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EXPEDITION REPORT

Expedition dates: 2 - 8 September 2012

Report published: May 2013

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

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EXPEDITION REPORT

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

Expedition dates:
2 - 8 September 2012

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Authors:
Jean-Luc Solandt
Marine Conservation Society &
Reef Check Co-ordinator Maldives

Matthias Hammer and Adam Stickler (editors)
Biosphere Expeditions

Abstract

One week of Reef Check surveys were carried out in September 2012 with Biosphere Expeditions volunteers in central Maldives atolls. Surveys concentrated on re-visiting sites that were initially surveyed prior to or just after the 1998 bleaching event. Coralwatch, and photo quadrat surveys (analysed using Coral Point Count software) were also carried out at most locations. An effort-based whale shark survey was carried out at Maamigili reef to the south of Ari atoll for five hours, with no sightings. Reef Check sites visited were predominantly inshore house reef and sheltered locations, both in North Male and Ari atolls. At most sites, coral cover had surpassed the surveyed coral cover since before the 1998 bleaching event. At other sites, coral cover was approaching that recorded prior to 1998. For example, Ellaidhoo house reef on the northeast side of Ari atoll had 42% live coral prior to the bleaching event in 1997. In 2012, the cover was 27%. Further south, the more sheltered reef of Angaga (12% rise in coral cover since 1997) and Vilamendhoo (where coral cover immediately post bleaching was 6%) increased to 45%. Observations from many other Maldives reefs since the 1998 bleaching event show an average coral cover of approximately 20-30%. Given the severity of the initial catastrophic bleaching, there has been a moderate to good recovery of corals in central Maldives atolls. Furthermore, given that other wide-scale potential stressors of Maldivian coral reefs (such as water quality and sedimentation) are relatively low, the potential for a full recovery of Maldives corals in many sites is good.

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2012 ވަނަ އަހަރުގެ ސެޕްޓެމްބަރ މަހު މެދުރާއްޖެތެރޭގައި ބަޔޮސްފިއަރ އެކްސްޕެޑިޝަންސްގެ ވޮލަންޓިއަރުން ވަނީ ހަފްތާއަކަށް ދެމިގެންދިއަ ރީފްޗެކް ސާރވޭތަކެއް ކޮށްފައެވެ.މި ސާރވޭތަކުގައި ބޮޑަށް އިސްކަންދެވިފައިވަނީ 1998 ވަނަ އަހަރު މުރަކަހުދުވުމުގެ ކުރިންނާއި ފަހުން ސާރވޭކުރެވިފައި ހުރި ސައިޓްތަކަށެވެ.ކޯރަލް ވޮޗް އާއި ފޮޓޯކްވަޑްރެޓް(ކޯރަލް ޕޮއިންޓް ކައުންޓް ސޮފްޓްވެއަރ މެދުވެރިކޮށް އެނަލައިޒް ކުރުމަށް)ބޭނުންކޮށްގެން ވަނީ ގިނަ ސަރަހައްދުތަކެއްގައި ސާރވޭ ކުރެވިފައެވެ.އަދި މާމިގިލި އަރި އަތޮޅު ދެކުނުންބޭރު މާމިގިލި ފަރުބޭރުން ވަނީ ފެހުރި ސާރވޭކުރުމަށްބޭނުކޮށް 5 ގަޑިއިރު ވަންދެން އެކަމުގެ މަސައްކަތް ކުރެވިފައެވެ.ނަމަވެސް ކަނޑުމަތިން ފެހުރި އެއްވެސް ފެނިފައެއް ނުވެއެވެ. ރީފްޗެކް ސާރވޭ ކުރެވުނު ސަރަހައްދުތަކަކީ ގިނަ ވަގުތު ފަރުގެ ތެރޭގައި ހުރި ރަށްތަކުގެ ގެފަރުތަކާއި ރާޅުން ސަލާމަތް ތަންތަނެވެ. އުތުރު މާލެ އަތޮޅާއި އަރިއަތޮޅުގެ 1998 ވަނަ އަހަރު މުރަކަހުދުވުމުގެ ކުރިން އޮތް ދިރޭ މުރަކަތަކުގެ މިންވަރު ގިނަ ސައިޓްތަކެއްގައި އިތުރުވެފައިވެއެވެ.މިގޮތުން އަރިއަތޮޅު އުތުރު އިރުމަތީ ފަރާތުގައި ހުރި އެއްލައިދޫ ގެފަރުގައި 1998 ވަނަ އަހަރު މުރަކަހުދުވުމުގެ ކުރިން ދިރޭ މުރަކަ 42 ގައެވެ.އަދި 2012 ވަނަ އަހަރު ކޮށްފައިވާ ސާރވޭއިން ދެއްކިގެންވަނީ މިއަދަދުވަނީ 27 އިންސައްތަ ދަށަށްދާފައެވެ. އަރިއަތޮޅު އަންގަގާ ރީސޯޓުގައި ކޮށްފައިވާ ސާރވޭ ދެއްކިގެންވަނީ 1997އާއި އަޅާބަލާއިރު ދިރޭމުރަކަ ވަނީ 12 އިންސައްތަ އިތުރުވެފައެވެ.އަދި އއ.ވިލަމެންދޫ (1998 ގެ މުރަކަހުދުވުމުގެ ފަހުން މުރަކައިގެ އިންސައްތަ 6)ގެ ސާރވޭއިން ދެއްކިގެންވަނީ މުރަކައިގެ އިންސައްތަ ވަނީ 45ކަށް އިތުރުވެފައެވެ.ދިރާސާކުރެވުނު ދެއްކިގެންވަނީ 1998ގައި މުރަކަހުދުވުމުގެ ހާދިސާއަށްފަހު ރާއްޖޭގެ އެހެން ސަރަހައްދުތަކުގެ ފަރުތަކުގައި ދިރޭ މުރަކައިގެ އިންސައްތަ އެވްރެޖް 20-30 އާއި ދެމެދެވެ.މިގޮތުން ރާއްޖެއަށް ދިމާވި މުރަކަހުދުވުމުގެ ކާރިސާގެ ބޮޑުމިނާ ބަލާއިރު މުރަކަ ރަނގަޅުވާން ފަށާ މިންވަރަކީ މުރަކަތަކަށް ކުރިއެރުމެއް ރަނގަޅު ހާލަތުގައި އޮތް ފަރުތަކެއް ކަމަށް ބެލެވެއެވެ.އަދި މީގެ އިތުރަށް މުރަކަ ރަނގަޅުވުމަށް ފަސޭހަވާ ގޮތަށް ދިވެހިރާއްޖޭގެ މުރަކަތަކަށް އަސަރުކުރާ ބޮޑެތި ކަންތައްތައް (މިސާލަކަށް ކަނޑުގެ ފެނުގެ ސާފުކަމާއި ސެޑިމެންޓޭޝަން) ދަށްމިންވަރަކަށް އޮތުމުން ރާއްޖޭގެ ގިނަ ސަރަހައްދުތަކުގައި ދިރޭ މުރަކައިގެ އަދަދު އިތުރުވުމުގެ ފުރުސަތު ހުރިކަން ދެކެވެއެވެ.

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 2 to 8 September 2012 with the aim of surveying and studying the expansive reefs that make up the 1192 Maldivian coral islands, including photographing whale sharks for a photo identification project when encountered. Although the Maldivian reef atolls comprise of a rich mixture of spectacular corals and a multitude of fish and other animals, the Maldives government identified a need for further research and monitoring work as far back as 1997. Biosphere Expeditions with this project is addressing this need and is working with the Marine Conservation Society and the Maldives 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 a Reef Check EcoDiver.

Many reefs in the Maldives are in a relatively pristine 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 and 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 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 will be 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, but there is a strong recovery in most reefs, with extensive recruitment and growth of branching corals.

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 thillas lie in areas of strong current and can be visited at times when jacks, snapper and shark forage for their prey. These reefs are 'fed' by the channels between the outer barrier reefs that punctuate this vast archipelago, where the diving can be exciting. The unique location and geology of the Maldives also makes it a rich area for filter feeding whale shark and manta rays, with observations of these species an exciting event for those on board live-aboard dive trips.

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

1.2. Research area

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

Figure 1.2a. Flag of the Maldives.

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

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

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

To date at least 209 hard coral species have been described from over 60 genera. 51 species of echinoderms, 5 species of sea grasses and 285 species of alga have also been identified.

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

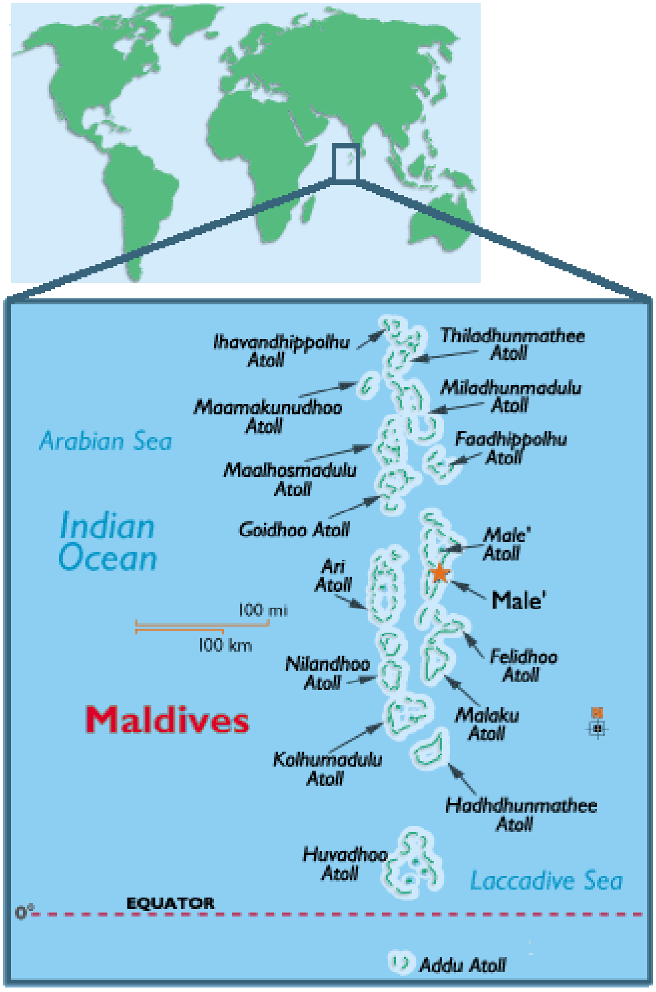

Figure 1.2b. The Maldives. An overview of Biosphere Expeditions' research sites, assembly points, base camp and office locations is at Google Maps.

1.3. Dates

2012: 2 - 8 September

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

Weather

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

Field communications

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

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

Transport & vehicles

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

Medical support and insurance

The expedition leader was a trained first aider and the expedition carried a comprehensive medical kit. The main hospital is in Male' city and there are medical posts on many of the resorts. There is a recompression chamber on Bandos Island Resort near Male' and one on Ari Atoll. Safety and emergency procedures were in place and there were no medical incidents during the expedition.

1.5. Scientist

Dr. Jean-Luc Solandt is a Londoner with a degree in Marine Biology from the University of Liverpool. After graduating, he spent a year diving on the Great Barrier Reef assisting field scientists in studies on fisheries and the ecology of soft corals and damselfish. He returned to the UK and enrolled in a Ph.D. in sea urchin ecology in Jamaica, based both in London and Jamaica. He went on to be an expedition science co-ordinator for projects in Tanzania, the Philippines and Fiji, and is now undertaking campaign and policy work in planning and developing Marine Protected Areas in the UK. He has been the Reef Check co-ordinator for the Maldives since 2005 and has thus far led three expeditions to undertake surveys inside and outside Marine Protected Areas on the islands. Jean-Luc has 800 dives clocked up since he trained to be a marine biologist 20 years ago.

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 all ages, nationalities and backgrounds. They were (with countries of residence):

2 - 8 September 2012

Mariyam Shidha Afzal* (Maldives), Jan Biekehör (Germany), Nicola Bush (UAE), Rebecca Caine (USA), Tanja Hildebrand (Germany), Kevin Howley, (UK), Hideko Kawabata (USA), Sandra Keeping* (UK), Jet Long (USA), Rafil Mohamed* (Maldives), Michael Preston* (USA), Laurence Romeo (UK), John Simpson (UAE), Rozelle Simpson (UAE), Mohamed Ushan* (Maldives). Also present was Rossella Meloni (Italy), expedition leader in training.

*Participants marked with a star took part in the expedition as part of an education and placement programme kindly supported by Soneva Resorts Maldives.

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

1.9. Expedition Budget

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

Income	£
Expedition contributions	18,355
Grants	15,796
Expenditure	
Staff includes local & international salaries, travel and expenses	6,867
Research includes equipment and other research expenses	556
Transport includes taxis and other local transport	28
Base includes board, lodging and other live-aboard services	11,956
Administration includes some admin and misc costs	35
Team recruitment Maldives as estimated % of PR costs for Biosphere Expeditions	4,240
Income – Expenditure	**8,309**
Total percentage spent directly on project	**76%**

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, then of the Maldives Marine Research Centre, for his unerring help and advice in setting up the project, to Agnes van Linden of the MV Carpe Diem for running like clockwork an excellent live-aboard research base and to JJ for local insights and advice in times of trouble. Biosphere Expeditions would also like to thank Soneva Resorts Maldives, Swarovski Optik, Snowgum and the Friends of Biosphere Expeditions for their sponsorship and/or in-kind support. We thank the crew of the MV Carpe Diem for being such excellent hosts. Thank you also to Richard Rees of the Maldives Whale Shark Research Programme. Many thanks to Yoosuf Rilwan (Assistant Research Officer, Marine Research Centre) and other members of the Marine Research Centre (MRC), Environment Protection Agency (EPA) and local consultancies who took part in the Reef Check training session at MRC in Male'. They included Mariyam Shidha Afzal (Research Officer, MRC), Mohammed Ushan (MRC & Darwin Reef Fish Project), Shafiya Naeem (Senior Research Officer, MRC), Abdul Aleem (Water Solutions), Hamdullah Shakeeb (Water Solutions), Ahmed Shan (Environment Protection Agency), Rifath Naeem (EPA), Aishath Laesha Mohamed (MRC), Hussain Ibrahim (EPA). We also thank M Shiham Adam (Director General, MRC) for facilitating the training.

1.11. Further information & enquiries

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

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

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 they emerge to form the atolls (see Figure 1.2a). The Maldives covers approximately 90,000 km^2, yet the land area covers less than 1% of this total (Spalding et al. 2001). Together, the Lakshadweeps and the Maldives constitute the largest series of atolls and faroes in the world (Riska and Sluka 2000).

The highest point of the islands is approximately 2.4 m as all the islands are naturally made from fine coral sand. About 10% (200) of the islands are inhabited, with by far the largest population living in Male' - the capital. Of the 316,000 population of the nation, 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 'faros' (the latter similar to giris, but ring-shaped reefs with a central lagoon) (Figure 2.1a). The outer reefs that fringe the atolls have the greatest expanse of coral growth, growing upwards and outwards towards the incoming current, thereby acting as breakwaters of swell and tide. Dead coral material from these atolls and inner patch reef drifts to the leeward sides of the outer reefs. This process of constant erosion of the reef material and deposition of sediments is responsible for constructing the 1,190 islands of the archipelago. This natural dynamic process has been altered by the numerous human habitations and stabilised to a degree by the colonisation of many of the islands by natural vegetation.

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

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

In terms of biodiversity, the Maldives atolls form part of the 'Chagos Stricture' and are an important stepping-stone between the reefs of the eastern Indian Ocean and those of East Africa (Spalding et al. 2001). The fauna therefore comprises elements of both eastern and western assemblages. Diversity is high with 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 with small amounts of bigeye also taken (Marine Stewardship Council). Up until 2010, Maldives fishermen solely used pole, line and hand line fishing techniques to take skipjack and yellowfin tuna. As such, the Maldivian tuna fishery has been marketed by many supermarkets in the UK as sustainable, because the volume of catch taken by pole and line is relatively small compared to many longline fisheries around the Indian Ocean and there is minimal by-catch of other fish, cetaceans and turtles. The Maldives has also recently banned shark fishing (2010), which can be regarded as a major conservation measure because of the catastrophic declines in the global populations of reef and pelagic predatory shark species (Graham et al. 2010). Although this is a commendable measure undertaken by the Maldives government, it is very difficult to enforce. The ban on the export of shark products introduced in 2011 has undoubtedly made it more difficult for Maldives-based fishers to trade in shark parts and anecdotal evidence from Maldives dive operators suggests that in some areas sharks appear to be increasing in number.

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

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

There has been a growing demand for reef fish species in recent decades, partly because of the expansion of the numbers of tourist resorts across the nation (Wood et al. 2011) and mostly because of the growth in the export market to the Far East, which is serviced by grouper cages that have been set up within a number of atolls. Wholesalers periodically visit the grouper cages that are stocked by local fishers to buy the fish to export live and fresh-chilled to foreign markets. A report by the Maldives Marine Research Centre (MRC) in 2005 highlighted a declining catch since 1997, three years after the commercial fishery started in 1994 (Sattar and Adams 2005). A further report by MRC in 2008 showed that demand for reef fish had tripled in the last 15 years and that a management strategy for grouper was needed to ensure sustainable catches into the future. MRC is now working with the Marine Conservation Society to develop a management plan for grouper.

2.1.2. Coral bleaching

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

1997 and 1998 surveys

During April and May 1998 a temperature of over 32^0 C was recorded in the Maldives for a period of more than four weeks. This led to mass bleaching down to at least 30 m (Edwards et al. 2001). Shallow reef communities suffered almost complete mortality with live coral cover of central reefs decreasing from about 42% to 2%, a 20-fold reduction from pre-bleaching cover. Since 2005 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 by local resort marine biologists. This study showed that the principle families to bleach were the shallow-water Acroporidae and Pocilliporidae. More resilient corals included the Agariciidae and Poritidae families that form more massive coral species. Other workers (e.g. Clark et al. 1999) found from a variety of sites visited that the 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. 80% of corals were dead and covered by fine filamentous algae.

