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EXPEDITION REPORT

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Authors:

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

Matthias Hammer (editor)
Biosphere Expeditions

Abstract

In 2018 Biosphere Expeditions ran its eighth annual Reef Check survey expedition to the Maldives since 2011. One week of surveys was carried out in July 2018 by local and international citizen scientists and a professional reef biologist in Ari atoll, the Maldives. Surveys using the Reef Check methodology were undertaken at three 'inner' and three 'outer' atoll sites and concentrated on re-visiting permanent monitoring sites that have been surveyed since 2011. Most of the locations surveyed in 2016 and 2017 were revisited to record medium-term impacts of the severe El Niño bleaching event in May 2016.

Coral cover for all North Ari sites varied between 39% and 0% with a mean of 15% live hard coral cover. Inner Ari atoll reefs (mean 2% cover) were found to be more severely bleached than the outer reef sites (mean 27%). This mirrors last year's data. Some inner reefs (e.g. Kudafalhu), which had been affected by coral-damaging storms in 2015, and by crown-of-thorns and bleaching in 2016, had extremely low coral cover (under 1%). A further inner reef site that was newly surveyed (Theluveligaa), had zero coral cover, with the habitat dominated by *Padina commersonii* (macroalgae) overgrowing branching corals, and even colonising sandflats in the inner lagoon of the site.

There were few large grouper and snapper present at all sites. The outer reefs, where many *Porites* and other massive colonies persist, appear to show higher survival (resistance) and recruitment/recovery patterns (resilience) to bleaching. Recruitment of juvenile corals (<10 cm in diameter) appears to be occurring at the shallowest depths, on dead table corals, in inner sheltered reefs and also on reef flats, dominated by anastomosed dead table corals, where coralline algae has already solidified the dead coral matrix. Recruitment of year 1 (<10 cm), and year 2 (<20 cm) corals appears to be higher on outer reefs facing deep water (such as at Dhigurah). These reefs are adjacent to oceanic waters and have substrata clear of turf and blue-green algae at shallower depths (>3 m).

Low parrotfish and surgeonfish densities and grazing at Kudafalhu and Thulivadelu indicate that the algal complex may now be too advanced (macrophytes with secondary metabolites and structural resistance to grazing) to be preferentially grazed by herbivorous fish. A corallimorph-dominated benthos remains at Dega Thila, which will be unlikely to recover to the rich coral community that persisted in shallow waters before 2016.

Our surveys indicate bleaching-resistance in the *Porites*-dominated forereefs adjacent to deep water outer reef sites. By contrast, we see limited opportunity for coral recovery on the very shallowest inner reef flats (<3 m depth), due to the heavy presence of corallimorphs, sponges, turfs and macroalgae.

A half-day effort-based whale shark survey was also carried out at the outer reef of South Ari Marine Protected Area on 26 July 2018. At 11:50 (after a 2.5 hour transect of Dhigurah reef), a 3.5 m male shark was observed in approximately 15 m of water, rising to the surface. The encounter lasted approximately four minutes. This animal had first been identified and recorded by the local Whale Shark Research Programme on 20 January 2018 through gill area analysis.

Currently the coral reefs of the Maldives are being 'loved to death' by foreign investment and tourism and short-sighted exploitative, anti-environmental and anti-social practices of the past government. The recent change in government (September 2018), preceded by the outgoing administration's announcement of three new Marine Protected Areas (MPAs) has provided hope that the environment may be considered in future planning decisions. We hope that the creation (in particular) of the Rasdhoo Madivaru MPA, where fish and coral health have been monitored for over a decade, will precipitate protection measures so that reefs, and with it the health of the nation as a whole, can start to recover. The dire situation of the past can improve, but only if the new administration delivers some of the profits (largely from tourism) into public services and proper environmental protection and thus safeguards the resources that generated these profits in the first place.

ޚުލާޞާކޮށް

ބަޔޮސްފިއަރ އެކްސްޕެޑިޝަންސްގެ ފަރާތުން 2011ވަނަ އަހަރުން ފެށިގެން ރާއްޖޭގައި ކުރިއަށް ގެންދާ އަހަރީ ރީފްޗެކް ސާރވޭތަކުގެ 8ވަނަ ސާރވޭ އެކްސްޕެޑިޝަން 2018 ވަނައަހަރު ވެސް ކުރިއަށް ގެންދެވުނެވެ. ދިވެހި އަދި ބޭރު ސިޓިޒަން ސައިންޓިސްޓުން އަދި ރީފް ޗެކް ޓްރޭނަރ ސްޕެޝަލިސްޓުންނާ ގުޅިގެން ދިރިއުޅުމުގައި މިސާރވޭ 01 ހަފްތާގެ މުއްދަތެއްގައި ކުރިއަށްގެންދިޔައެވެ. މިސާރވޭތައް ކުރިއަށް ގެންދިޔުމުގައި އަތޮޅުގެ 3 ސަރަހައްދުތަކުގައި، އަތޮޅު ބޮޑުން 3 ސަރަހައްދުގައެވެ. ރީފް ޗެކް މެތަޑޮލޮޖީ ބޭނުންކުރުމުގެ ކުރިން ރީފް ސާރވޭ ކުރިއަށް ގެންދިޔުމުން 2011 އިން ފެށިގެން ރީފް ސާރވޭކުރުމުގެ އެކިއެކި ސަރަހައްދުތަކަށެވެ. 2016 ވަނައަހަރު އަލް ނީނޯގެ ސަބަބުން ދިމާވި ކޯރަލް ބްލީޗިންގ ހާދިސާގެ ހާލަތު ދެނެގަތުމުގެ ގޮތުން 2016 އަދި 2017 ވަނަ އަހަރު ރީފް ސާރވޭކުރުމުގެ ބެސް ސަރަހައްދުތައް 2018 ވަނައަހަރުވެސް ރީފް ސާރވޭކުރެވުނެވެ.

އަދި އަތޮޅު އެކިއެކި ރީފްތަކުގައި ރީފް ސާރވޭކުރުމުގެ ސަރަހައްދުތަކުގައި ދިރުމުގެ ނިސްބަތް 0% އާއި 39% (އެވްރެޖްކޮށް 15%) އާއި ދެމެދުއެވެ. މިގޮތުން އަތޮޅުބޮޑުން ދިރިއުޅޭ ކޯރަލް ސަރަހައްދުތަކުގެ (ދިރުމުގެ ނިސްބަތް: 27%) އެވްރެޖުގައި ދިރިއުޅޭ ކޯރަލް ސަރަހައްދުތަކުގައި (ދިރިހުރި ހަލާކުވުމުގެ ނިސްބަތް: 2%) ގޮތުގައި މިއުސޫލު ބަދަލުވާން ފެށީ ކޯރަލްތަކެވެ. މިއީ މިދިޔަ އަހަރުގެ ދިރިއުޅޭ ނިސްބަތާ ދާދި އެއްގޮތް ނިސްބަތެކެވެ. އެވްރެޖުގައި ގޮތްތަކުގެ ބޮޑުއިން މިގެ ކުރިން ގޮތުގައި ސަބަބުތަކުގެ ސަބަބުން، ކޯރަލް އާލާވުމުގެ ސަބަބުން އަދި ބްލީޗިންގ ދެވަނަ އަރާފައިވާ ފެހިފަތްތަކުގައި (މިސާލަކަށް ކޮރަލް) ދިރޭ ކޯރަލްގެ މިންވަރު ވަރަށް ދަށްކަމަށް ފެންނަތީވެ (1% އަށްވުރެ ދަށް). މިގެ އިތުރުން މިއަހަރު އަލުން ރީފް ސާރވޭކުރުމުގެ ސަރަހައްދުތަކުގައި ބިފޯރ ގަޑީގައި ދިރިއުޅޭ އެއްބަސް ވަރަށް ނަންބަރު ފާހަގަ ކުރެވުނެވެ. އެސަރަހައްދުގައިވެސް މުޅި އެއްގޮތް ބޮޑެތިކޮށް "ޕިލާރ ކޯރަލް ސްޕީ" އާއި އެސަރަހައްދުގައި މުރާފައިވާ މުރަކަތައް މަދު އަދި ފެހި ބްލީޗިންގއާ ބިލެއްގެ މަތިގައި އެކި ފޮރުވަމުވެއެވެ.

ރީފް ސާރވޭތައް ހެދުމަށް ސަރަހައްދުތަކުގެ ކަނޑު ސައިޒުގެ ފާނަ އަދި ރަތްމަސް އާއިލާގެ ބާވަތްތައް ފެންނާ މަދު އަދަދުތަކެވެ. "ފޯރިޕިޝް" ފަދަ ބޮޑެތި ގޮތުގެ ބާވަތްތައް އެމެދުވުމާއި ފެހިތަކަށް ގުޅިފައިވާ އަސަރުކޮށްފައިވާ މިންވަރު ކުޅަދާނަކަމެއް ނުވަތަ އާބާދީއަށް ބަދަލުތަކަށް ފާހަގަ ކުރެވުނެވެ. އެވްރެޖުގައި ބިލް ރަސްބޮޑުތަކުގެ ހަމައެކަނި ބޮޑުވުމާއި ފެހިތަކުގެ މަދުވުމާއި ހަމަ މިގޮތުގައި ކުރިމަތިކަމަށް (10ސމ. އަށްވުރެ ކުދި ގޮއްޗެހިގެ) އާދައިން އާލާވަނީ ފެހި ކުރެވިއްޖެއެވެ. މިގެ އިތުރުން ބޮޑު ކުރީގެ މުރަކައިން ސަރަހައްދުތަކުގައި ކުރެއިން އާލާވި ހަމަވާމާ ރީފް ފެހިތަކަށް މިލިއަނުވެސް މުރަކާ އާލާވުމާ ފާހަގަ ކުރެވުނެވެ. ދިގުކަން ފަދަ ބޮޑުބަލިތަކުގައި އަތޮޅުގެ ބޮޑުކަމުގެ ހަތި ފެހިތަކުގައި 1 އަހަރުގެ (10ސމ.) އަދި 2 އަހަރުގެ (20ސމ.) ގެ މުރަކާ އާލާވުމަށް މިލިއަނަށް ފެށުނެވެ. މިފަދަ ހާލަތުގައި ބޮޑުކުރިކޮޅުތަކުގެ އަނބު ފެހިތަކުގެ، އެސަރަހައްދުގައި 3މ. އަށްވުރެ ފެންހިސާބުތަކުގައި އެކަމުގެ ބާވަތްތައް މަދުވެ.

ކުޅަދު އަދި ބިލިވެގެންނުން ފެނުން ވަރަށް އަދި ކަނޑުގެ ވައްތަރުތަކުގެ ފެނުން މިންވަރު މަދުކަމުން ދެވަނަ އެސަރަހައްދުތަކުގައި މިފަދަ އާބާދީއާ އެއްގޮތް ކޯރަލް ކުޅަދާނަ ވެސް މިބާވަތްތަކުގެ މަސް ކާބާވަތްތަކުގެ ފެހިގެ ވައްތަރުތަކުގެ ބިލުމުތަކާ ބާވަތްތަކުގެ މައްޗަށް ބިލިގަތުމާކަމެވެ. ގޮވެއްލުން އަދިވެސް ފެންނަނީ ކުރިމަތިލާގެ ވައްތަރުތަކުގެ މައްޗަށް ބިލުގަތުމާ ސަރަހައްދުތަކެވެ. މިސަރަހައްދުގައި 2016ގެ ކުރިން އާތޮ ފެހިގެ މުއްސަނދިކަން އަދުން ދިއައިސްކަމުގެ ސަރުކާރު.

މިރީފްތަކުން ދައްކާގޮތުގައި ފެންކަނޑައިގަނޑުގެ ފިޔައިޕިސް (ހިރި) އާއިލާގެ މުރަކައިގެ ބާވަތްތައް ގިނަ ބޮޑުފެހިކަން ގޮތުގައި ބެލިން ރައްކާތެރިވުމުގެ ބޭނުމެވެ. މިއާ ހިލާފަށް އަތޮޅުބޮޑު ބިލު ފެހިތަކުގައި (3މ. އަށްވުރެ ބިލު) ގޮތުގައިގެބެލިން ރައްކާތެރިވުމުގެ ބޭނު މާދަރުވެ. އެއީ މިސަރަހައްދުތަކުގައި މުރަކައިގެ ކުރިމަތިލެވި އަދި ސްޓާރފިޝްގެ ބާވަތްތައް ގިނަވެފައިވެ.

މިގޮ އިތުރުން 26 ޖުލައި 2018ގައި، "ސައުތު އަރި މަރިން ޕްރޮޓެކްޓެޑް އޭރިއާ" އިން ފެށިގެން ފެންނަ މިނިވަނ ބޮޑުވުމުގެ ގޮތުން ބައިދުވަހުގެ އެފަރާތް-ބޯސްޓް ދިރާސާއެއްވެސް ކުރެވުނެވެ. މިދިރާސާއިން 3.5މ ގެ ފިޔަވަން 01 ފަހަރު، ގާތްގަނޑަކަށް 15މ ފެންމިނުން މަތިންނަށް އަރަނިކޮށް ފެނުނެވެ. މިފަހަރު ފެނުނީ ދިގުމިނުން ފަރުގައި ގާތްގަނޑަކަށް 2.5 ގަޑިއިރު ދިރާސާކުރުމަށްފަހު ގަޑިން 11:50 ގައެވެ. މިފަހަރު ފެނުނީ ގާތްގަޑަކަށް 4 މިނިޓުގެ ވަގުތުކޮޅަކަށެވެ. މިފަހަރު ފެނުން ފަހަރު ފަހަރަށް ފެނުން ފާހަގަކުރެވިފައިވާ 20 ޖޫން 2018 ގައި އެސަރަހައްދުގައި ދިރާސާކުރާ "ފޮޓޯގްރާފް ރެކޯޑް ފްލޯސާރ" ގެ ދިރާސާ ދަތުރުތަކެވެ.

މިދުވަސްވަރު ރާއްޖެއިން ފެނިގެންދާ ބޮޑުގެ ވަރަށް ގިނަ ފަހަރެއްގެ އިންވެސްޓްކުރާ މަސްޖާރާއި، ކުރި ސަރުކާރުގެ ފަރާތުން ނިންމާފައިވާ ބިމާއްބޭނ ގެއްލުންވާފަދަ، އަދި އިޖުތިމާއީ ނުރައްކާ އަސަރުތަކެއްވެސް ހުރި ސަރަހައްދުތަކުގެ ނިޒާމުތަކަށް ކުރިމަތިވާ ސާބިތުކަމާ ދިމާވާ ބަދަލުތަކެވެ. އަޅުގަނޑުމެން ފިޔަވަޅުތައް ގަބޫލުކުރުމަށް ސަރުކާރު ބެލެހެއްޓުމުގެ ސަބަބުން، ކުރީގެ ސަރުކާރުގެ ދައުރު ހަމަކުރުމުގައި ގޮތްތަކުވެސް ކުރިއަރާފައިވާ 3 މަރިން ޕްރޮޓެކްޓެޑް އޭރިއާގެ ސަބަބުން، ކުރިއަށް އޮތްތަނުގައި މިފަދަ ކަންތައް ރާވާގެންދާއިރު ބިމާއްބޭނުމުގެ ވިސްނުމެއް ރާވާގަތުމަށް އޮޅިގެނެވެ. އަލުގަނޑުތަކުގެ އުސޫލުތައް ހިންގުމަށް ކުރިއަރާ މަރިން ޕްރޮޓެކްޓެޑް އޭރިއާ ހިމެނޭ ސަބަބުން، ހުރިހާ ސަރަހައްދެއް ރީފްތަކުގެ ފަރާތްތަކުގެ ސަރުކާރުގެ ކުރިއަރުވާފައިވާ ފަރުގެ ކަރަންޓް ބޮޑު ސަރަހައްދު ހަމަޖެހިފައިވުން އެއީ ހުރިހާ ސަބަބުން، ފަރުތަކުގައި އަދި މުޅި ޖަމާއަތުން ގާތްގަނޑަކަށް ކުރިއަރާ ދިގު މުއްދަތު ރަނގަޅު ކަމަށް ބާރުއަޅާ ބޭނުން ކުރާ މާލޭ ބޮޑު ސަރަހައްދު ކުރިއަރުވާ ގޮތް އަށްވުރެ މުހިއްމެވެ. އެކަމުގެ ހިސާބު ނުވަތަ ރަނގަޅު ގޮތް ދިމާވާ ރާއްޖޭގެ ރީފްތަކުގެ ފަރާތުން، ގައުމުގެ މަސައްކަތަށް ފާގަ ފެއިދާ (ހުރިހާ ސަރަހައްދަކަށް ފަރާތްތަކުގެ ސަބަބުން) ބިމާއި ހިމާޔަތްކުރުމުގެ ގޮތުން މަސައްކަތެއް އެކި ކަންތައް ކަނޑައެޅި ބޭނުންކުރެވިދާނެއެވެ.

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 21 to 27 July 2018 with the aim of surveying and studying recovery of reefs since the catastrophic 1998 and 2016 bleaching events. The project also ties in sightings of whale sharks with the work of a local charity – the Maldives Whale Shark Research Programme (MWSRP), based in southern Ari atoll. Although the Maldivian reef atolls comprise a rich mixture of spectacular corals and a multitude of fish and other animals, the Maldives government identified a need for further research and monitoring work as far back as 1997. Biosphere Expeditions with this project is addressing this need and is working with the Marine Conservation Society (MCS) and the MWSRP in order to provide vital data on reef health and whale shark sightings. Reef data collection follows an internationally recognised coral reef monitoring programme, called Reef Check, and is used to make informed management and conservation decisions. Whale shark photos are used by the MWSRP for their conservation efforts to record new sightings, and record sightings of previously identified individuals. This gives an impression of the overall population of these animals.

Coral reefs

Coral reef structures of the Maldives archipelago are diverse and rich. There are submerged coral mounds within inner atolls, often rising 50 m from the seabed to 10 m from the surface (thilas), other mounds that reach the surface (giris) and large barrier reefs, which surround these structures on the perimeter of the atolls, some of which are up to 40 km long. The islands of the Maldives are entirely made from the coral sand washed up onto the very shallowest coral platforms. More than 240 species of hard corals form the framework of a complex coral community, from the shallow branching coral dominated areas, to deeper systems of undercut caves and gullies dominated by soft corals and invertebrates. Most coral communities in the central reefs of the Maldives were still recovering from the mass bleaching event of 1998, prior to the 2016 bleaching event.

The recovery identified by our surveys (Afzal et al. 2016, Solandt and Hammer 2012 & 2015 & 2017a & 2018, Solandt et al. 2013 & 2014 & 2016), appears to have been reasonably strong in many inner atoll reefs since the 1998 bleaching event, with extensive recruitment and growth of branching and table *Acropora* corals (*A. hyacinthus* and *A. clathrata*) – many tables exceeded 3 m in diameter at reef tops (Dega Thila, Diga Thila, Kudafalhu) – even by 2005, and up to 2015. It is for this reason that our expedition has regularly focused on assessing reef health in areas initially surveyed prior to the 1998 mass bleaching event.

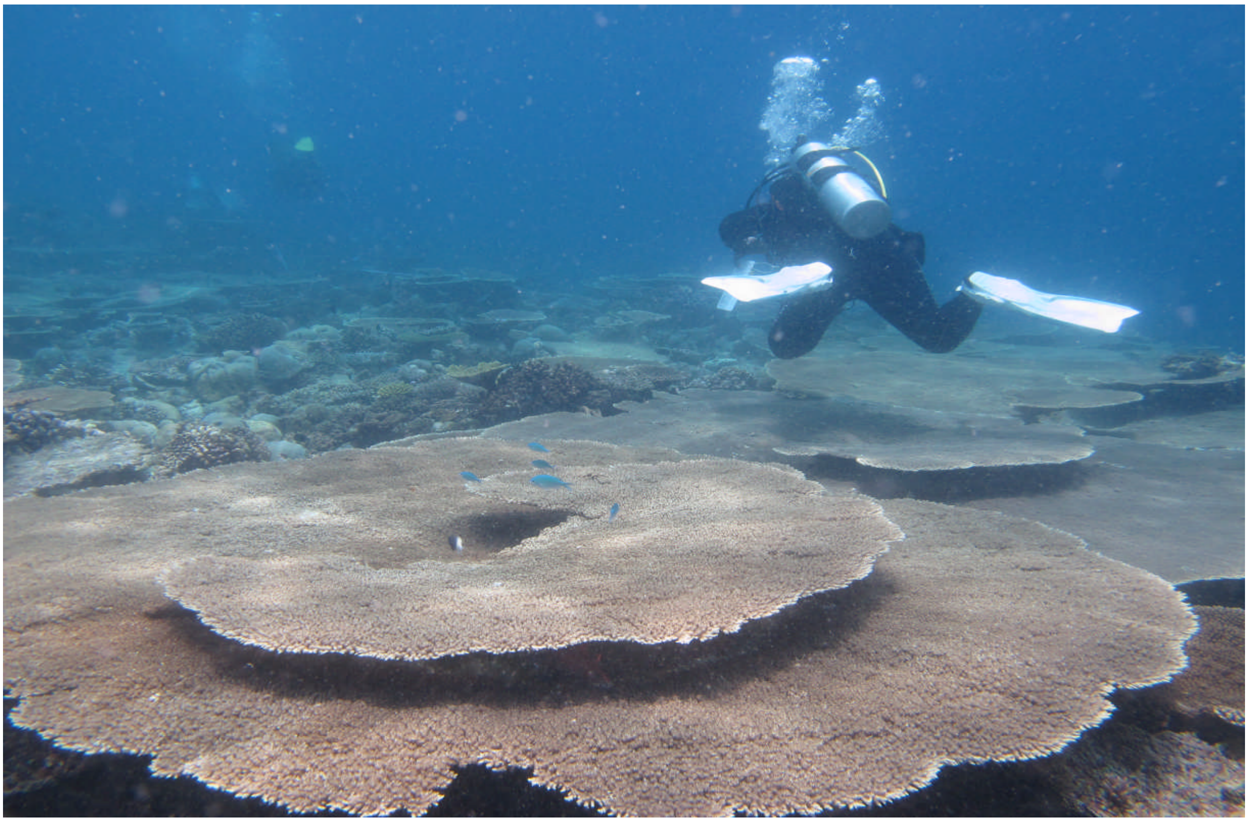

Figure 1.1a. Large *Acropora hyacinthus* colony (photo from c. 2008 at Dega giri) at 2 m depth.

