2018 KENYA OCEAN HEALTH INDEX

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CORDIO

Preliminary Ocean Health Index Assessment for Kenya

CORDIO EAST AFRICA

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Ocean Health Index - Kenya 2018

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OHI+ Kenya Report

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1. Kenya 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 Kenya OHI assessment was conducted as a participatory process involving government institutions and stakeholders, hosted nationally by the National Environmental Management Authority (NEMA) and Kenya Marine and Fisheries Research Institute (KMFRI), 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:

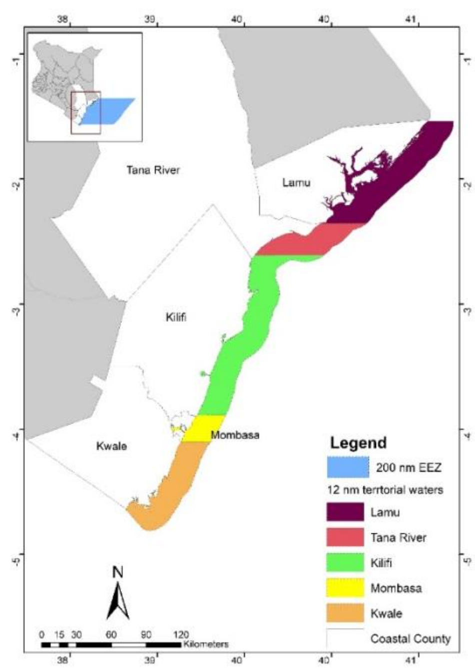
Each goal is scored on a scale of 0-100, with 100 representing optimized use of potential ocean benefits and services in a sustainable way.

1.1. Why now?

Kenya's use of ocean resources is set to expand; fisheries, tourism and shipping are key national sectors dependent on the ocean, County governments have new lead responsibilities through devolution, and a new Blue Economy drive is a top national development priority. This OHI analysis can help to align actors from diverse sectors and across scales, to ensure sustainable use of the ocean and future prosperity.

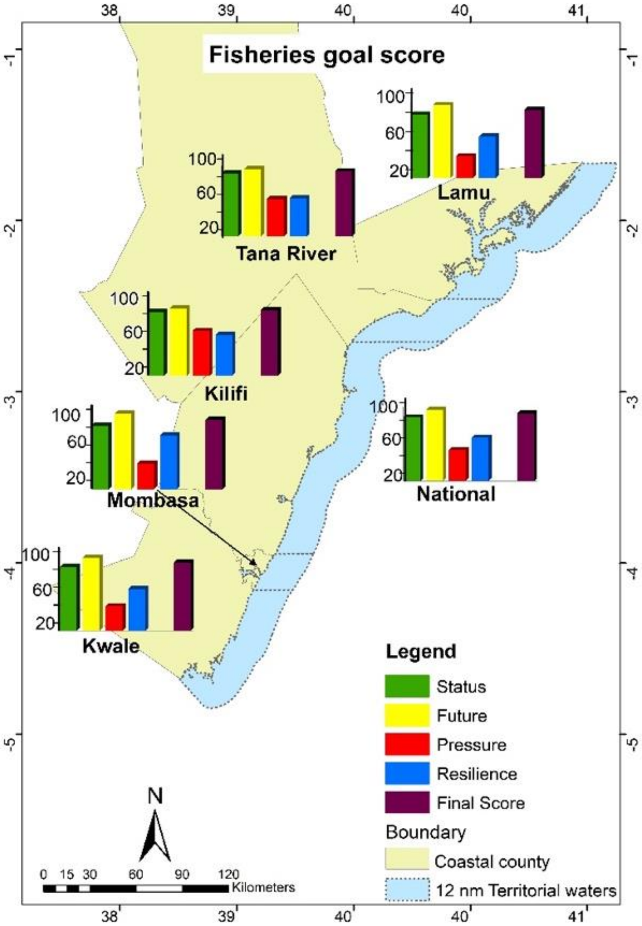
1.2. Tailoring the OHI to Kenya's needs and priorities

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



Counties are identified and empowered by Kenya's 2010 constitution as the main authorities for local government, however maritime boundaries for Counties are not specified in Kenyan law. Several options for maritime jurisdiction of the Counties 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 five County zones are identified (see map). Appropriate data were not available for the 12 nM to 200 nM EEZ boundary, so the goals were not assessed for this zone.

1.3. Key findings



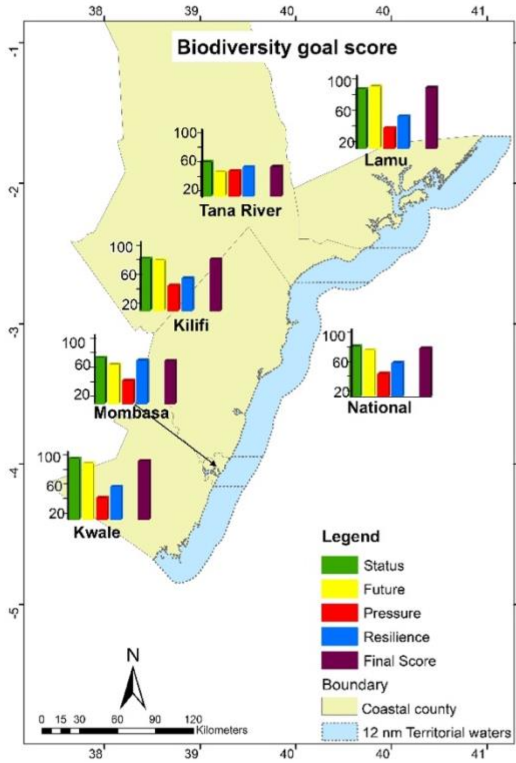
Food provision (fisheries) was the top priority goal. The Fisheries sub-goal aims to describe the amount of wild-caught seafood harvested and its sustainability for human consumption. We tested the Maximum Sustainable Yield fisheries model used in the OHI in the context of data-poor fisheries. Of the 25 taxa, only 6 had data available at County levels, and the data for only 1 of these met the requirements for MSY calculations. Twenty five stocks of fish (artisanal fisheries) and prawns were assessed using Maximum Sustainable Yield (MSY), 6 of these being from high-spatial resolution data, and 19 providing only national level results. Several assumptions and caveats in the data and method such as calculation of b/bmsy, lack of county-level data and data gaps for certain stocks led to large uncertainties in the final status scores.

Fisheries scores were very uniform across counties due to data limitations. Future scores were differentiated by variation in pressures (highest in Kilifi and Tana River) and resilience (highest in Mombasa), with resilience scores being higher than pressures. Twelve of the thirteen stocks evaluated at the species level were considered underexploited but the data-limited methods may not necessarily reflect the state of the tropical multi-species multi-gear system. Thus, this fishery result is only illustrative, and more suitable models for the existing length-based data should be trialed e.g. spawning potential ratio, to improve the fit of the assessment to data-poor fisheries to improve the fit of the assessment to data-poor fisheries and provide more accurate county-level scores.

Key Policy and Management Recommendations

1. Implement management and policy strategies for gears rather than fish sizes and species as they are easier to implement
2. Increase investment in monitoring and data collection to ensure data is collected at higher taxonomic levels and alongside effort information, and 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 Kenya's fisheries sector to a data-rich system
3. Support counties and BMUs to define co-management areas and implement area based management approaches to improve coastal fisheries status through capacity development, policy or legislation formulation and funding
4. Develop data and information sharing platforms and other mechanisms which can facilitate increased data access and sharing e.g. invest to operationalize fish catch national database

Biodiversity (marine habitats) was the second priority goal. 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 available at County levels, and on seagrasses only at a national level.



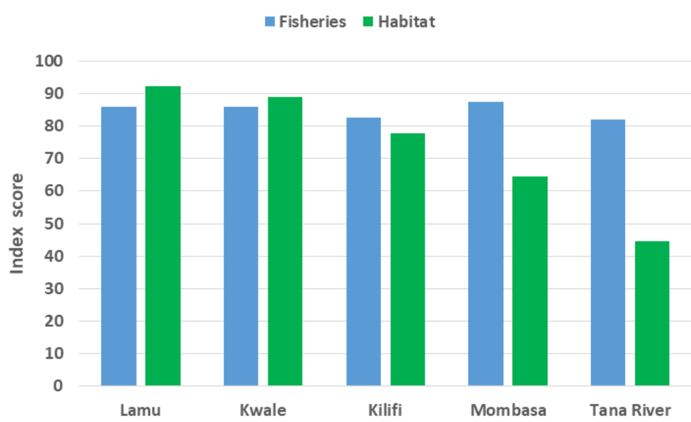
Lamu and Kwale counties scored highest for current and future status (final score of 92.4 and 89 respectively). Tana River scored the lowest (final score: 44.5) as the habitats assessed had no available data (coral reefs) or in small already-impacted patches (mangroves), and resilience is low due to inadequate governance and management. In all counties except Lamu, and overall (nationally), future ecosystem health will decline relative to today.

In all counties the pressures scores were slightly lower than the resilience scores, though future improvements in data and growing population and development may reverse this. Mombasa County's resilience score was the highest, due to its higher score for the County Development Index, and it meets the target of having 30% of its waters under protection.

The core variable and reference point for coral reef health, coral cover, generates some misleading results as degradation of coral reefs in Kenya since the 1998 mass bleaching event is clear. The lack of access to relevant data, and lower investment in monitoring data in early years are the key challenges. Overall the country has lost around 25% of its mangrove cover over the last two decades. Kwale and Lamu counties retain over 90% and 85% of their mangrove extent, while Tana River and Mombasa County are the most heavily impacted, having lost around 80% of their cover since the early 1990s.

