© Flickr/Thriol

2018 TANZANIA OCEAN HEALTH INDEX

TECHNICAL REPORT
DECEMBER 2018

CORDIO

Preliminary Ocean Health Index Assessment for Tanzania

CORDIO EAST AFRICA

December 2018

This project is funded by the European Union

Funded by: The preliminary OHI+ assessment was funded by the Indian Ocean Commission through the Biodiversity Project funded by the EU, grant number EDF/2016/382-097 GRT/CN 147, and the Dalio Foundation.

Written by:

CORDIO East Africa technical team

Gudka M, Ojwang L, Mabwa R, Mbugua J, Obura D, Obota C

CORDIO East Africa
#9 Kibaki Flats
Kenyatta Beach, Bamburi
Mombasa, Kenya
P. O. BOX 10135 - 80101
Tel: +254 736 341184
Email: info@cordioea.net

Special thanks to the Project Advisory and Technical Teams

OHI+ Tanzania Report

Table of Contents

1. Tanzania OHI - Summary for Decision-Makers 1
   1.1. Why now? 1
   1.2. Tailoring the OHI to Tanzania's needs and priorities 1
   1.3. Key findings 2
   1.4. Recommendations 4
2. Background 5
   2.1. What is the Ocean Health Index? 5
   2.2. Adapting the Index for Tanzania 5
   2.3. Applications of the framework, process and tool 6
3. Methodology 6
   3.1. OHI Framework 6
   3.2. Priority goals 8
   3.3. Spatial scale of assessment 9
      3.3.1. Recommendations 12
   4. Results 12
   4.1. Food provision: Fisheries 13
      4.1.1. Data 13
      4.1.2. Reference point 14
      4.1.3. Pressures and Resilience 14
      4.1.4. Challenges 15
      4.1.5. Recommendations 16
   4.2. Biodiversity goal 18
   Biodiversity: Habitat 18
      4.2.1. Results 19
      4.2.2. Challenges 23
      4.2.3. Recommendations 23
5. Conclusions 24
   5.1. Management and Policy recommendations 24
   5.2. Lessons learnt 25
   5.3. Challenges 26

5.4. Opportunities for further work....27
6. Acknowledgements....29
7. References....29
8. Appendices....31
8.1. Participants, stakeholders workshop, Tanzania February 2018....31
8.2. Participants, all technical team meetings, Tanzania May 2018 (28th-31st)....32
8.3. Participants technical and advisory team discussions, Zanzibar 23rd-25th July 2018....32
8.4. Participants dissemination meeting, Dar es Salaam, 5th December 2018....33
8.5. Project governance teams....33
8.5.1. TORs for project governance teams....36
8.6. Method - calculating the index....39
8.7. Fisheries model and analysis....41
8.7.1. OHI global fish species list for Tanzania....42
8.7.2. Pressure indicators - Fisheries sub-goal....43
8.7.3. Resilience indicators - Fisheries sub-goal....44
8.8. Habitat goal model and analysis....45
8.8.1. Pressure indicators - Habitat sub-goal....46
8.8.2. Resilience indicators - Habitat sub-goal....47

1. Tanzania OHI - Summary for Decision-Makers

The Ocean Health Index (OHI) scientifically combines key biological, physical, economic, cultural and social data to understand the health of a country's ocean resources. It reflects how well countries optimize potential ocean benefits and services in a sustainable way relative to a target, on a scale of 0 to 100. This Tanzania OHI assessment was conducted as a participatory process involving government institutions and stakeholders, hosted nationally by the Tanzania Fisheries Research Institute (TAFIRI) and Fisheries Education and Training Agency (FETA) with technical coordination by CORDIO East Africa, Conservation International and the National Center for Ecological Analysis and Synthesis (NCEAS, USA).

The OHI global framework measures 10 goals that encompass ocean health:

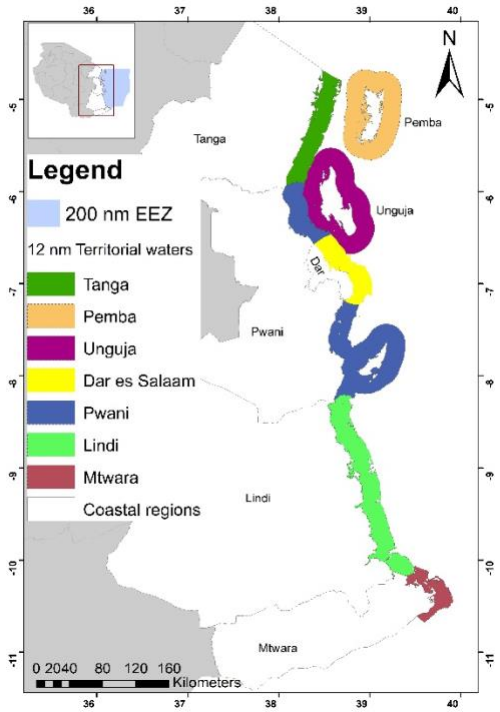
Each goal is scored on a scale of 0-100, with 100 representing optimized use of potential ocean benefits and services in a sustainable way.

1.1. Why now?

The ocean plays a significant role in socioeconomic development of the United Republic of Tanzania by supporting key economic sectors such as fisheries, tourism and shipping as well as its rich cultural heritage. The growing interest and inevitable investment in the 'Blue Economy' within a changing climate and growing population, poses additional risks. An OHI analysis can help to align actors from diverse sectors and across scales, to ensure sustainable use of the ocean for future prosperity.

1.2. Tailoring the OHI to Tanzania's needs and priorities

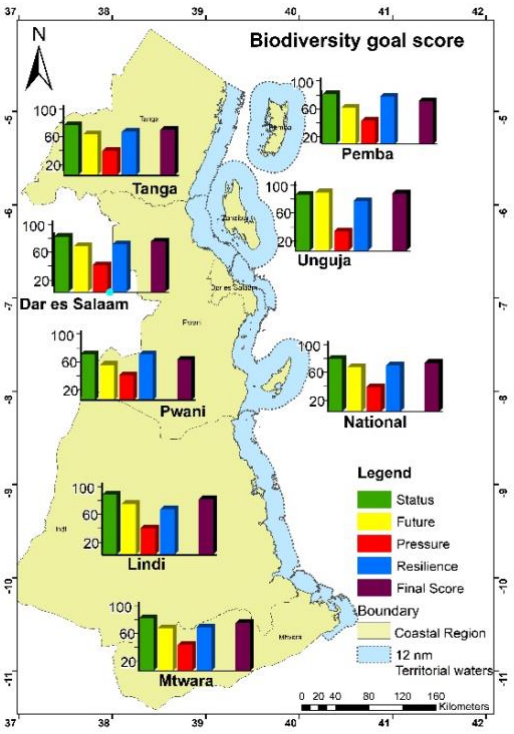
Stakeholders ranked the goals, selecting the top two as priorities for analysis: Food provision (by fisheries) and Biodiversity (coastal marine habitats).



Districts are identified and empowered by Tanzania's 1977 constitution as the main authorities for local government however maritime boundaries at a sub-national level are not specified in Tanzanian law. Several options for maritime jurisdiction of subnational level units were considered, from which the project identified operational zones that could be used to inform management of coastal marine resources. The 12 nM (nautical mile) territorial waters limit from the coastal baseline roughly matches the scope of coastal activities (e.g. fishing) and broad ecosystem boundaries (shallow waters from deep sea), and is consistent with the UN Law of the Sea and national legislation. Thus seven zones are identified (see map). Results from this assessment are preliminary and can be used as a baseline to develop and improve in future using more suitable and accurate metrics and data.

1.3. Key findings

Biodiversity (marine habitats): The Habitat sub-goal measures the average condition of critical marine habitats for a broad range of species, relative to a reference period. Data on coral reefs and mangroves were generated at the 'zones' levels, and on seagrasses only at a national level.



Tanzania scored fairly well overall, with a national score of 74.1. The overall score for each zone varies greatly with Pwani and Pemba scoring the lowest (61.6 and 65.5) while Unguja and Lindi had the highest scores (87.4 and 84.5 respectively). Recent trend in all zones is for a decrease (>13), with future state estimated to be appreciably lower than the current status except for Unguja (+3.1).

In all zones the pressures scores were lower than the resilience scores (all above 65). Unguja had both the lowest pressure and highest resilience scores (30 and 75.9), and together with Dar es Salaam are considered the most socially progressed based on the multi-dimensional poverty index. Dar es Salaam however also had the highest pressure score (41.3) partly attributed to its high coastal population, translating to highest intertidal pressure as well as highest chemical pollution levels and incidents of dynamite fishing. Mtwara and Tanga had the lowest resilience scores (66.2 and 66.7).

Habitat level results indicate the country has lost around 16% of its mangrove cover over almost a decade and a half, with Mtwara and Lindi retaining around 90% of their mangrove cover but Tanga and Pwani losing over a quarter of their area, and Dar over 30% of mangroves. Five of the seven zones showed declines in coral cover, with Pwani as the most impacted after losing about half its original living coral, whilst Mtwara and Pemba have lost around 40% and Unguja and Tanga about 30%. There was no variation in sea grass status score as OHI global analysis score of 0.855 was applied in all zones due to lack of data.

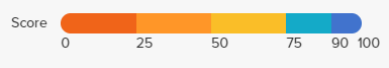
Key Policy and Management Recommendations

1. Support comprehensive mapping of all key habitats coupled with strong investment in national monitoring to produce detailed and consistent data for planning and decision making.
2. Develop and /or review national management plans for key marine ecosystems (e. g coral reefs, seagrassess, and mangroves) through an inclusive stakeholder process
3. Strengthen habitat management through finalization and operationalization of the Integrated Coastal Zone Management Strategy (Zanzibar) and National Integrated Coastal and Environmental Management Strategy (NICEMS) (mainland) strategies.
4. Increase community level resource co-management initiatives which are embedded within local government legal structures/frameworks e.g. BMUs to reduce various stressors on mangroves, seagrasses, coastal forest and coral reefs

5. Develop a national-scale strategic action plan on pollution (both nutrient and chemical) in all water bodies (oceans, rivers, lakes). For oceans, particular focus should be made to monitor around industrial and agricultural areas, ports and estuaries and river mouths
6. Examine the OHI indicators to identify key pressures and areas where management measures need to be strengthened either to resolve issues or preserve healthy habitat states
7. Invest in restoration of degraded habitats based on trials, best practices and methods with a proven success record

Food provision (fisheries) The Fisheries sub-goal aims to describe the amount of wild-caught seafood harvested and its sustainability for human consumption. It looks at both artisanal and commercial fisheries. For this preliminary assessment, only artisanal fisheries within the Tanzania's territorial waters was discussed, but only pressure and resilience scores were calculated due to data constraints i.e. availability, quality, timely access.

SCORE	MTWARA	LINDI	PWANI	DAR ES SALAAM	UNGUJA	TANGA	PEMBA	NATIONAL
PRESSURE	41.7	42.7	46.7	51.8	34.8	49.8	46.5	44.9
RESILIENCE	66.7	69.3	69.2	72.9	75.9	66.2	72.6	70.4



For all zones, pressure scores are lower than resilience scores, with all resilience scores above 65 (Unguja highest 75.9, Tanga lowest 66.2). Unguja and Dar es Salaam are considered the most socially progressed (lowest score for the multi-dimensional poverty index). Dar es Salaam however also had the highest pressure score (51.8, Unguja lowest 34.8) partly attributed to its high coastal population, translating to highest intertidal pressure as well as highest chemical pollution levels and incidents of dynamite fishing.

Technical discussions held during this project will help guide a subsequent analysis of this goal. Some key recommendations for future assessments from this process are listed below:

1. Test multiple models to assess status of artisanal fisheries in a data-poor case e.g. catch per unit effort (CPUE), MSY, Maximum Economic Yield, Spawning Potential Ratio (Spawning stock biomass) and Production-Biomass to see which model is best suited for the marine fisheries in Tanzania
2. Utilise MCS data collected to assess fisheries management effectiveness
3. Collate reports and summarised data from national stock assessments
4. Align the assessment to focus on the management priority fisheries, and based on this and available data select the stocks to assess from the stocks used in the global assessment for Tanzania
5. Work on how to incorporate more detailed information (effort, length-based estimates) from projects to supplement long-term monitoring data.

Key Policy and Management Recommendations

1. Increase investment in harmonized monitoring and data collection to ensure data is collected at higher taxonomic levels together with effort information at more fish landing sites across the country particularly in areas with limited access and low reporting. This will allow for more accurate assessments with the aim of moving Tanzania's fisheries sector to a data-rich system
2. Undertake stock assessments for all priority fisheries for management (prawn, tuna and tuna-like, octopus, coral reef, small pelagics) for the whole country.

3. Support attempts to develop an integrated, central fish catch database for Zanzibar (similar to that utilized in mainland Tanzania), which can be accessed by relevant institutions and linked to the mainland database for a fully-integrated national database. Sufficient measures should be put in place to ensure sustainable operation of both databases after completion of donor projects.
4. Support local governments and communities to implement area based management approaches to improve coastal fisheries status through capacity development, policy or legislation formulation, defining co-management and no-take zones and by providing adequate funding.
5. Assess effectiveness of existing regulations (e.g ban on dynamite fishing) on both catch and habitat quality to inform review where necessary and strengthen enforcement to reduce high pressures from destructive fishing practices.
6. Using sound scientific evidence, increase capacity for sustainable, domestic exploitation of off-shore fisheries including processing, through Zanzibar Fisheries Company (ZAFICO) and Tanzania Fisheries Cooperation (TAFICO) to improve food security
7. Build up metadata log of all catch data and stock assessments for both commercial and artisanal fisheries.

1.4. Recommendations

This preliminary analysis of two sub-goals of the OHI reveal its potential for future application to support national objectives and relevant authorities in the blue economy. The following recommendations focus on next steps for OHI goal assessments to produce tanngible results in ocean and coastal management:

- A relevant cross-sectoral entity should coordinate assessments to centralize the technical evaluation and integrate across levels of government, and the goals; Existing integrated frameworks for managing coastal zones such as the ICZM strategy (under ZEMA, Zanzibar) and NICES (under NEMC, mainland), that have a science to management component and have an active science and technical working group, could be a good entry point towards national operationalization and embedding of the OHI tool
- Each competent authority should be a goal 'custodian' to embed the evaluation in their official processes.
- Adequate resourcing, capacity and influence to undertake the assessments and implement recommendations should be assured
- Invest in monitoring and data collection programs for coastal and marine resources assessing status and trends, impact of interventions to inform decision-making and improve resource allocations, and determining knowledge gaps.
- Enhance cooperation between National and subnational levels of government (districts) with regards to natural resource use and management
- Sub-products such as status, pressure and resilience data layers and information can be used to inform planning processes at regional and national level

Priority actions in relation to goals:

- Fisheries goal - gather existing data and test various models to see which produce the most accurate scores
- Habitat goal – validate habitat condition values, include more habitats and attempt to fill data gaps
- Coastal Protection and Carbon Storage, can be calculated using the existing coral and mangrove data.
- Include offshore commercial fisheries to obtain an EEZ score
- The Biodiversity sub-goal, Species, using the Global IUCN Red List for species complemented with local studies and knowledge
- The Food Provision sub-goal, Mariculture, to reflect its growing future importance

2. Background

2.1. What is the Ocean Health Index?

The Ocean Health Index (OHI) is the first integrated assessment framework that scientifically combines key biological, physical, economic, cultural and social elements of the ocean's health. Using local data and institutions, OHI scores reflect how well coastal regions optimize their potential ocean benefits and services in a sustainable way relative to a target, on a scale of 0 to 100. The OHI framework integrates information from all relevant sectors into a single platform and offers various metrics to allow decision-makers to determine the appropriate balance of priorities among multiple uses to ensure that oceans can continue to sustainably deliver a range of benefits and services.

