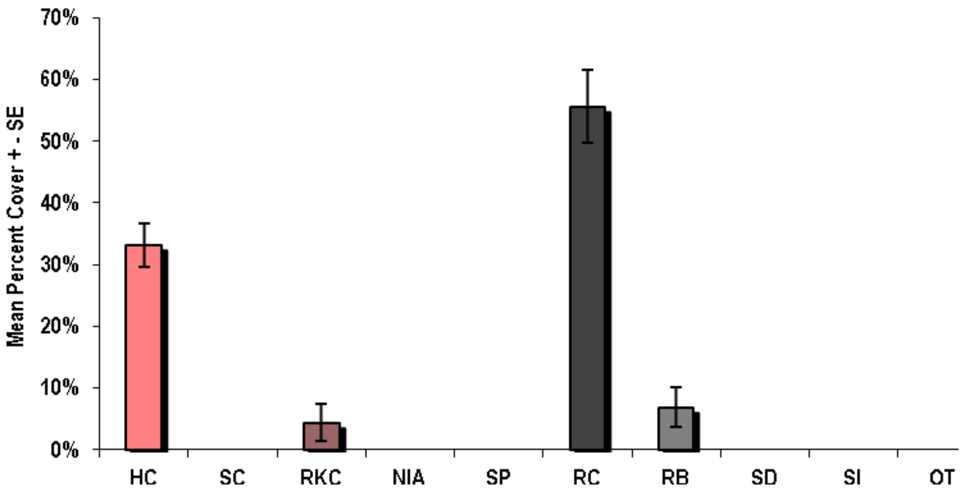


Figure 2.2.2q. Substrate cover at 5 m in 2013, showing the decrease in live coral cover, and a concomitant rise in rock (56%) and rubble (7%). See Figure 2.2.2a for codes.

Diggha CPC

A photo transect was carried out at Diggha Reef. Through human error it was carried out too deep (12 m) to undertake a detailed assessment of the shallow reef (4–6 m). It does, however, show the completely different assemblages of species and life forms that occur on deeper vertical faces of Maldives reefs (Fig. 2.2.2r).

Here ahermatypic (non-reef-building) life forms, such as zoanthids, hydroids and ascidians, are dominant. There is a much smaller proportion of both macroalgae (that tend to dominate horizontal free space and in shallower waters) and of course hermatypic (reef-building) corals.

Figure 2.2.2r. Typical CPC image of Diggha thilla at 12 m. *Halimeda* algae, ascidians and hydroids can be seen on the image and an azooxanthellate coral (*Tubastrea* sp., red circle) that does not require shallow water, as it gains its nutrition from heterotrophy (predation) rather than photosynthesis.

