THE CONSERVATION STATUS OF MARINE BIODIVERSITY OF THE WESTERN INDIAN OCEAN

R. Bullock, G. Ralph, E. Stump, F. Al Abdali, J. Al Asfoor, B. Al Buwaiqi, A. Al Kindi, A. Ambuali, T. Birge, P. Borsa, F. Di Dario, B. Everett, S. Fennessy, C. Fonseca, C. Gorman, A. Govender, H. Ho, W. Holleman, N. Jiddawi, M. Khan, H. Larson, C. Linardich, P. Matiku, K. Matsuura, C. Maunde, H. Motomura, T. Munroe, R. Nair, C. Obota, B. Polidoro, B. Russell, S. Shaheen, Y. Sithole, W. Smith-Vaniz, F. Uiblein, S. Weerts, A. Williams, S. Yahya, K. Carpenter

WESTERN INDIAN OCEAN

The IUCN Red List of Threatened Species™ - Regional Assessment

SSC
Species Survival Commission

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THE IUCN RED LIST OF THREATENED SPECIES™ – REGIONAL ASSESSMENT

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Back - Arabian Butterflyfish (*Chaetodon melapterus*); assessed as Least Concern; by D.P. Wilson and licensed under CC BY 2.0

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More information on the IUCN Red List is available on www.iucnredlist.org.

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Acknowledgements

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IUCN's Red Listing process relies on the willingness of scientists to contribute and pool their collective knowledge on species, in order to make the most reliable and up-to-date assessments. Without such commitment, this kind of regional overview would not be possible. We would therefore like to acknowledge and thank all of the people who gave their time and valuable expertise during the assessments. Thanks to Roger McManus and Jean-Christophe Vié for their guidance and support of the Global Marine Species Assessment initiative of IUCN's Global Species Programme Marine Biodiversity Unit since its inception.

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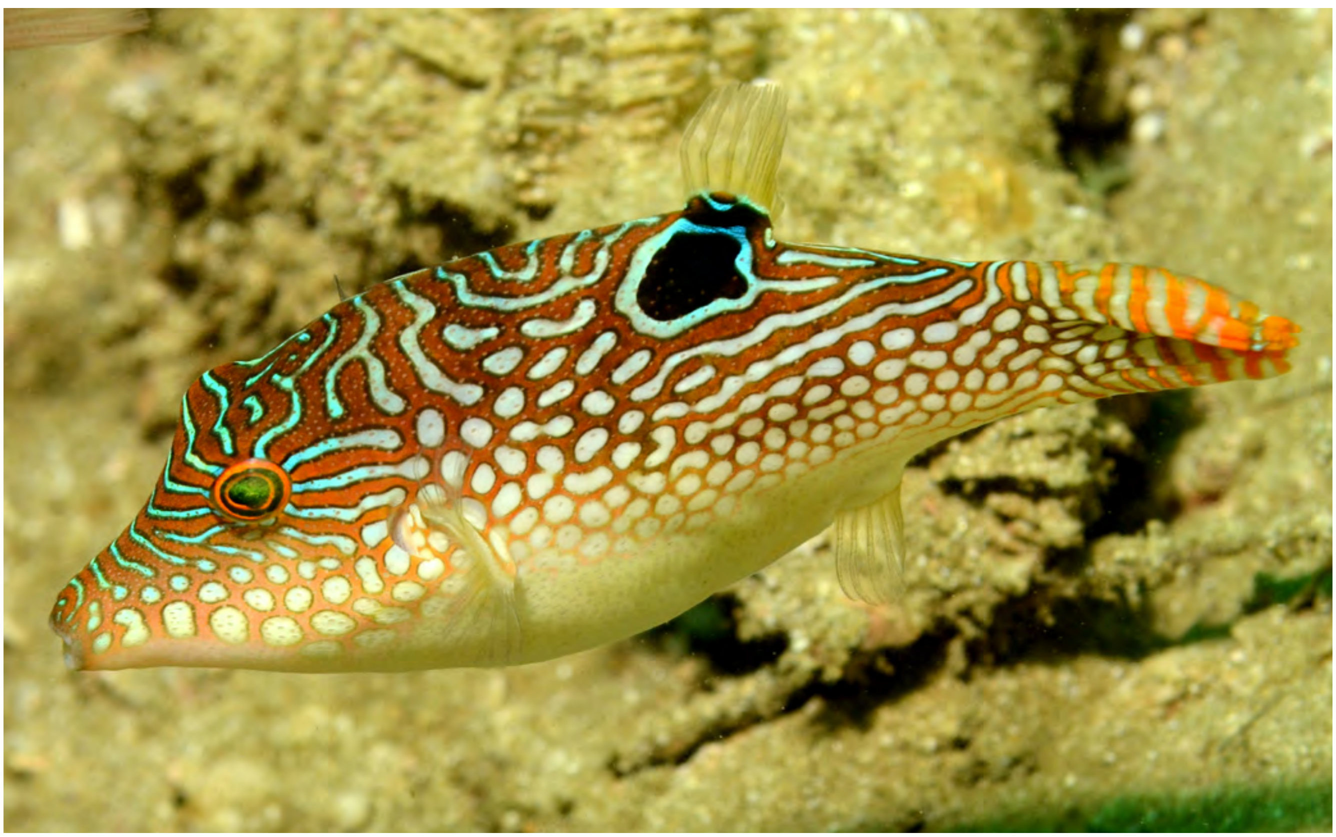


Spotted Sharpnose (*Canthigaster solandri*); assessed as Least Concern; by D.P. Wilson and licensed under CC BY 2.0

Executive summary

The Western Indian Ocean (WIO) is comprised of productive and highly diverse marine ecosystems that are rich sources of food security, livelihoods, and natural wonder. The ecological services that species provide are vital to the productivity of these ecosystems and healthy biodiversity is essential for the continued support of economies and local users. The stability of these valuable resources, however, is being eroded by growing threats to marine life from overexploitation, habitat degradation and climate change, all of which are causing serious reductions in marine ecosystem services and the ability of these ecosystems to support human communities. Quantifying the impacts of these threats and understanding the conservation status of the region's marine biodiversity is a critical step in applying informed management and conservation measures to mitigate loss and retain the ecological value of these systems.

The International Union for Conservation of Nature (IUCN) Red List Categories and Criteria are the most widely used and objective system of quantifying the conservation status of species. For this report, Red List assessments for marine fish species were produced and compiled with existing assessments for other marine species groups to generate a comprehensive assessment of the conservation status of the marine biodiversity of the WIO. The species assessed for this report were done so through clade-based and regionally focused Red List assessment workshops involving hundreds of taxonomic experts from around the world. To supplement assessments for marine fishes of the region, three workshops were held in Tanzania, Oman and South Africa over the course of three years from 2017 to 2019. Thirty-one marine fish experts from 14 countries participated in the three workshops.

Among the more than 4,000 species assessments compiled for this report, 473 species were identified as threatened or Near Threatened with extinction at the global level, according to the IUCN Red List Categories and Criteria. Incorporating uncertainty in the true status of Data Deficient species, between 7-24% of all species were estimated as being currently at risk of extinction, with a best estimate of 8% of all assessed species being threatened. Spatial analyses of species richness across the region identified hotspots of threatened species including the southern Red Sea and the southern coast of India. Major threats were analysed amongst threatened and Near Threatened species, of which more than 90% were found to be impacted by biological resource use, largely in the form of targeted fisheries and bycatch as well as illegal, unreported and unregulated fishing activities. Overexploitation was flagged as a driver of population decline for all threatened and Near Threatened cartilaginous fishes, mammals and sea turtles. The 237 threatened and Near Threatened reef-building corals are impacted by the same suite of fishing threats, including fisheries-related habitat degradation. In general, habitat degradation and destruction through pollution, coastal development and other habitat modifications emerged as a major threat across assessed species groups. From these analyses, this report highlights trends in research needs for species in the region, including priorities for fundamental biological and ecological research and quantifying trends in the populations of species.

Overall, with a best estimate of 8% threatened species, the conservation status of the Western Indian Ocean region is moderately high, relative to the status of the same taxonomic suite of species assessed in other regions. This comparatively high level of threatened biodiversity highlights the importance of timely and targeted conservation actions for the biodiversity of the region moving forward. The region has the highest levels of uncertainty in species status with 16.9% of the WIO species listed as Data Deficient, as compared to 11.0-15.8% in other tropical regions. The analyses presented here also highlight particularly threatened and susceptible taxonomic groups, geographical hotpots of conservation priority as well as trends in major anthropogenic threats. The assessments and analyses submitted in this report should inform conservation decision-making processes and will be valuable to policymakers, natural resource managers, environmental planners and NGOs.

Starry Moray (*Gymnothorax nudivomer*); assessed as Least Concern; by D.P. Wilson and licensed under CC BY 2.0

Commonly used acronyms

Red List Categories

EX	Extinct
EW	Extinct in the Wild
CR	Critically Endangered
EN	Endangered
VU	Vulnerable
NT	Near Threatened
LC	Least Concern
DD	Data Deficient
NE	Not Evaluated

International Organizations

IUCN	International Union for Conservation of Nature
SSC	Species Survival Commission
SSG	Species Specialist Group
RLA	Red List Authority
MBU	Marine Biodiversity Unit
FAO	Food and Agriculture Organization of the United Nations

Country Codes

BHR	Bahrain
IOT	British Indian Ocean Territory (Chagos Archipelago)
COM	Comoro Islands
DJI	Djibouti
EGY	Egypt
ERI	Eritrea
ATF	French Southern and Antarctic Lands (Bassas da India, Glorioso Islands, Ile Europa, Ile Tromelin, Juan de Nova Island)
IND	India
IRN	Iran
IRQ	Iraq
ISR	Israel
JOR	Jordan
KEN	Kenya
KWT	Kuwait
MDG	Madagascar
MDV	Maldives
MUS	Mauritius
MYT	Mayotte
MOZ	Mozambique
OMN	Oman
PAK	Pakistan
QAT	Qatar
REU	Réunion
SAU	Saudi Arabia
SYC	Seychelles
SOM	Somalia
ZAF	South Africa
LKA	Sri Lanka
SDN	Sudan
TZA	Tanzania
ARE	United Arab Emirates
YEM	Yemen

1. Background

1.1 The Western Indian Ocean region

The Indo-Pacific Ocean is the largest and most diverse marine ecological system on the planet. On its western periphery, covering approximately 30 million km² and spanning the waters of 32 countries and territories, lies the Western Indian Ocean (WIO; Figure 1). Climatically and geographically, this is a region of extremes. The northeastern range experiences heavy monsoon rains while the northwestern range is bordered by arid land and is characterized by large semi-enclosed bodies of water such as the Red Sea. Shallow coral reef, estuaries, seagrass and mangrove systems are all found in coastal areas. The contrasting habitats within the region may favour differentiated communities and endemism is likely to be higher where unique habitats occur (Kier et al., 2009). Unfortunately, due to multiple factors, this region is understudied and has much to be discovered (Wafar et al., 2011).

