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EXPEDITION REPORT

Expedition dates: 3 - 16 September 2011

Report published: July 2012

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

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

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Abstract

This study undertook survey dives in North Male’, Rasdhoo and South Ari Atolls between 6 and 15 September 2011, using the internationally accredited survey method Reef Check. Two one-week training and survey programmes with layperson volunteers were undertaken based on the live-aboard vessel MV Carpe Diem.

Training for each week lasted 2.5 days, allowing approximately three days per week to carry out surveys. 16 sites were surveyed, in sheltered thillas, faroes and channel locations where currents were light and the reef was of a gentle gradient. Data collected on coral cover showed little difference since the Marine Conservation Society started monitoring reef conditions in 2005, with a mean coral cover of 25% recorded from the 16 sites. Coral cover was generally higher in the shallower reef transects (<6 m) of the sheltered thilas in central and southern Ari atoll compared to deeper waters at the same sites, and generally compared to reefs visited in North Male Atoll..

It is widely accepted that there has been patchy recovery of the coral population since the notorious 1998 El Nino bleaching event that affected most central Maldives reefs down to 30 m depth. It is hard to confirm whether the coral cover monitored on these surveys is re-growth of affected colonies or new colonies recruited since 1998. The coral cover distribution was very patchy across all sites visited, with some sites (such as Kudafalu in central Ari atoll) having exceptional coral cover of over 70% along the shallow transects, whilst other generally more exposed sites (such as Bathalaa Maagaa) on the outer atoll slope, had coral cover of below 15%.

Fish populations at higher trophic levels (piscivores and apex predators) are low in size and abundance, particularly in shallow waters compared to other areas such as the Great Barrier Reef (Russ et al. 2008), where significant reef fish management measures have been introduced. Marine Protected Areas were not visited on this expedition, but house reefs that act as de facto MPAs did not appear to host significantly larger populations of commercially important species than open-access reefs, supporting observations by other concurrent Maldives reef fish survey projects (e.g. Fishwatch Maldives).

Surveys outlined in this report show the fragile nature of the reefs of the Maldives and that they are generally at a lower condition state than in the early 1990s. Coral cover is patchily distributed, whilst fish populations are a long way from those in pristine reef communities such as those recently surveyed on un-fished Indian Ocean reefs. Management recommendations are made to combat this state of affairs.

Finally, the whale shark surveys carried out at the Maamigili site in Ari Atoll showed clearly that this designated marine reserve is unmanaged and unregulated. There are multiple threats to the whale shark population at Maamigili, including, but not limited to, ship strike and very significant diver harassment. Regulation and enforcement patrols are urgently needed to ensure that the Maamigili whale shark site can be utilised sustainably to continue to generate value for local stakeholder economies without harming or destroying the whale shark population as the creator of this value or endangering operators and their customers. Whale shark operations in many locations in Western Australia could serve as benchmarks here on how to generate significant and sustainable income for local stakeholders sustainably and without harming the whale sharks.

Contents

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 3 to 16 September 2011 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. Shark fishing within the atolls was banned by the Maldivian government in 2008 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 reef 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 island, of which only about two hundred are inhabited.

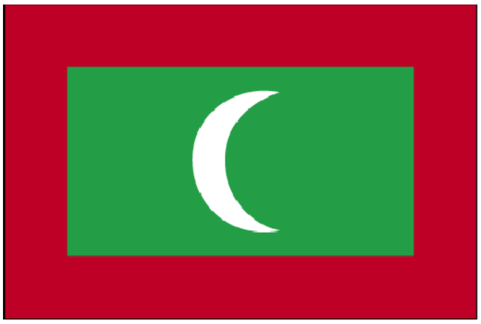

Figure 1.2a. Flag of the Maldives.

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 are 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

The expedition ran over two periods totalling two seven-day groups.

2011: 3 - 9 September | 10 - 16 September.

All groups were 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.

Tank refills and dive services were provided by the crew. 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 were 26-31°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 sent an expedition diary to the Biosphere Expeditions HQ every few days and this (text only) diary appeared on www.biosphere-expeditions.org/diary for friends and family to access. Excerpts of the diary with multimedia content such as pictures and video clips also appeared 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):

3 - 9 September 2011

Sue Baldwin (Australia), Nieves Becker (Germany), Cornelia Beisel (Germany), Jane Bloom (USA), Alexandra Bühler (Germany), Mona Frolova (Russia), Shareef Hussain* (Maldives), Majid Ibrahim* (Maldives), Rizwil Ismail (Malaysia), Uwe Kürsten (Germany), Tina Laier (Germany), Maria Mak (UK), Melanie McCaffery (USA), Marina Thompson Abdullah (Malaysia), Kate Wilson* (UK).

10 - 16 September 2011

Cornelia Beisel (Germany), Rita Bento (UAE), Jan Biekehör (Germany), Rick Boughton (Hong Kong, China), Alan Brundson (UK), Nicola Bush (UAE), Susannah Cogman (UK), Monique James (Australia), Uwe Kuersten (Germany), Tina Laier (Germany), Volker Lottmann (Germany) - journalist, Maria Mak (UK), Mohamed Mazin* (Maldives), Greg Mewkill (Australia), Susan Quine (UK), Nishan Thoufeeg* (Maldives), Jenny (Xiao Yan) Zhang (Hong Kong, China).

*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. Education and capacity-building

With the support of a grant from Soneva Resorts Maldives, Biosphere Expeditions produced an educational booklet for Maldivian school children and hosted Malidvian nationals and coral reef conservation professionals on the expedition, training them as Reef Check Eco Divers.

The booklet, 'THE ADVENTURES OF ANEES THE ANEMONEFISH', is based on an original story first put together by Dr Liz Wood, Coral Reef Officer of the Marine Conservation Society and the International Coral Reef Action Network, for a project in Sabah, Malaysia.

Liz Wood and Kate Wilson (see above) adapted the original into a Maldives version following a suggestion from Biosphere Expeditions. The new version was beautifully illustrated by local artist Angel Shujau.

'The Adventures of Anees the Anemonefish' is a story about a brave young anemonefish that goes on an adventure to find a safe place to live. He encounters many dangers, but also makes some good friends along the way. He comes across many threats to the reef including rubbish, anchor damage, overfishing and the warming of our oceans by climate change, until eventually he arrives in the safe haven of a marine protected area.

The colouring booklet was launched and delivered to the Maldives Department of Education in early September, just before the expedition departed. Ibrahim Ismail, Deputy Minister of Education, officially accepted the booklet on behalf of the Maldivian government.

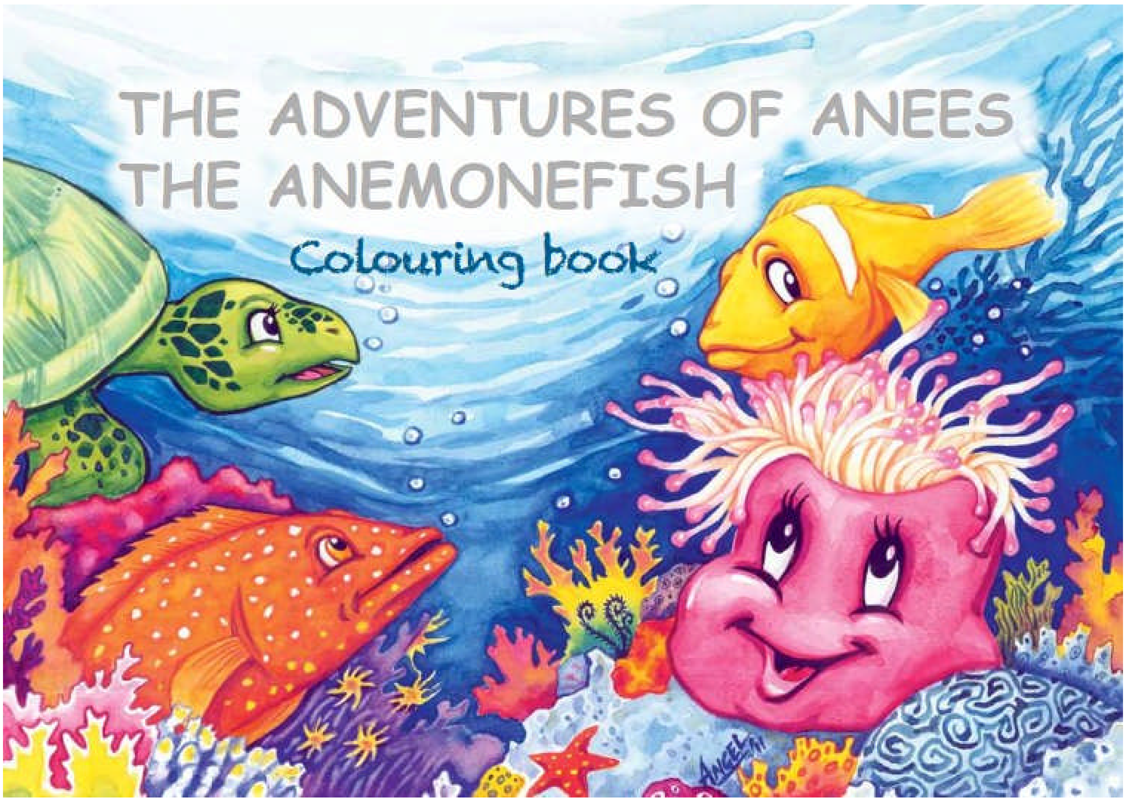

Figure 1.8a. Cover page of the educational booklet. Click here for the full version.

1.9. 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.

1.10. Expedition Budget

Each team member paid towards expedition costs a contribution of £1620 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	39,120
Grants	19,993
Expenditure	
Start-up costs includes setting up base, research, staff, logistics, etc.	3,579
Staff includes local & international salaries, travel and expenses	5,940
Research includes equipment and other research expenses	3,244
Education & capacity-building includes placements for locals, educational materials design & distribution, etc.	7,559
Transport includes taxis and other local transport	84
Base includes board, lodging and other live-aboard services	26,878
Administration includes office costs, permits, press conference and other local PR	737
Team recruitment Maldives as estimated % of PR costs for Biosphere Expeditions	4,240
Income – Expenditure	**6,852**
Total percentage spent directly on project	**88%**

1.11. 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, Land Rover, Cotswold Outdoor, Motorola, Swarovski Optik, Globetrotter Ausrüstung and the Friends of Biosphere Expeditions for their sponsorship and/or in-kind support. Many thanks to photojournalist Volker Lottmann for donating some of his excellent photos to Biosphere Expeditions for this expedition report and marketing purposes.

The authors would like to thank Liz Wood and Kate Wilson of the Marine Conservation Society for comments on the manuscript and also for drafting up an educational booklet, beautifully illustrated by Angel Shujau. We thank the crew of the MV Carpe Diem for being such excellent hosts, an in particular Sobah and Zeena for being our patient divemasters. Thank you also to Richard Rees of the Maldives Whale Shark Research Programme.