Many reefs in the central Maldives were starting to show signs of stress even before the 2016 bleaching event (Solandt et al. 2016, 2017a, 2018). Some remain resilient and are in good condition, but others were faring much worse with disease (principally white syndrome on *Acroporids*), predators (Crown-of-Thorns, *Drupella* snails), and persistent low-level bleaching prior to the 2016 major bleaching event (Solandt et al, 2016; Solandt and Hammerl, 2015). The change in coral to non-coral life forms observed between 2011 and 2018 were greatly affected by the 2016 bleaching event that reduced coral cover by about 25% over a year (Solandt and Hammer, 2017b, 2018). Many reefs are now showing prolonged (over two years) domination by algal turfs, macroalgae and some sponges (personal observation). Some deeper reef areas (over 3 m) have permanently shifted to a non-coral state dominated by turfs and corallimorphs (principally *Discosoma*) and rubble (Solandt and Hammer 2017a, 2018). The 2016 bleaching event seems to have had a severe long-term impact on some of the more sheltered reefs that lie inside the reef atoll rims (called 'inner-atoll reefs' in this report). More will be discussed at the end of this report. The question of resilience and recovery is also covered in this report and an associated publication (Cowburn et al. 2019) that uses Reef Check data.

In addition to supporting an expanding tourism and recreation industry, coral reefs also play an unrivalled role in supporting fisheries and in the culture and lifestyle of the people of the Maldives relative to most other Indian Ocean states. Tourism, reef fishing, coral sand mining, dredging, reclamation,the construction of maritime structures and pollution represent those impacts on coral reefs that can be directly managed in the Maldives. Resilience to the impacts of climate change can be monitored (e.g. to record recovery trajectories of different reefs to mass bleaching events). Reef Check offers an extremely useful tool to involve citizen scientists in coral reef conservation and inform local managers on where conservation action such as community-based management and MPAs should be targeted.

With the introduction of tourism to the Maldives in the 1970s, the country started to gain a major source of income and employment. Mass tourism in the Maldives is still concentrated around the atolls close to Male', and its infrastructure and resources entirely rely on rich and healthy reefs. Major investment in 'new growth' of the economy has been around tourism in the past five years, with a doubling in the number of islands being developed. There is a significant increase in the amount of licences being offered to resort developers around the more southern atolls. A new airport in Mamigili (south Ari) has opened up new areas for direct flights, increasing access to the area.

The remoteness of many reefs and their wide distribution make research and monitoring work costly and difficult. The reefs that have been best studied are in the central areas of North Male', Ari and Addu atolls (e.g. Pisapia et al. 2016). Data from these and previous Reef Check 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.

In order to assess a broad range of reef types, we surveyed inner (giri, thila and house) reefs and the outer slopes of atoll reefs around Ari atoll. This range of sites and habitats gave us a useful understanding of the relative resilience and recovery trajectories of different reef types and locations to the warming event of 2016.

Dives ranged from thilas, farus in inner reefs, channel walls and slopes, to fore- and back reefs, where gently sloping reefs are covered by hard corals and the regionally abundant black tube coral, Tubastrea. All of our survey dives were to a maximum 18 m depth, which generally are the shallow water areas that provide the richest coral growth.

Fish populations including whale sharks

The fish populations of the Maldives are exceptionally rich in terms of diversity, but the number, size and biomass of commercial reef species have been seriously impacted (Sattar et al. 2012). The Maldivian government in 2008 banned shark fishing within the atolls and their numbers appear to be increasing (according to anecdotal reports from some dive operators), and small reef sharks are still commonly observed in Maldivian lagoon waters. The Maldives are also a rich area for filter feeding whale sharks and manta rays (Fig. 1.1b), with observations of these species an exciting event for those on live-aboard dive trips. Currents feed the atolls between the outer barrier reefs that punctuate this vast archipelago, where the diving can be exciting, but difficult for undertaking Reef Check surveys. So places where many top predators are more prevalent (channels in deeper waters rich in currents) are unfortunately off-limits to Reef Check, but these areas do not provide the best conditions for coral reef growth.

Figure 1.1b. *Mobula alfredi* observed at Rasdhoo Madivaru on 23 July 2018 whilst laying a Reef Check transect.

The expedition undertook detailed observations of whale sharks when they were encountered between reef survey locations. Photographs of the gill areas of whale sharks are being used by the MWSRP to identify individuals in order to record presence / absence of whale sharks in the archipelago. The markings in and around the gill / pectoral fin areas are unique to each individual, and over 200 individuals have been recorded so far. The MWSRP can then match one individual's unique markings with the photographic record and add that image and the whale shark's location to their database, and see if it has been recorded before and where. This allows conservationists at the MWSRP to determine where individual sharks go, how often they are recorded at individual locations and whether further protection mechanisms are needed for individual hotspot locations.

1.2. Research area

The Maldives or Maldive Islands, officially Republic of Maldives, is a coral atoll-island country in the Indian Ocean formed by a chain of twenty-five 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 133,000. The total population is ~314,000. 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. But it is the 11th most-densely populated country on earth.

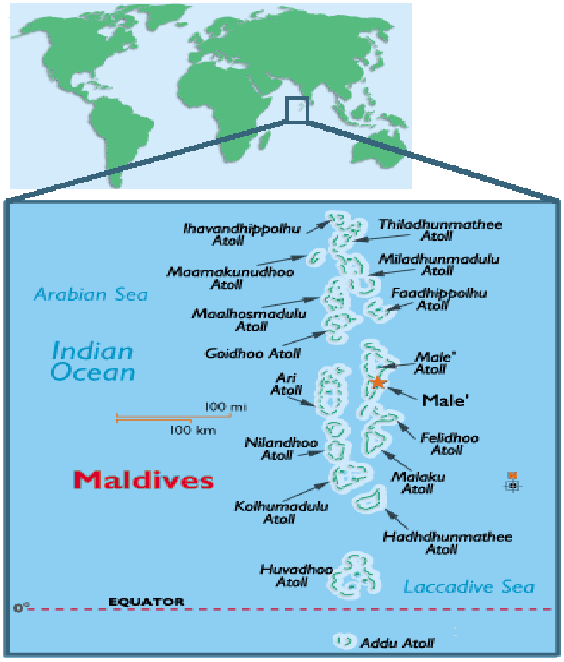

Figure 1.2b. The Maldives. An overview of Biosphere Expeditions' research sites, assembly points, base camp and office locations is at Google Maps.

Over 1,000 species of fish have so far been catalogued, including reef sharks, moray eels and a wide variety of rays such as manta, sting and eagle rays (Anderson et al. 1998).

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

To date at least 240 hard coral species have been described from 57 genera. 51 species of echinoderms, 5 species of sea grasses and 285 species of alga have also been identified.

1.3. Dates

2018: 21-27 July.

The expedition ran over a seven-day period (Saturday to Friday).

1.4. Local conditions & support

Weather

The Maldives has a tropical and maritime climate with two monsoon seasons. The average day temperature during the expedition months was 30°C with overcast, windy and rainy days, and occasional sunshine. Water temperature during the expedition was approximately 28°C at all sites, and at all depths (according to most dive computers).

Expedition base

The expedition was based on a modern four-deck, wooden build, 115 feet live-aboard boat, the MV Theia, with ten air-conditioned cabins, and an open air dining area. The boat was accompanied by a large traditional 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 provided all meals.

Figure 1.4a. The MV Theia expedition base.

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. Also on-board was full access to WiFi at all inner-atoll locations.

The expedition leader also posted a diary with multimedia content on Wordpress and excerpts of this were mirrored on Biosphere Expeditions' social media sites.

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. Emergency and evacuation procedures were in place, but did not have to be invoked as there were no emergency incidences, medical or otherwise.

1.5. Scientist

Dr. Jean-Luc Solandt is a Londoner with a degree in Marine Biology from the University of Liverpool. After graduating, he spent a year diving on the Great Barrier Reef assisting field scientists in studies on fisheries, and 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, managing and developing MPAs in the UK and is an advisor to the European Commission. He has been the leader and coordinator of Reef Check for the Maldives since 2005, and has thus far led over 10 expeditions to undertake surveys inside and outside MPAs on the islands. Jean-Luc has over a thousand dives clocked up since he trained to be a marine biologist 30 years ago.

1.6. Expedition leader

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

1.7. Expedition team

Doriane Da Silva (UAE), Sally Fahmy (the Netherlands), Jorge Goya (Peru), Liesl, Lukas, Matthias & Sophie Hammer (Germany & UK), Christopher Harris (Australia), Lewis Hines (UK), Drew & Lee Johnstone (South Africa), Kelsea Koch (USA), Jerred Seveyka (USA), Sylivie & Yannick Solandt (UK), Gemma Thompson (press, UK), Carlos Velasco (Colombia).

1.8. Partners

On this project Biosphere Expeditions worked with Reef Check, the MCS, the Maldives Marine Research Centre (MRC) of the Ministry of Fisheries and Agriculture, MWSRP, and the MV Theia, LaMer. Data will also be used in collaboration with the Global Coral Reef Monitoring Network, IUCN and the University of York. 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 with regards to the effectiveness of current Maldivian MPAs in their ability to protect and recover significant numbers and biomass of commercially important finfish. Around the expedition this year, MCS has been collaborating with IUCN colleagues to write a scientific paper detailing responses to the 2016 bleaching event. The manuscript has been submitted to Marine Ecological Progress Series, and is due for publication in 2019.

1.9. Expedition budget

Each participatin citizen scientist paid towards expedition costs a contribution of €2,140 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	27,694
Expenditure	
Staff includes local & international salaries, travel and expenses	6,001
Research includes equipment and other research expenses	200
Transport includes taxis and other local transport	0
Base includes board, lodging and other live-aboard services	16,854
Administration includes some admin and misc costs	125
Team recruitment Maldives as estimated % of PR costs for Biosphere Expeditions	8,676
Income – Expenditure	**-4,162**
Total percentage spent directly on project	**115%***

*This means that in 2018, the expedition ran at a loss and was supported over and above the income from the expedition contributions and grants by Biosphere Expeditions.

1.10. Acknowledgements

This study was conducted by Biosphere Expeditions, which runs wildlife conservation expeditions all over the globe. Without our expedition team members (listed above) who provided an expedition contribution and gave up their spare time to work as research assistants, none of this research would have been possible. The support team and staff (also mentioned above) were central to making it all work on the ground. Thank you to all of you and the ones we have not managed to mention by name (you know who you are) for making it all happen. Thank you also to Hussein Zahir of LaMer for guidance and advice. Biosphere Expeditions would also like to thank the Friends of Biosphere Expeditions for their sponsorship and/or in-kind support. We also thank the IUCN who have collaborated with us over recent months to produce a paper on bleaching resilience (Cowburn et al. 2019).

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 to the Maldives

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 the islands emerge to form the atolls (Fig. 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 faros in the world (Risk and Sluka 2000).

The highest point of the natural islands is approximately 2.4 m as all the islands are originally made from fine coral sand. About 10% (200) of the islands are inhabited, with by far the largest population living in Male' - the capital. Of the (approx.) 440,000 population of the nation, a little over 130,000 people live in the 1.8 km^2 of Male', making it one of the most densely populated urban areas on Earth (United Nations 2018 estimates[1]).

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) (Fig. 2.1a).

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

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[1] http://www.worldometers.info/world-population/maldives-population/

The outer reefs that fringe the atolls have the greatest historical 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 growth, erosion and deposition of corals to 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. Coral bleaching and generalised coral mortality has a significant bearing on these processes.

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. Global warming may have affected these seasonal trends in recent years, with less clear discrepancy between wet and dry seasons. The current direction, however, has remained relatively constant. Air temperature ranges between about 21°C and 31°C and varies little between seasons. The monsoon currents have a key bearing on the distribution of pelagic planktivorous animals across the archipelago. For example, Manta rays (*Mobula alfredi*) are often found in the sheltered sides of reefs relative to the incoming current, feeding on the plankton that drifts to the leeward side of the reef system (Anderson et al. 2011).

In terms of biodiversity, the Maldives atolls form part of the 'Chagos Stricture' and are an important stepping-stone between the reefs of the eastern Indian Ocean and those of East Africa (Spalding et al. 2001). The fauna therefore comprises elements of both eastern and western assemblages. Diversity is high with over 240 scleractinian corals, with maximum diversity reported towards the south (towards Huvadhoo Atoll) (Picheon and Bnezoni 2007, Risk and Sluka 2000). Over 1,000 fish species have been recorded in the Maldives, a large proportion of which are reef associated (Anderson et al. 1998).

Maldivian fisheries

Tourism and fisheries are the two main generators of income for the Maldives[2]. 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[3]). 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 (Miller et al., 2017). However, the stocks of tuna and other pelagic fish are at threat in the entire Indian Ocean, largely because of Illegal, Unregulated and Unreported (IUU) fishing, and because the EU has a large stake in fishing in 3rd party states. (The EU has negotiated quota to fish in the offshore (>12nm) waters of other states, and in international waters through the Indian Ocean Tuna Commission (IOTC) (Davies et al., 2015).

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[2] https://tradingeconomics.com/maldives/gdp-growth-annual
[3] https://fisheries.msc.org/en/fisheries/maldives-pole-line-tuna/about/

As tuna and other species do migrate outside of Maldives waters, this threat has led to the MCS downgrading the sustainability ratings of bigeye and yellowfin tuna in the past[4,5]. This is not necessarily the fault of Maldives fisheries management, but is a threat to the wider stock, that ranges outside Maldives waters. Such issues can only be solved by negotiations conducted within IOTC and through multilateral trade and quota agreements. However, many member states that are exploited by distant water fleets haven't put in effective measures for monitoring or control, or adequate protection in areas (such as MPAs) that should not be fished (Davies et al, 2015). The IOTC is relatively powerless in controlling IUU fishing in such expansive waters, and measures to control landings at ports are inadequate in terms of traceability of fishing activity and stocks[6]. It is well-known that Sri Lanka regularly has illegal long-liners working the offshore banks of the Maldives, and there is a concern in the number Fish Aggregating Devices (FADs) that are used in deep waters offshore to attract fish to areas where they can be harvested. Numbers of such FADs – both legally and illegally deployed in the Indian Ocean massively increased between 2007 and 2013 (Maufroy et al., 2016). There are increasing concerns over the industrialisation of the bait-fishing methods used in the Maldives. Vessels are using large in-water lighting arrays within the centre of lagoons in order to attract bait-fish (personal observation and communication). There is no monitoring on the sustainability and impact of such new, large-scale removal of this part of the food web.

The Maldives has also recently banned shark fishing (2010) throughout its waters, which can be regarded as a major conservation outcome because of the catastrophic declines in the global populations of reef and pelagic predatory shark species (Graham et al. 2010). Although this is a commendable measure undertaken by the Maldives government, it is very difficult to enforce without significant investment in water-borne enforcement vessels, and sufficient use of satellite monitoring technology to track potential foreign long-liners that will catch sharks. The Maldives licensed a 'small' number of Maldivian commercial long-liners to target billfish from 2011. The Maldives has a relevant enforcement department (the Environmental Protection Agency, EPA), but this is woefully underfunded. The application of more stringent enforcement tools (such as Automatic Identification System, AIS), and recording of fishing vessel activity as reported in 2017[7] will help eradicate IUU fishing. 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. Yet the problem will persist: The influx of Chinese construction workers around Male' has coincided with an image posted on the Maldives SharkWatch Facebook page (on 18 October 2018) of shark fins and skin drying outside a temporary work accommodation in Male' (see Fig. 2.1b).

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[4] http://iotc.org/sites/default/files/documents/science/species_summaries/english/Summary%20of%20Stock%20Status.pdf

[5] https://www.mcsuk.org/goodfishguide/fish/289

[6] https://stopillegalfishing.com/press-links/potentail-iuu-fishing-operators-maldivian-waters-get-serious-warnings/

[7] https://stopillegalfishing.com/press-links/potentail-iuu-fishing-operators-maldivian-waters-get-serious-warnings/

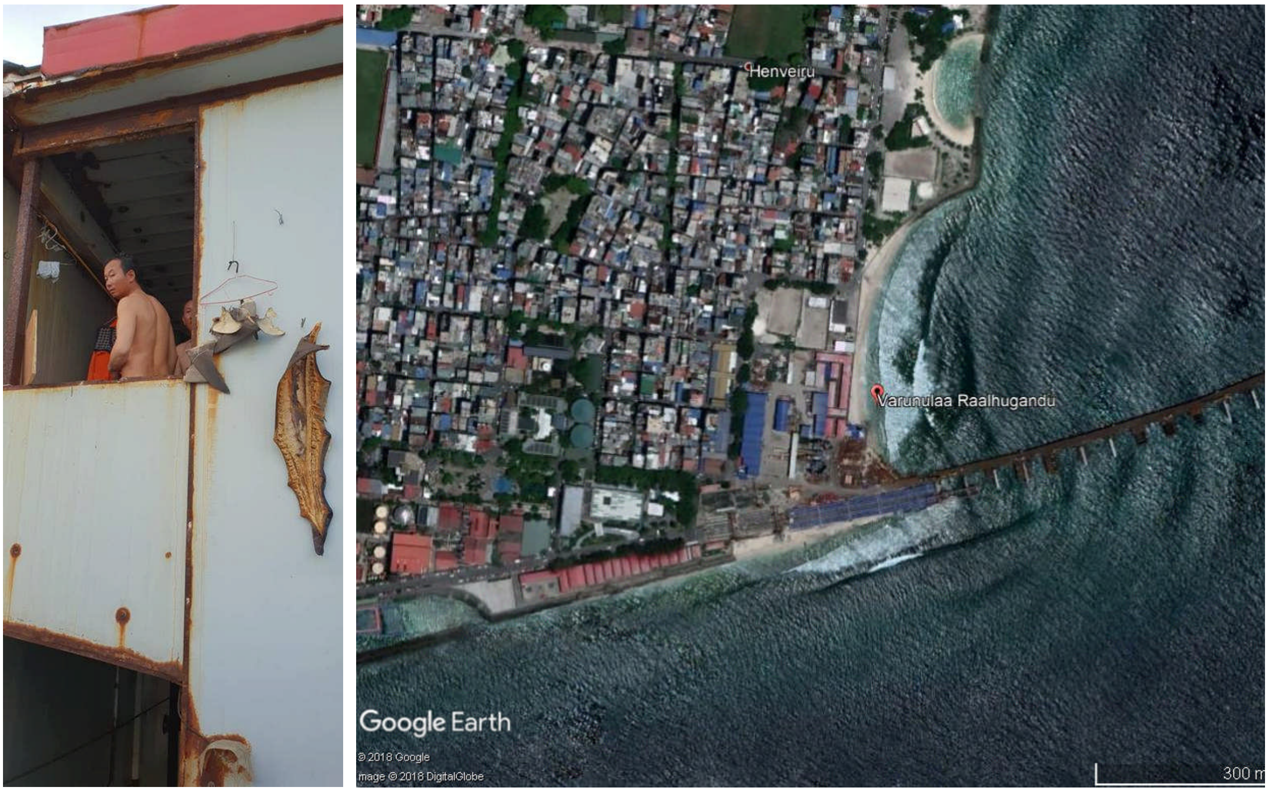

Figure 2.1b. A shark skin and fins drying beside an accommodation block in Male' for the Maldives bridge construction project. This image was recorded on the Maldives SharkWatch Facebook page.

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), was highly controversial. This was a reaction to the reduction in yellowfin catch by Maldivian fishermen recorded between 2005 (186,000 tonnes) and 2008 (117,000) (Minivan News 2010)[8], making traditional pole and line fishing techniques from larger vessels unprofitable.

There has been a growing demand for reef fish species in recent decades, partly because of the expansion in 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 Adam, 2005). A further report by MRC in 2008 showed that demand for reef fish had tripled in the last 15 years and that a management strategy for grouper was needed to ensure sustainable catches in the future (Sattar 2008). MRC has recently worked with the MCS in the past to develop a management plan for grouper.