The highly diverse marine biodiversity of the WIO has been a rich source of food security, livelihoods and natural wonder for the peoples in the region (UNEP-Nairobi Convention & WIOMSA, 2015). The ecological services that species provide are vital to the existence of these marine ecosystems (Palumbi et al., 2009) and a healthy biodiversity is essential for maintaining a safe operating space for humanity (Rockstrom et al., 2009). Unfortunately, growing threats to marine life from overexploitation, habitat degradation and climate change are seriously impacting marine ecosystems globally (Halpern et al., 2008; 2015). These threats are causing reductions in marine ecosystem services and the ability of the ecosystem to support human communities (Worm et al., 2006).

Some of the most heavily impacted marine biotas in the world are in the Western Indian Ocean where drastic reductions in coral cover occurred because of sustained heightened sea surface temperatures and subsequent widespread bleaching events in the late 1990s (Wilkinson et al., 1999). Human population growth in the region also poses substantial threats to the sustainability of coastal biota: many of the countries in the Western Indian Ocean are characterized by high population growth rates, high population density, and substantial rural to urban migrations (UNEP-Nairobi Convention & WIOMSA, 2015).

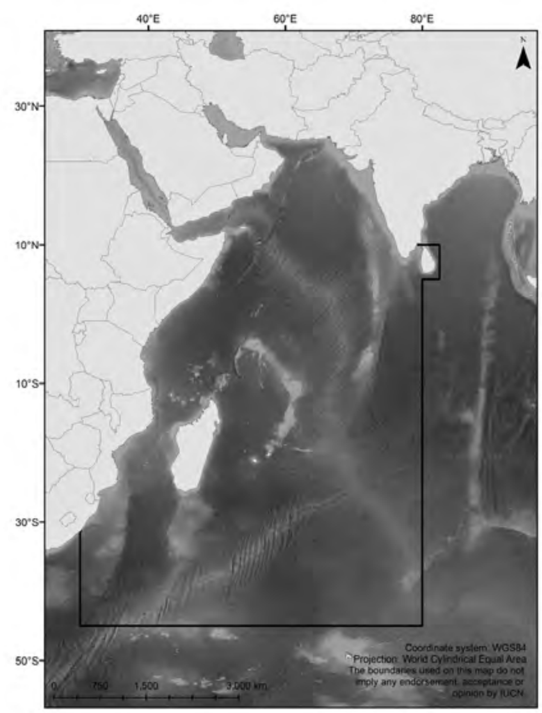


Figure 1: The boundaries of the Western Indian Ocean, based on the definition used in Fischer and Bianchi (1984).

1.2 Biodiversity and endemism

The WIO is associated with areas of high species richness and high endemism. It is ranked as one of the world's richest oceanic regions (Keesing & Irvine, 2005; Obura, 2012; Veron et al., 2015). An estimated 15% of all exclusively aquatic species known from the Western Indian Ocean are endemic to it (Richmond, 1997; 2001). Across taxa, high levels of endemism have been recorded in in the territorial waters of South Africa, the Red Sea, India, Mauritius, La Reunion, the Seychelles, India and the Maldives (Van der Elst et al., 2005; Keesing & Irvine, 2005; Obura, 2012; Briggs & Bowen, 2012; Borsa et al., 2016; DiBattista et al., 2016).

The productivity of the rich ecosystems of the WIO has so far supported economies and livelihoods in the region (Samoilys et al., 2015). Fisheries form a large economic sector in most nations, providing food security and employment in coastal communities, and contributing to national economies and GDPs (Carpenter et al., 1997; Jiddawi & Ohman, 2002; Belton & Thilsted, 2014; UNEP-Nairobi Convention & WIOMSA, 2015). Fisheries in the Western Indian Ocean region range from dynamic artisanal fisheries (also called subsistence or small-scale commercial fisheries), comprising a variety of gears used in near-shore environments, to semi-industrial and industrial targeted fisheries including near-shore shrimp trawling (Jiddawi & Ohman, 2002; Fennessy & Everett, 2015), pelagic long-lining and purse-seining (Cochrane & Japp, 2015), trap fisheries, and mixed demersal trawling (Carpenter et al., 1997; Belton & Thilsted, 2014; UNEP-Nairobi Convention & WIOMSA ,2015).

The biodiversity of the region supports a growing tourism industry; the economic value of which has grown rapidly in recent years, and in some parts of the WIO, exceeds that of fisheries (UNEP-Nairobi Convention & WIOMSA, 2015; Gossling, 2006). Tourists are drawn to the region's beaches, lagoons, coral reefs, wildlife, and coastal cultural sites (Gossling, 2006). Biodiversity also provides important aesthetic, cultural and spiritual services to coastal communities.

Knowledge of marine biodiversity in the WIO continues to expand and has benefited greatly from both internationally and locally driven research effort. International research expeditions, such as the Indian Ocean Expedition (1959 to 1965) that supported participants from 20 countries, considerably enhanced knowledge of marine biodiversity beyond shallow and easily accessible waters. However, current marine biodiversity research efforts are heterogenous across the region, varying according to the capacity among the different nations (Keesing & Irvine, 2005) and large gaps in sampling effort in the marine realm of the WIO remain (Wafar et al., 2011; Groeneveld & Koranteng, 2017).

Outside Malindi Fish Market, Zanzibar © G. Saluta.

1.3 Threats to marine biodiversity

Historically low levels of economic development in parts of the WIO have meant that, in some areas, the marine ecosystem may have been less impacted by coastal human activity. For example, arid nations such as Somalia and Sudan have low coastal populations densities due to lack of freshwater and high temperatures, thus limiting development and exploitation in the coastal zone (Halpern et al., 2008; Obura et al., 2017). However, contemporary increases in growth and development across the region are likely to increasingly impact marine biodiversity. Previous regional-scale work has highlighted "hotspots" of concern in the WIO region; biologically rich areas where high endemism combines with multiple threats including coastal and industrial development, global warming, pollution, and overfishing (Qasim, 1998; Roberts et al., 2002; Van der Elst et al., 2005). For example, Kenya, Tanzania and Mozambique have lost significant portions of their mangrove shoreline, coral reefs have declined due to major bleaching events and overexploitation of pelagic and demersal fish stocks has been reported since the 1980's (Obura et al., 2017). Similar findings have been reported across vast areas of the WIO including but not limited to the Arabian Gulf, Sri Lanka and the west coast of India (Gunawardena & Rowan, 2005; Sale et al., 2011; Vidyasagaran & Madhusoodanan, 2014). These impacts lead to a loss of ecosystem services from reefs, mangroves and seagrass beds as well as loss of livelihoods, food security and tourism value (Obura et al., 2017).

1.4 Assessment of extinction risk: IUCN Red List of Threatened Species™

The IUCN Red List Categories and Criteria reflect the principles of extinction risk theory (Mace et al., 2008) and are the most widely used and objective system of quantifying extinction risk across all taxa except microbiota (e.g., Butchart et al., 2005; De Grammont & Cuarón, 2006; Hoffman et al., 2008).

There are nine Red List categories for global assessments (Figure 2): Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), and Not Evaluated (NE) (IUCN, 2012).

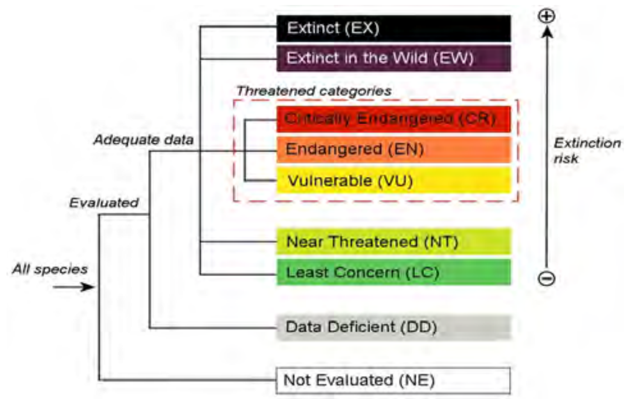
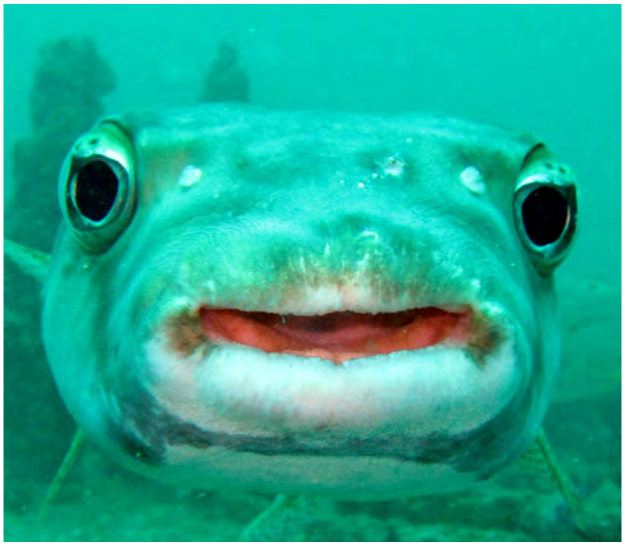


Figure 2: The IUCN Red List Categories.

Species that meet the quantitative thresholds under one or more of five distinct criteria are assigned to one of the three threatened categories (CR, EN or VU). For species that come very close to, but do not fully meet the thresholds for a threatened category, the Near Threatened category is applied. When there are no known major global-level threats, or the known threats to a species do not reach quantitative thresholds, a species is assessed as Least Concern. When assessment data indicate unquantified but known serious threats (e.g., fishing pressure) or that extent of distribution is poorly understood due to taxonomic uncertainty or lack of sampling effort, then the Red List Criteria cannot be applied until further research is conducted, and the species is assigned to the Data Deficient category. The Not Evaluated category is used to indicate a species that is recognized as valid, but that has not yet been assessed against the Red List Criteria (IUCN, 2012); these species are not included on the Red List.



Spot-fin Porcupinefish (*Diodon hystrix*); assessed as Least Concern; by D.P. Wilson and licensed under CC BY 2.0.

Each of the five Red List Criteria addresses one or both of the two premises of extinction risk theory: elevated risk of extinction occurs when (1) species' populations are small and/or (2) species have experienced, are experiencing or are likely to experience population declines at rates that are biologically infeasible for the population to remain viable in the wild (Mace et al., 2008; see https://www.iucnredlist.org/resources/categories-and-criteria for more information on Red List Categories and Criteria). Criterion A is commonly applied to wide-ranging species facing identifiable threat(s) that cause a population reduction beyond a species' ability to naturally sustain itself. The decline is scaled to the life history of the species by the generation length, which is defined as the average age of the parents of a cohort. Criterion B addresses species with restricted geographic range that are also characterized by fragmentation, fluctuations, or declines in range, habitat or individuals. Two metrics are used to describe the spatial distribution of extinction risk. Extent of Occurrence (EOO) is measured as the area of a minimum convex polygon that contains all known or inferred occurrences, and Area of Occupancy (AOO) is the area within the EOO that is inhabited by the species. Criterion C is applied to species with a naturally small population size and an observed, inferred or estimated continued decline of the number of mature individuals in a population. Criterion D addresses species with extremely small and/or restricted populations, and Criterion E relies on computer modeled extinction risk probabilities to estimate extinction risk.

