

# The Nekton Maldives taxonomic workshop: Exploring the biodiversity of shallow, mesophotic and deep-sea communities in Maldives

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## Abstract

The Nekton Maldives Taxonomic Workshop took place at the Maniyafushi Research Station in the Maldives between 12 and 23 February 2023. This workshop had two primary objectives. Firstly, it aimed to identify species from biological samples and underwater imagery collected during the Nekton Maldives Mission in 2022. Secondly, it sought to facilitate training and knowledge exchange sessions between early career researchers from the Maldives and international taxonomists. These sessions were designed to share knowledge and introduce fundamental taxonomy concepts and enhance practical identification skills for common reef benthic groups and major zooplankton taxonomic groups. A total of 24 people from 10 different countries were directly or indirectly involved with the workshop comprising nine taxonomic experts, eleven trainees and four organisers. Collectively, we identified 278 biological specimens including potentially undescribed species of hydroids, black corals, sponges and octocorals, 318 morphotypes for underwater footage and zooplankton composition congruent with previous reports from the Indian Ocean Region. Next steps will involve depositing the specimens into a more a permanent facility to facilitate the process of specimen description and knowledge transfer.

## Keywords

coral reefs, benthos, fish, knowledge exchange, capacity building, Indian Ocean

## Background

The Maldives Archipelago extends 870 km along longitude, from 7 degrees north to half a degree south of the Equator. It consists of 27 atolls and roughly 1192 islands and sandbanks, as documented by Stevens and Froman (2019). With more than 99% of its territory covered by water, the Maldives is a large ocean state within the Indian Ocean, with a vast exclusive economic zone (916,000 km<sup>2</sup>) and territorial waters area (67,000 km<sup>2</sup>). The Maldives' proximity to the ocean plays a pivotal role in its national success, as the country benefits immensely from the resources and opportunities the ocean offers. This vast water body delivers crucial ecosystem services, including food production, climate regulation and cultural benefits. The two primary sectors, tourism and fisheries, rely heavily on the ocean and its bounty. The tourism industry contributes significantly to the Maldives' GDP, while the fishing industry stands as one of the primary employment sources. The unique geographical makeup of the Maldives, combined with its vast oceanic territory, has cultivated an economy and culture deeply connected with the myriad resources and opportunities the ocean provides.

Largely comprised of coral atolls, coral reefs are an important component of the marine system in the Maldives. The size, complexity and rich diversity make the coral reefs of the Maldives globally significant, containing 3.1% of the world's coral reefs (Spalding et al. 2001). They support at least 248 species of zooxanthellate corals and 1,123 fish species, 883 of which are reef-dependent (<http://www.fishbase.org>). Most of the previous marine research in the Maldives has focused on reef-building scleractinian corals inhabiting shallow-waters, accessible by snorkelling or SCUBA (< 30 m) (Morri et al. 1995, Morri et al. 2015) or fisheries-targeted taxa, such as sea cucumbers (MEE 2017), reef-associated fish, for example, groupers and snappers (Sattar et al. 2011) and larger pelagic species, for example, Skipjack (*Katsuwonus pelamis*) and yellowfin (*Thunnus albacares*) tuna (Ahusan et al. 2018, Jauharee et al. 2021). Some of the early explorations of the Maldivian coral reefs include the Gardiner expedition 1899-1900; that of Agassiz in 1901-2; the Xarifa expedition, 1957-58; and the expedition to Addu atoll led by Dr. D.R. Stoddart in 1964 (Dryden et al. 2020). Since 1970, there has been a wealth of data derived from reef monitoring (e.g. Maldives coral reef monitoring since 1998, MEE (2017); the Noo Raajje expedition in 2021, Raajje (2021)) and on pelagic megafauna, such as manta rays and whale sharks (Anderson 2005, Stevens 2016). However, deeper benthic fauna, in mesophotic (30-150 m), rariphotic (150-300 m) and deep-sea reefs (> 300 m), are poorly explored and remain largely unknown. These provide many of the same ecosystem services as shallow coral reefs and act as refugia for several commercially important organisms, some which are threatened in shallow water (Holstein et al. 2019).

## The Nekton Maldives Mission (September - October 2022)

The Nekton Maldives Mission aimed to investigate shallow and deeper water reefs of the Maldives (surface to ~ 1000 m), documenting biological communities, diversity and

associated environmental conditions. The collected data will support a better understanding of the Maldives' deep ocean marine ecosystems and their current state and will help to clarify the impact of human activities on these living systems. Additionally, the data will be used to investigate the biogeographic patterns of life across the Indian Ocean. The scientific study of the Maldives' deep ocean ecosystems is critical for providing data that provides information for decision-making regarding sustainable management and conservation of marine resources.