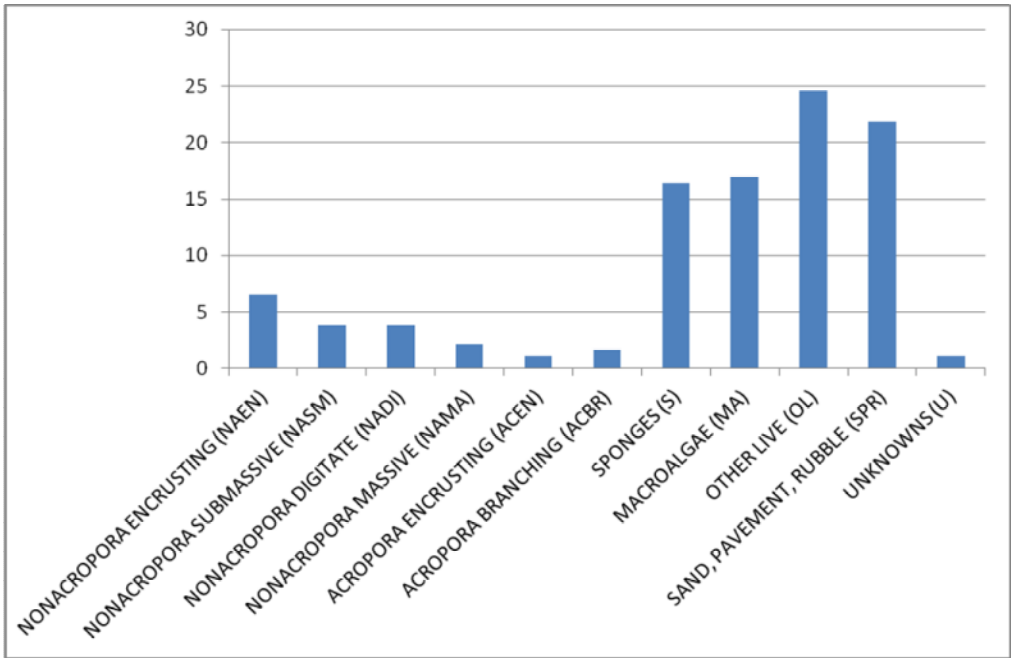


Figure 2.2.2s. Coral life forms and other living seabed groups at 12 m, Diggha thilla (from 16 replicate images). The site is heavily dominated by 'other live', macroalgae and sponge life forms. Combined live coral cover is 19.1% – considerably lower than in the shallow-water surveys. Furthermore, at this depth and this orientation (a wall), the coral life forms are very much more dominated by non-*Acropora* encrusting, submassive and digitate growth forms.

2.2.3. Fish / grouper populations

Fish populations

Fish populations did not vary considerably between sites, with similar trends at all sites and depths (Fig. 2.2.3a). The dominant family (in terms of numbers) recorded was butterflyfish, with parrotfish and snapper recorded at considerably lower densities. No humphead wrasses were recorded from any site and moray eels were rare.

Butterflyfish are superabundant on Maldives reefs, particularly in exposed or offshore reefs where planktivorous species are observed at very high densities. The Maldives is fairly unique in having such high densities of planktivorous reef-associated butterflyfish species.

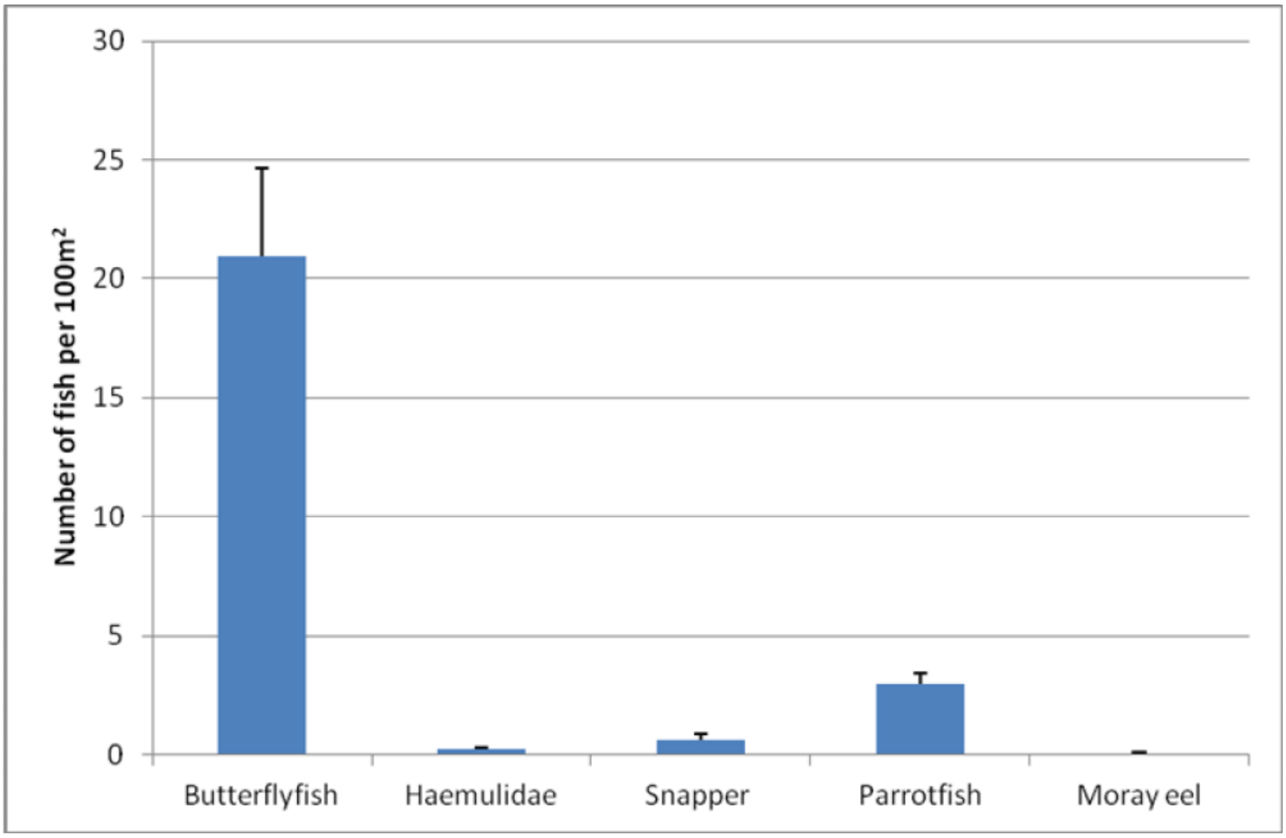


Figure 2.2.3a. Reef fish abundance from all sites at all depths combined for 2013 surveys (n=52). Abundances are mean numbers of fish per 100 m^2 (individual replicate of 20 m length x 5 m width).

