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EXPEDITION REPORT

Expedition dates: 7-13 September 2019
Report published: October 2020

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

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Authors:

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Marine Conservation Society &
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Matthias Hammer (editor)
Biosphere Expeditions

Abstract

In September 2019 Biosphere Expeditions ran its ninth annual Reef Check survey expedition to the Maldives. Local and international citizen scientists, supervised by a professional reef biologist, performed surveys for one week. We undertook surveys using the Reef Check methodology at exposed, semi-exposed and sheltered sites in South Male' and Vaavu atolls. The sites we visited were entirely new sites, chosen to compare the health of the reefs at South Male' and Vaavu atolls to the condition of reefs at Ari atoll, where our expeditions had monitored reefs annually since 2011. The reefs at Ari atoll had been hit particularly hard by the 2016 coral bleaching event, with live coral cover falling below 5% for inner atoll sites, and had not recovered by 2018.

We found that coral cover for all South Male' sites varied between 45% and 18%, with a mean of 27%, and that reef recovery appears greater for exposed outer reefs compared to sheltered inner reefs. Coral diversity was dominated by a greater range of species for inner reefs at South Male' and Vaavu atolls than at previous surveys at Ari atoll. Deeper areas of Guraidhoo inner reef and Beybe's bellybutton showed dominance of *Porites cylindrica* and *Turbinaria* sp. *(*possibly *reniformis)*. *Faviids* spp. and branching *Acropora* spp. were also present at inner reefs (inner Guraidhoo and Beybe's bellybutton). *Acropora,* the dominant coral genus before the 2016 bleaching event at central Ari atoll reefs, is now rare in some sites. For example, *Acropora* were almost absent at Kudafalhu as a result of bleaching stress (2016, 2017 and 2018 surveys). Nontheless, the genus appears to be present at reasonable densities at most South Male' and Vaavu inner reefs in 2019, but mixed in amongst a variety of other species.

During the expedition, there was isolated bleaching, but only of individual, small colonies, not older than two years. Such bleaching was of mostly *Pocillopora* and some *Acropora*. Colonies of both genuses that had survived the 2016 bleaching (i.e. larger colonies or massive colonies) appear not to have bleached.

A further warming event occurred between April and May 2020, after the expedition. This resulted in bleaching, which staff at Fulidhoo Dive centre at Vaavu atoll recorded, whom the lead author had Reef-Check trained immediately after the expedition . They also recorded greater bleaching at the inner reef site compared to the outer reef.

There was a single site in central South Male' atoll (Beybe's bellybutton) with low numbers of Crown of Thorns that appeared to be preferentially feeding on *Porites lobata*, rather than other species (*Acropora* were rare at this site).

We recorded very few large grouper and snapper at all sites, with an average density of 1 to 2.75 grouper (above 30 cm total length) per 500m^3 in outer reefs, with an absence of moderate-sized grouper, snapper or emperor individuals at inner reefs. We recorded whitetip and blacktip reef sharks at most sites, as well as hawksbill turtles.

We also performed a 3-hour effort-based whale shark survey at the outer reef of South Ari Marine Protected Area at the end of the expedition, on 12 September 2019, recording one 3 m juvenile shark.

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ބަޔޮސްފިއަރ އެކްސްޕެޑިޝަންސްގެ ފަރާތުން 2011ވަނަ އަހަރުން ފެށިގެން ރާއްޖޭގައި ކުރިއަށް ގެންދާ އަހަރީ ރީފްޗެކް ސާރވޭ، 9 ވަނަ ސާރވޭ އެކްސްޕެޑިޝަން 2019 ވަނައަހަރު ވެސް ކުރިއަށް ގެންގޮސްފައެވެ. ދިވެހި އަދި ބޭރު ސިޓިޒަން ސައިންޓިސްޓުން އަދި ރީފް ބަޔޮލޮޖިސްޓެއް ގުޅިގެން ރީފްޗެކްގައި މިމަސައްކަތުގެ 10 ފަރުގެ ހާލަތު ކުރިއަށް ގެންދިޔައެވެ. މިސާރވޭތަކުގެ ކުރިއަށް ގެންދިޔަ ޑޭޓާ ވޯލްޑްވައިޑް ޑޭޓާބޭސްގައި ރެކޯޑްކުރެވޭ. ރީފްޗެކުގެ ހާލަތު ރިސާރޗް ޓީމް ބެލުމުގައި ރީފްޗެކް މެތޮޑޮލޮޖީ ބޭނުންކުރެވިފައިވެއެވެ. ސާރވޭގެ ނަތީޖާ މަސައްކަތް 2016ވަނަ އަހަރުގެ ބްލީޗިންގ ހާދިސާއަށް ފަހު ފަރުތަކުގެ ހާލަތު ބަދަލުވެފައިވާ ގޮތް 2011ވަނަ އަހަރާއި ހިސާބުކޮށް ދައްކައިދެއެވެ. 5 ސާރވޭކުރެވުނު ފަރުތަކުގެ ނަތީޖާ.

ފަރުތަކުގެ ހަލާކުވުން ބޮޑުވެގެން ދިޔައީ ރީފް ކޯރަލް ކަވަރޭޖް ކުޑަވެފައިވާ ކަމުން 18% އާއި 45% އާއި 27% ދެމެދުގައި ކަމަށް ދެނެގަތެވެ. ފަރުތަކުގެ ހާލަތު ބެލުމަށް ކުރެވުނު ސާރވޭގެ ނަތީޖާއިން ދައްކާ ގޮތުގައި ފަރުތަކުގެ ހާލަތު ދިރުން ކުރިއަށް ދިޔަ ނަމަވެސް އަލުން ރަނގަޅުވަމުން އަންނަކަން ފެނެއެވެ. މިގޮތުން ފަރުތަކުގެ ކަވަރޭޖް ހެދިފައިވާ ރީފްތަކުގެ ހާލަތު ރަނގަޅުވަމުން ދާކަން ފެނިގެން ދެއެވެ. 2016 ވަނަ އަހަރުގެ ބްލީޗިންގ ހާދިސާއަށް ފަހު ފަރުތަކުގެ ކޯރަލް ކަވަރޭޖް ކުޑަވެފައިވާ ކަމަށް ސާރވޭތަކުން ދައްކައެވެ. 2019 އަހަރުގެ ސާރވޭގައި ކޯރަލް ކަވަރޭޖް އިތުރުވެފައިވާ ކަމަށް ފެނުނު ނަތީޖާއެވެ.

ދިރާސާ ކުރެވުނު ޓީމުގެ ތެރޭގައި (ކޯރަލް ރީފް) ފަރުތައް ހިމާޔަތް ކުރުމަށް ބޭނުންވާ ކަންކަމާ ގުޅޭ ގޮތުން ރިޕޯޓް ކުރެވިފައިވެއެވެ. ކޯރަލް ބްލީޗިންގ 2016ވަނަ އަހަރު ދިމާވި ބޮޑު ބްލީޗިންގ ހާދިސާ.

ފަރުތަކަށް ބޮޑެތި ނުރައްކަލެއް އަރަމުންދާ ކަމަށް ފެނެއެވެ. ވިޔަފާރީގެ ގޮތުން މަސްވެރިކަމުގެ ސަބަބުން ފަރުތަކަށް ގެއްލުން ލިބޭ ކަމަށް ފެނެއެވެ. 500 ގޯތި ބޮޑުވަރުގެ 2.75 ކިލޯ ބޮޑުމިނުގެ (30 ސެންޓިމީޓަރު) ފަރުގެ ހާލަތު ބަލައި ރިޕޯޓް ކުރެވިފައިވެއެވެ. ފަރުތަކުގެ ހާލަތު ރަނގަޅު ކުރުމަށް ކަންކަން ކުރުމަށް ހުށަހަޅައެވެ.

މިއީ ދިވެހިން 12 އަހަރުވަންދެން 2020ގައި "ސައިންސް އަދި މަހުގެ ފަރުތަކުގެ ބޭނުމަށް" އެއް ފަރުތަކުގެ ހިމާޔަތަށް މަސައްކަތް ކުރެވެމުންދާ ގޮތުގެ ނަތީޖާ 3 ވަނަ އަހަރުގެ ރިޕޯޓެވެ.

Contents

1. Expedition review

1.1. Background

Background information, location, conditions and the general research area are as described in Solandt & Hammer (2019).

1.2. Dates & team

The 2019 annual Reef Check survey ran over a week from 7 to 13 September 2019 with a team of national and international citizen scientists, a professional scientist, and an expedition leader.

The expedition team was recruited by Biosphere Expeditions and consisted of a mixture of ages, nationalities, and backgrounds. They were (in alphabetical order and with country of residence): Hassan Ahmed* (Maldives), James Chong (Australia), René Endres (Germany), Judy England (UK), Elfie Gloster (UK), Aidan Gray (Ireland), Roberta Gray-McMath (UK), Antonio Land (UK), Janet Land (UK), Jillian Manning (Australia), Ambika Mehta (UK), Farish Mohamed* (Maldives), Greta Montville (Switzerland), Graham Richards (UK), Florence Rohart (Germany).

*denotes a participant of the Biosphere Expeditions placement programme.

Dr. An Bollen, the expedition leader, was born in Leuven, Belgium, where she studied biology and completed a PhD in tropical ecology. At age 18, An went on a year-long exchange programme with a local family in Ecuador, sparking her passion for travel and exploration. An has worked for over 15 years in biodiversity conservation in the tropics, both in tropical rainforests as well as on coral reefs and often working closely with local communities. She has a soft spot for islands and called both Madagascar and the tiny island of Principe, off the west coast of Africa, home for a while. An has also organised and lead research expeditions on several occasions during her career. An is passionate about the underwater world, an amateur photographer and very much an outdoor, nature-loving person.

1.3. Partners

On this project Biosphere Expeditions worked with Reef Check, Save the Beach Maldives the Marine Conservation Society, the Maldives Marine Research Centre (MRC) of the Ministry of Fisheries and Agriculture, the Maldives Whales Shark Research Programme, MWSRP, LaMer and the MV Theia. Data will be used in collaboration with the Global Coral Reef Monitoring Network, IUCN and the University of York (UK).

1.4. 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 citizen scientists, 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 to the crew of MV Theia, our liveaboard expedition base, for being such excellent and capable hosts. Thank you also to Hussein Zahir of LaMer for guidance and advice, and Hassan Beybe and Farish Mohammed for welcoming expedition participants to Vilingili Island to discuss the work and infrastructure of 'Save the Beach' Maldives. 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).

1.5. 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.

1.6. Expedition budget

Each participating citizen scientist paid towards expedition costs a contribution of €2,180 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 visas 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	24,578
Expenditure	
Staff includes local & international salaries, travel, and expenses	2,570
Research includes equipment and other research expenses	931
Transport includes taxis and other local transport	0
Base includes board, lodging and other live-aboard services	17,080
Administration includes some admin and miscellaneous costs	130
Team recruitment Maldives as estimated % of PR costs for Biosphere Expeditions	4,981
Income – Expenditure	**-1,115**
Total percentage spent directly on project	**105%***

*This means that in 2019, the expedition ran at a loss and was supported over and above the income from the expedition contributions and grants by Biosphere Expeditions.

2. Reef Check survey

2.1. Introduction

Review up to 2019

A review of the rationale for the expedition and the situation in the Maldives up to 2019 is described in Solandt & Hammer (2019). This includes sub-chapters on Maldivian coral reefs, fisheries, coral bleaching, previous Reef Check surveys, descriptions of Marine Protected Areas (MPAs), governance and management, as well as the 1998 and 2015/2016 bleaching events.

Bleaching event and no expedition in 2020

At the time of writing (July 2020) another bleaching event has occurred in April/May 2020 (see appendix I).

After nine continuous annual Reef Check surveys (Solandt and Hammer 2017a, 2018 and 2019 and earlier reports on www.biosphere-expeditions.org/reports), there was no annual survey in 2020 because of the coronavirus pandemic. In effect the Maldives closed all tourism-related activities from March until 15 July 2020. However, Biosphere Expeditions determined that it was too risky to resume expeditions in 2020 and deferred the annual survey to August/September 2021. However, a community expedition is planned and being organised by graduates of the Biosphere Expeditions placement programme, so some data collection should still take place, and there are data from June 2020 in appendix I resulting from a training event conducted by the author after the 2019 expedition.

Summary of threats to Maldives reefs

Maldivian 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

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 (Maldives have semi-autonomous atoll councils that have some powers of local decision-making, particularly with regards to reef fishing). For example, 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, 2019), it is regrettable that the trajectory for over-fishing of the grouper population in the Maldives leading to decimation of the commercial fishery is a distinct possibility within the next few 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[1]. However, no concerted effort to protect grouper stocks from being fished out for domestic and foreign markets is taking place. Labelling some grouper spawning locations as 'protected spawning sites' may have been counterproductive as it leads to them being targeted, due to the lack of enforcement. Word-of-mouth discussions with experienced dive guides and fishermen have indicated that 'protected' and 'known' spawning channel locations are targeted by fishermen once they are discovered or protected by law (anonymous dive guide, personal communication). Many believe it is simply better 'management' to keep those channel locations where spawning is known to occur secret, and that it is counter-productive to confer protected status or management measures in such locations where proper enforcement is not available.

