

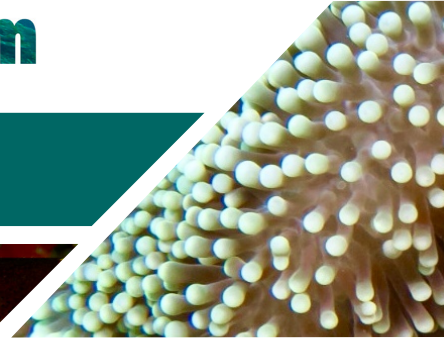
24th
July 2018



Second Maldives Marine Science Symposium



Abstract booklet



Conservation, Fisheries and Management
Coral Bleaching and Reef Restoration
Island and Reef Geomorphology
Marine Megafauna
Reef Ecology



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24th July 2018

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Ministry of Fisheries and Agriculture
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Second Maldives Marine Science Symposium 2018,
held on 24th July 2018, at The Maldives National University, Malé, Maldives.

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Note

1. The abstracts in this booklet maybe of preliminary findings, and may be subject to change. Hence, none should be cited without prior written permission from the author(s).
2. The abstracts were prepared and submitted well in advance of the symposium, to review by Scientific Committee and to meet the printing deadlines. As a result, some abstracts may have changed or may not have been presented at the symposium. Our apologies for inevitable omissions and errors.

Convener's Remarks

It is a great pleasure to be convening the second Maldives Marine Science Symposium (MMSS-2018), further enhanced by a selection of good quality papers on marine scientific research work carried out in the Maldives. Marine Research Centre (MRC) organized the first of this biennial symposia series in 2016, in partnership with the Maldives National University. The overarching objective of this symposia series is to provide an opportunity for researchers to present their work and facilitate dialogue among peers. A more important objective though is to encourage aspiring Maldivian researchers to foster a career in science profession and create a venue for communicating their work.

The abstracts we received for the second Symposium cover wide ranging topics reflecting some of the key challenges of managing coral reef systems in the Maldives; fisheries management, reef restoration and the use of new technology for monitoring reefs, to name a few. We received over 38 abstracts, of which 20 were selected by the Scientific Committee for oral presentation and 15 for poster presentations.

We hope that the Symposium programme will facilitate the exchange of information and ideas about current marine scientific research being carried out in the Maldives, and our collective effort will form a better understanding of the marine ecosystem of the Maldives. We at the Marine Research Centre (MRC) are keen to engage in research projects of common interest to strengthen our collaboration and diversify our knowledge.

The Symposium organizers wish to thank the Scientific Committee, particularly Dr. Charles Anderson and Dr. Steve Newman, for their editorial work on the abstracts presented in this publication. We thank all participants and their respective organisations for their contribution. We would also like to thank the Maldives National University for jointly hosting this MMSS symposia series.

Finally, the Symposium organizers wish to express our profound appreciation to the exclusive sponsor of MMSS-2018, Soneva and their founder, Mr. Sonu Shivdasani. The symposium was made possible by their very generous financial support and we wish to acknowledge the continuous engagement by Mr. Shivadasani in all matters related to marine conservation. Last but not the least, we want to thank our Minister Dr. Mohamed Shainee for all his encouragement in this endeavor.

MMSS-2018 Organizing Committee

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Keynote address

Maldives marine ecosystem threats and opportunities

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Abstract

The Maldives is fundamentally dependent on the marine environment, with biodiversity providing a significant resource base for the fisheries and tourism that underpin the economy. Thus understanding the extent and rate of impacts and change, both locally and globally, is necessary for long-term sustainability. Natural heritage in the Maldives historically supported traditional marine-based livelihoods which placed little pressure on marine resources. However, burgeoning global human populations and environment change threaten natural ecosystems, particularly sensitive and fragile coral reef ecosystems and the goods, services and livelihoods that they support.

Extensive coral bleaching, outbreaks of crown of thorn starfish and the pressures of human population, as well as changing land use and reclamation, all pose risks to coral reefs in the Maldives. Increasing frequency and magnitude of disturbances jeopardise ecosystem functioning and a strategic and coordinated approach to understanding the environment and the degree and rate of change is needed. As the impacts of global change are increasingly realised and observable, it is necessary to improve management of biodiversity and key ecosystems, informed by a combination of long-term monitoring and applied research that integrate social, biological, physical and economic disciplines.

The private sector in the Maldives supports marine biologists who can serve a role beyond that of the service industry, to support the understanding of long-term environmental change and ecosystem management. Standardized national monitoring protocols have been developed through a stakeholder inclusive process to support the generation of long-term data with substantial value to detect change, and to guide and inform management. Increased collaboration between public and private sectors at multiple scales can support capacity development, increase awareness, promote stewardship, and ensure resilience to achieve sustainable environmental, social and governance goals.

Session 1

Conservation, Fisheries and Management

Determination of size-maturity relationships for two of the most highly valued species of grouper in the Maldives

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Abstract

In recent decades fishing pressure on grouper species in the Maldives has dramatically increased. The commercial fishery for the export trade started in the late 1980s and within a few years the fishery was showing signs of overexploitation. The average size of groupers caught in the Maldives is decreasing. Between 70 and 90% of groupers caught for export are immature, indicating that the reproductive potential of targeted grouper populations has declined substantially.

Species-specific size limits were introduced as a fisheries management measure in 2014. However, these minimum sizes were considerably smaller than the theoretical maturity sizes proposed in the Grouper Fishery Management Plan, which were based on estimates from global data. Grouper fishermen argued that size limits derived from global data were not representative of maturity sizes in the Maldives. Therefore, size limits were agreed on the understanding that Maldivian data on size maturity would be collected to inform management.

At the request of the Ministry of Fisheries and Agriculture, BLUE in partnership with the Marine Research Centre and Six Senses Laamu conducted size-maturity assessments of five highly targeted grouper species (*Epinephelus fuscoguttatus*, *Epinephelus polyphekadion*, *Plectropomus areolatus*, *Plectropomus laevis* and *Plectropomus pessuliferus*) to provide evidence for the revision of national regulations. More than 400 groupers were sampled at collection cage systems in four atolls between February and October 2017. Sampling was carried out over the new moon period as this is the most likely time of spawning for the selected species.

To determine the size at maturation, the gonadosomatic index (GSI) was calculated for each individual. Size at maturity was successfully determined for two species: *Epinephelus polyphekadion* (40 cm) and *Plectropomus areolatus* (42 cm). Existing size limits are up to 50% smaller than actual size at maturation. Data collected were insufficient to determine size at maturity for the other three species, but this was close to being determined for *P. pessuliferus* and could be verified with minimal further sampling.

There was a lack of *E. fuscoguttatus* available for sampling at cage systems. Cage managers were also reluctant to sell us these fish, indicating that they are becoming a rarer but highly valuable resource. Demand for this species may drive it to the point of commercial extinction in parts of the Maldives unless strong action is taken to protect it.

The information collected shows that size-maturity relationships of grouper species in the Maldives are similar to the theoretical maturity lengths derived from global data. Where local data are lacking we recommend that size limits are based on global estimates of size maturity for all targeted species. This measure along with others will enable groupers to reproduce and begin the re-building of populations across the Maldives.

Pilot study on grow-out culture of sandfish (*Holothuria scabra*) in bottom-set sea cages in a lagoon

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Abstract

Mariculture is relatively new to the Maldives, and sandfish culture has been practiced in the country for a little over a decade. Currently, sandfish grow-out in pens is being carried out by island communities on a limited scale.

This study was carried out in the lagoon of Maniyafushi Island, South Malé Atoll, to determine the growth and survival of hatchery-produced juvenile sandfish cultured in bottom-set cages in a lagoon in order to assess the potential use of such cages in small scale sandfish grow-out operations. During this study, feed was introduced in each experimental cage at the rate of 3% of the total sea cucumber biomass in the cage (i.e. without varying stocking density and feeding frequency).

The results of this study showed that survival was high: mean survival was 97.1%. At the end of the 124 days culture period the animals reached a mean body weight of 147.05 g and yielded an average biomass of 1,424.64 gm⁻². The specific growth rate for the culture period was 1.58% day⁻¹.

Based on the growth and survival of sandfish in bottom-set cages used in this study and the performances of sandfish in other culture systems, it can be concluded that bottom-set cage is a suitable culture system for small scale grow-out of sandfish with feed inputs, particularly for early stages of grow-out. This type of cage can also be used for nursing smaller juveniles in the sea before putting them in sea pens for further growing. Further studies are needed to determine the most suitable cage size and materials, stocking density, culture period and scale of grow-out operation. Pen, bottom-set cage and off bottom cage can be used in different environmental conditions of the lagoons. These culture systems have the potential for widening sea cucumber grow-out in the country.

The first detailed study of a grouper spawning aggregation site in the Maldives

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Abstract

Groupers are important predators that play a critical ecological role on coral reefs. However, many of their life history traits make them vulnerable to overfishing. They are slow to mature and exhibit a high degree of site fidelity within home ranges and to spawning aggregation sites.

Previous research revealed that more than 87% of Maldivian grouper fishermen were aware of grouper spawning aggregations and were able to identify 175 spawning aggregation sites (SPAGs). Five of these sites were designated as no-take Marine Protected Areas in 2014. Initial surveys conducted by the Marine Research Centre (MRC) in 2013 noted grouper behaviour indicative of spawning aggregations, but results were insufficient to verify these sites as SPAGs. The Maldives Grouper Fisheries Management Plan (2011) recommends the protection of grouper SPAGs. This is crucial to ensure an increase in the reproductive potential of grouper populations and help to replenish declining stocks.