The fieldwork for the Expedition took place between the 4 September and 6 October 2022 onboard the *RV Odyssey*. It focused on seven sites, stretching from N Malé to Addu Atoll, covering a distance of 590 km in latitude (Fig. 1). Focusing on the N-NE aspects of the atolls, seven sites were documented across a range of biological and environmental parameters. Due to poor weather conditions, only a subset of surveys were made in one the sites (Favuhmulah) and solely multibeam data and environmental DNA data in another site (seamount *Satho Raha*). The expedition documented marine life and the environmental conditions they thrive in, from the surface down to approximately 900 m. Video transect surveys were conducted up to 500 m, baited videos captured footage up to 900 m and biological sample collections reached depths of 900 m. In total, the expedition made 352 deployments (submersible, remotely-operated vehicle and snorkel-transect surveys, CTD casts, neuston and mid-water zooplankton tows, baited remote underwater video and multibeam surveys) and collected more than 800 biological samples.

## **Nekton Maldives Taxonomic Workshop**

The taxonomic workshop was identified as a key post-expedition activity during the inception of the scientific programme. This workshop was designed both to accelerate the identification of collected data and specimens and to share knowledge about taxonomy amongst researchers at different career stages. The Workshop was co-organised by Maldives Marine Research Institute (MMRI) and Nekton and conducted at Maniyafushi Research Station on Maniyafushi, Maldives between 12 and 23 February 2023.

The workshop structure follows:

1. Focused identification sessions: Which comprised the identification of biological organisms from samples and video footage collected during the Expedition. This took place between 12 and 16 February 2023 with taxonomic experts and staff from Nekton and MMRI.
2. Taxonomic knowledge exchange and learning sessions (Table 2): Which focused on Maldivian early career researchers interacting with established taxonomists to introduce the basic concepts of taxonomy and to develop practical identification skills of common reef benthic groups, as well as major taxonomic groups of zooplankton, representative of the samples collected during the expedition. Taxonomic training consisted of in-person and online lectures, hands-on laboratory sessions with collected specimens and samples, as well as a short introduction to video annotation methods, which took place between 18 and 22 February 2023 and

both taxonomists and trainees participated. Lectures were recorded and together with other training material shared with trainees.

A total of 24 people from 10 different countries were directly or indirectly involved with the workshop, with diverse affiliations ranging from Universities and Research Institutes to Governmental Departments and Non-Governmental Organisations (Table 1; Fig. 2). Nine were taxonomic experts covering benthic (sponges, black corals, octocorals, hard corals, brittle stars) and planktonic (copepods, decapods, molluscs, larval fish) groups. Four of those physically attended the workshop and provided hands-on training sessions and lectures, while five joined remotely to give online lectures. A total of 13 individuals Maldives participated in the workshop.

## **Preliminary Results and Outputs**

During the workshop, we identified 271 biological specimens including octocorals (49), ophiuroids (brittle stars) (39), decapods (28), antipatharians (black corals) (25), sponges (18) and other groups. In addition, we identified at least 318 morphotypes (morphologically similar individuals that often corresponded to genus or family-level and more rarely to species-level classifications) from underwater footage (e.g. Fig. 3) including 75 octocorals, 65 scleractinians (hard corals), 52 sponges, 25 asteroids (sea stars), 21 black corals, 15 hydroids, 14 decapods (shrimps, lobsters, crabs), 12 actinarians (sea anemones), nine holothurians (sea cucumbers), eight sea urchins, seven gastropods, five bivalves, four ascidians, four zoanthids and two brittle stars. Due to limited time, limited equipment availability (e.g. no scanning electron microscopy and molecular lab) and the need to compare new specimens with type material stored in museum collections for species-level identification, specimen identification was typically limited to genus level. Despite this, we estimated that there could be a number of new species of hydroids, black corals, sponges and octocorals by the end of the workshop. Further in-depth examination of the specimens and genetic analysis is necessary to confirm these preliminary findings. Furthermore, much of the material collected from below > 60 m are likely new records for the Maldives, with possible depth range extensions globally, which may significantly increase the living space of those organisms. Comparing these preliminary findings with data from Seychelles (Stefanoudis et al. 2023), it seems that there is a more diverse black coral fauna in Maldives, although the opposite is true for sponges.