1.5 Project objectives

The conservation status of several important species that constitute the rich marine biodiversity of the Western Indian Ocean is unknown, a situation that can hinder effective conservation efforts in the region. In order to overcome this scenario, the IUCN Red List has formed the basis for many regional conservation planning initiatives. Additionally, IUCN Red List assessments are essential to Key Biodiversity Area (KBA) analyses. KBAs can be designated as targets needing conservation action to protect biodiversity with a larger taxonomic scope. Findings from this project could provide a unique opportunity to explore the identification of marine KBAs with broad taxonomic coverage.

IUCN Red List assessments are a key tool used in local, national, regional, and global biodiversity conservation. Regional or national Red Lists often form the basis of national listings for species-at-risk around the world. For example, in the USA, global Red List assessments for reef-building corals were used as the basis for a successful petition to list 88 species of corals under the United States Endangered Species Act. Some mega biodiverse countries, such as Brazil, also rely on IUCN Categories and Red List assessments in order to build their national conservation strategies and environment action plans (ICMBio/MMA, 2018). In the WIO region, re-assessments of the Red List status of reef-building corals are in development, which will track progress towards the Aichi Biodiversity Targets and post-2020 biodiversity goals. South Africa has included Red List status of marine species in support of its National Biodiversity Assessment (Van der Bank et al., 2019), as well as in supporting rationale for its recently-expanded MPA network (Skowno et al., 2019).

Celebes Flathead (*Thysanophyrs celebica*); assessed as Least Concern; by D.P. Wilson and licensed under CC BY 2.0

There is a distinct need for critical information to help progress towards international targets for biodiversity conservation, such as the United Nations Sustainable Development Goals (SDGs) and the Strategic Plan for the Convention on Biological Diversity (CBD). The aim of this project was therefore to assess the conservation status of WIO marine species and, alongside existing assessments for other key species groups, present these data as the foundation for strategic conservation in the Western Indian Ocean region.

The specific objectives of this project were to:

- assess the extinction risk of the marine fishes of the Western Indian Ocean region;
- analyze trends in the conservation status of all assessed marine biodiversity in the Western Indian Ocean;
- analyze trends in major threats and conservation needs across species to inform a state-of-knowledge report that can support regional marine and coastal planning initiatives; and
- build an inter-disciplinary, inter-organizational network of experts to champion the project and its findings. conserved and managed sustainably (e.g. mapping information).

2. Methods

2.1 Geographic scope

The Western Indian Ocean, broadly defined following Fischer and Bianchi (1984), encompasses the United Nations Food and Agriculture Organization's (FAO) fishing area 51 as well as the entirety of Sri Lanka (Figure 1). As defined, it is geographically spread over about 30 million km², 42% of which overlaps with Exclusive Economic Zones. The WIO region includes 32 countries and territories, the majority of which are considered developing economies (UN, 2019). Major currents, including the Agulhas Current, the Somali Coastal Current, the South Equatorial Current, and the Equatorial Counter Current, impact the distribution and productivity of biodiversity in the WIO.

2.2 Taxonomic scope

The analyses in this report reflect more than 4,000 valid marine species in 10 taxonomic and functional groups (Table 1). Within these taxonomic groups, only valid species that are primarily marine, native and present in the Western Indian Ocean (as defined herein) and published on the IUCN Red List are included. Taxa below species level (i.e., subspecies) were not assessed.

Taxonomy follows the standards adopted by the IUCN Species Survival Commission (SSC) Species Specialist Groups (SSGs) and Red List Authorities (RLAs) responsible for the specific taxonomic group. Higher taxonomic levels for the bony fishes primarily follow that set forth by Nelson (2006), and species-level taxonomy follows that of the California Academy of Science's online database Eschmeyer's Catalog of Fishes (Fricke et al., 2020). It is expected that the majority of Western Indian Ocean species in these taxonomic and functional groups have been included in this analysis; however, species recently described or reported from the Western Indian Ocean may have been omitted. As assessments for marine bony fishes are ongoing, the available assessments were supplemented by three Red List assessment workshops focused on species of the Western Indian Ocean.

Table 1: Number of Western Indian Ocean species assessed in each of the 10 functional groups included in this analysis.

Functional Group	Species
Mammals	46
Sea snakes	19
Sea turtles	5
Bony fishes	2990
Sharks and rays	264
Cone snails	183
Sea cucumbers	125
Reef-building corals	492
Mangroves	26
Seagrasses	17

Sohal Surgeonfish (*Acanthurus sohal*); assessed as Least Concern; by D.P. Wilson and licensed under CC BY 2.0.

2.3 Preliminary assessments and pre-workshop data collection

The IUCN Red List methodology is an objective, data-driven process based on extinction risk theory. For each species, the respective IUCN species authority (e.g., Species Specialist Group and/or Red List Authority) led the assessment process. All species-specific information was compiled into IUCN's Species Information Service (SIS) database, including data on the taxonomic classification, geographic distribution, population status and trends, habitats and ecology, threats and conservation measures.

2.4 Red List assessment workshops

The species included in this analysis were assessed during global, clade-based Red List assessment workshops involving hundreds of taxonomic experts from around the world. Three additional workshops focusing on fishes of the Western Indian Ocean were held in Zanzibar, Tanzania (July 2017); Muscat, Oman (June 2018); and Durban, South Africa (August 2019). Thirty-one marine fish experts from 14 countries participated in the three workshops (see Appendix for participant lists for each workshop).

The first day of each workshop consisted of an overview of the project's aim and scope, as well as a short training in the use and application of IUCN Red List methodology. During the remainder of the workshops, experts were separated into groups based on their taxonomic expertise. Guided by one of the facilitators, the experts reviewed the preliminary assessments generated during pre-workshop data collection efforts and contributed additional species-specific information as available. These data were then used to determine if the thresholds and sub-criteria were met for a threatened listing under at least one Red List criterion for each species.

2.5 Post-workshop review

Following the workshops, each species' assessment was edited, and outstanding questions resolved through further consultations with workshop participants, as well as with members of the relevant Species Specialist Groups and other experts who did not attend the workshops. When necessary, distribution maps were also revised. Each assessment was evaluated by at least one reviewer prior to a final review and consistency check completed by the IUCN Red List Unit.

Three estimates for the proportion of threatened species are used to account for the uncertainty around the true extinction risk faced by Data Deficient species. The first of these estimates uses a midpoint and assumes the same proportion of threatened species within the Data Deficient group as found across other categories. However, as the true status of Data Deficient species is unknown, a lower and upper bound bracket of proportion threatened is also calculated. The lower bound assumes that none of the Data Deficient species are threatened, while the upper bound assumes that all Data Deficient species are threatened (Table 2).

Table 2: The equations for the three estimates of the proportion of threatened species based on the IUCN Red List (IUCN, 2016). The IUCN Red List categories include the three threatened categories: Critically Endangered (CR), Endangered (EN) and Vulnerable (VU); Near Threatened (NT); Least Concern (LC); and Data Deficient (DD).

Estimate	Equation
Lower bound	(CR+EN+VU)/Assessed
Mid-point	(CR+EN+VU)/(Assessed-DD)
Upper bound	(CR+EN+VU)/(Assessed-DD)

2.6 Methodology for spatial analyses

Expert-vetted and reliable point records, as well as scientific literature and data on depth and habitat preferences, were used to generate distribution maps in ArcGIS 10.5 (software by ESRI Corp). For purposes of Red List assessments, coastal species are understood as species residing relatively near the shore in depths shallower than 200 m. Maps for coastal species were clipped to a buffered bathymetric layer, based on two-minute spatial bathymetry data made available by the National Marine Fisheries Service of the U.S. National Oceanographic and Atmospheric Administration (Amante & Eakins, 2009). The buffer was either 100 km from the coast or the 200 m depth contour, whichever was further from the coastline. This approach standardizes the way coastal species are mapped and produces uniform and comparable distribution maps. For pelagic and deep-sea species, distribution maps were digitized by hand relative to known depth preferences and habitat requirements.

Species richness analyses were conducted toevaluate biodiversity patterns in the Western Indian Ocean region for: 1) assessed marine species; 2) marine species listed in one of the three threatened categories (Critically Endangered, Endangered, and Vulnerable); and 3) marine species listed as Data Deficient. For all richness analyses, each species' distribution map was transformed into the World Cylindrical Equal Area Coordinate system and converted into a square grid raster of 10 x 10 km cell size. Each cell which the species polygon overlapped was assigned a value of "1". For each richness analysis, the selected rasters were added together so that the cells of the final raster represented the number of species that occupy each grid cell within the region.

Variegated Lizardfish (*Synodus variegatus*); assessed as Least Concern; by D.P. Wilson and licensed under CC BY 2.0

3. Results and discussion

3.1 Conservation status of marine biodiversity

Across the more than 4,000 assessed marine species of the Western Indian Ocean included here, about 71% were assessed as Least Concern (LC). These are primarily widely distributed and abundant species, or those with no known major threats. The three threatened categories account for a relatively small number of species, with 25 assessed as Critically Endangered (CR), 56 as Endangered (EN) and 195 as Vulnerable (VU). Another 197 species nearly met the thresholds and conditions for a threatened listing and were assessed as Near Threatened (NT). The remaining species were assessed as Data Deficient (DD), representing almost 20% of species (Figure 3).

Based on these species, the best estimate for the percentage threatened is 8%. Accounting for the uncertainty surrounding the true status of the species listed as DD, the percentage of threatened species ranges from 7%, if none of the DD species are threatened, to 24%, if all of the DD species are threatened.

Of the threatened species, about 87% were listed under criterion A, indicating a past, present or future projected population decline. The remaining species were listed under criterion B (26 species), criterion D (10 species); only five species were listed under multiple criteria.

