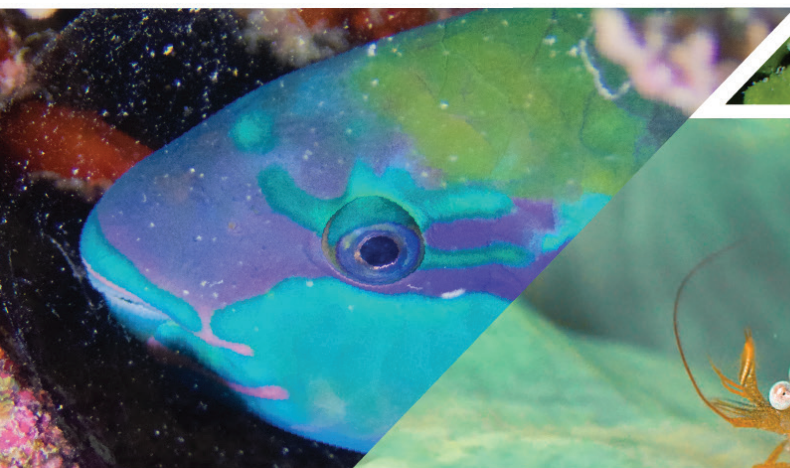


12th-13th
December 2020



Third **Maldives Marine Science Symposium**

Abstract booklet



Reef Monitoring and Coral Regeneration
Reef Biodiversity
Mangroves and Seagrasses
Mega-fauna
Fisheries and Management



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Abstract Booklet



Maldives Marine Research Institute
Ministry of Fisheries, Marine Resources and Agriculture
H. White Waves, Moonlight Hingun
Malé - 20025, Republic of Maldives

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Third Maldives Marine Science Symposium 2020,
held on 12th & 13th December 2020, via Zoom online video conferencing platform

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Note

1. The abstracts in this booklet may be of preliminary findings, and may be subject to change. None should be cited without prior written permission from the author(s).

2. Abstracts were prepared by the authors and subject to review by the Scientific Committee as well as minor editing for English and length. Abstracts were submitted well in advance of the symposium to meet editorial and distribution 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.

Conveners' Remarks

The Maldives Marine Research Institute is delighted to continue the biennial Maldives Marine Science Symposia (MMSS) series, hosting its third event in 2020. The amount and diversity of abstracts received for the past two symposia and current symposium indicate wider acceptance of the event by researchers, as a key platform to share knowledge and bring together the recent developments in marine research in the Maldives. We hope that exchange of information and ideas continue through the MMSS series to advance marine research in the Maldives.

The third MMSS features research from broad themes covering research on reef monitoring and coral regeneration, reef biodiversity, mangroves and seagrasses, mega-fauna and, fisheries and management. The wide-ranging topics covered under these themes enhance our understanding of the atoll ecosystems in the Maldives, providing a key foundation to build on and expand research under each theme.

The Symposium organizers wish to thank the Scientific Committee, particularly Dr. Charles Anderson for his editorial work on the abstracts presented in this publication. We thank all the researchers and their respective organizations for their contribution. In addition, we particularly like to note the interest and participation by researchers in the event, despite having to present the work through a virtual online platform due to ongoing Covid-19 pandemic. This symposium is made possible with the outstanding work by the Organisation Committee. We thank, in particular, Mohamed Shimal for the compilation of the abstracts, and his timely communications with the Scientific Committee on reviewing and editorial work for publication, and Ashwag Ismail for the layout and design of this abstract booklet. Last but not the least, we want to acknowledge and thank our Minister, Zaha Waheed for her continued guidance and commitment to advance marine scientific research in the Maldives.

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Session 1

Reef Monitoring and Coral Regeneration

An Assessment of the Current State of Maldivian Coral Reefs to Support Marine Spatial Planning Efforts

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Abstract

In January-February 2020, Waitt Institute, Scripps Institution of Oceanography, and the Maldives Marine Research Institute partnered together to survey 127 forereef sites across 15 atolls in the Northern and Central Maldives, in order to support future marine spatial planning efforts. Sites were classified as community, resort, or uninhabited sites based on the island use designation of the closest emergent land, and were surveyed for 1) fish abundance, diversity and biomass, 2) benthic community composition, 3) juvenile coral abundance and diversity, 4) reef rugosity, and 5) macroinvertebrate abundance and diversity. Fish survey data showed a high density of small-bodied planktivores, moderate densities of large-bodied herbivores, and low densities of top predators and sharks across the sites surveyed, but found no significant differences in fish biomass between different island use types. Coral cover was shown to have recovered somewhat from the 2016 bleaching event, with the current mean percent cover (19.4%) approximately half of what it was prior to 2016, but dominated by *Porites* rather than *Acropora*. This apparent recovery may be due in part to the high levels of recruitment recorded at the sites surveyed (mean=14.2 individuals/m²), likely facilitated by high herbivory rates. Island use type affected benthic and, to an extent, invertebrate communities, but did not significantly drive patterns in fish communities. The results from this study suggest that Maldivian reefs overall have the capacity for recovery following disturbance, but that local stressors may impact reef health at the local scale.

Assessing the Current Health of Coral Reefs on Laamu Atoll to Help Guide Future Management Decisions

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Abstract

The Maldives is one of the most coral-reef dependent nations in the world, and its people depend heavily on coral reefs for their livelihoods and food security. Unfortunately, the health and functioning of Maldivian reefs is being compromised by local threats like reef destruction, overfishing and pollution as well as global threats, like climate change. The 2016 mass coral bleaching event reduced coral cover across the Maldives by 75% on average, and by over 90% in some places.

In December 2018, the Laamu Atoll Council declared their intention to protect five areas in Laamu Atoll and that same year, the Government of Maldives committed to protecting at least one uninhabited island, one mangrove and one reef in each atoll. However, choosing and designing protected areas presents a challenge because there are few data available on the current state of the reefs in Laamu Atoll. This study aimed to assess the current health of coral reefs around Laamu Atoll, with a view to guiding future management decisions.

Twenty coral reef sites around Laamu Atoll were surveyed from July to August 2019. Video transects were taken and still images were assessed using Coral Point Count to determine substrate composition. Belt transects were used to estimate the abundance, richness and diversity of ecologically and/or commercially significant fish species, as well as the abundance of ecologically and/or commercially significant invertebrate species and reef impacts.

Results showed that mean live coral cover throughout the atoll was 19%, ranging from 7% to 34%. There was no significant difference in live coral cover between site types. The high abundance of coral-dependent species such as Chaetodontidae across all sites suggests that reefs have recovered to provide sufficient habitat of live coral, although no correlation was found between percentage live coral cover and fish abundance. Reef fish populations were diverse, with a mean of Simpson index values of 0.91 with a total of 110 different species recorded from the 9 fish families selected for the study. Eleven species of invertebrate belonging to Holothuroidea, *Tridacna* and Palinuridae were recorded. Coral predators (crown of thorns and cushion stars) were observed in large numbers at specific sites on the eastern side of the atoll.

This study provided an overview of the health of some of Laamu Atoll's coral reefs and a baseline against which future changes can be measured. Results provide an insight into areas of high biodiversity, and possibly even resilience, which should be prioritised for protection.

Seasonal Variation of Coral Recruit Density and Diversity: Preliminary Results from South and North Malé Atolls

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Abstract

Coral spawning records within the Maldives suggest that there are two main spawning seasons, the first 'main' spawning event occurring around March-April, with a second smaller spawning season around October-November. Given the dual spawning seasons, there is potential for recruitment of corals, and the capacity of reefs to recover, to differ between the two seasons. While there are numerous studies that investigate coral recruitment after mass bleaching events, studies that investigate potential seasonal differences within the Maldives are limited.

This study aimed to establish patterns of coral recruitment and assess potential differences in density and diversity of coral recruits between the two spawning seasons, whilst accounting for differences that could occur from variable anthropogenic stressors. Differences in genera between the recruit coral community and adult coral community were also investigated to understand mortality variability between stages of coral growth.

Two reefs in North Malé and two reefs in South Malé Atolls were surveyed 6 months apart in 2020: in late February and in early September. Four 20m transects were laid at 5m and 10m depths at permanently marked locations on each reef. Reef benthos was assessed using PIT at 0.5m intervals, while photoquadrats were taken every 2m on alternating sides to assess the adult coral community. For the first 5m of each transect line, recruit data were collected using a 1m belt. The genus and maximum diameter of corals measuring up to 100mm were recorded.