Preliminary screening of zooplankton samples revealed a great diversity of taxonomic groups, with copepods, appendicularians, chaetognaths, gastropods and decapod larvae dominating communities, which was congruent with previous reports from the Indian Ocean Region (Vineetha et al. 2018, Fernandes and Ramaiah 2019, Wimalasiri et al. 2021, Jagadeesan et al. 2013). A practical guide to the most common copepod genera of Maldives was created during the workshop, that can serve as a starting point for future zooplankton studies in Maldives.

Taxonomic knowledge exchange and learning sessions proved successful and beneficial for the participants. In total, 12.5 hours of lectures were delivered, 7 hours in-person and 5

hours online. Additionally, participants received 22 hours of hands-on lab practice on different aspects of taxonomic identification, including sub-sampling from specimens, sample processing, preservation, curation and making permanent slides for detailed analysis. Most importantly, the experts guided the participants on identifying specimens, based on macro and microscopic morphological features.

## Natural History Observations

During the 2-week workshop, several encounters with marine fauna were made. Snorkelling excursions around the island after the end of lectures/practicals and in a nearby sandbank about 2 km north of Maniyafushi during the weekend, resulted in frequent observations of the reef-building genera *Porites* (including massive colonies and the branching *Porites rus*) and *Pocillopora*, with crustose coralline algae, soft corals (e.g. *Sarcophyton*) also occasionally common. The most common reef fishes included red snapper (*Lutjanus bohar*), surgeonfish (e.g. *Acanthurus leucosternon*), triggerfish (Balistidae) and damselfish (Pomacanthidae). Juveniles of black-tip and white-tip reef sharks (*Carcharhinus melanopterus* and *Triaenodon obesus*) were also observed during snorkel surveys.

Bioluminescence was commonly observed at night (Fig. 4). After collection of some samples and analysis in the lab, it was confirmed to be caused by ostracods (Myodocopida, Cypridinidae) (Morin 2019).

Finally, one of the most iconic animals that inhabit Maniyafushi were ghost crabs (*Ocypode*). Their burrows form an integral part of the coastal landscape (Fig. 4).

## Next steps

The authors believe the specimens collected from the expedition are the first major collection of taxa greater than 30 m from the Maldives. The specimens currently stored in preservation fluids, primarily ethanol and kept refrigerated at Maniyafushi. However, due to the pressing need for proper storage facilities, MMRI and Nekton are actively seeking a suitable partner to loan the specimens to until the Maldives establishes the necessary infrastructure and skills to maintain them indefinitely.

Furthermore, any descriptions of new species can only be published once the specimens have been assigned an accession number and deposited in a museum or another registered institution. Therefore, the specimens need to be deposited into a better storage facility to ensure that their scientific value is not compromised.

To facilitate the process of specimen description and knowledge transfer, MMRI and Nekton have engaged experts who are interested in working with the specimens. They aim to establish a collaborative mechanism to enable knowledge and expertise transfer to occur alongside the process of specimen description. This will involve sharing expertise in

taxonomy, systematics and other relevant fields to ensure the accurate identification and description of the collected specimens.

In summary, the next steps involve depositing the specimens into a more resilient storage facility until a permanent facility can be identified and collaborating with experts to facilitate the process of specimen description and knowledge transfer. This will ensure that the scientific value of the specimens is preserved and they can be used to advance understanding of deep-sea taxa from the Maldives.

## **Acknowledgements**

We acknowledge the hospitality of the staff at Maniyafushi, who went beyond their duties to make the participant's stay enjoyable and feel welcomed. We also thank Denise Swanborn for producing Figure 1.

Since this workshop would not have been possible without the samples and data collected during the Nekton Maldives Mission, we would like to thank the extensive coalition of partners with diverse skills and backgrounds who made the expedition possible.

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This is Nekton Contribution No 37.

## Hosting institution

Maldives Marine Research Institute

## Ethics and security

All biological specimens processed during the workshop had appropriate permits in place, issued by the Government of Maldives.

## Author contributions

M.A. and P.V.S. prepared the original draft of the report. All authors contributed, provided feedback, reviewed and approved the final version.

## Conflicts of interest

The authors have declared that no competing interests exist.