1.12. 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.

2. Reef Check survey

2.1. Introduction and background

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

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

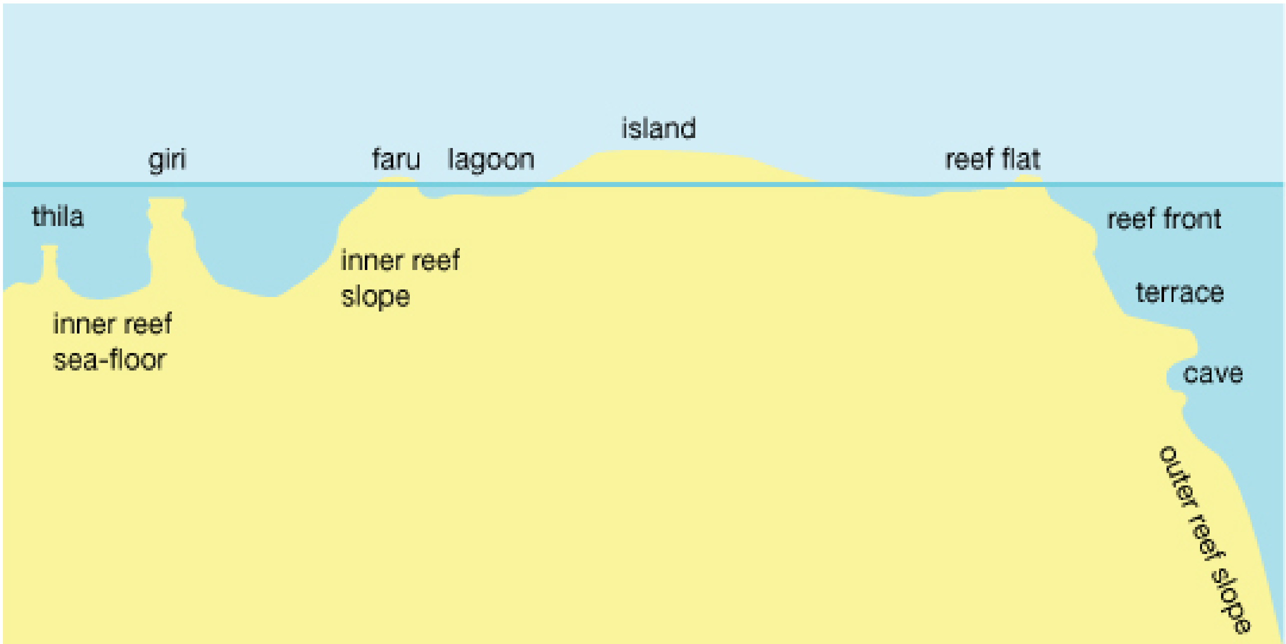

Figure 2.1a. Common reef structures of the Maldives (from Tim Godfrey).

The Maldives has two monsoon (wind and current) seasons. The Northeast monsoon brings in dry winds from the Asian continent that last between January and March. The relatively wet South-westerly monsoon runs from May to November. Air temperature ranges between about 31^0 and 21^0 Celsius 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.

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.

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 are meant to 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). Nine of the 25 small Maldives MPA dive sites were surveyed by the author 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 9 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. Private vessels, live-aboards and SCUBA diving are now banned in the Bay as of 2012 and a permit system is due to be put in place 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.

2.1.3. Maldives reef surveys using Reef Check

Reef Check has been carrying out volunteer dive surveys since 1997 - the International Year of the Reef (Hodgson 1999). It was designed to vastly increase the amount of information of the health status of the world's coral reefs in the absence of funding and manpower to mobilise enough reef scientists to carry out surveys themselves. It has successfully increased the capacity to record the health (and changing health) of reefs and their natural resources (Hodgson and Liebeler 2002).

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.

2.1.4. Planning & methods

Logistics, health and safety on board the vessel and recruitment of volunteers was carried out by Biosphere Expeditions. 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).

2.1.5. Survey sites (and dates surveyed)

Table 2.1.5a. Sites surveyed.

Site	Site name	Survey date	Latitude decimal degrees	Longitude decimal degrees	Atoll	Habitat
1	Laguna Beyru	5.9.11	4.1001	73.4169	South Male’	Backreef
2	Bathalaa Maagaa Nth	6.9.11	4.0522	72.9517	Ari (NE)	Forereef
3	Bathalaa Maagaa Sth	6.9.11	4.0375	72.9521	Ari (NE)	Channel
4	Dega thila	7.9.11	3.8335	72.7500	Ari (central)	Thila
5	Digga thila	7.9.11	3.7204	72.7530	Ari (central)	Thila
6	Maamigili airport	7.9.11	3.4668	72.8336	Ari (S)	Forereef
7	Holiday thila S	8.9.11	3.4865	72.8185	Ari (S)	Thila
8	Dhigura arches	8.9.11	3.5360	72.9180	Ari (SE)	Thila
9	Baros house reef	10.9.11	4.2835	73.4168	North Male’	Thila
10	Madivaru, Rasdhoo	11.9.11	4.2540	73.0003	Rasdhoo	Forereef
11	Kuramati Rasdhoo	12.9.11	4.2502	72.9834	Rasdhoo	Forereef
12	Madivaru 2, Rasdhoo	13.9.11	4.2543	73.0007	Rasdhoo	Forereef
13	Gangehi Island North	13.9.11	4.2506	72.7703	Ari (N)	Backreef
14	Gangehi Island reef	14.9.11	4.2173	72.7521	Ari (N)	Backreef
15	Kudafalu	14.9.11	4.0169	72.8016	Ari (central)	Thila
16	Holiday thila NW	15.9.11	3.4865	72.8185	Ari (S)	Thila

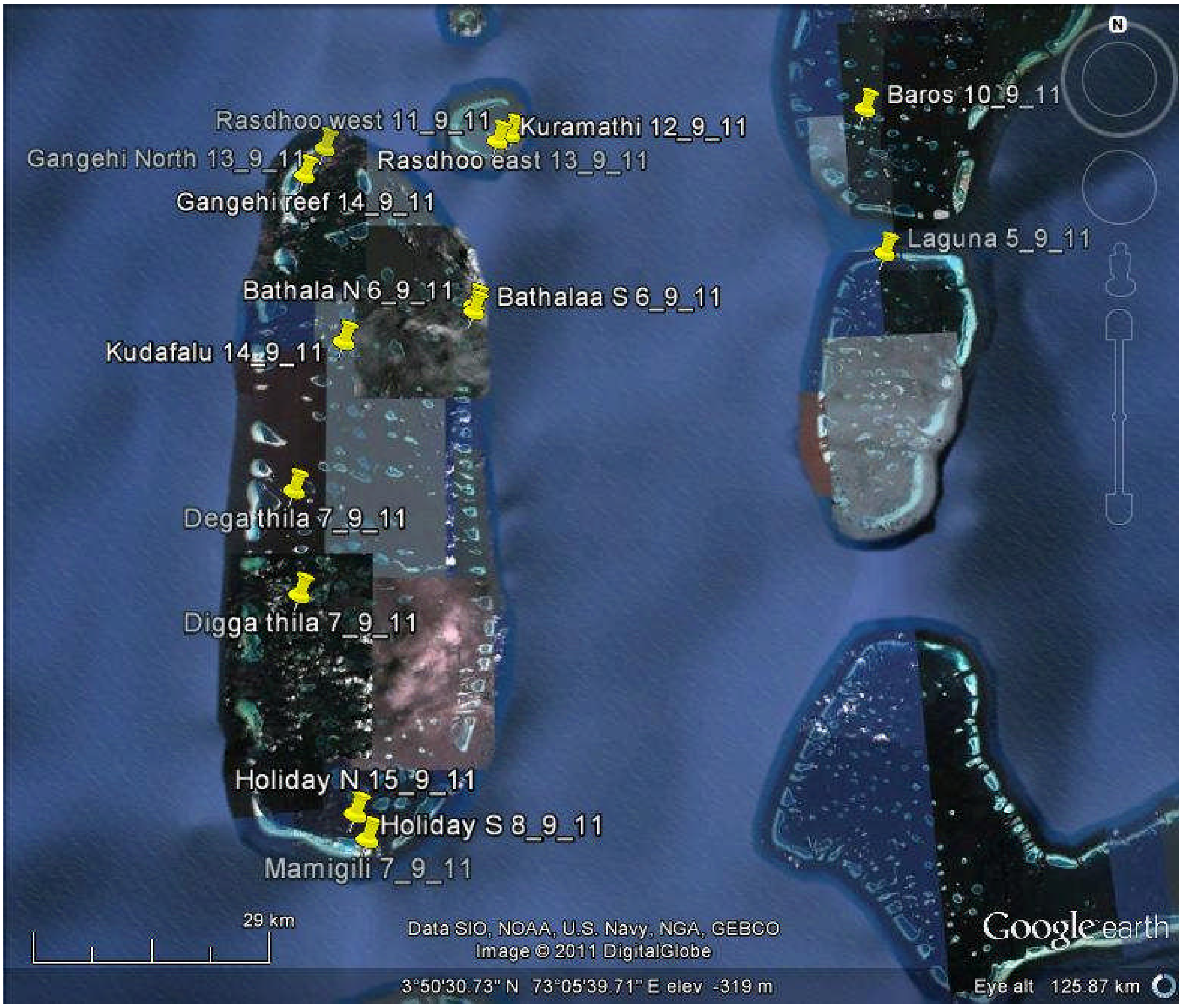

Figure 2.1.5a. Location of sites surveyed.

2.2. Results

2.2.1. Coral and associated seabed cover

There was considerable variability in the dominance of coral health at the sites surveyed. Much of this was because of the variety of sites, with forereefs and backreefs having generally lower coral cover than thilas (Figure 2.2.1a).

Most reefs surveyed had a higher coral cover at the shallowest depths (2-5 m), particularly the inner atoll thila reefs such as at Dega, Digga and Kudafalu and Holiday thilas (all within the inner Ari Atoll). At these sites, the coral cover exceeded 60% in coral cover at Dega and Kudafalu and averaged over 55% for the inner thila reefs.

For almost all surveys, deeper sites had lower cover than shallow sites. For example Kudafalu reef had coral cover of 78% along the shallow transect (4 m), whilst the deepest transect had a coral cover of 5%.

