Economic valuation and potential investment opportunities for the Trans-Boundary Conservation Area (TBCA) between Kenya and Tanzania

Final Report:

Ecosystem Service Valuation and Cost-Benefit Analysis

21 February 2023

PRIME AFRICA CONSULTANTS

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Preamble

This is the final report on the valuation of ecosystem services (ES) and the cost-benefit analysis for the implementation of the proposed Kenya-Tanzania coastal and marine Trans-Boundary Conservation Area (TBCA). For ease of reading, we refer to the proposed site as the Kenya-Tanzania TBCA, or the KT-TBCA.

This project includes six key methodological steps, comprising Activities 1.1-1.4 and 2.1-2.2, as set out in Figure 0-1 below. The seventh step, Activity 3 is conducted in a separate report.

This Deliverable, the *Final Report: Ecosystem Service Valuation and Cost-Benefit Analysis*, reports on the execution of all the above activities, excluding activity 3. It further incorporates all comments received by the project steering committee, including suggested edits.

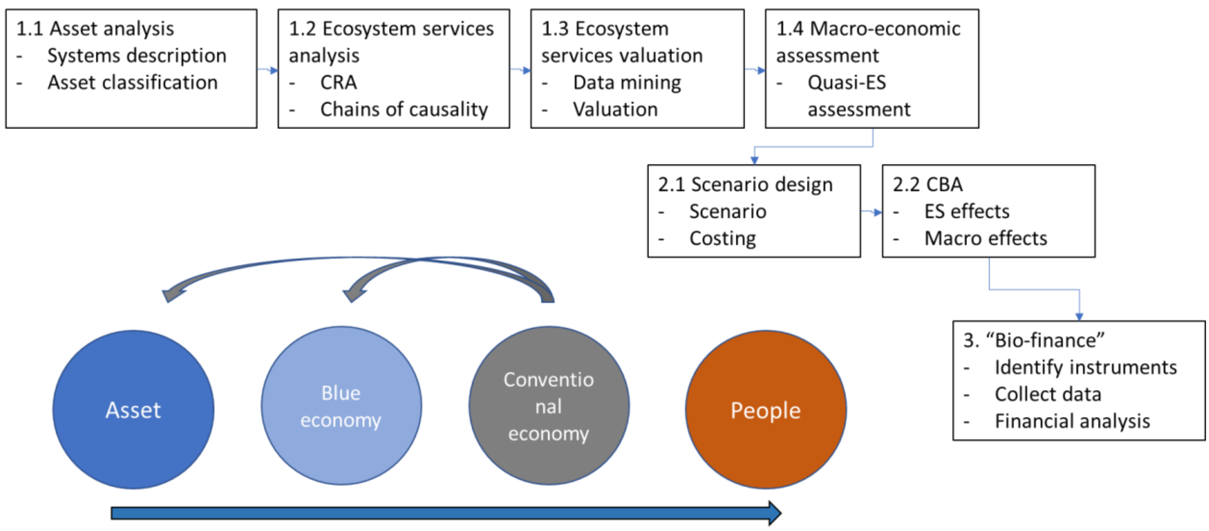

Figure 0-1: Schematic representation of the methodological approach of this study.

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Executive Summary

Summary in Brief

This study presents a cost benefit analysis (CBA) that evaluates the benefits achieved through implementation of a marine Trans-Boundary Conservation Area (TBCA) between Kenya and Tanzania against the costs of a well-funded set of marine protected area (MPA) management actions.

The CBA employed a systematic approach, starting with the development of a thorough understanding of the relevant ecosystems, the underlying natural assets, and the hazards that put these systems at risk. These hazards included direct anthropogenic risks (e.g., overharvesting), climate change, pollution of various types, and others. The resultant risks manifest as changes to the produced ecosystem services. The ecosystem services analysed included various provisioning services that local communities depend on for their livelihoods, as well as cultural services that local communities, residents of both countries, and international visitors all enjoy. We also applied a novel valuation technique to approximate the "existence" value of the unique habitats of the area and assessed various regulating services.

The ecosystem services valuation used a number of valuation tools embedded within a bio-economic model for the TBCA area. The CBA then proceeded to envisage the conservation and mitigation actions needed in a likely MPA management plan in order to mitigate the assessed risks to natural assets. We evaluated these management actions via the bio-economic model to estimate the quantum of mitigation impacts and the values and benefits from ecosystem services gained as a result. These benefits were further evaluated through quasi-economy-wide models to determine macro-economic impacts, such as GDP contribution and job creation.

We also estimated the cost of the conservation and mitigation actions using desk-top research. This research and analysis demonstrated that the resultant cost-benefit ratios highly favour the implementation of the TBCA. Additional financial analyses are under way to identify green investment opportunities that may serve to raise the funds needed to cover capital and operational costs of the TBCA activities.

Background

The Governments of Kenya and Tanzania, through their national Institutions (Kenya Wildlife Service (KWS) and the Marine Parks and Reserves Unit (MPRU)), respectively, have initiated a bilateral initiative between their two countries to investigate the options and possibility of developing a coastal and marine Trans-Boundary Conservation Area (TBCA) between the two countries. The proposed TBCA extends from the northern boundary of the Diani Chale Marine Reserve in Kenya to the southern boundary of Mkinga District in Tanzania (between Ulenge and Kwale Islands Marine Reserves) and includes marine and terrestrial areas. Marine and terrestrial areas are connected directly through a variety of habitats that include near-shore,

shore, estuarine, lagoon, mangroves, and similar habitats. They are also connected through freshwater systems, i.e., estuarine systems, are often highly dependent on nutrient influx from terrestrial systems. These habitats thus provide significant ecosystem services to humans, such as transport, food, recreation, and viewscapes that contribute to property value. Therefore, the degradation of these interconnected systems rapidly and directly affects the health of marine systems and the ecosystem services they deliver.

The planned TBCA is composed of a mosaic of highly productive habitats including coral reefs, which are rich in marine biodiversity and support many local fishing populations; rocky shores, which support a range of aquatic species; seagrass beds, which serve as fish breeding grounds and carbon sinks; intertidal reef flats, muddy or sandy flats, which are significant for burrowing shellfish and avifauna; and finally, mangroves and coastal forests, which support a conducive environment for fish and crustaceans, act as carbon sinks, and supply raw resources like timber to nearby communities. While no significant rivers debauch into the proposed TBCA, there are several smaller rivers that create significant estuarine habitats that are generally known to be important breeding sites for a range of fish species and coastal birds. There are many species that can be found in the TBCA such as Bony Fishes, Sharks and Rays, Invertebrates, Marine Mammals, Marine Turtles and Shore, and seabirds, all of which are dependent on the habitats in the area. Both the habitats and species form part of the ecosystem of the KT-TBCA that faces many hazards that put these ecosystem assets and ecosystem services at risk.

The Millennium Ecosystem Assessment (MEA), which introduced the idea of ecosystem services, views ecosystems as assets that yield a flow of services that are beneficial to people. Since the inception of the Millennium Ecosystem Assessment (2005), there have been a number of frameworks to further disaggregate and classify the benefits people derive from ecosystem services, such as The Economics of Ecosystems and Biodiversity (TEEB, 2010), the Common International Classification of Ecosystem Services (CICES, 2013), and the framework developed by the International Panel on Biodiversity and Ecosystem Services (IPBES, 2019). While each of these frameworks makes an effort to build upon the preceding frameworks, they all essentially follow a similar logic, in which ecosystem services and the benefits derived therefrom by beneficiaries are classified into three broad categories, namely provisioning services, where humans derive direct material benefit in the form of nutrition, energy sources, and raw materials (including biochemical and genetic materials); regulatory services, where direct and indirect benefits are derivable from ecosystem services; and cultural services, where an intangible benefit is received in terms of intellectual, spiritual, and symbolic significance attached to certain aspects of the ecosystem and environmental infrastructure. In certain instances, a fourth category is included to make a distinction between the regulating and supporting services inside a given ecosystem and the overall world system. Despite the introduction of later definitions, the MEA definition of ecosystem services remains an important starting point in ecosystem services valuation.

Ecosystem Services at Risk and their Values

Ecosystem services are dependent upon the extent (size) and state (functionality) of the ecosystem assets defined above. These assets within the ecosystems of the KT-TBCA face many hazards that put them and their ecosystem services at risk.

These hazards are caused by a number of variables, including: the world's rapidly expanding human population; poverty, inequality, and insufficient financial resources; environmental effects such pollution and sedimentation; climate change; and the oil and gas industry's commercial activities. Unsustainable fishing methods, habitat destruction, coastal deforestation, climate change that causes coastal flooding and saltwater intrusion, terrestrial effects like sedimentation brought on by terrestrial effects like agriculture, deforestation, and changes in river flows, pollution, altered freshwater flow, and finally terrorism and insecurity are the identified hazards in the area. These hazards manifest as risks to ecosystem service delivery, both inside the proposed TBCA area and within the social-ecological system within which it is located. The ultimate goal of the proposed KT-TBCA is to mitigate these hazards.

A Comparative Risk Assessment (CRA) method was used in order to assess, compare, and rank the risks to an ecosystem that arise from its exposure to one or more hazards. Here, the elements at risk are the different components, processes, and feedbacks that make up the ecosystem, as well as its emergent properties such as its self-organising capacity. The risk assessment was conducted using a status quo assumption, i.e., the risk levels consider asset status with the assumption that the KT-TBCA has not been declared and hazard sources have not been mitigated.

The CRA found that mangrove forests, seagrass meadows, coral reefs, and fish stocks all exhibit extreme risk of deteriorating ability to provide ongoing ecosystems. This is due to the degradation from human disturbance through harmful practices. Mangroves are the most heavily affected as half of the ecosystem services they provide face extreme levels of risk if no intervention takes place. Seagrass meadows and coral reefs are also both under significant pressure, putting most of the ecosystem services with which they are associated at high to extreme risk. Harmful fishing practices have been found to be the most significant hazard affecting on these ecosystem assets, which places pressure on fish stocks as these fishing practices cause a destruction of fish habitats. Freshwater provisioning and water quantity regulation were the only two ecosystem services that showed levels of risk no higher than medium. However, it was found that none of the ecosystem services were fully immune to the effects of hazards.

The CRA found the following ecosystem services to be the most at risk:

- Food Provisioning
- Raw Materials
- Carbon Sequestration

- Regulation of extreme events
- Ecotourism and Recreation
- Habitats

The ecosystem services within the TBCA and listed above are therefore evaluated in order to obtain an estimate of the values associated with their derived benefits. Estimating their value serves two purposes: first, it helps us emphasize how important these services are to the functioning of the economy by providing an estimate of the value that humans derive from the natural world; second, it enables us to weigh the costs and benefits of different policies that govern their use and protection.

This ecosystem valuation was conducted using a bio-economic model that was created to roughly represent the relationships between the study area's biological features and the local economy. This was done by developing a collection of valuation models for the various ecosystem services that are integrated into a system of production function. The model concentrated on developing valuation techniques, based on historical trends, for ecosystem services in their existing, unprotected state. This was done in order to develop an understanding of the current situation that may be used to evaluate potential future possibilities as well as the benefits derived from the environment. The values provided therefore offer a first step towards understanding what stands to be lost if these ecosystems are destroyed or degraded.

The asset value of the proposed KT-TBCA is a function of all its attributes. These attributes relate to the services provided by the assets which underly the ecosystems. Many of the features of the KT-TBCA are unique or scarce, which, in and of itself, suggests high ecological asset values. Thus, the proposed KT-TBCA area has significant value because of its role in the social-ecological system, which ultimately interconnects biodiversity and human well-being.

Table 0-1: Valuation summary of the ecosystem services of the KT-TBCA

Ecosystem Service	Estimated annual benefits (USD/a)		Asset value (NPV, USD)	
	Min	Max	Min	Max
Food provisioning	**14,859,000**	**17,527,000**	**228,737,000**	**269,949,000**
- *Fish harvest*	*6,254,000*	*7,315,000*	*98,142,000*	*114,202,000*
- *Aquaculture production*	*1,034,000*	*1,398,000*	*16,300,000*	*22,053,000*
Agricultural production	7,571,000	8,814,000	114,295,000	133,694,000
Raw materials	**995,000**	**1,346,000**	**13,633,000**	**18,447,000**
- *Charcoal*	*975,000*	*1,319,000*	*13,363,000*	*18,080,000*
- *Timber*	*20,000*	*27,000*	*270,000*	*367,000*
Carbon Cycling	**121,000**	**346,000**	**2,488,000**	**6,227,000**
- *Mangroves*	*424,000*	*518,000*	*7,337,000*	*8,968,000*
- *Seagrass*	*-303,000*	*-172,000*	*-4,849,000*	*-2,741,000*
Tourism and recreation	**65,810,000**	**117,227,000**	**996,422,000**	**1,774,933,000**
- *Tourism*	*63,663,000*	*113,487,000*	*963,915,000*	*1,718,311,000*
- *Recreation*	*2,147,000*	*3,740,000*	*32,507,000*	*56,622,000*
Regulation of extreme events	**564,000**	**940,000**	**8,534,000**	**14,224,000**
Scarce Habitats	**48,299,000**	**94,832,000**	**731,285,000**	**1,435,851,000**
Total	**130,648,000**	**232,218,000**	**1,981,099,000**	**3,519,631,000**

With an estimated value of nearly US$1.8 billion, tourism and recreation were found to have the highest ecosystem services value contribution to the TBCA. Services related to the maintenance of rare habitats had the second-highest value, with the total asset value ranging between roughly US$700 million and US$1.4 billion for the entirety of the proposed TBCA. The gathering of raw resources provides an estimated asset value of up to nearly US$18 million, and the provisioning of food, with an asset value of approximately US$200 million and annual benefit flows of around US$12 million to US$14 million per year, respectively. This demonstrates that, despite not having as high an asset value, they are crucial to the livelihoods of the nearby community. It was also found that the regulation of extreme events is a significant ecosystem function with an estimated annual benefit flow of between US$564,000 and US$940,000 for the region due to the role played by coastal assets in reducing the energy of waves created by storm surges and sub-oceanic earthquakes. The degradation of seagrass beds results in negative ecosystem service value because of disruption to its carbon sequestration service. The overall asset value of ecosystem services supplied is estimated to exceed $3.8 billion.

Cost-Benefit Analysis

Following the ecosystem services valuation, a cost-benefit analysis was conducted to evaluate the effects of implementing a TBCA. Essentially, this involved the following steps:

- Envisaging a desired MPA management plan
- Costing the activities of the likely MPA management plan
- Evaluating the mitigative effects the MPA management would have on the TBCA ecosystems and its effects on the at-risk ecosystem services
- Valuing the resulting changes in ecosystems services over time
- Comparing the benefits thus achieved against the costs of implementation.

The methods for estimating the MPA costs involve determining the programs that would be used to address the KT-TBCA as well as the associated costs. The management plans of other MPAs in Africa were utilized as a guide for creating these programs. Law enforcement, biodiversity monitoring, sustainable usage, tourism, community engagement, finance, administration and human resources, rehabilitation, and alternative use were all identified, and their associated costs were calculated. Each program's annual operational costs were calculated based on the number of employees and, where necessary, other operating expenses needed to carry out the program. Any additional operating expenses and overhead were calculated based on extensive study of MPA costs as well as an examination of the budgets and costs in existing protected area management plans. Prime Africa's understanding of what MPAs require and the data produced by MPAs in South Africa serve as the foundations for the capital items that the UNEP MPA demands. Here, the total annual cost was found to be $7 million, and the total capital costs required were $16.9 million. The capex costs were distributed over 4 years, with 50% needed in the year of implementation, 20% each in years

2 and 3, and 10% in year 4. Once the costs were identified, the next step was to identify the benefits associated with the proposed TBCA.

In order to conduct the cost-benefit analysis, an alternative scenario was created that utilized the present baseline. In this case, implementing a TBCA is the intervention scenario being considered. Under this scenario, a variety of interventions are anticipated to be put into place to reduce the risks to the ecological assets of this system, securing the flow of ecosystem services to the local community and other users. To determine how much of a change in some of the variables must occur in order for the resulting change to be significant, a statistical analysis of variance was performed.

According to estimations, an increase in fish catch and the extension of mangroves improves the value of fish catch and aquaculture by $3,300,000, resulting in a 39% increase in overall food provisioning services in the baseline over time. The value that the community receives for raw materials from mangroves is anticipated to remain unchanged despite the estimated reduction in mangrove harvesting of $995,000 due to the adoption of other timber sources. A 145% improvement over the baseline scenario would be seen in the region's carbon cycling services, increasing by over $900,000 per year. The increased revenue from improved tourism and recreational activities is anticipated to boost tourism revenue by $7,000,000 to $13,000,000 and recreation revenue by $400,000 to $700,000 per year. This represents an increase of around 11% in the annual benefit flows of these services. Lastly, a change in the region's overall habitat value of ecosystem services has been estimated between $3,000,000 and $6,000,000 per year; however, this is likely to be an underestimation due to the increased importance of the region for conservation that would result from expanded variety.

In the case of the CBA, the study was expanded upon by quantifying the macroeconomic advantages of ecosystem services in terms of GDP and employment. The macroeconomic benefits are expected to show a considerable higher level of value compared to the direct benefits to the local communities due to multiplier effects observed within the broader economies. The table below shows the expected macroeconomic benefits:

Table 0-2: Summary of macroeconomic benefits associated with the ecosystem services of the TBCA

		Minimum Economic impact (USD)	
Ecosystem Service	Industry	GDP	Compensation to Employees
Fish harvest	Fish and other fishing products; aquaculture products; support services to fishing	70,817,650	1,040,705
Aquaculture production	Fish and other fishing products; aquaculture products; support services to fishing	12,692,794	186,528
Agricultural production	Products of agriculture, hunting and related services	45,901,794	3,816,390
Charcoal	Manufacture of wood and of products of wood and cork	1,297,183	245,367
Timber	Products of forestry, logging, and related services	186,363	755
Mangroves	Public administration and defence services; compulsory social security services	1,881,428	1,152,006
Seagrass	Public administration and defence services; compulsory social security services	948,728	580,895
Tourism	Accommodation services	90,372,218	48,747,887
Recreation	Arts, entertainment, and recreation services	8,277,774	1,931,904
	Services furnished by membership organisations	826,905	359,025
Regulation of Extreme Events	Insurance, reinsurance, and pension funding services, except compulsory social security	1,747,261	1,100,812
	Services auxiliary to financial services and insurance services	473,854	10,785
Total		**233,526,544**	**58,011,269**

This table reveals that the two largest contributors to GDP are food provisioning services and tourism and recreation, with food provisioning accounting for the highest share due to its larger multiplier effect. The largest source of employment is also leisure and tourism. Only a small portion of the money made from raw materials is returned to GDP; instead, this aspect is more crucial to citizens' livelihoods because they are utilized for building and cooking. Due to the role that the coastal resources of the area can play in lowering damage caused by storm surges and sub-oceanic earthquakes, it has been discovered once more that regulating extreme events is a key ecosystem function.

The project was then projected to extend from 2023 to 2050, with the expectation that full benefits of MPA implementation would be realized by 2032. The lifetime project expenses are deducted from the benefits anticipated to be realized over the same time period in order to compute the overall cost benefit ratio (BCR), thus providing an estimation of the yearly net benefits. The net present value (NPV) of these net benefit flows is then calculated using these amounts at the discount rate.

The BCR associated with the estimated changes in net benefits shows a significant positive return, with the direct flow of benefits to local communities estimated a ratio of 2.08. This means that for every $1 spent on the implementation of a conservation strategy, over $2 of value would be expected to flow back into the local communities via the benefits from enjoyed from ecosystem services. In terms of the broader macroeconomic value of such an intervention, the BCR figure is considerably higher at 5.53. According to this analysis, for every $1 spent on this proposed MPA, around $5.50 in value is expected to be created in the broader economies of both Kenya and Tanzania.

Recommendations

- The findings of this study demonstrate favourable outcomes associated with implementing the KT-TBCA. Therefore, this course of action should be pursued.
- To assess other assets and support future valuation studies, better ecological asset and species monitoring and data collecting must be implemented.
- As the community contributes to the degradation of ecological resources, it is crucial to incorporate more community-led marine conservation methods. This could help change certain hazardous behaviors while the TBCA is still being established.
- Beach Management Units (BMUs) need to be managed sustainably in order to properly monitor and prevent the area's destructive fishing practices.
- Since exploitation of natural resources and poverty are directly related, developing alternative employment opportunities should be a primary focus in industries with high environmental stress.

Further Work

An investigation of green finance instruments to raise funds for covering the costs of TBCA activities has been conducted and has been submitted as a stand-alone report.

Abbreviations

ACEP	African Coelacanth Ecosystem Programme
CA	Conjoint Analysis
CBA	Cost-Benefit Analysis
CICES	Common International Classification of Ecosystem Services
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
COVID	Coronavirus Disease
CRA	Comparative Risk Assessment
CVM	Contingent Valuation Method
EACC	East African Coastal Current
EIA	Environmental Impact Assessment
ENSO	El Nino Southern Oscillation
ES	Ecosystem Services
FAO	Food and Agriculture Organisation of the United Nations
GVA	Gross Value Added
GWP	Global Water Partnership
HVM	Hedonic Valuation Method
IBA	Important Bird Area
IOD	Indian Ocean Dipole
IPBES	International Panel on Biodiversity and Ecosystem Services
ITF	Indonesian Through-flow
IUCN	International Union for Conservation of Nature and Natural Resources
km	kilometres
KT-TBCA	Kenya-Tanzania Transboundary Conservation Area
M	metre
MEA	Millennium Ecosystems Assessment
MPA	Marine Protected Area

NCP	Natures Contribution to People
NE	North-East
NEMC	Northeast Madagascar Current
SC	Somali Current
SE	South-East
SEC	South Equatorial Current
SECC	South Equatorial Counter-current
SST	Sea Surface Temperature
TACMP	Tanga Coelacanth Marine Park
TBCA	Transboundary Conservation Area
TCM	Travel Cost Method
TEEB	The Economic of Ecosystems and Biodiversity
UNCLOS	United Nations Convention on the Law of the Sea
WIO	Western Indian Ocean

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1 Marine Systems Background

The total asset value of the proposed KT-TBCA is a function of all its attributes. These attributes relate to the services provided by the assets that underly the ecosystems. This includes the role they play in habitat formation, carbon sequestration, maintaining genetic diversity, etc. Many features of the KT-TBCA are unique or scarce, which, in and of itself, suggests high ecological asset values. The existence of and habitat for Coelacanth is a prime example. However, in addition to such scarcity values, the proposed KT-TBCA area also carries significant value because of its role in the social-ecological system that ultimately interconnects biodiversity and human well-being.

"Biodiversity" is a popular term that is often used but arguably poorly understood. Our preferred definition is that of Noss (1990) (see below), which provides a foundation for systems ecology and captures the components, structure, and functionality of ecological systems.

Near-shore marine ecosystems are highly interconnected with weather systems, oceanic currents, and terrestrial and freshwater ecosystems. These interconnections manifest as co-dependencies through both natural processes and anthropogenic processes. Thus, a marine ecosystem can only be managed sustainably (including management with a view to climate change adaptation) if it is managed at a meta-system scale. Practically, this means that it should include the management of the system itself (in this case, the proposed KT-TBCA marine protected area (MPA)) and may also include the management of certain aspects of the marine, freshwater, and terrestrial systems to which it connects. The management plans for the proposed KT-TBCA need to survey and understand the hazards posed to the entire meta-system, hazards for which the proposed MPA intends to mitigate.

It is for this reason that the study needs to start with a systems description.

The point of departure for the assessment is the definition of biodiversity as provided by Noss (1990), who describes biodiversity as the composition, structure, and function of an ecosystem as follows:

- "**Composition** *has to do with the identity and variety of elements in a collection, and includes species lists and measures of species diversity and genetic diversity.*
- ***Structure*** *is the physical organization or pattern of a system, from habitat complexity as measured within communities to the pattern of patches and other elements at a landscape scale.*
- ***Function*** *involves ecological and evolutionary processes, including gene flow, disturbances, and nutrient cycling.*"

Thus, the attributes of ecosystems can be defined, measured, and analysed through a range of indicators that describe their components, structure, and functional processes.

The implication of the Noss definition is that biodiversity is more than simply the number of genes, species, ecosystems, or any other group of things in a defined area. Noss instead favours a characterization of biodiversity that identifies the major components at several levels of organization, including composition, structure, and function. Whereas the composition deals primarily with species and genetic diversity, structure focuses on a range of complex habitat and abiotic features within a system. Function deals with a large range of processes and flows that enable connection, cycling, and exchange.

Understanding how this complex system works is fundamental to an ecosystem services valuation. This is because the production of ecosystem services is underlain by ecosystem assets. One of the key challenges with establishing an ES valuation is to bring ecological assets into economic decision-making. Due to their role in the production processes of most economic activity, it is critical to accurately establish and reflect all ecological asset values.

Another challenge facing ES valuations lies in linking the effects of both hazards and mitigative management actions to the production of ecosystem services. The Millennium Ecosystems Assessment (MEA) refers to this as a chain of causality. A thorough systems description also underlies our understanding of relevant chains of causality.

In the considerable amount of work that preceded this study, two asset classes have been identified:

- Biodiversity assets that comprise a complex range of assets which have significant indirect economic value. This includes biotic and abiotic features of ecosystems, as well as the processes that take place as part of ecosystem functioning. So, this would specifically include critical key Species identified, Mangroves, Coral reefs, Seagrass beds, Freshwater systems, Intertidal mud flats, Shelf Zone (nearshore), and Oceanic areas.
- Fish stocks available for subsistence and commercial fisheries.

2 Defining the System

2.1 Boundaries of the system

The first part of the geographical entity due for assessment is contained within the boundaries of the intended new TBCA.

The proposed TBCA extends from the northern boundary of the Diani Chale Marine Reserve in Kenya to the southern boundary of Mkinga District in Tanzania (between Ulenge and Kwale Islands Marine Reserves), just north of the Tanga Coelacanth Marine Park (see Figure 2-2-1). The landward boundary would be the coastal wards in both countries, and the seaward boundary would correspond to the 200 m depth contour. The 200 m contour lies approximately 5 nautical miles offshore.

It is important to note that the Tanga Coelacanth Marine Park (TACMP) has been purposefully excluded from the proposed TBCA for reasons related to acceptance by stakeholders rather than for ecological reasons (Nairobi Convention, 2015). However, it is highly likely that the Coelacanth habitat extends northwards from the TACMP into the proposed KT-TBCA.

It should also be noted that the proposed KT-TBCA area would include marine and terrestrial areas. This larger meta-system footprint (excluding the local, regional, and national economies) includes the following:

- Terrestrial catchment areas that support flows of freshwater and detritus into the marine system (see below).
- Estuarine, near-shore, and offshore habitats for the estuary-dependent biota present within the system.
- The West Asia-East Africa flyway for migratory shorebirds.

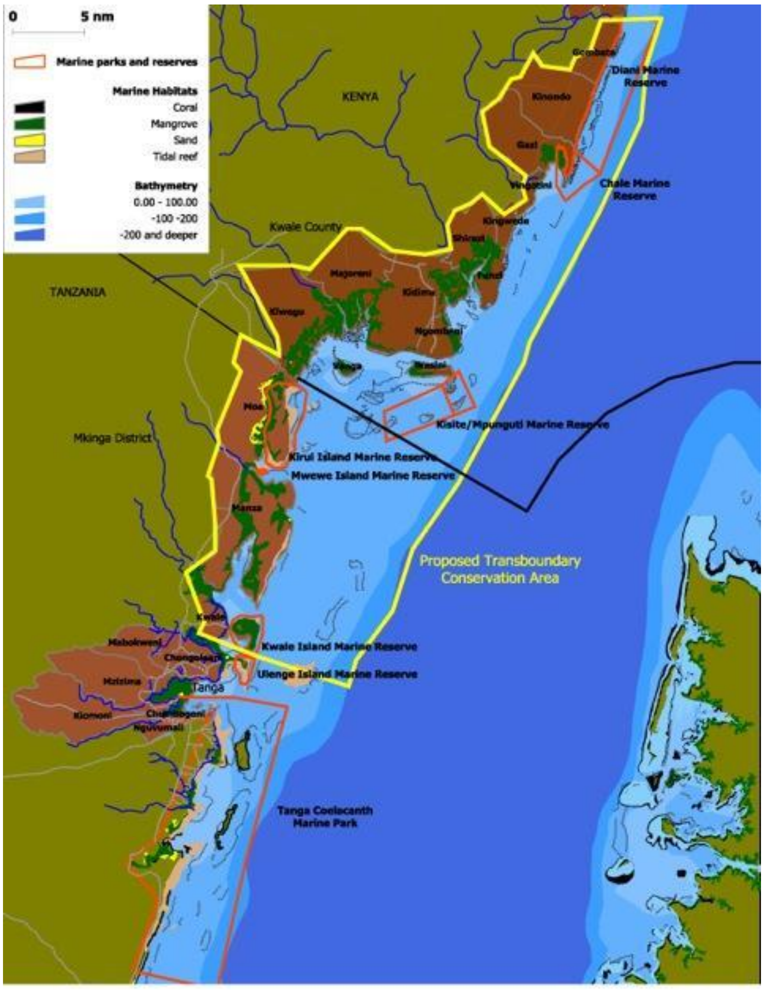

Figure 2-2-1. Preferred option for the delineation of the proposed TBCA. The yellow line demarcates the boundaries.

2.2 Connection of Marine Ecosystems to Terrestrial Ecosystems

Marine and terrestrial systems connect directly through a variety of habitats that include near-shore, shore, estuarine, lagoon, mangrove, and other similar habitats. Many species are specifically dependent on these habitats. These habitats also provide significant ecosystem services to humans, including transport (e.g., ports), food (e.g., fisheries, seagrass resources), recreation, and viewscapes that contribute to property value.

Marine and terrestrial systems also connect directly through freshwater systems. The seas' major oceans are characterised by natural variations in nutrient content (clear water seas and oceans are typically more nutrient deficient than those that are naturally murky). Ocean areas with exceptionally high nutrient contents are typically fed by upwellings originating from deep ocean processes. Those that are naturally less nutrient rich, specifically near-shore (i.e., estuarine systems), are often highly dependent on nutrient influx from terrestrial systems. Sediment movement also plays a role here. Some marine environments depend on terrestrially produced sediment as a system driver.

Thus, degradation of these interconnected systems rapidly and directly impacts the health of marine systems and the ecosystem services they deliver. Poorly planned dams and hydro-power schemes can disrupt nutrient and sediment flows. Land-based pollution, both solid and soluble, is also detrimental to marine ecosystems.

3 The KT-TBCA system

3.1 Method

The concept of ecosystem services was first established in the Millennium Ecosystem Assessment (MEA), where ecosystems are considered any assets that yield a flow of services of benefit to people, much like other capital stocks. Since the publication of the MEA, various reviews of ecosystem services frameworks have been completed. We discuss this extensively in section **Error! Reference source not found.** below.

Ecosystem assets are the biotic and abiotic components of the ecosystem that are subject to risks and hazards. We make extensive use of risk assessment methodology; refer to section **Error! Reference source not found.** below for a discussion of risk terminology and section 5 for an overview of the CRA methodology used as part of the ecosystem services valuation.

3.2 Hazards faced by the KT-TBCA system.

The ecosystems of the KT-TBCA face many hazards that put ecosystem assets and ecosystem services at risk. These hazards manifest as risks to ecosystem service delivery, both inside the proposed TBCA area and within the social-ecological system within which it is located. The ultimate goal of the proposed KT-TBCA is to mitigate these hazards.

We define an ecosystem hazard as any potential source of harm or adverse effect on an ecosystem. These ecological hazards result in ecological risk. For the purpose of this study, we use a very specific risk assessment terminology, as follows:

Ecological risk is the function of the likelihood and consequence of a hazard to which an ecological or resource asset is exposed. For this study, an asset is equivalent to a component of the ecosystem. Thus:

$$\text{Risk}_{\text{Asset}} = f(\text{likelihood, consequence})_{\text{Ecosystem Hazard}}$$

This risk categorisation is fundamental to the ecosystem services valuation process. It provides a systematic analysis method, informed by stakeholders and available evidence, to develop the necessary chains of causality that link ecological assets to ecosystem services. Further, it enables us to quantify the risks faced by the system.