Due to past political interference in the rule of law and due process, there were several developments that were patently counterproductive for the Maldives environment under the previous government. 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 tourism ministry[2]. This is not necessarily different from western democracies, where there is a genuine inability of citizens to challenge decisions in court due to prohibitive expense. We remain hopeful that this will change with the new political administration that was elected in October 2018. However, as of June 2019, there have only been empty pledges in manifestos, and the short-term impacts on the tourism industry for the Maldives from the Corvid-19 outbreak is likely to lead to greater fishing pressure from local islands, as imports and income decline.

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

2.2. Methods and planning

Biosphere Expeditions uses the Reef Check methodology for its coral reef surveys (see Solandt and Hammer 2015, Solandt et al. 2016, 2017a, 2018 and earlier reports on www.biosphere-expeditions.org/reports for details). The 2019 surveys were carried out with the aims of:

- Recording patterns of recovery and resilience from the 2016 bleaching in South Male' and Vaavu atolls
- Performing effort-based transects of the South Ari MPA reef for whale sharks
- Training two new Maldivian citizen science divers Hassan Beybe and Farish Mohammed as eco-diver trainers

We surveyed six sites (see Table 2.3a.) in South Male' (four sites) and Vaavu atoll (two sites). Training was conducted at reefs near Guraidhoo Island. We then trained and surveyed at eastern, central and southern South Male', at northern Vaavu and in a very sheltered site in west central Vaavu. Shallow dives were between 3 and 4 m, with deeper dives from 7 to 9 m.

All training was completed on board the MV Theia during the first three days of the expedition. Biosphere Expeditions recruited citizen scientists, carried out all logistics, and ensured health and safety on board the research vessel. The scientific programme, training, data collection, and analysis was led by Dr Jean-Luc Solandt, Reef Check Course Director.

2.3. Results

Sites surveyed

Sites surveyed during the 2019 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 surveyed based on accessibility to Male', aspect and exposure such that they resembled sites from previous expeditions in Ari Atoll.

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

Site name	Date	Latitude	Longitude	Inner / outer reef	Atoll
Kuda giri*	7.9.19	3 58.415 N	73 29.457 E	Inner	South Male'
Guraidhoo inner	9.9.19	3 54.339 N	73 27.303 E	Inner	South Male'
Guraidhoo outer	10.9.19	3 53.092 N	73 28.106 E	Outer	South Male'
Beybe's bellybutton	10.9.19	3 53.574 N	73 24.202 E	Inner	South Male'
Ranikan outer	11.9.19	3 50.082 N	73 22.102 E	Outer	South Male'
Fulidhoo outer	11.9.19	3 40.586 N	73 28.108 E	Outer	Vaavu
Farish's faru	12.9.19	3 37.018 N	73 22.373 E	Inner	Vaavu
Bathi giri**	17.9.19	3 39.787 N	73 25.219 E	Inner	Vaavu
Fulidhoo caves**	17.9.19	3 40.992 N	73 24.919 E	Outer	Vaavu
Kuda fushi**	18.9.19	3 39.686 N	73 24.482 E	Inner	Vaavu

*Training site: No data collected. **Dives with Fulidhoo dive centre.

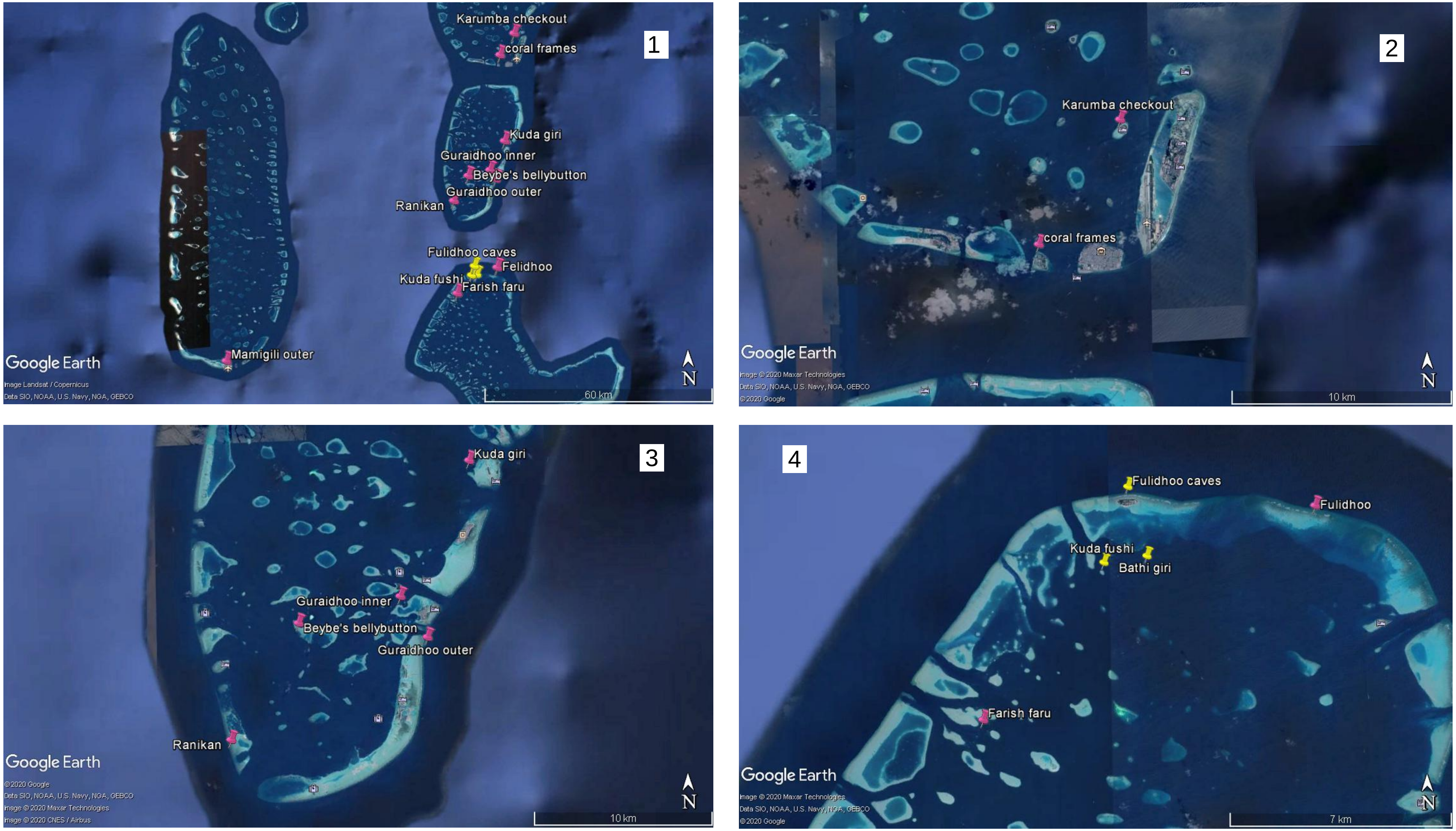

Figure 2.3a. Central Maldives atolls with survey locations. 1 – All sites; 2 - Training and 'coral frames' observations; 3 – Southern Male' sites; 4 – North Vaavu sites.

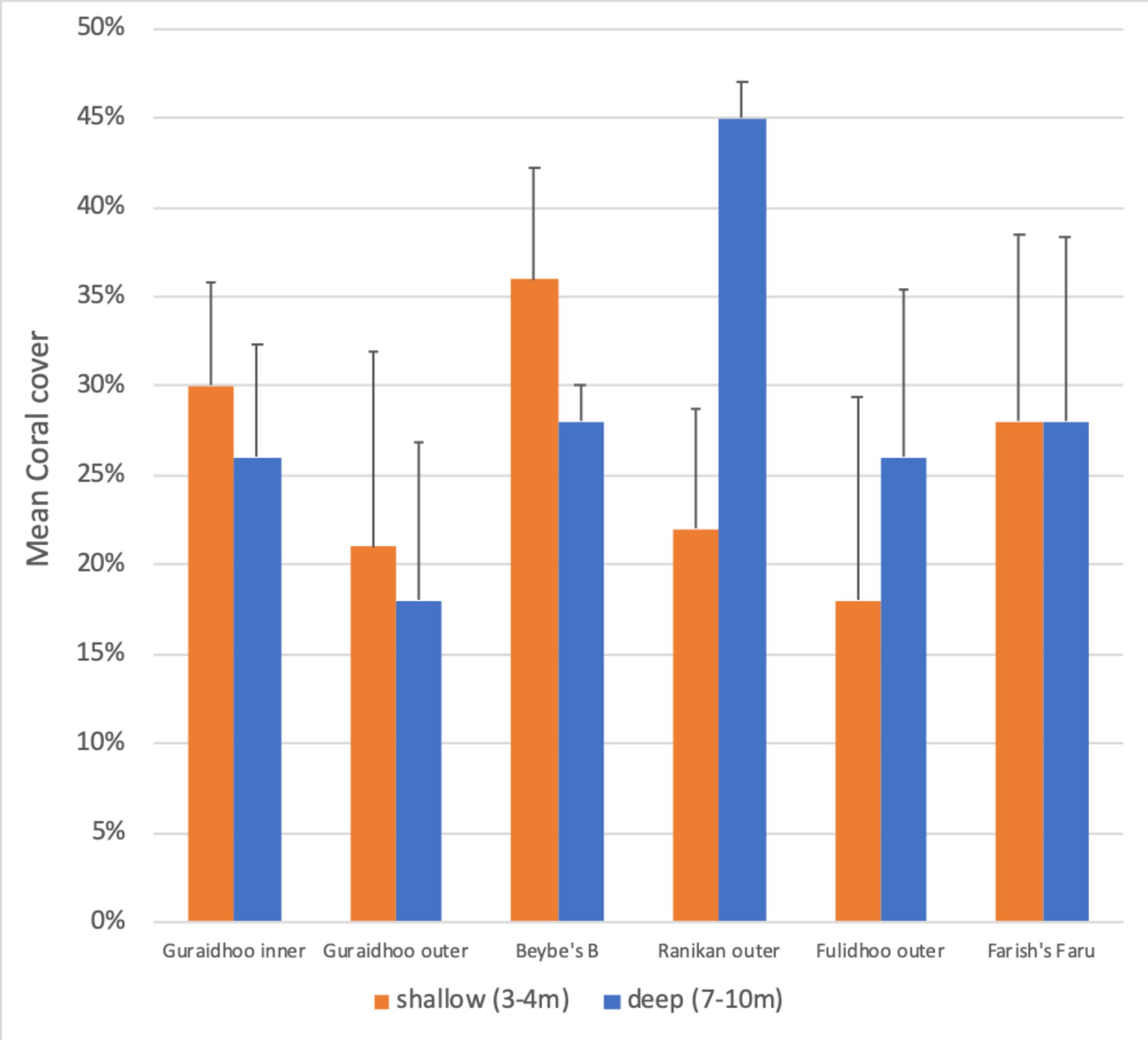

Figure 2.3b. Mean hard coral cover (+SD) at 3-4m and 7-10m depths (see Fig 2.3a for locations).

Mean hard coral (HC) cover ranged from 18 to 45% (Fig. 2.3b). The diversity of corals was greatest at sheltered inner atoll locations (particularly Beybe's Bellybutton and Farish's Faru).

Depth in sheltered inner reefs was generally correlated with greater diversity of coral lifeforms at 7 – 10 m compared to 3 – 4 m (Fig 2.3c).

Figure 2.3c. Coral reef at 10 – 12 m at Guraidhoo backreef, showing the wide diversity of coral lifeforms and species – particularly adjacent to the sandy seabed. Various branching, submassive foliose and massive lifeforms were present including *Pavona clavus* (top left); *Acropora* sp. branching (bottom left); *Diploastrea heliopora* (top right); *Turbinaria mesenterina* (middle right); *Porites cylindrica* (bottom right).

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

Figure 2.3e. Coral reef at 3 m at Fulidhoo caves, showing the most dominant recruiting genera *Acropora* (probably *A. hyacinthus*). The largest colonies are approximately 30 cm across but can grow to approximately 180 cm across.

Figure 2.3f. Coral mounds on sand at sheltered Farish's Faru site. At this site, a Maldivian grouper fishing vessel (Fig. 2.3h) was recorded having five snorkellers fishing with targeted techniques using handlines.