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

Some of the recommendations from past reports, including provision to increase the minimum landing sizes for some species into the grouper cages and for market, have met with resistance in some atolls. Given the small sizes of many species seen in the wild as outlined in previous reports (Solandt and Hammer 2015, Solandt et al. 2016, 2017a, 2018), it is regrettable that the trajectory for the Maldives fishing out their grouper population as a viable commercial species is a distinct possibility within the next ten years. A project by the Blue Marine Foundation has worked in the south with resort partners and the government to reform fisheries management around spawning locations at Laamu atoll[9], but other than that there appears to be no concerted effort to protect grouper stocks from being fished out. Labelling some grouper spawning locations as 'protected spawning sites' may have been counterproductive, in part leading to them being over-fished, more than protected. The MCS has learned that some 'protected' or 'known' spawning channel locations are effectively targeted by fishers once they are discovered, or protected by law (unnamed dive guide, *pers comm).* Some believe it is simply better 'management' to keep secret those channel locations where spawning is known to occur.

Due to past political interference in the rule of law and due process, there were a number of developments that were patently counterproductive for the Maldives environment under the previous administration. Resort development, and other major capital infrastructure project investments from overseas, were permitted despite contrary advice by The Environment Protection Agency (EPA) and MRC. Decisions by the EPA were effectively rejected by the powerful tourism ministry[10]. We hope this will change with the new political administration that was voted in in October 2018, but so far (June 2019) there have only been pledges in manifestos. Whether the administration can re-visit some of the more damaging deals done in the past is debatable. At least we hope there will be proper accountability of decision-making in the future. And that such measures are made in the national interest.

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 a stress response by corals whereby 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, coral and algal type, the temperature threshold at which corals become stressed in the Maldives is regularly cited as 30ºC (Edwards et al. 2001). The exact temperature and how long it persists elicit different responses in different coral species and genera. Broadly speaking, 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 from starvation, as it gains most of its energy from the sugars produced by the algal cells within its tissues.

[9] http://www.bluemarinefoundation.com/project/maldives/
[10] http://www.climatechangenews.com/2017/03/20/maldives-regime-imperils-coral-reefs-dash-cash/

1998 Reef Check surveys and bleaching event

During April and May 1998 a temperature of over 32ºC was recorded in the Maldives for a period of more than four weeks (Solandt and Hammer 2017a). This led to mass bleaching down to at least 30 m (Edwards et al. 2001). Shallow reef communities suffered almost 100% mortality with live coral cover of central reefs decreasing from about 42% to 2%, a 20-fold reduction from pre-bleaching coral cover. Since 2005, Reef Check surveys have observed few large colonies of massive reef building corals, and a much higher proportion of faster growing Acroporids and Pocilloporids, particularly at sheltered inner atoll reefs (personal observations and Cowburn et al., 2019). This suggests there has been patchy recovery due to recruitment of new, more ephemeral corals, rather than recovery from survival and regrowth of older colonies that recovered zooxanthellae immediately after the warming event.

The 1997 and 1998 Reef Check surveys were carried out by both MRC staff (Zahir et al. 1998) and by local resort marine biologists. Zahir and co-authors showed that the principal 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. Others (e.g. Clark et al. 1999) found that the coral cover in the range of 23-70% pre-bleaching fell to 0-10% post-bleaching in many sites.

The 2015/2016 El Niño / bleaching event

The El Niño of 2015/2016 was the second most significant bleaching event after the 1998 event, with large tracts of Indian Ocean reefs bleaching between March and May 2016 (see Fig. 2.1c). Before the bleaching event reached the Maldives, it devastated the reefs of Asia (Thailand, Malaysia, Indonesia and the Philippine archipelago). In addition, 22% of the reefs in the Great Barrier Reef were very seriously bleached and the wider Pacific Ocean saw bleaching throughout most of 2015.

Seawater temperatures were recorded by colleagues at Baros Maldives throughout the 2016 bleaching event. They recorded the temperatures at their house reef on the island from April to May 2016 (Table. 2.1a).

Table 2.1.a. Surface seawater temperatures (SST) recorded at Baros Maldives from 1 April through to 26 May 2016.

	Temperature degrees C			
	5 m	10 m	15 m	20 m
1-Apr-2016	30	30	29	29
7-Apr-2016	30	30	29	29
14-Apr-2016	31	30	30	30
21-Apr-2016	32	31	30	30
28-Apr-2016	32	32	31	31
5-May-2016	32	32	31	31
12-May-2016	31	30	30	30
19-May-2016	30	30	30	30
26-May-2016	30	30	30	30

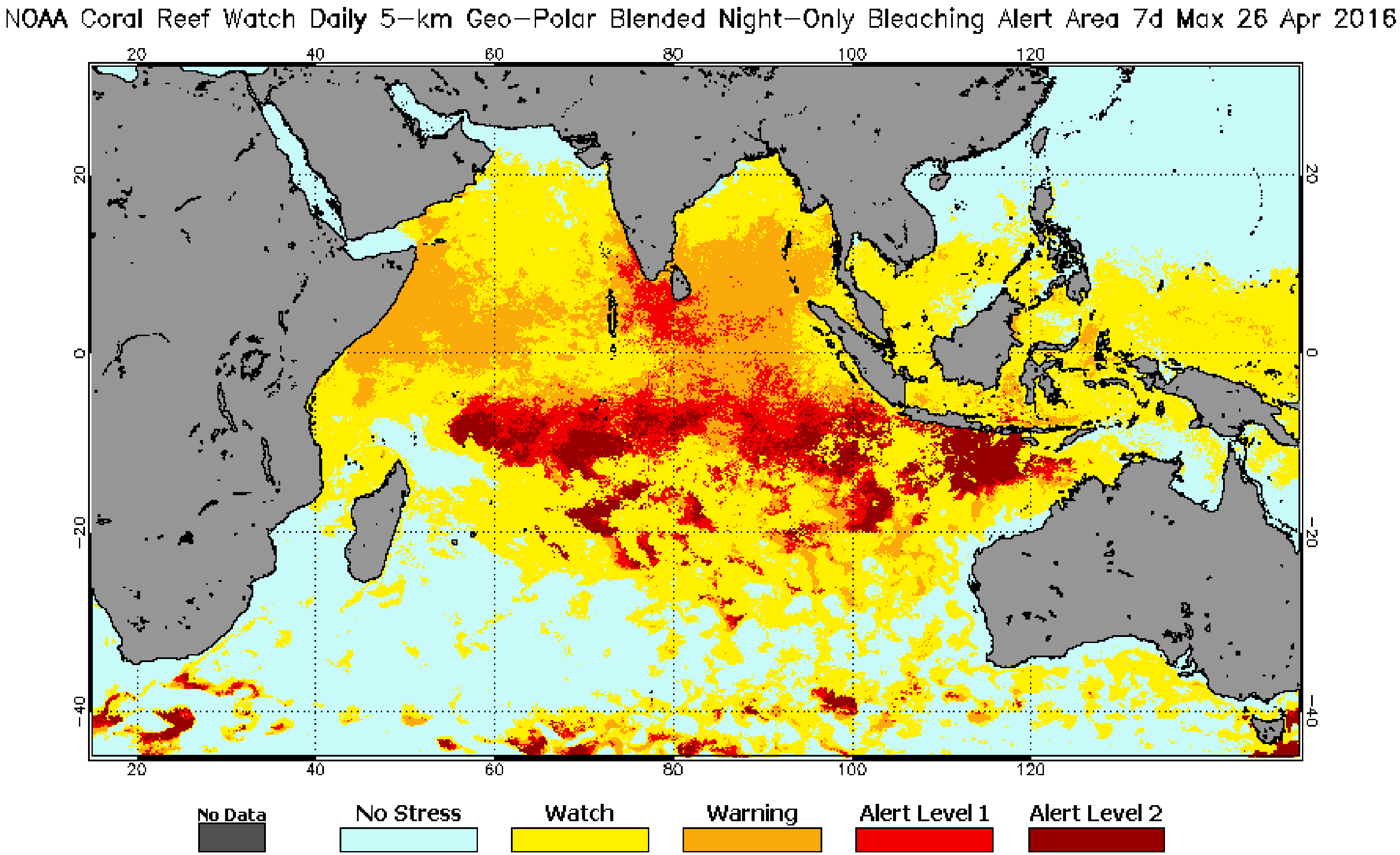

Figure 2.1c. Coral bleaching coincided with a warm water 'pulse' that moved from south to north over the islands between April and May 2016.

The 2016 bleaching event was similar to the 1998 bleaching event for its severity, longevity and impacts (Afzal et al. 2016). It is clear from the last 20 years of surveys that the 1998 event had a long-term impact on the coral cover and population of some reefs of the nation (see all Maldives Biosphere Expedition reports since 2011 by Solandt and various other authors, cited in the literature below). Direct loss of coral cover was less during the 2016 than the 1998 bleaching event, but only because reefs were at a lower baseline condition in 2015 than they were in 1997 (own observations, Pisapia et al. 2016 and Fig 2.1d). Solandt and Hammer (2017a, 2018) reported that the bleaching event had ramifications for the deeper reefs of inner atolls that have resulted in algae and other benthic lifeforms (e.g. sponges, ascidians and corrallimorphs) taking over the substrate.

The concern regarding the Great Barrier Reef and the Maldives, where such bleaching events appear catastrophic in the short term, is that of the ability of reefs to continue to recruit and grow whilst staving off the deleterious effects of repetitive bleaching events, as well as the effects of ocean acidification, which makes it more difficult for corals to assimilate carbonate skeletons (e.g. Perry and Morgan 2017). The continuous assimilation and growth of the entire coral structure of the Maldives (a so-called net positive carbon budget) is quite literally the physical foundation of the nation. It allows the Maldives to be structurally secure and to keep pace with a number of potentially catastrophic events such as (1) stronger storms (related to increased energy in the seas due to increased surface warming translated to ocean-derived weather events), (2) thermal expansion of our seas (due to increased temperature effects on the surface of the ocean) and (3) sea-level rise (due to melting ice-caps).

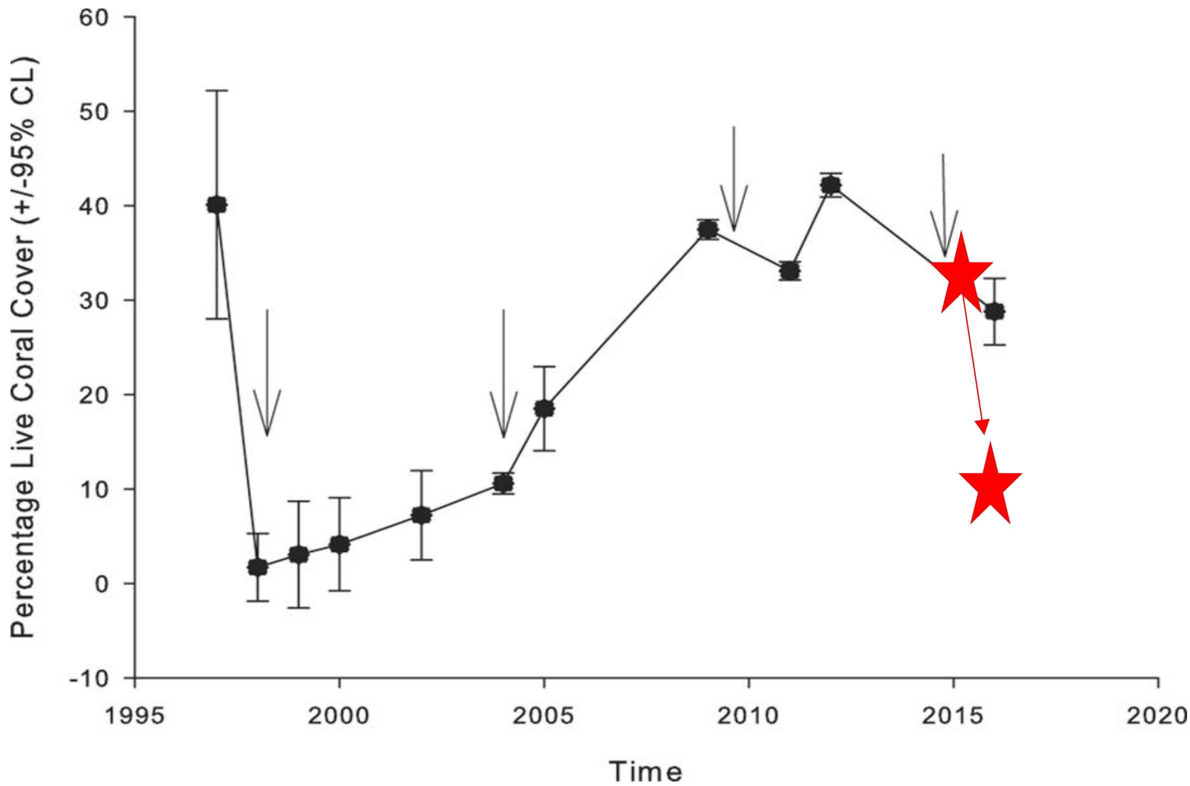

Figure 2.1d. Coral cover through various events in the recent Maldives history (from Pisapia et al. 2016) up to the end of 2016. Major events (arrows) are: 1998 - bleaching, 2004 – tsunami, 2010 – bleaching, 2015 – Crown-of-Thorns outbreak. The 2016 bleaching event impact (coral cover from 34% to 12% for the sites discussed in this report) is superimposed in red on this plot to give a sense of our own recent perspective (Solandt et al. 2017a).

Longer-term effects of bleaching events include erosion of dead coral skeletons to sand and rubble, which leads to less buffering of wave action around the atolls, which in turn leads to beach erosion. This carries significant potential cost for the Maldives[11], as explained above. Many surveys in recent years by our expeditions have identified rubble slopes at around 10-15 m depth at some of the more sheltered reefs. We believe these predominantly consist of corals that died during bleaching events and were broken down by subsequent wave action and the boring action of worms and bivalves (Solandt et al. 2013). Under gravity, they fell to the lower reaches of the reef. Expansive fields of coral rubble is a problem for recovery, as its continuous movement and erosion makes it near impossible for corals to grow once settled onto the moving substrate (Chong-Seng et al., 2014).

A University of British Columbia[12] survey by 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. If such observations were typical of the reefs we have surveyed since 2005, then the recovery and grazing of algae by herbivorous fish has been extraordinary to facilitate conditions for coral recruitment and growth (Pisapia et al., 2016).

Biosphere Expeditions and MCS undertook the first 'bleaching recovery' surveys in 2012, and found that the reefs of Ari atoll were generally recovering well, from the outer channel reefs of the north east, to the inner south central house reefs (including those at Angaga Island in the centre of the atoll) (Solandt et al. 2013). Surveys carried out in September 2015 found many sites to be affected by storms, leading to breakage of corals and damage to shallow and deeper reefs. Ari atoll was considered to have been less affected by the 1998 bleaching event than reefs nearer the capital, at North Male' atoll (Zahir, personal communication).

Summary of threats to Maldives reefs

Maldives reefs are under threat from both local anthropogenic and global climate-induced pressures. Key threats are:

- Climate change and associated sea surface temperature increases leading to coral bleaching (from human caused increases in CO_2 concentration)
- Increased atmospheric CO_2 concentration that results in seawater acidification; this leads to decreased skeletal strength of calcium carbonate-dependent corals, decreased growth rate, and decreased reproductive output of corals
- Overfishing of keystone species (e.g. predators of Crown-of-Thorns and herbivorous fish).
- Sedimentation and inappropriate/unsustainable atoll development
- Poor water treatment
- Solid waste

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[11] http://ecocare.mv/beach-erosion-a-vulnerable-scenario-in-the-maldives/
[12] http://www.math.ubc.ca/~hauert/publications/ReefCheck98/index.html

Marine Protected Areas (MPAs)

MPAs are a conservation tool that has increasingly been used to stave off and repair the worst impacts of over-exploitation and damage to our seas[13]. The IUCN has recorded 43 MPAs in the Maldives[14] covering less than 0.1% of the country's seas (Fig 2.1e).

In many tropical seas MPAs have been used to help recover fisheries resources. This works when there is limited encroachment due to adequate buy-in and enforcement (Leenhardt et al. 2015). However, enforcement and monitoring are where MPAs are lacking. They are often illegally fished, which can make their role unpopular with local stakeholders, as they prevent access to some people (such as fishermen that respect the rules), whilst transgressors take the benefits the MPAs accrue (Edgar et al. 2014). MPAs need to perform to be supported, and will always be at threat from fishers who need to make a living for their families. Nevertheless, there have been some successes of Maldives MPAs where there has been some investment in enforcement and awareness.

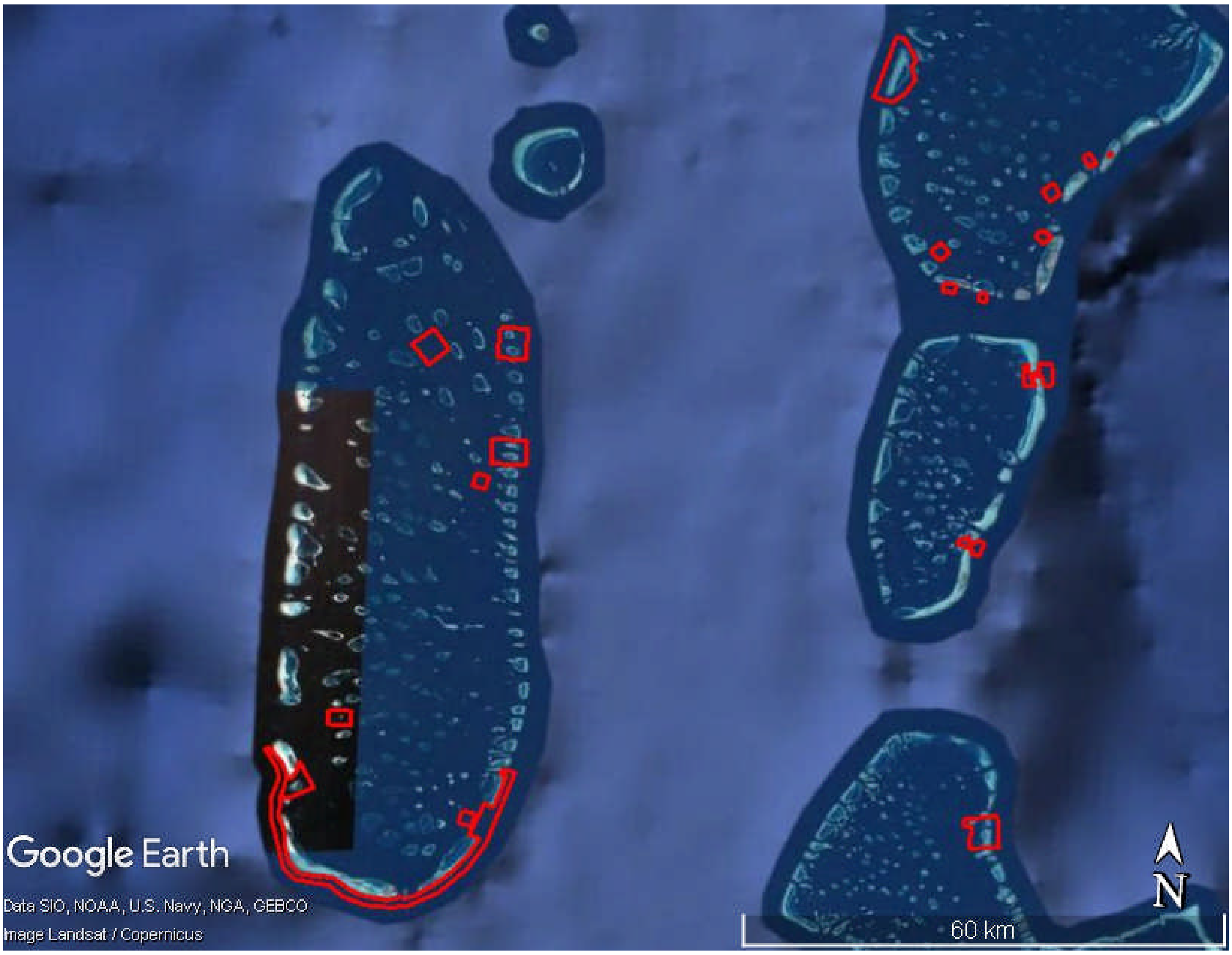

Figure 2.1e. MPAs of central Maldives atolls in July 2018. Source UNEP-WCMC.

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13 https://www.iucn.org/theme/marine-and-polar/our-work/marine-protected-areas
14 https://www.protectedplanet.net/country/MV/pdf

For example, the reserve in Baa Atoll (Hanifaru Bay) has been established in an area that is relatively easy to enforce for access to see whale shark and manta rays, as it is an enclosed reef with limited entry points (Fig. 2.1f)[15]. Heavy tourist use and the employment of local rangers who support the MPA have been key to the success of the MPA.

Figure 2.1f. Hanifaru Bay marine reserve, Baa atoll (designated in 2009).

By contrast, the Mamigili MPA in South Ari atoll is less successful, because of the lack of regulation of numbers of boats accessing the whale sharks, and its openness (it borders the open sea for its entire southern border) (see Fig. 2.3p).