The hazards faced by the KT-TBCA system primarily stem from the following drivers, as identified in the Strategic Action Programme for the Protection of the Coastal and Marine Environment of the Western Indian Ocean from Land-based Sources and Activities (UNEP, 2009):

1. The KT-TBCA area and its adjacent territories have rapidly-growing human populations with nearly 60% of rural communities dependent on marine and coastal resources for their livelihoods. These important economic activities may result in overfishing, illegal and destructive fishing practices, illegal harvesting of mangroves, and other unsustainable resource use behaviours. It is important to note that not all of these activities are necessarily illegal in nature. Often, systems of this nature are at risk as the result of the accumulated impacts of a large number of legal economic activities. For instance, mariculture of various species is an important economic activity that is widely promoted but may in and of itself be a hazard in certain settings. Population density in the Kenyan coastal region has been estimated to be increasing rapidly (GOK, 2017). This leads to increased waste generation and concentration in the region.
2. **Poverty, inequality, and inadequate financial resources** afflict much of the populace and governing structures throughout the region. This situation means that there is a heavy reliance on exploiting natural resources for livelihoods. Furthermore, this financial situation means that few people have access to good sanitation, adding to the pollution burden described below.
3. The system is also at risk from terrestrial impacts in various forms. This includes **pollution** of river systems, increased sedimentation resulting from poor agricultural practices, and illegal deforestation, and changes in river flows and detritus deposition resulting from dam construction and operations and other land use changes.
4. Underfunded and under resourced government agencies lead to **inadequate governance** in terms of policy, legal, and institutional capacity. As a result, management of coastal and marine ecosystems is ineffective.
5. **Climate change** (and natural variability) and associated impacts put ecosystems at risk. The general effects of climate change on marine environments have been well documented. These include changes in atmosphere and climate, ocean thermodynamics and circulation patterns, and ocean acidification. Ecological impacts on marine life may result from factors such as coral bleaching and ocean acidification or changes to water temperature, ocean currents, salinity, or river run-off. There is also the effect of sea-level rise and the increasing frequency of extreme weather events such as tropical cyclones and droughts. In this study area in particular, the emergence of stronger Indian Ocean Dipole (IOD) effects, especially in its positive

cycle, leads to increased water temperatures with the potential to impact regional weather patterns and sea currents.

6. Management inefficiencies and errors in coastal communities, policy makers, and entities mandated to protect ecosystems are caused by **insufficient knowledge and awareness**, gaps in knowledge, and poorly communicated information regarding the ES derived from healthy, well-functioning ecosystems.
7. **Oil and gas economic activities** pose hazards to the system. Tanzania has significant natural gas resources. Songo Songo, an island off the southeastern coast, and Mnazi Bay in southeast Tanzania – are both currently engaged in oil production and have an expected lifetime of 20 years. Oil and gas exploration continues, and the hazards to marine environments typically include habitat loss in the immediate vicinity of the oil and gas operations, and marine pollution associated with ship traffic.
8. Finally, a somewhat less direct hazard results from changes in human movement patterns. Eco-tourism is an extremely important economic activity in the system and carries strong interdependencies with the ecological assets of the system. Two hazards put eco-tourism at risk. First, **illegal trade and its associated piracy and poaching, as well as terrorism** activities put eco-tourism at risk. Second, the **COVID pandemic** has disrupted the eco-tourism industry.

The specific hazards which form the basis of the CRA and consequent ES valuation, stemming from the drivers identified above, can be grouped into three categories. These are summarized below and further expanded on in Table 3-1:

1. Physical alteration and destruction of habitats – these consist of degradation to mangrove forests, seagrass beds, coral reefs, and coastal forests, as well as changes to the shoreline.
2. Water and sediment quality degeneration due to pollution – key pollution categories identified are: microbial contamination, high suspended solids, chemical pollution, marine litter/solid waste, and eutrophication.
3. Alteration in freshwater flows and sediment loads from rivers – alteration in flows is largely associated with land use changes that affect the consumptive demand for water, as well as other physical factors affecting the natural flow of water, such as the construction of dams and wetland degradation. Sediment loads are also affected by the above alterations to river flows, while climate change is expected to have an impact on both sediments and flow variability as extreme weather events become more common.

The ecosystems potentially exposed to the environmental effects resulting from the above hazards encompass both the proposed TBCA as an entity as well as the metasystem within which it is located. We refer to these collectively in the rest of the document as the KT-TBCA metasystem

Table 3-1: Summary of Hazards (Adapted from Nairobi Convention, 2015)

Hazards	Hazard rating	Description of threat/possible mitigation measures
1. Unsustainable fishing	High	Poverty and lack of alternatives, combined with an increase in fishers and more efficient fishing equipment have resulted in declining catches. If this trend continues and benefits of the TBCA are not obvious, community support will likely erode. Improved management of MPAs and surrounding areas through co-management approaches are critical, and communities need to be made aware of tangible benefits of closed areas, equipment limitations, and improved management (adherence to fisheries regulations). Fisheries regulations need to be enforced, and illegal fishing methods must be effectively prosecuted.
2. Destruction of marine and coastal habitats	High	Increased reef activity and trampling of intertidal habitats, destructive fishing practices such as the use of dynamite, and ring nets set in shallow water, dredging for construction material, and potential harbour development all pose hazards. Physical alteration of the coastline can also occur through inappropriate infrastructure development. Monitoring, control, improved surveillance, and exclusion areas zoned for conservation purposes, as well as environmental best practices (i.e., EIAs) must be followed in the case of large-scale modifications to the coastal marine environments.
3. Coastal deforestation	Medium	Unsustainable harvesting of coastal forests, especially mangroves, lead to destruction and alteration of a primary habitat in the TBCA area. Careful forest management with improved collaboration between the agencies responsible, adherence to management guidelines, and replanting initiatives all need to be instituted, while no-take areas also need to be respected.
4. Climate change resulting in coastal flooding and salt water intrusion	Medium	This is a potential impact of climate change with possible intensified storms, increased rainfall, tidal surges, and increasing sea levels. This is exacerbated by destruction of mangroves and other coastal habitats that act as natural protection to these events. Saltwater intrusion is exacerbated through overuse of coastal ground water resources, which is sometimes associated with tourism development or agricultural practices. Coastal development needs to take these factors into consideration, and 'climate smart' designs should be implemented to ensure communities, infrastructure, and coastal land are protected from these threats.

Hazards	Hazard rating	Description of threat/possible mitigation measures
5. Terrestrial effects: Sedimentation resulting from terrestrial impacts such as agriculture, deforestation and changes in river flows	Medium	Increased sedimentation from land-based sources threatens the coastal environment through smothering coral reefs, mangroves, and seagrass beds. While important nutrient inflows come from this source, increased erosion through poor land-use practices in the river catchments can lead to habitat destruction. This is likely to increase with predicted increase in the number and intensity of rainfall events. Catchment management and the link between practices inland and coastal areas needs to be recognised, and joint management must be implemented between stakeholders.
6. Pollution	Medium	Pollution of the coastal zone can come from inland sources (pesticides, agricultural fertilizers, sewage, mining activities, etc.) or from activities in the marine environment (Oil and gas developments, shipping activities). The link between land-based activities and potential impacts on the coast needs to be considered in all management efforts. In terms of potential marine sources of pollution, oil spills likely pose the greatest threat. Following international best practices and adhering to global and national regulations for these activities is essential. This is especially true in the TBCA, where impacts would be serious to both biodiversity and livelihoods.
1. Alteration of freshwater flow	Low	Freshwater inflow into the marine environment is critical to the healthy functioning of coastal environments. In addition to providing nutrients to the coastal zone, estuarine environments rely on sufficient freshwater flows. These environments support productive ecological systems and livelihood options for coastal communities. Water abstraction upstream is the main threat to this inflow. These threats need to be managed with the agriculture and mining sectors, both of which require large amounts of water from rivers in the proposed TBCA area..
7. Terrorism and insecurity	High	Recent insecurity on the coast of Kenya, as well as the travel advisories issued by several countries supporting tourism in both Kenya and Tanzania, has had a profound effect on the coastal economy. This threat to the tourism sector could have serious negative repercussions for the proposed TBCA as tourism activity will be a major supporting sector. International and national efforts to address the issue of terrorism need to be intensified, and the negative perceptions about the Kenyan coast and east Africa as a tourist destination need to be addressed through improved marketing and diplomatic efforts.

3.3 Physiography and Oceanography

The entity lies between about 4 degrees 18 minutes and 5 degrees 1.12 minutes S along the coastlines of Kenya and Tanzania. It is located to the west of the Pemba Channel and its northern extension. The proposed TBCA boundary has a seaward boundary corresponding to the 200 m depth contour. The Pemba Channel and its northern extension are approximately 50 km wide, with a depth of up to 1,000 m. The channel has steep bathymetry, and the north flowing current provides connectivity and productive conditions for marine life.

However, several authors cite a lack of knowledge of the coastal geology and bathymetry of the channel (Masalu 2008, Painter 2020, Osuka et.al 2021).

3.3.1 Currents and Productivity

The dominant offshore current is the East African Coastal Current (EACC), which flows northward throughout the year. The EACC originates in the westward flowing South Equatorial Current (SEC), which flows in a latitudinal band around approximately 15-20^{o}S.

The SEC in turn is driven by a number of complex processes, including forces exerted by the Indonesian Through-flow (ITF) and atmospheric processes associated with the heating of the Indian/South Asian landmass, as well as equatorial oceanic heating and the formation of Hadley Cells (Nairobi Convention, 2015). During the boreal summer (northern hemisphere summer), the SEC is at its strongest, reaching velocities of ~1.5-2.0 m/s. A portion of the SEC deflects north of Madagascar to become the Northeast Madagascar Current (NEMC) until it reaches the coast of Africa, where it turns north to become the EACC. The EACC eventually becomes the Somali Current (SC).

During boreal winter, the SEC weakens to a velocity of ~0.5 m/s, ultimately playing a role in the reversing of the Somali Current. This south-flowing current can continue as far south as 4^{o}S, just north of the KT-TBCA northern boundary, after which it turns east to become the South Equatorial Counter-current (SECC).

The EACC is the dominant oceanographic influence along the system, via the Pemba Channel, and is characterised by oligotrophic (i.e., low nutrient levels and thus low productivity) surface waters.

Strong coastal gyres develop with the Somali Current, and upwelling takes place off the coast of Somalia. The convergence of the SC and EACC also induces upwelling of cold, nutrient-rich waters, resulting in higher productivity. The exact confluence of the two currents varies between December and February, and it also varies in its position along the south Kenyan coast (Jacobs et al., 2020).

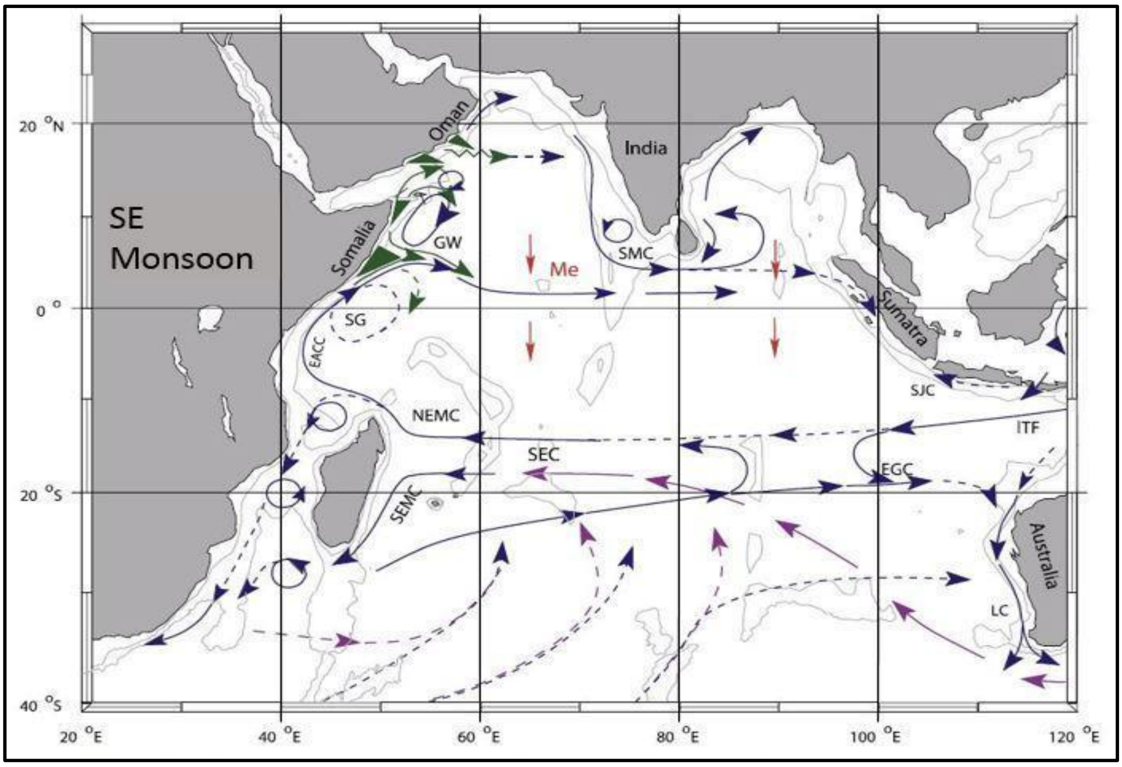

Figure 3-1. Representation of currents during the SE Monsoon (Source: Schott et al., 2009 as quoted in Nairobi Convention 2015)

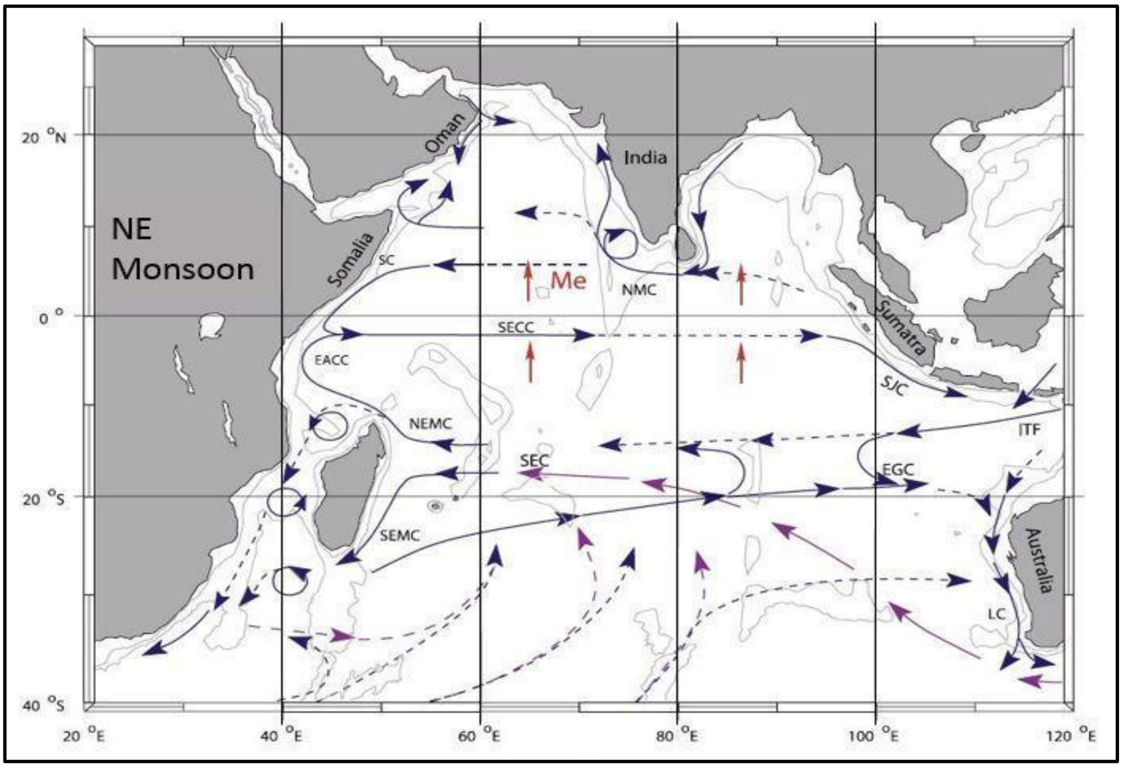

Figure 3-2. Representation of currents during the NE Monsoon (Source: Schott et al., 2009 as quoted in Nairobi Convention 2015)

3.3.2 *Shallow and mesophotic environments*

The proposed KT-TBCA system is a shallow and mesophotic[1] environment that connects to the major bathymetric and oceanographic attributes of the West Indian Ocean (WIO) in various ways.

The shallow marine environment (neritic zone[2]) of the narrow East African continental shelf, which characterises the KT-TBCA, is considered to be more heavily influenced by local tidal currents and terrestrial input of nutrients than by the offshore currents (Painter 2020).

3.4 Climate

The atmospheric processes that influence climatic conditions in the region of the proposed KT-TBCA are driven by processes that originate across the Indian Ocean (both north and south of the equator) as well as over the Pacific Ocean.

The coastal waters in the proposed TBCA are strongly influenced by the Indian Ocean's currents and climate, including the El Nino Southern Oscillation (ENSO) and IOD which, in turn, drive weather patterns, trade winds, rainfall, and primary productivity.

The main feature of the climate in the area of interest is Monsoons. During the austral winter (June-September), the south-easterly Trade Winds (SE Monsoon) are dominant as a result of the (boreal summer) heating of the large landmasses of the Indian Subcontinent and Asia. During the austral summer (November-February) however, the SE Trades are weaker, and the monsoon reverses due to significant (boreal winter) cooling of the Indian Subcontinent and Asia. This leads to the dominance of north-easterly Trade Winds (NE Monsoon).

The rainfall in the region is seasonal. Rainfall is lowest during the SE Monsoon months from May/June through September/October. The major rains fall during the NE Monsoon, with the so-called 'short rains' over the months of October through November. The main wet season (long rains) occurs from February/March to May as the NE Monsoon subsides. Mean annual rainfall ranges between 1,000mm and 1,600mm.

The IOD mode is the dominant driver of natural variability in the Indian Ocean. The IOD is a zonal anomaly in sea surface temperature (SST). It was first described by Saji et al. (1999) and Webster et al. (1999). This mode is independent of the El Niño-Southern Oscillation-forced variability. The IOD significantly affects the precipitation regime of East Africa during the "short rains" in September, October, and November. The precipitation amount in this

[1] Indicating the presence of both light dependent coral and algae and organisms that can be found in water with low light penetration.

[2] The shallow marine environment extending from mean low water down to 200-metre depths, generally corresponding to the continental shelf. Neritic waters are penetrated by varying amounts of sunlight, which permits photosynthesis by both planktonic and bottom-dwelling organisms (https://www.britannica.com/science/neritic-zone)

season is determined by the variability of the dipole mode. The rainfall patterns impact the coastal zone through freshwater run-off from several rivers in the proposed TBCA.

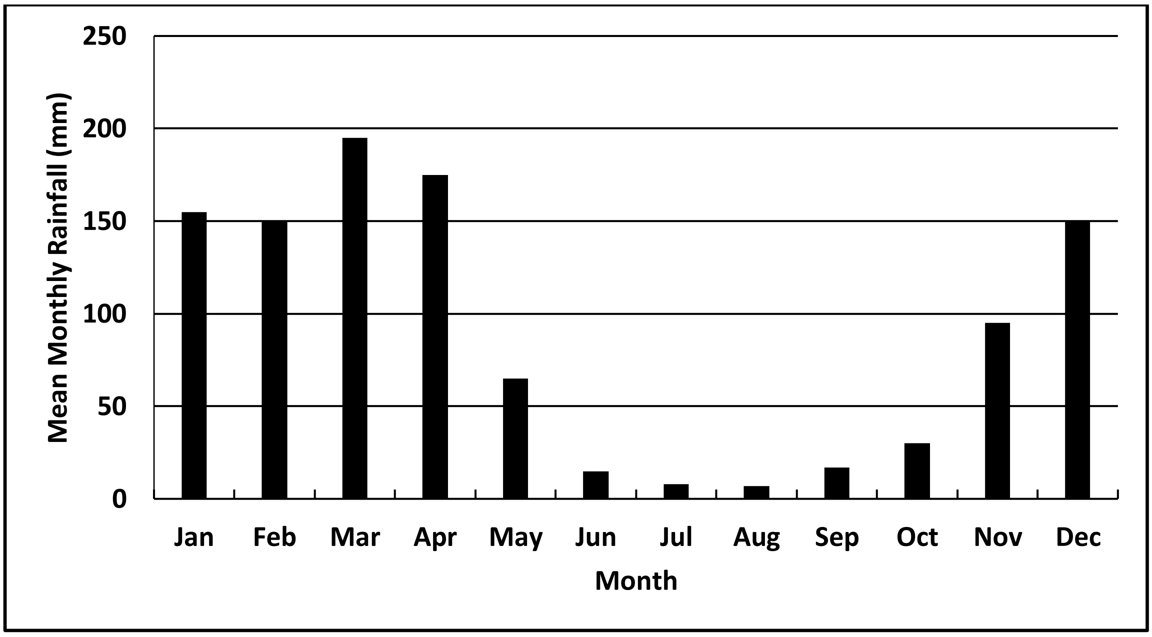

Figure 3-3. Mean Monthly Rainfall for Dar es Salaam 1990 to 2009 (Source: Anderson and Samoilys, 2015 as quoted in Nairobi Convention 2015)

3.5 Surface hydrology

In Kenya, the Athi Catchment is a key area of interest. Here, the key river is the Umba River, which flows from Tanzania to Kenya. The Umba River is only around 200 km long, draining a catchment of around 8,000 km^2. However, evidence suggests it may be a source of important nutrients into the KT-TBCA (Kimeli et al., 2021). The Umba is reported to have a volume of around 6100 m^3 per day, discharging into the TBCA at the town of Vanga on the Kenyan side of the border (KCG, 2018).

The only other river of significance flowing into the TBCA is the Ramisi, which also lies on the Kenyan side of the border. It is reported to have a volume of just under 8,200 m^3 per day, discharging at Bodo into the estuary behind Funzi island (KCG, 2018).

In Tanzania, the Pangani river basin comprises the terrestrial area just outside of the TK-TBCA. The basin covers an area of 43,650 km^2 with 95% of that space in Tanzania and 5% in Kenya. The river begins as a series of small streams draining from Mt. Kilimanjaro, Mt Meru, and the Pare and Usambara mountain ranges. It then flows into the Indian Ocean around 100 km south of the southern boundary of the proposed TBCA.

The river basin is a diverse ecosystem with fertile soils and high rainfall. Additionally, the region is used by over three million people for agriculture. A series of hydro-electric power stations along the 500 km long river also contribute about 17% towards Tanzania's national electricity demand.

Climate change has had adverse effects on the Pangani Basin. Flows have been reduced from several hundred to less than 40 m^3 per second. Population growth, deforestation, increasing numbers of livestock, the expansion of cultivated land, as well as freshwater fishing, mining and hydroelectric power activities have all led to excessive pressures on the basin's water resources (GWP, 2021).

In addition to these key river systems, multiple smaller rivers enter into the KT-TBCA from these two catchment areas (see **Error! Reference source not found.**).

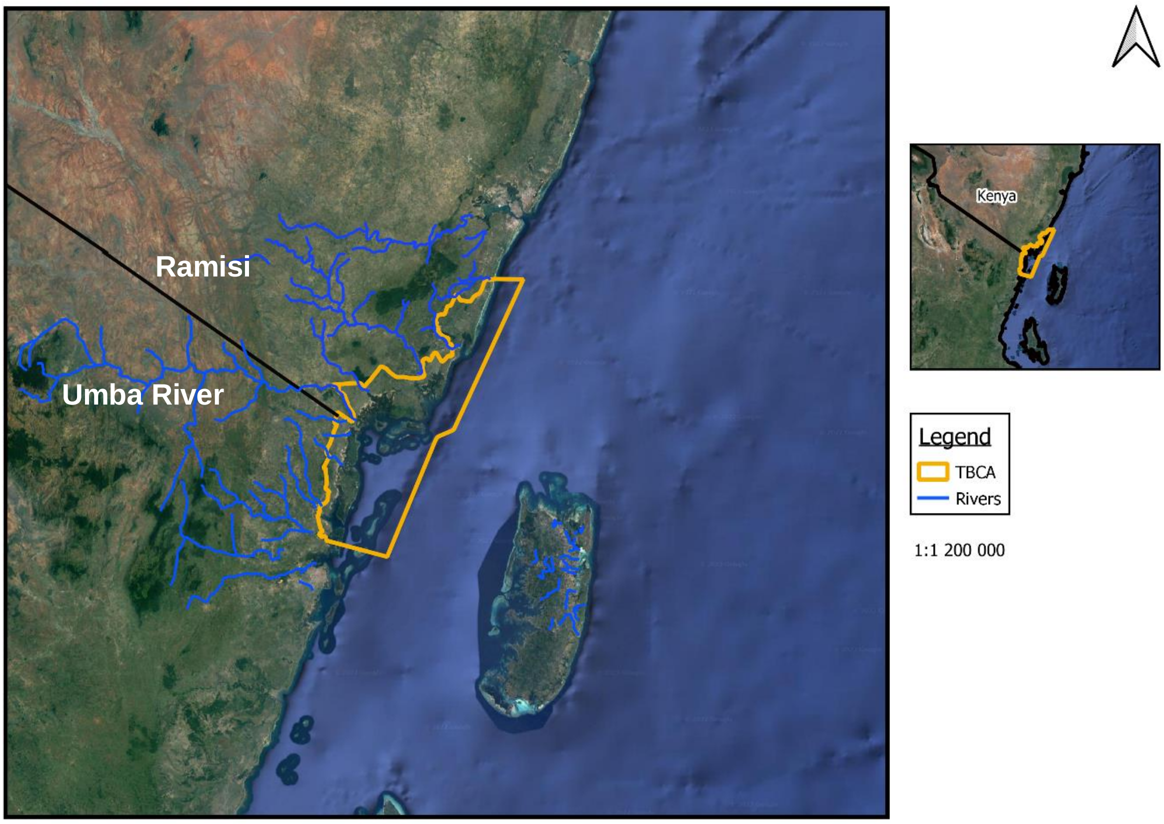

Figure 3-4: The Umba and Ramisi Rivers are the only two significant rivers flowing into the KT-TBCA

3.6 Groundwater and sub-surface water

Another hazard to the region is saltwater inundation of coastal aquifers and surface water. The primary factor that influences surface water salinity was determined to be changes in stream discharge as a result of precipitation events or anthropogenic modifications (McCormack, 2020). The impacts of these alterations may be amplified by climate change events such as changing rainfall patterns, sea level rise, and storm surges, especially in the presence of mangrove habitat loss. Implications of increased ground- and surface water salinity include lowered crop yield, water scarcity, and disruptions to estuarine processes.

3.7 Habitats

The proposed TBCA falls within the Monsoon Coast Ecoregion (The Nairobi Convention (2015) used Spalding's (2007) and Obura's (2012) definitions of ecoregions in the WIO). The Monsoon Coast Ecoregion runs from Mogadishu in southern Somalia, through Kenya and northern Tanzania, to Dar es Salaam. The five ecoregions depicted in Figure 3-5: Map of the WIO showing the position of Tanzania and Kenya, as well as Comoros, Madagascar, Seychelles, Somalia, Mozambique and South Africa. Ecoregions are defined by Obura (2012) based on the distribution of hard-coral species. (Source: Spalding et al., 2007; Obura, 2012. In Samoilys et al., 2015 as quoted in Nairobi Convention, 2015) are as follows (Table 3-2):

Table 3-2: Geographic range of the Monsoon Coast Ecoregion

No.	Geographic Range
1	Somalia
2	Southern Somalia, Kenya, northern Tanzania – monsoon coast
3	Northern Mozambique Channel: southern Tanzania, northern Mozambique
4	Southern Mozambique Channel: central southern Mozambique
5	Delagoa: southern Mozambique, northern South Africa

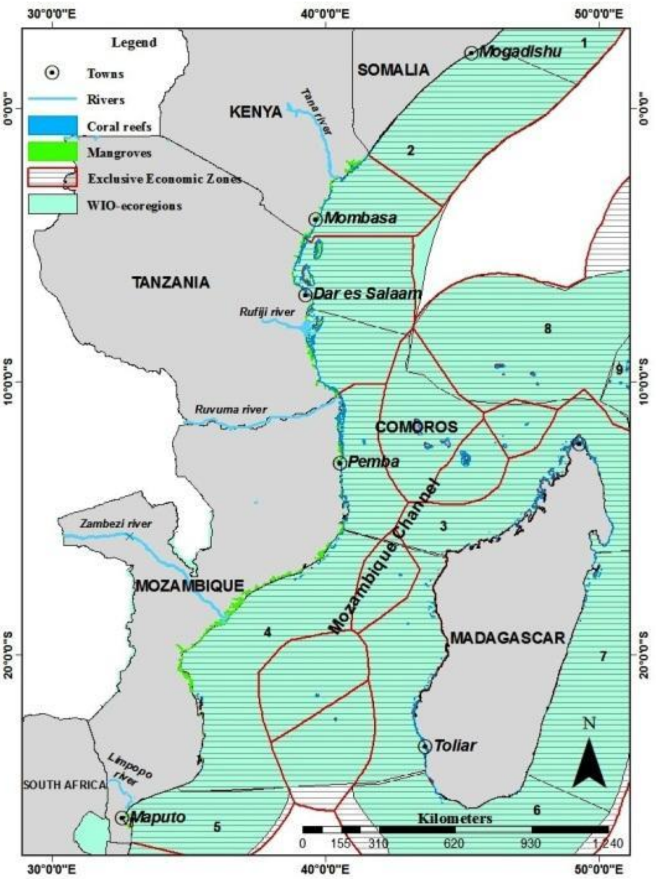

Figure 3-5: Map of the WIO showing the position of Tanzania and Kenya, as well as Comoros, Madagascar, Seychelles, Somalia, Mozambique and South Africa. Ecoregions are defined by Obura (2012) based on the distribution of hard-coral species. (Source: Spalding et al., 2007; Obura, 2012. In Samoilys et al., 2015 as quoted in Nairobi Convention, 2015)

The proposed TBCA is composed of a mosaic of highly productive habitats consisting primarily of coral reefs, rocky shores, seagrass beds, intertidal reef flats, muddy or sandy flats, mangroves, and coastal forests. Not far offshore (approximately 5 nautical miles on average), the continental slope also includes offshore canyons. While no significant rivers debauch into the proposed TBCA, there are several smaller rivers that create significant estuarine habitats that are known to be important breeding sites for a range of fish species as well as coastal birds.

The Nairobi Convention (2015) has combined information from various sources to produce a habitat map for the area (refer to Error! Reference source not found.). A key observation is the similarity in coastline habitat in both countries, emphasising the continuous and connected nature of habitats and ecological processes in the area. This is recognised in the WWF East Africa Marine Ecoregion process, as noted in the Nairobi Convention (2015).

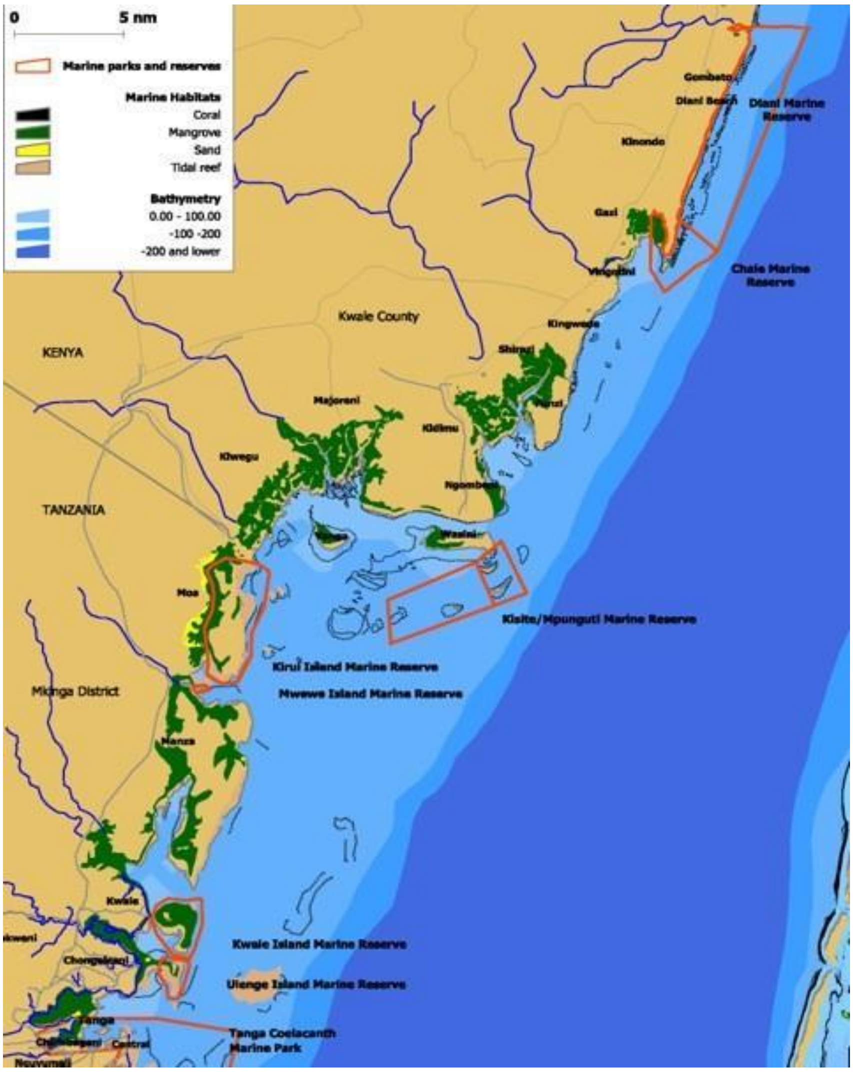

Figure 3-6: Map of areas of interest showing key habitats (Source: Nairobi Convention, 2015).