The overall distribution of coral recruit diameters was similar between 5m and 10m and showed similar patterns in the two sampling periods. The distribution was highly skewed towards juvenile corals (0-50 mm) at both depths during both seasons, although density of 5-10mm juveniles recorded at 5m during the February sampling was higher than September. However, distribution of recruits at individual reefs at 5m and 10m were more bimodal during the February sampling. Genera of the recruits recorded at 5m and 10m and between the reefs were similar although this pattern was not reflected with the adult coral community. Several genera of coral were only recorded as recruits during this study.

Reefs investigated here were similar in terms of coral recruitment and coral community despite being in two different atolls. This uniformity could suggest a degree of connectivity between Maldivian reefs, and that seasonality and anthropogenic stress may be a negligible driver in comparing the chosen reefs. However, these results are preliminary and a longer sampling period is required to establish conclusive seasonal patterns of recruitment as well as potential long-term impacts of anthropogenic influence.

Evidence of Coral Bleaching and Recovery in Noonu Atoll, Maldives 2020

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Abstract

Anthropogenic-based climate forcings have resulted in increasingly severe and recurrent instances of abnormally warm sea surface temperatures (SST) and consequent coral bleaching across the world's tropical and subtropical reef ecosystems. These effects have been particularly detrimental for reef health throughout the Maldives. During the 1998 mass bleaching event in the Indian Ocean, it was estimated that over 90% of corals in the shallow waters of the Maldives were killed. In 2016 the Maldives were subject to the second-largest mass bleaching event. This event was well researched, and results revealed bleaching of the roughly 50% of the corals and 20% mortality of surveyed corals.

The 2016 bleaching event prompted the creation of the Velaa Private Island Coral Project in September 2016. The goals of the Velaa Coral Project are to increase overall biodiversity of the reef and to conduct scientifically sound research to help future restoration efforts. During the 2016 bleaching event, monthly surveying of corals around Velaa Private Island (5.83°N, 73.21°E) was conducted. These surveys followed a protocol proposed and trained via IUCN Maldives. Here we examine the results of a study performed in 2020 which served as a continuation of the original surveying process. Monitoring was conducted on a weekly basis during times of peak heat stress, from the end of April until mid-June. Additionally, SST were monitored via temperature loggers. Once SST began normalizing, follow-up monitoring took place in August to track recovery. The data collected are of particular interest due to the lack of information obtained throughout the Maldives during this time, due to the limited availability of researchers as a result of constraints associated with COVID-19.

The benthic surveys were conducted at three sites and three separate habitats (reef flat, crest, and slope) were surveyed at each site. 1m x 10m belt transects were conducted at each habitat/site with three replicates for each locale. Imagery was collected for individual coral colonies and video was recorded across the entirety of each transect for ex-situ analysis. Monitoring was performed through the use of 100 m measuring tape, attached to rebar at the beginning of the monitored section. This ensured the same area was consistently surveyed.

SST peaked in May and made a gradual decline through June and July. Additional results showed a peak of bleaching which corresponded with warmer periods in May, recovery was apparent during June and July. Corals with the highest instances of bleaching were fast growing, branching corals, located in shallow waters. Corals least susceptible to bleaching were slow growing corals, found at deeper depths. Data such as this can be beneficial in guiding future restoration efforts.

Cross-Atoll Comparison of Benthic and Morphological Coral Reef Community Compositions in North Ari Atoll

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Abstract

A widely accepted yet poorly investigated postulation about Maldives reefs is that coral reefs located on the eastern and western edges of each atoll differ in terms of benthic composition. Despite much coral reef-based research in North Ari Atoll, there is limited research that has investigated outer reefs of the atoll and even fewer that have carried out comparisons.

This study compared and assessed whether there were differences between the benthic, coral generic, coral morphological diversity, percent cover and composition of parallel outer reefs on the western edge (exposed to the open ocean), and on the eastern edge (exposed to the inner ocean) of North Ari. Analysis was carried out on a subset of photoquadrat data take at 5m collected to ground-truth habitat maps. As data was collected for habitat mapping, transects targeted reef features visible on satellite within a latitudinal band rather than the reefs themselves rather than evaluation of a specific reef. Therefore, to control for variation due to inherent differences in reef features and transect lengths, three transects on the slope of the outer rim of each atoll edge were selected for analysis with fifty random images from each separate transect chosen for annotation to the lowest taxonomic level possible on CoralNet.

Results show that the Shannon diversity, biotic richness, and coral generic richness were significantly higher on the western edge of the atoll than on the eastern edge. Community analysis with PERMANOVA indicated that western-facing reefs significantly differed in composition from eastern-facing reefs in all three types of assemblages that were assessed, and the differences were driven by at least three different drivers for each assemblage. Similarly, percentage cover of major benthic categories were significantly different between the two atoll edges. While live coral and crustose coralline algae cover was higher in the western reefs, rubble and other abiotic categories were higher at the eastern reefs.

Within the Maldives, windward and leeward sides flip every monsoon season. As no environmental variables were directly measured, proxies will be utilized to assess what abiotic factors could be driving the differences observed. They could be attributed to differences in wave, current, wind exposure or forcing by variation of sea surface temperatures resulting from climate change. The results of this study support the postulation that western and eastern edges of Maldivian atolls differs in terms of benthic and coral assemblage and, as these reefs have not been assessed before, set a baseline to which future changes can be compared.

Multi-Temporal UAV Data and Object-Based Image Analysis (OBIA) for Estimation of Substrate Changes in a Post-Bleaching Scenario on a Maldivian Reef

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Abstract

Coral reefs are declining worldwide as a result of multiple natural and anthropogenic stressors, including regional-scale temperature-induced coral bleaching. Such events have caused significant coral mortality, leading to structural collapse of reefs and shifts in associated benthic communities. In this scenario, effective mapping techniques and best practices are critical to improving data collection to describe spatial and temporal patterns of coral reefs after a significant bleaching impact.

Our study investigated the potential of a consumer-grade drone, coupled with structural information from motion and object-based image analysis, as a tool to monitor changes in substrate composition and the associated environmental deterioration in a Maldivian shallow-water coral reef. Three key substrate types (hard coral, coral rubble and sand) were detected with high accuracy on high-resolution orthomosaics collected from four sub-areas. Multi-temporal acquisition of unmanned aerial vehicle (UAV) data allowed us to compare the classified maps over time (February 2017, November 2018) and obtain evidence of the relevant deterioration in structural complexity of flat reef environments that occurred after the 2016 mass bleaching event.

Our methodology offers a cost-effective procedure that is well suited to generate maps for the long-term monitoring of changes in substrate type and reef complexity in shallow water.

Turning Rubble to Reef: Quantifying Rubble Mobilisation and Binding Dynamics to Assess Recovery Potential of Disturbed Reefs

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Abstract

Production of rubble on coral reefs is increasing due to more frequent and severe disturbance events, including mass coral bleaching, cyclones and blast fishing. Recovery of rubble-dominated reefs is constrained by physical and biological processes, particularly rubble mobilisation and binding. Rubble that has been naturally stabilised by rubble-binding organisms can provide a solid substrate for coral recruitment. Conversely, the hydrodynamic mobilisation of unstable rubble can inhibit binding while also increasing mortality of recruits or fragments in the rubble by scouring or smothering, potentially limiting recovery and fixing the system in a rubble-dominated state.

Rubble mobilisation was investigated by tracking the transport of coral rubble in a controlled environment (wave flume) as well as a field environment (Vabbinfaru Reef, Maldives) while measuring the wave environment. Binding was investigated via surveys of natural rubble beds, and monitoring of experimentally-stabilised rubble over an 18-month period on Vabbinfaru Reef. An additional in-situ experiment on the reef slope investigated how the survival and growth of coral fragments was affected by the frequency of experimental scouring.

At least 50% of rubble was overturned when bottom orbital velocities reached a threshold of ~ 0.3 m/s, and this threshold decreased as rubble size and complexity decreased. In natural rubble beds, 20% of rubble was bound, but when rubble was experimentally stabilised, this increased to 70% after 6 months. Binding was more likely in reef slope than lagoon environments, and the most prevalent binders in both natural and stabilised scenarios were sponges. In the scour experiment, we found that increasing scour frequency caused sublethal effects including reduced tissue growth and pigmentation, and increased partial mortality, even in robust species (*Porites rus*). Thus, rubble beds that experience threshold mobilisation velocities more frequently than every 6 months will not bind well, with subsequent impacts on recruit survival, which varies among reefs depending on environmental factors including bathymetry and hydrodynamics.