Key Policy and Management Recommendations

1. Strengthen habitat protection through improved land-planning and enforcement of regulations, and increased protected areas (MPAs) particularly in Tana River.
2. Substantially scale up and update management of coral reefs, using the latest scientific recommendations to address increasing threat levels.
3. Counties should support implementation of community level co-management initiatives through BMUs and Community Forest Associations (CFAs) to reduce pressures on mangroves, seagrasses, coastal forest and coral reefs such as pollution, destructive fishing, encroachment etc.
4. Continue implementation of 2017 National Mangrove Management Plan to ensure effective conservation and stem declines particularly in Mombasa and Tana River
5. 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.
6. Develop a national management plan for coral reefs through an inclusive stakeholder process.
7. Prioritise stronger enforcement of environmental legislation outside of protected areas, particularly for pollution, and strongly enforce requirements for high quality ESIAs for coastal developments.



Overall results

Greater county-level disaggregation of habitat data (particularly for mangroves) compared to fisheries data, helps to provide a more accurate reflection of the real state.

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.

Climate change, increasing coastal population, infrastructural developments and energy projects will impose increased pressures on Kenya's coastal and marine ecosystems in coming years. This will translate into continued degradation if management measures are not scaled up in both quantity and quality. The coastal counties are already afflicted by issues such as flooding, food shortages and high-rates of poverty. Recognizing the importance of habitats and ecosystems as the foundations of coastal economic sectors, such as fishing and tourism, should give County governments the justification to invest in improved management to improve sustainability and approach scores of 100.

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:

- different agencies have authority over the sectors relevant to each goal, including the core data, and selection of model and reference points. Each competent authority should be a goal 'custodian' to embed the evaluation in their official processes (e.g. SDF&BE for fisheries, KWS for coral reefs, KFS for mangroves, etc.).
- enhanced cooperation between National and County governments is necessary to complement the sectoral focus of the former, the land-based jurisdiction of the latter, and to operationalize County maritime zones.
- A relevant high authority should coordinate assessments to centralize the technical evaluation and integrate across levels of government, and the goals.
- Sub-products such as status, pressure and resilience data layers and information can be used to inform planning processes at a county and national level.
- Adequate resourcing, capacity and influence to undertake the assessments and implement recommendations should be assured, within sector agencies and county and national government.

Priority actions in relation to goals:

- Fisheries goal - assess if more appropriate models can be used for existing data.
- Habitat goal - improve county-level data and reference points.
- Tourism and Recreation was identified as the third priority goal
- 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 Kenya

The project "Assessing the multi-sectoral context for biodiversity conservation in Kenya 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 NEMA and KMFRI.

The high reliance of Kenya's coastal economy and population on coastal and marine resources for food provision, livelihoods and cultural and economic activities has led the Kenyan government to invest in research, management and development efforts in its EEZ, such as the Blue Economy Strategy implementation, co-management initiatives, development of management plans for specific fisheries, gears and habitats (mangroves), Marine Spatial Planning, spatial planning in counties, ICZM Policy and Plan etc. This provides the opportunity for the OHI to be used as a monitoring and evaluation tool to support implementation of the Integrated Coastal Zone Management plans, ensure sustainable management and utilization of the resources and develop policies and strategies for ocean resource management.

The preliminary OHI assessment in Kenya 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.

Project Aims and Objectives

1. Undertake a preliminary Ocean Health Index assessment for Kenya
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

2.3. Applications of the framework, process and tool

The Ocean Health Index has multiple uses to facilitate multi-sectoral discussions on ocean use and management, and to track resource state. These can be grouped in four categories; data, planning, economy and country targets and references points (Table 1).

Table 1. Applications of the Ocean Health Index

THEME	USES OF THE OCEAN HEALTH INDEX
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 county 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.

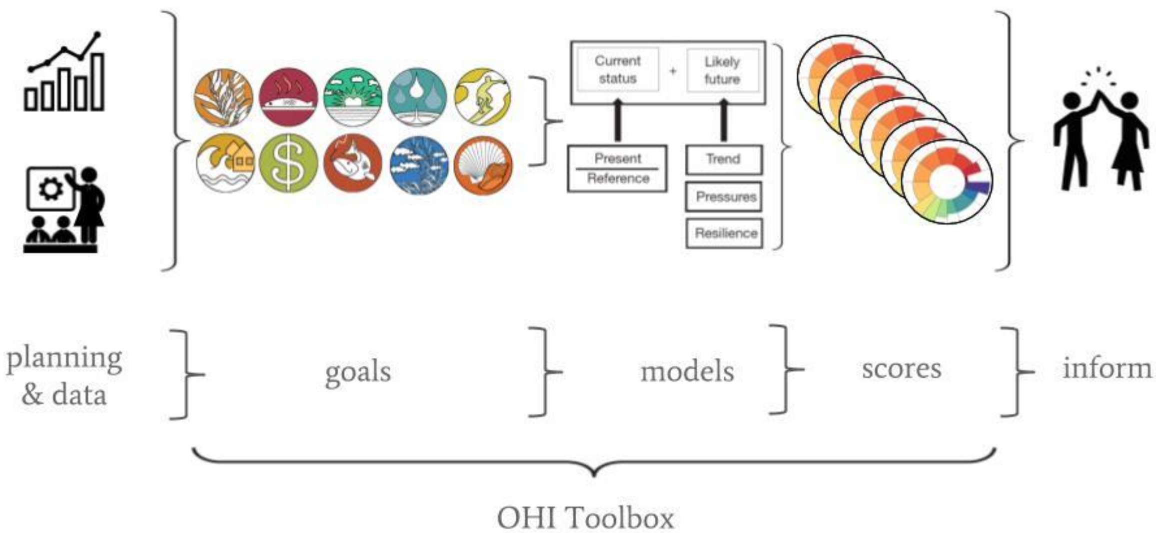


Figure 2. *Schematic of the assessment process for the Ocean Health Index, which is all supported by the online OHI toolbox.*

Details for calculating the index are provided in Appendix: Method - calculating the index (section 9.4).

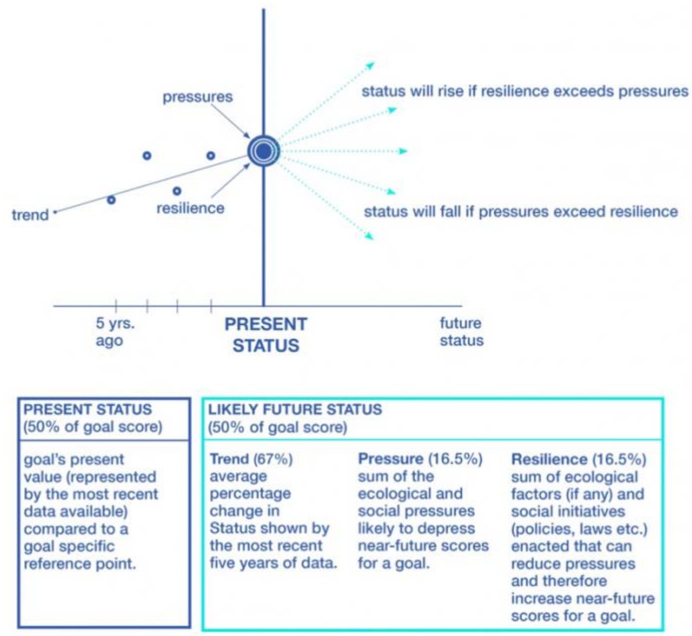


***Figure 3**. Schematic showing how the overall index is calculated, based on present status, and the likely future status, which itself is based on the recent trend (five years of data), pressures and resilience data.*

3.2. Priority goals

During the OHI stakeholder engagement workshop held in Mombasa in February 2018, seven sectors were ranked in order of importance, along with barriers to progress and recommendations to increase benefits (see Appendix section 9.8). The top two goals: **Food provision (wild-caught fisheries)** and **Biodiversity (critical habitats)** were addressed by the assessment.

Primary benefits:

1. **Food provision:** sustainable **wild-caught fisheries**, both near-shore and deep-sea, was identified as the number one ocean priority for the country. Sustainably delivering this benefit supports the achievement of the 'Food Security' priority to meet the local consumptive demand for protein established by the current administration of the Government of Kenya. Given the largely over-exploited status of coastal fisheries (Samoilys et al., 2017), there exists a mandate to support the exploitation of off-shore fisheries and reduce dependency on artisanal fisheries. This should help create jobs and livelihoods, reducing poverty levels and thus improving the coastal economy.

2. **Biodiversity:** ensuring the integrity of **critical habitats**, notably coral reefs and mangroves, as well as the protection of **migratory species** (primarily whales and dolphins). Healthy marine ecosystems are essential to providing services that support economic activities and maintain livelihood benefits, such as healthy coastal fisheries and tourism practices. The current state of biodiversity, is regarded to be in-line with global conventions as acceptable due to presence of protection levels and restrictions on exploitation in varying zones i.e. Marine Protected Areas (MPAs), community conservation areas and co-managed areas. The desired state is to preserve all marine and associated species (flora and fauna) and maintaining their integrity, enhance sustainable exploitation and provide refugia for threatened species through adequate definition of protection zones, enhancing and enforcing regulations and policing.

3. **Tourism and recreation:** tourism represents an important share of Kenya's coastal economy (Ongoma & Onyango, 2014), making it an important job and income generator for the region. Due to security threats in the recent past, the tourism sector has suffered losses, so there has been increased focus on attracting domestic tourists, while increasing security measures to regain market share with foreign tourists. However, both sectors are seasonal and there is a desire for sustainable tourism and recreation with high and frequent peak seasons. This should lead to benefits such as growth of the coastal economy, creation of jobs impacting on livelihoods and poverty reduction and alleviation.

4. **Coastal economies:** the role of the Mombasa maritime port in the economy cannot be underestimated, as it is the main port of entry for imported goods in the country and many other nations in the region. Unfortunately, many vessels leave the country 'empty' since there is a massive trade imbalance in the region (Atlas.media.mit.edu, n.d.). There is therefore a need to strengthen coastal economic production, processing, and manufacturing, as well as 'greening' port activities to minimize adverse environmental impacts, primarily pollution and habitat destruction. The benefit of transport and trade include an improved economy, increased trade, and livelihoods due to job creation. Other sea-ports are currently under development to increase maritime transport as a Blue Economy strategy, however it is important that port development is sustainable with a focus to SDGs.