3.7.1 Coral Reefs[3]

The entity is characterised by an abundance of coral reefs (refer to **Error! Reference source not found.Error! Reference source not found.**). These are typically shallow fringing reefs,

[3] Nairobi Convention 2015

sometimes enclosing a lagoon, with shallow and deeper patch reefs further offshore. The fringing reefs are often associated with seagrass beds.

Horrill, et al., (2001) recorded a total of 47 coral genera within the Tanga Coelocanth Marine Park (TACMP) with diversity increasing from 20 genera on the inshore fringing reefs to 24 on the inner patch reefs and 28 on the outer patch reefs. Similar patterns are expected on coral reefs in the KT-TBCA. Of the 407 km of coastline in the Tanga region, 97 km are bordered by distinct sections of fringing reefs, and there are at least 55 outer and inner patch reefs recognized in the area. This yields a total reef edge perimeter of 376 km in the region (Horrill et al., 2000). If this figure is extrapolated to the areas north of the border in Kenya, the overall reef edge area that would be included in the proposed TBCA is significant at a regional WIO level.

The reefs are rich in marine biodiversity and support many local fishing communities. In 1968, Tanga reefs were perceived as among the ‘best’ along the Tanzanian coastline (Ray, 1968). However, since then structural reef damage, overfishing, and associated declines in reef associated fish species has been prevalent. Most of the decline in reef health has been attributed to structural damage from dynamite fishing, particularly to the south of TACMP (off Kigombe) and near Tanga City. Weighted nets, boat anchors, and hulls flatten the top of shallow reefs and trample reefs exposed at the spring low tides, which also contributes to the decline in reef health. Meanwhile, the large increase in the number of fishers may play a role in the comparatively low fish abundances on reefs.

The reefs on the Kenyan side of the border tend to be better protected and managed than on the Tanzanian side. This is largely due to Kenya’s long-standing and well supervised national marine parks. About a decade ago, a network of community conservation areas was established. In the past, the Kenyan government tended to choose coral reefs to gazette as parks because of their aesthetic appeal and rich biodiversity. Later, the government introduced marine reserves that were larger than the parks and encompassed neighbouring seagrass beds and mangrove forests. The reserves provide a more balanced ecosystem-based approach to marine conservation and management. Unlike the parks, they accommodate carefully managed fishing by local communities. The good management of marine parks in Kenya has also led to significant recovery in fish populations over the last 20 years.

Corals are at risk because of sea-surface temperature increases resulting from global warming. The warmer water temperatures bleach corals, and it will eventually kill them if water temperatures continue to rise. Levels of coral bleaching from the extreme temperature during the 1998 El Niño event and the subsequent recovery of coral reefs have been quantified in the WIO. They show that recovery rates and resilience to bleaching vary considerably within the region. The northern Mozambique and southern Tanzanian coral reefs appear to be the most resilient with the quickest rate of recovery. Reefs throughout this region have been reported to be on a clear recovery trajectory after the bleaching event, which provides a positive indication that damaged reefs in the proposed TBCA could recover, both from bleaching and physical destruction. However, this will only happen with time and adequate protection.

3.7.2 Rocky Shores and Intertidal Mud Flats[4]

Much of the coastline of both the mainland and islands are composed of rocky shores made of fossilised coral. This is a geologically dominant component of the coastline close to the ocean. In many places, the shoreline is eroded, leaving steep rocky faces on the landward side of intertidal areas. Terrestrial vegetation is found on the landward side, while marine habitats occur on the seaward side of these rocky faces. **Error! Reference source not found.** shows such a rocky shore in southern Kenya. Rocky shores support many species of macro-algae, with 105 species of red, green, and brown algae identified within the TACMP.

Mud flats occur in shallow calm water bays on both sides of the border in the proposed TBCA. In Tanzania, these occur from Kilanje Creek at Mtang'ate Bay northwards to the Kenyan border, and in Tongoni within the TACMP. These ecosystems support a variety of aquatic fauna and are particularly important to burrowing shellfish and avifauna such as waders.

Figure 3-7. Rocky shore on Wasini Island, southern Kenya.

3.7.3 Seagrass Beds[5]

Although there are numerous patches of seagrass beds within the proposed TBCA, their spatial extent is poorly documented.

Seagrass habitat ranges from high intertidal to shallow subtidal soft bottoms such as sandy bays, mud flats, lagoons, and estuaries where they tend to form extensive mono- and multi-specific meadows. They often occur near coral reefs and mangroves. In the proposed TBCA, they are restricted to shallow water as they depend on sunlight for photosynthesis.

Of the 60 seagrass species identified worldwide, 13 are found in the WIO. Tanzania, Kenya, and Mozambique have the greatest diversity of seagrasses with 12 species widely distributed in each country. These are *Cymodocea serrulata, Cymodocea rotundata, Halodule wrightii,*

[4] Nairobi Convention 2015

[5] Nairobi Convention 2015

Halodule univernis, Halophila ovalis, Halophila minor, Halophila stipulacea, Enhalus acoroides, Syringodium isoetifolium, Thalassia hemprichii, Thalassodendron ciliatum, and *Zostera capensis*.

Kenya has 34 km^2 of seagrass beds. Some of the most extensive seagrass beds in Kenya are found within the proposed TBCA in the bays of Gazi (8 km^2) and Funzi, as well as in the back lagoons around Diani–Chale Island (4.5 km^2). Gazi Bay and the lagoons of Diani–Chale Island are essentially continuous and represent the largest seagrass area in Kenya.

Tanzania has not yet fully mapped the extent of this habitat in their country. The only area that has been studied is Mnazi Bay, where 50 km^2 of seagrass beds have been recorded.

These are keystone habitats and also play an important role as carbon sinks. The habitats serve as important nursery areas for juvenile fish species and as feeding grounds for endangered species like dugongs and turtles. Seagrass beds are recognized as important to local fisheries as well. Food fish such as rabbitfish (Siganidae), surgeonfish (Acanthuridae), and seagrass parrotfish (*Leptoscarus* spp.) preferentially graze the epiphytes on the seagrass. Meanwhile, larger fish such as snappers, groupers, and barracuda feed on the in-fauna of the seagrass beds.

Seagrass beds are vulnerable to human activities such as prawn trawling, seine, and drag netting. It is known that poor fishing practices such as the use of beach seines and dynamite fishing have accelerated since 2005 and continue to damage seagrass beds and their associated fauna and flora.

3.7.4 Mangroves

Mangroves form the most extensive coastal habitat in the proposed TBCA. The proposed TBCA has 9 of the 10 mangrove species found in the WIO. *Rhizophora mucronata* and *Ceriops tagal* predominate and can be found in almost all mangrove forests. The rarer species are *Heritiera littoralis* and *Xylocarpus moluccensis* can also be found here. Mangrove forests display a strong zonation of species controlled by the large tidal regime. The typical sea-to-land zonation pattern is *Sonneratia alba, R. mucronata, Brugeria gymnorrhiza, C. tagal, Avicennia marina, X. granatum, Luminitzera racemose,* and *H. littoralis.*

The Tanga region contains Tanzania's third-largest mangrove forest cover, with approximately 13,192 ha. 176.4 ha of mangrove area replanted. Natural mangrove cover has been largely maintained in the Muheza District, and large areas have been replanted (a total of over 200 ha, with 400,000 seedlings). In TACMP, mangroves are predominant in river estuaries as well as on Yambe and Karange Island. A large area of mangrove forest spans the villages of Mtambwe, Ndumi, Mwambani Mchukuuni, Jambe Island, and Geza as well as Mwarongo, Tongoni and a small strip south of Kigombe (CBD, 2012). Mangroves have been gazetted as forest reserves in Tanzania, which allow regulated extraction, since 1928. As a result, mangrove degradation and loss has occurred, though at a slower rate than in most other countries in the region. The widespread and excessive exploitation of mangroves for timber, fuel, and tannin is degrading some forests and putting them at risk. The national Mangrove

Management Project implements the Mangrove Management Plan at a nationwide scale. This program also encourages participatory monitoring with coastal villagers and includes regular replanting activities.

Estimates put Kenya's mangrove cover between 5,300 to 6,100 km^2, with 67% occurring in the northern Lamu area and 10% further south in Kilifi and Kwale Counties. Smaller mangrove areas are found on the south coast in creeks around Shimoni and Vanga and in the bays of Funzi and Gazi. Most of these forests do not occur in estuaries but in intertidal areas where there is submarine ground water discharge or seepage. The mangroves create a conducive habitat for finfish and crustaceans and are likely to support highly productive offshore fisheries. In Kenya, mangroves were declared government reserved forests in 1932 and are managed by County Forestry Officers, who supervise licensing, offtake, and conservation. Legislation governing mangrove management was implemented under the Forest Act (2005).

Many of the forests are in protected areas such as the Shimoni-Vanga area in the Kisite and Mpunguti Marine Park and Reserve. Despite the national protection status of these mangrove forests, however, they remain under threat from development.

3.8 Species[6]

3.8.1 Bony Fishes, Sharks and Rays

3.8.1.1 Coelacanth

Arguably the most famous fish in the region is the coelacanth, *Latimeria chalumnae*. This "living fossil fish" is considered endangered and is a CITES - Annex 1 species. It is also listed as critically endangered on the IUCN Red List. The coelacanth is the sole known remaining representative of a once widespread family of sarcopterygian (fleshy-finned) fish that were thought to have become extinct 70 million years ago. Two species of coelacanth are extant: the WIO species *Latimeria chalumnae*, and an Indonesian species, *L. menadoensis,* which is less widely distributed. Coelacanths are commonly found on sloping continental shelves. Initial reports suggested they occurred at depths of 300–400 m in sheltering caves and canyons that provided habitat for their prey. In this region, they have been sighted in the submarine canyons of the east and west coasts of the Mozambique Channel; the steep volcanic slopes of Comoros; off the northern Mozambique coastline; and off the coast of northern South Africa. More recently, they have been seen in much shallower depths of 75–100 m on the upper slopes of Pemba Channel canyons around Tanga.

Within the TACMP, coelacanths occur mainly along the outer island drop-offs. Due to the similarity in bathymetry further north in the proposed TBCA, it is expected that coelacanths likely are present there as well.

The unprecedented catch incidents of coelacanths in the Tanga area called for urgent management measures to protect the species in Tanzania to sustain representative reef and

[6] Adapted from Nairobi Convention 2015

deepwater ecosystems and ensure maintenance of the ecosystem processes on which coastal communities and coelacanths depend. The African Coelacanth Ecosystem Programme (ACEP) provides this management and is the result of international and regional concern over rising incidents of accidental catches in deep-water gill nets, particularly in northern Tanzania.

3.8.1.2 Bony Fishes

Some 380 fish species have been identified in the waters of the proposed TBCA (Spalding et al., 2001), mostly from landed catches and observations during underwater surveys. The most important families in reef fish catches are Lethrinidae, Lutjanidae, Siganidae, Scaridae, Labridae, and Mullidae. In the TACMP, there are large-scale differences in ecology and fish communities between reef areas that have been exposed to heavy fishing pressure and those that have been closed. Regular monitoring between 1995 and 2008 confirmed the low fish abundance and biomass in commercially exploited species, particularly groupers, snappers, emperors, grunts, and rabbit fish. Despite a gradually increasing trend in population densities from 1998-2001, especially on closed reefs, fish abundance has been largely declining since 2003. Snappers, emperors, grunts, and rabbitfish were the most important fisheries target groups. The biomass of this group was considered very low (about 8kg/ha) compared to an average biomass of 250 to 300kg/ha on closed reefs.

Other teleost fish species occurring in the proposed TBCA are also listed as threatened on the IUCN Red List and are rare or have regional or global significance. This includes the Napoleon wrasse, *Cheilinus undulates*; the Humphead parrotfish, *Bolbometopon muricatum*; the Giant grouper, *Epinephelus lanceolatus*; and the Red Sea, Arabian Gulf angelfish, and the *Apolemichthys xanthotis*.

3.8.1.3 Sharks and rays

Sharks are among the most threatened of all marine species, suffering from heavy fishing pressure and the shark-fin trade, combined with low fecundity and a consequent long regeneration time. Their life-history is generally poorly researched, and the animal receives relatively little conservation attention. Several species are likely to occur in the proposed TBCA area, including the Grey reef shark, *Carcharhinus amblyrhynchos*; the Whitecheek shark, *C. dussumieri*; the Black tip reef shark, *C. melanopterus*; the Blackspot shark, *C. sealei*; the Spot-tail shark, *C. sorrah*; the Black tail reef shark, *C. wheeleri*; the Milk shark, *Rhizoprionodon acutus*; and the White tip reef shark, *Triaenodon obesus*. These are mostly smaller species at less than 2 meters long and occur in coastal waters, which makes them accessible to local fishermen. Shark fisheries have existed for centuries in eastern Africa largely because the meat preserves well when salted and dried and can be traded along the coast.

Reef and oceanic sharks are widely dispersed in the oceans, but they have been taken in fisheries both purposefully and as accidentally, which has reduced their populations. In eastern Africa, the bull shark or Zambezi shark (*Carcharhinus leucas*) is often implicated in attacks on people, fuelling the general fear of sharks and diminishing enthusiasm for commitment to their conservation. The charismatic scalloped hammerhead shark (*Sphyrna lewini*) used to be abundant near steep reef slopes off Pemba Island, Tanzania, but their numbers have dwindled, likely due to the gill netting of juveniles in inshore waters and the overfishing of adults by foreign offshore fishing fleets. Great white sharks, *Carcharodon carcharias*, have also been periodically caught in the region, but the TBCA is likely to be on the very edge of their natural range, with larger concentrations further south in the more temperate waters off South Africa.

Whale sharks, *Rhincodon typus*, are widely distributed off the eastern African coast. This is a planktivorous, broad-ranging species. Their seasonal migration patterns cover thousands of kilometres. They can also reside year-round in equatorial zones. They are found in many areas with surface seawater temperatures of 18–30 ^{o}C and range across the entire Indian Ocean, as well as in the waters of the proposed TBCA. These sharks are considered *Vulnerable* under the IUCN Red List, and several other international instruments refer to them including those of CITES, UNCLOS, and the FAO.

The numbers of these sharks appear to have increased on the southern coast of Kenya in recent years, particularly around Diani, Galu and Chale Island. In 2011, an average of 20 whale sharks were spotted daily, whereas the previous average had been 20 in a year. There has been speculation that the increase in shark numbers is linked to greater volumes of mantis shrimp. It may also be related to better monitoring as a result of greater interest in this species.

Whale shark tourism has rapidly grown in importance, with regular seasonal sightings in Diani and at Mafia Island in Tanzania. Protection of this concentration at Diani and within the proposed TBCA thus provides both conservation and economic benefits.

Several rays also occur in the proposed TBCA, including the Manta ray, *Manta alfredi*. Rays are usually caught by local gill net fishermen, who salt their catch and sell it. This unsophisticated method has been popular in the region for decades. In Tanga, Tanzania, rays comprise 72% of the catch from gill nets (Anderson, 2004). The manta ray is the largest batoid fish in the world. They are most commonly found in productive coastal areas and are often encountered by divers around island groups, in shallow bays, tidal channels, and offshore seamounts and pinnacles (Dewar et al., 2008; Luiz et al., 2009; Marshall et al., 2009). Manta rays in eastern Africa have been included in the dried shark-meat trade for centuries. The effect on the species has not been documented, which highlights the need for more research and better conservation strategies.

The *Critically Endangered* knifetooth sawfish (*Anoxypristis cuspidate*) and longcomb sawfish (*Pristis zijron*) have been sighted on rare occasions in Kenya in the lower reaches of the Tana River and in Ungwana Bay to the river's north (Samoilys et al., 2011a). Recent surveys in Tanzania have also confirmed the presence of large-tooth sawfish (*Pristis microdon*) that are still captured occasionally from most localities on the mainland coast, including in Tanga (Gill Braulik, WCS, per comm., 2014). All sawfish are listed on Appendix 1 of CITES. They are the sole living family Pristidae within the order Pristiformes. Guitarfish also occur in the WIO, but there are no available data. Since they are likely to be exploited, they are probably highly depleted.

3.8.2 Invertebrates

The octopus, *Octopus cyanea*, forms the basis of important fisheries in the proposed TBCA. Research conducted on the Tanga coast prior to the establishment of TACMP indicates that densities of octopus were comparatively low with about 0.05 individuals/50m^2, possibly due to severe fishing pressure (Wells et al., 2007). However, octopus species grow extremely fast, increasing in weight by up to 200g in 10 days, and they can potentially support a highly productive fishery if it is well-managed. Population trends within the proposed TBCA should be carefully explored for that purpose.

The Coconut crab (*Birgus latro)* is endemic to the lower Mpunguti Island, having previously been more widespread. This is the only member of the genus *Birgus* and is the largest land-living arthropod.

Spiny and slipper lobsters are largely exploited and reported within the proposed TBCA area. A 1995 survey on the Tanzanian side of the border found low counts of lobsters on coastal and inner patch reefs, and no dedicated surveys have been conducted since then. Reef health monitoring recorded that spiny lobster densities seemed to vary largely between closed and open reefs and tended to be higher on closed reefs. Therefore, they should be continuously monitored.

Low counts of giant clams *(Tridacna* spp.) and spider conches *(Lambis* spp.) were recorded for coastal and inner patch reefs in the vicinity of the TACMP. Populations seem to have remained relatively stable since that time.

3.8.3 Marine Mammals

There are 37 species of marine mammals in the WIO. This includes 8 baleen whales, 2 or 3 sperm whales, 13 toothed whales, 13 dolphins, and 1 dugong. The eastern African coastline harbours important breeding grounds for several whale species. About 17 whale and 13 dolphin species are thought to occur in Mozambique, Tanzania, and Kenya. (Berggren and Coles, 2009). The exact number is yet to be determined as marine mammal surveys in the WIO have not been thorough. Whales and dolphins are subject to several chronic dangers, such as becoming entangled in fishing nets and drowning. Chemical pollution (heavy metals, pesticides, and other toxins) can also accumulate in their bodies as a result of ingesting contaminated prey. Marine debris, particularly plastics, is easily mistaken for food. Deep-water beaked whales and delphinids are also sensitive to acoustic disturbance caused by offshore exploration for oil and gas (Samoilys et al., 2015).

3.8.3.1 Dugongs

The dugong (*Dugong dugong*) is considered endangered in eastern Africa with the last remaining viable population (>300) found in the Bazaruto Archipelago in Mozambique. The dugong once ranged from Somalia to Mozambique and across to western Madagascar (WWF, 2004), but numbers have plummeted since the 1960s. The dugong is often fished for its meat, and it is also a common accidental victim of seine, gillnet, and trawl fishing. Habitat destruction and human encroachment have also contributed to its decline.

Dugongs are protected in both Kenya and Tanzania, yet their numbers continue to decline. In northern Tanzania, Dugongs were known to inhabit seagrass beds off the Tanga coast. Today, sightings are highly irregular with one caught in 2000 at Buyuni near Pangani and another sighted in May 2006 by divers at a 10m depth near Kigombe. Experts think that a small population might still exist near the Kenyan border at Mbaya/Kigomeni.

In Kenya, it is believed that dugongs may now remain only in very small numbers in the Lamu-Kiunga region (Dutton, 1998) and in Funzi Bay in the south of the country. There has been only one recent sighting in the northern area of Lamu-Kiunga. One dugong has been sighted each year (2007–2009) in Funzi Bay in southern Kenya. There have also been two sightings off Kisite-Mpunguti Marine Reserve further south (Samoilys et al., 2015).

3.8.3.2 Whales

Humpback whales, *Megaptera novaeangliae*, pass by the proposed TBCA during their annual south-north-south migration. This species is listed as *Vulnerable* (IUCN Red List). Like many whales, they feed in the Antarctic but breed further north in the tropics and subtropics during the austral winter. Most of the humpbacks are mothers with calves, and the busiest months are July to September. Those animals migrating past the proposed TBCA are believed to be part of a subpopulation comprising more than 6,000 animals from South Africa to Kenya. Evidence suggests these WIO humpbacks may be divided into two distinct genetic substocks (the mainland and the islands), while the Comorian substock may represent a connection between the two. Recent observations suggest Mozambique’s Bazaruto Archipelago is a major wintering ground for humpbacks with significant concentrations around Zanzibar as well.

All information from Mozambique, Tanzania, and Kenya contributes to a greater understanding of migration routes, behaviour patterns, population abundance, and threats (Richmond and Bisang, 2009). In 2011, nearly 2,000 sightings were recorded between June and December: ~1,300 in southern Mozambique, 572 in Tanzania, and 69 in Kenya (Samoilys et al., 2015).

Minke, sperm, and pilot whales, as well as orcas, have periodically been sighted off the Kenyan coast and could be occasional visitors to the proposed TBCA.

3.8.3.3 Dolphins

There are a handful of coastal dolphin species that are likely to be encountered in the proposed TBCA. This includes the spinner (*Stenella longirostris*), humpback (*Sousa chinensis*), and Indo-Pacific bottlenose dolphin (*Tursiops aduncus*). The spotted dolphin (*Stenella attenuata*) may also occur within the coastal waters in the area, although they are a more oceanic species. The Kisite-Mpunguti area in southern Kenya, which includes Kisite-Mpunguti Marine Protected Area (38 km^2), has been recognised for its diverse ecosystems and habitats including coral reefs, seagrass meadows, and mangrove forests. This supports a rich biodiversity that includes sea turtles, dolphins, whales, and coral reef fish species. This area has 2.8 times the biomass of the Tanga district in northern Tanzania (McClanahan et al., 2006) and the highest number of species recorded in visual transects along the Kenyan coast (McClanahan et al. 2010), highlighting the ecological importance of the area as a food resource for Indo-Pacific bottlenose dolphins.

All four dolphin of these species have high conservation value. Their coastal ranges, life history, and habits make them susceptible to harm from human activity, causing them to serve as an indicator species for the broad impact of human encroachment on the coastal marine environment (Samoilys et al., 2015)

3.8.4 Marine Turtles

All five of the WIO species of marine turtles are found in the proposed TBCA waters: the olive ridley (*Lepidochelys olivacea*), green (*Chelonia mydas*) hawksbill (*Eretmochelys imbricate*), leatherback (*Dermochelys coriacea*), and loggerhead turtle (*Caretta caretta*). The species with the greatest abundance in the WIO is the green turtle, followed by the hawksbill. All five species are on the IUCN Red List either as *Critically Endangered* (hawksbill, leatherback*)* or *Endangered* (green, olive ridley, and loggerhead) (Samoilys et al., 2015). While the area is not recognised as a major turtle nesting site in eastern Africa, it encompasses important feeding grounds and is likely to support foraging of all five species. The feeding grounds of the bottom-feeding sea turtles (green, hawksbill, olive ridley and loggerhead) include seagrass beds, coral reefs, sand and mud flats, and mangrove ecosystems, all of which are prevalent in the proposed TBCA. Turtle populations in Tanzania and Kenya have generally declined, largely due to the loss of their nesting sites (e.g., Maziwe Island south of the TACMP no longer supports nesting populations of these species), but also due to incidental and deliberate capture in gill nets. Pangani District, south of the proposed TBCA, is still considered an important feeding and nesting area for marine turtles (CBD, 2012). The taking of turtles is prohibited in both Tanzania and Kenya.

3.8.5 Shore and Seabirds

The mangrove swamps, coastal wetlands, salt pans, and sand banks in the proposed TBCA provide suitable feeding and roosting habitats for a number of bird species, such as egrets and migrant waders. Important species that can be found on this coastline include the greater sand plover (*Charadrius leschenaultii*), curlew sandpiper (*Calidris ferruginea*), and crab plover (*Dromas ardeola*). Kibo Saltpans (300 ha) in northern Tanga is an Important Bird Area. An area 4,400 ha South of Tanga and just outside the TACMP is another Important Bird roosting / feeding area.

Some of the offshore islands in the proposed TBCA provide important breeding localities for seabirds. Kisite Island is an Important Bird Area (IBA), hosting species such as the sooty tern (*Sterna fuscata*), large numbers (up to 1,000 breeding pairs recorded) of crested tern (*Thalasseus bergii*), and roseate terns (*Sterna dougallii*) (CBD, 2012).

3.9 Social context

3.9.1 Kwale County Kenya[7]

On the Kenyan side, the TBCA falls within Kwale County. This county is one of four Kenyan counties that lie on the coast. The TBCA falls within the two sub counties of Msambweni and Lunga Lunga (see **Error! Reference source not found.Error! Reference source not found.**), which have an estimated population on 185,983 and 245,541 respectively, with an average population density of 512 and 86 people per km^2 (KCG, 2018). This region has experienced significant population growth over the past few years.

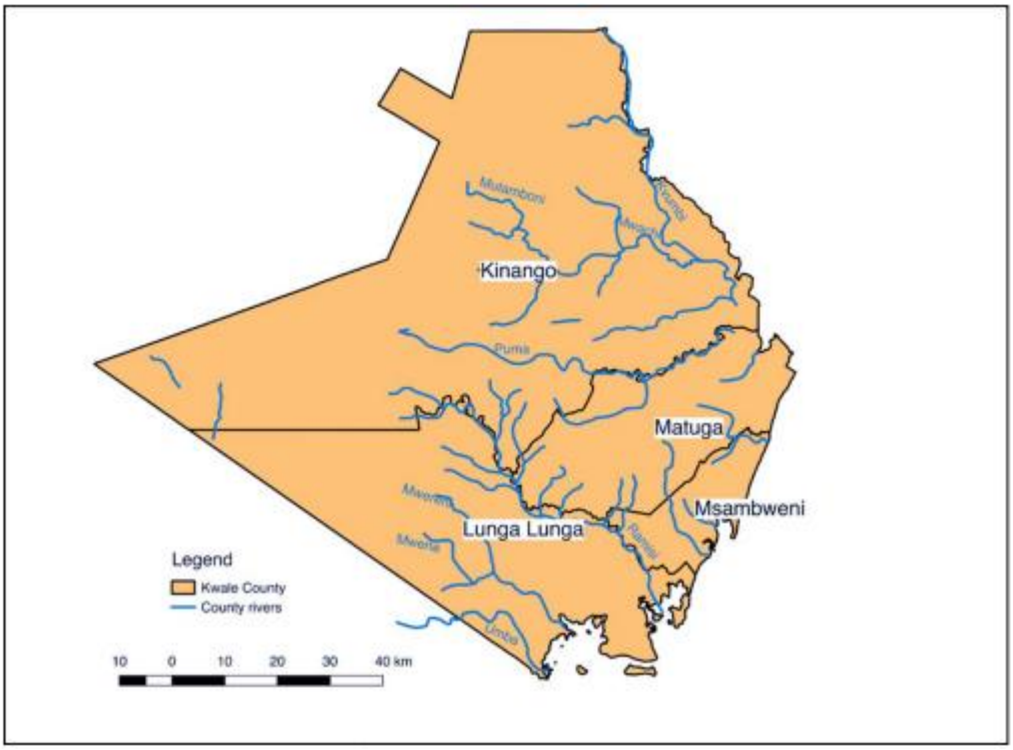

Figure 3-8: Kwale County constituencies (Kwale County Government, 2018)

The reported Gross County Product for 2017 was KES 86.278 million, or approximately US$ 742 million. This accounts for only 1.1% of total gross value added (GVA) for the country. Agriculture, forestry, and fishing made up the bulk of this, accounting for 46%, followed by Accommodation and food service activities at 8%; real estate activities at 7%; and finally trade and repairs, financial services, and education each accounting for 6%.

It is also important to note that Kwale contributed almost 12% to the country's total accommodation and food services revenue, pointing to the important role of tourism in the region. Further research, through primary data collection, demonstrates this as it shows that over 180 hotels exist within the Kenyan portion of the TBCA.

[7] Kwale County Integrated Development Plan (2018-2022)

Fuelwood remains the primary source of energy for cooking, with almost 72% of households in the county relying on this energy source. This is followed by over 12% using charcoal, with kerosene and LPG coming in at around 7.7% and 6.6%, respectively.

3.9.2 Tanga County Tanzania[8]

The proposed TBCA falls into the Tanga region on the Tanzanian side of the border. This region falls squarely within the boundaries of the Mkinga district (see **Error! Reference source not found.**). The population figures for this district were estimated to be around 118,000 in 2011, with an average annual growth rate of 1.27%, putting the population at an estimated 134,000 in 2021. This means the average population density is around 45 people per km^2.

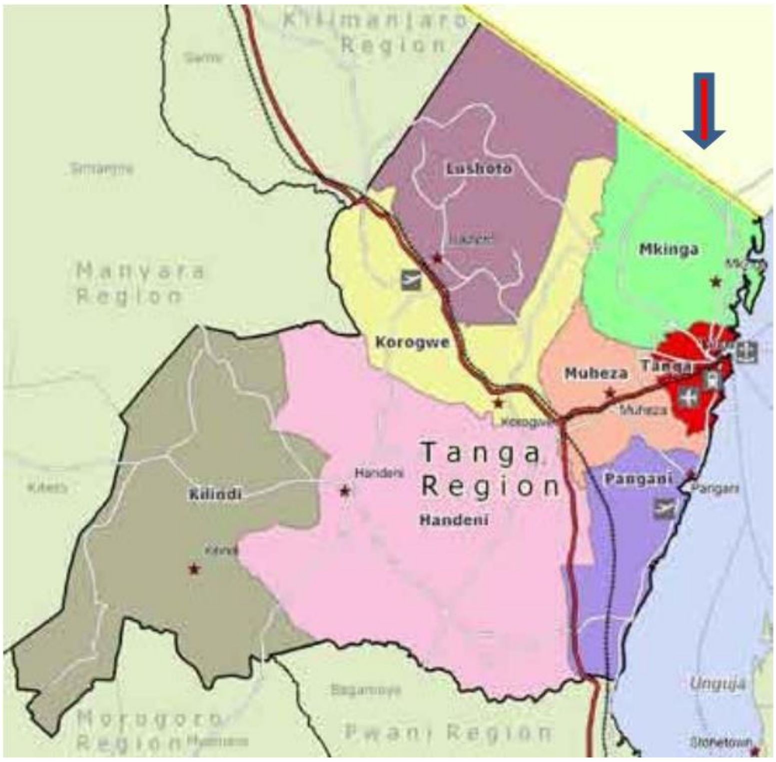

Figure 3-9: Mkinga District position within the Tanga region of Tanzania (from Aluri, 2013)

Over 80 percent of the local population is reported to be employed in the agricultural sector, while only 30 percent of a total of 250 thousand hectares of arable land is under cultivation. Approximately half of the cultivated land appears to be used for growing cash crops, with the other half being devoted to subsistence. Only small a fraction of commercial farming takes place, and livestock keeping is the second largest contributor to livelihoods in the district.

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[8] Mkinga District Council Integrated Development Plan (2011/12-2015/16)

Artisanal fishing is a key source of income in Mkinga. There were reported to be 21 fishing villages, with a total of 2,086 fishermen operating 396 small fishing vessels. An additional 70 seaweed farmers, 10 oyster dealers, and 20 fish farmers were also reported. The sector is reported to be struggling, as the industry has been beset by a number of challenges, namely illegal fishing and thus unsustainable harvest of fish resources; limited number of fisheries extension officers; poor handling of fisheries cases in the local magistrates courts; and rampant mangrove cutting, among other causes (MDC, 2011).

It is reported that most buildings in the Mkinga district are of very rural nature, with buildings being built "*by using wooden poles tied by rope and thin wooden members (fito), mud and thatched with palm leaves (makuti)*" (MDC, 2011). It is likely that few houses have access to electricity or piped water.

3.9.3 Infrastructure

No major ports exist within the proposed KT-TBCA. There are a number of fish landing sites situated in the numerous fishing villages on both sides of the border.

The Kenyan side of the border boasts a relatively well-developed road network, with tarred roads connecting most of the region, including the towns of Msambweni, Diani, Shimoni, Majoreni, and Vanga. Secondary roads provide access to other smaller villages.

On the Tanzanian side, there is a tarred road that runs through the TBCA between Parangu and Moa, with a secondary road running up from Moa that connects the smaller coastal settlements of Mayomboni and Mahandakini to the border with Kenya.

