Deep reef ecosystems of the Western Indian Ocean: addressing the great unknown

Abstract

Indian Ocean coral reef ecosystems are some of the least explored, least funded and least protected worldwide. "First Descent: Indian Ocean" represents a series of research expeditions undertaken by Nekton between 2018-2022 in partnership with Governments in the Indian Ocean region to contribute to establishing a baseline of marine life and catalyse 30% protection by 2030. Two recent expeditions, the 2018 WILDOCEANS/ACEP Comoros Mesophotic Biodiversity Expedition (led by WILDTRUST), and the 2019 First Descent: Seychelles (led by Nekton Foundation) systematically surveyed deeper reef ecosystems in those areas, resulting in collections of biological material and underwater footage.

In August 2019, taxonomic experts from across the globe, attended a workshop in order to identify the collected material and provide a first snapshot of the diversity of the surveyed habitats. Part of the workshop also focused on providing taxonomic training to host nation scientists and early career researchers.

This document is a report on the proceedings and some of the first outcomes of this workshop.
Keywords

Taxonomy, training, deep reefs, corals, sponges, Western Indian Ocean, Seychelles, Comoros, South Africa

Date and place

The taxonomic workshop was held at the National Research Foundation, South African Institute of Aquatic Biodiversity (NRF-SAIAB) in Grahamstown between the 1st to the 9th of August 2019.

List of participants

The workshop was divided in 2 parts:

- Part 1 (01.08.2019 – 05.08.2019) was attended by taxonomic experts only, who worked together in order to identify the collected biological specimens, and process the associated underwater footage.
- Part 2 (06.08.2019 – 09.08.2019) also included host nation scientists and early-career researchers, who were trained in the identification of the major groupings represented in the collected samples and imagery.

A total of 28 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.

Sixteen were taxonomic experts covering all major benthic groups. Six of those physically attended the workshop and provided hands-on training sessions and lectures, five joined remotely to give online lectures, and a further five were involved with identification of specimens post-workshop.

Finally, a total of nine individuals from Seychelles, Comoros and South Africa joined for the training session.

For a full list of participants see Table 1.

| Name            | Role                  | Affiliation       | Country of Institution | Nationality of individual |
|-----------------|-----------------------|-------------------|------------------------|--------------------------|
| Lucy Woodall    | Organiser; Benthic ecologist | University of Oxford | UK                     | UK                       |
| Name               | Role                      | Affiliation                                         | Country of Institution | Nationality of individual |
|--------------------|---------------------------|-----------------------------------------------------|------------------------|---------------------------|
| Paris Stefanoudis  | Organiser; Benthic ecologist | University of Oxford                                | UK                     | Greece                    |
| Sheena Telma       | Organiser                 | Ministry of Environment, Energy and Climate Change  | Seychelles             | Seychelles                |
| Kaveh-Samimi Namin*| Organiser; Octocoral Taxonomist | University of Oxford                                | UK                     | Iran                      |
| Carlos Moura       | Hydrozoan Taxonomist       | University of Azores                                 | Portugal               | Portugal                  |
| Jennifer Olbers    | Ophiuroid Taxonomist       | Ezemvelo KZN Wildlife                                | South Africa           | South Africa              |
| Liesl Janson       | Sponge Taxonomist          | Department of Environmental Affairs                  | South Africa           | South Africa              |
| Monika Bryce       | Octocoral Taxonomist       | Western Australia Museum                             | Australia              | Austria                   |
| Robyn Payne        | Sponge Taxonomist          | University of Western Cape                           | South Africa           | South Africa              |
| Toufiek Samaai     | Sponge Taxonomist          | Department of Environmental Affairs                  | South Africa           | South Africa              |
| Catherine McFadden*| Octocoral Taxonomist       | Harvey Mudd College                                  | USA                    | USA                       |
| Chris Mah*         | Sea star Taxonomist        | Smithsonian National Museum of Natural History       | USA                    | USA                       |
| Daniel Wagner*     | Black Coral Taxonomist     | NOAA                                                 | USA                    | USA                       |
| Rowana Walton*     | Scleractinian Taxonomist   | Consultant                                           | UK                     | UK                        |
| Charles Messing**  | Crinozoa Taxonomist        | Nova Southeastern University                         | USA                    | USA                       |
| Paul Clark**       | Brachyuran Crab Taxonomist | Natural History Museum London                        | UK                     | UK                        |
| Sammy De Grave**   | Caridean Shrimp Taxonomist | Oxford Museum of Natural History                    | UK                     | UK                        |
| Wayne Florence**   | Bryozoan Taxonomist        | Iziko South African Museum                           | South Africa           | South Africa              |
| Zoleka Filander**  | Sea Urchin Taxonomist      | Department of Environmental Affairs, South Africa    | South Africa           | South Africa              |
| Ashley Pothin      | Trainee                   | Ministry of Environment, Energy and Climate Change   | Seychelles             | Seychelles                |
| Name             | Role          | Affiliation                        | Country of Institution | Nationality of individual |
|------------------|---------------|-----------------------------------|------------------------|---------------------------|
| Ayesha Bobat     | Trainee       | WildTrust                         | South Africa           | South Africa              |
| Gilberte Gendron | Trainee       | Seychelles National Park Authority| Seychelles             | Seychelles                |
| Kady Ramjattan   | Trainee       | WildTrust                         | South Africa           | South Africa              |
| Louw Kyss        | Trainee       | Rhodes University                 | South Africa           | South Africa              |
| Rabia Somers     | Trainee       | Marine Conservation Society       | Seychelles             | Seychelles                |
| Ramadhoini Ali   | Trainee       | University of Comoros             | Comoros                | Comoros                   |
| Richard Jeanne   | Trainee       | Green Islands Foundation          | Seychelles             | Seychelles                |
| Stuart Laing     | Trainee       | University of Seychelles          | Seychelles             | South Africa              |