Commercial fish

Since surveying reefs of the Maldives since 2005, ReefCheck and MCS has recorded dominance of only smaller-sized grouper, and snapper species (Fig. 2.2.3b and c). Top predators are apparent, but larger snapper (such as *Lutjanus bohar*, the red snapper), are rarely recorded at the upper range of their potential maximum size.

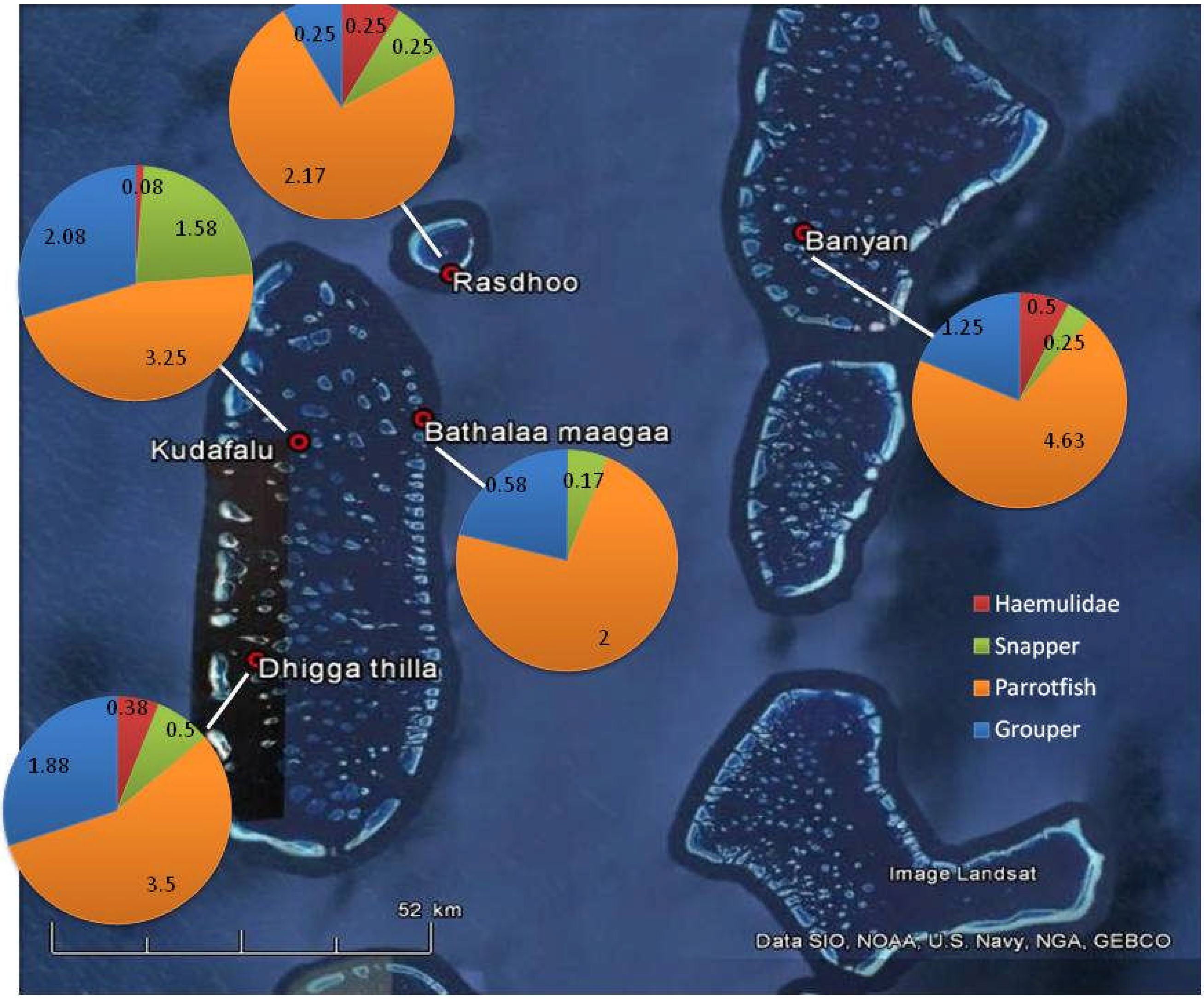


Figure 2.2.3b. Density map of important commercial fish families (Haemulidae, snapper and grouper > 30 cm and parrotfish > 20 cm) by site. Numbers are mean abundance of those families per 100 m^2 of reef. The pie charts effectively show the dominance of the different families.