4 The ecosystem services of the KT-TBCA

4.1 Ecosystem services framework selection

Since the inception of the Millennium Ecosystem Assessment (2005), there have been a number of frameworks established to further disaggregate and classify the benefits people derive from ecosystem services to allow for a thorough assessment of the economic value of these benefits. Amongst these are The Economics of Ecosystems and Biodiversity (TEEB, 2010), the Common International Classification of Ecosystem Services (CICES, 2013), and the framework developed by the International Panel on Biodiversity and Ecosystem Services (IPBES, 2019). Additional details about these frameworks can be found in **Error! Reference source not found.**. While each of these frameworks attempt to build upon one another, they essentially follow a similar logic, where ecosystem services and their derived benefits are classified into three broad categories, namely provisioning services, where humans derive direct material benefit in the form of nutrition, energy sources, and raw materials (including biochemical and genetic materials); regulatory services, where direct and indirect benefits are derived in the form of regular flows of biotic and abiotic components of ecosystems that allow for the regular, effective functioning of ecosystems; and cultural services, where an intangible benefit is received in terms of intellectual, spiritual, and symbolic significance attached to certain aspects of the ecosystem and environmental infrastructure. A fourth category is added in some cases to distinguish between regulating and supporting services in a specific delineated ecosystem and the global system as a whole. This may include the maintenance of options (IPBES); genetic diversity, biodiversity, and habitat (MEA, TEEB, IPBES); and largescale planetary processes, such as nutrient cycling and soil formation (MEA) and evolutionary or biological processes (IPBES). These frameworks contain essentially the same services and processes, differing only slightly in where or how those processes are classified.

Two key distinctions are explicitly defined by the IPBES that are tacitly implied within the other frameworks. These relate to the manner in which the benefits to people are derived from ecosystem services as well as the role played by social and cultural factors in the valuation of these benefits. First, regarding the benefits derived from ecosystems, the IPBES framework explicitly considers and distinguishes between the conversion of ecosystem services to benefits in terms of "nature's contributions to people," or the role that ecosystem services play in relation to the human institutional and physical systems, and the neutral processes whereby human systems derive benefits from natural systems without the need for any conversion or additional effort, defined as "nature's gifts to people." The second distinction of the IPBES framework relates to the manner in which it explicitly emphasises the importance of relational value of the benefits derived by different social and cultural groups from ecosystem services. Both these distinctions, while valuable, can be seen as implicit within the frameworks of the MEA, TEEB, and CICES. In the economic valuation of benefits derived from ecosystem services, specialists must consider the benefits received from the natural systems in relation to the value they represent in the social, cultural, and economic systems in which they occur. It is understood by former classifications that it is the interplay between the human and natural systems in which the value of benefits to humans can be best defined. There is value in the explicit acknowledgement of the interactive role played by the various social, economic, and cultural systems with the ecosystems under review, irrespective of the specific classification.

In the valuation of ecosystem services (ES), all the above frameworks are useful and provide insight. For the purposes of this study, we have used a blend of the ES categories laid out in the MEA and TEEB (as summarised in Table 4-1 on the following page). Moreover, our application of CRA methodology enables us to evaluate the causal linkages that IPBES seeks to define.

Table 4-1. Review and comparison of popular Ecosystem Service Frameworks commonly utilised in classifying natural benefits.

Ecosystem Services Typology as per MEA (2005)	Ecosystem Services Typology as per TEEB (2010)	Ecosystem Services Typology as per CICES (Haines-Young & Potschin, 2013)	Natures Contribution to People (NCP) as per IPBES (IPBES 2018; Diaz et al 2018, Kadykalo et al 2019)
Frames Ecosystem Services	*Frames Ecosystem Services*	*Frames Ecosystem Services using a hierarchical system*	*Frames the benefits, which drives the consideration of variation in benefits between groups of beneficiaries.*
Provisioning Services - Food - Fresh Water - Fibre - Fuelwood - Genetic resources - Biochemicals	**Provisioning Services** - Food - Fresh water - Raw materials - Genetic resources - Medicinal resources - Ornamental resources	**Provisioning** - Nutrition o biomass o water - Materials o biomass, fibre o water - Energy o biomass based energy sources o mechanical energy	**Material NCP (includes non-material elements)** 11. Energy 12. Food and feed 13. Materials, companionship, and labour 14. Medicinal, biochemical, and genetic resources
Regulating Services - Climate Regulation - Disease Regulation - Water Regulation - Water Purification	**Regulating Services** - Air quality regulation - Climate regulation - Moderation of extreme events - Regulation of water flows - Waste treatment - Erosion prevention - Maintenance of soil fertility - Pollination - Biological control	**Regulation and Maintenance** - Mediation of wastes, toxics, and other nuisances o mediation by biota o mediation by ecosystems - Mediation of flows o Mass o Liquids o gaseous/airflows - Maintenance of physical, chemical, and biological conditions o lifecycle maintenance, habitat and gene pool protection o pest and disease control o soil formation and composition o water conditions o atmospheric composition and climate regulation	**Regulating NCP** 1. Habitat creation and maintenance 2. Pollination and dispersal of seeds and other propagules 3. Regulation of air quality 4. Regulation of climate 5. Regulation of ocean acidification 6. Regulation of freshwater quantity, location, and timing 7. Regulation of freshwater and coastal water quality 8. Formation, protection, and decontamination of soils and sediments 9. Regulation of hazards and extreme events

			10. Regulation of detrimental organisms and biological processes
Ecosystem Services Typology as per MEA (2005)	Ecosystem Services Typology as per TEEB (2010)	Ecosystem Services Typology as per CICES (Haines-Young & Potschin, 2013)	Natures Contribution to People (NCP) as per IPBES (IPBES 2018; Diaz et al 2018, Kadykalo et al 2019)
Frames Ecosystem Services	*Frames Ecosystem Services*	*Frames Ecosystem Services using a hierarchical system*	*Frames the benefits, which drives the consideration of variation in benefits between groups of beneficiaries.*
Cultural Services - Aesthetic values - Spiritual/ religious values - Education - Recreation and ecotourism - Inspiration - Sense of place - Cultural heritage	**Cultural and Amenity Services** - Recreation, mental and physical health - Tourism - Aesthetic appreciation - Spiritual experience and sense of place	**Cultural Services** - Physical and intellectual interactions with ecosystems and land-/seascapes o Physical and experiential interactions o Intellectual and representational interactions - Spiritual, symbolic, and other interactions with ecosystems and land-/seascapes o Spiritual and/or emblematic o Other cultural outputs	**Non-Material NCP (includes material elements)** 15. Learning and inspiration 16. Physical and psychological experiences 17. Supporting identities
Supporting Services - Nutrient Cycling - Soil Formation - Primary Production - Habitat - Biodiversity	**Habitat Services** - Habitat for species - Maintenance of genetic diversity		**Material, Non-material and Regulating NCP** 18. Maintenance of options **Nature (Intrinsic) E.g.:** - Genetic Diversity, Species diversity - Evolutionary and ecological processes - Gaia, Mother Earth - Animal welfare / rights

4.2 Environmental Valuation Techniques: A Brief History and Future Challenges

The evolution of ecosystem services valuation techniques is characterised by a historically increasing demand for precise quantification of the values of these goods and services. It is also driven by various incidences of environmental disasters (Brown 2000). This drive has continued with the need to accurately assess the environmental costs and benefits of various conservation and development objectives.

One widely used approach employed by economists for decision-making support is the cost-benefit analysis (CBA). CBA was formalized in 1958 with the publication of the “Green Book,” a document intended to provide federal agencies in the USA with a consistent conceptual framework for conducting a benefit-cost analysis. Thereafter, over a period of 5 decades a variety of valuation methods were developed to estimate various aspects of value related to ecosystem services benefits. Methods such as the travel cost method (TCM); hedonic valuation method (HVM); contingent valuation method (CVM); and conjoint analysis (CA) each have separate interesting development histories.

All of the above, as well as other methods, follow one of two broad approaches and stated- or revealed preferences methods to value ecosystem assets and their services. In the stated preference method, economists ask people to place a value on ecological resources. In the observed behaviour (revealed preferences) method, economists study the actual choices of people to infer the value people place on ecological resources. Both of these approaches, however, have limitations. Whereas these valuation techniques are suitable for measuring provisioning and cultural services, they are not able to measure the value of regulating services. Today, the production function approach is considered to be best suited as a valuation method for these intermediate ecosystem services. This is because it addresses and overcomes many of the valuation weaknesses (Crafford, 2016). The limitations of this method, however, lie in its complexity, as it requires a wide range of reliable data.

Supporting services are considered so fundamental to ecosystem functioning that, without it, ecosystems would collapse. They are therefore not valued explicitly (Crafford, 2016).

4.3 Ecosystem Services

Ecosystem services are dependent upon the extent (size) and state (functionality) of the ecosystem assets defined above. Despite later definitions (refer to section **Error! Reference source not found.**), the MEA definition of ecosystem services remains an important starting point in ecosystem services valuation:

- Provisioning services
- Cultural services
- Regulating services

- Supporting services.

Provisioning services covers the production of food, water, fuel, fibres, biological materials, and genetic resources (these services have previously been referred to by other authors as environmental goods). Cultural services include non-consumptive uses of the environment for recreation, amenity, spiritual renewal, and so forth. The two categories of services comprise the services that are consumed by humans and can therefore also be defined as final consumption ecosystem services.

Regulating services includes the regulation of various cycles (e.g., climate and hydrology), the absorption of pollutants, storm buffering, erosion control, etc.

The supporting services cover the basic ecosystem functions and processes that underpin all other services. They are therefore embedded in those services and are not evaluated separately (more on this in the section on valuation).

Please see **Error! Reference source not found.** for a preliminary analysis of ecosystem services for the KT-TBCA. Each of these services may be yielded by the KT-TBCA system and will be evaluated in the work to follow in the later phases of this assignment.

Table 4-2. The categories for ecosystem services (ES) and its relevance to the KT-TBCA

Category of Ecosystem Services	Types of Services in the Category	Description	Note on Valuation
Supporting	Soil formation	Sediment retention and the accumulation of organic matter underpin other services	Supporting services are so fundamental and embedded in natural process that they are not valued individually
	Photosynthesis	A fundamental service provided by flora	
	Primary production	Rate of biomass produced by an ecosystem	
	Nutrient cycling	The process of the storage, recycling, processing, and acquisition of nutrients, which underpins all other ecosystem services	
	Water cycling	Affects climate, chemistry and biology and is fundamental to the delivery of all ecosystem services	
Regulating	Air quality regulation	Ecosystems both contribute and extract chemicals from the atmosphere that influence many aspects of air quality	This service is unlikely to be at risk in this case
	Climate regulation	Ecosystems influence climate both locally and globally. At a local scale, changes in land cover can affect both temperature and precipitation. At a global scale, ecosystems play an important role in	Several habitats in the entity (e.g., mangroves, coastal forests, and

Category of Ecosystem Services	Types of Services in the Category	Description	Note on Valuation
		the carbon cycle by either sequestering or emitting greenhouse gases.	seagrass beds) sink carbon. This ES needs to be assessed.
	Water regulation	The timing and magnitude of runoff and flooding can be strongly influenced by changes in land cover, including in alterations that change the water storage potential of the system such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas. Water regulation is also relevant to groundwater, including baseflow, near-surface water flows, recharge of aquifers, and salinisation of groundwater.	This ES has several aspects of relevance and needs to be assessed, including both surface water and groundwater regulation.
	Erosion regulation / sediment movement	Sediment movement is an important ecological process that can be disputed either by excessive (more than natural) erosion or obstruction of sediment movement pathways.	This ES is relevant and needs to be assessed.
	Water purification and waste treatment	Ecosystems can be a source of impurities in freshwater but can also help filter and decompose organic wastes introduced into inland waters and coastal and marine ecosystems.	This ES may be relevant to the study as the TBCA entity is a receiver of terrestrial pollution.
	Disease regulation	Changes in ecosystems can directly influence the abundance of human pathogens such as cholera and can alter the abundance of disease vectors such as mosquitoes.	This ES is unlikely to be relevant to the TBCA entity.

Category of Ecosystem Services	Types of Services in the Category	Description	Note on Valuation
	Pest regulation/Biological control	Ecosystem changes affect the prevalence of crop and livestock pests and diseases.	This ES is unlikely to be relevant to the TBCA entity.
	Pollination	Ecosystems that support pollinators are often important to the success of economies and genetic diversity. This refers to animal-assisted pollination done by bees, rather than wind pollination	This ES may be relevant to the TBCA entity, particularly the mangrove and coastal forest habitats.
	Detoxification	Biological processes are involved in the sequestration or detoxification of various chemical wastes introduced into the environment.	This ES is unlikely to be relevant to the TBCA entity.
	Natural hazard regulation	Storm protection, in the presence of coastal ecosystems such as mangroves and coral reefs, can dramatically reduce the damage caused by hurricanes or large waves.	This ES is likely to be relevant to the TBCA entity.
Provisioning	Food	Provisions of food from crops, livestock, marine, and freshwater capture fisheries, aquaculture, or wild plant and animal food products	Fish as food provision is an important ES in the entity.

Category of Ecosystem Services	Types of Services in the Category	Description	Note on Valuation
	Fresh water	Ecosystems provide storage and retention of water for domestic, industrial, and agricultural use.	Saltwater intrusion into nearshore freshwater systems is a hazard. Therefore, this ES is of interest.
	Wood and fibre	Direct benefits from wood for timber and pulp, biomass energy (fuelwood and charcoal consumption) and from the production of agricultural fibres such as cotton, silk, and hemp	Wood and fibre provision is an important ES in the entity.
	Biochemical and pharmaceutical products	Ecosystems provide natural products that have been used for biochemicals and pharmaceuticals and other natural products (such as cosmetics, personal care, bioremediation, biomonitoring, and ecological restoration.	This ES may possibly be relevant to the entity and needs further investigation.
	Genetic resources	The exploration of biodiversity for new products and industries, such as medicine, genes for plant pathogen resistance or ornamentals. Conserving genetic diversity maintains the potential to yield larger future benefits and ensures options for adapting to changing environments.	This ES is likely be relevant to the entity and needs further investigation.

Category of Ecosystem Services	Types of Services in the Category	Description	Note on Valuation
Cultural	Cultural diversity	The diversity of ecosystems is one factor influencing the diversity of cultures and the identity of specific cultures.	This ES is likely be relevant to the entity and needs further investigation.
	Spiritual and religious values	Many religions attach spiritual and religious values to ecosystems or their components.	This ES is likely be relevant to the entity and needs further investigation.
	Knowledge systems (traditional and formal)	Ecosystems influence the types of knowledge systems developed by different cultures.	This ES is likely be relevant to the entity and needs further investigation.
	Educational values	Ecosystems and their components and processes provide the basis for both formal and informal education in many societies.	This ES is likely be relevant to the entity and needs further investigation.
	Inspiration	Ecosystems provide a rich source of inspiration for activities such as art, folklore, national symbols, architecture, and advertising.	This ES is likely be relevant to the entity and needs further investigation.

Category of Ecosystem Services	Types of Services in the Category	Description	Note on Valuation
	Aesthetic values	Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, 'scenic drives,' and the selection of housing locations.	This ES is likely be relevant to the entity and needs further investigation.
	Social relations	Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies.	This ES is likely be relevant to the entity and needs further investigation.
	Sense of place	Many people value the 'sense of place' that is associated with recognized features of their environment, including aspects of the ecosystem.	This ES is likely be relevant to the entity and needs further investigation.
	Cultural heritage values	Many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species that serve to remind them of historic roots.	This ES is likely be relevant to the entity and needs further investigation.
	Recreation and ecotourism	People often choose the location for spending their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.	This ES is relevant to the entity and needs further investigation.

4.4 More on Selected Ecosystem Services

The suite of ecosystem services includes primarily the following, which have been adapted from the MEA (2005) and TEEB (2013) classification systems:

- Food provisioning – the supply of food from the natural environment, derived from ecological processes with minimal direct human influence on production.
- Fresh water (quality and quantity) – potable water that can be used for cooking, drinking and washing by people.
- Raw materials and energy sources – naturally harvested materials used by people for use in various human activities, such as heating sources for cooking.
- Biochemical and genetic resources – biological and genetic material used by humans in the production of medicines, alginates, or for improved breeding practices.
- Ecotourism and recreation – tourist activity focused on natural environments.
- Education and inspirational value – the process of learning that is dependent on the natural environment, the act of taking pleasure, and finding renewed vision, hope and enjoyment from natural environments.
- Sediment regulation – the prevention or slowing of the process of losing soil resources through the action of water and/or wind.
- Habitat – the geographical area and environment in which a particular species resides.
- Landscape and amenity value – appreciation of a locale's characteristics by humans.
- Regulation of extreme events – the lessening of the energy associated with storms and tidal waves; and
- Water purification and waste management – the removal of impurities and wastes from water.
- Climate regulation – the suite of biological and abiotic processes that regulate atmospheric processes and weather patterns.

4.4.1 Food Provisioning

The socio-economic profile of the communities in the area indicate that they are highly reliant on the direct provisioning of food from the ecosystems, particularly through fishing. Fishing is known to be the primary source of calories and income for many rural communities along the East African Coast.

Many near fish species are reliant on the various habitats found in the proposed TBCA. The long-term sustainability of this resource is linked to the healthy functioning of these coastal and marine ecosystems. Overfishing is a global threat to fish populations, and experience has shown that protected areas in which fishing is limited can have a significant impact on fish population on a much broader scale than just in the MPAs themselves.

4.4.2 Raw Material Provisioning

The use of mangroves for fuel (firewood and charcoal) and building timber has been found to be a major source of deforestation along the East African Coast (GoK, 2017; Muhando, 2011).

The use of such resources is integral to the livelihoods of local communities, however over-use and degradation may effect on the sustainability of these resources.

4.4.3 Biochemical and Genetic Resources

Biochemical resources are biological compounds and materials that are used in medicinal or other applications such as the production of alginates, food additives or biocides. While in some instances these resources are commercialised, they are often used directly in populations that are directly reliant on the natural provisioning services of ecosystems. Genetic resources are the genetic material contained in species. These resources do not have any present-day direct use value; instead, they provide value in the form of an option value and an indirect use value.

The option value of these resources depends on whether there is an endemic population at risk of extinction or a risk of genotype loss.

The genetic value of species will generally be higher if they are endemic to the area (implying that there are no other species that are perfect substitutes). Genetic resources that are not currently exploited are said to have both an option value, the value to future potential users of that resource, and a quasi-option value, the value of the yet to be uncovered information they provide.

The valuation of genetic resources is often linked to the valuation of bioprospecting, i.e., the value of ecosystems as "… storehouses of undiscovered pharmaceutical products or precursors …" (Naidoo and Ricketts 2006). Such ecosystem service values have recently been assessed by, for example, measuring the willingness of pharmaceutical companies to pay for the potential that an ecosystem may eventually provide new marketable products.

The beneficiaries of this set of ecosystem services are various individuals (including traditional healers) or firms in the healing, pharmaceutical, technology or trading sectors, as well as their clients, who may in future gain income or derive other utility from a particular genetic resource.

The indirect use value emanates from the value of species in the functional diversity of the system. In such cases, loss of a species (i.e., a reduction in biodiversity) may reduce the resilience of a system. Such effects are valued through the regulating services.

4.4.4 Tourism and Recreation

Tourism is a major revenue generation activity in the region, and it is expected that a significant portion of the benefits conferred by declaring an MPA will have the potential to be monetized through enhancing environmentally responsible ecotourism.

Initial research has shown that a significant tourism industry already exists in the Kenyan portion of the TBCA. Such tourism activity benefits local communities through employment in the industry as well as through providing a boost to a range of related industries linked to providing goods and services to the industry.

An investigation will be conducted to determine the current size of this industry and understand how it may benefit from the declaration of a protected area.

4.4.5 Natural Hazard Regulation - the Role of the KT-TBCA in the Metacommunity

The estuaries on the East Coast of Africa are subject to cyclical natural effects, such as extreme floods and droughts, as well as human influences, such as coastal development and water pollution. Thus, the aggregate ecological condition of the collection of estuaries is vulnerable to environmental hazards faced by the KT-TBCA, and the overall functioning depends on there being at any one time enough protected estuaries to hedge against failure in others.

Because the KT-TBCA entity has high biodiversity, it is especially important in mitigating disaster risks to other African East Coast estuaries, since it is permanently available to service the recolonisation of other zones that may suffer disastrous loss of biodiversity.

All services identified as being linked to the metacommunity are closely linked to the protection of biodiversity.

4.4.6 Aesthetic

Landscape character is a foundation to several ecosystem services as discussed above. Of these, however, only the aesthetic service remains to be further investigated, specifically its relation to property values as its relation to recreational services is captured elsewhere.

4.5 Ecological Assets and Ecosystem Services

Each identified ES, unique to each asset class, is classified and assigned an appropriate valuation technique. The most appropriate classification system is used based on MEA[9] and TEEB[10] classifications, definitions, and nomenclature. The classified ES will be listed in the MPA asset register.

4.6 Measures of Value

It is important to understand that various measures of value exist and can be used for valuation techniques. The first important distinction to be made is between flows and stocks. Flows involve flows of benefits or costs that are measured over a defined time period, usually a year. They are akin to income statement items. These flows of benefits themselves can be measured through a variety of indicators such as revenue, or GVA.

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[9] "Millennium Ecosystem Assessment" - https://www.millenniumassessment.org/

[10] "The Economics of Ecosystems and Biodiversity" - http://www.teebweb.org/

Stocks are assets and are comparable to balance sheets items. Asset value can be measured through the discounted value of the ecosystem services that it produces, or through other suitable techniques.

4.7 Setting up a Valuation Framework

xIn setting up a valuation framework, the following broad steps need to be followed:

1. Develop a systems description – This describes the system analysed, the meta-system within which it is located, and any beneficiaries; and forms the basis for an informal valuation study.
2. Map the ecosystem services – This is a transactional mapping, following the most preferred ecosystem definition framework.
3. Select appropriate valuation techniques for each relevant ecosystem service – This selection is based both on relative importance of the ecosystem service and availability of suitable data.
4. Conduct the valuation process, including a comprehensive valuation of the status quo (and where necessary, baseline scenario).
5. Identify relevant scenarios and policy options and specify parameters for valuation.
6. Apply valuation methodologies to the identified scenario using the same process as per step 4.
7. Perform cost-benefit analyses by comparing the scenario to the status quo or baseline.

5 Comparative Risk Assessment

5.1 Overview

The detailed CRA below highlights the hazards associated with each of the ecological assets, then assesses the likelihood and consequence of those hazards impacting the ability of the assets to provide their associated range of ecosystems services. Table 5-1. Risks to ecosystem services per asset class in the KT-TBCA (a black box indicates no perceived risk, or ecosystem service is not material in terms of the asset). provides a summary of the aggregated risk levels to the ES's listed in the left column (as a function of likelihood and consequence of the risk manifesting as impact) associated with the ability of the natural assets, listed in the top row, to continue to provide these services at the assessed levels of impact. Expanded definitions of the metrics and indicators associated with this table are provided in the subsequent paragraphs and tables.

Table 5-1. Risks to ecosystem services per asset class in the KT-TBCA (a black box indicates no perceived risk, or ecosystem service is not material in terms of the asset).

KEY	Extreme	High	Medium	Low	N/A

Ecosystem Service Provided (MEA, 2003 & TEEB, 2013)	**Risk of Status quo Scenario to ES (L-Low; M-Medium; H-High; E-Extreme)**							
	Mangroves	**Seagrasses**	**Tidal Flats**	**Freshwater Systems**	**Coral Reef**	**Shelf Zone**	**Oceanic Zone**	**Fish Stock**
Food provisioning	E	E	H	H	E	M	L	E
Fresh water provisioning	L			M				
Raw materials (Fuel and Fibre)	E			M				
Biochemical and Genetic Resources	M	H	M	L	H	M	L	H
Carbon Sequestration	E	E	L	L	M	L	L	
Water Quantity Regulation	L	L	L	M				
Regulation of extreme events	E	H	H	M	H	L		
Waste Assimilation	E	E	M	H		L		
Sediment Regulation	E	E	H	H	E	L		
Landscape and Amenity Value	M	L	L	H	M	L	L	E
Ecotourism & Recreation	H	H	H	H	E	M	L	H
Educational and Inspirational Value	E	E	H	M	E	M	L	E
Aesthetic Appreciation	E	H	H	H	E	L	L	L
Spiritual & cultural heritage, Sense of place	H	H	H	M	M	L	L	E
Habitat	E	E	H	H	E	H	H	E

The risk assessment was conducted using a status quo assumption, i.e., the risk levels consider asset status with the assumption that the KT-TBCA has not been declared and hazard sources have not been mitigated. It is intended that this process will provide clarity on the impact declaring the KT-TBCA will have on the natural assets within its confines.

The summary presented in Table 5-1 can be considered from either the ES (column 1) or asset class (row 2) perspective. Consideration of the asset classes facilitates an understanding of the assets that are at greatest risk of providing diminishing or no ES. Consideration from the perspective of the ES currently rendered enables an understanding of the resilience of the landscape/seascape (i.e., all assets in the proposed KT-TBCA). This includes its ability to continue providing value should one or more specific asset class no longer be able to provide services.

Key findings of this CRA include:

- Four of the eight ecological assets identified show extreme risk of deteriorating ability to provide ongoing ecosystem services. These are mangrove forests, seagrass meadows, coral reefs, and fish stocks. This is largely due to the degradation from human disturbance through harmful practices.
- Of these, ecosystem services by mangroves appear to be the most heavily impacted. Mangroves are found to be under considerable pressure due to unsustainable harvesting as well as destruction to make space for alternative land use. Due to these impacts, over half of the ecosystem services provided by mangroves face extreme levels of risk without intervention.
- Seagrass meadows and coral reefs are also both under significant pressure, putting most of the ecosystem services with which they are associated at high to extreme risk. Harmful fishing practices have been found to be the most significant hazard impacting these ecosystem assets.
- The pressure placed on fish stocks from unsustainable fishing practices and the commensurate destruction of fish habitats is impeding the availability of ecosystem services. This means this asset is at extreme risk, which is particularly worrying when considering the vital role marine fish play in the diet of local populations. Unless addressed directly, this could have severe consequences.
- While freshwater systems are found to be under pressure, the potential for the declaration of a conservation area to mitigate the associated hazards is questionable, and the lack of any major rivers flowing into the system also somewhat mitigates the consequences of potential risks.
- None of the ecosystem services assessed were found to be immune to the impacts of hazards facing the underlying assets. Only two of the ecosystem services – freshwater provisioning, and water quantity regulation – exhibit levels of risk lower than medium.

5.2 CRA methodology

A comparative risk assessment (CRA) is used to:

- Systematically explore the chain of causality linking:
  - Hazards to ecosystem assets and
  - Ecosystem assets to ecosystem services
- Quantify the level of risk posed by hazards to ecosystem services
- Prioritise the ecosystem services that are to be valued

CRA is a method for assessing, comparing, ranking, and formally describing the risks in an environment with different elements and varying available data. This process is widely accepted as an approach to deal with a heterogeneous problem with environmental and developmental complexity. It also helps when it is necessary to draw together information from both explicit scientific sources, tacit knowledge, and relevant opinion.

Akin to ecological risk assessment, which is the process of predicting or estimating the likelihood and magnitude of adverse ecological effects that may arise as a result of one or more threats, it is a precursor to the ecosystem services valuation.

The output is a prioritised list of risks, with full diagnostic and causal descriptions for each priority risk. CRA provides an assessment and ranking of risks to an ecosystem that arise from its exposure to one or more hazards, where the elements at risk are the different components, processes, and feedback that make up the ecosystem, as well as its emergent properties such as its self-organising capacity.

The output of this element of the assessment is a prioritised list of environmental risks to the KT-TBCA that arise from the hazards identified. These hazards are to be assessed separately for each of the ecological or resource assets, with and without the mitigative effects of implementing the TBCA.

Ecological risk is the function of the likelihood and consequence of a hazard to which an ecological or resource asset is exposed. For this study, an asset is equivalent to a component of the ecosystem. Thus:

Risk = f(likelihood, consequence) of environmental effect on an ecosystem asset

The consequence of the hazard is the change in the service from the environmental effect of the development on the exposed asset. The asset is equivalent to the physical component of the ecosystem upon which a flow of ecosystem services depends. The environmental effect is any change in ecosystem service for each asset at risk, mitigated and unmitigated.

The systems analysis and asset identification above provide the identification of environmental services linked to each asset as well as their exposure - and vulnerability to, development. It also provides the basis for the systematic formulation of the chain of causality between environmental effects and marginal ecosystem services changes. Thus, the workflow for the CRA is as follows:

1. Hazard analysis determines and describes the causal effects of the hazards at a level of discrimination appropriate to the structure of the KT-TBCA entity.
2. Identification and description of potential development hazards
3. Specification of the array of hazards for each option that would arise from the development and determination of which asset(s) would be exposed to these hazards
4. Determination of the likelihood that a given hazard would realise for each asset-service combination, according to **Error! Reference source not found.**
5. Determination of the consequence of each hazard for each combination, according to **Error! Reference source not found.**
6. Assessment of the risk(s) according to **Error! Reference source not found.**
7. Ranking of the risks for each option, according to assessed risk levels
8. Description of each risk, including the underlying chain of causality between environmental effect and its consequence.

Table 5-2. Likelihood classes of a hazard causing a negative effect on ecosystem services rendered by the identified asset classes[11].

Likelihood Rating	Assessed Probability of Occurrence	Description
Almost certain	> 90%	Extremely or very likely, or virtually certain. Is expected to occur.
Likely	> 66%	Will probably occur
Possible	> 50%	More likely to occur than not
Unlikely	< 50%	May occur
Very unlikely	< 10%	Could occur
Extremely unlikely	< 5%	May occur only in exceptional circumstances

[11] Qualitative and quantitative classes of likelihood of a hazard (environmental effect, or resultant change in the flow of an ecosystem service) eventuating from the hazards faced by the KT-TBCA and of having an environmental consequence to a service from an environmental asset (adapted from the classification adopted by the IPCC (2007)).

Table 5-3. Qualitative measures of consequence to ecosystem services in the KT-TBCA arising from the hazards to which it is exposed.

Level of Consequence		Environmental Effect
1	Catastrophic	Substantial permanent loss of environmental service that requires mitigation or offset.
2	Major	Major effect on the asset or service that will require several years to recover and substantial mitigation.
3	Moderate	Serious effect on the asset or service that will take a few years to recover with no or little mitigation.
4	Minor	Discernible effect on the asset or service, but with rapid recovery, and does not require mitigation.
5	Insignificant	Negligible effect on the asset or service

Table 5-4. Levels of risk, assessed as the product of likelihood and consequence in the event of an environmental effect on an asset within the system.

Likelihood Rating	Consequence Rating				
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	L	M	H	E	E
Likely	L	M	H	E	E
Possible	L	M	H	H	E
Unlikely	L	L	M	H	E
Very unlikely	L	L	L	H	E
Extremely unlikely	L	L	L	M	H

5.3 Description of Hazards to Ecosystem Assets

The CRA method described above is ideally applied by ecosystem asset and to each ecosystem service. The assessment of priority hazards to the identified asset classes is described below. The hazards associated with each asset are described in general terms, with the likelihood and consequence of these hazards, i.e., the risk, being explored in more depth in the next section on ecosystem services.

5.3.1 Mangroves

Mangroves are at risk from a diverse suite of anthropogenic and natural hazards. In terms of anthropogenic hazards, direct hazards include over-utilisation of wood and leaf products and clear-felling and clearing for coastal development. Examples of such development commonly include housing and allied infrastructure, or infrastructure associated with food production, including salt production and Artemia culture[12], as well as shrimp farming. While significant signs of salt production ponds are visible on the Tanzanian side of the boarder, little information can be found on the extent of the damage this development has wrought on the associated mangrove habitats.

Indirect sources of anthropogenic hazards primarily include pollution entering mangroves, carried by rainfall runoff and stormwater. The composition of the runoff-contaminated pollutants is mediated by the nature and scale of the activities undertaken in the catchment. Catchment land use change contributes to pollution. It is well established that where conversion of natural land to other land use types occurs, erosion rates usually increase (over both the short- and long-term, depending on the new land's use[13]) (Dunne, 1979). Climate change effects that impact mangroves are increases in air and water temperature, changes in frequency and storm intensity of precipitation, and increases in atmospheric CO_2. Perhaps the most problematic hazard caused by climate change is sea level rise, which has been linked to death due to inundation on the seaward side of the mangrove forest (He et al., 2007) and changes to species composition (Gilman et al. 2008), both of which reduce productivity of the mangrove forest. Lastly, storm surges have the potential to damage mangroves by uprooting trees, causing coastal erosion, and destroying habitat for ecological assemblages that are important to the health of mangroves.

It is also important to acknowledge that the hazards described above do not occur in isolation, and the mosaic of hazards and interplay amongst certain hazards may amplify (or attenuate) each of the related hazards. An example of amplification of hazards would be the occurrence

[12] Artemia is a genus of brine shrimp commonly used as feed for larval fish and crustaceans. Artemia are often cultured in salt ponds, where their dormant eggs are harvested and sold to aquaculture facilities.