Secondary benefits:

5. **Climate regulation and coastal protection:** important to protect and restore key coastal habitats, notably coral reefs, seagrasses, mangroves, and marshes, that sequester and store atmospheric carbon, as well as buffer the coastal zone from shoreline degradation and erosion through climate effects such as sea-level rise. Coastal protection is variable in different locations along the coast.

6. **Coastal livelihoods:** Income generation through economic improvement, sustainable 'blue' resource exploitation and adequate allocation will create opportunities across numerous marine and coastal economic sectors and reduce the high rate of unemployment for coastal communities

7. **Clean waters:** there are concerns about increased pollution, mostly land-based sources from urban towns and cities, agricultural practices, as well as pollutants from inland activities reaching the ocean via rivers. There are no formal sewage and waste treatment facilities operational along the coat, so lots of waste directly enters the ocean.

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+ Kenya assessment should be undertaken at a county level. Therefore, each county was assessed, based on the activities and benefits accrued from a defined ocean area adjacent to their terrestrial boundaries.

According to Kenyan law, County jurisdiction ends on land and the ocean is national territory (Maritime Zones, n.d.). Therefore to provide a score for each County based on their use of the adjacent sea, we allocated a portion of the coastal sea to each County. To identify the boundaries for this portion, we undertook a transparent process, through consultations with technical and advisory team members. Some considerations:

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 county to national, but not the other way.

2. At what level of management (county, national) 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 county level, 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?

Following consultations the seaward boundary assigned to Counties 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 (offshore fisheries and other data were not available for analysis). County boundaries were extended into the ocean along latitudinal lines to be consistent with the demarcation of the national border with Tanzania.

Coastal counties such as Lamu and Kwale (WWF Kenya, 2018) are in the process of developing County Spatial Plans, and are willing to take management responsibility of their adjacent ocean. The 12nM limit identified here seems optimal for this, as it is on a similar scale at which fisheries and other coastal activities operate, management targets and operations may be implemented, and policy decisions made.

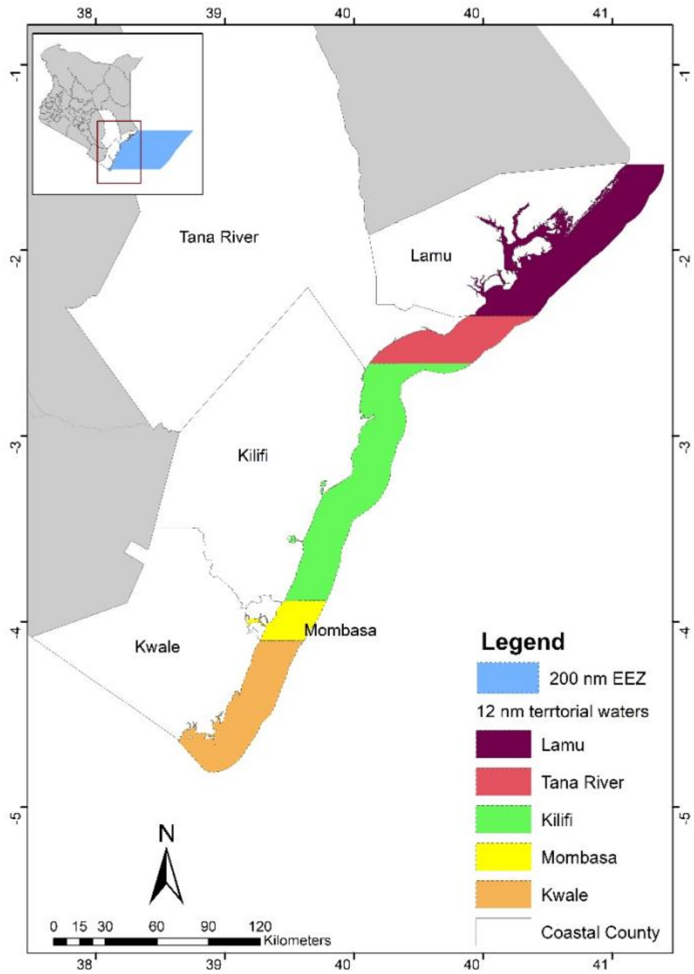


Figure 4*. Map showing delineation of soft county boundaries forming 5 'regions' for the assessment. The proposed sub-divisions of Kenya's ocean territory are purely hypothetical and have been made solely for the purpose of the OHI+ Kenya assessment. The demarcations may be considered as potential management areas for the respective counties under assessment, however, this is beyond the scope of this report.*

Challenges

- There is no official demarcation of county jurisdiction in the ocean, therefore developing these operational boundaries in a justifiable manner required careful and multi-level discussions
- Some counties may disagree with allocation of resources
- The OHI is based on an ecosystem-based approach. Administrative boundaries don't align to ecosystems.
- Most socio-economic activities in the ocean do not strictly follow county boundaries e.g. fishers move from one county to another, some fishing grounds extend beyond boundaries
- Many problems in the ocean emanate from elsewhere e.g. pollution from land-based sources and its transport by ocean currents.
- Planned government activities e.g. offshore oil and gas exploration blocks overlap counties

Alternative options that were considered included the following:

1. To avoid sensitivities on demarcating ocean boundaries between counties, report from point samples within each county.
2. Consider using ecological or geomorphological units, such as Tudor Creek, Ungwana bay etc. provided relevant information is available
3. Consider other offshore boundaries for county zones, such as 5nM to match artisanal fishing practices, the contiguous boundary of 24nM (recognized under UNCLOS).

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.

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 country or region is harvesting seafood to the ecosystem's optimum production potential in a sustainable manner.

For this assessment, only artisanal fisheries and the semi-industrial prawn-trawling fishery were assessed for the 5 coastal counties within the territorial waters.

4.1.1. Methods

Data

Long time-series catch, effort and length-based fish species data was the ideal data required, from which fisheries assessment models could be calculated to assess the status and sustainability at a county-scale.

Kenya has a consistent long-term catch monitoring system recording only total catches for certain taxa implemented by Kenya Fisheries Service (KeFS). 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. Detailed stock assessments of Kenyan coastal fisheries is still fairly scanty (Table 2).

Table 2. Available artisanal fish catch and landing data

Data	Owner	Period	Notes
Catch assessment data including length-weight (for artisanal fishery)	KMFRI	2001 – 2017 (with temporal gaps)	Data available from KMFRI. • General, family level data – from 2001 (CAS program) • Species level – from 2009 • Data collected at least 2 landing sites per county (total of 11 landing sites) from 2007, 2009, 2017 (temporal gaps) • KCDP Project – from 2013 – 2015. Detailed monitoring at over 20 landing sites

Catch assessment data (CAS) including length-weight	KeFS	2013-2017	Data has information on fishing grounds, landing sites, effort and gear. Some vessels record data at the species level.
Catch and effort data	KeFS	2013 – 2015	Data contains artisanal landings; Shallow and deep-water trawl data, long line fisheries data.
Marine Fish Production data	KeFS	2002 – 2016	Data is at the family level and is not linked to gears, or Fisheries grounds. Data is reported at county level; previously recorded at district level under the old governance structure.
Fisheries Frame Survey	KeFs	2012, 2014, 2016	Survey reports are produced after every 2 years outlining information on fish production factors e.g. fishing effort.
CAS data (artisanal)	CORDIO	1999-2006, 2009-2010, 2015-2016	Data is collected up to species level, from Diani-Chale (5-6 landing sites), Msambweni (5 landing sites from Gazi, Mkunguni, Mwandamo, Mwaembe, Munje). Data includes Fish Aggregating Devices (FADs) data
KCDP stock assessment technical reports	KMFRI	2013 - 2015	Small and medium pelagics, Siganus sutor, Malindi-Ungwana Bay small-scale prawn fishery

Reference point

The global assessment uses the Maximum Sustainable Yield (MSY) as a reference point to assess sustainability. For tropical fisheries which are multi-gear and multi-species, alternative models were considered such as Maximum Economic Yield, Spawning Potential Ratio (Spawning stock biomass) and Production-Biomass (area-based productivity measure for different habitats). In the end, MSY was selected to maintain consistency with the models developed for the global OHI analysis, and because the quality and availability of data limited use of other models.

Taxa selection

Fish taxa were selected on the basis that they contribute to food provision in the country. 25 fish taxa at various identification levels (species, genus, family) were used in the analysis, filtered from a more extensive list used in the global analysis through expert judgment (Table 3). Out of these, 6 taxa had long-term catch data at a county resolution, and for the other stocks, catch data were acquired from the global OHI dataset (detailed explanation in Appendix section 9.5. Fisheries model and analysis).

Table 3. Final list of stocks included in the OHI+ Kenya analysis for the Fisheries sub-goal. 6 stocks have local catch data and 13 species have b/bmsy values calculated

Stock	**Local catch data**	**b/bmsy**	**Stock**	**Local catch data**	**b/bmsy**
Carcharhinus falciformis		✓	*Lethrinus sp.*		
Carcharhinus melanopterus		✓	*Metapenaeus monoceros*		
Coryphaena hippurus		✓	*Metapenaeus sp.*		
Diagramma pictum		✓	*Octopus cyanea*		✓
Fenneropenaeus indicus		✓	*Panulirus sp.*	✓	

Gerres oyena		✓	*Parupeneus indicus*		
Haemulidae			*Penaeus monodon*		✓
Istiophorus platypterus	✓	✓	*Penaeus semisulcatus*		✓
Lethrinidae			*Peneius indicus*	✓	
Lethrinus harak			*Rastrelliger kanagurta*	✓	
Lethrinus lentjan		✓	*Siganus sutor*	✓	
Lethrinus nebulosus		✓	*Sphyraena sp.*	✓	
Lethrinus olivaceus		✓			

<u>Status and trends</u>

Food provision from wild caught fisheries was assessed by estimating population biomass relative to the biomass that can deliver maximum sustainable yield (B/B_{MSY}) for each stock. Details of the analysis are presented in Appendix: Fisheries model and analysis (section 9.5). Data from local sources was combined with values from external databases, and gap-filling measures had to be applied. To calculate the status for each county and year, B/B_{MSY} values were converted to a stock status score between 0 -1 that penalizes both over- and under-harvesting. To obtain the overall status for each county, the status for all stocks were averaged using a geometric mean weighted by the average catch (tonnes) of each stock (C). This method assures that the dominant stocks have heavier weighting in the analysis (so e.g. small stocks that are doing poorly don't have an excessive influence on the overall score). This data was used to assign the status in the most recent year, and for establishing trend over the previous 5 years for predicting future status.