Grouper populations and size

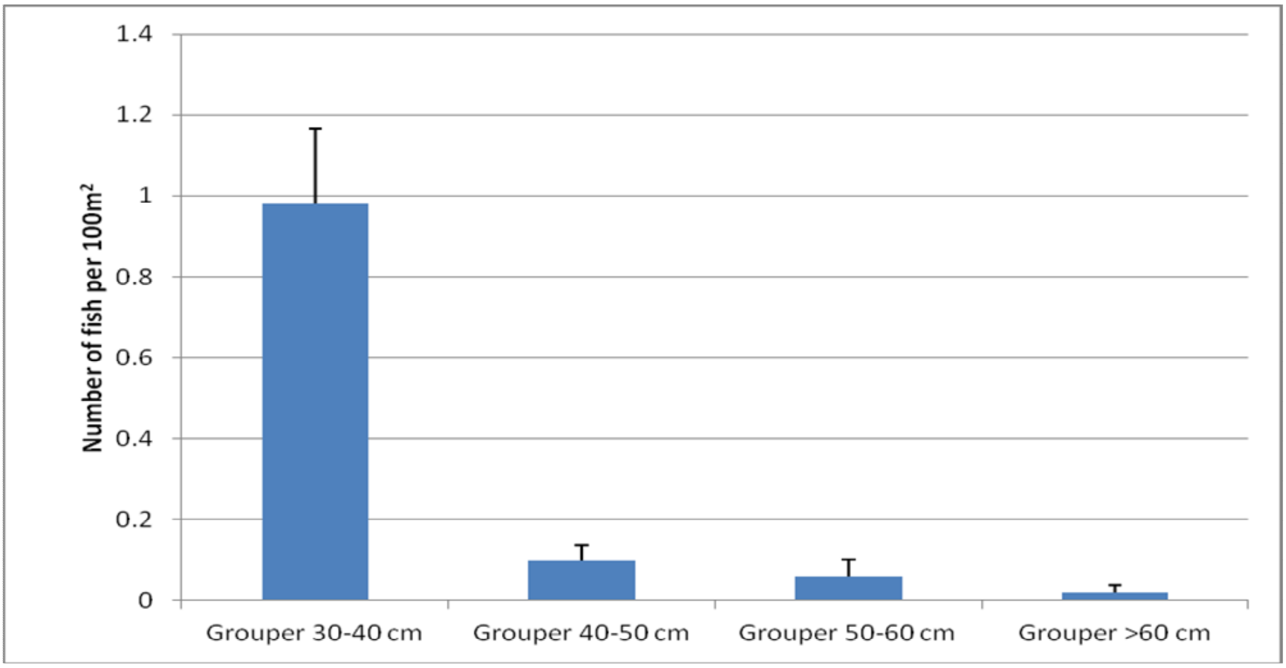


Figure 2.2.3c. Grouper sizes recorded on reefs. Abundances are mean numbers of fish per 100 m^2 (individual replicate of 20 m x 5 m (width) x 5 m (height)). Data are from 52 'replicates' from all surveys at all depths.

2.2.4 Other fish populations

Sharks were occasionally recorded at most of the sites visited – once at Rasdhoo, Diggha and Bathalaa Maagaa (from three transects) and none at Kudafalhu or Banyan Tree. No mantas were observed at the sites. Shark species recorded were blacktip and whitetip reef sharks.

2.2.5. Bleaching

There was no bleaching of note occurring within the Maldives reefs visited in 2013. Although there is a 'percentage' of <1% of the population bleached, the actual percentage is probably very much lower than this.

