Mesophotic Coral Ecosystems

A lifeboat for coral reefs?

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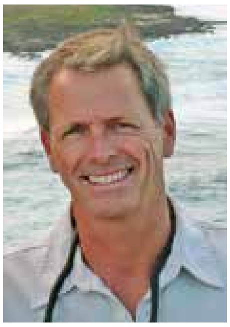

In memory of Dr. John J. Rooney (1960–2016) and his dedication to exploring and understanding mesophotic coral ecosystems.

Citation
Baker, E.K., Puglise, K.A. and Harris, P.T. (Eds.). (2016). *Mesophotic coral ecosystems — A lifeboat for coral reefs?* The United Nations Environment Programme and GRID-Arendal, Nairobi and Arendal, 98 p.

ISBN: 978-82-7701-150-9

Cover photo: Bright blue ascidians, known as sea squirts, are found thriving at 50 metres (164 feet) among corals, greenish brown algae (*Lobophora*) and red, orange, and brown sponges off La Parguera, Puerto Rico (photo Héctor Ruiz).

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Foreword

It should come as no surprise to you that coral reef ecosystems are in trouble. Humans have left an indelible mark on these ecosystems, resulting in almost 20 per cent of coral reefs disappearing. Unless we change the status quo, another 35 per cent are expected to be lost in the next 40 years.

Coral reefs provide both tangible and intangible benefits to the lives of millions of people. From providing food and income to protecting our coasts from damaging storms, coral reefs make an incalculable contribution to coastal communities, as well as to the organisms that depend on them.

Is there something we can do to help improve their chances of survival? In 2014, the United Nations Environment Programme convened a workshop to examine whether there were additional management strategies that we could employ to increase the resilience and resistance of coral reef ecosystems to arrest their decline. One of the recommendations of the *Scientific Workshop on Coral Reef Resilience in Planning and Decision-support Frameworks* was to develop knowledge products on emerging issues, such as investigating the role of little-known mesophotic coral reef ecosystems (MCEs) in coral reef resilience. Could these intermediate depth reefs serve as “lifeboats” for increasingly stressed coral reef ecosystems?

This report aims to address this question by bringing together thirty-five MCE experts from around the globe to document what is known about MCEs, the threats they face and the gaps in our understanding. MCEs are one of the few remaining ecosystems on earth that remain largely unexplored. While MCEs are deeper and more remote than shallow coral ecosystems, they are still subject to some of the same impacts such as bleaching and habitat destruction. We are just beginning to understand MCEs, but they have provided a glimmer of hope that, in some locations, they may resist some of the most immediate impacts of climate change, and may be able to help re-seed damaged or destroyed surface reefs and fish populations. Their ability to do this depends on how well we manage them.

I hope this report can help catalyze greater efforts to understand and protect mesophotic deep reefs, as a key part of efforts towards achieving the Sustainable Development Agenda and in particular target 14 on oceans.

Achim Steiner
UNEP Executive Director and Under-Secretary-General of the United Nations

Summary and recommendations

Picture a coral reef — most people will probably imagine brightly coloured corals, fish and other animals swimming in well-lit shallow waters. In fact, the coral reefs that live close to the surface of the sea — the ones that we can swim, snorkel, or dive near and see from space — are only a small portion of the complete coral reef ecosystem. Light-dependent corals can live in much deeper water (up to a depth of 150 m in clear waters). The shallow coral reefs from the surface of the sea to 30–40 m below are more like the tip of an iceberg; they are the more visible part of an extensive coral ecosystem that reaches into depths far beyond where most people visit. These intermediate depth reefs, known as mesophotic coral ecosystems (MCEs), are the subject of this report.

Although MCEs are widespread and diverse, they remain largely unexplored in most parts of the world, and there is little awareness of their importance among policy makers and resource managers. As a result, MCEs are for the most part not considered in conservation planning, marine zoning and other marine policy and management frameworks. The goal of this report is to raise awareness in policy makers and resource managers by providing an accessible summary on MCEs, including a discussion of the ecosystem services they provide, the threats they face, and the gaps in our understanding.

Mesophotic coral ecosystems (MCEs) are characterized by light-dependent corals and associated communities typically found at depths ranging from 30–40 m and extending to over 150 m in tropical and subtropical regions. They are populated with organisms typically associated with shallow coral reefs, such as corals, macroalgae, sponges, and fish, as well as species unique to mesophotic depths or deeper.