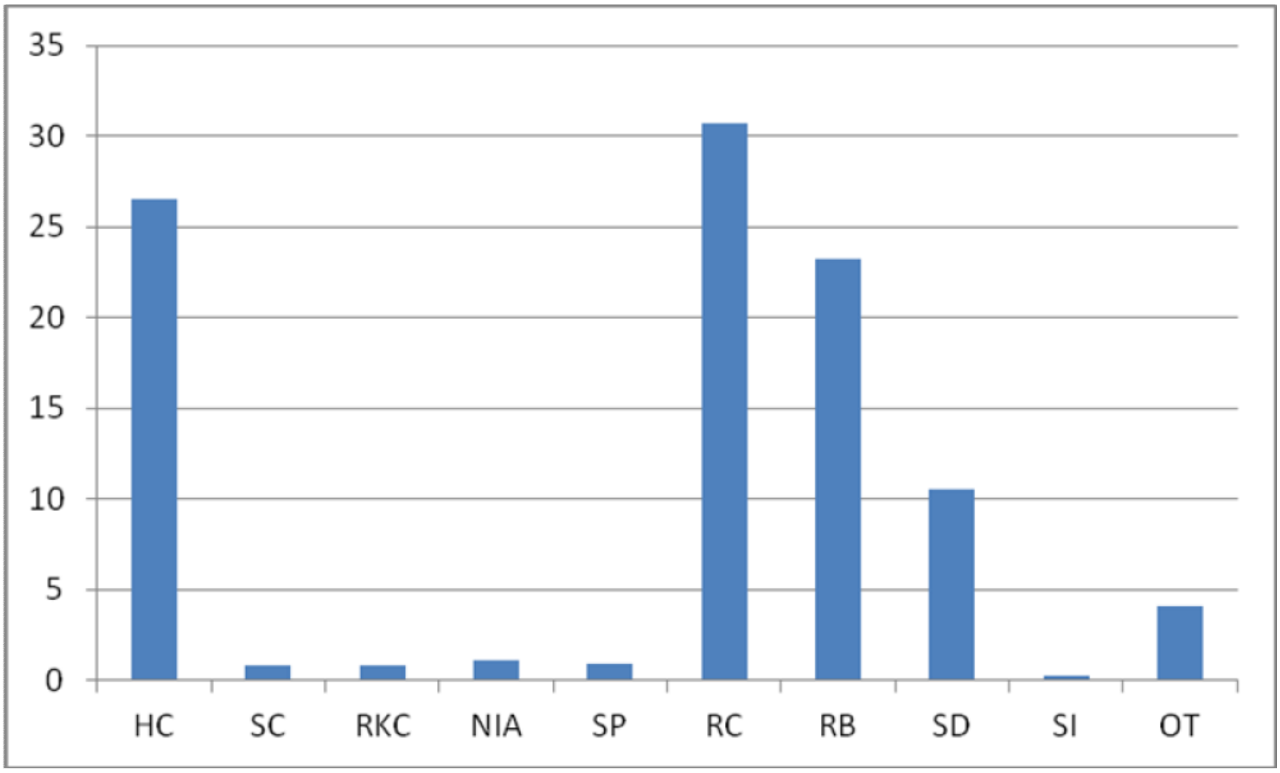

Figure 2.2.1a. Overall seabed cover from all sites surveyed (figures are percent cover). Habitat codes are HC (hard coral), SC (soft coral), RKC (recently killed coral, corals killed within approximately the past year), NIA (nutrient indicating algae, predominantly fleshy macroalgae that are nutrient limited such as Lobophora), SP (sponge), RC (rock), RB (rubble), SD (sand), SI (silt), OT (other, such as cnidarians, zooanthids).

Figure 2.2.1b. Shallow Dega thila. Often the shallow, sheltered thila reefs were dominated by table *Acropora* species such as the ones shown. Often these colonies measured in excess of 2.5 m. Image courtesy of Kate Wilson.

Figure 2.2.1c. A deep survey at Kudafalu thila. The coral cover at the shallow depth at this site was 74%, but at 15 m decreased to16%. This depth distinction in coral cover was typical of many inner thilas. Image courtesy of Voker Lottmann.

Forereef fringing reef sites in shallow waters on the outer edge of atolls (such as Rasdhoo and Maamigili) had lower coral cover (approximately 22%), whereas the backreefs in shallow waters of the outer fringing reefs of the atolls had the lowest coral cover of approximately 6%. Observation showed that the coral cover clearly decreased with increasing depth. One site (Kudafalu thila) in particular appeared to be affected by nutrient indicator algae (NIA), possibly associated with an upstream nutrient source. Kudafalu thila is approximately 0.5 km South/Southeast of a resort that could be the point source of this contribution to the community.

2.2.2. Fish populations

Planktivorous and omnivorous butterflyfish the most abundant fish family surveyed (Figure 2.2.2a) with approximately 22 individuals recorded on each 20 x 5 m replicate. Other Reef Check indicator fish such as snapper, sweetlips and grouper were relatively rare on surveys. Bumphead parrotfish were recorded once on a single survey. Humphead wrasse were similarly rare on transect, but were occasionally observed outside. Mature parrotfish (greater than 20 cm size) were relatively common with an average of 4.67 individuals recorded per $100m^{-2}$ replicate (each transect is divided into 4 x 20 x 5 m replicates; each one of the $100m^{-2}$ areas is identical to each other on each survey in order to provide an estimate of the variability across each survey site). Grouper (greater than 30 cm size) were not common along transects, with only an average of 1.2 animals per $100m^{-2}$ replicate survey. 80% of commercially available grouper were in the smallest size category on the reefs visited during surveys (between 30 and 40 cm), indicating that larger grouper are absent from shallow reefs surveyed.

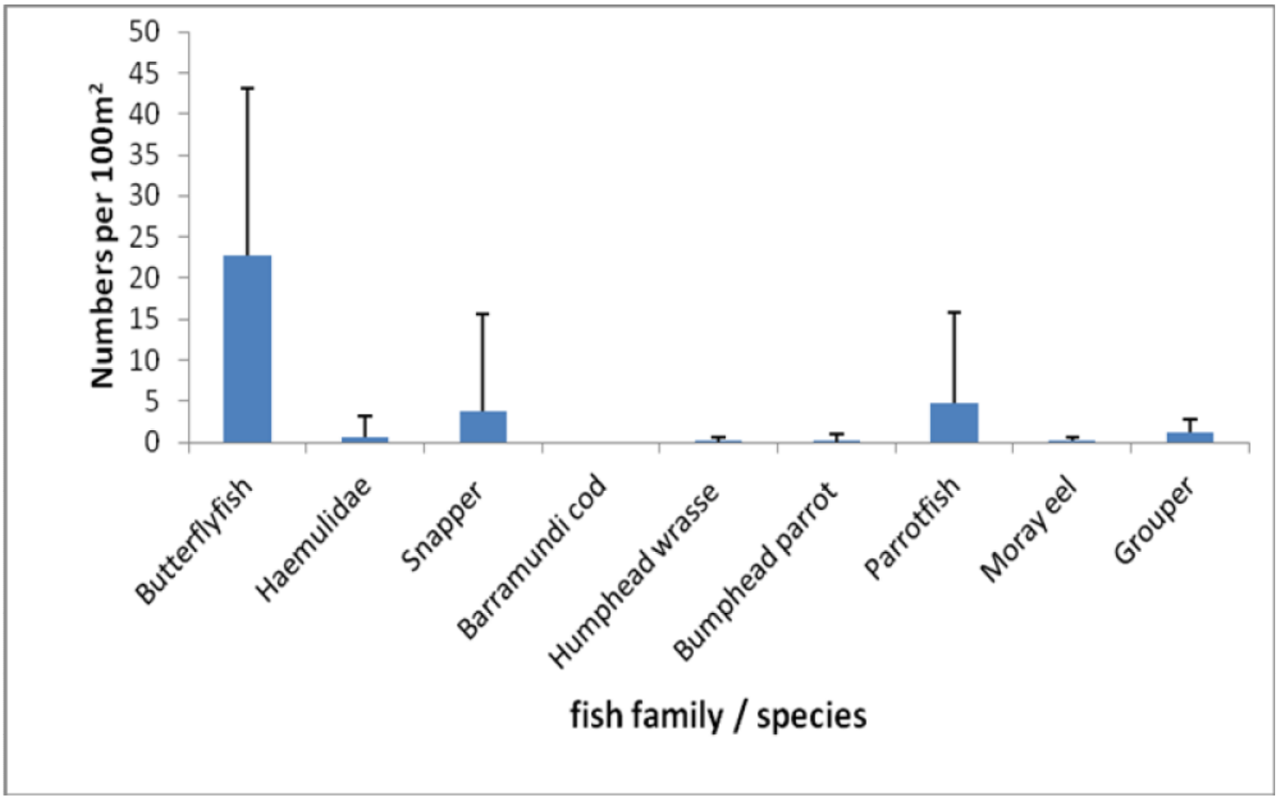

Figure 2.2.2a. Overall fish populations.