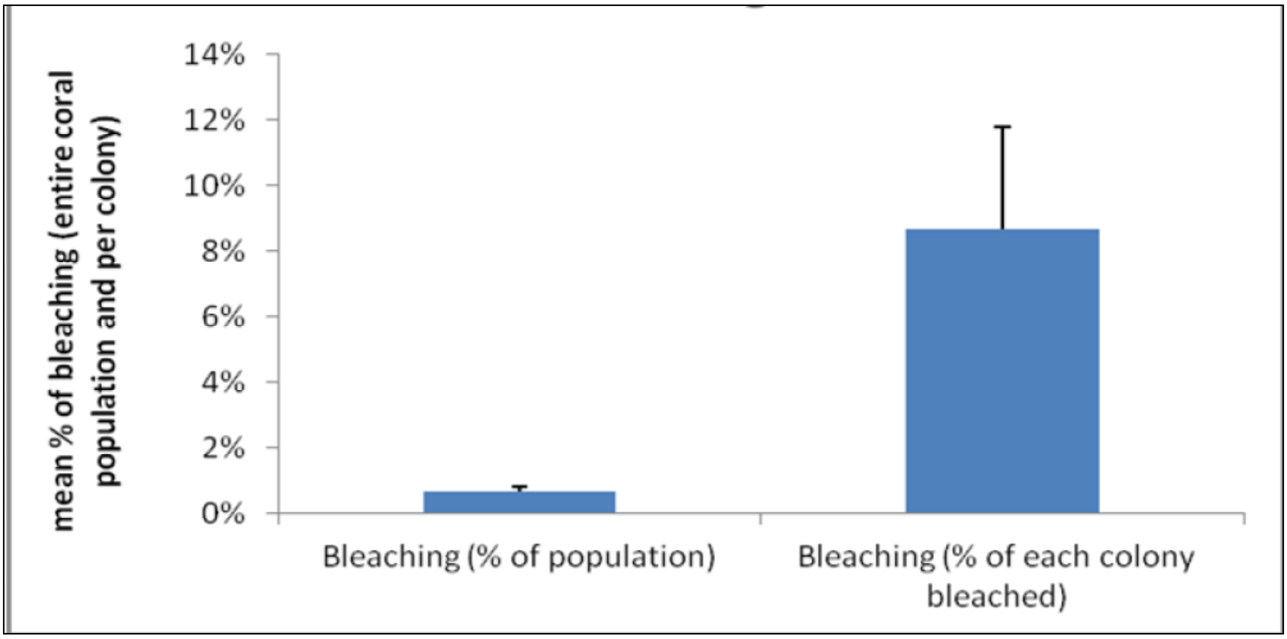


Figure 2.2.5a. Percentage of the live population of corals affected by bleaching, and the percentage of each colony that was bleached.

2.2.6 Disease

A very proportion of the living coral community was considered to be affected by disease (Fig. 2.2.6a). This data may only be represented by a single colony affected by something akin to black band or whiteband disease. ‘Whiteband disease’ may not be such, but may actually be white syndrome.