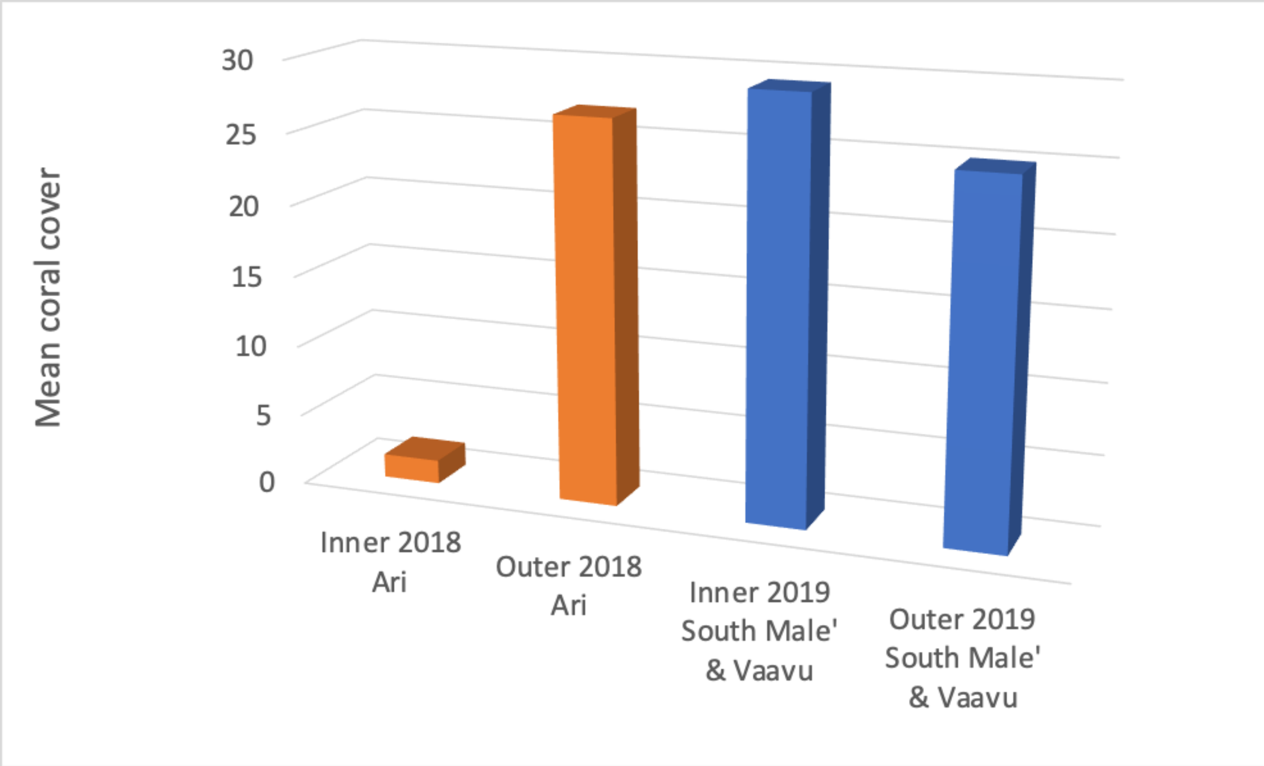

Figure 2.3g. Mean coral cover at Ari atoll sites in 2018 compared to similar South Male' and Vaavu sites in 2019. Mean coral cover (+SD) was determined by pooling all sites sampled in 2018 and 2019.

There was a significant difference (t-test, $p<0.002$) in the coral cover of inner reefs in Vaavu and South Male' atolls (29%) compared to similar sites in North and South Ari atolls (2%) (Fig. 2.3g). Outer reefs had similar coral cover with South Male' and Vaavu reefs at 25% and Ari reefs at 27%.

Figure 2.3h. Grouper fishing vessel at Farish's Faru, Vaavu atoll. Recorded at dawn on 12.9.19.

Figure 2.3i&j. Photos of the coral reef at Thelivagaa from July 2018. Thelivagaa is a sheltered lagoon site in eastern Ari atoll where coral cover was <1%. The benthos was dominated by *Padina* sp., an algae that responds well to high nutrient loading. Broken and dead branching *Acropora* thickets were interspersed with algae growing between branches.

Figure 2.3k. Coral recruits observed at the exposed Ranikan outer forereef at approximately 10 m depth. The largest recruit shown (on left) is an *Acropora* species. The others are *Pocillopora verrucosa*.

Fish populations

Bleaching episodes in the past have caused a loss of diversity and complexity of the three-dimensional habitat (Jones et al. 2004). Previous research conducted after the 1998 global bleaching event found that the loss of habitat had a considerable impact on the diversity and abundance of many reef fish species and families (Pratchett et al. 2011). It is therefore important to monitor the diversity and abundance of fishes present on reefs to determine the effects of such disturbance events on the wider marine community.

Figure 2.3l. Mean fish populations at South Male' and Vaavu atoll sites.

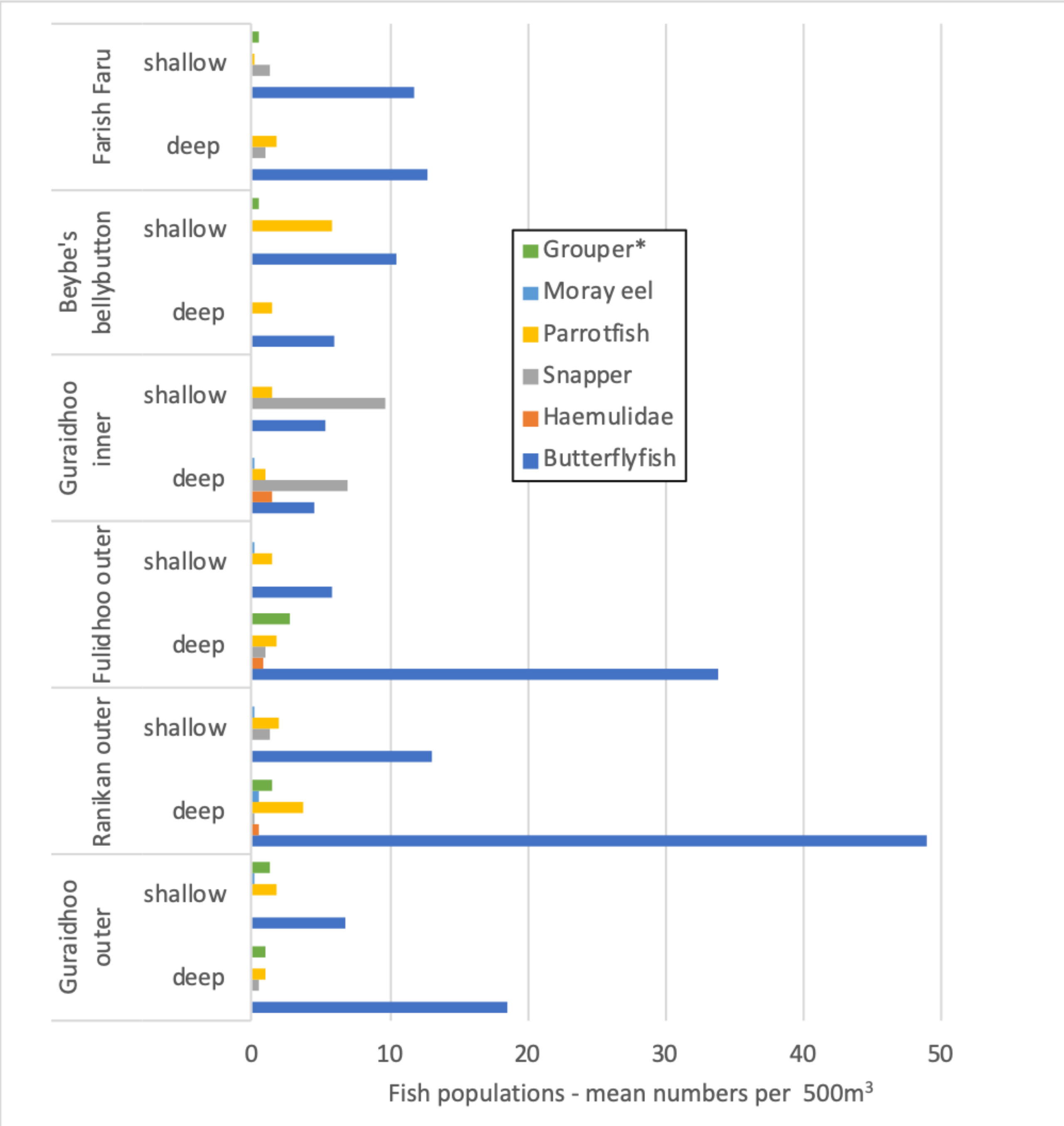

Figure 2.3l. Fish populations (per 500 m^3 replicate) from all sites surveyed in 2019.
*Grouper were pooled data from all size classes. Only parrotfish over 20 cm were recorded.

As with previous years, butterflyfish were the most abundant Reef Check lifeform, dominating most sites (Fig. 2.3l), particularly at Ranikan outer reef where a mean of 49±7.6 (SD) individuals were recorded per $500m^3$. Forereef habitats were dominated by planktivorous butterflyfish more than inner reefs (e.g. by *Heniochus diphreutes* and *Hemitaurichthys polylepis*). Guraidhoo inner reef had a significantly higher abundance of snappers (*t*-test, $p<0.03$), dominated by blue-lined snapper *Lutjanus kasmira*. Grouper (Epinephelidae) populations were relatively low across sites but were observed more often at the outer reefs.

Figure 2.3m. Fish populations at Guraidhoo backreef were dominated by omnivores: *Lutjanus kasmira* (blue-stripe snapper) and *Gnathodentex aureolineatus* (a species of bream) in a mixed school.

Invertebrate populations

Low numbers of invertebrates were observed during the 2019 survey trip. Giant clams, *Tridacna* spp., were relatively common but on the lower end of their size range. Guraidhoo backreef was unusual in that seven individuals were recorded across all four replicate areas (400 m^2), with individuals at a large size (40 - 50 cm). Crown of Thorns, *Acanthaster planci,* individuals were only recorded at Beybe's bellybutton – an isolated site a considerable distance from the nearest developed island within the south-central part of South Male' atoll.

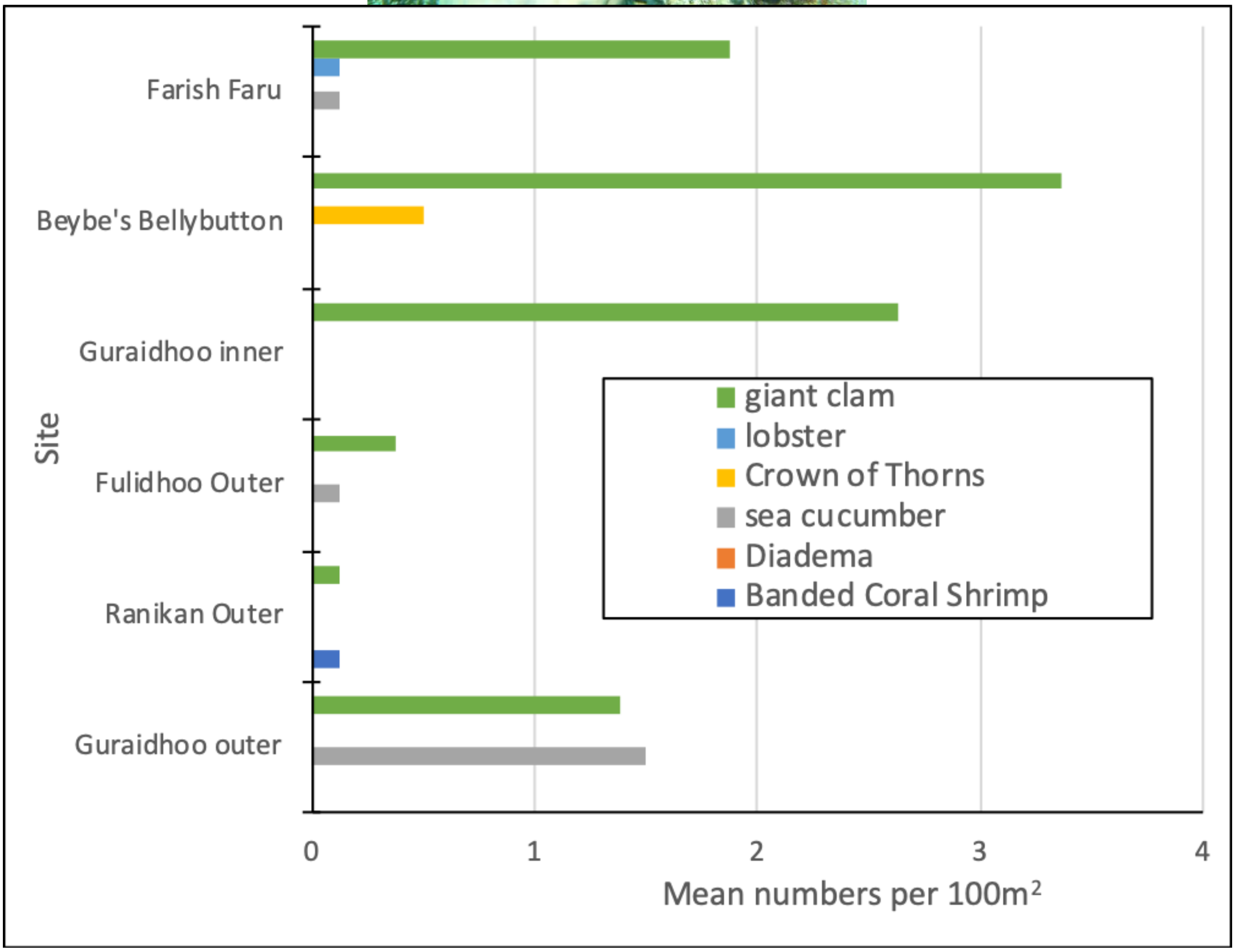

Figure 2.3n. Mean numbers of invertebrates at each site recorded on Reef Check dives in 2019 (no SD were plotted due to the large numbers affecting the scale of the chart). The largest giant clam individuals were recorded at Guraidhoo backreef, with seven individuals' shell length 40 – 50 cm. Four Crown of Thorns were recorded at Beybe's bellybutton.