2.2. Adapting the Index for Tanzania

The project "Assessing the multi-sectoral context for biodiversity conservation in Tanzania using the Ocean Health Index organizing framework and decision-making tool" was implemented from July 2017 to September 2018. Funding was provided by the Indian Ocean Commission and Dalio Foundation to Conservation International (CI), which subcontracted CORDIO East Africa for technical implementation. The primary national partners were Tanzania Fisheries Research Institute (TAFIRI) and Fisheries Education and Training Agency (FETA).

The ocean has continued to play a significant role in socioeconomic development of the Republic of Tanzania. The nation boasts key marine ecosystems (such as coral reefs, mangroves, seagrass beds and beaches) upon which the rich culture and livelihoods of a significant proportion of its population is embedded (Kebede, Brown, & Nicholls, 2010). Fisheries, tourism, mining and shipping are among the key sectors directly linked to these ecosystems. Over the years, the high dependence on the coastal and marine resources often characterized with unsustainable exploitation has compromised the integrity of the ecosystems. In response, the leadership has made deliberate efforts in improving the governance of its marine resources through key policy and legal frameworks such as the ICZM strategy and various tools (MPAs, MSP, EBA) used for coastal management in Tanzania. The locals through community-led initiatives, are equally contributing to the management of these resources. OHI, with a local focus can thus help by providing the evidence required for optimal and sustainable use of the marine resources particularly as the Blue Economy continues to take the center stage in national agenda.

P**roject aims and objectives**

1. Undertake a preliminary Ocean Health Index assessment for Tanzania
2. Lay the groundwork for possible future assessments
3. Engage relevant stakeholders to inform them about the tool and framework and its potential uses
4. Identify national management priorities related to the ocean
5. Train local technicians to undertake the independent assessment
6. Embed the tool within national institutions or processes

The preliminary OHI assessment in Tanzania was a stakeholder led process, where through a series of focused meetings with experts from key government management and research institutions, academic institutions and NGOs, the issues around ocean conservation were discussed using the OHI framework as a guiding mechanism. The assessment aimed to build and improve on the OHI global assessment, through the use of local datasets and more applicable targets.

2.3. Applications of the framework, process and tool

The potential use of the Ocean Health Index as a framework to facilitate multi-sectoral discussions on ocean use and management, and as a tool to track resource state, have been outlined in the table below in four categories; data, planning, economy and country targets and references points,.

Table 1. Applications of the Ocean Health Index

THEME	USES
Data	1. Identify available local data as well as gaps in information; biological, governance, social, pollution etc. 2. Improve data sharing via stakeholder collaboration 3. Improve access to data through a central repository 4. Increase data management skills and capacity in relevant local institutions
Planning and management	1. Bring forth diverse scenarios leading to adequate prioritization and integration of stakeholder goals 2. Contribute to or support development of effective ocean policies, strategies, plans and regulations. 3. Track effectiveness of management interventions to achieve targets and improved ocean health 4. Identify management and funding priorities for investment 5. Implement Sustainable Development Goals
Economy	1. Inform on areas to invest; allocate funds for sustainable resource exploitation 2. Ignite initiation of dialogue on resource allocation
National targets & reference points	1. Assist the country in setting targets and reference points at attainable scales. 2. Streamline national and sub-national development reporting procedures 3. Establish targets and evaluate the effectiveness of interventions

3. Methodology

3.1. OHI Framework

Methods for calculating the OHI were developed at a global scale and released in 2012, combining dozens of data sets to produce annual Index scores for coastal nations and territories (Halpern et al., 2012). The global analysis has been repeated annually with a focus on improving methods and data (Halpern et al., 2017, 2015; Lowndes et al., 2017; ohi-science.org, 2017). The OHI identifies 10 goals that encompass ocean health: Food Provision, Natural Products, Clean Water, Coastal Protection, Carbon Storage, Biodiversity, Tourism & Recreation, Livelihoods & Economies, Artisanal Fishing Opportunities, and Sense of Place (Fig. 1). These goals are scored on a scale of 0-100, reflecting how well coastal regions are optimizing their potential ocean benefits and services in a sustainable way relative to a reference point: a score of 100 indicates optimal sustainable achievement of a goal target. For full, current global methods, see ohi-science.org/ohi-global.

Figure 1. *The ten goals of the Ocean Health Index*

At country levels, independent assessments (OHI+) allow for exploration of variables influencing ocean health at the smaller scales where policy and management decisions are made. Targets for goals are created using stakeholder input, higher resolution data, indicators, and priorities, which produce scores that better reflect local priorities. This enables communities, managers, policy makers, scientists to better and more holistically understand, track, and communicate the status of local marine ecosystems, and to design strategic management actions to improve overall ocean health.

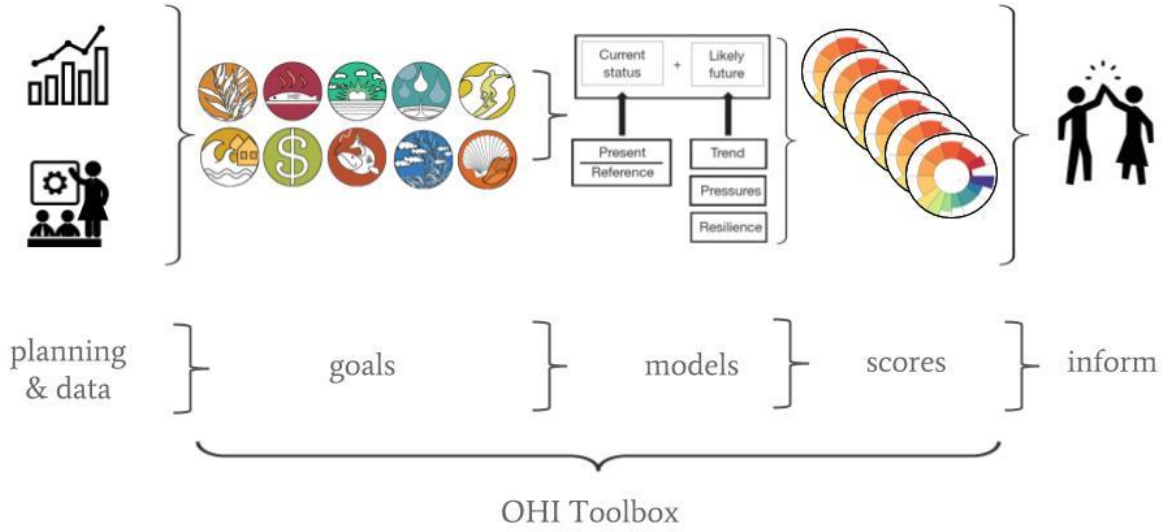


Figure 2*. Schematic of the assessment process for the Ocean Health Index, which is all supported by the online OHI toolbox.*

Details for calculating the index are provided in Appendix: Method - calculating the index (section 8.5).

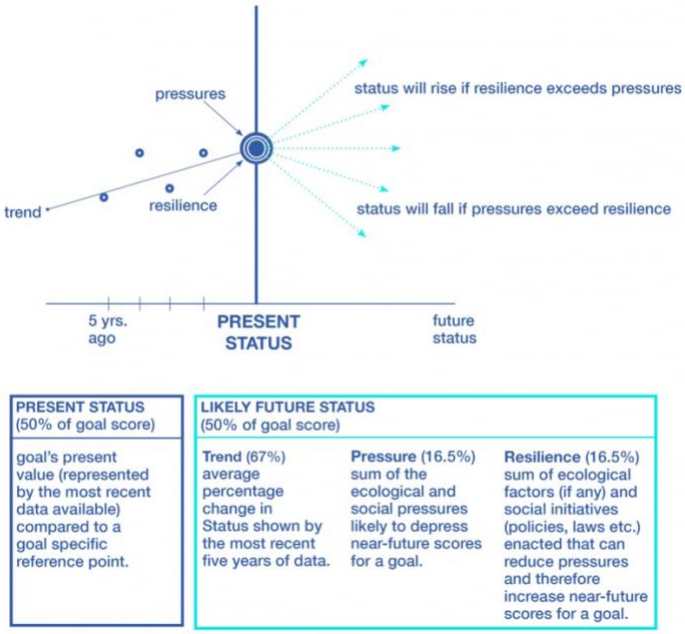


***Figure 3**. Schematic showing how the overall index is calculated, based on present status, and the likely future status, which itself is based on the recent trend (five years of data), pressures and resilience data.*

3.2. Priority goals

During the OHI stakeholder engagement workshop held in Dar es Salaam in February 2018, six sectors were ranked in order of importance. The top two goals: **Food provision (wild-caught fisheries)** and **Biodiversity (critical habitats)** were addressed by this assessment.

Primary benefits:

1. **Food provision**: sustainable wild-caught fisheries and mariculture were determined as the number one ocean priority for the country, to meet the local consumptive demand for protein (nutrition and food security) and to boost the economy through exploitation of deep-sea fisheries. With observed human population migrations towards the coast, there has been increased pressure on fisheries resources. This is coupled with nefarious practices, like dynamite fishing, which remain prevalent among some communities, and illegal, underreported, and unregulated (IUU) fishing conducted predominantly by foreign vessels. There are therefore large opportunities to improve regulatory frameworks of the industry, strengthen capacities on sustainable practices, and develop a healthy mariculture industry that can support food security goals while providing a good source of livelihoods.

2. **Biodiversity, coastal protection, and carbon storage**: Biodiversity was prioritized due to the need to preserve all marine and associated species (flora and fauna) including migratory species such as whales, as well as maintaining the integrity of critical habitats notably coral reefs, seagrasses, and mangroves as healthy marine ecosystems are essential in Tanzania for controlling erosion, preserving sites of cultural/economic importance, regulating climate and sustaining biodiversity.

3. **Coastal livelihoods and economies, and natural products**: As the coastal populations grow in Tanzania, there is an increased need to provide income security and economic prosperity. Sustainable production of seaweeds, salt, and other renewable ocean resources was identified as a priority for the country, along with the need to develop the associated infrastructure required for these industries to thrive, including ports, landing sites, and transportation networks. Large trade imbalances mean that the many containers that bring goods to the country return empty. This presents an opportunity to develop sustainable coastal activities, such as processing of natural products, to increase international trade. However any strategies must ensure that there is an equitable distribution of ocean and coastal economic benefits, with a focus on increasing employment in coastal communities, and co-managing/owning the producing resources with investors.

Secondary benefits:

4. **Cultural identity:** the preservation of traditional and indigenous knowledge and practices was highlighted as a main secondary benefit. There is a strong desire to ensure that coastal communities are explicitly and actively engaged in conservation activities. This also highlighted the need to develop and implement formal education and capacity development programs to ensure that local and scientific knowledge work in tandem to achieve conservation objectives.

5. **Land/coastal resources:** access to wood and timber resources was highlighted as a need for many coastal communities.

6. **Tourism and recreation**: tourism in the country is strongly dominated by the terrestrial safari industry, yet the potential for expanding sustainable ocean based tourism is enormous. The country has healthy coral reef populations, is in the migration path for many mega-fauna species, including whale sharks, and has many World Heritage Sites of cultural and religious importance. A sustainable coastal tourism industry could support local economies, provide sources of income and employment, and provide a financial incentive for the protection of natural resources.

3.3. Spatial scale of assessment

While the global OHI is focused on national EEZs as the main units, national OHI assessments can go down to finer scales. A key recommendation of the stakeholder engagement workshop, was that the OHI+ Tanzania assessment should be undertaken at an appropriate sub-national level e.g. district, region etc.

According to Tanzanian law, the ocean is national territory. Therefore to provide a score for each sub-national 'zone' based on their use of the adjacent sea, we allocated a portion of the coastal sea to each. To identify the boundaries for this portion, we undertook a transparent process, through consultations with technical and advisory team members.

Some considerations include:

1. The spatial resolution of the data is important for determining the scale of assessment. It is possible to aggregate data up i.e. from district to region, but not the other way.
2. At what scale is it useful to inform decision making and management?
3. To what extent can marine resources be managed at a sub-national level?
4. Is there activity in the EEZ and is there data up to 200 nautical miles or is most data available for only near-shore or coastal areas?
5. If split at a regional/district, how far should jurisdiction extend offshore?

6. How well can boundaries be drawn that fit ecological units in the sea, e.g. in relation to habitats, depth, currents and other parameters?
7. How should the assessment cater for the non-union matters with regards to management of coastal and marine resources

Following consultations the seaward boundary assigned to each operational 'zone' was set at the Territorial Waters boundary defined under the UN Law of the Sea (United Nations, 1982), or 12nM (nautical miles) from the coastal baseline. The EEZ was classified from 12nM to 200nM (Fig. 4), however was not considered for this preliminary assessment, as only artisanal fisheries and nearshore coastal and marine ecosystems were assessed. Zonal boundaries were extended into the ocean along latitudinal lines to be consistent with the demarcation of the national borders with Kenya in the North and Mozambique in the South. Where the 12nm territorial waters overlap between mainland Tanzania and Zanzibar zones, an equal distance was allocated to both (Fig. 4). In total, there are 7 zones for Tanzania (5 zones on mainland Tanzania and 2 zones on Zanzibar).

Challenges

- There is no official demarcation of sub-national jurisdiction in the ocean, therefore attribution of these operational boundaries in a justifiable manner required careful and multi-level discussions
- Some regions may disagree with allocation of resources
- The OHI is based on an ecosystem-based approach. Administrative boundaries don't necessarily align to ecosystems or socio-economic activities e.g. fishing
- Most problems in ocean emanate from elsewhere e.g. pollution from urban areas such as Dar es Salaam extends to adjacent regions and those affected districts have little control.
- Planned government activities e.g. offshore oil and gas exploration blocks overlap regions.
- Cumbersome to undertake this preliminary analysis at an administrative regional or district level due to the high number of divisions.

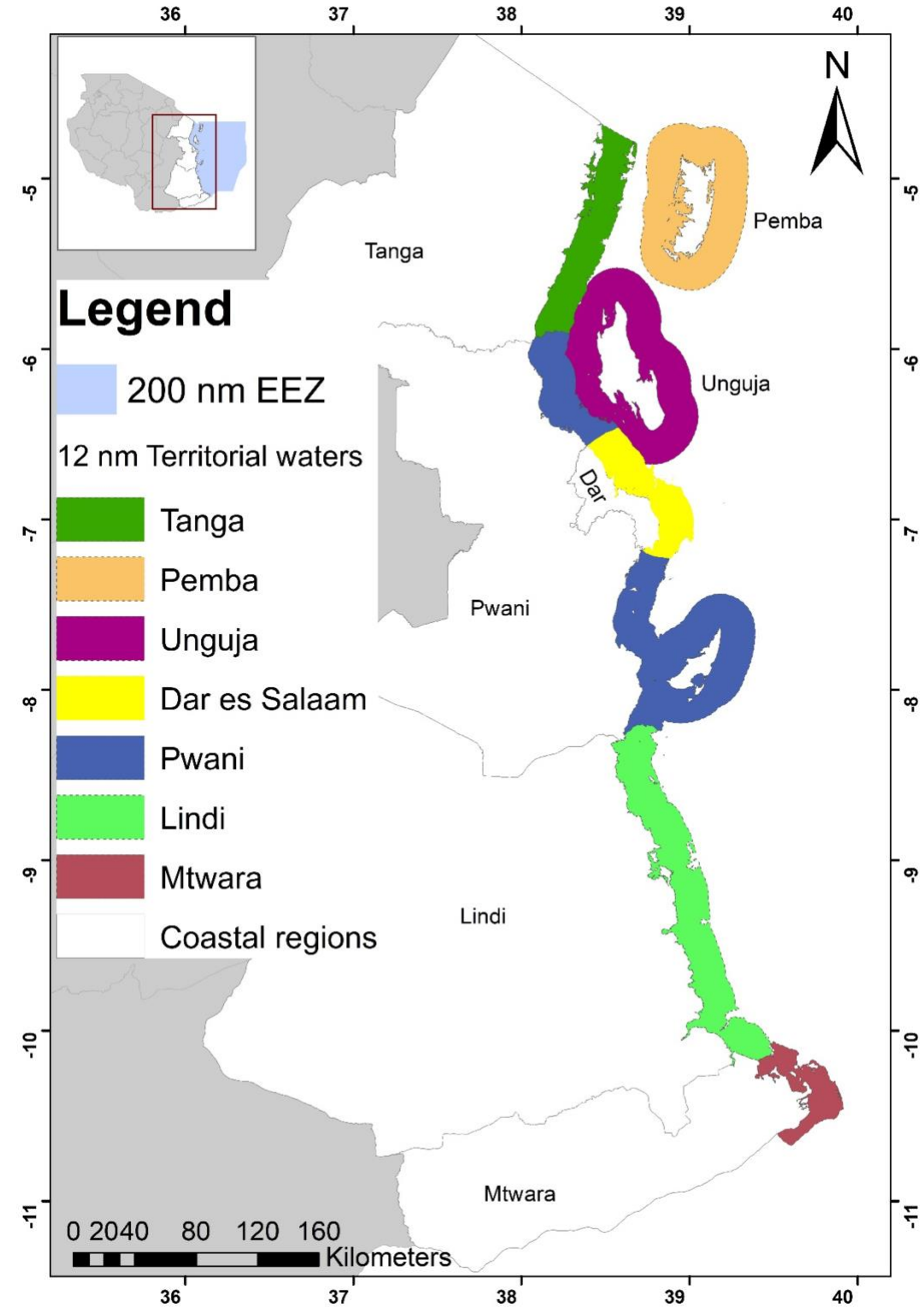


Figure 4. Map showing delineation of soft boundaries forming 7 'zones' for the assessment extending 12nm offshore to the end of the territorial waters. The proposed sub-divisions of Tanzania's ocean territory are purely hypothetical and have been made solely for the purpose of the OHI+ Tanzania assessment. The demarcations may be considered as potential management areas for the respective zones under assessment, however, this is beyond the scope of this report.