*Indicates taxonomic experts that could not attend the workshop, but gave a remote lecture
**Indicates taxonomic experts that could not attend the workshop, but who will process biological samples post-workshop

**Background**

The Indian Ocean is among the least known ([http://www.obis.org](http://www.obis.org)), least funded (<2% of all financial commitments at Our Oceans 2018 was aimed for the Indian Ocean) and least protected water mass ([http://www.mpatlas.org](http://www.mpatlas.org)), with its coastal population highly reliant on seafood harvests (e.g. Obura et al. 2017). Global threats from the consequences of climate change (e.g. increased storm intensity and increased frequency and severity of coral bleaching events), and local effects of human activities (e.g. fishing, pollution) are evident and cumulative (e.g. Hoegh-Guldberg et al. 2014, Breitburg et al. 2018, Watson et al. 2012), highlighting the need for a better understanding and management of Indian Ocean marine ecosystems.

Most of the past and present reef surveys and monitoring efforts in the Indian Ocean have been focusing on shallow-waters (≤30 m), leaving adjacent, deeper mesophotic (30‒150 m) habitats understudied (Pyle and Copus 2019). Much less is known about species connectivity between the mesophotic zone and those that inhabit deeper reef habitats, such as those located in the rariphotic zone (150‒300m). If we are to sustainably manage and conserve those deeper reef habitats to help ensure they thrive and provide a full range of ecosystem services, it is imperative to know what lives there.

Nekton Foundation launched “**First Descent: Indian Ocean**”, a series of research expeditions to take place between 2018-2022 in order to contribute to establishing a baseline of marine life in the Indian Ocean and address the issues raised above. In 2018, Nekton successfully collaborated with other research organisations ([WildTrust](http://www.wildtrust.org)) to conduct
field research in Comoros, and in 2019 completed its first major research expedition in Seychelles, working with, and on behalf of the Government of Seychelles.

During 48 days the First Descent expedition collected hundreds of biological samples from depths between 10–250 m. The real challenge, however, was still ahead: the processing, statistical analysis, and interpretation of the collected marine data. Taxonomic workshops represent invaluable tools to expedite this process. These events represent a unique opportunity to bring together participating scientists and taxonomic experts across the globe, in order to accelerate the taxonomic identification and analysis. At the same time, if designed appropriately, they can also provide training to early career researchers from the world's best experts, thus ensuring that taxonomic knowledge and expertise is passed on to the next generation of marine scientists.

Aims of the workshop

The aims of the workshop were two-fold:

1. To accelerate the assessment of the deeper reef biodiversity of the Western Indian Ocean (WIO) fauna and flora, by examining biological specimens and underwater footage collected during the 2019 First Descent: Seychelles expedition. Additional specimens collected in the Comoros Archipelago during the 2018 WILDOCEANS/ACEP Comoros Mesophotic Biodiversity Expedition (led by WILDTRUST) were also included to better understand community similarities between those neighbouring regions.