Key questions addressed in this report include: can MCEs provide a refuge for the many species in shallow water reef ecosystems that are facing increasing threats from human activities? If shallow reefs (< 30–40 m) continue to decline, can MCEs provide the stock to re-populate them? The answer is of course that it depends on the species involved. In some situations, MCEs may provide this ecosystem service and act as "lifeboats" for nearby, connected shallower reefs that have been damaged. In other cases, however, MCEs may be just as vulnerable as shallower reefs to the range of human pressures exerted upon them.

Whether or not they are lifeboats for shallow reef species, MCEs are worthy of protection, both for their inherent biodiversity and for the wide range of ecosystem goods and

Table 1. Key differences between shallow and mesophotic coral ecosystems.

	Shallow-water coral reef ecosystems	Mesophotic coral ecosystems (MCEs)
Depth range	• 0 to approx. 30–40 m. • Lower depth corresponds to a moderate faunal transition. • Detectable in satellite images.	• From approx. 30–40 m to deeper than 150 m. • Lower depth limit varies by location due to di erences in light penetration and other abiotic factors. • Not detectable in satellite images.
Dominant habitat-building taxa	• Dominant species are zooxanthellate scleractinian corals, octocorals, calcareous and foliose macroalgae and sponges.	• Dominant species are plate-like and encrusting zooxanthellate scleractinian corals, octocorals, antipatharians, calcareous and foliose macroalgae and sponges.
Light levels	• Generally well-lit environments. Shallow reefs can become light-limited in turbid waters (e.g. near estuaries).	• Generally middle- to low-light environments.
Thermal regime	• Generally stable thermal regime. Shallow, stratified waters with high residence time may be subject to extreme thermal events causing coral bleaching.	• Generally temperatures are cooler and naturally more variable on MCEs than on shallower reefs, especially those located on the continental slope, which are subject to internal waves.Deeper water column may protect MCEs from extreme (warm) thermal events.
Hydrodynamic regime	• Subject to breaking waves and turbulence, except in sheltered lagoons. • Wave-induced shear stress and mobilition of seafloor sediments. • High residence times within lagoons.	• Below the depth a ected by breaking waves. • Seafloor generally una ected by wave motion. Powerful storms can directly and indirectly impact MCEs (resuspend sediment or cause a debris avalanche), especially in the upper mesophotic zone (30–50 m).

Table 2. Summary of the major anthropogenic threats to MCEs and current and potential management actions that may help mitigate these threats.

	Shallow-water coral reef ecosystems	Mesophotic coral ecosystems (MCEs)
Major anthropogenic threats	• Fishing (overfishing, destructive fishing with dynamite and poison, and damage from lost fishing gear) • Thermal stress (bleaching) from ocean warming • Diseases • Pollution (land-based) • Invasive species • Tourism and recreation • Anchor damage • Coral mining (for aggregate and lime) • Coastal development • Marine aquarium trade	• Fishing (overfishing and damage from lost fishing gear) • Thermal stress (bleaching) reduced exposure to warm water stress • Diseases • Pollution: reduced exposure to land-based sources; exposed to deep-water sewage outfalls and dredging spoils • Invasive species • Tourism and recreation (reduced exposure) • Anchor damage (reduced exposure) • Coral mining (reduced to negligible exposure) • Marine aquarium trade • Oil and gas exploration • Cable and pipelines
Management actions (current and potential)	• Fishing closures • Marine protected areas (MPAs) • Wastewater treatment and management to reduce pollution • Shipping industry guidelines to curb introduced species • Shipping industry guidelines to restrict discharge of oil • Ensure that international trade of reef species, their parts and products is sustainable • Placement of fixed mooring buoys to reduce anchor damage • Tourism guidelines to reduce reef damage • Coral reef rehabilitation for damaged areas • Public education and involvement	• Fishing closures • MPAs (MCEs are not considered in most countries) • Wastewater treatment and management to reduce pollution (potential) • Shipping industry guidelines to curb introduced species (potential) • Shipping industry guidelines to restrict discharge of oil (potential) • Ensure that international trade of mesophotic reef species, their parts and products is sustainable (potential) • Placement of fixed mooring buoys to reduce anchor damage (potential) • Diving guidelines to reduce reef damage (potential) • Guidelines for oil and gas exploration, alternative energy, cable and pipelines (potential)

services they provide. The biodiversity of MCEs is comparable to that of shallow reefs, yet there are also unique species that are found only in MCEs and/or deeper water. Table 1 shows key differences between MCEs and shallow reefs.