Predicting the natural stabilisation and recovery potential of degraded, rubble-dominated areas is valuable given the current trajectory of coral reefs. Degraded reefs with poor recovery potential could be prioritised for management strategies that include implementation of assisted rubble stabilisation.

Improving Resilience of Coral Ecosystems to Extreme Temperature Events through an Innovative Reef Cooling System

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Abstract

Coral reefs support immense biodiversity and provide important ecosystem services to many millions of people. However, they are degrading rapidly in response to numerous anthropogenic drivers the most important of which is caused by the increase in temperature. Three recent global mass bleaching events (1998, 2010 and 2015/16) were associated with El Niño-Southern Oscillation (ENSO) warm events. In order to try to reduce the impact of climate change on coral survival, scientists are trying several approaches to help them adapt, including transplanting lab-fertilized corals into the wild. A more radical step, which is yet to be widely applied to coral reefs, entails a shift from passive ecosystem management to active ecosystem intervention. We therefore asked ourselves how to reduce the water temperature from 32°C, a temperature recorded in recent years that can cause the death of the corals, to 28°C, a temperature suitable for their survival.

Our idea is to force a water recirculation, from the bottom to the top, in order to bring to the surface water with a temperature compatible with the life of the corals. It is known that water circulation, from bottom to top, has already been used in different situations. For instance, eutrophication of large lakes and pollution of ports have both been mitigated by recirculating water through the use of hydraulic systems.

Our innovative ecological engineering solution goes through the design of an ad hoc hydraulic system to preserve coral reef biodiversity around resort islands, for the mutual benefit of humans and nature. The development of severe stratification within the coral reef water body could be avoided using pumps to force vertical water movement and mixing of the water column. The technical solution could be air injection systems using a compressor to deliver air through lines connected to perforated pipes or other simple diffusers placed near the bottom. When the colder water reaches the coral reef surface it flows across the surface and eventually sinks, mixing with the warmer water.

Suitability Assessment of Mid-Water Lagoon Nurseries for Coral Restoration in the Maldives

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Abstract

Maldivian coral reefs are currently facing many stress factors and may require assistance, especially if coral health is poor and recovery is slow locally. In the case of desired and heavily frequented reefs, such as resort house reefs, in situ coral restoration can be a useful tool in assisting natural recovery.

Mid-water coral nurseries appear to be a cost-effective technique for rearing large numbers of coral fragments to suitable transplantation size, but information on rigorous and long-term testing of this method in the Maldives is very limited. Here we present the results from rearing 799 coral fragments from 3 different genera in mid-water lagoon nurseries in two different locations in the Maldives, using a comprehensive short- and long-term monitoring approach. A total of 5 nurseries were constructed and assessed between 2017 and 2020 in the sheltered, semi-enclosed lagoons of Magoodhoo local island in Faafu Atoll and Athuruga resort island in Ari Atoll. A comprehensive protocol for monitoring fragment survival, health condition, linear and three-dimensional growth, apical tip development, evidence for diseases or predation and environmental conditions was applied along with a 2-phase monitoring schedule to both sites.

Overall, our results suggest that the use of mid- water lagoon nurseries is a feasible, inexpensive and promising technique for rearing corals in the Maldives. Fragment survival was generally very high, typically exceeding 90% survivorship for the genera *Acropora* and *Pocillopora*. Comparison across locations and coral genera also revealed that the survival and growth of corals was affected differently not only by predation and diseases but also as a function of time, indicating that the time frame for the nursing phase and its monitoring is an important consideration.

By applying a common monitoring protocol over a long-term period, we hope to provide a comprehensive assessment, first benchmark results and useful insight into best practices for applying this restoration technique in the Maldives.

Growth and Survivorship of Hard Coral Species for Their First Year in a Rope Nursery

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Abstract

Following the detrimental bleaching event in May 2016 many organizations in the Maldives are attempting to use different coral propagation methods to assist local reef recovery. Gili Lankanfushi Maldives has an established a Coral Lines Project, and this study aimed to determine the survival and growth rates of coral fragments in the coral line nursery.

A total of 174 lines with coral fragments of *Acropora* species were monitored and their growth and survival were calculated after the annual monitoring of each line. After a year of growth on ropes, *Acropora muricata* was seen to have a mean growth of 129.7mm (SD $\pm$ 25.8mm) while *Acropora latistella* had the least with 18.0mm (SD $\pm$ 2.5mm). *Acropora florida* had the highest mean survival percentage with 91.9% (n = 1 line) after a year, while *Acropora digitifera* with 20.9% (SD $\pm$ 4.6%) survival had the least. Growth and survival were also categorized by the month in which coral lines were made. Lines that were made in March had the highest mean growth rate of 70.5mm per year (SD $\pm$ 48.9mm), while lines that were made in February had the lowest mean growth rate of 21.1mm per year (SD $\pm$ 34.5mm). Lines that were made in June had the highest survival of 75.7% (SD $\pm$ 20.6%) while ones made in November had the lowest survival of 51.2% (SD $\pm$ 32.5%). Kruskal-Wallis tests revealed that all the categories of data of growth and survival of coral fragments, except that of survival in relation to month of deployment, were significantly different from each other.

Given that some species thrive better and grow more than others during certain times of the year when they are first fragmented and deployed on a line, it may be beneficial to fragment more of certain species during certain months for higher growth rates and survival. However, more analysis, taking into account both species and timing of line creation at the same time, could provide a more in-depth understanding of how these factors affect the growth and survival of coral rope nurseries. Nevertheless, the results presented here can still be useful for the future development and future choices of the coral nursery for Gili Lankanfushi's Coral Line Project and other similar coral rope nurseries in the Maldives.

Natural and Non-Natural Mitigation Tools for Maldivian Coral Diseases

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Abstract

Coral diseases are emerging as a major threat to coral reefs worldwide but very few mitigation strategies have been proposed and developed so far to control this threat. Here, as a case natural mitigation tool, we show how a largely over-looked association such as that between hydrozoans and scleractinian corals could be possibly associated with a reduction in coral susceptibility to ever-increasing predator and disease outbreaks. We show that, after accounting for geographical, ecological and co-evolutionary factors, signs of disease and corallivory are significantly lower in coral colonies hosting hydrozoans than in ones that are hydrozoan-free.

In addition, as an example of a potential non-natural mitigation tool, we demonstrate that recently developed bi-layer human skin wound treatment patches containing antiseptics and natural antioxidants with controlled release capacity can be adapted to treat scleractinian coral wounds effectively. Coral injuries were treated to reduce the number of entry points for organisms that could lead to diseases, and were monitored both in tanks and in the ocean in Maldives. The corals tolerated both biomaterials as well as the antiseptics incorporated in these materials. The treatments displayed self-adhering properties, tunable dissolution time and biocompatibility, and also stimulated regeneration properties within the coral wound.

These findings have important implications for our understanding of the ecology of coral reefs, and for their conservation in the current scenario of global change. Indeed, they suggest that symbiotic hydrozoans may play an active role in protecting their scleractinian hosts from stresses induced by warming water temperatures. Our results also suggest that certain human skin wound treatment materials can be successfully adapted to the curing of coral wounds and delivery of specific drugs to slow down, reduce or even stop the spread of coral diseases.

Session 2

Reef Biodiversity

New Insights into the Ecology and Corallivory of *Culcita* spp. (Echinodermata: Asteroidea) in the Republic of Maldives

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Abstract

The cushion sea star *Culcita* spp. (like the Crown-of-Thorns Seastar, CoTS, *Acanthaster* spp.) is a coral predator. It feeds on corals by everting its stomach, removing only the coral tissue without affecting the carbonate skeleton, digesting the tissue in situ and leaving scars which appear like relatively large white spots. The main difference between these two seastars is that *Acanthaster* has a higher fecundity and can sometimes cause large population outbreaks with disastrous consequences for coral reefs, while similar explosions of cushion seastar populations have rarely been reported. Nevertheless, average densities of *Culcita* are typically higher than the number of individuals observed in non-outbreak populations of *Acanthaster*. This suggests that the cushion sea star, due to its continual removal of living coral, may represent a persistent force in affecting coral cover abundance and composition.