2. Provide training to host nation scientists and early career researchers on mesophotic and deeper benthic organisms, including corals, sponges and other invertebrates, which will help contribute towards creating a legacy for long-term research and effective science-based ocean management for marine biodiversity.

Agenda

During the first part of the workshop, the majority of activities took place in a laboratory setting in order to facilitate the identification of collected specimens by the taxonomists. During the training part, it was a mixture of lectures introducing the trainees to the major benthic taxonomic groups typical in reef habitats, followed by hands-on practical sessions with representative samples from some of these groups (see Fig. 1). Other events included a safari trip, and post-workshop social gatherings, which gave the participants the opportunity to get to know each other better and network. A full list of the activities that took place can be found on the workshop's agenda in Table 2.
| Date     | Time         | Activity                                           | Place          | Responsible    |
|----------|--------------|----------------------------------------------------|----------------|----------------|
| 01-08-19 | 09:00-09:30  | Introduction to taxonomic experts and safety tour | Library        | Lucy Woodall   |
|          | 09:30-10:00  | Coffee break                                      | Library        |                |
|          | 10:00-12:30  | ID session 1                                       | Laboratory     | All taxonomic experts |
|          | 12:30-13:30  | Lunch break                                        | Cafeteria      |                |
|          | 13:30-15:00  | ID session 2                                       | Laboratory     | All taxonomic experts |
|          | 15:00-15:30  | Coffee break                                       | Cafeteria      |                |
|          | 15:30-16:30  | ID session 3                                       | Laboratory     | All taxonomic experts |
|          | 16:30-17:30  | Catch up session                                   | Laboratory     | Lucy Woodall   |
|          | 19:00        | Networking event                                   | Local venue    | All participants |
| 02-08-19 | 08:45-10:30  | ID session 1                                       | Laboratory     | All taxonomic experts |
|          | 10:30-11:00  | Coffee break                                       | Library        |                |
|          | 11:00-12:30  | ID session 2                                       | Laboratory     | All taxonomic experts |
|          | 12:30-13:30  | Lunch break                                        | Cafeteria      |                |
|          | 13:30-15:00  | ID session 3                                       | Laboratory     | All taxonomic experts |
|          | 15:00-15:30  | Coffee break                                       | Library        |                |
|          | 15:30-16:45  | ID session 4                                       | Laboratory     | All taxonomic experts |
|          | 16:45-17:00  | Catch up session                                   | Laboratory     | Lucy Woodall   |
|          | 19:00        | Networking event                                   | Local venue    | All participants |
| 03-08-19 | 08:45-10:30  | ID session 1                                       | Laboratory     | All taxonomic experts |
|          | 10:30-11:00  | Coffee break                                       | Library        |                |
|          | 11:00-13:00  | ID session 2                                       | Laboratory     | All taxonomic experts |
|          | 19:00        | Networking event                                   | All participants |
| 04-08-19 |             | Safari trip to Addo Elephant National Park         | All participants |                |
| 05-08-19 | 08:45-10:30  | ID session 1                                       | Laboratory     | All taxonomic experts |
|          | 10:30-11:00  | Coffee break                                       | Library        |                |
|          | 11:00-12:30  | ID session 2                                       | Laboratory     | All taxonomic experts |
|          | 12:30-13:30  | Lunch break                                        | Cafeteria      |                |