[13] Conversion of virgin forest to agriculture enhances erosion over the short to long term, while conversion to built environment usually results in enhanced erosion over the short term.

of a storm surge in a deforested mangrove forest causing greater damage to the mangrove and infrastructure than if the mangrove was healthy and not overharvested.

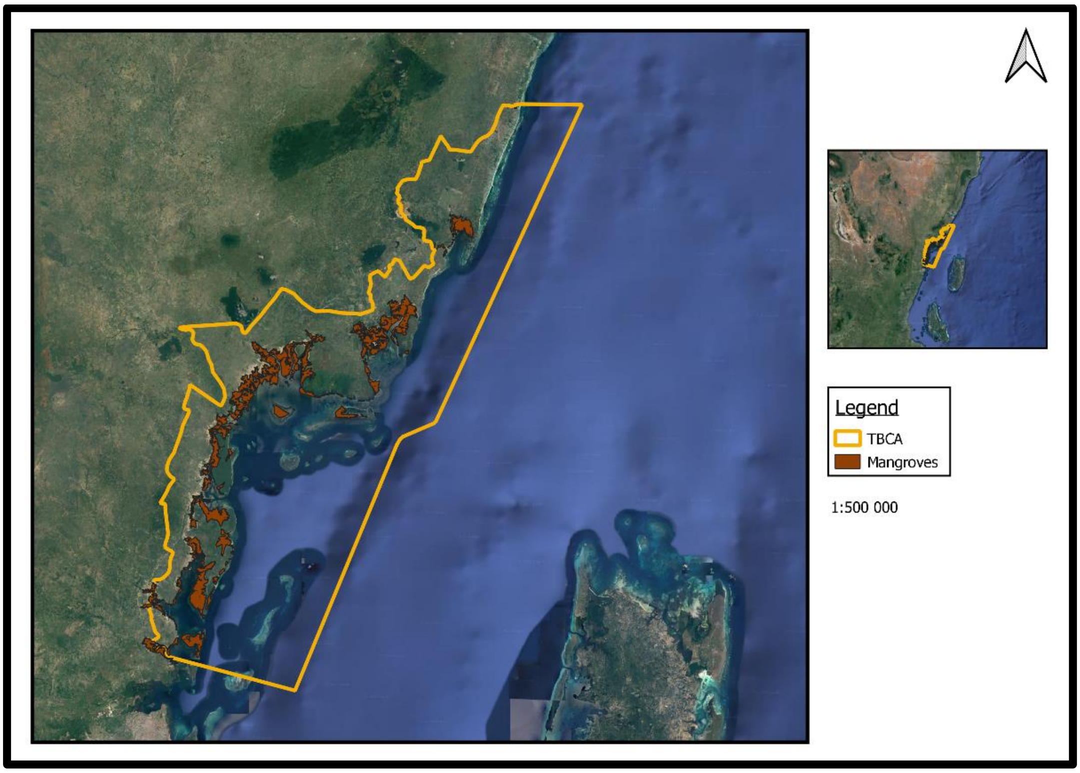


Figure 5-1. Mangrove cover within the proposed KT-TBCA (estimated to be around 9,000 to 11,000 ha)

With respect to the ecosystem services likely to be negatively affected by the hazards identified above, the comparative risk assessment process identified the following ecosystem services linked to the mangroves of the area as important in the context of the KT-TBCA:

- Carbon sequestration – Mangroves are known to be one of the most effective carbon sinks of any type of ecosystem.
- Ecotourism – The health of all ecosystem assets may be linked to ecotourism, as visitors generally pay to interact with pristine systems.
- Education and inspirational value – Mangrove ecosystems around the world each provide unique and varied opportunities for the building of scientific knowledge. Such intact systems also play an integral role in the development and passing on of indigenous knowledge, while also providing a sense of place and connection to the environment.
- Sediment regulation – One of the primary functions of mangroves is stabilising sediments against erosion, both from land and from the sea. The narrow continental shelf found in the region points to the importance of mangroves in ensuring that coastal erosion does not take place. They also provide stability for other ecological assets such as seagrass beds and corals.

- Habitat – Mangroves provide a key habitat for a wide range of species, including fish, birds, crustaceans, and other marine organisms.
- Raw materials and energy sources – Evidence points to intensive use of mangroves for fuelwood and timber in the greater region.
- Regulation of extreme events – The importance of intact mangroves in lessening of the energy associated with storms and tidal waves, both in terms of water and wind, is significant.
- Waste assimilation – Mangroves play a key role in regulating pollution from terrestrial sources by slowing its flow and creating an environment where harmful compounds can be broken down through biological and chemical processes.

As described above with respect to hazards, ES also occur as a mosaic and are the result of a complex interplay between biotic and abiotic factors and conditions. Perturbations in the form of hazards may diminish the variety and magnitude of ES provisioning. In cases where systems ecology is poorly understood, or large perturbations occur, some ES may be lost entirely from the system (Beisner, 2012). This is demonstrated in numerous examples of collapsed fisheries (most often due to shifts in food web interactions and overharvesting).

Information on the total extent of mangrove cover in the proposed TBCA is unclear. Geospatial data estimates it to be in the realm of 11,000 ha, showing an increase in mangrove cover of around 1,600 ha from 1996 to 2016 (Bunting, 2018; UNEP-WCMC, 2017). While this may be due to conservation and replating efforts on both sides of the border (Gazi Bay in particular has been implementing efforts to improve management of its mangrove systems (GoK, 2017) and various conservation have been declared before and during the period by both Kenya and Tanzania), there is a high probability that the accuracy of this data is subject to inconsistencies presented by changing technology and the commensurate remote sensing capability over time (Harcourt, 2018).

5.3.2 Coral Reefs

Coral reefs are susceptible to anthropogenic hazards. Reefs occurring adjacent to continental land masses are at greater risk than those in atolls as they lie in closer proximity to human activity. Direct hazards are pollution including domestic sewage and industrial effluents. These hazards can be exacerbated by catchment land use changes and coastal urbanisation. Coral reefs are also at risk from illegal fishing practises including dynamite and explosives fishing (a major issue in Tanzania) and overharvesting. Irresponsible tourism wherein reefs are damaged by divers and snorkelers can also be problematic in poorly regulated settings.

Coral reefs are also extremely susceptible to climate change impacts, specifically warming ocean temperatures and ocean acidification. While periodic, short increases in sea temperature do not usually result in coral bleaching, periods of sustained high sea temperatures cause the coral to expel their zooxanthellae and eventually lead to coral death. This was observed and documented during the 1998 coral bleaching event in the WIO. Sea level rise, which is also associated with climate change, will lead to long term changes in the photic profile of the water column and thus the photosynthetic efficiencies of certain coral species. Storm surges also have the potential to break hard coral species. Sedimentation may also harm reefs, although with few major rivers discharging into the entity, this is not considered a major concern for this region.

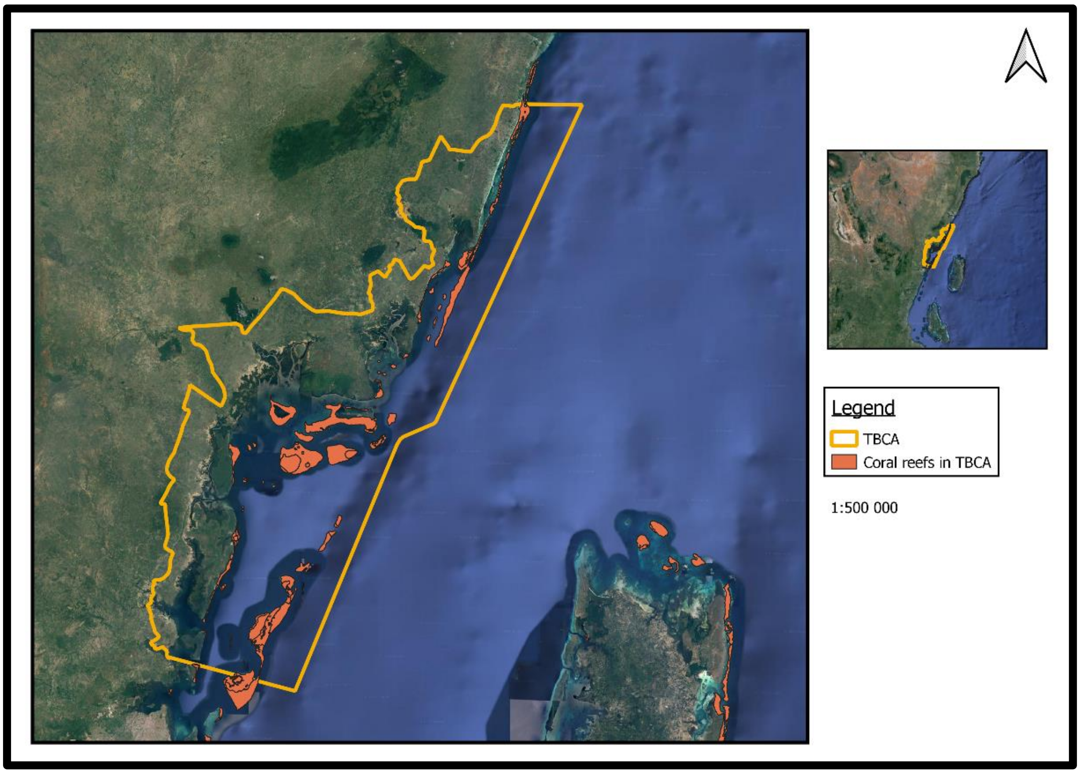


Figure 5-2: Coral reefs within the proposed KT-TBCA

With respect to the ecosystem services from coral reefs that are likely to be negatively affected by the hazards identified above, the comparative risk assessment process identified the following to be important:

- Ecotourism – Snorkelling and diving are popular tourist activities that, if effectively managed, could be harnessed to boost the revenue of the region significantly.
- Education and inspirational value – Coral reefs are iconic natural infrastructure assets that provide many opportunities for study and natural inspiration.
- Sediment regulation – The type and extent of fringing coral reefs found in the area likely play a significant role in preventing erosion of the shore from marine processes and maintaining stability of the intertidal flats.
- Food provisioning – A large portion of the fish species harvested by artisanal fishers in the area are closely linked with the coral reefs, although the corals themselves are not used for any food products.
- Genetic resources – There is evidence of resistance to bleaching in some of the coral populations of the area. This points to potentially important genetic resources for the maintenance of widespread coral reefs. However, there currently appears to be little evidence of any benefit being derived from the corals directly.

- Habitat – as noted, the coral reefs provide an important habitat for fish linked to human consumption, while they are also associated with a number of other species of molluscs, bivalves, and other marine organisms.
- Landscape and amenity value – Due to the value attached to corals in terms of attracting tourists, this may be considered to be significant.
- Recreation – Recreational diving, snorkelling, and fishing are all closely linked to the coral reefs.
- Regulation of extreme events – Corals play an important role in reducing the wave energy of storm surges and tidal waves.

It is estimated that the total area of coral reefs within the TBCA amount is approximately 36,500 ha (UNEP-WCMC, 2021).

5.3.3 Intertidal Mud Flats

For many years, intertidal mud flats were not considered economically important due to their barrenness. As such, many across the world were converted to agricultural land through drainage and embankment to prevent saltwater ingress (Reise et al. 2010). This process preceded the industrial age and continues to this day throughout the world. Even where mud flats have been rehabilitated, the compaction of soils often means that the pre-conversion assemblages of biota cannot recolonise the area (Murray et al., 2015).

Post-industrial activities that present hazards to tidal flats include dredging for port developments with the purpose of improving improve navigability for ships. Increased ship transit is also associated with colonisation by alien invasive species mainly through the ships' ballast water releases. Other human activities such as catchment land use changes and pollution-contaminated runoff may present hazardous conditions to the assemblages of biota living in tidal mud flats, despite their ability to filter contaminants arising from land-based activities. Food production related hazards to tidal mud flats include conversion of mud flat areas for the production of salt, shrimp production, and Artemia as feedstock. Additionally, as a habitat and nursery area for a variety of shellfish, bivalves, and some finfish, hazards to fish stocks may occur where these resources are overharvested (directly or as bycatch).

Other hazards to tidal mud flats include storm surges (which are linked to erosion), climate change, and sea level rise. Changes to the hydrological regime (water depth, temperature, salinity, pH, etc.) are extremely important to the ecological function of mud flats, and negative impacts present a hazard to these ecosystem assets. Occurring only in a narrow band in relation to sea level, mud flats may easily be inundated by rising sea levels.

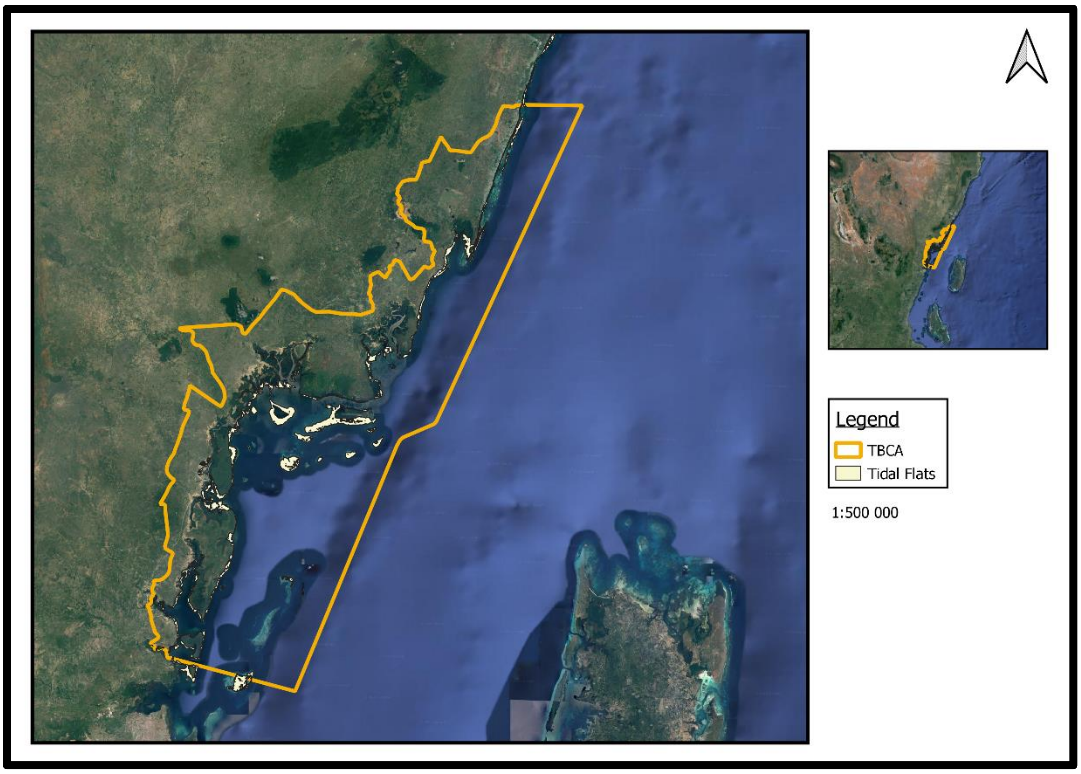


Figure 5-3: : Tidal flats within the proposed KT-TBCA

With respect to the intertidal mud flats ecosystem services that are likely to be negatively affected by the hazards identified above, the comparative risk assessment process identified the following to be important in the context of the KT-TBCA:

- Ecotourism – While mud- and sandflats are not typically associated with tourism activities, they may play host to certain ‘flagship species’ that accentuate tourism potential.
- Education and inspirational value – As one of the most threatened ecosystem types in the world, mudflats hold potential educational value.
- Sediment regulation – Mudflats play a role in reducing sedimentation loads on nearby coral ecosystems, although with no significant rivers discharging into the area, this may be of marginal value.
- Habitat – Mudflats are important habitats for a number of species, primarily shrimp.
- Regulation of extreme events – Mudflats, like corals, play an important role in reducing the wave energy associated with violent storms and tidal waves.

The total area of intertidal flats within the proposed K-T TBCA is estimated to be around 17,800 ha (Murray, 2019)

5.3.4 Seagrass Beds

Seagrasses are highly photosynthetically productive, and they provide nursery areas and habitat for many commercially important fish species. Moreover, they are used as feeding

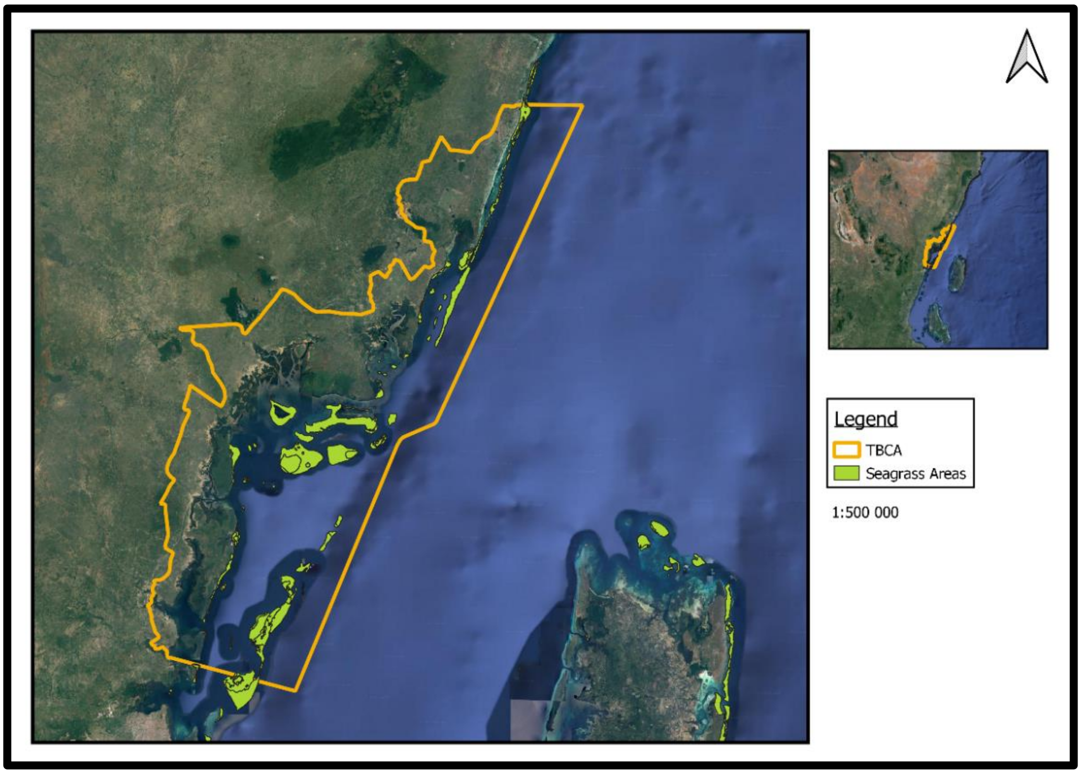


Figure 5-4: : Seagrass areas occurring in the region of the proposed KT-TBCA

grounds for some endangered species such as the dugong. Seagrasses are integral to filtering of water where they occur, reducing the presence of pollutants and impurities in sea water. Seagrasses are also highly efficient as a carbon sink (UNEP, 2020; Harcourt, 2018). Hazards to seagrasses include dredging of estuaries and nearshore areas, trawling of seagrass beds, and seaweed farming, all of which lead to denuding and thinning of the beds and reduction in individual plant health. Seagrass bed and individual plant health may also be negatively affected by polluted runoff, which may leave plants more vulnerable to parasites.

Coastal urbanisation and catchment land use change may lead to siltation of seagrass beds, and if siltation occurs at a substantial rate, the beds may be completely inundated. Irresponsible tourism may also be harmful to seagrass beds through trampling, and the removal of certain biota present in the habitat. In a similar way, overharvesting of bivalves and other filter feeders living in seagrass beds is linked to diminishing water quality, which creates a negative feedback loop that amplifies poor water quality, thereby diminishing conditions for seagrass growth (de la Torre-Castro, 2006).

As is the case for tidal mud flats, seagrasses occur in a narrow range of water depth. This means that they are susceptible to the effects on water chemistry caused by climate change, as well as any sustained rise in sea levels. The photic properties of the water column are one element of water depth that presents hazards to deeper-dwelling seagrasses.

Seagrass beds are estimated to comprise a total area between 17,000 and 19,000 ha within the proposed KT-TBCA. Studies from Gazi and Vanga bays in Kenya have demonstrated that between 1986 and 2000 seagrass cover increased by nearly 5%. Unfortunately, this trend was severely reversed between 2000 and 2016, when seagrass cover appears to have reduced by almost 30% (Harcourt, 2018). Based on this trend, it may be expected that only half of the current seagrass cover will remain by 2050.

With respect to seagrass beds' ecosystem services that are likely to be negatively affected by the hazards identified above, the comparative risk assessment process identified the following to be important in the context of the KT-TBCA:

- Carbon sequestration – Seagrass meadows have been shown to play a vital role in climate regulation through the storage of carbon in associated sediments.
- Ecotourism – The role seagrass beds play as a habitat for endangered species, such as dugongs, points towards their significance in terms of their ecotourism value.
- Sediment regulation – Seagrass meadows play an important role in stabilising sediments in these coastal areas.
- Food provisioning – Due to the important role played by seagrass in the habitats of many marine species used as food, their importance in food provisioning is significant, although it is questionable whether they are used as food for humans in this area.
- Genetic resources – While evidence exists of the use of seagrasses in traditional medicines in different parts of the world, little information exists on this in the local context.
- Habitat – As noted under food provisioning, this is an important constituent of habitat formation.
- Regulation of extreme events – Seagrass beds appear to play an important role in reducing and dissipating the energy of waves.
- Water purification and waste management – Seagrasses are known to play a highly significant role in water purification, which helps maintain the health of coastal ecosystems.

5.3.5 Freshwater/Estuarine Systems

While only representing a small area within the proposed KT-TBCA, freshwater systems are an integral asset within the larger system. Given their adjacency and importance to human activities, they are often heavily degraded, especially in areas where people live a subsistence lifestyle. Human utilisation of these systems includes clearing of riparian vegetation, which is a major cause of erosion as well as siltation of seagrass and coral assets. Where upstream catchment land use changes see reductions in freshwater flows as a result of dam building or heavy water abstraction, freshwater systems are often subjected to higher levels of silt deposition. This hazard enhances recruitment of vegetation in river channels (e.g., reedbeds); this increased channel roughness amplifies the frequency and magnitude of flood events (James and King, 2010). When construction and development of infrastructure takes place within riparian areas, upslope erosion and instream sedimentation may be exacerbated, as is pollution of water resources. Conversion of greenfield areas to developed sites is also often accompanied by higher energy stormwater flows, which are capable of carrying higher sediment loads into streams and the ocean.

The hazard of climate change is likely to influence the hydrological regime in the locale. Shifts in the timing, frequency, and intensity of rainfall events in the catchment are anticipated and likely will trend towards lower frequency and intensity, meaning lower overall freshwater availability (WWF, 2006).

With respect to the freshwater ecosystem services that are likely to be negatively affected by the hazards identified above, the comparative risk assessment process identified the following to be important in the context of the KT-TBCA:

- Food provisioning – Freshwater systems play a key role in depositing nutrients into the coastal habitats upon which many species used by humans for food depend.
- Fresh water (quality and quantity) – The mixing of freshwater and saltwater in estuarine systems is an important habitat formation service. However, the sourcing of fresh water by local communities is unclear.
- Habitat – As noted above, the associated freshwater systems connected to the proposed TBCA play an important role in coastal habitat formation.
- Landscape and amenity value – It is often desirable to landholders to be located near freshwater systems.
- Raw materials and energy source – Mud and clay sourced from freshwater systems is often an important raw material used for building, however, information on the use of such raw materials in the local context is limited.
- Recreation – Swimming and bathing in freshwater systems is often a popular pastime, although it is unclear how prevalent this is locally.
- Water purification and waste management – Rivers and streams play an important role in carrying away waste. However, in this context they are more a source of waste being carried into the coastal region from terrestrial sources.

5.3.6 Shelf Zone

Research on fisheries on the Kenyan and Tanzanian coast indicate that the shelf (neritic) zone (indicated by the light blue area in **Error! Reference source not found.**) is primarily exploited by subsistence, artisanal, and small-scale fisherfolk. While low capital investment is a feature of these fisheries, they are nevertheless important as they employ more people and harvest more resources in both Tanzania and Kenya than the commercial fleets of these countries (International Waters, 2013 a and b).

The types of hazards facing these assets (and consequently the fisheries they host) are varied but primarily anthropogenic in nature. Illegal fishing activities including overfishing and poor trawling practises are major hazards, and evidence from Kenya indicates that finfish stocks were showing signs of depletion almost a decade ago (International Waters, 2013a). Tanzanian prawn and shrimp trawling has ceased operations for an extended period due to declines in the resource (International Waters, 2013b). Land-based human activities also have the potential to cause harm in the neritic zone through polluted runoff entering the ocean as well as catchment land uses causing sediment loading in off-shore waters.

Lastly, climate change and the likelihood of changing water chemistry and quality in the neritic zone may be more pronounced than in the oceanic zone due to its proximity to land. According to the FAO (2020), the tropical oceans of Africa and Asia may see reduced productivity of fisheries resources due to warmer ocean temperatures. Increasing sea levels may also exacerbate storm surges in the region. These have the potential to damage fisheries infrastructure as well as existing nursery areas relied upon by shellfish, bivalves, and finfish.

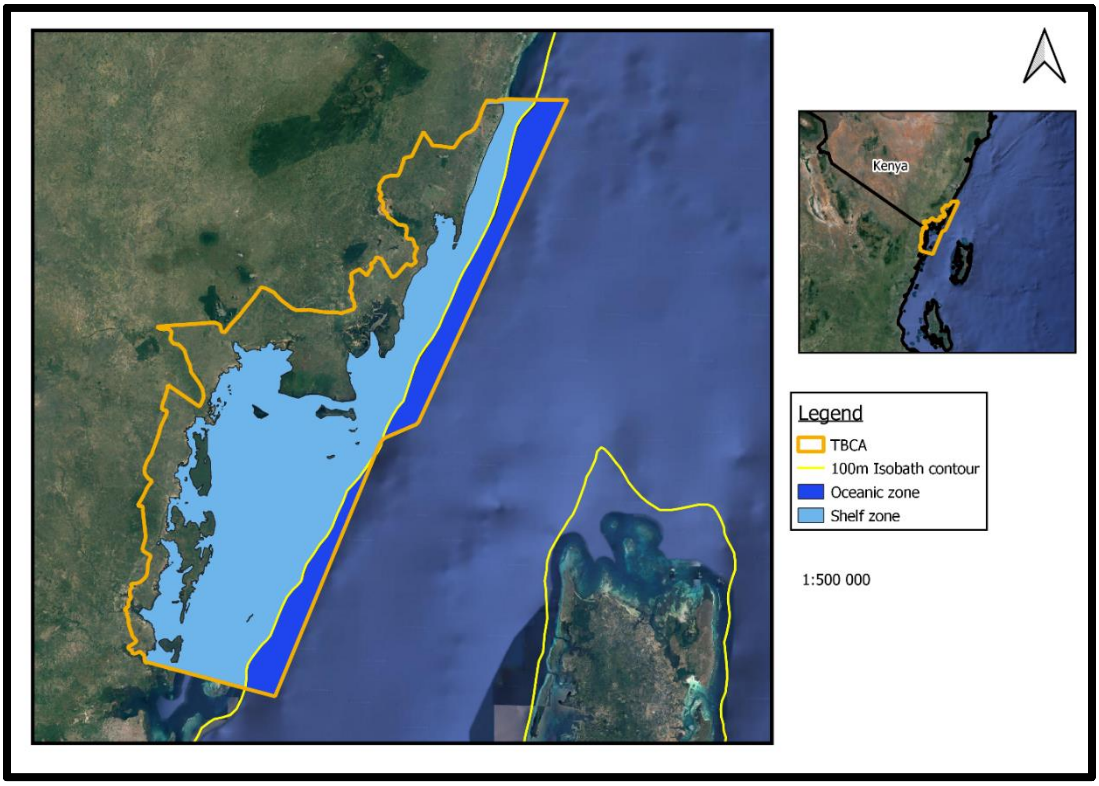


Figure 5-5. Isobath contour areas within the proposed KT-TBCA

With respect to the shelf zone ecosystem services that are likely to be negatively affected by the hazards identified above, the comparative risk assessment process identified the following to be important in the context of the KT-TBCA:

- Ecotourism – Many ecotourism activities associated with coastal areas are intrinsically linked to the neritic zone.
- Education and inspirational value – The ocean holds a special place in the identity of many coastal communities, while also presenting an endless resource for the passing on of knowledge and generation of new knowledge.
- Habitat – The neritic zone is the region in which all of the habitat zones discussed thus far are located.

- Recreation – Snorkelling, diving, and fishing activities are all conducted in this zone.
- Regulation of extreme events – By providing the underlying structure for the assets already discussed, the neritic zone may be said to be of importance in reducing the energy of storm surges and tidal waves.

5.3.7 Oceanic Zone

The oceanic zone is the deeper section of the Indian Ocean, a portion of which lies within the proposed boundary of the KT-TBCA (as indicated by the darker blue section within the KT-TBCA, appearing in **Error! Reference source not found.**). It is within this portion of the ocean where commercial fisheries operate. Currently, it appears that the oceanic fisheries resources of both Kenya and Tanzania are mostly under-exploited, with Kenya showing increasing catch trends and Tanzania showing stable catch trends between 2007 – 2016 (FAO, 2020).

Whether the FAO (2020) trends are accurate, the hazard of over-exploitation is still a matter of concern. Reports of foreign trawling vessels entering exclusive economic zone waters of the two countries to fish illegally may mean that accurate catch data may not be available after 2016.

The effects of pollution in the oceanic zone would superficially appear to be of lower concern in the oceanic zone, but recent research and information indicate that the ubiquity of micro-plastics in the ocean could lead to declining fish health and reproductive rates (FAO, 2017). Currently, this has only been confirmed in laboratory research. However, the concerns of potential bioaccumulation of microplastics in pelagic fish is not currently quantifiable by financially feasible methods, meaning that we do not currently have a means to measure the magnitude of this problem.

The effects of climate change on the deeper ocean include likely warming, especially in tropical African waters (FAO, 2020) and changes to water chemistry.

With respect to the oceanic zone services that are likely to be negatively affected by the hazards identified above, the comparative risk assessment process identified the following to be important in the context of the KT-TBCA:

- Climate change regulation – Oceans have been shown to play a significant role in the release of oxygen and the sequestration of carbon dioxide.
- Education and inspirational value – The ocean holds a special place in the identity of many coastal communities, and it presents an endless resource for the passing on of knowledge and generation of new knowledge.
- Genetic resources – Although little evidence exists of local communities making use of products derived from the genetic resources of the deep ocean, the deep sea is a source of a range of such resources, with many yet untapped in this growing research area.
- Habitat – Oceanic processes and currents form the basis for a wide range of habitats.

5.3.8 *Fish Stocks*

Fish stocks are a critical asset as the fish population largely determines the volume of catch landed and the effectiveness of fishing that takes place in the area. The estimated number of fish species in Kenyan and Tanzanian coastal waters varies widely. Species targeted specifically for fishing are in the hundreds and include both pelagic and demersal species (Silas, 2022; GOK, 2017; Samoilys, 2016).

Reports indicate that fish populations are at risk, particularly in the neritic shelf area, due to a variety of human and environmental factors. Overfishing is one of the most serious threats to the TBCA's fish stocks. This is due to a variety of factors including population growth, inadequate fishing regulations and enforcement, and a lack of knowledge about fish populations. This, combined with irresponsible fishing tactics, has resulted in a significant decrease in fish stocks. For example, dynamite fishing can be used to catch a large number of fish, but it ends up harming the habitat and thus fish breeding. This, in turn, reduces the next period's fish stock.

Land use change, and particularly mining, can also harm the marine environment by causing sedimentation, changes in water acidity, and stream channel and flow modifications. Sediment accumulates naturally in streams and can be a helpful component of anadromous fish habitat at modest levels. However, large quantities of suspended sediment in the stream bed can displace plants, invertebrates, and insects. This has an impact on fish food sources, resulting in smaller and fewer fish.

Port and maritime activities taking place along the coast also present the possibility of marine contamination. Exploitation of marine based fossil fuel resources often pose a significant risk, while cargo, fuel, and other chemicals utilized by ships may also end up un the ecosystem, posing a significant pollution concern.

Climate change effects such as increases in water temperatures, rising sea levels, increased water salinity, and ocean acidification all have an impact on various aspects of fish stocks, including growth rate, feed intake, and changes in breeding grounds/habitat.

5.4 Assessment of Risk to Ecosystem Services

Below, we present a concise narrative on the risks to each ES, and well as our considered opinion on whether the declaration of the KT-TBCA will mitigate or prevent hazards to each ES.