In this study, the main ecological traits and the corallivorous behavior of the cushion seastar diet have been investigated. At each study site, the presence of *Culcita* was recorded by applying the roving SCUBA diving technique. For every cushion seastar encountered different ecological parameters were noted: size, depth, activity, presence of predated corals. Data were analysed through standard statistical methods and feeding preferences were obtained through the Ivlev's Electivity Index and the Standardized Forage Ratio.

Most cushion seastars were found on shallow substrates (<10m), with a relatively low coral cover (10-30%). Size of individuals differed depending on the coral cover of their habitat and the reef zone where they were found. Seastars showed a predilection for small coral recruits (<5cm diameter) of the genera *Pocillopora* and *Pavona*, which despite being not particularly abundant in the study area, were preferentially preyed upon.

Considering its preferential predation of recruits and juvenile coral colonies and its predilection for some specific coral genera, *Culcita* might affect reef recovery and resilience following other stress events, and generate local shifts in coral community composition and structure. For this reason, further ecological investigations on larger scales and quantitative analyses on population dynamics and on the possibility of outbreak generation should be considered.

Maldivian Symbiotic Hydrozoans: Diversity, Ecology and Evolution

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Abstract

Hydrozoans are widespread cnidarians, found worldwide from shallow to deep waters. They play important ecosystem roles and are particularly diverse and abundant in tropical shallow waters. Moreover, many species establish symbiotic relationships with other organisms, including corals, octocorals, sponges and bryozoans. However, the diversity, ecology and evolution of tropical symbiotic hydrozoans are still poorly understood.

In this work, we show the results obtained in the last years through the analysis of several tropical samples, most of which coming from Maldivian reefs. Specifically, we used an integrative approach (including morphological, genetic, ecological and evolutionary analyses) to disentangle the real diversity of these organisms, to better understand the relationships with their hosts, and to study their biogeography and evolution.

Our results show that the genetic diversity of these organisms is much higher than expected, especially considering their conserved morphological features. The presence of cryptic species (species genetically but not morphologically distinguishable) is demonstrated for many taxa, and different species show variable degrees of host-specificity and geographical distribution, with the Maldives being recognized as a hotspot for the biodiversity of these organisms. Overall, both host specialist and generalist species are recovered. In many cases, these species show a widespread distributional range, but a few taxa seem to be endemic to specific regions. However, no Maldivian endemic species are at the moment known, as is also the case for other coral reef organisms.

These findings shed light on an overlooked but ecologically important group of organisms and provide new insights into coral reef symbioses.

Molecular Diversity of Maldivian Demosponges and Genetic Connectivity with other Indian Ocean Sponge Faunas

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Abstract

Sponges are pivotal members of coral reef communities. They fulfil vital ecological functions, e.g. maintaining reef integrity by substrate consolidation, supporting biological diversity by habitat formation and nutrient cycling for other organisms through the 'sponge loop'. Estimation of sponge diversity is challenging due to the difficulty of determining and delineating sponge species by morphology. Nevertheless, the assessment of sponge diversity is necessary to monitor changes in total reef diversity, for example as a result of climate change. So far, only 40 species of demosponges, the largest class of sponges, have been reported from the Maldives, which may not fully represent the total demosponge diversity.

To further increase our understanding of Maldives' sponge biodiversity we analyzed demosponge collections with a DNA-based approach and then compared the results with previous diversity assessments based on morphological species identification. We assessed genetic connectivity between the Maldives and other Indian Ocean regions and the degree of endemism of Maldivian demosponges.

About 300 demosponge specimens, partly collected from Lhaviyani Atoll (Vavvaru, KorallionLab), and Faafu Atoll (Magoodhoo, MaRHE Research Center) were analyzed. They were DNA barcoded with partial ribosomal (28S rDNA) and mitochondrial (CO1) sequences. Genotypes were classified into molecular operational taxonomic units (MOTUs) prior to comparison with MOTUs from other Indian Ocean regions, including Mayotte, Western Indonesia, Western Australia, the Red Sea and the Gulf of Arabia.

Our molecular data indicate far higher demosponge diversity than currently estimated by means of morphology. Endemism is high, with comparatively few MOTUs overlapping with those from sponge faunas of the other Indian Ocean regions. Maldivian demosponge diversity is largely unexplored and the species described so far may not reflect actual species diversity. The Maldivian data corroborate findings from diversity analyses of other Indo-Pacific regions where the degree of endemism is comparatively high and just a few MOTUs overlap with other marine regions. These results highlight the need for additional research to better understand the diversity (and changes thereof) of these important coral reef animals.

Diversity of Calcareous Sponges of the Maldives

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Abstract

Sponges of the class Calcarea (calcareous sponges) are characterized by their ability to form skeletons of calcitic spicules, and this characterises and differentiates them from other sponges with siliceous biomineralogy. This unique feature may impact their resilience to climate change and may make them vulnerable to ocean acidification, as are reef-forming corals. However, little is known about the diversity of these sponges in the Maldives, or how future ecological changes may impact their diversity. To date, only eight species of calcareous sponges have been recorded from the Maldives, of which three were only described in the last two years.

Our research goal was to establish a baseline on the actual diversity of the calcareous sponge fauna of the Maldives, which is a prerequisite to detect changes in the sponge faunas in the future.

We sampled calcareous sponge specimens in Faafu (Magoodhoo, MaRHE Research Center) and Lhaviyani (Vavvaru, KorallionLab) Atolls. The DNA-guided analysis included sequencing and phylogenetically analysing a standard DNA barcoding marker (partial 28S rDNA). We studied morphology with histological sections, SEM of spicules and µCT.

In our ongoing inspection of biodiversity, we identified species previously not recorded from the Maldives, which in some cases are new to science. An examination of only 74 specimens identified 23 operational taxonomic units, likely species. Therefore, the current knowledge of the calcareous sponge fauna of the Maldives is a gross underestimation of the actual diversity. We find it to comprise more species than the fauna of the Red Sea, a biodiversity and endemism hotspot, where we applied a similar sampling and analysis regime.

The biodiversity of calcareous sponges in the Maldives is much higher than the current records show. The Maldives can be considered a biodiversity hotspot for the group.

Session 3

Mangroves and Seagrasses

To what Extent do Seagrass Ecosystems Support Marine Food Webs? Maldives Meadows within a Global Context

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Abstract

As part of a global study coordinated by the Smithsonian Institution, Maldives Underwater Initiative established a study site in Laamu Atoll to better understand the role of seagrass meadows within the marine food web. At each of the 32 current study locations distributed across six continents, three 50m transects were installed within a continuous seagrass meadow. Along these transects multiple standardized sampling methods were used to record abundance and species richness of primary producers, i.e., seagrass (quadrat observations and shoot count) and macroalgae (collection, identification and dry weight), in addition to epifaunal invertebrates (collection, identification and size) and fish (diver visual survey, count and size estimation).

In the Maldives, seagrass meadow density and cover were particularly high, with the majority of plots recording above 60% cover (while many sites globally attained <25% cover), and a median of 23 shoots per 10 cm² (vs. global median of 27). Three species of seagrass were observed within the Maldives study site, compared to a global median of two. Total fish abundance was 398 individuals (nearly two times greater than the global median of 234), distributed among 13 species (vs. global median of 15). A particularly notable group observed at the Maldives site was the parrotfish (accounting for 47% of all individuals). The most abundant of these was *Calotomus spinidens*, which feeds mostly on seagrass, algae and associated epifauna. Commercially important fish species observed included snapper ($n = 32$, mean length 8.8 cm SE $\pm$ 3.0) and emperor ($n = 78$, mean length 12.2 cm SE $\pm$ 6.8), particularly *Lethrinus harak*, known to predate upon crustaceans, mollusks, echinoderms and small fish. *Carcharhinus melanopterus* was also observed during surveys. Presumably as a result of high fish abundance, epifaunal invertebrate abundance and diversity was low, reflecting the rapidity with which these organisms are consumed in tropical seagrass beds.

Compared to other seagrass sites throughout the world, the Laamu site occupies the higher end of seagrass cover, diversity and habitat provisioning. This suggests that the Maldives site represents a healthy, thriving ecosystem with high production capacity to accommodate juvenile commercial fish species and mesopredators. Nevertheless, seagrasses face global threats from changing climate, and particularly in this region, land reclamation and dredging, which could jeopardize seagrass ecosystems and the fish communities they support. The results of this study not only provide the first insight into the role of seagrass meadows within complex food webs, but also allow the visualisation of Maldives meadows within the global context as particularly productive ecosystems deserving of greater attention and protection.