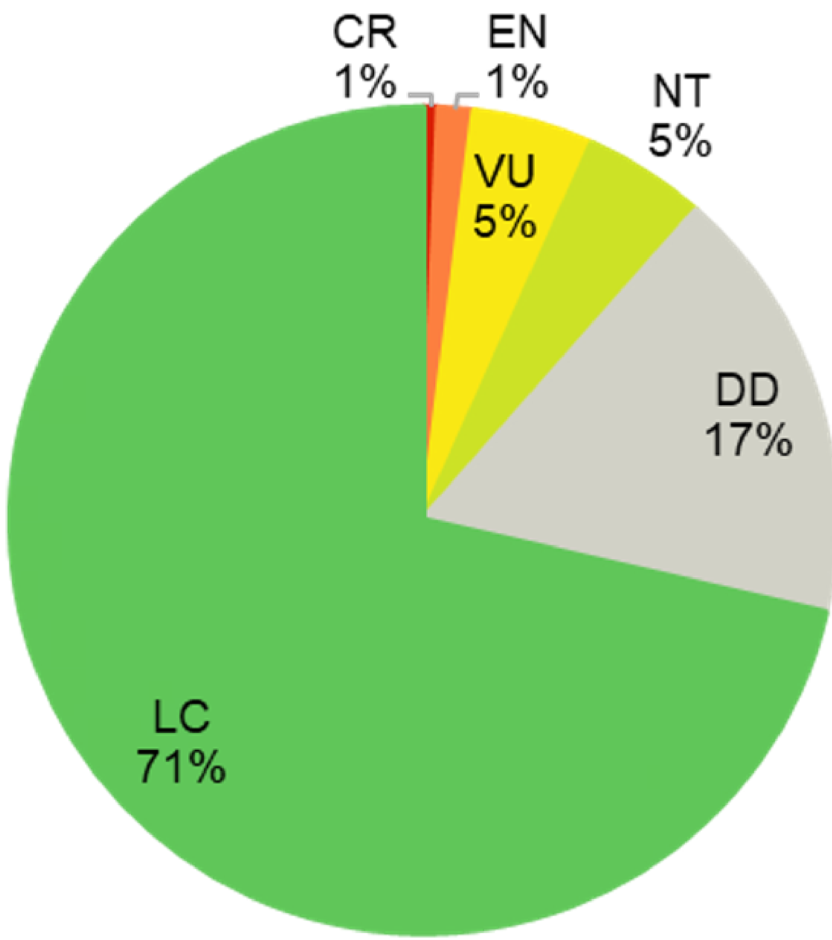


Figure 3: Percentage of species listed in each of the IUCN Red List categories. CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient.

3.2 Trends by taxonomic group

The number of assessed species and estimates of percentage threatened varied widely by taxonomic group (Figure 4, Table 3). Across the taxa included here, the highest and lowest percentage of threatened species occurred in the marine reptiles. All five of the sea turtles that occur within the WIO were considered threatened, while none of the 19 species of sea snakes were considered threatened. Seven of the 46 marine mammals, including cetaceans, pinnipeds and sirenians, were listed as threatened; however, a high percentage of these species were listed as DD (28%).

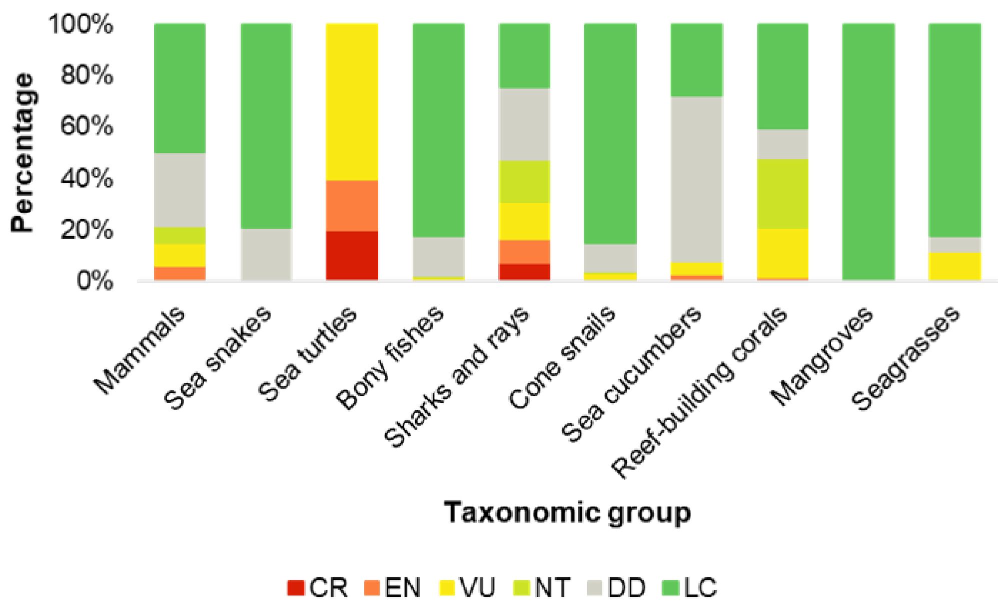


Figure 4: Percentage of species listed in each of the IUCN Red List categories by taxonomic group. CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient.

Table 3: Number of species and estimates of the percentage of threatened species for each taxonomic group included here. The percentage of threatened species estimates follow the recommendations in IUCN (2016). The best estimate is the midpoint, which assumes the Data Deficient species are as threatened as non-Data Deficient species, while the lower and upper bounds assume that none, and all, of the Data Deficient species are threatened, respectively.

Taxon	Species	Lower	Midpoint	Upper
Mammals	46	15%	21%	43%
Sea snakes	19	0%	0%	21%
Sea turtles	5	100%	100%	100%
Bony fishes	2990	2%	2%	18%
Sharks and rays	264	31%	43%	59%
Cone snails	183	3%	4%	15%
Sea cucumbers	125	8%	22%	72%
Reef-building corals	492	21%	24%	33%
Mangroves	26	0%	0%	0%
Seagrasses	17	12%	13%	18%

The majority of marine vertebrates are fishes, with over 17,000 valid species (Fricke et al., 2020). Estimates of fish diversity in the WIO region vary; Smith and Heemstra (1986) report on about 2,200 species from southern Africa (Namibia to Mozambique), Heemstra et al. (in press) include well over 3,600 species of coastal fishes in the WIO. While much of the WIO ichthyofauna is of Indo-Pacific origin (Smith & Heemstra, 1986), there are several pockets of relatively high endemism; for example, about 15% of marine fishes are endemic to the Red Sea (Bogorodsky & Randall, 2018; Golani & Fricke, 2018) and 13% are endemic to South Africa (Van der Elst et al., 2005). New species continue to be described throughout the WIO, for example from the Mascarene Plateau (Russell & Tweddle, 2013; Russell, 2015; Greenfield & Gordon, 2019; Voronina, 2019) and Zanzibar, Tanzania (Tea et al., 2019), indicating that our understanding of the diversity of WIO fishes is certainly incomplete. Even large, non-cryptic taxa have been described from this region in the last decade. Among the cartilaginous fishes, including the sharks, rays, skates and chimaeras, the best estimate for the proportion of threatened species was 43%; the Arabian Sea has one of the highest proportions of threatened cartilaginous fishes globally (Jabado et al., 2018). A relatively low proportion of bony fishes were threatened, with only about 2% of the nearly 3,000 species listed in a threatened category.

Comprehensive conservation assessments of invertebrates are limited in the WIO, with assessments completed only for the cone snails (Gastropoda: Conidae), sea cucumbers (Holothuroidea), and reef-building corals (Anthozoa: Scleractinia). In general, few cone snails were threatened, while 22% of sea cucumbers and 24% of reef-building corals were threatened.

The marine plants, mangroves and seagrasses, are widely distributed in coastal regions. About 30% of the 140 species known globally occur in the WIO region. These species provide fundamental ecosystem services, including flood protection, nutrient and organic matter processing, and sediment control, and support fisheries in tropical and subtropical fisheries around the globe (Costanza et al., 1997). Overall, the risk of global extinction to these marine plants remains low in the WIO, with only two species of seagrasses listed as VU and one as DD.

Townsend's Anthias (*Pseudanthias townsendi*); assessed as Least Concern; by D.P. Wilson and licensed under CC BY 2.0

3.3 Spatial distribution of species

The highest richness of all assessed marine species, with upwards of 1,300 species per 100 m², occurred in the tropics along the coast of central East Africa, in the oceanic islands and Sri Lanka (Figure 5). Generally, richness was higher along the coast, as compared to offshore.

The shallow, semi-enclosed Persian/Arabian Gulf was an exception, with lower overall richness compared to other coastal areas; the results of its relatively young geological age and harsh environmental conditions (e.g., Sheppard et al., 2010).

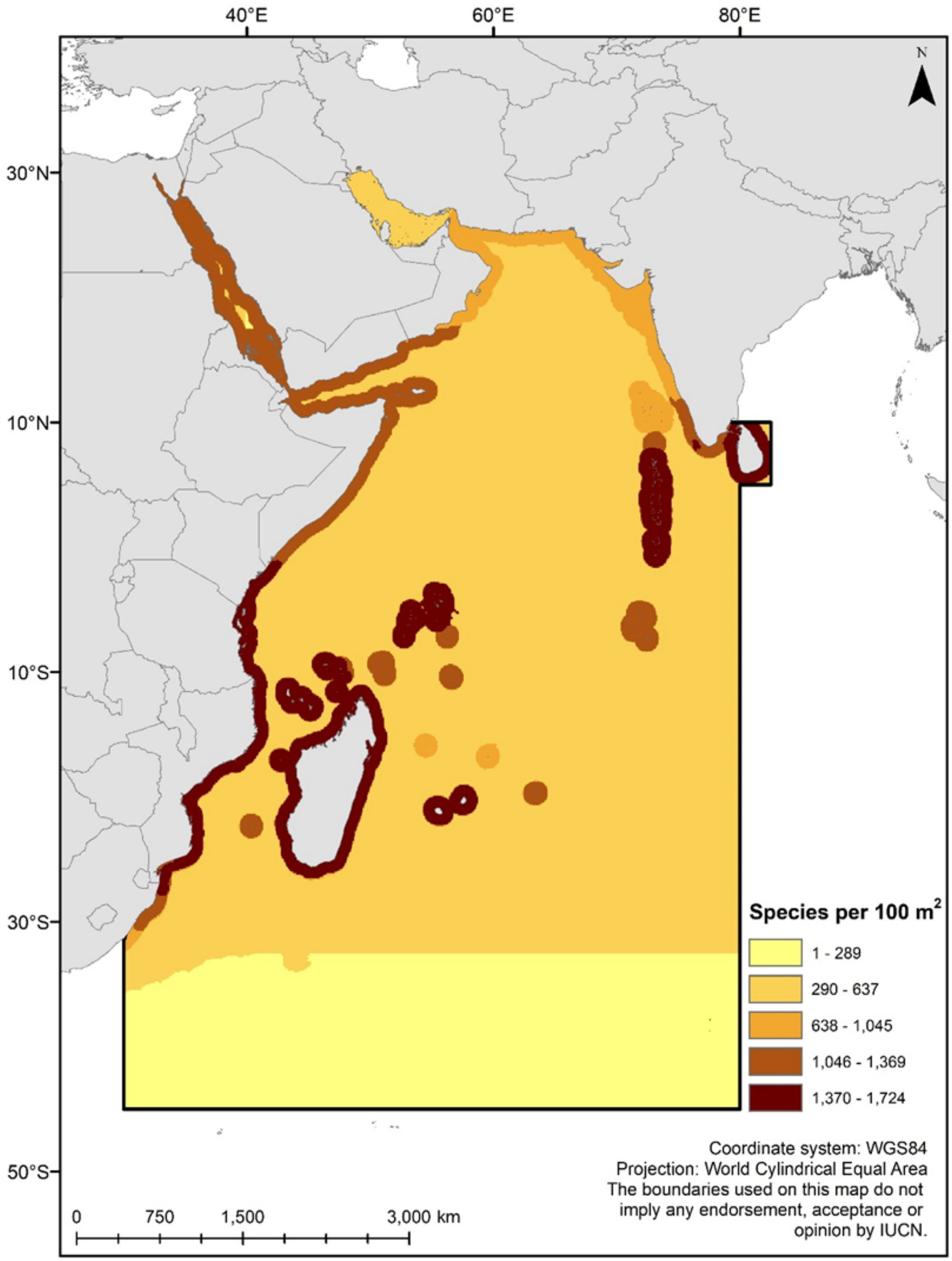


Figure 5: Distribution of the marine species of the Western Indian Ocean that have been assessed against the IUCN Red List Categories and Criteria.