2.1.3. Marine Protected Areas (MPAs)

Between 1995 and 1999 the Maldives set up 25 MPAs around well-known dive sites, whilst three larger reserves were set up in 2010 (www.epa.gov.mv). The 25 MPAs were established to protect dive sites and should be managed as no-take zones that prevent the capture of live bait for the tuna fishery and also for fisheries for all reef-associated species (such as grouper). One of the authors (Jean-Luc Solandt) surveyed nine of the 25 small Maldives MPA dive sites in 2008 with little statistical evidence that the biomass and number of exploited 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 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.

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

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, sea surface temperature increases leading to coral bleaching.
- Increased atmospheric CO2 concentration that results in 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.

[2] http://www.math.ubc.ca/~hauert/publications/Reef Check98/index.html

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 past decade has seen the Maldives embark on a process to further establish Marine Protected Areas, and to lobby for decreases in global CO_2 emissions.

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

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

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.

Rapid environmental degradation that is not being adequately reported - The status of Maldives reefs has been heavily modified over the past 30 years since the 1998 bleaching event through 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.

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

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

In the past, the Maldives has lacked a champion for the protection and recovery of marine resources. However, the Maldives government has recently been making very well intended statements to reverse this trend. In June 2012, Dr Mariyam Shakeela, 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.

2.1.6. Maldives reef surveys

In order to help the Maldives in facing up to some of these issues, The Marine Conservation Society and Biosphere Expeditions 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).
- 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 20 sites in two years, compiled and quality assessed the data, and sent it to Maldivian and international coral reef monitoring programmes.
- Trained five individuals employed in government marine resource assessment surveys and from the tourist and diving industry whilst on liveaboard expeditions. We've 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 2012 surveys and training using Reef Check

The 2012 surveys were carried out specifically at sites that have been monitored a year before or just after the catastrophic 1998 bleaching event to:

- Record and compare the condition of the reefs now to 15 years before.
- Record other variables such as fish and invertebrate populations.
- Carry out effort-based transects of the whale shark MPA Maamigili reef.
- Undertake a week of Reef Check training[3] for Marine Research Centre, Environment Protection Agency, and local consultants in Male.
- Undertake Reef Check teacher training for select MRC staff to allow them to train others in the Reef Check methodology.

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[3] http://Reef Check.org/ecoaction/Reef-Check-EcoDiver-Trainer.php

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).

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 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 a 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 thee ones carried out by Biosphere Expeditions for the purpose of this study, are necessary to realise fully the potential to gather data from a greater range of sites.

2.1.6. Planning & methods

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

All training was carried out on board the MV Carpe Diem. In-water training was undertaken at Baros house reef, Rasdhoo Madivaru and at the Northern (outer slope) of Laguna reef in South 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 additions divers on all surveys record the presence / absence of sharks, manta rays, cetaceans, turtles and other unusual megafauna.

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

2.2. Results

2.2.1. Pre and post 1998 bleaching results

The first international Reef Check[4] 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[5].

In order to identify reefs surveyed before and during the 1998 bleaching event, we visited three reefs (four sites) in Ari atoll that were first surveyed in 1997 (before the bleaching event), or 1998 (just after the bleaching event) to compare the live coral cover, and to record of the recovery of these sites (Fig 2.2.1a-d). Further sites will be visited in 2013 to record the changes to coral cover and any recovery.

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

Coral Point Count[6] (CPC) software was used subsequently to analyse photoquadrats for dominance of different hard coral life forms. These were either classed as being in Acropora or from non-Acropora genera. The different life forms include digitate; encrusting; branching, table, foliose, encrusting and mushroom corals. Photos were taken at a height of approximately 2 m off the substrate, covering an area of between 1 and 4 m^2. Photos were taken at approximately 5 m intervals along each transect. 15 random points were generated on each photo, and all coral life forms were distinguished, Excel files created that generated a mean cover for each life form category. We also carried out 'CoralWatch'[7] at a number of sites to provide data for this Australia-based project. This project allows volunteers to record the colour of individual coral colonies. The colour of corals provides a very coarse health index of corals and the intensity of zooxanthellae within the coral tissue. Data are not presented here.

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[4] http://www.Reef Check.org/
[5] http://www.math.ubc.ca/~hauert/publications/Reef Check98/sites.html
[6] http://www.nova.edu/ocean/cpce/
[7] http://www.coralwatch.org/web/guest/home1

Finally we carried out an effort-based transect along the Maamigili MPA along the southern shore of Ari atoll to count whale sharks. The survey was carried out for 5 hours between 11:00 and 16:00 on 8 September 2013. No whale sharks were observed during the entire transect.

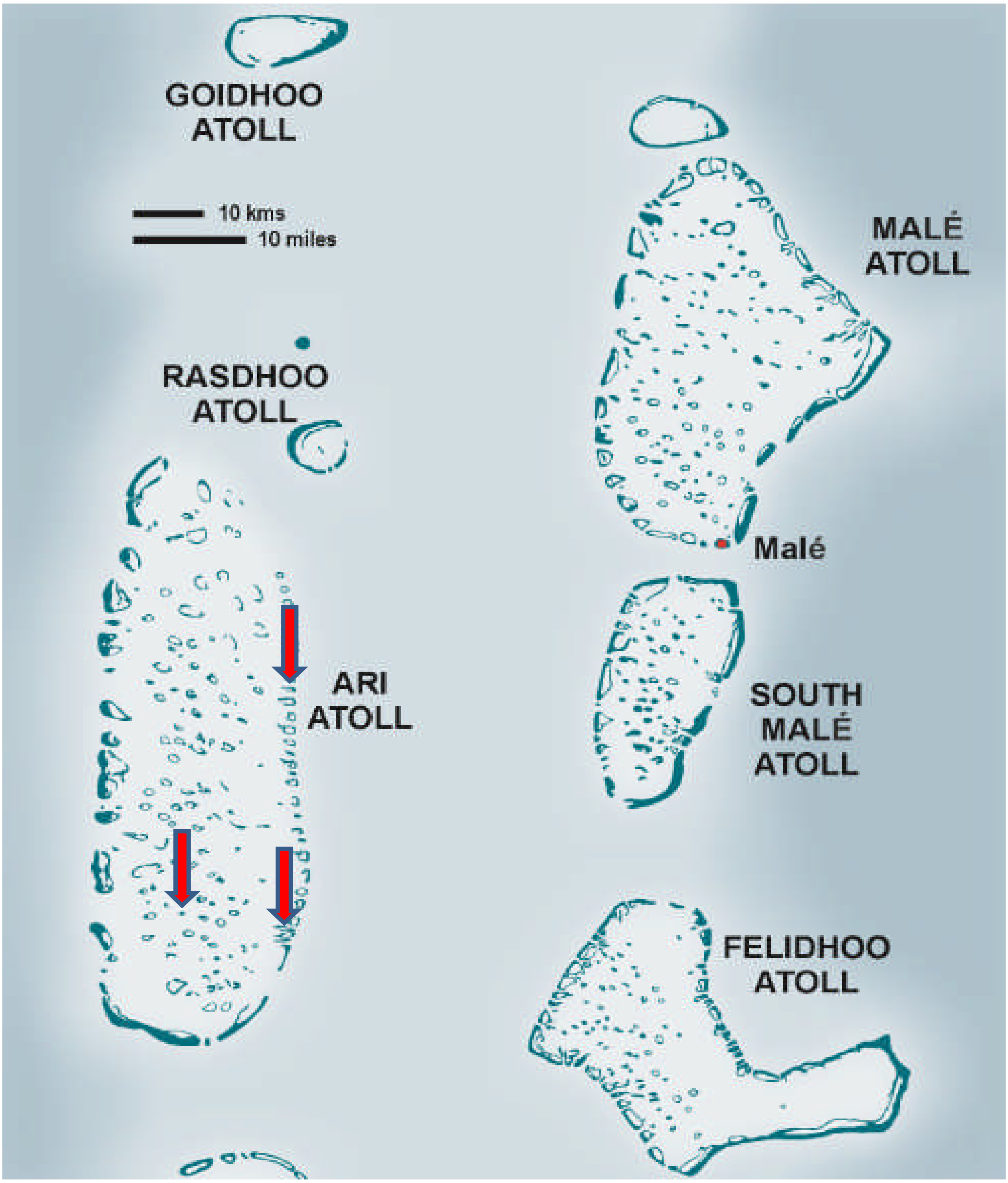

Figure 2.2.1a. Location of the three Ari atoll sites resurveyed using the Reef Check methodology in 2012. The northern most site is Ellaidhoo, the southwestern site is Angaga (where two surveys were carried out) and the southeastern site Vilamendhoo.

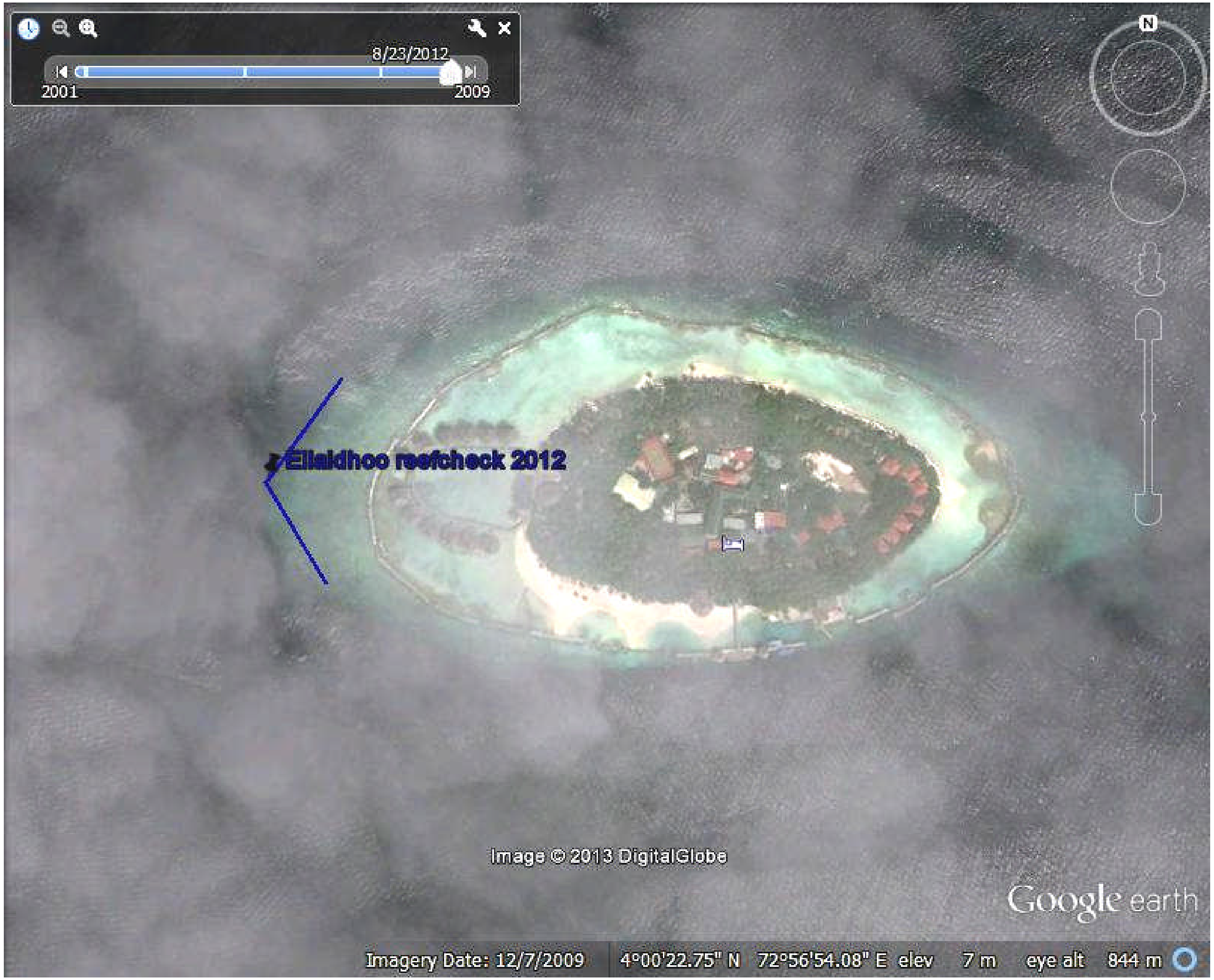

Figure 2.2.1b. Location of the 2012 survey at Ellaidhoo. The lines indicate the direction and distance of the 100m surveys.

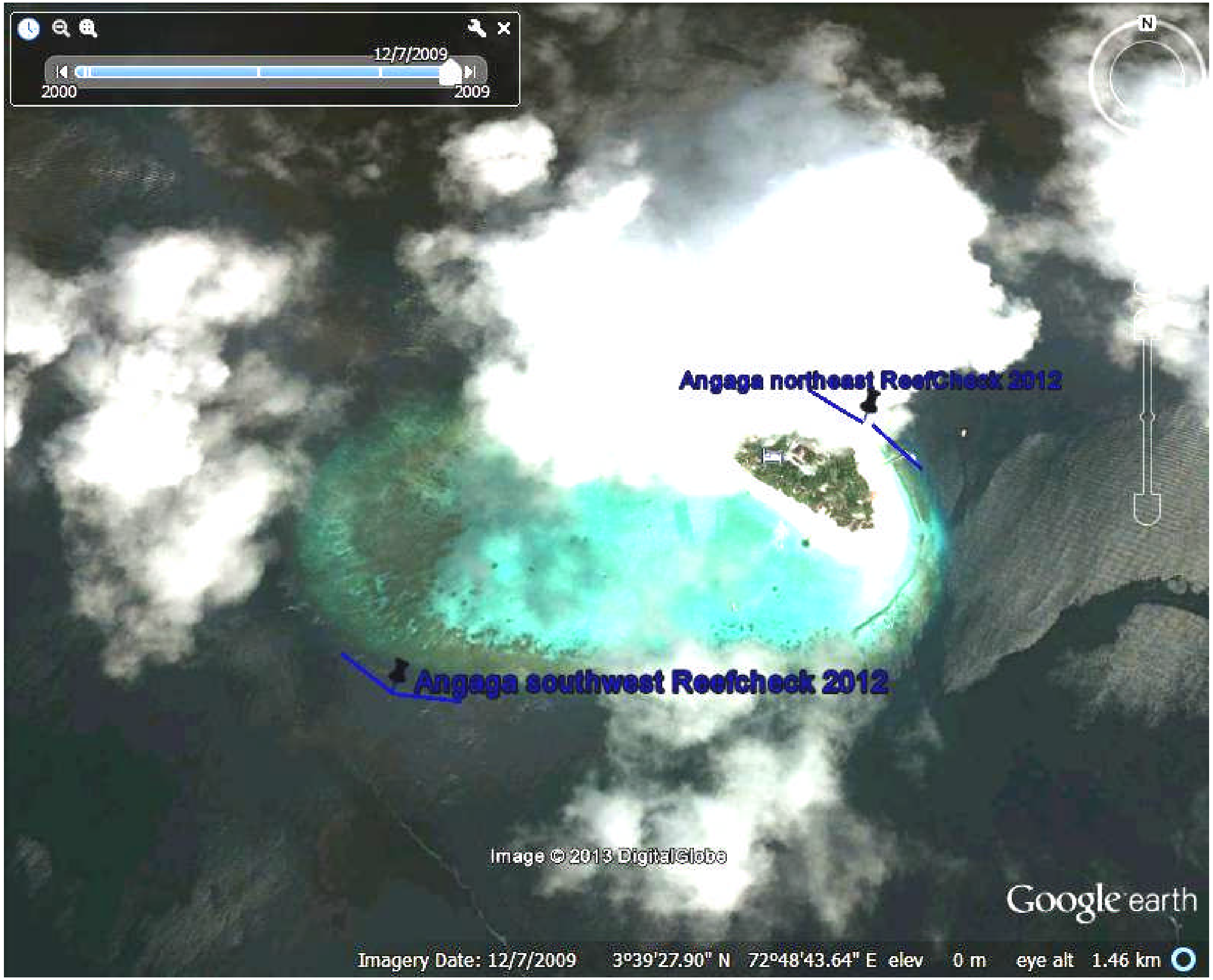

Figure 2.2.1c. Location of the northeast and southwest 2012 surveys at Angaga house reef. The lines indicate the direction and distance covered by the 100 m surveys.

Figure 2.2.1d. The location of the 2012 survey at Vilamendhoo house reef. The lines indicate the distance and direction of the 100 m surveys.

2.2.2. Bleaching / coral cover

Ellaidhoo house reef - Ellaidhoo is a small island reef on the eastern side of Ari atoll. It has a westward and eastward facing reef. The island hosts a resort and there are water huts built out on the west side of the coral shelf. The reef is exposed to relatively strong east and westward currents during the tidal cycle, with deep water lying just to the east of the island. The reef on the west side (where the survey was carried out) is predominantly comprised of bedrock in shallow depths, shelving to deeper depths of over 450 at 10 m depth. The reef in shallow waters (< 10 m) forms boulder-like structures around which fish shelter from the current.