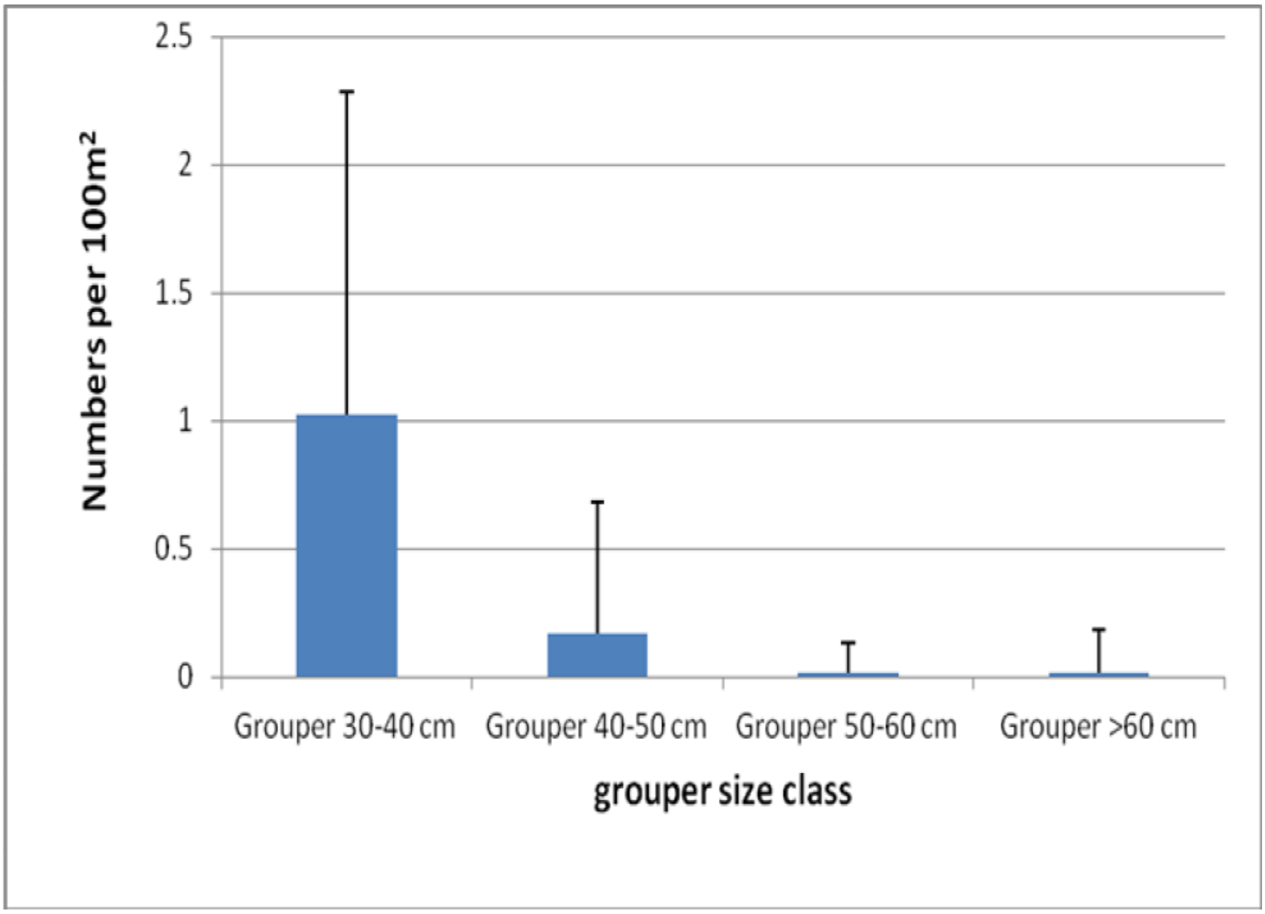

Figure 2.2.2b. Mean grouper numbers per replicate transect and mean size class.

2.2.3. Invertebrate populations

Commercial sea cucumbers and giant clams were dominant amongst the Reef check indicator species. Sea cucumbers recorded by Reef Check are both commercially and ecologically important as they recycle nutrients and capture carbon (by recycling nutrients within sediments) (Figure 2.2.3a). Giant clams are relatively common on surveys, with over one recoded per 100 m-^{2} replicate. The mean size of clams was low (Figure 2.2.3b).

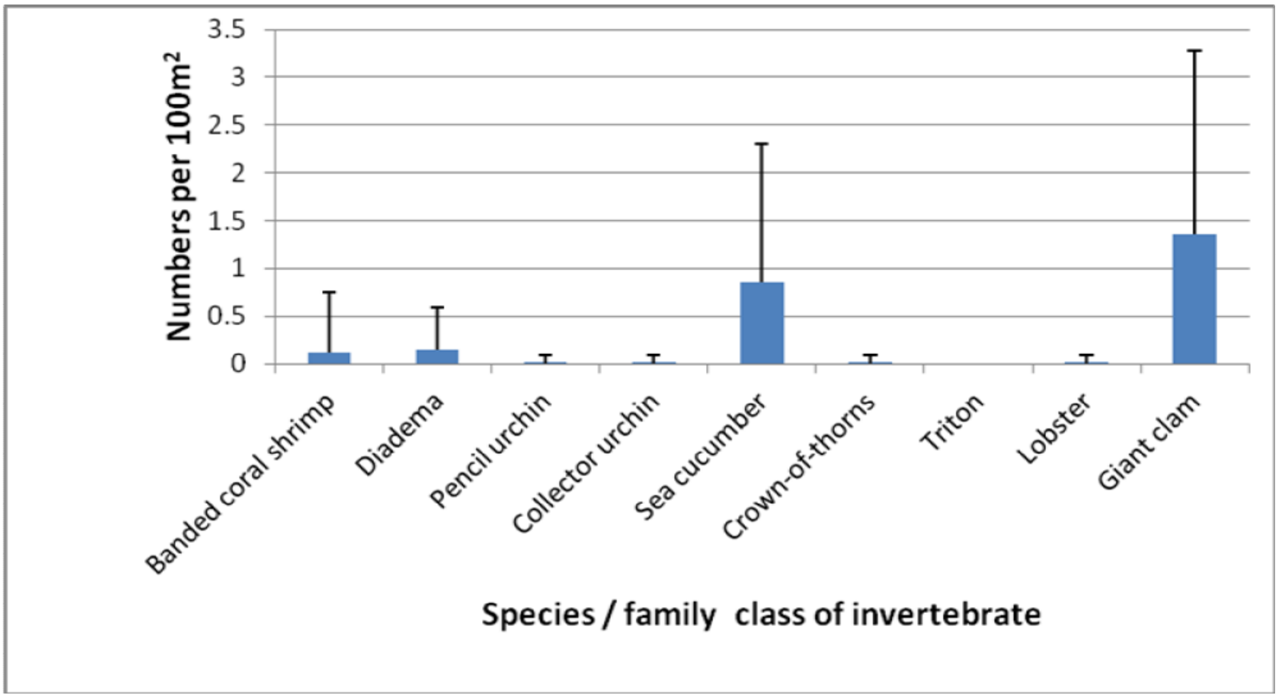

Figure 2.2.3a. Invertebrates recorded.

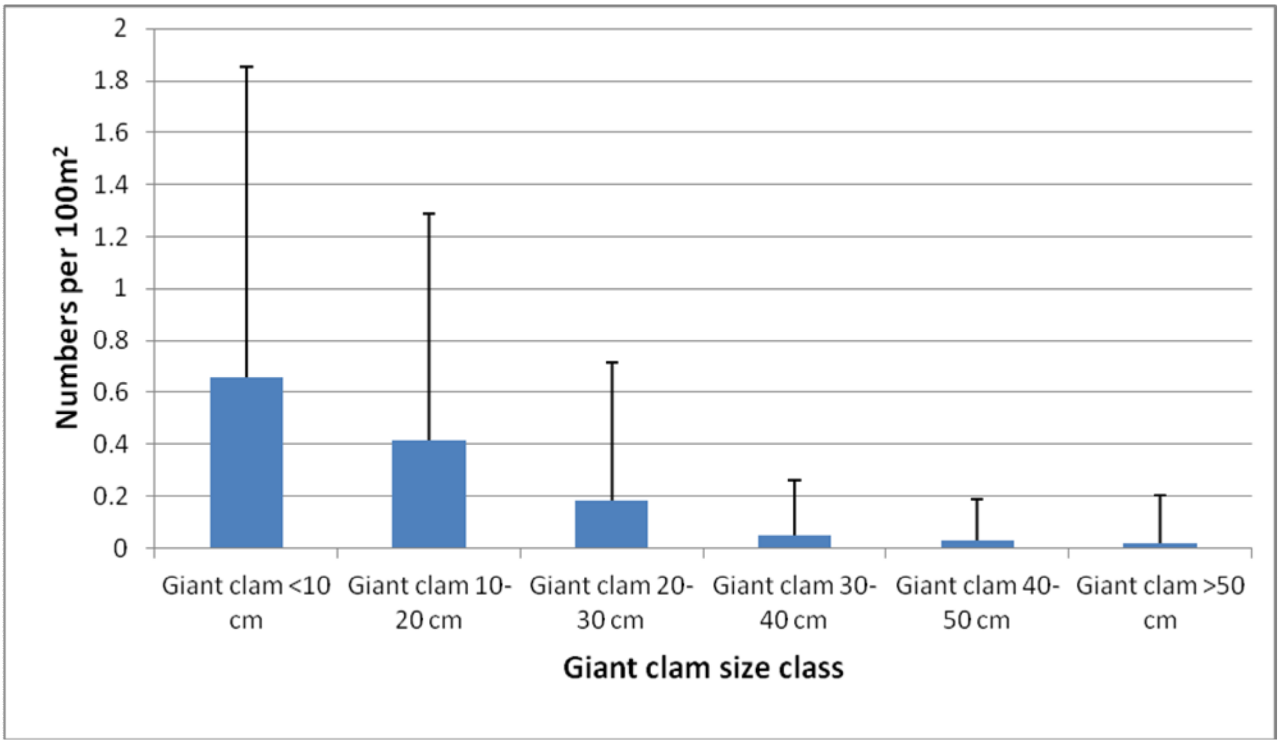

Figure 2.2.3b. Giant clam size classes recorded.

2.2.4. Impacts

The most frequent impacts, as defined by Reef Check, to reefs surveyed were from a form of white-band disease, bleaching (at the level of individual colonies) and predation by the corallivorous *Drupella* sp snail. The latter is probably the most frequently observed cause of mortality to the coral colonies during the surveys. *Drupella* predation appeared to mainly be concentrated on the *Pocilloporidae* family of corals.

It is important to note here that their feeding activities result in white coral patches that look similar to bleached coral. This led to confusion amongst some of the volunteers and some incorrect records of bleaching. Volunteers were reminded to look for the snails when coming across white corals.

Incidents of perceived anchor damage was absent or very rare and dynamite fishing does not occur in the Maldives. The lost fishing gear (trash) records were of line that was entangled in the coral bedrock (fig. 10).

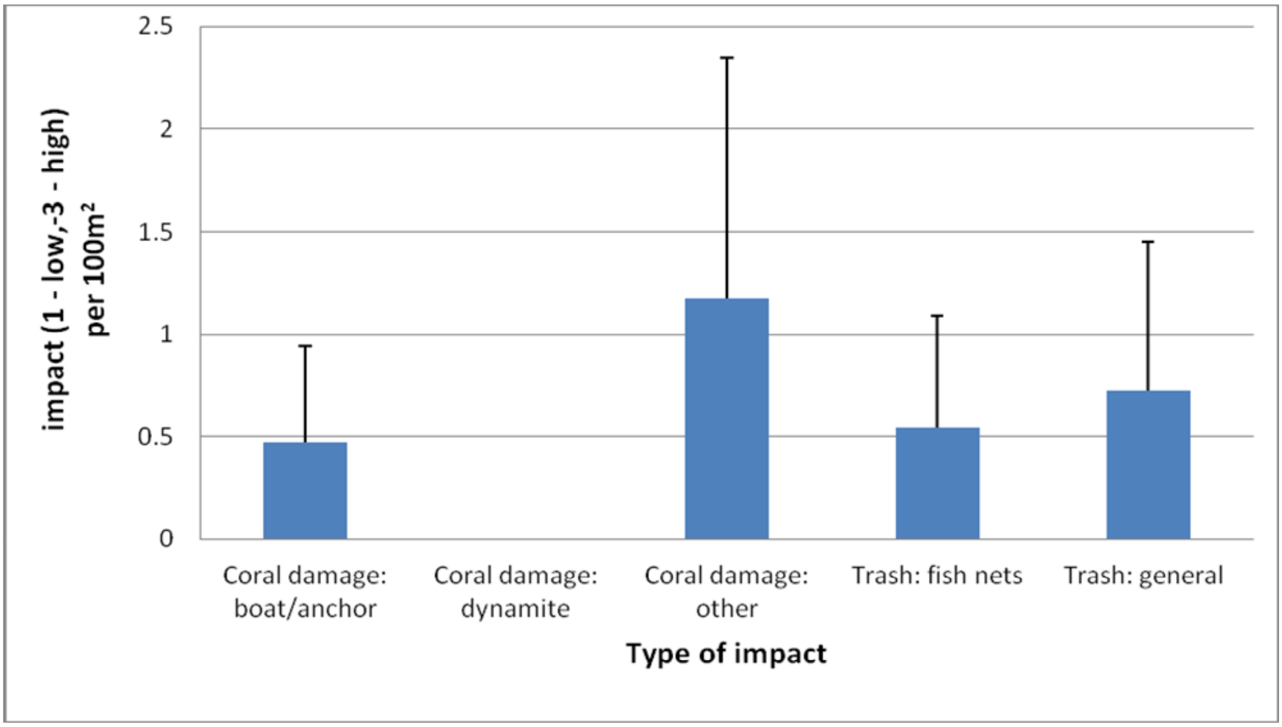

Figure 2.2.4a. Relative level of different impacts on the reef. Coral damage (other) was dominated by *Drupella* corallivorous snail predation.