The east coast of Africa (Kenya, Tanzania and Mozambique), the Western Indian Ocean Islands, the Red Sea, the southern coasts of India and the coastal regions of Sri Lanka were areas with highest numbers of threatened species, with higher richness of threatened species in coastal waters as compared to offshore (Figure 6). In the southern Red Sea and along the southern coast of India, however, the number of threatened species was higher than would be expected based on the overall number of species alone.

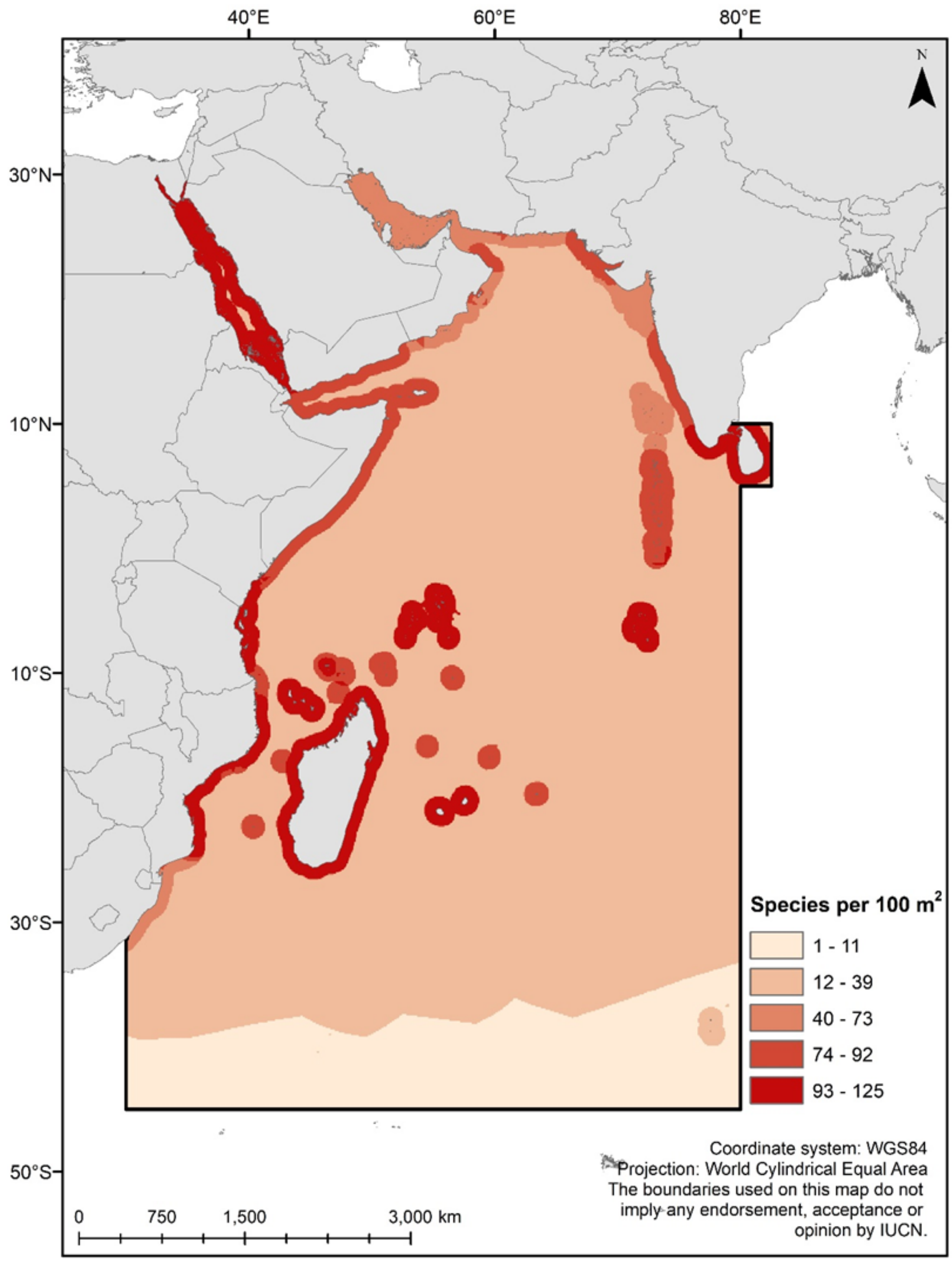


Figure 6: Distribution of the threatened marine species of the Western Indian Ocean that have been assessed against the IUCN Red List Categories and Criteria.

Data Deficient species tended to be patchily distributed throughout the region, which may be a result of the limited information available regarding the distribution of many species assessed as DD. Highest numbers of DD species occur off South Africa, Madagascar, and Sri Lanka, followed by the Red Sea (Figure 7).

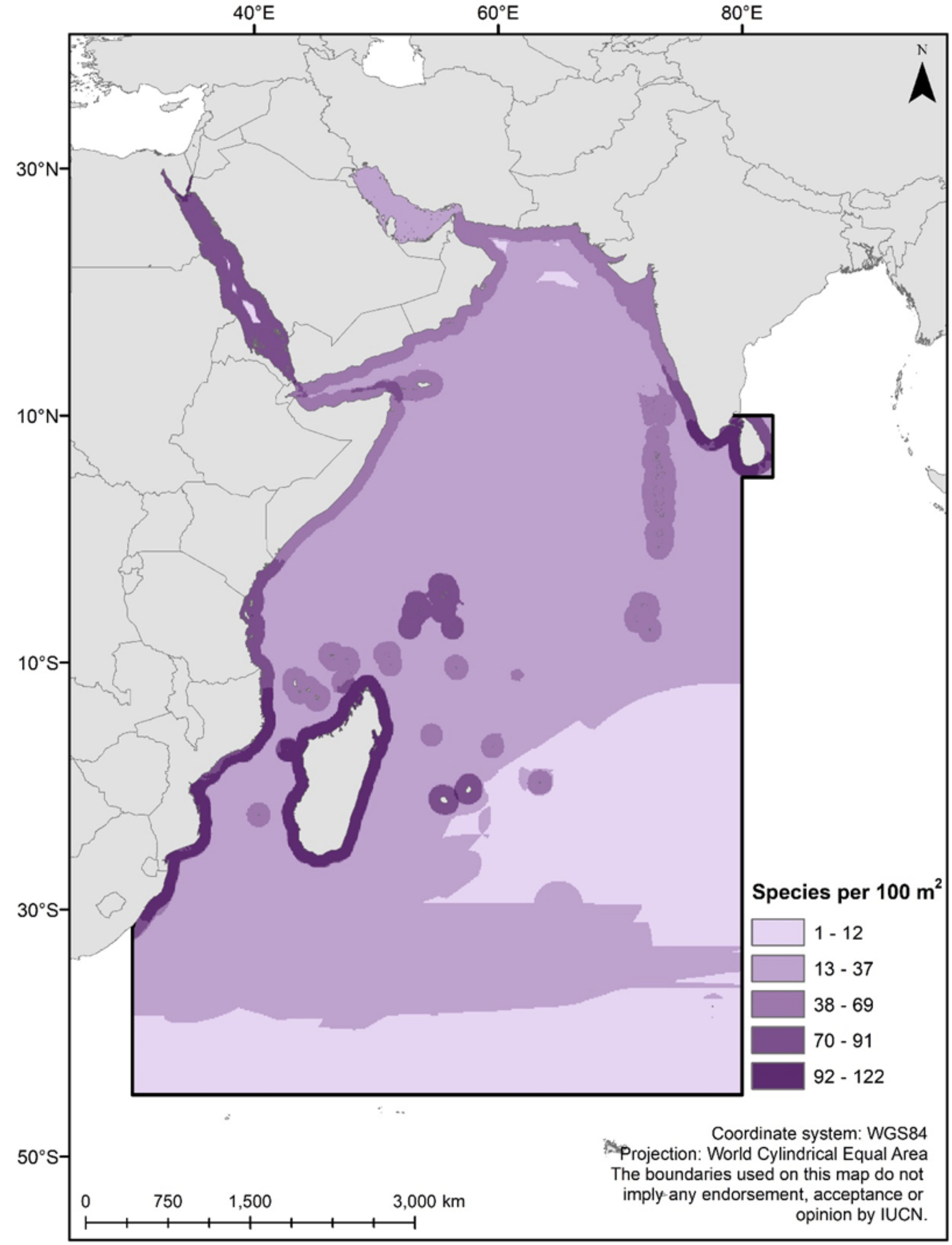


Figure 7: Distribution of the Data Deficient marine species of the Western Indian Ocean that have been assessed against the IUCN Red List Categories and Criteria.

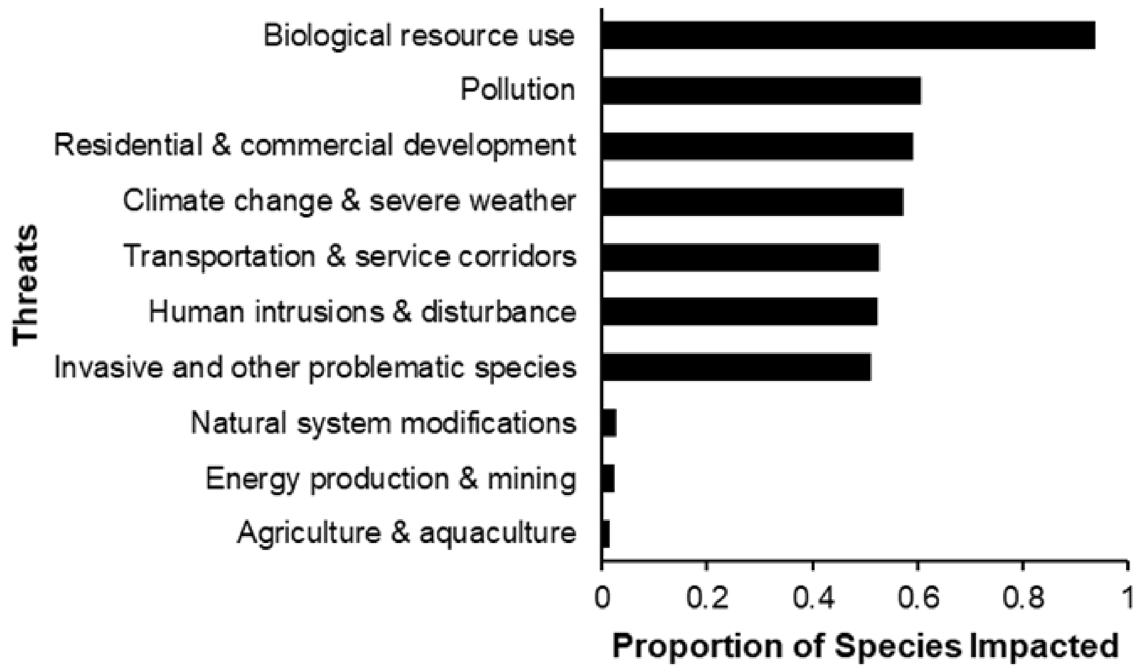


Figure 8: Proportion of species assessed as threatened (Critically Endangered, Endangered and Vulnerable) or Near Threatened that are impacted by various threats. Species are often impacted by more than one threat.