While buffered from some of the natural and anthropogenic threats faced by shallow reefs, MCEs are nevertheless vulnerable to many of the same threats, such as fishing, pollution, thermal stress, diseases and tropical cyclones, albeit to differing extents (Table 2). MCEs also face threats from oil and gas exploration and cable and pipeline laying, which are less common on shallow reefs. For light-dependent mesophotic reef organisms living at low light levels (1 per cent of that found at the sea surface), anything that inhibits light reaching the depths (e.g. sedimentation, turbidity or pollution) has an impact on their survival. In general, there remains much to be discovered about the extent of impacts from natural and anthropogenic threats on MCEs.

While some pressures on MCEs are global in origin, and require a global response, many others are regional or local. It is important that measures to protect an individual MCE take an adaptive, ecosystem-based approach to address the cumulative impacts, considering both global pressures and specific local pressures. Most of the management tools used to protect and conserve shallow coral reefs can also be used to protect and conserve MCEs (Table 2).

Guidance for resource managers

While this report primarily provides scientific background information for policy makers and resource managers on MCEs to improve their awareness of these ecosystems, we would be remiss if we did not also provide some guidance on actions that could be taken, based on our current knowledge. To this end, we have identified the following actions that resource managers may take to improve the conservation and management of MCEs.

1. Identify whether MCEs may exist within your jurisdiction.
2. Identify threats to the MCEs that exist in your area and viable options for managing them (see Table 2 for examples of management actions).
3. Determine whether existing marine managed areas for shallow reefs needs to be extended to include nearby MCEs.
4. Expand shallow reef monitoring programmes to include MCE habitats.
5. Introduce awareness-raising and education programmes for the public and policy and decision-makers about MCEs and the need for them to be included in marine spatial planning.

The main recommendations made in this report (see text box on guidance for resource managers) relate to this lack of awareness of MCEs, the anthropogenic threats facing them, and the immediate actions that can be taken, at the local and regional levels, to protect and conserve them.

Although the study of MCEs has increased exponentially in the past 30 years, there are still large gaps in our scientific knowledge of them, especially in comparison with shallow reefs. The best way to close these information gaps is to focus research efforts on answering questions that are critical to enabling resource managers to make informed decisions about MCE protection and conservation. For MCEs, the most crucial information is what scientists would call "baseline information", including information on their location, biological and physical characteristics, threats, condition and the causes and consequences of that condition. The key questions for resource managers and the corresponding research priorities to address them are detailed in Table 3.

Table 3. Key management questions and their related research priorities that would enable policy makers and resource managers to make informed decisions on MCE protection and conservation.

	Management questions	Research priority	Anticipated management focused products
High priority	Where are MCEs located?	Locate where MCEs exist, with a priority in the equatorial regions of the Indo-West Pacific region, eastern Atlantic Ocean, and the Pacific coasts of Mexico, Central America and South America.	Detailed maps showing the distribution of MCEs.
	What controls where MCEs are found?	Understand the geological and physical processes that control MCE distribution to enable us to predict where MCEs occur.	Models and maps showing predicted MCE habitat.
	Are MCEs connected to shallower coral ecosystems and can they serve as refuges for impacted shallow reef species?	Understand the genetic, ecological and oceanographic connectivity of MCEs with shallow reefs and other MCEs. Determine whether MCEs can serve as refugia and reseed shallow reefs (or vice versa).	Maps of larval dispersal pathways for key mesophotic species under di erent oceanographic scenarios. Population connectivity information for key mesophotic species.
Priority	What organisms are found in MCEs?	Characterize MCE biodiversity to better understand, protect and conserve MCEs. Characterize community structure, including patterns of distribution and abundance.	Inventory of species associated with MCEs. Information on mesophotic species taxonomy, life history, and responses to environmental conditions (including tolerance limits) that are useful for modelling impacts to climate change and other disturbances. Distribution and abundance estimates for key mesophotic species.
	What ecological role do MCEs play?	Understand the role of MCEs in supporting various life stages of living marine resources and the processes that regulate these ecosystems.	Descriptions of trophic structures and food web models. Descriptions of the range of habitat types and their distribution, how they are utilized and how these relationships change over time.
	What are the impacts from natural and anthropogenic threats on MCEs?	Determine the anthropogenic and natural threats to MCEs and assess the ecological impacts and their subsequent recovery, if any, from them.	Maps depicting the distribution and intensity of human activities in areas known to contain MCEs. Areas recommended for protection as a marine protected area. Technologies or methods designed to reduce interactions between harmful activities (such as fishing gear) and MCEs.