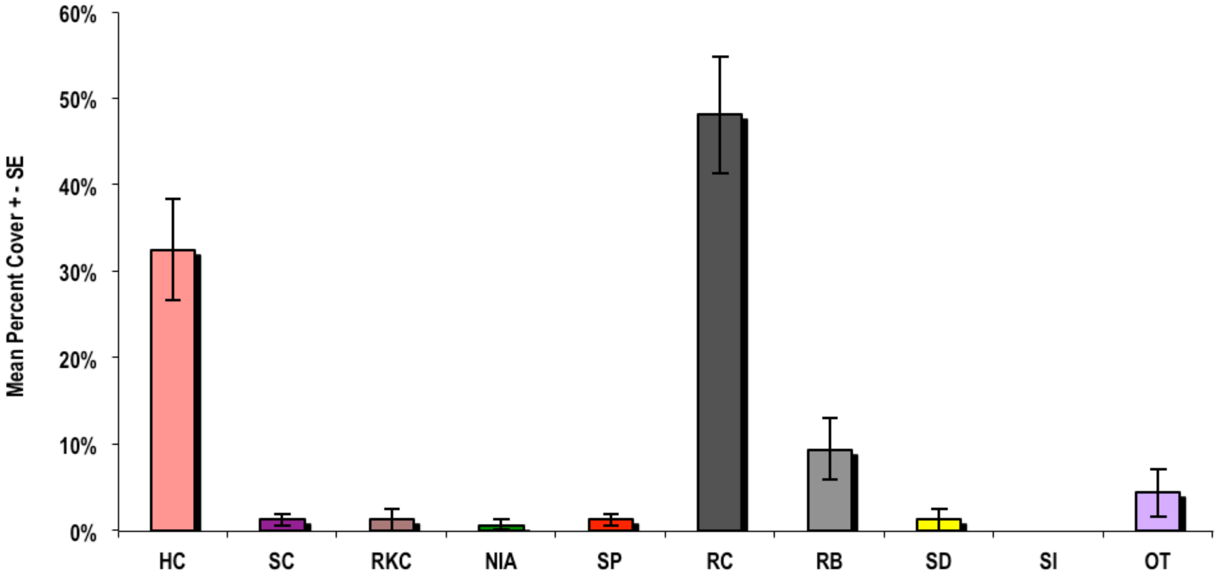

Figure 2.2.2a. Ellaidhoo shallow (3 m). (HC – Hard Coral; SC – Soft Coral, RKC – Recently Killed Coral, NIA – Nutrient Indicator Algae, SP – Sponge, RC – Rock, RB – Rubble, SD – Sand, SI – Silt, OT – Other).

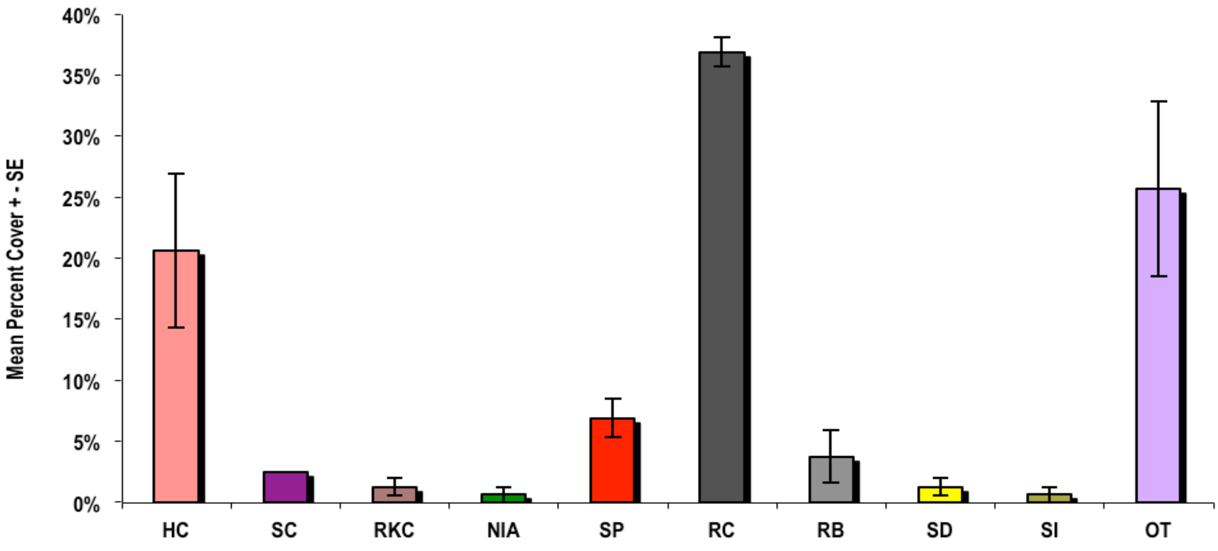

Figure 2.2.2b. Ellaidhoo medium (9m).

The surveys at Ellaidhoo reef in 2012 showed moderate coral cover. Much of the reef was dominated by rock that was clear of algae (NIA was low). As this site is in an exposed location, it is unsurprising that the coral cover was relatively low. Results for coral cover in 1997 prior to the bleaching were of 50.63% live coral at 3 m, and 34.38% cover at 10 m.

Angaga house reef - Angaga reef is an oval-shaped reef to the south central area of Ari atoll. The reef is a classic mid-atoll house reef, with slopes of approximately 30-450 down to approximately 25-30 m, where the sand seabed of the atoll floor meets the coral reef. The central area of the reef hosts a lagoon (Fig 2.2.1c). The site was extensively surveyed in 1998 (Hauert et a., 1998) and revealed extensive bleaching mortality (over 80%).

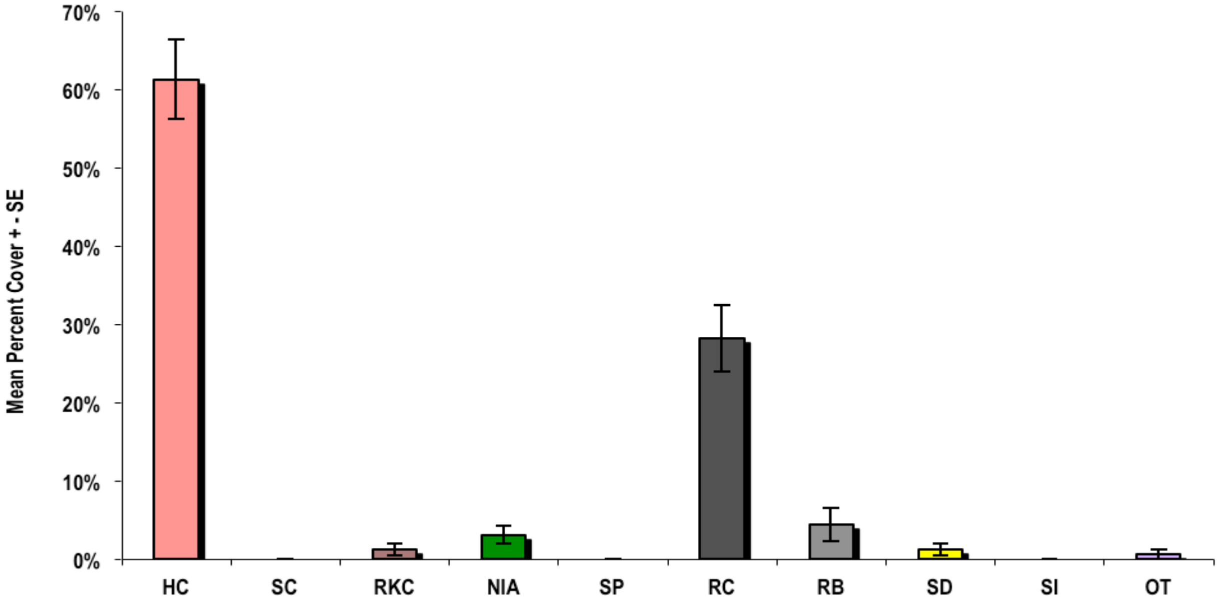

Figure 2.2.2c. Angaga northeast shallow (3 m).

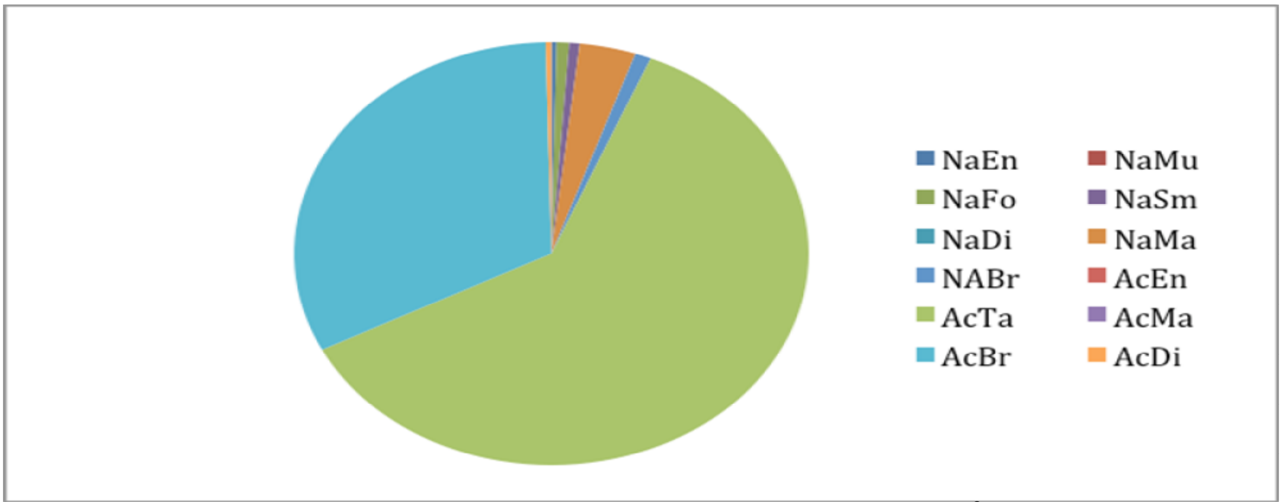

Figure 2.2.2d. CPC data (data on coral life forms from photo transects analysed using CPC[8]). Coral life forms at Angaga house reef at 3 m depth (data from CPC analysed photoquadrats, n=39). The two most dominant life forms are table Acropora (AcTa) and branching Acropora (AcBr).

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

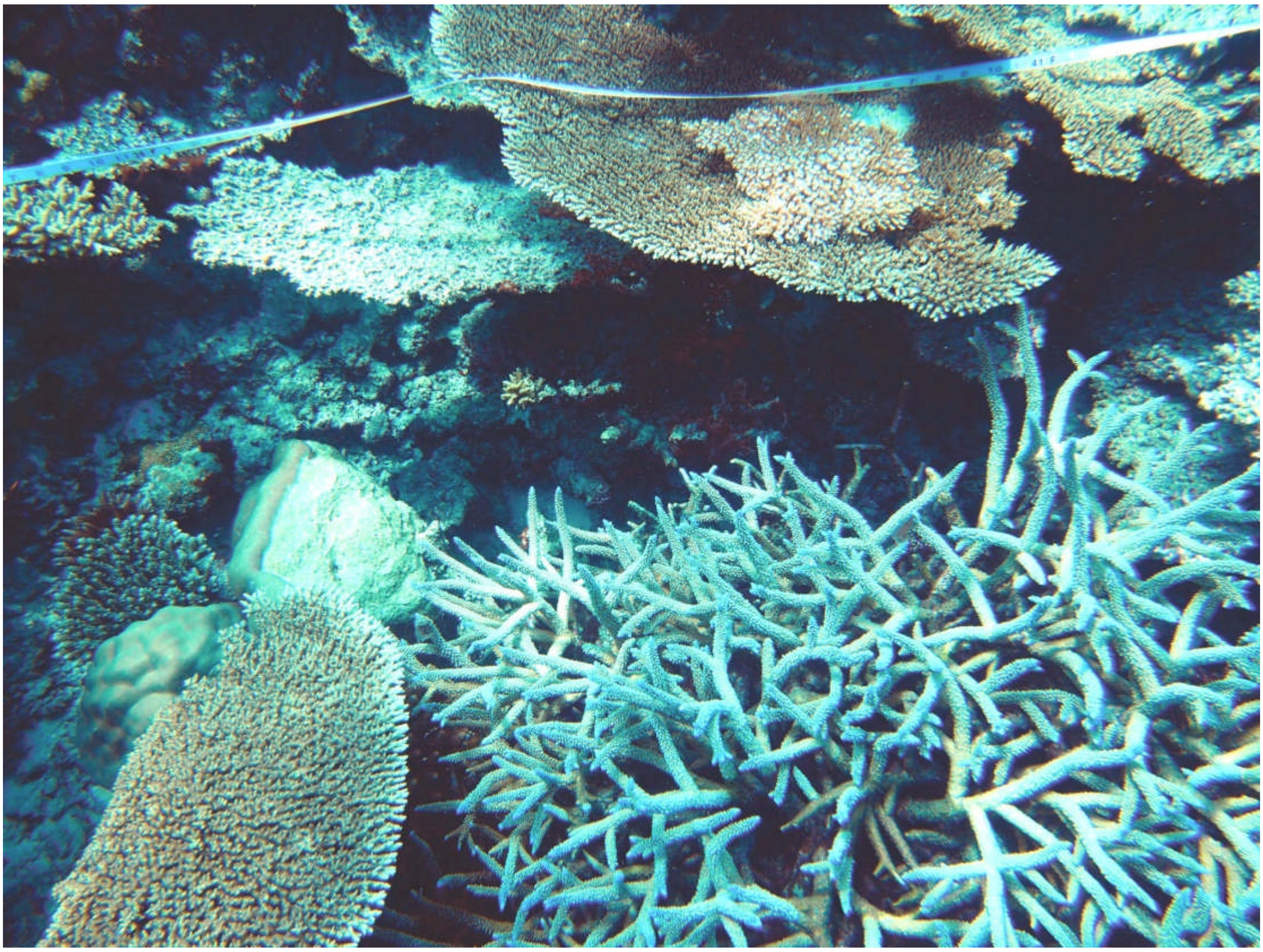

Figure 2.2.2e. Typical CPC image of the 3 m transect at Angaga northeast house reef.

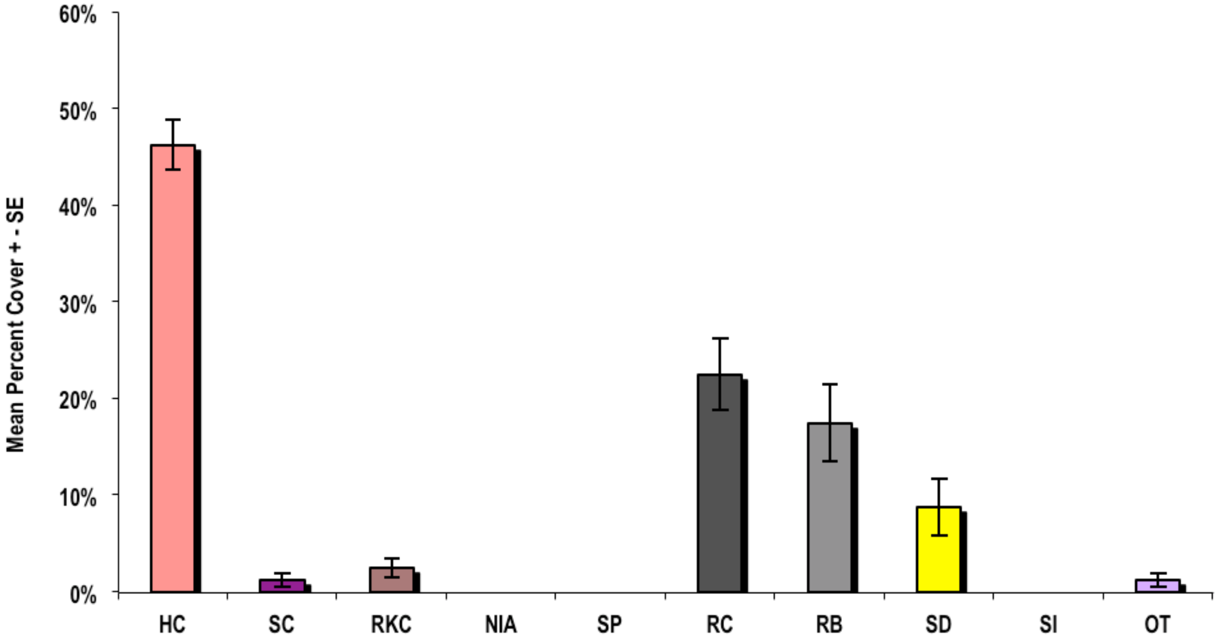

Figure 2.2.2f. Angaga northeast deep (12m).The coral cover at Angaga reef was high, with healthy large table Acropora colonies in shallow waters.

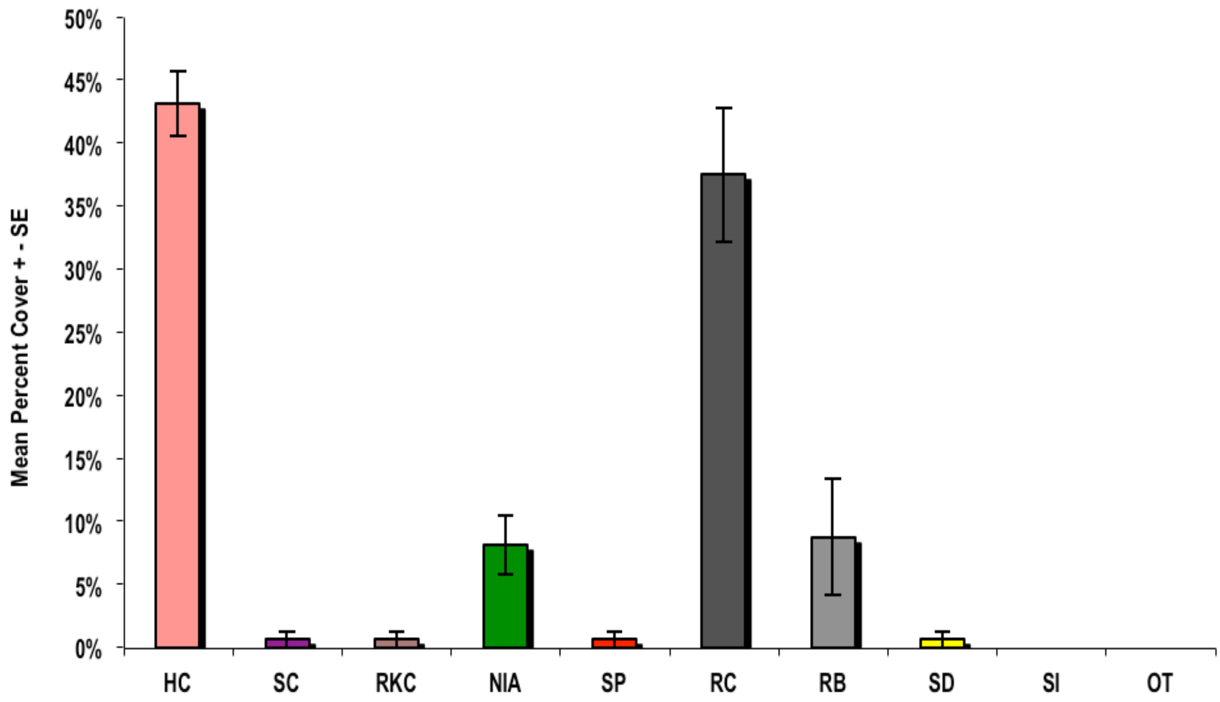

Figure 2.2.2g. Angaga southwest shallow (4 m).