3.4 Threats

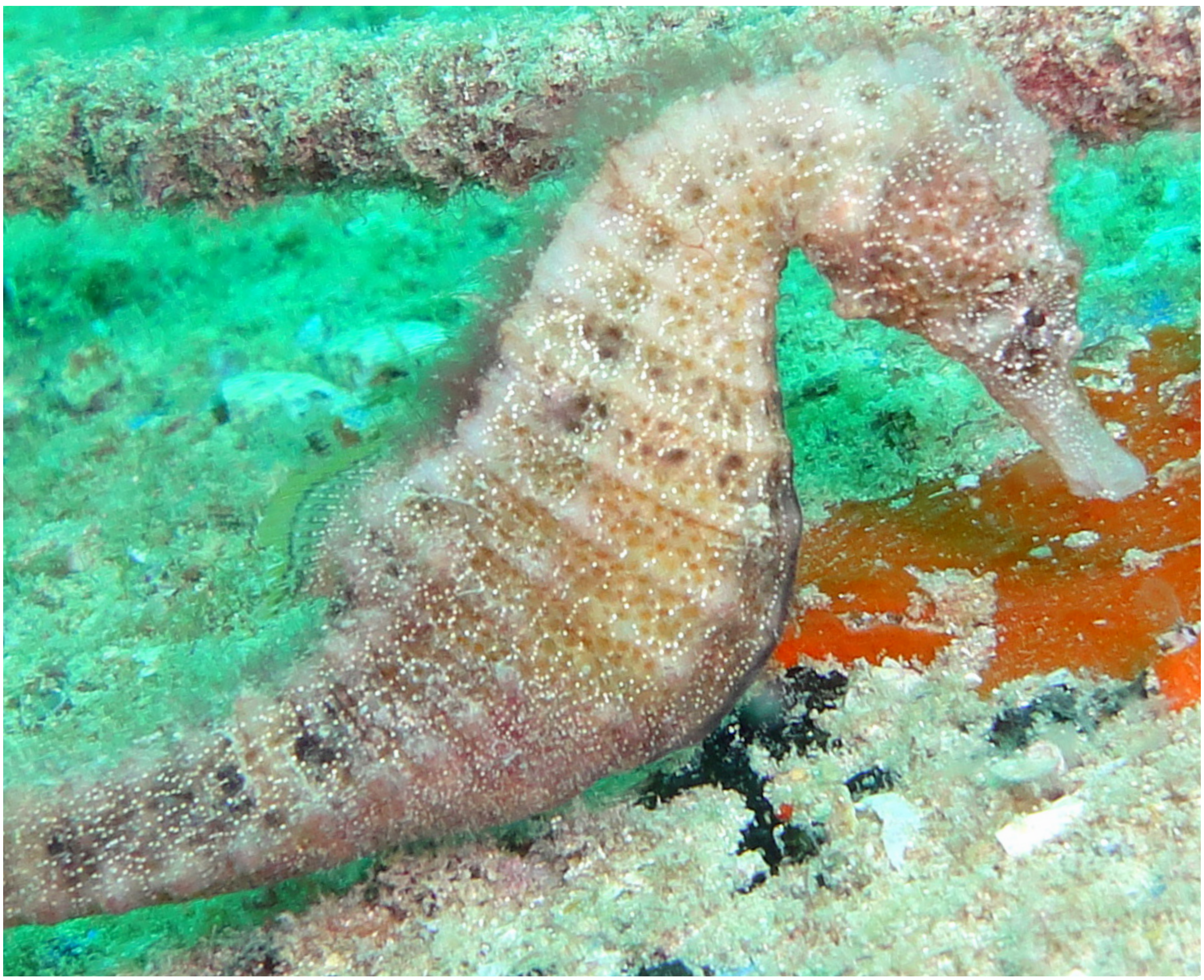
More than 90% of the threatened and Near Threatened species are impacted by biological resource use, either through direct, targeted fisheries, through illegal, unreported and unregulated fishing or indirectly through bycatch or habitat degradation (Figure 8). In particular, overexploitation was flagged as a driver for all threatened and Near Threatened cartilaginous fishes, mammals and sea turtles; these typically long-lived, late-maturing species may be particularly susceptible to declines (e.g., Dulvy et al., 2014). The 237 threatened and Near Threatened reef-building corals, which represent nearly half of all the species in these categories, are impacted by the same suite of threats, including fisheries-related habitat degradation; climate change and severe weather; human intrusions and disturbance; invasive and other problematic species, genes and diseases; pollution; residential and commercial development; and transportation and service corridors.

Habitat degradation and destruction through pollution, coastal development and other habitat modifications emerged as a major threat across species groups assessed. These anthropogenic activities can lead to physical damage, changes in chemical water quality (eutrophication), sedimentation, the introduction of pollutants, and microbial contamination. Ultimately, habitat loss can lead to ecosystem phase shifts in which the dominant structuring species (i.e., corals, seagrasses, and/or mangroves) are replaced (Done, 1992; McManus & Polsenberg, 2004). Phase shifts ripple through the ecosystem (Done, 1992), many causing a net loss of biodiversity as habitat quality declines (McManus & Polsenberg, 2004).

Climate change further emerged as a major driver of extinction risk for some taxa in some sub-regions of the WIO. In the northwestern WIO, climate change, aggravated by local stressors such as coastal development, has been implicated in the decline of coral assemblages in the Arabian Gulf and Red Sea (Riegl, 2001;

Burt et al., 2014). The Red Sea has high levels of coral endemism (DiBattista et al., 2016), while both regions have limited connectivity to other parts of the WIO, and high and variable salinity and temperature (Sheppard et al., 1992; Riegl, 2001). Corals in these regions are vulnerable to environmental fluctuations as they are already existing at the edge of the environmental and/or thermal tolerances (Cheung et al., 2009; Sheppard et al., 2012; Buchanan et al., 2016). In the southwestern WIO, South Africa has distinct biogeographic zones that are primarily defined by differences in temperature (Turpie et al., 2000). This biogeography contributes to high endemism in the area (Turpie et al., 2000; Skowno et al., 2019; van der Bank, 2019). Here, climate change has led to shifting distributions of commercially important fishes and invertebrates, with social, ecological, and economic impacts that complicate resource management (Sink et al., 2012).

In addition to species directly affected by climate change, the survival of some species, such as those that are coral dependent (Munda, 1997; Booth & Wellington, 1998; Gardiner & Jones, 2005; Pratchett et al., 2013), is determined by the extent of suitable live coral habitat (Jones et al., 2004; Munday et al., 2008; Pratchett et al., 2013). These taxa are likely to experience population declines as a response to reduced habitat availability resulting from climate change effects (AGEDI, 2015; Buchanan et al., 2016).



Spotted Seahorse (*Hippocampus kuda*); assessed as Vulnerable; by D.P. Wilson and licensed under CC BY 2.0

3.5 Research needs

Our results highlight several key research needs, including those for habitat-forming species and exploited species. Approaches for economic valuation can further contribute to biodiversity conservation.

Habitat-forming species provide valuable ecosystem services that support both human and non-human ecosystems; however, limited high-resolution information is available throughout much of the WIO on the distribution and abundance of these species. These research needs should be elevated within existing research and resource management frameworks of the respective nation-states and territories of the Western Indian Ocean region, and by regional resource management organizations. Mangroves, corals, and seagrasses primarily occur in shallow waters, and as such a substantial portion of that existing biodiversity lies within territorial and EEZ boundaries (AGEDI, 2015). Outside of national territorial boundaries and EEZs, regional habitat-based research programs fulfilled under the mandates of Regional Fisheries Management Organizations (RFMOs) and arrangements such as the Southern Indian Ocean Fisheries Agreement, have the potential to enhance and synthesize the highly variable existing knowledge of the distribution of habitat-forming species. For example, previous studies have highlighted the need for a regional approach to coral reef mapping in the Persian Gulf (e.g., Burt et al., 2014; Buchanan et al., 2016; Grizzle et al., 2016).

Overexploitation of target and non-target marine species was identified as a primary driver of extinction risk in at least 90% of threatened and NT species. Fishes, in general, had a high proportion of species targeted in single- and multi-species fisheries, while threatened and NT mammals, sea turtles and reef-building corals were negatively impacted by incidental take as bycatch and fisheries-related habitat degradation. Given the susceptibility of many species to fishing activity, there is a pronounced need for greater characterization of regional fisheries, and for

Malindi Fish Market, Zanzibar © G. Saluta.

fundamental biological and ecological research at multiple scales, from municipal to regional, to support data-driven assessments of the current status of impacted species. Quantitative metrics such as maximum size, length-frequency distribution, age at first maturity, assessments of discard mortality, and catch-per-unit effort can be used to quantify population trends. Quantifying population trends is a crucial exercise that supports resource management and conservation programs, as well as the Red List assessment process.

Economic valuation can contribute to biodiversity conservation by enabling the optimal allocation of limited management resources. Loss of local or regional biodiversity can result in a corresponding loss in the provision of goods and services, some of which have tangible economic value, including reduced resilience and resistance to change, declining environmental health, reduced fisheries potential, and lost recreational opportunities (Beaumont et al., 2008; de Groot et al., 2010). Valuing these potential losses can empower managers to divert resources towards important and attainable biodiversity and ecosystem services goals.

3.6. Existing conservation tools

Municipal, provincial and state/territorial governments are tasked with fulfilling various environmental mandates, many of which are focused on economic development, food security, and poverty alleviation. Incorporating marine biodiversity conservation goals and strategies into existing policy and enforcing policies will ensure continued ecosystem support for coastal human communities, contribute to sustainable development initiatives, and can bolster provincial and national economies through fisheries and tourism.

The open ocean, or high seas, are cooperatively managed by Regional Fisheries Management Organizations, international organizations formed by participating countries with fishing interests in an area. RFMOs such as the Indian Ocean Tuna Commission, and agreements such as the Southern Indian Ocean Fisheries Agreement, can implement management actions including setting catch and effort limits and implementing gear restrictions, as well as mandates to advance research within their respective domains. Both management and research functions of these bodies have the potential to advance the marine biodiversity and habitat conservation in the region. Additionally, more regionally specific initiatives offer means to implement and monitor fisheries management plans, establish ecosystem approaches to fisheries management and thereby achieve sustainable development goals. One example of such a regional initiative is that of the United Nations Industrial Development Organization (UNIDO) project of the Republic of Sudan, which is building institutional capacities for an eco-system approach to management of the marine fishery in Sudan with aim to improving sustainable management and development of artisanal and semi-industrial fisheries (UNIDO, 2019).