Other impacts, including bleaching

Coral damage is recorded by the Reef Check methodology in terms of direct impacts on corals, including diseases (‘counts’ rather than the identification of specific ‘pathogens’). Reef Check also estimates the amount of bleaching as a proportion of the live population, and the proportion of bleached compared to live tissue for each bleached colony (Fig. 2.3p).

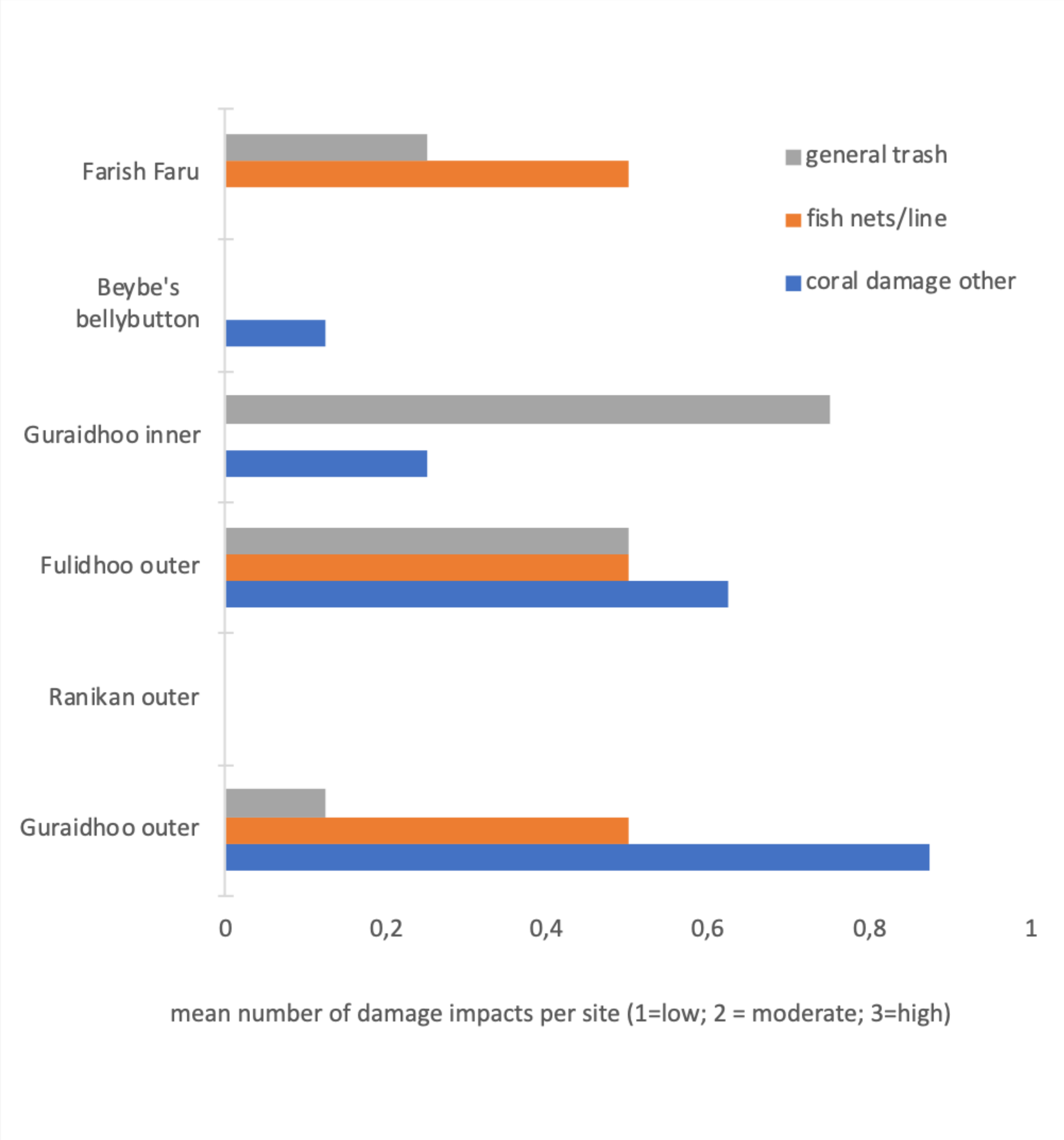

Figure 2.3o. Impacts observed across all sites and recorded on a semi-quantitative scale (on the x-axis, 1 = 1-2 observations, 2 = 3-4 observations, 3 = >5 observations).

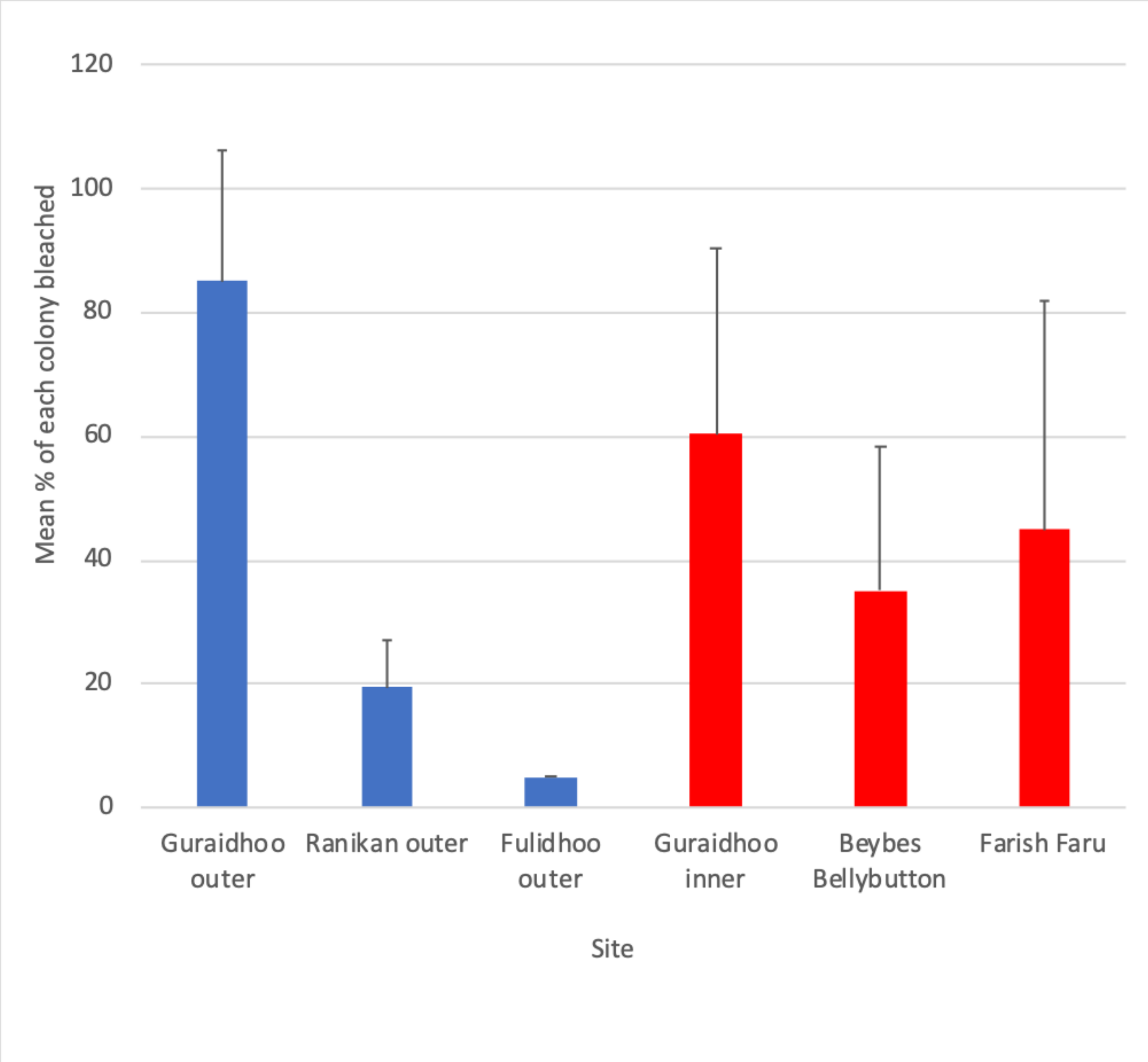

Figure 2.3p. Mean percent total live hard coral population (+SD) that is bleached (blue bars) at outer reef sites compared to inner reef sites (red bars) in 2019. Partial bleaching of predominantly *Porites* massive colonies was recorded more commonly on outer reefs (Ranikan and Fulidhoo) compared to inner reefs where bleaching was more substantial per colony.

Little impact from human activity was directly recorded at the 2019 sites. 'Trash' was predominantly discarded fishing lines that had snagged on the reef. A small 1 m^2 piece of fishing net was recorded at Ranikan outer reef. Line fishing by snorkellers was witnessed at Farish's faru during the expedition (Fig 2.3h). This is a common method for catching fish for the local tourism trade, with the catch being chilled. Captured live grouper are also kept alive in a saltwater container aboard the vessels before being transferred to cages for 'growing on' to a larger marketable size. These are then commonly exported by international merchants.

Other marine life and noteworthy observations

Reef Check surveys record incidences of unusual, rare, or threatened marine life, both on and off transect (Table 2.3b).

Table 2.3b: Other noteworthy observations – off transect (not observed during survey).

Site name	Observations	Atoll	Inner/outer reef
Kurumba reef*	Hawksbill turtle, lobster, moray eels, black tip reef sharks. All *Pocillopora* colonies under 10 cm bleached. Low coral cover (<10% estimated)	South Male'	Inner
Kuda giri**	Blue-lined trevally, giant trevally *Caranx ignobilis*, Red and humpback snapper. Some healthy small table *Acropora* on west side of giri.	South Male'	Inner
Guraidhoo inner	1 white tip reef shark, 1 hawksbill turtle. Very rich and diverse coral assemblage, including sediment-tolerant varieties below 10 m.	South Male'	Inner
Guraidhoo outer	1 white tip reef shark, 6 eagle ray, 1 green turtle.	South Male'	Outer
Beybe's bellybutton	1 hawksbill, 4 Crown of Thorns. *Porites cylindrica* dominant in shallow waters. Large numbers of snapper (blue-lined, 2-spot, humpback) at 10m+ depth.	South Male'	Inner
Ranikan outer	4 white tip reef sharks; 2 dead giant clams, Pygmy mobula ray (*Mobula* sp.), large marbled grouper (<50 cm), scribbled filefish, 3 large red snapper and school of long-nose emperor off transect.	South Male'	Outer
Fulidhoo outer	1 white tip reef shark, spider conch, 1 hawksbill turtle, many parrotfish.	Vaavu	Outer
Farish's faru	Moderate sized hawksbill turtle, large 'ray', Napoleon wrasse, 1 moray eel between replicates. 3 large parrotfish beyond end of transect.	Vaavu	Inner

*checkout dive location
**training site

Whale shark sightings

A half-day effort-based whale shark survey was conducted at the outer reef of South Ari MPA, yielding one encounter at the airport (Maamigili) to the south of the airport runway on 12th September 2019. The shark was spotted at midday – but only from the survey vessel. The animal was identified as male and approximately 3 m in length. The encounter with this shark lasted for about 20 seconds and video was captured by phone.

Figure 2.3q. Whale shark observed and recorded on 12.9.2019.