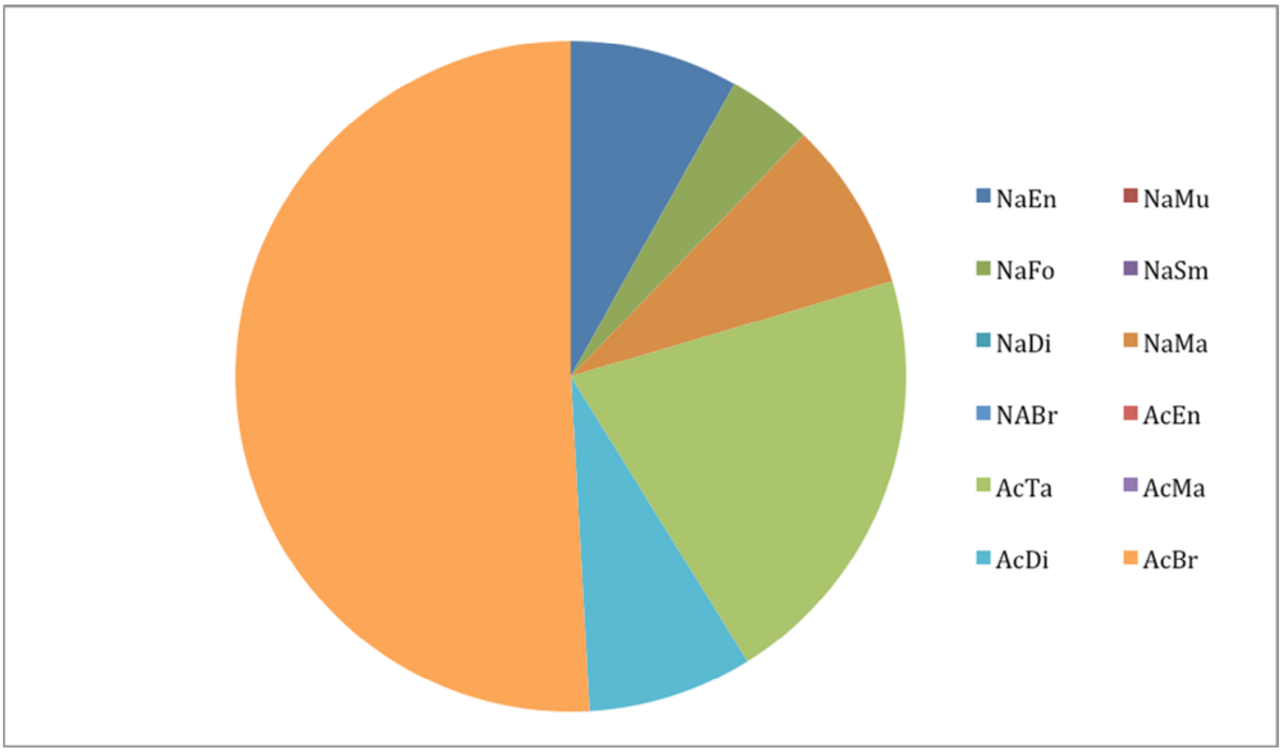

Figure 2.2.2h. CPC data (coral life forms) at Angaga (southwest) at 4 m depth. Life forms are dominated by branching Acropora (AcBr). Table Acropora were also relatively common, followed by digitate Acropora. There were also a relatively high proportion of massive and encrusting coral life forms.

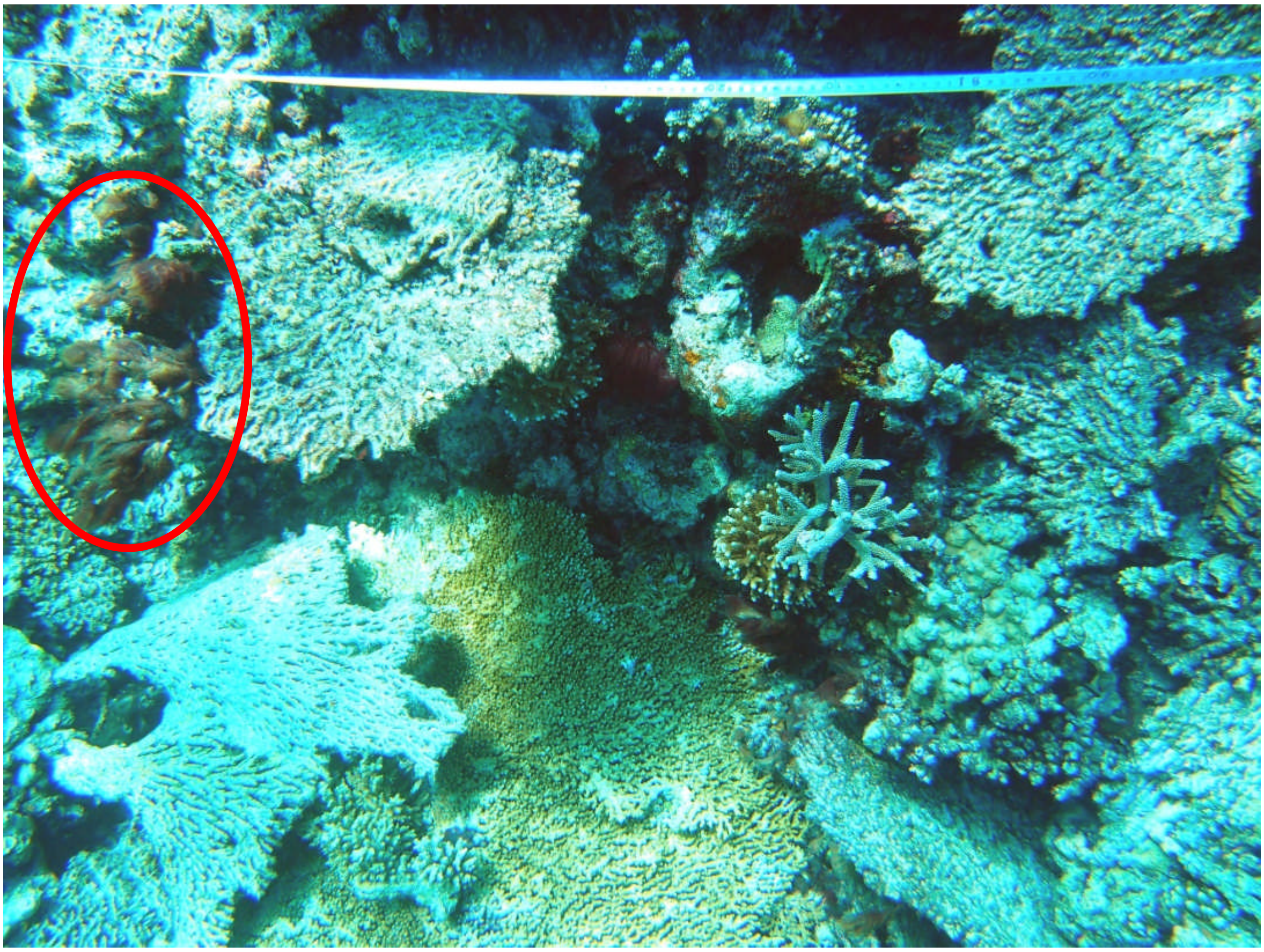

Figure 2.2.2i. Coral life forms at 4 m, Angaga southwest, showing both live and dead table Acropora and live branching Acropora near to the centre of the image. There is some nutrient indicator algae (red circle), that was fairly common on this transect.

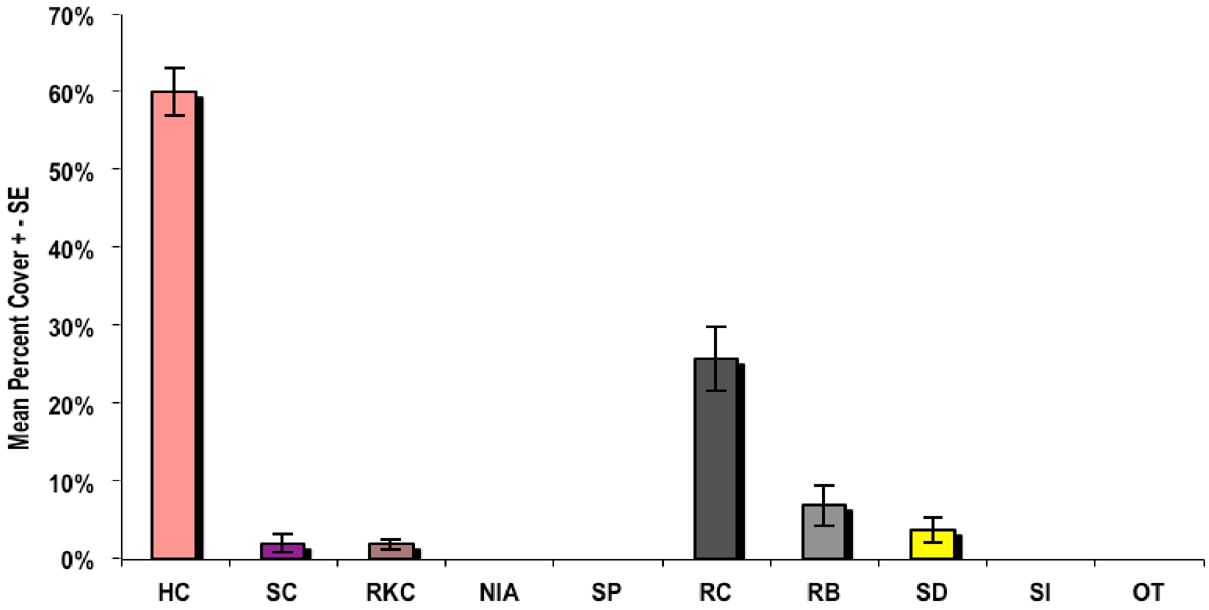

Figure 2.2.2j. Angaga southwest deep (12 m).

The coral growth at Angaga southwest was perhaps more healthy than the growth at the northeast site of the reef. At 12 m, the coral cover was 60% at the southwest part of the site. At 12 m on the northeast survey, the coral cover was 46%. According to GCRMN protocols, these represent good coral cover percentages. Approximately 5 m of the southwest survey transect was covered in large tracts of filamentous algae. These algae smothered the living coral and are cause for concern. Approximately 2% of the corals were recently killed corals and there was some evidence of *Drupella* predation in amongst branching coral colonies.

Vilamendhoo house reef - Vilamendhoo was initially surveyed just after the 1998 bleaching event using Reef Check. Coral cover was only 5.63% at 3 m, and 6.88% at 10 m. This percentage cover has now increased to 48% (3 m) and 26% (1 0m), revealing considerable recovery of the coral population.

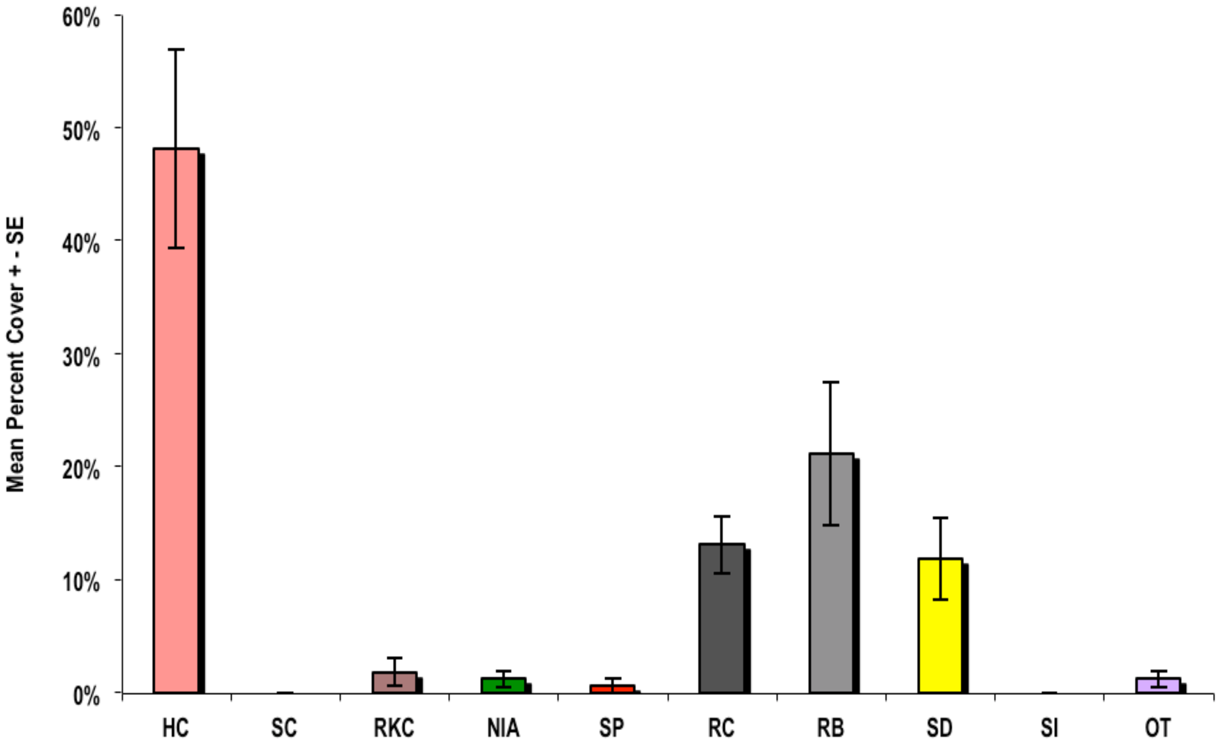

Figure 2.2.2k. Vilamendhoo house reef (3 m). Benthic cover.

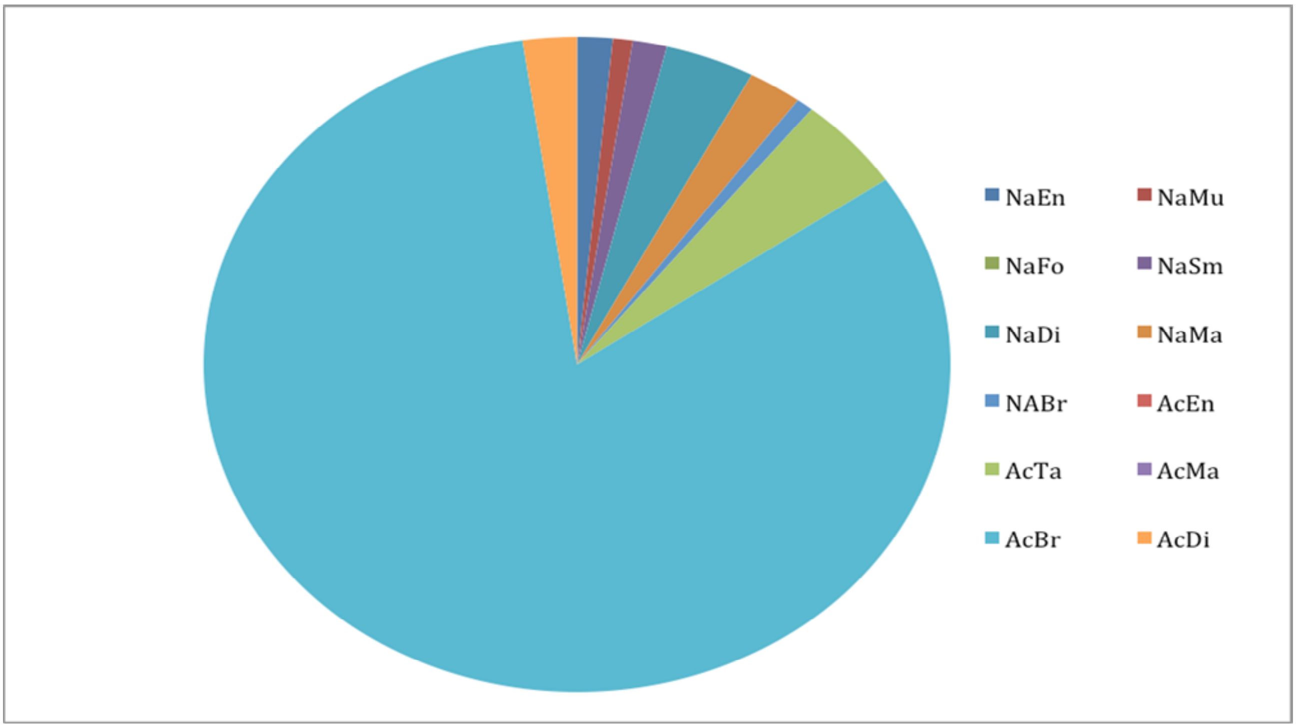

Figure 2.2.2l. CPC data, coral life forms at 3 m depth, southwest Vilamendhoo. The dominant life form is branching Acropora coral (82% of all coral life forms).

Figure 2.2.2m. Vilamendhoo reef at 3 m showing healthy live branching and table Acropora.