<u>Pressures and Resilience</u>

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 the Kenyan context (Table 4). Details on each pressure and resilience indicator including sources of data are given in the Appendices (9.6.1).

Table 4. Pressure and resilience measures included in the Fisheries sub-goal analysis

Pressures:	**Resilience:**
• Intertidal habitat destruction • Weakness of social progress • Weakness of governance • Subtidal soft bottom habitat destruction • Nutrient pollution • Destructive fishing practices • Fishing intensity • Demand for fish • Bycatch from prawn trawling	• condition of species located within 3nm offshore of each region • Percentage of territorial waters under protection compared to 30% target • Percentage of territorial waters designated no-take areas compared to 10% target • Protected area management effectiveness • Artisanal fisheries management effectiveness • Social progress • Strength of governance

The following indicators were not included in the analysis due to data availability or because they were considered to not be a major issues for artisanal fisheries in Kenya: bycatch due to artisanal fishing, chemical pollution, subtidal hardbottom habitat destruction.

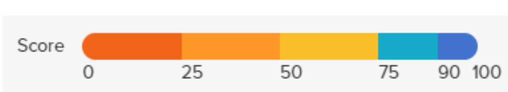
4.1.2. Results

A large proportion of stocks (36%) had a status score of 1, and 91% of stocks scored above 0.99 (only 2 stocks scored less: Haemulidae sp. and Lethrinidae sp.) (see Appendix section 9.6 Table 13). This very low degree of variation among the scores can be attributed to significant data weaknesses: only 25% of the stocks assessed had catch data disaggregated at a county level, and just under 50% of stocks had scores which had to be gap-filled using median scores, due to lack of B/Bmsy information. For the 13 stocks which had b/bmsy values calculated each year (Table 3), 97.12% of records showed b/bmsy values > 1.05, and therefore most stocks were considered underexploited. Only one species *Penaeus semisulcatus* was considered overexploited (b/bmsy<0.95). Lethrinidae spp. had the lowest score by a significant margin, with a national status score of 0.790, partially due to being penalized for being at family level (as per Appendix section 9.6 Table 12). This is important as Lethrinidae account for between 45-78% of the catch across years and counties. However assumptions used in the calculation of B/Bmsy in a data-poor case has likely lead to inaccurate estimates.

Unfortunately county level calculations of status were not possible due to data limitations. The national status score of 80 (and due to dominance of national rather than county-level data). The variation in future and final scores are due to different values for the various pressure and resilience indicators. Due to this, the scores varied over a relatively narrow range, with fisheries in Mombasa scoring the highest (87.6), followed by Kwale, and Lamu (≈86). Kilifi and Tana River received the lowest scores (≈82) with a national average of 84.8 (*Table 5*). The recent trend in all counties is for an increase in catch; likely because in all counties pressure scores are lower than resilience scores, so the model estimates improved catch in the future relevant to the present. The improvement in future scores is highest for Mombasa (where dependence on fisheries is relatively low) and Lamu (where stocks are more remote and in better current condition).

Table 5. *Fisheries sub-goal scores for status, future, pressure, resilience and overall score by county, and the national average. Maximum score possible is 100; for each score category the colours indicate performance relative to the scale under the table, except pressures which is inversed.*

Score	Kwale	Mombasa	Kilifi	Tana River	Lamu	National
Status	80.4	80.1	80.4	79.1	79.9	80
Future	91.8	95.1	84.8	84.8	92.1	89.7
Pressure	30.9	32.4	56.5	47.2	27.5	38.9
Resilience	52.5	67.8	51.6	47.9	52.4	54.4
Final Score	86.1	87.6	82.6	82	86	84.8



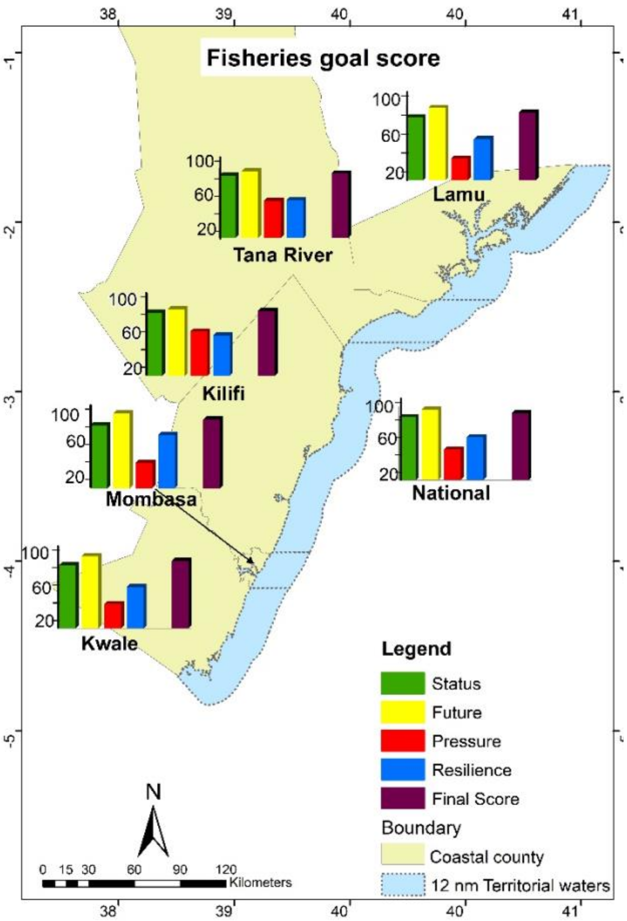


Figure 5. *Status, future, pressure, resilience and final/overall scores for each coastal county and the national averages from the Fisheries sub-goal analysis*

The pressures on fisheries in each county have been scored as relatively low, with Lamu scoring the lowest with 27.5 and only Kilifi scoring above 50. Kilifi has the highest number of fishers, prawn trawling activities causing bycatch and soft-bottom habitat destruction. It also scored highest for intertidal habitat destruction (population within 8 km of shore). Tana River had the second highest pressures because it had the lowest score for the governance and social indicators County Performance Index and County Development Index, and has ongoing prawn trawling activities. Despite Lamu having high-levels of destructive fishing practices employing e.g. use of beach seines, there is no trawling, a low population pressure, and the County was 2nd in the CDI, behind Mombasa.

Mombasa, despite the high population density and pressure had a relatively low pressure score (32.4), as it is the most socially developed, has few fishermen and no trawling activities. Resilience in Mombasa (67.8) stands well above the rest (≈50), because of stronger social progress and fisheries management effectiveness, and it meets the target of having 30% of its waters under protection. Kwale had the best MPA effectiveness score (Management Effectiveness Tracking Tool), for Kisite-Mpunguti Marine Park and Reserve. Tana River had the lowest resilience score, because it performed poorly in the CDI and CPI, and has no MPAs and NTAs (no-take areas).

Assumptions and caveats

calculation of b/bmsy: b/bmsy calculations are tricky to perform in data-poor cases, and although the data-limited methods used to calculate these values have been published and reported, it is still unclear on their accuracy and applicability for tropical artisanal fisheries which are multi-gear and multi-species.

lack of county-level data: Low degree of variation among the scores is attributed to significant data weaknesses: only 25% of the stocks assessed had catch data disaggregated at a county level. Additionally b/bmsy values were national values. Data for only 1 stock met the requirements for MSY calculations (b/bmsy and local catch)

data gaps: just under 50% of stocks had scores which had to be gap-filled using median scores, due to lack of b/bmsy information. This added to the homogeneity of scores and considerably increased the uncertainty in the status score. Additionally lost catch due to the influence of migrant fishers from neighboring Tanzania particularly for Kwale County, as well as significant underreporting of catch (Maina, 2012; MRAG, 2005) are likely to have a significant influence on the actual status of fisheries in nearshore waters.

Thus, this fishery result is only illustrative, and more suitable models for the existing length-based data should be trialed e.g. spawning potential ratio, to improve the fit of the assessment to data-poor fisheries and provide more accurate county-level scores.

4.1.3. Challenges

- *Quality of data*: Catch data are collected at coarse taxonomic levels with some common groupings accounting for multiple species e.g. functional group, genus and family levels. Species level data is available but is from selected landing sites and for relatively shorter temporal scales.
- *Data gaps:* Both spatial and temporal gaps exist for catch data across all counties. Spatial gaps in catch data are obviously more evident in counties with scanty resources for monitoring (GoK, 2016). Tana River is a case in point, despite it being in the Malindi-Ungwana bay productive zone fertilized by outflow from the Sabaki and Tana rivers
- *Allocating catch between counties*: Often catches are landed in a different county to where they were caught. Ideally, catch should be attributed to where the fish were caught, as it is more important for management to know about the productivity of the fishing grounds (i.e. the amount of fish produced and caught in their jurisdiction) rather than the amount of fish landed.
- *Data access*: Catch data is scattered across and within institutions, with no operational and up-to-date central national database. Acquiring data from holders has been a long-standing issue among marine research and management institutions and scientists.