Alternative options

District level

A district level assessment required setting each district as an OHI 'zone' and attributing a predetermined extent of the ocean (nm) to each district.. The remaining ocean area, around both Zanzibar and mainland Tanzania is to be treated as the EEZ, and a separate 'zone'. 3nm was chosen to avoid overlapping boundaries between Mafia and Rufiji. Assessment at this level was considered very useful as it allowed determination of how districts are performing in terms of both the status of their marine resources and management, and local benefits to the people. However, to have policy level impact, the outputs should also target the ministry responsible for key resources e.g. fisheries management. This level of assessment involves a large number of coastal districts (27) which would have complicated the analysis considering the time, data, and level of stakeholder engagement required.

Fisheries management regions

There are three fisheries management zones in Tanzania's ocean territory:

i. The Exclusive Economic Zone (EEZ) managed by the Deep-Sea Fishing Authority (DSFA),
ii. The territorial waters along the mainland managed by the Department of Fisheries in mainland Tanzania.
iii. The territorial waters around Zanzibar managed by the Department of Fisheries Development in Zanzibar.

Dividing the ocean territory based on the fisheries management zones, focuses more on the fisheries sub-goal hence may not be ideal for the other goals

3.3.1. Recommendations

The need to have future assessments conducted at a district-level and even higher spatial resolutions such as for Marine Conservation Areas, was emphasized owing to variations in characteristics of districts which are significant for internal management. Therefore, it was proposed that both existing and any new data generated be organised by districts to the extent possible, as a way to lay the groundwork for future assessments.

4. Results

A complete analysis of all 10 goals was neither targeted nor possible during this project. The priority goals were assessed through a series of focused Technical Team meetings and consultations with Advisory Team members to discuss data availability, reference points, targets, goal models etc.

For the preliminary OHI+ Tanzania assessment three sub- goals (Fisheries, Species, and Habitat) were discussed but only one sub-goal was computed: Habitat (under the Biodiversity goal) based on data availability and access and time constraints of the project. Results from this assessment are preliminary and can be used as a baseline to develop and improve in future using more suitable and accurate metrics and data.

4.1. Food provision: Fisheries

The Fisheries sub-goal aims to describe the amount of wild-caught seafood harvested and its sustainability for human consumption. The model used in the OHI global assessment compares fish catch landings with Maximum Sustainable Yield. A score of 100 means the zone is harvesting seafood to the ecosystem's optimum production potential in a sustainable manner. It was the most highly-prioritized goal by stakeholders.

The sub-goal looks at both artisanal and commercial fisheries. The technical team proposed replacement of the term 'commercial' fisheries with 'semi-industrial' (internal engine, larger size boats) as the latter is more commonly used in Tanzania. For this preliminary assessment, only artisanal fisheries within the mainland and Zanzibar territorial waters was discussed as it accounts for nearly 95% of fishing (Jiddawi & Ohman, 2002).

4.1.1. Data

Long time-series catch, effort and length-based fish species data were the ideal data requirements, from which a multitude of models could be calculated to assess the status and sustainability of various stocks.

Artisanal fisheries in Tanzania are managed separately in mainland Tanzania and Zanzibar, with long-term, nation-wide monitoring and fish catch data collection conducted by the respective Departments in charge of Fisheries in each jurisdiction. Underreporting of the data in fisheries has been a huge problem and affect actual total landings reported. Other key institutions with catch data include TAFIRI, WWF, Mwambao Coastal Community Network, and the Institute of Marine Science (IMS).

Artisanal fisheries data are mostly recorded at fish group or family level. Department of Fisheries mainland have a large fish catch dataset spanning several years, though analysis has been very limited. A shared database holds catch data for mainland Tanzania. Different institutions (state and non-state) contribute data to the database and have authorised access. A similar approach is being considered in Zanzibar. Department of Fisheries Development Zanzibar have fish catch data spanning 10 years (2008 – 2017) aggregated for Zanzibar containing information for 19 fish groups (e.g. grouper) on catch (kgs) and the corresponding monetary value in Tshs.

There is also data from frame surveys, ideally conducted every 2 years, however this has not been consistent (for mainland 2007, 2009 and 2016 while the 2018 report is yet to be finalised, and Zanzibar 2007, 2016 reports). Catch assessment survey reports are produced annually in form of fisheries statistics reports. More detailed information (effort, length-based estimates) has been collected by various institutions at specific landing sites, however this is generally project based and only runs for a few years.

Most recent stock assessments have been conducted by TAFIRI and focus on some of the priority fisheries for mainland Tanzania with the latest assessments being on tuna, prawn and octopus fisheries. Zanzibar last conducted stock assessments over 20 years ago. Other relevant past work include: Marine and Coastal Environment Management Project (MACEMP) with catch data collected over a period of 6 months; SWIOFish project with 5-year dataset on octopus; and project based catch data collected by university students working with IMS and UDSM.

4.1.2. Reference point

The global assessment uses the Maximum Sustainable Yield (MSY) as a reference point to assess sustainability and was approved as a possible reference point for fisheries management in Tanzania. However since tropical fisheries are multi-gear and multi-species, alternative models should also be considered, such as Maximum Economic Yield, Spawning Potential Ratio (Spawning stock biomass) and Production-Biomass (area-based productivity measure for different habitats), to see which models work best.

Priority species

There are five (5) priority fisheries in mainland Tanzania with national management plans namely, Prawn, Tuna and tuna-like species, coral reef species, octopus and small pelagics. Four (4) of these, with the exception of Prawn fishery, apply to Zanzibar as well. Zanzibar has initiated the process of developing management plans for coral reef species, octopus and small pelagics fisheries. Fisheries management in Tanzania involves restrictions based on size, gear, methods, time and season. There are no quotas in place to control commercial fisheries while gear selectivity controls size of catch.

Taxa selection

Fish taxa under this goal should be selected on the basis that they contribute to food provision in the country, and are part of the priority fisheries for management. The 165 plus fish taxa (at various identification levels i.e. species, genus, family) used in the global analysis can form the foundation for taxa selection for the OHI+ assessment (see Appendix section 8.6.1) through appropriate review mechanisms including expert judgment. The review process should consider key taxonomic groups with long-term catch data at the agreed spatial resolution of assessment, as well as those which have had technical stock assessments undertaken and for the other taxa, data can be acquired from the global OHI dataset (detailed explanation in the 'Model and Analysis' section).

4.1.3. Pressures and Resilience

The pressure and resilience indicators were selected during Technical Team discussions and consist of indicators that were retained from OHI global assessment, as well as additional pressures appropriate for Tanzania's context (Table 2). Details on each pressure and resilience indicator including sources of data are given in the Appendices (see sections 8.6.2 and 8.6.3).

Table 2. Pressure and resilience measures to be included in the Fisheries sub-goal analysis

Pressures:	**Resilience:**
• Intertidal habitat destruction • Weakness of social progress • Weakness of governance • Subtidal hardbottom habitat destruction • By-catch due to artisanal fishing • Coastal chemical pollution • Coastal nutrient pollution	• condition of species located within 3nm offshore of each region • Percentage of territorial waters under protection compared to 30% target • Protected area management effectiveness • Artisanal fisheries management effectiveness • Social progress • Strength of governance

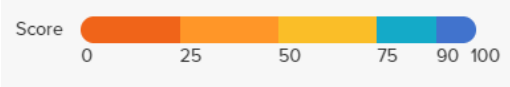
• blast and poison fishing	• Water quality

Although commercial fishing was not discussed in this pilot assessment, by catch from commercial fishing was included as a pressure in the global assessment while commercial fishing management which deals with regulations and management of commercial fishing, was included as a resilience indicator. Details on the effectiveness of the later can be obtained from Deep Sea Fishing Authority.

The following indicators were not included in the analysis due to data availability but were considered to be an issue: subtidal soft-bottom habitat destruction and percentage of catch caught using destructive (or illegal) fishing gears.

Table 3. Fisheries sub-goal scores for pressure and resilience by zone, and the national average (average of each zone). Maximum score possible is 100; for each score category the colours indicate performance relative to the scale under the table, except pressures which is the inverse (higher score indicates higher pressures)

SCORE	MTWARA	LINDI	PWANI	DAR ES SALAAM	UNGUJA	TANGA	PEMBA	NATIONAL
PRESSURE	41.7	42.7	46.7	51.8	34.8	49.8	46.5	44.9
RESILIENCE	66.7	69.3	69.2	72.9	75.9	66.2	72.6	70.4



For all zones, pressure scores are lower than resilience scores, with all resilience scores above 65 (Table 3). Unguja had the lowest pressure and highest resilience scores, and together with Dar es Salaam are considered the most socially progressed (lowest score for the multi-dimensional poverty index), with Lindi and Tanga the least. Dar es Salaam had the highest pressure score due to its high coastal population which causes high intertidal pressure, and also dynamite fishing occurred heavily there as well as in Tanga, Pemba and Pwani. Mtwara scored the highest for nutrient pollution, and Dar the highest for chemical pollution although pollution levels are low overall.

4.1.4. Challenges

- *Quality of data*: National monitoring programs only collect fish catch data in Kgs, and usually at a course family level, limiting the applications and analysis possible. Project based data is usually collected at a more detailed level but is often from a limited number of landing sites.
- *Data gaps:* Both spatial and temporal gaps exist for catch data. Future assessment needs to work on how to incorporate project specific data to supplement long-term monitoring data. *Allocating catch between zones:* Often catches are landed in areas different from those in which they were caught. Ideally, catch from artisanal fisheries should be attributed to the area where the fish were caught, to inform decision makers about the productivity of their fishing grounds (i.e. the amount of fish caught in their jurisdiction), as this can allow for development of site-level fisheries management strategies.
- *Usability of data*: Existing long term catch data held by key government institutions e.g. fisheries departments is yet to be analysed. Complementary data is scattered across and within institutions in

different formats, though having an operational and populated central national database will help resolve this issue.

- *Access to data*: Generally there was a willingness to share data for this assessment despite data-sharing being a long standing issue among marine science institutions and scientists in the WIO. However measures to improve sharing further still need to be considered e.g. databases and sharing-agreements, as well as making technical stock assessments publically available on websites
- *Changes in the project governance teams:* Representatives from the Department of Fisheries (mainland) project Advisory Team, as well as important technical contacts, direct affiliation with the department changed during the course of the project, making it very challenging to acquire the required data, despite making a formal data request.

4.1.5. Recommendations

Policy and Management

1. Strengthen the role of institutions at the subnational level (district and regional) in management of adjacent fishing areas in the territorial waters by establishing clear management jurisdictions
2. Assess effectiveness of existing regulations (e.g. ban on dynamite fishing) on both catch and habitat quality to inform review where necessary, and strengthen enforcement to reduce high pressures from destructive fishing practices.
3. Support local governments and communities to implement area based management approaches to improve coastal fisheries status through capacity development, policy or legislation formulation, defining co-management and no-take areas and by providing adequate funding.
4. Undertake stock assessments for all priority fisheries for management (prawn, tuna and tuna-like, octopus, coral reef, small pelagics) for the whole country.
5. Using sound scientific evidence, increase capacity for sustainable, domestic exploitation of off-shore fisheries including processing, through Zanzibar Fisheries Company (ZAFICO) and Tanzania Fisheries Cooperation (TAFICO) to improve food security
6. Support attempts to develop an integrated, central fish catch database for Zanzibar (similar to that utilized in mainland Tanzania), which can be accessed by relevant institutions and linked to the mainland database for a fully-integrated national database. Sufficient measures should be put in place to ensure sustainable operation of both databases after completion of donor projects.

Monitoring and data collection

1. Increase investment in harmonized monitoring and data collection to ensure data is collected at higher taxonomic levels together with effort and fishing ground information at more fish landing sites across the country particularly in areas with limited access and low reporting. This will allow for more accurate assessments with the aim of moving Tanzania's fisheries sector to a data-rich system
2. Build up metadata log of all catch data and stock assessments for both commercial and artisanal fisheries.

Future OHI assessments

The following suggestions can help effectively undertake the Fisheries sub-goal analysis in subsequent assessments:

6. Include the offshore industrial and semi-industrial fisheries as part of the assessment through engagement with the Deep Sea Fishing Authority
7. Assessment should be based on fish caught within a zone rather than landed catches which may be caught from neighbouring areas. Some artisanal fishing of Tuna and Tuna-like species takes place outside the 12nm territorial waters.
8. Assessment may focus on gear types using indicator species per gear. Some studies have already been done on gear selectivity in multi-species fisheries to identify the target species caught by different artisanal gears in the region (Tuda, Wolff, & Breckwoldt, 2016).
9. Alternative models: try using catch per unit effort (CPUE) for artisanal fisheries calculated from CAS data, and the Spawning Biomass model, to compare with results from MSY to see which model is better suited for the multi-species and mult-gear marine fisheries in Tanzania.
10. Include Mariculture in overall fisheries goal assessments. Tanzania scored close to zero in the OHI global assessment due to lack of available data, and data was not sufficient for this national analysis. However, there is some ongoing mariculture activity (i.e. fish and seaweed) as well as developments proposed for the future.
11. Assess the two levels of tuna and tuna-like fisheries; the industrial tuna fisheries and the small-scale tuna fisheries. This will focus on species such as little mackerel (small coastal tuna like species) and the highly migratory species such as the yellow fin, bigeye and skipjack tunas.
12. The indicators proposed in the BMU monitoring tool can be used to assess community-level fisheries management effectiveness. Some key aspect to be considered in the performance of BMUs include:
    a. *Administration***:** number of registered BMUs as per the requirements of Fisheries Act; gender representation, existence of minutes of meetings, BMU networks
    b. *Management plans and implementation*: approved BMU management plan, by-laws, development and management reports, identified co-management areas and community conservation areas, sanitation facilities, annual trend of catches.
    c. *Financial management systems:* approved workplan and budget, audited accounts, Financial report, access to credit facilities, Active BMU bank account
    d. *Monitoring, control and surveillance:* patrols, fisheries data and reports, compliance reports and licence registers
13. Utilise MCS data collected by the respective Fisheries Departments to assess fisheries management effectiveness
14. Collate reports and summarised data on recently assessed fisheries stocks from TAFIRI– octopus, prawn, tuna fisheries on mainland
15. Use local high-resolution data to score all pressure and resilience indicators and include pressure indicators to account for destructive fishing practices based on the weighted proportion of illegal gears (reef seines, spear guns etc.) employed per zone, and the level of fishing

Research

8. Identify fishing 'hot-spots' in the EEZ to help inform fisheries management
9. Asses the level of artisanal fishing that happens between the 12 and 24nM zone.
10. Formulate measures to ensure subnational level data is recorded at the lowest possible spatial scale and no data is lost in the process
11. Conduct scientific studies to assess any improvements in fish catch and habitat quality to support the narratives of fishermen on the positive effects of improved enforcement since the ban of dynamite fishing was effected.
12. Undertake technical stock assessments for pending priority fisheries.