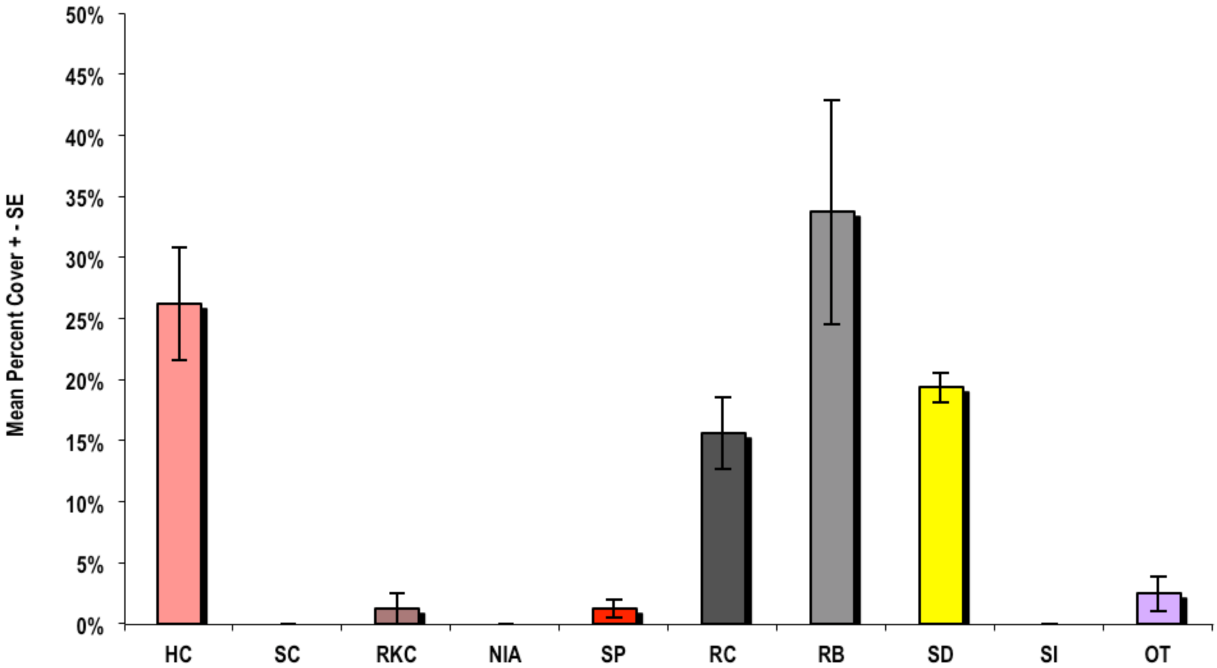

Figure 2.2.2n. Vilamendhoo house reef (10 m). Benthic cover.

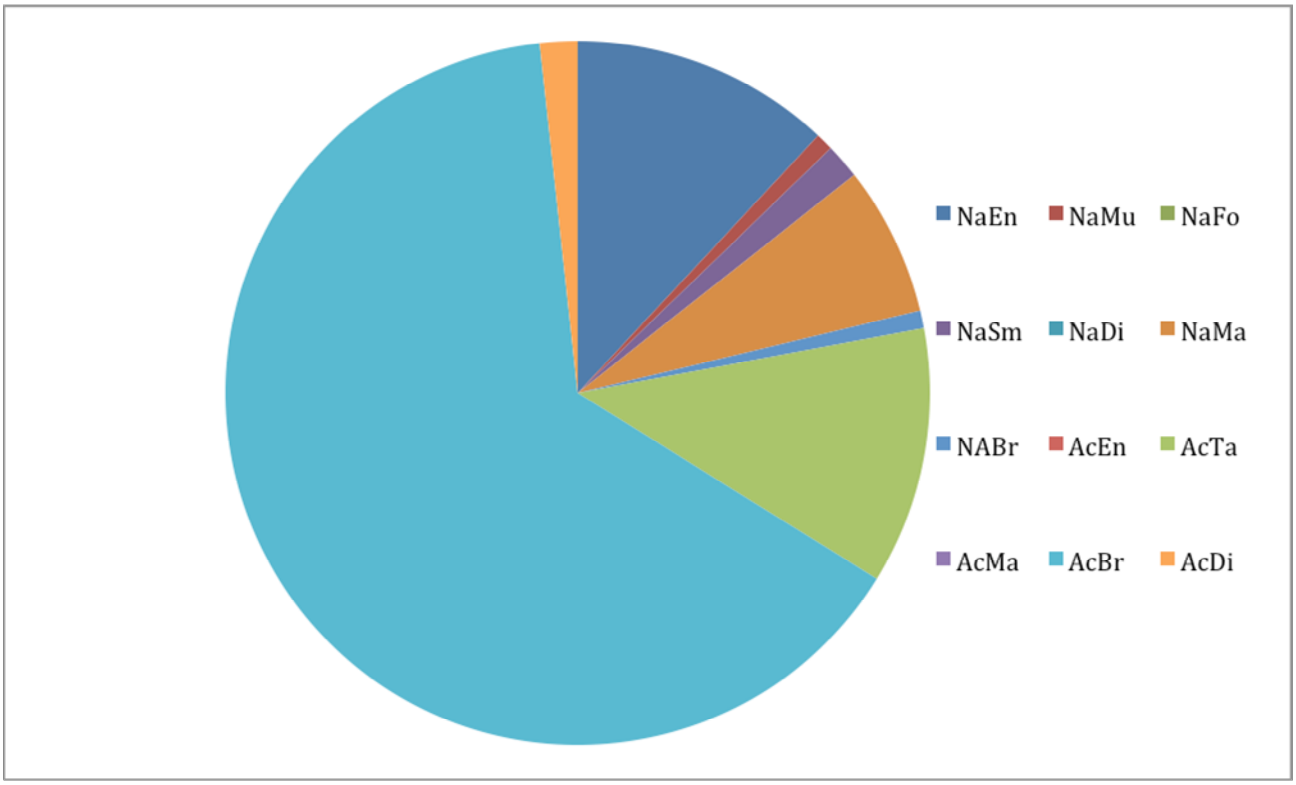

Figure 2.2.2o. CPC data, Coral life forms at 10 m Vilamendhoo

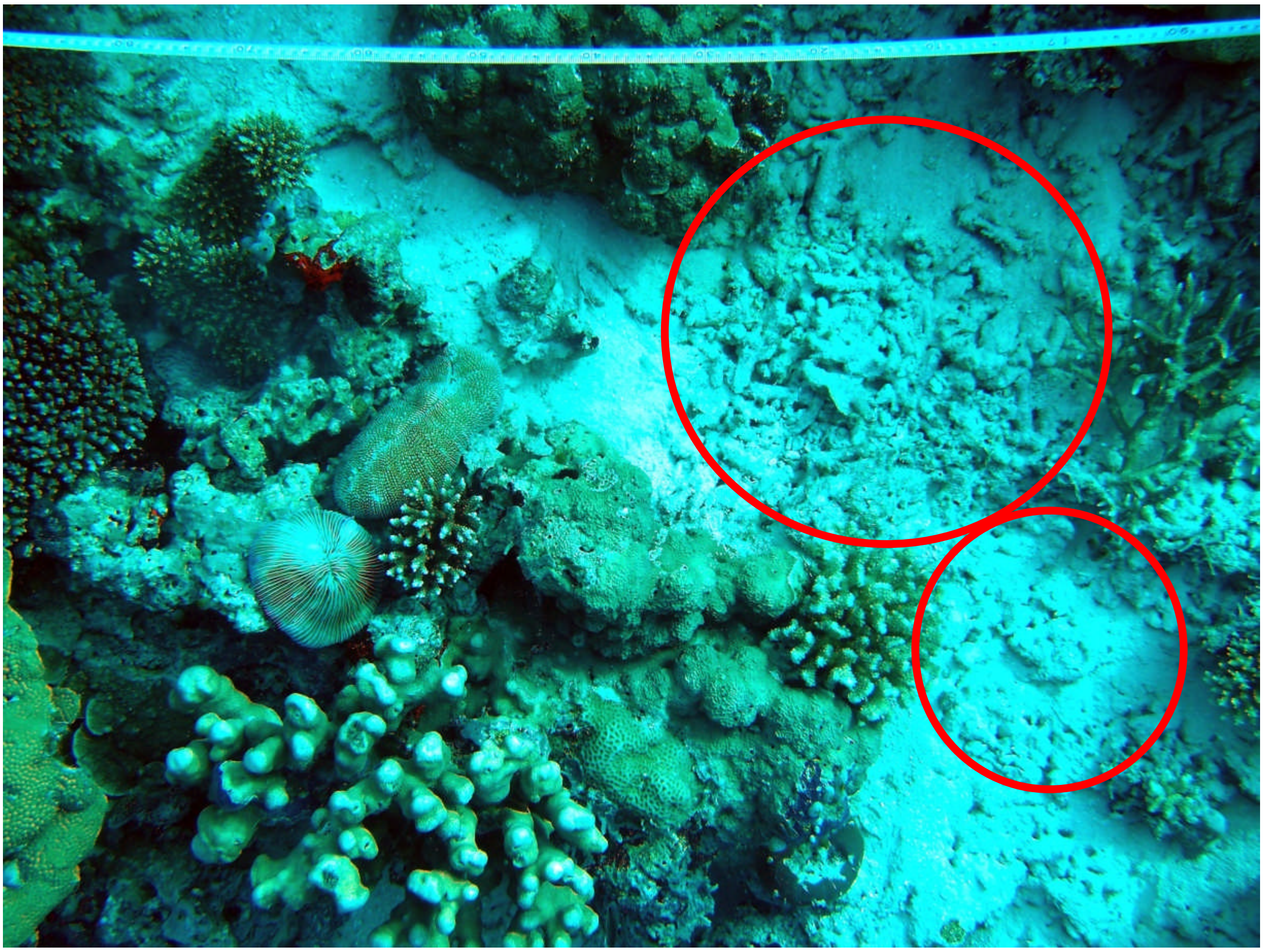

Figure 2.2.2p. Typical habitat at 10 m, Vilamendhoo. Note the submassive, encrusting, digitate and mushroom corals (no circles) in addition to rubble and sandy habitat (red circles).

The major difference in habitat between these depths was the dominance of coral rubble at the higher depth. At 10 m, the coral rubble covered 34% of the area of the transect. Coral rubble does not provide a basis on which healthy corals can grow. Coral rubble at 3 m was 21%, a lower percentage cover. A very low percentage of the population was bleached (< 1%). Five colonies were observed with *Drupella* snails that were feeding on the corals.

Table 2.2.2a. Summary of observed coral cover (1997,1998 immediately after bleaching, 2012)

Site	Depth (m)	1997 ('98 for *Vilamendhoo)	2012	% bleaching
Ellaidhoo housereef	3	50.63	33	NA
	8	34.38	21	NA
Angaga Northeast	3	49.38	61	NA
	12	26.88	46	NA
Angaga Southwest	3	30.63 / 58.75	43	NA
	12	21.25 / 59.38	60	NA
Vilamendhoo*	3	5.63	48 / 61	85
	10	6.88	26	90

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

2.2.3. Fish / grouper populations

Fish populations

Fish populations did not vary considerably between sites, with similar trends at all sites and depths. The dominant family recorded were the butterflyfish, with parrotfish and snapper family numbers recorded at considerably lower densities. No humphead wrasses were recorded from these sites and moray eels were rare.

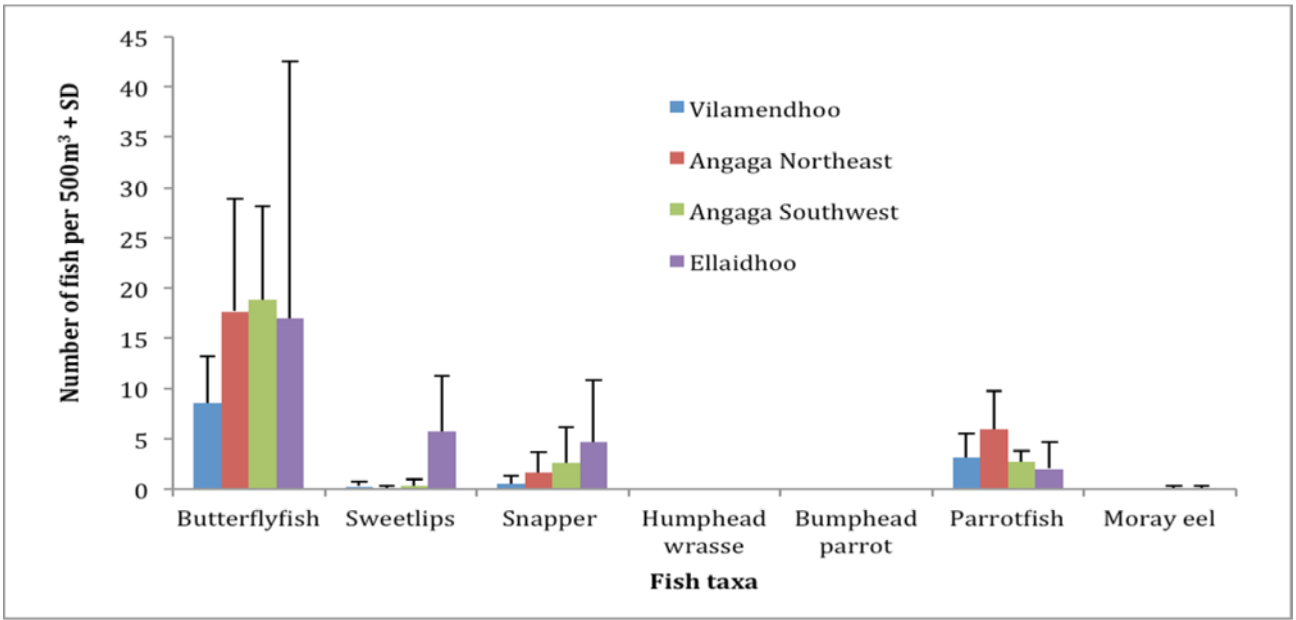

Figure 2.2.3a. Fish populations at the three reefs (four sites) surveyed.

Grouper populations and size

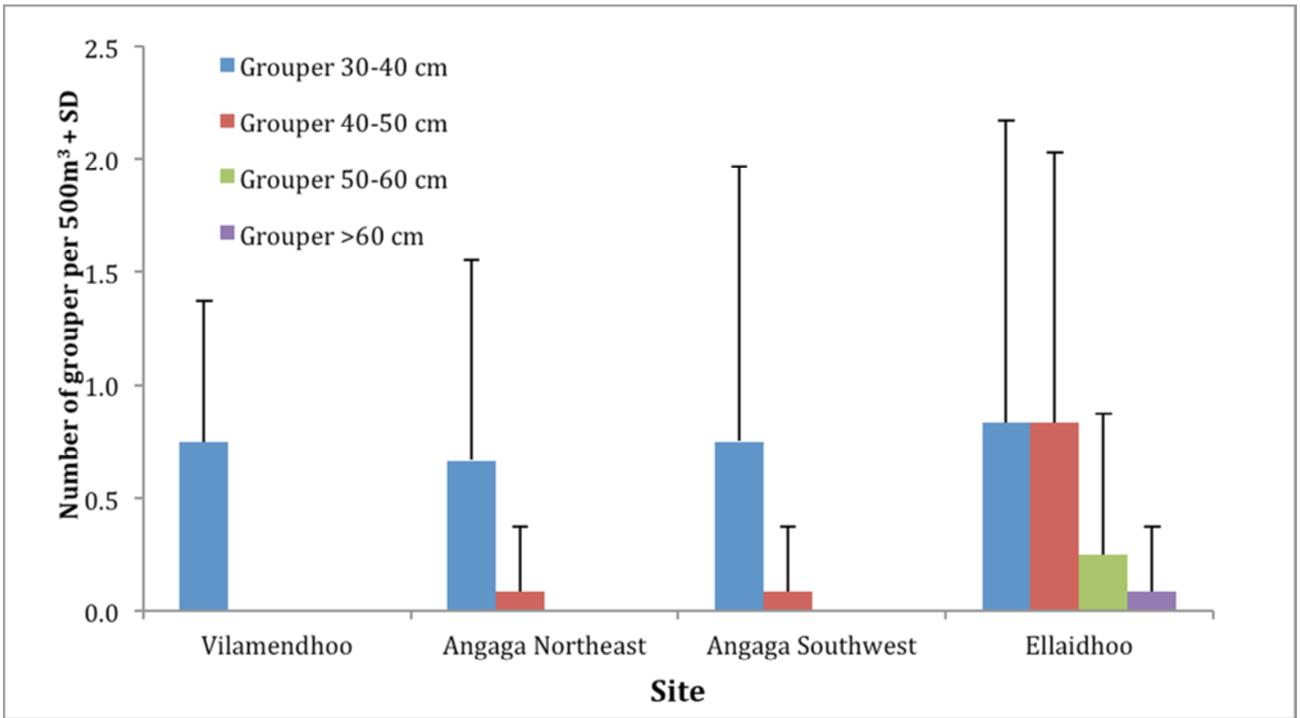

Figure 2.2.3b. Grouper populations at three different reefs (four sites) in 2013.

The fish population data suggest that the most diverse, abundant and greatest biomass of species and families is at Ellaidhoo (Fig. 2.3.1a). Ellaidhoo has the largest groupers observed, with one individual recorded at over 60 cm (Fig. 2.3.2a).

2.2.4. Invertebrates

Reef Check surveys a variety of invertebrate species for their importance as indicators of overfishing (e.g. lobster, giant clam, sea cucumber), overharvesting (e.g. tritons trumpet, collector urchin, pencil urchin, banded coral shrimp), key coral predators (e.g. Crown of Thorns) and knock-on effects of overfishing (e.g. Diadema urchin population explosions). The numbers of all key indicator species was low, with numbers of giant clams being at an average of less than one individual per 100 m^2. No lobsters were recorded at the three reefs (four sites) surveyed. This is a clear indicator of overfishing. Under natural conditions these species would aggregate on ledges and overhangs.