Many WIO nations are signatories to international environmental agreements, including the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Convention on Biological Diversity (CBD), the Convention on Migratory Species (CMS), the International Convention for the Regulation of Whaling (IWC), the UN Convention on the Law of the Sea (UNCLOS), and the UN Sustainable Development Goals (SDGs). These agreements have the potential to bolster marine conservation efforts at the regional scale by aligning the goals of individual nation-states, promoting regional cooperation, drawing political and legal frameworks for use and governance in the region's oceans and seas.

Marine protected areas (MPAs) are another broadly applied tool. IUCN identifies a protected area as clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (Dudley, 2008; Day et al., 2019). MPAs are tailored to protected management of natural marine areas. MPAs are created by delineating zones with associated permitted and non-permitted uses (IUCN Global Marine and Polar Programme, 2020). The countries and territories of the WIO have designated many small, coastal protected areas, as well as several large oceanic protected areas, including the British Indian Ocean Territory Marine Protected Area (Chagos), UK; Mayotte and Iles Eparses, France; Amirantes to Fortune Bank and Aldabra Group, Seychelles; South Africa's recently expanded MPA network (IUCN, 2004; UNEP-WCMC & IUCN, 2020). In some cases, these protected areas have assisted countries in meeting Aichi targets and SDGs. Enforcement of MPAs is a vital element impacting their conservation benefit (Edgar et al., 2014).

3.7 Species conservation successes

Within the WIO various studies have investigated the efficacy of different conservation initiatives and methods. In response to the major coral bleaching event of 1998, Frontier-Tanzania implemented surveys to measure the recovery of corals within and outside of the Misali Island Marine Conservation Areas (MIMCA) (Poonian, 2008). The study showed that reduced fishing pressure in the protected area sustained populations of herbivorous fish that reduce algal overgrowth and thus promote coral recovery.

An assessment of locally managed marine areas (LMMAs) in 2014 found that, though LMMAs protect large areas, many are under-supported by legal structures and enforcement mechanisms (Rocliffe et al., 2014).

One strong example of success in species conservation and management in the region comes from a Conservation Leadership Programme (CLP) initiative. The CLP supported the creation of a non-governmental organization titled Community Centred Conservation or C3. Operating in Comoros and Madagascar, this NGO has used innovative approaches to promote the conservation of species in the region. C3 research on Dugong populations was central in developing an international protocol for rapid assessment of dugong populations which is now used worldwide (conservationleadershipprogramme.org accessed on 17th of July 2020; Whitty et al., 2010) and further support from CLP expanded the work of C3 to data collection for sharks and turtles in addition to dugongs. Funding support facilitated the employment of resource managers and eco-guards as well as development of alternative livelihood cooperatives. The work of C3 is having a significant impact on the conservation status of its target species within the Nosy Hara marine park where cases of illegal fishing and hunting are now being recorded and reported. Since the start of the project there have been no recorded infractions within the park and no reports of sea turtle or dugong mortality (conservationleadershipprogramme.org accessed on 17th of July 2020).

Well-structured and strategically funded projects such as this can be powerful tools for species conservation. The above described project focused on species of clear conservation priority but, moving forward, future projects would benefit greatly from the information provided by the conservation status report presented here. This report offers a list of priority taxa, as relates to their risk of extinction, as well as key information on the threats currently driving their decline.

Stellate Puffer (*Arothron stellatus*); assessed as Least Concern; by D.P. Wilson and licensed under CC BY 2.0

4. Conclusions and recommendations

4.1 Overview

Our report identifies, among more than 4,000 species across diverse taxonomic groups, 473 species that are threatened or Near Threatened with extinction at the global level, according to the IUCN Red List Categories and Criteria. The status of species is based on evaluations made by a network of experts who carried out biodiversity assessments according to the IUCN Red List Categories and Criteria. Complete assessments are freely available on the IUCN Red List website (http://www.iucnredlist.org).

The conservation status of in the WIO region (midpoint = 8.0%) is moderately high, relative to the status of the same taxonomic suite of species assessed in other regions. For example, of the five tropical FAO zones, the midpoint of threatened species in the Western Central Atlantic (6.0%), Eastern Central Pacific (6.3%) and Eastern Central Atlantic (7.8%) are lower, while the Western Central Pacific (8.2%) and Eastern Indian Ocean (8.6%) are higher (IUCN, 2020). However, uncertainty is highest in the WIO: 16.9% of the WIO species are listed as DD, as compared to 11.0-15.8% in the other tropical regions.

Species richness analyses identified hotspots of threatened species such as the southern Red Sea and along the southern coast of India that could be explored for prioritizing conservation action. Major threats are identified for each taxonomic group, and recommendations for conservation actions are suggested. The data in each species account provide key resources for decision-makers, policymakers, natural resource managers, environmental planners and NGOs.

Humpback Turretfish (*Tetrosomus gibbosus*); assessed as Least Concern; by D.P. Wilson and licensed under CC BY 2.0

4.2 Application of project results

The value of the Red List extends far beyond the assignation of threat status. The Red List, in conjunction with the data gathered to support it, has become an increasingly powerful tool for conservation planning, management, monitoring, and decision making (Rodrigues et al., 2006). These assessments are valuable both individually, and when aggregated for analyses, such as those that have been presented in this report.

National governments are the institutions that have the most power to directly influence conservation action and legislation (Miller et al., 2007). Species lists generated through the IUCN Red List process can serve as a starting point for the generation of national Red Lists and lists of species of conservation concern (Keller & Bollman, 2004; von May et al., 2008). IUCN recommends use of the IUCN Guidelines for Application of the IUCN Red List Criteria at Regional Levels (Gärdenfors et al., 2001; IUCN, 2003) when adapting global assessments to the regional or national scale.

Environmental literacy is necessary to address many problems currently facing biodiversity (Bickford et al., 2012). Individual assessments provide peer-reviewed information that can be used in awareness and appreciation campaigns and initiatives. In addition to providing a justified conservation assessment for each species, individual IUCN Red List accounts provide concise summaries of geographic distribution, population status, habitat and ecology, life history, and uses and trade for each species, alongside relevant, cited references found predominantly in peer-reviewed scientific literature. These assessments can be used by protected area managers, zoos, aquariums, retailers and wholesalers, tour guides, educational institutions, and science communicators to raise biodiversity and environmental awareness among audiences, visitors, customers and clients (Bickford et al., 2012). They can also be used as reference material by researchers in biodiversity, ecology and conservation as well as other related fields.

Synthesizing Red List assessments provides a powerful means for exploring, visualizing, and summarizing trends across space, and across species groups, as has been done for this report. Some species that have undergone re-assessment are candidates for analyses of changes in conservation status over time and in response to conservation action as part of the Red List Index. Global-level analyses of Red List results across entire clades contributes widely to our understanding of extinction risk of taxa (Carpenter et al., 2008; Polidoro et al., 2010; Short et al., 2011; Comeros-Raynal et al., 2012), identified regional biodiversity hotspots of species richness and endemism (Polidoro et al., 2012; Buchanan et al., 2016; Linardich et al., 2018), and presented novel patterns in use and trade (Purcell et al., 2014; Stump et al., 2018). The results of this project serve as an important baseline from which future assessments can be compared, assessing trends in conservation status over meaningful timescales and thus assessing effectiveness of conservation measures over time.

One of the most effective ways to utilize aggregated Red List assessments for conservation purposes is the identification and delineation of Key Biodiversity Areas (KBAs). KBAs effectively and iteratively identify areas of species composition that are either highly vulnerable (threatened) or irreplaceable (restricted range) and prioritize areas that will benefit the most from site-level conservation actions (Edgar et al., 2008; IUCN, 2016; Day et al., 2019). Red List assessments provide foundational information regarding a species' distribution, extinction risk status and plausible threats for KBA analyses. In this regard, the species assessments and analyses presented in this report could inform KBA analyses for areas of particular importance within the WIO.

4.3 General conservation strategies and tools

Various conservation strategies and tools are relevant to addressing regional and global biodiversity needs. The Red List assessments, encompassing not only the threat status of a species, but also the accompanying distribution, life history, ecology, population trends, and threat information, can and are being used to guide resource management at multiple scales. From assessments at a single site, such as environmental impact assessments (Meynell, 2005) to national-scale evaluations, such as in national development policies and legislation and multilateral agreements (Rodrigues et al., 2006), Red List assessments and the associated temporal Red List Index, are essential benchmarks.

The Red List Assessment process provides a powerful tool for identifying knowledge gaps. For example, despite their commercial importance, many commercial species were assessed as Data Deficient, due to a lack of time-series data to apply the IUCN Red List criteria. Fisheries catch and effort data are a valuable source of population information within the context of the Red List process and are the foundation of quantitative fisheries management exercises. However, in many cases, landings are recorded only to the family or genus level, or species are frequently misidentified. These management issues occur globally in fisheries, and the IUCN Red List can be used as a tool to prioritize research needs for such species.

Raising awareness of the value and vulnerability of the WIO's marine biodiversity among resource users, managers, the public, politicians, and authorities is an ongoing conservation need. This can be more effective when also focusing on conservation strategies that are already being employed at the local, national, and regional scales. Regionally, UNEP's Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the WIO provides a framework and forum for such strategies. In collaboration with, amongst others, the Western Indian Ocean Marine Science Association, the South West Indian Ocean Fisheries Commission, IUCN, and the Convention on Biological Diversity, the Nairobi Convention Secretariat leads initiatives (past, current and future) such as the State of the Coast Report, Outlooks on MPAs and Critical Habitats, and the Strategic Action Plan for the protection of the WIO, all of which heighten awareness of biodiversity issues.

Strategies for raising awareness of the value and vulnerability of the WIO's marine biodiversity include:

- Adopting flagship species – a flagship species is a species selected to act as an ambassador, icon or symbol for a defined habitat, issue, protected area campaign or environmental cause (Bowen-Jones & Entwistle, 2002).
- Hosting events designed to create awareness of resident biodiversity and among a wide range of communities, such as national conferences. Effective events will focus on regional biodiversity and existing conservation tools and strategies.
- Incorporating biodiversity topics in educational curricula for school-aged children (Van Weellie & Walls, 2002; Lindemann-Matthies et al., 2011).
- Incorporating Red List Assessment Categories of organisms on display in zoos and aquariums (Whitehead, 1995).
- Deploying social media campaigns to raise the profile of local biodiversity and conservation issues (Bickford et al., 2012).