Bleaching did not occur at a population scale on Maldivian reefs at the time of the surveys. 2.03% of the population of live colonies surveyed were considered to be bleached. Of those colonies that were partially bleached, an average of 57% of the live colony surface of the corals was bleached. On some surveys, 100% of the colony was affected (Figure 2.2.4b).

18% of replicate transects had at least one colony of coral affected by a pathogenic infection *resembling* either white band (more commonly) or black band disease. When disease condition was observed, there was no indication of coral predators near to colonies. This disease condition usually affected table *Acropora* colonies, generally on the shallowest transects (below 6 m).

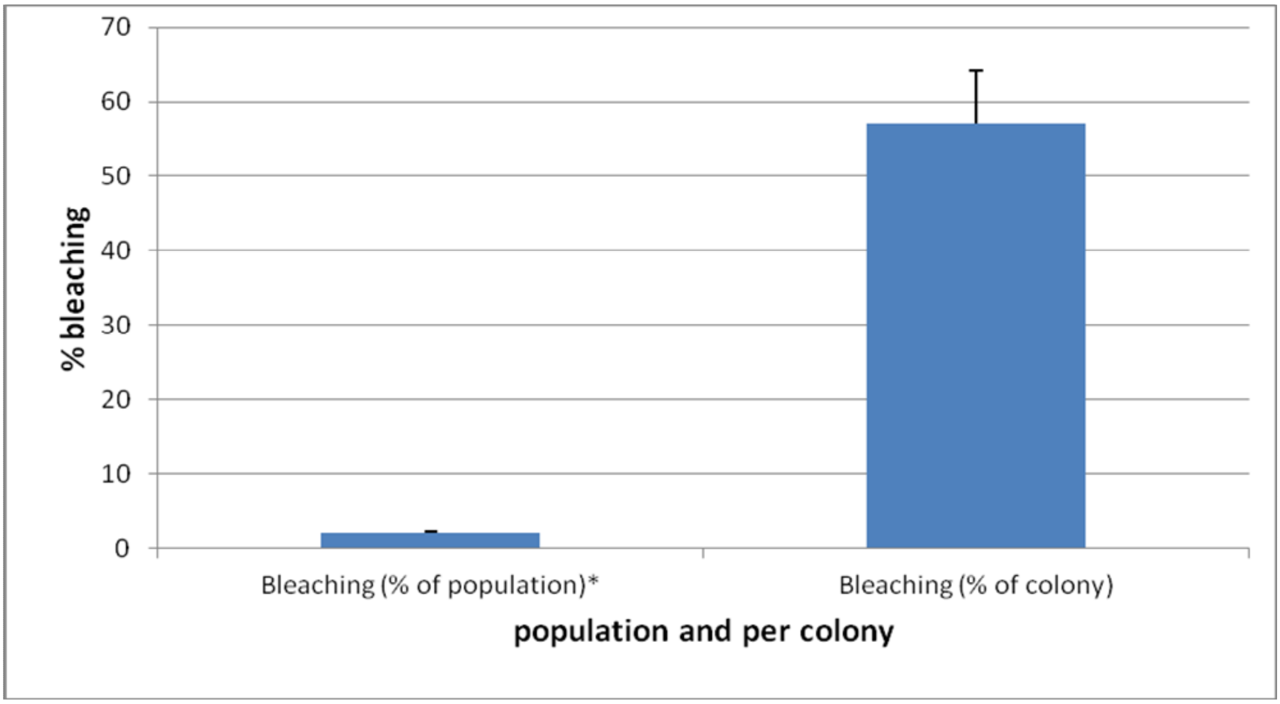

Figure 2.2.4b. Bleaching – mean percentage of both the coral population (left) and by colony (right).

2.2.5. Baros resort data

In October 2010 Baros Maldives was trained to become a Reef Check Centre by the author and surveys were undertaken on the house reef. The house reef was surveyed again in 2011.

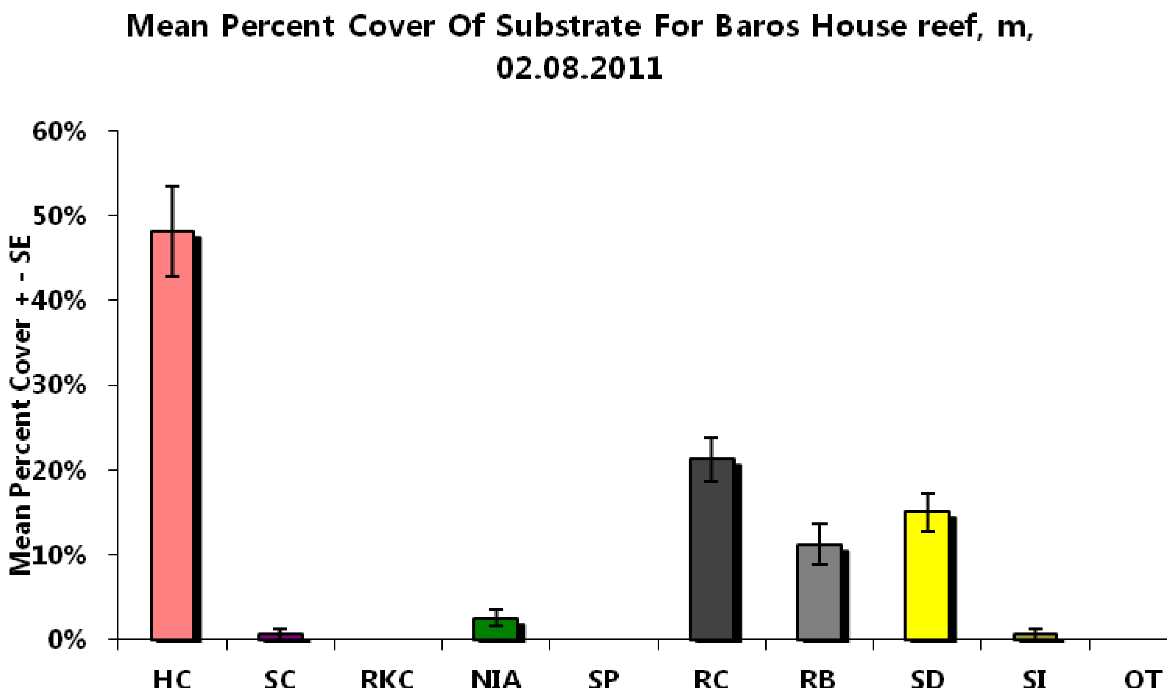

Figure 2.2.5a. Percentage cover of substrate at Baros house reef (North Male' atoll) on 2.8.11. Survey data recorded by Baros staff, Magali Marion and Ronny van Dorp. Transect depth was 8 m. Coral damage was recorded on a few limited number of *Acopora* colonies, principally from *Drupella*.

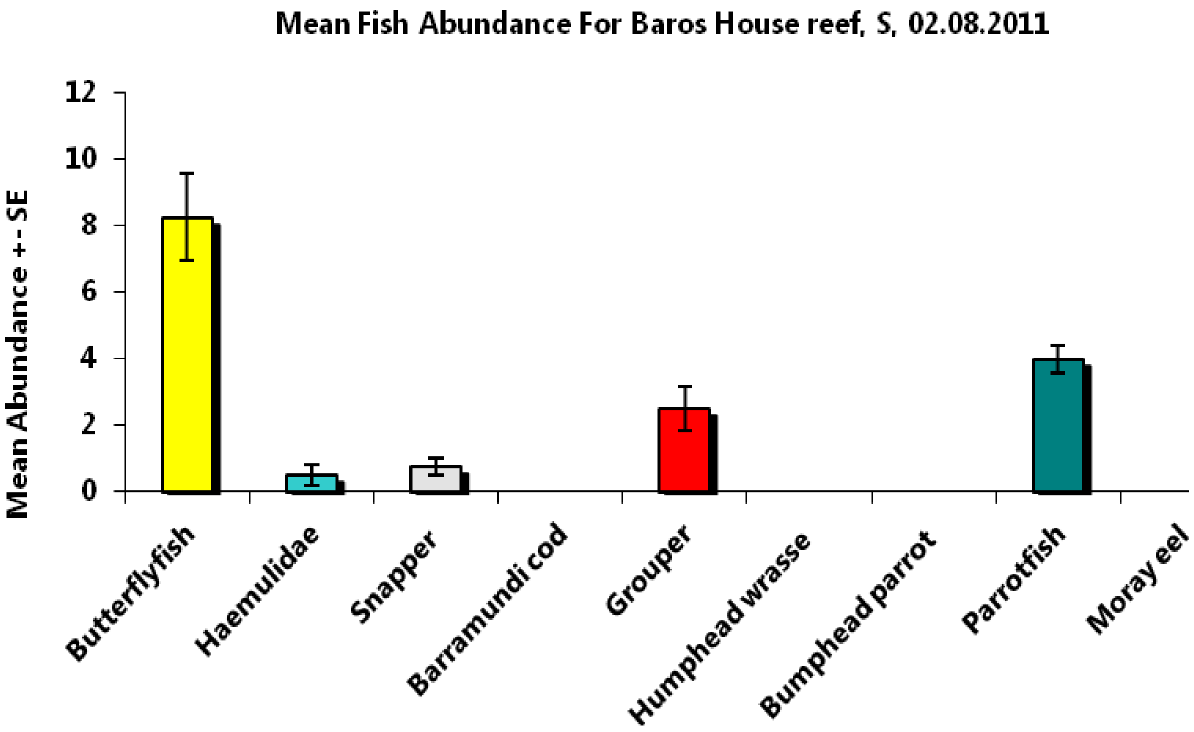

Figure 2.2.5b. Numbers of fish at Baros house reef (North Male' atoll) per 100m2 of reef on 23.3.11. Survey data recorded by Baros staff, Magali Marion and Ronny Van Dorp and Regis Noly. Transect depth was 8 m.