Characterisation of Seagrass Meadows and Associated Fish Assemblages in Laamu Atoll, Maldives

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Abstract

Seagrass meadows form the basis of highly productive coastal ecosystems, however, none have been mapped or described in the Maldives. In 2018, both the Laamu Atoll Council and the Government of the Maldives committed to protecting various marine areas. Unfortunately, the protection of seagrasses was not considered in either commitment. The Atoll Council's key motivations for proposing conservation measures were to protect the Atoll's coral reefs and fisheries. Assessing the contribution of seagrass ecosystems to fisheries and coral reef productivity is therefore a priority.

This project aimed to map the extent of the seagrass meadows; characterise the seagrass and associated fish communities within the meadows; examine drivers behind the differences in seagrass fish assemblages; and assess the nursery habitat function of the seagrass habitats, with a particular focus on fish families that are important for fisheries or the function of coral reefs. Seagrass meadows around three islands (Hithadhoo, Gaadhoo and Maabaidhoo) in Laamu Atoll were surveyed in July and August 2019. Meadows were mapped using Google satellite imagery and seagrass characteristics were surveyed using random quadrat sampling. Fish assemblages were characterised using underwater visual census and stationary remote underwater videos.

Across all three sites, five species of seagrass were recorded (*Thalassia hemprichii*, *Thalassodendron ciliatum*, *Halodule pinifolia*, *Syringodium isoetifolium* and *Cymodocea rotundata*), typical of species assemblages found in the Indo-Pacific bioregion. *T. ciliatum* was found to be the dominant species, accounting for approximately 62% of the seagrass cover. A sixth species, *Halophila ovalis* has also been reported from Laamu. High fish diversity was recorded across the meadows, with fish abundance and species richness highest around Gaadhoo and diversity highest around Maabaidhoo. A total of 141 fish species representing 31 families were recorded. Parrotfish (Scaridae) were the most abundant fishes across the surveys. Juvenile fish proportions were high across all sites, suggesting these meadows may act as nursery habitats. Comparison between transect and RUV methods for fish surveys found that species richness and abundance were higher in the transect method, while diversity was similar for both methods. Results demonstrate the value of these seagrass meadows for coral reef productivity and recovery and provide justification for their inclusion in forthcoming protected areas. Our results also contribute towards the Government's plans to create a national inventory of seagrass beds as is outlined in its five-year National Strategic Action plan.

Daily Variation of the Associated Microbial Community and the Hsp60 Expression in the Maldivian Seagrass *Thalassia hemprichii*

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Abstract

We studied the marine seagrass *Thalassia hemprichii* from the lagoon of Magoodhoo Island (Faafu Atoll, Maldives), which is characterized by remarkable daily shifts in temperature and light. The plant's associated microbial communities and the expression of the chloroplast chaperonin Hsp60 were simultaneously analyzed during the diel cycle. Plants showed a significant up-regulation of Hsp60 expression from 0800h to 1400h, in correspondence with the increase in temperature and light, confirming their role as a defense mechanism against photoinhibition and oxidative damage. However, a further significant increase of the Hsp60 level was also observed when irradiance and temperature dropped, suggesting that the cellular stress was still in progress. The plant-associated microbial communities showed differences by plant compartment and sampling time, with the aboveground compartment (leaves) being much more dynamic than the belowground one (roots/rhizomes). In the phyllosphere, a progressive shift during the day from the absolute dominance of the Gammaproteobacteria class (mainly represented by the family Enterobacteraceae) to an increase of biodiversity due to the rise of Alphaproteobacteria was observed. Below ground, the microbial diversity was much lower than above ground, with Gammaproteobacteria being the most represented class through all sampling times. Vibrionaceae were most abundant at 0800h and 1800h, decreasing slightly at 1400h, when they were partially replaced by Halomonadaceae.

The combination of biochemical and microbial markers allowed assessment of plant stress response and improved knowledge of seagrass adaptation to harsh and changing environmental conditions, allowing the detection of early signs of change in the plant's physiological state. Furthermore, the variation of both Hsp60 expression and associated bacterial communities in response to light and temperature fluctuations support the 'holobiont' theory, which considers the plant/microorganisms association as a functional unit (in a similar way to that suggested for corals).

A Characterization and Comparison of the Mangrove Habitats and their Fish Assemblages on the Islands of Hithadhoo and Maabaidhoo, Laamu Atoll

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Abstract

Mangroves protect island communities from storm damage and erosion. They also provide a habitat for marine and terrestrial species supporting recreational and commercial fisheries as well as providing household and daily use items. Crucially, they are a source and sink for nutrients and carbon and can help to mitigate climate change. Mangroves are known to grow on at least 150 of the Maldivian islands yet few mangroves have been mapped or described.

In December 2018, Laamu Atoll Council proposed five areas in Laamu Atoll for national protection as part of the Government's pledge to 'protect at least one island, one mangrove and one reef' in each atoll. Maabaidhoo mangrove has been chosen as one of these areas, while Hithadhoo Island Council has prioritized the mangrove at Hithadhoo Island for protection. Implementing management presents a challenge because there are few data available on these mangroves. Stakeholders require a comprehensive understanding of the current health of the mangroves and the services they provide to guide future management decisions.

This study aimed to assess two mangrove systems and their associated fish communities on the islands of Hithadhoo and Maabaidhoo to determine the variation in habitat use and fish presence between two different types of mangrove systems. Specifically, the study aimed to determine if and how fish communities differ between sites, considering mangrove root structure, spatial distribution of mangrove patches and distance from the main sea channel. Baseline surveys were conducted to describe the faunal distribution of each site. Fish sampling was conducted using underwater video cameras (UVCs). UVCs were deployed with increasing distance from the sea inlet to establish patterns of utilization of fish across the mangrove area.

Species composition of mangroves differed significantly between sites with Hithadhoo consisting mainly of *Rhizophora mucronata* and *Ceriops tagal*, and Maabaidhoo consisting solely of *Pemphis acidula*. Thirty-one taxa from 18 fish families were recorded, many of which were reef-associated. Both sites provided habitats for juveniles, including five species of economic importance and one recorded only once before from the Maldives, *Epinephelus malabaricus*.

These results confirm the importance of mangrove forests as nursery grounds for fish and provide evidence that they support fishery and tourism industries. They also provide new and important information for resource managers and should be of use to guide future conservation strategies for mangroves in Laamu Atoll.

Session 4

Mega-fauna

Humpback Whales (*Megaptera novaeangliae*) in the Maldives*R. Charles ANDERSON**Manta Marine, Malé. anderson@dhivehinet.net.mv***Abstract**

Humpback whales are not common in the Maldives and almost nothing is known locally about their biology. The aims of this study were to compile records of humpback whales (mostly from social media) and to provide the first insights into their ecology in Maldivian waters.

Over 40 records were compiled, dating back to the first reported occurrence in 1993. The data demonstrate that there are two main seasons of occurrence: December-January (northern winter) and June-October (southern winter). Humpback whales that occur during June-October are relatively abundant ($n = 40$) and sightings are increasing in frequency. These whales are believed to belong to the southern hemisphere population that feed in the Southern Ocean during the austral summer and mostly breed in the SW Indian Ocean during the austral winter (IWC breeding stock C). Calves have been reported, with the frequency of occurrence increasing from 0% of sightings in June-July to roughly 60% of sightings in September-October. During the five-year period 2015-2019, 2 out of 20 humpback whales seen were reported to be entangled with fishing gear; this may be a significant cause of mortality within the region.

In contrast to the whales seen during June-October, there were few records of humpback whales during December-January ($n = 4$) with none since 2001. These whales are believed to belong to the Arabian Sea population. That population is known to be small and decreasing in abundance, and is listed as Endangered by IUCN.

Green Turtle Nesting in Laamu

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Abstract

Nesting research is a crucial component of sea turtle conservation. As sea turtles come ashore to nest, monitoring nesting activity is widely recognised as the easiest way to increase understanding and improve implementation of effective conservation measures. To date, there have been few sea turtle nesting studies conducted in Maldives. In this study, we report on the nesting activity of green sea turtles (*Chelonia mydas*) at two sites in Laamu Atoll: Olhuveli (Six Senses Laamu) and Gaadhoo. The study expands on previous research conducted on Olhuveli (presented at MMSS in 2018) and incorporates research into nesting and poaching activity on Gaadhoo. Gaadhoo has long been identified as one of the most important green turtle nesting hotspots in Maldives. This study aims to better understand the status of Laamu's nesting green turtle population and works to establish a replicable research standard that can be used to further understanding of nesting sea turtle populations nationwide.