In partnership with the Ministry of Fisheries and Agriculture, Six Senses Laamu and the Laamu Atoll Council, Blue Marine Foundation (BLUE) and MRC completed dive surveys to locate and verify grouper SPAGs in Laamu Atoll between September 2016 and August 2017. Beforehand, fishermen interviews were conducted to collect information on the general location of known SPAGs in the atoll. Exploratory dives and timed swim surveys at multiple locations initially identified aggregation sites and collected preliminary information on the aggregations. One site was selected for a detailed assessment over multiple months. Underwater Visual Census (UVC) surveys were completed each day over a month to determine the prevalent lunar phase for the aggregation. Grouper species, abundance, size and behaviour were recorded. Observations strongly suggested spawning activity during the new moon period for four grouper species (*Epinephelus fuscoguttatus*, *Plectropomus areolatus*, *Epinephelus polyphekadion* and *Plectropomus laevis*). For each species, a baseline non-spawning density was calculated from the mean abundance of species over the non-spawning lunar period (full moon). UVC surveys were repeated at the selected site over 8 days of the new moon period in April and August 2017.

At the main selected site, the density of all four species of grouper exceeded the spawning aggregation threshold over at least one new moon phase, providing direct evidence of a spawning aggregation. Indirect verification was also made from observations of behaviour and colour patterns specifically associated with spawning. Highest densities were recorded for two grouper species: *E. fuscoguttatus* and *P. areolatus*. Monthly changes in densities of all four grouper species suggested some seasonal variation in the aggregation. Our findings show similarities to other grouper SPAGs in the Indo-Pacific region that have the same or similar species composition. This is the first detailed study of a grouper SPAG in the Maldives and provides a standard for the assessment of other grouper aggregations as well as data to inform management.

A fisher knowledge assessment of grouper fishing on Laamu Atoll: evidence for improved management of the fishery

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Abstract

In the last forty years fishing pressure on grouper species in the Maldives has dramatically increased. As populations of highly targeted species declined in the central atolls, fishing for groupers moved out to the more distant atolls, including Laamu. Management measures, including size limits and the protection of some grouper spawning aggregation sites (SPAGs), were introduced in 2014 but have not been very effective to date.

Commercial exploitation of groupers on Laamu Atoll has been occurring for over 20 years with signs of overfishing reported as far back as 1998. There have been no recent focused studies of the Laamu fishery and there is a lack of information on its status and of grouper populations for this atoll. In partnership with Marine Research Centre, the Ministry of Fisheries and Agriculture, Six Senses Laamu and Laamu Atoll Council, the Blue Marine Foundation (BLUE) conducted a fisher knowledge assessment in Laamu Atoll. The aim was to gain a comprehensive understanding of the grouper fishery on the atoll, including the location of grouper spawning aggregations (SPAGs). This knowledge will help to formulate recommendations to improve the management of the fishery and protect local grouper populations.

Between November 2016 and May 2017, 119 fishermen from all 11 inhabited islands on the atoll were interviewed either individually or in focus groups. Interviews covered a range of topics including the average size and catch of targeted species, fishing effort and location, spawning aggregation sites, socio-economic characteristics, external fishing pressure and existing management measures.

Our findings from fishermen indicate that the current level of fishing pressure on Laamu Atoll for groupers targeted for export is unsustainable. Overexploitation and targeting of spawning aggregations over at least thirty years has led to the decline in the size and abundance of groupers, an increase in fishing effort and an overall reduction in income from groupers for fishermen. Furthermore, there is a lack of awareness of existing national regulations for grouper amongst fishermen in Laamu Atoll. More than 80% of fishermen were not aware of current management measures for the fishery and none could accurately describe existing catch size limits for grouper species.

The Laamu fishing community recognizes that grouper stocks have declined, and the need for action, with 85% supporting better management of the fishery including measures to restrict gear, limit catches and protect spawning aggregation sites in the atoll. Most fishermen are willing to be involved in island- or atoll-based management to help safeguard grouper populations.

This study also indicates that grouper populations in more distant, less studied atolls have declined and provides further justification for better management of the grouper fishery across the whole country. There is also a need for improved communication of existing management measures to grouper fishermen and for enforcement at the atoll level.

Using high-resolution Unmanned Aerial Vehicle (UAV) images and AI (Artificial Intelligence) system to automatically intercept and quantify plastic pollution on Maldivian shores

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Abstract

Plastic pollution is one of the biggest threats to our oceans. Annually we release into the seas some 4.8 to 12.7 millions of tonnes of plastic. Part of this enormous amount floats on the surface of the ocean for years before being degraded to microplastic (particles of plastic < 5mm). During this cycle, plastics can be transported for miles and can be deposited on beaches far away from their place of origin. The Republic of the Maldives with its long coastline and geographical position in the middle of the Indian Ocean represents the perfect place for the deposition of plastic debris. Every beach on inhabited, uninhabited or resort islands is covered with plastic wastes from different sources.

Using a consumer-grade drone (DJI Phantom 4) we acquired high-resolution aerial images from the shores of different islands in the southern part of Faafu Atoll. Using a machine learning algorithm, carried out by our research group, we were able to automatically detect and quantify plastics from the images. We calculated the area covered by plastic and we classified the different types of litter. This methodology significantly reduces survey times and allowed us to easily monitor the spatial and temporal trends of plastic debris deposition over time.

Species composition and exploitation trends from the proforma export data of the Maldives aquarium fishery

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Abstract

The Maldives Aquarium Fishery (MAF) has existed since 1979. The fishery exploits small-sized reef-associated fish, which are exported live to Europe and Asia. Over the years, the fishery has undergone considerable expansion in terms of species composition, harvested numbers and areas of operation.

In order to monitor the expanding fishery, Marine Research Centre introduced a 'Proforma Aquarium Fish Export Form' in the mid-1990s, as an obligation at the time of exporting a shipment. Over the years this has yielded a dataset of considerable value. As this is the only source of species-level information available and harvests are exclusively for export, it is reasonable to assume that export data would be a proxy for harvests in the fishery, thus shedding light on the trends in fishery output.

This study presents the overall trends in the Proforma Export dataset and highlights important areas for research and data collection. The dataset comprised of numbers of fish by species, exported from 2000-2015, except for 2001, 2008, 2012 and 2013 and covers 55% of total export by numbers (as reported by the Maldives Customs Service).

The results showed that the fishery exploits no less than 300 species of fish. However, only a handful make up the bulk of exports, with 20 species contributing up to 70% of the total exports every year. *Pseudanthias squamipinnis* (Sea Goldie) consistently ranks as the most exported species accounting between 15-25% of annual exports and represented 18% of the whole dataset (all years). *Acanthurus leucosternon* (Powderblue Surgeonfish), *Nemateleotris magnifica* (Fire Goby), *Labroides dimidiatus* (Blue-streak Cleaner Wrasse) and *Pseudanthias evansi* (Yellowback Anthias) consistently appear within the top 5 species.

Composition of the twenty most exploited species has also changed over time. The reason for the shifts could be a combination of change in market demand and/or abundance of the species. Some fishes, such several of the butterflyfish (Family Chaetodontidae) are obligate or facultative corallivores, and their abundance and distribution would be highly dependent on the health of the coral reefs. Abundance and distribution of species that are less dependent on the reefs, could as well be impacted by other environmental factors.

Absence of local demand and market for the products, a single export channel and the fact that a small number of species represent the bulk of exports are all conducive to stringent monitoring of the fishery. In order to maximize the use of resources, future research and monitoring efforts need to focus on these aspects of the fishery, while not excluding species that might be of special importance.

Conservation of atoll ecosystems: individual reefs as units of conservation in the Maldives

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Abstract

Maldivians have lived as small communities on coral reef islands in harmony and sustainably for millennia. Coral reefs provided a living, livelihoods, comfort and security to atoll communities. We are intricately intertwined with the reefs for our very survival, protection and income. With the advent of mass tourism in the 1970s the natural beauty of coral islands became the centre of attention and attraction. Income and livelihoods improved from coral reef products and resources (coconuts and palms, islands, beaches, corals, shells, fish) which did not have any little value before the advent of tourism. Uninhabited islands, previously only good for firewood and coconuts, were converted to million dollar products virtually overnight.

The 1980s and 1990s brought some much needed management initiatives to coral reefs, mainly as a response to global warming and sea-level rise projections. The most important and outstanding outcome of the conservation efforts of the 1990s was the banning of coral mining, which had been a widespread and most destructive activity for many centuries. But apart from that there little progress in coral reef conservation. We have developed legal instruments (EIAs) to address development impacts on reefs. But governments have constantly struggled to come to terms of with EIA procedures so that the process has weakened considerably over time. Concerns are growing about the lack of meaningful, lasting and sustained management initiatives for coral reefs. The need to develop practical and locally driven solutions for atoll type coral reef conservation and development is apparent.