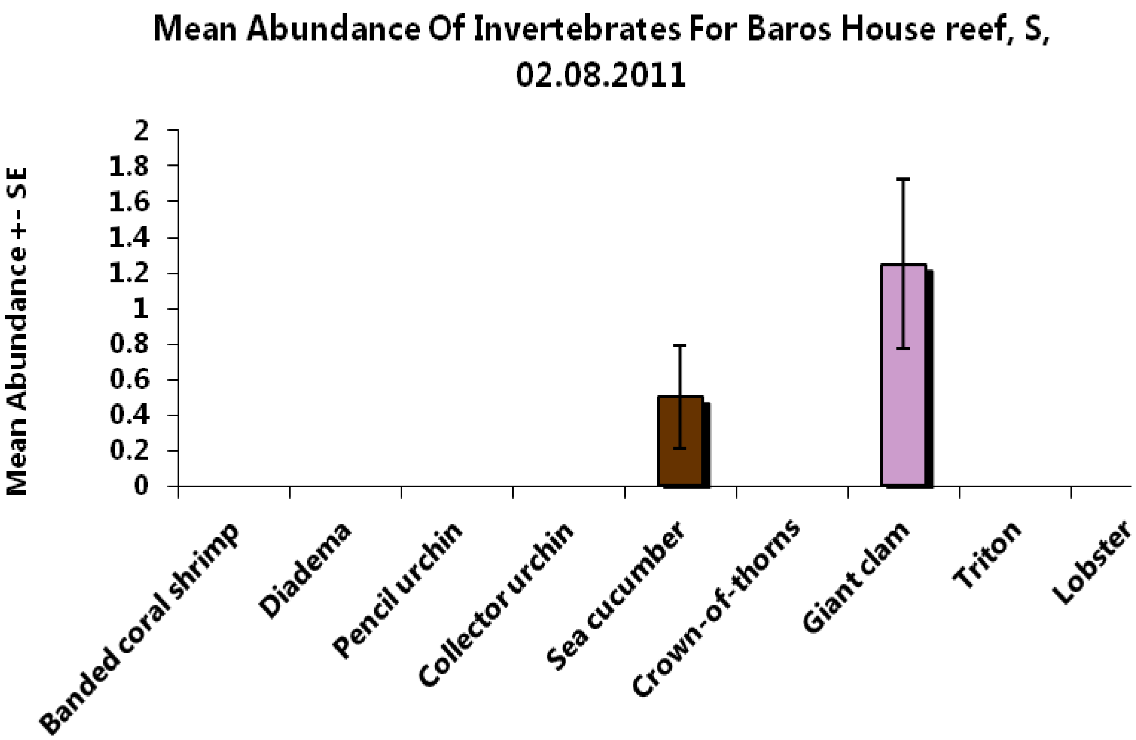

Figure 2.2.5c. Numbers of invertebrates at Baros house reef (North Male' atoll) per 100m2 of reef on 23.3.11. Survey data recorded by Baros staff, Magali Marion and Ronny Van Dorp. Transect depth was 8 m.

2.3. Discussion and conclusions

Central Maldives reefs in 2011 (specifically North Male' and Ari Atolls) appeared to be in similar condition to reefs visited by MCS in 2005. There is little indication that reefs are changing to a significant degree since 1998, although there has clearly been recruitment and growth of a wide range of coral species since the devastating bleaching event at some sites (Solandt et al. 2009). A mean coral cover at all sites from all depths to 15 m of 25% is typical of MCS surveys dating back to 2005, but is an increase from those surveys carried out by the Marine Research Centre scientists reported in the 2005 status assessment of Indian Ocean reefs (Zahir et al. 2005).

Our surveys showed little incidence of impact from coral eating crown-of-thorn starfish (*Acanthaster planci*) though many reefs, including the training reef of Baros, had significant numbers of cushion starfish that eat small and juvenile *Acropora* and *Pocillopora* coral. However, these are not thought to be significant in terms of their impact on the wider coral ecosystem, although they have been reported to outbreak in certain areas in the Southern atolls (Zahir et al. 2010). Surveys did report significant numbers of the corallivorous snail *Drupella* that we consider to be a consistent low-level threat (H. Schumacher, personal observation). Feeding scars from these snails were evident at the vast majority of sites visited, though they tended to be found only on one or two corals per transect. Research by McClanahan (1994) indicates that increased numbers of *Drupella* are seen on reefs where fishing occurs relative to unfished (MPA) sites in Kenya. This suggests that *Drupella* are limited by predation rather than physical, dietary or reproductive factors.

It is clear that there is a low diversity of corals that dominate benthic cover at most sites visited during our surveys in the very shallowest of water. The horizontal shallow surfaces of sheltered thilas are predictably dominated by plating forms of *Acropora* and the more ephemeral branching and digitate species of *Pocilloporidae* and *Acropora* in terms of number of colonies and surface coverage (Risk and Sluka 2000). Large *Porites*, meandrinid, brain and submassive forms (e.g. *Lobophyllia Symphyllia* and *Favia*) are rarer on the shallowest reefs visited in central atolls. As the effects of bleaching on vulnerable species become better understood, it has been observed and predicted by a number of Indian Ocean scientists that reefs are becoming dominated by smaller numbers of families and growth forms (Sheppard 2003). After widescale bleaching events many areas (including the Maldives) have seen the recruitment and recovery of more ephemeral fast-growing species in advance of slower growing massive coral reef taxa. Another prediction by scientists projecting the impacts of climate change is that Indian Ocean reefs will eventually be dominated by taxa and lifeforms that are more tolerant to bleaching (Grimsditch and Salm 2006) and can host zooxanthellae clades that are more resistant to increased temperatures (Carpenter et al. 2008). Is this prognosis a conservation concern for the Maldives? It is not possible to draw definitive conclusions about the current and future health of the entire Maldives reef system after surveying only a small number of sites since 1998. If future bleaching events simplify the coral community to life-forms that are not 'reef-building' in their growth form, then this could be a catastrophic geological turning point for the nation, which will only be realised in the next few decades. Furthermore, if future bleaching events are exacerbated by acidification that has been proven to decrease the calcification and reproductive rate of corals (De'ath *et al*., 2008), then the prognosis for corals of the Maldives and the very nation is not good.

Reef fish populations of the Maldives indicate a trend similar to many coral reef regions of the world, where the biomass of top-predators such as grouper and emperor species is initially fished out to then be replaced by smaller carnivorous species such as snapper and some emperor species. Many central reefs of the Maldives are dominated by these snapper and emperor species and the larger grouper species are absent, or at a very small size, with many recent observations of animals below breeding size (Wood et al. 2011). The larger species of predatory fish are dominated by jack and dogtooth tuna, which are not necessarily associated with the survey sites under normal conditions. Indeed a recent survey of Maldivian reefs in 2008 showed that the reefs are now dominated by planktivorous species, particularly the red-tooth triggerfish *Odonus niger* (Solandt et al, 2009).

Unsurprisingly reefs tend to do better, the further they are from human populated areas (Barrot et al. 2010) and the more stringent the marine protected area designation. For the central atoll lagoons where Biosphere Expeditions and MCS have been operating, there has clearly been a patchy recovery from bleaching impacts and the fish populations of commercial species are low relative to pristine reefs and reefs that have enforced management measures in place. For example, the Great Barrier Reef in Australia has relatively higher densities of coral trout (a common grouper) compared to the Maldives (Russ et al. 2008). Where Maldives densities of ALL larger groupers from our surveys are approximately 12 per 1,000 m^{-2}, densities of a single grouper species - coral trout (*Plectropomus leopardus*) - on the Great Barrier Reef are more commonly recorded at between 10 and 20 fish per $1{,}000m^{-2}$. For six of the eight regions studied on the Great Barrier Reef, populations of this species increased by between 57 and 75% in only 1.5 years (Russ et al. 2008) within no-take zones compared to surrounding fished areas. However, the no-take zones of the Great Barrier Reef are of a vastly greater scale than those of the relatively small Maldivian dive sites and therefore act as significant fisheries recovery areas for the entire Great Barrier Reef, which in turn support surrounding areas by spilling over fish to open access fishing grounds.

Management recommendations

As a precautionary management measure, and to promote the recovery of fish and coral populations, it would be clearly beneficial to increase the number and particularly the size of no-take marine protected areas across the nation (Lester et al. 2009). For the impact of MPAs to be beneficial, it is imperative that in the first instance there is enforcement of protection, coupled with education and liaison with local fishers – as part of the national curriculum and for the fishermen and civil servants – to be shown the positive impact of no-take marine protected areas. A meta-analysis of global no-take marine reserves shows a vast increase (over 400%) in the biomass of previously exploited reef species in response to protection (Lester et al. 2009). No-take zones can therefore be considered as critical management tools for fisheries rather than measures to exclude or disenfranchise fishermen, as they will benefit from spill-over and increased reproductive output from reserves to outside fished areas.

The key findings from scientific papers can sometimes be taken in isolation, however, the studies detailing the effects of climate change, chronic stresses such as overfishing and disease across the tropical reefs of the world indicate some clear trends:

1. Coral reefs are more vulnerable now than at any point during their history.
2. The bleaching event of 1998 has not been resolved by either recruitment or re-growth of colonies affected at that time. Recovery has been patchy.
3. Monitoring must continue in order to determine patterns of recovery from the bleaching event and therefore provide an indication of which reefs are more resilient to the effects of mass mortalities of corals.
4. There is pressure from both internal (tourism) and external markets to increase the tuna (pelagic) and reef fisheries for consumption.
5. Well-managed no-take MPAs are one of the solutions to recovery, as protected reefs increase the size, biomass and number of previously exploited fish species.
6. Minimum and maximum sizes for landings of finfish could stabilise the reef fish population and provide a healthy sustainable fishery into the future.
7. Protecting small fish from capture until they reach breeding size and protecting those larger fish (males and females) that produce more eggs will secure greater recruitment returns to the fishery.
8. Protecting key grouper spawning sites from fishing will allow much higher rates of reproduction and eliminate overfishing of adult males and females at an essential time in their life-history for replenishment of the population.

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3. Whale shark surveys

3.1. Introduction

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

The survey task for this part of the study was to record the number of sharks, size, sex, location date and time. This survey involved constant watches either side of the vessel MV Carpe Diem as she steamed 300 m from the reef crest of Maamigili in a Southwesterly to Westerly direction, then back again (Figure 3.2a).