On Olhuveli, nesting and hatching data have been collected since 2011, and excavation data since 2018. The green turtle nesting season typically runs from April to November. Greater numbers of nests were recorded in 2018 (n = 29) and 2019 (n = 24) than in previous years (n = 3 - 18). Average inter-nesting period was 11.5 days, slightly lower than both national and regional estimates, however mean incubation time (57.4 days) was consistent with average incubation times reported elsewhere in Maldives. Nests were excavated 48h post-hatching. Clutch size was similar in 2018 (mean = 94.7 eggs) and 2019 (mean = 102.7 eggs), but varied between individual nesting females: larger females laid larger clutches. Hatching success, although similar in both nesting seasons (mean 2018 = 69.1%; 2019 = 70.9%), also varied between individuals. This could be due to differences in the environmental conditions experienced, or could reflect variation in the condition of nesting females - nest hatching success may decline in later life.

On Gaadhoo, nesting and poaching data have been collected since 2018. This study likely underestimates the true extent of nesting activity on Gaadhoo as nesting surveys were conducted relatively infrequently (every 10 days on average). 56 suspected green turtle nests were reported between April 2019 and March 2020, fewer than were reported between April 2018 and March 2019 (n = 76). However, the proportion of suspected nests reported as poached was notably greater in 2018-19 (68.4%) than in 2019-20 (37.5%). This decline in poaching activity could be the result of increased presence of researchers on the island. Green turtles appear to nest year-round on Gaadhoo with no seasonal pattern in nesting activity identified.

Continued data collection will offer further insight into Laamu's nesting green turtle population. It is hoped this study can help inspire similar long-term studies at other sites nationwide.

Swimming with Turtles: The Behaviour of Sea Turtles in Proximity to Tourist Resorts in the Maldives

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Abstract

The Republic of Maldives is a small island nation in the Northern Indian Ocean famous for its marine biodiversity. With over one million visitors per year in 2018, more people than ever have been visiting the country. With them comes an increase in activities such as snorkelling and diving. Marine megafauna such as whale sharks, manta rays and sea turtles are major attractions for many visitors.

In this study we analysed photographic snapshots and video footage of sea turtles in various shallow coastal habitats in Lhaviyani Atoll taken over an 11 month period during a photo identification project to monitor the resident turtle population. We surveyed on 15 different locations to determine preferences in habitat use, intra-species interactions depending on turtle density, as well as habituation to the presence of humans. Survey areas were classified according to tourism pressure (i.e. the daily probability of human-turtle interactions) to further evaluate the influence of tourism on the resident sea turtle population. The behaviour of individual turtles was tracked over time with the help of a photo identification database to assess behavioural changes resulting from repeated human-turtle interactions.

Representative findings are discussed relating to the current recommendations (Code of Conduct) regarding sea turtle encounters during recreational activities in order to further refine these recommendations.

Eyes on the Reef: Using Remote Cameras to Uncover the Hidden Habits of Reef Manta Rays (*Mobula alfredi*) in the Maldives

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Abstract

The Maldives is home to the world's largest population of reef manta rays (*Mobula alfredi*), which generates over US\$8 million annually directly from manta tourism. Tourists regularly dive and snorkel at cleaning stations: ecologically important sites where *M. alfredi* socialize, court, mate and additionally, rid themselves of harmful bacteria and parasites through their symbiotic relationship with cleaner fish. SCUBA diving offers only short glimpses of manta ray activity at these sites, greatly limiting data collection and the ability to monitor these sites in the absence of human presence. With novel technologies, remote cameras can be deployed instead of human observers to effectively monitor *M. alfredi* activity. In a country which relies heavily on the economic benefit of manta tourism, understanding temporal changes in site use and the potential impacts of tourism is increasingly important.

In combination with remote underwater video cameras (RUVs), this study used a novel remote underwater time-lapse camera to allow uninterrupted, long-term monitoring of cleaning stations for the first time. Photographic identification (photo-ID) records, combined with environmental data, were used to reveal habitat use patterns in the absence of human presence, as well as identify environmental drivers that influence these patterns.

Cameras were deployed in 2019 between May and November to assess visitation patterns in relation to the phase of the moon, water temperature and time of high tide. From sunrise to sunset, time-lapse cameras captured one image every minute while RUVs recorded continuous video for up to 4 hours. Distinct periods of visitation (sighting events) and photo-IDs of *M. alfredi* were determined from the footage. Nine individuals were sighted only on RUV deployments and not by human observation, three of which were newly identified in 2019. Of the observed courtship activity in 2019, 42% was recorded by RUV cameras. While monthly sightings were lowest in May, sightings peaked in October. Preliminary findings for time-lapse cameras suggest a similar trend.

Assessing the impacts of tourism on significant habitats requires the examination of *M. alfredi* site visitation patterns and behaviours in the absence of human presence which can be successfully conducted by novel underwater recording devices. In addition to contributing photo-ID records, long-term monitoring systems can record sighting events facilitating the examination of temporal visitation patterns, their environmental drivers and site fidelity among individuals. This research can provide robust, scientific guidance for maintaining successful, sustainable manta tourism activities.

Gone with the Wind: Seasonal Distribution and Habitat use by the Reef Manta Ray (*Mobula alfredi*) in the Maldives, Implications for Conservation

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Abstract

The Maldives supports the world's largest known subpopulation of reef manta rays (*Mobula alfredi*). This subpopulation undergoes seasonal migrations which are thought to be linked to peaks in ocean productivity induced by the South Asian Monsoon. Although reef mantas are protected from targeted fisheries in the Maldives, increasing pressures from unsustainable tourism activities means their effective conservation relies upon knowledge of the species' habitat use, seasonal distribution, and the environmental influences on their movements.

The objective of this research project was to assist conservation planning by: (1) identifying locations used by reef manta rays throughout the Maldives Archipelago; (2) identifying the primary function of these sites for the species; (3) determining which environmental drivers influence site use; and (4) determining annual patterns in reef manta ray presence at these sites.

Between 2005 and 2017, Manta Trust researchers took over 54,000 identification photographs (photo-ID) of 4,411 individual reef manta rays, all of which were individually identified (using their unique gill-plate spot pattern), and recorded their behaviour (cleaning, feeding, cruising or courtship). These data were used to identify key aggregation sites throughout the Maldives and assess the primary function and annual visitation patterns at these sites. The environmental influences of the patterns observed were investigated using multiple linear regression modelling. Reef manta rays were recorded at 273 different sites throughout the Maldives, 48 of which (with >100 sightings at each) were classified as key areas of habitat use. These locations are utilised seasonally (either in the northeast or southwest monsoon). Modelling identified that the southwest monsoon winds drive these patterns during both seasons along with chlorophyll-a concentration on the down-current side of the atolls.

In a country where climate change and touristic pressure are increasingly threatening this species and its habitat, the identification of key areas of habitat use and temporal changes in the use of these sites may highlight the areas that should be prioritised for protection. By anticipating potential adverse impacts to reef manta rays at the locations identified in this study, and acting now to mitigate these threats, this species, their habitat, and the tourist industry which depends on them, can be safeguarded.

The Impact of Injury on Apparent Survival of Whale Sharks (*Rhincodon typus*) in the South Ari Atoll Marine Protected Area, Maldives

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Abstract

The whale shark (*Rhincodon typus*) is an endangered species with a declining global population. The South Ari Atoll Marine Protected Area (SAMPA), Maldives, is one of the few locations globally where year-long residency of individuals occurs. This SAMPA population appears to consist almost exclusively of immature males. Due to its year-round residency, this local population is subjected to a high degree of tourism pressure. This ecotourism contributes to the high level of interest and protection offered to whale sharks by the local community. Unfortunately, if regulations are not followed or enforced, tourism can bring with it major stressors, such as accidental injuries. We used survey data collected by the Maldives Whale Shark Research Programme (MWSRP) from the years 2006-2019. POPAN capture-mark-recapture models and lagged identification rate analysis were conducted to assess the effect of major injuries on whale shark residency within SAMPA. We found individuals with major injuries had a higher apparent survival in the area than those without. Lagged identification rates also demonstrated that sharks with major injuries are more likely to return to the area. We suggest that major injuries result in sharks prolonging their time in the developmental habitat. These findings have implications for individual fitness and the population viability of this endangered species. We propose targeted conservation strategies be considered to protect sharks from further injury. Based on the spatio-temporal distributions of sharks, and current local knowledge of sighting patterns, speed limit zones and propeller-exclusion zones should be implemented and enforced. If carried out alongside tourist education, these measures will contribute towards the protection of whale sharks within SAMPA and beyond.