This paper presents new concepts for coral reef management in the Maldives, with special emphasis on the unique geography and formation of atolls as integrated elements in reef management. We have tried to adopt integrated management models such as the establishment of MPAs, LMMAs, IRRM and other mechanisms, but with limited success. This paper attempts to define natural atolls and reefs in a local context and to identify characteristics of individual reefs as conservation units for atoll reefs in the Maldives. It is argued that meaningful conservation and management of coral reefs of the Maldives can be best achieved by localized studies for individual reefs in light of their physical, biological and ecological characteristics and human interactions. For effective conservation habitat complexity on individual reefs need to be mapped for every coral reef in the Maldives. The connectivity of habitats within and amongst reefs of atolls is of paramount importance in conservation planning for atoll type reefs. Community usage of reefs have traditionally centered on resources that are linked to a particular reef or reefs characterized by particular favorable habitats (scad fishing, bait fishing, reef fishing). Conservation plans for individual reefs can identify and address dominant commercial and other reef species by their habitat types and the true ecological values that warrant conservation.

Session 2

Coral Bleaching and Reef Restoration

Rising from the rubble: how substrate stability affects reef recovery

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Abstract

The intensity and frequency of tropical cyclones, storms and global coral bleaching events are predicted to increase with warming ocean temperatures. Reefs will have increasingly smaller windows of time to recover between successive disturbance events and may suffer more severe damage, with the structure of reefs 'flattening' over time. Damage to corals results in the localised accumulation of unconsolidated coral rubble.

Unconsolidated rubble is generally considered unfavourable for hard coral recruitment because it can move easily with waves and currents, consequently destroying newly-settled coral recruits. Recovery in such environments is commonly slow, depending on the level of wave exposure, rubble size and coral larval supply. However, if rubble is bound or cemented together by biological organisms, it may form a stable, consolidated substrate for successful coral attachment and recruitment.

Despite the influence of unconsolidated rubble on reef recovery rates, there are few studies on post-disturbance rubble movement and the subsequent effects on coral recruitment. This project explores the physical and biological dynamics occurring in areas of unconsolidated rubble on coral reefs. Fieldwork is being conducted on Vabbinfaru Reef in the Maldives, in collaboration with Banyan Tree Vabbinfaru Resort. The Maldives is an ideal location for studying rubble dynamics due to the presence of vast rubble accumulations following the 2016 bleaching event. The objective of the research is to address key knowledge gaps concerning three aspects of coral rubble dynamics: the conditions required for rubble movement; rubble binding/consolidation rates; and survival of coral recruits on unconsolidated rubble.

As this research is ongoing, this presentation will concentrate on findings so far from the investigation of coral recruit survival on unconsolidated rubble. To replicate coral 'recruits' growing on rubble pieces, small fragments of *Porites rus* and *Pocillopora verrucosa* were collected from the Vabbinfaru reef slope and glued onto coral fragging plugs. Over a 2.5-month period, recruits were submitted to abrasion and flipping at varying intervals to replicate a rubble piece tumbling with the current. Recruits were abraded and flipped either: every 2-3 days (high frequency group); every 8 days (medium frequency group); every 21 days (low frequency group); or never (control group). When compared to the control group, the loss in the proportion of healthy tissue of recruits was significantly higher in the high and medium frequency groups, but not in the low frequency group.

An improved understanding of coral rubble dynamics will help managers to predict which areas of damaged reefs are likely to have low recruitment and long recovery times without intervention. These areas can be given priority for the implementation of active restoration methods, such as rubble stabilisation, to hasten recovery

Lesion healing of *Pocillopora* corals in an artificial nursery vs natural reef environment in the Maldives

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Abstract

Scleractinian corals incur damage from a variety of natural and anthropogenic sources. In order to tolerate these stressors, corals have developed critical wound healing processes that regenerate lost polyps and repair epithelial lesions. This is particularly relevant in reef restoration techniques where lesions are intentionally inflicted through fragmentation. Similarly, the high density of colonies in artificially constructed coral nurseries can lead to disease outbreaks. Determining the rate of recovery from artificial and disease related inflictions, which can depend on both intrinsic and extrinsic factors, has potential to enhance reef restoration practices in the Maldives and worldwide. Here, digital photography is used to investigate the gross pathology of wound repair and lesion regenerative capacity in contrasting artificial nursery and natural reef environments.

Monitoring took place at two sites (reef, 3~4m and nursery, 7~8m). Five *Pocillopora* sp. colonies were selected from the nursery and one branch removed from each to generate a lesion site. The detached nubbins were added to a separate rope for monitoring. Twenty colonies were transported to the reef-flat site and left for 24 hours to allow for lesion creation resulting from fish predation. Digital photographs of the lesions were taken immediately and at 48 hours after inception and then at weekly intervals thereafter. Measured parameters for recovery included: initial lesion extent, pigment shade of recovering symbionts and density of regenerated polyps at three stages of development.

Gross observations of the lesion sites on day 0 showed bare white skeleton with hollow corallites bereft of all tissue. All nursery fragments remained unchanged until day 9 where lesions showed translucent tissue progressing inward from the epithelial edge. On day 16 re-pigmentation and polyp regeneration became apparent at both sites; total polyp density at the lesion site was 0.66 and 0.25 (polyps mm⁻²) in the nursery and reef specimens respectively. Polyp density increased at an average rate of 0.18 and 0.15 (polyps mm⁻², respectively) per week until final monitoring where an average of 1.00 (polyps mm⁻²) (100% of colonies) had reached stage 3 development in the nursery compared to 0.07 (polyps mm⁻²) (40% of colonies) on the reef. By day 23 tissues had an average darkest pigment shade of 3.8 and 5.2 (respectively) and upon final monitoring 100% of the nursery colonies exhibited shade 2 (considered healthy) compared to 40% of colonies on the reef.

Here, we identified that the specific conditions offered in a nursery setting may favor tissue recovery over natural reef environments. All nursery colonies, regardless of the initial lesion or colony size, exhibited full recovery, whereas those in the natural reef environment did not. This may be explained by additional pressures on the reef, such as persistent predation, prompting colonies to allocate fewer resources toward lesion recovery. These findings provide support for a nursery phase in coral restoration.

Homeward bound: growth dynamics of hermatypic nursery-grown corals transplanted back to their native reef

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Abstract

Enhanced coral growth rates may accelerate reef restoration. Coral transplants with higher growth rates have the potential to reduce time to sexual maturity and promote structural and ecological complexity, ultimately reducing the recovery time for degraded reefs.

Over 1,000 corals that were cultivated in Maldives' first floating rope nurseries have been transplanted back to their native reef. This study aims to examine the survival and growth dynamics of coral transplants using this large-scale restoration technique in the Maldives. The specific objectives of this study are to determine any correlations between (a) growth rate and depth of coral transplants; (b) growth rate and coral colony size; and (c) both depth and size in relation to coral colony survival.

Coral growth was determined by calculating the Ecological Volume Index (EVI) and growth constant (k) of 200 coral transplants at three monitoring intervals: 0 days, 90 days, and 180 days. Depth range was established from 3m-7m with 40 transplanted corals monitored for growth and survival at each metre from 3-7m. Corals were divided into three size classes based on EVI recorded on day 0: 0-1,000cm³, 1,001-2,000cm³, and 2,001-3,000cm³.

The results of this study are ongoing with 180-day monitoring to commence in June 2018. Preliminary results show an overall transplant survival rate of 96.3% with colony mortality only recorded at the shallowest depth (3m). Results for survival rates do not include partial mortality. Average growth rate of transplants in the smallest size class was five times higher than the middle size class with average growth rates of 0.042cm³ month⁻¹ and 0.0084cm³ month⁻¹, respectively. The large size class displayed a negative growth rate (-0.0081cm³ month⁻¹) due to partial mortality of monitored transplants. Results for growth rates in relation to depth are ongoing with preliminary data indicating an increase in average growth rate with increasing depth.

Preliminary results indicate that both size and depth influence growth rates. Coral transplants with an initial volume ≤1,000cm³ grew five times faster on average than those with volumes >1,000cm³. Reasons for this may include rapid extension to prevent predation from other reef organisms or in relation to competition for resources with other nearby transplants. While results for growth rate in comparison to depth are currently limited, we expect to see a correlation with average growth rate increasing as depth increases. Overall, 90-day monitoring showed greater success of transplants at lower depths in relation to both survival and growth. The 180-day monitoring will provide further details, however, initial results indicate that specific parameters may increase the growth rate of coral transplants using this restoration method and thereby increase the rate of reef recovery.

Coral reef monitoring in remote island reefs; Maldives case study

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Abstract

Coral reefs in the Maldives have undergone severe threats over the past years with more recent during the global coral bleaching episode in 2016. The recent bleaching episode swept around 60-70% of live coral cover across the nation. Coral reefs are of epitome importance to a nation such as Maldives where islands are harbored by a natural house reef. The island safeguard, food security and socio economy of Maldives are both directly and indirectly connected with the reefs hence the rationale for securing a safeguard for these fragile coral reefs is of priority.

This paper will outline the existing national monitoring efforts carried out to monitor the coral reefs with recommendation on strategic actions that can be taken at national and local level for long term coral reef monitoring. The aftermath of 1998 bleaching events in the Maldives prompted national marine research institute to allocate certain reefs as monitoring sites which can be said as the initiation of coral reef monitoring in the Maldives by the government. 12 reefs across the nation which represents North, Central and south of the Maldives were considered as “National Coral Reef Monitoring Sites”, where periodic reef monitoring has been carried out. Furthermore to these sites, under the Maldives Environmental Management Project (MEMP) funded by World Bank, another 15 reefs were allocated as regular monitoring sites in 2011. National Marine Research Institute has been carrying out periodic monitoring of these reefs to understand the changes in the coral reef systems.