4.2. Biodiversity goal

The goal is assessed based on 2 sub-goals: Species and Habitat; and assesses the condition and conservation status of species and habitat. A score of 100 means all species are at very low risk of extinction, and all habitats are conserved. The preliminary assessment focused on the habitat sub goal.

Biodiversity: Habitat

The Habitat sub-goal measures the average condition of marine habitats that provide critical habitat. This sub-goal is considered a proxy for the condition of the broad suite of marine species. The Habitat sub-goal focused on the three key coastal and marine habitats on the Tanzanian coast: coral reefs, seagrasses and mangroves. For each of these habitats, health and trend layers were calculated and used to score the goal.

DATA	SOURCE (S)	COMMENTS
Mangrove cover	World Conservation Monitoring Centre (WCMC), Global Mangrove Watch, Global Land Analysis & Discovery (GLAD)	Reference data (1992) - WCMC, Raw satellite images land cover (2011-2014) - GLAD Global Mangrove Watch – 2010 mangrove cover
Coral reef condition	WIO GCRMN benthic dataset (CORDIO)	Hard coral cover used as a proxy
Seagrasses	(Waycott et al., 2009)	OHI global

Status and trends - coral reefs

Percentage hard coral cover was used as a proxy for coral reef health. In 1998 there was a massive coral bleaching event due to a record-high El Nino combined with the then hottest year on record, affecting several areas along the Tanzanian coast to varying degrees (Mohammed S Mohammed, Christopher Muhando, & Haji Machano, 2000). We therefore assumed that pre-1998 coral cover values would be an accurate proxy of pristine conditions. Hard coral cover was averaged across the 2-3 most recent years of *in situ* monitoring data for each zone (to account for monitoring errors which could exist for values from a single year; Dar es Salaam is the only zone with 1 year of recent data) to get recent cover values. The ratio of recent cover to reference cover was calculated to produce zonal coral reef health (status) scores (capped at 1). The linear trend across the latest 5 years (2013-2017) of data for each zone was calculated after using linear regression models to fill temporal gaps when required for a zone (see Appendix section 8.7 for more details).

Status and trends – mangroves

Detailed site-based studies on mangrove health in Tanzania have only been conducted at a few selected areas but not across the entire coast. We therefore used remotely-sensed mangrove extent (in kilometre square) as a proxy-measure of mangrove health to allow coast-wide comparisons. The entire extent of mangrove cover for Tanzania has been estimated in national surveys on several occasions, with the most recent estimate being in 2001 (Mnangwone, I.Y, 2005). Other assessments in the literature were done as part of global studies which used differing methods. Existing data were deemed unsuitable for this analysis because it could not be accessed in vector format suitable for disaggregation to zonal levels. Due to this limitation, a mangrove extent analysis was undertaken. This involved quantification of mangrove cover for each zone for the year 2000 (Hamilton & Stuart, 2015) and 2010 (Bunting P. et al., 2018) from processed images, and 2011-2014 from un-processed satellite images of the entire Tanzanian coast (Global Land Analysis & Discovery, https://glad.umd.edu/gladmaps/globalmap.php#) using digital image

classification techniques. Mangrove health was calculated as the ratio of recent mangrove cover (2014) to reference cover (2000) for each zone. The linear trend was calculated across the latest 5 years of data (2010-2014) for each zone (see Appendix section 8.7 for more details).

Status and trends - seagrasses

Because of the sparse seagrass data available, seagrass condition was based on the OHI global national value and therefore all zones were attributed the same score in this assessment. The OHI global score was calculated on a per-site basis from Waycott et al. (2009), which provides seagrass habitat extent for several sites around the world over several years. Reference condition was calculated as the mean of the three oldest years between 1975-1985, or the two earliest years if needed. For the current condition we used the mean of the three most recent years after 2000 or the two most recent years.

Pressure and resilience

Pressures:	**Resilience:**
• Intertidal Habitat destruction • Sea surface temperature • Weakness of social progress • Weakness of governance • Nutrient pollution • Chemical pollution • Sea level rise • Oil and Gas activity • Subtidal hard bottom habitat destruction (dynamite fishing) • blast and poison fishing	• Condition of species located within 3nm offshore of each region • Percentage of territorial waters under protection compared to 30% target • Protected area management effectiveness • Artisanal fisheries management effectiveness • Social progress • Strength of governance • Management of waters to preserve biodiversity

The following indicators were not included in the analysis due to data availability but were considered to be an issue: subtidal soft-bottom habitat destruction, ocean acidification, salinity and total suspended solids and percentage of catch caught using destructive fishing gears.

4.2.1. Results

Coral reefs

Pre-1998 data on hard coral cover were available in the literature, which helped us ascertain accurate reference hard coral cover levels for each zone. Dar es Salaam and Lindi both scored 1 for current status because hard coral cover improved compared to the pre-1998 reference cover (Table 4). Reefs around Songosongo in Lindi have shown resistance to bleaching and this could be one of the reasons why they are in a good state (Gudka et al., 2018). For Dar es Salaam, the most recent record was from 2008, therefore the results need to be updated to get an accurate representation of reef health following the 2016 bleaching event.

Five of the seven zones showed declines in coral cover, with Pwani the most impacted having lost about half its original living coral, whilst Mtwara and Pemba have lost around 40% and Unguja and Tanga about 30%. The results of this analysis are affected by monitoring inconsistencies and temporal gaps in data but still provide an accurate representation of reef decline as all zones (except Dar es Salaam) have been

monitored for at least two years since 2015. Unguja has the most consistent data, but there are large data gaps in other zones, particularly between 2000 and 2014.

Table 4. Hard coral cover and current status scores for each zone (from north to south) using pre-1998 data as a reference point

Zone	*Recent hard coral cover (%)*	*Ref hard coral cover (%)*	*Zone status score*
Pemba	31.5	53.7	0.586
Tanga	37.2	53	0.701
Unguja	36.1	50.2	0.719
Pwani	34.1	69.5	0.49
Dar es Salaam	53	50.1	1
Lindi	44.3	35	1
Mtwara	35.8	57.5	0.622

It is important to note that focusing on hard coral cover omits the increase in fleshy algae that has been documented over the same period (Gudka et al., 2018; Obura et al., 2017), which further impacts the health of reefs.

Given the expected increases in local as well as global pressures on reefs in the imminent future (e.g. pollution, rising ocean temperatures and ocean acidification), and the substantial declines in health to date, it is vital that management of these ecosystems is substantially scaled up and updated using the latest scientific recommendations, to meet these higher threat levels. These investments in management should try maintain ecological functioning and service provision of the resources e.g. tourism activities and fisheries production, as well as provide secondary benefits such as clean waters and coastal protection.

Mangroves

Mtwara and Lindi are in a healthy state having retained around 90% of their mangrove cover over the last 14 years. Pemba is also in a moderately healthy state with over 80% cover retained. Tanga and Pwani have both lost just over a quarter of their area, and Dar is the most heavily impacted having lost over 30% of mangroves since 2000, although this is only about 5km^2 in absolute terms (Table 5).

Table 5. Mangrove extent in each zone in 1992 and 2014 and zone status scores as the ratio of the two covers

Zone	*Ref cover (2000) km^2*	*Recent cover (2014) km^2*	*Zone status score*
Pemba	92.3	76.6	0.830
Tanga	129.7	95.6	0.737
Unguja	45.1	83.8	1.000
Pwani	596.4	443.4	0.743
Dar es Salaam	19.2	13.2	0.687
Lindi	271.6	243.9	0.898
Mtwara	89.5	83.6	0.934

Overall the country has lost around 16% of its mangrove cover over almost a decade and a half. This is possibly due to increased population and development of coastal cities, unsustainable harvesting for timber and other materials, charcoal production, as well as clearing for conversion into agricultural land for farming (Mnangwone, I.Y, 2005). The results indicate that Unguja's mangrove cover has almost doubled, however this may be erroneous and not reflect the true picture on the ground due to differences in estimation techniques of recent and reference cover, time of the survey or misclassification of mangroves with mangrove associated species present in the zone. Several studies have estimated the mangrove cover on the island to be around 50 – 60 km^2 (Mchenga & I Ali, 2015) which would make the 2000 estimations low, and the 2014 values high, exaggerating the apparent improvement in cover. Therefore the areas classified as mangroves will need to be reviewed and verified by experts.

It is important to note that cover is not a complete measure of health and status of mangrove forests, and in future assessments should be complemented with other indicators for a more comprehensive understanding.

Although the rate of decline may not be as drastic as in other countries in the region, the declines are unsustainable and certainly indicate that management measures need to be stepped up.

Seagrasses

We were unable to obtain geographically and temporally extensive data on seagrass condition along the coast of Tanzania, and therefore had to use the results for Tanzania from the OHI global analysis (status score of 0.855). This meant that there was no inter-zone score variation. Seagrasses are a vital marine habitat, providing a variety of important ecosystem services and are likely highly threatened in Tanzania through coastal and near-shore activities. Some site based studies have been undertaken through various projects (ASCLME, 2012; Semesi, Beer, & Björk, 2009), however there is an urgent need to invest in large-scale long-term monitoring.

Overall

The overall goal score for each zone varies greatly with Pwani scoring the lowest with 61.6 and Unguja the highest with a score of 87.4 followed by Lindi with 84.5 (both these zones scored 1 for one of the habitat status) (Table 6). Tanzania scored fairly well overall, with a national (zonal average) score of 74.1. However the recent trend in all zones is for a decline and the model estimates the future state for all zones to be appreciably lower than the current status except for Unguja. However, a positive message is that for all zones, pressure scores are lower than resilience scores, with all resilience scores above 65. Unguja, somewhat surprisingly had the lowest pressure and highest resilience scores, and together with Dar es Salaam are considered the most socially progressed (lowest score for the multi-dimensional poverty index), with Lindi and Tanga the least. Mtwara and Lindi had the highest oil and gas activity, with extraction ongoing (historical and current), but this was not considered a major impact on habitats. Dar es Salaam due to its high coastal population, scored far above the other zones for intertidal pressure, and dynamite fishing was also considered to occur most there as well as in Tanga, Pemba and Pwani. The change in sea level is predicted to increase moderately across the coast of Tanzania, with Dar es Salaam and Pwani having a slightly greater difference than the other zones. This level of sea rise could have significant impacts particularly on low lying areas, underscoring the need to start planning for future change now (Kebede et al., 2010). Mtwara scored the highest for nutrient pollution, and Dar the highest for chemical pollution although pollution levels are low overall. Some aspects like tourism activity, level

of fishing and development were not considered as pressures due to lack of data and metrics to measure them. For the resilience indicators only 3 out of the 7 indicators had high-resolution data for each zone, and for the other 4 the same value from the OHI global analysis was attributed to each zone. Therefore these preliminary pressure and resilience results can be improved with better localized data and inclusion of more metrics.

Table 6. Habitat sub-goal analysis scores for status, future, pressure, resilience and overall sub-goal score by zone, and the national average (average of each zone). Maximum score possible is 100; for each score category the colours indicate performance relative to the scale under the table, except pressures which is the inverse

SCORE	MTWARA	LINDI	PWANI	DAR ES SALAAM	UNGUJA	TANGA	PEMBA	NATIONAL
STATUS	80.4	91.8	69.6	84.7	85.8	76.5	75.7	80.6
FUTURE	65.4	77.3	53.5	69.9	88.9	62.4	55.2	67.5
PRESSURE	39.8	40.7	37.7	41.3	30	37.5	35.3	37.5
RESILIENCE	66.7	69.3	69.2	72.9	75.9	66.2	72.6	70.4
FINAL SCORE	**72.9**	84.5	**61.6**	**77.3**	87.4	**69.4**	**65.5**	**74.1**

Score
0 25 50 75 90 100

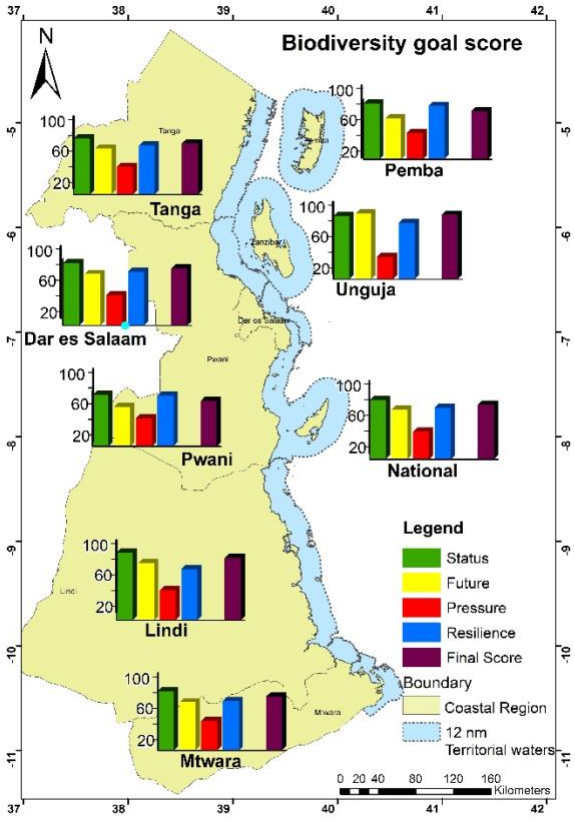


Figure 5. Status, future, pressure, resilience and final/overall scores for each coastal zone and the national averages from the Habitat sub-goal analysis

Data gaps for example with the METT results for Zanzibar MCAs, or limited access to data meant that values from the global assessment had to be used for a number of indicators as placeholders (see Appendix section 8.7.2). Although not penalized in this assessment, it is important to note that there is only one no-take (fishing) area within Tanzania's territorial waters.

With mega-infrastructural developments planned in the next decade including offshore oil and gas extraction, climate change and increased coastal populations, this OHI score could provide an important baseline for the zones to track the impact from these increased pressures on Tanzania's coastal and marine ecosystems. If management measures are not scaled up in both quantity and quality, these pressures will translate into continued degradation of habitats. The coastal areas are already afflicted by issues such as flooding, food shortages and high-rates of poverty, and it is important that national and local governments realize the importance of habitats and ecosystems as an integral component to building resilience and overcoming the impending challenges.

4.2.2. Challenges

- *Data availability:* No national mapping of seagrass and coral reef habitats
- *Data gaps:* Both spatial and temporal gaps exist for seagrasses, coral reefs and mangrove health data across all zones. For sea grass, very few studies have been done.
- *Data access*: Data is scattered across and within institutions, with no operational central national databases. Efforts were made to compile a national dataset for coral reefs however a considerable amount of data has not been contributed to this. Acquiring data from holders has been a long-standing issue among marine research and management institutions and scientists.