Drivers of Reef Shark Abundance and Spatial Distribution across an Oceanic Atoll

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Abstract

A better understanding of reef shark abundance, species-habitat associations and their key environmental drivers is needed to inform spatial management plans and assess risk to key threats such as overexploitation and habitat degradation. Using Baited Remote Underwater Videos (BRUVs) this study assessed patterns in shark abundance and spatial distribution in North Malé Atoll, Maldives. In total 198 sharks from eight species were recorded with an average abundance of 0.78 ± 0.91 sharks h^{-1} . We modelled shark abundance against biotic and abiotic variables at 50 sites and found that the biomass of low trophic order fish (specifically herbivores) had the greatest effect on abundance. Average shark abundance was above that of heavily fished locations, yet below that of remote islands deemed to be pristine, suggesting populations are relatively healthy but not yet recovered from exploitation. The importance of prey biomass in predicting spatial patterns in shark abundance highlights the need for ecosystem level conservation measures on coral reefs to support the conservation and recovery of shark populations.

Citizen Science Surveys of One of the World's Most Threatened Coral Reef Fish, the Napoleon Wrasse, in Laamu Atoll Indicate Successful Management of the Species

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Abstract

The Napoleon, or Humphead, Wrasse (*Cheilinus undulatus*), is one of the largest coral reef-associated fishes. They are particularly easy to overfish and are one of the most highly valued in the international live reef food fish trade. In 1995, Maldives was one of the first countries to protect this species due to its declining numbers and pressure from the tourism industry, as large individuals are iconic for dive tourism. But despite protection, there is some evidence of continued fishing, and experienced dive guides report that larger fish previously seen on popular dive sites are no longer seen today. It is, therefore, of interest to understand the current status of the species in the Maldives and how it has responded to protection. The only previous study of the species in the Maldives was conducted in Laamu Atoll in 1995-1997 (Sluka, 2000, Atoll Research Bulletin).

From January 2018 to March 2020, surveys were conducted in Laamu Atoll during all SCUBA diving excursions from Six Senses Laamu resort. Dives were conducted between 5m and 30m depth by trained observers who recorded sightings, environmental conditions and size estimates, within pre-defined, regularly used areas. Only sites with a total survey time or distance of more than 10 hours or 10 km were included. Data from 23 sites, across four reef habitats types were analysed (2,546.2 hours, 656.42km distance and 3,214 fish observations). Total mean abundance was found to be 2.29 fish/ha, and for large fish (>100cm) this was 0.75 fish/ha. There was significant difference in abundance between habitat types. Channels exhibited the highest abundance (5.4 fish/ha) followed by outer reefs (2.8 fish/ha). Channels also showed the highest abundance of large fish (1.5 fish/ha) and a significant increase in total abundance across the 27-month survey period. There was indication of spawning aggregations at 10 sites, primarily in channels. Mean aggregation densities ranged from 8 to 20 fish/ha, an increase of 4.2 to 8.4 times the mean site density.

The high densities recorded, and the substantial number of large fish seen, are signs of a healthy population and an affirmation of successful management. These numbers compare favourably with studies elsewhere. It is clear that fishing can quickly reduce densities and remove the largest (male) fish, and hence management is critical, and also that habitat is a key determinant of density. Maldives is one of few countries globally where divers can still be guaranteed to see large fish on most dives.

Megafauna Observations of Laamu Atoll: The Tourism Industry Provides a Platform for Sustainable and Valuable Data Collection

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Abstract

Marine megafauna hold key roles in sustaining healthy ecosystems but also attract tourists that sustain the economy of many small island developing states. Protection of marine species in the Maldives has previously been driven by pressure from the tourism industry, with all sharks, turtles, rays and Napoleon wrasse (*Cheilinus undulatus*) being included on Maldives list of protected species. There is an opportunity to utilise diving and snorkelling excursions to help drive conservation and research efforts through collecting a data at minimal additional effort. Such sustained monitoring can provide data to inform species baselines and habitat use.

Megafauna sightings have been recorded by Six Senses Laamu resort, Laamu Atoll, since 2014 under the guidance of multiple national projects. In 2018, efforts were refined into a cohesive, succinct protocol reporting all sharks, rays, turtles, Napoleon wrasse and crown-of-thorns starfish (*Acanthaster planci*) observed on every resort dive and snorkel excursion. In addition, survey start time, duration, environmental factors (current strength and direction, temperature, horizontal water visibility), and items of trash collected were also recorded. Observers were snorkel and dive guides trained in species identification and the survey protocol.

In 2019 alone, 2,259 surveys were conducted on 364 days of the year, amounting to 1,864 survey hours. Thirty species were recorded, including 12 shark, 14 ray and 3 turtle species. Only 1.2% of surveys were discounted due to missing information. Channels were found to be significant areas for megafauna, supporting high mean sightings of spotted eagle rays (*Aetobatus narinari*), white tip reef sharks (*Triaenodon obesus*), grey reef sharks (*Carcharhinus amblyrhynchos*) and napoleon wrasse. Sightings were elevated at channel locations during the NE monsoon, with peaks in average sightings for multiple species in October and November. The inverse was found for black tip reef sharks (*Carcharhinus melanopterus*). Reef manta rays (*Mobula alfredi*) were found almost exclusively at channel locations and cowtail rays (*Pastinachus sephen*) were sighted most at seagrass meadows. Turtles exhibited were abundant throughout the year. Green turtles (*Chelonia mydas*) showed preference for channel corners and outer reefs, whereas hawksbill turtles (*Eretmochelys imbricata*) appeared more generalist.

This report provides proposes a framework to collect vast amounts of data within normal operations of a tourist resort and can be elaborated or simplified, depending on the organisation's capacity. Understanding spatial and temporal trends of megafauna species may help extend protective measures not only for individual species, but to the key areas they inhabit.

Session 5

Fisheries and Management

Marine Spatial Planning: an Experience in the Maldives

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Abstract

Marine Spatial Planning (MSP) presents the potential to sustainably manage maritime activities, limit the multiple anthropogenic impacts affecting the marine environment, and promote adaptation strategies to climate change by balancing socio-economic and environmental goals.

To drive toward such ends, a 7-day intensive MSP training workshop was held in Magoodhoo, Faafu Atoll, at the premises of the MaRHE Center, in January 2020. The workshop involved MSP practitioners belonging to diverse fields (e.g. ecology, biology, planning, law) from all over the world, to develop and test an MPS approach for creating synergies between socio-economic development and marine conservation in the Maldives. The multidisciplinary and peer-to-peer learning environment was instrumental in addressing both opportunities and critical issues through a knowledge building process. Such a process was fed by the best available knowledge and a range of different activities that included comparison sessions with MSP experts, field visits for acquiring knowledge and perceptions from the surrounding environment and the inhabitants, stakeholder engagement, desk-based analysis, groups work and simulations.

The application of an ecosystem-based approach was pivotal for taking into consideration nature protection priorities (e.g. preserve key habitats such as coral reefs, mangroves, seagrass beds, and protect target species as marine mammals and sea turtles) and local people's needs and traditions. The key sectors (tourism, fisheries and transportation) were underpinned with a focus on the Maldivian Western-Central atolls, by envisioning hypothetical future scenarios of development and how these could affect the needs and expectations of locals, together with ad hoc marine conservation measures. The diverse economic sectors were integrated together to boost a coordinated and shared development, and land-sea connections and interactions were recognized as having a paramount relevance, especially in this insular context.

Ultimately, this experience in the Maldives catalysed consideration of marine planning in the Maldives while helping broaden the community of MSP practitioners worldwide. Importantly, it provides new knowledge to drive an informed marine spatial plan and sustainable development in the Maldives.

A Current Overview of the General Reef Fishery in the Maldives Based on Fishery Sampling

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Abstract

The general reef fishery (i.e. that which catches reef and reef-associated fin-fish, excluding the grouper fishery), has long existed at a small scale in the Maldives. However, the fishery expanded over the last three decades, to become a commercial fishery now mainly driven by growing demand from tourism establishments. This expansion of the fishery has seen the emergence of intermediary traders linking island fishers to wider markets.