The 25 MPAs that were established in the 1990s to protect dive sites and their fish populations have been heavily dived and are likely to have been damaged (in their physical structure and through coral damage) by contact with diver fins, hands and dangling equipment (Barker and Roberts 2004). But diver damage is negligent compared to coral bleaching and overfishing impacts.

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15 http://www.mv.undp.org/content/maldives/en/home/ourwork/environmentandenergy/successstories/biosphereserve.html

Although these MPAs are meant to be protected from fishing (to help support interest from divers)[16], there is no significant difference in numbers of fish between inside and outside the MPAs (Solandt et al. 2009, Coward 2013). These results suggest that fishing has continued since designation. It is clear from our observations and fish surveys carried out in the past (Solandt et al. 2009) that Maldives MPAs are failing to provide greater fishing biomass. Whilst MPAs cannot provide immediate protection from bleaching, associated management and protection from damage and over-fishing can keep the ecosystem balance healthy and provide good conditions for recovery (Bruno et al. 2018). These conditions include waters clear of sedimentation, healthy fish populations, and high populations of algal grazers, which help facilitate more rapid recovery from such catastrophic events such as the 1998 and 2016 coral bleaching events. Such effects will only occur, however, where protection is real, i.e. where it is facilitated by adequate enforcement and education.

Multi-million-pound investment is needed to provide boats, access from local islands, wardens, training, equipment and a local judiciary that can prosecute transgressions and infractions in MPAs. Only then will there be the potential for MPAs to boost natural resources. Philanthropists are willing to invest in countries such as the Maldives to create such mechanisms (e.g. the Berteorelli Foundation[17]). However such investment is more likely if there are limits to corruption, government is secure, and investment is properly put towards legitimate enforcement of protected area rules. Since few of these conditions are likely to be met in the Maldives (for example, the country is ranked 124th out of 180 on Transparency International's global corruption index[18]), investors will naturally be wary.

Governance and management issues

There are a number of governance, socio-economic and political issues within the Maldives that reduce the ability of local, regional and national management agencies to deal with such pressing issues. Paradoxically, the Maldives has embarked on a political platform to establish more MPAs and lobby for decreases in global CO_2 emissions (under the Nasheed administration from 2009 up to 2012). Political and government instability since then has led to a minimal focus on these objectives. For example, the previous government pushed more tourist islands[19] whereby international reporters have detailed a lack of due (legal) process in their sale to offshore middlemen, acting on behalf of hotel chains. A new government since September last year has pledged 'transparency' of future affairs relating to tourism, but there are no apparent developments on dealing with historical miss-selling of land under the previous administration.

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16 https://maldivestourism.net/maldives/protected/
17 https://www.fondation-bertarelli.org/
18 https://www.transparency.org/cpi2018
19 https://www.aljazeera.com/news/2018/09/report-exposes-maldives-orgy-corruption-election-180917121608752.html

There is a chasm between the understanding of political leaders in what constitutes good marine resource management (e.g. the establishment of MPAs on paper) and the requirements to make them work – for both biodiversity and local communities. Perhaps it is wilful ignorance[20]. This is as much a problem in the UK, as it is in the Maldives. Solutions require extensive interaction between community-based scientists and practitioners with government officials – at the highest levels. Only with investment into developing solutions and effective marine protection governance systems will nations start to recover biodiversity[21].

Biosphere Expeditions surveys are carried out on an annual basis to record conditions at permanent monitoring sites in North Male' and Ari atolls, and to undertake bleaching recovery survey assessment dives. They are relatively cost-effective as fee-paying citizen scientists and external funding help support the work. But in order to really expand the knowledge of reefs and their status, we need many more Maldivians to progress Reef Check-style projects, which is why Biosphere Expeditions has had a placement programme with the aim of seeding community-based monitoring programmes.

Out of this programme have come various initiatives such as educational booklets in 2011, the first-ever all-Maldivian Reef Check survey in 2014, and continued community-based survey efforts in 2016 and 2017. Most recently, graduates of the placement programme founded Reef Check Maldives. However, in the current political and economic climate it is hard to retain traction with graduates as they avoid controversial subjects such as reef protection and seek paid, rather than voluntary, work.

Maldives reef surveys

In order to help the Maldives in facing up to some of these issues, Biosphere Expeditions and the MCS have been developing a survey and training programme, which aims to:

- Increase the information base on the status of Maldives reefs in collaboration with local partners (e.g. the MRC / MWSRP / EPA / LaMer Group / Save the Beach/Gemana)
- Build capacity in local marine management and resource assessment (e.g. Reef Check surveys at the local island Vilingili with NGO 'Save the Beach').
- 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 (e.g. Baros Maldives)

[20] http://www.socialpolicyconnections.com.au/?p=13730
[21] https://s3.amazonaws.com/wwfassets/downloads/lpr2018_summary_report_spreads.pdf

In order to undertake this, Biosphere Expeditions has:

- Undertaken Reef Check surveys at over 30 sites in seven years, compiled and quality-assessed the data, and sent it to Maldivian and international coral reef monitoring programmes

- Trained eight individuals employed in government marine resource assessment surveys, NGOs and from the tourist and diving industry whilst on liveaboard expeditions; we have also undertaken training of ten individuals (private consultants, resort marine biologists, EPA and MRC staff) in Male' after an expedition (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 operators and have collaborated with resorts to train staff and provide them with Reef Check and other reef survey resources

- Funded Maldivian Reef Check teams (purchasing training packs, transect tapes and recording equipment).

2.2. Methods and planning

Biosphere Expeditions uses the Reef Check methodology for its coral reef surveys. The 2018 surveys were carried out with the aims of:

- Recording patterns of recovery and resilience from the 2016 bleaching

- Carrying out effort-based transects of the South Ari MPA reef for whale sharks

- Visiting a 'hope spot'[22] as indicated to us by Hussein Zahir in South Ari atoll (Theluveligaa) as listed in the IUCN bleaching report of 2016

- Develop potential new initiatives for reef conservation in the Maldives

For the expedition (21-27 July 2018) we surveyed six sites (see Table 2.3a.) in Ari atoll. The initial training site was meant to be at Baros Maldives, but was left after the initial dive assessment as it was so damaged (<5% coral cover). We then trained and surveyed at Rasdhoo Madivaru and Rasdhoo East, with ensuing surveys at two depths (4 – 6 m and 9 – 11 m) at Bathalaa maagaa, Kudafalhu, Dega giri, Theluveligaa (a new site – a 'hope spot' according to local experts) and Dhigurah Wall to the south of the atoll (see Fig. 2.3a).

All training was carried out on board the MV Theia during the first three days of the expedition. The methodology used was the internationally accredited Reef Check method as described in previous reports (Afzal et al. 2016, Solandt and Hammer 2017a).

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[22] 'Hope Spot' is an area where there appears to be resistance to bleaching. However, as we didn't receive a GPS position from IUCN or MRC, we couldn't find the specific location. As such we dived the extremely sheltered inner lagoon that was found to be dominated by algae, and likely to have been heavily affected by bleaching in 2016.

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

In addition to the Reef Check surveys, up to 20 images were taken along the transect of one or more dives at each site for subsequent analysis for assessing coral lifeforms. Images were taken of frames between 20 and 50 cm wide (identifiable along the Reef Check transect, with the transect within the image frame).

Images were subsequently loaded into Coral Point Count (CPC), which was used to generate ten random points over each image, and subsequently record the proportion of different coral lifeforms at all sites.

2.3. Results

Sites surveyed

Sites surveyed during the 2018 expedition were a mixture of inner atoll sites (thilas and giris) and outer reef walls and slopes. Sites (Table 2.3a / Fig 2.3a) were selected on the basis that Biosphere Expeditions and MCS had surveyed these areas since 2005 (Rasdhoo madivaru) and 2008 (Dega thila), thus giving a longer-term perspective to the data of reefs that had been recovering since the 1998 bleaching event. We also wanted to understand any differences in patterns between the more sheltered inner atoll reefs with lesser water circulation and depth, and the outer reefs, which are adjacent to much greater water depths.

Table 2.3a. Site names and locations. See also Figure 2.3a below.

Site name	Date	Latitude	Longitude	Inner / outer reef	Atoll
Baros Maldives*	21.7.18	4 17.231 N	73 25.264 E	Inner	North Male’
Rasdhoo madivaru	23.7.18	4 15.947 N	73 00.170 E	Outer	North Ari
Bathalaa maagaa	24.7.18	4 30.340 N	75 57.410 E	Outer	North Ari
Kudafalhu	24.7.18	4 01.052 N	72 48.311 E	Inner	North Ari
Dega thila	25.7.18	3 50.680 N	72 45.072 E	Inner	South Ari
Theluveligaa	25.7.18	3 39.926 N	72 53.945 E	Inner	South Ari
Dhigurah Wall	26.7.18	3 30.799 N	72 55.016 E	Outer	South Ari

*Training site: No data collected.

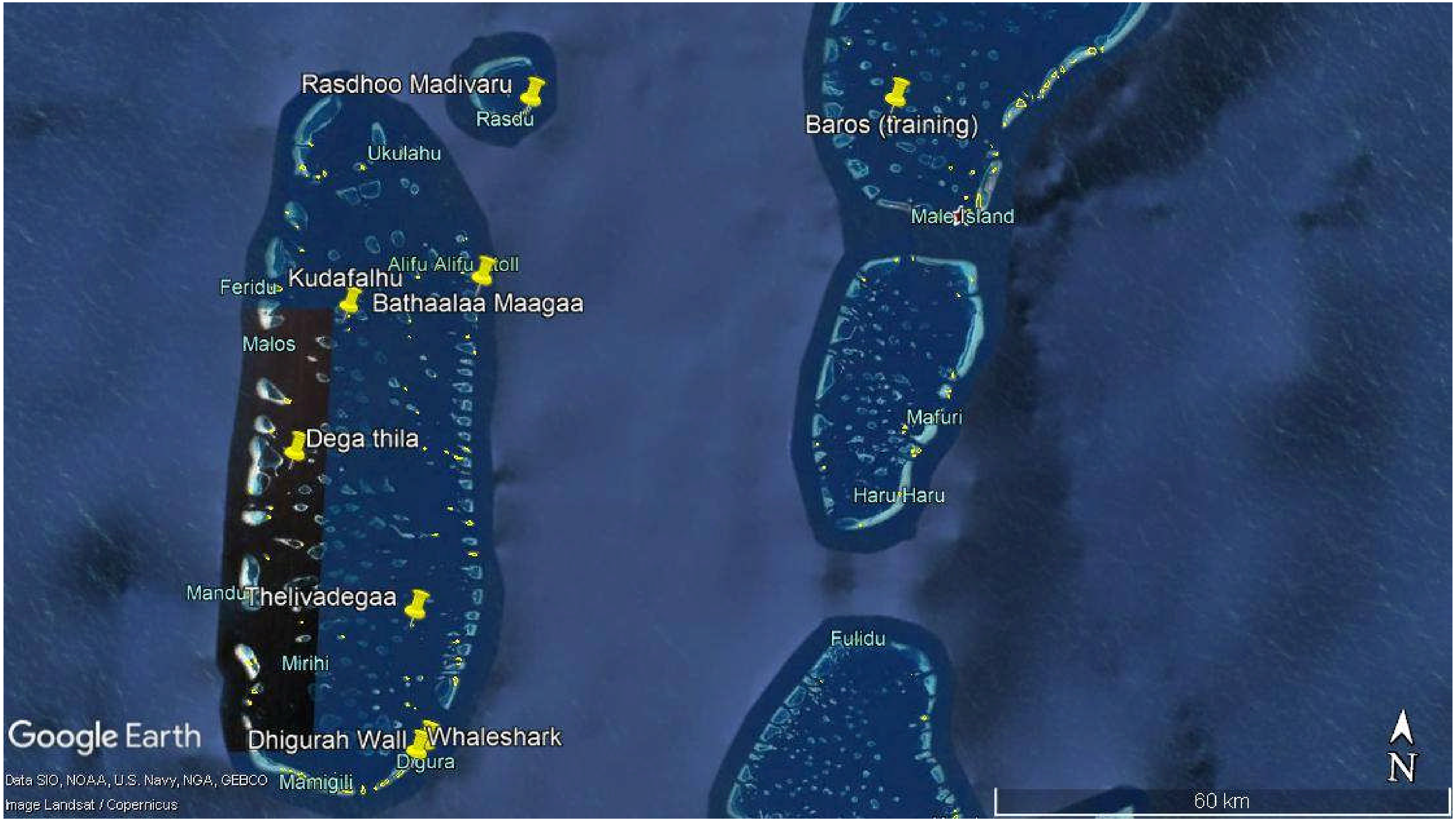


Figure 2.3a. Central Maldives atolls with the survey locations. The sighting of the whale shark was in almost the identical position (although a little further southwest) to the survey at Dhigurah Wall.

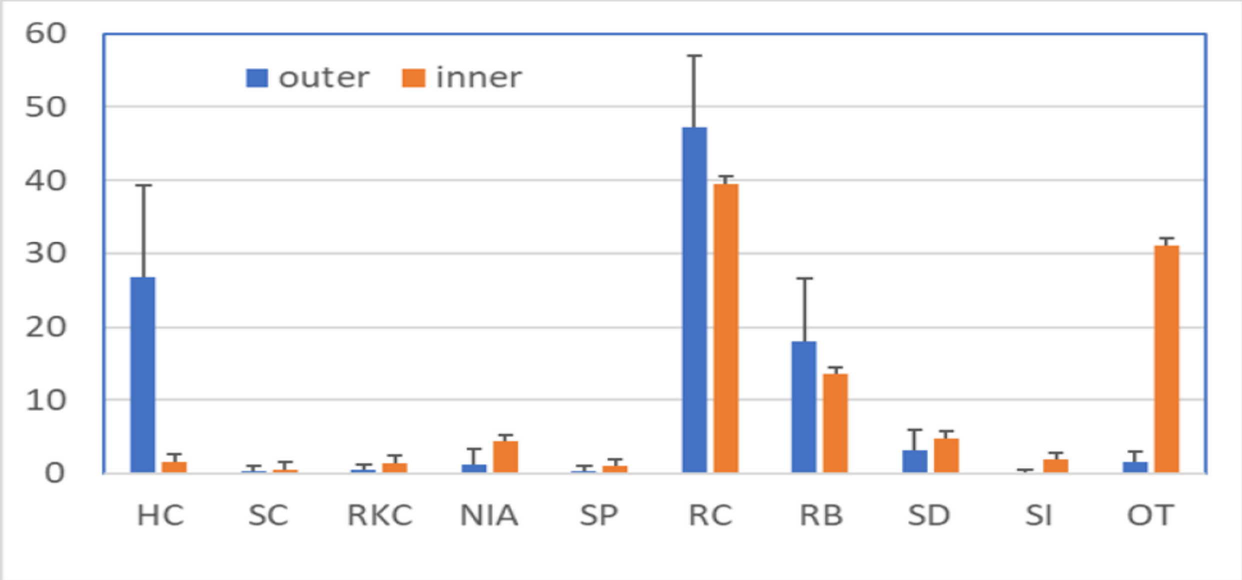


Figure 2.3b. Mean substrate composition (+SD) at 5 m depth in inner and outer reefs (see Fig 2.3a for locations). HC = hard coral, SC = soft coral, RKC = recently killed coral, NIA = nutrient indicator algae, SP = sponge, RC = rock, RB = rubble, SD = sand, SI = silt, OT = other.

Hard coral (HC) cover was significantly higher at outer than inner reefs (Fig. 2.3b), as it was in 2017. Many of the coral genera that had dominated outer reefs in 2017 were still present and healthy. These tended to be robust encrusting and massive growth forms, dominated by *Porites lutea* and *P. lobata,* and the bleaching-tolerant *Pocillopora meandrina* and *P. verrucosa*. The latter genera (other than the bleaching intolerant *Seriatopora hystrix* that used to be ubiquitous on shallow reefs of the Maldives) were also recruiting well to Maldives reefs on reef flats and outer reef walls.

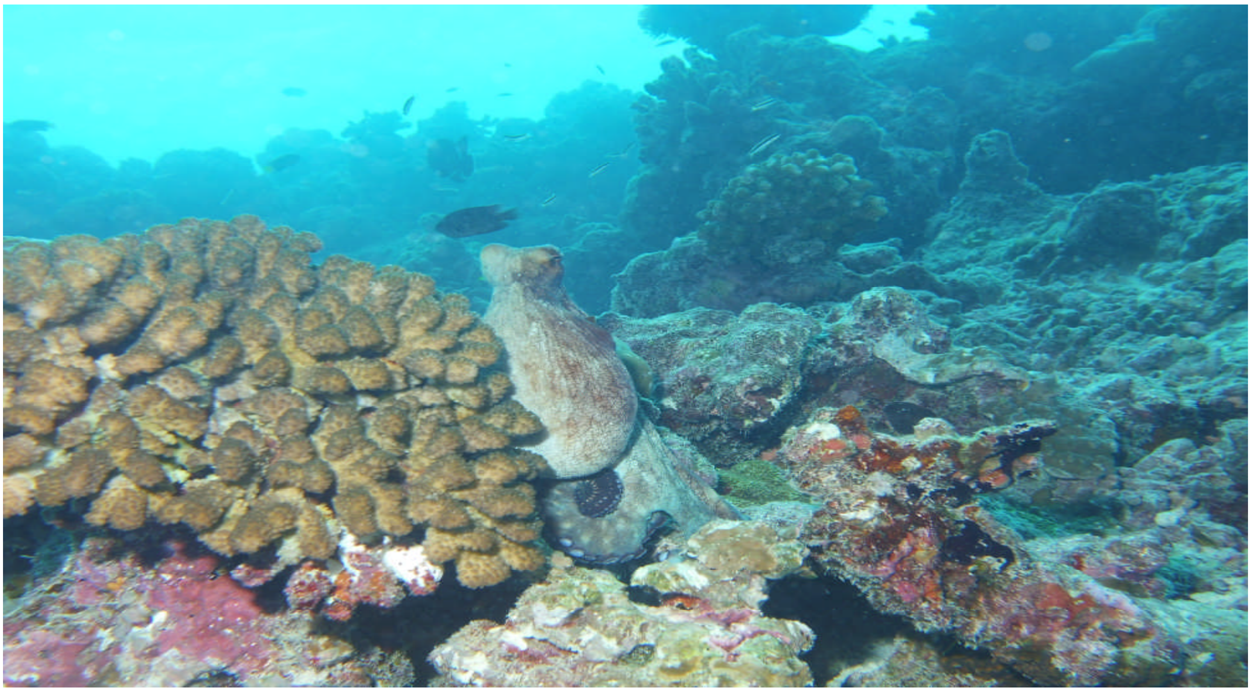


Figure 2.3c. Coral reef at 5 m at Rasdhoo showing the dominant genera *Pocillopora* in shallow water, next to a common reef octopus (*Octopus cyanaeus*). Another *Pocillopora* (about 25 cm wide) is in the background.

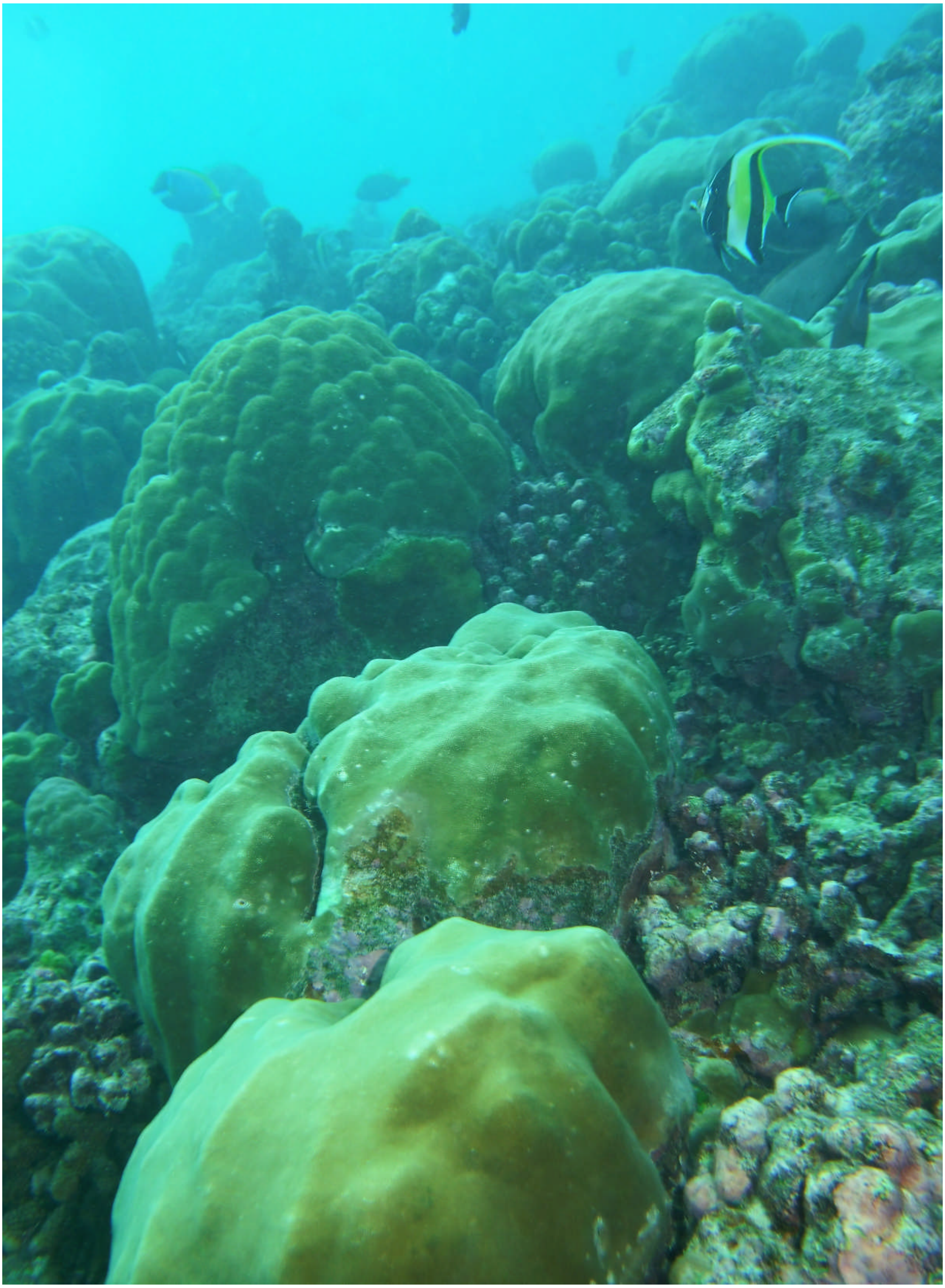


Figure 2.3d. Coral reef at 5 m at Rasdhoo showing the dominant genera *Porites* in shallow water.