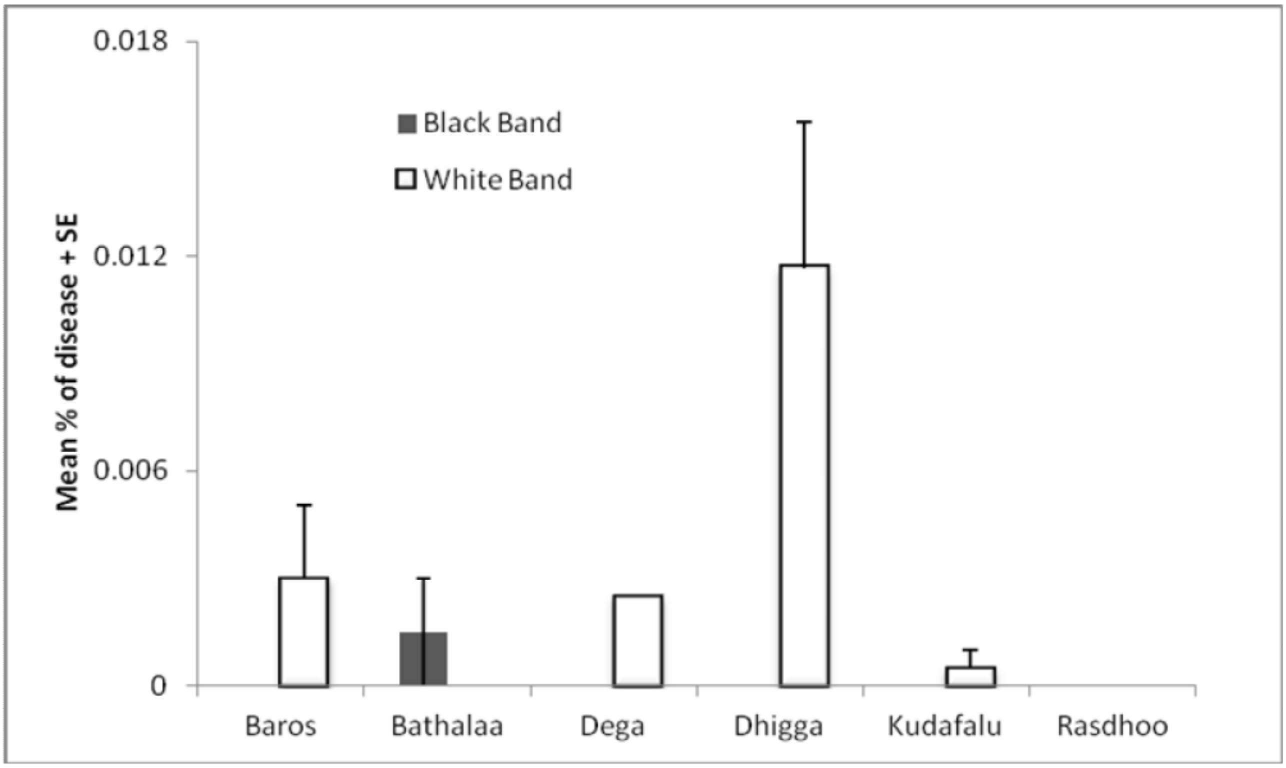


Figure 2.2.6a. Mean % diseased colonies as a percentage of the whole live coral population at a variety of sites since 2008. Overall, this shows the very low percentage of disease affecting live coral colonies. NB: ‘white band disease’ could mean ‘white syndrome’.

2.3. Discussion and conclusions

Reef Check 2013 surveys show no significant difference in trends compared to other years for all sites other than Diggha thilla that appears to have been affected by storm damage. Surveys suggest that there continues to be a trend of recovery of corals from the 1998 bleaching event, although direct comparison of before/after 1998 data hasn't been considered here. Many shallow-water house reefs of resorts are probably approaching something akin to climax communities where the ephemeral species such as *Acropora* table and branching species have either reached maximum size, or where they are competing with other shallow water corals for space. This appears to be the case at the shallow Kudafalhu, Diggha and Banyan Tree sites.