As part of SFRDP, a strategic general reef fishery sampling program was initiated to conduct fishery sampling across the country. The ultimate objective was to support resource assessments and sustainable management of the fishery. Here, we present an overview of the general reef fishery from data collected through the program, focusing on landing site-based sampling from late March 2018 to early February 2020. The landing site islands chosen were places where major reef fishing occurs and an intermediary trader(s) operates. At each landing site, field officers were based at the island for about a week to collect fishery information from reef fishing vessels and conduct catch sampling.

Sampling from 15 landing site islands covering 246 fishing trips was conducted. The majority of reef fishing trips were carried out using dinghies followed by mid-sized vessels (dhoanis), representing 76% and 21.5% of the sampled fishing trips respectively. Median catch per trip is lower for dinghies with 21.1kg compared to 72.0 kg for dhoanis. The three most commonly used fishing gears were: weighted handline in 44.7% of trips, handline 19.3% and dropline 13.5%. Five families accounted for 95% of the total catch, with Lutjanidae being most dominant (39.6%), followed by Lethrinidae (21.8%), Carangidae (20.1%), Serranidae (11.6%) and Sphyraenidae (2.2%). At least 98 species were recorded in catch, with 50% of total catch comprised by five species: *Lutjanus bohar* (16.7%), *Aprion virescens* (12%), *Lutjanus gibbus* (9.1%), *Lethrinus xanthochilus* (8.4%) and *Lethrinus microdon* (5.3%).

In comparison with earlier reviews, our results indicate that catch composition has stayed relatively similar in the fishery. However, the extent of reef fishing is likely to have increased over the years with widespread use of small dinghies for reef fishing. With this expansion of fishing effort and economic significance for island communities, there is a need for continuous monitoring to support resource assessment and sustainable management.

A Current Overview of the Grouper Fishery in the Maldives Based on Landing Site Sampling

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Abstract

The grouper fishery in the Maldives initially began as a small-scale fishery in the late 1980s. With the expansion of the Southeast Asian live reef food fish trade (LRFFT), the Maldivian grouper fishery expanded into an export-oriented, highly targeted fishery in the early 1990s. Since then the fishery has escalated throughout the entire Maldives, catering for the export demand. With support from the Sustainable Fisheries Resource Development Project of the World Bank, MMRI initiated a sampling program to collect data from all Maldivian landing sites. For this study, grouper fishery data were collected during March 2018 to February 2020 at grouper collecting points, where exporters deployed grouper holding cages or collecting vessels to collect the groupers from fishermen every 3 days.

Sampling was conducted on board holding cages or collecting vessels over a 10-14 day period each month. Over two years sampling has been carried out at 6 landing sites covering 232 fishing trips where 91% of the trips represent vessels (dhoanis) ranging from 22-64 FT in length while the rest (9%) represent dinghies. The dinghy fishermen are believed to be part time, and conduct single day trips. They collect their catch in their own small cages until collector vessels arrive, unlike dhoanis which mostly conduct continuous 3 day trips. Average catch per trip for dhoanis is 602 fish per 3 day trip. Fishing is conducted mainly during the day and the main gear used is visually-aided handline. Weighted handlines are sometimes used at night when targeting aggregation sites, although the use of underwater gaffs and torches is becoming a trend in this night fishery. A total of 28 species of groupers was observed during our sampling. The top 10 accounted for 92.2% of the total catch with *Cephalopholis argus* being most dominant (21.8%), followed by *Aethaloperca rogaa* (20.1%), *Anyperodon leucogrammicus* (9.9%), *Variola louti* (9.3%), *C. miniata* (6.7%), *Plectropomus areolatus* (6.2%), *P. pessuliferus* (6%), *Epinephelus polyphekadion* (5.6%), *E. spilotoceps* (3.5%) and *P. laevis* (3.2%).

In comparison with the last review in 2011 the results show that the top most exploited species in terms of catch composition has stayed the same except for *E. fuscoguttatus* which decreased from 3.8% to 0.8% of the catch. This confirms fishermen's and exporters' reports of decreased availability. Our results further support the importance of proper management and enforcement for the fishery to be sustainable, and the value of continuous sampling and monitoring.

Data Limited Length-Based Assessment for Maldives Reef Fisheries with Preliminary Results for Two Species

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Abstract

The inception and relatively rapid expansion of commercial fisheries for reef and reef-associated fin fish due to demand from international, tourist and domestic markets resulted in increased exploitation of these resources over the past three decades or so. However, with the cultural and economic importance of tuna fisheries, fishery and scientific data collection have until recently concentrated on tunas and tuna fisheries. This has resulted in a lack of understanding of reef fish resources, hampering provision of adequate management advice.

The World Bank funded Sustainable Fisheries Resources Development Project, which started in 2017, presented an opportunity to establish a scientific data collection program across the country to support assessment of reef resources and provide evidence-based advice for sustainable management of the different fisheries that depend on these resources. The Project supports fishery sampling and data collection from key landing sites for grouper and the general reef-fish fisheries.

Here, we present a data limited method for estimating the Spawning Potential Ratio (SPR) with uncertainty using single length samples with preliminary contrasting results for two grouper species: *Epinephelus fuscoguttatus* and *Plectropomus pessuliferus*. SPR estimates the proportion of mature fish biomass in the fished population compared to its unexploited state. If spawning biomass falls below 30% of the unexploited state, the stock is considered at risk of recruitment overfishing. For most fisheries, it is possible to collect single samples of length compositions of catches in a short period. These data can be used for an initial assessment of stock status and to provide management advice. A Bayesian risk-based length catch curve was developed to estimate mortality and selectivity. This was extended to estimate SPR using length-weight and length-at-maturity data. The output is an estimate of risk of overfishing and some advice on potential impact of scaled changes in fishing effort and size at first capture. Further scientific work focused on species most at risk can be recommended.

Evidencing Sustainability Credentials of Maldives Pole and Line Fisheries - Estimating Non-Targets and ETP Interactions

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Abstract

Providing evidence for environmental credentials is necessary for third party verification of sustainability standards in fisheries. The Maldives pole-and-line fishery is popular for its low environmental impact, but lacks published scientific evidence for its claims. Following its MSC certification in 2012, IPNLF in collaboration with the Maldives Marine Research Institute (MMRI, formerly the Marine Research Centre, MRC) started a sampling and observer program. Two of us, IN and IS, took part on regular pole-and-line fishing trips to observe and sample the catch, paying particular attention to bycatch and interaction with ETP species among others. The program started in 2014, and has so far resulted in detailed sampling of 164 regular pole-and-line trips covering 98 bait fishing and 374 fishing events. The results of the first 100 trips (2014-2015) have been published in PLOS one and in IPNLF technical reports. The data collected in 2019-2020 have not been analyzed although relevant data have been submitted to the Indian Ocean Tuna Commission (IOTC) by the Maldivian authorities as part of their IOTC compliance. We present here a summary of the full data set, including a comparison of changes occurring in the fishery; duration of fishing trips and times shared for bait fishing and tuna fishing; changes in interaction with ETP species; and changes in targeting of schools.

Estimating Time Series of Tuna Consumption in the Maldives

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Abstract

Maldives has one of the highest fish consumption rates in the world. Estimates range from 95-160 kg of fish per person per year. This demonstrates the Maldives' high dependence on fish for protein and its importance to food security of the country. Yet, there are very few published reports on how these numbers are calculated and the sources of error in estimating them. Reliable estimation of fish consumption is important for public policy formulation and fishery management and even for measuring Sustainable Development Goals.

In the Maldives roughly 90% of reported national landings are tuna, primarily skipjack and yellowfin. By using time series of tuna exports and catch data, available from the public domain, we demonstrate that consumption times series can be reliably estimated by the difference between total catch and exports provided that yield ratios of export categories are available. By carefully reviewing the time series of export data and grouping exports products into five categories we estimate product fresh weights by conversion (yield) ratios from members of Maldivian Seafood Exporters and Processors Association (MSPEA).

Based on domestic population estimates of the Maldives by the National Bureau of Statistics we estimate a mean ($\pm$ standard deviation) consumption of 143.5 ± 48.9 kg per person per year for 1998-2019. This estimate excludes consumption by foreigners in the Maldives and resident tourists. Furthermore, this also excludes landings of reef fish, of which we assume 90% would be consumed locally. Our data set and estimates provide a framework for future improvement and hopefully make is type of information more widely available for policy formulation and fisheries governance.