2.2.5. Impacts, disease and bleaching

The level of direct anthropogenic impacts that damage the coral environment is low (Fig. 2.2.2m). It is very difficult to discern coral damage from anchors, boats, divers and fishers, both from each other and from storm damage. The most likely cause of overturned reefs in the Maldives is from storm damage, as this is only observed for entire single colonies of table corals. There is seldom any surrounding tissue / colony damage when a colony is observed overturned. This suggests that the larger colonies are probably occasionally overturned by wave action. One impact that is commonly observed is localised predation by *Drupella* sp. on coral colonies, particularly branching Acropora and Pocillopora. However, the densities of these populations are not a problem at an ecosystem scale.

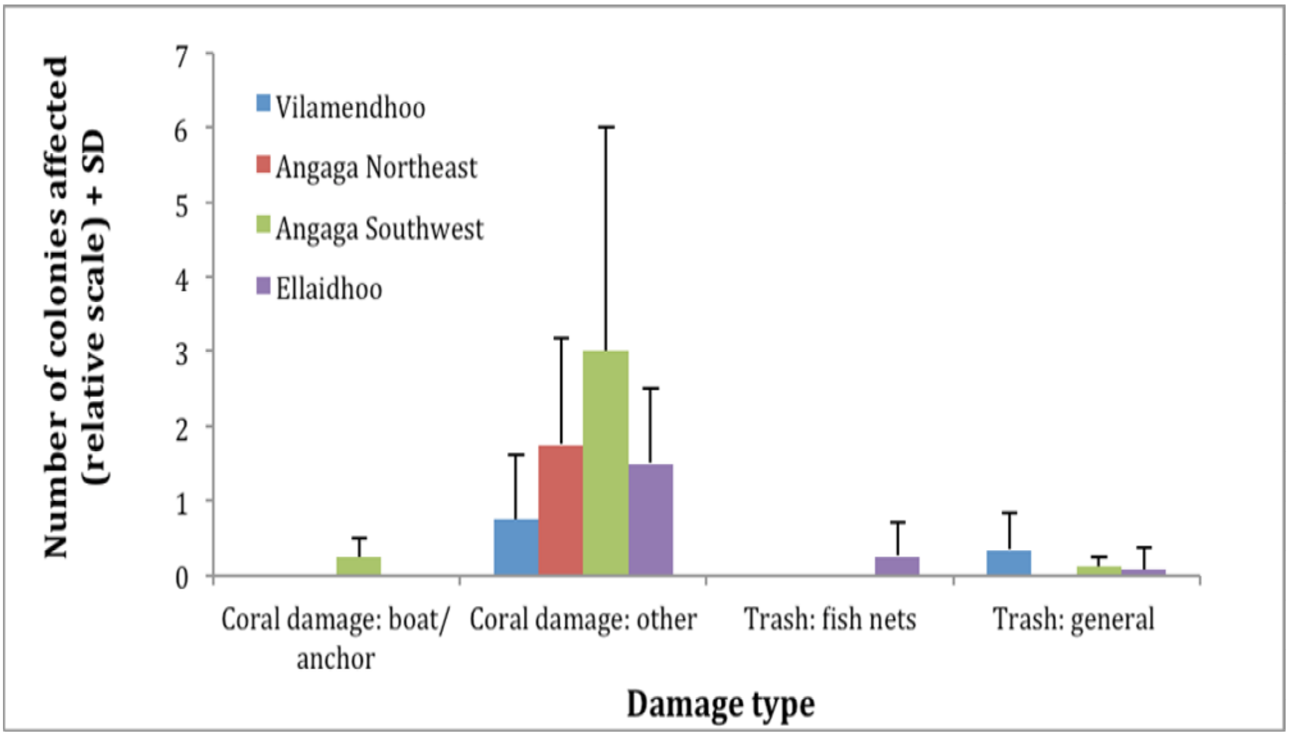

Figure 2.2.5a. Impacts from different sources (according to the Reef Check criteria). There is no dynamite fishing in the Maldives and direct impacts from boats and divers is hard to discern There is very little broken coral on the reefs. The ‘coral damage: other’ category is dominated by *Drupella* predation of live colonies. (1=low damage (1 damaged colony); 2 = medium damage (2-4 damaged colonies); 3 = high damage (5+ damaged colonies).

The 2012 Maldives Reef Check / Biosphere Expedition surveys concentrated on the recovery of coral reefs from the 1998 bleaching event. Reef Check records the current impact of disease, predation and bleaching on reefs (Fig. 2.2.2n-o). There was some indication of a similar condition to 'white band' disease that is particularly prevalent in the Caribbean.

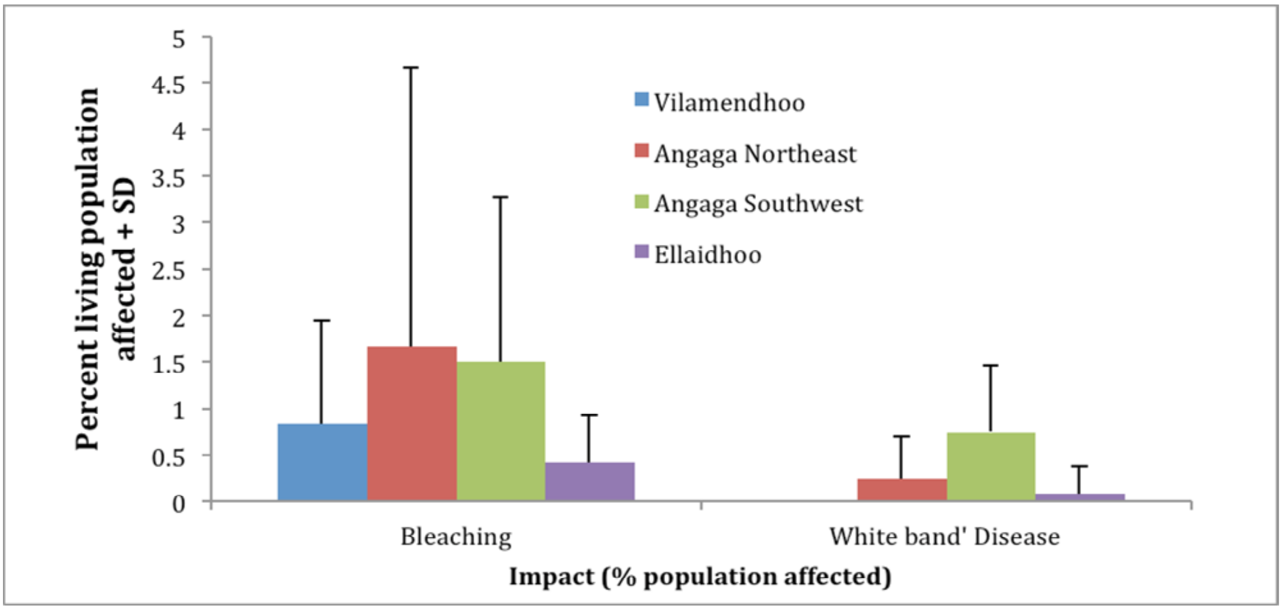

Figure 2.2.5b. The percentage of the entire living coral population within Reef Check survey transects that are (1) bleached and (2) affected by a pathogen resembling 'white band' / white syndrome disease.

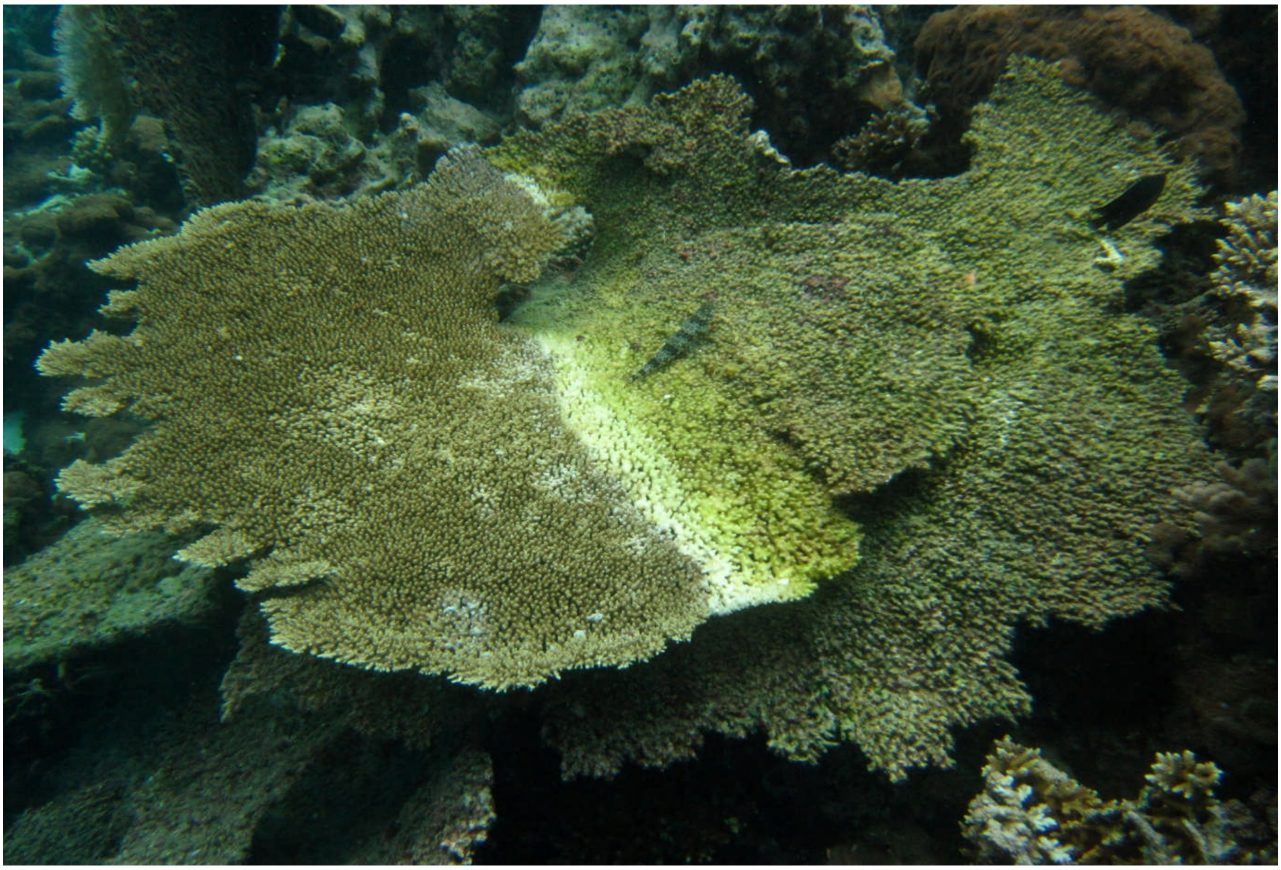

Figure 2.2.5c. A table coral Acropora colony showing the distinctive white band associated with the pathogen 'white syndrome' (Montano et al. 2012). This is recorded in Reef Check Maldives as 'white band disease'.

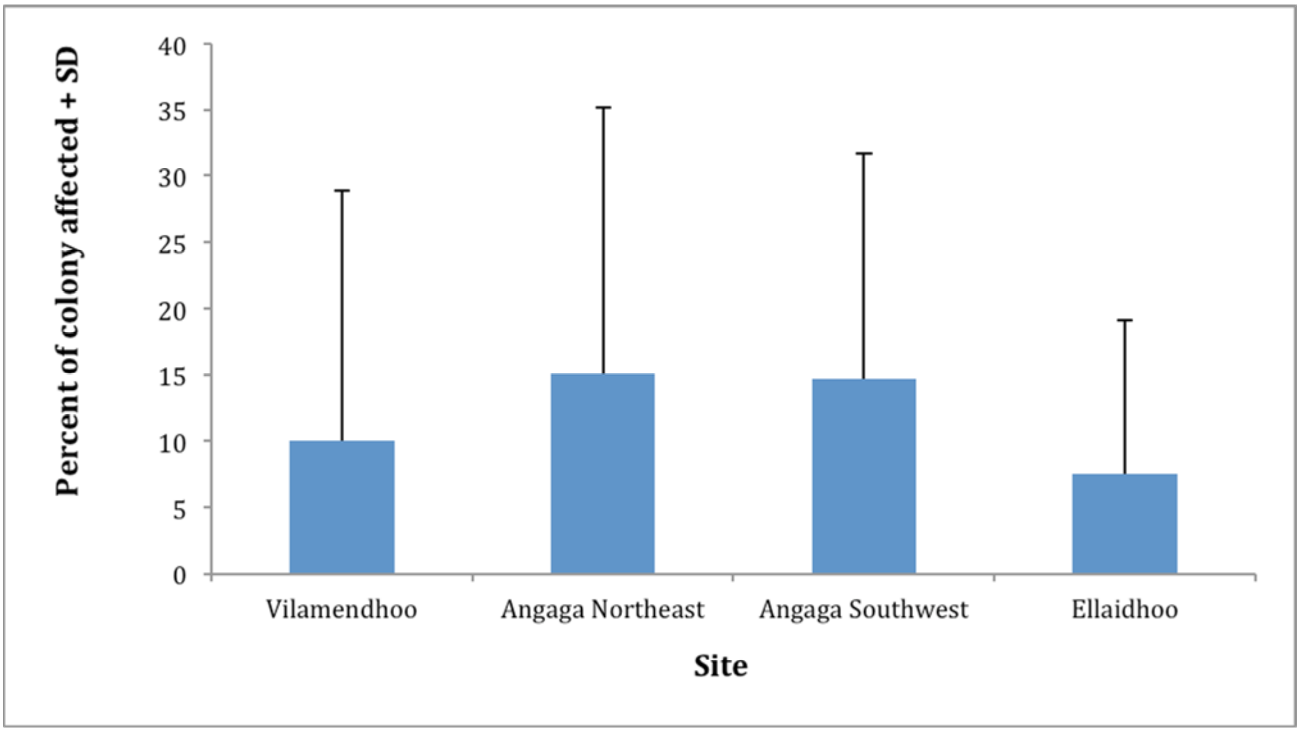

Figure 2.2.5d. The percent cover of individual colonies that are in some way bleached.

Whilst there is good evidence that the bleached colonies represent a very small proportion of the live coral population (on average less than 2%), there is a wide range in the amount that individual colonies are bleached (the range is between 5 and 60%). Volunteers are carefully trained to ensure that they record truly bleached colonies as opposed to colonies that have been predated on by *Drupella* or Crown of Thorns starfish. Divers are taught to look out for both these species whenever a white colony is observed.

2.2.6. Other sites (including training sites, Baros Maldives surveys)

Other sites visited during the surveys were:

- Biyadhoo (training Biosphere Expeditions volunteers)
- Orimas Faru
- Embudhoo (training Maldives Marine Research Centre staff)

Survey data were also made available from the permanent monitoring undertaken at Baros Maldives on the house reef by the dive staff (Karin Spijker and Ronny van Dorp).

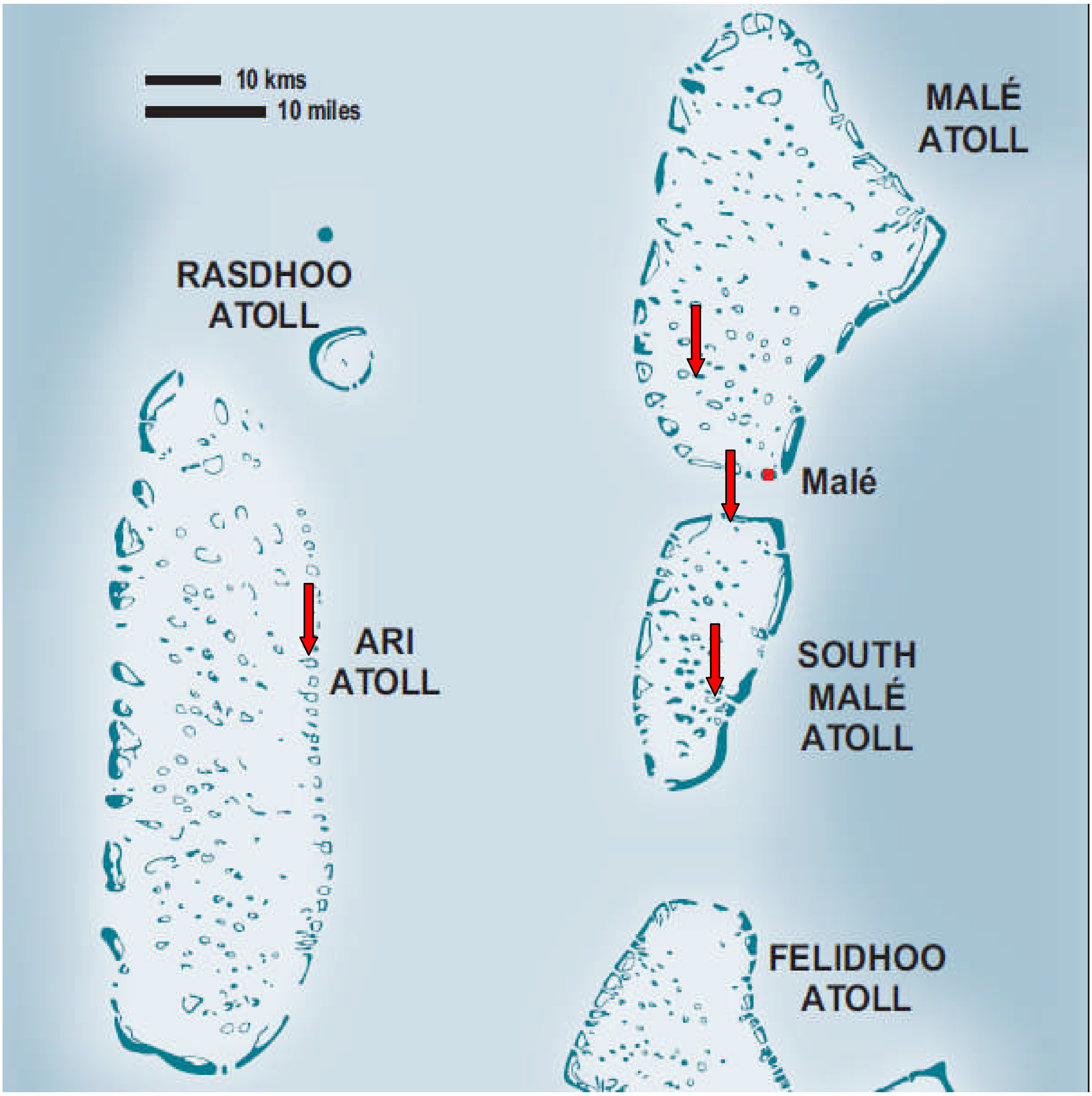

Figure 2.2.6a. Other sites surveyed. In east Ari atoll, Orimas Faru. In South Male atoll, Biyadhoo (south-eastern most site) and Embudhoo (northern site). In North Male atoll, Baros Maldives.