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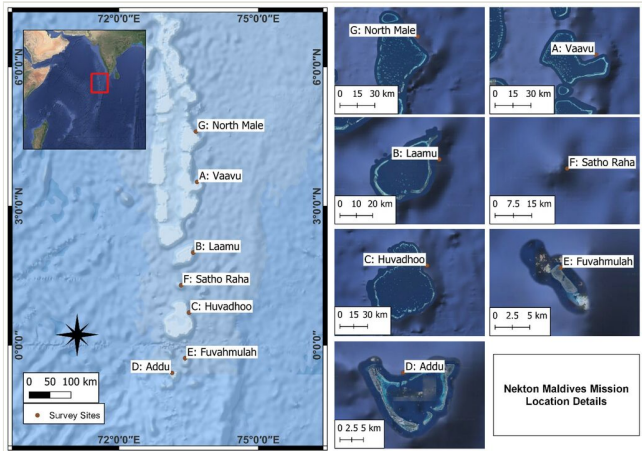


Figure 1.  
Survey sites investigated during the Nekton Maldives Mission.



Figure 2.

Workshop Group Photo. Bottom left to right: Hassan Ahmed, Farah Amjad, Nuria Rico-Seijo, Hawwa Nabaaha Nashid, Fathimath Shazra Mueen, Fathmath Shuhaina and Eenas Mohamed Riyaz. Top left to right: Ahmed Haiman Rasheed, Raidh Ameen, Hussain Khalid, Kaveh Samimi-Namin, Toufiek Samaai, Dave Conway, Paris Stefanoudis, Mohammed Ahusan, Ibrahim Yaish, Erika Gress, Ahmed Fizal and Irthisham Zareer.

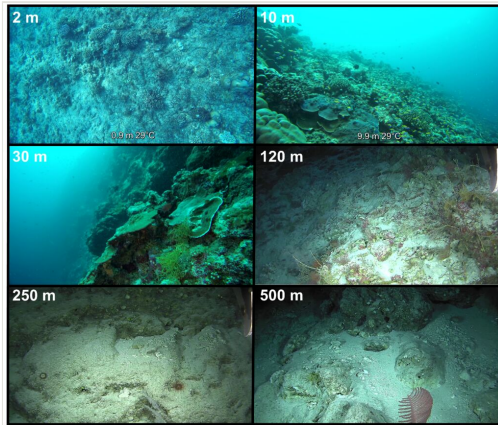


Figure 3.  
Representative habitats per surveyed depth in Fuvahmulah.



Figure 4.  
Bioluminescence observations (top) and ghost crab burrows (bottom) on the beaches of Maniyafushi.

Table 1.

List of participants, their role and affiliation.

Name	Role	Affiliation	Country of Institutional Affiliation	Country of Origin
Mohammed Ahusan	Co-organiser; Fisheries Researcher	Maldives Marine Research Institute	Maldives	Maldives
Farah Amjad	Co-organiser; Benthic Ecologist	Nekton Foundation	Maldives	Maldives
Nuria Rico Seijo	Co-organiser; Zooplankton Ecologist	Nekton Foundation	United Kingdom	Spain
Paris Stefanoudis	Co-organiser; Benthic and Fish Ecologist	Nekton Foundation; University of Oxford	United Kingdom	Greece
Dave Conway	Zooplankton Taxonomist	Marine Biological Association of the UK	United Kingdom	United Kingdom
Erika Gress	Black Coral Taxonomist	James Cook University	Australia	Mexico
Toufiek Samaai	Sponge Taxonomist	Department of Forestry, Fisheries and the Environment	South Africa	South Africa
Kaveh-Samimi Namin	Octocoral Taxonomist	Naturalis Biodiversity Center	Netherlands	Iran
Maria Moreno Alcántara*	Mollusc Taxonomist	Universidad Autónoma de Nayarit	Mexico	Mexico
Jennifer Olbers*	Brittle and Basket Star Taxonomist	WildTrusts	South Africa	South Africa
Sylvia Jiménez Rosenberg*	Ichthyoplankton Taxonomist	CICIMAR-IPN	Mexico	Mexico
Mariyam Shidha Afzal*	Hard coral Taxonomist	University of the Ryukyus	Japan	Maldives
Udeshika Wimalasiri*	Copepod Taxonomist	Institute of Tropical Marine Science	Sri Lanka	Sri Lanka
Hassan Ahmed	Trainee	Save the Beach Maldives	Maldives	Maldives
Raidh Ameen	Trainee	Small Island Research Group	Maldives	Maldives
Ahmed Fizal	Trainee	Individual	Maldives	Maldives
Irthisham Hassan	Trainee	Maldives whale shark research programme	Maldives	Maldives
Hussain Khalid	Trainee	Individual	Maldives	Maldives
Fathimath Shazra Mueen	Trainee	Maldives Marine Research Institute	Maldives	Maldives
Hawwa Nabaaha Nashid	Trainee	Ministry of Environment, Climate Change and Technology	Maldives	Maldives

Ahmed Haiman Rasheed	Trainee	MTCC	Maldives	Maldives
Eenas Mohamed Riyaz	Trainee	Environment Protection Agency	Maldives	Maldives
Fathmath Shuhaina	Trainee	Baros Maldives - Universal Enterprise	Maldives	Maldives
Ibrahim Yaish	Trainee	Maldives Marine Research Institute	Maldives	Maldives
*Indicates taxonomists that participated in the workshop remotely, by giving an online lecture.				