To standardize the coral reef data system in the Maldives, the Climate Change Adaptation Project (CCAP) funded for web based centralized data base system where coral reef data can be stored. The “coral database” is purposed to serve as a national platform where marine biologists, government agencies and other active stakeholders in the reef monitoring can store the reef monitoring data. To further streamline the data shared in the coral database, protocols have been developed where the data base users are to be trained. This is made to ensure uniformity among the data shared within the database. Coral database is a perfect model, if implemented successfully to follow in remote reef monitoring such as Maldivian reefs. Although there were 15 NCRM sites allocated in 1998, due to budget constraints and human resources, periodic monitoring of these reefs came to a halt. A centralized database system with uniform surveying methodology for all users to follow can be used to address the existing challenges in the coral reef monitoring in the Maldives. The coral database need to be further more outreached to locals, dive centers, live boards and NGO's to ensure people across the nation can contribute to reef monitoring through the database. If the scope of the database is widened across the nation, each year full datasets on reef which represents every atoll of the Maldives can be made available. As the users will be of different levels, with same methodology the scope and magnitude of parameters is recommended to be adjusted as per the preferences of the users. This will ensure that the database includes both rapid/preliminary level and in-depth surveying data.

Session 3

Island and Reef Geomorphology

Use of high-resolution drone images to realize detailed coral reefs habitat maps of Southern Faafu Atoll, Republic of the Maldives

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Abstract

The Republic of the Maldives is a small island state with a unique geographic configuration. The one-meter elevation of most of the islands makes the Maldives one of the countries most vulnerable to the impacts of climate change. Healthy coral reefs are essential for the survival of the Maldivian islands, due to their capacity to keep-up with rising sea-level. Nevertheless, the Maldivian coral reefs are threatened by anthropic and climatic issues and during April and May 2016 they faced a massive coral bleaching followed by extremely high rates of mortality.

In our study, we collected high resolution images using a consumer grade drone, (DJI Phantom 4) along different sectors of coral reefs surrounding inhabited and uninhabited islands of southern Faafu Atoll. The data acquired were processed in order to map the extension and the composition of shallow lagoons habitat, from the beach to the reef crest. Comparing these new results with habitat maps realized using satellite image databases from 2011 to 2016 (RapidEye, Sentinel 2) and field data (snorkelling and diving transects), we were able to produce habitat change maps and correlate these changes to environmental disturbances. In addition, high resolution images (1.5 cm/pixel) were collected in situ, at selected locations, in order to realize a 3D model of shallow reef communities using structure from motion photogrammetry technologies. These 3D optical models will be used as the first step of a 3-year monitoring campaign aiming to observe changes in the 3D structural complexity of the reef after the 2016 bleaching event.

The whole study will focus on the integration of multi-scale maps to investigate, on a multi-temporal scale, ecological and geomorphological shifts in the study area and to determine relationships with human activities (agriculture, land reclamation, new infrastructure) and pressures related to global climate changes.

Coral island sediment volume calculation

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Abstract

Global sea levels are projected to rise ~60cm by 2100. Consequently the United Nations Environmental panel stated under these current rates of change, the Maldives would be uninhabitable by this time. Within 100m proximity of Maldivian shorelines are 99% of resort accommodation and 90% of resort infrastructure. Having experienced record high tourist arrivals in 2017, coastline monitoring, analysis and engineering is now urgently required to safeguard the Maldives, future wellbeing.

Typically, coastal erosion monitoring has been limited to planar analysis of mainland beach profiles, assessing costly 2D high altitude aerial or satellite imagery. Consumer grade Unmanned Aerial Vehicles (UAVs) provide cost effective, ultra-high resolution (<10cm) imagery, capable of generating 3D models through photogrammetry techniques. This allows precise volume calculation of sediments, including coral island volumes.

UAV flights were operated on the resort islands of Vabbinfaru and Ihuru, in North Malé Atoll, using a DJI Phantom 3 Professional UAV. Images were captured at an altitude of 68m, with a frontal/side overlap of 90%/80% resulting in a final resolution of 3.22cm. Keypoints were generated from images, using Pix4D Mapper, followed by processing of the dense point cloud and 3D mesh generation. Final outputs consisted of 2D orthomosaics and 3D topographic models for both islands. The resulting data sets allowed calculation of island sediment volumes as well as the generation of baseline coral island data layers. These initial findings provide a reference dataset for future monitoring from which monsoonal induced sediment shifts can be analysed. This will include the net gain/loss of coral island sediment volumes from post monsoonal surveys. Techniques applied in this study can now also be extended regionally across the Maldives, aiming to map coral island resilience across monsoonal shifts and sea level change. Methods applied in this study not only demonstrate the capacity for sediment monitoring, but also highlight the wider practicality of consumer grade drones and commercial photogrammetry software for use in rapid coastline monitoring and management.

Reef island dynamics and mechanisms of change in Huvadhoo Atoll, Maldives

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Abstract

Planform changes in 184 reef islands in Huvadhoo Atoll, Republic of Maldives were quantified in the context of global environmental change and anthropogenic impacts. Aggregated at the atoll scale, results show that, over the past four decades, total land area increased by 59 ha (2.4%). Land reclamation of 93.8 ha on 12 inhabited islands was the dominant factor in the increase in land area. Excluding reclaimed islands from the dataset reveals net erosion of atoll island area of 28.5 ha (1.5%). Erosion was prevalent on 45% of islands with remaining islands being stable (40%) or increasing in area (15%). A relationship between island size and planform change was identified. Small islands (<10 ha) were dominated by erosional responses whereas larger islands were dominated by accretion.

Results suggest future transformation in atoll land resources to fewer smaller islands but an increase in size of larger islands. Results also indicate that all islands changed, underscoring the dynamic nature of islands on reef surfaces. Ten distinct styles of island adjustment were identified from the dataset. Direct human impact, through reclamation, was found to have a more significant impact on island change in the atoll than other factors such as sea level change and changes in reefal sediment supply. Implications for the Maldives are discussed and indicate that land resources for ongoing habitation will persist across the next century though the location of tourism activities on smaller islands places this valuable economic sector at risk. Analysis of historic island change provides a rich information source to reconsider landuse planning in the context of climate change adaptation.

Session 4

Marine Megafauna

Comparing length measurement methods and estimating growth parameters of free-swimming whale sharks (*Rhincodon typus*) near South Ari Atoll, Maldives

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Abstract

Whale sharks (*Rhincodon typus*) are an endangered species whose growth and reproductive biology are poorly understood. Given their conservation concern, estimating growth parameters, as traditionally derived from vertebral samples of dead animals, is challenging. Estimating growth parameters from live, free-swimming whale sharks would eliminate these concerns and allow for larger sample sizes and therefore, more robust estimates of life history parameters. This approach may be feasible for whale sharks because individuals can be identified by their unique natural markings and are known to form seasonal and year-round aggregations. As a result, individuals can be measured over time allowing for estimates of growth parameters.

The objectives of this study were: (1) to assess relative accuracy and precision of the three different methods of length measurement; (2) to determine size differences between new, transient and returning sharks at South Ari Atoll, Maldives; and (3) to determine growth parameters for whale sharks that aggregate at South Ari Atoll using data from free-swimming sharks and compare these parameters to published growth parameters.

We used a non-invasive approach to investigate growth parameters of whale sharks frequenting South Ari Atoll, by analyzing repeat measurements of free-swimming sharks over a 10-year period. Total lengths of the sharks were estimated by three measurement methods.

Visual estimates underestimated the sizes of large sharks, while laser and tape measurements yielded similar results to one another. The Maldives aggregation consisted primarily of male (91%) juvenile (total length = 3.16 – 8.00 m) sharks. Sharks new to the area were significantly smaller than returning sharks, which suggests that this site may constitute a secondary nursery ground. Estimates of von Bertalanffy (VBG) growth parameters for combined sexes ($L_{\infty} = 19.6$ m, $k = 0.021$ yr⁻¹) were calculated from 186 encounters with 44 sharks. For males, VBG parameters ($L_{\infty} = 18.1$ m, $k = 0.023$ yr⁻¹) were calculated from 177 encounters with 40 sharks and correspond to a male age at maturity of ~25 years and longevity of ~130 years.

The possibility that South Ari Atoll may serve as a secondary nursery has important management implications. Juveniles nearing maturity are an important age class with regard to population stability and recovery at the regional and possibly global scale.

The close agreement of our non-invasive methods with traditional age and growth method using vertebral band analysis, suggests our methods are valid for estimating growth parameters, although they may not be suitable for measuring growth rates over short periods of time. These non-invasive methods can be applied to other aggregation sites where individuals can be reliably distinguished and re-identified over time. Differences between our estimates and those from other studies underscore the need for regional studies.