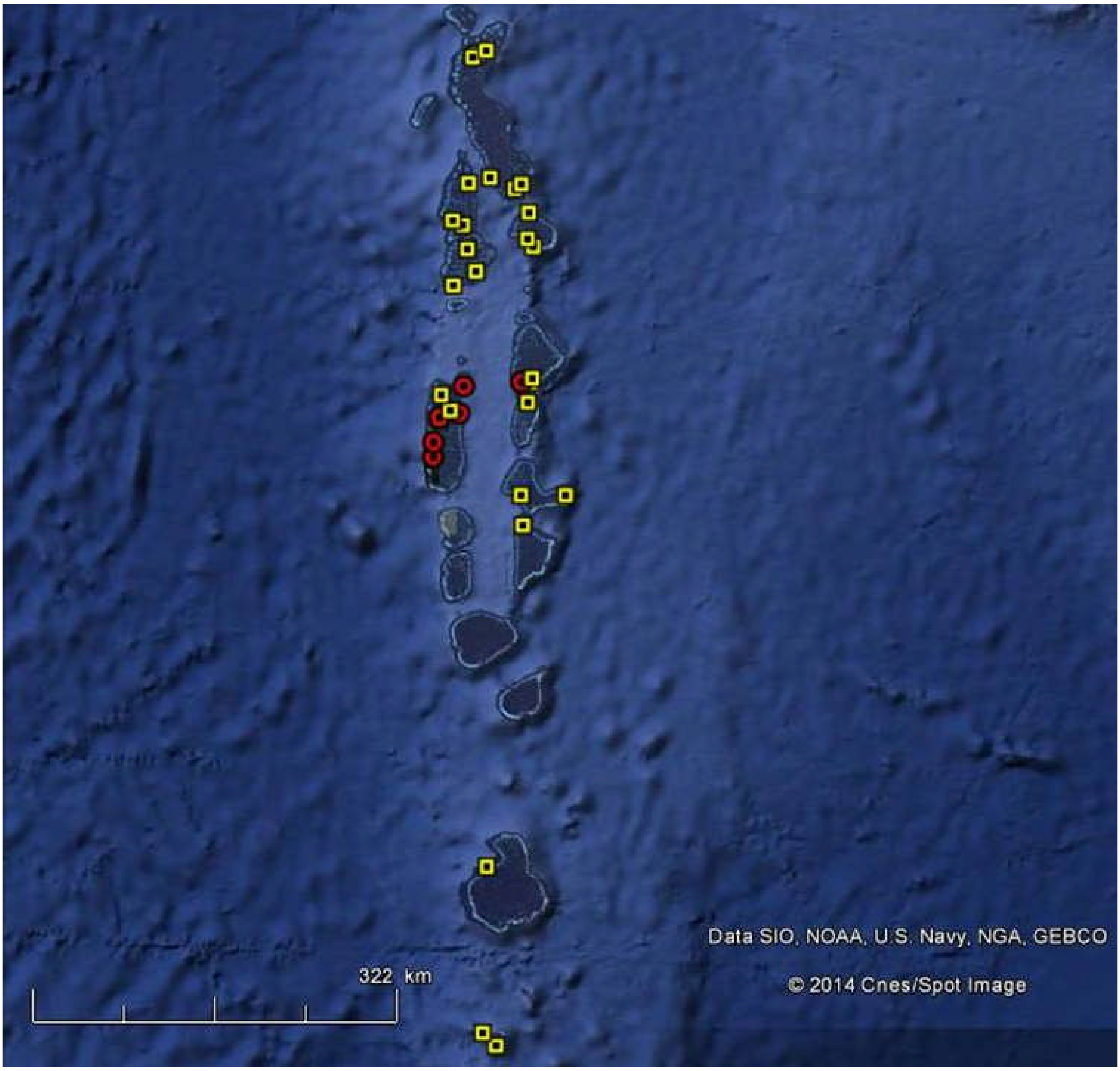


Figure 2.3a. Location of Reef Check (Biosphere Expeditions / MCS) permanent monitoring sites (red), and MRC National Coral Reef Monitoring sites (yellow).

The authors have been working closely with MRC who have a much wider distribution of permanent monitoring sites. We have contributed our permanent monitoring site data from a number of sites where we have more than one year of data (Fig. 2.3a).

A monitoring report is currently being compiled at MRC (summer 2014) looking at the health status of reefs since 2009. The northern sites of the Maldives appear to be generally in worse condition than the central sites. This appears to have generally been the case for at least a decade, with central and southern sites recovering more rapidly. The sites in best condition appear to be the southern sites at Gan (which lies below the equator) and Huvadhoo Atoll which is one of the largest and deepest atolls in the world, which lies just north of the equator. These sites appear to have had very little long-term damage from the 1998 bleaching event.

An exception to this is the decrease in abundance of live hard coral cover at Diggha thilla to the southwest of Ari Atoll. Here there has been a statistically significant decrease in abundance of live hard corals from the original Biosphere Expeditions survey in 2011 (56% to 33%). The shallow-water (< 5 m) community recorded in 2011 was hit by a storm in early 2013 that may have contributed to the decreased live coral cover, a concomitant increase in bare rock (37% to 56%), and an increase in rubble from 3 to 7%. Biosphere Expeditions will return to this site in the future to record any recovery in coral cover associated with the site.

Figure 2.3b. Location of Biosphere Expeditions / MCS sites (red) with more than one year of data. Yellow dots are locations of MRC permanent monitoring locations. A: Baros Maldives; B: Rasdhoo Madivaru; C: Bathalaa Maagaa; D: Kudafalhu; E: Dega thilla; F: Diggha thilla. Note the large 3 km wide open channel to the west of Diggha thilla.

Other impacts

The number of sites where *Drupella* are found feeding on corals is increasing and there are increasing incidences of disease (principally by 'white syndrome'). 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 have an accurate record of relative incidences of these two different disease events. Although both the numbers and abundances of corals that are affected by either disease or *Drupella* is 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. It is of concern that we are seeing any disease at all in Maldivian reefs, even in isolated patches.

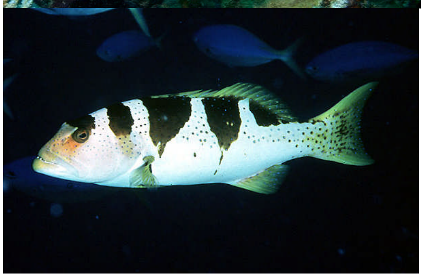
Fish populations

Many fish populations of the central Maldives suffer from overfishing, particularly of top-level carnivores. These are generally the first fish to be exploited (for food) on coral reefs, with secondary carnivores, omnivores and finally herbivores exploited. This is generally the case on all tropical reefs, but the Maldives is slightly different in that there is a large fishery for bait fish (dominated by both blue and sliver sprat, cardinalfish, fusiliers and anchovy)[6]. These fish are captured using small-mesh nets laid over reefs and transported live to fishing grounds outside the atolls where they are used to attract yellowfin and skipjack tuna.