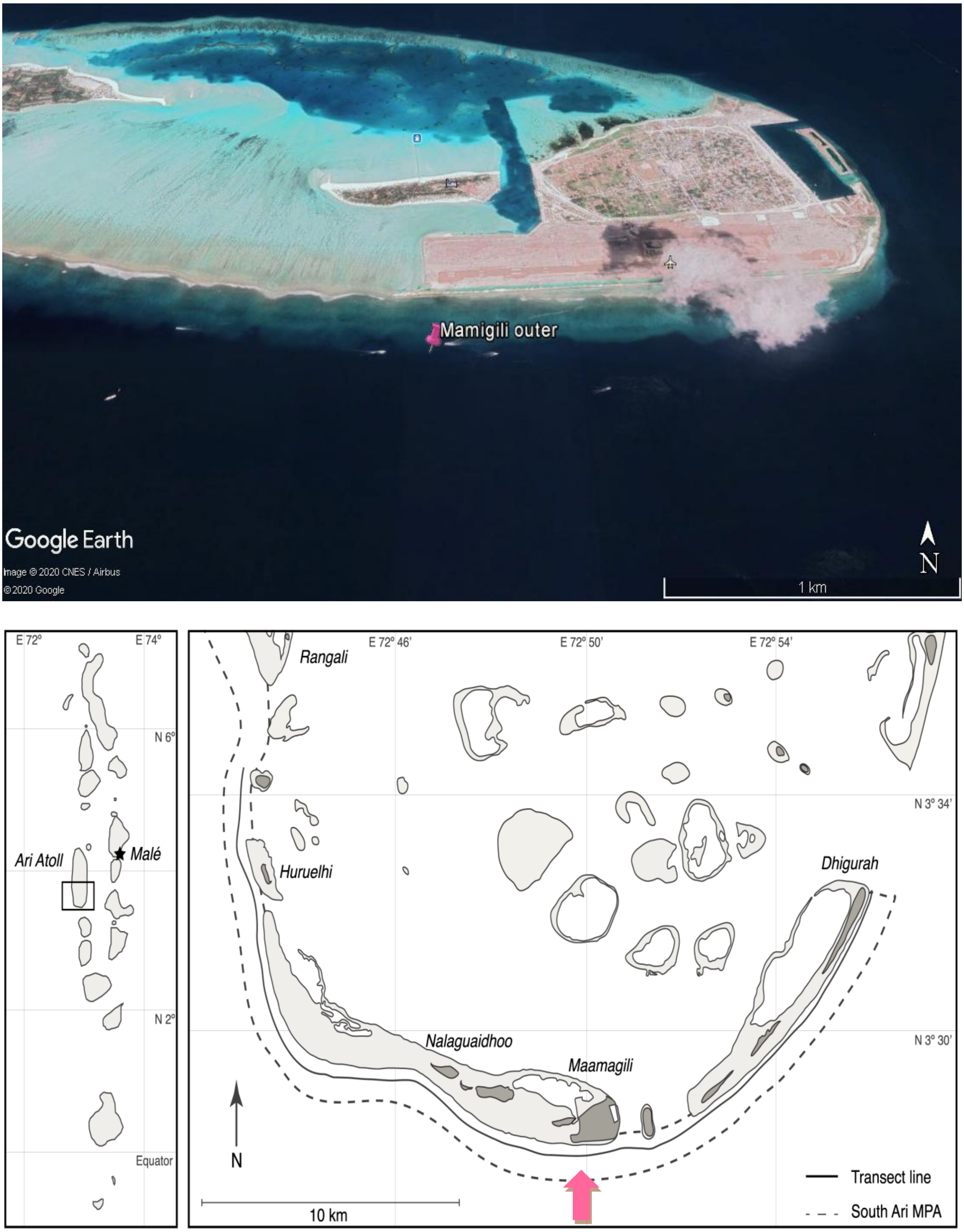

Figure 2.3r. The Maamigili MPA in South Ari atoll, Maldives. Pink arrow indicates location of the shark sighting on 12 September 2019. The MPA measures 42 km^2, is narrow, and extends along a large exposed southerly facing reef. It runs from the reef crest out in a southerly and westerly direction 600 and 900 m out to the open sea.

2.4. Discussion

The key difference in the observations from the inner reefs visited during this expedition compared to our long-term monitoring sites at Ari atoll is that the general health and coral species diversity was greater at Vaavu and South Male' atolls. From our observations it would appear that the reefs of South Male' atoll are currently faring better than those of Ari atoll where the same – or similar – oceanographic conditions occur.

The great diversity of corals (particularly at Guraidhoo backreef) provided many niches for different assemblages of species and made for interesting diving. The upper reefs at Kudafalhu and Holiday thila were coral- and rock-dominated to >20m depth. At Guraidhoo, the complex nature of the reef geomorphology led to sand at about 15 m depth, then to a coral platform-ridge leading in a north-westerly direction from the main backreef slope. This heterogenous structure led to very sheltered reef conditions, with whips and sea fans, and *Antipathes* colonies.

The key difference between the 2018 and 2019 observations has been that the inner reefs at Vaavu and South Male' atolls appear to be much healthier than the inner reefs of Ari atoll. Such regional differences in response to bleaching was also witnessed in 1998, where researchers found that Ari atoll was more heavily impacted than North and South Male' atolls[3]. When the lead author of this report started visiting the reefs of North Male' and Ari atoll in 2005, it appeared that the *Acropora* coral populations of North Ari fared better than those of North Male' atoll (Fig. 2.4b). This is likely due to successful recruitment, rather than survival of colonies from the initial bleaching event. By 2005, seven years after the initial bleaching event, many reefs appeared to have achieved maximum growth rates for table *Acropora* colonies in shallow water (personal observation).

We received reports (April/May 2020) that bleaching is again affecting the reefs of the Maldives (Fig 2.4c). The projection for potential bleaching at the beginning of this year was for 'alert level 2' that predicted 'severe bleaching and significant mortality likely' for the entire Maldives (also see appendix I).

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. Extrapolating observations of coral response to bleaching at such large, global spatial scales (Sully et al. 2019) must be treated with caution, because of the coarse scale at which such assessments operate.

[3] https://thimaaveshi.files.wordpress.com/2009/09/status-of-coral-reefs-of-maldives-after-bleaching-event-in-19881.pdf

Figure 2.4a. Guraidhoo backreef, demonstrating the sheltered nature of the reef. Diverse fish assemblages were recorded in association with this complex habitat.

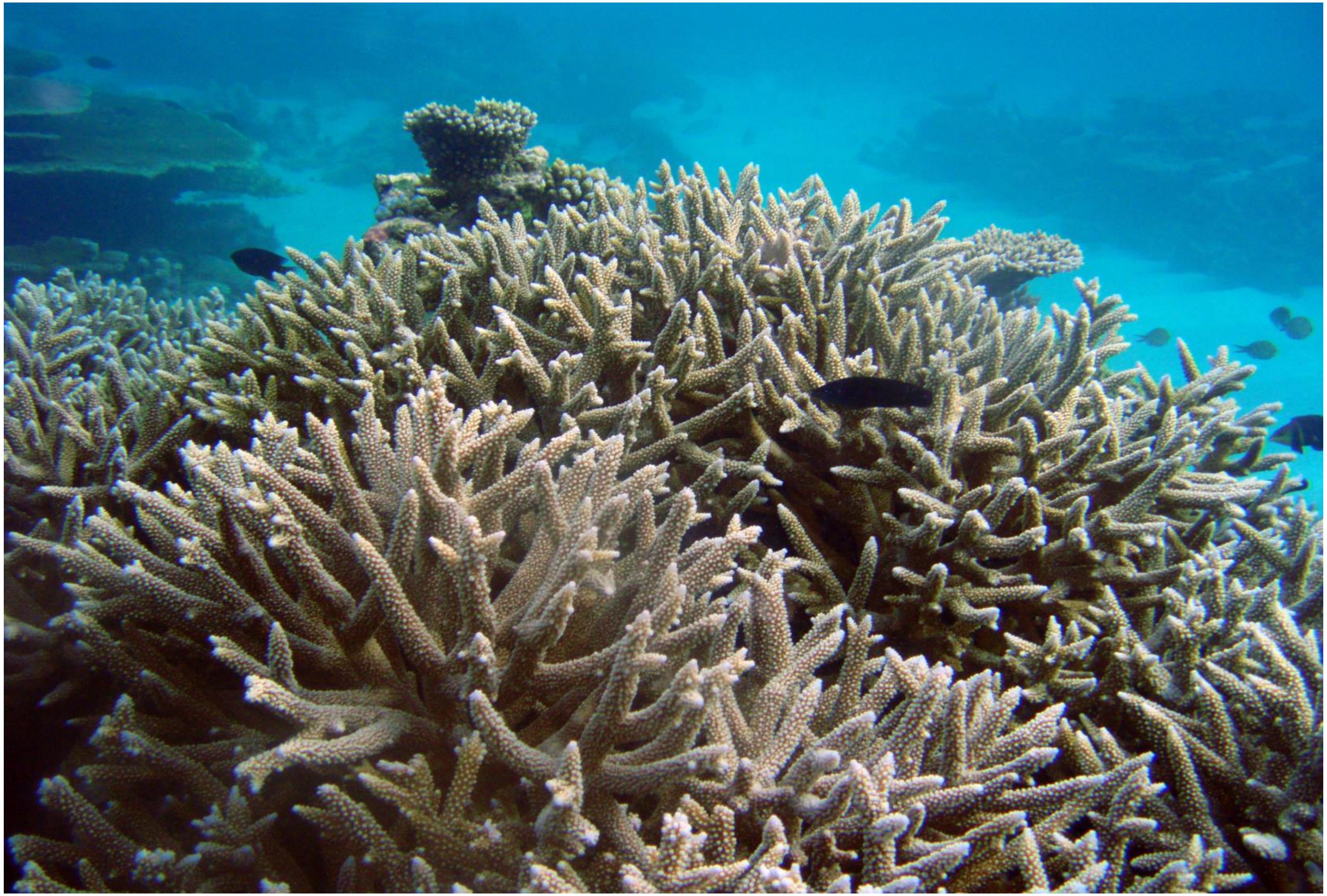

Figure 2.4b. Luxurient *Acropora nobilis* thickets in the foreground and large, plating *Acropora hyacinthus* and *A. cytherea*. (photo taken by JL Solandt in 2008). Both colonies are at 1.5m depth, in an area in central Ari atoll (Dega giri) that was heavily bleached during the 2016 bleaching event (Solandt and Hammer 2017a).

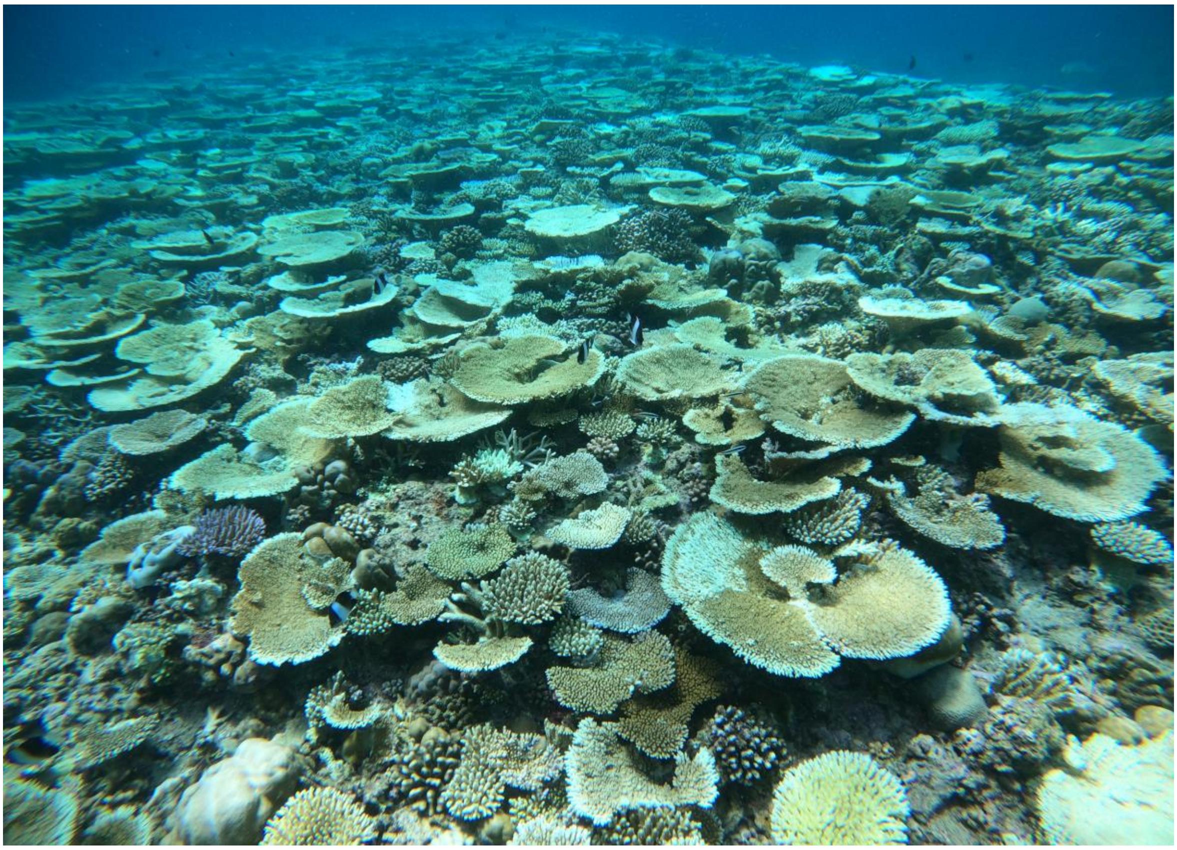

Figure 2.4c. Photos taken at Fulidhoo Caves (Vaavu atoll) in April 2020 (top) showing recovered *Acropora* corals (about 30 cm across) bleached, or in the middle of a bleaching response (white and pale colonies respectively). On the bottom image is another more sheltered reef (Bathi Giri) that had more severe bleaching (see appendix I).