Social and ecological assessment of the efficacy of a shark ban in the Maldives

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Abstract

Widespread exploitation of sharks has resulted in substantial declines in shark populations, with 30% of shark species globally at risk of extinction. Almost half of shark species are data deficient and subsequently the precautionary approach has resulted in shark fishing bans instigated over vast areas in 13 countries. Assessing the impact and efficacy of shark sanctuaries is challenging and evidence-based conservation urgently requires long-term data sets against which social and ecological change can be measured. Greater understanding of the links between local perceptions and support for fisheries closures is also needed for successful fisheries management. This interdisciplinary project utilized low cost techniques to quantify temporal and spatial change in shark distributions and abundance. Building on preliminary work historical data was ascertained using Local Ecological Knowledge of former shark fishers (n=51) while contemporary shark distributions and abundance were assessed using Baited remote underwater video (n=300). Local perceptions and depredation issues concerning fishers were investigated through remote (n=70) and in-person interviews.

Initial analyses of BRUV footage detected 188 sharks on 40% of deployed BRUVs with a maximum of four sharks on a single BRUV. Sharks were ubiquitous across the sites surveyed in North Malé Atoll, however, hotspots were evident from kernel density mapping. Mapping of LEK data identified historical trends in shark species distribution, abundance and size. Fishers perceive a significant increase in shark encounters post-2010 for grey reef and whale sharks, while encounters with scalloped hammerheads, tiger sharks and silky sharks greatly declined. Shark depredation (damage to gear and loss of bait or hooked fish) was consistently highlighted throughout interviews. Grey reef sharks were considered as the greatest disturbance by 61% of fishers with a general consensus that shark disturbance is highest within the atoll. This research provides valuable information on the status of Maldivian shark populations allowing accurate assessment of the efficacy of the shark ban. Consideration of local perceptions towards sharks will ensure management is reflective of local priorities and concerns resulting in increased support for current and future management of shark populations.

Seasonal occurrences of reef nanta ray at Rasfari north reef (North Malé Atoll)

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Abstract

The Maldives is home to the largest known population of reef manta rays (*Mobula alfredi*) in the world. They show seasonal migrations within the country, strongly influenced by the availability and productivity of their main food, the zooplankton, which, in turn, is linked to the monsoon current circulation patterns. There are two monsoons in the country: the North East monsoon (December to April) with currents mainly westward and blooms of zooplankton on the west side of the atolls, and the South West monsoon (May to November) with currents mainly eastward and blooms of zooplankton on the east side of the atolls.

In North Malé Atoll, manta rays aggregate at Rasfari North reef (4°26'28"N 73°21'45"E) during the North East monsoon. The site is a cleaning station for the mantas and close to feeding sites. We studied the seasonal occurrences of reef manta rays at that using photo-identification. Data were collected from 2004 to 2018, and combined sightings from the Manta Ecology Project, Manta Matcher (an international manta encounter database) and the marine biologists from Coco Bodu Hithi resort during guided snorkelling or scuba diving trips. In total, 428 individuals were identified by photo-identification. The majority of the individuals (48.8%) were seen only once, 43.5% of individuals were seen between 2 and 10 times, and 7.7% of individuals were seen more than 10 times, up to a maximum of 25 times. Among the 428 individuals identified, 51.4% were females and 45.6% males, with only 3.0% of the individuals being classified as unknown sex due to the lack of pelvic area picture. Within-year the highest rate of mantas re-sighted more than once represented 64.6% to 65.0% for 2015-2016 and 2017-2018 seasons, respectively, suggesting a degree of site fidelity. These data provide an insight into local manta ray abundance. However, long-term data collection and increased survey effort are required to provide further insight on individual site fidelity.

This study is an example of valuable data being provided from Citizen Science projects. Divers and snorkelers trained in manta photo-identification have contributed useful data which can be analysed by local marine scientists in order to improve the knowledge of reef manta ray abundance and population dynamics.

Does tourist behavior affect reef manta ray feeding behavior? An analysis of human and *Mobula alfredi* interactions in Baa Atoll, Maldives

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Abstract

The number of tourists travelling to the Maldives specifically to swim with charismatic marine megafauna has increased over recent years. Manta ray tourism in the Maldives is estimated to be worth US\$ 8.1 million annually in direct revenue alone. This type of tourism clearly has significant benefits to the Maldivian economy but there is anecdotal evidence that large numbers of tourists at popular dive and snorkel sites are having a negative impact on reef manta rays' (*Mobula alfredi*) natural behaviour.

This study investigated human and manta ray tourism interactions by collecting video footage (n = 431) over a two-month period in Baa Atoll, Maldives at five feeding aggregation sites. The aim was to identify and quantify whether human in-water snorkelling conduct negatively affects reef manta rays' feeding behaviour.

Each interaction was video-recorded and analysed, and individual manta rays were identified using the Maldivian Manta Ray Project Identification Database. Human behaviour was separated into 4 categories, increasing in severity, from passively observing the manta to chasing. The manta rays' response was also separated into 4 categories, the least severe of which was the manta ray showing no visible response to the human presence. The most severe response was recorded as a 'flight' reaction – when the manta ray fled the interaction with the tourist using a sudden burst of speed. Direction of approach and distance between human and manta were also recorded for each interaction.

Tourists obstructing the path of the manta significantly increased the likelihood of the manta displaying avoidance behaviour, as did approaching the manta ray from the front. Tourists positioned between 0 and 3 m of the manta significantly increased the probability of avoidance behaviour from the manta. Diving under/near mantas from the front also strongly increased the probability of avoidance behaviour. However, passively observing the manta, characterised as the tourist floating horizontally in the water with their arms close to their body and not kicking, was found to significantly decrease the likelihood of causing a strong reaction from the manta. Mantas recorded at sites where juveniles are regularly observed also reacted more strongly to human behaviour.

These findings reveal key recommendations: (1) tourists should observe mantas passively, (2) a minimum of 3 m distance should be maintained between human and manta, (3) approach from the side of the focal manta ray, (4) inexperienced snorkelers should not dive underneath or near manta rays, (5) tourists should not dive in front of mantas, (6) at sites where juveniles are regularly sighted, be more cautious when approaching manta rays. All results and recommendations support the Manta Trust Code of Conduct for Tourism Interactions and can be applied to swim-with-manta-ray experiences worldwide.

Rediscovery of Deraniyagala's Beaked Whale (*Mesoplodon hotaula*)

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Abstract

The complete skeleton, including tusks, of a mature male beaked whale was found in a shop Malé. It was initially identified as a specimen of Ginkgo-toothed Beaked Whale (*Mesoplodon ginkgodens*). But genetic and morphological analysis showed it to be a distinct species. Further specimens discovered in Seychelles and the Pacific confirmed the distinctiveness of this taxon. A female beaked whale, stranded in Sri Lanka in 1963, was described as a new species, *Mesoplodon hotaula*, but immediately synonymized with *M. ginkgodens*. Analysis of the holotype, held in the National Museum in Colombo, confirmed that *M. hotaula* is indeed a valid species, close to but distinct from *M. ginkgodens*. The new specimens from Maldives and elsewhere are conspecific with the *M. hotaula* holotype. This species name has now been resurrected, based entirely on strandings data. Sightings at sea in the Maldives in 2017 have revealed the live appearance of *M. hotaula* for the first time.

Turtle populations, habitat use and nesting in Laamu Atoll

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Abstract

In the Maldives, green turtles (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*) occur in globally-significant numbers. Both species are listed on the IUCN's Red List of Threatened Species: *C. mydas* as Endangered and *E. imbricata* as Critically Endangered. Historically, adults of *C. mydas* have been hunted for meat and *E. imbricata* for tortoiseshell. These activities were prohibited by the Maldivian government in 1995 and the collecting of eggs was banned in 2005. Despite this, illegal poaching still occurs and there has been little systematic data collected on populations of sea turtles in the Maldives.

Laamu Atoll is important for both *C. mydas* and *E. imbricata*. In particular, *C. mydas* nest on beaches in the atoll and L. Gaadhoo was identified in a 2015 study as the most significant nesting site in the country. The current study aims to understand the population sizes and habitat use of *C. mydas* and *E. imbricata*, and to identify nesting patterns of *C. mydas*. Data were collected opportunistically between 2013 and 2016, and systematically from July 2016–December 2017. Individual turtles were identified using photo-ID of each turtle's unique facial scute patterns. Data were collected from 22 sites within Laamu Atoll by SCUBA diving and snorkeling. Over the 2013–2017 period, 323 turtles were identified: 150 *C. mydas* and 173 *E. imbricata*. Most green turtles (55%) were adult females and most hawksbill turtles were juveniles (49%). In 2017, 1,737 hours of survey effort resulted in 3,698 turtle sightings. However, only 22% of sightings resulted in successful IDs. In 2017, sightings of individual turtles ranged from 1–63, with a mode of 1. Only four *C. mydas* and seven *E. imbricata* individuals were recorded at multiple sites and, of these, only three hawksbill turtles were sighted on disconnected reefs. These findings indicate some level of site fidelity for Laamu turtles.

Chelonia mydas nesting and hatching data for Olhuveli island (on which Six Senses Laamu is located) have been collected since the resort's opening in 2011. The number of true nests identified each year ranged from 3–15, with a total of 54 nests identified over the 7-year period. Nests were dug one week after hatchling emergence to count the eggs and determine nesting success. In 2017, eight true nests were identified and of the 782 eggs laid, 65% emerged as live hatchlings and 33% remained as undeveloped eggs. Across all 7 years, the development days ranged from 49–68, with a mean of 55 days. Nesting occurred throughout the year, with the exception of January, and peaked between May and July. Hatching occurred from January to October and peaked between July and August.