Table 2. Agenda for the Workshop.
| Date       | Time           | Activity                                           | Place          | Responsible                                                                 |
|------------|----------------|----------------------------------------------------|----------------|----------------------------------------------------------------------------|
| 06-08-19   | 08:45-09:15    | Introduction to trainees and safety tour           | Library        | Lucy Woodall                                                               |
|            | 09:15-10:00    | Lecture 1 - Scleractinian Taxonomy*                | Library        | Rowana Walton                                                              |
|            | 10:00-12:30    | Lecture 2 - Sponge Taxonomy                        | Library        | Toufiek Samaai                                                             |
|            | 11:00-12:30    | ID training session 1: Sponges                     | Laboratory     | Toufiek Samaai, Liesl Janson, Robyn Payne                                 |
|            | 12:30-13:30    | Lunch break                                       | Cafeteria      |                                                                           |
|            | 13:45-15:00    | ID training session 2: Sponges                     | Library        | Toufiek Samaai, Liesl Janson, Robyn Payne                                 |
|            | 15:00-15:30    | Coffee break                                       | Library        |                                                                           |
|            | 15:30-16:30    | Lecture 3 - Sea Star Taxonomy*                     | Library        | Chris Mah                                                                  |
|            | 16:30-17:00    | Catch up session                                  | Laboratory     | Lucy Woodall                                                               |
|            | 19:00          | Networking event                                  | Local venue    | All participants                                                            |
| 07-08-19   | 08:45-09:45    | Lecture 1 - Hydrozoan Taxonomy                     | Library        | Carlos Moura                                                               |
|            | 09:45-10:00    | Coffee break                                       | Library        |                                                                           |
|            | 10:00-11:00    | Lecture 2 - Octocoral Sample Collection, Processing and Identification Techniques* | Library        | Kaveh Samimi-Namin                                                         |
|            | 11:00-12:30    | ID training session 1: Octocorals                 | Laboratory     |                                                                           |
|            | 12:30-13:30    | Lunch break                                       | Cafeteria      |                                                                           |
|            | 13:30-14:00    | Lecture 3 - Octocoral Taxonomy                     | Library        | Monika Bryce                                                               |
|            | 14:00-15:00    | ID training session 2: Octocorals                 | Laboratory     | Monika Bryce                                                               |
|            | 15:00-15:30    | Coffee break                                       | Library        |                                                                           |
| Date          | Time           | Activity                                                                 | Place                  | Responsible                      |
|--------------|----------------|--------------------------------------------------------------------------|------------------------|----------------------------------|
|              | 15:30-16:00    | Lecture 4 - Ophiuroid Taxonomy                                           | Library                | Jennifer Olbers                  |
|              | 16:00-17:00    | ID training session 3: Ophiuroids                                        | Laboratory             | Jennifer Olbers                  |
|              | 17:00-18:00    | Lecture 5 - Octocoral Systematics*                                       | Library                | Catherine McFadden                |
|              | 19:00          | Networking event                                                          | Local venue            | All participants                 |
| 08-08-19     | 08:45-09:30    | ID training session 1: Using Underwater Benthic Footage                  | Library                | Paris Stefanoudis                |
|              | 09:30-10:00    | Coffee break                                                              | Library                |                                  |
|              | 10:00-12:30    | ID training session 2: Focus on Underwater Benthic Footage               | Library                | Paris Stefanoudis                |
|              | 12:30-13:30    | Lunch break                                                               | Cafeteria              |                                  |
|              | 13:30-15:00    | ID training session 3: Focus on Underwater Benthic Footage               | Library                | Paris Stefanoudis                |
|              | 15:00-15:30    | Coffee break                                                              | Library                |                                  |
|              | 15:30-16:45    | ID training session 4: Free session customised to trainees' needs        | Laboratory             | All taxonomic experts            |
|              | 16:45-17:00    | Catch up session                                                          | Laboratory             | Paris Stefanoudis                |
|              | 19:00          | Networking event                                                          | Local venue            | All participants                 |
| 09-08-19     | 08:45-10:00    | Practical Session: Using z-stacking in a Stereomicroscope                | Laboratory             | Jennifer Olbers                  |
|              | 10:00-10:30    | Coffee break                                                              | Library                |                                  |
|              | 10:30-12:30    | ID training session 1: Free session customised to trainees' needs        | Laboratory             | All taxonomic experts            |
|              | 12:30-13:30    | Lunch break                                                               | Cafeteria              |                                  |
|              | 13:30-15:00    | Cleaning lab and curating samples                                        | Laboratory             | All taxonomic experts, Paris Stefanoudis and Sheena Talma |
|              | 15:00-16:00    | Lecture 1 - Black Coral Taxonomy*                                         | Library                | Daniel Wagner                     |
|              | 16:00-16:15    | Wrap-up session                                                           | Library                | Paris Stefanoudis                |
|              | 19:00          | Networking event                                                          | Local venue            | All participants                 |

*Indicates lecture given remotely
Key outcomes and discussions

During the workshop, we identified a total of 632 biological samples from the Seychelles expedition, including subsamples of larger organisms taken for post-workshop molecular and scanning electron microscopy work. These included (in decreasing order): 189 sponges, 99 octocorals, 67 brittle stars, 52 crabs, 36 hydroids, 19 sea urchins, 17 shrimps, 14 crinoids, 12 gastropods, 10 red algae, 9 sea stars, 9 polychaetes, 8 green algae, 7 bryozoans, 6 bivalves. The remaining 78 was a combination of other taxonomic groups and fin clips of fish, the latter to be used to facilitate an additional study led by one of the participants.

The respective numbers for the Comoros survey were 44 biological samples: 20 octocorals, 7 sponges, 3 crinoids and 14 belonging to other groups.