5.4.1 *Food Provisioning*

Food provisioning is at extreme risk in mangroves, seagrass beds, coral reefs, and in fish stocks. This is a result of the interconnected and additive nature of the hazards facing these assets, primarily due to the high likelihood and major consequence of physical alteration and destruction of habitats featured prominently in this risk assessment.

Tidal flats and freshwater systems correspond with a high risk to food provisioning due to likely and moderate effects like pollution and alteration of freshwater flows. Over longer time scales, the effects of a changing climate could also change the hazard status of mangroves in the KT-TBCA.

The oceanic zone is currently deemed to be low risk, but changes in pollution from offshore fossil fuel exploration, as well as increased pressure from industrial fishing, do have the potential to change this status if not appropriately managed.

Table 5-5: Risk of Status quo Scenario to Food Provisioning

Ecosystem Service Provided (MEA, 2003 & TEEB, 2013)	Risk of Status quo Scenario to ES (L-Low; M-Medium; H-High; E-Extreme)							
	Mangroves	Seagrasses	Tidal Flats	Freshwater Systems	Coral Reef	Shelf Zone	Oceanic Zone	Fish Stock
Food Provisioning	E	E	H	H	E	M	L	E

The declaration of the KT-TBCA would undoubtably reduce the risks facing these ecosystem assets. However, simply declaring the KT-TBCA will be insufficient; monitoring and enforcement measures must be implemented to ensure resource safeguarding and prevent the destruction of habitats.

5.4.2 Freshwater Provisioning

An important distinction must be made between the freshwater systems considered an asset in this ecosystem and the freshwater provisioning service, which relates to how human usage of fresh water is affected by changes to this system.

The coastal location of the KT-TBCA means that mangrove and freshwater assets are influenced by land use changes occurring in the adjacent catchments. It is important to note that no significant rivers discharge into the area, thus the risks associated with water quality and flows and sediment quality and loads are somewhat reduced.

This potential hazard is extremely complex and is impossible to manage from the perspective of the KT-TBCA. Also, due to the consideration of freshwater inflows rather than outflows, the logical approach of the comparative risk assessment is to exclude freshwater provisioning from the list of ecosystem services to be valued in this study.

Table 5-6: Risk of Status quo Scenario to Fresh Water Provisioning

Ecosystem Service Provided (MEA, 2003 & TEEB, 2013)	Risk of Status quo Scenario to ES (L-Low; M-Medium; H-High; E-Extreme)							
	Mangroves	Seagrasses	Tidal Flats	Freshwater Systems	Coral Reef	Shelf Zone	Oceanic Zone	Fish Stock
Fresh water provisioning	L			M				

Declaration of the KT-TBCA will likely not affect freshwater provisioning either negatively or positively.

5.4.3 Biochemical and Genetic Resources

Maintenance of genetic diversity is important in promoting healthy and sustainable populations of biota. There is a linkage between hazards and risks to the maintenance of genetic diversity and the degree of utilisation of a biotic resource. Higher utilisation/exploitation rates are linked to reduction in genetic diversity and the genetic health of species (Kenchington, 2003). Thus, in assets where biota are more heavily exploited, the hazards to genetic resources are greater.

Within seagrass beds and coral reefs, the risk and likelihood posed by all major hazards is high, with a potentially major consequences for the option values of the genetic resources in in these asset systems.

The biochemical and genetic resources of tidal flats and fish stocks both exhibit a likelihood rating of likely or almost certain for all the potential hazards, with moderate consequences expected. They therefore exhibit a high risk status for this ES.

The shelf zone and the freshwater systems, which will likely or almost certainly almost be affected by the whole range of hazards, respectively, are expected to have only minor consequences arising from these hazards in terms of this ES, providing a risk rating of medium.

For the oceanic zone, the likelihood of being affected is rated as unlikely, with the consequences believed to be insignificant at this stage, thus warranting only a low-risk rating.

Table 5-7: Risk of Status quo Scenario to Biochemical and Genetic Resources

Ecosystem Service Provided (MEA, 2003 & TEEB, 2013)	Risk of Status quo Scenario to ES (L-Low; M-Medium; H-High; E-Extreme)							
	Mangroves	Seagrasses	Tidal Flats	Freshwater Systems	Coral Reef	Shelf Zone	Oceanic Zone	Fish Stock
Biochemical and Genetic Resources	M	H	M	L	H	M	L	H

Declaration of the KT-TBCA would be beneficial for maintaining and possibly improving the genetic health of all species occurring in the KT-TBCA. For endangered species, species with limited ranges, and keystone species within these assets, the reserve would be of particular importance in contributing to the genetic health of these species.

5.4.4 Raw Materials (Fuel and Fibre)

The use of raw materials from sea grasses, intertidal flats, coral reefs, and the shelf and ocean zones are not considered material to this assessment because they are either non-existent or easily substituted from other assets in the system. This is indicated by the black blocks.

Research indicated that the most important source of raw materials in the locale comes from mangrove and freshwater system assets. All hazards negatively affecting the provisioning of raw materials are anthropogenically derived. These mostly relate to the displacement of mangrove trees for aquaculture and salt production, but also from over-utilization for fuel and as building materials. Over the longer term, climate change and sea level rise will increase in prominence as hazards to raw material availability. In freshwater systems, clearing of riparian vegetation and climate change feature most prominently as hazards of concern.

The likelihood of this ES being affected in mangroves is considered to be almost certain, with the consequences being major to the continued provision of this ES. For freshwater systems, although the likelihood is considered high, the consequences are expected to be minor to this ES.

Table 5-8: Risk of Status quo Scenario to Raw Materials

Ecosystem Service Provided (MEA, 2003 & TEEB, 2013)	Risk of Status quo Scenario to ES (L-Low; M-Medium; H-High; E-Extreme)							
	Mangroves	Seagrasses	Tidal Flats	Freshwater Systems	Coral Reef	Shelf Zone	Oceanic Zone	Fish Stock
Raw Materials (Fuel and Fibre)	E			M				

Protection of the aforementioned assets under the banner of the KT-TBCA will improve the provision of raw materials from mangroves, assuming regulations are properly enforced. It is unlikely that the implementation of a CA will affect the provision of this service from freshwater systems, as the hazards are mostly located outside the proposed area.

5.4.5 Carbon Sequestration

The ability to maintain climate regulation services is currently at extreme risk in seagrass and mangrove systems, medium risk in coral reefs, and low risk in all the other assets, save for fish stocks which are not linked to this service.

Mangroves and seagrasses are known to be vital carbon sinks, reportedly being more effective at capturing and storing carbon than any other terrestrial systems. The range of hazards is highly likely to affect the ability of these assets to perform their regulating function, with the consequences expected to me major.

The reason for the lower hazard profile in tidal flats, freshwater systems, and shelf- and oceanic zones is due to the fact that these assets have a relatively insignificant effect on carbon sequestration at the level of the TBCA.

Table 5-9: Risk of Status quo Scenario to Carbon Sequestration

Ecosystem Service Provided (MEA, 2003 & TEEB, 2013)	Risk of Status quo Scenario to ES (L-Low; M-Medium; H-High; E-Extreme)							
	Mangroves	Seagrasses	Tidal Flats	Freshwater Systems	Coral Reef	Shelf Zone	Oceanic Zone	Fish Stock
Carbon Sequestration	E	E	L	L	M	L	L	

A formal declaration of the KT-TBCA would mitigate the risk to climate regulation as an ES in mangroves and seagrasses. It is assumed that ecological functions would lead to lower human interference if the KT-TBCA is declared. The ability of healthier ecosystems to regulate climate when free from interference is well-established in both terrestrial and marine environments (Malhi et al., 2020).

5.4.6 Regulation of Extreme Events

During a storm, sea waves increase in energy and have the potential to damage ecosystem and infrastructure assets along the coastal strip. Occasional tidal waves may also have the same effect. Mangroves, intact seagrasses, and coral reefs effectively reduce wave energy during storm conditions, meaning there is lower potential of damage to ecosystems and manmade infrastructure. However, where these assets are degraded their ability to attenuate storms is similarly degraded. This effect is particularly prominent when human infrastructure is sited within clearcut areas where these ecosystem assets were previously intact (such as salt, Artemia, and other aquaculture facilities built in areas that were previously mangrove forest). Unfortunately, degraded ecosystem assets also become more prone to further storm surges in a positive feedback loop, exacerbating the damage to these assets. The causes of the degradation of these ecosystem assets are myriad, but they are primarily caused by human over-exploitation.

On the landward side, freshwater systems also have the potential to protect coastal communities from flooding, provided they are healthy. Overharvesting of riparian plants for fuel and fibre decreases the ability of these assets to absorb flood energy, making them more susceptible to flooding and erosion. Catchment land use changes are also an important factor (often a hazard), especially when natural cover is converted to bare soils or harder surfaces on which runoff flows more quickly and with higher energy.

While the provision of this ES is likely to be affected by the range of hazards in most of the ecosystem assets, the consequences are only expected to be major in the mangrove systems, with seagrasses, tidal flats, and coral reefs associated with moderate consequences, and freshwater systems exhibiting minor consequences.

Table 5-10: Risk of Status quo Scenario to Regulation of extreme events

Ecosystem Service Provided (MEA, 2003 & TEEB, 2013)	**Risk of Status quo Scenario to ES (L-Low; M-Medium; H-High; E-Extreme)**							
	Mangroves	**Seagrasses**	**Tidal Flats**	**Freshwater Systems**	**Coral Reef**	**Shelf Zone**	**Oceanic Zone**	**Fish Stock**
Regulation of extreme events	E	H	H	M	H	L		

Through the protection offered by a potential KT-TBCA, regulation of extreme events as an ES will be maintained and strengthened over time. This mitigation will benefit these ecosystem assets.

5.4.7 Waste Assimilation

Land-based human activities such as land use change and industrial activity are responsible for increasing sediment loading and diverse pollutants in rivers and nearshore ecosystem assets. Mangroves, seagrass beds, and freshwater systems, and to a lesser extent tidal flats, provide an extremely important water purification (and waste treatment) ES function. When the area and/or quality of these ecosystem assets is reduced as a result of salt and aquaculture production, catchment land use change and/or heavy pollution loading (almost certain), the ability of these assets to purify water resources, both potable and seawater, is reduced, leading to severe consequences. The importance of water purification and waste treatment by seagrass beds and mangroves should not be undervalued. By performing this ES, coral reefs and shelf zone fisheries are protected from pollution, turbid waters, and sedimentation.

Table 5-11: Risk of Status quo Scenario to Water Purification and Waste Treatment

Ecosystem Service Provided (MEA, 2003 & TEEB, 2013)	**Risk of Status quo Scenario to ES (L-Low; M-Medium; H-High; E-Extreme)**							
	Mangroves	**Seagrasses**	**Tidal Flats**	**Freshwater Systems**	**Coral Reef**	**Shelf Zone**	**Oceanic Zone**	**Fish Stock**
Water Purification and Waste treatment	E	E	M	H		L		

The declaration of the KT-TBCA is not expected to have a major effect on purification of freshwater systems as the asset makes up a very small proportion of the KT-TBCA. In addition, this hazard arises outside of the KT-TBCA. However, the hazards of pollution and sediment loading will be mitigated by declaration of the KT-TBCA through the protection of mangroves, seagrass beds, and intertidal mud flats.

5.4.8 Sediment Regulation

Management and mitigation of erosion is critical, as prevention or limitation of erosion underpins many other ES and human expectations such as healthy food systems, clean water provisioning, and the physical safety of people and infrastructure. All assets in the assessment play a role in this ES, except for the oceanic zone and fish stocks and, to an insignificant extent, the shelf zone. In the context of the proposed KT-TBCA, management of both terrestrial and coastal erosion is important. However, hazards to the nearshore assets (seagrass beds and intertidal flats) were noted to operate in a highly interconnected manner. This means that the potential additive effect of the hazards is difficult to assess and/or quantify.

It is also important to consider the role of coral reefs in erosion control and regulation of sediments. By reducing wave energy, especially during storm surges, coral reefs protect shorelines from erosion. Damage to reefs minimises their ability to protect coastlines.

The conservative approach in this analysis leads to an estimation of the risk to this ES being considered extreme in mangroves, seagrasses, and coral reefs. This is due to consequences rated as major, with tidal flats and freshwater systems representing moderate consequences.

Table 5-12: Risk of Status quo scenario to Sediment Regulation

Ecosystem Service Provided (MEA, 2003 & TEEB, 2013)	Risk of Status quo Scenario to ES (L-Low; M-Medium; H-High; E-Extreme)							
	Mangroves	Seagrasses	Tidal Flats	Freshwater Systems	Coral Reef	Shelf Zone	Oceanic Zone	Fish Stock
Sediment Regulation	E	E	H	H	E	L		

Protection of the locale by means of the KT-TBCA will contribute positively to reducing the consequences of hazards and improving the ability of the afore-mentioned assets to reduce erosion rates in the KT-TBCA

5.4.9 Ecotourism and Recreation

Hazards afflicting ecotourism are significant (likely or almost certain) in all assets except the oceanic zone. These assets are ecologically productive and act as a magnet for tourists. This is particularly true for coral reefs, which harbour many species of tropical fish and provide highly sought after experience for scuba divers and snorkellers. The range of hazards result in a deterioration of the health of the asset thereby, diminishing its ecotourism value.

Recreational opportunities are negatively affected through overutilization of assets, which leads to degradation of the asset's quality. Additionally, the assets that are either easily accessible and/or considered attractive for recreational purposes (such as the seagrasses and coral reefs) may be negatively impacted by uncontrolled recreational activity through heavy foot traffic or touching and breaking of corals, some of which are extremely sensitive. Pollution in runoff from land-based activities and catchment land use changes are another important hazard negatively affecting all of the identified assets. While it is acknowledged that mangroves, seagrasses, and tidal flats are all capable of filtering pollution (an important feature of these assets), their capacity to filter is limited, and exceeding their capacity will increase pollution in other assets in the system as well as damage the assets themselves.

For most of these assets, the consequences on this ES are expected to be moderate, providing a risk rating of high, except for coral reefs, where the consequences are likely to be major primarily due to their prominence as a draw card for tourists. The effect of hazards on the shelf zone and the oceanic zone are expected to have minor and insignificant impacts on this ES, respectively.

Table 5-13: Risk of Status quo Scenario to Ecotourism and Recreation

Ecosystem Service Provided (MEA, 2003 & TEEB, 2013)	Risk of Status quo Scenario to ES (L-Low; M-Medium; H-High; E-Extreme)							
	Mangroves	Seagrasses	Tidal Flats	Freshwater Systems	Coral Reef	Shelf Zone	Oceanic Zone	Fish Stock
Ecotourism & Recreation	H	H	H	H	E	M	L	H

It is expected that if the KT-TBCA is declared, ecotourism as an ES will be boosted as a result of the improving health of the ecosystem assets present in the KT-TBCA. If recreation activities are sustainable and well managed, then the declaration of the reserve will enhance the provision of this ecosystem service.

5.4.10 Educational and Inspirational Value

It could be argued that the educational value of the variety of ecosystem assets in the proposed KT-TBCA exists irrespective of the health of these assets. In some cases, the educational value of the assets may even increase as they deteriorate. For example, where human activities create hazards for assets, lessons can be learned from how the hazards create negative impacts and how remediation can restore ecological function. In terms of inspirational value, however, intact and well-functioning ecosystem assets will provide greater inspirational value than damaged assets.

The likelihood of this ES being affected is likely to almost certain for all the assets except for the oceanic zone, which will unlikely or only possibly be affected at the scale of the TBCA. In terms of the consequences of hazards to this ES, they are greatest in the mangrove, seagrass, coral reef, and fish stock assets, with a rating of at least major. The rating attached for tidal flats and freshwater systems is moderate, and the rating for the shelf zone is minor.

Table 5-14: Risk of Status quo Scenario to Educational and Inspirational Values

Ecosystem Service Provided (MEA, 2003 & TEEB, 2013)	Risk of Status quo Scenario to ES (L-Low; M-Medium; H-High; E-Extreme)							
	Mangroves	Seagrasses	Tidal Flats	Freshwater Systems	Coral Reef	Shelf Zone	Oceanic Zone	Fish Stock
Educational and Inspirational Value	E	E	H	H	E	M	L	E

The formalisation of the KT-TBCA will contribute positively to educational and inspirational value as an ecosystem service as it will reduce the likelihood and consequences of risks to this ES by providing protection to the underlying assets

5.4.11 Landscape and Amenity Value

Generally, landscapes less impacted by human activities are considered to have greater landscape value. With respect to amenity value, assets with an intact suite of ES provide greater amenity for people utilising those assets. Thus, assets that are impacted by human use, especially where these uses become unsustainable, comprise lower amenity value. This principle holds true for all the assets assessed in this CRA.

While the likelihood of this ES being impacted by the range of hazards facing the underlying assets is likely, or at the very least possible, the consequences of these impacts are largely expected to be minor or even insignificant. This is not the case for fish stocks and freshwater systems, however, which are closely linked to the amenities enjoyed by local populations, thus posing major and moderate consequences to this ES in these assets, respectively.

Table 5-15: Risk of Status quo Scenario to Landscape and Amenity Value

Ecosystem Service Provided (MEA, 2003 & TEEB, 2013)	Risk of Status quo Scenario to ES (L-Low; M-Medium; H-High; E-Extreme)							
	Mangroves	Seagrasses	Tidal Flats	Freshwater Systems	Coral Reef	Shelf Zone	Oceanic Zone	Fish Stock
Landscape and Amenity Value	M	M	L	H	M	L	L	E

The KT-TBCA will exclude or reduce several types of human impact on the assets within the KT-TBCA. In doing so, it is likely that the landscape value will increase, or at the very least remain constant. Amenity value will likely also increase, particularly for those assets that are currently over-exploited.

5.4.12 Habitat

The CRA process employed in this study assessed comparative risks within each asset class, rather than across assets. Consistently, hazards are rated as high or extreme risk levels within each asset. The diverse array of anthropogenic hazards almost always negatively impact habitat, and several natural hazards such as storm surges have a similar effect. The additive effect of these different hazards cannot be ignored, and the potential for collective effects exceeding the sum of individual hazard effects adds complexity in understanding how to manage each hazard individually.

Table 5-16: Risk of Status quo Scenario to Habitat

Ecosystem Service Provided (MEA, 2003 & TEEB, 2013)	Risk of Status quo Scenario to ES (L-Low; M-Medium; H-High; E-Extreme)							
	Mangroves	Seagrasses	Tidal Flats	Freshwater Systems	Coral Reef	Shelf Zone	Oceanic Zone	Fish Stock
Habitat	E	E	H	H	E	H	H	E

It is understood that declaring the KT-TBCA will reduce extractive activities within the boundaries of the KT-TBCA. This will have the effect of reducing pressures on the various habitats present with each asset class and likely improve habitat in the KT-TBCA.

6 Ecosystem Services Valuation

6.1 Methodological Overview

A bio-economic model was developed for this study, which aims to approximate the interactions between the biological features of the study area and the local economy. This was done through formulating a set of valuation models for the various ecosystem services, which are embedded within a production function system. The valuation model for each ecosystem service draws on the available data regarding the extent and condition of the underlying ecological assets, along with the socio-economic data particular to the region. The impacts that the consumption of these services have on the ecological assets is then fed back into the model to simulate the feedback loops between the natural and economic systems. This approach is highly data-intensive and requires a significant amount of data mining blended with expert insights into the linkages between economic activities and ecological processes.

The resultant bio-economic model facilitates the valuation of ecosystem services in the local context, while providing the functionality for assessing the impact of planned interventions, such as increased protection, on these benefit flows. The baseline valuation provided by this model, as presented below, essentially serves to calibrate the model in preparation for the evaluation of the proposed conservation scenario.

6.2 Summary

The ecosystem services identified above as facing significant risk from the range of hazards affecting the underlying assets present within the proposed TBCA are further investigated below to establish an estimate of the values associated with the benefits derived by humans at the local, regional, and global levels.

This stage of the valuation focuses on building valuation methods for the ecosystem services in their current, unprotected state based on historical trends. This is done to create an understanding of the status quo against which future scenarios can be assessed. The purpose of the valuation is to create an understanding of the benefits accrued from the natural environment. The values provided are thus a first step in understanding what stands to be lost if these ecosystems are lost or degraded. The following iteration of this report will thus assess the necessary costs of protecting these ecosystems along with the potential changes from conservation, thus enabling informed decisions to be made around the costs and benefits of any proposed conservation activities.

For each ecosystem service being valued, a set structure of reporting is followed. Each ES is presented in four sections that cover the necessary background and methodological approach. An estimate of the value associated with each specific ES is then provided.

First, the ES is placed into context within the proposed TBCA. A general description of the ES is provided, along with a description of the ES in this specific setting.

Second, the beneficiaries of the benefits flowing from this ES are identified. These are largely the local populations, which rely heavily on their environment for sustaining their livelihoods. Natural capital is widely accepted to play the most vital role in the lives of people living at or below the poverty line. This is found to be the case for many of the communities of this region, particularly those on the Tanzanian side of the border within this proposed conservation area.

Third, the specific methodology applied to the valuation of the respective ES is described. A range of economic and statistical techniques are required to arrive at a feasible value estimate for an ecosystem service. Many of the services are not associated with traded or even tradeable goods. In these cases, a more theoretical approach is required, which is explained where necessary.

Finally, the estimated value of the ES is provided. This value is expressed in a few different ways. Where possible, an estimate is provided of the volume of benefits flowing to beneficiaries over the course of a year, e.g., tonnes per annum of fish harvested. The corresponding estimate of annual value flows in monetary terms is provided, expressed in US dollars per annum for each ES. An overall asset value is then estimated based on a calculation of the net present value (NPV) of the flow of benefits up to the year 2050.

Table 6-1below provides a summary of the estimated values associated with the range of ES. This is followed by the salient highlights from the analysis, with further explanation of these ES and their associated values provided in the sections that follow.

Table 6-1: Valuation summary of the ecosystem services of the KT-TBCA

Ecosystem Service	Estimated annual benefits (USD/a)		Asset value (NPV, USD)	
	Min	Max	Min	Max
Food provisioning	***14,859,000***	***17,527,000***	***228,737,000***	***269,949,000***
Fish harvest	6,254,000	7,315,000	98,142,000	114,202,000
Aquaculture production	1,034,000	1,398,000	16,300,000	22,053,000
Agricultural production	7,571,000	8,814,000	114,295,000	133,694,000
Raw materials	***995,000***	***1,346,000***	***13,633,000***	***18,447,000***
Charcoal	975,000	1,319,000	13,363,000	18,080,000
Timber	20,000	27,000	270,000	367,000
Carbon Cycling	***121,000***	***346,000***	***2,488,000***	***6,227,000***
Mangroves	424,000	518,000	7,337,000	8,968,000
Seagrass	-303,000	-172,000	-4,849,000	-2,741,000
Tourism and recreation	***65,810,000***	***117,227,000***	***996,422,000***	***1,774,933,000***
Tourism	63,663,000	113,487,000	963,915,000	1,718,311,000
Recreation	2,147,000	3,740,000	32,507,000	56,622,000
Regulation of extreme events	***564,000***	***940,000***	***8,534,000***	***14,224,000***

Ecosystem Service	Estimated annual benefits (USD/a)		Asset value (NPV, USD)	
	Min	Max	Min	Max
Scarce Habitats	***48,299,000***	***94,832,000***	***731,285,000***	***1,435,851,000***
Total	**130,648,000**	**232,218,000**	**1,981,099,000**	**3,519,631,000**

- Tourism and recreation were found to represent the highest value of all the ecosystem services evaluated. The pristine nature of the area imbues it with abundant potential for highly sought-after recreational activities such as snorkelling, scuba diving, sightseeing, and whale watching. Degradation of the natural assets of the area could have significant negative effects on these services.
- The services associated with the maintenance of scarce habitats were found to represent the second highest value in the proposed KT-TBCA. Services linked to this include a range of values derived from the existence value of this area, including genetic diversity, educational and inspirational value, aesthetic appreciation, and spiritual and cultural heritage and sense of place. Conserving this area would go a long way to ensuring this value is maintained.
- Food provisioning, although not reflecting as high a value in monetary terms as the previous two categories of services, is likely the most important ecosystem service to local beneficiaries, as many communities are highly reliant on the ability of the ecosystems to sustain them. If not managed carefully, this ability may be impaired by unsustainable activities, particularly the destruction of key habitats.
- Collection of raw materials, primarily wood from mangrove forests for building and cooking, is also likely integral to the livelihoods of many of the local population. Alternatives to these raw materials may need to be introduced along with appropriate management of the existing resources, to forestall severe levels of degradation to these assets.
- The regulation of extreme events was found to be a significant ecosystem service due to the role the coastal assets of the region can play in reducing the energy of waves caused by storm surges and sub-oceanic earthquakes. The value derived from this service would likely increase were the area more developed, insofar as any development does not impede on the functioning and ability of the underlying natural assets to provide this service.
- The role of this region in carbon sequestration was found to be significantly affected by the degradation of mangrove and seagrass assets. Were these assets to be effectively managed, and restored to healthy functioning and their natural extent, this ecosystem service would likely provide significantly increased benefits, with the possibility of potential for revenue generation through PES schemes.

6.3 Food Provisioning

6.3.1 Background

Food provisioning as an ecosystem service includes a wide range of plant and animal foodstuffs collected from the natural environment and farmed through agricultural practices. The level at which such food products are collected and farmed may or may not be sustainable, however. The sustainable use of ecosystem services is dependent on the size of the flows of those services, as well as the underlying ecological stocks.

Flows of ecosystems services, which in this case is the overall quantity of food products harvested, are only part of the picture. While it is possible to calculate an indicative value for the provisioning of food products at a given time using limited data, a detailed study of the variation in the underlying stock of natural capital is required to understand more clearly the sustainable offtake value that can be sustained into perpetuity. This can to some extent be derived from an analysis of the state of the underlying ecological assets. However, currently the data on these assets is somewhat erratic.

Fishing is reported to be the primary source of protein in the region. Some aquacultural activities have been reported, and small-scale agriculture takes place mostly for subsistence purposes. Other than fishing, little evidence exists of wild food collection in the form of wild fruit, nuts, or other plant material. Considering the aquatic nature of this region and the aims of the conservation area to protect the marine environment, this valuation primarily focused on the value derived from fishing. This is followed by a brief description of the value associated with aquaculture and agriculture. It should be noted that the values associated with these provisioning services, particularly that of agriculture, encompass a wide range of supporting services provided by the underlying ecosystems.

6.3.2 Beneficiaries

The beneficiaries of food provisioning are almost exclusively the local communities who rely on locally caught fish as their primary source of protein. This population consists mostly of small fishing villages, particularly on the Tanzanian side of the border. These communities practice subsistence agriculture, and to some extent engage in small-scale aquaculture.

There appears to have been significant growth in aquaculture in Tanzania over the past few decades, with the sector contributing increased value to coastal communities (FAO, 2022). To these communities, the value associated with the fish resources and agricultural produce goes beyond the mere market price of the fish caught here, as they are reliant on this provisioning service for their continued existence. The use of market prices does, however, provide a proxy for the value associated with this service.

6.3.3 Methodology

A production function method, along with market pricing, was used to estimate the value of this ecosystem service, in conjunction with a bio-physical model that simulates the population dynamics of the fish stock for this region.

To understand the relationship between fisheries' capture and the variables that feed into it, this study estimated two types of models. The data utilized for the study is time series data that runs from 2001 to 2009. The first model is a static model that shows the link between each independent variable and the number of fish caught. The following specification of the relationship was tested using the Ordinary Least Squares (OLS) regression:

$$Ht_{Catch} = C + CT_{CPUE} + ET_{EFFORT} + SART_1 + SMANT_{Mangrove} + STCT_{Temp} \quad (1)$$

Where:

Ht	– the total catch for the year in kilograms
CT_{CPUE}	– catch per unit effort
ET_{EFFORT}	– number of hours spent fishing
$SART_1$	– delayed variable for yearly rainfall
$SMANT_{Mangrove}$	– extent of mangrove coverage
$STCT_{Temp}$	– annual temperature change

The estimation results are shown in **Error! Reference source not found.** below.

Table 6-2: Estimation outputs for effects of different variables on fish catch

Dependent Variable: HT_CATCH				
Variable	Coefficient	Std, Error	t-Statistic	Prob,
CT_CPUE	4,158705	0,119471	34,8094	0,0008
ET_EFFORT	1712340	71248,89	24,03321	0,0017
SART_1	6,44341	87,87082	0,073328	0,9482
SMANT_MANGROVE	148,7528	58,29129	2,551888	0,1253
STCT_TEMP_CHANGE	-266609	117753	-2,264135	0,1519
C	-1,4E+07	2876097	-4,825493	0,0404
R-squared	0,999401	Mean dependent var		7439250
Adjusted R-squared	0,997905	S,D, dependent var		824652,8
S,E, of regression	37747,36	Akaike info criterion		24,02892
Sum squared resid	2,85E+09	Schwarz criterion		24,08851
Log likelihood	-90,1157	Hannan-Quinn criter,		23,62707
F-statistic	667,7857	Durbin-Watson stat		1,319708
Prob(F-statistic)	0,001496			

According to the OLS output, there is a positive link between the quantity of fish caught and the number of hours spent fishing, the catch per unit effort (CPUE), annual rainfall, and mangrove coverage area. It would seem reasonable to expect a positive link between catch per unit effort and catch level. Because there is currently insufficient data available to measure fish stocks in the WIO, some research (Maunder et al., 2016) employs the CPUE as a measure of fish abundance. Following Maunder et al.'s assumptions, the positive link between CPUE and catch will hold, as a greater abundance of fish would be expected to result in a greater catch for the same amount of effort. Similarly, there is a link between overall effort and catch, meaning more hours spent fishing increases the likelihood of more fish being caught. There is a negative association between water temperatures and catch. This is because rising temperatures have a severe impact on fish habitats, resulting in a loss of spawning grounds. Furthermore, changes in temperature may result in a decrease in oxygen levels, reducing fish abundance and, subsequently, fish harvest. The model has an R-squared value of 99 percent, which means that the independent variables in equation 1 explain 99 percent of the changes in Fish Catch levels.

The second model is a dynamic model. A Seemingly Unrelated Regression Analysis was run using a system of 3 equations as stated below:

$$ET_{effort} = C(1) * HT_1 + C(2) * ET_1 \quad (2)$$

$$\frac{CT - CT_1}{CT_1} = C(3) + C(4) * \left(\frac{CT_1}{LOG(STEC)}\right) + C(5) * ET_1 \quad (3)$$

$$STEC = C(6) + C(7) * SART_1 + C(8) * SART_2 \quad (4)$$

Equation 2 (Table 6.2) demonstrates that the number of fish caught and the level of effort utilized have a substantial and positive association, confirming the conclusions of the OLS estimation. Furthermore, it demonstrates that previous-year efforts are related to current-year efforts. That result is expected because it shows that not only does the number of hours lead to an increase in the number of fish caught; if a fisherman puts in a lot of effort and has a large catch for the current year, he will most likely put in even more effort the following year to catch even more fish.

The link between STEC (a variable that monitors the environment) and Effort is another key element to consider. The data in **Error! Reference source not found.** suggest that when the environment is abundant, fishing requires less effort. That is, the richer the marine environment, the more fish will be spawned as a result of the environment, thus resulting in a higher fish catch with less effort..

Table 6-3: SUR estimation results

System: ANALYSIS
Estimation Method: Seemingly Unrelated Regression
Sample: 2002 2009

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	3.27E-07	1.29E-07	2.533250	0.0239
C(2)	0.418561	0.228203	1.834165	0.0880
C(3)	3.121127	0.692230	4.508802	0.0005
C(4)	-7.86E-06	1.51E-06	-5.216688	0.0001
C(5)	-0.298641	0.103125	-2.895925	0.0117
C(6)	2.44E-07	4.03E-13	604665.8	0.0000
C(7)	0.564813	3.56E-16	1.59E+15	0.0000
C(8)	2.794436	3.62E-16	7.72E+15	0.0000

Determinant residual covariance 0.000000

Equation: ET_EFFORT = C(1)*HT_1 + C(2)*ET_1
Observations: 8

R-squared	0.047500	Mean dependent var	4.262500
Adjusted R-squared	-0.111250	S.D. dependent var	0.403334
S.E. of regression	0.425178	Sum squared resid	1.084659
Durbin-Watson stat	2.081413		

Equation: _CT___CT_1__CT_1 = C(3) + C(4)*(CT_1/LOG(STEC)) + C(5)*ET_1
Observations: 7

R-squared	0.531226	Mean dependent var	-0.009735
Adjusted R-squared	0.296839	S.D. dependent var	0.205640
S.E. of regression	0.172439	Sum squared resid	0.118941
Durbin-Watson stat	1.716988		

Equation: STEC = C(6) + C(7)*SART_1 + C(8)*SART_2
Observations: 7

R-squared	1.000000	Mean dependent var	2196.804
Adjusted R-squared	1.000000	S.D. dependent var	499.1533
S.E. of regression	0.000000	Sum squared resid	0.000000

This analysis also illustrates an exceptionally strong link between rainfall and fish populations. This points to the role of nutrient cycling as a supporting service, the value of which is largely captured in this provisioning service valuation.