The fine-scale nature of Reef Check surveys (over 100 m of reef) shows the stochastic nature of reef populations that are the result of recruitment, succession and idiosyncratic environmental variables (e.g. tide, depth, aspect, wave action, oxygen and temperature). We saw similar outer reefs (Ranikan, Guraidhoo outer and Fulidhoo outer) to those surveyed in the past at Ari atoll (Rasdhoo, Bathaalaa and outer Dhigurah wall) (Solandt and Hammer 2019). Healthy outer reefs in the 2019 surveys have a lower coral species diversity compared to healthy inner reef sites (particularly at Guraidhoo inner reef). Outer reefs in 2019 were dominated in shallow waters (<6 m) by *Porites* mounds (*P. lobata*). There was a zone at all outer reefs (Ranikan, Fulidhoo outer and Dhigurah wall) from 7 – 10 m where there was considerable recruitment of young *Acropora* and *Pocillopora* that has also been observed at the southernmost reefs of Ari atoll. However, the amount of large, mature *Acropora* colonies (reaching over 20cm in length) of outer reefs is low. We consider this to be a factor of bleaching, wave action, and competition by more successful coral lifeforms.

Other biological findings in this report

Over the past 10 years some of the inner reef sites that we have observed at Ari atoll are progressing through a 'phase shift' (Hughes 1994) from coral reefs to algal and sponge-dominated seabed biotopes. However, this effect was not apparent at South Male' and Vaavu, with the exception of a very sheltered reef - Farish's faru to the west of Vaavu, which was suffering from the infestation of a fast-growing sponge.

A 'phase shift' occurred in Jamaica and over much of the Caribbean in the early 1990s (Knowlton and Jackson 2008) due to a loss of herbivores over a prolonged amount of time due to overfishing (of parrotfish) and disease (of *Diadema* urchin grazing). Coupled with land-based nutrient input and catastrophic impact from hurricanes that destroyed the living coral framework, the marine environment shifted from a coral-dominated state to an algal dominated state within 3 years. This shift appears to be occurring on many inner atoll reefs of the Maldives. When the reefs are free of herbivory (largely due to overfishing of parrotfish and surgeonfish), the remaining fish and invertebrate populations are not adapted to consuming the species of algae that start to dominate affected reefs (e.g. *Dictyota, Padina*). Some larger more complex algae (e.g. *Sargassum* sp. and *Padina* sp.) are leathery and/or defended from herbivores by toxic secondary metabolites and/or calcification of tissues. At the Great Barrier Reef, for example, certain acanthurid species (surgeonfishes, tangs and unicornfishes) preferentially feed on small *Sargassum* plants, whilst chubs (Kyphosidae) preferentially fed on larger plants (Hoey 2010). *Padina* sp. was particularly dominant at Theluveligaa inner reef (Ari atoll) that was severely affected by bleaching in 2016. This reef had already experienced a 'phase shift' from coral to macroalgal dominance when surveyed in July 2018 (Solandt and Hammer, 2019) (Fig 2.3i). *Padina spp* have calcareous rings within their tissues, making it nutritionally less rich to grazers and more difficult to digest.

The interesting aspect of the dominance of a sponge community at the extremely sheltered Vaavu atoll site 'Farish's faru' is that sponges are now an increasingly dominant feature of the substrate in addition to algae, coral, and bare rock with algal turf since our first observations of Maldives reefs in 2005-2011 (Fig 2.4c). Hughes et al. (1999) suggest that replacement of corals by algae is driven by nutrient input, a link that has been understood for decades by coral reef managers.

A factor perhaps affecting the sponge dominance observed by the expedition, 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, which shows no resort / inhabited islands near to the dive site. It is also extremely sheltered, allowing fleshy algae to persist, as wave action and surge is low.

Figure 2.4c. Farish's faru reef at Vaavu atoll (exact location kept confidential on request). The lack of inhabited islands near this reef may have resulted in a different response to the bleaching of 2016 by becoming less dominated by algae and more by opportunistic sponges.

Whale shark sighting

There was one sighting of a single 3 m male whale shark at the Maamagili MPA in the vicinity of the island of Maamigili on 12 September 2019 after 2.5 hours of transiting along the reef. The shark was swimming in a relaxed fashion along the reef, at about 4 knots and was first encountered under the expedition vessel.

Recent research carried out by the University of York[4] has identified common oceanographic factors between areas of whale shark hotspots around the world (Australia, Belize, Mexico and Maamigili 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 over 400 m (on average) in order to feed in persistent 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, and need to spend time in shallow waters to warm up.

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 from the CO_2 that remains in the atmosphere and to be released from the planet's terrestrial and marine surfaces even if we cut emissions today (Zickfield and Herrrington 2015). Unfortunately, the International Energy Agency (IEA) has described that geo-political priorities to maintain oil and gas exploration and consumption as 'stubborn' in relation to the urgently needed change of human habits[5].

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; Richardson et al. 2018) 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 (Norstrom et al 2009)). This trend is not new and has been observed 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 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 stability and prosperity in favour of short-term financial gains, profit and power.

All of these issues have had associated costs. Many Maldivians would indeed argue that the tourism and fisheries have helped provide jobs for Maldivian citizens. This is undoubtedly true, but at what cost? Immediate concerns over climate-driven sea-level rise were recently addressed by the policies and actions of former President Mohammed Nasheed (in office 2008 – 2012). He was concerned over climate predictions resulting in sea level rise and increased storms that have already inundated parts of the country.

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[4] https://www.york.ac.uk/news-and-events/news/2018/research/research-reveals-secret-to-whale-shark-hotspots/
[5] https://www.iea.org/reports/world-energy-outlook-2019

There are various climate models that predict the Maldives to be underwater within 10 to 80 years (e.g. Viner and Agnew 2000[6]). However, since Nasheed's political demise in early 2012, there has been scant regard to adapting local policies to reduce CO_2 emissions, or to establish environmental policies that will benefit the most needy, away from the commerce of Male' and the tourism industry. Part of the (now passed) '100-day pledge' from the new government was to increase green taxes and increase transparency of decision-making and financial accounting for different government departments within the first three months of power.

President Nasheed was from the Maldives Democratic Party (MDP), as is the current government. The MDP has a record of emphasis on good governance, including the environment. The 2018 MDP election manifesto used the catchphrase 'blue economy' and they have published a policy document for 2019-2023[7].

Green tax has been levied[8] since October 2016. With tourist arrival numbers (approximately 1 million) in recent years, it is estimated that the Maldives collected over $50 million up until COVID travel restrictions in Spring 2020. The question is therefore not lack of money for improved governance of the environment. Instead it is lack of transparency about what green tax funds are used for. Our contacts in the Maldives environmental movement have stated that green tax investment priority rests with projects or infrastructure that produce tangible 'capital' outputs, such as water and sewage treatment or waste management. There is no process for public or civil society to tap into green tax funding to collect data and publish reports on understanding environmental quality and trends for improving environmental governance. As such many of our contacts in the Maldives must seek donor money continuously in order to undertake research and protection of MPAs, run projects to enhance fish populations and/or work in areas to establish favourable conditions for coral recovery. Such long-term programmes often become projects that are forced to demonstrate short-term gains in order to attract any funding at all. We believe that this means that long-term work on MPA recovery is neglected. This is a problem that is by no means unique to the Maldives, but also apparent in the UK (e.g. Solandt, 2018). Politicians by and large want results within a single legislation period of a few years. This is often out of step with the reality of MPA timings. For example, it typically takes 10-20 years for MPAs to show fish stock and/or environmental recovery from areas where development and/or fishing has been restricted (e.g. Arran in Scotland[9]). Such returns on investment are both difficult to guarantee, enforce, and measure. And they need administrations with power over decades (requiring strong laws). This can happen, but they need appropriate layers of government and a functioning democracy to support the rule of law and belief in the outcomes.

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[6] https://crudata.uea.ac.uk/cru/posters/2000-11-DV-tourism.pdf
[7] https://storage.googleapis.com/presidency.gov.mv/Documents/SAP2019-2023.pdf
[8] https://www.mira.gov.mv/GreenTax.aspx

[9] https://www.theguardian.com/environment/2020/feb/25/how-no-take-zones-revived-one-devastated-scottish-fishery-isle-of-arran

In the Maldives, there has been a push to increase tourist numbers since 2015. In 2018, visitor numbers increased to 1,403,000 from 1,088,000 in 2014[10]. The total number of resorts now stands at 145, with 521 'guest houses' being developed on local islands as an increasing share of the tourism market (the lead author stayed on the local island Fulidhoo during the training of the Fulidhoo dive centre staff). In 2018 the proportion of tourists from Asia was 25%, an increase by 30% since 2014.

The Maldives has been proactive in developing new markets in the face of more traditional tourism markets from Europe declining, mainly as a result of political unrest in the Maldives and the availability of alternative, less controversial holiday destinations. However, investment in tourism has not been matched by environmental precaution, or the "polluter pays" principle that is seen in UK and EU laws, with the intent to stave off the worst impacts of this growth. Empty '100-day' pledges over protecting one coral reef, mangrove and island per atoll were made by the new government, but not followed through. In the future, the government wants to protect at least 14% of each atoll . Proper financial accounting of healthy marine ecosystems would help with showcasing the importance of intact nature for the country's wellbeing, but it appears that the political will is simply not there.

The recent instability of the political situation in the Maldives over the past decade[11], 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 country's Gross Domestic Product, but the impacts on the wider ecosystem and population are 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 and religious extremism 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.

Recent resort developments in the Maldives under the (now past) Maldivian government[12] have not considered the on-costs (e.g. social, coral reef degradation, fish habitat and waste treatment costs) of developments to the environment in planning and remedial works. As a result of over-exploitation, 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 or other commercial development.

[10] https://www.tourism.gov.mv/dms/document/f5f522de183dde8f0f012884cecb1706.pdf
[11] https://www.bbc.com/news/world-south-asia-40827633
[12] https://www.aljazeera.com/program/investigations/2016/6/9/stealing-paradise/

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 administration's 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 regarding environmental issues[13]. 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 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'[14]) will benefit the public by providing clean drinking water, clean energy, secure housing, schools, education, health, etc. Whilst the new Maldives government appears to be more environmentally aware, the impact of the previous 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 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 like that of Baa atoll. Despite the progressive political intentions of such statements, there was no strategy from government agencies, such as the EPA or MRC. Similar promises by the UK government to designate a world-class network of MPAs has been met with pitiful budgets for enacting and enforcing subsequent controls and enforcement on fishing vessels. So, the trend is global, not national, for many political leaders to pay lip-service to (marine) environmental recovery whilst at the same time pursuing a highly destructive neoliberal agenda.

In the Maldives, this is in part due to recent political turmoil, but also due to a previous government that had no interest in investing in stewardship of its national marine estate. Indeed, since Biosphere Expeditions started working in the Maldives in 2011, cuts to the Marine Research Centre 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

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[13] https://magazin.zenith.me/de/politik/mohamed-aslam-%C3%BCber-klimawandel-extremismus-und-politik-auf-den-malediven (published online in 'Zenith', June 18, 2018)
[14] https://neweconomics.org/2008/07/green-new-deal

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 a result of Western tourists being tainted with the colonial brush as well as 'foreign' conservation efforts being considered alongside unsustainable foreign investment in the tourist industry that is at odds with the cultural norms. The Marine Conservation Society and Biosphere Expeditions can do all the monitoring they want, but without enforcement, boats, trained officers, surveillance of vessels (that all cost 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 investment into coral reef protection, fisheries restrictions and water and waste treatment is made, will conservation actually deliver for people.

We believe that an entirely different approach is needed to manage the Maldives: a system whereby power is granted to atoll councils with a need to sustain local economies, growth and all within environmentally sensible and sustainable limits. This will also result in the 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 tourism 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[15].

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. The Maldives government has the power to make the 'paradise effect' of the Maldives help to pay for its recovery.

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 impacted – particularly in North Ari and North Male' atolls – and the impact of various events and different environmental conditions continues to lead to greater biodiversity loss since the lead author (JL Solandt) started visiting the Maldives in 2005 (Fig. 2.4d).

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

Figure 2.4d. Whilst outer reefs (red pins) have similar appearance to each other in terms of dominant coral species, amount of sponge, algae and other settling benthic species, there has been a great range of different responses to the bleaching event, resilience and species recruitment and recovery in the inner reef areas (yellow pins).

This is apparent both within the coral diversity itself (see Guraidhoo backreef in particular), but also in the different types of organisms and phyla that appear to be in competition for space with coral. For example, Dega giri in western central Ari atoll is dominated by corallimorphs, Banyan Tree and Baros in North Male' atoll are being colonised by some forms of encrusting sponges that grow close to the substrate, whereas Farish's faru reef in the west of Vaavu atoll has fleshy lobed sponges that appears to be growing in many areas (Fig. 2.4e).