There are still reasonable numbers of grouper in most sites visited in the 2013 surveys, but their mean sizes are small. They are dominated by lyretail (*Variola louti*), coral hind (*Cephalopholis miniata*), peacock (*Cephalopholis argus*), redmouth (*Aethaloperca rogaa*), and blacksaddle (*Plectropomus laevis*) grouper. The redmouth, peacock and coral hind grouper are generally cryptic species, as are most epinephalid (leopard) grouper. The lyretail and blacksaddle species tend to be more frequently observed in waters above the reef and are easily recorded by volunteers. The five species commonly observed on reefs had an average size of 36.6 cm. Therefore, given that 85% of grouper surveyed were smaller than 40 cm, most fish are likely to be below sexual maturity (when they change from female to male) (Table 2.3a). This is reflected in the catch composition recorded by the Darwin Reef Fish Project for the 2010–2011 surveys, where on average, of five grouper species commonly recorded by Reef Check, over 70% of fish landed were immature (Wood et al. 2011). Statistics are particularly concerning for the larger species such as *P. laevis*, Epinephalids and *V. louti* (Table 2.3a). The solution to rebalance the grouper population is to fully adopt the recommendations from the Darwin Reef Fish Project for minimum landing sizes, respect the grouper spawning locations already protected and develop further closed areas for commercial species. Resorts can play their part in respecting the ‘no-take’ status of their reefs, ensuring that guests, hotel staff and local populations do not fish from key house reef or entire home reef areas wherever possible.

[6] www.fao.org/docrep/x5623e/x5623e0k.htm

Table 2.3a. Key grouper species size at sexual maturity and maximum size[7].

	Maximum size (cm)	Size at sexual maturity (cm)	DRFP[8] percent immature landings (2010–2011 data)	Photo (www.fishbase.org)
Variola louti (lyretail)	83	41	88.75	
Cephalopholis miniata (coral hind)	50	26	8.52	
Cephalopholis argus (peacock grouper)	60	22	79.70	
Aethaloperca rogaa (redmouth grouper)	60	34	74.32	
Plectropomus laevis (blacksaddle grouper)	125	60	98.85	

[7] Data from www.fishbase.org
[8] Darwin Reef Fish Project

Reef shark populations appear low on most reefs visited, with a mean (±SE) of 0.21 ± 0.06 sharks observed per 100 m^2 per site (data from all Maldivian sites in central atolls since 2005). That means that only one shark was observed (on average) per survey. This is important, as surveyors are undertaking a swim along a known distance with Reef Check, so it is a useful measure of the true abundance of Maldivian sharks. The most dominant species were both whitetip and blacktip reef sharks. The most consistent number of sharks observed by 'Maldives Sharkwatch' at sites was between one and two individual sharks (on 45% of surveys) (Ushan et al. 2012). Our data lie within this range.

The shark population is currently protected in the entire Maldives, so hopefully this population will now grow.

Disease and bleaching

Disease and bleaching appear to be of low importance at present. We have recorded very little incidence of coral damage in the survey sites visited. There is a small concern over the damage witnessed at Diggha thilla; however, this appears to have been based on storm damage, rather than induced by disease, predation or bleaching impacts.

Recommendations (repeated from 2012[9] report)

Managers and politicians must be pro-active in managing what they can at the local level to prevent a shift to algal-dominated reefs from happening. We therefore recommend that:

- Fish populations are protected and sustainable fisheries established. Minimum and maximum size limits for grouper must be considered and no-take zones around spawning locations must be enforced and expanded.

- MPAs are used as a measure to promote sustainable fishing. One in every three reefs should be considered for this sort of no-take protection measure.

- Pollution must be tackled to prevent diffuse pollution promoting algal growth.

The local islands, their political administrators and resorts should adhere to and enforce these environmental standards where possible in order to stave off the most severe detrimental effects of climate-driven change to the health of the reefs.

[9] http://www.biosphere-expeditions.org/images/stories/pdfs/reports/report-maldives12.pdf

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Appendix I: Expedition diary and reports

A multimedia expedition diary is available at http://biosphereexpeditions.wordpress.com/category/expedition-blogs/maldives-2013/

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