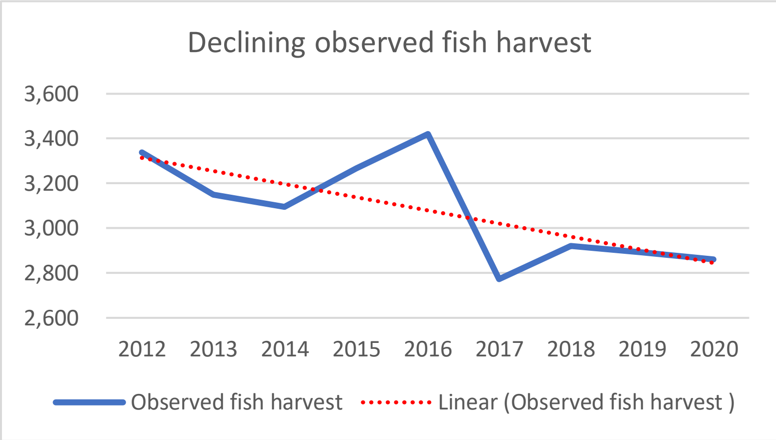
For aquaculture and agriculture, a market price methodology is employed. The estimated values are scaled down from the values associated with these activities for the broader region, based on land area, population, and population density.

6.3.4 Valuation

The total food provisioning services of the proposed KT-TBCA are estimated to have an asset value of approximately US$200 million, with annual benefit flows of around US$12 million to US$14 million per year.

Table 6-4: Valuation summary of food provisioning services of the KT-TBCA

Ecosystem Service	Estimated annual benefits				Asset value (NPV, USD, 5% discount rate)	
	t/a		USD/a		Min	Max
	Min	Max	Min	Max		
Food provisioning	***9,200***	***10,500***	***14,859,000***	***17,527,000***	***228,737,000***	***269,949,000***
Fish harvest	2,900	3,100	6,254,000	7,315,000	98,142,000	114,202,000
Aquaculture production	500	700	1,034,000	1,398,000	16,300,000	22,053,000



Agricultural production	5,800	6,700	7,571,000	8,814,000	114,295,000	133,694,000

The asset value associated with the food provision services of marine fisheries for the TBCA is estimated to be in the region of US$100 million. Around 3,000 tonnes of marine fish are estimated to be caught annually within the study area. Over the past several years, there appears to have been a declining trend in the region's fish catch. There a variety of potential causes, but this may point to the impact that the destruction of key habitats is having on fish populations.

For aquaculture, it is estimated that the asset value of the food provision is up to US$21 million. Scaled down estimates for the region show that aquaculture production amounts to more than 600 tonnes. The industry seems to be growing steadily, however, the impact this can have on natural habitats and the flow of other ecosystem services may be more pronounced if this activity is not managed appropriately.

Figure 6-1: Observed decline in fish harvest in the area

Food provisioning ecosystem services in the form of agricultural production is calculated to have an asset value of approximately US$70 million to US$80 million, conferring annual benefits to the local population to the tune of around US$5 million per year. Agricultural land in the area is reported to be largely underutilized (MDC, 2011), pointing to the likely increase in these values in the future. Care should be taken, however, to regulate the potential negative externalities associated with agriculture, such as increased levels of chemical fertilisers that can exert severe impacts on aquatic ecosystems.

6.4 Raw Materials Provisioning

6.4.1 Background

The provisioning of raw materials for building, fuel, and fibre plays a key role in providing inhabitants living in close proximity to the ecosystems with a variety of natural material benefits. These benefits include the provision of products such as grass and reeds for thatching, timber and poles for building, firewood (often processed and used in the form of charcoal) for fuel, or sand and mud for building or other purposes.

Evidence exists of the extensive use of mangrove poles for building (GoK, 2017; Muhando, 2011; UNEP, 2009), with much of this occurring through illegal logging. There also appears to be evidence of coral structures being harvested for use as bricks (**Error! Reference source not found.**), as mentioned in a local government report (MDC, 2011). While data could be sourced for deforestation rates in the region, little information exists on the use of coral in the building process, either as bricks or in the production of lime.

As with other provisioning services, there is a sustainable offtake volume below which harvesting of these resources may not have a negative impact on the ecosystems. However, with rapidly increasing populations in the region (NEMA, 2017), it is to be expected that the pressure being put on these systems likely exceeds sustainable harvest levels. The data gathering function of the proposed conservation area would provide much needed data to adequately calculate the sustainable offtake for a number of resources in the region.

Figure 6-2: Raw materials harvested from surrounding ecosystems are often used for construction, Galu Beach (Street View, 2022)

6.4.2 Beneficiaries

The largely rural communities inhabiting the terrestrial portion of the TBCA rely heavily on the provision of ecosystem services, particularly given the high poverty rates associated with the region. On the Kenyan side, the poverty rate in Kwale County is estimated to be around 44 to 49% (NEMA, 2017), while on the Tanzanian side this figure is closer to 80% (MDC, 2011). It is widely understood that communities associated with such high levels of poverty often resort to unsustainable resource use in order to meet their basic needs for survival (Kairo, 2010). Some of the most unsustainable of this resource use is often related to building materials and fuelwood, often in the form of charcoal. Estimates form the Kenyan National forestry indicate that around 70% of the wood requirements of communities living adjacent to forests is supplied by mangroves.

6.4.3 Methodology

To estimate the value of raw materials harvested from the region, this study focussed primarily on the harvest of wood for fuel in the form of charcoal and for building timber in the form of poles. For both charcoal and timber, a market prices method has been used for valuation.

For charcoal, an estimate was conducted of the average volume of charcoal consumed per person based on national data for Kenya and Tanzania. This was multiplied by the estimated number of people living within the proposed TBCA boundaries, then multiplied by the average price of charcoal for the preceding years.

Thus, the function associated with charcoal may be expressed as follows:

$$VRM_C = f(CONS_C; POP_{TBCA}; P_C)$$

Where:

VRM_c	– Value of charcoal as a raw material
$CONS_c$	– Consumption of charcoal
POP_{TBCA}	– Estimated population within the proposed TBCA
P_C	– Price of charcoal.

For timber, a similar method was employed, where the data on the wood extracts from mangroves in Kwale over the preceding years was used to calculate an average number of poles per person per year. This was then extrapolated out to the estimated population living within the TBCA. An estimated price for poles on the open market within the region was sourced to then provide an estimate of the value generated from the harvesting of poles from mangroves for timber purposes.

The function associated with charcoal can thus be expressed as follows:

$$VRM_T = f(H_T; POP_{TBCA}; P_T)$$

Where:

VRM_T	– Value of timber as a raw material
H_T	– Harvest of timber
POP_{TBCA}	– Estimated population within the proposed TBCA
P_T	– Price of timber, in price per pole.

6.4.4 Valuation

The application of the above market pricing methodology yielded an estimated asset value associated with raw material provisioning of up to nearly US$31 million, with annual benefits of around US$2 million each year.

Table 6-5: Valuation summary of raw materials provisioning services of the KT-TBCA

Ecosystem Service	Units	Estimated annual benefits				Asset value (NPV, USD, 5% discount rate)	
		Volume		USD/a		Min	Max
		Min	Max	Min	Max		
Raw materials				***995,000***	***1,346,000***	***13,633,000***	***18,447,000***
Charcoal	t/a	2,900	3,900	975,000	1,319,000	13,363,000	18,080,000
Timber	Poles/a	2,000	2,700	20,000	27,000	270,000	367,000

An estimated 3,000 to 4,000 tonnes of charcoal was calculated to be produced and consumed in the area within the TBCA each year, amounting to around 20 to 30 kg per person annually. This is estimated to have an annual value of up to US$1.3 million per year. For timber, it is estimated that benefits accruing to the communities of the area amount to over US$700,000 each year.

Growing populations and increasing rates of deforestation point to the importance of raw material provisioning services on local communities. The values presented are based on current and historical rates of extraction and are likely to be unsustainable. While the protection of these resources is vital, it is likely that such protective measures will reduce the flow of benefits over the short term, ensuring that a manageable level of use is maintained into perpetuity.

6.5 Scarce Habitats

6.5.1 Background

Cultural services are defined in the MEA as “Nonmaterial benefits derived from ecosystems” (MEA, 2005). The valuation of such nonmaterial benefits is not as straightforward as finding direct proxy values for a service provided. There are, however, methods to accomplish this, and an alternative to conventional valuation of a system could be the demonstration of value through the willingness to protect or improve such a system. For example, the size of an investment grant into the maintenance or protection of a natural system may serve as a proxy for the value of such a system. It is noted that this is not a perfect method as grants are often below requirements. However, it provides a snapshot of the potential quantification of such intrinsic value.

One such investor is the Global Environmental Facility (GEF). The GEF functions to assist with the protection of the environment and to promote environmentally sustainable development. More specifically, the GEF provides grants that transform environmental projects with national benefits to projects with global environmental benefits. The projects and funding provided are an expert-based reflection of priority areas that need attention. Thus, the methodological premise is that the attention given to specific ecological systems may be used as an indicative proxy whereby valuation can be based. Therefore, an indicator of the intrinsic and substitutability value of the KT-TBCA would be the magnitude of financial contribution that has been provided towards the improved maintenance of similar ecosystems by the GEF.

Furthermore, this approach may not accurately quantify the magnitude as it relies on available grant data (of which unavailability does not mean zero value nor does relatively small amounts mean no value). It is important, however, to acknowledge that the substitutability and intrinsic value will likely cause the total value of ecosystems to be magnified.

This calculated value would be based on a proxy that demonstrates a technique for the intrinsic valuation of similar habitats. This value should not be seen as a direct market value but rather as a demonstration of the magnitude of the value placed on these ecosystems.

The ecosystem services included in this value encompass: education and inspirational services; landscape and amenity values; aesthetic appreciation; spiritual experience, cultural heritage, and sense of place; and to some extent the option value placed on genetic diversit, and the maintenance of globally important habitats.

6.5.2 Beneficiaries

The beneficiaries of cultural services encompass not only those who directly benefit, for instance through direct spiritual ties to the specific region in question or those who benefit from the scenic and aesthetic value of the landscape, but also global wellbeing through the mere existence value of such natural landscapes and the genetic value that they hold through their biodiversity. In this analysis, the beneficiaries are assumed to encompass all individuals and organisations across the spectrum who may have an interest in conserving this region for any of the following reasons: spiritual and religious value, aesthetic value, inspirational value, educational value, sense of place, and cultural heritage.

6.5.3 Methodology

A proprietary model has been developed based on the revealed willingness to pay method. This serves to estimate the broader value of the range of non-material cultural services. This model makes use of data collected from the Green Environmental Facility (GEF) on projects conducted on the African continent over the past 20 years. A wide range of data was collected on the various parameters that formed part of these projects. This data was utilised to generate a demand function based on the species richness within a given region. This demand function can be plotted in the form a demand curve (**Error! Reference source not found.**), illustrating the relationship between species diversity and the revealed willingness to pay through conservation project investment. An indicative price per species was thus calculated to provide an estimate of the global willingness to pay for the existence value of a certain habitat.

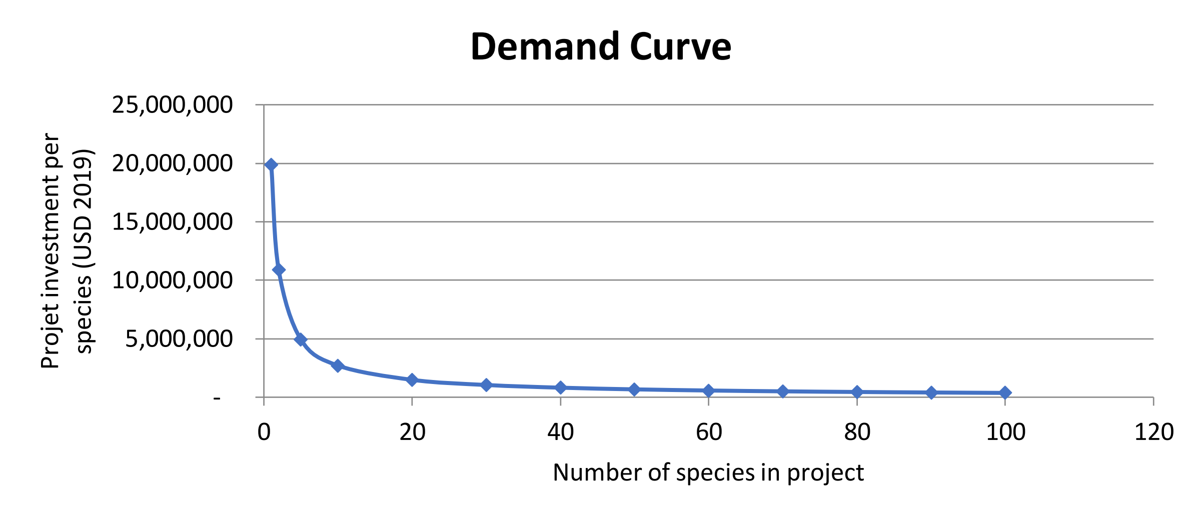


Figure 6-3: Demand curve illustrating the relationship between project investment and species richness of a given region.

Based on the findings of Samoilys (2015) there is believed to be a particularly high species richness off the East African Coast in this region of the West Indian Ocean. The region hosts numerous species of fish, molluscs, and hard corals, as well as birds, marine mammals, and aquatic plants.

Thus, the value of this bundle of services can be expressed as follows:

$$VCS= f(WTP_c; Area_{pr}; SD_{pr})$$

Where:

VCS - Value of cultural services as indicated by the global willingness to pay

WTP_c – Willingness to pay, or the proposed budget of the local authorities and international conservation entities

$Area_{pr}$ – Size of the protected area (ha)

SD_{pr} – Species diversity of the protected area (number of species).

6.5.4 Valuation

Using the above function, a minimum global willingness to pay of US$19.8 million is expected for an area in this region with the lowest diversity of species. This increases at a decreasing rate, reaching a marginal value of US$368,000 for each additional species above that threshold.

The results of this analysis revealed an estimated total asset value ranging between approximately US$700 million and US$1.3 billion for the entirety of the proposed TBCA. Expressing the value as an annual flow of benefits is essentially immaterial, as the flow of benefits is not linked to any financial flows or flows of material goods and services. However, it may be said that a global benefit of up to nearly US$90 million is derived from this area annually through the mere existence of the ecosystems and their underlying natural assets..

Table 6-6: Valuation summary of scarce habitat services of the KT-TBCA

Ecosystem Service	Estimated annual benefits (USD/a)		Asset value (NPV, USD, 5% discount rate)	
	Min	Max	Min	Max
Scarce Habitats	48,299,000	94,832,000	731,285,000	1,435,851,000

While these benefit flows may not necessarily be monetised, this value points to the significant intrinsic value of the range of natural assets in the region, and the benefits conferred on society. Thus, the importance of protecting it is significant to ensure that future generations may derive similar benefits.

6.6 Tourism and Recreation

6.6.1 Background

The distinction between tourism and recreation is generally regarded to be defined by distance travelled. The World Tourism Organisation (UNWTO, 2022) defines tourism as follows: "*Tourism is a social, cultural and economic phenomenon which entails the movement of people to countries or places outside their usual environment for personal or business/professional purposes."* Tourists often partake in a range of activities in the place they're visiting and consume local products and services. All of this contributes towards tourism revenue for the area. One of the primary sources of income for protected areas is often the revenue generated from these tourism activities. While a wide range of expenditures can be related to tourism, the primary source of revenue is related to accommodations, with a lesser portion generated through other activities. For the purposes of this study, revenue associated with accommodation is taken as the primary indicator for tourism, regardless of whether this accommodation is made use of my local or international tourists. Meanwhile, other activities, such dolphin viewing excursions for example, are used for the basis for recreation.

6.6.2 Beneficiaries

There exist a large number of hotels and resorts in and around the proposed TBCA. The beneficiaries of this service include the visitors who enjoy the accommodation, sightseeing, snorkelling, fishing, and various other activities; the owners of these businesses who receive an income in the form of profit; the local population, who have found employment in these businesses; and the governments of the respective countries, who receive a dividend in the form of taxes from these business operators.

The Kenyan side of the border appears to have a considerably more well-developed tourism sector. A total of 193 hotels were found to be located on the Kenyan side, located primarily in the northern area between Funzi Island and Diani Beach, with the highest density in the award winning Galu/Diani Beach area (Brilliant-Africa, 2022). The Tanzanian portion of the TBCA is characterised mainly by small rural fishing villages, with only 18 hotels identified on this side of the border. This indicates that there is likely significant scope for expanding the tourism market for the region as a whole.

6.6.3 Methodology

The value of tourism was derived from available data on the existing tourism industry within the proposed TBCA, making use of a market pricing methodology. Primary research was conducted in order to gauge the size of the tourism industry in the region, as detailed below:

- We looked at all of the hotels and lodges indicated on the adjacent map in order to determine the number of hotels in the area.
- The pink dots on the map indicate the places with the most available lodging.
- The majority of the TBCA's accommodation in Kenya is situated around Ukunda, near the beaches of Diani and Galu.
- The next stage was to gather the total number of beds available as well as the price per night from each lodging website in order to calculate the total number of beds available and the average price per night for tourists.
- The average duration of stay was collected from KNBS tourism data as well as the Tanzania tourism survey provided by TNBS.
- The occupancy rates were also obtained from the national statistics bureaus of each country, and are pre-covid rates. The table below summarises the total number of hotels in each area.

	Totel Hotels identified in area
Kenya	193
Tanzania	18

Figure 6-4: Approach to tourism services valuation within the proposed KT-TBCA

The total number of beds available at each accommodation facility was used to compute the overall available bed nights. The occupancy rate numbers originate from national data for Kenya and Tanzania for the preceding years, and the number of bed nights was determined by multiplying the number of beds by 365. The average occupancy rate for each area, as well as the average number of visits, were used to determine the anticipated numbers for accommodation income. Data was also obtained for pricing of wildlife tourism activities in the region or viewing of marine mammals such as whales and dolphins. This was then multiplied by a factor of likelihood applied to the estimated number of visitor (Gounden et al., 2020).

Thus the value of this service can be expressed as follows:

$$VTS = f(ABN; OCC; ARR; ACT)$$

Where:

VTS - value of tourism services

ABN - all available bed nights

OCC - average occupancy rate

ARR - average rack rate

ACT - tourism activities

Expected bed nights is a factor of the total number of beds available throughout the year and occupancy rates as revealed through tourism data.

Assuming that these values remain fixed for the foreseeable future, we are able to calculate the expected flow of revenue for the tourism sector in terms of accommodation income.

6.6.4 Valuation

Using the method above, the asset value of tourism and recreation ecosystem services conferred by the intact ecosystem of the proposed KT-TBCA is estimated at nearly US$1.8 billion.

Table 6-7: Valuation summary of tourism and recreation services of the KT-TBCA

Ecosystem Service	Estimated annual benefits (USD/a)		Asset value (NPV, USD, 5% discount rate)	
	Min	Max	Min	Max
Tourism and recreation	***65,810,000***	***117,227,000***	***996,422,000***	***1,774,933,000***
Tourism	63,663,000	113,487,000	963,915,000	1,718,311,000
Recreation	2,147,000	3,740,000	32,507,000	56,622,000

Tourism benefits account for the bulk of this value. It has been calculated that the annual revenue flows for tourism may be up to US$113 million per year within the TBCA, with recreational services reaching an upper bound of US$3.7 million.

As noted above, while the tourism potential on the Kenyan side of the border appears to be fully developed, there appears to be significant scope for the improved monetization of this ecosystem service benefit on the Tanzanian side. Many of the activities found in the region relate directly to protected areas, such as Wasini and Kusite. It is likely that the management activities of a broader conservation area would further spur further development of the tourism industry in this area.

6.7 Carbon Sequestration

6.7.1 Background

Climate regulation as an ecosystem service relates both to the local as well as global scales. Locally, temperature and precipitation can be affected by changes in land cover. On a global scale, a single ecosystem can either mitigate or contribute to climate change by acting as either a carbon sink or carbon source. Photosynthesis is the primary process responsible for the removal of carbon from the atmosphere. This carbon is stored in both biomass, i.e., the woody and herbaceous matter of all living plants and trees, and below ground organic and inorganic carbon, i.e., the carbon stored within soils and rocks.

As ecosystems become degraded, they often switch from being a net remover of carbon to a net producer. This happens through a number of processes. First, as these ecosystems become degraded, their ability to sequester carbon becomes compromised due to the reduction of growing plant matter. This results in reduced primary production. Second, much of the carbon stored in the sediments by the root systems is released back into the environment. If the woody plant matter is used as a source of fuelwood, the release of carbon is further expanded through the direct emissions of carbon into the atmosphere.

Coastal vegetation habitats are particularly productive environments from a climate regulation perspective. They account for considerably higher rates of carbon removal and storage compared to almost any other type of ecosystem. The efficiency of these types of ecosystems lies in both their high rates of primary productivity – the production of plant matter, largely associated with the fast growth rates associated with mangroves – as well as their proficiency in trapping organic matter and storing it in a low decomposition environment in the sediments. For this reason, mangrove forests have a considerably higher efficiency rate of carbon storage than terrestrial forests. Seagrasses, like mangroves, help to stabilise sediment and therefore lock away carbon, burying a significant amount of the organic carbon produced in the oceans.

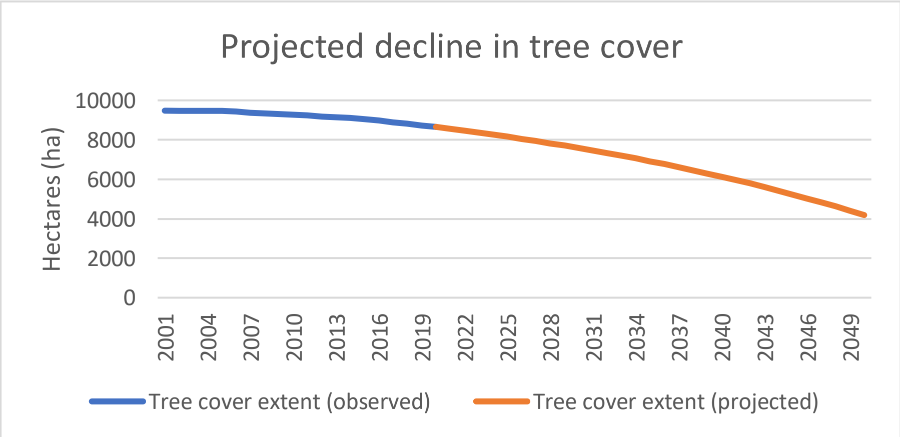


Figure 6-5: Projected tree cover decline (based on data from

There is evidence that forest cover in the proposed TBCA has been decreasing over the preceding two decades (WIOMSA, 2019; Mongabay, 2022). While this is true on both the Kenyan and Tanzanian sides, the tree cover loss in the Mkinga area on the Tanzanian side of the border appears to be considerably more pronounced. Due to data constraints, for the purposes of this study it is assumed that this tree cover loss relates primarily to mangrove forests, as mangroves appear to account for the majority of the tree cover in this area.

As noted above in the CRA, the key driver of the degradation of this environmental asset appears to be deforestation due to human activity. This may be related to wood extraction and removal for fuelwood or charcoal, and timber. It may also be related to extraction to enable other land uses such as aquaculture or salt production.

6.7.2 Beneficiaries

The beneficiaries of this ecosystem service range from the local to the global scale, as does the reach of this service (MEA, 2005). While the large-scale service of climate change mitigation through the capture and storage of carbon benefits the world on a global scale, the exact nature of these benefits is difficult to quantify for a small area of protected forests. Many studies have attempted to place a value on the impact to the global economy from an increase in global average temperatures (Hoegh-Guldberg et al., 2018). Such studies largely remain theoretical, and thus vary widely in their estimates.

On a local scale, the direct benefits of climate regulation can take many forms. These include, as noted above, the potential changes in temperature and precipitation. Once again, attributing these potential changes to a change in the functioning of a specific, relatively small-scale ecosystem requires detailed model ensembles combined with high resolution data. As a proxy for this, the payments for ecosystem services, which are becoming an important tool in the development of strategies for conserving key ecosystems, can be used as a measure of the potential benefits to local communities from taking an active role in such conservation.

A nearby project, located at Gazi on the Kenyan coast just north of the proposed TBCA, has been tapping into these benefits over the preceding years (GoK, 2017). A host of measures have been implemented to ensure the existing mangrove forests are protected, and citizens have even restored forests in areas that were previously degraded. They also have engaged in silviculture to provide for the needs of the community for building materials and fuelwood, which has yielded some notable benefits through trading carbon credits on the voluntary carbon markets. For the purposes of this study, we used the potential earnings to the local communities from halting deforestation within the mangrove areas as an indicator of the value that may be derived from this activity in terms of climate regulation.

6.7.3 Methodology

As discussed above, the climate regulation function of mangroves and seagrasses, through the capture and removal of carbon, is a significant factor in the overall value of these ecosystems. Using the methodology established by the IPCC (Kennedy et al., 2013) for carbon sequestration and loss from coastal wetlands (primarily mangroves and seagrasses), the calculation in this analysis has been based on available data for deforestation and seagrass loss in the region of the TBCA and observed carbon sequestration rates for mangrove forests and seagrass meadows (GoK, 2017; KNFS, 2017; Jones et al., 2020;

Seranno et a., 2021). This, along with current market prices for carbon credits, thus provides a market price valuation of the climate regulation services provided by this ecosystem.

The function associated with this ecosystem service can thus be expressed as follows:

$$VCRS = f(P_C; NCA_{PR})$$

With $NCA_{pr} = f(DEF_{MG}; AL_{SG})$

Where:

$VCRS$ – Value of climate regulation services as indicated by the global willingness to pay on the international voluntary carbon markets

P_C – Price of a carbon credit on the open market

NCA_{PR} – Net carbon accumulation

DEF_{MG} – Deforestation of mangroves

AL_{SG} – Area loss of seagrass cover

6.7.4 Valuation

The value of carbon sequestration for the region is severely affected by the destruction of mangrove and seagrass assets. Based on historical data, it is estimated that the overall asset value of this ecosystem service is currently at a maximum of just below US$5.8 million, with annual flows of up to US$320,000, accounting for a net carbon sequestration rate in the range of 7,000 to 23,000 tonnes of carbon annually.

Table 6-8: Valuation summary of carbon sequestration services of the KT-TBCA

Ecosystem Service	Estimated annual benefits				Asset value (NPV, USD, 5% discount rate)	
	tC/a		USD/a		Min	Max
	Min	Max	Min	Max		
Carbon Cycling	***8,600***	***24,700***	***121,000***	***346,000***	***2,488,000***	***6,227,000***
Mangroves	30,300	37,000	424,000	518,000	7,337,000	8,968,000

Seagrass	-21,700	-12,300	-303,000	-172,000	-4,849,000	-2,741,000

Based on the high rates of seagrass loss in the area and the significant carbon amount of carbon released from sediments associated with seagrass meadows, we found that seagrass represents a net source of carbon based on historical data, as indicated by the negative numbers linked to seagrass.

Due to the highly productive nature of mangroves and seagrasses in terms of capturing and storing carbon dioxide, it is likely that the benefits associated with this ecosystem service will increase significantly if the ecosystem assets can be effectively protected through the declaration of a conservation area.

While the value calculated in this study provides an estimate of the overall net value of carbon sequestration and release, it should be noted that this is not necessarily a monetizable value for carbon credits, which would require a measure of additionality. Given the current rates of disturbance associated with these productive assets, there is likely significant scope for this in a protected scenario.

6.8 Regulation of Extreme Events

6.8.1 Background

Regulation of extreme events is classified as a regulating service under the MEA (2005). This is a service associated primarily with coastal ecosystems, and thus is of particular importance to this valuation. Mangroves, along with shallow coral reefs, and to an extent intertidal flats and intact seagrass beds, serve as a protective barrier for communities situated along the coast. These systems reduce the impact of tsunamis or storm surges, especially during earthquakes occurring in or near the ocean, or when particularly violent storms are experienced offshore.

6.8.2 Beneficiaries

The primary beneficiaries of the storm surge protection offered by intact coastal ecosystems are the communities living near the coast, typically composed of settlements nestled behind mangrove forests. During intense storm surge or tsunami events, these coastal settlements can become inundated by seawater, destroying homes, livelihoods, and infrastructure. This can result in the displacement of large numbers of people, depending on the population of the area, and the imposition of significant costs in terms of damage to infrastructure.

6.8.3 Methodology

The protective value of intact coastal ecosystems can thus be modelled using insurance premiums as the likelihood of a claim during these surges is expected to be high when the mangroves are not available. Put simply, a damage avoided valuation method is used to estimate the benefits of maintaining an intact ecosystem in this analysis.

Data on previous tsunamis that had a measurable impact on coastal countries was collected with the objective of deriving the cost of recovery after such an event took place. The data collected indicated that most, if not all, major tsunamis resulted from earthquakes. As little data exists on the effect of storm surges for this region, this analysis focuses on the tsunami data.

Due to the high number of potential earthquakes within the chosen area for both countries, only earthquakes of magnitude 4.0 are evaluated, and it is assumed that those higher than 6.3 are likely to cause serious economic damage. Magnitude is expressed in whole numbers and decimal fractions. For example, a magnitude 5.3 is a moderate earthquake, and 6.3 is a strong earthquake (USGS, 2022).

Due to limitations of cost data for Tanzania and Kenya in terms of probability, we use classical probability as follows:

Probability = Number of potential events / Total number of potential events (P=N/T)

Furthermore, it is assumed that the number of claims follow a Poisson distribution with only one claim following the occurrence of 1 earthquake above the 6.3 magnitude in our area. We further assumed that there is only one claim paid at the end of a constant duration, and since there was only one potential event which could have given rise to a claim, the claim would occur at the end of the entire duration. The duration chosen here was the period between the first known and recorded potential event (1920- first event in 1938) to the year 2020. (100 year period).

The basic insurance risk model formula used is (from Ruin Theory - CT6 Actuarial Statistical Models):

$$Premium = (1 - \Theta)\, \lambda\, E(X)$$

Where:

Θ - represents a percentage of insurer's profit (mark-up value)

λ – the expected number of claims, which is 1 in our case but can vary.

$E(X)$ – the expected aggregate claim, the amount of claim.

6.8.4 Valuation

The above analysis, considering the probability of a significant event occurring based on available data, yielded an estimated annual benefit flow of extreme hazard regulation between US$564,000 and US$940,000 per year for the region of the TBCA, providing an asset value for the protective function of the coastal ecosystems of the area of approximately US$14.2 million at the upper limit.

Table 6-9: **Valuation summary of regulation of extreme events services of the KT-TBCA**

Ecosystem Service	Estimated annual benefits (USD/a)		Asset value (NPV, USD, 5% discount rate)	
	Min	Max	Min	Max
Regulation of extreme events	564,000	940,000	8,534,000	14,224,000

This analysis does not explicitly take into account the health of the underlying ecosystem assets. As these assets, particularly the mangrove forests, coral reefs, and seagrass beds, become degraded, the ability of the system to provide this service is diminished. Protecting these underlying assets would secure this value by reducing their degradation.

6.9 Overview of Valuation Methods

We were created a bio-economic model for this study using the Guidelines on Methodologies for the Valuation of Coastal and Marine Ecosystems document, with the goal of approximating the interactions between the biological features of the study region and the local economy. This was accomplished by developing a collection of valuation models for the numerous ecosystem services that are integrated into a system of production function. Costing techniques such as the following were also used:

- Market pricing, which was utilized to determine the market value of fish and aquaculture as well as the market value of wood and charcoal derived from mangroves
- Travel costs, which were used to determine the revenue obtained from tourism accommodation as well as recreational activities
- The Cost of Carbon, which was used to determine the price of carbon credits and the value of climate regulation services provided by mangroves and seagrass beds
- The Contingent Valuation method, which was also used in determining the willingness to pay by international conservation entities for changes to ecosystem services

Using these techniques, we were able to establish a baseline valuation that demonstrates how the preservation of biological features leads to greater ecosystem services that benefit the community and local businesses while also providing a better environment

7 Cost Benefit Analysis

A cost benefit analysis (CBA) is used to evaluate a decision or potential project by weighing the costs and benefits of the project in order to determine its profitability. For the area under review in this analysis, the costs relate to the management of the protected area, including all capital and operating costs associated with the range of activities that would need to be implemented. These costs must be assessed against the potential changes in benefits arising from improved protection. The analysis below provides a broad description of the activities that may be undertaken if protection is established, high-level estimates of the costs involved, and estimated effects on the benefit flows linked to the protection of this area. The approach used for this CBA was inspired by a **Guide to Cost-Benefit Analysis of Investment Projects**, Economic appraisal tool for Cohesion Policy (2014-2022) and **Figure 7-1** below, which illustrates the approach used in this analysis.