A longer dataset of turtle IDs in Laamu Atoll will offer further insights into local populations, movements and habitat use. Further investigations into turtle sizes, behaviour and movement patterns would also enhance our understanding of Laamu Atoll turtle populations.

Session 5

Reef Ecology

Prevalence, host range and distribution of coral diseases in the central Republic of Maldives

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Abstract

Coral diseases are one of the most important causes of coral reef decline worldwide. Coral diseases in the Indo-Pacific are currently considered one of the 15 globally important threats requiring conservation attention. Although they are well investigated in some areas of the Caribbean and the Great Barrier Reef, they have been poorly studied in the Indian Ocean, and particularly in the Maldives, where the presence of coral pathologies has been reported only recently. In order to fill this gap, we investigated the temporal and spatial variability in prevalence, local host range and distribution of five coral diseases, namely brown band disease (BrB), skeleton eroding band (SEB), black band disease (BBD), ulcerative white spot (UWS) and white syndrome (WS). In the central part of the Maldivian Archipelago we estimated an overall disease prevalence of approximately 1.51%. North Malé Atoll was the most affected area; however, coral diseases were present at all study sites. WS was the most widespread disease, whereas BBD affected the highest number of scleractinian genera. We found symptoms of disease on 18 genera belonging to eight families. *Acropora* was the most affected genus in terms of pathogen diversity. Moreover, our preliminary temporal investigations revealed an increase of both coral diseases during the last 4 years. These results provide baseline disease levels for the Maldives and can therefore serve to monitoring future change.

The ecology of planktivores on a tropical coral reef

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Abstract

The health of tropical coral reefs around the world continues to decline. Understanding some of the intricate dynamics that occur in these environments can help us to predict their responses to changing climates. Planktivores are secondary consumers and thus represent an important trophic level in reef ecosystems and demonstrate the significance of planktonic nutrients to that ecosystem. Often described as a 'wall of mouths' that aggregate on the edges of coral reefs, planktivores strip plankton from ocean currents and redistribute their energy within the reef ecosystem. More recent studies found plankton to support the majority of biomass on temperate reefs, yet planktivore populations remain poorly quantified in tropical coral reef settings, and the importance of this source of nutrition to coral reef communities remains largely unknown.

This study aimed to quantify populations of planktivorous fish on a coral reef in tropical Maldives. It aimed to analyse temporal variability, both within and between days, and any spatial patterns of planktivorous fish behaviour observed around Vabbinfaru Island. The study was conducted using two modified underwater visual census methods: belt transect surveys (SCUBA) for detailed temporal assessment; and stationary point counts (snorkeling) for rapid spatial assessments.

This study found planktivores to dominate much of the fish community biomass (~68% at one site) on shallow platforms around the island. Obligate and facultative planktivores had different relationships with variables such as tide, diel cycle and benthic composition. These relationships supported the general concept that oceanic currents (and their associated plankton) form an important source of energy for reef systems. No significant relationship was found between planktivores and time, which supports the notion that inherent variability among reef communities is driven by other ecological processes.

Planktivore feeding behavior was largely exhibited west of the island, where ocean currents are strongest during the South West Monsoon, when the study was conducted. Large planktivore biomass was also observed sheltering, east of the island. This contrast illustrates the notion of feeding versus shelter, in context of how fish species use different areas of the reef for certain purposes; but also supports the idea that oceanic plankton forms an important source of nutrition for the reef community and influences their behavior. A novel aspect of this ecological study is detailed consideration of both temporal and spatial variability, at relatively small scales, providing a holistic assessment of an important trophic level in the marine food-web. Furthermore, this study is unique in its quantification of planktivore biomass in a tropical coral reef setting; supporting similar research findings from temperate rocky reefs.

Abstracts of Poster Presentations

The effectiveness of a marine environmental education program in the Maldives

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Abstract

During 2017 the Maldivian Manta Ray Project implemented a five-month marine environmental education program in Baa Atoll. Incorporating environmental education at school can develop environmentally-aware individuals who may mitigate environmental issues and assist sustainable development. The Baa Atoll Marine Education Program was a 50-hour course designed to teach secondary school students about the marine environment, threats to the marine environment and conservation efforts, and focused on providing field experience to deepen theory learning. Six core modules were conducted for 26 participating 13-16 year old students from Baa Kendhoo School. These comprised: Tropical Marine Ecosystems, Coral Reef Ecosystems, Turtles and Reef Fish, Marine Protected Areas, Waste, and Climate Change.

The Maldives relies heavily on healthy marine biodiversity, which is poorly protected and increasingly vulnerable to anthropogenic threats. Tourism has become an important economical feature to Baa Atoll. Anthropogenic hazards and lack of marine education among local communities have impacted sustainable tourism developments in the atoll. The course aimed to improve students' marine environmental knowledge, awareness and engagement.

Pre-program and post-program surveys were undertaken to assess the effectiveness of marine education for improving these attributes. Survey responses were coded using a Likert-like scale. Qualitative and quantitative analyses were performed to identify categorical relationships, assess differences in pre- and post-program survey results and examine the influence of gender or school grade.

Students' marine environmental engagement, awareness and knowledge increased after the program. Tests revealed mean participant knowledge increased for 83% of environmental topics pre to post-program. The program was highly effective, achieving a mean effectiveness score of 21 out of 25, and increased 90% of participants' in-water confidence, as well as pro-environmental behaviour and recreational and academic interest in the sea. Considerable gender disparity was identified, with females scoring lower than males in all categories. Females were 27% less likely than males to go swimming or want to go swimming in the sea. Religious principles or cultural norms could have impacted females' lower marine engagement scores.

The study shows environmental education could increase the number of young Maldivians in marine conservation occupations and mitigate a prevalent environmental education deficiency in the Maldives. Increased marine environmental education incorporating in-water fieldtrips could increase marine participation and awareness, and improve environmental management in the Maldives. Due to strong gender disparity such programmes should be expanded in the future to bring female participants into the marine environment. Overall it can be concluded that this programme would be an effective tool to conduct in more schools.

Assessing potential use of Moderate Resolution Imaging Spectroradiometer (MODIS) SST data for thermal front mapping around Maldives

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Abstract

Oceanic thermal fronts are boundary lines separating two water masses with distinct temperature profiles. Areas around thermal fronts have been demonstrated as regions of high fishery productivity and to be associated with migratory routes of some species.

In order to assess the prospect of using front maps to identify potential areas of high fishery productivity and their potential use in migratory species research, an exploratory thermal front mapping exercise was carried out for 2016 using publicly accessible 8-Day Level 3 Sea Surface Temperature (SST) Standard Mapped Image products of MODIS Aqua satellite, with a spatial resolution of 4.63km. The Area of Interest (AoI) for this study is bounded by 69.06 E - 77.75 E and 3.53 S - 8.14 N, for which only SST pixel values having a quality flag of 1 from SST product were selected for front detection. The process was carried out using a suite of software packages; ArcMap (with Marine Geo-spatial Ecology Toolbox – MGET), QGIS and SeaDAS. The front detection was implemented using the Cayula-Cornillion Single Image Edge Detection Algorithm of MGET, with thermal fronts considered to be the boundary of SST separated by 0.45 degree Celsius.

It was observed that 15 ± 11 % and 48 ± 26 % of pixels within the AoI were not available for front detection during northeast monsoon and southwest monsoon respectively. Unavailability of SST data, both due to pixels with unacceptable level of quality and no data pixels in original dataset was a major shortcoming for mapping thermal fronts during southwest monsoon period. Hence this indicates that, even with the inherent limitations of the chosen dataset, front mapping from remotely sensed SST products of MODIS would largely be restricted to northeast monsoon period as this is the period when the sky is most clear.

The result of this study indicates that while thermal front mapping with spatially coarse resolution SST datasets may provide some valuable information within a restricted time period for Maldives, the actual benefits may not be realized without spatially and temporally high resolution remotely sensed SST products whose coverage and quality is not immensely hindered by cloud cover. Furthermore, use of other supplementary data, such as remotely sensed chlorophyll data and fishery data could be necessary to strengthen and aid inferences with regard to identifying areas of high fishery productivity and possibly migratory routes of species.

Diel modulation of the Hsp70 and Hsp60 in three scleractinian coral species living in a Maldivian shallow reef

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Abstract

In scleractinian corals different processes, behaviours and physiological regulations are associated with the daily variation of temperature and light. On shallow reefs these can vary widely and regularly reach extreme levels. However, the modulation of cellular defence mechanisms in response to natural environmental fluctuations remains still little known. In this study, the expression of cellular stress mechanisms such as the Heat shock proteins Hsp70 and Hsp60 was analyzed in coral colonies adapted to live in a shallow lagoon, during three consecutive days characterized by the same temperature/light trend. In particular, three different coral species with a different susceptibility to stresses have been compared. Each species showed a significant diel modulation of both Hsps, which also displayed a coordinated expression. However, the diel modulations of both Hsps were species-specific and only that of the branching *Acropora tenuis* appeared correlated with the temperature. All the species displayed high Hsp levels at 13.00 and 16.00, probably as protection from heat shocks and oxidative damages produced by the elevated values of temperature and luminance. Taken together, the results may provide useful information about the cellular mechanisms involved in the corals' adaptation to extreme conditions.