4.2.3. Recommendations

Policy and Management

1. Support comprehensive mapping of all key habitats coupled with strong investment in national monitoring to produce detailed and consistent data for planning and decision making.
2. Develop and /or review national management plans for key marine ecosystems (e. g coral reefs, seagrassess, and mangroves) through an inclusive stakeholder process
3. Strengthen habitat management through finalization and operationalization of Integrated Coastal Zone Management Strategy (Zanzibar) and National Integrated Coastal Environment Management Strategy (mainland).
4. Implementation of no-take marine areas using the latest ecological and socioeconomic data as a basis, and through an inclusive stakeholder process.
5. Strengthen community level resource co-management initiatives which are embedded within local government legal structures/frameworks e.g. BMUs to reduce various stressors on mangroves, seagrasses, coastal forest and coral reefs
6. Develop a national-scale strategic action plan on pollution (both nutrient and chemical) in all water bodies (oceans, rivers, lakes). For oceans, particular focus should be made to monitor around urban, industrial and agricultural areas, ports and estuaries and river mouths
7. Examine the OHI indicators to identify key pressures and areas where management measures need to be strengthened either to resolve issues or preserve healthy habitat states
8. Invest in restoration of degraded habitats based on trials, best practices and methods with a proven success record

Future OHI assessments

1. Various targets in the National Biodiversity Action plan can be used in future OHI+ assessments
2. Utilise products generated from past works such as the development of ZANSEA/TANSEA atlases as baselines.
3. Future assessments should include three other coastal and marine habitats:
   a) *Beaches and sand dunes* –Both mainland Tanzania and Zanzibar have a number of significant beaches which may be impacted by erosion and sea level rise.
   b) *Deltas and river estuaries* –These biodiverse areas are heavily impacted by pollution, mining and other activities.
   c) *Coastal forests* - highly threatened, extremely biodiverse and likely to provide important ecological services to adjacent nearshore habitats.
4. Experts to review areas classified as mangroves in shape-files and as well as literature, in order to validate mangrove cover values particularly for Unguja.

5. Look into using other indicators from local detailed studies of mangrove health e.g. standing density, to develop an index of condition rather than just using cover.
6. Seagrasses should be assessed using local data to provide variance in scores between regions and districts.
7. Fill in data gaps in the national GCRMN coral dataset as much as possible and use a combination of fleshy algae and hard coral cover to create a metric of coral health
8. Modify the goal model such that it takes into account the extent of a habitat in a region so areas with larger areas of habitat score more favorably for biodiversity conservation.
9. Assess the other Biodiversity sub-goal; Species. Use the Global IUCN Red List status for species from a select number of taxonomic groups for each zone but complement the IUCN categories with local studies and knowledge to ensure classifications in each region are locally appropriate. Local experts can score the abundance of each species in each 'region' and these scores can be averaged. Taxonomic groups to consider for the assessment include; turtles, birds, marine mammals, fish (demersal, small pelagic, medium pelagic, large pelagic e.g. sharks), coelacanth, corals, mangroves, seagrasses and other key taxa within mangroves and seagrass habitats.
10. Assess the other two habitat-based goals i.e. Coastal Protection and Carbon Storage as these will require less effort since the toolbox already contains required coral and mangrove data.
11. Engage and involve departments mandated with managing mangrove and coastal forests

Future research

1. Conduct scientific studies to assess any improvements in habitat quality since the ban on dynamite fishing was affected.

2. Build up metadata log and an inventory of all habitat mapping that has been conducted in both Zanzibar and mainland Tanzania.

3. Conduct detailed national mapping of marine and coastal habitats.

5. Conclusions

5.1. Management and Policy recommendations

1. Invest in monitoring and data collection programs for ecosystems and fisheries focusing on assessing status and trends, impact of interventions to inform decision-making and improve resource allocations, and determining knowledge gaps. The programs should include resource users such as the local communities and capacity building to facilitate acquisition of required skills.

2. Develop data and information sharing platforms and other mechanisms which can facilitate increased data access and sharing. This should be coupled with documentation and sharing of lessons on how institutions are sharing and using data for decision making to track their effectiveness.

3. Revive the 'Tanzania Marine Forum' and develop new protocols for co-management and sharing of information.

4. Increase community inclusion in management of coastal and marine resources by upscaling and strengthening co-management efforts, and promoting alternative livelihood options selected and

designed by communities based on local knowledge and proven success and which factor in the entire value chain.

5. Investments in training, access to financing mechanisms, cross-sectoral collaborations with the private sector and processing of natural products can provide economic benefits and incentives for sustainable ocean and coastal resource management.

6. Implement 'marine spatial planning (MSP)' processes using the various sub-products from the preliminary OHI analysis

7. Enhance cooperation between National and subnational levels of government, and with neighbouring states particularly with regards to fisheries (nearshore and offshore) and natural resource management.

5.2. Lessons learnt

Utility of framework: The pilot assessment demonstrated the utility of the OHI framework as a conversation starter and guide to frame discussions on ocean governance and coastal management. It can also serve as a tool to facilitate generation and uptake of local data in decision making. Although a lot of coastal and marine research has been conducted and data generated, there is need to define what qualifies as "evidence" in ocean governance and how to generate and avail this information to facilitate transition to science based planning and decision making. The OHI framework can help identify what kind of information is needed to make required or necessary management decisions.

Timeframe: Learning how to conduct the assessment i.e. what data is required, how to operate the toolbox etc., stakeholder engagement, technical discussions and acquiring data, made undertaking this preliminary assessment an intensive and time-consuming endeavour. Therefore though the capacity developed through this pilot will make subsequent assessments more efficient, it is important to ensure there is a realistic and appropriate implementation period to achieve the various objectives.

Spatial scale of assessment: The assessment process highlighted a gap with regards to delineation and authority over ocean governance at a sub-national level, and between territorial waters in Zanzibar and Tanzania mainland. This has implications on how, what and where policies and decision are made with regards to nearshore coastal and marine resources governance, and need to be addressed.

Goal prioritisation: Prioritisation of goals can differ at different spatial scales for OHI + assessments based on geographical context, particularly the extent of coasts and islands, and mandates and subnational visions. . For instance, Tanzania mainland and Zanzibar (comprised of two islands) have two different national economic visions namely MKUKUTA and KUZA 3 strategy respectively. KUZA 3 prioritised Tourism, Fisheries and Cultural systems.

Stakeholder engagement: Understanding the governance context in which the assessment is being conducted is critical in designing an effective stakeholder engagement plan. Adequate engagement of all key actors in a multi-level governance system right from the beginning promotes ownership of the process and mitigates issues of under-representation in the project governance structure, prioritisation of goals, determining spatial scale, understanding issues around data access and integrating assessment

with other ongoing initiatives. Credibility of the institution is also important in coordinating the assessment and institutions with a regional acceptance can play this role before it is taken up by appropriate government institutions. In addition, personal relationships as individuals or institutions is critical in leveraging for the implementation of the assessment. Other key attributes that underpin the success of stakeholder engagements include institutional, personal and group commitment to the process, and high level of trust and close collaboration between institutions.

Establishing governance teams: Contacting the highest level of authority in a department or institution to get endorsement and a contact person for a process is important. However, staff turnover and transfers affect momentum of the assessment especially if the key contact person relocates or takes more responsibilities which affect their availability and commitment to the assessment.

Validation and dissemination: Technical review of project outputs helps in minimising controversies in findings for instance due to oversights or use of obsolete data. Sit-in reviews are preferred as opposed to electronic communications, most of which received little to no feedback from project governance teams. In the past, dissemination of research findings has generally been poor, with most information posted on institutional websites but remain unknown to the decision makers and the stakeholders. Dissemination can include sub-national and institutional level meetings in conjunction with a conventional national-level dissemination workshop to ensure key actors are well informed of the findings of the project. Relevant institutions can host these meetings at little to no cost but, project funding needs to factor in this level of engagement to cater for contexts where this is not possible.

Sustainability measures: It is important to build adequate local capacity to apply the OHI. Most researchers and institutions in Tanzania are not conversant with the R, Git hub etc, limiting their involvements in technical aspects of the OHI. Alternative methods of delivering the OHI tool box training should be sought as relying on a webinar, YouTube, will be a challenge to institutions and areas with unstable internet connection (e.g. for Zanzibar). Conservation International and other relevant organisations such as WIOMSA should consider building capacity of other suitable institutions to establish a community of practice in the WIO. The national assessments should be embedded in institutions with a wider mandate over coastal and marine resource use and management. Both mainland and Zanzibar can leverage existing windows of opportunity such as the current focus on blue economy, national processes such as preparation of the state of the coast report and national projects such as SWIOFish to promote the use of the OHI framework and the index as a decision support tool.

Coordinating remotely: Working remotely from Kenya, as well as having Technical Team members based in various parts of Tanzania (Zanzibar, Dar es Salaam, Bagamoyo and Dodoma), made it logistically complicated and costly to organize ad-hoc, focused technical meetings which are key to driving the process forward particularly to resolve emerging issues and gather data. Remote communications such as phone and email, largely proved ineffective. Having a project coordinator on the ground can help facilitate the process.

5.3. Challenges

Barriers, obstacles and threats to achieving priority ocean benefits

1. **Knowledge management and human capacity**: the main challenge to optimizing ocean and coastal management is knowledge management in its broadest sense. The issues can be sub-categorized, but not limited to:

   Research and data management: there remains limited data collection, accessibility to existing information, and research interpretation for policy-making. This is affecting policy harmonization efforts as well as establishment of priorities and associated required investments.

   Institutional arrangements: there is limited collaboration between and within various government agencies and research institutions. The process for sharing knowledge and information is ineffective, and there is minimal sharing of best practices and or emerging issues/technologies among institutions.

   Local governance: at the district level, there is very minimal institutional capacity on ocean and coastal resource management, and the little governance that exists is fragmented with marginal alignment between subnational, national, and regional ocean policies.

   Community capacity: low literacy and lack of skilled employment in the country places a burden on the management of ocean resources.

2. **Inadequate governance, policies, and enforcement**: the existing ocean and coastal management regulations and policies do not provide a conducive environment for creating a sense of ownership by coastal communities. Many policies, including the Integrated Coastal Zone Management policy and fisheries legislation are outdated and revisions are not conducted in a timely manner. Lack of adequate zoning regulations and planning for the maritime space is leading to increases in habitat destruction and/or conversion.

3. **Economic barriers**: the lack of alternative income generating activities places a large burden on subsistence use of natural resources.

4. **Infrastructure:** ocean and coastal infrastructure is inadequate which limits the capacity for advancing sustainable economic development.

5. **Population growth:** unchecked population growth, mostly due to positive migrating from inland areas towards the coast is putting a lot of pressure on coastal ecosystems.

6. **Cultural practices:** many coastal communities have not ceased many harmful cultural practices in the environmental domain. The lack of training coupled with minimal exposure to new technologies, limits the capacity of these coastal communities to shift cultural perceptions towards environmental conservation as a means to ensure human well-being.

5.4. Opportunities for further work

The OHI framework has multiple potential uses on its own as well as in combination with other tools that have been used in ocean and coastal management. This preliminary assessment has shown that there is scope for long-term use of this tool in Tanzania. Most of the institutions engaged in both mainland Tanzania and Zanzibar expressed the need to conduct full assessments. However for successful uptake, the process needs to be driven by an interested and relevant national institution(s), with

ministerial level approval if possible. This should allow for better overall coordination as wells as address some of the challenges related to data access and protocols such as seeking permissions. In addition, each competent authority should be a goal 'custodian' to embed the evaluation in their official processes (e.g. Ministries in charge of fisheries for fisheries, MPNRU and MCU for coral reefs, Forest Service for mangroves and coastal forests, etc). Adequate resourcing and capacity to undertake the assessments and implement recommendations should be assured, within sector agencies as wells as subnational and national government. Some potential partners recommended to drive OHI development in the future include TAFIRI, National Environment Management Council, Zanzibar Environmental Management Authority, Department of Fisheries Development and Institute of Marine Science.

With the experience obtained through this project, CORDIO can play a technical role, supporting to train staff in national institutions and help guide the process. Sub-products such as data layers and information can be used to inform Marine Spatial Planning processes at different scales depending on the level of disaggregation of the data.

In the current Tanzania context, there are several possibilities for use of the OHI tool. The National Environment Management Council (NEMC) and Department of Environment (Zanzibar) is mandated to report on the environment (e.g. through national State of the Coast reports), hence can use the tool as a repeatable method to track state and elegantly and simply present these results.

The Marine Park and Reserves Unit manages 8 national MPAs along the coast of Tanzania mainland while Marine Conservation Unit is in charge of 5 Marine Conservation Areas along Zanzibar's coastline. The two can use a tailored version of the OHI to track the state of their habitats and species within their MPAs and measure success of adaptive management strategies, as well as quantify the other ocean benefits e.g. natural products, coastal protection, carbon storage etc., accrued from these sites. Some of the opportunities include the pending review of the Management plan for the Dar Es Salaam Reserve system which was developed around 2005/6 and making a strong case for establishment of no-take zones in Zanzibar.

The national ministries and departments in charge of fisheries at regional and district levels can use this tool directly to continue to track the Fisheries and Mariculture sub-goals performance. This process can help improve partnerships and data sharing with key research institutions such as TAFIRI and IMS, with higher learning institutions such as UDSM and SUZA and with NGOs such as Sea sense and Mwambao. In addition they can measure effectiveness of new management practices, help inform management, identify further gaps and increase investment in monitoring and data collection to help increase accuracy of the results.

The growing interest and inevitable investment in the 'Blue Economy' underpin sustainability of practices to maintain integrity of any exploited natural resources. Challenges of balancing access to various ecosystem benefits and the potential threats e.g. for oil and gas provide a scope for marine spatial planning especially in Zanzibar as the maritime space is limited.. This creates a platform for tangible contribution of national research institutions and NGOs with regards to providing information that can enable decision makers decide on how to go about key investment and development issues.

The framework provides a mechanism to devise innovative uses of different combinations of data often generated as statistics of a given area or from research findings to feed into management more directly.

Long term monitoring is lacking for key coastal and marine resources as well as associated threats. These initiatives can be resource intensive and are often crowded out by other national priorities targeting direct service delivery to the citizens. The framework can prompt responsible institutions to target investment in monitoring as the tool is data dependent. In addition, national and regional OHI assessments can provide a basis to seek reliable funding for extensive assessments from national, regional and global sources such as GEF, GCF.

A regional approach to the assessment can also be beneficial. This can look into the regional issues based on political boundaries, levels of management scenarios and regimes in the countries, to help in harmonisation of key institutions in the WIO region among other concerns.

6. Acknowledgements

The preliminary OHI+ assessment was funded by Indian Ocean Commission through their Biodiversity Project, grant number EDF/2016/382-097 GRT/CN 147, and the Dalio Foundation. We would like to thank TAFIRI and FETA for agreeing to be national partners. We would also like to express our sincere gratitude to all data contributors and participants of stakeholder engagements and technical meetings. Members of the technical and advisory teams (list in the Appendix section 8.5) who contributed vital expertise, information and advise to guide this process. Special mention goes to Islam Mchenga (MALF, Zanzibar), Semvua Mzighani (TAFIRI), Rashid Tamatamah (MALF Mainland), Rose Salemma (NEMC) , Narriman Jiddawi (IMS) and Baraka Kalangahe (IOC).

7. References

ASCLME. (2012). National Marine Ecosystem Diagnostic Analysis. Tanzania. Contribution to the Agulhas and Somali Current Large Marine Ecosystems Project (supported by UNDP with GEF grant financing). Retrieved from http://hdl.handle.net/20.500.11822/25887

Bunting P., Rosenqvist A., Lucas R., Rebelo L-M, Hilarides L, Thomas N., … Finlayson C.M. (2018). The Global Mangrove Watch – a New 2010 Global Baseline of Mangrove Extent. Remote Sensing.

Burke, L., Reytar, K., Spalding, M., & Perry, A. (2011). Reefs at Risk Revisited.