4.1.4. Recommendations

Recommendations presented here are derived from the discussions held with the Technical and Advisory Teams. Implementing these recommendations will improve the reliability of future assessments.

Policy and Management

1. Implement management and policy strategies for gears rather than fish sizes and species as they are easier to implement
2. Increase investment in monitoring and data collection to ensure data is collected at higher taxonomic levels and alongside effort information, and 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
3. Ensure ‘fishing grounds’ are recorded for nearshore fisheries in future data collection
4. Continue discussions between Kenya Fisheries Service and County Fisheries departments to encourage increased and improved county management of BMUs
5. Determine sustainable fisheries management targets: Catch-per-unit effort, biomass, and number of fishers per Km^2
6. Support counties and BMUs to define co-management areas and implement area based management approaches to improve coastal fisheries status through capacity development, policy or legislation formulation and funding
7. Expand opportunities for sustainable domestic exploitation of off-shore fisheries for food security
8. Incorporate the OHI metric into policy circles and fisheries management approaches to support and contribute to the Blue Economy movement

9. Put in place measures to improve data collection so the fisheries sector moves to being a data-rich system rather than data-poor
10. Map fishing grounds in each county so that all local fishing locations are assigned to a fishing ground. Use the FAO, IOTC method for zoning pelagics and sport-fishing as a template
11. Undertake stock assessments for all priority fisheries for management using existing data

Future OHI assessments

The following suggestions can help improve the Fisheries analysis in subsequent assessments:

1. Include the offshore commercial fisheries as part of the assessment as they form an essential part of the Kenyan fisheries
2. Assessment should be based on fish caught within a county rather than landed catches which may be caught from neighbouring counties.
3. 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).
4. Alternative models: try using catch per unit effort (CPUE) for artisanal fisheries calculated from CAS data collected during KCDP, and the Spawning Biomass model, to compare with results from MSY to see which model is better suited for the marine fisheries in Kenya.
5. Include Mariculture in overall fisheries goal assessments. Kenya scored a 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.
6. 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.
7. Include the sea cucumber fishery due to probable over-exploitation and declines (Conand & Muthiga, 2007). However, it is very important to select a representative group of species/fisheries to ensure results are not biased by selecting only heavily targeted groups.
8. Addition of another pressure indicator to account for development of ports and related port activities, however this will depend on defining a suitable metric and data availability e.g. fishers displaced
9. Relate scores from habitat sub-goal calculations to Fisheries score calculations e.g. instead of population as a proxy for inter-tidal habitat destruction, could use the status score for mangroves, or the overall habitat status score

Research

1. Identify fishing ‘hot-spots’ in the EEZ to help inform fisheries management
2. Re-run a Probability Susceptibility Analysis (PSA) model (part of SICA analysis) with current data to update the list of priority species
3. Assess the status of the sea cucumber industry which is perceived to be heavily exploited
4. Assess the level of artisanal fishing happening between the 12nM and 24nM zone.
5. Formulate measures to ensure county data is recorded in the county; and no data is lost in the process due to under-reporting.
6. Use the CAS data to determine what percentage of records are caught and landed in different counties

4.2. Biodiversity: Habitat sub-goal

The Habitat sub-goal measures the average condition of marine habitats present in each region that provide critical habitat for a broad range of species. 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 Kenya coast: coral reefs, seagrasses and mangroves. For each of these habitats health and trend layers were calculated and used to score the goal.

Table 6*. Habitat data used in sub-goal calculations*

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

4.2.1. Methods

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 hottest year on record, which killed between 50 – 90% of living coral at sites across Kenya (Obura et al., 2002). We therefore assumed that pre-1998 coral cover values would be an accurate proxy of pristine conditions. Hard coral cover was averaged across the 3 most recent years of *in situ* monitoring data for sub-regions (to account for monitoring errors which could exist for values from a single year) to get recent cover values. The ratio of recent cover to reference cover was calculated for those sub-regions which had both sets of data (capped at 1); a total of 8 sub-regions (Lamu, Kiunga MNR, Watamu, Malindi, Kilifi, Mombasa MMP, Diani- Chale, Kisite) across 4 counties. Sub-regional scores were averaged to produce county coral reef health (status) scores. The linear trend across the latest 5 years of data for each county was calculated (see Appendix section 9.6 for more details).

Status and trends – mangroves

Detailed site-based studies on mangrove health in Kenya 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 Kenya has been estimated in national surveys on two occasions i.e. 1950 and 1992 (GoK, 2017). Other assessments in the literature were done as part of global studies which used differing methods, and were deemed inappropriate for this study because we could not access the spatial data in vector format to disaggregate to county levels, or we found errors with delineation of some mangrove areas e.g. north-east of Pate Island. We quantified mangrove cover for each county for the years 1992 (Taylor, M., Ravilious, C., & Green, E. P., 2003) and 2010 (Bunting P. et al., 2018) from processed images, and 2011-2014 from un-processed satellite images of the Kenyan 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 (1992) for each county. The linear trend across the latest 5 years of data (2010-2014) for each county was calculated (see Appendix section 9.6 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 Counties were attributed the same score in this assessment (status score of 0.855). 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.

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 the Kenyan context (Table 7). Details on each pressure and resilience indicator including sources of data are given in the Appendices (see sections 9.7.1 and 9.7.2).

Table 7. *Pressure and resilience measures included in the Habitat sub-goal analysis*

Pressures:	Resilience:
• Intertidal Habitat destruction • Sea surface temperature • Weakness of social progress • Weakness of governance • Subtidal soft bottom habitat destruction • Nutrient pollution • Chemical pollution • Destructive fishing practices • Sea level rise	• Condition of species located within 3nm offshore of each region • Percentage of territorial waters under protection compared to 30% target • Percentage of territorial waters designated no-take areas compared to 10% target • Protected area management effectiveness • Artisanal fisheries management effectiveness • Social progress • Strength of governance

The following indicators were not included in the analysis due to data availability or because they were considered to not be a major issues for habitats in Kenya: bycatch due to artisanal fishing, chemical pollution, subtidal hard-bottom habitat destruction, ocean acidification, salinity and total suspended solids.

4.2.2. Results

Coral reefs

Pre-1998 data on hard coral cover is scarce, and in a number of cases were aggregated e.g. protected vs. un-protected sites, making it unsuitable for use in this analysis. Reference data for Lamu is only from 2 sites and no data was available for Tana River County (which had to be excluded). This, together with the inconsistency in sites monitored and temporal gaps in data (monitoring of sites around Kiunga Marine National Reserve and Diani-Chale has been very limited since 2008) made it hard to make direct and accurate comparisons between recent and reference hard coral cover for the same sites. Therefore, the fact that hard coral cover appears to have remained the same or improved for 3 out of the 4 counties assessed, is likely an artefact of the data rather than an accurate representation of reef health (Table 8). The only declines in coral cover were in Watamu and Malindi, which are both protected by marine parks. Nonetheless, it is still relatively positive that given the massive impact that the 1998 bleaching event had on reefs, in the 15-18 years since, there seems to have been substantial recovery at a number of sites, but only focusing on hard coral cover omits the increase in fleshy algae that has been documented over the same period (Gudka et al., 2018; D. O. Obura et al., 2017). Coral cover varies between 17 – 30% on average across sub-regions, which is relatively low compared to other countries in the region (D. O. Obura et al., 2017). It is likely that there have also been large changes in species composition and diversity, as well as structural complexity of reefs (Claar et al., 2018; McClanahan et al., 2001), which will affect the services that the reefs can provide.

Table 8. *Hard coral cover results for sub-regions and current status scores for each County for which recent and reference (pre-1998) hard coral cover data were available*

County	*Sub-region*	*Recent hard coral cover (%)*	*Reference hard coral cover (%)*	*Sub-regional score*	*County status score*
Mombasa	Mombasa	26.0	23.9	1	1
Kwale	Diani Chale	11.5	4.7	1	1
Kwale	Kisite	30.6	23.5	1	
Kilifi	Kilifi	27.9	16.7	1	0.847
Kilifi	Malindi	21.4	29.7	0.719	
Kilifi	Watamu	22.6	27.5	0.821	
Lamu	Kiunga MNR	17.7	14.1	1	1
Lamu	Lamu	19.4	10.4	1	

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), 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, coastal protection, and improved human health.

Mangroves

Overall the country has lost around 25% of its mangrove cover since 1992. Kwale and Lamu counties are in a healthy state having retained over 90% and 85% of their mangrove cover over the last 22 years respectively. In absolute terms, Lamu has lost the equivalent of Kilifi County's entire mangrove area (Table 9). Tana River and Mombasa County are the most heavily impacted counties having lost around 80% of their cover since the early 1990s. In Mombasa this is mainly attributed to the rapid rise in development of the city over the last two decades which has increased demand for coastal land. This, coupled with poor urban-planning and land-management and weak enforcement of environmental management regulations has led to the dramatic loss in mangrove habitat.

***Table 9**. Mangrove extent in each County in 1992 and 2014 and county status scores as the ration of the two covers*

County	*Recent cover (2014) km²*	*Reference cover (1992) km²*	*County status score*
Mombasa	7.15	30.80	0.23
Kwale	89.00	96.72	0.92
Kilifi	54.78	81.19	0.67
Tana River	11.31	61.60	0.18
Lamu	314.52	367.87	0.85

In Tana River County, the remaining mangrove area is present in two small pockets of forest, making it even more vulnerable to complete deforestation. Declines are likely due to unsustainable harvesting for timber and other materials, charcoal production, as well as clearing for conversion into agricultural land for farming (GoK, 2017). Historically, management in this county has been weak, with no official management areas established in the coastal and marine environment (Baker et al., 2015). However, the decline may be biased due to differences in estimation techniques of recent and reference cover, time of the survey, misclassification of mangroves with mangrove-associated species e.g. *Barringtonia racemosa* and *Thespasia sp*. that exist as thick shrubs on the water side of the river as well as *Sueda monoica* on the landward side (GoK, 2017).