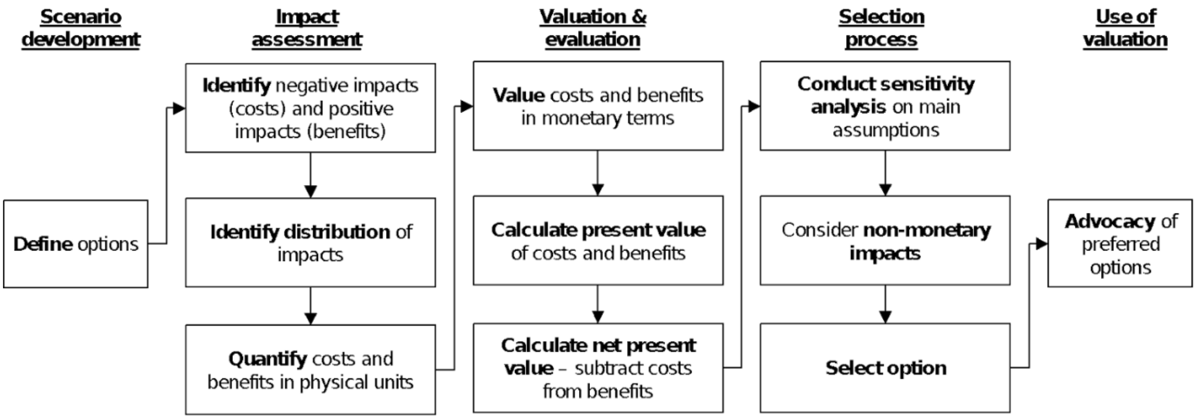


Figure 7-1: Methodological steps in cost-benefit analysis (source: Brander and van Beukering, 2015)

7.1 Background on the CBA

The ecosystems of the proposed TBCA have been shown to play a significant role in the livelihoods of the local communities and the economies of both Kenya and Tanzania. Evidence suggests that the ecological assets underpinning these ecosystems are at risk due to a range of anthropological hazards linked to climate change, overexploitation and unsustainable use, pollution, and other hazards. Under these circumstances, continued degradation is likely to have a continued negative effect on the functioning of these ecosystems and ultimately result in a reduction of the very ecosystem services that provide benefits to the local communities. The implementation of a TBCA and its subsequent management plan will assist in protecting existing assets as well as avoiding further degradation of natural assets.

In order to execute the CBA, we used the valuation conducted and reported on in section 6 to value the baseline scenario. This baseline case is a “do nothing” scenario, in which no protection is enacted and the identified risks remain unmitigated.

We then valued the alternative scenario of establishing the TBCA (refer to section 7.2.2). This was accomplished in several steps:

- We developed a hypothetical, but realistic, MPA management plan containing a range of conservation, sustainable use, and rehabilitation practices.
- We costed the above management actions, both in terms of capital and operational costs.
- We applied learnings from the conducted CRA (section 9) and used its outcomes to quantify and project the mitigative effects of the various management actions on the relevant biophysical input parameters in the valuation model.
- We conducted a valuation of the natural assets for the scenario where the TBCA is implemented, providing us with a set of net benefits when compared to the baseline scenario.
- The resultant net benefits, compared to the costs of mitigation, provided the cost-benefit analysis.

For each ecosystem service, there are three broad sets of beneficiaries. These include the local communities who rely on the ecosystem assets for provisioning and cultural services; citizens of Kenya and Tanzania who derive both direct and indirect benefits from the ecosystem; and other stakeholders who reside in other parts of the world and may visit as tourists or gain other benefits from the system. The value gained by these beneficiaries was measured as specified in chapter 6. In the CBA, we measure results in three economic effects: the first affects community members directly, the second involves the value non-citizens receive, and finally we measured the macro-economic benefits in terms of GDP and employment. As a result, the options and scenarios were evaluated first in terms of their benefits to the beneficiary communities and then their benefits to the national economies of Kenya and Tanzania.

7.2 Scenario Development (Definition of Options)

7.2.1 Baseline Scenario

In this analysis, the baseline scenario represents the current conditions in which there is no TBCA. This is characterised by unrestricted access and exposure to unmitigated risks across the full range of natural assets. This includes all natural assets discussed in section 5 above.

This scenario was valued in section 6, where through data analysis and forecasting it was found that while the ecosystem services in the area are beneficial to the local population, the mangroves and seagrass beds are thought to be declining as a result of fishing techniques and unrestricted harvesting that endangers and degrades the underlying assets. In a CBA, it is important to establish this baseline because it will enable us to track and evaluate the project's estimated performance over time with respect to the anticipated benefits and costs, as well as help determine conservation management goals.

7.2.2 Conservation Scenario

The intervention scenario under consideration is that of implementing a TBCA. Under this scenario, it is expected that a range of interventions may be implemented to mitigate the risks to the ecological assets of this system, thereby securing the flow of ecosystem services to the local community and other beneficiaries.

The creation of a TBCA management plan is a complex undertaking that requires extensive consultation and on-the-ground planning. This planning involves, among other things, the identification of programmes and activities to be undertaken by the management authorities. For the purposes of this study, and with the understanding that a detailed MPA management plan is still to be created, a high-level cost estimate of a likely management plan for the TBCA was developed. This was used as the cost basis for assessing the trade-offs against ecosystem services benefits gained, and it was compared across the two scenarios evaluated. Because an MPA management plan does not yet exist, we developed several hypothetical conservation interventions comprising a range of activities to which costs were allocated. These activities are not intended to be viewed as suggestions for implementation, but serve purely as a basis for the indicative costs for use in the CBA

Since the bioeconomic model's value calculations are connected to the biological assets, any modifications done to mangroves or seagrasses will subsequently affect the ecosystem services. Because of this, the proposed interventions will concentrate on reducing the use of resources related to mangrove forests and seagrass meadows or an increase in those assets.

Mangrove forests in the region have also been found to be in decline. It is assumed that this is largely attributable to harvesting of mangroves for fuelwood and timber by local communities. Visual analysis shows that, on the Tanzanian side of the border, aquaculture and salt production may play a significant role in the clearing of mangrove forests, however data on these effects is lacking. The degradation of this asset has many knock-on effects on the flow of ecosystem services. It is expected that under the status quo this degradation will continue to accelerate as there is increasing pressure from growing populations in the region. This growth and pressure appears to be outpacing improvements in living standards.

Mangroves play a central role in the healthy functioning of coastal ecosystems. They represent an important nursery area for juvenile fish populations and help to ensure the health of fish stocks. International evidence suggests that mangroves can reduce the rate of saltwater intrusion, which can significantly benefit low-lying coastal agricultural areas. Further, the hazard regulation function of mangroves is greater where forests remain intact. Carbon sequestration linked to mangroves has also been shown to be significant, and they potentially represent a net source of carbon even as they become degraded, due the large quantities of carbon they store in sediments. Furthermore, they are an important source of fuelwood and timber for local communities. The flows of all these benefits are expected to increase as the mangrove forests’ conditions improve.

The Mangrove Forests and the Seagrass Beds are this system's primary ecological assets. As a result, this CBA will focus on expected benefits from three management actions that were identified in relation to these two assets:

- Restoration
- Alternate use of the assets
- Continued sustainable use of the assets

This study does recognize that there are other management options outside of the ecological assets that can be considered in the implementation of the TBCA. These are further clarified in the following section and are accounted for in the costing analysis.

7.3 Potential MPA Management Plan

7.3.1 Enabling sustainable use and benefit sharing

Conservation is important because it aims to maintain ecological processes and their life-support systems as well as ensure the sustainable use of species and ecosystems (IUCN, 1980). Activities that promote conservation help encourage sustainable use of ecological resources and ensure that future generations will continue to benefit from the same resources.

Typically, MPAs, and conservation areas more generally, implement a range of activities to ensure the protection of the ecological assets forming the foundation of the local ecosystems. These programmes are aimed at:

- Implementing a scientific programme that enables adaptive management
- Controlling access and restricting harmful activities
- Providing alternative use options
- Implementing restoration in sites exposed to degradation are the most common
- Enhancing eco-tourism
- Establishing community-led conservation activities

7.3.2 Implementing a scientific programme that enables adaptive management

Adaptive management is a systematic process for improving environmental management policies and practices in a way that incorporates uncertainty and learning. During the implementation of a restoration project, the development of an enabling program will give managers a process to experiment with and test alternative solutions for restoring an ecosystem. Ideally, adaptive management leads to robust decisions, successful restoration project designs, cost-effective investments, and faster goal achievement.

A scientific program can be put into action to properly realize the benefits of the TBCA's implementation. In order to track the restoration progress, this program may include the monitoring of climate changes, species composition, and habitat change. This will help in delivering dependable, fundamental data about the ecosystem over time that might not have been observed otherwise. In order to discover which management options are most effective, the program may also include data review and assessment.

7.3.3 Controlling access and restricting harmful activities

Controlling access to areas of high ecological importance would likely play a major role in the management of the KT-TBCA. This may take the form of no take zones and/or low-take zones for various forms of faunal and floral harvesting activities. This may lead to reduced pressure on fish stocks directly from reducing overfishing and thus reduce the associated damage to ecological assets such as seagrass meadows and coral reefs, among other benefits. Thus, the valuation model inputs that may be used to measure the mitigative effects of access restriction may include catch per unit effort, in terms of fish stocks, and extent and condition of seagrass meadows and coral reefs.

Limiting resource extraction is another measure that could be considered. This relates to both marine resources, i.e., fish stocks, as well as terrestrial resources represented by mangroves. Due to the reliance of local populations on both the marine and terrestrial resources, this may be a more appropriate course of action than restricting access altogether. For instance, the introduction of more efficient cookstoves could play an important role in this by reducing the volume of fuelwood required by local communities.

Both approaches require the deployment of considerable resources. These relate to the construction of the requisite infrastructure, purchasing of equipment, training and employment of staff, and ongoing administrative costs related to maintenance and continuous monitoring and improvement.

7.3.4 Alternative use options

The alternative livelihood component is based on a reduction of the current degradation of mangroves by reducing reliance on the raw material provisioning services of the local ecosystem through introducing an alternative option.

For this option, it is envisaged that purpose driven woodlots could be developed to provide both timber and fuelwood to the communities to substitute the collection of these resources from the natural forests. The associated reduction in mangrove degradation will benefit a wide range of ecosystem services linked to the health and extent of mangrove cover. It will also benefit local communities and the broader economies of Kenya and Tanzania.

7.3.5 Restoration options

Restoration or rehabilitation activities may play an important role in the implementation of this MPA. Broad targets for restoration have been set globally for the restoration of degraded aquatic ecosystems, with more targeted interventions planned for the WIOMSA region. These relate specifically to mangrove forests and seagrass meadows.

The restoration option is independent of the conservation options in that it is not reliant on other activities related to reduction of degradation and deforestation. The benefits of mangrove and seagrass restoration is expected to have a direct positive effect on the food provisioning services and carbon cycling services and an indirect positive benefit on the tourism services. A replanting initiative would be beneficial in restoring some of the lost land and would help counteract the current rate of degradation. The degradation of seagrasses pose a risk to the ecological service of carbon cycling due to their current conditions. Therefore, there is only one option for the seagrass asset: replanting or restoration.

7.3.6 Tourism enhancement

Specific programmes aimed at enhancing the tourism industry in the area may be pursued through improved regulation of tourism providers and broad marketing strategies. Improvement in the condition of the local ecosystems would likely result in some of the improved areas gaining increased recognition as quality attractions for tourism activities. Consequently, the creation of an MPA and the improvement of the environment may result in higher hotel occupancy rates.

7.3.7 Community-led conservation activities

By introducing community-based activities that will motivate and empower people to maintain biodiversity, sustain traditional ways of life, and assist in developing political support for existing protected areas, conservation activities and programs can have a significant positive influence on local communities. As a result of these efforts, communities will be better informed on the long-term consequences of the continued unsustainable usage of natural resources.

These community-based operations can involve local fishermen who collaborate with the government to create no-take zones and use less destructive fishing techniques. The community could also help with projects to replant degraded mangrove forest areas. As plastic is known to disrupt marine life and harm habitats along its path, the community could also take part in clean-up efforts to lessen the severity of marine pollution. This would also support global initiatives to reduce the quantity of plastic that ends up in the water and threatens aquatic life.

7.4 Estimating MPA management plan implementation costs

It is important to determine and understand the MPA costs involved in identifying programmes to be applied to the Kenya-Tanzania TBCA (KT-TBCA) as well as the costs of implementing these programmes. To accomplish this, management plans applied in other MPA's in Africa were used to assist in designing the programmes for the KT-TBCA.

The management activities needed to respond to the MPA management plan requirements as set out in section 11.3 include:

1. Law Enforcement
2. Biodiversity Monitoring
3. Sustainable use

4. Tourism
5. Community engagement
6. Finance, Administration and Human Resources
7. Rehabilitation
8. Alternative use

The programmes selected for the MPA are based on Prime Africa's knowledge of MPA systems, discussions with management of existing MPA's in South Africa, and analysis of protected area management plans for MPA's around the world. The annual operating costs for each programme are based on the staff compliment and, where applicable, other operating costs required to carry out the programme. The staff compliment was based on information obtained from existing MPA's in South Africa and adapted for the KT-TBCA. Any other required operating costs are based on an analysis of the costs and budgets in protected area management plans for other MPA's and vast research into MPA costs. The overhead cost items are also based on analysis of protected area management plans and existing knowledge of MPA costs. The capital items required by the UNEP MPA are also based on Prime Africa's knowledge of what MPA's need, as well as information provided by MPA's in South Africa. Once a list of items was developed, each item was costed individually by conducting desktop searches for the prices of these items.

The table below presents a summary of the costs for the TBCA. This shows the different programmes to be conducted at the MPA as well as the annual operating costs and, if applicable, capital costs required for each programme. The table also shows the overhead and repairs and maintenance costs separately, as these costs are not allocated to a specific programme. Following these are the remaining capital costs for the capital items required for the TBCA.

Table 7-1: Summary of the assumed annual operating costs and capital costs for the implementation of the KT-TBCA

Annual Programme Cost Item	Annual Costs (USD)	Capital Costs (USD)
Law Enforcement	400,000	620,000
Biodiversity Monitoring	400,000	80,000
Sustainable Use	300,000	500,000
Tourism	115,000	100,000

Community Engagement	215,000	
Finance, Admin & HR	555,000	
Rehabilitation	4,000,000	
Alternative Use	200,000	350,000
Additional Annual Costs:		
Repairs and Maintenance	705,000	
Overheads	570,000	
Total Annual Costs	**7,460,000**	
Capital Expenditure:		
Land Cruiser SUV		200,000
Quadbikes		40,000
Aircraft		500,000
Monitoring equipment		44,000
Launch Site		400,000
Administrations Office		525,000
Annual Programme Cost Item (continued)	**Annual Costs (USD)**	**Capital Costs (USD)**
Staff Accommodation		2,100,000
Field Rangers Office		600,000
Stores and Workshop facilities		800,000
Roads		3,000,000
Fencing		1,500,000
Gate houses		150,000
Water system		2,000,000

Sewerage Minor assets		450,000 3,000,000
Total Capex:		**16,959,000**

The costs for each programme are detailed below.

Staff Costs

The staff compliment for the KT-TBCA is based on a typical MPA staff compliment. This information was sourced from data provided directly from an existing MPA. The number of staff was, however, adjusted to reflect the size of the KT-TBCA. The staff compliment includes staff such as a reserve manager, financial manager, human resources manager, admin clerks, marine biologists, field rangers, and gate guards, amongst others. The annual salary for each staff member was then determined to obtain the total employee costs for the KT-TBCA.

Next, each of the aforementioned programs was given a staff member allocation that matched the goals of the program with the staff member's regular responsibilities. In this manner, the staff costs are included in each program's annual costs. Thus, the annual cost for each programme is based on the required staff, capital items, and any other relevant costs.

Law Enforcement

The purpose of this programme would be to protect the MPA's natural assets and prevent any illegal activities that might cause harm to the marine environment's natural resources. The annual operating cost for this programme equates to US$400,000. The programme would also require once-off capital costs relating to the purchase of large patrol boats and construction of observation posts. It was estimated that the MPA would require 2 large patrol boats and 6 observation posts. The once-off capital cost for this programme is therefore estimated to be US$620,000.

Biodiversity Monitoring

This programme would serve to monitor the ecosystem and all its components, processes, habitats, and functions in order to prevent threats to biodiversity and maintain the system in a stable, natural state. The annual operating costs for this programme equate to US$400,000. The once-off capital costs for this programme equate to US$80,000. These costs consist of the typical equipment needed to monitor the ecosystem. This was sourced from information supplied by an existing established MPA. It includes items such as cameras, GPS, thermal imagers, and drone services, among others.

Sustainable Use

The purpose of this programme would be to ensure that any harvesting from the MPA is done with the relevant permissions and in a manner that does not negatively affect the ecosystem, i.e., does not cause further loss to the mangrove cover or biodiversity loss. The annual operating costs are estimated to be US$300,000. These costs are composed of employee costs and costs to monitor fish harvests and monitor the mangrove cover.

Eco-Tourism

The purpose of this programme is to develop tourism within the MPA in a sustainable manner to serve as a revenue source for the MPA, help cover the costs, and make the public more aware of the importance of biodiversity and conservation. The programme consists of activities such as overall tourism oversight, managing the concession process for any day tours and activities, and marketing the MPA. The costs of these activities are based on the costs expensed for similar activities at other MPA's throughout Africa. The estimated annual operating costs are US$115,000. This programme also requires upfront capital costs to develop a robust entry and revenue system to ensure all revenue is collected. This would amount to US$100,000.

Community Engagement and Community-led Conservation

The purpose of this programme would be to maintain relationships with surrounding communities. It involves working jointly with the communities to address issues of common concern, resolve any disputes, and communicate marine information. The annual operating costs for this programme are estimated to be US$215,000. This includes items such as community project support and extension and outreach programmes.

Finance, Administration and Human Resources Management

This programme supports the effective implementation of all the other programmes and is crucial in helping other programmes achieve their targets. As such, it is important not to underestimate the costs of this programme. Here, the costs mainly consist of employee costs for staff members such as the reserve manager, financial manager, and human resources manager, among others. The annual operating costs are estimated to be US$555,000.

Rehabilitation

This programme will focus on the rehabilitation of mangroves in the MPA. Based on research conducted by The Nature Conservancy, rehabilitation costs for mangrove restoration are US$4,000 per hectare for hydrological restoration. Hydrological restoration is the most effective. The annual operating costs for this programme are US$4,000,000, which will cover employee and other required operational costs.

Alternative Use

The alternative use programme will provide the community with an alternative timber source. It involves costs to purchase land and plant trees and costs for harvest support. The annual operating cost is US$200,000 and the capital cost is US$350,000.

Repairs and Maintenance

The annual costs for repairs and maintenance consist of employee costs for the staff members responsible for overseeing the repairs and the cost for the actual repair work. Together, this annual cost is US$705,000.

Overhead

These are common costs that are not allocated to a specific programme but are still required to ensure the MPA functions effectively. They include costs such as telephone and fax, insurance, staff welfare, cleaning materials, electricity and gas, and IT expenses. The annual operating cost for overhead is expected to be US$570,000.

Other Capital Costs

This includes any additional capital items that the KT-TBCA would require. These items were costed individually, with information sourced from internet searches and other protected area management plans. The capital items include vehicles, quadbikes, an aircraft, rubber ducks, boat launch sites, an administration office, staff accommodation, a field rangers' office, stores and workshop facilities, roads, fencing, gate houses, water and sewerage, and other minor assets. The total cost for these items is US$15,309,000.

7.5 Valuing the Benefits of Implementing the MPA Management Plan

7.5.1 Overview

An economic analysis was conducted using the baseline scenario and the defined conservation management options. In order to determine the changes in values brought about by these conservation options, it was first necessary to identify realistic changes in ecological assets and the resources they supply and thereafter integrate those potential changes into the bioeconomic model. The indicators are based on an examination of the alterations that would result in notable differences in the environment and the ensuing ecosystem services.

Changes to the ecological assets influence all ecosystem services because the model is linked; as a result, these changes are split out per ecosystem service, with a summary table displaying the net changes in values. The effects are then used to determine the Benefit-Cost-Ratio (BCR), an indicator that depicts the relationship between the proposed project's relative costs and benefits. Thus, the BCR ratio will show whether the TBCA will result in a positive net present value for its investors and beneficiaries.

7.5.2 Indicators

For the purposes of this study, we have assumed that conservation activities could have the following effects:

- Fish catch, measured in catch per unit effort, is assumed to increase by 20%. This is based on a statistical analysis of variance that was conducted to ascertain how much of a change in the fishery variables must occur in order for the change in catch to be significant.
- The analysis also found that the most notable percentage difference with the mangroves in regard to fish harvest was a 10% change.
- Deforestation of mangroves is targeted at a 100% reduction within 10 years of the implementation of the TBCA, resulting from the intervention options discussed above.

- Restoration of mangrove coverage is targeted through the restoration programme aimed at replanting 100 ha per annum.
- Seagrass cover loss is targeted to be reduced by 100% within 10 years of the implementation of the TBCA. This will be accomplished through the restriction of destructive fishing practices, combined with effective monitoring and enforcement.
- As with mangroves, restoration of 100 ha per annum of seagrass is assumed to form a part of the management activities.
- An indirect expected increase of 10.5% in the number of available beds is assumed over the medium term.
- An increase of 19% in the rate of visitors taking part in recreational activities is assumed over the medium to long term due to improvements in the ecotourism-linked activities associated with healthier ecosystems.

7.5.3 Impact Assessment

In order to assess the proposed conservation scenario against the baseline, the impacts of the scenario must be identified. These indicators relate to both the costs and benefits being assessed in the CBA. Indicators of costs relate to both the financial cost of implementing activities as well as the visible outputs associated with those costs, i.e., the infrastructure, employees, and data. Indicators of the benefits' impacts may take two forms: physical indicators related to the extent and condition of the ecological assets, and economic indicators represented by changes to the estimated flow of ecosystem services, both directly to local communities and indirectly to the broader economies of Kenya and Tanzania. These impacts would be achieved as the result of targeted activities carried out under the conservation implementation, a set of which are hypothesized below.

7.6 Evaluation of Costs and Benefits

Following the identification of potential MPA management plans and scenarios and their associated costs, the next step is to proceed with the modelling. First, we model Scenario 1, which includes the costs and outcomes of implementing the management plan. This model can then be compared against the baseline using the selected indicators/inputs to determine the advantages of each alteration.

The ecosystem service valuation section of this report established the flow of benefits from ecosystem services to the community. In the case of the CBA, the study was expanded upon by quantifying the macroeconomic advantages of ecosystem services in terms of GDP and employment. The advantages of conservation efforts will be divided in this section between those provided to the community and those provided to the economy.

It is expected that the flow of ecosystem services would decrease over the long term under the baseline scenario as there would be no mitigation of the system's harmful impacts. Under a conservation scenario, the activities and costs incurred for mitigation will likely maintain or improve the flow of these services and cause their net present benefit to increase. This is not to say that the flow of services will increase in real terms across all sectors, but at the very least, the volume of services will be maintained at a sustainable level, thus increasing the net present benefit.

The macroeconomic benefits are expected to show a considerably higher value than the direct benefits to local communities due to multiplier effects observed within the broader economies. These are summarized in below, followed by a detailed description of the estimated benefits to local communities.

Table 7-2 shows that:

- The largest contributor to GDP is food provisioning services. This is because the industries that profit from these services (agriculture and fishing) exhibit a significant GDP multiplier effect.
- The hospitality and leisure industries have a lower multiplier effect on GDP but a higher effect on employment. Therefore, tourism and recreation are the biggest contributors to employment even if they are the second-largest contributor to GDP and the highest contributor to ES value.
- Raw Materials do not contribute as much to GDP as these are used by community members for cooking and building and are hence more apparent in the livelihoods of community members.
- The regulation of extreme events was once again found to be a significant ecosystem service due to the role played by coastal assets of the region in reducing the energy of waves caused by storm surges and sub-oceanic earthquakes.
- Food Provisioning services are the biggest contributor to GDP. This supports the findings of the baseline analysis which determined that Food provisioning services are the most important ecosystem service to local beneficiaries.

Table 7-2: Summary of macroeconomic values associated with enhanced flows of ecosystem services

		Minimum Economic impact (USD)	
Ecosystem Service	**Industry**	**GDP**	**Compensation to Employees**
Fish harvest	Fish and other fishing products; aquaculture products; support services to fishing	70,818,000	1,041,000
Aquaculture production	Fish and other fishing products; aquaculture products; support services to fishing	12,693,000	187,000
Agricultural production	Products of agriculture, hunting and related services	45,902,000	3,816,000
Charcoal	Manufacture of wood and wood/cork products	1,297,000	245,000
Timber	Products of forestry, logging, and related services	186,000	1,000
Mangroves	Public administration and defence services; compulsory social security services	1,881,000	1,152,000
Seagrass	Public administration and defence services; compulsory social security services	949,000	581,000
Tourism	Accommodation services	90,372,000	48,748,000
Recreation	Arts, entertainment, and recreation services	8,278,000	1,932,000
	Services furnished by membership organisations	827,000	359,000
Regulation of extreme events	Insurance, reinsurance, and pension funding services, except compulsory social security	1,747,000	1,101,000

	Services auxiliary to financial services and insurance services	474,000	11,000
Total	**Total**	**233,527,000**	**58,011,000**

Forecasts for the project's costs and benefits are provided for the years 2023 through 2050. This wide range is provided because the project's benefits may not actually be realized for many months or even years. In this project, it is anticipated that 100% of the advantages would be realized in 2032, with only 10% of the benefits realized in 2023.

This analysis shows that the overall benefit cost ratio (BCR) associated with the estimated changes in net benefits over the period 2023 to 2050 show a significant positive return. In order to calculate the BCR, the lifetime project costs are subtracted from the expected benefits over the same period. This provides an estimate of the annual net benefits. These annual figures are then discounted to generate the net present value (NPV) of these net benefit flows. This process was followed for the benefits flowing directly to the local communities, as well the macroeconomic benefits calculated for the economies of Kenya and Tanzania.

The BCR associated with the direct flow of benefits to local communities is estimated to be 2.08. This means that for every $1 spent on the implementation of a conservation strategy, over $2 of value would be expected to flow back into the local communities via the benefits from ecosystem services.

In terms of the broader macroeconomic value of such an intervention, the BCR figure is considerably higher at 5.53. According to this analysis, for every $1 spent on this proposed MPA, around $5.50 in value is expected to be created in the broader economies of Kenya and Tanzania, combined.

Table 7-3: Summary of NPV Benefits

Beneficiary	NPV of Benefits	NPV of Costs	BCR
Local Communities	263,054,000	126,655,000	2.08
Combined national economies	700,009,000	126,655,000	5.53

Therefore, it is the finding of this study that the positive return associated with the implementation of the KT-TBCA makes such a course of action favourable and should thus be pursued.

7.6.1 Food Provisioning

The combined effects of improved protection of mangrove forests and seagrass meadows, along with the restoration of these ecological assets, is expected to have a positive effect on the range of food provisioning services evaluated.

Fish catch is anticipated to rise as a result of an increase in mangrove and seagrass extent. This is because an improvement in the condition of these assets is anticipated to raise the catch-per-unit-effort, which is a variable for fish abundance, since the number of species in the area is anticipated to grow due to improved habitats.

An analysis was conducted on each variable in order to determine how the various options will affect the total value of food provisioning. The 20% increase in catch-per-unit-effort, combined with the 10% increase in mangroves with regard to fish harvest, results in a $3,300,000 increase in the value of fish harvest and aquaculture. Furthermore, the combined increase in fish harvest and aquaculture will result in a minimum increase of $18,000,000 in GDP and a $270,000 increase in employment.

The reduction in saltwater intrusion on coastal agricultural areas due to an increase in mangrove cover is also expected to increase agricultural production. The combined effect of the activities discussed above is expected to increase the annual value of agricultural production in the area by approximately $2,500,000. Consequently, this will lead to an anticipated rise in GDP of $13,000,000 and an additional increase in employment of $500,000.

Table 7-4: Summary of total changes in Food Provisioning

Ecosystem Service	Estimated Annual Benefits (USD/a)	
	Min	Max
Food provisioning	***5,764,000***	***5,921,000***
Fish harvest	2,840,000	2,841,000
Aquaculture production	441,000	597,000
Agricultural production	2,483,000	2,484,000

Overall, the food provisioning services are estimated to increase by 39% from the baseline over the analyzed period.

7.6.2 Raw Materials

The presented conservation activities all have a favourable effect on both food provisioning and carbon cycling, but the benefits derived by local communities from raw materials provisioning is expected to decline. The restriction of raw material harvesting and collection activities from mangrove forests would result in a direct reduction in the available wood and charcoal being sourced from the ecosystem. This is likely to have a significant effect on local communities. This reduction could be mitigated through the implementation of alternative sources of these resources by means of the development of timber lots, managed specifically to substitute the harvesting of these resources from natural sources. Further measures that may be taken to reduce the volume of fuelwood required could include the adoption of more efficient cookstoves that require fewer raw materials. While this reduction in mangrove harvesting is expected to reduce the raw materials provisioning service by a value of approximately $995,000, the sustainable resource use and alternative use programmes included in the cost descriptions above would be expected to offset this reduction.

Despite the reduction in benefits associated with this ecosystem service, the broader long-term effect on local communities is expected to be positive, as they will see an improved environment on account of restored mangrove forests and seagrass beds.

Table 7-5: Summary of total changes in Raw Materials

Ecosystem Service	Estimated Annual Benefits (USD/a)	
	Min	Max
Raw materials	***995,000***	***1,346,000***
Charcoal	975,000	1,319,000
Timber	14,000	17,000

7.6.3 Carbon Cycling

The reduction in deforestation and degradation of mangrove forests and seagrass meadows, combined with restoration activities, is expected to result in a significant increase in the value of carbon cycling services.

In the baseline scenario, the increasing rates of degradation saw seagrass represented as a net source of carbon. Effective management of this ecological asset is expected to result in it becoming a carbon sink in the medium to long term. The volume of carbon sequestered by mangroves is therefore expected to increase as greater restoration efforts are undertaken and as these forests age over time.

While it is highly likely that the price of carbon credits will see a significant increase in coming years, for the purposes of this analysis this price was held constant to assess the change in the carbon sequestration benefits attributable to the improvement of the ecosystem only. If price expectations are taken into consideration, the value of this ES is likely to be significantly higher.

It is expected that the value attributable to the improvement in the carbon cycling services of the region would increase by over $900,000, representing a 145% improvement over the base case.

Table 7-6: Summary of total changes in Carbon Cycling

Ecosystem Service	Estimated Annual Benefits (USD/a)	
	Min	Max
Carbon Cycling	*885,000*	*1,028,000*
Mangroves	493,000	602,000
Seagrass	392,000	426,000

7.6.4 Tourism and Recreation

Included in the hypothesised management scenario is a programme aimed at enhancing the tourism value of the proposed MPA.

According to a prior study on the advantages of MPAs for tourism, the formation of an MPA has been shown to result in a 10.5% increase in available beds as well as a further 19% increase in the percentage of visitors who engage in recreational activities.

The implementation of a conservation strategy and associated activities aimed at enhancing the tourism and recreational offerings is expected to add an additional $7,000,000 to $13,000,000 to tourism revenue. Similarly, the additional increase in recreation revenue is estimated to range between $400,000 and $700,000. This equates to an increase of approximately 11% on the annual benefit flows of these services.

A minimum gain in GDP of $8,000,000 and an increase in employment of $4,000,000 are also anticipated as a result of these improvements.

Table 7-7: Summary of total changes in Tourism and Recreation

Ecosystem Service	Estimated Annual Benefits (USD/a)	
	Min	Max
Tourism and recreation	***7,411,000***	***13,195,000***
Tourism	7,003,000	12,484,000
Recreation	408,000	711,000

7.6.5 *Scarce Habitats*

Improved conservation management is expected to have a positive effect on the biodiversity of the region. Literature suggests that increases in species diversity of around 10% can be expected as a result of conservation practices (Davies et al., 2017; Gray et al., 2015).

While the value ascribable to such a change in the overall habitat value of ecosystem services has been estimated to fall between $3,000,000 and $6,000,000, this is likely to be a severe underestimation, as such improved diversity would cause the region to become an even more important area of conservation.

Table 7-8: Summary of total changes in Scarce Habitats

Ecosystem Service	Estimated Annual Benefits (USD/a)	
	Min	Max
Scarce Habitats	3,148,000	6,182,000

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