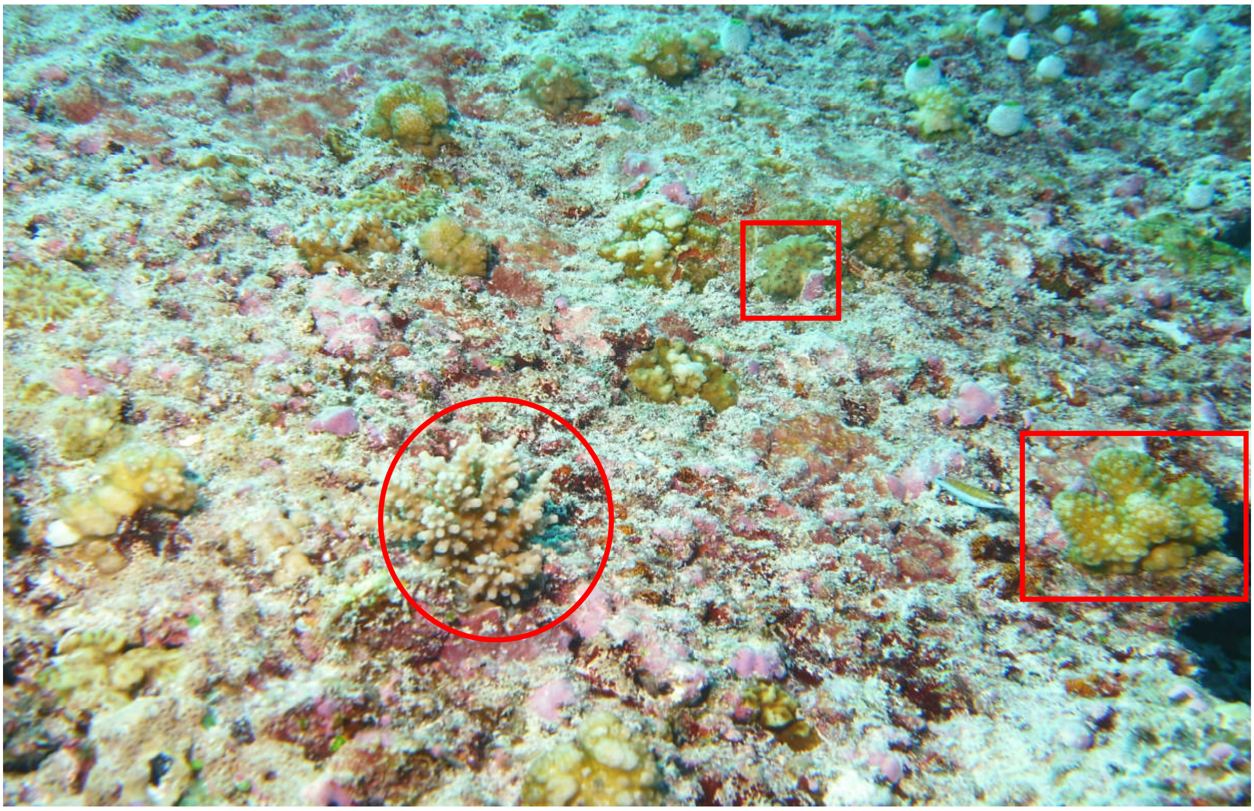


Figure 2.3e. Coral reef at 10 m at Dhigurah Wall showing the most dominant recruiting genera *Pocillopora* (rectangle). Also *Acropora* (circled), and even an unidentified species of *Favites* (square). Image size is 40cm x 30cm (LxW).

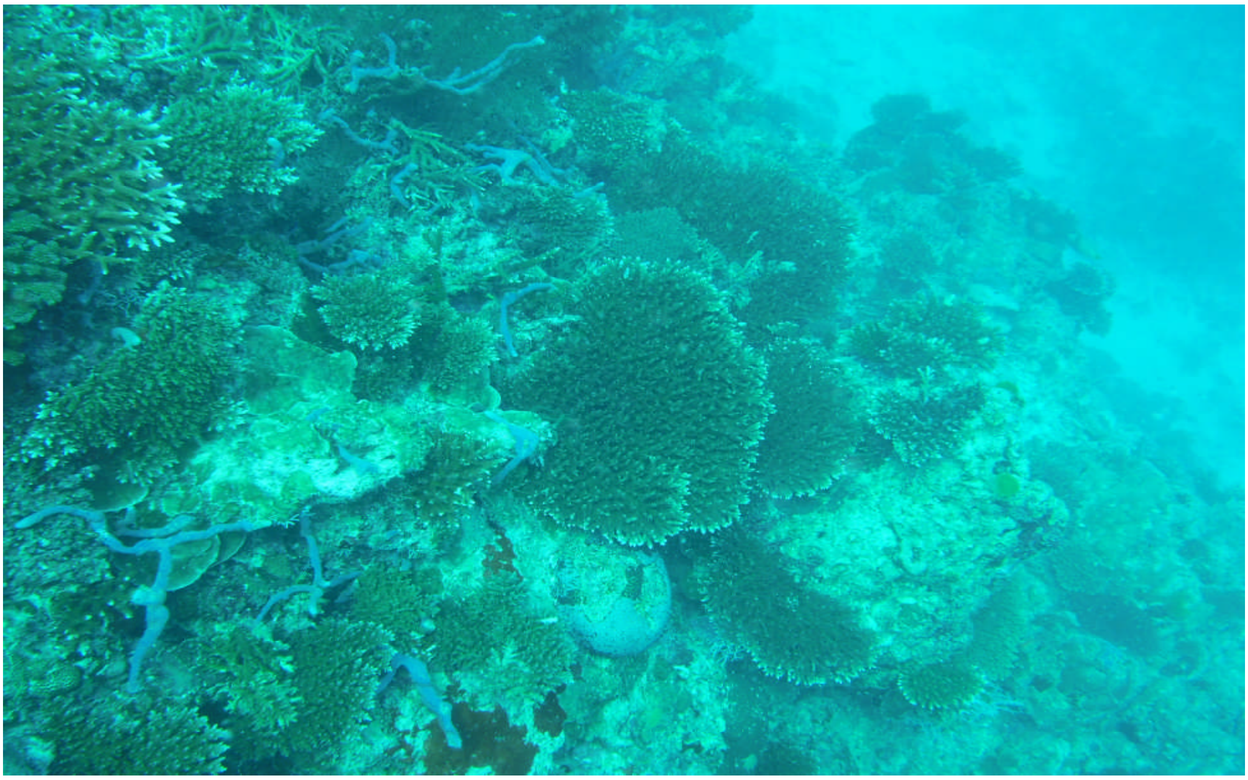


Figure 2.3f. Coral reef at 10 m at Kuda giri (southeast South Male' atoll) showing the area of greatest cover of *Acropora* colonies observed in the entire expedition. This was not a survey dive.

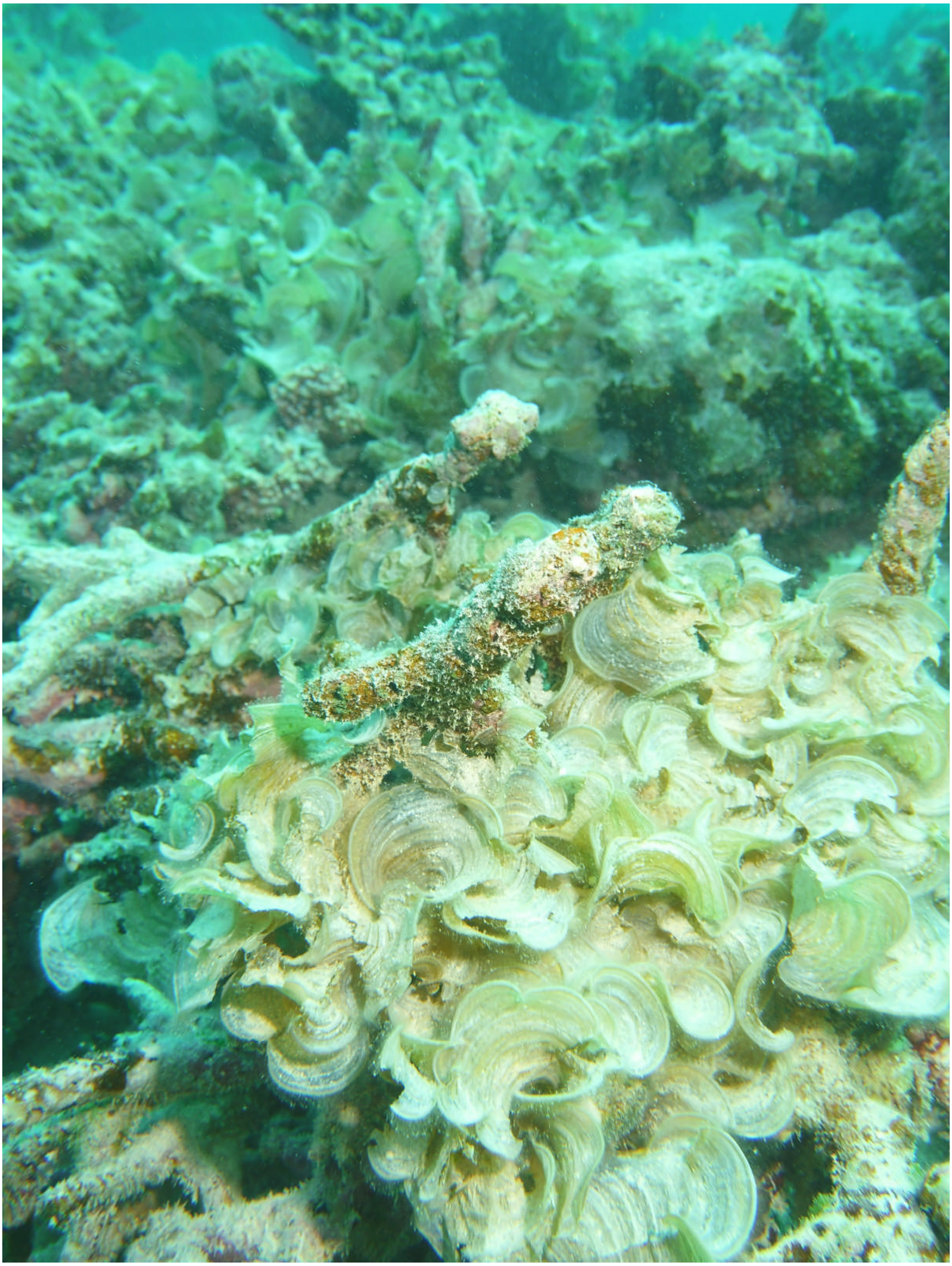


Figure 2.3g. Sheltered lagoon reef at 7m at Theluveligaa. Note the heavy infestation of *Padina commersonii* that was both attached to dead coral, and lying in amongst sand mounds within the 10 m deep sheltered lagoon floor.

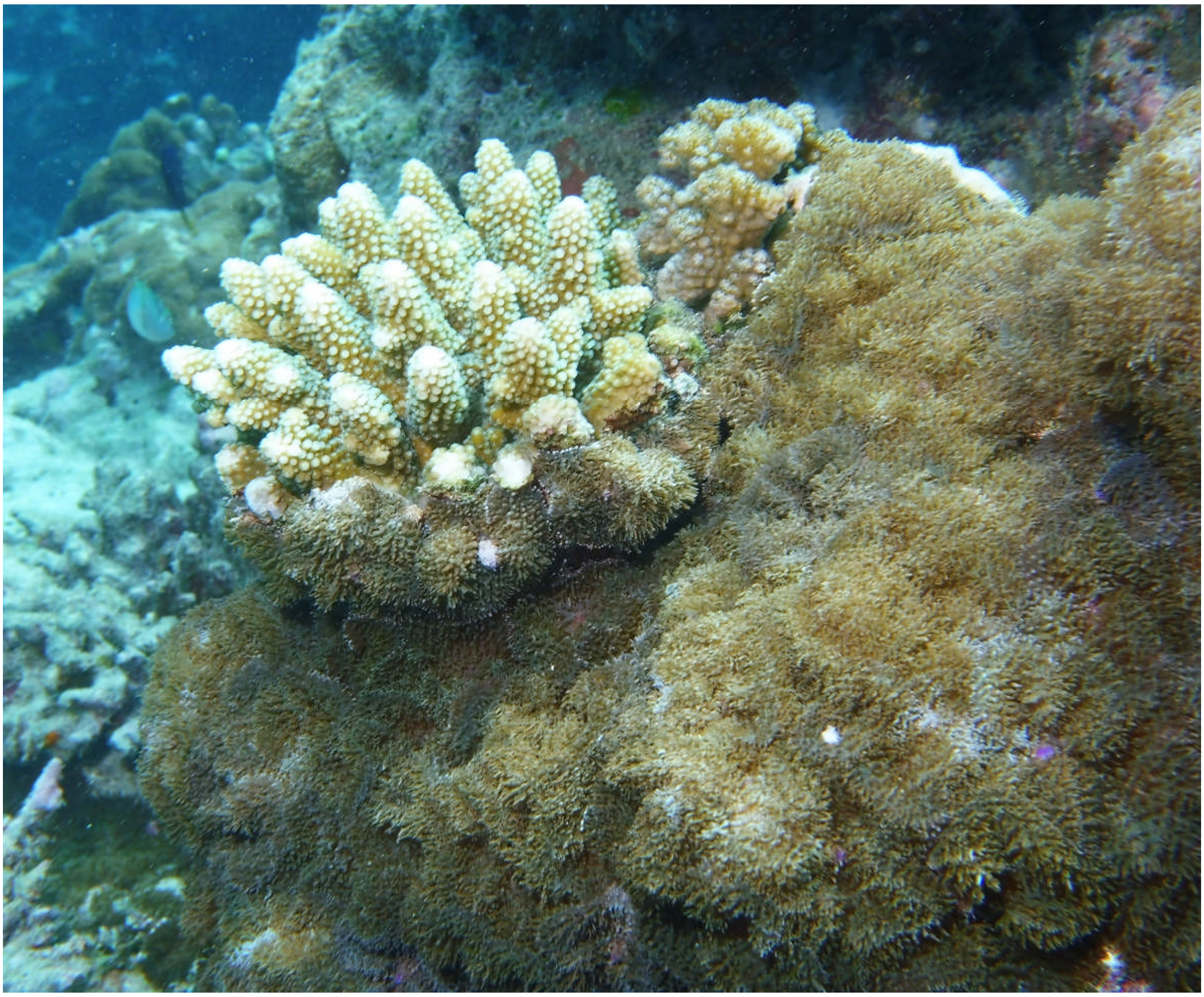


Figure 2.3h. Coral reef at 3 m at Dega thila. Note the infestation of *Discosoma* corrallimorph that is growing right up to the digitate *Acropora* (possibly *A. humilis*).

Figure 2.3i&j. Coral reef at 14 m at Dega thila (left) and 14 m at an unnamed reef, Vaavu atoll (right). These show colonies of staghorn *Acropora* corals found either in sheltered deeper reefs (>10 m) or in back reefs, where these two images were taken. Staghorn colonies were a rare find. Note the density and health of the thicket at Vaavu atoll.

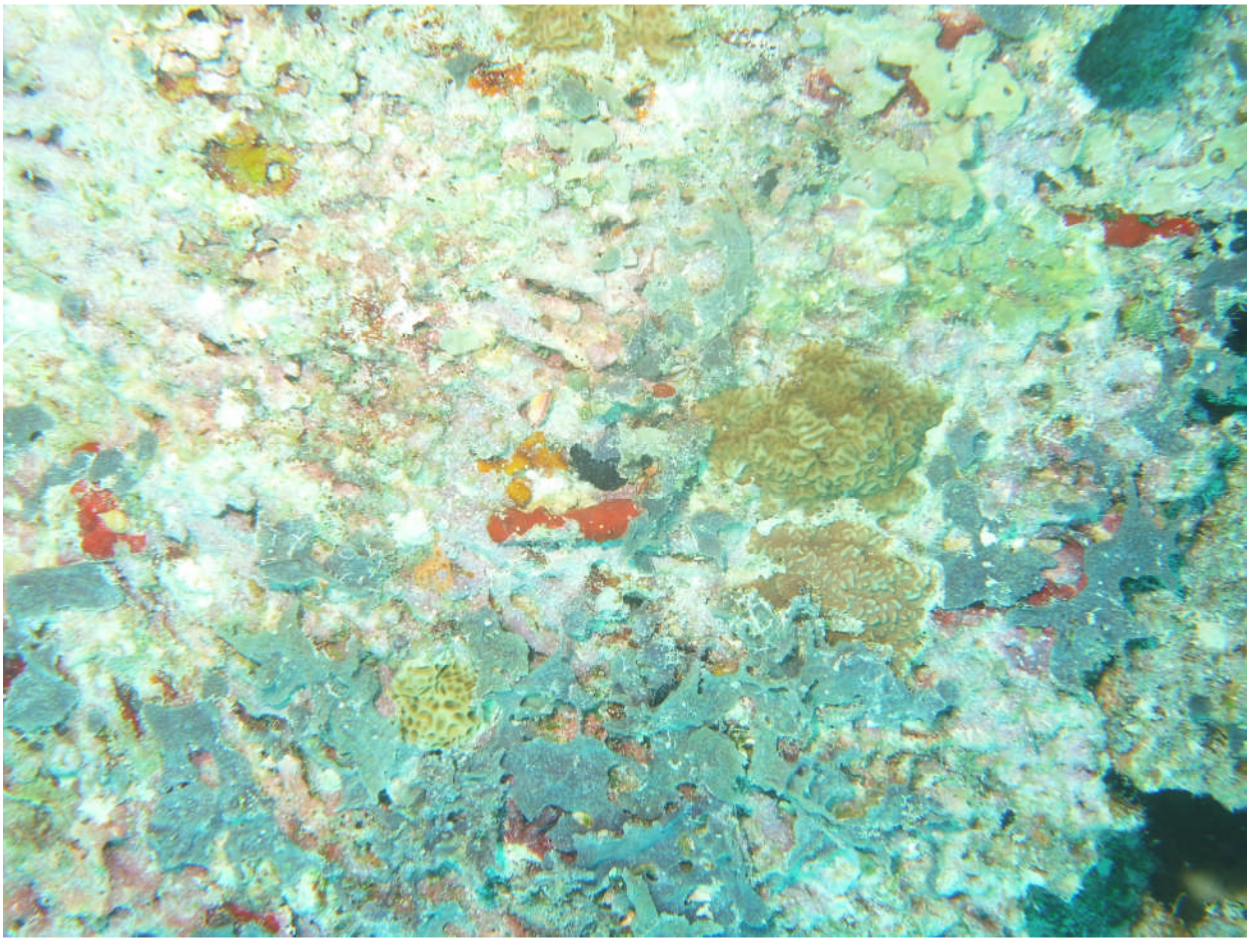


Figure 2.3k. Coral recruits of two species at Vaavu atoll, unnamed reef. The juvenile coral on the lower central part of the image could be a *Favites*, whilst the two in the centre right appear to be encrusting species. Note the heavy infestation of an unidentified grey sponge. This sponge has become more abundant at inner reefs since coral bleaching.

Fish populations

After bleaching episodes in the past, there has been a loss of diversity of three-dimensional living habitat (Jones et al. 2004). It is important to report on numbers and diversity of fishes present on reefs to see the effects of such disturbance events on the wider marine community. Such research in the past from the 1998 global bleaching event has shown a considerable impact on many reef fish species and families (Pratchett et al, 2011).