Costello, C., Ovando, D., Clavelle, T., Strauss, C. K., Hilborn, R., Melnychuk, M. C., … Leland, A. (2016). Global fishery prospects under contrasting management regimes. Proceedings of the National Academy of Sciences of the United States of America, 113(18), 5125–5129. https://doi.org/10.1073/pnas.1520420113

Costello, C., Ovando, D., Hilborn, R., Gaines, S. D., Deschenes, O., & Lester, S. E. (2012). Status and solutions for the world's unassessed fisheries. Science (New York, N.Y.), 338(6106), 517–520. https://doi.org/10.1126/science.1223389

Gudka, M., Obura, D. O., Mwaura, J., Porter, S., Yahya, S., & Mabwa, R. (2018). Impact of the 3rd Global Coral Bleaching Event on the Western Indian Ocean in 2016. Global Coral Reef Monitoring Network (GCRMN)/Indian Ocean Commission. Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/25700/CORDIO_GCRMN2018_Post_Bleaching_WIO.pdf?sequence=2&isAllowed=y

Halpern, B. S., Frazier, M., Afflerbach, J., O'Hara, C., Katona, S., Lowndes, J. S. S., … Polsenberg, J. (2017). Drivers and implications of change in global ocean health over the past five years. PLOS ONE, 12(7), e0178267. https://doi.org/10.1371/journal.pone.0178267

Halpern, B. S., Longo, C., Hardy, D., McLeod, K. L., Samhouri, J. F., Katona, S. K., … Zeller, D. (2012). An index to assess the health and benefits of the global ocean. Nature, 488(7413), 615–620. https://doi.org/10.1038/nature11397

Halpern, B. S., Longo, C., Lowndes, J. S. S., Best, B. D., Frazier, M., Katona, S. K., … Selig, E. R. (2015). Patterns and Emerging Trends in Global Ocean Health. PLOS ONE, 10(3), e0117863. https://doi.org/10.1371/journal.pone.0117863

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., … Watson, R. (2008). A Global Map of Human Impact on Marine Ecosystems. Science, 319(5865), 948–952. https://doi.org/10.1126/science.1149345

Hamilton, & Stuart. (2015). CGMFC-21, MFW, Global Mangrove Levels by Pixel (~30m), 2000 - 2012. Harvard Dataverse, V3. https://doi.org/10.7910/DVN/HKGBGS

Jiddawi, N. S., & Ohman, M. C. (2002). Marine fisheries in Tanzania. Ambio, 31(7–8), 518–527.

Kebede, A. S., Brown, S., & Nicholls, R. J. (2010). SYNTHESIS REPORT: The Implications of Climate Change and Sea-Level Rise in Tanzania − THE COASTAL ZONES, 32.

Lowndes, J. S. S., Best, B. D., Scarborough, C., Afflerbach, J. C., Frazier, M. R., O'Hara, C. C., … Halpern, B. S. (2017). Our path to better science in less time using open data science tools. Nature Ecology & Evolution, 1(6), 0160. https://doi.org/10.1038/s41559-017-0160

Martell, S., & Froese, R. (2012). A simple method for estimating MSY from catch and resilience. Fish and Fisheries, 14(4), 504–514. https://doi.org/10.1111/j.1467-2979.2012.00485.x

Mchenga, I., & I Ali, A. (2015). A Review of Status of Mangrove Forest in Zanzibar Island, Tanzania. International Journal of Research and Review, 5182.

Mnangwone, I.Y. (2005). Global Forest Resources Assessment (FRA) 2005 country report - Tanzania. FAO.

Mohammed S Mohammed, Christopher Muhando, & Haji Machano. (2000). Assessment of coral reef degredation in Tanzania: Results of coral reef monitoring 1999. In CORDIO Status Report 2000.

Mora, C., Myers, R. A., Coll, M., Libralato, S., Pitcher, T. J., Sumaila, R. U., … Worm, B. (2009). Management Effectiveness of the World's Marine Fisheries. PLOS Biology, 7(6), e1000131. https://doi.org/10.1371/journal.pbio.1000131

Obura, D. O., Gudka, M., Abdou Rabi, F., Bijoux, J., Freed, S., Gian, S. B., … S Ahamada. (2017). Coral reef status report for the Western Indian Ocean (2017) (p. 144). Global Coral Reef Monitoring Network (GCRMN)/International Coral Reef Initiative (ICRI). Indian Ocean Commission (IOC). Retrieved from https://www.icriforum.org/sites/default/files/COI%20REEF%20LR%20F2.compressed.pdf

ohi-science.org. (2017). Annual OHI global assessments. Retrieved November 7, 2018, from http://ohi-science.org/ohi-global/

Ricard, D., Minto, C., Jensen, O. P., & Baum, J. K. (2012). Examining the knowledge base and status of commercially exploited marine species with the RAM Legacy Stock Assessment Database. Fish and Fisheries, 13(4), 380–398. https://doi.org/10.1111/j.1467-2979.2011.00435.x

Semesi, I. S., Beer, S., & Björk, M. (2009). Seagrass photosynthesis controls rates of calcification and photosynthesis of calcareous macroalgae in a tropical seagrass meadow. Marine Ecology Progress Series, 382, 41–47. https://doi.org/10.3354/meps07973

Thorson, J. T., Minto, C., Minte-Vera, C. V., Kleisner, K. M., & Longo, C. (2013). A new role for effort dynamics in the theory of harvested populations and data-poor stock assessment. Canadian Journal of Fisheries and Aquatic Sciences, 70(12), 1829–1844. https://doi.org/10.1139/cjfas-2013-0280

Tuda, P. M., Wolff, M., & Breckwoldt, A. (2016). Size structure and gear selectivity of target species in the multispecies multigear fishery of the Kenyan South Coast. Ocean and Coastal Management, 130(October 2017), 95–106. https://doi.org/10.1016/j.ocecoaman.2016.06.001

United Nations. (1982). United Nations Convention on the Law of the Sea. Retrieved from http://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf

Watson, R. A. (2017). A database of global marine commercial, small-scale, illegal and unreported fisheries catch 1950–2014. Scientific Data, 4, 170039.

Waycott, M., Duarte, C. M., Carruthers, T. J. B., Orth, R. J., Dennison, W. C., Olyarnik, S., … Williams, S. L. (2009). Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proceedings of the National Academy of Sciences, 106(30), 12377–12381. https://doi.org/10.1073/pnas.0905620106

8. Appendices

8.1. Participants, stakeholders workshop, Tanzania February 2018

	Individual	**Institution**	**Designation**
	Dr. Semvua Mzighani	TAFIRI	Director of Research
	Dr. Ambakisye Simtoe	FETA	Director
	Dr. Daniel Shilla	UDSM	Senior lecturer
	Laugen Mathew	WWF	GIS Specialist
	Dr. Godfrey Christopher	FETA	Coastal Resource Tutor
	Olipa Simon	UDSM	Senior GIS Scientist
	John Chikomo	JET	Executive Director
	Dr. Blandina Lugendo	UDSM	Scientist
	Elia Sabula	WWF	MREO
	Dr. Lorna Slade	Mwambao Community Network	Director
	Peter Alele	CI	Africa Field Director
	Jasson John	UDSM	Lecturer
	Joseph Mwalugelo		Consultatnt
	Dr. Lindsey West	SEA SENSE	Director
	Erich Pacheo	CI	Director, OHI
	Baraka Kalangahe	CFP officer Tanzania/IOC Biodiversity	CFP officer Tanzania
	Dr. David Obura	CORDIO	Director
	Lenice Ojwang	CORDIO	Researcher

	Dr. Johanna Polsenberg	CI	Senior Director
	Mbarake Kilima	Fish Market	Secretary general
	A. silumbu	PRADA	Director
	Nason Nason	KEPA, Kivukoni	Chairperson
	M.S. Mohidin	CHAWAWAMI	Coordinator
	Marisa Kraft	CI	Regional Communications Digital Officer
	Ally Kibwana	Fish Market	Chairman
	Mfaume A. Ally	YVK	Chairperson
	Sospeter Mapande	YVK	Member
	Tabby Kabu	CI	Technical Operations
	Edson Fungo	SEDIO	Chairperson
	Dr. Elikana Kalumanga	UDSM	Researcher

8.2. Participants, all technical team meetings, Tanzania May 2018 (28th-31st)

	Name	Institution	E-mail
1	Dr. Semvua Mzighani	TAFIRI	mzighani@yahoo.com
2	Dr. Ambakisye Simtoe	FETA	ambakisyes@yahoo.com
3	Said Mgeleka	TAFIRI	smgeleka@gmail.com
4	Baraka Kalangahe	IOC Biodiversity	Baraka.kalangahe@ioc.coi
5	Dr. Semvua Mzighani	TAFIRI	mzighani@yahoo.com
6	Dr. Blandina Lugendo	UDSM	blugendo@udsm.ac.tz
7	Godfrey Christopher	FETA	gochriga@gmail.com
8	Alawi H. Hija	DOE- Zanzibar	Alawihija99@hotmail.com
9	Lugendo A. Bunto	SAFSO/MAL	Bunto2005@gmail.com
10	Upendo Hamidu	SAFSI/MAL	upendoh@yahoo.com
11	Laugen R. Matthew	WWF	lmathew@wwfafrica.org
12	Lydia Mwakanema	WWF	lmwakanema@wwfafrica.org
13	Dr. Lindsey West	SEA SENSE	lindsey@seasense.org
14	Rose Sallema Mtui	NEMC	nrsallema@yahoo.com
15	Magreth Mchome	MPNRU	maggiemchome@gmail.com
16	Anita Julius	MPNRU	akilewo2011@yahoo.com
17	John Komakoma	MPNRU	jkomakoma@gmail.com
19	Mishal Gudka	CORDIO EA	mgudka@cordioea.net
20	Lenice Ojwang	CORDIO East Africa	lojwang@cordioea.net
21	Clay O. Obota	CORDIO East Africa	cobota@cordioea.net

8.3. Participants technical and advisory team discussions, Zanzibar 23rd-25th July 2018

	Name	Designation /Institution	E-mail
1	Dr. Lorna Slade	Mwambao Community Network	lornaslade@mwambao.or.tz
2	Ali Thani	Mwambao Community Network	
3	Dr. Ali M. Ussi	The State University of Zanzibar (SUZA)	amau04@gmail.com
4	Said S. Bakari	The State University of Zanzibar (SUZA)	saidbakary@yahoo.com
5	Idrissa Y. Hamad	The State University of Zanzibar (SUZA)	iyhamad11@gmail.com
6	Dr. Islam S. Salum	Min. of Agriculture, Natural Resource, Livestock	banumchenga@gmail.com
7	Dr. Narriman S.	Institute of Marine Science (IMS)	n_jiddawi@yahoo.com
8	Rukia Kitula	Institute of Marine Science (IMS)	rkitula@yahoo.com
9	Dr. Mathius Igulu	Western Indian Ocean Marine Science Association	migulu@wiomsa.org
10	Lilian Omollo	Western Indian Ocean Marine Science Association	lilian@wiomsa.org

11	Emma Forseberg	Western Indian Ocean Marine Science Association	emma@wiomsa.org
12	Jaala Simba	Marine Conservation Unit	myunimchoozani@hotmail.com
13	Ali Said Mkarafuu	Marine Conservation Unit (MIMCA)	
14	Anas M. Othman	Marine Conservation Unit (MBCA)	amasoudathman@gmail.com
15	Mkubwa S.	Department of Fisheries Development	kiambonimajaliwa@yahoo.com
16	Mwaka H.	Marine Conservation Unit	Mwakahaji12@gmail.com
17	Daniel H. Pandu	Department of Fisheries Development	dhpandu@gmail.com
18	Haji Haj	Department of Fisheries Development	dikokuu@hotmail.com
19	Mwadini Haji	Department of Fisheries Development	mwadinihaji@gmail.com
20	Hamad Khalif	Department of Fisheries Development	hamadikhatibu@gmail.com
21	Aboud S. Jumbe	Department of Environment Planning and Research	aboud.jumbe@gmail.com
22	Sheha M.Juma	Zanzibar Environment Management Authority	sheha_mjaja@hotmail.com
23	Ali I. Badu	Zanzibar Environment Management Authority	badawyali@gmail.com
24	Farhat	Department of Environment	fmbarouk@gmail.com
25	Alawi Haji	Department of Environment	Alawihija99@hotmail.com

8.4. Participants dissemination meeting, Dar es Salaam, 5th December 2018

	Name	**Institution**	**email**
1	Ms. Rose Sallema	Tanzania Environment Management Authority (TEMA)	nrsallema@yahoo.com
2	Dr. Daniel Shilla	University of Dar es Salaam (UDSM)	dshilla@yahoo.com
3	Mr. Mfaume Athuman	Youth Vision Kigamboni	johnsosy@gmail.com; youthv@yahoo.com
4	Mr. John Komakoma	Marine Park & Reserves Unit (MPRU)	jkomakoma@gmail.com
5	Mr. Alawi Hija	Department of Environment , Zanzibar	Alawihija99@hotmail.com
6	Mr. Hashim Chande	Department of Fisheries Development, Zanzibar	hasheemoumin@gmail.com
7	Dr. Narriman Jiddawi	Institute of Marine Sciences (IMS)	n_jiddawi@yahoo.com
8	Dr. Islam Mchenga	Ministry of Agriculture, Natural Resources, Livestock and Fisheries , Zanzibar	banumchenga@gmail.com
9	Dr. Mohamed Choum	Department of Fisheries Development, Zanzibar	mcjuma2003@yahoo.com
10	Mr. Baraka Kalangahe	IOC/Biodiversity focal Point, Tanzania	baraka.kalangahe@coi-ioc.com
11	Dr. Godfrey Christopher	Fisheries Education and Training Agency (FETA)	gochriga@gmail.com
12	Dr. Yahaya Mgawe	Fisheries Education and Training Agency (FETA)	ymgawe@yahoo.com
13	Mr. Randall Mabwa	CORDIO East Africa	rmabwa@cordioea.net
14	Dr. Melita Samoilys	CORDIO East Africa	msamoilys@cordioea.net
15	Mr. Mishal Gudka	CORDIO East Africa	mgudka@cordioea.net
16	Ms. Lenice Ojwang	CORDIO East Africa	lojwang@cordioea.net

8.5. Project governance teams

	Advisory team		
	Name	**Institution**	**Contact**
1	Ms. Teikwa Emelda	Vice president's office	taikwa@gmail.com

2	Dr. Yahaya Mgawe	Fisheries Education and Training Agency (FETA)	ymgawe@yahoo.com
3	Ms. Lucy Magembe	The Nature Conservancy (TNC)	lmagembe@tnc.org
4	Dr. Rashid Tamatamah	Ministry of Livestock and Fisheries	rashid.tamatamah@uvuvi.go.tz
5	Ms. Lydia Mwakanema	WWF Tanzania Country Office	lmwakanema@wwfafrica.org
6	Dr. Islam Mchenga	Ministry of Agriculture, Natural Resources, Livestock and Fisheries , Zanzibar	banumchenga@gmail.com
7	Ms. Farhat Mbraouk	Department of Environment , Zanzibar	fmbarouk@gmail.com
8	Mr. Sheha Mjaja.	Zanzibar Environmental Management Authority (ZEMA)	sheha-mjaja@hotmail.com
9	Director, fisheries department	Ministry of Livestock and Fisheries Development (mainland)	

	Technical team		
1	Dr. Semvua Mzighani	Tanzania Fisheries Research Institute (TAFIRI)	mzighani@yahoo.com
2	Ms. Rose Sallema Mtui	National Environment Management Council (NEMC)	nrsallema@yahoo.com
3	Dr. Ambakisye Simtoe	Fisheries Education and Training Agency (FETA)	ambakisyes@yahoo.com
4	Mr. Baraka Kalangahe	IOC/Biodiversity focal Point, Tanzania	baraka.kalangahe@coi-ioc.com
5	Dr. Blandina Lugendo	University of Dar es Salaam (UDSM)	blugendo@udsm.ac.tz
6	Mr. Daniel Nkondola	Ministry of Livestock and Fisheries	dnkondola@hotmail.com
7	Dr. Daniel Shilla	University of Dar es Salaam (UDSM)	dshilla@yahoo.com
8	Mr. John Sospeter	Youth Vision Kigamboni	johnsosy@gmail.com
9	Dr. Lindsey West	Sea sense	lindsey@seasense.org
10	Dr. Jasson John	University of Dar es Salaam	jassonjohn@yahoo.com
11	Mr. Laugen R. Mathew	WWF Tanzania Country Office	lmathew@wwfafrica.org
12	Ms. Olipa Simon	Institute of Natural Resources Assessment (UDSM)	olipasimon@yahoo.com
13	Jeniffer O'Leary	The Nature Conservancy (TNC)	jennifer.oleary@tnc.org
14	Mr Alawi Hija	Department of Environment , Zanzibar	Alawihija99@hotmail.com
15	Mr. Hashim Chande Muumin	Department of Fisheries Development, Zanzibar	hasheemoumin@gmail.com
16	Dr. Ali M. Ussi	Department of Natural Sciences, State University of Zanzibar (SUZA)	amau04@gmail.com
17	Dr Narriman Jiddawi	Institute of Marine Sciences (IMS)	n_jiddawi@yahoo.com
18	Dr. Lorna Slade	Mwambao Coastal Community Network	lornaslade@mwambao.or.tz

OHI Global Support Team

1. Peter Alele— Africa Field Director, Vital Signs palele@conservation.org
2. Tabby Njung'e— Technical Operations Manager, Vital Signs tnjunge@conservation.org
3. Erich J Pacheco — Program Director epacheco@conservation.org
4. Julia Lowndes — Program Scientist lowndes@nceas.ucsb.edu

5. Erin O'Reilly — Communications Coordinator oreilly@nceas.ucsb.edu

OHI CORDIO Team

1. David Obura- Director, CORDIO dobura@cordioea.net
2. Mishal Gudka-Project manager mgudka@cordioea.net
3. Lenice Ojwang-Stakeholder engagement, lojwang@cordioea.net
4. Randall Mabwa – Data analysis, rmabwa@cordioea.net
5. James Mbugua-GIS expert jmbugua@cordioea.net
6. Clay Obota-Fisheries cobota@cordioea.net

8.5.1. TORs for project governance teams

TANZANIA ADVISORY GROUP

The Advisory Group assures the national context and relevance for implementation of OHI+. The assessment must be done considering local and national priorities, barriers/obstacles, and management needs, and the Advisory Group plays a role to both assure the analysis is relevant to these, and represents the OHI+ analysis in national contexts to peers and other government and stakeholder groups.