Coral restoration in the Maldives: an evaluation of the effectiveness of popular restoration methodologies

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Abstract

Maldivian hermatypic coral reefs have been exposed to disturbances for centuries. Historically, corals have been mined for building material. Now reef exploitation has increased with land reclamation, harbour construction and resort island development. The first recorded coral bleaching event in the Maldives in 1998 sparked concern for the future of the reefs. Since then Maldives has been exposed to another major coral bleaching event (2016). As a result, many tourist resorts have responded with efforts to rejuvenate their house reefs. Although there are extensive coral restoration projects in the Maldives, there is limited literature establishing the success of such projects. This presentation is the first to elucidate the success of three methods of coral restoration in the Maldives and provides suggestions for future improvements.

The objective of this project was to evaluate the effectiveness of three commonly used coral restoration techniques as reef management tools in the Maldives: coral transplantation; coral modular frames; and coral gardening. Coral growth was measured using vernier calipers to determine the height and width of both the coral fragments and coral colonies. Coral health was measured by percentage of healthy tissue present and signs of predation or disease were noted. Results of the data are still being extrapolated with respect to pooling across the three methods, however rough estimates thus far of the individual projects success are given below.

Method	Survival rate	% growth	Disease	Predation
Transplantation	~ 10 %	N/A	N/A	Drupella & Coralliophila
Modular frames	~ 68 %	N/A	White syndrome	Drupella & Coralliophila
Coral Gardening	~ 85 %	N/A	White syndrome	Fish

Preliminary data indicate that the three methods each have their strengths and weaknesses. So far the coral gardening technique proves to be the most successful with respect to survival. Due to the relatively long nursery phase no immediate rejuvenation results are initially seen on the reef, extending the amount of time before resort guests experience visual impacts from the project. Nevertheless the nursery phase provides larger and more resilient coral colonies with respect to total size and coral health respectively.

All coral relocation methods give an immediate visual impact to the reef, however, of the three methods tested, coral gardening gave the highest growth and survival rates. Evaluating such popular reef restoration methods is important for both the development of the projects, and also for increased understanding for best practises of these restoration tools for reef managers.

Status and changes in coral communities in five different reefs in the Maldives after the 1998 and 2016 bleaching events

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Abstract

The coral reefs of the world were hit by the largest coral bleaching event in the wake of the 2015 to 2016 El Niño event. The frequency and severity of coral bleaching has intensified over recent decades, and some coral reef scientists predict that many coral reefs will be lost by 2050 and that remaining coral communities will be dominated by massive and encrusting coral species. The coral reefs of the Maldives were severely impacted by the bleaching events which occurred during 1998 and 2016. During both bleaching events, around 80% of the live coral cover was lost from Maldivian reefs.

The objectives of this study were to quantify the impacts caused by the two major coral bleaching events to hit Maldives and to identify the similarities between them. Five different reefs from five different atolls were surveyed for mean live coral cover and coral family composition after the two major bleaching events. Permanent transects were laid and each time the same transect was used to conduct the surveys. The point intercept method and line intercept method were used to estimate live coral cover. The coral families present before and after each bleaching event were identified by using both photo quadrats and in situ data collection.

The study results showed that mean coral cover had decreased in all the five sites after each bleaching episode, and demonstrated that the 1998 bleaching event was more severe than the 2016 bleaching event. The southern site showed more resilience compared to the central and northern sites in 2016 compared to the bleaching in 1998. The coral families recorded under this survey showed similar impacts after these two major bleaching events. However, some of the species which were absent after the 1998 bleaching event were found after the 2016 bleaching event, and after both bleaching events massive and encrusting species of coral had survived.

Muraka Bageecha Thulushdhoo: a pilot project for coral conservation and education

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Abstract

Coral reefs of the Maldives have been severely affected by successive episodes of elevated seawater temperature and island development over recent years. In February 2018, reefs around Thulushdhoo island, North Malé Atoll, exhibited live coral cover as low as 10% average.

MURAKA BAGEECHA means Coral Garden in Maldivian language (Dhivehi). This coral conservation project started on the local island of Thulushdhoo in February 2018 with the cooperation of local community members such as dive centers, guest houses and schools. All joined their efforts to relocate nearby threatened corals to their house reef, to create an area where corals can continue to flourish. Objectives of the project are twofold: coral conservation by creating a high diversity and live coral cover area, and education by presenting our project to schools and taking children and their parents snorkeling to the coral garden.

The project can be divided in 4 main steps: 1) transplantation of live coral colonies in a preselected area; 2) tagging of the relocated corals and physical delineation of the coral garden (safe swimming and snorkeling area); 3) public awareness and education with presentations, social media coverage and snorkeling trips; and 4) long-term monitoring of the coral reef health.

In order to transplant corals, live coral heads are detached from their substrate and place into plastic cradles for transportation. Once arrived at the coral garden area they are reattached to the rocks using cement. Tags with numbers are placed next to each new coral to be able to monitor their survival and growth. A few days after cementing, algae and other fouling organisms start growing on the cement and relocated corals can hardly be differentiated from natural ones.

Long term success of the project will be covered with a combination of academic science, social media and citizen science: #murakabageechathulusdhoo Facebook page is exposing all the actions undertaken for the project with videos, photo albums, and explanations and is followed by a rapidly growing local community. Long term monitoring of the coral garden will be partially performed by the followers taking pictures of the tagged corals following our guidelines.

In May 2018, more than 100 corals of 10 different species had been successfully relocated and tagged in the muraka bageecha area. Baseline monitoring using scale pictures and coral health visual assessment is performed as the project is progressing. Muraka Bageecha project is followed by more than 150 members in less than 2 months. First presentations and snorkeling trips with local children and their parents as well as meetings with school representative have also started.

Lessons learnt from installing a mid-water rope coral nursery

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Abstract

In the Maldives, coral bleaching events have impacted upon local reefs. These events reinforce the need for active reef restoration activities, such as coral gardening. This is a two-step process where coral fragments are grown out in favorable nursery conditions and transplanted onto degraded sites. In the Maldives, resorts are at a unique advantage with the resources to undertake such restoration projects.

Mid-water nurseries are one option for coral gardening, with several advantages over other methods: situated away from reefs and above the substrate they reduce predation rates; in areas of high water flow they provide food for corals; and the nursery structure itself can be moved deeper in the water column, if there is a risk of bleaching in the local area. This poster details the practical aspects of deploying and monitoring what we believe to be the second mid-water rope nursery in the Maldives. The aim of Six Senses Laamu's restoration project is to increase coral cover and diversity on the resort's house reef.

The nursery structure is anchored in 28 m of water, with the nursery itself sitting at 8 m. The bathymetry of the island necessitated such a deep anchoring point and this posed several logistical challenges. Deployment required 13 work hours. The nursery contains 742 coral fragments of 10 species of *Acropora* and *Pocillopora*. Seventy-one per cent of fragments were collected systematically from donor colonies (< 10% volume fragmented) based on target species and the remainder were opportunistically collected from broken fragments. Collection took 47 work hours and planting took an additional 42 hours.

Four months of monitoring indicates that donor colonies have not suffered adverse effects due to fragmenting, with a mean health index of 1.45 (1 being least tissue death, 6 being the most) across all species. Fragment survival remains high, at 95%. Fifty-seven per cent of fragments that have died belong to one species (*Acropora aculeus*), which we would discourage future projects from using. Tissue death has been greatest in fragments collected opportunistically (health index 2.4, compared to 1.7 for systematically-collected fragments), which brought algae into the nursery with them. Fragment loss due to detachment and death due to disease, predation and sponge growth remain below 1% collectively. Following planting, all *Acropora* species attached to the rope within 1 month while *Pocillopora* species took 2 months to attach. Following attachment, we have observed small increases in Ecological Volumes (which approximate a cylinder), with a mean of +32% across all species. Species displaying the greatest mean increases in volume are *Pocillopora verrucosa* (mean of +159%) and *Acropora divaricata* (+69%).

The next phase will be to identify and characterize transplant sites in anticipation of transplant trials beginning in December 2018 and full-scale out-planting in 2019. The lessons learnt from Six Senses Laamu's mid-water rope nursery should be broadly applicable across the Maldives and may serve as a guide to others wishing to implement this model.

The use of photo identification for sea turtle population analysis in Lhaviyani Atoll, a Maldivian green turtle hotspot

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Abstract

Photo identification of individuals provides an effective and non-invasive tool to study populations of marine megafauna. It requires little training to take photos suitable for identification and thus allows for the incorporation of opportunistic data produced by recreational divers and snorkelers and professional trained scientists alike. Such a database provides the basis for a detailed and regular “capture-mark-recapture” monitoring program, which can be utilized to estimate population sizes and structures, and to monitor movements between different habitats.

Sightings of green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and olive ridley turtles (*Lepidochelys olivacea*) were recorded in Lhaviyani Atoll, starting in 2010. The first two species are resident to the Maldives with documented nesting populations, whereas olive ridley turtles are most often encountered entangled in ghost nets drifting through the archipelago; they are not known to nest in the country. For population analyses, only the resident green and hawksbill turtles were taken into account.

Regular photo ID data were collected in Lhaviyani Atoll for 18 months up until April 2018, with sporadic data ranging back to 2010. For testing with various capture-recapture models, only the regular sampling interval of 18 month was used.