Biyadhoo survey results

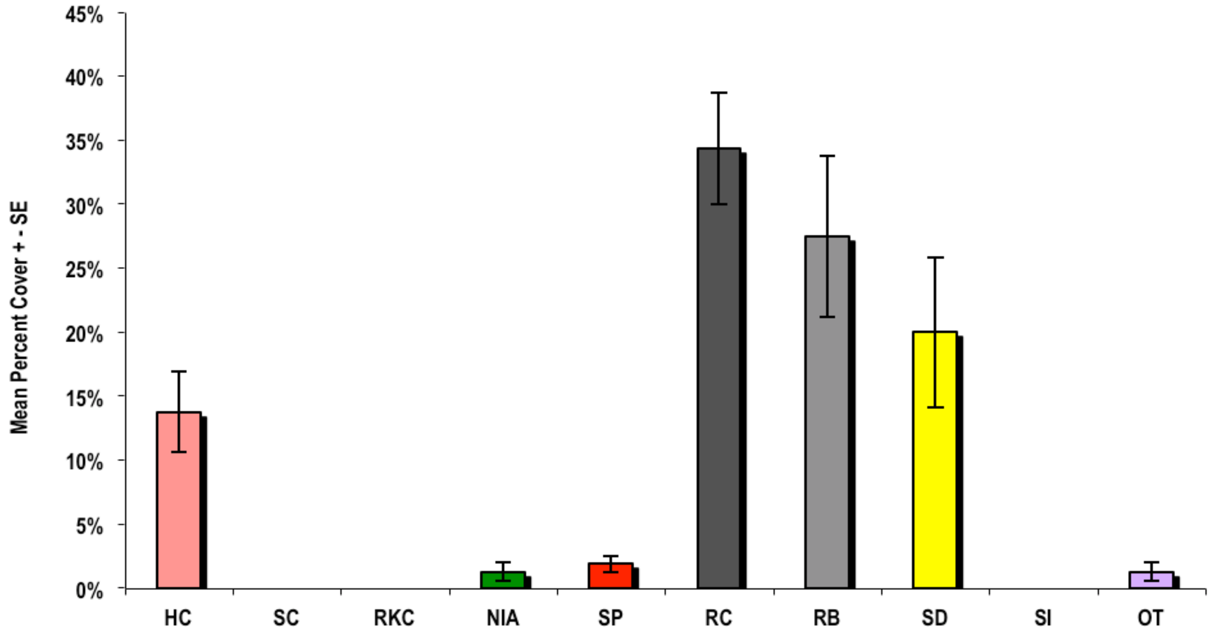

Figure 2.2.6b. Benthic cover at Biyadhoo house reef (10 m). The coral cover at this site is low. However, there is considerable bare rock. High rubble and sand cover is a potential problem for recruitment of corals, because it is not a suitable habitat for settlement of juvenile corals. The reef is located in a back reef environment of sheltered waters. These areas are often where fine sediments will 'settle out' of the water column. The comment from the survey divers was of rubble, fine silt and coral damage found on the survey.

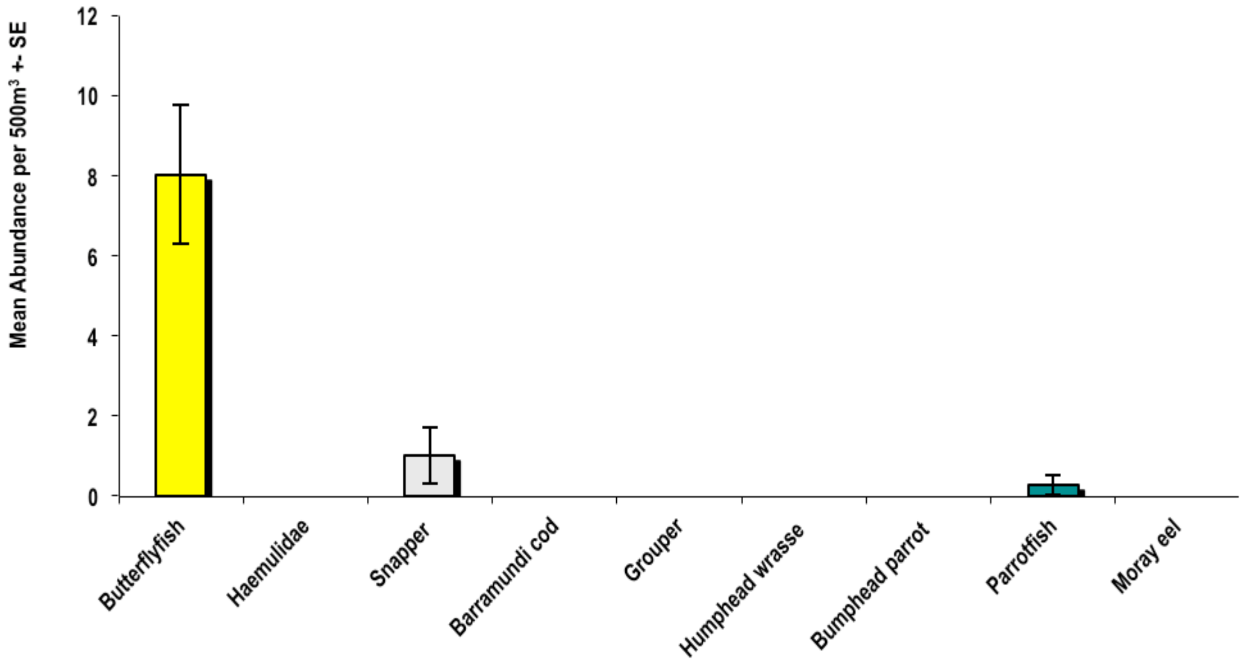

Figure 2.2.6c. Fish populations at Biyadhoo reef, southwest South Male' atoll. There are low population numbers for all species, including the parrotfish population that feeds on algae that competes for space with coral recruits.

Orimas Faru survey results

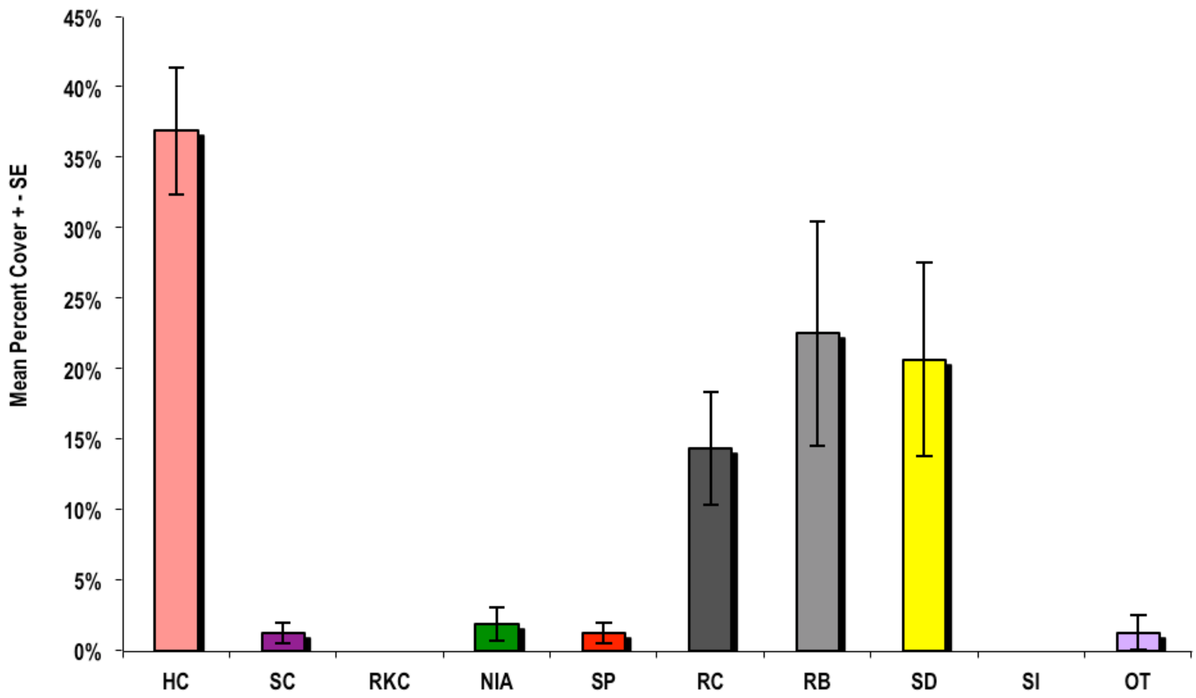

Figure 2.2.6d. Benthic composition at Orimas Faru, eastern Ari atoll at 12 m depth.

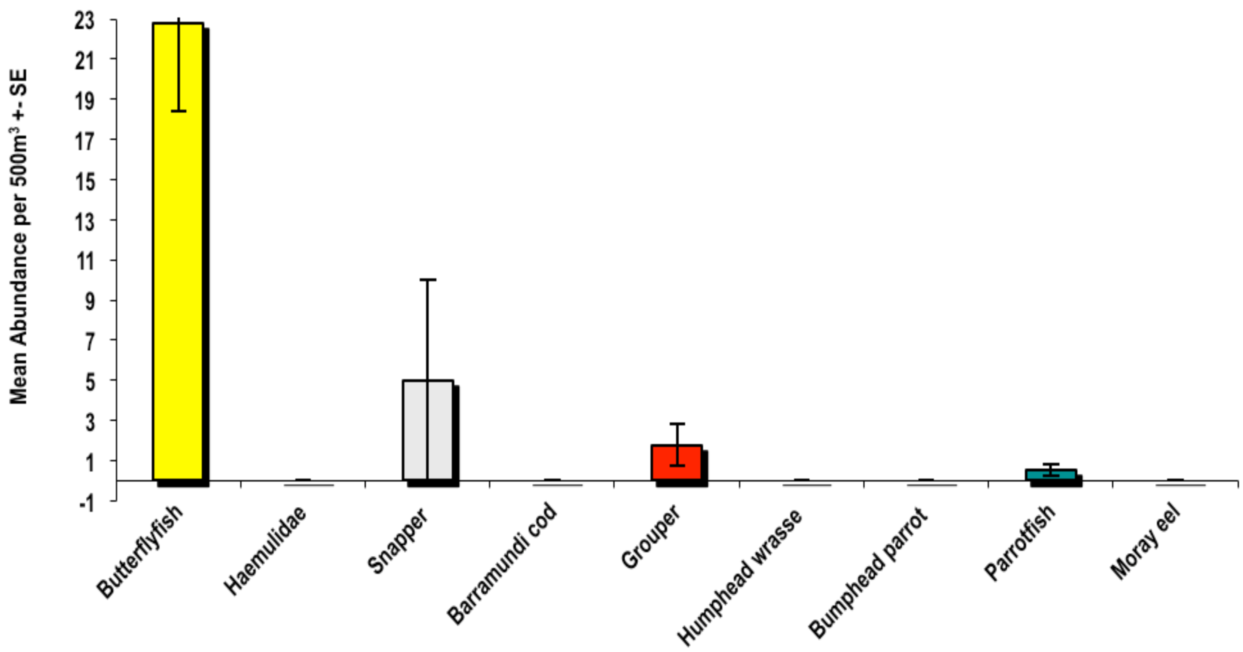

Figure 2.2.6e. Fish populations at Orimas Faru at 12 m depth.

There were very few invertebrates recorded from this site, with some giant clams and one tiger cowrie. There was minimal bleaching recorded at this site (< 1% of the coral population affected). There was no disease recorded. This site was very close to the MPA at this site (just to the east).

At least five colonies in each of the first three replicates of the transect had *Drupella* scars. There was no bleaching or incidence of disease. Considerable numbers of discarded, snagged fishing line were recorded along the transect.

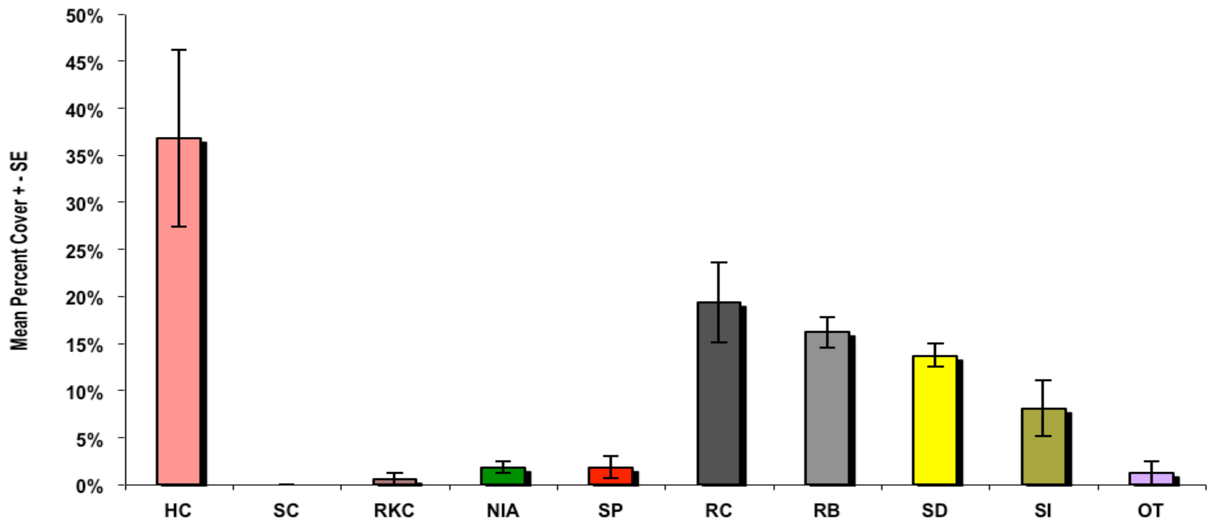

Figure 2.2.6f. Embudhoo backreef surveyed at 12 m by members of the Marine Research Centre. The reef was dominated by soft sediments spilling over the reef crest. It is an area where sand is gathered for the cement industry and for the replenishment of nearby resort island beaches.

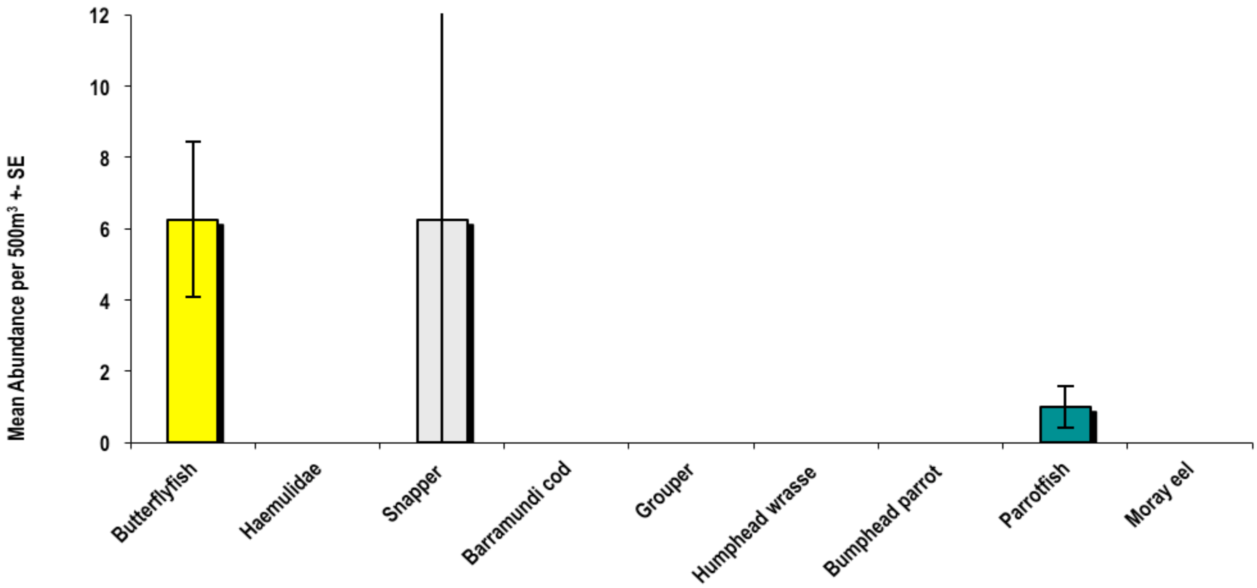

Figure 2.2.6g. Fish populations at 1 2m depth. The high standard error bars for the snapper population illustrate the patchiness in distribution of the species (25 animals were recorded in the first replicate, with none in the subsequent three).