Group structure and role

The Advisory Group will comprise representatives from key national and local/coastal institutions with a strong stake in ocean management. They represent the policy framing for the analysis and provide a pathway for sustainability of the OHI+ in the national context beyond the term of the initiating project. In some cases, institutions represented on the Advisory Group will have technical experts in the project Technical Team, providing direct links between the assessment and policy.

Objectives:

1. Guide technical team during OHI analysis by aligning targets with national ocean management priorities
2. Publicize OHI process within management and policy circles
3. Disseminate outputs at relevant national ocean policy and management discussions
4. Support integration of the OHI process within existing national management structures e.g. ICZM
5. Inform the development of a 5-year National ocean strategic action plan.
6. Support the establishment of a National Ocean Indicator Framework.
7. Establish SMART (Specific, Measurable, Ambitious, Realistic, Time-sensitive) management targets for each of the 10 OHI goals.

How the group will work

The Advisory Group will work through in-person meetings and remote communication (telephone, email, via the toolbox etc.). No technical requirements are expected.

Group membership

Members have been drawn from institutions in Tanzania mainland and Zanzibar.

TANZANIA TECHNICAL TEAM

The Technical Team is central to the success of the implementation of OHI+. The assessment must be done considering local priorities, barriers/obstacles, and management needs, and the Technical Team must bring the requisite skill set, and be able to adapt to data and analysis available.

Team structure and skills needed

The Technical Team will comprise the following:

8. **Core team:** that is very knowledgeable about the OHI framework and process, with specific members having backgrounds in marine science and tasked with information gathering and communication or with information processing and the Toolbox (or better yet, a combination of the two). This is the role assigned to CORDIO through Conservation International. Their responsibility is to manage the overall analytical process and run the OHI+ Toolbox.

9. **Goal-keepers**: small teams of 1-3 people that lead each priority goal, and/or key pressures/resilience themes. Their role is to identify relevant data and provide or facilitate access to the data, contribute to technical decisions on reference points and models, and assess relevant pressures and resilience measures to capture local management efforts and social conditions that can counteract existing pressures.

Key responsibilities.

The technical team member will work closely (as per available time) with CORDIO, Conservation International and partners in;

- Defining boundaries for assessment and management aligned with scales of decision making.
- Acquire and or provide information and data necessary to tailor the OHI process to the needs of the country focusing primarily on specific variables of local importance cultural preferences, and relative importance of ocean and coastal features
- Participate in OHI methods and tools trainings via skype or in person as relevant so they are able to independently carry out future assessments. This will include training the OHI toolbox that utilizes R-Studio and GIS software) which are open source. The goal is to institutionalize the knowledge from the OHI assessment within various public institutions so that future assessments will provide information about the effectiveness of management interventions and policies to improve ocean health relative to established targets.

Duration

The technical team will be active till the end of the OHI analysis phase approximately by November 2018.

Team membership

Members have been drawn from institutions in Tanzania mainland and Zanzibar.

How the team will work

The Core Team and Goal-Keepers will work through in-person meetings and remote communication (telephone, email, via the toolbox, etc). Work will be coordinated by the Core Team. Often times, by working on similar goals at the same time, the same person/team can be the lead on multiple goals.

The toolbox is built upon the programming language R (R-studio and Github are the main platforms used). The technical team member(s) need to be skilled in R. At least one member of the team must be well versed in GIS software to set regional boundaries and undertake any spatial analysis.

Relationship between the Technical Team and Advisory Group

The Advisory Group represents the policy oversight of the analysis, like a Steering Committee, to keep the work on track to maximize policy relevance and uptake of the analysis in the national context. The Technical Team undertakes the primary analysis, relying most heavily on its Core Team, and with specific inputs and technical guidance by 'Goal-Keepers'.

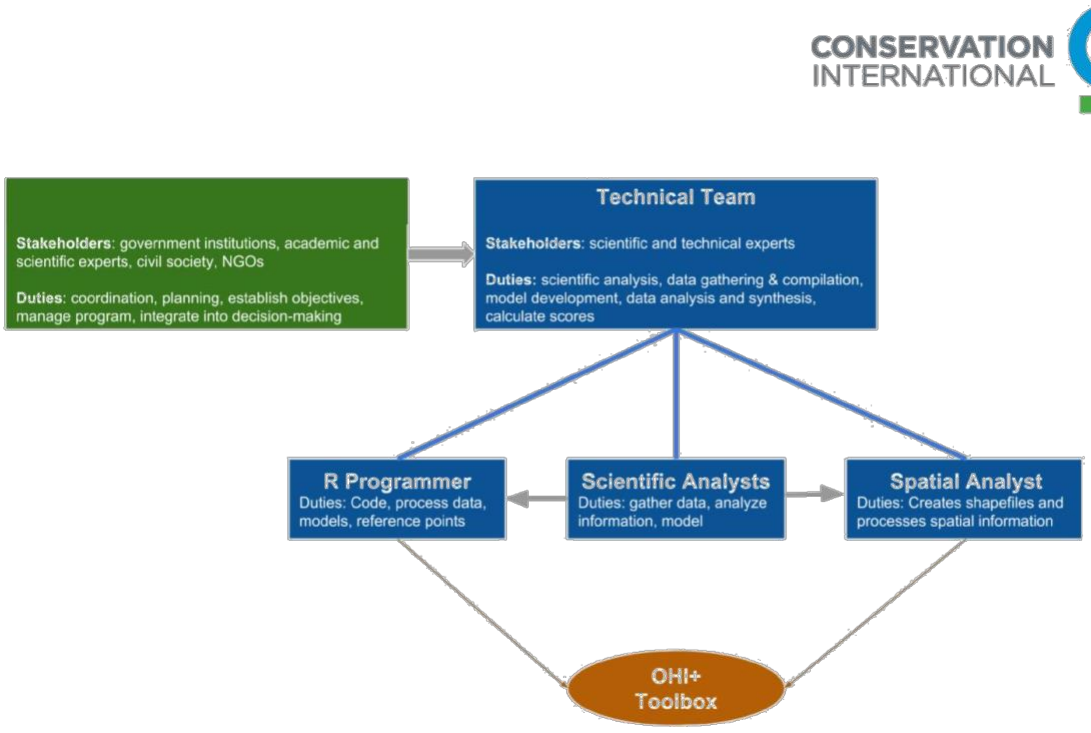
The Technical Team will report on key milestones of its work to the Advisory Group, whose role is to assure continued relevance of the analysis in the context of the national priorities established for each Goal. Key milestones may include:

- Determination of specific datasets, reference points, models, pressures and resilience variable for each priority Goal
- Calculation of preliminary output for each Goal
- Comparison among Goal results and compilation of a synthetic index for the country based on the Goals selected for analysis.

Other stakeholders may be involved in relation to specific goals, datasets and elements of the analysis, which will be documented for each goal.

The Technical Team will work to a schedule determined by the data available and analyses and will prepare reports on progress in each Goal as indicated above and circulate these among the Advisory Group. On a quarterly basis, a meeting of the Advisory Group will be called to verify/confirm progress and discuss any pending issues requiring consultation.

Sample OHI Team structure, and relationship between Advisory Group and Technical Team:



8.6. Method - calculating the index

The index (I_{global}) score is the sum of the regional scores (I_{region}). Regions are combined by area-weighted average (a).

$$I_{global} = \frac{\sum_{i=1}^{N} a_i I_{region,i}}{\sum_{i=1}^{N} a_i}$$

The regional scores (I_{region}) are the sum of all the individual goal scores (G_i). All goals were given equal weight in the index (w_g).

$$I_{region} = \frac{\sum_{g=1}^{N} w_g G_g}{\sum_{g=1}^{N} w_g}$$

The goal score (G_i) is the average of current status (50% of the goal score) and probable future state (50% of the goal score).

$$G = \frac{x + x_f}{2}$$

The goal current status (x) is calculated using available indicators in relation to a stakeholder set reference point (see goal models & data below for specific models for each goal). The probable future status (x_f) measures the cumulative pressures (negative impacts on a goal score), cumulative resilience (positive impacts on a goal score) and trend (projected goal status in five years). The future status score is the near future score projection of a goal calculated as the current goal status multiplied by the 5 year status trend (T) and the difference in the resilience (r) and pressure (p) applied to that goal (Halpern et al., 2012).

$$x_{i,f} = [1 + \beta T_i + (1-\beta)(r_i - p_i)] X_i$$

The trend is given a higher weight (β) than the pressure/resilience component. This value was chosen based on the assumption that trend is a better indicator of the near future condition than indirect measures of pressure and resilience (Halpern et al., 2012). All pressure and resilience values are scaled from 0 to 1 and trend is constrained to -1.0 to +1.0.

Pressures and Resilience

Cumulative pressures acting on each goal are calculated as the sum of ecological (P_E) and social pressures (P_S):

$$p = \gamma * p_E + (1 - \gamma) * p_S$$

Where γ is the relative weight for ecological vs. social pressures, set as equal (0.5). Each pressure layer is assigned to an ecological or social category, with ecological pressures further assigned to one of five subcategories (pollution, alien species, habitat destruction, fishing pressure, and climate change). Each

ecological pressure layer is then applied to relevant goals and assigned a rank sensitivity or the weight of the pressure on that goal from 1 to 3 with 1 being low impact, 2 being medium impact, and 3 being high impact. Ecological pressures are then calculated as the weighted average of the pressure scores for each category for each goal (see Halpern et al. 2012). Social pressures are unweighted, and the social pressure exerted on a goal is calculated as the average of the all the social pressures applied to that goal (Halpern et al. 2012).

Resilience layers are assigned to three categories: ecological integrity, regulatory efforts, and social integrity. Ecological integrity and regulatory effort resilience scores address ecological pressures and therefore are averaged together and added to the social integrity resilience scores for each goal (Halpern et al. 2012).

The pressure and resilience layers help capture the complex interactions social and ecological interactions that are exerted on each goal.

The OHI Toolbox

The OHI Toolbox is the engine that powers all OHI assessments. By utilizing R scripts and GitHub repositories, it combines prepared data, goal models, and pressures and resilience layers to calculate OHI scores.

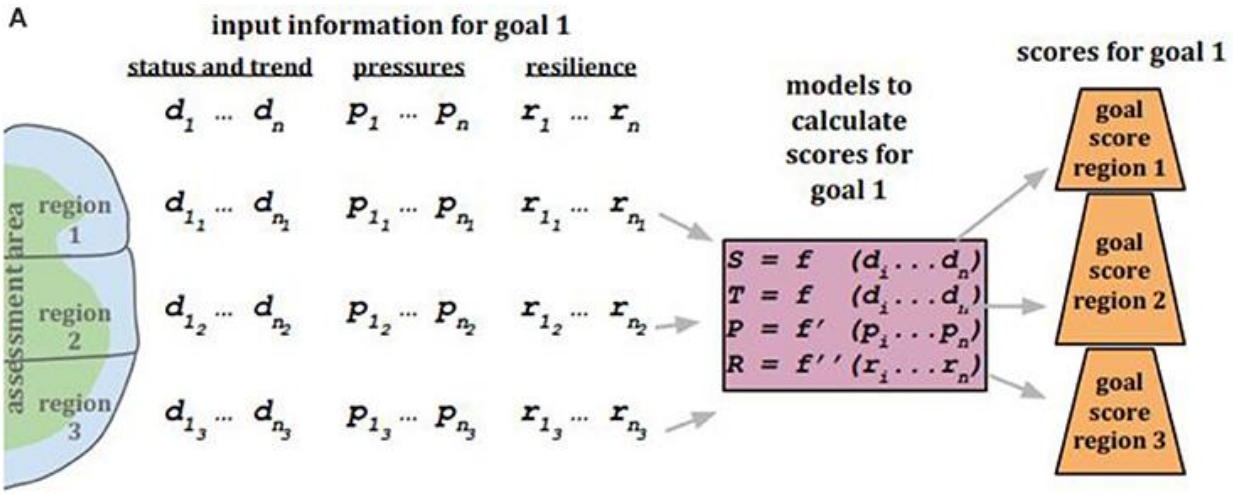


Figure 6 Overview of the data analysis process within the OHI Toolbox. Source: Borja et al. 2016 (www.frontiersin.org/articles/10.3389/fmars.2016.00020/full)

8.7. Fisheries model and analysis

Food provision from wild caught fisheries is assessed by estimating population biomass relative to the biomass that can deliver maximum sustainable yield (B/B_{MSY}) for each stock. When available, B/B_{MSY} values are obtained from the RAM Legacy Stock Assessment Database (Ricard et al., 2012), which contains stock assessment information for a portion of global fish stocks. When RAM data were not available, data-limited approaches are used. These approaches have been developed to estimate B/B_{MSY} values using globally available catch data (Costello et al., 2016, 2012; Martell & Froese, 2012; Thorson et al., 2013) Rosenberg *et al.* 2014). To calculate the status for each region and year, B/B_{MSY} values are converted to a stock status score between 0 -1 that penalizes both over- and under-harvesting. To obtain the overall status for each region (x_{fis}), the stock status scores (*SS)* for all the stocks within a region were averaged using a geometric mean weighted by the average catch (tonnes) of each stock (C):

$$x_{fis} = \prod_{i=1}^{n} SS_i^{\left(\frac{C_i}{\sum C_i}\right)}$$

i is an individual taxon and *n* is the total number of taxa in the reported catch for each region throughout the time-series, and *C* is the average catch, since the first non null record, for each taxon within each region.

A geometric weighted mean is used to account for the portfolio effect of exploiting a diverse suite of resources, such that small stocks that are doing poorly will have a stronger influence on the overall score than they would using an arithmetic weighted mean, even though their *C* contributes relatively little to the overall tonnage of harvested seafood within a given region. The behavior of the geometric mean is such that improving a well-performing stock is not rewarded as much as improving one that is doing poorly. This behavior is desirable because the recovery of stocks in poor condition requires more effort and can have more important effects on the system than making a species that is already abundant even more abundant. In this way, the score is not solely driven by absolute tonnes of fish produced and accounts for preserving the health of a diversity of species.