The outer reefs, in shallow water in particular – appear to be very similar in almost all locations – particularly where the drop-off is more extreme. Dhigurah, Rasdhoo, Ranikan and Guraidhoo outer all resemble one another, have similar coral, coral rock, sponge, and algal counts (Fig. 2.4d).

We can also establish that the more we look, the more differences we see. Claiming that 'one atoll is faring better then another' is difficult to state for sure, but there were patterns from the inner reefs visited at Vaavu and South Male' atolls that would suggest that the biological diversity of the coral assemblages in these reefs is cause for optimism.

After nine years of annual Reef Check surveys, we posit that there are five types of reef location and environmental condition, four of them inner reef types:

1. **Exposed outer reefs** associated with greater current, wave action and adjacent to very deep water are generally more resilient to bleaching (because of dominance of greater bleaching-resistant coral lifeforms and cooler, deeper adjacent seawater – Cowburn et al. 2019).

2. **Inner reefs**, which

A. are dominated by bleaching-intolerant species such as branching *Acropora* and *Pocillopora*, which are consequently more vulnerable to disease, *Drupella* predation, Crown of Thorns grazing, sponge/algal recruitment and growth. In the Maldives, these reefs now appear to be dominated by coral rock and turf algae. They may still be able to recruit corals and grow back to being coral dominated (e.g. Kudafalhu).

B. are exhibiting a phase change from a coral-dominated state to an algal, sponge and *Discosoma* (non-coral) state (e.g. Dega giri).

C. have adapted to climate-induced bleaching with more bleaching-tolerant coral species persisting or outcompeting *Acropora* recruits, sponge, algae, and other competitors (e.g. Guraidhoo backreef).

D. appear to have some resistance with species that were hitherto described as having low thermal tolerance (e.g. Farish's faru) with large thickets of *Acropora* corals. Note that this is the rarest form of reef we observed in our surveys since the 2016 bleaching event.

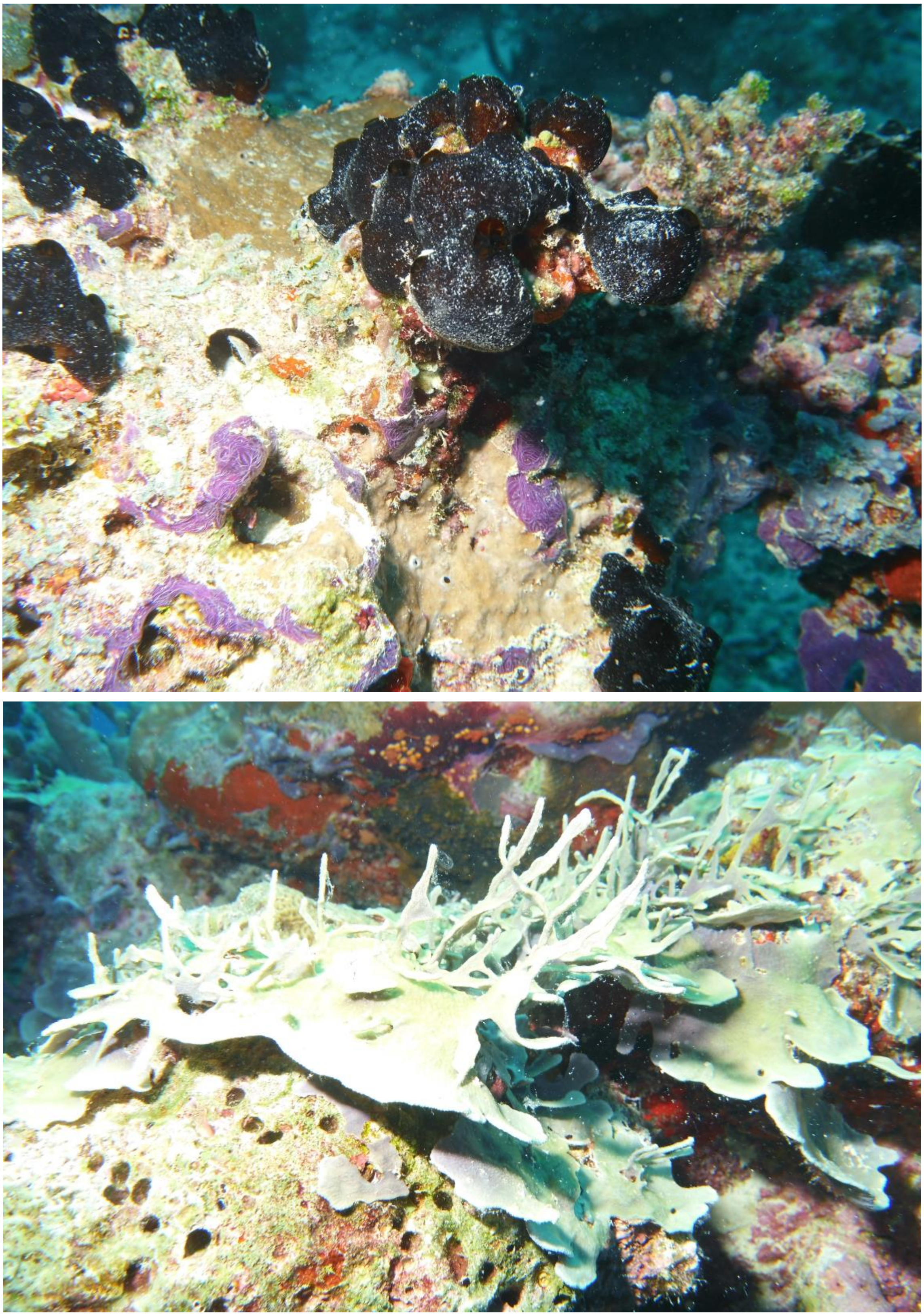

Figure 2.4e. Whilst the literature is mostly concerned with the dominance of algae, such as turf and macroalgae, as post-bleaching reef colonisers, the Maldives has a multitude of species and phyla settling the substrate post-bleaching. Top: Baros Maldives in July 2018, dominated by two species of sponge. The encrusting pink form, *Haliclona nematifera* is particularly effective at growing around the base of live corals, competing with them for space and nutrients. The black sponge is likely *Aka mucosum* that has been reported to 'bore' its way through living coral. Bottom: Farish's faru was dominated by this unidentified sponge. Many coral heads had this distinctive lifeform.

Our recommendations on issues related to the vulnerability of the Maldives have been highlighted in previous reports available from the Biosphere Expeditions website. Our observations and training will hopefully increase awareness. 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 to help remediate the damage from bleaching, over-development and overfishing. Research has shown that recovery projections from bleaching events become more protracted over time, whilst more frequent bleaching events occur. Therefore, the Maldives will need decades to recruit and grow corals to resemble the reefs before the 1998 bleaching event. However, with the 2020 bleaching event occurring just four years after the last event, the ability to be resilient to such events is being tested more than ever before. As such, it is likely that the reefs will never regenerate to the levels seen in 1997 and before, and indeed, the species guilds – of corals at the very least – will be very different, particularly for inner atoll reefs.

Our recommendation are:

1. Resource either the EPA, or each atoll council, with 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 are not 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 and enforcement officers 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[16], 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.

[16] Grouper cages exist in at least five atolls where fish are corralled before being shipped to Asian 'live fish' markets.

7. Introduce size limits on grouper fisheries as previously recommended to government[17], which includes:
   a. regulated fishing
   b. mandatory logbooks and data collection
   c. long-term monitoring of catch, abundance and spawning aggregation sites
   d. national level awareness-raising programme
   e. a mobile-phone technology Vessel Monitoring scheme for Maldives-registered fishing vessels such that enforcement can be done by using satellite technology[18]

8. Ensure that the fisheries department has 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. 2.4f).

10. Ensure that the EPA is provided with enough budget (via for example a tourism tax) to enable it to be present (with an officer) 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.

[17] https://www.mcsuk.org/downloads/coral_reefs/Maldives_Grouper%20_fishery_Management_Plan.pdf (page 19).
[18] https://globalfishingwatch.org/

Figure 2.4f. 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 regulation.

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Appendix I: Surveys and training at Vaavu atoll (Fulidhoo dive[19]) and 2020 bleaching

After the week-long Biosphere Expeditions survey, the lead author led some Reef Check training at Fulidhoo Dive Centre on the island of Fulidhoo in Vaavu atoll. This island is 90 minutes in a speedboat south from Male' (Fig. Ia).

Surveys were only undertaken at shallow transect depth locations as part of the training of three dive staff (Akuram Ahmed, Mohammed Rifaad, Raffhan Ahmed) and two directors (Ali Miuraj and Adele Verdier-Stott).

Training dives were carried out at Bathi giri (a sheltered inner reef) and at Fulidhoo caves (an exposed outer atoll site just to the north of the island) in September 2019. Training (dive staff carried out one dive each of substrate, fish, invertebrates and impacts) was completed on 5/6 May 2020 by the dive staff revisiting the two sites where training took place.

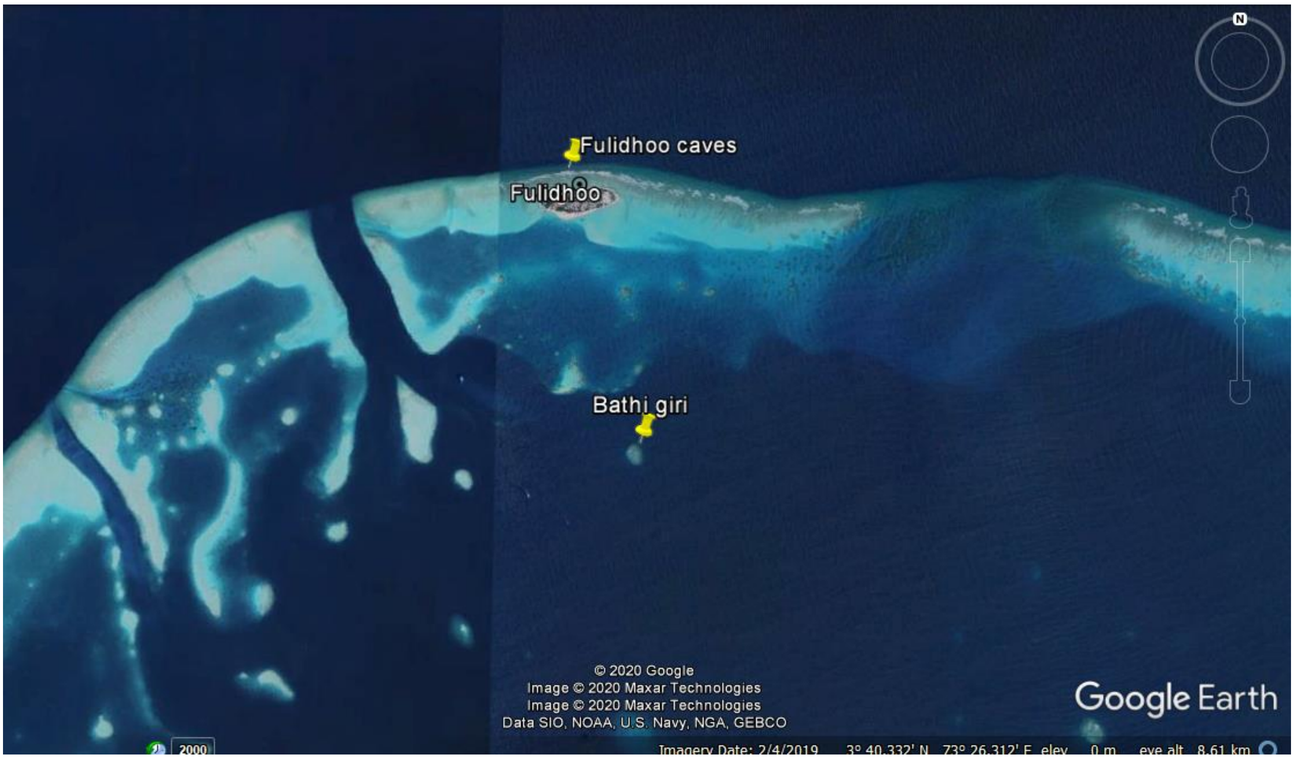

Figure Ia. Training of Fulidhoo divers (and data collection) took place at Bathi giri and Fulidhoo caves at the northern end of Vaavu atoll.