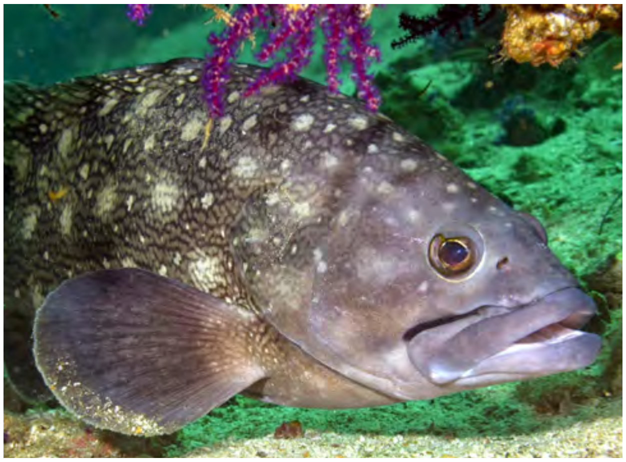
Areas for potential improvement in the governance of the oceans and coastal environment in the WIO region include addressing policy and legislative inadequacies, increasing institutional capacities, raising awareness, improving access to financial resources and mechanisms, and improving knowledge management. Translation of international agreements and commitments into national law is heterogenous across the region. Continuing improvements in technical capacity, scientific output, access to financial resources, strengthening of political will and prioritization, and reduced political instability will contribute to regional improvements in management of marine areas (UNEP-Nairobi Convention & WIOMSA, 2015). WIO Threatened Species Task Forces have been suggested as means to mobilize capacity to deal with threatened marine species and habitat (UNEP-Nairobi Convention & WIOMSA, 2015).

Bluestripe Pipefish (*Doryrhamphus excisus*); assessed as Least Concern; by D.P. Wilson and licensed under CC BY 2.0

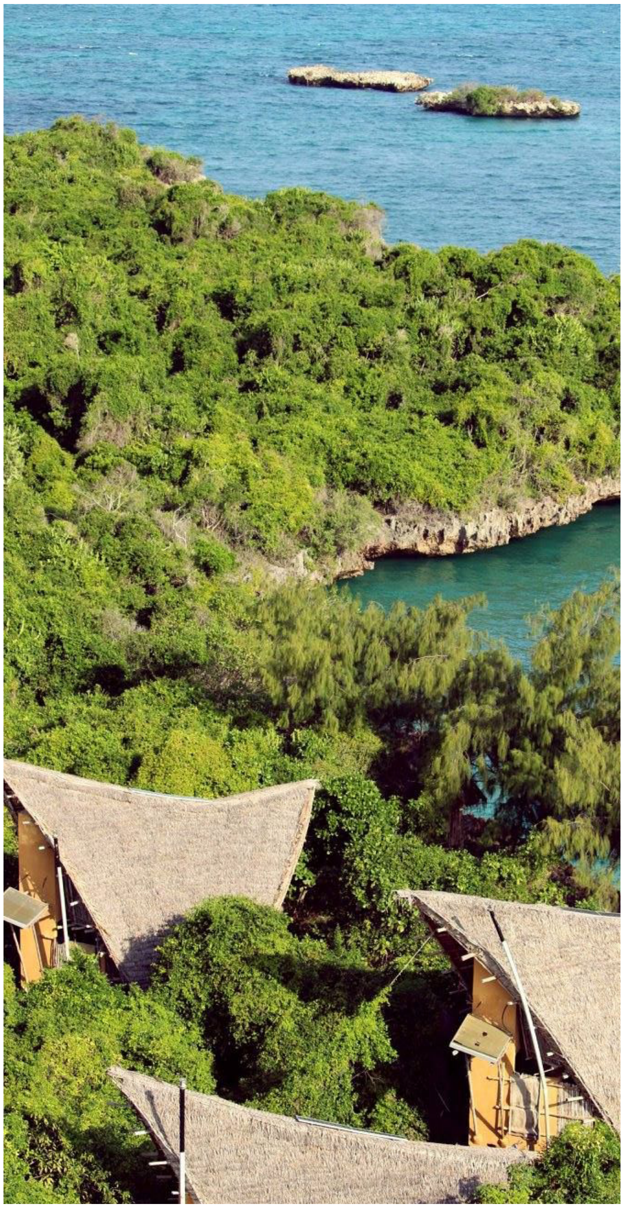
4.4 Next steps

This report includes numerous new assessments of marine species in the Western Indian Ocean, representing a substantial contribution to knowledge of the distribution, population status, habitat, ecology, conservation status, threats, and extinction risk of marine biodiversity in the region. Despite this substantial taxonomic coverage, there remain species and species groups that are unassessed in the region; marine invertebrate assessments, in particular, are lacking. Completing these assessments, and performing re-assessments at regular intervals, is a valuable exercise that contributes to characterizing the status of regional biodiversity and the relative impact of conservation initiatives.

Two very effective methods for implementing conservation in the marine environment are the identification of KBAs (Edgar et al., 2008) and the subsequent installation of marine protected area networks where the KBAs have been identified (McLeod et al., 2009). KBAs are an iterative and site-based methodology of identifying where conservation measures will be most effective in protecting biodiversity. The Red List assessments resulting from this study are integral to completing the KBA process. Founded on the concepts of vulnerability and irreplaceability, KBAs enable conservation managers to identify places where (a) conservation is most needed to preserve biodiversity and (b) places where marine areas can feasibly be managed and protected (Langhammer et al., 2007). Where KBAs are identified, marine conservation managers and other stakeholders can delineate a network of protected areas that encompass the identified KBAs, allowing for high degrees of connectivity between the sites, as well as passageways and refuge for highly mobile and migratory species (Eken et al., 2004). Large, multi-jurisdictional MPAs are not the only effective means of instituting protected areas for marine environments; in some regions, community-based management strategies have been effective in establishing and maintaining small, no-take marine protected areas (Weeks et al., 2014).



Whitespotted Grouper (*Epinephelus coeruleopunctatus*); assessed as Least Concern; by D.P. Wilson and licensed under CC BY 2.0.



Chumbe Island Coral Park Nature Reserve and Reef Sanctuary © G. Saluta

The IUCN Red List of Threatened Species™ fulfills one of the key objectives of the IUCN, to share the knowledge gathered by its global community of over 10,000 scientists and conservation professionals. Training in the application of biodiversity data sets to species and site-based management and enforcement activities is available through the IUCN Conservation Planning Specialist Group, the IUCN Species Monitoring Specialist Group, and the IUCN World Commission on Protected Areas/ Species Survival Commission Joint Task Force on Biodiversity and Protected Areas.

The following reference documents provide valuable tools for using IUCN Red List Assessments to inform area-based conservation measures:

- *A Global Standard for the Identification of Key Biodiversity Areas*. Version 1.0 (2016)
- *Guidelines for Applying Protected Area Management Categories* (2008)
- *Guidelines for applying the IUCN protected area management categories to marine protected areas.* Second edition (2019)

For more information on using the IUCN Red List of Threatened Species™ to inform conservation planning, including KBAs and protected areas, please reach out to the following:

- IUCN Global Marine and Polar Programme
- IUCN Marine Conservation Committee
- World Commission on Protected Areas – Marine Division
- Species Survival Commissions (SSC) Specialist Groups
- Commission on Environmental Law (CEL) Oceans Law and Governance Specialist Group

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Note: for the extensive literature used to compile each species assessment, please see each species account on the IUCN Red List (www.iucnredlist.org).

Appendix: Expert participants

Table 1: Expert participants at the 2017 IUCN Red List workshop in Zanzibar, Tanzania, with institutional affiliations and country of residence, organized alphabetically by family name.

Participant Name	Affiliation	Country
Tiffany Birge	Old Dominion University/IUCN	USA
Philippe Borsa	Institut de recherche pour le développement (IRD)	France
Robert Bullock	The Deep Aquarium/IUCN	England
Kent Carpenter	Old Dominion University/IUCN	USA
Fabio Di Dario	Universidade Federal do Rio de Janeiro	Brazil
Narriman Jiddawi	Institute of Marine Sciences, University of Dar es Salaam	Tanzania
Moazzam Khan	WWF-Pakistan	Pakistan
Helen Larson	Museum and Art Gallery of the Northern Territory	Australia
Keiichi Matsuura	National Museum of Nature and Science	Japan
Hiroyuki Motomura	The Kagoshima University Museum	Japan
Clay Obota	Coastal Oceans Research and Development - Indian Ocean (CORDIO)	Kenya
Beth Polidoro	Arizona State University/IUCN	USA
Gina Ralph	Old Dominion University/IUCN	USA
William Smith-Vaniz	Florida Museum of Natural History, University of Florida	USA
Saleh Yahya	Institute of Marine Sciences, University of Dar es Salaam	Tanzania

Workshop group photo in Zanzibar © G. Ralph.

Table 2: Expert participants at the 2018 IUCN Red List workshop in Muscat, Oman, with institutional affiliations and country of residence, organized alphabetically by family name.

Participant Name	Affiliation	Country
Farid Saud Hamed Al Abdali	Sultan Qaboos University	Oman
Jenan Al Asfoor	Environment Society of Oman	Oman
Asma Al Bulushi	Environment Society of Oman	Oman
Bader Al Buwaiqi	Sultan Qaboos University	Oman
Abdullah Sulaiman Musbah Al Kindi	Sultan Qaboos University	Oman
Aisha Ambuali	Sultan Qaboos University	Oman
Philippe Borsa	Institut de Recherche pour le Développement	France
Kent Carpenter	Old Dominion University/IUCN	USA
Anesh Govender	Sultan Qaboos University	Oman
Helen Larson	Museum & Art Gallery of the Northern Territory	Australia
Christi Linardich	Old Dominion University/IUCN	USA
Beth Polidoro	Arizona State University/IUCN	USA
Gina Ralph	Old Dominion University/IUCN	USA
Barry Russell	Museum & Art Gallery of the Northern Territory	Australia
Alan Williams	Commonwealth Scientific and Industrial Research Organisation	Australia

Workshop group photo in Muscat © G. Ralph.

Table 3: Expert participants at the 2019 IUCN Red List workshop in Durban, South Africa, with institutional affiliations and country of residence, organized alphabetically by family name.

Participant Name	Affiliation	Country
Robert Bullock	The Deep Aquarium/IUCN	England
Bernadine Everett	South African Association for Marine Biological Research Oceanographic Research Institute	South Africa
Sean Fennessy	South African Association for Marine Biological Research Oceanographic Research Institute	South Africa
Catarina Fonseca	Oceanario de Lisboa/IUCN	Portugal
Claire Gorman	Old Dominion University/IUCN	USA
Hans Ho	Institute of Marine Biology, National Dong Hwa University	Taiwan
Wouter Holleman	South African Institute for Aquatic Biodiversity	South Africa
Christi Linardich	Old Dominion University/IUCN	USA
Patroba Matiku	Tanzania Fisheries Research Institute	Tanzania
Claque Maunde	National Institute of Fisheries Research	Mozambique
Thomas Munroe	U.S. National Marine Fisheries Service/Smithsonian Institution	USA
Rekha Nair	India Central Marine Fisheries Research Institute	India
Gina Ralph	Old Dominion University/IUCN	USA
Barry Russell	Museum & Art Gallery of the Northern Territory	Australia
Yonela Sithole	South African Institute for Aquatic Biodiversity	South Africa
Franz Uiblein	Institute of Marine Research	Norway
Steven Weerts	Council for Scientific and Industrial Research Durban	South Africa
Alan Williams	Commonwealth Scientific and Industrial Research Organisation	Australia

Workshop group photo in Durban © G. Ralph

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