Because the reef fish counts of Reef Check are limited to a very narrow range of indicator species and families (snapper – lutjanids; butterflyfish – chaetodontids, and parrotfish – scarids), we can only use a very coarse assessment of what such an event may mean for the species and habitats of the Maldives. We can assess the impacts on those reefs that are less exposed to oceanic conditions, and that have been 'harder hit' by bleaching events (i.e. the inner reefs), compared to those reefs that have maintained better coral populations (i.e. the outer reefs). We analysed both butterflyfish and parrotfish numbers on inner and outer reefs, pre- and post-bleaching (for shallow transect depths).

We compared fish population data from regularly visited RC sites before and after the 2016 bleaching event (Fig 2.3l). Butterflyfish populations showed an overall decrease in absolute densities of counts at both inner and outer reefs, in deep and shallow waters (Fig. 2.3l). Inner reef butterflyfish species counts were low after the bleaching event in sheltered areas compared to before 2016 (Fig 2.3l(b)). However, this was not a statistically significant result (Mann-Whitney *U*-test, n=20, 312, $p<0.1$). None of the comparisons were statistically significant, largely because of the low sample sizes and large variance within and between sites.

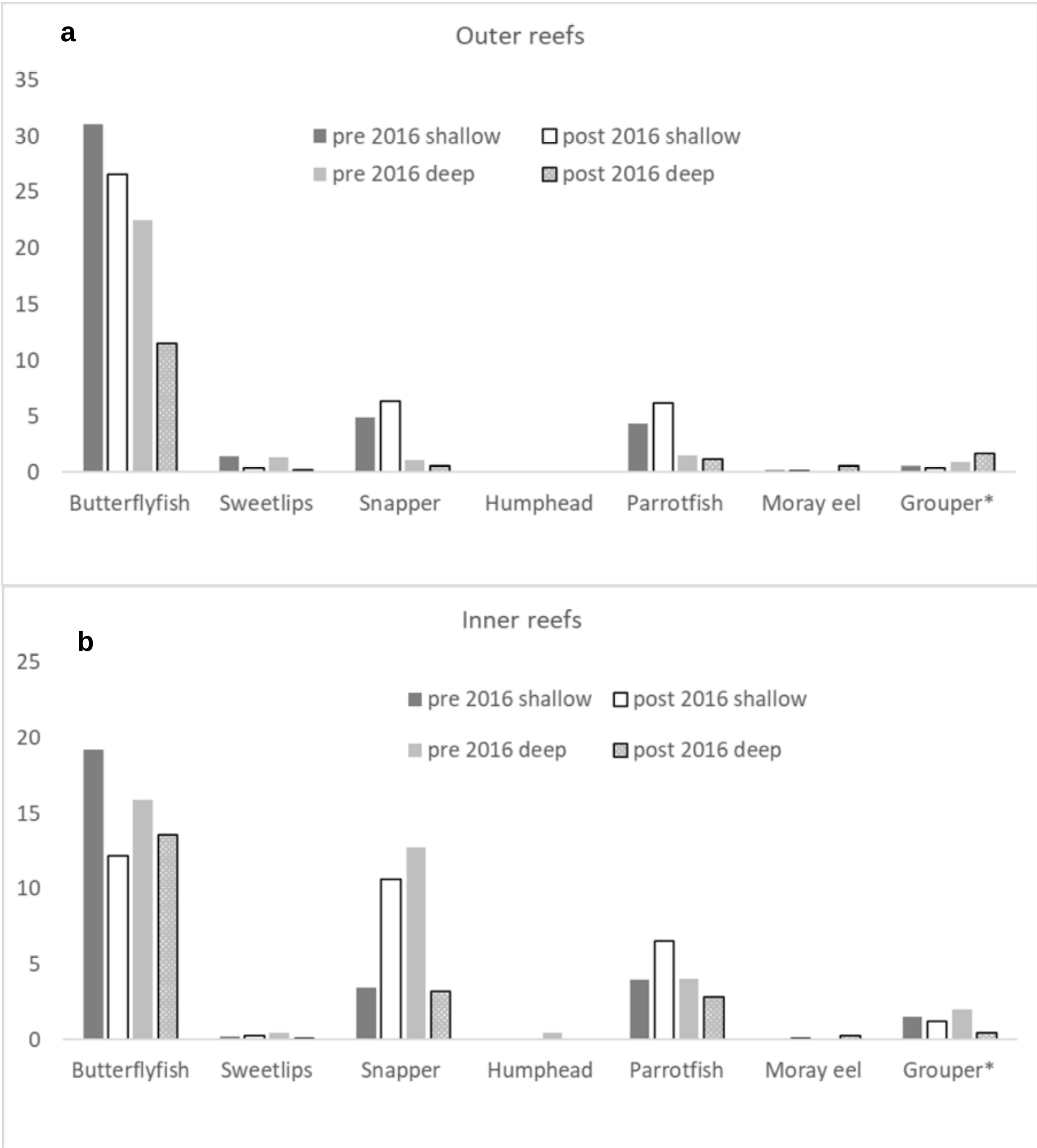


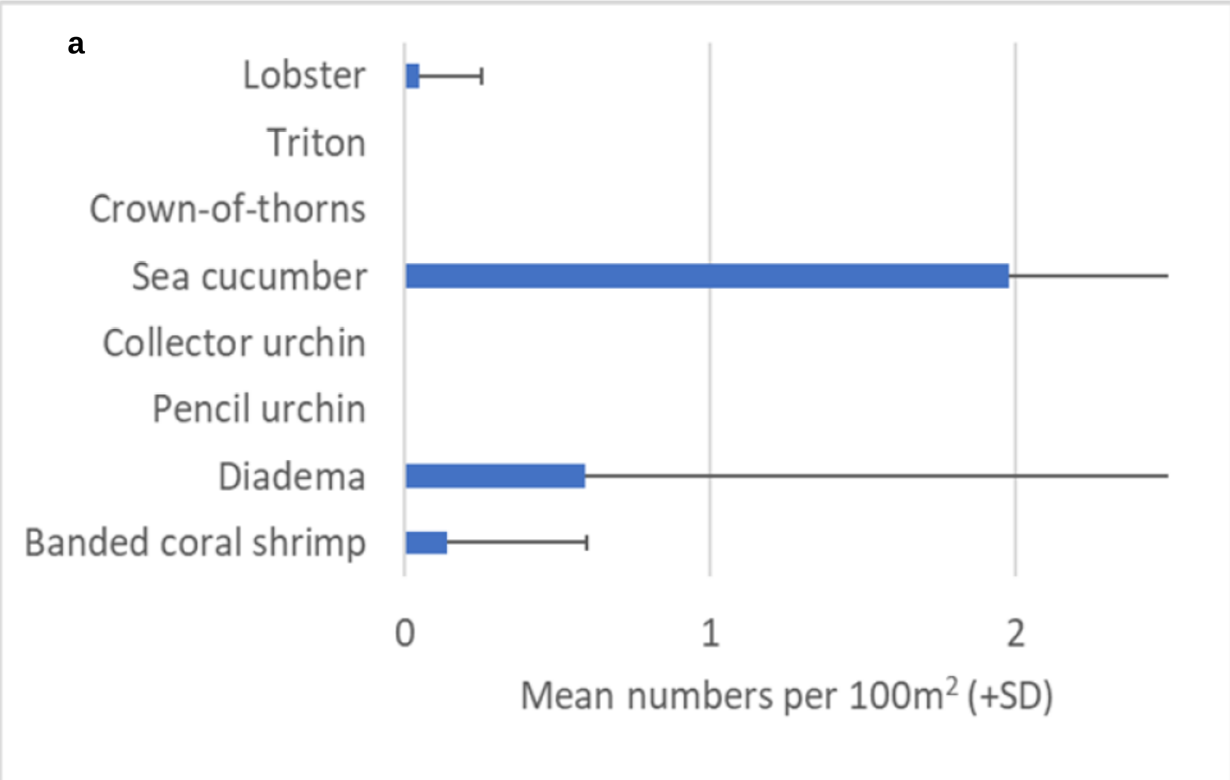
Figure 2.3l (a top and b bottom). Fish populations (per 500m^3 replicate) from regularly visited inner (Dega thila, Baros Maldives house reef, Holiday thila, Kudafalhu) and outer reefs (Rasdhoo madivaru and Bathaalaa maagaa) before and after the 2016 bleaching event from all previous Reef Check expeditions (2011 to 2018). *Grouper are pooled data from all size classes. Parrotfish are only recorded over 20 cm.

Another result that was not statistically significant, but was replicated at inner and outer reefs, was a greater number of parrotfish sightings at inner reefs (64% increase in numbers) after the bleaching event at the *shallower* transects. But parrotfish numbers were reduced at both inner and outer reefs at *deeper* depths after the bleaching event (Fig. 2.3l a&b). Snapper populations showed the same pattern; increasing at shallower depths (particularly for inner reefs) and falling in deep reefs post-bleaching. This trend was particularly marked at inner shallow reefs (202% increase from 3.5 to 10.6 individuals per 500 m^3), with a large fall in deeper areas (75% from 12.8 to 3.2 individuals per 500 m^3). The overall result is that almost all fish were reduced after bleaching at deeper depths other than a slight increase for grouper on outer reefs.

Invertebrate populations

Indicator invertebrate population counts showed low numbers in line with previous expeditions. Surveys observed small lobsters (at both Bathaalaa maagaa and at Rasdhoo madivaru); sea cucumbers and banded coral shrimp (at Dhigurah Wall and Bathaalaa maagaa), and *Diadema* urchins only once (at Bathaalaa maagaa). No Crown-of-thorns starfish were recorded.

Diadema urchins showed the greatest variance in number, with 25 recorded at Bathaalaa maagaa at 10 m, with one at the shallow transect. This is probably as a result of observer error, with citizen scientists prone to recording the small rock-boring sea urchin as *Diadema*. Despite intensive training, this continues to be an issue with some recorders. Giant clams were again fairly dominant this year. However, we are concerned about observer error here too, as a similar *Tridacnidae* clam (*T. crocea*) can be mistaken for the exposed giant clam *T. gigas*.



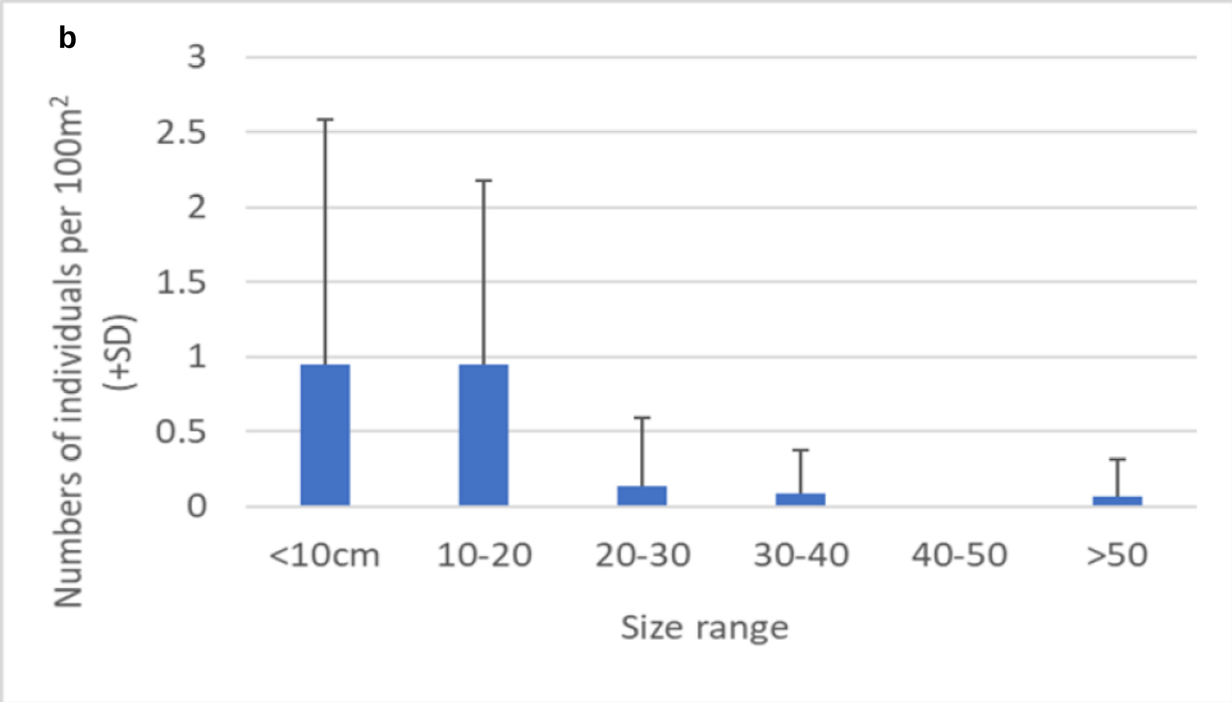


Figure 2.3m (a top and b bottom). a: Numbers of different invertebrates recorded on the dives at North Ari of all sites combined from 2018 data. Note the absence of crown-of-thorns. These heavily infested Kudafalhu in 2017, but were completely absent from all sites in 2018. b: Average numbers of giant clams along the transect for all sites and depths combined. Note that there are concerns over the accuracy of the giant clam data due to misidentification issues.

Other impacts, including bleaching

Coral damage is recorded by the Reef Check methodology in terms of direct impacts on corals, diseases (incidences rather than specific 'pathogens'), the amount of bleaching per live population and per affected colony within each replicate.

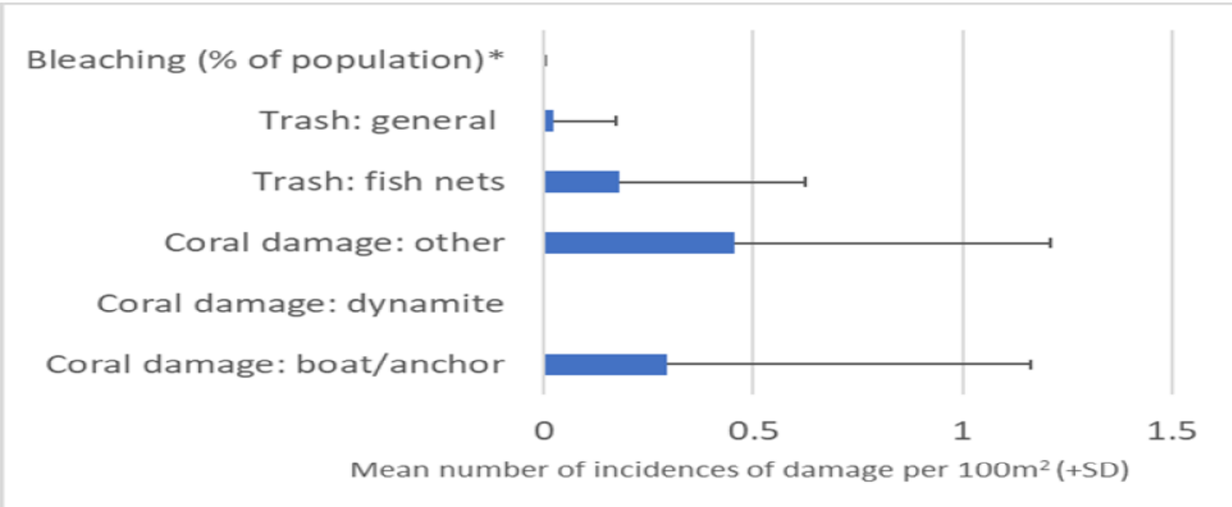


Figure 2.3n. Impacts observed. Measured as a semi-quantitative scale (on the X axis, a semi-quantitative scale is used. 1 = 1-2 observations; 2 = 3-4 observations, 3 = >5 observations). *The total live population is assessed from each replicate, and the amount of that population that is estimated to have bleached is recorded here.

Coral damage in the Reef Check category ‘other’ in the Maldives is usually associated with predation by *Drupella* coralivorous snails. These were most abundant at Dhigurah Wall. Coral damage at Kudafalhu was predominantly due to anchor damage according to surveyors. However, this may simply be storm damage affecting the coral reef that had seen large storms in 2015, and crown-of-thorns and bleaching impacts in 2016. As a result, much of the delicate (predominantly table) coral colonies had fallen and turned into rubble by the time of these surveys in July 2018, perhaps resembling anchor damage. The net result for that reef was a badly degraded reef with coral cover of under 5% and with very limited recruitment that was observed only in the top 2 m of the water column.

Other marine life and noteworthy observations

Reef Check surveys record incidences of unusual, rare or threatened marine life, both on transect and off transect (Fig. 2.3p; Table 2.3b). Manta are rarely recorded at our permanent monitoring stations, but three were recorded at Rasdhoo madivaru, where they have been seen to benefit from upwelling of plankton on the fore-reef slope.

Table 2.3b: Other noteworthy observations.

Site name	Observation	Atoll	Inner/outer reef
Rasdhoo Madivaru	1 stingray, 3 manta, 2 hawksbill, 1 octopus	North Ari	Outer
Bathaalaa maagaa	2 white tip reef sharks	North Ari	Outer
Kudafalhu	1 crown-of-thorns; 4 dead giant clams	North Ari	Inner
Dega thila	4 white tip reef sharks; 2 dead giant clams	South Ari	Inner
Theluveligaa	1 white tip reef shark	South Ari	Inner
Dhigurah Wall	1 many banded pipefish; 3 tiger cowrie; 1 network lamellaria cowrie; 1 chromodoris nudibranch; 1 whale shark seen three hours after the survey commenced.	South Ari	Outer

Whale shark sightings

A half-day effort-based whale shark survey was also carried out at the outer reef of South Ari MPA, yielding one encounter at Maamigili on 26 July 2018 at approximately 11:50. The animal was a 3.5 m long male and had previously been identified by the MWSRP as 'WS350 Hudhu Veli'. This shark was first identified on the same reef by MWSRP on 20 January 2018. MWSRP (who survey for 4-6 hours every day) had seen very few sharks in the week of our survey. The encounter with this shark lasted for about five minutes, initially at the 6 - 7 m drop off point on the shelf front, then rising slowly to the surface over about 70 m horizontal distance, reaching the surface, whereupon it was possible to then dive down to see the claspers. The shark was no longer than twice the length of the average male (human) with fins on, so was estimated as being no larger than 3.5 m (Fig 2.3o).

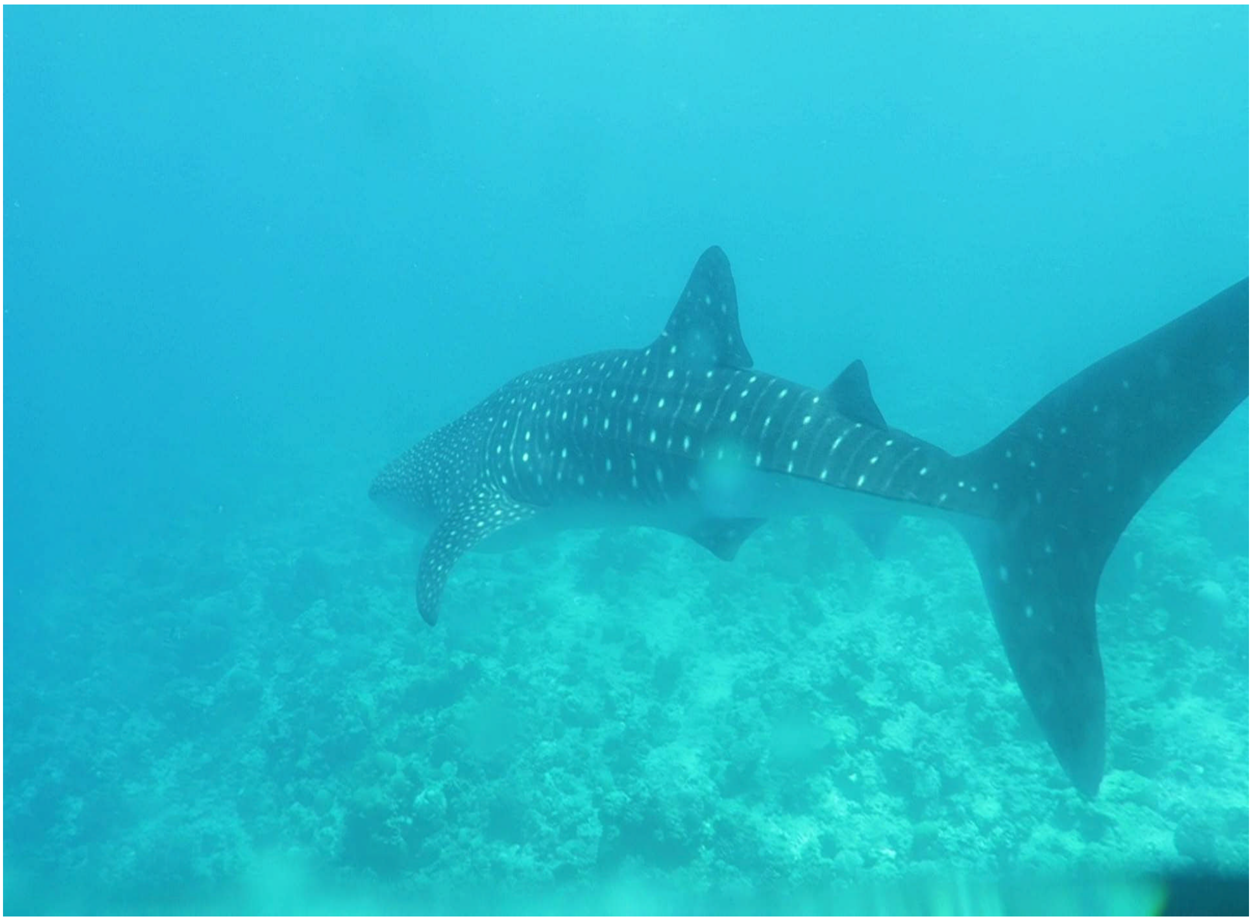


Figure 2.3o. Whale shark observed and recorded on 26 July 2018.
There is also a video clip of the encounter at https://youtu.be/AKIHE9ULDuE.