Table 2.

The agenda of the training-component of the workshop.

19 Feb 2023	20 Feb 2023		21 Feb 2023	22 Feb 2023	23 Feb 2023
0800-0830 Lecture - Nekton Maldives Mission (Paris Stefanoudis)	0800-0830 Lecture - Nekton Maldives Mission Sample Collection (Nuria Rico Seijo)		0800-0900 Online Lecture - Fish larvae (Sylvia Jiménez Rosenberg)	0800-0900 Online Lecture - Molluscs (María Moreno)	0900-1000 Lecture on Maldives Marine Research Institute Current Research (Mohamed Ahusan) + Group Photo
0830-1000 Participant Speed Presentations	0830-0900 Lecture - Nekton Maldives Mission Video Collection (Paris Stefanoudis)				
	0900-1000 Lecture - Black Corals (Erika Gress)				
1000-1100 Welcoming Ceremony by the Minister of Fisheries	1000-1030 Tea Break		1000-1030 Tea Break	1000-1030 Tea Break	1000-1200 Sample curation; Cleaning lab spaces; Packing
	10.30-11.30 Lecture – Octocorals (Kaveh Samimi-Namin)		1030-1130 Online Lecture - Brittle Stars (Jennifer Olbers)	1030-1130 Online Lecture - Scleractinians (Mariam Shida)	
1100-1200 Lecture - Zooplankton (Dave Conway)	1130-1200 Taster ID and training session (Group A) - Black Corals (Erika Gress)	1130-1200 Taster ID and training session (Group B) - Octocorals (Kaveh Samimi-Namin)	1130-1200 Studying samples related to the lectures / Zooplankton net sampling demonstration	1130-1200 Looking at samples related to the lectures	
1200-1300 Lunch Break	1200-1300 Lunch Break		1200-1300 Lunch Break	1200-1300 Lunch Break	1200-1300 Lunch Break
1300-1400 Lecture – Sponges (Toufiek Samaai)	1300-1400 Taster ID and training session (Group A) (continued) - Black Corals (Erika Gress)	1300-1400 Taster ID and training session (Group B) (continued) - Octocorals (Kaveh Samimi-Namin)	1300-1400 Studying samples related to the lectures (continued)	1300-1400 Looking at samples related to the lectures (continued)	1300-1600 Sample curation; Cleaning lab spaces; Packing

1400-1530 Taster ID and training session (Group A) - Sponges (Toufiek Samaai)	1400-1530 Taster ID and training session (Group B) - Zooplankton (Dave Conway)	1400-1530 Taster ID and training session (Group B) - Black Corals (Erika Gress)	1400-1530 Taster ID and training session (Group A) - Octocorals (Kaveh Samimi- Namin)	1400-1545 In-depth ID and training session - Octocorals (Kaveh Samimi- Namin)	1400-1545 In-depth ID and training session - Copepods and Fish larvae (Dave Conway & Nuria Rico- Seijo)	1400-1545 Training session - Video Morphotype Screening and Intro to SeaGIS Video Annotation Software (Paris Stefanoudis & Farah Amjad)	1615-1800 In-depth ID and training session - Other zooplankton groups not covered in lectures (Dave Conway & Nuria Rico- Seijo)	1700 - All transported to Male
1530-1615 Tea Break		1530-1615 Tea Break		1545-1615 Tea Break		1545-1615 Tea Break		
1615-1745 Taster ID and training session (Group B) - Sponges (Toufiek Samaai)	1615-1745 Taster ID and training session (Group A) - Zooplankton (Dave Conway)	16.15-17.15 Lecture Decapods (Dave Conway)		1615-1800 In-depth ID and training session - Black Corals (Erika Gress)	1615-1800 In-depth ID and training session - Decapods (Dave Conway & Nuria Rico- Seijo)	1615-1800 In-depth ID and training session - Sponges (Toufiek Samaai)	1615-1800 In-depth ID and training session - Molluscs (Dave Conway & Nuria Rico- Seijo)	