Baros Maldives survey results

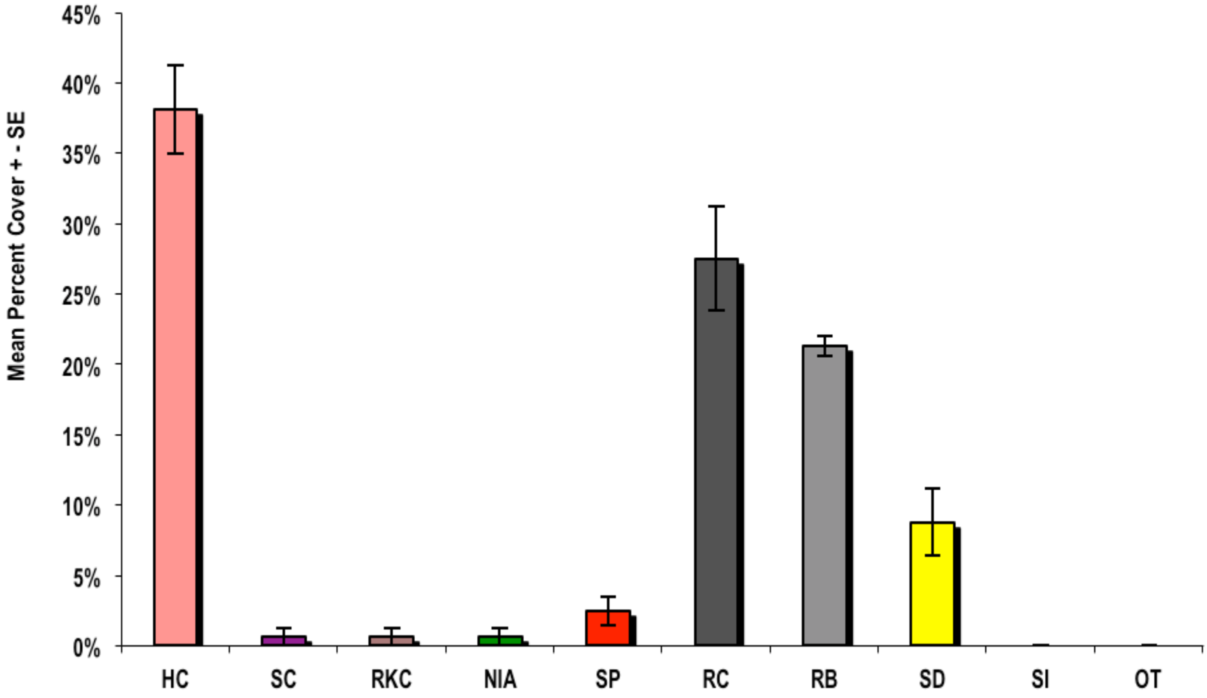

Figure 2.2.6h. Benthic cover at Baros at 10 m. Baros Maldives shows good coral cover for its house reef.

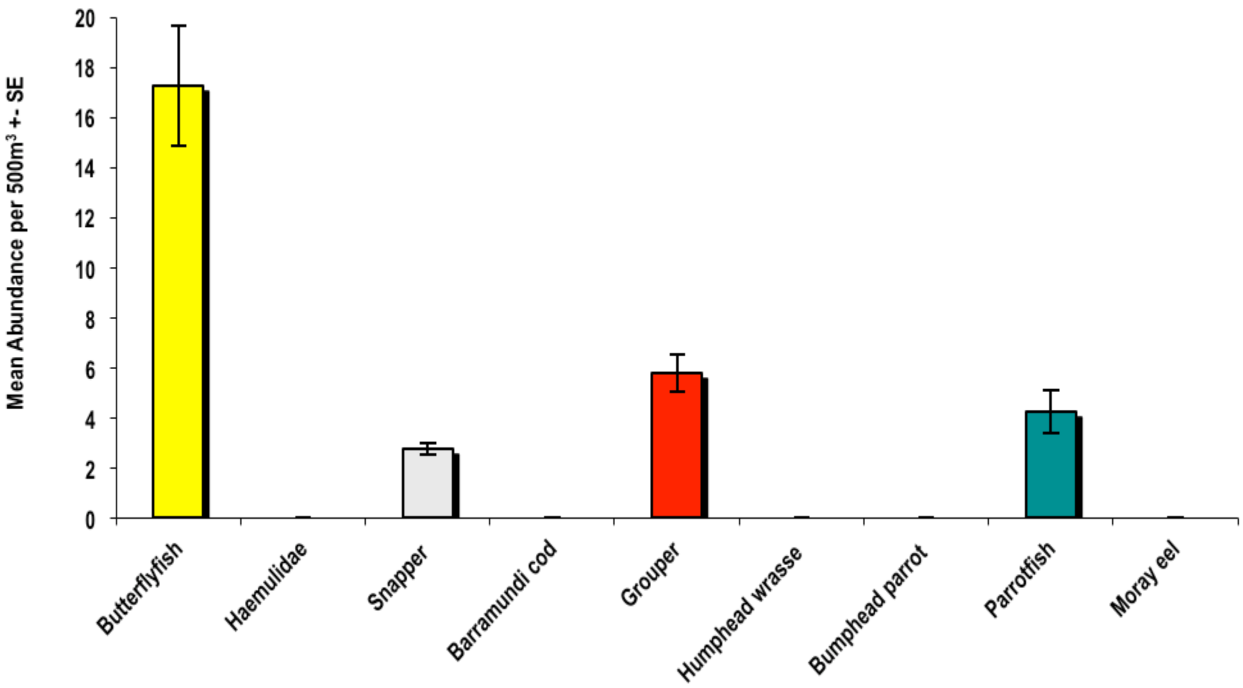

Figure 2.2.6i. Fish populations at Baros Maldives at 10 m. Note the relatively large numbers of grouper.

The largest numbers of grouper (dominated by the smallest size class of 30 - 40cm individuals) for all sites surveyed in 2012 was at Baros. Baros Maldives is a high profile resort that shows commitment to conservation through its involvement in Reef Check since 2010. The Marince Conservation Society trained Baros Maldives staff in Reef Check survey techniques in 2010. Since then the resort has carried out surveys on an annual basis, predominantly on the house reef on the northeast side of the island. This year's surveys took place on the southern side of the island.

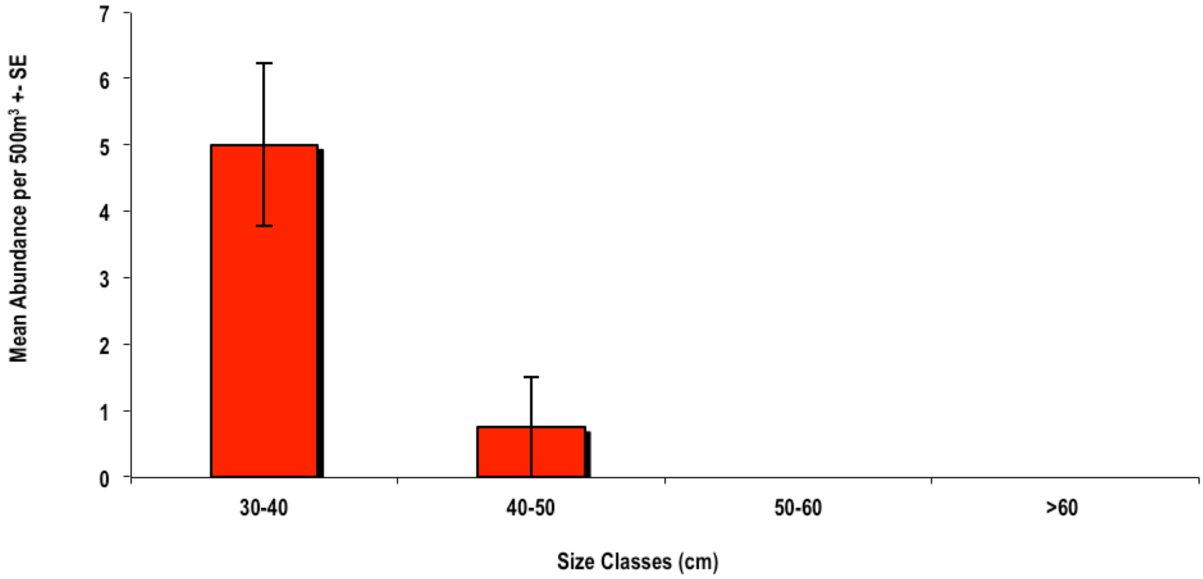

Figure 2.2.6j. Grouper size classes at Baros Maldives.

One lobster, two sea cucumbers and two giant clams were observed on the entire survey transect at 10 m depth. No lobsters were observed at any other Maldives site.

2.2.7. Reef Check training at MRC

After the one-week fieldwork liveaboard phase, the second week involved training Maldivian marine biological and conservation management staff at the Marine Research Centre (MRC) in Male'. Training was facilitated by Yoosuf Rilwan, the head of the marine monitoring programme at MRC and included four staff members from MRC, three from the Environment Protection Agency (EPA) and two from local consultancies, 'Water Solutions'[9] and 'CDE'[10]. Two of the MRC staff had already been on the liveaboard expedition the previous week, passed all tests to the required standard and had undertaken two full surveys. During the second week, they undertook some of the training under supervision by Dr JL Solandt. This allowed them to achieve the level of Reef Check EcoDiver trainer. Classroom training, ID tests and registration were carried at MRC HQ in Male', with fieldwork undertaken at Embudhoo backreef (results section above).

[9] http://www.water-solutions.biz/
[10] http://cde.com.mv/

Figure 2.2.7a. Some of the MRC participants with their Reef Check certifications, September 2012.

Training was also given in the use of the benthic cover survey software ‘Coral Point Count’ (CPC). However, this was ineffective because the required coral code file for assigning categories could not be loaded onto MRC computers.

The principle reason for undertaking the training with MRC staff was to ensure that there is consistency in the application and use of Reef Check methodology by MRC field surveyors in the future. Up until now, the methodology has been adapted with different areas of the survey not applied (e.g. the inclusion of the site form reports). Thus the data have not been sent to RC HQ in the past for comparative analysis both within the Indian Ocean and the wider Indo-Pacific region. It is important that the Maldives provides its monitoring data in a format that is comparable with other Indo-Pacific areas, as one of the major questions reef managers are now asking is how resilient different regions are to climate change and other impacts.

Unfortunately, the monitoring budget for MRC appears to have been drastically cut in the recent past, with little information coming out of the MRC in terms of reef condition (published or as 'grey' literature posted on their website). MRC has historically surveyed reefs from the far north to the deep south of the country, providing a range in site area that is far greater in spatial coverage than that provided by the Biosphere Expeditions surveys, which concentrate on central Maldives reefs. The most recent Global Coral Reef Monitoring Network (GCRMN) report of coral condition from 2008 did not provide detailed information on coral cover and fish assemblages from Maldivian permanent monitoring sites.

Recently the Maldives has also attracted a wide variety of different monitoring projects initiated by different partners, such as 'Bleachwatch', 'FishWatch', 'and Sharkwatch'. These programmes are all specific in their design, yet Reef Check is the only truly comprehensive reef health assessment monitoring project that records information from such a wide variety of parameters (e.g. fish, corals, invertebrates, impacts and anthropogenic activities).

It is hoped that the successful training of Maldivian coral reef surveyors can facilitate closer collaboration between Biosphere Expeditions, liveaboard operators and resorts undertaking Reef Check surveys, and within the permanent monitoring sites regularly surveyed by MRC.

2.3. Discussion and conclusions

Bleaching

The severity of the 1998 six week high temperature anomaly led to the most comprehensive bleaching event in the Maldives. Water temperatures reached up to 36°C and lead to up to 80% mortality of corals down to 30 m (Zahir et al. 2005, Edwards et al. 2001).

There was a further bleaching event in 2010 that affected large swathes of the Maldives. Many central reefs had 10-15% of shallow-water colonies completely bleached, whilst the remaining coral tissue was starting to pale. However, the difference of this bleaching event in 2010 compared to 1998 was both that corals suffered a lower maximum temperature and the waters at the highest temperature were not in contact with the reef for an extended time period, as they were in 1998. In 1998, the hot water area was in contact with the Maldives area for approximately six weeks (March – May). However, in 2010 the waters cooled after a short time period with the maximum recorded temperature at 32°C.

The data presented here from the three reefs visited since 1998 show a considerable recovery in percent live coral cover from the bleaching events. However, Ellaidhoo reef shows a reduction in the original coral cover of approximately 30% for both the 3 m and 7 m depth transects from pre-bleaching conditions. The other two reefs have shown recovery at or beyond the level of cover first observed in 1997 or during (for Vilamendhoo) the bleaching event in 1998. Our surveys lack a definitive understanding of the complexity of the coral population and its species and growth forms at the sites visited in 1997 and 1998, so it is difficult to comment on the response of coral species themselves. It could be that recruitment and growth of slower-growing massive colonies is still occurring and that it may be some years before a climax community state (Connell and Slatyer 1977) is reached. Undertaking photo quadrats at these three reefs, albeit outside the scope of the Biosphere Expeditions surveys, would give an impression of the types of corals that are growing in 2012 and this would provide a useful evidence base if there is any further catastrophic event affecting the population of the reefs.

Resilience

The survey results above and in previous years are encouraging in terms of demonstrating the current resilience of Maldives reefs to mass-bleaching events. It is clear that the isolated clear waters far from continental landmasses have provided the right conditions for recruitment and recovery from such events over the past 13 years (compared to many other Indian Ocean regions and countries). For example, the Seychelles saw little recovery since the 1998 bleaching event in many of its sites (Ledlie et al. 2007).

Much research has been carried out since the 1998 (and subsequent) bleaching events, showing that sedimentation, overfishing of algal-eating parrotfish and surgeonfish, point source pollution and other factors compound the impact and potential recovery of reefs from initial climate-driven bleaching events (Grimsditch and Salm 2006). This decline has been seen by some experts as being accelerated, exacerbated and inevitable due to the global $C0_2$ output increase (Veron et al. 2009).

The Maldives has over 1,000 islands and countless other faroes and giris that have likely had different responses to the bleaching event. It would appear that in very general terms the coral reefs nearer to the more heavily populated centres, such as North Male' and South Male' atoll have seen the most suppressed recovery from the 1998 bleaching event (e.g. a loss of coral cover between 1998 and 2005 of between 25 and 80% was recorded in a 2005 study by Graham et al. (2008) concentrated around North and South Male' atolls). Experienced surveyors from the Marine Conservation Society have also reported that the westernmost atolls (that would include the sites visited in these surveys) have recovered better than the eastern most atolls.

The Maldives does not suffer from the chronic overfishing of herbivorous fish that is seen throughout much of the Caribbean and Southeast Asia, nor the considerable sedimentation from river run-off in Jamaica and the Philippines (Spalding et al. 2001).

However, the combination of point source pollution, climate-induced bleaching and acidification will have detrimental consequences for the Maldives unless the $C0_2$ levels in the atmosphere reduce to less than 350 ppm. This was highlighted by the Maldives as recently as 2009. The immediate concern for Maldives politicians is sea-level rise from the impacts of increased $C0_2$. Yet the combined impact of acid conditions and increased temperatures are of course equally important to the maintenance of the very corals on which the Maldives exist.

The key ecological question for the Maldives government is what is the prognosis for Maldives reefs given the increasing likelihood of more bleaching events and increasing acidification? Resilience of systems can be tied in to the time sequence available to species and families of corals to adapt their physiology and life histories to the impending changes. Many authors have illustrated that the changes we are forcing through the environment are at a greater rate than that experienced in the 250 million years that current coral species have existed (Veron, 2008).

Alternative ecological 'stable states'

It is clear that areas of the Maldives have been vastly changed by the bleaching events that have turned coral reefs to an 'alternate stable state'.

Jamaica's reefs serve as an example of what is meant by 'alternate stable state'. Reefs in Jamaica were once dominated by rich coral growth, but have now been affected by so many synergistic impacts that they have turned to an alternate state of being algal-dominated (Hughes 1994). Similar state changes from coral to algal-dominated have been documented for the Seychelles (Ledlie et al. 2007) and the Great Barrier Reef (Hughes et al. 2011). The new 'algal' state is 'stable' because it needs a number of coincidental factors to change to encourage coral recruitment and growth to then outcompete and outgrow settling algae. These factors (1) a recovery of herbivores to graze away the algae, (2) a good source of coral recruits, (3) reduced sedimentation, (4) a lowering of ocean acidification to encourage good coral growth, (5) lowering of sea temperatures to reduce the incidents of bleaching that have affected the Caribbean in recent years that will (6) reduce the number of storm disturbance events (such as hurricanes) that have increased in frequency with increased sea temperatures. Therefore, a number of factors will need to change to provide good conditions for coral reef recovery.

Turning back to the Maldives, the shallow reef called 'Adhureys Rock' first surveyed in 2005 is now dominated by *Didemnum* ascidians and *Discosoma* corallimorphs whose only natural predator is hawksbill turtles (Solandt and Wood 2005). It is very likely that the ascidians and corallimorphs gained an ecological foothold after the bleaching event of 1998 and surveys showed their colonisation was so dominant that the chance of coral recovery in the near future is low. Fortunately it is rare to observe reefs in the condition of Adhureys Rock across the Maldives.

An opportunity to adapt?

There is some evidence that corals can adapt to changing environments from the Persian Gulf, where corals have naturally had to endure water temperatures of up to 36°C (Bento and Hammer 2012). Here there is a lower diversity of families of hard corals and a lower diversity at the species level. However, corals survive in temperature and salinity conditions that would kill corals elsewhere and these more resistant populations may spread southwards to colonise the reefs of the Maldives in time. However, the impact of acidification that has been tested in lab conditions not only lowers the reproductive output of corals, but also the vegetative growth and structural integrity of the coral skeleton itself (Veron et al., 1998).

Questions for management

The effects of wide-scale impacts such as climate change and increased $C0_2$ begs the question of what can be done in terms of governance. Many of the sites surveyed since 2005 have shown good recovery from the initial bleaching event. It is clear that the trajectory for positive change is moderate to good for most of the 50-odd Maldivian sites that have been surveyed using the Reef Check methodology over the past 7 years.

However, the potential for synergistic impacts from local factors such as overfishing, inappropriate development and pollution can and should be managed by national and local government, tourism, local island groups. Only with the development of capacity-building, training and resources committed to conservation at the local atoll and island level will mitigating measures be implemented. Luckily for the Maldives it currently lacks many of the varied and most harmful practices that have laid waste to large tracts of other Indian Ocean coral reefs. Yet, this may only delay, rather than prevent, the onset of alternate stable states for many reefs.

Recommendations

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:

- 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 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.

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Appendix I: Expedition diary and reports

A multimedia expedition diary is available on http://biosphereexpeditions.wordpress.com/category/expedition-blogs/maldives-2012/

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