Here we present results on turtle abundance, population structure, population trends, apparent survival and temporary emigration rates for selected locations in Lhaviyani Atoll. The results from our monitoring efforts help us to understand how single sea turtle habitats are connected and thus provide the foundation for evidence-based decisions on the establishment and effectiveness of designated protected areas.

A summary of current knowledge on oceanic manta ray (*Mobula birostris*) demographics in the Maldives

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Abstract

The Maldives is widely regarded as one of the best places in the world to swim with manta rays. The tourism industry from manta related activities is thought to generate in the region of USD 8.1 million in revenue per year for the Maldivian economy.

The Maldivian Manta Ray Project, the founding project of UK and US registered charity Manta Trust, has been studying manta rays in the Maldives since 2005. With over 55,000 sightings of around 4,500 known individuals (and a total estimated population between 6-7,000 individuals), the Maldives is home to potentially the largest population of reef manta rays (*Mobula alfredi*) in the world. Despite extensive and ever growing knowledge of *M. alfredi* movements and migrations, knowledge on oceanic manta rays (*Mobula birostris*) in Maldivian waters is far more limited.

As of April 2018, 367 sightings of 358 individual *Mobula birostris* have been recorded through our own research and contributions from citizen science using photo identification. The majority of sightings are from the southern atolls, particularly Fuvahmulah (79%). Only 9 re-sightings have been recorded, indicating a significantly larger population, possibly in the region of tens of thousands. In three separate years, we have observed mass aggregations of oceanic manta rays around Fuvahmulah Island during the same period. The most commonly displayed behaviour during these encounters is cruising, however, anecdotal evidence suggests the possibility of this site being used as a mating site. For a solitary species which spends much of its life in the open ocean, timed aggregations would be invaluable for reproductive purposes.

In 2011, surveys of Negombo and Mirissa fish markets in Sri Lanka to evaluate the extent of the manta fishery in Sri Lanka estimated that 1,055 *M. birostris* are landed every year. Worryingly, 87% of these were juvenile and sub-adults indicating a potential 'nursery' ground close to Sri Lankan shores. Close proximity of the intense manta fishery in Sri Lanka to the Maldives provides ample reason to study *M. birostris* movements more closely.

The extent of connectivity and gene flow between regions has significant implications for the susceptibility of the species to fisheries. Determining the movements and extent of possible genetic flow between *M. birostris* seen in the Maldives and those seen elsewhere in the Indian Ocean is vital to make informed protective measures. A variety of research techniques are available to measure connectivity over varying spatial and temporal scales, with satellite telemetry providing a powerful tool for tracking mid-range temporal and spatial movements. It is hoped that using some of these methods in the future to study manta movements will help to protect and conserve oceanic mantas in Maldivian waters.

Variability in tropical reef fish communities estimated by underwater visual census in the Maldives

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Abstract

Many reef community studies do not include variability of fish assemblages over short time scales such as days and hours. This study aimed to develop an understanding of the inherent variability associated with the Underwater Visual Census (UVC) methodology, by studying tropical reef fish assemblages over short temporal scales of days and hours. One site, on the south side of Vabbinfaru reef platform, was sampled by UVC, using four replicate transects over days and hours (within one day). A total of 210 species, 35 families and five functional groups were identified.

While the whole community biomass and abundance did not vary significantly over time, contributing families and functional groups demonstrated significant variability. Planktivores consistently contributed the most to mean biomass, abundance and variability, followed by piscivores. Fusiliers were the main contributor to the variability of abundance and biomass at all of the time intervals, showing the least significant relationship with time (hours and days). Site attached families (Gobies, Blennies and Parrotfish) showed the least variability. Although herbivores showed significant differences between and among day intervals, they consistently displayed the lowest variability. There was no 'real' relationship with time for any of the families or functional groups, suggesting variability associated with coral reef fish is random, or due to other factors that were not studied, for example the tides and lunar cycle.

Due to the restrictions of diving, we did not sample early in the morning or at dusk, therefore more studies focusing on this variability and the movement of species associated with light are necessary. This study confirms that the continual monitoring of tropical coral reefs using UVC should allow for inherent variability within fish communities related to the characteristics of functional groups and families, when designing methodologies for management plans, the detectability and precision of these groups should be taken into account.

Status of Baa Atoll sea anemones and their clownfish populations

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Abstract

The 2016 El Niño event caused sea surface temperature anomalies, with 32°C heating peaks from April to mid-May 2016, precipitating one of the strongest coral bleaching and mortality events recorded. More generally, rising sea temperatures are also causing coral mortality. Although hard coral bleaching has been well documented in the Maldives, little is known about the consequences of bleaching for other symbiotic organisms like the giant anemones, and consequently for their associated clownfishes. Like reef corals, giant sea anemones have a symbiotic relationship with zooxanthellae that live in their tissues. During periods of environmental stress, such as increased water temperature or low salinity, anemones expel their zooxanthellae, inducing a whitening phase. This condition is not necessarily fatal but does increase the risk of mortality for the anemone.

The objective of this research was to assess the species richness, abundance and health status of anemones and anemonefish on Baa Atoll reefs two years after the 2016 bleaching event. This survey provides baseline data to monitor the effect of high temperatures on the coral reef ecosystems and contributes data on reef anemones and anemonefishes of the Maldives.

From November 2017 to April 2018, underwater visual surveys (timed-swims) were conducted at 16 sites across Baa Atoll, resulting in searches of 21 % of the Baa Atoll islands. Five species of host anemones were recorded: *Heteractis magnifica* (73%), *Heteractis aurora* (0.9%), *Stichodactyla mertensii* (18.7%), *Entacmaea quadricolor* (6.2%) and *Cryptodendrum adhaesivum* (1.3%). Two species of anemonefish were hosted in these anemones: *Amphiprion nigripes* (76%), *Amphiprion clarkii* (24%) as well as three species of nonexclusive fish residents (*Dascyllus trimaculatus*, juvenile *Thalassoma lunares* and juvenile *Thalassoma amblycephalum*). Total counts of anemones and anemonefish (all species combined) were 225 and 938, respectively. Results showed 85.8% of the anemones recorded were healthy, 14% were nearly bleached and 0.4% were bleached.

Only one anemone was found totally bleached in this survey, and the majority were in good condition. However, there is a lack of previous data to compare the current status of the Baa Atoll reef anemones with that before 2016. Anemones are long-lived animals with low natural mortality; the future of these symbiotic organisms will be mainly dependent of their ability to cope with global warming (and also with aquarium collection).

Assessing feeding preferences of the corallivorous seastar *Acanthaster planci* during an outbreak in Ari Atoll, Republic of Maldives

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Abstract

The corallivorous Crown-of-Thorns Seastars (CoTS), *Acanthaster* spp. (excluding *A. brevispinus*), have received increasing attention due to their negative impacts on coral reefs in the Indo-Pacific. Outbreaks of CoTS may lead to high mortality of coral communities, causing ecological shift to an algal-dominant community. A key aspect driving the effects of CoTS outbreaks on coral reefs is related to their preferred diet. In particular, studies on various species of CoTS showed a strong preference for corals of the family Acroporidae, such as the genera *Acropora* and *Montipora*, as well as corals of the family Pocilloporidae, such as the genera *Pocillopora* and *Stylophora*; in contrast, CoTS tend to avoid corals of the family Poritidae.

In this study, we highlighted the feeding preferences of *Acanthaster planci* during an outbreak in central Ari Atoll, Republic of Maldives. The feeding preferences were evaluated considering the scleractinian coral eaten or recently eaten by 775 seastars. The data were collected using a specific protocol for each individual encountered during the snorkelling or diving survey. In addition, data were collected on the coral cover in order to build a 'frame of reference' that could be used in comparison with the diet of *A. planci*. Photoquadrats were used to determine the composition and structure of the benthic community. Finally, to explore the food preference of *A. planci*, the Ivlev's electivity index (1961) (E) were used. A positive E value for the genera *Dipsastraea* and *Favites* were found while the results were negative for the remaining genera and families, with the exception of *Psammocora*, which had a value of 0, indicating random feeding. However, *A. planci* mostly consumed corals of the genus *Porites*, which was the less palatable but the most abundant genus in the study area.

These results refer to a specific situation in which the 2016 coral bleaching increased coral mortality. In fact, the coral bleaching event in 2016 may have restricted the diet of *A. planci*, posing strong constraints on the food preferences. Nevertheless, CoTS have been reported to switch their diet in the absence of their favourite prey. Yet, the dynamics of CoTS outbreaks remain unclear, despite being one of the most significant disturbances on coral reefs in the Indian Ocean. For this reason, further studies on outbreaks of different species of CoTS in different areas are fundamentally necessary. Finally, our results provide useful insights regarding outbreaks of *A. planci* in the Republic of Maldives.

Fish herbivory and nutrient loads as drivers of *Turbinaria ornata*

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Abstract

Coral reefs worldwide are in regression and several reef systems are experiencing a shift from coral dominance to algal dominance. There are several biotic and abiotic factors that control the spread of macro algae on a coral reef. A significant presence of macro algae *Turbinaria ornata* has been observed in the reef system of Villingili. It is hypothesized that there are links between the herbivore fish community of the reef and the present nutrient load of the water column as driving factors in a dominance of macro algal cover. Additionally, relationships between live coral cover and *Turbinaria ornata* presence were investigated.