In 2014, there appears to have been an accelerated decline in mangrove cover, possibly linked to the devolution of resource management responsibilities to county governments from national government, which led to a period of lower enforcement and management as the authorities tried to organize themselves and adapt.

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.

Seagrasses

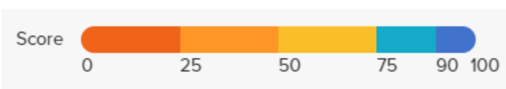
We were unable to obtain geographically extensive data on seagrass condition along the coast of Kenya, and therefore had to use the results for Kenya from the OHI global analysis. This meant that there was no inter-county score variation. Seagrasses are a vital marine habitat, providing a variety of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

Overall

The overall score for each county varies greatly with Tana River scoring the lowest with a score of 44.5 and Lamu highest with a score of 92.4 (Table 10, Fig. 6). The national average score was 73.6. The recent trend in all counties is for a decrease, and the model estimates the future state for all counties except Lamu to be lower than the current status. A positive message is that for all counties pressure scores are below 40, with Kilifi County and Tana River County scoring worst and Lamu County best, and all pressure scores are lower than the resilience scores. Kilifi has prawn trawling activities which cause soft-bottom habitat destruction, the highest proportion of destructive fishing practices and the intertidal habitat destruction (population within 8 km of shore). Tana River had the second highest pressures because it had the lowest score for the governance and social progress indicators (County Performance Index and County Development Index respectively), has ongoing prawn trawling activities, as well as the highest nutrient pollution levels. Despite Lamu having high-levels of destructive fishing practices e.g. use of beach seines, there is no trawling, a low population pressure, and the County scored 2nd in the CDI, behind Mombasa. Mombasa County's resilience score was higher than the other counties, at 65 because of stronger social progress and fisheries management effectiveness, and it meets the target of having 30% of its waters under protection. Kwale had the best MPA effectiveness score (Management Effectiveness Tracking Tool), for Kisite-Mpunguti Marine Park and Reserve. Tana River had the lowest resilience score, because it performed poorly in the CDI and CPI, and has no MPAs and NTAs (no-take areas).

***Table 10**. Habitat sub-goal analysis for status, future, pressure, resilience and overall score by county, and the national average. Maximum score possible is 100; for each score category the colours indicate performance relative to the scale under the table, except pressures which is inversed.*

Score	Kwale	Mombasa	Kilifi	Tana River	Lamu	National
Status	92.5	69.5	79.1	51.8	90.2	76.6
Future	85.5	59.4	76.6	37.3	94.5	70.7
Pressure	32.8	34.5	37.5	38	30.8	34.7
Resilience	49.8	65	48.6	44.2	48.9	51.3
Final Score	89	**64.5**	77.8	**44.5**	**92.4**	**73.6**



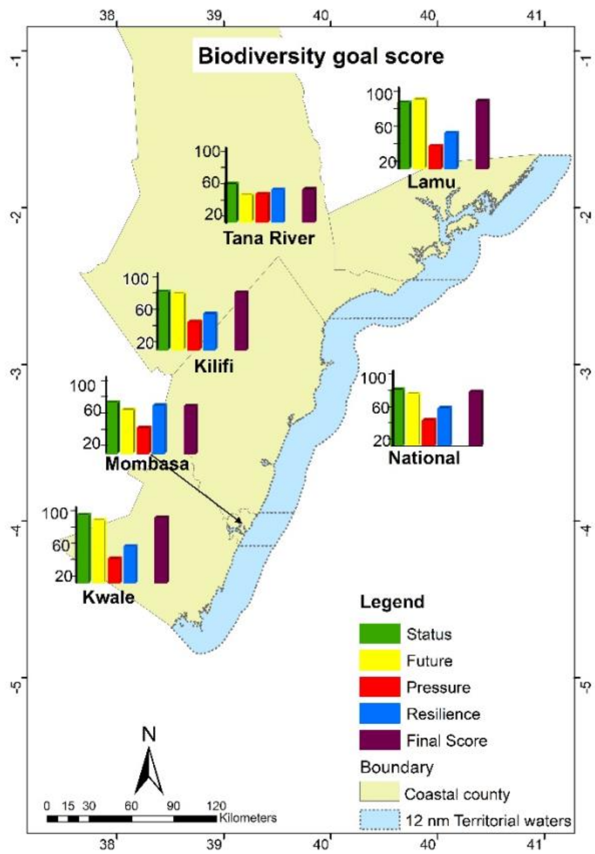


Figure 6. *Status, future, pressure, resilience and final/overall scores for each coastal county and the national averages from the Habitat sub-goal analysis*

Kwale and Lamu scored highly, while Kilifi was in a moderately healthy state, and Mombasa and Tana River both faring poorly. However both Lamu County and Kwale County have mega-infrastructure developments planned in the next decade (LAPPSET and the coal plant in Lamu; SIDEP in Kwale), increasing the future risks to their relatively healthy marine habitats. This OHI score could therefore prove an important baseline for the counties to track the impact of these projects.

Climate change, increased coastal populations, infrastructural developments and energy projects are likely to cause increased pressures on Kenya's coastal and marine ecosystems and will translate into continued degradation if management measures are not scaled up in both quantity and quality. The coastal counties are already afflicted by issues such as flooding, food shortages and high-rates of poverty, and it is important that County governments realize the importance of habitats and ecosystems as an integral component to building resilience and overcoming the impending challenges.

4.2.3. Challenges

- *Data availability:* No national mapping of seagrass and coral reef habitats
- *Data gaps:* Both spatial and temporal gaps exist for sea grass, coral reef and mangrove health data across all counties. 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.

4.2.4. Recommendations

Policy and management

1. Use the results and data outputs from the assessment to inform Marine Spatial Planning at various levels (National and County) and resource management purposes
2. Strengthen habitat protection through improved land-planning and enforcement of regulations, and increased protected areas (MPAs) particularly in Tana River

3. Counties should support implementation of community level co-management initiatives through BMUs and Community Forest Associations (CFAs) to reduce pressures on mangroves, seagrasses, coastal forest and coral reefs such as pollution, destructive fishing, encroachment etc
4. Together with relevant county departments to 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
5. Use a proactive approach to management in Lamu and Kwale County to preserve the healthy state of habitats in the face of mega-development projects i.e. LAPPSET, SIDEP
6. Continue implementation of 2017 National Mangrove Management Plan to ensure effective conservation and stem declines particularly in Mombasa and Tana River
7. Develop a national management plan for coral reefs through an inclusive stakeholder process
8. Prioritise, advocate and invest in stronger enforcement of environmental legislation outside of protected areas
9. Develop a national-scale strategic action plan on pollution (both nutrient and chemical) in all water bodies (oceans, rivers, lakes, creeks and estuaries). For oceans, particular focus should be made to monitor around urban areas, agricultural areas and estuaries and river mouths
10. 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.
11. Invest in restoration of degraded habitats based on trials, best practices and methods with a proven success record

Future OHI assessments

1. Future assessments should include 3 other coastal and marine habitats:
   a) Beaches and sand dunes – there has been an observable shift in beach profiles due to human interactions such as developments, erosion etc. As part of the KENSEA project an assessment of coastlines was done, with KMFRI holding the data.
   b) Deltas and river estuaries –biodiverse areas such as Tana delta (RAMSAR site) and other river estuaries e.g. Sabaki estuary and River Ramisi are heavily impacted by pollution, mining and other activities. The condition of these ecosystems can be assessed through proxies such as alteration of flow, degree of mangrove alteration, plant and animal species abundance and diversity etc.
   c) Coastal forests - highly threatened, extremely biodiverse and likely to provide important ecological services to adjacent nearshore habitats.
2. Seagrasses should be assessed using local data to provide variance in scores between counties
3. 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
4. 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
5. 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 county 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), corals, mangroves, seagrasses and other key taxa within mangroves and seagrass habitats.

6. Using a combination of fleshy algae and hard coral cover to create a metric of coral health
7. 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
8. Inclusion of an indicator to account for development pressure
9. If coral reef pre-1998 data is limited, look into using a different baseline or different metric other than hard coral cover to assess coral reef condition

Future research

1. Reef surveys of Kiunga MNR and Diani Chale sites to be prioritized due to large temporal gaps
2. Detailed and extensive surveys of seagrass and mangrove health
3. Extensive habitat mapping of seagrass and coral reefs across the coast
4. Studies to understand the relationship, interactions and potential benefits of coastal forests on adjacent marine ecosystems
5. KFS to study what may be going on the grounds regarding mangrove declines in Tana River

5. Overall results and discussion

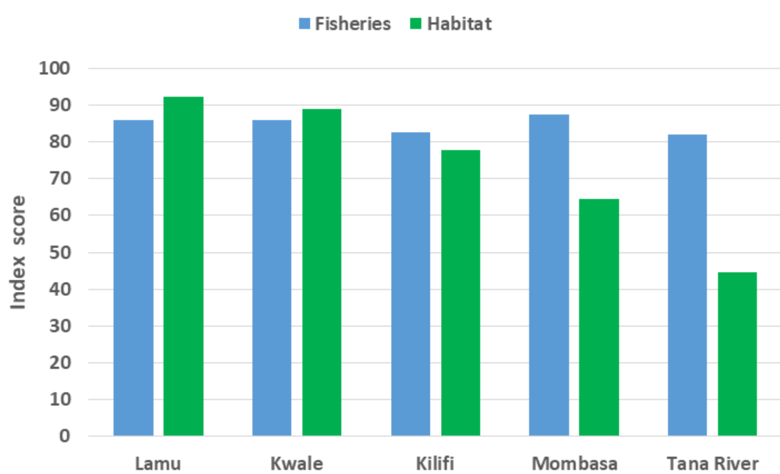


Figure 7. *Overall scores for fisheries and habitat sub-goals, ordered by decreasing aggregate score.*

The importance of data disaggregation is shown by comparing habitat results (where 2 out of 3 components had disaggregated data thus high differentiation among counties) with fisheries results (where >96% of scores were homogeneous among taxa and counties, so low differentiation among counties). Results from this assessment are preliminary, and certain aspects need further validation but they can be used as a baseline to develop and improve in future using more suitable and accurate metrics and data.