On 8 September 2011 no sharks were observed during four hours of steaming along this transect. On 15 September 2011 the vessel steamed for two hours and two sharks were detected. After getting into the water, interaction between people (Biosphere Expeditions volunteers and others) and the sharks was observed and recorded (Table 3.2a) and photos of the left (LHS) and right (RHS) gills where taken for later identification purposes by the Maldives Whale Shark Research Programme.

3.2. Results

Table 3.2.a. Whale shark observations at Mamigili on 15.9.11.

	Shark #1 (M1)	Shark # 2 (M2)
Date (and time)	15.9.11 (11:30)	15.9.11 (13:50)
Lat / long	3 28.881 / 72 53.118	3 29.759 / 72 54.287
Depth	10-5 m	1-5 m
Direction of swim	?	Southwest
Length	5 m	3 m
Sex	Male	Male
Behaviour	Surfacing, then diving	Surface surrounded by snorkellers and divers, swimming gently at first
Photo	Yes, RHS	RHS and LHS
Vessels present	6 ‘boats’, 3 dhonis	6 ‘boats’, 2 dhonis, 3 dinghies
Whale Shark Research Programme name (first recorded)	WS036. ‘Duncan’ (2007)	WS 163. ‘Jean-Luc’. (2011).
Snorkellers’ behaviour	Not recorded	6 snorkellers within 1 m either side of shark & many more behind. One on top of shark (despite receiving code of conduct briefing) who then touched the shark. Overall one diver and 2 snorkellers touched shark. Dhoni crew of 'Sunset Dream' reprimanded diver. Crew of MV Carpe Diem cancelled further shark surveys after seeing the shark touched by expedition participants. Total number of people in 20 minutes with the shark was about 35 snorkellers and 10 divers.

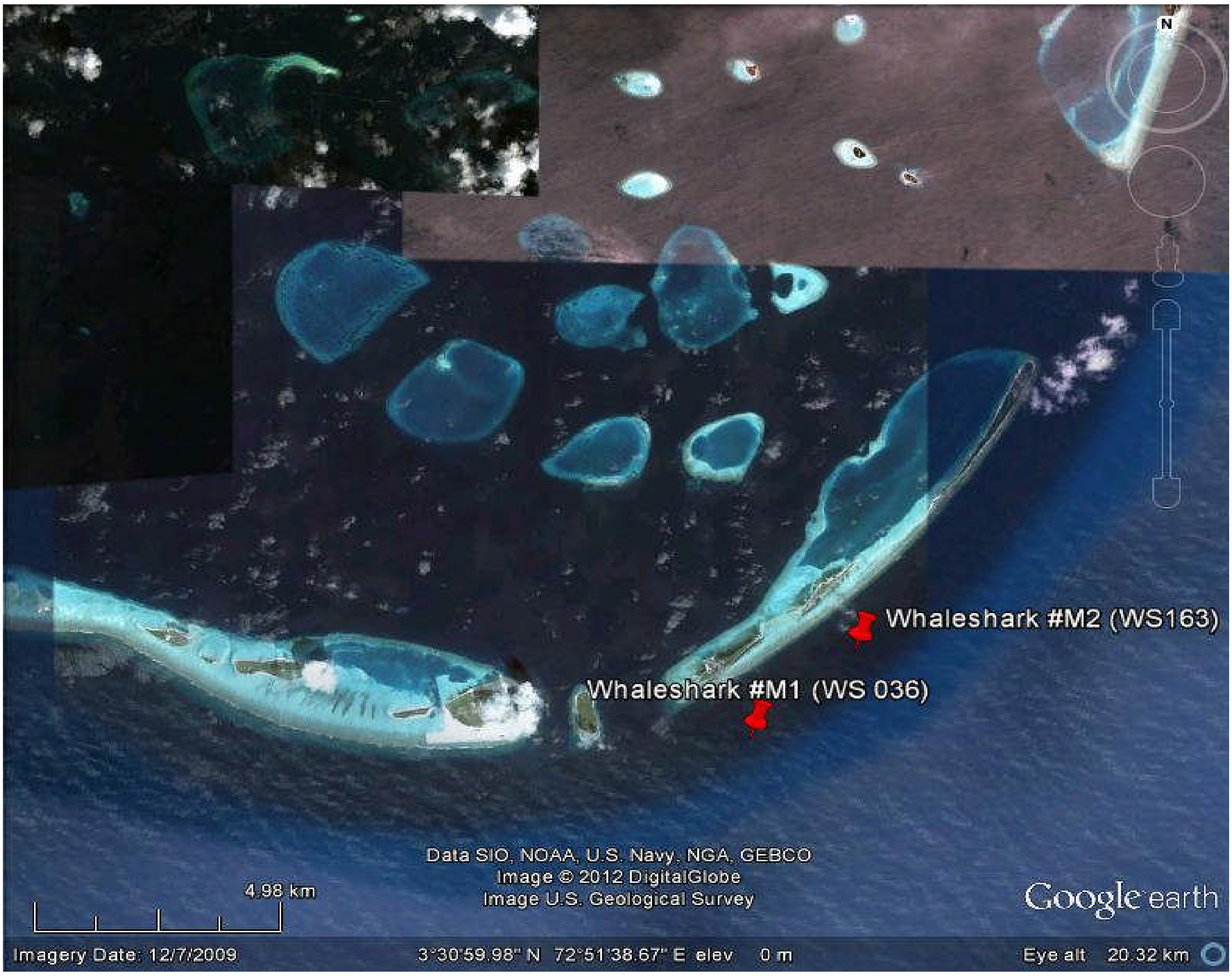

Figure 3.2a. Location of two whale sharks sightings by the expedition on 15.9.11.

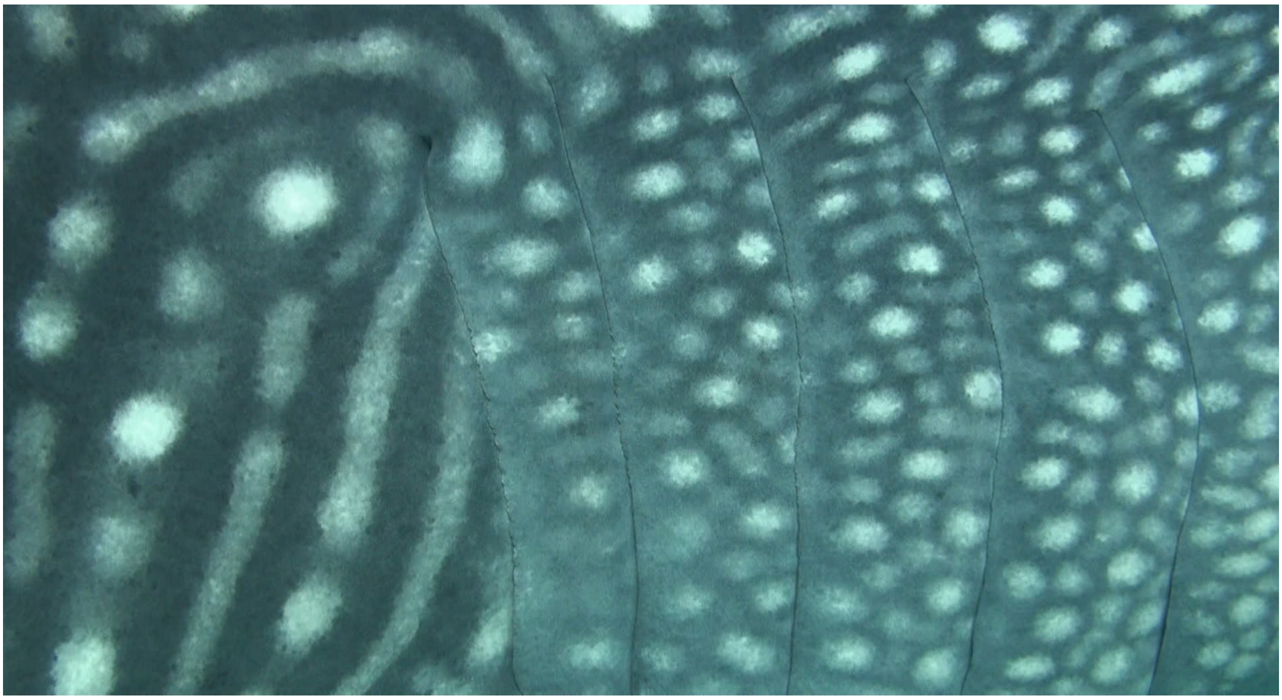

Figure 3.2b. RHS of whale shark M2. Photos such as this were used by the Maldives Whale Shark Research Programme to identify individual sharks.

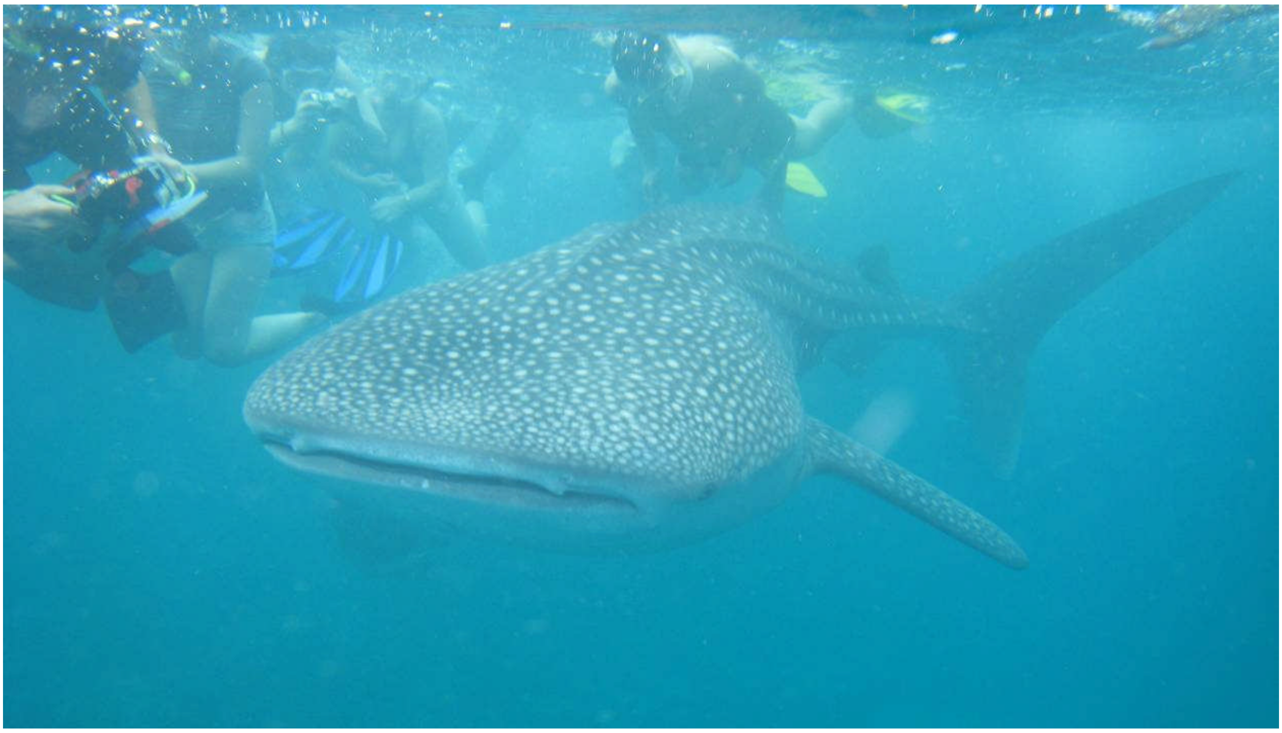

Figure 3.2c. Whale shark M2 (WS163) surrounded by snorkellers from Biosphere Expeditions. Two divers from the expedition touched this juvenile shark and were subsequently banned from the last dive of the expedition.