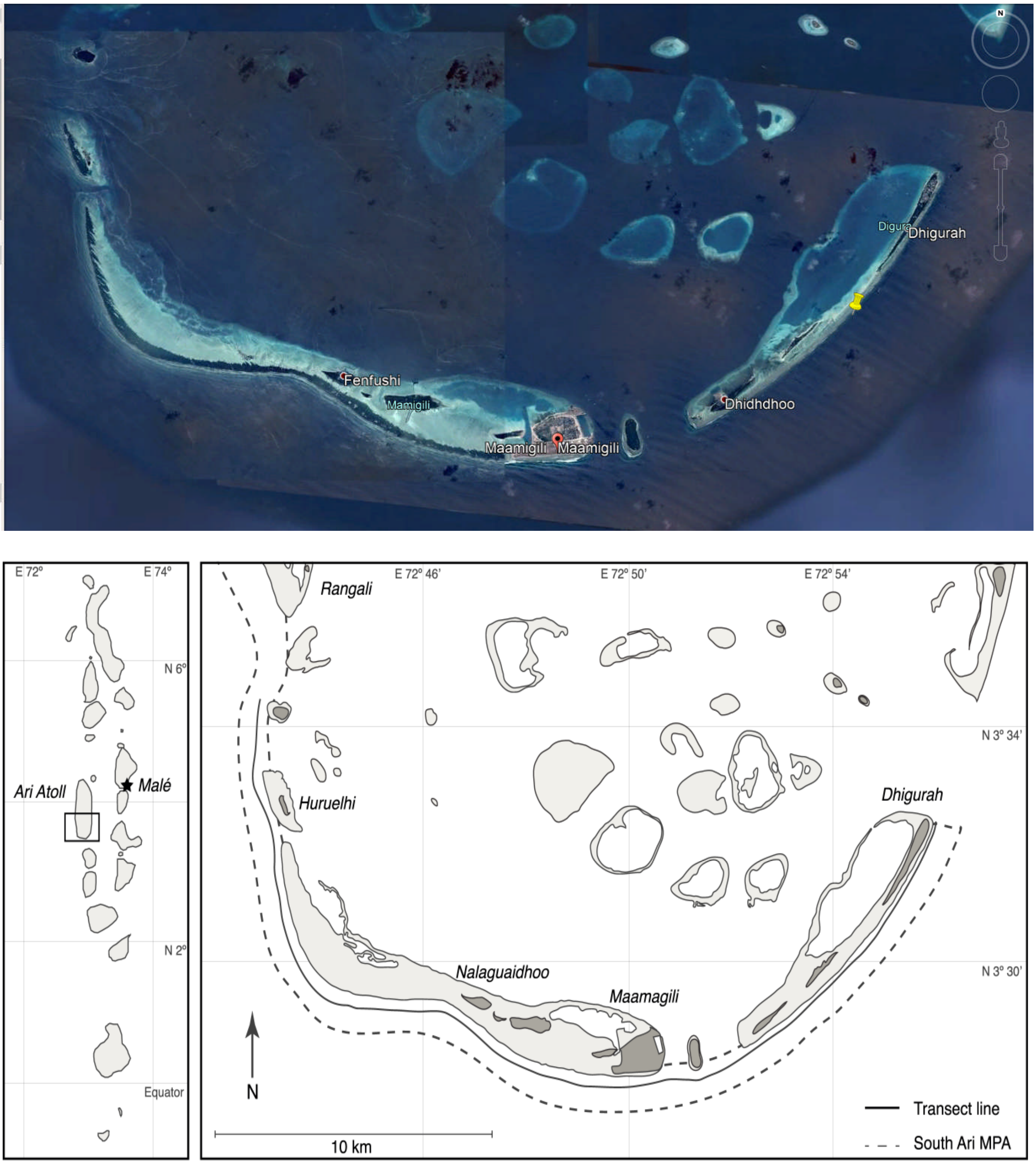


Figure 2.3p. The Mamigili MPA in South Ari atoll, Maldives. At a size of only 42km^2, it is narrow, but it extends along a large exposed southerly facing reef. It runs from the reef crest out in a southerly and westerly direction 600 and 900 m out to the open sea. The yellow mark is where the shark was encountered on 26 July 2018 at 11:50.

2.4. Discussion

MPA designation

The outgoing Maldives government passed laws in September 2018, creating three new MPAs[23]. These are currently in statute and were based on data from the EPA[24] and MRC that had been advocating for a number of years.

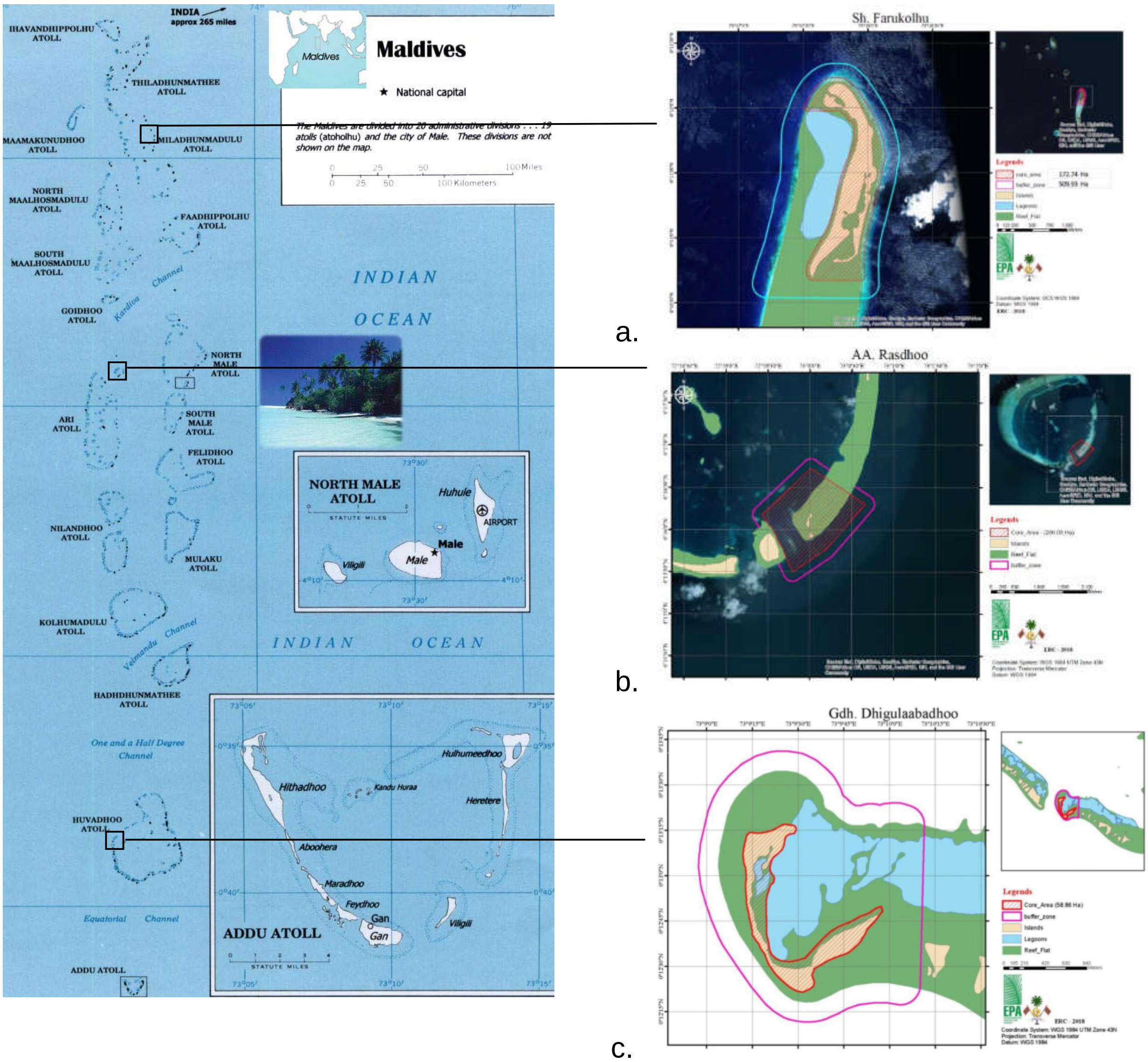


Figure 2.4a. Three new Marine Protected Areas designated in September 2018.
a. Faukolhu, b. Rasdhoo Madivaru, c. Dhigulaabadhoo.

[23] https://maldivesindependent.com/environment/environment-ministry-declares-three-new-protected-areas-141940
[24] https://www.cbd.int/doc/meetings/mar/ebsaws-2015-01/other/ebsaws-2015-01-template-maldives-en.pdf

The sites have been confirmed and are established as IUCN Cat I and Cat VI sites, namely sites that are no-take and no-dumping, and sites that are established for the protection of a particular species or habitat.

Two sites (a. and c. above) are predominantly wetlands that were threatened by potential airport developments to the north and south of the country (Fig. 2.4a). Developing major infrastructure projects on islands that host significant mangroves, seagrass beds and sheltered lagoons is likely very damaging to fish nurseries for subadult fish and essential recruitment grounds for juvenile fish that recruit out of the plankton. Destroying wetland habitats has a negative impact on reef fish populations (Mumby et al. 2004)[25].

Rasdhoo Madivaru has been advocated for protection by Reef Check Maldives, dive liveaboards and Maldivians for at least 20 years. Some dive masters have already described the site as an MPA to visiting scientists before (personal communication with dive masters on MV Sea Spirit from 2005-2007), probably as a consequence of its popularity as a dive site over and above any other use. The MCS started diving at the site in 2005, and since then the snapper and sweetlips fish populations have declined (Fig. 2.4b). The schools of red, midnight, black and white snapper, and horse-eye jacks have all reduced. We still, however, observe white tip reef shark and grey reef shark off the slope, and during this survey recorded three mantas moving in an easterly direction away from the site.

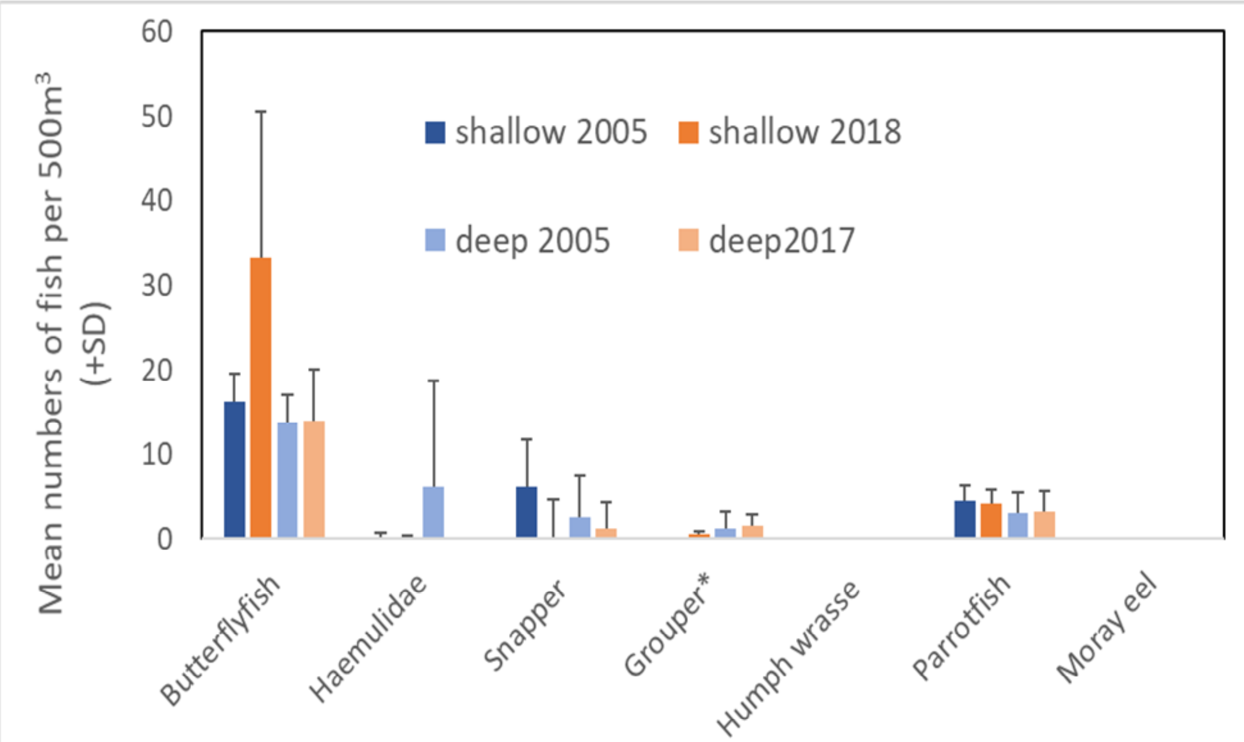


Figure 2.4b. Numbers of fish in 2005 and 2017/2018 at Rasdhoo Madivaru.
Note the decline in sweetlips (*Haemulidae*) and snapper (*Lutjanidae*).

[25] http://news.bbc.co.uk/1/hi/sci/tech/3458827.stm

The MPA designation is unlikely to affect the coral population of the site, since research has shown that MPA designations do not directly have an impact on susceptibility to coral reef bleaching (Strain et al. 2018). However, the key point about Rasdhoo madivaru, is that, as well as hosting megafauna popular with divers (manta, sharks, eagle rays), outer exposed wall reefs do appear to be resilient to thermal-induced bleaching in areas where surveys were conducted. We have postulated (Solandt and Hammer 2017a, 2018) that this may be because of the proximity to deeper cool water that allows mixing of deep and shallow water during warming events (Cowburn et al., 2019), and because the species that naturally occur in shallow exposed waters in areas of considerable wave action at the edge of drop-offs (large porites and faviids, favites, meandrina) are *also* resilient to temperature-induced coral bleaching (Marshall and Baird 2000).

A recent study (Sully et al. 2019) revealed that reefs nearer the equator that experience daily temperature variance (perhaps due to current-induced upwelling) are more resistant to bleaching. Bleaching response variability is also complicated by environmental variables (surge/light) that influenced the coral community before the advent of mass bleaching events in the 1980s. As such, extrapolating out considerations of coral response to bleaching in such papers at such large global spatial scales (Sully et al. 2019) has to be treated with caution.

The 'outer wall effect' was also evident at Dhigurah Wall, a site with a very similar reef profile to Rasdhoo madivaru that also lies within an MPA for whale sharks. At Dhigurah Wall, the coral assemblages, sizes, and high recruitment suggest similar oceanographic variables to those at Rasdhoo madivaru, making it a resilient reef, and one that can recover more readily from bleaching events than the inner reefs we have surveyed. By contrast, it is sad to report that we cannot recommend any of the inner reefs (many of them house reefs for resorts) for added protection, because large areas of these reefs deeper than the top 2 - 3 m appear to have been irrevocably damaged by the bleaching of 2016, crown-of-thorn infestations and subsequent colonisation by non-coral lifeforms (e.g. sponges, *Discosoma*, turf and macroalgae). This was evident at Baros, for example, which the expedition had used as a training site for many years (Solandt and Hammer 2017a, 2018), but which had to be abandoned as a training site in 2018, because the reef was so degraded.

Other biological findings in this report

The story of coral reefs around the world between 2016 and 2018 was one of catastrophic habitat loss[26]. The hard coral reefs that dominated the Maldives and Great Barrier Reef, and all the reefs of the 'coral triangle' (reefs of Papua New Guinea, Malaysia, Indonesia and the Philippines) all bleached. Reefs exposed to oceanic conditions fare better than inner reefs in both resilience and with larger numbers of coral recruits (Fig 2.3b), particularly at Dhigurah Wall. Nevertheless, the corals that survive and recruit appear to be far less species-diverse than those we are 'losing'. Such structural and diverse changes to the coral community (in effect to the diversity of habitat) will undoubtedly have a knock-on effect on the coral reef fish and invertebrate assemblages.

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[26] https://coralreefwatch.noaa.gov/satellite/analyses_guidance/global_coral_bleaching_2014-17_status.php

This effect is bound to be negative (decreasing functional redundancy, or resistance to further perturbations such as crown-of-thorns, or disease outbreaks (Richardson et al. 2018)).

We are very concerned that the inner reefs remain badly affected by the 2016 bleaching. For some sites we are witnessing a ‘phase shift’ (Hughes 1994) to algal and sponge-dominated seabed biotopes. This is what has happened in Jamaica and over much of the Caribbean since the 1990s (Knowlton and Jackson 2008). This shift appears to be occurring on many inner-atoll reefs of the Maldives. Some fish grazers are not adapted to consuming the heavily defended species of algae that are now starting to colonise affected reefs (i.e. species that are heavily calcified or that have toxic secondary metabolites, such as *Sargassum* sp. and *Padina* sp.). At the Great Barrier Reef, for example, certain acanthurid species preferentially feed on smaller *Sargassum* plants, than chubs (*Kyphosidae*) that preferentially fed on larger plants (Hoey 2010). *Padina* sp. was particularly dominant at Theluveligaa – an inner reef near to a resort. *Padina* has calcareous rings within its tissues, making it nutritionally less rich to grazers, and more difficult to digest.

Two new sites that we visited (both on this survey at Theluveligaa inner lagoon, and during a subsequent pleasure diving trip by the lead author to a sheltered backreef location at Vaavu atoll) showed a shift from coral to algal communities. Theluveligaa is an inner reef site to the east of South Ari atoll (that was surveyed during the Reef Check expedition). ‘Unnamed reef’ is an unnamed back/inner reef site to the west of Vaavu atoll (Fig.2.4c bottom). Both reefs appear to be suffering infestation of – respectively – algae and sponges, overgrowing large areas of dead coral colonies. The former site, Theluveligaa, shows stress in relation to the algal overgrowth and turfs growing on the dead coral skeletons (Fig. 2.3h).

The interesting aspect of the decline at Vaavu atoll is that the over-growth is to a lesser degree, but is dominated is by sponges (Fig 2.3k) rather than algae. Scientific literature suggests that the decline in coral state that is replaced by algae is one exacerbated by nutrient input (Hughes et al. 1999) and this has been understood for decades by coral reef managers. Theluveligaa is a resort island and our survey was conducted close within 300 m of the beach. Research has shown that the influence of nutrients diffusing into the water column from populated islands has an impact on nearby reefs (MEE 2017, Pisapia et al. 2017). That encompasses the area we surveyed, particularly as we were surveying within a sheltered shallow lagoon where entrainment of the waters would be greater than either on the reef flat, or outer margins of this inner reef (Fig 2.4c).

The reef of Vaavu, whilst not surveyed by the Reef Check methodology, was badly affected by sponges overgrowing dead coral colonies. Whilst there was markedly less algae than at the inner reefs of Ari atoll at Vaavu, there were indications of a ‘phase’ shift’ of corals outcompeted by sponges (Fig. 2.3k). A factor perhaps affecting this sponge dominance relative to algal dominance is the relatively remote location of this site from direct pollution input from a populated island (see Fig 2.4c bottom). In this image there are no resort / inhabited islands near to the dive site.