[19] http://www.fulidhoodive.com/

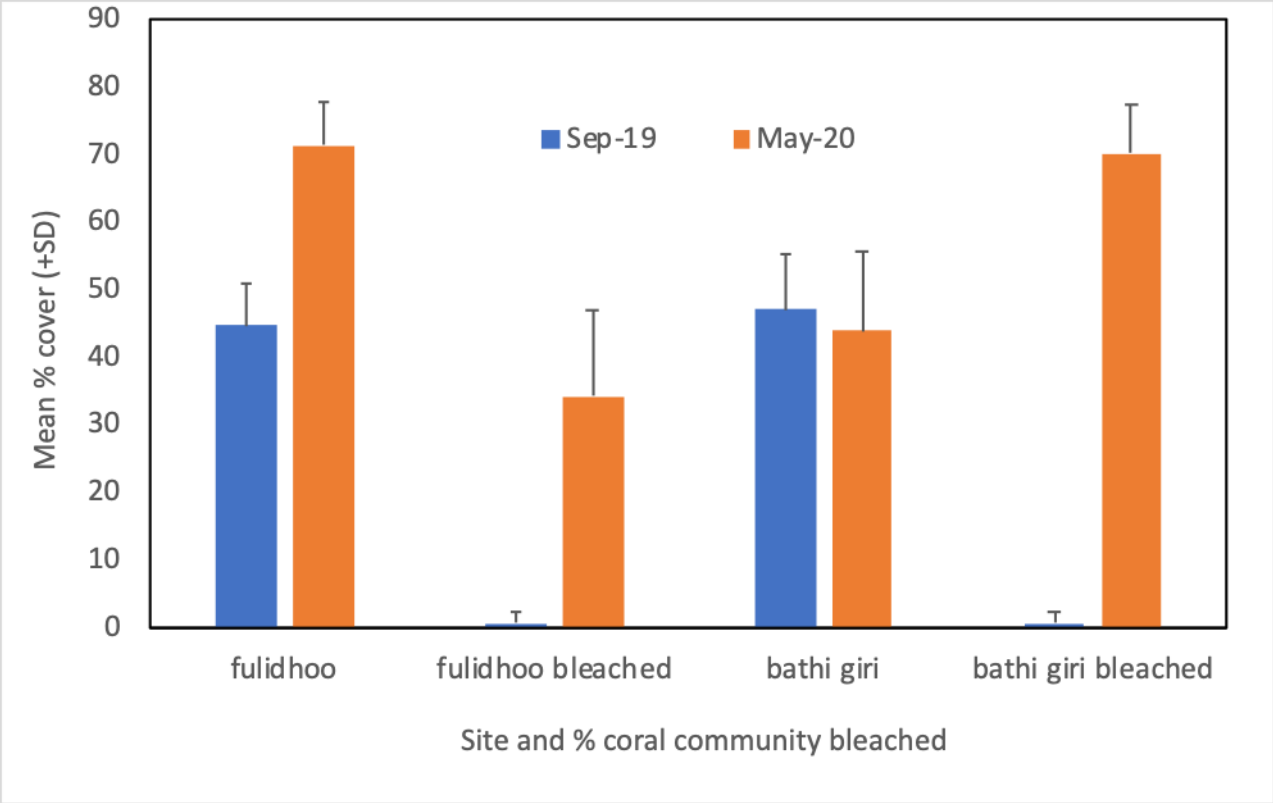

Figure Ib. Bleaching impacts at Fulidhoo atoll. The proportion of the live coral community 'bleached' in September 2019 (during training) was extremely low (<1%). The live coral population at Fulidhoo caves increased from 45% in September 2019 to 71% by May 2020. This percentage was compromised by the May bleaching event as 34% of the live corals were bleached. At Bathi giri, the coral cover was 47% in September 2019, and fell to 42% in May 2020. The recorded proportion of this population bleached was higher (at 70%) in May 2020.

Whilst the coral population at both sites was healthy in 2019, it is clear that the Fulidhoo population was continuing to grow in size and therefore cover (from 45% to 71%). This is largely because of the large population of fast-growth table *Acropora* colonies that dominated the coral cover at the site. A bleaching event in May 2020 changed all this and it is clear from images and data recorded by newly-qualified Fulidhoo dive centre staff that the bleaching was more severe at the inner reef of Bathi giri, with 70% of the live coral community suffering from bleaching (Fig. Ib).

We believe that the difference in severity of colony bleaching (at the time the images were taken) is related to water flow and retention. The Fulidhoo cave corals are partially bleached, rather than totally bleached (Fig. Ic). The flow regime is greater and water retention lower at Fulidhoo caves relative to inner atoll reefs (such as at Bathi giri), which would likely result in cooler water temperatures. The bleaching period appeared quite protracted (from NOAA data), with most warm water over the Maldives from about 10 April until the end of the month (Fig. Id).

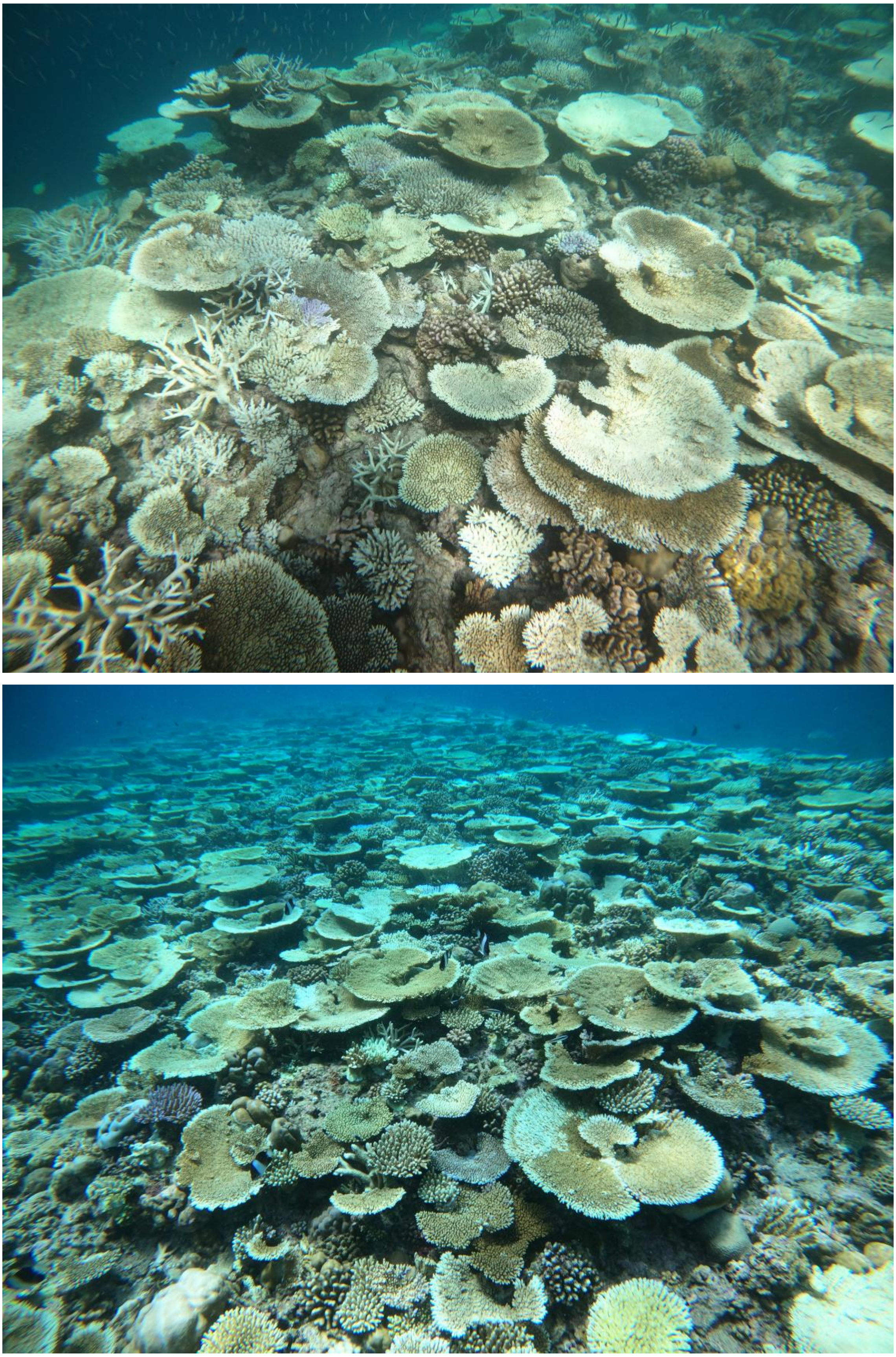

Figure Ic. Bleaching impacts at (top) Bathi giri inner reef, and (bottom) at Fulidhoo caves outer reef (May 2020). It appears that there is less bleaching at Fulidhoo caves compared to Bathi giri.

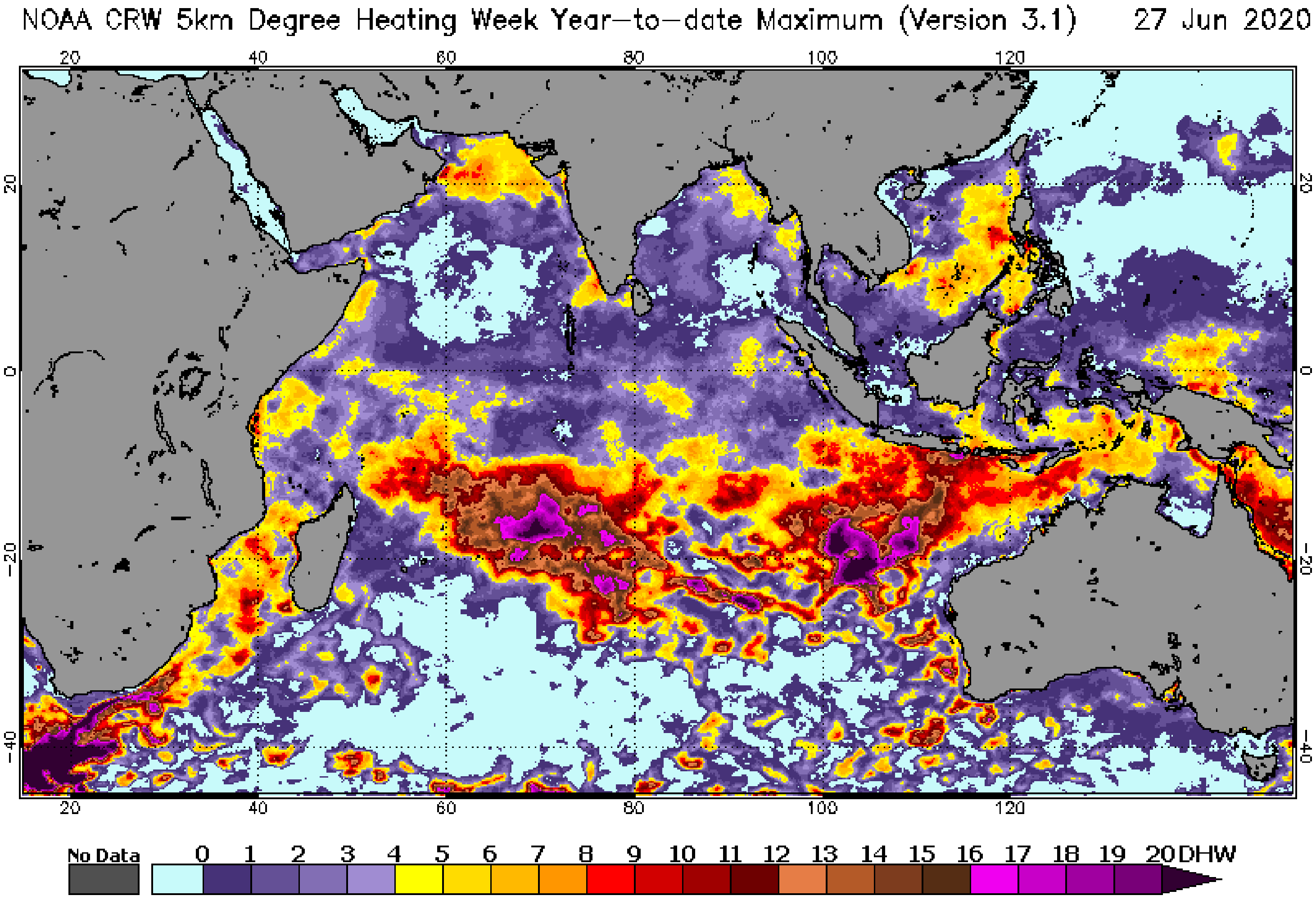

Figure Id. Degree 'heating' weeks for the Indian Ocean (NOAA) from January 2020 until late June 2020. This suggests that the Maldives was impacted by hot water for between one and three weeks.

Appendix II: Expedition reports, publications, diary & further information

2019 expedition results with voiceover:
https://www.researchgate.net/publication/344449665_Presentation_Little_and_large_surveying_and_safeguarding_coral_reefs_whale_sharks_in_the_Maldives_September_2019

Project updates, reports and publications:
https://www.researchgate.net/project/Maldives-citizen-science-reef-surveys-and-conservation-using-Reef-Check-methodology-whale-shark-surveys

All expedition reports, including this and previous expedition reports:
https://www.biosphere-expeditions.org/reports

Expedition diary/blog:
https://blog.biosphere-expeditions.org/category/expedition-blogs/maldives-2019/

Expedition details, background, pictures, videos, etc.
https://www.biosphere-expeditions.org/maldives