6. Conclusions

6.1. Management and Policy recommendations

Strengthen ocean governance and management

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

2. Enhance cooperation between National and County governments particularly with regards to nearshore fisheries and natural resource management

3. Invest in restoration of degraded habitats based on trials, best practices and methods with a proven success record

4. Develop data and information sharing platforms and other mechanisms which can facilitate increased data access and sharing

5. Encourage Counties to take management responsibility of their adjacent ocean through some kind of co-management system with National government.

6. Increase community inclusion in management by establishing co-management efforts

7. Improved governance with regards to stronger implementation and enforcement of laws, strategies and management plans e.g. conduct adequate ESIAs for coastal developments

8. Encourage cross-sectoral collaborations in resource conservation e.g. public and private

9. Support coordination of the inter-ministerial Blue Economy Task Force and National Integrated Coastal Zone Management committee

10. Invest in programs to develop technical skills in conservation management, data collection and management, processing of raw materials for value addition, and research and technology

6.2. Challenges

Barriers, obstacles and threats to achieving priority ocean benefits

1. **Limited human and financial capacity:** the lack of education and competences on ocean and coastal resources and management is a major obstacle hindering the achievement of priority ocean benefits.

2. **Inadequate governance and enforcement:** while there are many policies and laws regulating ocean and coastal resources, there is weak integration and fragmented planning among national and county authorities. Recent efforts seeking to address this problem e.g. the 'National Integrated Coastal Zone Management Committee' and the 'Interministerial Blue Economy Task Force' should be supported further as there remains a gap between existing policies and enforcement, training, and implementation of priorities.

3. **Data accessibility:** Measures which facilitate data sharing e.g. data citations, data papers, use of centralized repositories, need to be explored and invested in to encourage greater intra and inter-

institution data sharing which will lead to improved products to support management. Institutions and donors need to take responsibility to ensure project outputs are made accessible, particularly those funded by public resources.

4. **Monitoring and data collection to inform management:** the lack of consistent resource monitoring e.g. for coral reefs, fish catch data (quality), habitat mapping, offshore resources including fish stocks, has meant that data gaps have restricted appropriate management action. This requires concerted investment and a multi-institutional (both public and NGO) approach, to support detailed monitoring to build robust baseline information or update time-series information and develop sustainable data collection strategies.

6.3. Opportunities for further work

The OHI framework and tool has multiple uses. This preliminary assessment has shown that there is scope for long-term use of this tool in the country. However for successful uptake, the process should be driven by an interested national institution(s), with ministerial level approval if possible. This should allow for more open data access and permissions. Likely require around 24 months to complete a full Ocean Health Index, where all 10 goals are assessed completely. 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

In the current Kenyan context, there are several possibilities for use of the OHI tool. The National Environment Management Authority (NEMA) is mandated to report on the environment and produce the national State of the Coast reports, and can use the tool and results as a repeatable method to track state and elegantly and simply present these results.

Kenya Wildlife Service manages 5 national MPAs along the coast of Kenya, and can use a tailored version of the OHI to track the state of their habitats 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 their sites.

Kenya Fisheries Service (KeFS) and various Fisheries Departments at county level 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 KMFRI and other institutions, 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.

With the interest and inevitable investment in the ‘Blue Economy’ strategy, it is important to ensure sustainability of practices to maintain integrity of any exploited natural resources. The OHI provides a suitable tool for this. Jumuia ya Kaunti za Pwani (JKP) association could provide a useful entity to encourage counties to utilize the OHI, as it already provides a framework to bring together all coastal counties, and has a mandate to explore Blue Economy strategies.

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9. Appendices

9.1. Participants, Kenya stakeholders engagement workshop February 2018

Individual	**Institution**
Stephen Katua	NEMA
Dan Ashitiva	NEMA
James Kamula	NEMA
Kennedy Ondimu	MENR
Keziah Odemba	Ministry of Tourism
Lilian Mwihaki	KMFRI
Dr. Nina Wambiji	KMFRI
Peter Musembi	KMFRI
Patrick Gwada	KMFRI
Nathaniel Mwangeka	Kwale County Natural Resources Network (KCNRN)
Mtengo	Shimoni BMU
Chemuku Wekesa	KEFRI
Dr. Benard Fulanda	Pwani University

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Mike Olendo	WWF
Ahmed Kuso	Lower Tana Delta Conservation Trust
Dr. David Obura	CORDIO
Lenice Ojwang	CORDIO
James Mbugua	CORDIO
Randall Mabwa	CORDIO
Dishon Murage	Seacology
Elizabeth Mueni	Kenya Fisheries Service
Agatha Ogada	East Africa Wildlife Society (EAWLS)
Brendan Muli	Kwetu Training Centre
Mr. Albert Musando	Lafarge Ecosystems
Wahome Kariuki	KFS
Ambrose Kinganda	NMK
Albert Gamoe	KWS
Jacqueline Benard	KWS
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Lilian Ayimba	KTRA
Michael Mbaru	KMA
Josphat Mwangongo	WRA
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Francis Kombe	Mombasa County Govt
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9.2. Participants, Kenya stakeholders dissemination workshop November 2018

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Ngatia Ndarathi.	Local Ocean Trust
Agatha Ogada	Blue Ventures
Dishon Murage	Seacology
Donald Wagaka	County Department of Fisheries Mombasa
Nina Wambiji	KMFRI
Edward Mwamuye	East Africa Wildlife Society (EAWLS)
Elizabeth Mueni	Kenya Fisheries Service
George Maina	TNC
Japhet Moroa	CDA
Jennifer O'Leary	TNC
Julius Owino	Kenya Coast Tourism Association (KCTA)
Juma Mashanga	Community Touch Kenya (Comtouch)

Albert Musando	Lafarge Ecosystems
Titus Jefwa	COMRED
Stephen Katua	NEMA
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Saidi Abdulahi	County Department Natural Resources/Env Tana River
Mohammed Pakia	Kwale County Department of Environment
Salama Mwafrika	Kwale County Department of Environment
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Wachira Mwangi	Nation Media

9.3. Participants, all technical meetings

Individual	Institution
Dr Bernerd Fulanda	Pwani University
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Jennifer O'Leary	TNC
Judith Nyunja	WWF
Gladys Okemwa	KMFRI
Johnstone Omukoto	KMFRI
Japhet Moroa	CDA
Donald Wagaka	County Department of Fisheries Mombasa
Edward Muye	County Department of Fisheries Mombasa
Sonia Kabibi Mumba	County Department of Fisheries Kilifi
John M Gachuru	County Department of Fisheries Kilifi

9.3.1. Project governance

Technical team

Organization	Representative(s)
Pwani University	Dr. Benerd Fulanda
TNC	George Maina Jennifer O'Leary
NEMA	James Kamula
CORDIO	Dr. David Obura
KMFRI	Dr. Nina Wambiji Dr. Gladys Okemwa
CDA	Japhet Moroa
Kenya Fisheries Service	Elizabeth Mueni
WWF Kenya	Dr. Judith Nyunja

Advisory team

Organization	Representative(s)
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Ministry of Tourism	Keziah Odemba
Kenya Fisheries Service	Elizabeth Mueni
KFS	Wahome Kariuki
KWS	Arthur Tuda
Kenya Maritime Association	Michael Mbaru
KMFRI	Dr. James Kairo

9.4. 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).

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).

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

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

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.

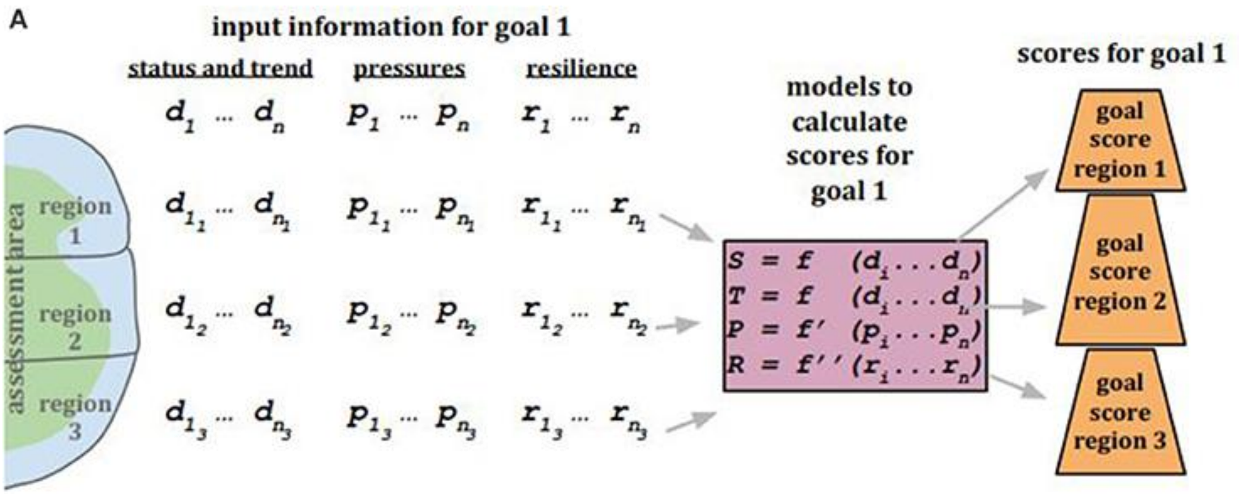

Figure 8 Overview of the data analysis process within the OHI Toolbox. Source: Borja et al. 2016 (www.frontiersin.org/articles/10.3389/fmars.2016.00020/full)