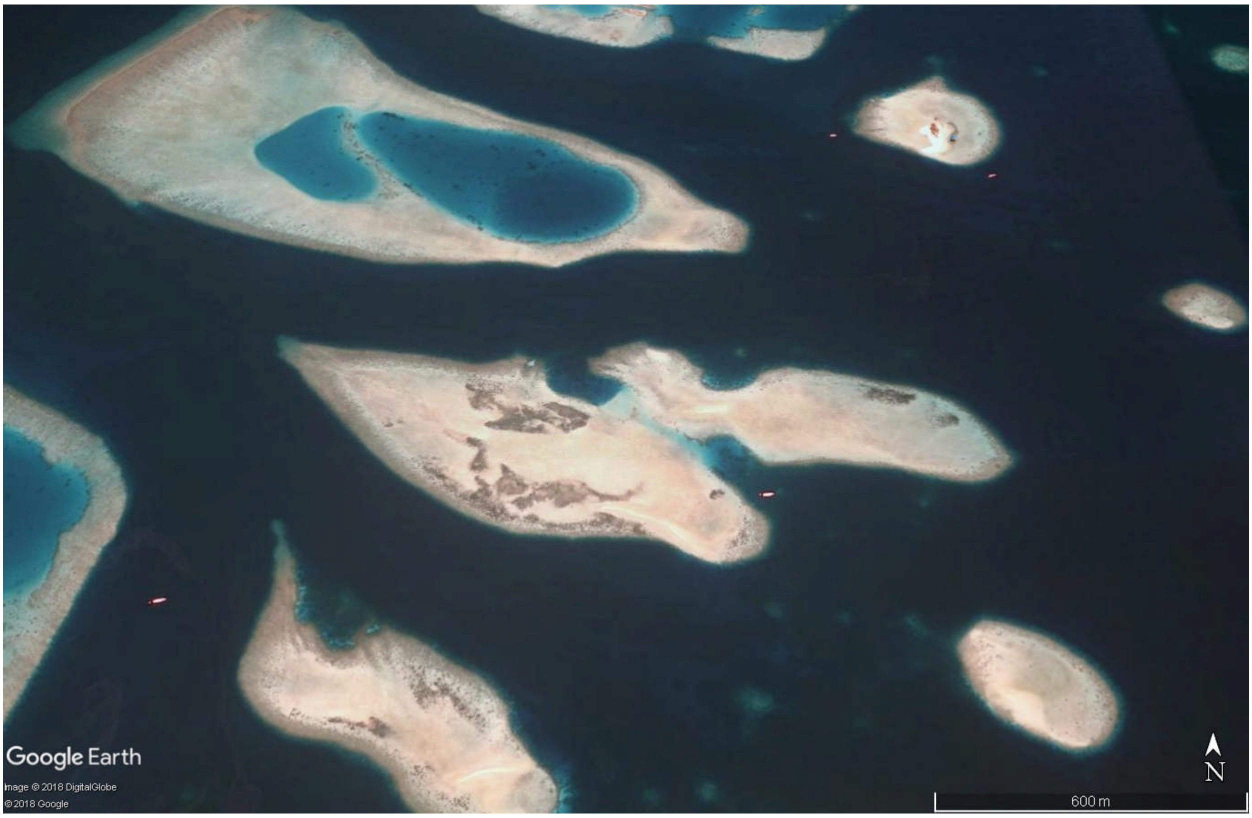

Figure 2.4c. Top: Theluveligaa to the southeast of Ari atoll. Surveys were carried out near to where the jetty meets the eastern lagoon (red cross). Bottom: Unnamed reef at Vaavu atoll (exact location kept confidential on request). The lack of inhabited islands near to this reef may have resulted in a different response to the bleaching of 2016; to become less dominated by algae and more by opportunistic sponges.

Whale shark sighting

There was one sighting of a single 3.5 m male whale shark at the Mamagili MPA in the vicinity of the island of Dhigurah Wall (Fig. 2.3o) on 26 July 2018 at 11:50[27]. The shark was swimming in a relaxed fashion along the reef, at about 4 knots, first encountered at about 10 m depth, then rising to the surface over about 50 m, then diving again. Even though the shark was surrounded by snorkellers for much of this period, it did not adjust its direction or speed during the five minute encounter.

Recent research carried out by the University of York[28] has identified common oceanographic factors between areas of whale shark hotspots around the world (Australia, Belize, Mexico and Mamigili in the Maldives). All these sites are in areas of upwelling, or where deep water is adjacent to warm shallow areas (Copping et al. 2018). It is thought that as the sharks are ectotherms (cold blooded), they need to rise to shallow depths to warm up before plunging to (on average) over 400 m in order to feed in persistant horizontal 'fronts', where their planktonic food is thought to aggregate. These hotspots are dominated by young sharks <10 m length), perhaps suggesting that at a smaller size, they are more vulnerable to stress from their deep-water dives.

Outlook

We are living in unprecedented times, with climate change 'locked in' for at least the next 20+ years (Brown and Caldera 2017). If we were to reduce CO_2 emissions today to below 350 ppm (the level at which most scientists believe we will reduce global temperatures), we still have a lag-phase built into the system (Zickfield and Herrrington 2015). Unfortunately, the International Energy Agency (IEA) has said that 2018 would see an increase in CO_2 being emitted into the atmosphere[29]. So the global political drive to push the Paris agreement is not working.

The impacts of climate breakdown will be multifarious and overwhelmingly negative to human existence as we know it today. The central Maldives can serve as a particularly stark example with a very worrying trend emerging: One of long-term and short-term impacts making a lasting impression on the coral assemblages, fish populations (Sattar et al. 2012) and the general health of the marine life surrounding the islands, with increasing incidences of disease (Montano et al. 2012), crown-of-thorns (Saponari et al. 2014) and corallimorph outbreaks. This trend is not new and has been emerging since the mid to late 1990s. The decline of the Maldives reefs was set in motion in the 1990s by four principal factors: (1) The first mass-bleaching event in 1998 triggered by climate change events such as El Niño, ocean acidification, and increased sea surface temperature, (2) the development of commercial fisheries for the live fish trade (principally targeting grouper), (3) the large-scale expansion of the tourism infrastructure, (4) the ignorant or wilful inaction of recent governments, sacrificing long-term gains in favour of short-term power.

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[27] https://youtu.be/AKIHE9ULDuE
[28] https://www.york.ac.uk/news-and-events/news/2018/research/research-reveals-secret-to-whale-shark-hotspots/
[29] https://qz.com/1417078/global-carbon-emissions-are-set-to-rise-in-2018/

All of these issues have had associated costs. Many Maldivians would indeed argue that the second and third points have helped provide jobs for Maldivian citizens. This is undoubtedly true; but at what cost? The initial area of concern (point 1) has recently been initially mitigated for by the policies and actions of former President Mohammed Nasheed (president 2008 – 2012). He was concerned over climate predictions resulting in sea level rise and increased storminess that could inundate the country. There are various climate models that predict the Maldives to be underwater within 30 to 100 years (e.g. Viner and Agnew 2000[30]). However, since his political demise in early 2012, there has been scant regard to adapting local policies to reduce CO_2 emissions, nor to establish environmental policies that will benefit the most needy, away from the commerce of Male' and the tourism industry. Part of the new '100-day pledge' from the new government was to increase green taxes and increase transparency. Whether this has actually happened is not known to the authors at this time.

Since 2015 there has been a push to increase tourist numbers. In 2017, visitor numbers increased to 1,389,542[31], with 27 new resorts planned for construction in 2017 alone. The proportion of tourists from China was 25% of the total in 2017, showing that the Maldives has been flexible in developing new markets whilst more traditional tourism markets from Europe fall (in the face of political unrest in the Maldives and the availability of alternative, less controversial holiday destinations). Investment in tourism is not matched by environmental precaution, or the "polluter pays" principle that is seen in UK and EU laws, that could stave off the worst impacts of this growth. There have been '100-day' pledges by the new government (that haven't come to fruition) over protecting one coral reef, mangrove and island per atoll. In total, government wants to declare 14% of each atoll as protected in the future. Proper financial accounting of healthy marine ecosystems will help this malaise.

The recent instability of the political situation in the Maldives over the past decade[32], along with increased national debt, have led to a policy response to increase land and island reclamation for tourism expansion, which we argue goes beyond sustainable limits. This may have a short-term positive impact on the GDP of the islands, but the impacts on the wider ecosystem and population are very likely to be negative in the long run – as they have been in the short term. Many of the islands of the Maldives are built on naturally 'shifting sands', so the concretion of the foundations of islands works against nature's natural buffering – that is to literally 'move' the sands at the tops of reefs into new areas from time to time. The development of 'sea walls' and other concretions around islands only borrows time away from natural erosion and movement.

Political instability and the rise of nationalism in politics only exacerbates the situation, as agendas of such movements tend towards policies of neoliberal growth (which on a finite planet is an impossibility), without accounting effectively for environmental goods and services that provide healthy livelihoods for the majority of citizens.

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[30] https://crudata.uea.ac.uk/cru/posters/2000-11-DV-tourism.pdf
[31] http://divemagazine.co.uk/travel/7979-is-paradise-lost-maldives-special-report
[32] https://www.bbc.com/news/world-south-asia-40827633

Recent resort developments in the Maldives under the (now past) Maldivian government[33] have not taken into account the on-costs of developments to the environment in planning and remedial works. As a result of over-exploitation and development, and climate change impacts, the Maldivian environment is now less able to deliver fish, coastal protection, homes and clean environments to its people. Infrastructure such as major capital investment in waste treatment, reef habitat protection or creation and fish enhancement tools are not used to 'buffer' resort development (or other commercial development).

The Maldivian public are more concerned about housing, food and security and are largely unaware of the longer-term security a healthy marine environment used to offer previous generations. Given the past administrations' disregard for these issues, as well as social education and democracy, people have been powerless to act. Centralisation of decision-making by the previous president and a corrupt government resulted in the rejection of proposed conservation measures by local islands in North Ari (Grimsditch, personal communication). As such the previous government has not felt pressured to deliver on laws and create effective governance structures to deal with these issues at a scale required to meet the challenge. A June 2018 article interviewed the ex-environment minister in office (Mohamed Aslam who was minister up to 2009) about the attitudes of the Maldivian public with regard to environmental issues[34]. He implied there was no need for the two major political leaders to use environmental issues in their recent election campaigns, as these were not vote-winning issues. But given the designation of the three MPAs prior to the election, perhaps he was wrong. History has taught us that an environmentally conscious government policy (e.g. the green 'new deal'[35]) will benefit the public– by providing clean drinking water, clean energy, secure housing, schools, education, health, etc. Whilst the new Maldives government is appearing to be more environmentally aware (although it hasn't met its ambitious 100-day pledge as yet), the impact of the previous Maldivian government has been to leave the country in debt to investment from China and Saudi Arabia. This has led to considerable debts that need to be 'serviced' in future years. This too may affect environmental policy.

Reversing the trend

Before 2008, the Maldives lacked a champion for the protection and recovery of marine resources. However, the Maldives government of Nasheed once made very well intended statements to reverse this trend. In June 2012, Dr Mariyam Shakeela, the (then) Minister for Environment and Energy, announced a programme of work between 2013 and 2017 in order to achieve UNESCO Biosphere Reserve status for the entire nation. According to this plan, at least half the atolls of the nation were to implement marine conservation efforts similar to that of Baa atoll. Despite the progressive political intentions of such statements, there was no strategy from government agencies tasked with dealing with this – such as the EPA or MRC.

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[33] The UK is ineffective at quantitatively accounting for ecosystem goods and services, when functioning close to their natural state, relative to the current impacted state.
[34] https://magazin.zenith.me/de/politik/mohamed-aslam-%C3%BCber-klimawandel-extremismus-und-politik-auf-den-malediven (published online in 'Zenith', June 18, 2018)
[35] https://neweconomics.org/2008/07/green-new-deal

This is in part due to recent political turmoil, but also due to a (now past) government that had no interest in investing into stewardship of its national marine estate. Indeed, since Biosphere Expeditions started working in the Maldives in 2011, cuts to the MRC have seen drastic reductions in its staff, and the monitoring team that existed since 2009 has been effectively disbanded. Regular monitoring of sites that informed the international community of the health status of Maldives reefs was predominantly undertaken by outside agencies (such as IUCN, international scientists, and Biosphere Expeditions). Many Maldives citizens have strong scepticism towards western conservation work. This is likely as a result of 'foreign' conservation efforts being considered alongside unsustainable foreign investment in the tourist industry that is at odds with the cultural norms. MCS and Biosphere Expeditions can do all the monitoring they want, but without enforcement, boats, trained officers, surveillance of vessels (that all costs millions) and without a judiciary that actually fines companies and individuals that fish in MPAs, and damage the coral reefs, there will be little support for conservation. Only after those investments are made will 'conservation' actually deliver for people.

We believe that an entirely different approach is needed to managing the Maldives: a system whereby power is devolved to atoll councils with a need to sustain local economies, growth and all within environmentally sensible and sustainable limits. This will also result in well-being and security for local islands and populations, with funding available for local infrastructure moved away from private to public areas (e.g. better housing, schools, shoreline protection, MPA and fisheries enforcement). For example, the revenue from points 2 and 3 above does not necessarily stay within the Maldives, because of corporate foreign ownership of many of the businesses. This is inevitable to a certain degree within the tourism sector, but is regrettable within the export business for live fish. The latter will only ever result in the demand of the market being met overseas, with no intrinsic value associated with the quality of the local resource or quality of life. The demand from foreign markets can be met from other fish-rich nations if the Maldives runs out of larger fish. But where does this leave the island communities themselves? Indeed prices for some fish are now so high (large live grouper can fetch hundreds of US dollars per kilogramme in restaurants) that demand will continue to rise, even if fishers have to travel to increasingly remote atolls and countries. Clearly the environmental assets that allow income for foreign markets do not 'feed the nation', but do provide large incomes for a few within the political and business elite. The UK and many western economies have also seen recent wealth gaps between the richest and poorest, with associated declines in the state of society[36].

The Maldives is a 'canary in the coal mine' for global environmental destruction and unbalanced power. The dire situation of the past can improve, but only if the new administration delivers some of the profits (largely from tourism) into public services and proper environmental protection. Foreigners love the Maldives to death at the moment. The Maldives government can make that 'love' help pay for its recovery.

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[36] https://theconversation.com/dont-listen-to-the-rich-inequality-is-bad-for-everyone-81952

Conclusions

So how do we explain the multifarious factors that affect the current condition we see on the reefs of the Maldives? It is hard to tell what is going on from a few isolated sites, but the general trend is that the inner reefs have been widely and largely impacted, whilst the outer reefs are less affected, and some sites actually recovered 14 months after the initial bleaching event. There is also the propensity for the bleaching severity to be not as bad at depth. However, these patterns are only from a few sites, with little time over the course of the Biosphere Expeditions / MCS surveys to really understand the pattern on a much wider scale. Impacts coincident with depth appear to be observed by other surveyors (e.g. IUCN) from a greater array of North Ari sites (Cowburn et al., 2019).

We posit that there are three types of reef location and condition:

1. Exposed outer reefs associated with greater current, wave action and adjacent to very deep water are generally more resilient to bleaching.
2. Inner reefs that are more affected by disease, *Drupella*, Crown-of-Thorns and bleaching-intolerant assemblages of corals
3. Inner reefs that are exhibiting a phase change from a coral-dominated state to an algal, sponge and *Discosoma* (non-coral) state

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

Recommended actions

1. Resource either the EPA, or each atoll council, environmental officers to be present (with an office, officials and boats) on each island atoll to control unsustainable fishing, dredging and construction. Pay them sufficiently such that they aren't tempted to fish themselves, or ignore illegal fishing. Re-visiting the de-centralisation act would help facilitate local protection.

2. Fund sufficient EPA officers, and atoll council law courts to arrest and fine transgressions in MPAs and island house reefs. A Protected Areas Act with a duty to monitor and enforce could enable progress in this area.

3. Give the EPA finance to stop developments where environmental damage is being caused (such as sediment outflows on live healthy reefs) above levels stated in Environment Impact Assessments. Enable EPA to do its job properly by divesting funds from developers to enforcers such that they have the staff and materials to effectively enforce their duties.

4. EPA officials must have knowledge of pristine environmental baseline conditions to assess the impacts of developments relative to healthy baselines. They need funding to visit pristine reefs in remote parts of the archipelago to support them.

5. Ensure that fisheries department officials work collaboratively with the EPA in assessing fisheries activities at resorts, grouper cages[37], processing facilities and at airports.

6. Ensure that every resort has to enact reef enhancement programmes that are not solely based on construction of reef walls, but enable the development and growth of reef pyramids and fore-reef coral structures to allow sustainable growth under the water of a living wave barrier. Ensure advice from the MRC scientists and engineers is used to guide these efforts.

7. Introduce size limits on grouper fisheries as previously recommended to government[38], which includes:
   i. regulated fishing
   ii. mandatory logbooks and data collection
   iii. long-term monitoring of catch, abundance and spawning aggregation sites
   iv. national level awareness-raising programme.
   v. Put mobile-phone technology Vessel Monitoring Scheme equipment onto all Maldivian registered fishing vessels such that enforcement can be done by using satellite technology[39].

8. Ensure that the fisheries department have enforcement officers based at fish cages to ensure that grouper size limits are met.

9. Ensure that EPA and fisheries department officers are stationed at protected grouper spawning areas (see below, Fig. 3f).

10. Ensure that the EPA is provided enough budget – (via for example a tourism tax) such that it is able to be present (with an officer present) on most tourism islands, and can enforce law and, if necessary, prosecute.

11. Ensure that the MRC is enabled, through an environment tax, to undertake rapid reef health assessment monitoring at all Maldivian resorts as a matter of law, and that the reports from the standard monitoring assessment are annually reported to government and made public.

12. Ensure all enforcement, fines and prosecutions under the powers of the EPA and fisheries department are vetted by an independent body of accountants, lawyers and governance experts that includes officials, managers and scientists from the EPA, MRC and fisheries department of the Maldives.

[37] Grouper cages exist in at least five atolls where fish are corralled before being shipped to Asian 'live fish' markets.
[38] https://www.mcsuk.org/downloads/coral_reefs/Maldives_Grouper%20_fishery_Management_Plan.pdf (page 19).
[39] http://www.fao.org/fishery/vms/en

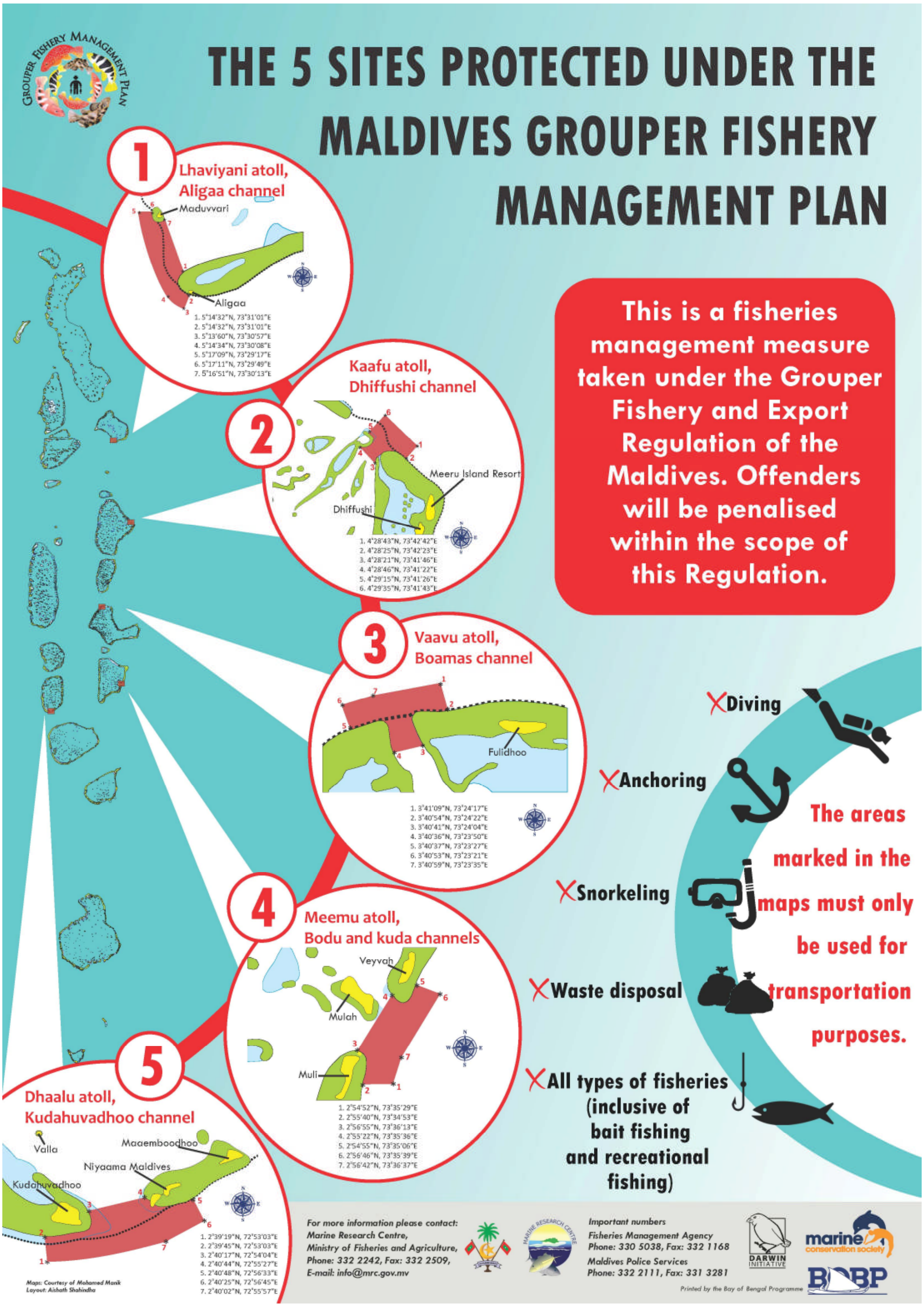

Figure 2.4d. Location of the protected spawning areas that have bans on fishing in five atolls, as agreed by law after consultation with industry and government in 2011, but with little implementation of monitoring or control of activity.

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Appendix I: Expedition diary and reports

A multimedia expedition diary is available on https://blog.biosphere-expeditions.org/category/expedition-blogs/maldives-2018/

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