We also reviewed hundreds of taxa in their natural environment by examining the rich underwater footage collected from both research expeditions.

As a result of the participating experts it was possible, in just two weeks, to gain first impressions of the diversity of Seychellois and Comorian reefs. This task would have taken months, or in some cases it would have not been possible at all, if it was tackled by a few individuals or one institution alone. Initial results, revealed numerous genera and species
of sponges and corals, many of which represented new records for Seychelles and Comoros and in some cases for the whole of the Indian Ocean, as well as significant depth range extensions, thus improving our knowledge of the biogeography for the region. Interestingly, taxonomic experts thought they found potentially dozens of new species, both from shallow and deeper waters, indicating that reefs in the WIO are still poorly known. Additional, more detailed taxonomic work will be required to confirm those initial beliefs in the coming months.

Through the lectures and practical laboratory sessions, host nation scientists and early career researchers were able to obtain a holistic understanding of the different benthic groups present in reef ecosystems, and the multitude of steps required to make accurate identifications. Participants learnt, that identification of physical samples is a time-consuming, yet necessary process, which typically involves the use of stereo- and light microscopes along with identification guides, but in many cases requires additional steps such as comparisons with type specimens in museum collections, or the use of scanning electron microscopy and DNA sequencing. For those dealing with identifications of specimens from underwater imagery and videos, it became clear that identification is often made to the lowest taxonomic level possible, which depending on the taxon might be to genus or family level. Furthermore, matching the commonly observed organisms in marine footage with physically collected samples, can enhance the taxonomic robustness of a study.

Conclusions

Overall, throughout the industrious nine days at NRF-SAIAB, we were able to enhance our taxonomic knowledge of the WIO reef fauna and provide networking opportunities and potentially foster new collaborations between scientists from the region. The provided training and knowledge exchange opportunities for host nation scientists and early career researchers, will hopefully prove useful in the coming years.

Acknowledgements

We wish to thank NRF-SAIAB for being such excellent hosts and providing assistance with all associated logistics. In particular we wish to thank Dr. Angus Patterson for enabling us to host the workshop in NRF-SAIAB, Naniswa Nyoka for assisting with catering, travel and accommodation of all participants, Nkosinathi Mazungula and Maditaba Meltaf for providing access to laboratory and video-conferencing facilities, and finally, the Seychelles Ministry of Environment Energy and Climate Change for facilitating the transfers of all genetic material from Seychelles to South Africa.

This is Nekton Contribution No. 18.
Hosting institution
National Research Foundation, South African Institute of Aquatic Biodiversity

Ethics and security
All biological specimens processed during the workshop had appropriate permits in place, issued by the Government of Seychelles.
No CITES listed specimens were used.

Conflicts of interest
We have no conflict of interest to report.

References

- Breitburg D, Levin LA, Oschlies A, Grégoire M, Chavez FP, Conley DJ, Garçon V, Gilbert D, Gutiérrez D, Isensee K, Jacinto GS, Limburg KE, Montes I, Naqvi SWA, Pitcher GC, Rabalais NN, Roman MR, Rose KA, Seibel BA, Telszewski M, Yasuhara M, Zhang J (2018) Declining oxygen in the global ocean and coastal waters. Science 359 (6371). https://doi.org/10.1126/science.aam7240
- Hoegh-Guldberg O, Cai R, Poloczanska ES, Brewer PG, Sundby S, Hilmi K, Fabry VJ, Jung S (2014) The Ocean. In: Barros VR, Field CB, Dokken DJ, Mastrandrea MD, Mach KJ, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (Eds) Climate Change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1655-1731 pp.
- Obura D, Smits M, Chaudhry T, McPhillips J, Beal D, Astier C (2017) Reviving the Western Indian Ocean Economy: Actions for a sustainable future. WWF International, Gland, Switzerland, 64 pp.
- Pyle R, Copus J (2019) Mesophotic Coral Ecosystems: Introduction and Overview. In: Loya Y, Puglise KA, Bridge TCL (Eds) Mesophotic coral ecosystems. Coral reefs of the World. Vol. 12. Springer, Cham. https://doi.org/10.1007/978-3-319-92735-0_1
- Watson RA, Cheung WWL, Anticamara JA, Sumaila RU, Zeller D, Pauly D (2012) Global marine yield halved as fishing intensity redoubles. Fish and Fisheries 14 (4): 493-503. https://doi.org/10.1111/j.1467-2979.2012.00483.x