9.5. Data and sources

Table 11. *Available biodiversity and habitat data in Kenya*

Report Title	Institution
Sensitivity Habitat mapping	KMFRI
Biodiversity assessments and coast-wide mapping	KMFRI
Fishing ground habitat map for Lamu	WWF
National Mangrove management plan	KMFRI
Shoreline management strategy	NEMA
2nd Edition of State of the Coast Report	NEMA

9.6. 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, Minto, Minte-Vera, Kleisner, & Longo, 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 12. *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)

Table 13. *Status scores for each of the 25 stocks included in the Fisheries sub-goal calculations for each county*

Stock	Mombasa	Kwale	Kilifi	Tana River	Lamu	National
Carcharhinus falciformis	1.000	1.000	1.000	1.000	1.000	1.000
Carcharhinus melanopterus	1.000	1.000	1.000	1.000	1.000	1.000
Coryphaena hippurus	1.000	1.000	1.000	1.000	1.000	1.000
Diagramma pictum	1.000	1.000	1.000	1.000	1.000	1.000
Fenneropenaeus indicus	1.000	1.000	1.000	1.000	1.000	1.000
Gerres oyena	0.999	0.999	0.999	0.999	0.999	0.999
Haemulidae sp.	0.974	0.974	0.974	0.971	0.974	0.973
Istiophorus platypterus	0.999	0.999	0.997	1.000	1.000	0.999
Lethrinidae sp.	0.792	0.796	0.794	0.772	0.796	0.790
Lethrinus harak	1.000	1.000	1.000	1.000	1.000	1.000
Lethrinus lentjan	1.000	1.000	1.000	1.000	1.000	1.000
Lethrinus nebulosus	0.999	0.999	0.999	0.999	0.999	0.999
Lethrinus olivaceus	1.000	1.000	1.000	1.000	1.000	1.000
Lethrinus sp.	0.999	0.999	0.999	0.999	0.999	0.999
Metapenaeus monoceros	0.995	0.995	0.995	0.995	0.995	0.995
Metapenaeus sp.	1.000	1.000	1.000	1.000	1.000	1.000
Octopus cyanea	0.998	0.998	0.998	0.998	0.998	0.998
Panulirus sp.	0.999	0.997	0.998	0.998	0.993	0.997
Parupeneus indicus	0.999	0.999	0.999	0.999	0.999	0.999
Penaeus monodon	0.998	0.998	0.998	0.998	0.998	0.998
Penaeus semisulcatus	0.991	0.992	0.991	0.990	0.992	0.991
Peneius indicus	0.986	0.998	0.997	0.996	0.998	0.995
Rastrelliger kanagurta	0.998	0.995	0.996	1.000	1.000	0.998
Siganus sutor	0.994	0.991	0.992	0.999	0.978	0.991
Sphyraena sp.	0.996	0.992	0.995	0.999	0.996	0.996

9.6.1. 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	Inverse of the County Development Index	Local	Commission on Revenue Allocation (CRA) (http://www.crakenya.org/wp-content/uploads/2013/10/CREATING-A-COUNTY-DEVELOPMENT-INDEX-TO-IDENTIFY-MARGINALISED-COUNTIES.pdf)
Weakness of governance	The inverse of County Performance Index scores	Local	CountyTrak Performance Index Infotrack (http://countytrak.infotrakresearch.com/county-regions/)
Subtidal soft bottom habitat destruction	Prawn trawling effort as a proxy	Local	Shallow water prawn fishing dataset, 2016 – 2017, Kenya Fisheries Service (KeFS).
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)
Destructive fishing practices	Weighted proportion of illegal gears	Local	Marine Artisanal Fisheries Frame Survey 2016, Kenya Report.
Fishing intensity	Proportion of total number of fishers per county to the total number of fishers	Local	Marine Artisanal Fisheries Frame Survey 2016, Kenya Report.
Demand for fish	Coastal population density within 25mi from the shore	Local	Socioeconomic Data and Applications Centre (SEDAC) http://sedac.ciesin.columbia.edu/data/set/gpw-v4-population-density-rev10/ 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.
Bycatch from prawn trawling	Percentage of landed bycatch (non-target fish)	Local	Kenya Marine and Fisheries Research Institute (KMFRI). Status of the Kenya shallow water industrial prawn trawling season 2017. KMFRI Research Report No. OCS/FIS/2017-2018/020-029. 35pp.

9.6.2. 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 compared to 30% target	Local	http://www.mpatlas.org/data/download/ Database: Marine Conservation Institute. (2015). MPAtlas. Seattle, WA. www.mpatlas.org 2015
No-take areas	Percentage of territorial waters designated no-take areas compared to 10% 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	Kenya Wildlife Service_METT results for MPAs
Artisanal fisheries management effectiveness	Index score from survey responses on fisheries management at the county level and BMU effectiveness	Local	BMU Needs assessment data – KeFS and Survey responses on county level fisheries management
Social progress	County Development Index	Local	Commission on Revenue Allocation (CRA) (http://www.crakenya.org/wp-content/uploads/2013/10/CREATING-A-COUNTY-DEVELOPMENT-INDEX-TO-IDENTIFY-MARGINALISED-COUNTIES.pdf)
Strength of governance	County Performance Index	Local	Infotrack (http://countytrak.infotrakresearch.com/county-regions/)

9.7. 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 (county) 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).

9.7.1. 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	Inverse of the County Development Index	Local	Commission on Revenue Allocation (CRA) (http://www.crakenya.org/wp-content/uploads/2013/10/CREATING-A-COUNTY-DEVELOPMENT-INDEX-TO-IDENTIFY-MARGINALISED-COUNTIES.pdf)
Weakness of governance	The inverse of County Performance Index scores	Local	CountyTrak Performance Index Infotrack (http://countytrak.infotrakresearch.com/county-regions/)
Subtidal soft bottom habitat destruction	Prawn trawling effort as a proxy	Local	Shallow water prawn fishing dataset, 2016 – 2017, Kenya Fisheries Service (KeFS).
Nutrient pollution	Level of pollution intensity within 12nm	Local	Modelled nutrient pollution within 3nm 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 3nm	Global	Halpern et al. 2008
Destructive fishing practices	Weighted proportion of illegal gears	Local	Marine Artisanal Fisheries Frame Survey 2016, Kenya Report.
Sea level rise	Monthly mean sea level anomalies	Global	satellite altimetry data (http://www.aviso.altimetry.fr/en/data/products/sea-surface-height-products/global/msla-mean-climatology.html)

9.7.2. 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
No-take areas	Percentage of territorial waters designated no-take areas compared to 10% 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	Kenya Wildlife Service_METT results for MPAs
Artisanal fisheries management effectiveness	Index score from survey responses on fisheries management at the county level and BMU effectiveness	Local	BMU Needs assessment data – KeFS and Survey responses on county level fisheries management
Social progress	County Development Index	Local	Commission on Revenue Allocation (CRA) (http://www.crakenya.org/wp-content/uploads/2013/10/CREATING-A-COUNTY-DEVELOPMENT-INDEX-TO-IDENTIFY-MARGINALISED-COUNTIES.pdf)
Strength of governance	County Performance Index	Local	Infotrack (http://countytrak.infotrakresearch.com/county-regions/)

9.8. Goal-specific barriers and recommendations

This section summarizes key barriers to progress and recommendations to increase benefits generated by discussions during goal prioritization. They provide material for considering next steps for action, based on the findings on food provision and biodiversity goals.

1. Food provision: sustainable wild-caught fisheries.

Barriers to progress	Recommendations to increase benefits

Lack of credit to fishermen development and welfare	Provide credit and incentives to improve fisher-folk welfare
limited access to EEZ	offering alternative source of information
over-dependency and over-exploitation of near shore fisheries	exploit the EEZ to improve commercial fisheries
poor technology: infrastructure affecting post-harvest handling and processing hence limiting value addition to fisheries	invest in technology to improve fisheries processing and create awareness on alternative blue economy resources
lack of proper implementation of research findings	

2. Biodiversity: critical habitats, notably coral reefs and mangroves

Barriers to progress	Recommendations to increase benefits
Community resistance to conservation	Creating community awareness through education
limited research activities due to lack of adequate funding	Prioritizing biodiversity through allocation of funds towards conservation
lack of awareness on the need to preserve species and habitat diversity	improve implementation of laws/policies while enacting local laws with reference to international treating and SDG 14.
transboundary exploitation of species	identifying vulnerable species for conservation
pollution from different forms of waste (solid waste raw sewage, industrial effluence) which affects species and habitats	
destructive fisheries that may lead to extinction of over-targeted species	
encroachment on protected marine areas through activities such as poaching,	
climate change	

3. **Tourism and recreation**

Barriers to progress	Recommendations to increase benefits
Political instability	Improve security
Insecurity from external and internal threats.	Improve political stability through democratic rule and adherence to the constitution.
Lack of adequate skilled labor force.	Encourage community participation in tourism activities. Expand training and capacity development for tourism operators to diversify sustainable tourism activities, strengthen marketing of the coastal zones, and increase domestic tourism
Habitat degradation affecting recreational sites and ecosystems.	Support of tourism management and policy reforms that introduce an ecosystem-based management approach

High investment costs hindering small players in the sector; difficulty in conducting business and lack of adequate marketing for existing products.	Ease the cost of investment in the tourism sector.
Travel advisories and bans due to varying factors such as bad politics and security.	

4. **Coastal economies**

Barriers to progress	**Recommendations to increase benefits**
Inadequate infrastructure	Ease the cost of business; create incentives to boost investment in the maritime sector
Limited specialist skills	Develop curriculum to produce maritime -based skills.
Lack of state owned maritime vessels	Advocate for sustainable and environmentally friendly expansion of ports
Lack of incentives to invest	Enhance adequate implementation of the blue economy policies
high operational costs	Foster sustainable incentives to increase marine trade and exports from marine ports