B/B_{MSY} values were used to derive stock status scores, *SS*, such that the best score is achieved for stocks at B/B_{MSY} = 1%, with a 5% error buffer, and it decreases as the distance of *B* from B/B_{MSY} increases, due to under- or over-exploitation. For each species reported, within each major fishing area, the stock status score was calculated as:

$$SS=\begin{cases} B/B_{MSY} & if \;\; B/B_{MSY} < 0.95 \\ 1 & if \;\; 0.95 \leq B/B_{MSY} \leq 1.05 \\ max\{1-\alpha(B/B_{MSY}-1.05),\ \beta\} & if \;\; B/B_{MSY} > 1.05 \end{cases}$$

where, for $B/B_{MSY} < 1$ (with a 5% buffer), status declines with direct proportionality to the decline of β with respect to B/B_{MSY}, while for B/B_{MSY} >1 (with a 5% buffer), status declines at rate α, where α=0.5, so that as the distance of β from B/B_{MSY} increases, status is penalized by half of that distance. For B/B_{MSY} >1.05, β is the minimum score a stock can get, and was set at β=0.25. The α value ensures that the penalty for under-harvested stocks is half of that for over-harvested stocks (α=1.0 would assign equal penalty). The β value ensures stocks with $B/B_{MSY} > 1.4$ due to, for example, an exceptionally productive year, are not unduly penalized, and also recognizes that it is much easier to improve the goal score when stocks are under-harvested (i.e., increase fishing pressure) than it is when populations are over-harvested and need to be rebuilt. Both parameters α and β were chosen arbitrarily because there is no established convention

for this particular approach. Thus, consistent with previous work (Halpern *et al.* 2012), countries are rewarded for having wild stocks at the biomass that can sustainably deliver the maximum sustainable yield, +/-5% to allow for measurement error, and are penalized for both over- or under-harvesting.

Missing status scores, *SS*, needed to be gapfilled for a large proportion of the catch (12/25 stocks). Gapfilling was necessary because B/B_{MSY} values could only be estimated for taxa identified to the species level. Furthermore, B/B_{MSY} values for some species were not able to be estimated due to model non-convergence or too few years of catch data. Missing status scores were gapfilled using the median status scores of the stocks sharing a region and year, the median value was then adjusted using a taxonomic reporting penalty (see Table 12 below). For catch not reported to the species level, a penalty was applied for increasingly coarser taxonomic reporting, as this is considered a sign of minimal monitoring and management. The penalty is based on the ISSCAAP convention for taxon codes (http://www.fao.org/fishery/collection/asfis/en), which defines 6 levels of taxonomic aggregation, from 6 (species) to 1 (order or higher). When g<6g<6, a penalized gapfilled value for status was estimated for the taxa in each region:

Table 7. *Penalties applied to gapfilled stock status scores based on level of identification of stocks. The penalty is multiplied by the gapfilled stock status score to obtain the final stock status score.*

ISSCAAP Taxon Code	Description	Penalty (gapfilled score multiplied by value)
1	Marine fishes not identified, Miscellaneous marine molluscs	0.1
2	Class, Subclass, Subphylum (e.g., Cephalopoda, Holocephali, Crustacea)	0.25
3	Order (e.g., Chimaeriformes, Octopoda)	0.5
4	Family (e.g., Lamnidae, Squillidae)	0.8
5	Genus (e.g., Strongylocentrotus, Scyllarides)	0.9
6	Species	1 (no penality)

8.7.1. OHI global fish species list for Tanzania

Stocks			
Acanthocybium_solandri	*Elagatis_bipinnulata*	*Mugilidae*	*Scaridae*
Acanthuridae	*Elasmobranchii*	*Mullidae*	*Sciaenidae*
Alopias_vulpinus	*Engraulidae*	*Muraenesocidae*	*Scomberomorus_commerson*
Alopias	*Epinephelus*	*Muraenidae*	*Scomberomorus*
Anguilliformes	*Euthynnus_affinis*	*Myctophidae*	*Scombridae*
Ariidae	*Fenneropenaeus_indicus*	*Nemipteridae*	*Scombroidea*
Auxis_rochei	*Gadiformes*	*Nemipterus*	*Scylla_serrata*
Auxis_thazard	*Galeocerdo_cuvier*	*Nephropidae*	*Selar_crumenophthalmus*
Auxis	*Gazza_minuta*	*Octopoda*	*Sepia_latimanus*
Batoidea	*Gempylidae*	*Octopodidae*	*Sepiidae*
Berycidae	*Gerreidae*	*Octopus_cyanea*	*Seriola_dumerili*
Bivalvia	*Gerres_oblongus*	*Octopus*	*Seriola*

Bramidae	*Gerres_oyena*	*Ommastrephes_bartramii*	*Serranidae*
Caesionidae	*Gerres*	*Ostraciidae*	*Siganidae*
Carangidae	*Haemulidae*	*Palinuridae*	*Siganus*
Carangoides_malabaricus	*Haliporoides_sibogae*	*Panulirus*	*Sillaginidae*
Caranx_ignobilis	*Hemiramphidae*	*Pelates_quadrilineatus*	*Soleidae*
Carcharhinidae	*Hexanchus_griseus*	*Pellona_ditchela*	*Sparidae*
Carcharhinus_brachyurus	*Holothuriidae*	*Penaeidae*	*Sphyraena*
Carcharhinus_falciformis	*Inermiidae*	*Penaeus_monodon*	*Sphyraenidae*
Carcharhinus_galapagensis	*Istiompax_indica*	*Penaeus_semisulcatus*	*Sphyrna_lewini*
Carcharhinus_limbatus	*Istiophoridae*	*Penaeus*	*Sphyrna_zygaena*
Carcharhinus_longimanus	*Istiophorus_platypterus*	*Perciformes*	*Sphyrna*
Carcharhinus_obscurus	*Isurus_oxyrinchus*	*Platycephalidae*	*Sphyrnidae*
Carcharhinus_plumbeus	*Isurus_paucus*	*Pleuronectiformes*	*Stromateidae*
Carcharhinus	*Isurus*	*Plotosus_lineatus*	*Synodontidae*
Centrolophidae	*Kajikia_audax*	*Pomacentridae*	*Terapontidae*
Cephalopoda	*Katsuwonus_pelamis*	*Pomadasys_stridens*	*Tetrapturus_angustirostris*
Chirocentrus_nudus	*Labridae*	*Pomadasys*	*Teuthida*
Chirocentrus	*Lamniformes*	*Pomatomus_saltatrix*	*Thunnus_alalunga*
Chondrichthyes	*Lampris_guttatus*	*Portunidae*	*Thunnus_albacares*
Clupeidae	*Leiognathidae*	*Portunus_pelagicus*	*Thunnus_obesus*
Clupeiformes	*Leiognathus_equulus*	*Prionace_glauca*	*Thunnus*
Congridae	*Lepidocybium_flavobrunneum*	*Psettodes_erumei*	*Trachurus*
Coryphaena_hippurus	*Lethrinidae*	*Psettodidae*	*Trichiuridae*
Coryphaena	*Lethrinus_harak*	*Rachycentridae*	*Trichiurus_lepturus*
Decapoda	*Lobotes_surinamensis*	*Rachycentron_canadum*	*Upeneus_vittatus*
Decapterus_macrosoma	*Loliginidae*	*Rajiformes*	*Upeneus*
Decapterus_russelli	*Lophiidae*	*Rastrelliger_kanagurta*	*Xiphias_gladius*
Diodon	*Lutjanidae*	*Rastrelliger*	*Zeidae*
Diodontidae	*Makaira*	*Ruvettus_pretiosus*	
Echeneidae	*Malacostraca*	*Sarda_orientalis*	
Echidna_nebulosa	*Metapenaeus_monoceros*	*Sardinella*	

8.7.2. Pressure indicators - Fisheries sub-goal

Indicator	Metric/Measure	Scale	Data Source(s)
Intertidal habitat destruction	Human population within 5-miles of the coastline	Local	Centre for International Earth Science Information Network - CIESIN - Columbia University. 2017. Gridded Population of the World, Version 4 (GPWv4): Population count, Revision 10. Palisades, NY: NASA Socioeconomic

			Data and Applications Center (SEDAC). https://doi.org/10.7927/H4DZ068D.
Weakness of social progress	Multi-dimensional poverty index	Local	Tanzania Human Development Report 2014 (http://hdr.undp.org/en/content/tanzania-human-development-report-2014)
Weakness of governance	Inverse of Worldwide Governance Indicator score for Tanzania for 2015	Global	The Worldwide Governance Indicator (WGI) is composed of six dimensions of governance: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, control of corruption. (http://info.worldbank.org/governance/wgi/#home)
Subtidal hard bottom habitat destruction	Level of dynamite fishing as a proxy	Local	Tanzania Dynamite Monitoring Network 2009. Map prepared for World Resources Institute
Nutrient pollution	Level of pollution intensity within 12nm	Local	Modelled nutrient pollution within 12nm of coastline based on fertilizer consumption https://ohi.nceas.ucsb.edu/data/data/nutrient_pollution (Halpern et al., 2008)
Chemical pollution	land-based organic pollution (pesticide data), land-based inorganic pollution, ocean pollution (shipping and ports) within 12nm	Local	Modelled chemical pollution within 12nm of coastline for 2013 (Halpern et al., 2008) https://ohi.nceas.ucsb.edu/data/data/chem_pollution
By-catch due to artisanal fishing	Extent of artisanal fishing as a proxy	Global	summed catch from low bycatch gear types (e.g., hook and line, purse seines) (Watson, 2017) https://github.com/OHI-Science/ohi-global/blob/draft/eez/layers/fp_art_lb.csv
Blast and poison fishing	Presence of destructive artisanal blast and poison (cyanide) fishing based on survey observations and expert opinion used as proxy	Global	Reefs at Risk Revisited (Burke et al., 2011) https://github.com/OHI-Science/ohi-global/blob/draft/eez/layers/fp_art_hb.csv

8.7.3. Resilience indicators - Fisheries sub-goal

Indicator	Metric/Measure	Scale	Data Source(s)
Coastal ecological integrity	condition of species located within 3nm offshore of each region	Global	IUCN Red List of Threatened species (http://www.iucnredlist.org/) IUCN Species range maps (shapefiles, used preferentially) AquaMaps (http://www.aquamaps.org/,
Coastal protected marine areas	Percentage of territorial waters under protection	Local	http://www.mpatlas.org/data/download/ Database: Marine Conservation Institute. (2015). MPAtlas. Seattle, WA. www.mpatlas.org 2015

	compared to 30% target		
Protected area management effectiveness	Management Effectiveness Tracking Tool (METT) scores	Local	2018 MPRU METT results for MPAs
Artisanal fisheries management effectiveness	Scores based on expert-opinion survey answers related to quality of management of small-scale fishing	Global	Global data were extracted from (Mora et al., 2009), Figure S4. https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1000131
Social progress	Inverse of multi-dimensional poverty index	Local	Tanzania Human Development Report 2014 (http://hdr.undp.org/en/content/tanzania-human-development-report-2014)
Strength of governance	Worldwide Governance Indicator score for Tanzania for 2015	Global	The Worldwide Governance Indicator (WGI) is composed of six dimensions of governance: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, control of corruption. (http://info.worldbank.org/governance/wgi/#home)
Management of waters to preserve biodiversity	Country responses to the Convention on Biological Diversity (CBD) Third National Report (2005).	Global	Country responses to the Convention on Biological Diversity (CBD) Third National Report (2005). https://github.com/OHI-Science/ohi-global/blob/draft/eez/layers/po_water.csv

Water quality

8.8. Habitat goal model and analysis

The status of the habitat sub-goal, x_{hab}, was assessed as the average of the health/condition estimates, *C*, for each habitat, *k*, present in a region; measured as the loss of habitat and/or % degradation of remaining habitat, such that:

$$x_{hab} = \frac{\sum_{k=1}^{N} C_k}{N}$$

where, $C_k = C_c/C_r$ and *N* is the number of habitats in a region. C_c is the current condition and C_r is the reference condition specific to each *k* habitat present in the region. This formulation ensures that each country is assessed only for those habitats that can exist.

For both coral reef and mangrove data, the linear trend across the latest 5 years of data for each region was calculated and the trend score was normalised using the following formula:

$$\frac{\text{linear change in cover per year}}{\text{cover of the first year}} \times \text{number of years}$$ (score>1 capped at 1, and score<-1, capped at -1).

8.8.1. Pressure indicators - Habitat sub-goal

Indicator	Metric/Measure	Scale	Data Source(s)
Intertidal Habitat destruction	Human population within 5-miles of the coastline	Local	Centre for International Earth Science Information Network - CIESIN - Columbia University. 2017. Gridded Population of the World, Version 4 (GPWv4): Population count, Revision 10. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/H4DZ068D.
Sea surface temperature	Sea surface temperature anomaly	Global	Coral Reef Temperature Anomaly Database (CoRTAD) (Casey et al. 2015), which is produced by the NOAA National Center for Environmental Information (NCEI)
Weakness of social progress	Multi-dimensional Poverty Index	Local	Tanzania Human Development Report 2014 (http://hdr.undp.org/en/content/tanzania-human-development-report-2014)
Weakness of governance	Inverse of Worldwide Governance Indicator score for Tanzania for 2015	Global	The Worldwide Governance Indicator (WGI) is composed of six dimensions of governance: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, control of corruption. (http://info.worldbank.org/governance/wgi/#home)
Nutrient pollution	Level of pollution intensity within 12nm	Local	Modelled nutrient pollution within 12nm of coastline based on fertilizer consumption https://ohi.nceas.ucsb.edu/data/data/nutrient_pollution (Halpern et al. 2008)
Chemical pollution	land-based organic pollution (pesticide data), land-based inorganic pollution, ocean pollution (shipping and ports) within 12nm	Local	Modelled chemical pollution within 12nm of coastline for 2013 (Halpern et al. 2008) https://ohi.nceas.ucsb.edu/data/data/chem_pollution
Sea level rise	Monthly mean sea level anomalies	Local	changes in sea level (mm) from 1993 through 2015 compared to a reference period from 1993-2012 satellite altimetry data (http://www.aviso.altimetry.fr/en/data/products/sea-surface-height-products/global/msla-mean-climatology.html)
Subtidal hardbottom habitat destruction	Level of dynamite fishing as a proxy	Local	Tanzania Dynamite Monitoring Network 2009. Map prepared for World Resources Institute
Oil and gas activity	Level of activity based on expert opinion. Categories: ongoing extraction activity – 1; Development- of infrastructure 0.75; Exploration/Seismic tests – 0.5; Planning – .25	Local	https://github.com/OHI-Science/tza/tree/master/prep/pressures/Oil%20and%20Gas
Blast and poison fishing	Presence of destructive artisanal blast and	Global	Reefs at Risk Revisited (Burke et al. 2011)

	poison (cyanide) fishing based on survey observations and expert opinion used as proxy	https://github.com/OHI-Science/ohi-global/blob/draft/eez/layers/fp_art_hb.csv

8.8.2. Resilience indicators - Habitat sub-goal

Indicator	Metric/Measure	Scale	Data Source(s)
Coastal ecological integrity	condition of species located within 3nm offshore of each region	Global	IUCN Red List of Threatened species (http://www.iucnredlist.org/) IUCN Species range maps (shapefiles, used preferentially) AquaMaps (http://www.aquamaps.org/,
Coastal protected marine areas	Percentage of territorial waters under protection compared to 30% target	Local	http://www.mpatlas.org/data/download/ Database: Marine Conservation Institute. (2015). MPAtlas. Seattle, WA. www.mpatlas.org 2015
Protected area management effectiveness	Management Effectiveness Tracking Tool (METT) scores	Local	2018 MPRU METT results for MPAs
Artisanal fisheries management effectiveness	Scores based on expert-opinion survey answers related to quality of management of small-scale fishing	Global	Global data were extracted from Mora et al. (2009), Figure S4. https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1000131
Social progress	Inverse of multi-dimensional poverty index	Local	Tanzania Human Development Report 2014 (http://hdr.undp.org/en/content/tanzania-human-development-report-2014)
Strength of governance	Worldwide Governance Indicator score for Tanzania for 2015	Global	The Worldwide Governance Indicator (WGI) is composed of six dimensions of governance: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, control of corruption. (http://info.worldbank.org/governance/wgi/#home)
Management of waters to preserve biodiversity	Country responses to the Convention on Biological Diversity (CBD) Third National Report (2005).	Global	Country responses to the Convention on Biological Diversity (CBD) Third National Report (2005). https://github.com/OHI-Science/ohi-global/blob/draft/eez/layers/po_water.csv