3.3. Conclusions

The Maamigili site (42 km^2) in Ari Atoll was designated a marine reserve in September 2010. However, it is completely unmanaged and unregulated. The potential effect of ship strike to the sharks and diver harassment is clear from our own observations, as well as the photographic records of damaged fins and dorsal surfaces of sharks by Norman, (1999).

Regulation and patrols are needed to ensure that the Maamigilii whale shark site is heavily regulated to ensure that only one vessel can interact with any one whale shark at any time. Furthermore, a code of conduct should be made legal (in terms of harassment of sharks) to provide the necessary means for local boat operators and tourist resorts to have their guests fined as a deterrent.

The whale shark and manta ray tourist operations at Coral Bay, Ningaloo Reef in Western Australia experienced by one of the authors can serve as a model of how a sustainable income can be derived from a natural spectacle without harming the wildlife that provides the spectacle.

3.4. References

Norman, B.M. (1999) Aspects of the biology and ecotourism industry of the whale shark *Rhincodon typus* in North-Western Australia. M.Phil. Thesis (Murdoch University, Western Australia).

Appendix I: Expedition diary

29 July

Welcome to the first entry of the diary for our brand-new Maldives coral reef & whale shark expedition. I am Dr. Matthias Hammer, founder & executive director of Biosphere Expeditions and I will also be your expedition leader on this new expedition.

I have put a short welcome message on our Facebook page www.facebook.com/biosphere.expeditions1 (you do not need to have a Facebook account to see the diary updates - just click on the link and then go to the "Wall"). As you can see on there, I am a week ahead of you all, the weather is predictably beautiful, as are the islands. The water temperature is a balmy 29ºC and the fish and corals are there – at least in the few places I have dived in over the last couple of days ;)

We've already made a big impact over here with the forthcoming press conference and launch of the reef educational booklet, the scholarship places, etc. (see http://www.biosphere-expeditions.org/biosphere-expeditions-and-six-senses-offer-maldivians-chance-to-partake-in-coral-reef-conserv.html) for details, so lots of people will be following our work. This we can all be very proud of, but we'll also all be ambassadors for participatory conservation or citizen science or whatever label you want to put on it. So let's all enjoy our time in this amazing place and collect lots of good and useful data for Jean-Luc and our very welcoming and hospitable Maldivian hosts!

My mobile number on the Maldives is +960 7570825. Remember that this phone number is for emergency communication only (such as being late for assembly). I am overlooking a white beach, azure sea and a beautiful sunset as I write this and I look forward to you joining me over here soon.

Safe travels

Matthias

30 August

In preparation for our expedition, I am currently at Soneva Fushi, a swish resort by Six Senses, who is kindly supporting our work. Part of the deal with them is that we train the resort to become a Reef Check Centre and today we went for our first Reef Check practice dive on their house reef in Baa atoll. You can see some pictures and a video of the dive at www.facebook.com/biosphere.expeditions1 (a copy of the video is also at www.youtube.com/watch?v=pPdYNrReAFU). It should give you an idea of what a Reef Check dive looks like.

1 September

I have just finished training a Reef Check team at Soneva Fushi. Group 1 of our expedition is next! Tomorrow I will take the sea plane to Male' to set up the Carpe Diem and run around like a headless chicken trying to get everything ready in time. Attached is the draft day-to-day schedule, subject to approval by our expedition scientist (who also arrives tomorrow) and just in case you were under the impression you are coming to the Maldives for a nice holiday ;)

I am a great believer in that you get as much out as you put in, and this is your project as much as it is ours, so group 1, please bear with us as we try to hit the groove on this trailblazing first-ever Biosphere Expeditions Maldives project. I am sure there will be teething problems as we sort out the details of our expedition, but I am sure we'll also have a lot of fun in between all the classroom sessions ;) - Safe travels & I'll see you before the press conference on Saturday, group 1.

4 September

Our first-ever Maldives expedition kicked off with the press conference launching our educational booklet (see http://www.biosphere-expeditions.org/images/stories/pdfs/education/Maldives%20educational%20booklet.pdf) to the press & the Maldives. Ibrahim Ismail, Deputy Minister of Education, came to the conference and officially accepted the booklet on behalf of the Maldivian government. He also had many kind things to say about the booklet, the expedition and the participants, thanking everyone for their enthusiam and efforts. (The picture shows from left to right: Angel Shujau, the person who illustrated the book; Matthias Hammer, Biosphere Expeditions founder & executive director; Kate Wilson, marine biologist from Suneva Fushi by Six Senses who drafted the text; Jean-Luc Solandt, expedition scientist from the Marine Conservation Society and Reef Check co-ordinator for the Maldives; Ibrahim Ismail, Deputy Minister of Education).

From there group 1 went onto our liveboard base and straight into Reef Check training, swapping classroom with dives sessions, learning Reef Check's indicator fish, invertebrates and substrates. As I type this, everyone is busy swatting up for the fish ID test after dinner tonight. Wish them luck!

6 September

Our Reef Check training is done and everyone is now qualified to collect data. So out (or down) we went yesterday to do our first real Reef Check surveys at three depths (4 m, 8 m, 12 m). It all went well and after dark we threw in a fun night dive. As I type this, we are steaming over to Ari atoll, where we will get into some serious Reef Checking and later in the week visiting a whale shark hotspot in the hope of collecting some data on these too.

7 September

We've had some great Reef Check dives, one with a wipping current (not so great) but with a manta ray sailing by gracefully in the current. We've also come across black- and white-tip reef sharks, a nurse shark, plenty of turtles and dive sites with a stunning 100% hard coral coverage. There's also a 05.30 yoga class on the sun deck each day, but alas only for this week as the yogi is leaving ;) If that's a bit too early, you can get a 30 minute lie-in, ready for the first Reef Check dive.

We've really hit the groove and the team look like they've done nothing but Reef Check for a while. Well done everyone.

Last night we watched the sunset from a little uninhabited island, fringed by silky soft white sand. The hard life of a marine biologist!

Oh, and check out some press coverage as a result of our press coverage at http://minivannews.com/environment/volunteer-team-collecting-data-to-protect-maldives-reef-ecosystems-24971/print/.

9 September

The whale sharks eluded us yesterday as we were cruising up and down South Ari atoll for hours yesterday, so no data to add for us on that score. But lots of data to add to our Reef Check database with another stunning reef dive in the morning and a consolatory twiglight dive in the late afternoon with J-L, Jenn, Riz, Conny, Kate & Sue showing total commitment by insisting to collect more data on what was originally billed as a last fun dive.

This brings our trailblazing slot to an end. I type this as we steam back to Male' for the changeover. J-L has just given us an excellent presentation putting all our work into context and enlightening us further, as he has done all week, on coral reef biology. Thank you for all your hard work - sorry we couldn't top it with whale sharks, but's that's nature, which is what we're all here for.

Safe travels, trailblazers. Don't forget to share your pictures via www.biosphere-expeditions.org/pictureshare. See you tomorrow, slot 2!

11 September

Team 2 arrived safely, but with it a spell of bad weather. The ride from Male' to our liveaboard was very choppy, the skies were overcast and it was gray and rainy. This has not changed for the last couple of days and weather fronts like this usally last 2-3 days.

Our first training dive was at beautiful Baros again and this morning we made the crossing over to Rasdhoo atoll. At the end of a bumpy ride we were rewared by the best dive yet. You name it, Rasdhoo had it - HC, RKC, SC, SP, NIA (for those in the know) sharks, rays, humphead wrasse, great fish diversity and beautiful coral gardens.

We're halfway through the Reef Check training, hopefully through the worst of the weather and in celebratory mood. Happy brithday Alan!

14 September

The weather has been pretty horrible with thick clouds, rain and high wind at times. We even had to call one dive off, because of the wind & waves. Unperturbed by this, the team all passed their tests and are now qualified Indo-Pacific EcoDivers. With the qualifications under our belts, we have gone into Reef Check mode ticking sites off first in Rashdoo and now in North Ari atoll. On the way back from one of the Reef Check dives we came across two manta rays and spent some time with them. We've also thrown in a fun twilight dive.

We're making our way towards South Ari and the whale shark site now, surveying as we move south. Tomorrow will be our whale shark survey day - wish us luck (and better weather!).

15 September

Good luck on all fronts: really good Reef Check dives, great fun dives, the weather has broken with a great sunset a couple of hours ago, and most of all, we came across two whale sharks (one male, 5 m; one female, 3 m) today on our whale shark research day!

This brings to an end a great first expedition to the Maldives. All that remains tomorrow is to go full steam to Male', give a few interviews to a Maldives TV film crew that is awaiting our return and declare the 2011 coral reef and whale shark expedition officially closed & a success. Thank you to all of you who have made this happen, and thank you to the two teams for your enthusiasm and making it all come true. Safe travels home and we will hopefully see you again, some day, somewhere on another expedition.

Matthias

P.S. I have uploaded lots of pictures to www.facebook.com/media/set/?set=a.10150277999424472.337681.132594724471 and will also share some on our "pictureshare" site in due course. Please do this too via www.biosphere-expeditions.org/pictureshare.

P.P.S. Thank you for the picture Wendy.

20 September

Some news just in from the Maldives Whale Shark Research Programme (MWSRP):

"We have managed to ID the photograph of one of the sharks you sent me. It is WS036 Duncan. He has been spotted since 2007 and is a regular on the reef. He was also one of the sharks we satellite-tagged back in 2008. He made a considerable round trip to the Laccadives off India and back to South Ari in under 3 weeks."